5.20.17.12. Sensor Failure:

a. Sensor shall be deemed outside of its widest possible operating range if any of the following are true:

1. Feedback less than 2 mA from any 4 to 20 mA transducer; or
2. Temperature reading less than 0°F from any temperature sensor.

b. Any sensor that goes outside of its widest possible operating range.

1. If the sensor is used for monitoring only: Level 3.
2. If the sensor is used for control: Level 2.

5.20.18. Automatic Fault Detection and Diagnostics

The Automatic Fault Detection and Diagnostics (AFDD) routines for chilled water plants continually assess plant performance by comparing the values of BAS inputs and outputs to a subset of potential fault conditions. The subset of potential fault conditions that is assessed at any point depends on the Operating State of the plant, as determined by the positions of the isolation valves and statuses of pumps. Time delays are applied to the evaluation and reporting of fault conditions, to suppress false alarms. Fault conditions that pass these filters are reported to the building operator as alarms along with a series of possible causes.

These equations assume that the plant is equipped with isolation valves, as well as a pump status monitoring. If any of these components are not present, the associated tests, and variables should be omitted from the programming.

Note that these faults rely on reasonably accurate measurement of water temperature. Extra precision sensors installed in thermowells with thermal paste are strongly recommended for best accuracy.

5.20.18.1. AFDD conditions are evaluated continuously for the plant.

5.20.18.2. The Operating State (OS) of the plant shall be defined by the commanded positions of the valves and status feedback from the pumps in accordance with the following table.

The Operating State is distinct from and should not be confused with the chilled water plant stage.

OS#1 – OS#5 represent normal operating states during which a fault may nevertheless occur if so determined by the fault condition tests below.

Edit the table below. Delete rows and columns that do not apply.

Operating State	Chiller CHW Isolation Valves (if Series Chillers)	Chiller CHW Isolation Valves or Dedicated PCHWPs (if Parallel Chillers)	Chiller CW Isolation Valves or Dedicated CWPs (if water-cooled)	CHW Pump Status	CW Pump Status (if water-cooled and headered)	WSE CHW Pump Status (if WSE with HX Pump)	WSE CHW Diverting Valve (if WSE with HX diverting valve)	WSE CW Isolation Valve (if WSE)	Chiller Bypass Valve (if primary-only or WSE)
#1: Disabled	All Open	All Closed/Off	All Closed/Off	All Off	All Off	Off	Open	Closed	Closed
#2: One Chiller Enabled	One Closed, All Others Open	One Open/On, All Others Closed/Off	One Modulating, All Others Closed/Off	Any On	Any On	Off	100% Open	Closed	Closed
#3: More than one Chiller Enabled	Both Closed	More than one Open/On	More than one modulating	Any On	Any On	Off	100% Open	Closed	Closed
#4: Waterside Economizer-only	All Open	All Closed/Off	All Closed/Off	Any On	Any On	On	< 100% Open	Open	Open
#5: Integrated Waterside Economizer	Any Open or Any Closed	Any Open/On or Any Closed/Off	Any Modulating or Any Closed/Off	Any On	Any On	On	< 100% Open	Open	Closed

5.20.18.3. The following points must be available to the AFDD routines for the chilled water plant:

Retain the following two variables for primary-secondary plants and primary-only plants where pump speed is controlled to maintain differential pressure. Delete otherwise.

a. DP = Chilled water loop differential pressure (each loop, where applicable)

b. DPSP = Chilled water loop differential pressure setpoint (each loop, where applicable)

Retain the following variable if there is a flow meter in the primary loop. Delete otherwise.

c. $FLOW_P$ = Primary chilled water flow

Retain the following variable if there is a flow meter in the secondary loop. Delete otherwise.

d. $FLOW_S$ = Secondary chilled water flow

Retain the following two variables for Primary-only chilled water plants with a minimum flow bypass valve. Delete otherwise.

e. MFBPV = Chilled water minimum flow bypass valve command; $0\% \leq MFBPV \leq 100\%$

f. CHW-MinFlowSP = Effective minimum chilled water flow setpoint (MinFlowRatio multiplied by the sum of CHW-DesFlowX of enabled chillers).

Retain the following two variables for water-cooled plants. Delete otherwise.

g. SpeedCT = Cooling tower speed command; $0\% \leq SpeedCT \leq 100\%$

h. $Status_{CWP}$ = Lead condenser water pump status

i. $Status_{PCHWP}$ = Lead primary chilled water pump status

Retain the following variable for primary-secondary plants. Delete otherwise.

j. $Status_{SCHWP}$ = Lead secondary chilled water pump status

Retain the following variable for plants with waterside economizers where CHW flow through the WSE is controlled by a variable speed HX pump. Delete otherwise.

k. $Status_{WSEHXP}$ = Waterside economizer heat exchanger pump status

l. CHWST = Common chilled water supply temperature leaving the chillers

m. CHWSTSP = Chilled water supply temperature setpoint

n. CHWRT = Common chilled water return temperature entering the chillers

Retain the following two variables for water-cooled plants. Delete otherwise.

o. CWST = Condenser water supply temperature

p. CWSTdes = Lowest condenser water supply temperature at chiller selection conditions for chillers; CWSTdes shall be the lowest CWSTdesX of all chillers

Retain the following two variables for plants with waterside economizers. Delete otherwise.

q. $CHWRT_{BeforeWSE}$ = Chilled water return temperature before the waterside economizer

r. $CHWRT_{AfterWSE}$ = Chilled water return temperature after the waterside economizer

s. $CHWST_{CH\text{-}x}$ = CH-x chilled water supply temperature (each chiller)

t. $CHWRT_{CH\text{-}x}$ = CH-x chilled water return temperature (each chiller)

Retain the following two variables for water-cooled plants. Delete otherwise.

u. CWSTCH-x = CH-x condenser water supply temperature (each chiller)

v. CWRTCH-x = CH-x condenser water return temperature (each chiller)

Retain the following two variables for plants with waterside economizers. Delete otherwise.

w. $CWRT_{HX}$ = Waterside economizer condenser water return temperature

x. DAHX = Design heat exchanger approach

y. RefrigEvapTempCH-x = CH-x refrigerant evaporating temperature (each chiller)

Retain the following variable for water-cooled plants. Delete otherwise.

z. RefrigCondTempCH-x = CH-x refrigerant condensing temperature (each chiller)

aa. CHW-ISOCH-x = CH-x chilled water isolation valve commanded position (each chiller)

Retain the following variable for water-cooled plants with headered CW pumps. Delete otherwise.

bb. CW-ISOCH-x = CH-x condenser water isolation valve commanded position; 0% ≤ CW-ISOCH-x ≤ 100% if modulating, open/closed if two-position (each chiller)

Retain the following variable for plants with waterside economizers where CHW flow through the WSE is controlled by a modulating diverting valve. Delete otherwise.

cc. WSE-HX-CHW-DIV = Waterside economizer chilled water diverting valve commanded position; 0% ≤ WSE-HX-CHW-DIV ≤ 100%

Retain the following variable for plants with waterside economizers. Delete otherwise.

dd. WSE-HX-CW-ISO = Waterside economizer condenser water isolation valve commanded position; open/closed

Retain the following variable for plants where system gauge pressure is monitored. Delete otherwise.

ee. PGAUGE = Chilled water system gauge pressure

The chiller chilled water supply temperature, chiller condenser water return temperature, refrigerant evaporating and condensing temperature points are listed as optional in 4.10.1 because they are typically networked points that are read via a chiller network interface rather than through hardwired connections. Where a chiller network interface or specific points are not available, omit the associated fault conditions.

5.20.18.4. The following values must be continuously calculated by the AFDD routines:

a. 5-minute rolling averages with 1-minute sampling time of the following point values; operator shall have the ability to adjust the averaging window and sampling period for each point independently

1. $CHWST_{AVG}$ = rolling average of the common chilled water supply temperature

2. $CHWRT_{AVG}$ = rolling average of the common chilled water return temperature

Retain the following two variables for plants with waterside economizers. Delete otherwise.

3. $CHWRT_{BEFOREWSE, AVG}$ = rolling average of the chilled water return temperature before the waterside economizer

4. $CHWRT_{AFTERWSE, AVG}$ = rolling average of the chilled water return temperature after the waterside economizer

Retain the following four variables for water-cooled plants. Delete otherwise.

5. $CWST_{AVG}$ = rolling average of the common condenser water supply temperature
6. $CWRT_{AVG}$ = rolling average of the common condenser water return temperature
7. $CWST_{CH\text{-}x, AVG}$ = rolling average of CH-x condenser water supply temperature (each chiller)
8. $CWRT_{CH\text{-}x, AVG}$ = rolling average of CH-x condenser water return temperature (each chiller)
9. $CHWST_{CH\text{-}x, AVG}$ = rolling average of CH-x chilled water supply temperature (each chiller)
10. $CHWRT_{CH\text{-}x, AVG}$ = rolling average of CH-x chilled water return temperature (each chiller)

Retain the following variable for plants with waterside economizers. Delete otherwise.

11. $CWRT_{HX, AVG}$ = rolling average of the waterside economizer heat exchanger condenser water return temperature

Retain the following variable for plants where system gauge pressure is monitored. Delete otherwise.

12. $P_{GAUGE, AVG}$ = rolling average of chilled water system gauge pressure

Retain the following variable for primary-secondary plants and primary-only plants where pump speed is controlled to maintain differential pressure. Delete otherwise.

13. DP_{AVG} = rolling average of loop differential pressure (each loop, where applicable)

Retain the following variable if there is a flow meter in the primary loop. Delete otherwise.

14. $FLOW_{P, AVG}$ = rolling average of primary chilled water flow

Retain the following variable if there is a flow meter in the secondary loop. Delete otherwise.

15. $FLOW_{S, AVG}$ = rolling average of secondary chilled water flow

Retain the following variable for water-cooled plants. Delete otherwise.

16. RefrigCondTempCH-x, AVG = rolling average of CH-x refrigerant condensing temperature (each chiller)
17. RefrigEvapTempCH-x, AVG = rolling average of CH-x refrigerant evaporating temperature (each chiller)

b. CHW-FlowCH-X (each chiller)

Retain the following section for plants with parallel chillers and headered primary chilled water pumps. Delete otherwise.

1. For plants with parallel chillers and headered primary chilled water pumps: 1 if $CHW\text{-}ISO_{CH\text{-}x} > 0$, 0 if $CHW\text{-}ISO_{CH\text{-}X} = 0$

Retain the following section for plants with parallel chillers and dedicated primary chilled water pumps. Delete otherwise.

2. For plants with parallel chillers and dedicated primary chilled water pumps: 1 if $Status_{PCHWP}$ = On, 0 if $Status_{PCHWP}$ = Off.

Retain the following section for plants with series chillers. Delete otherwise.

3. For plants with series chillers: 1 if CHW-$ISO_{CH\text{-}x}$ <100, 0 if CHW-$ISO_{CH\text{-}X}$ = 100 (each chiller)

Retain the following variable for water-cooled plants. Delete otherwise.

c. CW-FlowCH-X (each chiller)

Retain the following section for plants with headered condenser water pumps and modulating condenser water isolation valves. Delete otherwise.

1. For plants with headered condenser water pumps and if condenser water isolation valve is modulating: 1 if CW-$ISO_{CH\text{-}x}$ > 0% open, 0 if CW-$ISO_{CH\text{-}X}$ = 0% open (each chiller)

Retain the following section for plants with headered condenser water pumps and two-position condenser water isolation valves. Delete otherwise.

2. For plants with headered condenser water pumps and if condenser water isolation valve is two-position: 1 if CW-$ISO_{CH\text{-}X}$ = open, 0 if CW-$ISO_{CH\text{-}X}$ = closed (each chiller)

Retain the following section for plants with dedicated condenser water pumps. Delete otherwise.

3. For plants with dedicated condenser pumps: 1 if $Status_{CWP}$ = on, 0 if $Status_{CWP}$ = off

d. ΔOS = number of changes in Operating State during the previous 60 minutes (moving window)

e. ΔStage = number of chilled water plant stage changes during the previous 60 minutes (moving window)

f. StartsCH-x = number of CH-x starts in the last 60 mins (each chiller)

5.20.18.5. The following internal variables shall be defined. All parameters are adjustable by the operator, with initial values as given below:

The default values have been intentionally biased towards minimizing false alarms at the expense of missing real alarms. This avoids excessive false alarms that will erode user confidence and responsiveness. However, if the goal is to achieve the best possible energy performance and system operation, these values should be adjusted based on field measurement and operational experience.

Values for physical factors such as pump heat and sensor error can be measured in the field or derived from trend logs and hardware submittals. Likewise, the switch delays can be refined by observing the time required to achieve quasi steady state operation in trend data.

Other factors can be tuned by observing false positives and false negatives (i.e., unreported faults). If transient conditions or noise cause false alarms, increase the alarm delay. Likewise, failure to report real faults can be addressed by adjusting the temperature, pressure or flow thresholds.

Variable Name	Description	Default Value
ε_{CHWT}	Temperature error threshold for chilled water temperature sensors	2°F
Retain the following variable for water-cooled plants. Delete otherwise.		
ε_{CWT}	Temperature error threshold for condenser water temperature sensors	2°F
Retain the following variable for primary-secondary and primary-only plants where pump speed is controlled to maintain differential pressure. Delete otherwise.		

Variable Name	Description	Default Value
ε_{DP}	Differential pressure error threshold for DP sensor	2 psi
Retain the following variable for plants with a flow meter. Delete otherwise.		
ε_{FM}	Flow error threshold for flow meter	20 gpm
ε_{VFDSPD}	VFD speed error threshold	5%
Retain the following variable for primary-only plants with a minimum flow bypass valve. Delete otherwise.		
ε_{MFBVP}	Minimum flow bypass valve position error threshold	5%
Retain the following variable for plants where system gauge pressure is monitored. Delete otherwise.		
CHW-ETPreChargePress	Chilled water system expansion tank pre-charge pressure	See mechanical schedule (psig)
Retain the following variable for water-cooled plants. Delete otherwise.		
$Approach_{COND}$	Condenser approach threshold	4°F
$Approach_{EVAP}$	Evaporator approach threshold	3°F
$CHStarts_{MAX}$	Maximum number of chiller starts during the previous 60 minutes (moving window)	2
ΔOS_{MAX}	Maximum number of changes in Operating State during the previous 60 minutes (moving window)	2
$\Delta Stage_{MAX}$	Maximum number of chilled water plant stage changes during the previous 60 minutes (moving window)	2
StageDelay	Time in minutes to suspend Fault Condition evaluation after a change in stage	30
AlarmDelay	Time in minutes that a Fault Condition must persist before triggering an alarm	30
TestModeDelay	Time in minutes that Test Mode is enabled	120

TestModeDelay ensures that normal fault reporting occurs after the testing and commissioning process is completed as prescribed in Section 5.20.18.12.

5.20.18.6. The following are potential Fault Conditions that can be evaluated by the AFDD routines. If the equation statement is true, then the specified fault condition exists. The Fault Conditions to be evaluated at any given time will depend on the Operating State of the chilled water plant.

Edit the table below. Remove fault conditions that do not apply.

Retain the following fault condition for plants with any chilled water pumps controlled to maintain differential pressure. Delete otherwise. Duplicate the following fault condition for each differential pressure sensor.			
FC#1	**Equation**	$DP_{AVG} > \varepsilon_{DSP}$ and $Status_{CHWP} = Off$	**Applies to OS #1**
	Description	Differential pressure is too high with the chilled water pumps off	
	Possible Diagnosis	DP sensor error	
Retain the following fault condition if there is a flow meter in the primary loop. Delete otherwise.			
FC#2	**Equation**	$FLOW_{P,\ AVG} > \varepsilon_{FM}$ and $Status_{PCHWP} = Off$	**Applies to OS #1**
	Description	Primary chilled water flow is too high with the chilled water pumps off	
	Possible Diagnosis	Flow meter error	
Retain the following fault condition for primary-secondary plants with a flow meter in the secondary loop. Delete otherwise. Duplicate the following fault condition for each secondary loop flow meter.			
FC#3	**Equation**	$FLOW_{S,\ AVG} > \varepsilon_{FM}$ and $Status_{SCHWP} = Off$	**Applies to OS #1**
	Description	Secondary chilled water flow is too high with the chilled water pumps off	
	Possible Diagnosis	Flow meter error	
Retain the following fault condition for primary-secondary plants and primary-only plants where pump speed is controlled to maintain differential pressure. Delete otherwise. Duplicate the following fault condition for each differential pressure sensor and/or each secondary loop where pump speed is controlled to maintain differential pressure.			
FC#4	**Equation**	$DP_{AVG} < DPSP - \varepsilon_{DP}$ and $Speed_{CHWP} \geq 99\% - \varepsilon_{VFDSPD}$	**Applies to OS #2 – #5**
	Description	Chilled water loop differential pressure is too low with chilled water pump(s) at full speed.	
	Possible Diagnosis	Problem with VFD Mechanical problem with pump(s) Pump(s) are undersized Differential pressure setpoint is too high CHWST is too high Primary flow is higher than the design evaporator flow of the operating chillers	

Retain the following fault condition for primary-only plants with a minimum flow bypass valve. Delete otherwise.			
FC#5	**Equation**	$FLOW_{P,\ AVG} < \text{CHW-MinFlowSp} - \varepsilon_{FM}$ and $MFBPV \geq 99\% - \varepsilon_{MFBPV}$	**Applies to OS #2, #3, #5**
	Description	Primary chilled water flow is too low with the minimum flow bypass valve fully open.	
	Possible Diagnosis	Problem with minimum flow bypass valve Problem with chiller CHW isolation valves Minimum loop differential pressure setpoint too low	
FC#6	**Equation**	$CHWST_{AVG} - \varepsilon_{CHWT} \geq CHWSTSP$	**Applies to OS #2 – #5**
	Description	Chilled water supply temperature is too high	
	Possible Diagnosis	Mechanical problem with chillers Primary flow is higher than the design evaporator flow of the operating chillers	
Retain the following fault condition for plants where system gauge pressure is monitored. Delete otherwise.			
FC#7	**Equation**	$\text{CHW-P}_{GAUGE,\ AVG} < 0.9 * \text{CHW-ETPreChargePress}$	**Applies to OS #1 – #5**
	Description	Chilled water system gauge pressure is too low	
	Possible Diagnosis	Possible chilled water system leak	
Retain the following fault condition for water-cooled plants with chiller network interfaces. Delete otherwise.			
FC#8	**Equation**	$Approach_{COND} \geq RefrigCondTemp_{CH\text{-}x,\ AVG} - CWRT_{CH\text{-}x,\ AVG}$	**Applies to OS #2, #3, #5**
	Description	Condenser approach is too high	
	Possible Diagnosis	Possible condenser fouling or blocked condenser tubes Low condenser water temperature Low condenser water flow	
Retain the following fault condition for plants with chiller network interfaces. Delete otherwise.			
FC#9	**Equation**	$Approach_{EVAP} \geq CHWST_{CH\text{-}x,\ AVG} - RefrigEvapTemp_{CH\text{-}x,\ AVG}$	**Applies to OS #2, #3, #5**
	Description	Evaporator approach is too high	
	Possible Diagnosis	Possible evaporator fouling or blocked evaporator tubes Low refrigeration charge Contaminated refrigeration charge	

Retain the following fault condition for parallel chilled water plants with chiller network interfaces. Delete otherwise.			
FC#10	**Equation**	$\lvert (\sum(\text{CHW-Flow}_{CH\text{-}X} * \text{CHWST}_{CH\text{-}X}) / \sum\text{CHW-Flow}_{CH\text{-}X}) - \text{CHWST}_{AVG} \rvert > \varepsilon_{CHWT}$ and $\sum\text{CHW-Flow}_{CH\text{-}X} = 1$	**Applies to OS #2, #5**
	Description	Deviation between the active chiller chilled water supply temperature and the common chilled water supply temperature is too high.	
	Possible Diagnosis	A chilled water supply temperature sensor is out of calibration	
Retain the following fault condition for parallel chilled water plants with chiller network interfaces. Delete otherwise.			
FC#11	**Equation**	$\lvert (\sum(\text{CHW-Flow}_{CH\text{-}X} * \text{CHWRT}_{CH\text{-}X}) / \sum\text{CHW-Flow}_{CH\text{-}X}) - \text{CHWRT}_{AVG} \rvert > \varepsilon_{CHWT}$ and $\sum\text{CHW-Flow}_{CH\text{-}X} = 1$	**Applies to OS #2, #5**
	Description	Deviation between the active chiller chilled water return temperature and the common chilled water return temperature is too high.	
	Possible Diagnosis	A chilled water return temperature sensor is out of calibration	
Retain the following two fault conditions for water-cooled plants with chiller network interfaces. Delete otherwise.			
FC#12	**Equation**	$\lvert (\sum(\text{CW-Flow}_{CH\text{-}X} * \text{CWST}_{CH\text{-}X}) / \sum\text{CW-Flow}_{CH\text{-}X}) - \text{CWST}_{AVG} \rvert > \varepsilon_{CWT}$ and $\sum\text{CW-Flow}_{CH\text{-}X} = 1$	**Applies to OS #2**
	Description	Deviation between the active chiller condenser water supply temperature and the common condenser water supply temperature is too high.	
	Possible Diagnosis	A condenser water supply temperature sensor is out of calibration	
FC#13	**Equation**	$\lvert (\sum(\text{CW-Flow}_{CH\text{-}X} * \text{CWRT}_{CH\text{-}X}) / \sum\text{CW-Flow}_{CH\text{-}X}) - \text{CWRT}_{AVG} \rvert > \varepsilon_{CWT}$ and $\sum\text{CW-Flow}_{CH\text{-}X} = 1$	**Applies to OS #2**
	Description	Deviation between the active chiller condenser water return temperature and the common condenser water return temperature is too high.	
	Possible Diagnosis	A condenser water return temperature sensor is out of calibration	
Retain the following fault condition for water-cooled plants. Delete otherwise.			

FC#14	**Equation**	$CWST_{AVG} - \varepsilon_{CWT} \geq DesCWSTdes$ and $SpeedCT \geq 99\% - \varepsilon_{VFDSPD}$	**Applies to OS #2, #3**
	Description	Condenser water supply temperature is too high with cooling tower(s) at full speed.	
	Possible Diagnosis	Problem with cooling tower VFD Mechanical problem with cooling tower(s) Cooling tower(s) undersized	
Retain the following three fault conditions for plants with a waterside economizer. Delete otherwise.			
FC#15	**Equation**	$\lvert CWRT_{HX, AVG} - CWRT_{AVG} \rvert > \varepsilon_{CWT}$ and $\sum CW\text{-}Flow_{CH\text{-}X} = 0$ and WSE-HX-CW-ISO = 1	**Applies to OS #4**
	Description	Deviation between the active waterside economizer condenser water return temperature and the common condenser water return temperature is too high.	
	Possible Diagnosis	A condenser water return temperature sensor is out of calibration	
FC#16	**Equation**	$CWST_{AVG} - CHWRT_{AFTERWSE, AVG} > (1.5 * DA_{HX}) + \varepsilon_{CHWRT}$	**Applies to OS #4, #5**
	Description	Heat exchanger approach is high	
	Possible Diagnosis	Possible heat exchanger fouling or blocked heat exchanger tubes	
FC#17	**Equation**	$\lvert CHWRTBeforeWSE - CHWRTAfterWSE \rvert > \varepsilon_{CHWT}$ and $Status_{WSE\text{-}HX\text{-}P}$ = Off (if HX Pump) or WSE-HX-CHW-DIV = 100% (if diverting valve)	**Applies to OS #4, #5**
	Description	Deviation between the chilled water return temperature before and after the waterside economizer is too high.	
	Possible Diagnosis	A chilled water return temperature sensor is out of calibration	
FC#18	**Equation**	$\Delta OS > \Delta OS_{MAX}$	**Applies to OS #1 – #5**
	Description	Too many changes in Operating State	
	Possible Diagnosis	Unstable control due to poorly tuned loop or mechanical problem	
FC#19	**Equation**	$\Delta StartsCH\text{-}x > \Delta CHStart_{MAX}$	**Applies to OS #2, #3, #5**
	Description	Too many chiller starts	
	Possible Diagnosis	Chiller is cycling due to load loads. Chiller is oversized and/or has insufficient turndown capability. Chiller stage-up threshold may be set too low.	
FC#20	**Equation**	$\Delta Stage > \Delta Stage_{MAX}$	**Applies to OS #1 – #5**
	Description	Too many stage changes	
	Possible Diagnosis	Staging thresholds and/or delays need to be adjusted	

5.20.18.7. A subset of all potential fault conditions is evaluated by the AFDD routines. The set of applicable fault conditions depends on the Operating State of the plant:

Edit the list of operating states and associated fault conditions to match those in the operating state and fault condition tables above.

a. In OS #1 (Disabled), the following Fault Conditions shall be evaluated:

1. FC#1: Differential pressure is too high with the chilled water pumps off
2. FC#2: Primary chilled water flow is too high with the primary chilled water pumps off
3. FC#3: Secondary chilled water flow is too high with the secondary chilled water pumps off
4. FC#7: Chilled water system gauge pressure is too low
5. FC#18: Too many changes in operating state
6. FC#20: Too many stage changes

b. In OS#2 (One chiller enabled without WSE), the following Fault Conditions shall be evaluated:

1. FC#4: Chilled water loop differential pressure is too low with chilled water pump(s) at full speed.
2. FC#5: Primary chilled water flow is too low with the minimum flow bypass valve fully open.
3. FC#6: Chilled water supply temperature is too high
4. FC#7: Chilled water system gauge pressure is too low
5. FC#8: Condenser approach is too high
6. FC#9: Evaporator approach is too high
7. FC#10: A chilled water supply temperature sensor is out of calibration
8. FC#11: A chilled water return temperature sensor is out of calibration
9. FC#12: A condenser water supply temperature sensor is out of calibration
10. FC#13: A condenser water return temperature sensor is out of calibration
11. FC#14: Condenser water supply temperature is too high with cooling tower(s) at full speed
12. FC#18: Too many changes in Operating State
13. FC#19: Too many chiller starts
14. FC#20: Too many stage changes

c. In OS#3 (More than one chiller enabled), the following Fault Conditions shall be evaluated:

1. FC#4: Chilled water loop differential pressure is too low with chilled water pump(s) at full speed.
2. FC#5: Primary chilled water flow is too low with the minimum flow bypass valve fully open.
3. FC#6: Chilled water supply temperature is too high