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

1997–2010

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 2010. The data sources for this report include:

- License Event Reports (LERs), 1997 to 2010
- Equipment Performance and Information Exchange (EPIX), 1997 to 2010

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

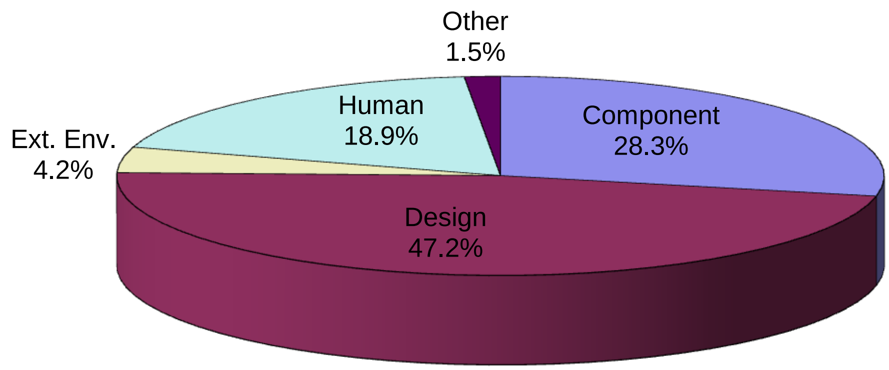
licensee to inspect/test the redundant component, resulting in the discovery that the same defective condition exists on both components. This demonstrates that detection of failures during the testing and surveillance program prevents CCF events from occurring during actual demand situations.

- 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.

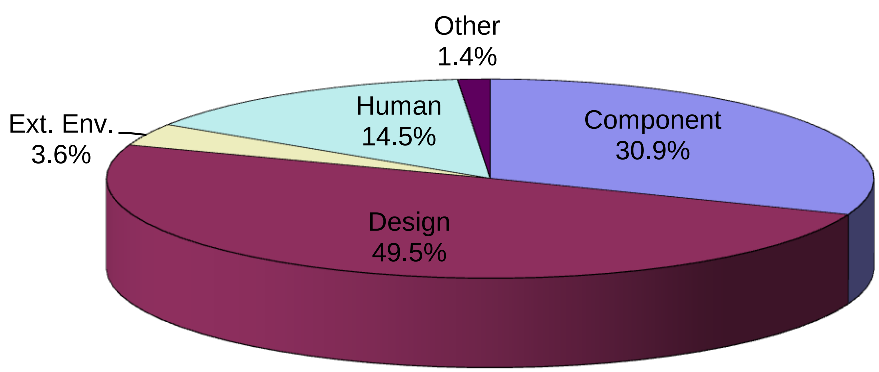
With respect to quantification of CCFs, the overall conclusion is that, based on the evaluation of over 20 years of operating experience data, CCF parameters for similar components vary among systems and failure modes. In addition, the CCF failure parameters have decreased over time.

Table 1. Component types and systems analyzed for CCF events (1997–2010).

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

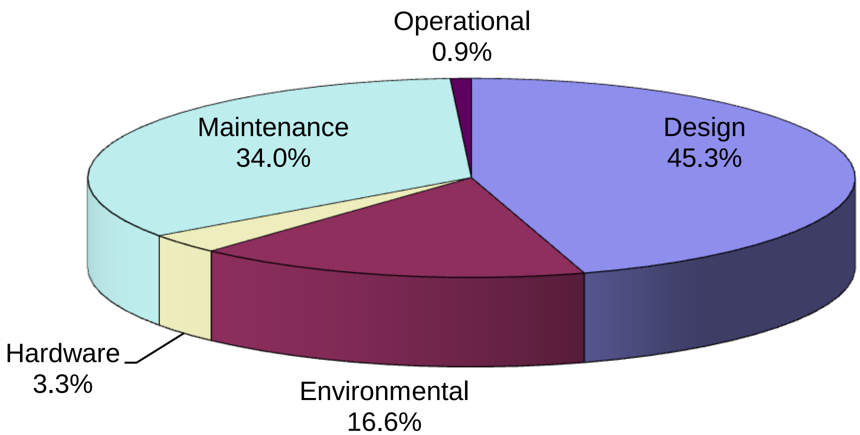


Distribution of causes of complete and partial CCF events

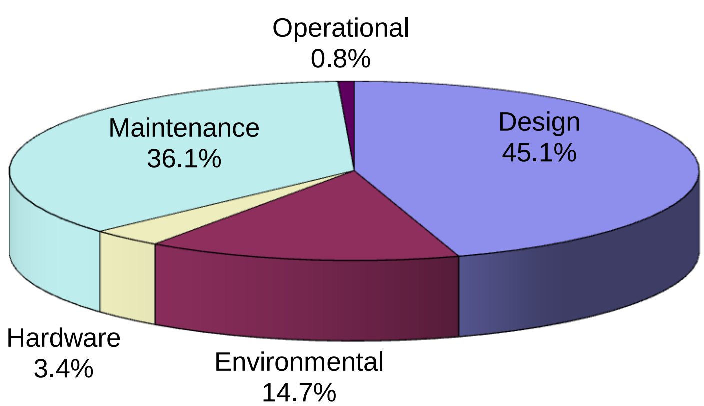


Distribution of causes of only the complete CCF events.

Figure 1. Distribution of CCF events by proximate cause.



Distribution of coupling factors for both complete and partial events.



Distribution of coupling factors for only the complete CCF events.

Figure 2 Distribution of CCF events by coupling factor.

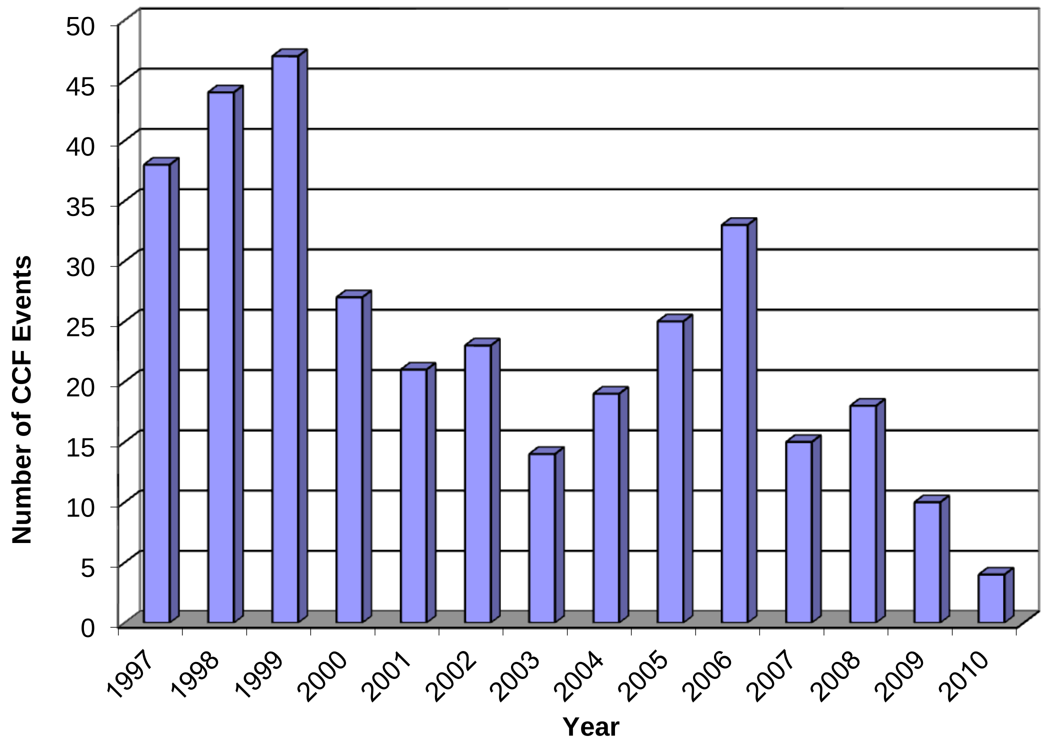


Figure 3 Distribution of all CCF events by year.

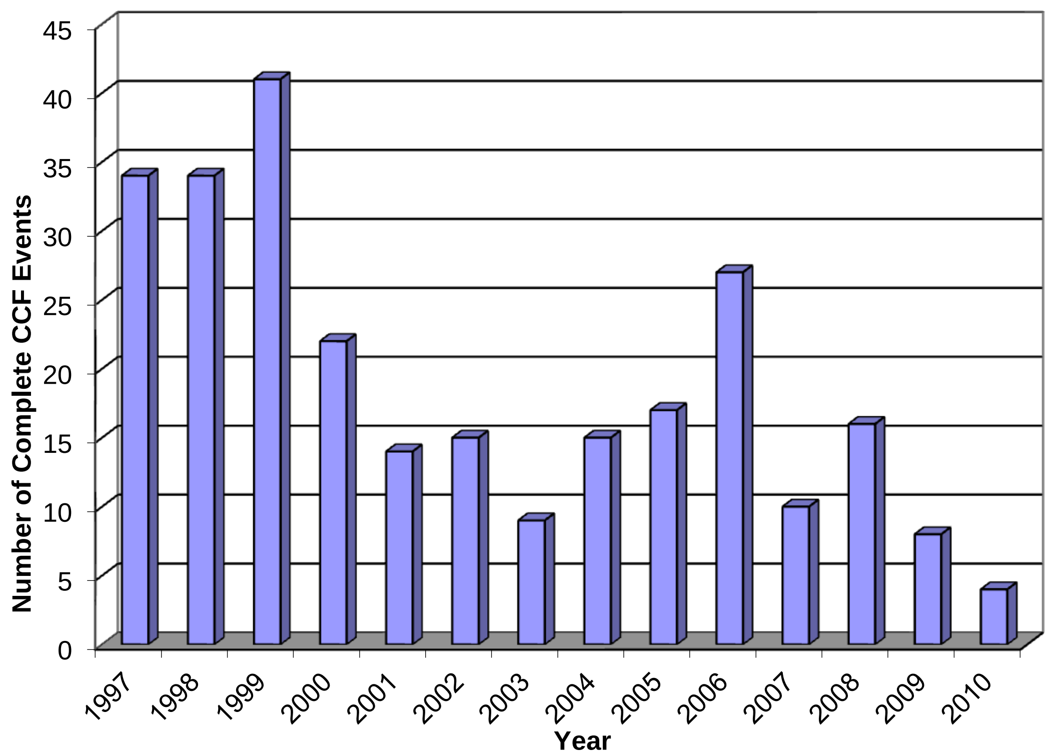


Figure 4. Distribution of complete CCF events by year.

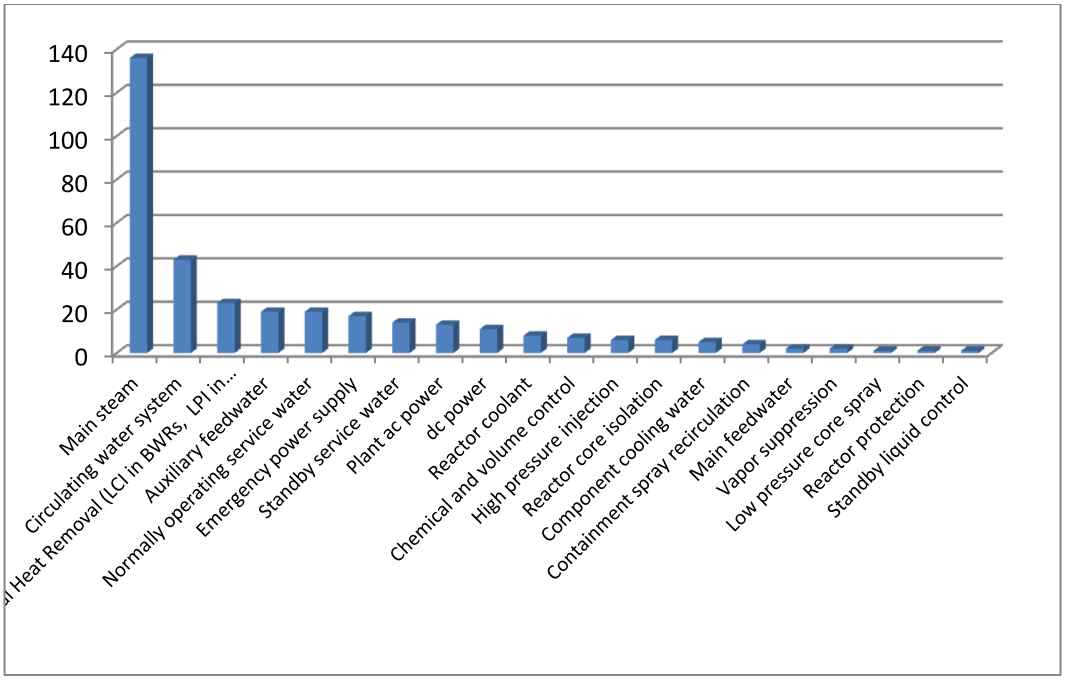


Figure 5. Distribution of all CCF events by system.

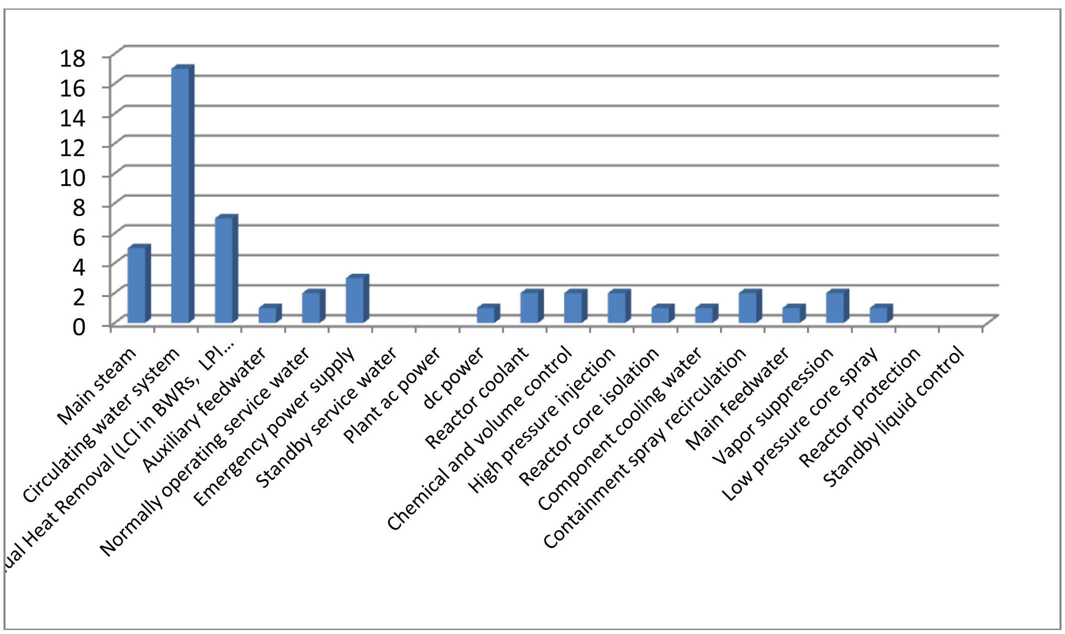


Figure 6. Distribution of complete CCF events by system.

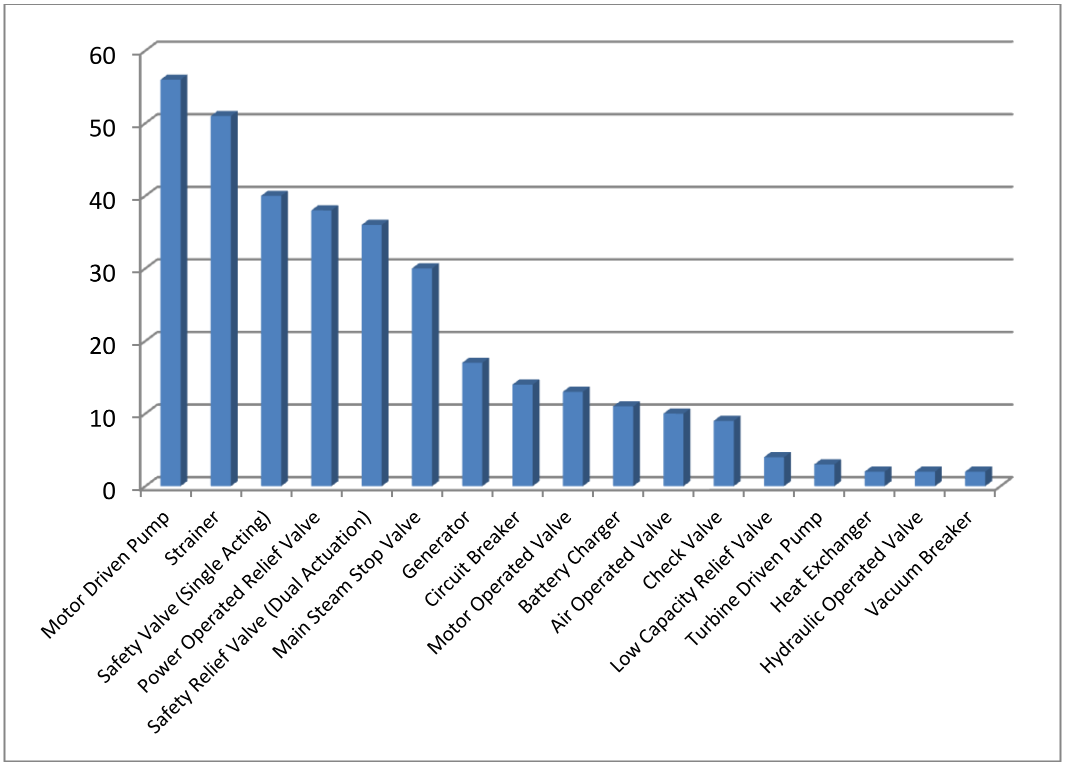


Figure 7. Distribution of all CCF events by component type.

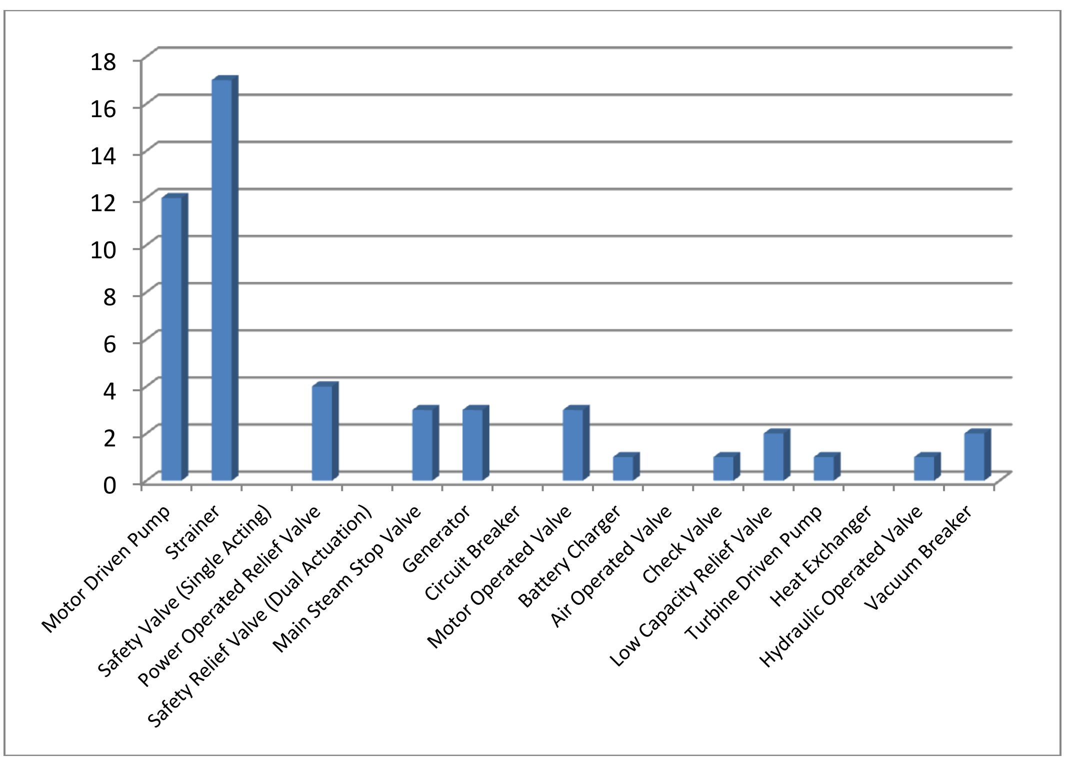


Figure 8. Distribution of complete CCF events by component type.