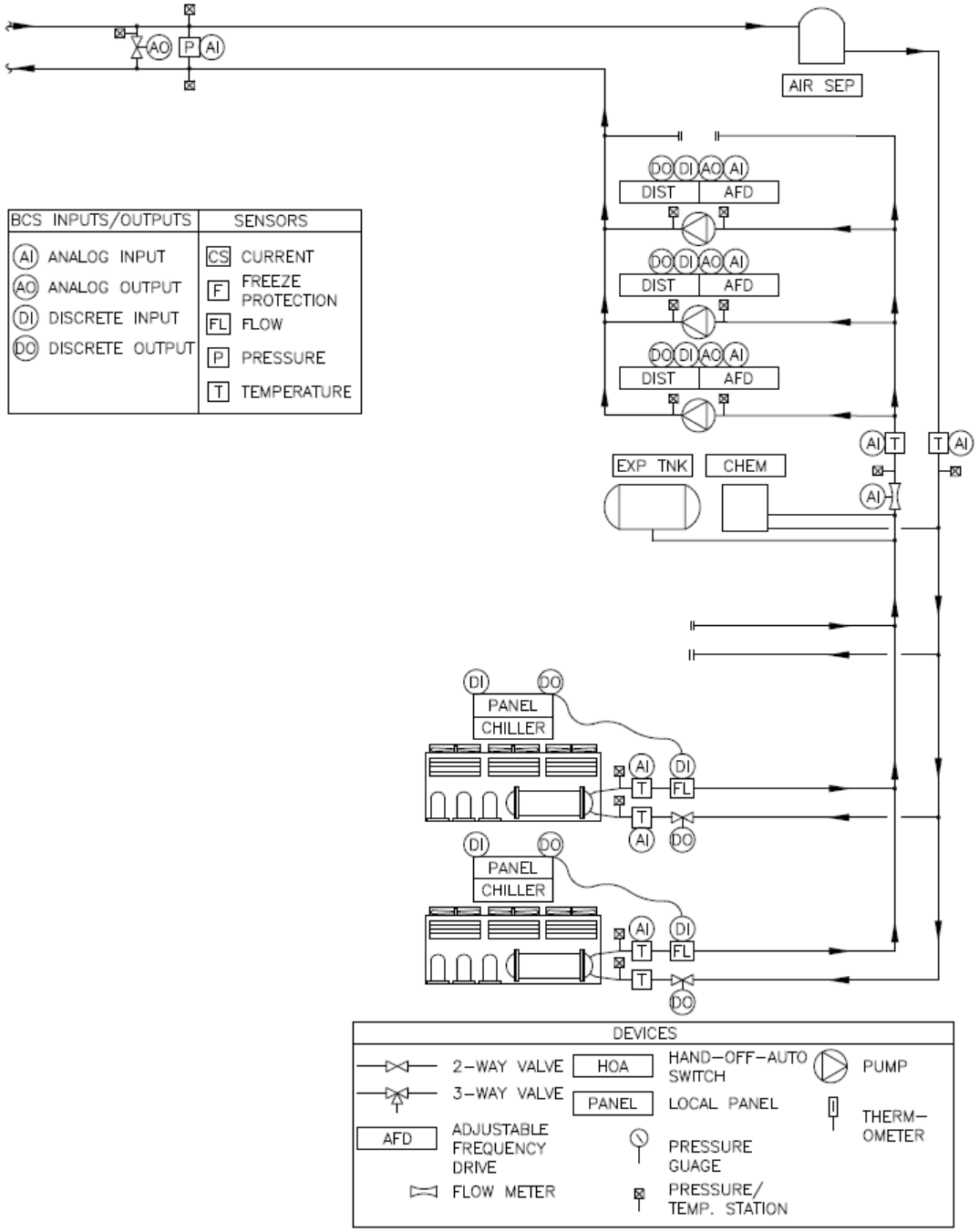
CHILLED WATER PLANT – AIR-COOLED – BYPASS CHILLED WATER DISTRIBUTION

1. INTRODUCTION

This sample functional performance test (FPT) procedure is for a hypothetical air-cooled chilled water plant with bypass chilled water distribution.

The following system diagram is intended to communicate information about this hypothetical system and is not required to be included as part of any FPT.



2. NOTABLE SYSTEM FEATURES

The purpose of this section is to identify notable system features to facilitate an understanding of system operation.

Notable system features include:

a. Each chiller is selected to meet 50-percent of system requirements yielding no redundant chiller.

b. Each chilled water distribution pump is selected to meet 100-percent of a single chiller's requirements yielding one redundant pump.

c. Terminal equipment is selected such that system net temperature change is always greater than chiller evaporator temperature change ensuring system chilled water demand never exceeds that allowed by active chillers.

d. Distribution pumping optimization control algorithm resets pump speed based on valve position of terminal equipment to minimize distribution pump energy usage.

e. Chilled water bypass control algorithm maintains minimum flow equivalent to the maximum flow required by either the number of chillers with open evaporator valves or flow required by the number of active distribution pumps:
Min Flow = Max((Open Evap Valves)(Flow / Chiller),(Active Pumps)(Flow / Pump))

f. Plant activation and multiple chiller operation control algorithms inherently include duty status rotation for all equipment.

g. Plant deactivation operation mode includes Operator options to not set or to set plant deactivation parameters for stable chiller operation based on plant and connected load characteristics.
   - Deactivation option one allows setting minimum running load current of last enabled chiller and period required to disable next inactive chiller circuit / to deactivate plant, and / or
   - Deactivation option two allows setting minimum system load and period required to disable next inactive chiller circuit / to deactivate plant

h. Plant activation operation mode includes Operator options to not set or to set staged plant activation parameters for stable chiller operation based on plant and connected load characteristics.
   - Stage one activation allows setting minimum number of system terminal equipment control valves commanded from their 0-percent open position and period required to enable next active distribution pump, and
   - Stage two activation allows setting minimum system flow rate and period required to enable next active chiller circuit

i. Multiple chiller operation mode includes Operator options to not set or to set parameters to enable next active chiller circuit and to disable next inactive chiller circuit for maximized plant efficiency based on plant characteristics.
   - Activation option one allows setting minimum running load current of last enabled chiller and period required to enable next active chiller circuit, and / or
   - Activation option two allows setting minimum system load and period required to enable next active chiller circuit

- Deactivation option one allows setting minimum running load current of last enabled chiller and period required to disable next inactive chiller circuit, and / or
- Deactivation option two allows setting minimum system load and period required to disable next inactive chiller circuit

j. Multiple chiller operation mode includes calculation of actual load based on supply water setpoint temperature, chiller loop return water actual temperature, and chiller loop actual flow to maintain an accurate load calculation during transition time during manufacturer's initial load limiting initiated when next active chiller's evaporator isolation valve is commanded to its 100-percent open position.

k. Low chilled water return temperature alarm condition includes visual indication of net system temperature change being significantly less than design thus negatively impacting central plant efficiency.

3. CONCLUSIONS AND RECOMMENDATIONS

The purpose of this section is to identify conclusions and recommendations based on control system feature observations, point-to-point observations, actuator observations, and system operation observations.

It is concluded that this system [does / does not perform] in accordance with contract requirements.

It is recommended that this system [be / not be] accepted by the government.

The following system control enhancements are recommended:

4. TEST CONDITIONS

The purpose of this section is to identify conditions occurring at time of testing.

Test date: _____
Test begin time: _____
Test end time: _____
Test begin outside air temp: _____
Test end outside air temp: _____

5. EQUIPMENT IDENTIFICATION

The purpose of this section is to identify equipment included in this system.

Chiller: _____
Chiller: _____
Distribution pump: _____
Distribution pump: _____
Distribution pump: _____

6. ATTENDEES

The purpose of this section is to identify persons present during system functional performance testing.

ATTENDEES			
REPRESENTING	**NAME**	**COMPANY**	**TELEPHONE NUMBER**
Mechanical Commissioning Specialist:			
Owner's Representative:			
Mechanical Contractor:			
Controls Contractor:			
Test & Balance Contractor:			

7. CONTROL SYSTEM FEATURE OBSERVATIONS

The purpose of this section is to identify control system features including control point description, imbedded / visible type, adjustable / monitoring type, actual value, setpoint value / alarm range.

Abbreviations used in the matrix below include:

a. Unit:
   Unit of measure for control point.
b. Imbedded / Visible:
   I - Imbedded such that control point is not observable by Operator.
   V - Visible such that control point is observable by Operator.
c. Type:
   A1 - Both setpoint and minimum / maximum alarm or alarm range are adjustable by Operator.
   A2 - Only minimum / maximum alarm or alarm range is adjustable by Operator.
   A3 - Only setpoint is adjustable by Operator.
   M - Control point is visible, but not adjustable by Operator.

d. Value / Status:

As-found imbedded or visible value or status of control point observed prior to control point(s) manipulation.

A - Status of control point is in alarm.

N - Status of control point is normal operation.

e. Setpt / Alarm Range:

Alarm Min - Alarm activated when actual value is equal to or less than alarm activation setpoint.

Setpt - Setpoint.

Alarm Max - Alarm activated when actual value is equal to or greater than alarm activation setpoint.

CONTROL SYSTEM FEATURES								
POINT DESCRIPTION	**UNIT**	**VISIBLE / IMBEDDED**	**TYPE**	**VALUE / STATUS**	**SETPT / ALARM**			**NOTES**
					ALARM MIN	**SETPT**	**ALARM MAX**	
Chiller (___):								
Entering temp					-	-	-	
Leaving temp					-	-		
Flow					-	-	-	
Valve position	% Open				-	-	-	
Chiller (___):								
Entering temp					-	-	-	
Leaving temp					-	-		
Flow					-	-	-	
Valve position	% Open				-	-	-	
Distribution pump (___):								
Status					-	-	-	
Speed					-	-	-	
Distribution pump (___):								
Status					-	-	-	
Speed					-	-	-	
Distribution pump (___):								
Status					-	-	-	
Speed					-	-	-	
Chiller loop:								
Supply temp								
Return temp						-	-	
Flow					-			
Bypass:								
Valve position	% Open				-	-	-	
Valve setpoint					-		-	

8. POINT-TO-POINT OBSERVATIONS

The purpose of this section is to identify system meters and sensors have been calibrated.

Abbreviations used in the matrix below include:

a. Display:

As-found imbedded or visible value of control point documented at Operator workstation at same time measurement or observation occurred and prior to control point(s) manipulation.

Value / status is recorded for both locations when control point is displayed locally at equipment Operator workstation.

b. Measured / Observed:

As-found imbedded or visible value of control point measured or observed at same time documentation of value at Operator workstation occurred and prior to control point(s) manipulation.

POINT-TO-POINT			
POINT DESCRIPTION	**DISPLAY (LOCAL / CONTROL SYSTEM)**	**MEASURED / OBSERVED**	**NOTES**
Chiller (___):			
Entering temp			
Leaving temp			
Flow	/		
Chiller (___):			
Entering temp			
Leaving temp			
Flow	/		
Chiller loop:			
Supply temp			
Return temp			
Flow	/		

9. ACTUATOR AND MOTOR OBSERVATIONS

The purpose of this section is to identify actuator responses to commands from the control system.

Abbreviations used in the matrix below include:

a. Type:

A - Actuator / controlled device is controlled by an analog control signal.

D - Actuator / controlled device is controlled by a discrete (binary) control signal.

b. Maximum Command:

Control system command resulting in actuator moving controlled device to its full open position with maximum / full flow across device.

c. Minimum Command:

Control system command resulting in actuator moving controlled device to its full closed position with minimum / no flow across device.

d. Signal:

   Output from control system measured in units of 0 to 100 percent, 0 to 10 volts, etc.

e. Position:

   Position of controlled device (not actuator) physically observed that corresponds to control system signal observed in units of 0-percent open (minimum / no flow across device) and 100-percent open (maximum / full flow across device).

ACTUATORS AND MOTORS						
ACTUATOR DESCRIPTION	**TYPE**	**MAXIMUM COMMAND**		**MINIMUM COMMAND**		**NOTES**
		SIGNAL	**POSITION / SPEED**	**SIGNAL**	**POSITION / SPEED**	
Chiller (___) isolation valve						
Chiller (___) isolation valve						
Bypass valve						
Distribution pump (___) speed						
Distribution pump (___) speed						
Distribution pump (___) speed						

10. VARIABLE FREQUENCY DRIVE OBSERVATIONS

The purpose of this section is to identify characteristics of variable frequency drives (VFD’s).

Procedure for obtaining characteristics included:

a. Procedure for documenting maximum motor speed allowed by VFD included:
   - Record served motor’s nameplate full load current
   - Confirm / manually set VFD’s maximum allowed speed of 60 Hz
   - Manually set VFD hand-off-auto switch to “hand” position
   - Manually set VFD to maximum allowed speed of 60 Hz
   - Record served motor’s running load current at motor conductors

b. Procedure for documenting minimum safe motor speed allowed by VFD included:
   - Manually set VFD speed to 24 Hz
   - Repeatedly decreased VFD speed by 3 Hz and recorded served motor’s running load amperes until running load amperes increases
   - Set VFD’s minimum allowed speed equivalent to speed at which running load amperes increased plus 3 Hz
   - Manually set VFD speed to VFD’s minimum allowed speed
   - Record served motor’s running load amperes at motor conductors

VARIABLE FREQUENCY DRIVE INFORMATION														
PARAMETER DESCRIPTION	**SERVED EQUIPMENT**													
Data for maximum motor speed allowed by VFD:														
Motor nameplate full load current														
VFD maximum allowed speed (Hz)														
Running load current with VFD at 60 Hz														
Data for minimum safe motor speed allowed by VFD:														
Current at 24 Hz														
Current at 21 Hz														
Current at 18 Hz														
Current at 15 Hz														
Current at 12 Hz														
Current at 9 Hz														
Current at 6 Hz														
Minimum allowed speed (Hz)														
Current at minimum allowed speed (Amps)														

11. SYSTEM OPERATION OBSERVATIONS

The purpose of this section is to document results from system-based testing of responses for each control algorithm, operation mode, and alarm condition resulting from manipulated control point(s).

Testing is sequentially grouped based on similar functions to maximize testing efficiency and is categorized as follows:

a. As-found conditions.
b. Control algorithms.
c. Operation modes.
d. Alarm conditions.

Control algorithms initiated by operation modes are tested prior to testing operation modes.
Operation modes initiated by alarm conditions are tested prior to testing alarm conditions.

Because point-to-point and actuator observations were physically made, system responses are observed from Operator workstation unless indicated otherwise.

Some equipment / component responses may be combined in a single test.

The following control algorithm testing is provided in the matrix below:

a. Distribution pumping.
b. Chilled water bypass.
c. Distribution pumping optimization.

The following operation mode testing is provided in the matrix below:

a. Plant deactivation.
b. Plant activation.
c. Single chiller.
d. Multiple chiller.

The following alarm condition testing is provided in the matrix below:

a. High chilled water supply temperature.
b. Low chilled water supply temperature.
c. High chilled water flow.
d. Low chilled water return temperature.
e. Distribution pump general fault.
f. Distribution pump failure type one.
g. Chiller evaporator temperature.
h. Chiller general fault.
i. Chiller failure.
j. Distribution pump failure type two.
k. Chiller opposite status.
l. Distribution pump opposite status.

Abbreviations used in the matrix below include:

a. Test Method:
   Manipulated parameter(s) necessary to produce expected system response.
b. Expected Response:
   Anticipated system reaction to manipulated parameter(s).
c. Comments:
   Commissioning specialist’s issues related to observations.
d. Pass / Fail:
   P - Expected response is observed without issues of concern.
   F - Expected response is not observed resulting in noted issues of concern.
e. Miscellaneous:
   CS - Control signal.

SYSTEM OPERATION				
STEP	**TEST METHOD**	**EXPECTED RESPONSE**	**COMMENTS**	**PASS/ FAIL**
As-Found Conditions				
01	To observe as-found conditions: • Confirm system is activated • Record observations in expected response /comments columns prior to manipulating parameters	Chiller (___):		
02		Status: _____		
03		% Output: _____		
04		Ent evap temp: _____		
05		Lve evap temp: _____		
06		Evap valve pos: _____		
07		Chiller (___):		
08		Status: _____		
09		% Output: _____		
10		Ent evap temp: _____		
11		Lve evap temp: _____		
12		Evap valve pos: _____		
13		Distribution pump (___):		
14		Status: _____		
15		Speed: _____		
16		Distribution pump (___):		
17		Status: _____		
18		Speed: _____		
19		Distribution pump (___):		
20		Status: _____		
21		Speed: _____		
22		Chiller loop:		
23		Supply temp: _____		
24		Return temp: _____		
25		Flow: _____		
26		System loop:		
27		Supply temp: _____		
28		Return temp: _____		
29		Flow: _____		
30		Bypass:		
31		Valve position: _____		
32		Facility:		
33		Temperature: _____		
34		Humidity: _____		

SYSTEM OPERATION				
STEP	**TEST METHOD**	**EXPECTED RESPONSE**	**COMMENTS**	**PASS/ FAIL**
Distribution Pumping Control Algorithm Design Control Sequence: Upon detection of this algorithm having been activated, the control system shall: • Set setpoint pressure equivalent to 15 psid when distribution pumping optimization control algorithm is inactive and that set by distribution pumping optimization control algorithm when it is active • Continuously set distribution pump disable setpoint flow equivalent to 90-percent of capacity of enabled distribution pumps minus one distribution pump • Continuously set next active distribution pump equivalent to the inactive distribution pump with shortest runtime • Continuously set next inactive distribution pump equivalent to the active distribution pump with longest runtime • Monitor pressure sensor located is system loop • Command enabled distribution pump(s) toward their maximum allowed motor speed upon detection of actual pressure being less than setpoint • Enable next active distribution pump upon detection of enabled distribution pumps having been commanded to their maximum allowed motor speed and actual pressure being less than setpoint for a two-minute period • Enabled distribution pumps equally share load • Command enabled distribution pump(s) toward their minimum allowed motor speed upon detection of actual pressure being greater than setpoint • Disable next inactive distribution pump upon detection of chilled water actual flow being equal to or less than distribution pump disable setpoint flow for a two-minute period				
35	To prepare for system response: • Deactivate distribution pumping optimization • Observe system status	Setpoint pressure set	CS of _____	
36		Distribution pump disable setpoint flow set	CS of _____	
37		Next active distribution pump set	CS of _____	
38		Next inactive distribution pump set	CS of _____	
39		Pressure sensor monitored	CS of _____	

SYSTEM OPERATION				
STEP	**TEST METHOD**	**EXPECTED RESPONSE**	**COMMENTS**	**PASS/ FAIL**
40	To observe system response to deficient capacity: • Override setpoint pressure to slightly greater than actual pressure	Enabled distribution pump(s) commanded towards their maximum allowed motor speed	CS of _____	
41	To observe system response to continued deficient capacity: • Override setpoint pressure to significantly greater than actual pressure	Two-minute period passes without control system action		
42		Next active distribution pump enabled	CS of _____	
43		Enabled distribution pump drives indicate nominally equivalent output	CS of _____	
44	To observe system response to excessive capacity: • Override setpoint pressure to slightly less than actual pressure	Enabled distribution pumps commanded towards their minimum allowed motor speed	CS of _____	
45	To observe system response to continued excessive capacity: • Override set load to significantly less than set distribution pump disable setpoint flow	Two-minute period passes without control system action		
46		Next inactive distribution pump disabled	CS of _____	
47	To observe system response to excessive system flow: • Override all terminal equipment control valves to their 100-percent open position	Enabled distribution pumps flow limited maximum allowed chiller loop setpoint flow	CS of _____	
48	Release all overrides	System returns to pre-test conditions		

SYSTEM OPERATION				
STEP	**TEST METHOD**	**EXPECTED RESPONSE**	**COMMENTS**	**PASS/ FAIL**
Chilled Water Bypass Control Algorithm Design Control Sequence: Upon detection of this algorithm having been activated, the control system shall: • Set bypass water setpoint flow equivalent to the maximum of the product of chillers with evaporator valves commanded to their 100-percent open position and 180 gpm and the product of the number of active distribution pumps and 25-percent of pump maximum flow • Reset bypass water setpoint flow for one additional chiller upon detection of next active chiller being enabled • Reset bypass water setpoint flow for one less chiller two minutes after disabling next inactive chiller • Monitor water flow meter located in chiller loop • Command chilled water bypass valve towards its 100-percent open position upon detection of actual flow being less than setpoint • Command chilled water bypass valve towards its 0-percent open position upon detection of actual flow being greater than setpoint				
49	To prepare for system response: • Initiate minimum load to maintain single chiller at minimum allowable stable output • Observe system status	Chilled water bypass setpoint flow set	CS of _____	
50		Water flow meter monitored	CS of _____	
51	To observe system response to deficient flow: • Override setpoint water flow to slightly greater than actual flow	Chilled water bypass valve commanded towards its 100-percent open position	CS of _____	
52	To observe system response to excessive flow: • Override setpoint water flow to slightly less than actual flow	Chilled water bypass valve commanded towards its 0-percent open position	CS of _____	
53	To observe system response to increased number of active chillers: • Initiate increased number of active chillers	Bypass water setpoint flow reset	CS of _____	
54		Enabled distribution pumps commanded towards their maximum allowed motor speed	CS of _____	
55		Next active chiller circuit enabled	CS of _____	

SYSTEM OPERATION				
STEP	**TEST METHOD**	**EXPECTED RESPONSE**	**COMMENTS**	**PASS/ FAIL**
56	To observe system response to decreased number of active chillers: • Initiate decreased number of active chillers	Next inactive chiller circuit disabled	CS of _____	
57		Two-minute period passes without control system action		
58		Bypass water setpoint flow reset	CS of _____	
59	Release all overrides	System returns to pre-test conditions		
Distribution Pumping Optimization Control Algorithm Design Control Sequence: Upon detection of this algorithm having been activated, the control system shall: • Monitor each terminal equipment's control valve position • Command enabled pump(s) toward their maximum allowed motor speed upon detection of any control valve having been commanded to greater than its 95-percent open position • Command enabled pump(s) toward their minimum allowed motor speed upon detection of no control valve having been commanded to greater than its 80-percent open position and no control valve having been commanded to greater than its 95-percent open position				
60	To prepare for system response: • Observe system status	Each terminal equipment's control valve position monitored	CS of _____	
61	To observe system response to deficient pressure: • Override one control valve to its 97-percent open position	Enabled pump(s) commanded towards their maximum allowed motor speed	CS of _____	
62	To observe system response to excessive pressure: • Override all control valves to their 50-percent open position	Enabled pump(s) commanded towards their minimum allowed motor speed	CS of _____	
63	Release all overrides	System returns to pre-test conditions		

SYSTEM OPERATION				
STEP	**TEST METHOD**	**EXPECTED RESPONSE**	**COMMENTS**	**PASS/ FAIL**
Plant Deactivation Operation Mode Design Control Sequence: Upon detection of completion of plant activation operation mode and only one chiller being active, the control system shall: • Set next inactive chiller circuit disable / plant deactivation setpoints equivalent to: – Operator option one: Minimum running load current of last enabled chiller and disable period, and / or – Operator option two: Minimum system load and disable period, or – No Operator input default: All terminal equipment control valves having been commanded to their 0-percent open position for a five-minute disable period • Disable next inactive chiller circuit upon detection of Operator option one and / or option two disable parameter(s) having occurred and disable period(s) having passed • Disable next inactive chiller circuit upon detection of no Operator option one or option two inputs, default disable parameter having occurred, and disable period having passed • Take no action for a two-minute period • Disable all distribution pumps • Deactivate distribution pumping control algorithm • Deactivate distribution pumping optimization control algorithm • Command all chiller evaporator isolation valves to their 0-percent open position • Deactivate chilled water bypass control algorithm				
64	To prepare for system response: • Set Operator option one next inactive chiller circuit disable / plant deactivation setpoint and set disable period • Observe system status • Release Operator inputs • Set Operator option two next inactive chiller circuit disable / plant deactivation setpoint and set disable period • Observe system status • Release Operator inputs • Observe system status	Operator option one for next inactive chiller circuit disable / plant deactivation setpoint set	CS of _____	
65		Operator option one for next inactive chiller circuit disable / plant deactivation period set	CS of _____	
66		Operator option two for next inactive chiller circuit disable / plant deactivation setpoint set	CS of _____	
67		Operator option two for next inactive chiller circuit disable / plant deactivation period set	CS of _____	
68		No Operator input default for next inactive chiller circuit disable / plant deactivation setpoint set	CS of _____	
69		No Operator input default for next inactive chiller circuit disable / plant deactivation period set	CS of _____	

SYSTEM OPERATION				
STEP	**TEST METHOD**	**EXPECTED RESPONSE**	**COMMENTS**	**PASS/ FAIL**
70	To observe system response: • Override all terminal equipment control valves to their 0-percent open position	Five-minute period passes without control system action		
71		All chillers disabled	CS of _____	
72		Two-minute period passes without control system action		
73		All distribution pumps disabled	CS of _____	
74		Distribution pumping control algorithm deactivated	CS of _____	
75		Distribution pumping optimization control algorithm deactivated	CS of _____	
76		Each chiller's evaporator isolation valve commanded to its 0-percent open position	CS of _____	
77		Chilled water bypass control algorithm deactivated	CS of _____	

SYSTEM OPERATION				
STEP	**TEST METHOD**	**EXPECTED RESPONSE**	**COMMENTS**	**PASS/ FAIL**
Plant Activation Operation Mode Design Control Sequence: Upon detection of no chiller being active, the control system shall: • Set stage one next active distribution pump enable setpoints equivalent to: – Operator option: Minimum number of system control valves commanded from their 0-percent open position and enable period, or – No Operator input default: Any single system control valve having been commanded from its 0-percent open position for a 15-minute enable period • Set stage two next active chiller circuit enable setpoints equivalent to: – Operator option: Minimum system flow and enable period, or – No Operator input default: 15-Percent of maximum system flow for a 15-minute enable period • Continuously set next active distribution pump equivalent to the inactive distribution pump with shortest runtime • Continuously set next active chiller circuit equivalent to the inactive chiller with shortest runtime • Monitor chilled water flow meter located in chiller loop • Command next active chiller's evaporator isolation valve to its 100-percent open position upon detection of stage one parameter having occurred and stage one enable period having passed • Enable next active distribution pump • Activate distribution pumping control algorithm • Activate distribution pumping optimization control algorithm • Enable next active chiller upon detection of stage two activation parameter having occurred and stage two activation period having passed • Activate chilled water bypass control algorithm			
78	To prepare for system response: • Set Operator stage one next active distribution pump enable setpoint and set enable period • Observe system status • Release Operator inputs • Observe system status • Set Operator stage two next active chiller circuit enable setpoint and set enable period • Observe system status	Operator stage one for next active distribution pump enable setpoint set	CS of _____	
79		Operator stage one for next active distribution pump enable period set	CS of _____	
80		No Operator input default for next active distribution pump enable setpoint set	CS of _____	
81		No Operator input default for next active distribution pump activation period set	CS of _____	
82		Operator stage two for next active chiller circuit enable setpoint set	CS of _____	

SYSTEM OPERATION				
STEP	**TEST METHOD**	**EXPECTED RESPONSE**	**COMMENTS**	**PASS/ FAIL**
83	• Release Operator inputs • Observe system status	Operator stage two for next active chiller circuit enable period set	CS of _____	
84		No Operator input default for next active chiller circuit enable setpoint set	CS of _____	
85		No Operator input default for next active chiller circuit enable period set	CS of _____	
86		Next active distribution pump set	CS of _____	
87		Next active chiller set	CS of _____	
88		Chilled water flow monitored	CS of _____	
89	To observe system response: • Override one terminal equipment control valve from its 0-percent open position	15-Minute period passes without control system action		
90		Next active chiller's evaporator isolation valve commanded to its 100-percent open position	CS of _____	
91		Next active distribution pump enabled	CS of _____	
92		Distribution pumping control algorithm activated	CS of _____	
93		Distribution pumping optimization control algorithm activated	CS of _____	
94		Chilled water bypass control algorithm activated	CS of _____	
95		System loop chilled water flow measured	CS of _____	
96		Five-minute stage two enable period passes without control system action		
97		Next active chiller enabled	CS of _____	

SYSTEM OPERATION				
STEP	**TEST METHOD**	**EXPECTED RESPONSE**	**COMMENTS**	**PASS/ FAIL**
Single Chiller Operation Mode Design Control Sequence: Upon detection of completion of plant activation operation mode, the control system shall: • Monitor chilled water supply temperature sensor located in chiller loop • Forward supply water setpoint temperature of 44.0 °F to all chiller control panels • Enabled chiller output matches load				
98	To prepare for system response: • Observe system status	Chilled water supply temperature monitored	CS of _____	
99		Supply water setpoint temperature forwarded to all chiller control panels	CS of _____	
100	To observe system response to excessive capacity: • Override supply water setpoint temperature to slightly greater than actual temperature	Enabled chiller control panel indicates decreased output	CS of _____	
101	To observe system response to deficient capacity: • Override supply water setpoint temperature to slightly less than actual temperature	Enabled chiller control panel indicates increased output	CS of _____	
102	Release all overrides	System returns to pre-test conditions		

SYSTEM OPERATION				
STEP	**TEST METHOD**	**EXPECTED RESPONSE**	**COMMENTS**	**PASS/ FAIL**
Multiple Chiller Operation Mode Design Control Sequence: Upon detection of completion of plant activation operation mode, the control system shall: • Set next active chiller circuit enable setpoints equivalent to: – Operator option one: Minimum running load current of last enabled chiller and enable period, and / or – Operator option two: Minimum system load and enable period, or – No Operator input default: Actual chilled water supply temperature being equal to or greater than two degrees above setpoint temperature for a five-minute enable period • Set next inactive chiller circuit disable setpoints equivalent to: – Operator option one: Minimum running load current of last enabled chiller and disable period, and / or – Operator option two: Minimum system load and disable period, or – No Operator input default: System actual load being equal to or less than 90-percent of capacity of enabled chillers minus capacity of one chiller for a five-minute disable period • Continuously calculate actual load based on supply water setpoint temperature and input from chiller loop's supply return water temperature sensor and chiller loop's water flow meter • Continuously set next active chiller circuit equivalent to the inactive chiller with shortest runtime • Continuously set next inactive chiller circuit equivalent to the active chiller with longest runtime • Monitor chiller water supply water temperature sensor located in chilled loop • Forward supply water setpoint temperature of 44.0 °F to all chiller control panels • Command next active chiller's evaporator isolation valve to its 100-percent open position upon detection of Operator option one and / or option two enable parameter(s) having occurred and enable period(s) having passed • Command next active chiller's evaporator isolation valve to its 100-percent open position upon detection of no Operator option one or option two inputs and default enable parameter having occurred and enable period having passed • Enable next active chiller • Enabled chillers equally share load • Disable next inactive chiller upon detection of Operator option one and / or option two disable parameter(s) having occurred and disable period(s) having passed • Disable next inactive chiller upon detection of no Operator option one or option two inputs, default disable parameter having occurred, and disable period having passed • Take no action for a two-minute period • Command next inactive chiller's evaporator isolation valve to its 0-percent open position			

SYSTEM OPERATION				
STEP	**TEST METHOD**	**EXPECTED RESPONSE**	**COMMENTS**	**PASS/ FAIL**
103	To prepare for system response: • Set Operator option one next active chiller circuit enable setpoint and set enable period • Observe system status • Release Operator inputs • Set Operator option two next active chiller circuit enable setpoint and set enable period • Observe system status • Release Operator inputs • Set Operator option one next inactive chiller circuit disable setpoint and set disable period • Observe system status • Release Operator inputs • Set Operator option two next inactive chiller circuit disable setpoint and set disable period • Observe system status • Release Operator inputs • Observe system status	Operator option one for next active chiller circuit enable setpoint set	CS of _____	
104		Operator option one for next active chiller circuit enable period set	CS of _____	
105		Operator option two for next active chiller circuit enable setpoint set	CS of _____	
106		Operator option two for next active chiller circuit enable period set	CS of _____	
107		No Operator input default for next active chiller circuit enable setpoint set	CS of _____	
108		No Operator input default for next active chiller circuit enable period set	CS of _____	
109		Operator option one for next inactive chiller circuit disable setpoint set	CS of _____	
110		Operator option one for next inactive chiller circuit disable period set	CS of _____	
111		Operator option two for next inactive chiller circuit disable setpoint set	CS of _____	
112		Operator option two for next inactive chiller circuit disable period set	CS of _____	
113		No Operator input default for next inactive chiller circuit disable setpoint set	CS of _____	
114		No Operator input default for next inactive chiller circuit disable period set	CS of _____	
115		Chilled water supply temperature monitored	CS of _____	
116		Load calculated	CS of _____	

SYSTEM OPERATION				
STEP	**TEST METHOD**	**EXPECTED RESPONSE**	**COMMENTS**	**PASS/ FAIL**
117		Supply water setpoint temperature forwarded to all chiller control panels	CS of _____	
118	To observe system response to deficient capacity: • Override supply water setpoint temperature to significantly less than actual temperature	Five-minute period passes without control system action		
119		Next active chiller's evaporator isolation valve commanded to its 100-percent open position	CS of _____	
120		Next active chiller enabled	CS of _____	
121		Enabled chiller control panels indicate nominally equivalent increased output	CS of _____	
122	To observe system response to excessive capacity: • Override calculated load to significantly less than set chiller circuit disable setpoint load	Enabled chiller control panels indicate nominally equivalent decreased output	CS of _____	
123		Five-minute period passes without control system action		
124		Next inactive chiller disabled	CS of _____	
125		Two-minute period passes without control system action		
126		Next inactive chiller chiller's evaporator isolation valve commanded to its 0-percent open position	CS of _____	
127	Release all overrides	System returns to pre-test conditions		

SYSTEM OPERATION				
STEP	**TEST METHOD**	**EXPECTED RESPONSE**	**COMMENTS**	**PASS/ FAIL**
High Chilled Water Supply Temperature Alarm Condition Design Control Sequence: Upon detection of initiation of plant activation operation mode, the control system shall: • Set high chilled water alarm setpoint temperature equivalent to control setpoint plus 10.0 °F • Continuously set next active chiller circuit equivalent to the inactive chiller with shortest runtime • Monitor chilled water supply temperature sensor located in chiller loop supply • Take no action during chiller manufacturer's load limiting at chiller start-up • Initiate audible and visual alarms at Operator workstation upon detection of actual supply water temperature being equal to or greater than alarm setpoint temperature for a 15-mintue period • Maintain enabled chiller statuses • Enable next active chiller circuit				
128	To prepare for system response: • Observe system status	Alarm setpoint temperature set	CS of _____	
129		Next active chiller circuit set	CS of _____	
130		Chilled water supply temperature monitored	CS of _____	
131	To observe system response: • Override high supply water alarm setpoint temperature to significantly less than actual temperature	15-minute period passes without control system action		
132		Audible and visual alarms initiated at Operator workstation		
133		Enabled chiller statuses maintained	CS of _____	
134		Next active chiller circuit enabled	CS of _____	
135	Release all overrides	System returns to pre-test conditions		

SYSTEM OPERATION				
STEP	**TEST METHOD**	**EXPECTED RESPONSE**	**COMMENTS**	**PASS/ FAIL**
Low Chilled Water Supply Temperature Alarm Condition Design Control Sequence: Upon detection of initiation of plant activation operation mode, the control system shall: • Set low chilled water alarm setpoint temperature equivalent to control setpoint minus 10.0 °F • Monitor chilled water supply temperature sensor located in chiller loop supply • Initiate audible and visual alarms at Operator workstation upon detection of actual supply water temperature being equal to or less than alarm setpoint temperature for a 15-mintue period • Maintain chiller statuses				
136	To prepare for system response: • Observe system status	Alarm setpoint temperature set	CS of _____	
137	To observe system response: • Override low supply water alarm setpoint temperature to significantly greater than actual temperature	15-minute period passes without control system action		
138		Audible and visual alarms initiated at Operator workstation		
139		Chiller statuses maintained	CS of _____	
140	Release all overrides	System returns to pre-test conditions		
High Chilled Water Flow Alarm Condition Design Control Sequence: Upon detection of initiation of plant activation operation mode, the control system shall: • Continuously set high chilled water alarm setpoint flow equivalent to the product of the number of active chillers and 120 gpm • Continuously set next active chiller circuit equivalent to the inactive chiller with shortest runtime • Monitor chilled water flow meter located in chiller loop • Initiate audible and visual alarms at Operator workstation upon detection of actual chiller loop water flow being equal to or greater than alarm setpoint flow • Enable next active chiller circuit				
141	To prepare for system response: • Initiate single chiller operation mode • Observe system status	High chilled water alarm setpoint flow set	CS of _____	
142		Chiller loop water flow monitored	CS of _____	
143		Single chiller operation mode initiated	CS of _____	

SYSTEM OPERATION				
STEP	**TEST METHOD**	**EXPECTED RESPONSE**	**COMMENTS**	**PASS/ FAIL**
144	To observe system response to excessive system flow: • Override all terminal equipment control valves to their 100-percent open position	Audible and visual alarms initiated at Operator workstation		
145		Next active chiller circuit enabled	CS of _____	
146	Release all overrides	System returns to pre-test conditions		
Low Chilled Water Return Temperature Alarm Condition Design Control Sequence: Upon detection of receiving enable command, the control system shall: • Set chilled water return low limit alarm setpoint temperature equivalent to control setpoint minus 6.0 °F • Monitor chilled water return temperature sensor located in chiller loop return • Take no action during chiller manufacturer's load limiting at chiller start-up • Initiate audible alarm at Operator workstation upon detection of actual return water temperature being equal to or greater than alarm setpoint temperature for a 15-mintue period • Maintain enabled chiller statuses				
147	To observe system response to excessive heating: • Override chilled water return low limit alarm setpoint temperature to significantly greater than actual temperature	15-Minute period passes without control system action		
148		Visual alarm initiated at Operator workstation		
149		Enabled chiller statuses maintained	CS of _____	
150	Release all overrides	System returns to pre-test conditions		
Distribution Pump (___) General Fault Alarm Condition Design Control Sequence: Upon detection of initiation of plant activation operation mode and distribution pump general fault alarm, the control system shall: • Initiate visual alarm at Operator workstation • Maintain system active status				
151	To observe system response: • Initiate general fault at adjustable frequency drive	Visual alarm initiated at Operator workstation		
152		System status maintained	CS of _____	

SYSTEM OPERATION				
STEP	**TEST METHOD**	**EXPECTED RESPONSE**	**COMMENTS**	**PASS/ FAIL**
153	Release all overrides	System returns to pre-test conditions		
Distribution Pump (___) General Fault Alarm Condition				
154	To observe system response: • Initiate general fault at adjustable frequency drive	Visual alarm initiated at Operator workstation		
155		System status maintained	CS of _____	
156	Release all overrides	System returns to pre-test conditions		
Distribution Pump (___) General Fault Alarm Condition				
157	To observe system response: • Initiate general fault at adjustable frequency drive	Visual alarm initiated at Operator workstation		
158		System status maintained	CS of _____	
159	Release all overrides	System returns to pre-test conditions		
Distribution Pump (___) Failure Type One Alarm Condition Design Control Sequence: Upon detection of initiation of plant activation operation mode and distribution pump failure alarm status with more than one distribution pump being active, the control system shall: • Continuously set next active distribution pump equivalent to the inactive distribution pump with shortest runtime • Initiate audible and visual alarms at Operator workstation • Disable failed distribution pump • Enable next active distribution pump				
160	To prepare for system response: • Observe system status	Next active distribution pump set	CS of _____	
161	To observe system response: • Manually turn distribution pump's disconnect switch to off position	Audible and visual alarms initiated at Operator workstation		
162		Filed distribution pump disabled	CS of _____	
163		Next active distribution pump enabled	CS of _____	

SYSTEM OPERATION				
STEP	**TEST METHOD**	**EXPECTED RESPONSE**	**COMMENTS**	**PASS/ FAIL**
164	Release all overrides	System returns to pre-test conditions		
Distribution Pump (___) Failure Type One Alarm Condition				
165	To prepare for system response: • Observe system status	Next active distribution pump set	CS of _____	
166	To observe system response: • Manually turn distribution pump's disconnect switch to off position	Audible and visual alarms initiated at Operator workstation		
167		Filed distribution pump disabled	CS of _____	
168		Next active distribution pump enabled	CS of _____	
169	Release all overrides	System returns to pre-test conditions		
Distribution Pump (___) Failure Type One Alarm Condition				
170	To prepare for system response: • Observe system status	Next active distribution pump set	CS of _____	
171	To observe system response: • Manually turn distribution pump's disconnect switch to off position	Audible and visual alarms initiated at Operator workstation		
172		Filed distribution pump disabled	CS of _____	
173		Next active distribution pump enabled	CS of _____	
174	Release all overrides	System returns to pre-test conditions		

SYSTEM OPERATION				
STEP	**TEST METHOD**	**EXPECTED RESPONSE**	**COMMENTS**	**PASS/ FAIL**
Chiller (___) Evaporator Temperature Alarm Condition Design Control Sequence: Upon detection of initiation of plant activation operation mode, the control system shall: • Set chiller evaporator high limit alarm setpoint temperature equivalent to supply water setpoint temperature plus 5.0 °F • Monitor chiller supply water temperature sensor located in chiller evaporator outlet • Take no action during chiller manufacturer's load limiting at chiller start-up • Initiate audible and visual alarms at Operator workstation upon detection of actual supply water temperature being equal to or greater than alarm setpoint temperature for a 15-mintue period • Maintain enabled chiller statuses				
175	To observe system response to excessive heating: • Override evaporator high limit alarm setpoint temperature to significantly less than actual temperature	15-Minute period passes without control system action		
176		Audible and visual alarms initiated at Operator workstation		
177		Enabled chiller statuses maintained	CS of _____	
178	Release all overrides	System returns to pre-test conditions		
Chiller (___) Evaporator Temperature Alarm Condition				
179	To observe system response to excessive heating: • Override evaporator high limit alarm setpoint temperature to significantly less than actual temperature	15-Minute period passes without control system action		
180		Audible and visual alarms initiated at Operator workstation		
181		Enabled chiller statuses maintained	CS of _____	
182	Release all overrides	System returns to pre-test conditions		
Chiller (___) General Fault Alarm Condition Design Control Sequence: Upon detection of initiation of plant activation operation mode and chiller general fault alarm, the control system shall: • Initiate visual alarm at Operator workstation • Maintain system active status				
183	To observe system response:	Visual alarm initiated at Operator workstation		

SYSTEM OPERATION				
STEP	**TEST METHOD**	**EXPECTED RESPONSE**	**COMMENTS**	**PASS/ FAIL**
184	• Initiate general fault at local control panel	System status maintained	CS of _____	
185	Release all overrides	System returns to pre-test conditions		
Chiller (___) General Fault Alarm Condition				
186	To observe system response: • Initiate general fault at local control panel	Visual alarm initiated at Operator workstation		
187		System status maintained	CS of _____	
188	Release all overrides	System returns to pre-test conditions		
Chiller (___) Failure Alarm Condition Design Control Sequence: Upon detection of initiation of plant activation operation mode and a chiller failure alarm status, the control system shall: • Continuously set next active chiller circuit equivalent to the inactive chiller with shortest runtime • Initiate audible and visual alarms at Operator workstation • Disable chiller in alarm • Enable next active chiller circuit • Maintain distribution pump statuses				
189	To prepare for system response: • Observe system status	Next active chiller circuit set	CS of _____	
190	To observe system response: • Manually turn chiller's disconnect switch to off position	Audible and visual alarms initiated at Operator workstation		
191		Chiller in alarm disabled	CS of _____	
192		Next active chiller circuit enabled	CS of _____	
193		Distribution pump statuses maintained	CS of _____	
194	Release all overrides	System returns to pre-test conditions		

SYSTEM OPERATION				
STEP	**TEST METHOD**	**EXPECTED RESPONSE**	**COMMENTS**	**PASS/ FAIL**
Distribution Pump (___) Failure Type Two Alarm Condition Design Control Sequence: Upon detection of initiation of plant activation operation mode and a distribution pump failure alarm status with one distribution pump being active, the control system shall: • Initiate audible and visual alarms at Operator workstation • Disable failed distribution pump • Initiate plant deactivation operation mode • Initiate plant activation operation mode				
195	To observe system response: • Manually turn distribution pump's disconnect switch to off position	Audible and visual alarms initiated at Operator workstation		
196		Failed distribution pump disabled	CS of _____	
197		Plant deactivation operation mode initiated	CS of _____	
198		Plant activation operation mode initiated	CS of _____	
199	Release all overrides	System returns to pre-test conditions		
Chiller (___) Opposite Status Alarm Condition Design Control Sequence: Upon detection of initiation of plant activation operation mode and status being opposite command, the control system shall: • Initiate audible and visual alarms at Operator workstation • Maintain system active status				
200	To observe system response to equipment off status: • Override system to inactive status • Manually set chiller to "off" at chiller control panel • Enable chiller at control system	Audible and visual alarms initiated at Operator workstation		
201		Equipment and system status maintained	CS of _____	
202	To observe system response to equipment on status:	Audible and visual alarms initiated at Operator workstation		

SYSTEM OPERATION				
STEP	**TEST METHOD**	**EXPECTED RESPONSE**	**COMMENTS**	**PASS/ FAIL**
203	• Maintain system inactive status • Manually set chiller to “on” at chiller control panel • Disable chiller at control system	Equipment and system status maintained	CS of _____	
204	Release selected overrides	Selected components return to pre-test conditions		
Chiller (___) Opposite Status Alarm Condition				
205	To observe system response to equipment off status:	Audible and visual alarms initiated at Operator workstation		
206	• Maintain system inactive status • Manually set chiller to “off” at chiller control panel • Enable chiller at control system	Equipment and system status maintained	CS of _____	
207	To observe system response to equipment on status:	Audible and visual alarms initiated at Operator workstation		
208	• Maintain system inactive status • Manually set chiller to “on” at chiller control panel • Disable chiller at control system	Equipment and system status maintained	CS of _____	
209	Release selected overrides	Selected components return to pre-test conditions		
Distribution Pump (___) Opposite Status Alarm Condition Design Control Sequence: Upon detection of initiation of plant activation operation mode and status being opposite command, the control system shall: • Initiate audible and visual alarms at Operator workstation • Maintain system active status				
210	To observe system response to equipment off status:	Audible and visual alarms initiated at Operator workstation		

SYSTEM OPERATION				
STEP	**TEST METHOD**	**EXPECTED RESPONSE**	**COMMENTS**	**PASS/ FAIL**
211	• Maintain system inactive status • Manually set hand-off-auto switch at adjustable frequency drive to “off” position	Equipment and system status maintained	CS of _____	
212	To observe system response to equipment on status:	Audible and visual alarms initiated at Operator workstation		
213	• Maintain system inactive status • Manually set hand-off-auto switch at adjustable frequency drive to “on” position	Equipment and system status maintained	CS of _____	
214	Release selected overrides	Selected components return to pre-test conditions		
Distribution Pump (___) Opposite Status Alarm Condition				
215	To observe system response to equipment off status:	Audible and visual alarms initiated at Operator workstation		
216	• Maintain system inactive status • Manually set hand-off-auto switch at adjustable frequency drive to “off” position	Equipment and system status maintained	CS of _____	
217	To observe system response to equipment on status:	Audible and visual alarms initiated at Operator workstation		
218	• Maintain system inactive status • Manually set hand-off-auto switch at adjustable frequency drive to “on” position	Equipment and system status maintained	CS of _____	
219	Release selected overrides	Selected components return to pre-test conditions		
Distribution Pump (___) Opposite Status Alarm Condition				
220	To observe system response to equipment off status:	Audible and visual alarms initiated at Operator workstation		

SYSTEM OPERATION				
STEP	**TEST METHOD**	**EXPECTED RESPONSE**	**COMMENTS**	**PASS/ FAIL**
221	• Maintain system inactive status • Manually set hand-off-auto switch at adjustable frequency drive to “off” position	Equipment and system status maintained	CS of _____	
222	To observe system response to equipment on status: • Maintain system inactive status • Manually set hand-off-auto switch at adjustable frequency drive to “on” position	Audible and visual alarms initiated at Operator workstation		
223	Release all overrides	System returns to pre-test conditions		

-- End of Test --