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

1980–2007

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 1980 through 2007. The data sources for this report include:

- License Event Reports (LERs), 1980 to 2007
- Nuclear Plant Reliability Data System (NPRDS), 1980 to 1996
- Equipment Performance and Information Exchange (EPIX), 1997 to 2007

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). Other components and failure modes, such as failure to close for reactor trip breakers, were found in the source data; these events were coded and entered into the CCF database.

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.

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

- A review of the calculation of alpha factors from the 2005 CCF database to the 2007 CCF database revealed that most applications were changed only a few percent either increasing or decreasing. (See the parameter estimation reports for 2005 and 2007 at the CCF Parameters Web Site.) However, two applications show significant change between the 2005 CCF database and the 2007 database:
    - The check valve fail to open application in 2005 used data from 1980 to 2005. The check valve fail to open application in 2007 uses data from 1991 to 2007. The result is a decreased estimate of the alpha factors by about 75%.

    - The safety relief valves (SRVs or Target Rock dual acting relief valves) fail to open application increased the number of CCF events due to corrosion bonding by a factor of two from the 2005 to the 2007 CCF databases (the starting date of both applications is 1991). The result of calculating the alpha factors shows results from a 100% to a 2000% increase in *n of n* (e.g., 3 of 3) alpha factors.

- 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.

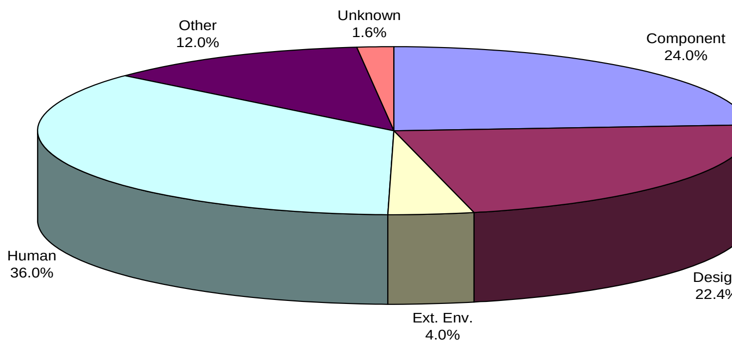
- The CCF database contains several examples where both CCF and independent events recur at some, but not all, plants, perhaps indicating ineffective root cause analysis and corrective action. Examples of repeated events are water in compressed air systems, pump seal wear-out, and turbine governor misadjustments. 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.

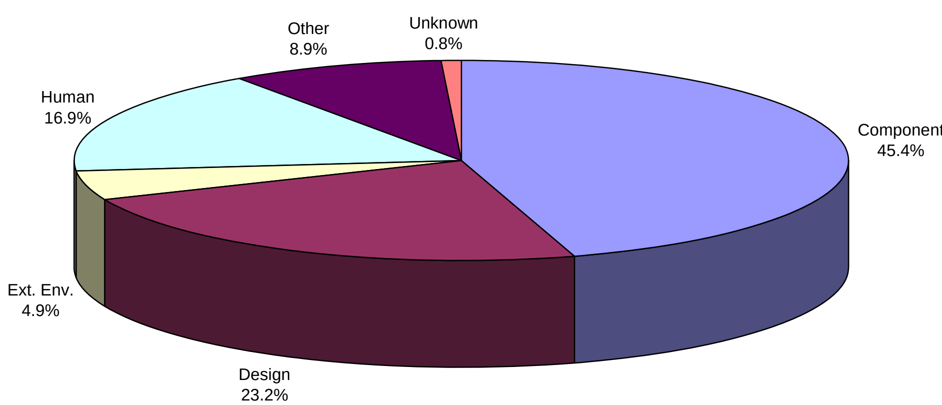
With respect to quantification of CCFs, the overall conclusion is that, based on the evaluation of over 20 years of operating experience data, CCF parameters for similar components vary among systems and failure modes. In addition, the CCF failure parameters have decreased over time.

Table 1. Component types and systems analyzed for CCF events (1980–2007).

Component Type	Systems Analyzed for Component Types
Air-Operated Valves	Auxiliary Feedwater (PWR)
	Emergency/Essential Service Water
	High Pressure Coolant Injection (BWR)
	High Pressure Safety Injection (PWR)
	Isolation Condenser
	Main Steam
	Reactor Core Isolation Cooling
	Residual Heat Removal
Batteries/Chargers	DC Power Distribution
Check Valves	Auxiliary Feedwater (PWR)
	Containment Spray
	Containment Vacuum Relief
	Emergency/Essential Service Water
	Emergency/Essential Service Water
	High Pressure Coolant Injection (BWR)
	High Pressure Safety Injection (PWR)
	Main Steam
	Reactor Core Isolation Cooling
	Residual Heat Removal
Circuit Breakers	AC Power Distribution
	DC Power Distribution
	Reactor Protection
Emergency Diesel Generators	Emergency Power
Heat Exchangers	Component Cooling Water
	Containment Spray
	Isolation Condenser
	Residual Heat Removal
Main Steam Isolation Valves	Main Steam
Motor-Operated Valves	Auxiliary Feedwater (PWR)
	Containment Spray
	Emergency/Essential Service Water
	High Pressure Coolant Injection (BWR)
	High Pressure Safety Injection (PWR)
	High Pressure Safety Injection (PWR)
	Isolation Condenser
	Main Steam
	Reactor Coolant
	Reactor Core Isolation Cooling
	Residual Heat Removal
Pumps	Auxiliary Feedwater (PWR)
	Component Cooling Water
	Containment Spray
	Emergency/Essential Service Water
	High Pressure Coolant Injection (BWR)
	High Pressure Safety Injection (PWR)
	Low Pressure Core Spray
	Residual Heat Removal
	Standby Liquid Control
Safety and Relief Valves	Main Steam
	Reactor Coolant
Strainers	Emergency/Essential Service Water
	Residual Heat Removal

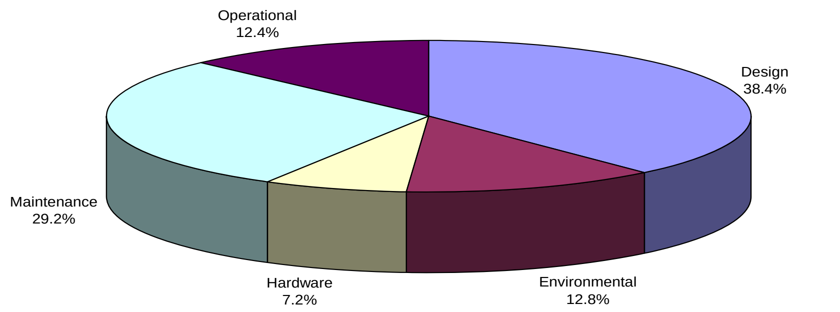


Distribution of causes of only the complete CCF events.

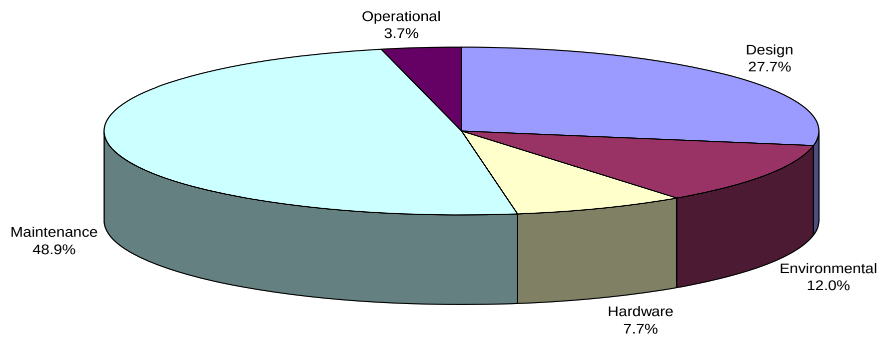


Distribution of causes of complete and partial CCF events

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

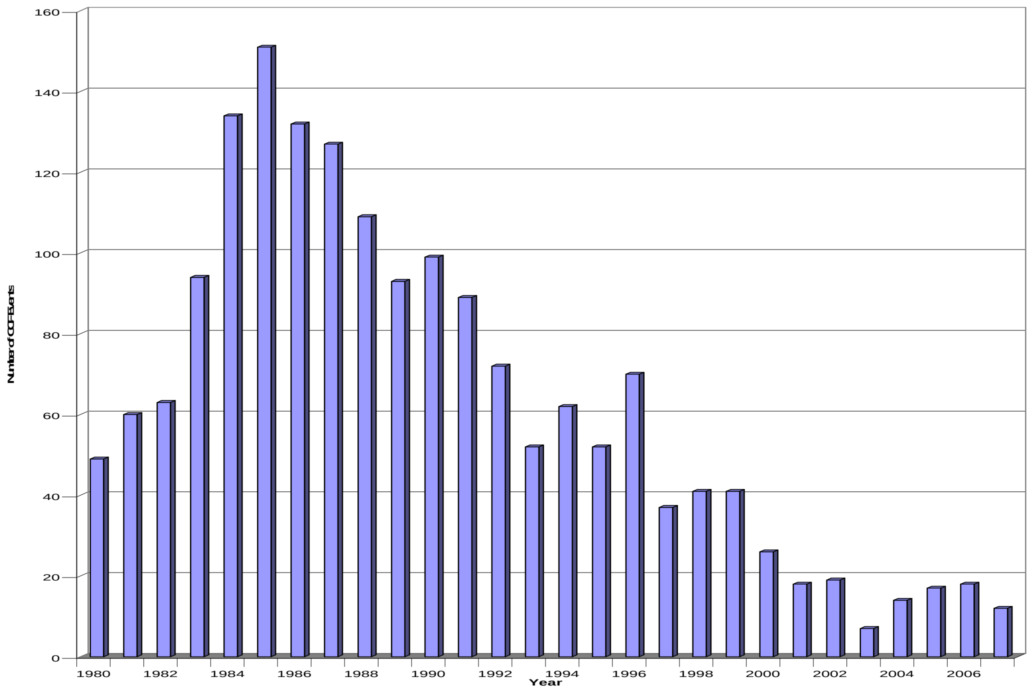


Figure 3 Distribution of all CCF events by year.

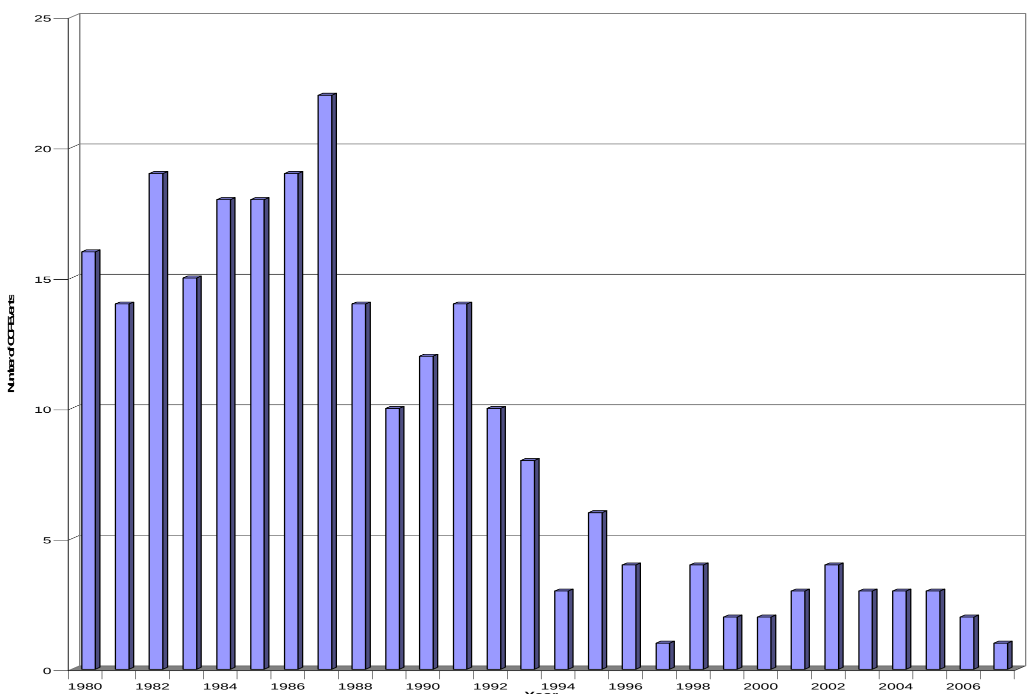


Figure 4. Distribution of complete CCF events by year.

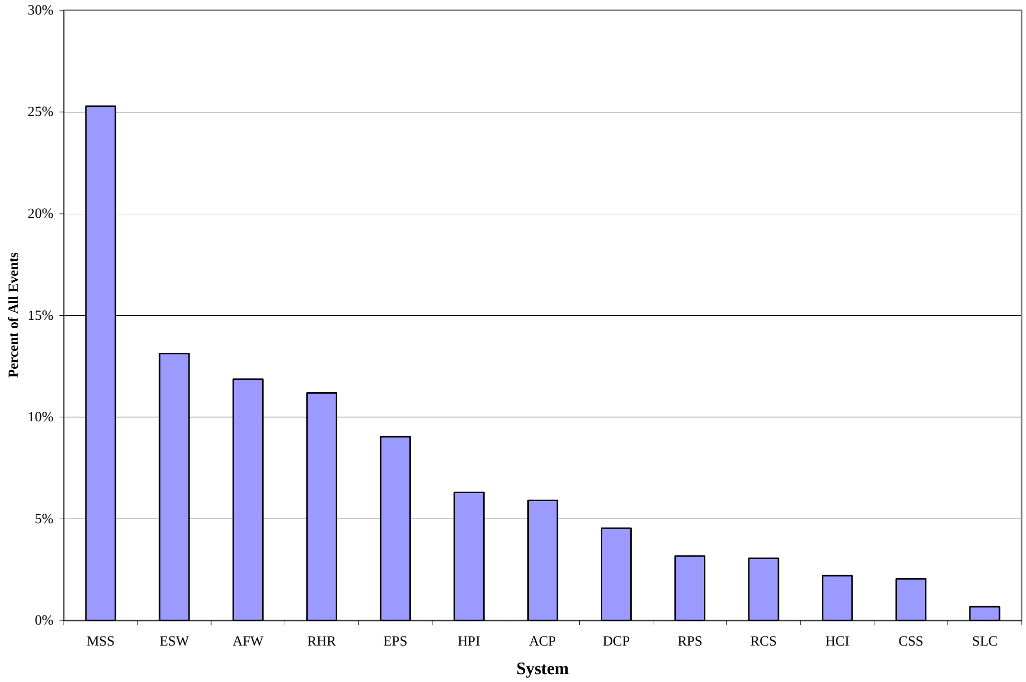


Figure 5. Distribution of all CCF events by system

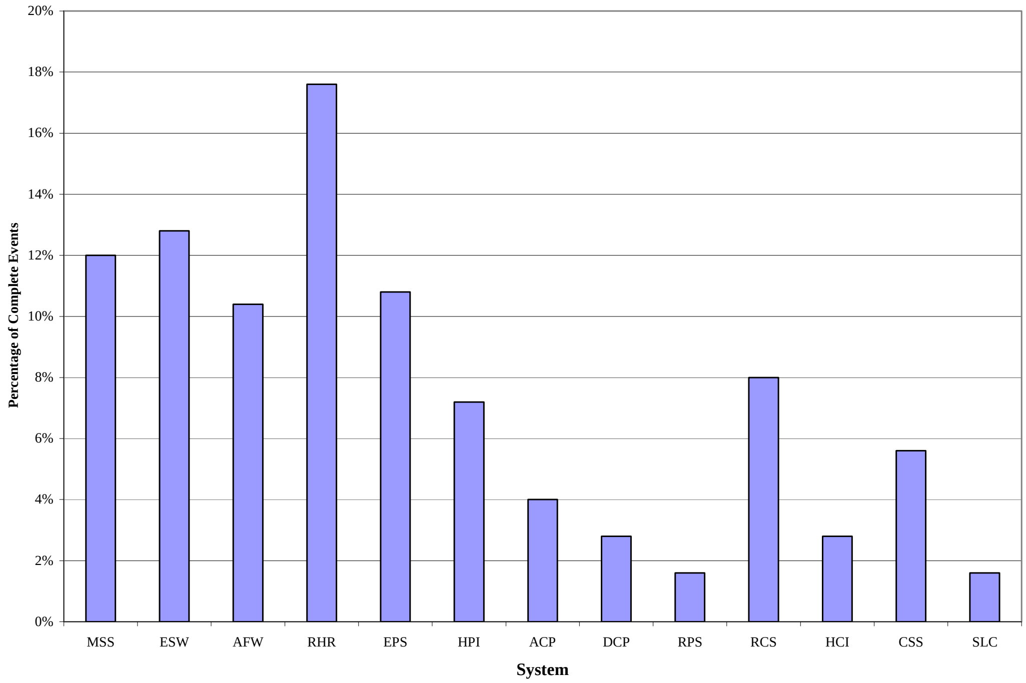


Figure 6. Distribution of complete CCF events by system