BABCOCK & WILCOX RPS EXECUTIVE SUMMARY

This report documents an analysis of the safety-related performance of the reactor protection system (RPS) at U.S. Babcock & Wilcox (B&W) commercial nuclear reactors during the period 1984 through 1998. The objectives of the study were the following: (1) to estimate RPS unavailability based on operational experience data and compare the results with models used in probabilistic risk assessments (PRAs) and individual plant examinations (IPEs), and (2) to review the operational data from an engineering perspective to determine trends and patterns, and to gain additional insights into RPS performance. The B&W RPS designs covered in the unavailability estimation include two versions. Fault trees developed for this study were based on these two versions, which are representative of all B&W plants.

Babcock & Wilcox RPS operational data were collected from Licensee Event Reports as recorded in the Sequence Coding and Search System and the Nuclear Plant Reliability Data System. The period covered 1984 through 1998. Data from both sources were evaluated by engineers with operational experience at nuclear power plants. Approximately 600 events were evaluated for applicability to this study. Those data not excluded were further characterized as to the type of RPS component, type of failure, failure detection, status of the plant during the failure, etc. Characterized data include both independent component failures and common-cause failures (CCFs) of more than one component. The CCF data were classified as outlined in the report *Common-Cause Failure Data Collection and Analysis System* (NUREG/CR-6268). Component demand counts were obtained from plant reactor trip histories and component test frequency information.

The risk-based analysis of the RPS operational data focused on obtaining failure probabilities for component independent failure and CCF events in the RPS fault tree. The level of detail of the basic events includes the following: channel trip signal sensor/transmitters and associated bistables, relays, and control rod drives and control rods. CCF events were modeled for all redundant, similar types of components.

Fault trees for the two versions of the B&W RPS were developed and quantified using U.S. B&W commercial nuclear reactor data from the period 1984 through 1998. All B&W plants use a design similar to the Oconee RPS except the Davis-Besse plant. The Davis-Besse design is unique to Davis-Besse and was modeled separately. Table ES-1 summarizes the results of this study.

Table ES-1. Babcock & Wilcox fault tree model results with uncertainty.

	5%	Mean	95%
Oconee Model			
No credit for manual trip by operator	1.3E-7	7.8E-7	2.4E-6
Credit for manual trip by operator	1.8E-9	8.7E-9	2.5E-8
Davis-Besse Model			
No credit for manual trip by operator	2.6E-7	1.6E-6	4.8E-6
Credit for manual trip by operator	3.1E-8	8.4E-7	3.2E-6

The computed mean unavailability estimates were 7.8E-7 and 1.6E-6 (with no credit for manual trips). These are comparable to the values given in B&W IPEs, which ranged from 1.0E-6 to 5.0E-6, and other similar reports. Common-cause failures contribute greater than 99 percent to the overall unavailability of the various designs. The individual component failure probabilities are generally comparable to failure probability estimates listed in previous reports.

The RPS fault tree was also quantified allowing credit for manual scram by the operator (with a failure probability of 0.01). Operator action reduces the RPS unavailability by approximately 99 percent (8.7E-9, Oconee design) and 48 percent (8.4E-7, Davis-Besse design).

Several general insights were obtained from this study:

- Neither design shows a significant contribution from the trip breakers/diverse trip segment.

- The Oconee design shows no contribution from the rods segment but the Davis-Besse design shows a significant contribution from this segment. This is because of the separation of the rods that are dropped by the diverse electronic trip. The Oconee design trips the safety rods with the trip breakers and the regulating rods with the diverse trip. This has the effect of having both a diverse means of tripping rods and a diverse group of rods that are tripped in the Oconee model. The Davis-Besse design trips all rods with both means.

- Issues from the early 1980s that affected the performance of the reactor trip breakers (e.g., dirt, wear, lack of lubrication, and component failure) are not currently evident. Automatic actuation of the shunt trip mechanism within the reactor trip breakers and improved maintenance have resulted in improved performance of these components.

- Overall, trends in unplanned trips at B&W reactors decreased significantly over the time span of this study. Due to sparse data, trends in component failure probabilities and counts of CCF events are not significant in the B&W data. Trends for the pooled PWR overall CCF rate of occurrence used in this study showed a statistically significant decreasing trend. Relays, pressure sensor/transmitters, and undervoltage coils all showed significant decreasing trends.

- The causes of the Babcock & Wilcox CCF events are similar to those of the rest of the industry. That is, over all RPS designs for all vendors for all of the components in this study, the vast majority (80 percent) of RPS common-cause failure events can be attributed to either normal wear or out-of-specification conditions. These events, are typically degraded states, rather than complete failures. Design and manufacturing causes led to the next highest category (7 percent) and human errors (operations, maintenance, and procedures) were the next highest category (6 percent). Environmental problems and the state of other components (e.g., power supplies) led to the remaining RPS common-cause failure events. No evidence was found that these proportions are changing over time.

- The principal method of detection of failures of components in this study was either by testing or by observation during routine plant tours. No failures were detected by actual trip demands. No change over time in the overall distribution of the detection method is apparent.