

Table 9.2.8-4—Safety Chilled Water System Failure Analysis
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Component	Component Function	Failure Mode	Failure Mechanism	Failure Symptoms/Effect	Can SCWS Satisfy Mission Success Criteria? Notes (1), (2), (3), (4)
SCWS 30QKA	Supply Chilled Water to User Exchangers	Passive failure, leak > makeup can handle	Mechanical	System pressure falls below minimum requirement.	<p>Yes. If SCWS Train 1 is out for maintenance (see Note 3 typical) and a failure occurs in Train 2, there is a second SCWS cross-tied pair Trains 3 & 4 that serves its associated user exchangers. Cooling function remains for Div 3 and 4.</p> <p>Yes. If SCWS Train 1 is out for maintenance and a failure occurs in Train 4, Train 2 would remain supplying Div 1 and 2 user exchangers. Cooling function remains for Div 1 and 2.</p> <p>Train 3 can be administratively operated in independent division operation. Shut down 4. If this is performed along with the above, cooling function remains for Div 1, 2, and 3.</p>
SCWS Expansion Tank 30QKA10/20/30/40 BB101	Maintains pressure in the system.	Tank diaphragm fails to maintain system pressure or loss of nitrogen pressure	Mechanical/I&C	System pressure falls below minimum requirement.	<p>YES. For cross-tie operation, two expansion tanks are inter-connected by the cross-tie. Each expansion tank serves two SCWS divisions. If SCWS Train 1 is out for maintenance and a failure occurs in Train 2 tank, there is a second SCWS cross-tied pair Trains 3 & 4 that serves its associated user exchangers. Cooling function remains for Div 3 and 4.</p> <p>YES. For cross-tie operation, two expansion tanks are inter-connected by the cross-tie. Each expansion tank serves two SCWS divisions. If SCWS Train 1 is out for maintenance and a failure occurs in Train 4 tank, cooling function remains for Div 1 and 2 served by Train 2 tank and cooling function remains for Div 3 and 4 served by Train 3 tank.</p> <p>Train 3 can be administratively operated in independent division operation. Shut down 4. If this is performed along with the above, cooling function remains for Div 1, 2, and 3.</p>
SCWS Pump 30QKA10/20/30/40 AP107/108	Provides flow of water to each user.	Pump fails during normal operation	Mechanical, Electrical, I&C	Loss of chilled water flow to the users.	<p>Yes. If SCWS Train 1 is out for maintenance, and failure of one pump in Train 2 occurs, there is a second SCWS cross-tied pair 3 & 4 that serves its associated user exchangers. Cooling function remains for Div 3 and 4.</p> <p>Train 2 can be administratively operated with one remaining pump in independent division operation. If this is performed along with the above, cooling function remains for Div 2, 3 and 4. Note (5)</p> <p>Yes. If SCWS Train 1 is out for maintenance and failure of one pump in Train 4 occurs, start standby Train 3 SCWS which will continue to supply both Div 3 and 4. There is a second SCWS cross-tied pair 1 & 2 with SCWS Train 2 operating that serves Div 1 & 2 user exchangers. Cooling function remains for Div 1, 2, 3 and 4.</p>
SCWS Air Cooled Chiller 30QKA10/40 AH112 Note (6)	Transfers heat from the SCWS water to the refrigerant then transfers heat from the refrigerant to the air flow which is the heat sink for SCWS 1 and 4.	Chiller fails during normal operation.	Mechanical, Electrical, I&C	Loss of ability to provide chilled water at design temperature.	<p>Yes. If SCWS Train 1 is out for maintenance, and failure of the chiller in Train 2 occurs, there is a second SCWS cross-tied pair 3 & 4 that serves its associated user exchangers. Cooling function remains for Div 3 and 4. Note (7)</p> <p>Yes. If SCWS Train 1 is out for maintenance and failure of the chiller in Train 4 occurs, start standby Train 3 SCWS which will continue to supply both Div 3 and 4. There is a second SCWS cross-tied pair 1 & 2 with SCWS Train 2 operating that serves Div 1 & 2 user exchangers. Cooling function remains for Div 1, 2, 3 and 4</p>

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Component	Component Function	Failure Mode	Failure Mechanism	Failure Symptoms/Effect	Can SCWS Satisfy Mission Success Criteria? Notes (1), (2), (3), (4)
SCWS Ventilation Equipment for Air Cooled Chiller 30QKA10/40	Transfer heat from SCWS 1 and 4 to Outside Air	Ventilation fails during normal operation	Mechanical, Electrical, I&C	Loss of ability to provide chilled water at design temperature.	Yes. Bounded by the above two items for the SCWS air cooled chiller.
SCWS Water Cooled Chiller 30QKA20/30 AH112 Note (6)	Transfers heat from the SCWS water to the refrigerant then transfers heat from the refrigerant to Component Cooling Water System (CCWS) which is the heat sink for SCWS 2 and 3.	Chiller fails during normal operation.	Mechanical, Electrical, I&C	Loss of ability to provide chilled water at design temperature.	Yes. If SCWS Train 1 is out for maintenance, and failure of the chiller in Train 2 occurs, there is a second SCWS cross-tied pair 3 & 4 that serves its associated user exchangers. Cooling function remains for Div 3 and 4. Note (7) Loss of Division 2 of CCWS is equivalent to this case.
					Yes. If SCWS Train 1 is out for maintenance and failure of the chiller in Train 3 occurs, start standby Train 4 SCWS which will continue to supply both Div 3 and 4. There is a second SCWS cross-tied pair 1 & 2 with SCWS Train 2 operating that serves Div 1 & 2 user exchangers. Cooling function remains for Div 1, 2, 3 and 4. Loss of Division 3 of CCWS is equivalent to this case.
Bypass Control Valve 30QKA10/20/30/40 AA101	Prevents freezing of the evaporator tubes.	Does not modulate to desired position	Mechanical, Electrical, I&C	Freezing the evaporator tubes	Yes. If SCWS Train 1 is out for maintenance and failure occurs in Train 2 bypass valve, there is a second SCWS cross-tied pair 3 & 4 that serves its associated user exchangers. Cooling function remains for Div 3 and 4. Note (8)
					Yes, If SCWS Train 1 is out for maintenance and a failure occurs in Train 4 bypass valve, switch to the standby Train 3 in cross-tied pair 3 & 4. Train 2 would remain supplying Div 1 and 2 user exchangers. Cooling function remains for Div 1, 2, 3 and 4. Note (8)
				Valve inadvertently opens, bypassing too much flow. Either the operational division valve or stand-by division valve in each pair.	Yes. If SCWS Train 1 is out for maintenance and a failure occurs in Train 2 bypass valve, there is a second SCWS cross-tie pair 3 & 4 that serves its associated user exchangers. Cooling function remains for Div 3 and 4. Yes, If SCWS Train 1 is out for maintenance and a failure occurs in Train 4 bypass valve, train 2 would remain supplying Div 1 and 2 user exchangers. Cooling function remains for Div 1 and 2. Train 3 can be administratively operated in independent division operation. Shut down 4. If this is performed along with the above, cooling function remains for Div 1, 2 and 3.

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Component	Component Function	Failure Mode	Failure Mechanism	Failure Symptoms/Effect	Can SCWS Satisfy Mission Success Criteria? Notes (1), (2), (3), (4)
Flow Control Valve for 30SAC01/02/03/04 AC001 Valve # 30QKC10/20/30/40 AA101	Controls flow through the HVAC cooling coil 30SAC01/02/03/04 AC001.	Does not modulate to desired position	Mechanical, Electrical, I&C	Loss of control of chilled water flow for the affected SAC exchanger in one division.	<p>Yes. If SCWS Train 1 is out for maintenance and a failure occurs in Train 2 flow control valve, there is a second SCWS cross-tie pair 3 & 4 that serves its associated user exchangers. Cooling function remains for Div 3 and 4.</p> <p>If the maintenance in SCWS Train 1 does not affect the Train 1 flow control valve 30QKC10AA101, cooling function remains for Div 1, 3 and 4.</p> <p>Yes, If SCWS Train 1 is out for maintenance and a failure occurs in Train 4 flow control valve, train 2 would remain supplying Div 1 and 2 user exchangers. Cooling function remains for Div 1 and 2.</p> <p>If failure of the Train 4 flow control valve 30QKC40AA101 does not affect overall SCWS operation, cooling function remains for Div 1, 2, 3 and 4 except for the affected SAC user exchanger.</p> <p>If failure of the Train 4 flow control valve 30QK40AA101 affects overall SCWS operation, Train 3 can be administratively operated in independent division operation. Shut down 4. If this is performed along with the above, cooling remains for Div 1, 2 and 3.</p>
Flow Control Valve for 30SAB01/02/03/04 AC001 Valve # 30QKB10/20/30/40 AA101	Controls flow through the HVAC cooling coil 30SAB01/02/03/04 AC001.	Does not modulate to desired position	Mechanical, Electrical, I&C	Loss of control of chilled water flow for the affected SAB exchanger in one SAB train.	<p>Yes. If SCWS Train 1 is out for maintenance and a failure occurs in Train 2 flow control valve, there is a second SCWS cross-tie pair 3 & 4 that serves its associated user exchangers. Cooling function remains for Div 3 and 4.</p> <p>If the maintenance in SCWS Train 1 does not affect the Train 1 flow control valve 30QKB10AA101, cooling function remains for Div 1, 2 and 4.</p> <p>Yes, If SCWS Train 1 is out for maintenance and a failure occurs in Train 4 flow control valve, train 2 would remain supplying Div 1 and 2 user exchangers. Cooling function remains for Div 1 and 2.</p> <p>If failure of the Train 4 flow control valve 30QKB40AA101 does not affect overall SCWS operation, cooling function remains for Div 1, 2, 3 and 4 except for the affected user exchanger.</p> <p>If failure of the Train 4 flow control valve 30QKB40AA101 affects overall SCWS operation, Train 3 can be administratively operated in independent division operation. Shut down 4. If this is performed along with the above, cooling function remains for Div 1, 2 and 3.</p>
Flow Control Valve for LHSI Pump Seal Cooler Valve # 30QKA10/40 AA025	Controls flow through the LHSI pump seal cooler.	Does not open.	Mechanical, Electrical, I&C	Loss of chilled water flow for the affected LHSI pump in one division.	<p>Yes, If SCWS Train 1 is out for maintenance and a failure occurs in Train 4 flow control valve, there are two CCWS divisions that serve LHSI pumps 2 & 3. Shutdown Div 4 LHSI pump. Div 1 and Div 2 user exchangers continue to be supplied from cross-tied pair 1 & 2 supplied by SCWS Train 2. Continue to operate cross-tied pair 3 and 4. Cooling function remains for Div 1, 2 and 3 LHSI pumps. For other user exchangers, cooling function remains for Div 1, 2, 3 and 4.</p>

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Component	Component Function	Failure Mode	Failure Mechanism	Failure Symptoms/Effect	Can SCWS Satisfy Mission Success Criteria? Notes (1), (2), (3), (4)
Cross-tie Valves 30QKA10/20/30/ 40AA102	Connect supply side of SCWS Div 1 to Div 2 and Div 3 to Div 4.	Fail open	Mechanical, Electrical, I&C	Prevents independent divisional operation which requires cross-tie valves to be closed.	Yes, the associated cross-tie valve in the divisional pair, which is in series with the affected valve, remains closed. No effect on cooling function.
		Fail closed	Mechanical, Electrical, I&C	Prevents cross-tie operation which requires cross-tie valves to be open.	Yes. If SCWS Train 1 is out for maintenance and a cross-tie valve fails closed in Train 2, there is a second SCWS cross-tie pair 3 & 4 that serves its associated user exchangers. Cooling function remains for Div 3 and 4. Train 2 can be administratively operated in independent division operation. If this is performed along with the above, cooling function remains for Div 2, 3 and 4.
					Yes. If SCWS Train 1 is out for maintenance and a cross-tie valve fails closed in Train 4, there is a second SCWS cross-tie pair 1 & 2 that serves its associated user exchangers. Cooling function remains for Div 1 and 2. Trains 3 and 4 can be administratively operated in independent division operation. If this is performed along with the above, cooling function remains for Div 1, 2, 3 and 4.
Cross-tie Valves 30QKA10/20/30/ 40AA103	Connect return side of SCWS Div 1 to Div 2 and Div 3 to Div 4	Fail open	Mechanical, Electrical, I&C	Prevents independent divisional operation which requires cross-tie valves to be closed.	Yes, the associated cross-tie valve in the divisional pair, which is in series with the affected valve, remains closed. No effect on cooling function.
		Fail closed	Mechanical, Electrical, I&C	Prevents cross-tie operation which requires cross-tie valves to be open.	Yes. If SCWS Train 1 is out for maintenance and a cross-tie valve fails closed in Train 2, there is a second SCWS cross-tie pair 3 & 4 that serves its associated user exchangers. Cooling function remains for Div 3 and 4. Train 2 can be administratively operated in independent division operation. If this is performed along with the above, cooling function remains for Div 2, 3 and 4.
					Yes. If SCWS Train 1 is out for maintenance and a cross-tie valve fails closed in Train 4, there is a second SCWS cross-tie pair 1 & 2 that serves its associated user exchangers. Cooling function remains for Div 1 and 2 Trains 3 and 4 can be administratively operated in independent division operation. If this is performed along with the above, cooling function remains for Div 1, 2, 3 and 4.
SAC HVAC Cooling Coils	Heat transfer via SCWS.	Clogged tubes/ structural degradation/ tube rupture	Mechanical	Loss of heat transfer capabilities.	YES. Bounded by passive failure indicated in first item of this table.
SAB HVAC Cooling Coils	Heat transfer via SCWS.	Clogged tubes/ structural degradation/ tube rupture	Mechanical	Loss of heat transfer capabilities.	YES. Bounded by passive failure indicated in first item of this table.
KLC HVAC Cooling Coils	Heat transfer via SCWS.	Clogged tubes/ structural degradation/ tube rupture	Mechanical	Loss of heat transfer capabilities.	YES. Bounded by passive failure indicated in first item of this table.
KLL HVAC Cooling Coils	Heat transfer via SCWS.	Clogged tubes/ structural degradation/ tube rupture	Mechanical	Loss of heat transfer capabilities.	YES. Bounded by passive failure indicated in first item of this table.

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Component	Component Function	Failure Mode	Failure Mechanism	Failure Symptoms/Effect	Can SCWS Satisfy Mission Success Criteria? Notes (1), (2), (3), (4)
LHSI Pump Motor and Seal Coolers 30JNG10/40 AP001	Heat transfer via SCWS.	Clogged tubes/ structural degradation/ tube rupture	Mechanical	Loss of heat transfer capabilities. For LHSI pump seal cooler, tube rupture could result in contamination of SCWS.	YES. Bounded by passive failure indicated in first item of this table.

Notes:

1. This analysis considers safety chilled water system (SCWS) with loss of off-site power (LOOP) and one SCWS train unavailable due to maintenance with normal cross-tie operation.
2. Mission success requires, for all modes of operation, that SCWS supply chilled water to two divisions of SAC, SAB, and KLC; one division of KLL; and along with component cooling water system, supply two LHSI pumps motor and seal cooler.
3. One SCWS train is assumed to be out for maintenance with the following components out of service: SCWS chiller unit and/or two pumps.
4. SCWS Trains 1 and 4 are essentially identical. SCWS Trains 2 and 3 are essentially identical. The chilled water circuits of all four SCWS trains are essentially identical except for the HVAC user exchangers served. Therefore, this analysis will identify the identical components in the “Component” column and populate the table once.
5. In cross-tie operation two pumps in the operating train of each divisional pair provides flow to two divisions. One pump in independent division operation provides flow to its division.
6. The chiller unit for each SCWS train includes the condenser, evaporator, compressors, and other refrigerant system components.
7. If there is a failure of one of the four 25 percent compressors in a specific train, the cross-tied configuration can switch to the standby train in each divisional pair. Either Division 1 or 2 is capable of providing the design capacity for both Divisions 1 and 2. Either Division 3 or 4 is capable of providing the design capacity for both Divisions 3 and 4.
8. In cross-tie operation the SCWS bypass valve in the operating train of each divisional pair provides the bypass function. The bypass valve in the standby division of each pair is closed.