

# General Insights from Analysis of Common-Cause Failure Data at U.S. Nuclear Power Plants

## 1997–2012

The common-cause failure (CCF) study uses operating experience to characterize the frequency and nature of component failure data from operating U.S. commercial nuclear power plants. The evaluation is based on the operating experience from 1997 through 2012. The data sources for this report include:

- License Event Reports (LERs), 1997 to 2012
- Equipment Performance and Information Exchange (EPIX), 1997 to 2012

The CCF database is a rich source of information on various aspects of CCF. Exploring the full potential of the database merits a dedicated activity and is outside the scope of the current effort, which has focused on building the infrastructure for such analyses. Nevertheless, some general observations have been made on the character of CCF events, including their causes and shared cause factors, and frequency of occurrence. Some of these insights are summarized in this section.

[Table 1](#) lists the systems and component types for which CCF events have been collected and entered into the database. The events are further classified by failure modes (e.g., pump fails to start, valve fails to open).

Basic information about the nature of CCF events is displayed in [Figure 1](#) and [Figure 2](#). These figures illustrate the distribution of CCF event proximate causes and coupling factors, respectively. This information provides a general picture of the types of events that may be expected to occur, and what design features might be most susceptible to CCF events. These figures also illustrate the different characteristics of partial CCF events and complete CCF events (events with timing factor, shared cause factor, and component degradation values for each component in the common-cause component group (CCCG) = 1.0). [Figure 3](#) and [Figure 4](#) display the number of CCF events by year of occurrence. [Figure 5](#) and [Figure 6](#) show the distribution of CCF events by system. [Figure 7](#) and [Figure 8](#) show the distribution of CCF events by component.

A general review of the actual events and the distributions provided in [Figure 1](#) and [Figure 2](#) reveals the following insights regarding CCF events:

- Human errors related to procedures caused a small percentage of the total events, but the impact of the individual events is usually greater, since human errors have overridden the programmatic controls. This is illustrated by comparing [Figure 1](#), the All CCF events case with the Complete CCF events case, which shows that human error causes a larger portion of complete CCF events than all CCF events. The examples of events caused by human error are all EDG day tanks simultaneously drained for chemistry surveillance, and two pump breakers racked out as the plant changed modes from shutdown to power.
- A vast majority of All CCF events are not due to multiple failures in response to an operational demand, but result from a “condition of equipment.” The most common is inspection or surveillance test of one component revealing a deficiency that prompts the licensee to inspect/test the redundant component, resulting in the discovery that the same

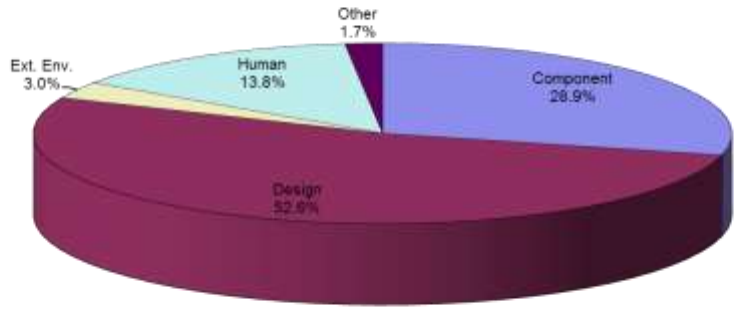
defective condition exists on both components. This demonstrates that detection of failures during the testing and surveillance program prevents CCF events from occurring during actual demand situations.

- A major contributor to CCF events is programmatic maintenance practices. The frequency of scheduling has been a factor in the numerous wear-caused and aging-caused events. Additionally, the quality of the maintenance, both in the procedures and in performance of the maintenance activities, is an essential factor. Similar events have occurred at different plants—lubrication of circuit breakers (too much, too little, or too long between lubrications), improperly set torque and limit switches on MOVs that are reported as misadjustments and not setpoint drift. This indicates that there are maintenance practices that need to be reviewed to reduce CCF potential. However, the maintenance issue generally does not cause complete CCF events.
- Among complete CCF events, design problems are an important contributor. Many of the design-related events resulted from a design modification, indicating that perhaps the modification review processes were not rigorous and resulted in CCF susceptibilities.
- The CCF database contains several examples where both CCF and independent events recur at some, but not all, plants, perhaps indicating ineffective root cause analysis and corrective action. Examples of repeated events are water in compressed air systems, pump seal wear-out, and turbine governor misadjustments. Additionally, not all plants experience the same type of recurring event. This indicates that plant-to-plant variability exists in the CCF parameters that might cause the CCF parameter estimates for some plants to be higher than the industry average, for some component and system combinations. Thus, it is very important to perform plant-specific CCF parameter estimations for plant-specific PRAs and reliability studies.
- The trends show that All CCF events and Complete CCF events have been decreasing with time.

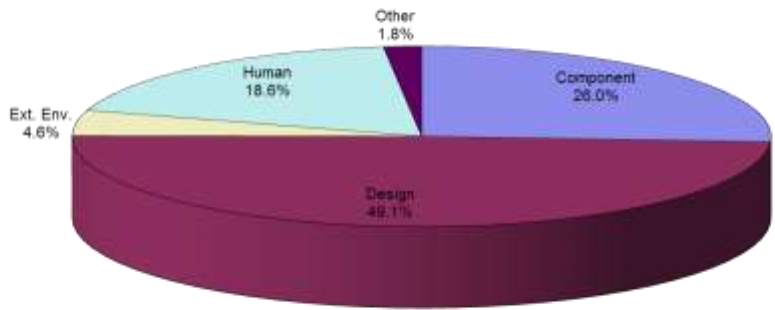
With respect to quantification of CCFs, the overall conclusion is that, based on the evaluation of over 20 years of operating experience data, CCF parameters for similar components vary among systems and failure modes. In addition, the CCF failure parameters have decreased over time.

**Table 1. Component types and systems analyzed for CCF events (1997–2012).**

<b>Component Type</b>	<b>System</b>	<b>Component Type</b>	<b>System</b>
Air Operated Valve	Auxiliary feedwater	Motor Driven Pump	Auxiliary feedwater
	High pressure injection		Chemical and volume control
	Isolation condenser		Component cooling water
	Main feedwater		Containment spray recirculation
	Main steam		High pressure injection
	Residual Heat Removal (LCI in BWRs; LPI in PWRs)		Main feedwater
Battery	dc power	Motor Driven Pump	Normally operating service water
Battery Charger	dc power		Residual Heat Removal (LCI in BWRs; LPI in PWRs)
Check Valve	Auxiliary feedwater	Motor Operated Valve	Standby liquid control
	Containment spray recirculation		Standby service water
	Normally operating service water		Auxiliary feedwater
	Reactor core isolation		High pressure injection
	Residual Heat Removal (LCI in BWRs; LPI in PWRs)		Low pressure core spray
			Reactor core isolation
Circuit Breaker	Plant ac power	Power Operated Relief Valve	Residual Heat Removal (LCI in BWRs; LPI in PWRs)
	Reactor protection		Main steam
Compressor	Instrument air	Safety Relief Valve (Dual Actuation)	Reactor coolant
Generator	Emergency power supply		Safety Valve (Single Acting)
Heat Exchanger	Component cooling water	Strainer	Main steam
Hydraulic Operated Valve	Auxiliary feedwater		Circulating water system
	Residual Heat Removal (LCI in BWRs; LPI in PWRs)	Normally operating service water	
Low Capacity Relief Valve	Chemical and volume control	Turbine Driven Pump	Standby service water
	Component cooling water		Auxiliary feedwater
	Normally operating service water	Reactor core isolation	
	Residual Heat Removal (LCI in BWRs; LPI in PWRs)	Vacuum Breaker	
Main Steam Stop Valve	Main steam		Vapor suppression

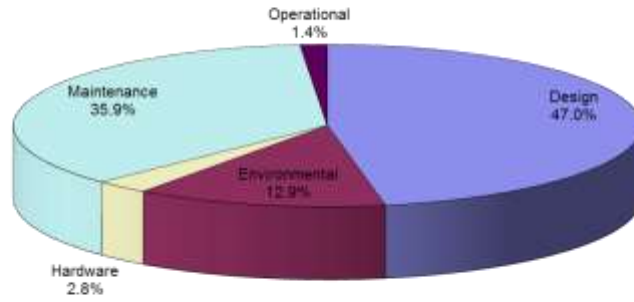


Distribution of causes of only the complete CCF events.

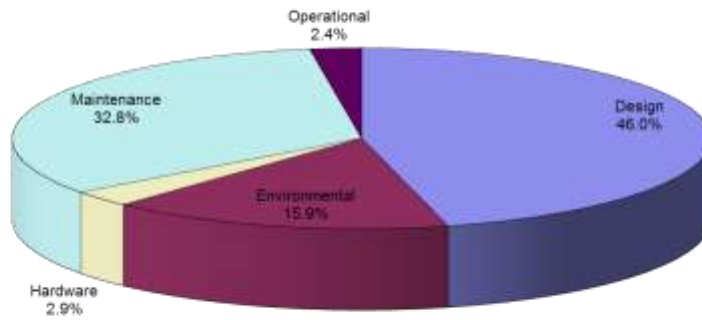


Distribution of causes of complete and partial CCF events

**Figure 1. Distribution of CCF events by proximate cause.**

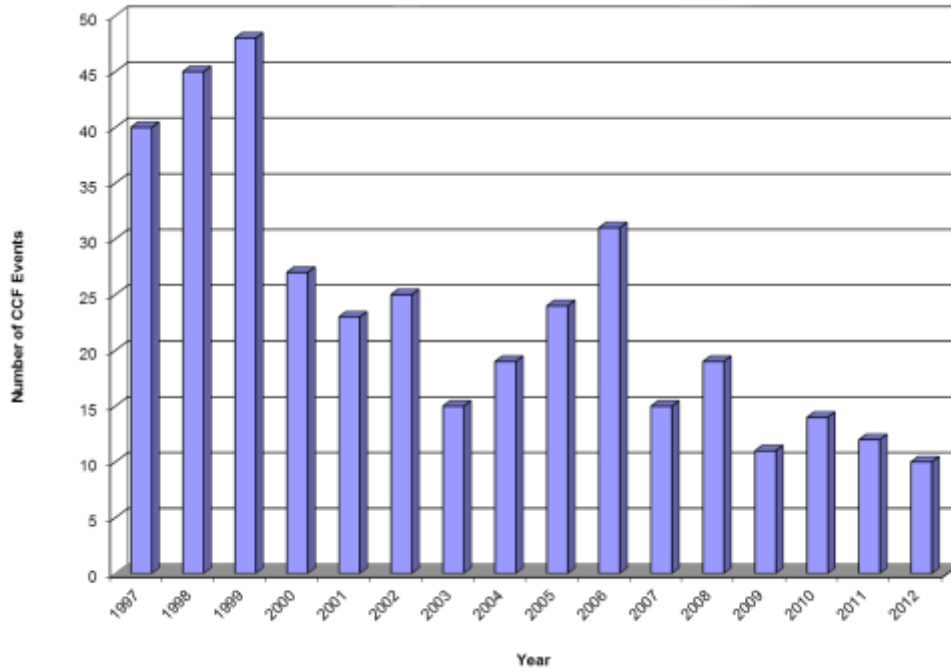


Distribution of coupling factors for only the complete CCF events.

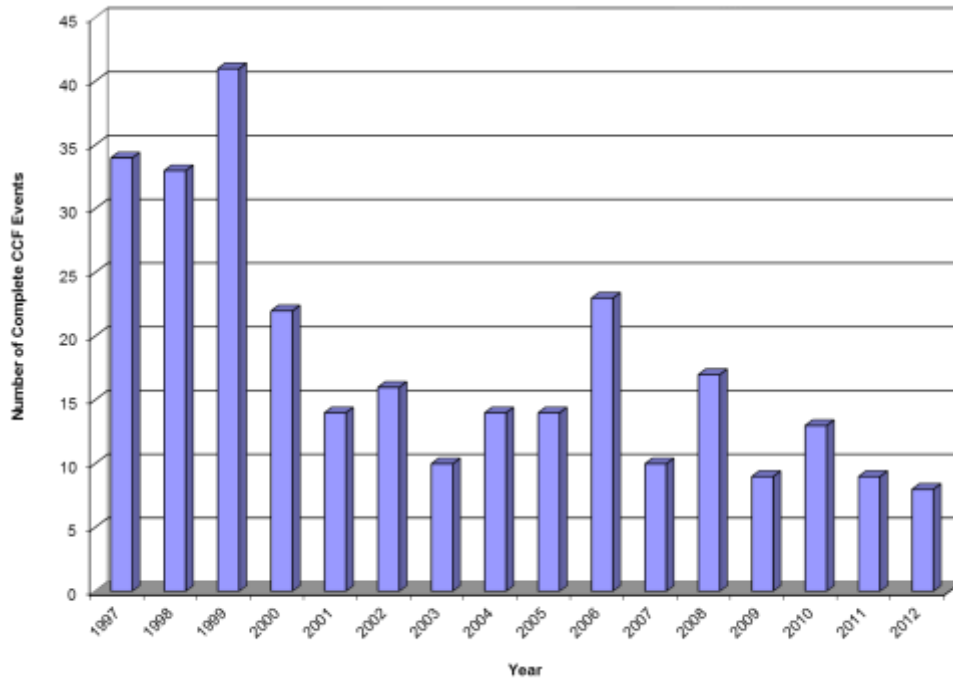


Distribution of coupling factors for both complete and partial events.

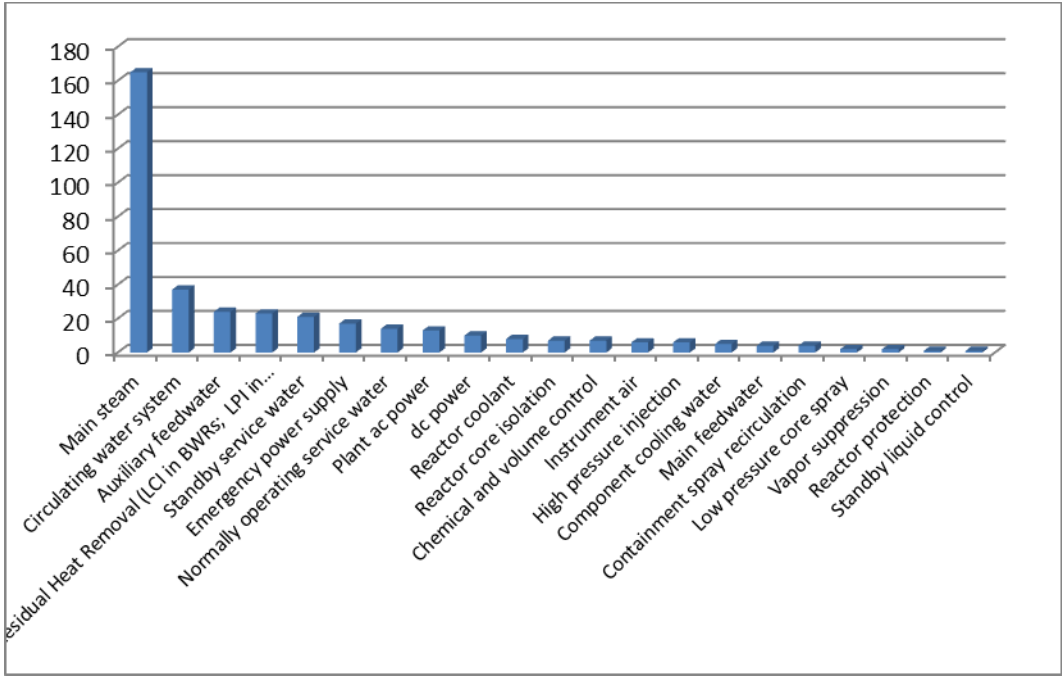
**Figure 2 Distribution of CCF events by coupling factor.**



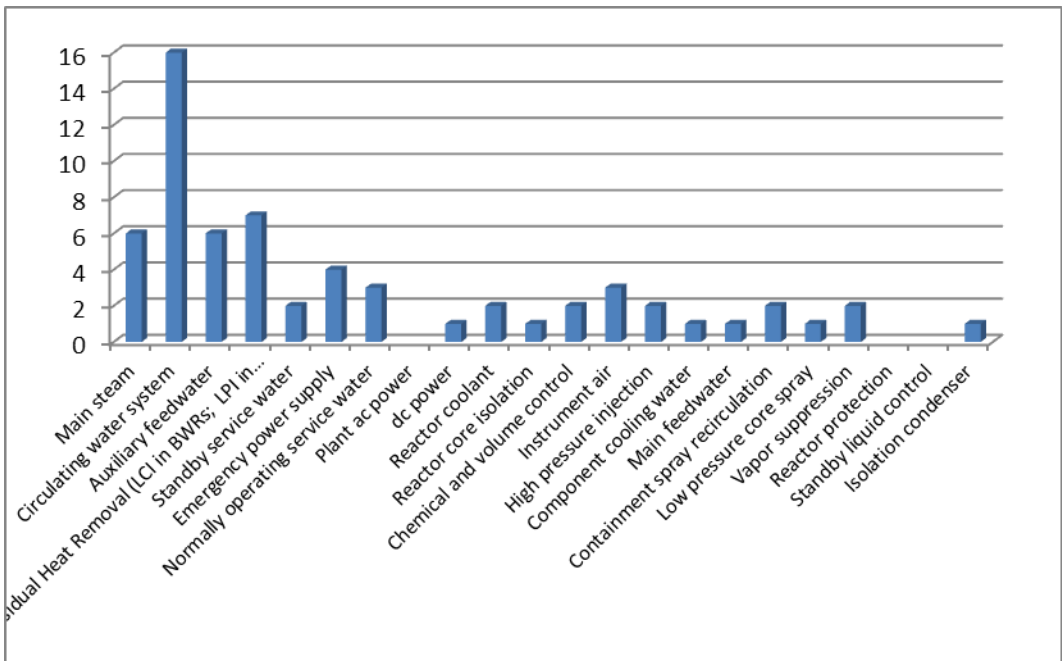
**Figure 3 Distribution of all CCF events by year.**



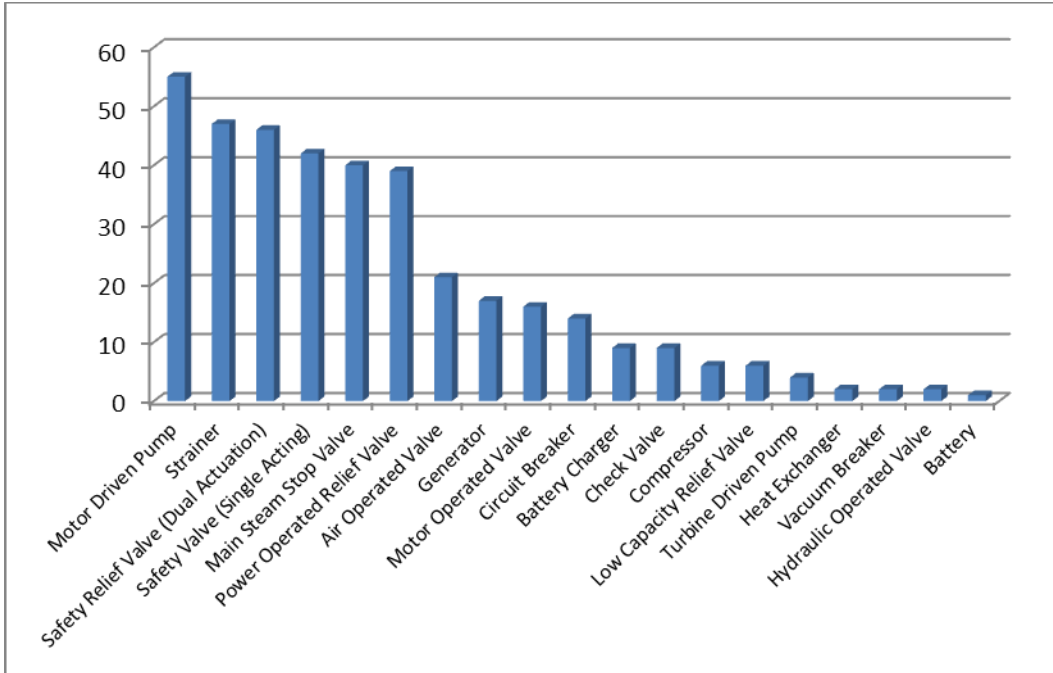
**Figure 4. Distribution of complete CCF events by year.**



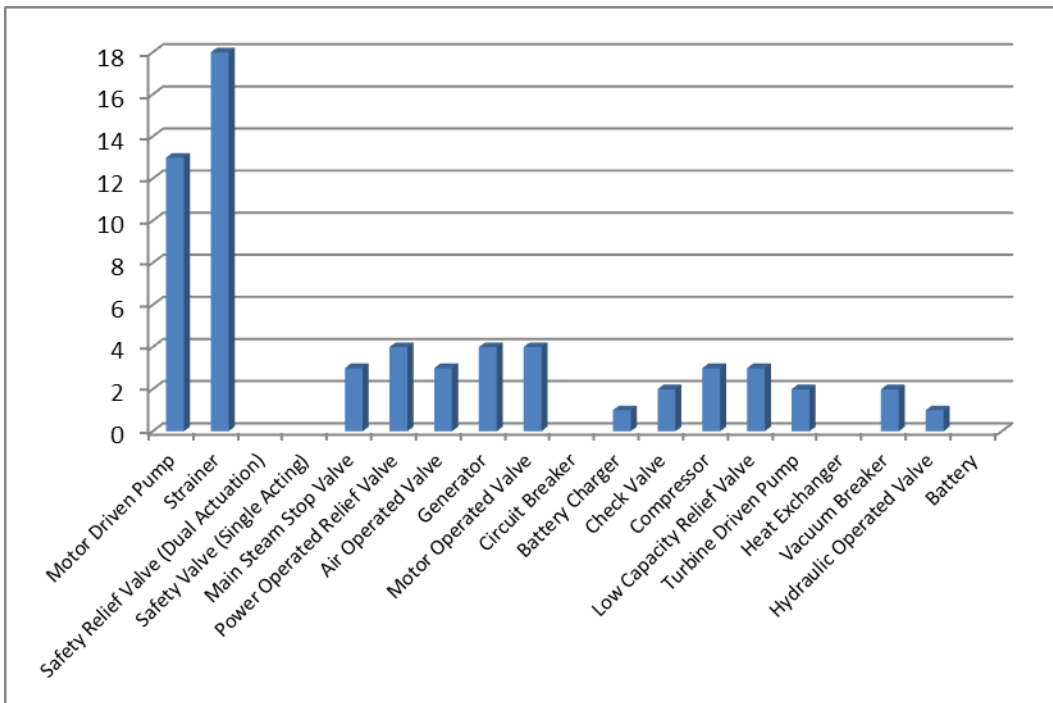
**Figure 5. Distribution of all CCF events by system.**



**Figure 6. Distribution of complete CCF events by system.**



**Figure 7. Distribution of all CCF events by component type.**



**Figure 8. Distribution of complete CCF events by component type.**



Component Type	System	Failure Mode	Count by Component Type and Failure Mode		Count by Component Type				
			CCF Events	Independent Events	CCF Events	Independent Events			
Air Operated Valve	Auxiliary feedwater	Fail to Close	2	34	21	238			
		Fail to Open	3	36					
		Fail to Open/Close	1	2					
		Fail to Operate	1	3					
		UA (Maint)	1	9					
	High pressure injection	Fail to Close	1	3					
	Isolation condenser	Fail to Close	1						
	Main feedwater	Fail to Close	2	35					
	Main steam	Fail to Close	2	22					
		Fail to Control	3	26					
		Fail to Open	1	47					
		Fail to Open	1	21					
	Residual Heat Removal (LCI in BWRs; LPI in PWRs)	Fail to Open	1	21					
		UA (Other Comp)	2						
Battery	dc power	Fail to Operate	1	40	1	40			
Battery Charger	dc power	Fail to Operate	9	292	9	292			
Check Valve	Auxiliary feedwater	Fail to Close	1	6	9	40			
		Leak (Internal)	2	11					
	Containment spray recirculation	Leak (Internal)	1	6					
	Normally operating service water	Fail to Close	1	4					
	Reactor core isolation	Leak (Internal)	1	2					
	Residual Heat Removal (LCI in BWRs; LPI in PWRs)	Leak (Internal)	3	11					
	Circuit Breaker	Plant ac power	Fail to Close	1			148	14	301
			Fail to Open	6			50		
			Spurious Operation	3			60		
			UA (Maint)	3			23		
Compressor	Reactor protection	Fail to Close	1	20	6	643			
	Instrument air	Fail to Run	4	450					
Generator		Emergency power supply	Fail to Start	2	193	17	1307		
	Fail to Load/Run		3	265					
	Fail to Run		5	188					
	Fail to Start		4	281					
Heat Exchanger	Component cooling water	UA (Maint)	5	573	2	25			
		Loss of Heat Transfer	2	25					

Component Type	System	Failure Mode	Count by Component Type and Failure Mode		Count by Component Type	
			CCF Events	Independent Events	CCF Events	Independent Events
Hydraulic Operated Valve	Auxiliary feedwater	Fail to Open/Close	1		2	1
	Residual Heat Removal (LCI in BWRs; LPI in PWRs)	Fail to Open	1	1		
Low Capacity Relief Valve	Chemical and volume control Component cooling water	Fail to Open	1	3	6	16
		Setpoint	1	2		
		Normally operating service water	2	4		
		Residual Heat Removal (LCI in BWRs; LPI in PWRs)	1	2		
Main Steam Stop Valve	Main steam	Setpoint	1	5		
		Fail to Close	8	66	40	203
		Fail to Open	3	32		
		Leak (Internal)	24	62		
		Spurious Operation	3	18		
Motor Driven Pump	Auxiliary feedwater	UA (Maint)	2	25		
		Fail to Run <1H	2	8	55	1049
		Fail to Start	2	39		
	Chemical and volume control	UA (Other Comp)	1	10		
		Fail to Run	2	150		
		UA (Maint)	3	63		
		UA (Other Comp)	1	14		
	Component cooling water	Fail to Run	2	62		
	Containment spray recirculation	Fail to Start	3	31		
	High pressure injection	Fail to Run >1H	3	19		
		Fail to Start	1	51		
	Main feedwater	Fail to Run	2	13		
	Normally operating service water	Fail to Run	3	63		
		Fail to Run >1H	1			
	Residual Heat Removal (LCI in BWRs; LPI in PWRs)	Fail to Run <1H	1	8		
Fail to Run >1H		1	23			
Fail to Start		8	67			
Standby liquid control	Fail to Start	1	15			
Standby service water	Fail to Run <1H	1	22			
	Fail to Run >1H	6	99			
	Fail to Start	8	131			

Component Type	System	Failure Mode	Count by Component Type and Failure Mode		Count by Component Type		
			CCF Events	Independent Events	CCF Events	Independent Events	
Motor Operated Valve	Auxiliary feedwater	UA (Maint)	3	161	16	399	
		Fail to Close	2	31			
		Fail to Open	1	37			
		Fail to Operate	1	2			
	High pressure injection	Leak (Internal)	1	5			
		Low pressure core spray	Fail to Close	1			13
	Reactor core isolation	Spurious Operation	Fail to Close	1	1		
			Fail to Open	1	17		
			Leak (Internal)	2	22		
	Residual Heat Removal (LCI in BWRs; LPI in PWRs)	Fail to Close	Leak (Internal)	2	13		
			Fail to Open	1	84		
Fail to Open			2	146			
Leak (Internal)			1	28			
Power Operated Relief Valve	Main steam	Automatic Close Control Function	1	1	39	243	
		Fail to Close	1	19			
		Fail to Open	1	32			
		Fail to Open	7	90			
		Setpoint	18	12			
		Spurious Operation	1	22			
		UA (Maint)	1	14			
	Reactor coolant	UA (Other Comp)	1	18			
		Automatic Open	1	3			
		Fail to Open	2	20			
		Leak (Internal)	2	9			
		Low Pressure	2	1			
		UA (Maint)	1	2			
Safety Relief Valve (Dual Actuation)	Main steam	Automatic Open	1	1	46	99	
		Fail to Open	6	23			
		Leak (Internal)	4	23			
		Setpoint	33	38			
		Spurious Operation	1	11			
		UA (Other Comp)	1	3			

Component Type	System	Failure Mode	Count by Component Type and Failure Mode		Count by Component Type	
			CCF Events	Independent Events	CCF Events	Independent Events
Safety Valve (Single Acting)	Main steam	Fail to Close	1	6	42	54
		Fail to Open	3	1		
Strainer	Circulating water system	Setpoint	38	47	47	250
		Bypass	2	3		
		Fail to Operate	19	53		
		Plug	16	35		
Turbine Driven Pump	Normally operating service water	Fail to Operate	3	107	4	191
		Plug	4	40		
	Standby service water	Plug	3	12		
		Auxiliary feedwater	Fail to Run <1H	1		
	Fail to Start		1	82		
	Vacuum Breaker	Reactor core isolation	UA (Other Comp)	1		
Vapor suppression			Fail to Start	1	51	
			Fail to Open	1	9	
		Leak (Internal)	1	3	2	12
		Total	378	5403	378	5403