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ABSTRACT

This report documents an analysis of the safety-related performance of the reactor protection system (RPS) at U.S. Westinghouse commercial reactors during the period 1984 through 1995. Westinghouse RPS designs analyzed in this report include those with solid state protection system trains and Analog Series 7300 or Eagle-21 channels. The analysis is based on a four-loop plant design. RPS operational data were collected for all U.S. Westinghouse commercial reactors from the Nuclear Plant Reliability Data System and Licensee Event Reports. A risk-based analysis was performed on the data to estimate the observed unavailability of the RPS, based on a fault tree model of the system. An engineering analysis of trends and patterns was also performed on the data to provide additional insights into RPS performance. RPS unavailability results obtained from the data were compared with existing unavailability estimates from Individual Plant Examinations and other reports.

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EXECUTIVE SUMMARY

This report documents an analysis of the safety-related performance of the reactor protection system (RPS) at U.S. Westinghouse commercial reactors during the period 1984 through 1995. 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 Westinghouse RPS designs covered in the unavailability estimation include those with solid state protection system (SSPS) trains and Analog Series 7300 or Eagle-21 channels. The fault trees developed for these designs assumed a four-loop plant.

Westinghouse RPS operational data were collected from Licensee Event Reports as reported in the Sequence Coding and Search System and the Nuclear Plant Reliability Data System. The period covered 1984 through 1995. Data from both sources were evaluated by engineers with operational experience at nuclear power plants. Approximately 15,000 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: reactor trip breakers (mechanical/electrical portion, undervoltage coil, and shunt trip coil); SSPS undervoltage driver and universal cards; and channel trip sensor/transmitters, signal processing modules, and associated bistables and relays. CCF events were modeled for all redundant, similar types of components.

Quantification of the fault tree models resulted in a mean unavailability (failure probability upon demand) of 2.2E-5 (with no credit for manual scram by the operator) for the Analog Series 7300 design. The lower 5^{th} percentile is 5.8E-6 and the upper 95^{th} percentile is 5.7E-5. Approximately 95% of the overall RPS unavailability is from CCF events. CCF of the two undervoltage driver cards (one per train) is the dominant contributor (46.1%) to RPS unavailability. Other important CCF events involve the channel bistables (11.5%), train universal cards (9.7%), channel signal processing modules (7.8%), reactor trip breakers (7.4%), and rods (5.5%). Results for the Eagle-21 RPS design are similar, with a mean unavailability of 2.0E-5.

Both the Analog Series 7300 and Eagle-21 RPS designs have a single undervoltage driver card in each of the two trains. Failure of both of these cards results in failure of RPS (unless manual scram is credited). This CCF event is the dominant contributor (almost 50%) to RPS unavailability. In 1989, a CCF event

involving both driver cards occurred while the plant was shut down. The failures were caused by maintenance activities and were detected before the plant returned to power. Since then, the driver card design has been changed to minimize the chance of such maintenance activities causing such failures. Also, plant procedures for such maintenance have been improved. However, CCF of both of these cards is still predicted to be a dominant contributor to RPS unavailability.

Issues related to reactor trip breakers, arising during the early 1980s, are no longer dominant with respect to RPS unavailability. (This is true for both cases of RPS unavailabilities: without crediting operator action and crediting operator action.) Automatic actuation of the shunt trip mechanism within the reactor trip breakers and improved maintenance procedures have resulted in improved performance of these components.

The Analog Series 7300 and Eagle-21 RPS designs have comparable unavailabilities. This occurs because the Eagle-21 design considered in this report involves only the channel processing portion of the RPS. The dominant contributors to RPS unavailability result from other portions of the RPS.

The RPS fault trees were also quantified allowing credit for manual scram by the operator. The resulting mean unavailabilities are 5.5E-6 for the Analog Series 7300 design and 4.5E-6 for the Eagle-21 design. Therefore, operator action reduces the RPS unavailability by approximately 75%. This reduction is significant and occurs mainly because the manual scram signal bypasses the dominant undervoltage driver card failures. For the Analog Series 7300 design, CCF of the two reactor trip breakers is the dominant event, contributing 29.1% to the RPS unavailability. Other important CCF events involve the channel bistables (27.9%), rods (21.7%), and channel signal processing modules (18.9%). Contributors to the Eagle-21 unavailability are similar.

RPS unavailability estimates from Individual Plant Examinations (IPEs) and other sources range from approximately 1.0E-6 to 1.0E-4. Because of the lack of detailed information in the IPE submittals, it is not clear which estimates included credit for operator action. The IPE range of RPS unavailabilities covers the uncertainty ranges obtained in this study, based on the analysis of data from 1984 through 1995. However, most of these other sources estimated that the trip breaker CCF events would dominate the RPS unavailability. In this study such events contribute less than 10% when no credit is taken for manual scram by the operator, and approximately 30% if credit is taken.

The engineering analysis identified decreasing trends in component failure and CCF event counts for several RPS components. No increasing trends were identified over the period 1984 through 1995.

Finally, not many significant Westinghouse RPS CCF events were identified from the period 1984 through 1995. Therefore, current practices appear to be effective in preventing such events.

FOREWORD

This report provides information relevant to the reliability of the Westinghouse reactor protection system (RPS). It summarizes the event data used in the analysis. The results, findings, conclusions, and information contained in this study, the initiating event update study, and related system reliability studies conducted by the Office for Analysis and Evaluation of Operational Data are intended to support several risk-informed regulatory activities. This includes providing information about relevant operating experience that can be used to enhance plant inspections of risk-important systems and information used to support staff technical reviews of proposed license amendments, including risk-informed applications. In the future, this work will be used in the development of risk-based performance indicators that will be based to a large extent on plant-specific system and equipment performance.

Findings and conclusions from the analyses of the Westinghouse RPS, which are based on 1984–1995 operating experience, are presented in the Executive Summary. The results of the quantitative analysis and engineering analysis are presented in Sections 3 and 4, respectively. The information to support risk-informed regulatory activities related to the Westinghouse RPS is summarized in Table F-1. This table provides a condensed index of risk-important data and results presented in discussions, tables, figures, and appendices.

The application of results to plant-specific applications may require a more detailed review of the relevant Licensee Event Report (LER) and Nuclear Plant Reliability Data System (NPRDS) data cited in this report. This review is needed to determine if generic experiences described in this report and specific aspects of the RPS events documented in the LER and NPRDS failure records are applicable to the design and operational features at a specific plant or site. Factors such as RPS design, specific components installed in the system, and test and maintenance practices would need to be considered in light of specific information provided in the LER and NPRDS failure records. Other documents such as logs, reports, and inspection reports that contain information about plant-specific experience (e.g., maintenance, operation, or surveillance testing) should be reviewed during plant inspections to supplement the information contained in this report.

Additional insights may be gained about plant-specific performance by examining the specific events in light of the overall industry performance. In addition, a review of recent LERs and plant-specific component failure information in NPRDS or the Equipment Performance Information Exchange (EPIX) may yield indications of whether performance has undergone any significant change since the last year of this report. A search of the LER database can be conducted through the NRC's Sequence Coding and Search System (SCSS) to identify the RPS events that occurred after the period covered by this report. SCSS contains the full text LERs and is accessible by NRC staff from the SCSS home page (http://scss.ornl.gov/). Nuclear industry organizations and the general public can obtain information from the SCSS on a cost recovery basis by contacting the Oak Ridge National Laboratory directly.

Periodic updates to the information in this report will occur as additional data become available.

Charles E. Rossi, Director
Safety Programs Division
Office for Analysis and Evaluation
of Operational Data

Table F-1. Summary of risk-important information specific to Westinghouse reactor protection system.

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ACRONYMS

ACRS	Advisory Committee on Reactor Safety (U.S. NRC)
AEOD	Analysis and Evaluation of Operational Data (U.S. NRC Office)
AMSAC	ATWS mitigation system actuation circuitry
ATWS	anticipated transient without scram
BME	breaker mechanical (mechanical/electrical portion of reactor trip breaker)
BSN	breaker shunt (shunt trip coil portion of reactor trip breaker)
BUV	breaker undervoltage (undervoltage coil portion of reactor trip breaker)
C21	channel 21 (Eagle-21 portion of channel)
CBI	channel bistable
CCF	common-cause failure
CCP	channel calculator for pressure (channel pressure processing module)
CCX	channel calculator crossover (CCF involving CDT, CCP, or CMM)
CDT	channel delta temperature (channel ΔT processing module)
CF	complete failure
CMM	channel mismatch (channel processing module for steam generator low water level mismatch with steam flow and feedwater flow)
CPR	channel pressure (channel pressure sensor/transmitter)
CRD	control rod drive (same as CRDM)
CRDM	control rod drive mechanism
CTP	channel temperature (temperature sensor/transmitter)
FS	fail-safe (component failure not impacting safety function)
INEEL	Idaho National Engineering and Environmental Laboratory
IPE	Individual Plant Examination
NF	no failure
NFS	non-fail-safe (component failure impacting safety function)
NRC	Nuclear Regulatory Commission (U.S.)

NPRDS	Nuclear Plant Reliability Data System
PRA	probabilistic risk assessment
PWR	pressurized water reactor or power to shunt trip coils
RCCA	rod control cluster assembly
RMA	rod mechanical assembly (RCCA)
ROD	rod (RPS RCCA or RCCA/CRDM combination)
RPS	reactor protection system
RTB	reactor trip breaker
SCSS	Sequence Coding and Search System
TLC	trip logic card (RPS train universal card)
TLR	trip logic relay
UC	unknown completeness (unknown if failure was CF or NF)
UKN	unknown (unknown if failure was NFS or FS)
UVL	undervoltage (RPS train undervoltage driver card)

TERMINOLOGY

Breaker segment—The portion of the Westinghouse reactor protection system that includes the reactor trip breakers and bypass trip breakers. Included are two reactor trip breakers and two bypass trip breakers. Each breaker is divided into mechanical, undervoltage coil, and shunt trip coil portions.

Channel segment—The portion of the Westinghouse reactor protection system that includes trip signal sensor/transmitters and other components contained in the instrumentation racks (signal processing modules or Eagle-21 modules and bistables). For the trip signals modeled in this report, there are three channels in the channel segment in a three-loop plant and four channels in four- and two-loop plants.

Common-cause failure—A dependent failure in which two or more similar component fault states exist simultaneously, or within a short time interval, and are a direct result of a shared cause.

Common-cause failure model—A model for classifying and quantifying the probabilities of common-cause failures. The alpha factor model is used in this study.

Instrumentation rack—The cabinet containing the channel components (other than trip signal sensor/transmitters) of the Westinghouse reactor protection system.

Logic cabinet—The cabinet containing the train components of the Westinghouse reactor protection system.

Reactor protection system—The complex control system comprising numerous electronic and mechanical components that provides the ability to produce an automatic or manual rapid shutdown of a nuclear reactor, given plant upset conditions that require a reactor trip.

Rod segment—The portion of the Westinghouse reactor protection system that includes the control rod drive mechanisms and the rod control cluster assemblies. There are approximately 40 to 60 rod control cluster assemblies and associated control rod drive mechanisms.

Scram—Automatic or manual actuation of the reactor protection system, resulting in insertion of rod control cluster assemblies into the core and shutdown of the nuclear reaction. Also called a reactor trip.

Train segment—The portion of the Westinghouse reactor protection system that is housed in the logic cabinet (trip logic relays, universal cards, undervoltage driver cards, and auto shunt trip relay). There are two trains in the train segment in all Westinghouse reactor protection system designs.

Unavailability—The probability that the reactor protection system will not actuate (and result in a reactor trip), given a demand for the system to actuate.

Unreliability—The probability that the reactor protection system will not fulfill its mission, given a demand for the system. Unreliability typically involves both failure to actuate and failure to continue to function for an appropriate mission time. However, the reactor protection system has no mission time. Therefore, for the reactor protection system, unreliability and unavailability are the same.

Reliability Study: Westinghouse Reactor Protection System, 1984–1995

1. INTRODUCTION

The U.S. Nuclear Regulatory Commission's (NRC's) Office for Analysis and Evaluation of Operational Data (AEOD) has, in cooperation with other NRC offices, undertaken an effort to ensure that the stated NRC policy to expand the use of probabilistic risk assessment (PRA) within the agency is implemented in a consistent and predictable manner. As part of this effort, the AEOD Safety Programs Division has undertaken to monitor and report upon the functional reliability of risk-important systems in commercial nuclear power plants. The approach is to compare estimates and associated assumptions found in PRAs to actual operating experience. The first phase of the review involves the identification of risk-important systems from a PRA perspective and the performance of reliability and trending analysis on these identified systems. As part of this review, a risk-related performance evaluation of the reactor protection system (RPS) in Westinghouse pressurized water reactors (PWRs) was performed.

An abbreviated U.S. history of regulatory issues related to RPS and anticipated transient without scram (ATWS) begins with a 1969 concern[1] from the Advisory Committee on Reactor Safeguards (ACRS) that RPS common mode failures might result in unreliabilities higher than previously thought. At that time, ATWS events were considered to have frequencies lower than 1E-6/y, based on the levels of redundancy in RPS designs. Therefore, such events were not included in the design basis for U.S. nuclear power plants. This concern was followed by issuance of WASH-1270[2] in 1973, in which the RPS unavailability (probability of failure upon demand) was estimated to be 6.9E-5 (median value). Based on this information and the fact that increasing numbers of nuclear reactors were being built and operated in the U.S., it was recommended that ATWS events be considered in the safety analysis of nuclear reactors. In 1978, NUREG-0460[2] was issued. In that report, the RPS unavailability was estimated to be in the range 1E-5 to 1E-4, assuming no credit for operator action. An unavailability of 3E-5 was recommended, allowing for some improvements in design and performance. In addition, it was recommended that consideration be given to additional systems that would help to mitigate ATWS events, given failure of the RPS. The 1980 boiling water reactor (BWR) Browns Ferry Unit 3 event in which 76 of 185 control rods failed to insert fully and the 1983 PWR Salem Unit 1 low-power ATWS events (failure of the undervoltage coils to open the reactor trip breakers) led to NUREG-1000[3] and Generic Letter 83-28.[4] These documents discussed actions to improve RPS reliability, including automatic actuation of shunt trip mechanisms in Westinghouse and Babcock & Wilcox reactor trip breaker designs. Previously, the shunt trip mechanism was actuated only by operators using manual trip switches in the control room. Finally, 49FR26036[5] in 1984, Generic Letter 85-06[6] in 1985 and 10CFR50.62[7] in 1986 outlined requirements for diverse ATWS mitigation systems.

The risk-related performance evaluation in this study measures RPS unavailability using actual operating experience. To perform this evaluation, system unavailability was evaluated using two levels of detail: the entire system (without distinguishing components within the system), and the system broken down into components such as sensors, logic modules, and breakers. The modeling of components in the RPS was necessary because the U.S. operating experience during the period 1984 through 1995 does not include any RPS system failures. (The Salem reactor trip breaker common-cause failures in 1983 could be considered system failures. However, the breakers were modified to eliminate or minimize such failures.) Therefore, unavailability results for the RPS modeled at the system level provide limited information. Additional unavailability information is gained by working at the component level, at which actual failures have occurred. RPS unavailability in this evaluation is concerned with failure of the function of the system to shut down the reactor given a plant upset condition requiring a reactor trip.

Component or system failures causing spurious reactor trips or not affecting the shutdown function of the RPS are not considered in this report. However, failures and associated demands that occurred during tests of portions of the RPS are included in the component level evaluation of the RPS unavailability, even though such demands do not model a complete system response for accident mitigation. This is in contrast to previous system studies, in which such partial system tests generally were not used.

It should be noted that the RPS boundary for this study does not include ATWS mitigation systems added or modified in the late 1980s. For Westinghouse nuclear reactors, this system is the ATWS Mitigation System Actuation Circuitry (AMSAC). Also, this study deals mainly with automatic actuation of the RPS. However, operator action to manually actuate the RPS is also covered as a sensitivity.

The RPS unavailability study is based on U.S. Westinghouse RPS operational experience data from the period 1984 through 1995, as reported in both the Nuclear Plant Reliability Data System (NPRDS)[8] and Licensee Event Reports (LERs) found in the Sequence Coding and Search System (SCSS).[9] The year 1984 was chosen as the starting point for data collection, to evaluate RPS performance following the Salem Unit 1 low-power ATWS event and subsequent reviews of reactor trip breaker maintenance procedures and automation of the shunt trip device.

The objectives of the study were the following:

1. Estimate RPS unavailability based on operation data, and compare the results with the assumptions, models, and data used in PRAs and Individual Plant Examinations (IPEs).

2. Provide an engineering analysis of the factors affecting system unavailability, and determine if trends and patterns are present in the RPS operational data.

The remainder of this report is arranged in five sections. Section 2 describes the scope of the study, including a system description for the RPS, description of the fault tree models used in the analysis, and descriptions of the data collection, characterization, and analysis. Section 3 contains the unavailability results from the operational data and comparisons with PRA/IPE RPS results. Section 4 provides the results of the engineering analysis of the operational data. Section 5 is the summary and conclusions. Finally, Section 6 contains the references.

There are also seven appendices in this report. Appendix A provides a detailed explanation of the methods used for data collection, characterization, and analysis. Appendix B gives a summary of the operational data. The detailed statistical analyses are presented in Appendix C. The fault tree model is included in Appendix D. Common-cause failure modeling information is presented in Appendix E. The fault tree quantification results—cut sets and importance rankings—are in Appendix F. Finally, sensitivity analysis results are presented in Appendix G.

2. SCOPE OF STUDY

This study documents an analysis of the operational experience of the Westinghouse RPS from 1984 through 1995. The analysis focused on the ability of the RPS to automatically shut down the reactor given a plant upset condition requiring a reactor trip while the plant is at full power. The term “reactor trip” refers to a rapid insertion of control rods into the reactor core to inhibit the nuclear reaction. RPS spurious reactor trips or component failures not affecting the automatic shutdown function were not considered. A Westinghouse RPS description is provided, followed by a description of the RPS fault tree used in the study. The section concludes with a description of the data collection, characterization, and analysis.

2.1 System Description

2.1.1 System Operation

The Westinghouse RPS is a complex control system comprising numerous electronic components that combine to provide the ability to produce an automatic or manual rapid shutdown of the nuclear reactor, known as a reactor trip or scram. In spite of its complexity, the Westinghouse RPS can be roughly divided into four segments—rods, trip breakers, logic cabinet (containing the two trains of the RPS), and instrumentation rack—as shown in Figure 1. The rods segment includes the rod control cluster assemblies (RCCAs) and control rod drive mechanisms (CRDMs). Westinghouse RPSs typically have 40 to 60 RCCAs and associated CRDMs. The trip breaker segment includes the reactor trip breakers and associated undervoltage devices and shunt trip devices. Most of the Westinghouse RPSs have DB-50 type reactor trip breakers, while some of the newer plants have DS-416 versions. For the logic cabinet, approximately 70% of the RPSs have solid state logic termed the Solid State Protection System (SSPS), while the remaining 30% have analog logic. Finally, for the instrumentation rack approximately 85% of the RPSs have analog systems to process the signals, while the remaining 15% have converted to the Eagle-21 solid state system.

RPS Segments			
Instrumentation Rack	Logic Cabinet	Trip Breakers	Rods
Generally, 3 channels for 3-loop plants, 4 channels for 2- and 4-loop plants; analog (Analog Series 7300 or earlier) or Eagle-21 signal processing (note that the sensors are located within containment rather than in the instrumentation racks)	2 trains; SSPS or analog logic	2 reactor trip breakers (and 2 bypass breakers); DB-50 or DS-416 design; automated shunt trip and undervoltage trip	40 to 60 RCCAs and associated CRDMs

Figure 1. Segments of Westinghouse RPS.

The analysis of the Westinghouse RPS is based on a four-loop plant with either an Eagle-21 or Analog Series 7300 sensor processing system and an SSPS for the logic cabinet. This configuration has been used in generic analyses of Westinghouse RPSs as representative of most designs.[10, 11] A simplified diagram of the SSPS/Analog Series 7300 design is presented in Figure 2. The SSPS/Eagle-21 modification is shown in Figure 3. The following discussions concerning system operation and system testing refer to the SSPS/Analog Series 7300 RPS design. The SSPS/Eagle-21 design is covered in Section 2.1.3.

In Figure 2, there are two RPS trains in the logic cabinet, trains A and B. These trains receive trip signals from the channels, process the signals, and then open the reactor trip breakers (RTBs) given appropriate combinations of signals from the channels. The channel portion of the RPS includes many different types of trip signals, as indicated in Table 1.[12] The trip signals include various neutron flux indications, pressurizer pressure and level, reactor coolant flow, steam generator level, and others. Several of the signals involve measurements in each of the four loops of the reactor, with a trip signal being generated if at least two of the four loop measurements exceed a setpoint. Shown in the simplified RPS diagram in Figure 2 are sensor/transmitters and signal processing modules associated with the overpower ΔT and pressurizer high pressure trip signals. (These two signals, along with others, protect the plant from uncontrolled rod withdrawal transients while at power.[12]) For each loop there are cold leg and hot leg coolant temperature sensor/transmitters that combine to determine the loop ΔT and $T_{average}$. This information, along with flux information (not shown in Figure 2), is converted by the processing module and sent to the associated bistable, which trips if the bistable setpoint is reached. Similarly, there are four pressure sensor/transmitters for the pressurizer, one for each channel. The pressure processing module converts the pressure signal and sends it to the associated bistable.

The logic cabinet or SSPS in Figure 2 includes two trains. When a bistable in the instrumentation rack trips, it actuates associated relays in both of the trains. The solid state logic module, or universal card, for that trip parameter (one in each train) then determines whether sufficient relays have actuated (i.e., two of four for pressurizer high pressure). If so, a trip signal is sent to the undervoltage driver card (one in each train), which then opens the RTB associated with that train.

In Figure 2, there are two normally-closed RTBs and two normally-open bypass trip breakers. The bypass trip breakers are used only when testing the reactor trip breakers. Train A of the RPS logic actuates RTB-A and train B of the logic actuates RTB-B. Opening of either RTB disconnects AC power from the rod control motor generator sets to the rod drive power cabinets, which results in the RCCAs dropping into the reactor core and shutting down the nuclear reaction. During plant operation, the normally-energized undervoltage coil maintains the RTB in a closed position. The shunt trip coil is normally de-energized. An undervoltage driver card trip signal results in de-energization of the undervoltage coil and energizing (through the auto shunt trip relay) of the shunt trip coil, either of which will open the RTB.

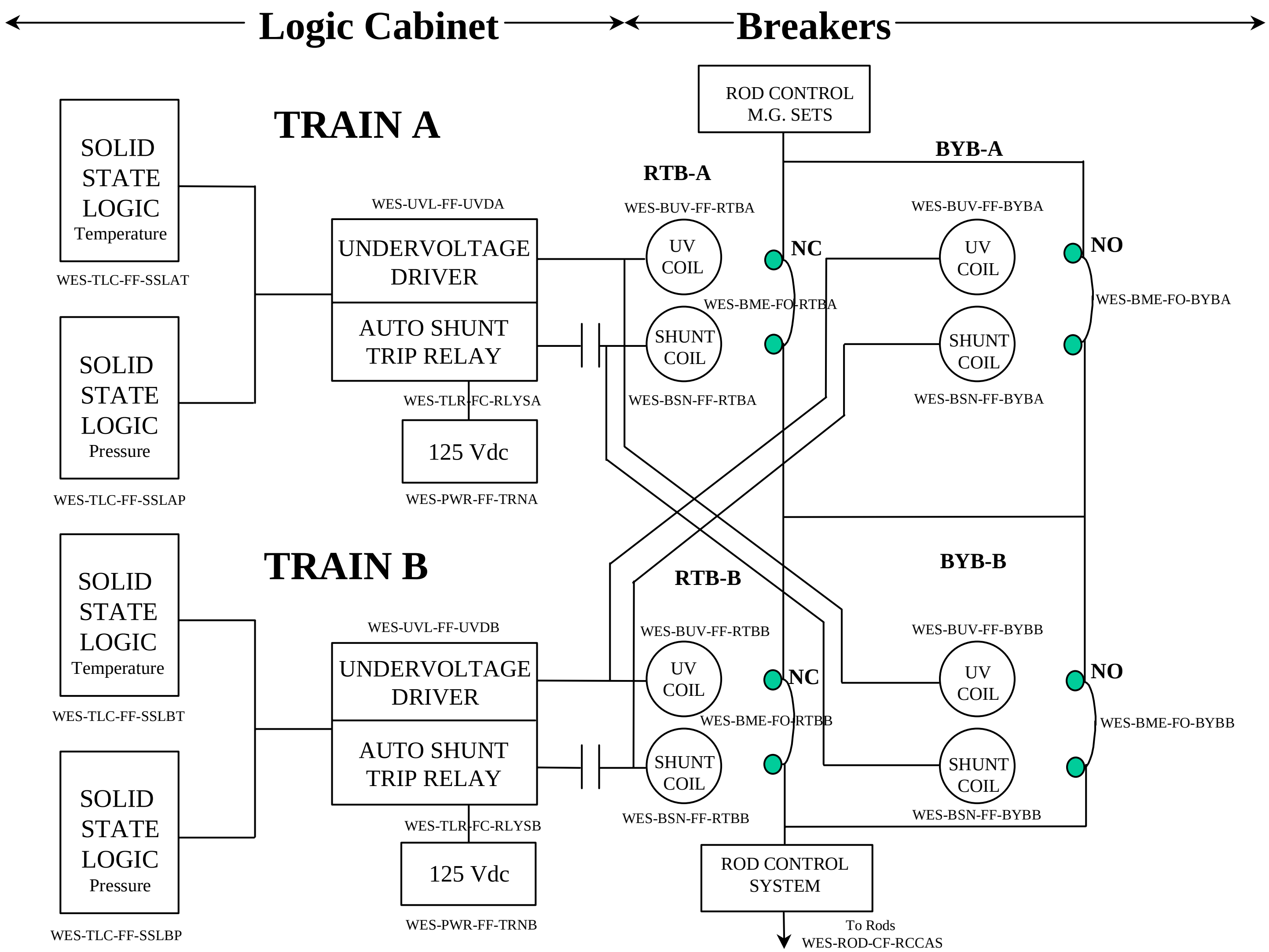


Figure 2. Westinghouse RPS simplified diagram (Analog Series 7300).

Scope of Study

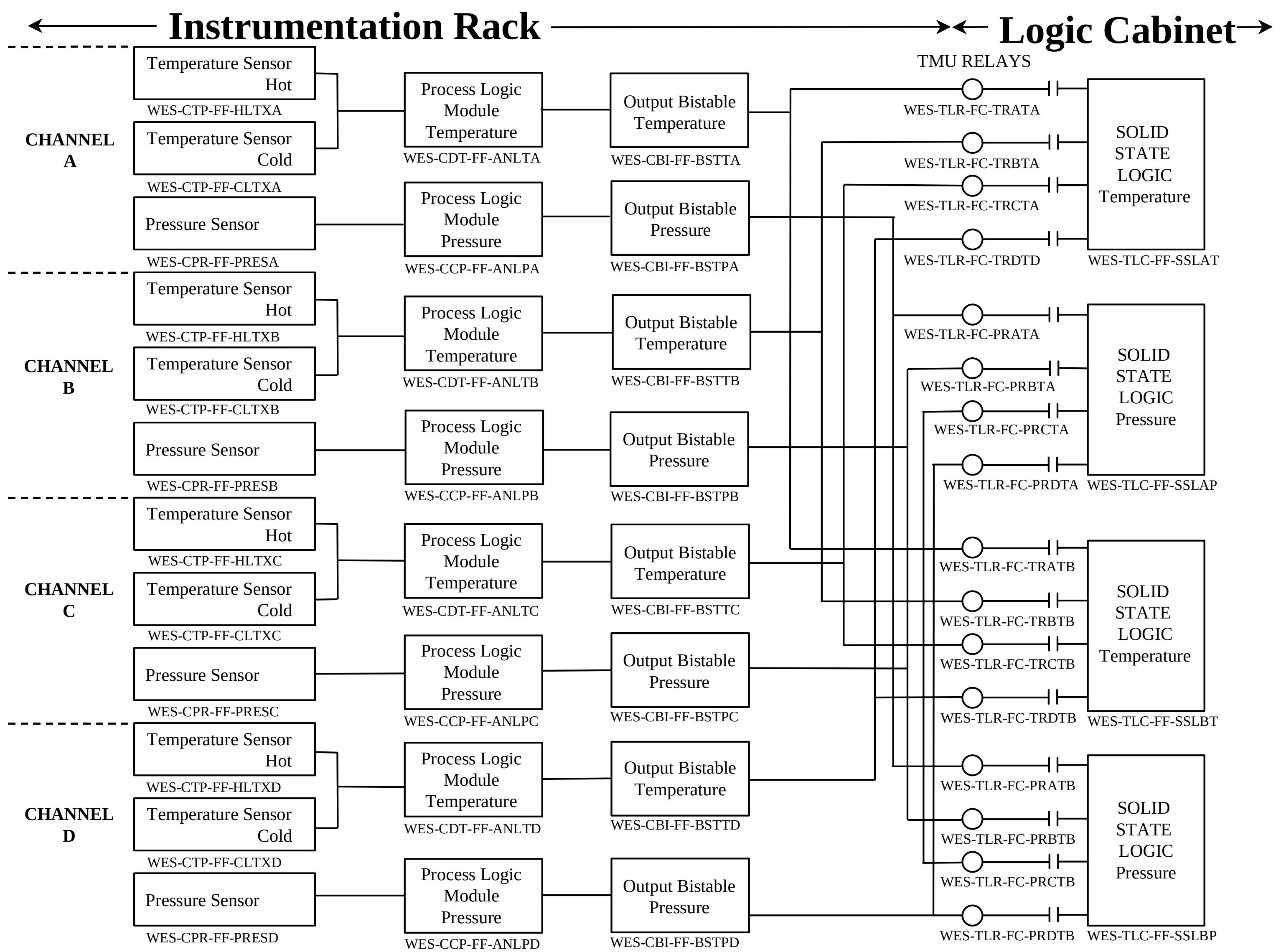


Figure 2. (continued).

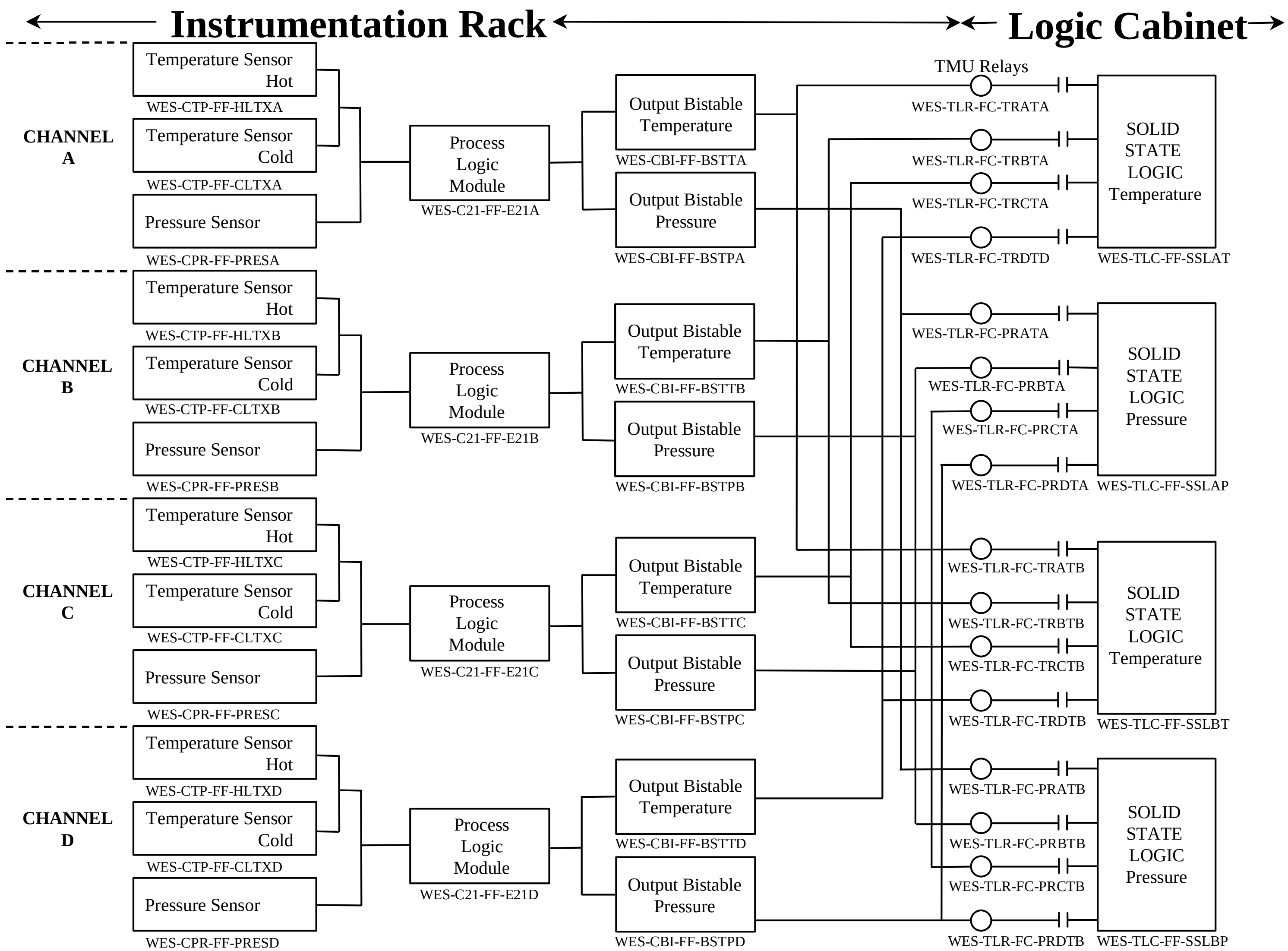


Figure 3. Westinghouse RPS simplified diagram (Eagle-21).

Table 1. Representative Westinghouse RPS trip signals.

Trip Signal	Trip Logic[a]	Purpose of Trip
1. Source range high neutron flux	1 of 2 sensors	Prevent an inadvertent power increase while subcritical or at low power
2. Intermediate range high neutron flux	1 of 2 sensors	Prevent an inadvertent power increase at low power
3. Power range high neutron flux (low setpoint)	2 of 4 sensors	Prevent an inadvertent power increase while at power
4. Power range high neutron flux (high setpoint)	2 of 4 sensors	Limit maximum power level
5. High positive rate, neutron flux	2 of 4 sensors	Limit power excursions
6. High negative rate, neutron flux	2 of 4 sensors	Prevent unacceptable power distributions
7. Overtemperature ΔT	2 of 4 overtemperature ΔT signals (one for each loop)	Prevent operation with a DNBR < 1.30[c]
8. Overpower ΔT[b]	2 of 4 overpower ΔT signals (one for each loop)	Prevent excessive power density
9. Pressurizer low pressure	2 of 4 sensors	Prevent DNBR < 1.30[c]
10. Pressurizer high pressure[b]	2 of 4 sensors	Protect integrity of reactor coolant system pressure boundary
11. Pressurizer high water level	2 of 3 sensors	Prevent solid water operations
12. Low reactor coolant flow	2 of 3 sensors in any one of four loops	Ensure adequate loop flow to remove core heat
13. Reactor coolant pump undervoltage	2 of 4 buses	Ensure adequate loop flow to remove core heat
14. Reactor coolant pump underfrequency	2 of 4 buses	Ensure adequate loop flow to remove core heat
15. Steam generator low water level (mismatch with steamflow/feedflow)	1 of 2 level sensors coincident with 1 of 2 mismatches in the same steam generator (four steam generators)	Anticipate loss of heat sink
16. Turbine trip	2 of 3 low autostop oil pressure or 4 of 4 turbine stop valves shut	Remove heat source if steam load is lost to steam generators

a. A four-loop reactor design is assumed.

b. These two signals are modeled in the RPS fault tree used for this study.

c. DNBR = departure from nucleate boiling ratio

2.1.2 System Testing

RPS testing addresses the four segments of the RPS indicated in Figure 1. For RPS channels (instrumentation rack), there are typically four types of tests: channel checks (qualitative verification of instrument channel behavior) every 12 hours, quarterly (every three months) functional tests, calibration tests every refueling or 18 months, and time response tests every refueling or 18 months.[11, 12] Channel checks detect gross sensor/transmitter failures and drift. The functional tests for analog channels are performed using a test switch that aligns the channel input to test jacks (bypassing the sensor) and the output bistable to the test lamp. The test input signal is then increased until the bistable trips, as indicated by the test lamp. This test is repeated for each of the trip parameters feeding into the channel. Before 1986, this channel functional test was required to be performed monthly and involved putting the channel into a tripped condition (half reactor trip condition) during the test. However, in 1986 Westinghouse obtained approval to perform such tests quarterly, rather than monthly, and to place the channel into a bypass condition, rather than a tripped condition. (Some Westinghouse plants cannot place a channel into a bypass condition without jumpers or removing leads. In such cases the channel must be placed into a tripped condition.) It is not known when each Westinghouse plant switched from monthly to quarterly testing of the channels. This report assumes quarterly testing for all of the plants over the entire period 1984 through 1995. However, a sensitivity study, presented in Appendix G, covers the assumption of monthly testing. The refueling or 18-month calibration tests cover the sensor/transmitters. Finally, the refueling or 18-month time response tests are similar to the quarterly functional tests, but include measurement of the time for the channel to respond to changes in inputs.

For the logic cabinet segment (train) of the RPS, two types of tests apply: staggered monthly functional tests (each train tested every two months) and refueling or 18-month time response tests. The staggered monthly test essentially isolates the SSPS from the channels and places the train into a bypass condition. (A tripped condition would result in a reactor trip.) A semi-automatic test panel is used to generate all possible combinations of channel inputs and test the SSPS response up to, but not including, the RTB undervoltage and shunt trip coils. Before 1986, this test was performed bimonthly. However, by 1992 the testing routine had changed to staggered monthly.[14] Both testing routines result in the same number of tests per year.

Two types of tests also apply to the RTBs and bypass trip breakers, similar to the logic cabinet tests. The staggered monthly functional test involves separate testing of the undervoltage and shunt trip coil mechanisms for opening the RTB, performed by using manual pushbuttons located near the RTBs. Before the RTB is tested, the associated bypass trip breaker is tested and placed into service (closed). During the test of the RTB, the associated train is in a bypass condition. This leaves only the other train available to respond to plant upset conditions. However, this train actuates both the RTB and the associated bypass trip breaker, either of which can interrupt power to the rod drive power cabinets. After the test, the bypass trip breaker is removed from service. Similar to the SSPS, this test was performed bimonthly before 1986, but has since changed to staggered monthly. The time response test every refueling or 18 months measures the time the RTB requires to open.

Finally, the rod segment of the RPS involves two types of tests: monthly limited movement tests of each RCCA/CRDM, and RCCA drop timing tests every refueling or 18 months.

2.1.3 Eagle-21 Description

The Eagle-21 upgrade to the RPS, as modeled in this report and shown in Figure 3, replaces the channel process logic modules with an integrated, solid-state Eagle-21 module.[13] Otherwise, the same sensor/transmitters and bistables are used. The Eagle-21 upgrade allows for increased on-line monitoring and diagnostics, and more efficient quarterly testing. The increased on-line monitoring results in most failures being detected almost instantaneously, rather than during quarterly testing.

2.1.4 System Boundary

The RPS boundary for this study includes the four segments indicated in Figures 1, 2, and 3: channels (instrumentation rack), logic cabinet, trip breakers, and rods. Also included is the control room operator who pushes the manual reactor trip button. The ATWS mitigation system AMSAC is not included.

2.2 System Fault Tree

This section contains a brief description of the Westinghouse RPS fault tree developed for this study. The actual fault tree is presented in Appendix D. The analysis of the Westinghouse RPS is based on a four-loop plant with either an Eagle-21 or an Analog Series 7300 sensor processing system and an SSPS logic cabinet. As mentioned in Section 2.1.1, this configuration has been used in generic analyses of Westinghouse RPSs as representative of most of the various designs and configurations. It should be noted that the RPS fault tree development represents a moderate level of detail, reflecting the purpose of this project to collect actual RPS performance data and assemble the data into overall RPS unavailability estimates. The level of detail of the fault tree reflects the level of detail available from the component failure information in NPRDS and the LERs.

The top event in the RPS fault tree is “Reactor Protection System (RPS) Fails.” RPS failure at this top level is defined as an insufficient number of RCCAs dropping into the core to inhibit the nuclear reaction. Various plant upset conditions can result in differing requirements for the minimum number of RCCAs to drop into the core, and the positions of the RCCAs within the core can also be important. The Seabrook Probabilistic Safety Assessment conservatively used two or more RCCAs failing to insert as the RPS failure criterion.[15] Also, WASH-1400 conservatively used three or more RCCAs failing to insert. However, NUREG-0460 indicates for a specific Westinghouse reactor study, 25 RCCAs failing to insert will still result in a shutdown of the nuclear reaction for most initiating events and 10 RCCAs failing to insert will shutdown the nuclear reaction for almost all initiating events.[1] Therefore, the RCCA failure criterion might range from 2 to 25 RCCAs failing to insert into the core upon demand. The lower limit is very conservative, while the upper limit may not be appropriate given severe plant upset conditions or asymmetric patterns of RCCA failures. For this study, 10 or more RCCAs failing to fully insert into the core was chosen as the RPS failure criterion. See Appendices E and G for details on a sensitivity analysis performed for this failure criterion.

It should be noted that the structure of the RPS fault tree is independent of the selection of the number of RCCAs having to fail to insert into the core. For the rest of the fault tree, failure to remove power from the CRDMs results in all of the RCCAs failing to insert. Failure to remove power from the CRDMs results if both RTBs fail to open, if both SSPS trains fail to actuate the RTBs, or if three of four channels fail to generate reactor trip signals.

The level of detail in the RPS fault tree includes RTBs and bypass trip breakers (broken down into mechanical/electrical, undervoltage coil, and shunt trip coil), undervoltage driver and universal cards in the SSPS, selected relays, temperature and pressure sensor/transmitters, Eagle-21 and analog process logic modules, and bistables. The Eagle-21 and Analog Series 7300 RPS designs are distinguished by minor changes in the channel portion of the fault tree, with a house event used to turn on the applicable basic events. Within the channels, two trip parameters are modeled: overpower ΔT and pressurizer high pressure (see Table 1). These are two parameters that would detect an uncontrolled rod withdrawal transient while the plant is at power. In general, at least three RPS parameters are available to initiate a trip signal for any type of plant upset condition requiring a reactor trip.[12] Only two parameters are included in the fault tree to simplify the tree. (The size of the RPS fault tree presented in Appendix D would nearly double if three parameters were included.) Note that a sensitivity analysis presented in Appendix G of this report addresses the potential impacts on the results if three trip parameters were included in the fault tree.

Common-cause failures (CCFs) across similar components were explicitly modeled in the RPS fault tree. Examples of such components include the mechanical/electrical, undervoltage coil, and shunt trip coil portions of the RTBs and bypass trip breakers, undervoltage driver cards, universal cards, analog or Eagle-21 processors, sensor/transmitters, relays, and bistables. In general, the common-cause modeling in the RPS fault tree is limited to the events that fail enough components to fail that portion of the RPS. For example, for channels, three or four of four must fail in order for the RPS to fail to generate a reactor trip signal. Therefore, common-cause modeling for the channels includes such events as three or four out of four pressure signal processing modules failing. Lower order CCF events, such as two out of four components failing, are not modeled in the fault tree. Such events would have to be combined with an independent failure for the three out of four failure criterion to be met.

Test and maintenance outages and associated RPS configurations are modeled for RTB/SSPS and channel outages. For channel outages, the fault tree channel was developed assuming that a channel out for testing or maintenance is placed into the bypass mode, rather than a tripped mode. As mentioned earlier, Westinghouse obtained NRC approval for placing channels in bypass during testing or maintenance in 1986, as long as jumpers or lifting of leads is not needed in order to place the channel into bypass. Test and maintenance outages for all four channels are combined, for simplicity, into a single outage event for channel A in the RPS fault tree. For RTB or SSPS train testing or maintenance, that train is placed into a bypass mode, so only the other train is available to respond to plant upset conditions. Train outages are modeled individually for trains A and B.

2.3 Operational Data Collection, Characterization, and Analysis

The RPS data collection, characterization, and analysis process is shown in Figure 4. The major tasks include failure data collection and characterization, demand data collection, and data analysis. Each of these major tasks is discussed below. Also discussed is the engineering analysis of the data. A more detailed explanation of the process is presented in Appendix A.

2.3.1 Inoperability Data Collection and Characterization

The RPS is a system required by technical specifications to be operable when the reactor vessel pressure is above 150 psig (some plants have a 90 psig requirement); therefore, all occurrences that result in the system not being operable must be reported in LERs to be in compliance with 10 CFR 50.73(a)(2)(i)(B). In addition, 10 CFR 50.73(a)(2)(vii) requires the licensee to report all common-cause failures resulting in a loss of capability for safe shutdown. Therefore, the SCSS LER database should include all occurrences when the RPS was not operable and all common-cause failures of the RPS.

However, the LERs will not normally report RPS component independent failures. Therefore, the LER search was supplemented by the NPRDS data search. NPRDS data were downloaded for all RPS and control rod drive system records for the years 1984 through 1995. The SCSS database was searched for all RPS failures for the same period. In addition, the NRC's Performance Indicator database was used to obtain a list of unplanned RPS demands (reactor trips).

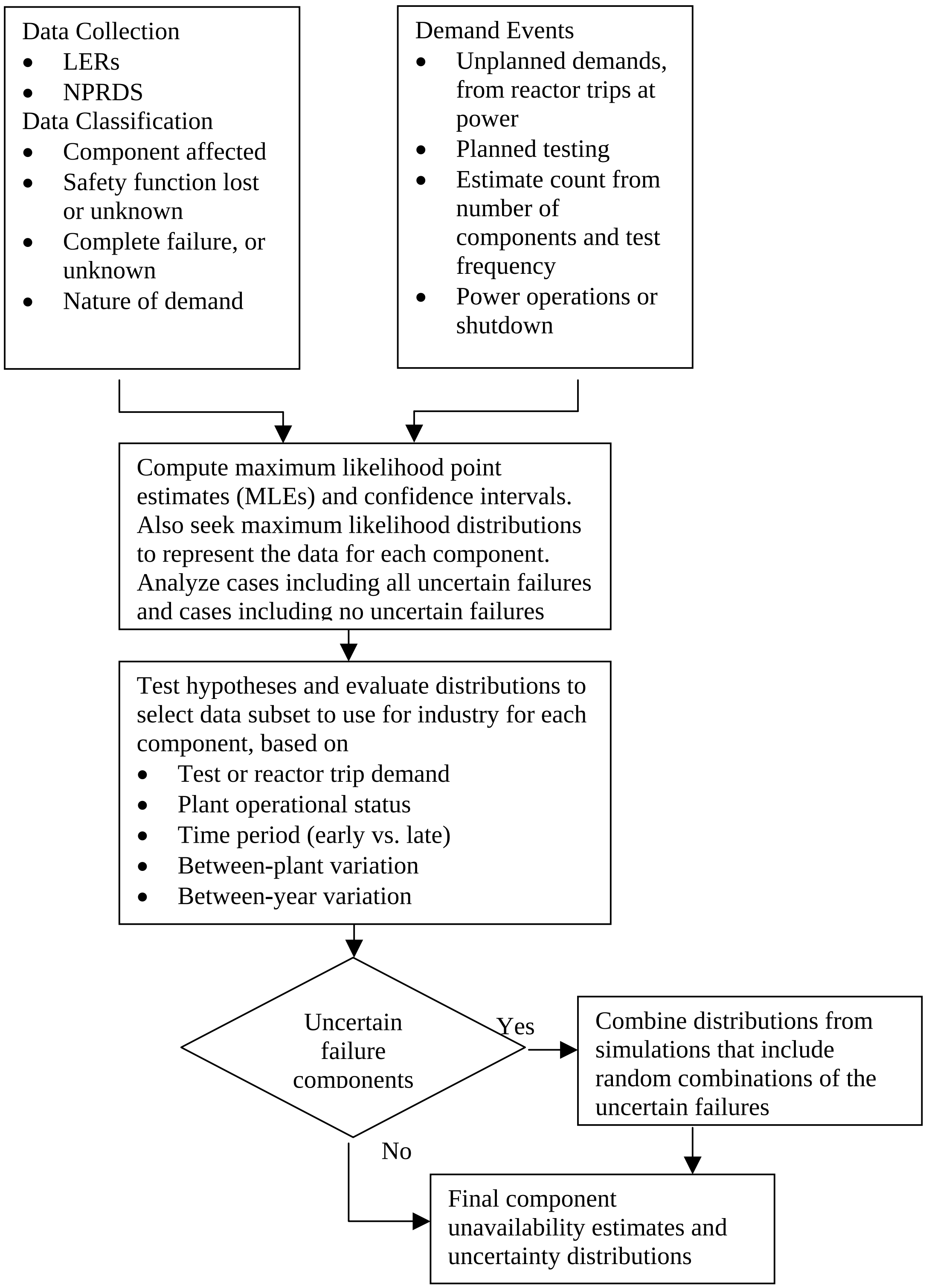


Figure 4. Data collection, characterization, and analysis process.

The NPRDS reportable scope for RPSs and control rod drive systems includes the components modeled in the fault tree described in Section 2.2 and presented in Appendix D. Therefore, the NPRDS data search should identify all RPS component failures. However, it is not clear from the NPRDS reportable scope documentation on the control rod drive system whether individual RCCA or CRDM failures would be reported. Therefore, the independent failure counts of the RCCAs and CRDMs identified in this study may be low compared with actual plant experience. Also, NPRDS stopped reporting RCCA failures after March 15, 1994.

In this report, the term inoperability is used to describe any RPS event reported by NPRDS or the LERs. The inoperabilities are classified as fail-safe (FS) or non-fail-safe (NFS) for the purposes of this study. The term NFS is used to identify the subset of inoperabilities for which the safety function of the RPS component was impacted. An example of a NFS event is a mechanical failure of the RTB to open given a valid signal to open. The term FS is used to describe the subset of inoperabilities for which the safety function of the RPS component was not impacted. Using the RTB as an example, a spurious opening of the RTB is a FS event for the purposes of this study. For some events it was not clear whether the inoperability is FS or NFS. In such cases the event was coded as unknown (UKN).

Inoperability events were further classified with respect to the degree of failure. An event that resulted in complete failure of a component was classified as a complete failure (CF). The mechanical failure of an RTB to open given a valid signal to open is a CF (and NFS) event. Events that indicated some degradation of the component, but with the component still able to function, were classified as no failure (NF). An example of a NF event is an RTB with mechanical tolerances out of specification, but which is still able to open when demanded. For some events it was not clear whether the inoperability was CF or NF. In such cases the event was coded as unknown completeness (UC).

A summary of the data classification scheme is presented in Figure 5. In the figure, there are nine bins into which the data can be placed. These nine bins represent combinations of the three types of safety function impact (NFS, UKN, or FS) and the three degrees of failure completeness (CF, UC, or NF). As indicated by the shaded area in Figure 5, the data classification results in one bin containing non-fail-safe/complete failures (NFS/CF), and three bins (NFS/UC, UKN/CF, and UKN/UC) that contain events that are potentially NFS/CF. For these three bins, a lack of information in the data event reports did not allow the data analyst to determine whether the events were NFS/CF. The other five bins do not contain NFS/CF events and generally were not used in the data analysis.

	Safety Function Impact		
Failure Completeness	NFS/CF (safety function impact, complete failure)	UKN/CF (unknown safety function impact, complete failure; potential NFS/CF)	FS/CF (no safety function impact, complete failure)
	NFS/UC (safety function impact, unknown completeness; potential NFS/CF)	UKN/UC (unknown safety function impact, unknown completeness; potential NFS/CF)	FS/UC (no safety function impact, unknown completeness)
	NFS/NF (safety function impact, no failure)	UKN/NF (unknown safety function impact, no failure)	FS/NF (no safety function impact, no failure)

Figure 5. Data classification scheme.

The data characterization followed a three-step process: an initial review and classification by personnel with operator level nuclear plant experience, a consistency check by the same personnel (reviewing work performed by others), and a final, focused review by instrumentation and control and RPS experts. This effort involved approximately 15,000 NPRDS and LER records.

2.3.2 Demand Data Collection and Characterization

Demand counts for the RPS include both unplanned system demands or unplanned reactor trips while the plant is at power, and tests of RPS components. These demands meet two necessary criteria: (1) the demands must be identifiable, countable, and associated with specific RPS components, and (2) the demands must reasonably approximate the conditions being considered in this study. Unplanned reactor trips clearly meet these criteria for the RPS RTBs and trains. However, these reactor trips do not meet the first criterion for channel components, because it is not clear what reactor trip signals existed for each unplanned reactor trip. For example, not all unplanned reactor trips might have resulted in a pressurizer high pressure. The RPS component tests clearly meet the first criterion. Because of the types of tests, they also meet the second criterion, i.e., the tests are felt to adequately approximate conditions associated with unplanned reactor trips.

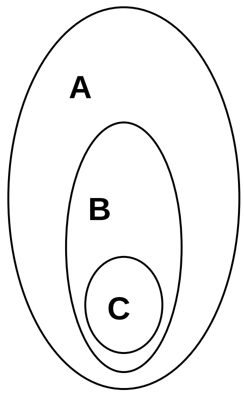
For unplanned demands, the LER Performance Indicator data describe all unplanned reactor trips while plants are critical. The reactor trip LERs were screened to determine whether the reactor trips were automatic or manual, since each type exercises different portions of the RPS. For RPS component tests, it was assumed that RTBs and SSPS trains are tested on a staggered monthly basis, while channels and transmitters are tested quarterly. Sensors are tested (calibrated) every 18 months. More details on the counting of demands are presented in Appendix A.

2.3.3 Data Analysis

In Figure 4, the data analysis steps shown cover the risk-based analysis of the operational data, leading to the quantification of RPS unavailability. Not shown in Figure 4 is the engineering analysis of the operational data. The risk-based analysis involves analysis of the data to determine the appropriate subset of data for each component unavailability calculation. Then simulations can be performed to characterize the uncertainty associated with each component unavailability.

The risk-based analysis of the operational data (Section 3) and engineering analysis of the operational data (Sections 4.1 and 4.2) are largely based on two different data sets. The Venn diagram in Figure 6 illustrates the relationship between these data sets. Data set A represents all of the LER and NPRDS events that identified an RPS inoperability. Data set B represents the inoperabilities that resulted in a complete loss of the safety function of the RPS component, or the NFS/CF events (and some fraction of the NFS/UC, UKN/CF, and UKN/UC events). Finally, data set C represents the NFS/CF events (and some fraction of the NFS/UC, UKN/CF, and UKN/UC events) for which the corresponding demands could be counted. Data set C (or a subset of C) is used for the failure upon demand risk-based analysis of the RPS components. Data set C contains all NFS/CF events (and some fraction of the NFS/UC, UKN/CF, and UKN/UC events) that occurred during either an unplanned reactor trip while the plant was critical or a periodic surveillance test.

The purpose of the engineering analysis is to provide qualitative insights into RPS performance. The engineering analysis focused on data set B in Figure 6, which includes data set C as a subset. Data set A was not used for the engineering analysis because the additional FS events in that data set were not judged to be informative with respect to RPS failure to scram, which is the focus of this report.



A RPS inoperabilities identified in NPRDS or LERs

B RPS inoperabilities that are NFS

C RPS NFS events whose demand count could be estimated

Figure 6. RPS data sets.

In contrast to the risk-based analysis of operational data to obtain component failures upon demand, which used data set C, the CCF analysis used data set B. This is appropriate because the CCF analysis is concerned with what fraction of all NFS events involved more than one component. Such an analysis does not require that the failures be matched to demands. The engineering analysis of CCF events, in Section 4, also used data set B.

3. RISK-BASED ANALYSIS OF THE OPERATIONAL DATA

3.1 Unavailability Estimates Based on System Operational Data

If the Westinghouse RPS is evaluated at the system level with no consideration of plant-to-plant variations in RPS designs, then a system failure probability can be estimated based on the total system failures and total system demands. For the period 1984 through 1995, there were no total system failures in 1845 demands (unplanned reactor trips). Assuming a Jeffreys noninformative prior and applying a Bayesian update with this evidence results in an RPS mean unavailability (failure probability upon demand) of 2.7E-4, with a lower 5th percentile of 1.1E-6 and an upper 95th percentile of 1.0E-3. (See Appendix A for more details on the Bayesian update process. With no failures, the Jeffreys noninformative prior assumes one-half failure.) Because no failures occurred, the uncertainty bound on this estimate is broad. Also, the estimate is most likely a conservative upper bound on RPS performance during that period, given previous estimates of RPS unavailabilities (Section 3.3).

If the staggered monthly tests of both trains of the RPS are considered as system demands, then the Westinghouse RPS evidence for the period 1984 through 1995 is no system failures in 1845 reactor trips and 543.7 reactor-years of operation. Multiplying the 543.7 reactor-years by six tests per year results in 3262 system tests. Therefore, the total number of system demands during the period 1984 through 1995 is 1845 reactor trips plus 3262 tests, or 5107 demands. The RPS mean unavailability is then 9.8E-5.

These system level failure estimates are based on no system failures and a limited number of system demands. The unavailabilities are believed to be conservatively high. In order to obtain a more realistic RPS unavailability estimate, an RPS fault tree was also developed, as discussed in the following section. That approach could make use of additional RPS component failure data.

3.2 Unavailability Estimates Based on Component Operational Data

3.2.1 Fault Tree Unavailability Results

The Westinghouse RPS fault tree presented in Appendix D and discussed in Section 2.2 was quantified using the SAPHIRE computer code.[16] Fault tree basic event probabilities are presented in Tables 2 through 4. The basic events are divided into three groups: component independent failure events (Table 2), CCF events (Table 3), and other types of events such as test and maintenance outages and operator errors (Table 4). Failure probabilities for the component independent failures were obtained from the Westinghouse RPS data as discussed in Section 2.3. Details of the methodology are discussed in Appendix A, a summary of the data is presented in Appendix B, and the results of the analyses are presented in Appendix C. All of the component independent failure probabilities listed in Table 2 are based on actual Westinghouse RPS component failure events during the period 1984 through 1995, except for the 125 Vdc power supplies to the shunt trip coils. However, depending on the results of the data analysis, the failure probabilities may or may not include the following data subgroups: reactor trip-related failures and demands, failures while plants are shut down, and 1984 through 1989 data. The component failure probabilities in Table 2 are, in general, comparable to those presented in previous reports listing generic component failure probabilities.[11, 12, 17 and 18]

The CCF event probabilities in Table 3 are based on the Westinghouse RPS CCF data during the period 1984 through 1995. However, the CCF event probabilities are also influenced by the prior used in the Bayesian updating of the common-cause α parameters. The prior for this study was developed from the overall Westinghouse RPS CCF database. A summary of the Westinghouse CCF data is presented in Appendix B, while the actual details of the CCF calculations are in Appendix E. In general, the CCF events reflect multipliers (from the alpha equations) of 0.04 to 0.002 on the component failure probabilities (Q_T's) in Table 2.

Table 2. Westinghouse RPS fault tree independent failure basic events.

Component Code	Component Type	Fault Tree Basic Event	Number of Failures[a]	Number of Demands or Hours	Modeled Variation[b]	Distribution	Bayes 5%, Mean, 95%	Basic Event Description
BME	Reactor trip breaker (mechanical/electrical)	WES-BME-FO-RTBA,B WES-BME-FO-BYBA,B	0 (0.0)	13546	Sampling	Lognormal	3.8E-6 3.7E-5 1.2E-4	Trip breaker failure to open (mechanical/electrical failure that defeats both undervoltage and shunt trip devices)
BSN	Reactor trip breaker (shunt trip)	WES-BSN-FF-RTBA,B WES-BSN-FF-BYBA,B	8 (7.5)	13048	Year	Lognormal	1.4E-4 5.8E-4 1.5E-3	Shunt trip failure to energize and open the reactor trip breaker
BUV	Reactor trip breaker (undervoltage coil)	WES-BUV-FF-RTBA,B WES-BUV-FF-BYBA,B	2 (2.0)	9856	Sampling	Lognormal	8.3E-5 2.5E-4 5.6E-4	Undervoltage coil failure to de-energize and open the reactor trip breaker
C21	Eagle-21 channel processor	WES-C21-FF-E21A,B,C,D	11 (10.6)	972577h	Plant	Lognormal	7.4E-6 6.5E-5 2.1E-4	Eagle-21 channel processor fails to process reactor trip signals and send appropriate outputs to channel bistables (8.2E-6/h*8h repair time) [c]
CBI	Channel bistable	WES-CBI-FF-BSTPA,B,C,D WES-CBI-FF-BSTTA,B,C,D	44 (40.0)	56235	Plant	Lognormal	6.0E-5 7.5E-4 2.5E-3	Channel bistable fails to trip at its setpoint and actuate its train relays
CCP	Channel pressure processing module	WES-CCP-FF-ANLPA,B,C,D	14 (5.6)	38115	Plant	Lognormal	1.2E-5 1.6E-4 5.4E-4	Channel pressure processing module (Analog Series 7300) fails to process a reactor trip signal and send appropriate output to the channel bistable
CCX	Combination of 3 types of channel processing modules	None (supports CCX CCF events in fault tree)	43 (17.2)	22272	Plant	Lognormal	2.8E-4 7.8E-4 1.6E-3	Channel pressure, ΔT, or steam flow mismatch processing module (Analog Series 7300) fails to process a reactor trip signal and send appropriate output to the channel bistable
CDT	Channel ΔT processing module	WES-CDT-FF-ANLPA,B,C,D	36 (15.1)	3157	Plant	Lognormal	1.5E-3 4.8E-3 1.1E-2	Channel ΔT processing module (Analog Series 7300) fails to process a reactor trip signal and send appropriate output to the channel bistable
CPR	Channel pressure sensor/ transmitter	WES-CPR-FF-PRESA,B,C,D	3 (0.2)	5832	Sampling	Lognormal	1.3E-5 1.2E-4 3.7E-4	Channel pressure sensor/transmitter fails to detect a high pressure and send appropriate output to the channel processing module

Table 2. (continued).

Component Code	Component Type	Fault Tree Basic Event	Number of Failures[a]	Number of Demands or Hours	Modeled Variation[b]	Distribution	Bayes 5%, Mean, 95%	Basic Event Description
CTP	Channel temperature sensor/ transmitter	WES-CTP-FF-CLTXA,B,C,D WES-CTP-FF-HLTXA,B,C,D	11 (8.2)	14423	Plant	Lognormal	3.1E-4 6.0E-4 1.0E-3	Channel temperature sensor/transmitter fails to detect a high/low temperature and send appropriate output to the channel processing module
PWR	125 Vdc power to shunt trip	WES-PWR-FF-TRNA,B	NA[d]	NA[d]	NA[d]	Lognormal	2.3E-6 6.0E-5 2.3E-4	125 Vdc power to the shunt trip fails (1.0E-5/h*6h repair time)
ROD	RCCA and CRDM combined	None (supports ROD CCF event in fault tree)	2 (1.0)	102088	Sampling	Lognormal	2.6E-6 1.5E-5 4.1E-5	Failure of RCCA/CRDM, resulting in failure of RCCA to insert into the core
TLC	SSPS universal card	WES-TLC-FF-SSLAP,T WES-TLC-FF-SSLBP,T	24 (23.0)	58220	Plant	Lognormal	1.4E-5 3.8E-5 1.4E-3	SSPS universal card fails to recognize a reactor trip combination and send appropriate output to the train undervoltage driver card
TLR	Channel bistable relay; train undervoltage driver card relay	WES-TLR-FC-PRATA,B WES-TLR-FC-PRBTA,B WES-TLR-FC-PRCTA,B WES-TLR-FC-PRCTA,B WES-TLR-FC-TRATA,B WES-TLR-FC-TRBTA,B WES-TLR-FC-TRCTA,B WES-TLR-FC-TRDTA,B WES-TLS-FC-RLYSA,B	7 (6.2)	168686	Plant	Lognormal	5.8E-6 3.9E-5 9.7E-5	Relay associated with channel bistable fails to respond to bistable trip; undervoltage driver card shunt trip relay fails to respond
UVL	SSPS undervoltage driver card	WES-UVL-FF-UVDA,B	2 (2.0)	7424	Sampling	Lognormal	1.1E-4 3.4E-4 7.4E-4	SSPS undervoltage driver card fails to respond to a universal card reactor trip signal

a. Includes uncertain events and CCF events. The number in parentheses is the weighted average number of failures, resulting from the inclusion of uncertain events from data bins NFS/UC, UKN/CF, and UKN/UC (explained in Section 2.3.1).

b. Modeled variation indicates the type of data grouping used to determine the uncertainty bands. For example, for the plant-to-plant variation, data were organized by plant to obtain component failure probabilities per plant. Then the plant failure probabilities were combined to obtain the mean and variance for the component uncertainty distribution. See Appendix A for more details.

c. A failure detection and repair duration of eight hours was assumed. The failures are annunciated in the control room.

d. Power failure data were not analyzed as part of this study. The failure rate per hour was obtained from Reference 17 (Table 4, p. 23). The six-hour repair time was estimated from the reactor trip breaker maintenance duration in Reference 11.

Table 3. Westinghouse RPS fault tree CCF basic events.

Component Code	Component Type	Basic Event(s)	Number of CCF Events	Distribution	Bayes 5%, Mean, 95%	Basic Event Description
BME	Reactor trip breaker (mechanical/ electrical)	WES-BME-CF-RTBAB, RANBB, RBNBA	1	Lognormal	4.6E-8 1.6E-6 6.2E-6	CCF of 2 of 2 trip breakers (mechanical/electrical failures)
BSN	Reactor trip breaker (shunt trip)	WES-BSN-CF-RTBAB, RANBB, RBNBA	1	Lognormal	1.1E-6 2.1E-5 7.6E-5	CCF of 2 of 2 trip breaker shunt trip coils
BUV	Reactor trip breaker (undervoltage coil)	WES-BUV-CF-RTBAB, RANBB, RBNBA	1	Lognormal	6.3E-7 9.7E-6 3.4E-5	CCF of 2 of 2 trip breaker undervoltage coils
C21	Eagle-21 channel processor	WES-C21-CF-E2OF3	2	Lognormal	3.0E-8 5.1E-7 1.8E-6	CCF of 2 or more of 3 Eagle-21 channel modules (1 channel bypassed)
		WES-C21-CF-E3OF4	2	Lognormal	3.6E-9 1.5E-7 5.8E-7	CCF of 3 or more of 4 Eagle-21 channel modules
CBI	Channel bistable	WES-CBI-CF-4OF6	43	Lognormal	2.9E-7 8.2E-6 3.1E-5	CCF of 4 or more of 6 channel bistables (1 channel bypassed)
		WES-CBI-CF-6OF8	43	Lognormal	3.8E-8 2.7E-6 1.0E-5	CCF of 6 or more of 8 channel bistables
		WES-CBI-CF-P2OF3	43	Lognormal	1.9E-6 4.2E-5 1.6E-4	CCF of 2 or more of 3 pressurizer high pressure bistables (1 channel bypassed)
		WES-CBI-CF-P3OF4	43	Lognormal	2.2E-7 1.2E-5 4.6E-5	CCF of 3 or more of 4 pressurizer high pressure bistables
		WES-CBI-CF-T2OF3	43	Lognormal	1.9E-6 4.2E-5 1.6E-4	CCF of 2 or more of 3 overtemperature ΔT bistables (1 channel bypassed)
		WES-CBI-CF-T3OF4	43	Lognormal	2.2E-7 1.2E-5 4.6E-5	CCF of 3 or more of 4 overtemperature ΔT bistables

Table 3. (continued).

Component Code	Component Type	Basic Event(s)	Number of CCF Events	Distribution	Bayes 5%, Mean, 95%	Basic Event Description
CCP	Channel pressure processing module	WES-CCP-CF-P2OF3	2	Lognormal	6.5E-7 1.5E-5 5.6E-5	CCF of 2 or more of 3 pressurizer high pressure signal processing (1 channel bypassed)
		WES-CCP-CF-P3OF4	2	Lognormal	8.2E-8 4.5E-6 1.7E-5	CCF of 3 or more of 4 pressurizer high pressure signal processing
CCX		WES-CCX-CF-4OF6	5	Lognormal	8.7E-7 6.3E-6 1.9E-5	CCF of 2 or more of 3 pressurizer high pressure signal processing (1 channel bypassed) and CCF of 2 or more of 3 overtemperature ΔT signal processing (1 channel bypassed)
		WES-CCX-CF-6OF8	5	Lognormal	8.0E-8 1.8E-6 6.8E-6	CCF of 3 or more of 4 pressurizer high pressure signal processing And CCF of 3 or more of 4 overtemperature ΔT signal processing
CDT	Channel ΔT processing module	WES-CDT-CF-T2OF3	51	Lognormal	6.8E-5 2.5E-4 5.9E-4	CCF of 2 or more of 3 overtemperature ΔT signal processing (1 channel bypassed)
		WES-CDT-CF-T3OF4	51	Lognormal	9.8E-6 5.6E-5 1.6E-4	CCF of 3 or more of 4 overtemperature ΔT signal processing
CPR	Channel pressure sensor/transmitter	WES-CPR-CF-P2OF3	29	Lognormal	7.5E-7 7.7E-6 2.5E-5	CCF of 2 or more of 3 pressurizer pressure sensor/transmitters (1 channel bypassed)
		WES-CPR-CF-P3OF4	29	Lognormal	1.3E-7 2.1E-6 7.3E-6	CCF of 3 or more of 4 pressurizer pressure sensor/transmitters
CTP	Channel temperature sensor/transmitter	WES-CTP-CF-T2OF6	29	Lognormal	3.1E-5 7.5E-5 1.4E-4	CCF of 1 or more of 2 reactor coolant temperature sensor/transmitters in 2 or more of 3 loops (1 channel bypassed)
		WES-CTP-CF-T3OF8	29	Lognormal	1.3E-5 3.7E-5 7.7E-5	CCF of 1 or more of 2 reactor coolant temperature sensor/transmitters in 3 or more of 4 loops
PWR	125 Vdc power to shunt trip	WES-PWR-CF-TRNAB	NA	Lognormal	4.1E-8 3.4E-6 1.3E-5	CCF of 2 of 2 125 Vdc power supplies to trip breaker shunt trip coils (RPS prior used with no CCF events)

Table 3. (continued).

Component Code	Component Type	Basic Event(s)	Number of CCF Events	Distribution	Bayes 5%, Mean, 95%	Basic Event Description
ROD	Control rod (including rod control cluster assembly)	WES-ROD-CF-RCCAS	2	Lognormal	2.0E-7 1.2E-6 3.5E-6	CCF of 10 or more of 50 RCCA/CRDMs
TLC	SSPS universal card	WES-TLC-CF-SSLA	6	Lognormal	2.0E-7 1.7E-5 6.6E-5	CCF of 2 of 2 (pressurizer pressure and ΔT) universal cards in train A
		WES-TLC-CF-SSLB	6	Lognormal	2.0E-7 1.7E-5 6.6E-5	CCF of 2 of 2 (pressurizer pressure and ΔT) universal cards in train B
		WES-TLC-CF-SSLAB	6	Lognormal	6.2E-9 2.1E-6 7.2E-6	CCF of 4 of 4 (pressurizer pressure and ΔT) universal cards in both trains
TLR	Channel bistable relay; undervoltage driver card relay	WES-TLR-CF-12O16	8	Lognormal	2.6E-9 8.1E-8 3.1E-7	CCF of 3 or more of 4 TMU relays for 4 of 4 trip signals
		WES-TLR-CF-8OF12	8	Lognormal	1.4E-8 2.1E-7 7.2E-7	CCF of 2 or more of 3 TMU relays for 4 of 4 trip signals (1 channel bypassed)
		WES-TLR-CF-PRA23	8	Lognormal	6.4E-7 5.1E-6 1.6E-5	CCF of 2 or more of 3 TMU pressurizer pressure relays in train A (1 channel bypassed)
		WES-TLR-CF-PRA34	8	Lognormal	7.1E-8 1.5E-6 5.6E-6	CCF of 3 or more of 4 TMU pressurizer pressure relays in train A
		WES-TLR-CF-PRB23	8	Lognormal	6.4E-7 5.1E-6 1.6E-5	CCF of 2 or more of 3 TMU pressurizer pressure relays in train B (1 channel bypassed)
		WES-TLR-CF-PRB34	8	Lognormal	7.1E-8 1.5E-6 5.6E-6	CCF of 3 or more of 4 TMU pressurizer pressure relays in train B
		WES-TLR-CF-RLA46	8	Lognormal	9.5E-8 1.0E-6 3.3E-6	CCF of 2 or more of 3 TMU pressurizer pressure relays and CCF of 2 or more of 3 TMU ΔT relays in train A (1 channel bypassed)
		WES-TLR-CF-RLA68	8	Lognormal	1.1E-8 3.3E-7 1.2E-6	CCF of 3 or more of 4 TMU pressurizer pressure relays and CCF of 3 or more of 4 TMU ΔT relays in train A

Table 3. (continued).

Component Code	Component Type	Basic Event(s)	Number of CCF Events	Distribution	Bayes 5%, Mean, 95%	Basic Event Description
TLR (continued)	Channel bistable relay; undervoltage driver card relay	WES-TLR-CF-RLB46	8	Lognormal	9.5E-8 1.0E-6 3.3E-6	CCF of 2 or more of 3 TMU pressurizer pressure relays and CCF of 2 or more of 3 TMU ΔT relays in train B
		WES-TLR-CF-RLB68	8	Lognormal	1.1E-8 3.3E-7 1.2E-6	CCF of 3 or more of 4 TMU pressurizer pressure relays and CCF of 3 or more of 4 TMU ΔT relays in train B
		WES-TLR-CF-TRBAB	8	Lognormal	1.2E-7 2.0E-6 7.2E-6	CCF of 2 of 2 shunt trip relays
		WES-TLR-CF-TRA23	8	Lognormal	6.4E-7 5.1E-6 1.6E-5	CCF of 2 or more of 3 TMU ΔT relays in train A (1 channel bypassed)
		WES-TLR-CF-TRA34	8	Lognormal	7.1E-8 1.5E-6 5.6E-6	CCF of 3 or more of 4 TMU ΔT relays in train A
		WES-TLR-CF-TRB23	8	Lognormal	6.4E-7 5.1E-6 1.6E-5	CCF of 2 or more of 3 TMU ΔT relays in train B (1 channel bypassed)
		WES-TLR-CF-TRB34	8	Lognormal	7.1E-8 1.5E-6 5.6E-6	CCF of 3 or more of 4 TMU ΔT relays in train B
UVL	SSPS undervoltage driver card	WES-UVL-CF-UVDAB	0 [a]	Lognormal	6.5E-7 1.0E-5 3.7E-5	CCF of 2 of 2 undervoltage driver cards

a. The single CCF event (listed in Appendix B) occurred during maintenance while shut down and was detected before the plant returned to power. This event was not used in the base case quantification, but is addressed as a sensitivity case.

Table 4. Westinghouse RPS fault tree other basic events.

Basic Event	Distribution	Lower Bound, Mean, Upper Bound	Basic Event Description	Notes
WES-BME-TM-RTBA	Uniform	0.0 1.4E-3 2.8E-3	Train A SSPS or reactor trip breaker out (bypassed) for test or maintenance	Assumes 2 hours every other month for SSPS train and breaker testing and maintenance. The upper bound assumes 4 hours.
WES-BME-TM-RTBB	Uniform	0.0 1.4E-3 2.8E-3	Train B SSPS or reactor trip breaker out (bypassed) for test or maintenance	Assumes 2 hours every other month for SSPS train and breaker testing and maintenance. The upper bound assumes 4 hours.
WES-CCP-TM-CHA (Analog Series 7300)	Uniform	0.0 5.8E-2 1.2E-1	Channel out (bypassed) for test or maintenance	Assumes 2 hours for each trip signal (16 trip signals) per channel per quarter for testing and maintenance. This event covers outages for all four channels. The upper bound assumes 4 hours.
WES-CCP-TM-CHA (Eagle-21)	Uniform	0.0 2.9E-2 5.8E-2	Channel out (bypassed) for test or maintenance	Assumes 1 hour for each trip signal (16 trip signals) per channel per quarter for testing and maintenance. This event covers outages for all four channels. The upper bound assumes 2 hours.
WES-XHE-XE-NSGNL	None	1.0 (5.0E-1)[a]	Operator fails to manually actuate RPS given failure of the trip signals	No credit is given for operator action in the base case quantification.
WES-XHE-XE-SIGNL	None	1.0 (1.0E-2)[a]	Operator fails to manually actuate RPS given success of trip signals	No credit is given for operator action in the base case quantification.

a. The failure probabilities in parentheses are used for the case where credit is given for the operator pressing the manual scram switch. If the reactor trip signals are present in the control room, then the 1.0E-2 failure probability is applicable. If most of the reactor trip signals have failed to annunciate in the control room, then the 5.0E-1 failure probability is applicable. The fault tree results listed in Appendix F indicate which failure probability is applicable for each cut set.

The remaining fault tree basic events in Table 4 involve test and maintenance outages and operator errors. For the base case quantification, no credit was taken for operator actions to manually actuate the RPS, so both operator actions have failure probabilities of 1.0. The failure probabilities in parentheses are applicable if credit is taken for operator action. The RPS train/breaker test and maintenance outage events were quantified assuming two hours every other month for testing and maintenance for each train/breaker. The channel test and maintenance outage event models outages for all four channels. An average of 32 hours per three-month test (two hours per trip signal) per channel was assumed for test and maintenance outages for the Analog Series 7300 design. For the Eagle-21 design, an average of 16 hours per three-month test (one hour per trip signal) was assumed.

Using the RPS basic event mean probabilities presented in Tables 2 through 4, the Westinghouse RPS mean unavailability (failure probability upon demand) is 2.2E-5, assuming no credit for operator action. This result is for a four-loop plant with Analog Series 7300 channel processing. If credit is taken for operator action to actuate the manual scram switch, the mean unavailability is 5.5E-6. The RPS mean unavailability is 2.0E-5 for the Eagle-21 version, and 4.5E-6 with credit for operator action. The cut sets from the RPS fault tree quantifications performed using SAPHIRE are presented in Appendix F. Basic event importance rankings are also presented in Appendix F. The dominant failures for the Analog Series 7300 RPS design involve CCFs of the undervoltage driver cards, channel bistables, channel signal processing modules, SSPS universal cards, RTBs, and RCCAs. Dominant failures for the Eagle-21 design are similar to those listed for the Analog Series 7300 design.

RPS segment (trip breakers, trains, channels, and rods) contributions to the overall demand unavailability are summarized in Tables 5 and 6. For both designs, the train and channel failures are dominant, given no credit for operator action. If credit is given for manual scram by the operator, then the train contribution drops significantly. This occurs because the manual scram signal bypasses the dominant undervoltage driver card failures.

Table 5. Westinghouse RPS unavailabilities (Analog Series 7300).

	Unavailability (Point Estimate)	
RPS Segment	No Credit for Manual Scram by Operator	Credit for Manual Scram by Operator
Train	1.3E-5 (63.0%)	1.3E-7 (2.4%)
Channel	5.1E-6 (23.8%)	2.6E-6 (46.9%)
Trip breaker	1.6E-6 (7.6%)	1.6E-6 (29.1%)
Rod	1.2E-6 (5.6%)	1.2E-6 (21.7%)
Total RPS	2.2E-5	5.5E-6

Table 6. Westinghouse RPS unavailabilities (Eagle-21).

	Unavailability (Point Estimate)	
RPS Segment	No Credit for Manual Scram by Operator	Credit for Manual Scram by Operator
Train	1.3E-5 (69.3%)	1.3E-7 (2.9%)
Channel	3.1E-6 (16.1%)	1.6E-6 (34.8%)
Trip breaker	1.6E-6 (8.4%)	1.6E-6 (35.7%)
Rod	1.2E-6 (6.2%)	1.2E-6 (26.6%)
Total RPS	2.0E-5	4.5E-6

Another way to segment the Westinghouse RPS unavailabilities is to identify the percentage of the total unavailability contributed by independent failures versus CCF events. Such a breakdown is not exact, because RPS cut sets can include combinations of independent failures and CCF events. However, if one assigns all cut sets with one or more CCF events to the CCF category, then the breakdown is clear. For the Analog Series 7300 design, the CCF contribution to overall RPS unavailability is 95%. This indicates that the underlying RPS unavailability from independent failures is 5%, or approximately 1E-6. The dominant CCF events for the Analog Series 7300 design (see Appendix F) are the following: CCF of both train undervoltage driver cards (46.1% of the RPS total unavailability), CCF of six of eight channel bistables (11.5%), CCF of four of four train universal cards (9.7%), CCF of six of eight channel signal processing modules (7.8%), CCF of two of two RTBs (7.4%), and CCF of 10 or more RCCAs to insert (5.5%).

The Eagle-21 design has a CCF contribution of 94% to overall RPS unavailability. The dominant CCF events are similar to those for the Analog Series 7300.

Various sensitivity analyses were performed on the RPS fault tree quantification results. These sensitivity analyses are discussed in Appendix G.

3.2.2 Fault Tree Uncertainty Analysis

An uncertainty analysis was performed on the Westinghouse RPS fault tree cut sets listed in Appendix F. The fault tree uncertainty analysis was performed using the SAPHIRE code. To perform the uncertainty analysis, uncertainty distributions for each of the fault tree basic events are required. The uncertainty distributions for the basic events involving independent failures of RPS components were obtained from the data statistical analysis presented in Appendix C. The component demand failure probabilities were modeled by lognormal distributions. Note that the component failure rates (per hour) were converted to unavailabilities by multiplying by the repair time (eight hours for the Eagle-21 annunciated failures and six hours for power to the shunt trip coils).

Uncertainty distributions for the CCF basic events required additional calculations. Each CCF basic event is represented by an equation involving the component total failure rate, Q_T, and the CCF α's. (See Appendix E for details.) The uncertainty distributions for Q_T were obtained from the statistical analysis results presented in Appendix C. Uncertainty distributions for the component-specific α's were obtained from the methodology discussed in Appendix E. Each of the α's was assumed to have a beta distribution. The uncertainty distributions for each CCF basic event equation were then evaluated and fit to lognormal distributions. This information was then input to the SAPHIRE calculations.

The results of the uncertainty analysis of the Westinghouse RPS fault tree model are presented in Table 7. These results were obtained using a Latin Hypercube simulation with 10,000 samples.

3.3 Comparison with PRAs and Other Sources

Similar to the approaches used in this study, RPS unavailability has been estimated previously from overall system data or from data for individual components within the system. The component approach requires a logic model such as a fault tree to relate component performance to overall system performance. This section summarizes early RPS unavailability estimates using both methods and more recent Westinghouse Individual Plant Examination (IPE) estimates.

WASH-1270, published in 1973, estimated the RPS unavailability to be 6.9E-5 (median), based on two RPS failures (N-Reactor and German Kahl reactor events) in 1627 reactor-years of operation. Of this combined experience, approximately 1000 reactor-years were from naval reactors. The Electric Power

Table 7. Westinghouse RPS uncertainty results.

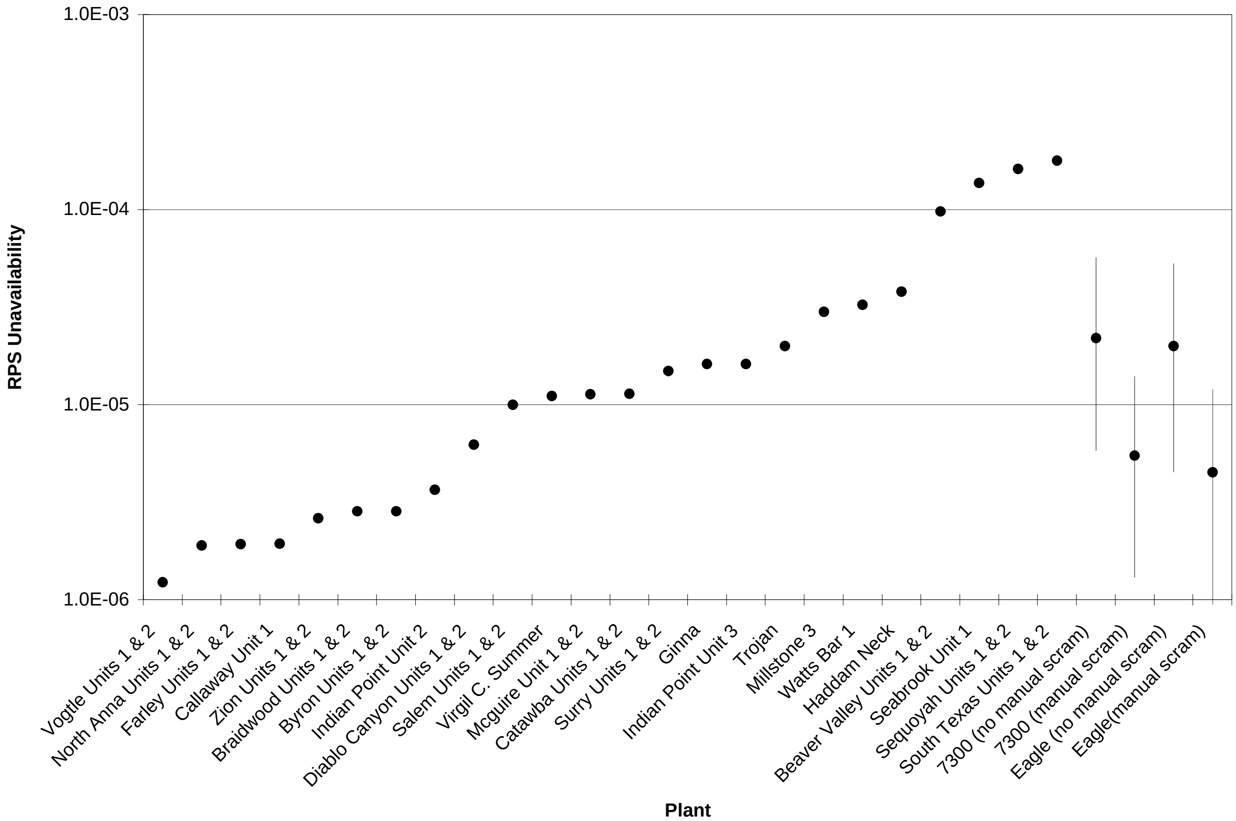
RPS Design and Case	Unavailability			
	5th Percentile	Median	Mean	95th Percentile
Analog Series 7300 (no credit for manual scram by operator)	5.8E-6	1.5E-5	2.2E-5	5.7E-5
Analog Series 7300 (credit for manual scram by operator)	1.3E-6	3.8E-6	5.4E-6	1.4E-5
Eagle-21 (no credit for manual scram by operator)	4.5E-6	1.3E-5	2.0E-5	5.3E-5
Eagle-21 (credit for manual scram by operator)	8.8E-7	2.6E-6	4.5E-6	1.2E-5

Research Institute ATWS study in 1976 estimated the RPS unavailability to be 3.0E-6 (median), based on no failures in 110,000 reactor trips (75,000 of these were naval reactor trips).[18] Finally, NUREG-0460 in 1978 estimated the RPS unavailability to be 1.1E-4 (median), based on one failure (German Kahl reactor event) in approximately 700 reactor-years. However, that document recommended a value of 3E-5 to account for expected improvements in design and operation. Therefore, early RPS unavailabilities based on system level data ranged from 3.0E-6 (median) to 1.1E-4 (median), depending upon the types of nuclear reactor experience included and the inclusion or exclusion of RPS failure events.

Early RPS unavailability estimates using component data and fault tree logic models include WASH-1400 and the Seabrook PRA. WASH-1400 estimated the RPS unavailability to be 3.6E-5 (median). The dominant contributors were the trip breaker segment of the RPS (48%) and the rods segment (47%). In the Seabrook PRA, the RPS unavailability was estimated to be 4.2E-4 (median). Dominant contributors were the trip breaker segment (92%) and the rods segment (7%). Note that both of these unavailability estimates apply to RPSs without automatic shunt trip actuation of the reactor trip breakers. Therefore, these estimates are higher than for the case where there is automatic shunt trip actuation, which is the case for all U.S. RPS reactor trip breakers.

Finally, RPS unavailability estimates from the Westinghouse IPEs are presented in Figure 7. The RPS unavailability estimates range from 1.2E-6 (mean) to 1.8E-4 (mean). Details concerning modeling and quantification of the RPS unreliabilities in these IPEs are limited. However, it appears that in many of the studies a simple fault tree logic model was used and quantified using RPS segment data. The wide range of estimates is believed to result from differences in modeling assumptions and generic data used, rather than actual design differences or variations in plant-specific data. For those IPEs listing contributors to RPS unavailability, the trip breakers were dominant. It should also be noted that some of the lower unavailability estimates may have included operator actions to manually scram the reactor or remove power to the control rod motor generator sets. All of the IPE RPS unavailability estimates apply to RPSs with automatic shunt trip actuation.

Also shown in Figure 7 are the Westinghouse Analog Series 7300 and Eagle-21 RPS unavailability distributions obtained in this study. The mean unavailabilities are 2.2E-5 and 2.0E-5, respectively, for the case in which no credit is allowed for manual scram by the operator. These values lie approximately in the middle of the range of the IPE estimates. If credit is allowed for manual scram by the operator, then the Analog Series 7300 and Eagle-21 unavailabilities are 5.5E-6 and 4.5E-6, respectively. These values lie within the lower range of the IPE estimates. Most of the IPE estimates lie within the uncertainty bounds from this study.



Note: The ranges shown for the 7300 (Analog Series 7300) and Eagle (Eagle-21) results from this study are the 5th and 95th percentiles. All other data points are mean values.

Figure 7. Westinghouse IPE RPS unavailabilities.

3.4 Regulatory Implications

The regulatory history of the RPS can be divided into two distinct areas: general ATWS concerns, and RPS component or segment issues. The general ATWS concerns are covered in NUREG-0460, SECY-83-293, and 10 CFR 50.62. NUREG-0460 outlined the U.S. NRC's concerns about the potential for ATWS events at U.S. commercial nuclear power plants. That document proposed several alternatives for commercial plants to implement in order to reduce the frequency and consequences of ATWS events. SECY-83-293 included the proposed final ATWS rule, while 10 CFR 50.62 is the final ATWS rule. In those three documents, the assumed Westinghouse RPS unavailabilities ranged from 1.5E-5 to 6.0E-5. These unavailabilities did not credit manual scram by the operator. (NUREG-0460 lists several reasons why such credit was not taken.) The Westinghouse RPS unavailabilities (with no credit for manual scram by the operator) obtained in this report are 2.2E-5 for the Analog Series 7300 design and 2.0E-5 for the Eagle-21 design. These values lie within the range used in the development of the ATWS rule, so the RPS results from this study support the ATWS rulemaking.

With respect to RPS components or segments, three issues were identified from the document review discussed previously: reactor trip breaker unavailability, channel testing, and SSPS undervoltage driver card unavailability. The reactor trip breaker unavailability issue arose from the Salem low-power ATWS events in 1983. The issue is discussed in detail in NUREG-1000. Recommendations resulting from this issue included better breaker testing and maintenance programs, and automatic actuation of the shunt trip coil. (The Salem ATWS events would not have occurred if the shunt trip coils had automatically actuated from the reactor trip signals.) Using Westinghouse reactor trip breaker (DB-50 and DS-416 designs) data through 1982, the breaker unavailability was determined to be 4E-3. In addition, SECY-83-293 indicated a CCF (both reactor trip breakers) unavailability of 2E-4 without automatic actuation of the shunt trip coils and 5E-5 with automatic actuation. The corresponding unavailabilities obtained in this study are 2.9E-4 for a reactor trip breaker (undervoltage coil and mechanical unavailabilities) and 1.6E-6 for CCF of both breakers (with automatic shunt trip actuation). Both of the study results are significantly lower than the 1983 document values. Therefore, reactor trip breaker performance has improved considerably since 1983.

In 1986, Westinghouse obtained approval to change RPS channel testing procedures.[11, 12] In most cases, the channel test interval was changed from one month to three months. In addition, during testing the channel could be placed in the bypass mode, rather than the tripped mode. Both of these changes have the potential to increase the unavailability of the RPS. The base case RPS results, obtained with only two trip signals modeled, indicate that the channels contributed approximately 20% to the overall RPS unavailability. However, a sensitivity analysis presented in Appendix G indicates that if three trip signals had been modeled, the channel contribution would have dropped to approximately 10%. Because at least three trip signals are expected for almost all plant upset conditions requiring a reactor trip, the 10% contribution from channels is considered to be more appropriate. Because the channel contribution to RPS failure is not dominant, the changing of the channel test intervals from one month to three months does not appear to have had a significant adverse effect on RPS unavailability.

The final RPS component issue is the unavailability of the SSPS undervoltage driver cards. This was covered in Generic Issue 115, "Enhancement of the Reliability of Westinghouse Solid State Protection System."[10] In that study, five failures of undervoltage driver cards were identified up through 1985. Four of the five failures were caused by maintenance activities that failed the cards while the plants were shutdown. Such maintenance-induced failures of the undervoltage driver cards continued to appear through 1991, including a CCF event involving both cards in 1989. However, that CCF event was not included in the calculation of RPS unavailability because the failures were caused by maintenance during shutdown and were detected before the plant returned to power. Some plants have addressed this potential problem by requiring testing of the undervoltage driver cards if certain types of maintenance are performed on the SSPS and by replacing the cards with a modified card with a fuse, which minimizes the chances of this type of failure. No undervoltage driver card failures were identified since 1991, as is indicated in Appendix B, Table B-1. An analysis of Generic Issue 115 was discussed in NUREG/CR-5197. In that document, the undervoltage driver card unavailability was assumed to be 5.2E-4, based on an assumed test interval of 360 hours. The data analysis for the period 1984 through 1995 indicates an unavailability of 3.4E-4. This value is approximately 65% of the value used in NUREG/CR-5197, so undervoltage driver card performance appears to have improved slightly since 1985.

4. ENGINEERING ANALYSIS OF THE OPERATIONAL DATA

4.1 System Evaluation

At a system level, the change in RPS performance over time can be roughly characterized by examining the trends of component failures and CCFs over time. A review of the component independent failure counts in Table B-1 of Appendix B indicates a drop of approximately 55% over the years, from a high of 81 failures in 1985 and 1987 to a low of 38 in 1995. The CCF counts in Table B-2 of Appendix B indicate a drop of approximately 80% over the years, from 23 in 1986 to a low of five in 1994. These trends tend to support the premise that RPS performance has improved during the period 1984 through 1995. Detailed analyses of trends for component failures and CCFs over time are presented in the following sections.

The trend in system demands (reactor trips) over time, although not an indicator of RPS unavailability, is one of several indicators of plant safety performance. As indicated in Figure 8, the rate of unplanned reactor trips has dropped approximately 90% over the period 1984 through 1995.

As indicated in Section 3.1, there were no RPS failures during the period 1984 through 1995. However, several train failures occurred during unplanned reactor trips. Two undervoltage driver card failures occurred during unplanned reactor trips. These events occurred in 1985 and 1991. Because there is only one such card in each train, a card failure results in a train failure. None of these failures were associated with the RTBs. In addition, unlike the trip breakers, if one train is bypassed for testing or maintenance, then the undervoltage driver card in the other train is a single failure for the system. (For the breakers, if a train is bypassed there are still two trip breakers that must fail in order for the other train to fail—the RTB and the appropriate bypass trip breaker.) Therefore, the undervoltage driver cards in the

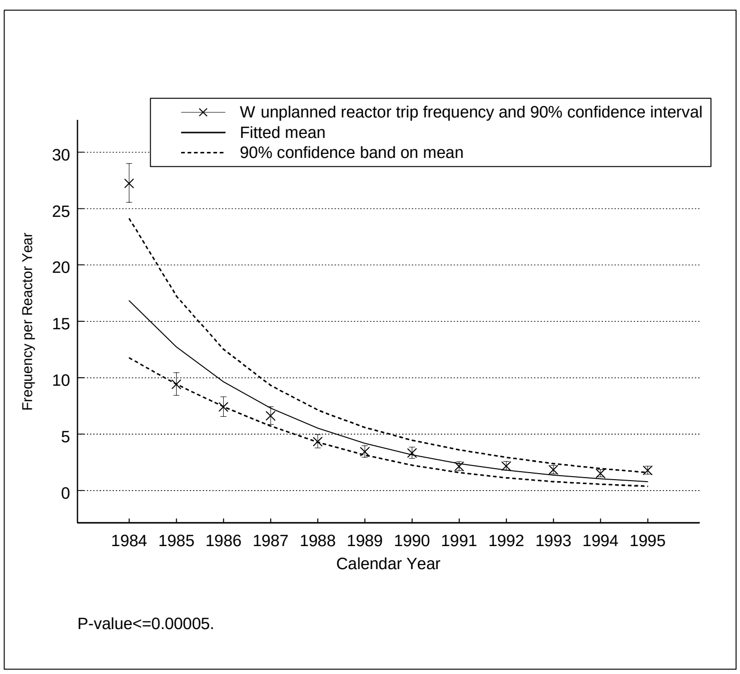


Figure 8. Westinghouse unplanned reactor trip trend analysis.

Westinghouse RPS design are a potential weak link. However, the overall system performance during the period 1984 through 1995 has been good.

No complete channel failures during unplanned reactor trips were identified during the review of the RPS data. However, because of the complexity and diversity of RPS channels and the uncertainty in determining associated trip signals, it is difficult to determine whether an entire channel failed during an unplanned reactor trip. Therefore, it is possible that some complete channel failures might have occurred and were not identified as such in the data review. The Eagle-21 signal processing module failures identified in this study are complete channel failures. However, none of these failures occurred during an unplanned reactor trip. All of the failures were annunciated in the control room and repaired within hours.

4.2 Component Evaluation

Over 15,000 LER and NPRDS records were reviewed for the Westinghouse RPS study. Data analysts classified these events into the nine bins shown in Figure 5 in Section 2. The highlighted NFS/CF bin contains events involving complete failure of the component's safety function of concern. The other three highlighted bins contain events that may be NFS/CF, but insufficient information prevented the data analysts from classifying the events as NFS/CF. (In the quantification of RPS unavailability discussed in Section 3 of this report, a fraction of the events in the three bins was considered to be NFS/CF and was added to the events already in the NFS/CF bin.) Westinghouse RPS component failure data used in this study are summarized in Table B-1 in Appendix B (independent failures only) and Table C-1 in Appendix C (independent and CCF events).

Approximately 800 to 900 failure events (depending whether CCF events are considered) were identified from the 15,000 events for the period 1984 through 1995. Of this total, approximately 50% are NFS/CF bin events. The other 50% are from the other three data bins. The ΔT signal processing modules and bistables contribute 60% of the failure events. Other significant components in terms of failure event counts include the pressure and temperature sensor/transmitters and the relays. Although none of these component independent failures contribute significantly to the overall RPS unavailability, CCF of the bistables is an important contributor. Therefore, the independent failures of the bistables contribute significantly to the RPS unavailability through the bistable CCF event probabilities.

The Westinghouse RPS component data were analyzed for trends over time. The data were analyzed using two sets of data: (1) data from only the NFS/CF bin, and (2) data from all four data bins (with potential NFS/CF events). Results for each year, expressed as frequencies, are the numbers of component failures divided by the numbers of component years. Note that the data analyzed in Section 3 are a subset of the data analyzed in this section. (Section 3 data are generally those associated with countable demands.) Results indicate significant trends over time (all decreasing) for seven of the 14 components: temperature sensor/transmitter, Eagle-21 processor, ΔT signal processing module, signal processing module (three types), bistable, SSPS undervoltage driver, and the trip breaker undervoltage coil. These trends are shown in Figures 9 through 15. All of the trends indicate a drop in failure rates of 50% or more from 1984 to 1995. For the other seven components, no significant trends were detected.

Section 3 results highlighted the importance of the train undervoltage driver cards to RPS unavailability. A review of the card failures indicated that most were the result of shutdown maintenance activities that failed the cards. This issue had been identified in Generic Issue 115, as discussed in Section 3.4 of this report. A new card was designed to eliminate such failures. No maintenance-related failures were identified after June 1991, so a combination of card replacements and more sensitivity of plant personnel towards maintenance activities around the RPS logic cabinets and switchgear have reduced the undervoltage driver card unavailability, compared with the value calculated from data up

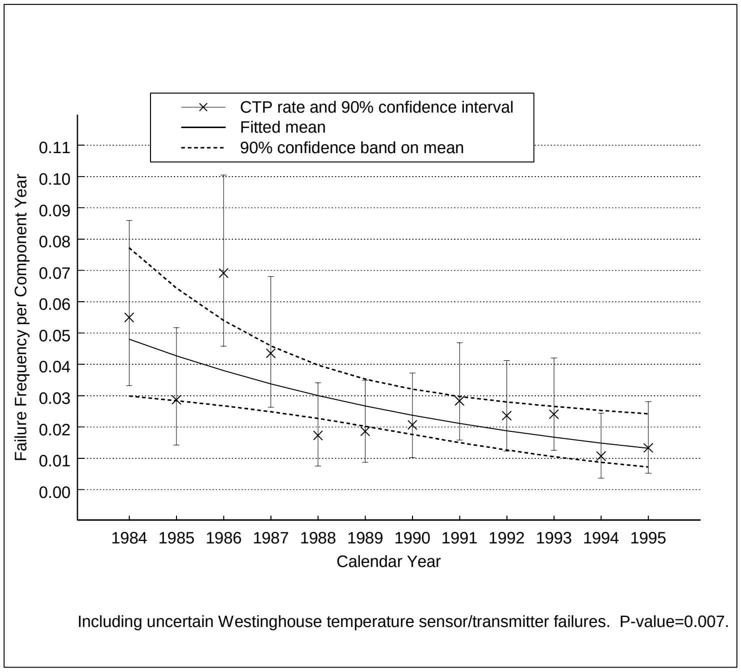


Figure 9. Temperature sensor/transmitter failure trend analysis.

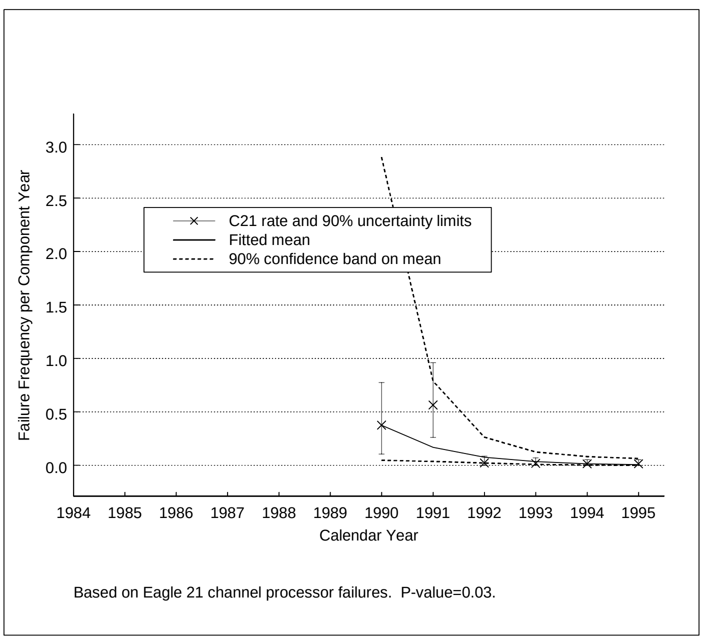


Figure 10. Eagle-21 channel processor failure trend analysis.

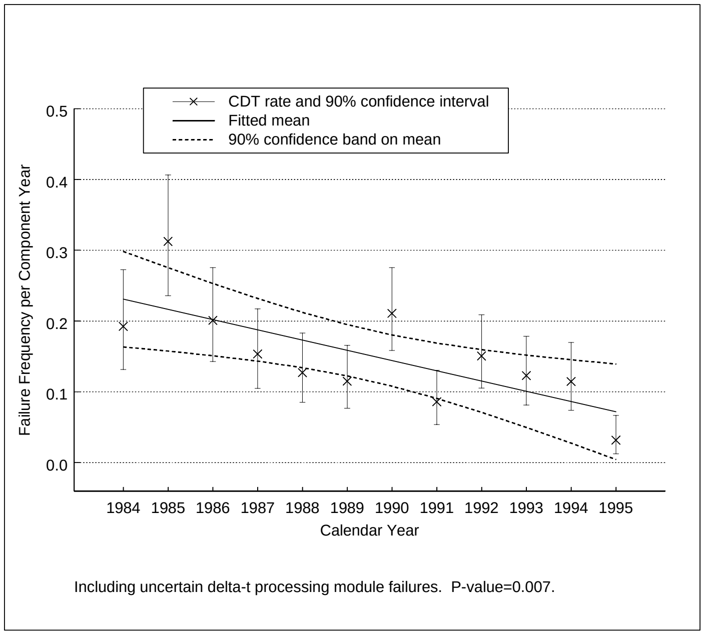


Figure 11. ΔT processing module failure trend analysis.

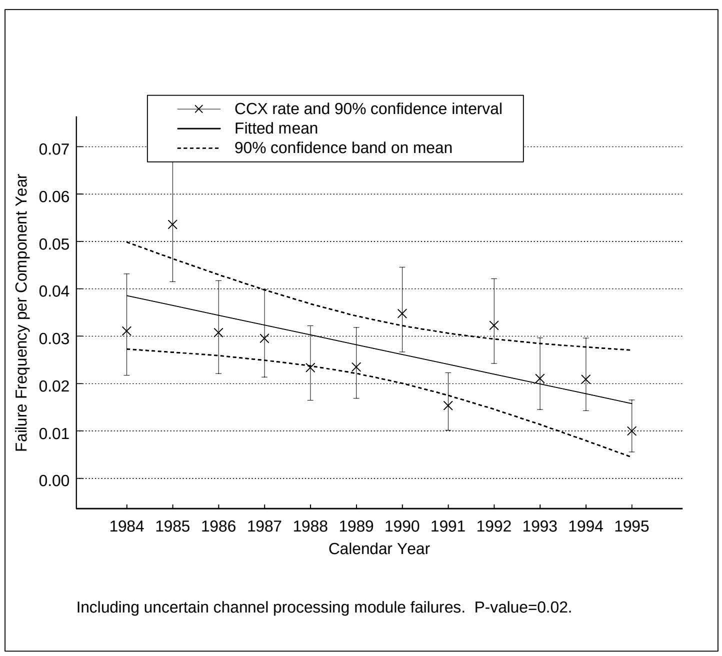


Figure 12. Signal processing module (three types) failure trend analysis.

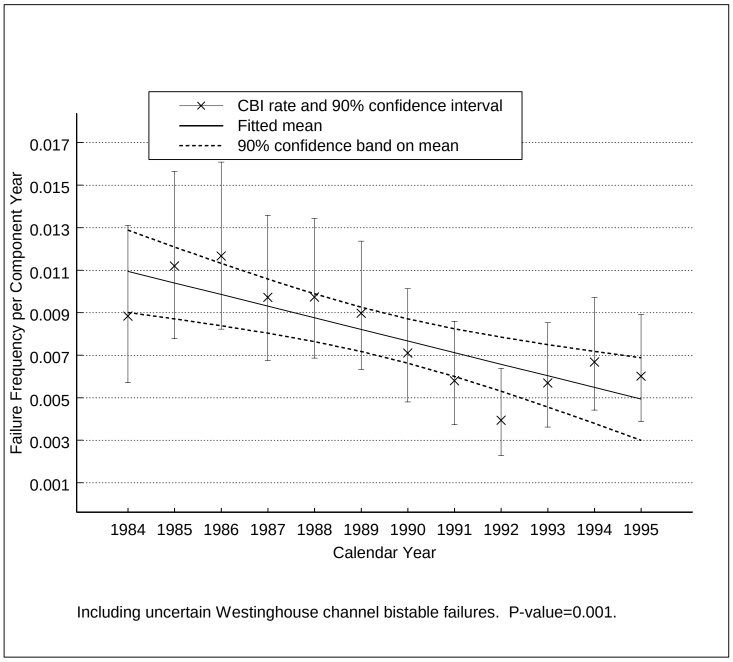


Figure 13. Bistable failure trend analysis.

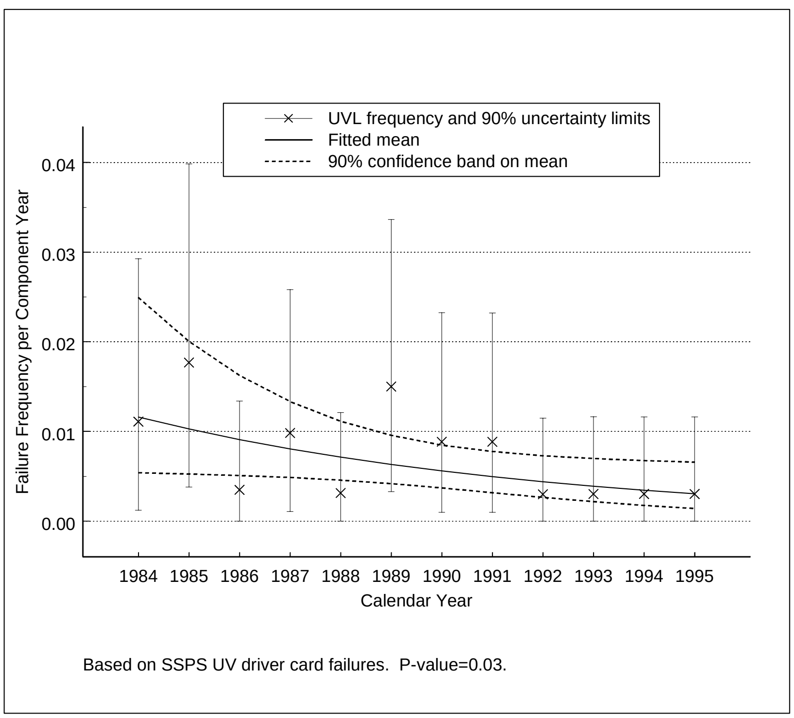


Figure 14. SSPS undervoltage driver card failure trend analysis.

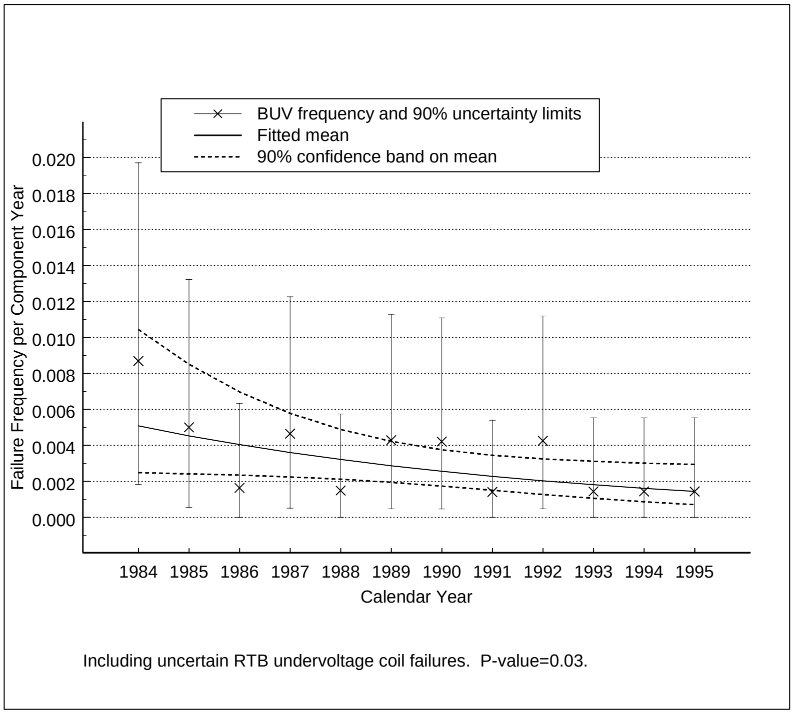


Figure 15. Reactor trip breaker undervoltage coil failure trend analysis.

through 1985. It should be noted that the maintenance-induced failures would normally be detected when the RPS is tested prior to startup. However, the June 1991 event involved failure to detect the undervoltage driver card maintenance-induced failure before startup. The failure was detected while the plant was at power, when an unplanned reactor trip occurred. A post-reactor trip review indicated that the card had failed.

Reactor trip breaker unavailability has been an issue with Westinghouse RPSs since the 1983 Salem low-power ATWS events. Following those events, the trip breaker configuration was changed to allow for automatic actuation of the shunt trip coil, which represents a diverse mechanism for opening the trip breakers. In this study, the trip breakers were broken down into three subcomponents: the mechanical/electrical portion of the breaker, the undervoltage coil and trip attachment, and the shunt trip coil and trip attachment. Either coil and trip attachment can open the trip breaker. However, if the mechanical/electrical portion of the breaker is failed, then neither coil can open the breaker. Therefore, the most important failures of the trip breakers are those associated with the mechanical/electrical portion. As indicated in Table B-1 of Appendix B, five such failures (BME events) were identified. No significant trends over time were identified. In addition, none of these failures occurred during unplanned reactor trips. All five were identified from testing while the plants were shut down. The five failures included two mechanical bindings (one resulting from a weld failure) and three events involving failures of the contacts and switches when the trip breaker was racked in. The data analysis performed in Section 3.2 identified a difference between failure rates from reactor trips and testing while the plants are at power and failure rates from testing while the plants are shut down. The three failures involving contacts and switches appear to be maintenance-related (associated with racking the trip breakers completely out) and would normally be detected following post-maintenance testing. The two mechanical binding events may or may not have been caused by shutdown maintenance.

Another subcomponent of the trip breakers is the undervoltage coil and trip attachment. This coil is normally energized, and de-energizes to allow the trip breaker to open by a spring mechanism. Table B-1 of Appendix B lists seven failures of the undervoltage coils during the period 1984 through 1995. The failures generally were identified as unknown or aging effects. As indicated previously, there is a decreasing trend over time associated with these failures. Also, the data analysis performed in Section 3.2 identified a difference between failure rates during testing while the plants are at power and failure rates from testing while the plants are shut down. It is not known why such a difference should exist.

The final subcomponent associated with the trip breakers is the shunt trip coil and trip attachment. This device is normally de-energized, and energizes to open the trip breaker. The shunt trip coil is a more powerful device for opening the trip breaker, compared with the undervoltage coil mechanism. The shunt trip coil failures were failures to actuate the coil, except for one event that stated the shunt trip coil burned up. No trend over time was observed.

In the channels of the RPS, two types of trip signal processing modules were modeled for the Analog Series 7300 design: overtemperature and overpower ΔT signal processing modules and pressurizer pressure signal processing modules. Both types of modules receive trip signal indications from sensor/transmitters and process the signals into an output that is sent to the trip signal bistable. The bistable then trips when the signal reaches the trip setpoint. The ΔT signal processing module is a very complex set of subcomponents such as amplifiers, resistors, diodes, function generators, and summators. Because of its complexity, this module has a relatively high unavailability (4.8E-3, from Table 2), compared with the much simpler pressurizer pressure signal-processing module (1.6E-4). However, the performance of the ΔT signal-processing module has been improving with time, as shown in Figure 11.

In the Eagle-21 RPS design, the Eagle-21 processing module replaces all of the channel trip signal processing modules found in the Analog Series 7300 design. The Eagle-21 processing module was modeled as a single component for each channel. This is a very simplistic modeling approach, because the Eagle-21 module (one for each channel) is a complex device, including signal processing and continuous self-checking. In addition to the continuous self-checking, the Eagle-21 modules are tested quarterly. A review of the Eagle-21 failures indicated many events involving only a portion of the module (e.g., a single trip signal), while some other events involved complete failure of the module. For this study, only the failures of the module involving three or more trip signals were considered. All of these failures were annunciated in the control room, and repairs were made. Therefore, the unavailability from such failures is small. Most of the 11 Eagle-21 failures listed in Table B-1 of Appendix B involved a functional lockup of all channel trip signal processing, caused by a timing problem with a computer chip clock generator. In all cases, the faulty computer chip was replaced with a version from a different manufacturer. Figure 10 shows the performance of the Eagle 21 modules over time.

4.3 CCF Evaluation

The Westinghouse RPS CCF data involve CCF and potential CCF events. A total CCF event involves complete failure (degradation factor of 1.0) of each of the components in the common cause component group, with additional factors such as shared cause and timing assigned values of 1.0. (See Appendices B and E for additional discussions of the CCF model and failure degradation and other factors.) Additional CCF events involve complete failure of several (but not all) of the components in the common cause component group. Finally, potential CCFs involve events in which one or more of the degradation or other factors has a value less than 1.0.

Westinghouse RPS CCF data are summarized in Tables B-2 and B-3 in Appendix B. Approximately 170 CCF and potential CCF events were identified for the period 1984 through 1995. Of that total, approximately 15% are actual CCF events, with the remaining 85% classified as potential CCF events. However, only one of the actual CCF events is a total CCF event, the undervoltage driver card CCF in 1989. The rest involve failures ranging from two of three components to six of 64. The two-of-three component CCFs are more significant than the others are because a higher fraction of the components in the common cause component group failed. In general, as the size of the group increases, the significance of the Westinghouse RPS CCFs decreases.

Most of the significant CCF events are associated with the ΔT signal processing models. Also the pressure sensor/transmitters have a few significant CCF events. However, neither of these component CCFs is a dominant contributor to RPS unavailability. The undervoltage driver card total CCF event involved complete failures of both cards. However, that event was not used in the base case quantification, as explained in the following section. Therefore, very few significant CCF events were identified for the Westinghouse RPS. Because of the relatively few significant CCF events identified, it was important to identify and use the potential CCFs in the quantification of the RPS unavailability. In general, it appears that current maintenance and testing procedures are effective in preventing the occurrence of significant CCF events.

There are two separate factors contributing to CCF event probabilities: CCF events that are used to calculate the alpha factors, and Q_T, which is the component failure probability due to both independent and common-cause factors. In order to identify trends in CCFs, both of these contributors are examined in the following sections.

4.3.1 CCF Event Trends

All of the CCF events involving the 14 RPS components were analyzed for trends over time. Results for each year, expressed as frequencies, are the number of CCF events divided by the number of reactor years. Three of the component CCF events had decreasing trends over time. The ΔT processing module CCF event trend is presented in Figure 16. The other two component CCF trends, for temperature sensor/transmitters and pressure sensor/transmitters, are shown in Figures 17 and 18. None of the components are dominant contributors to overall RPS unavailability, as evaluated in Section 3.2. None of the other component CCF events exhibited statistically significant trends over time over the period 1984 through 1995.

The dominant CCF events with respect to RPS unavailability for both the Analog Series 7300 and Eagle 21 designs, as evaluated in Section 3.2, involve the undervoltage driver cards, the bistables, channel trip signal-processing modules, train universal cards, trip breakers, and RCCAs. With respect to the undervoltage driver cards, only one CCF event (UVL) was identified. That 1989 event involved maintenance activities that failed both cards. Such maintenance activities occur only while the plant is shutdown. In addition, the failed cards were detected before the plant returned to power. This CCF event was not used in the RPS unavailability quantification discussed in Section 3.2. Therefore, the resultant probability for both undervoltage driver cards failing due to a CCF is dominated by the CCF prior developed for this study. A sensitivity study (Appendix G) was performed to assess the impact on RPS unavailability if that CCF event were to be included, and the impact was a 62% increase in the RPS unavailability for the Analog Series 7300 design and a 69% increase for the Eagle 21 design. (For the cases where credit is taken for manual scram by the operator, the increases are 2.4% and 3%, respectively.) Therefore, the issue of whether to include this CCF event in the quantification is important. Two factors tend to minimize the issue. The first is that Westinghouse has designed a new card that is not as susceptible to the maintenance-induced failures seen in the data. It is not known how many of the Westinghouse plants have changed to the new card design, but no card failures have been reported since 1991. The second factor is that plants are more aware of the potential for such failures and have improved procedures to check for card failures following such maintenance. However, these procedures

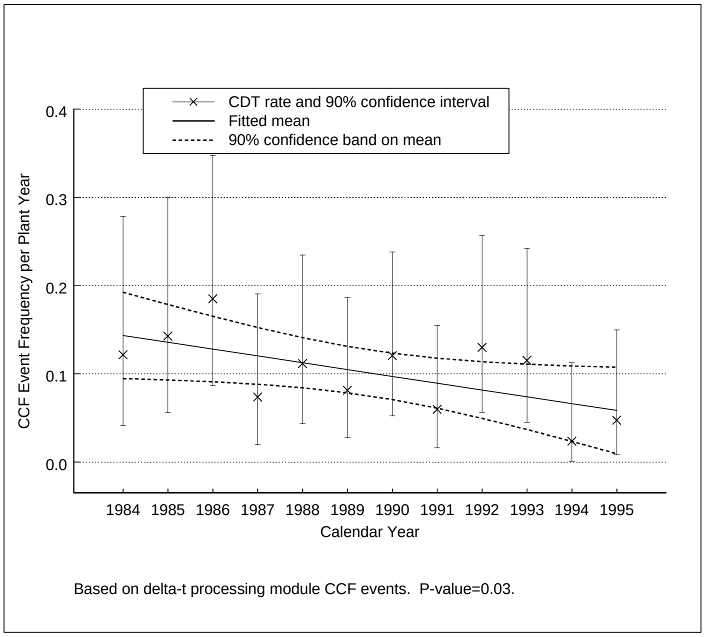


Figure 16. ΔT processing module CCF event trend analysis.

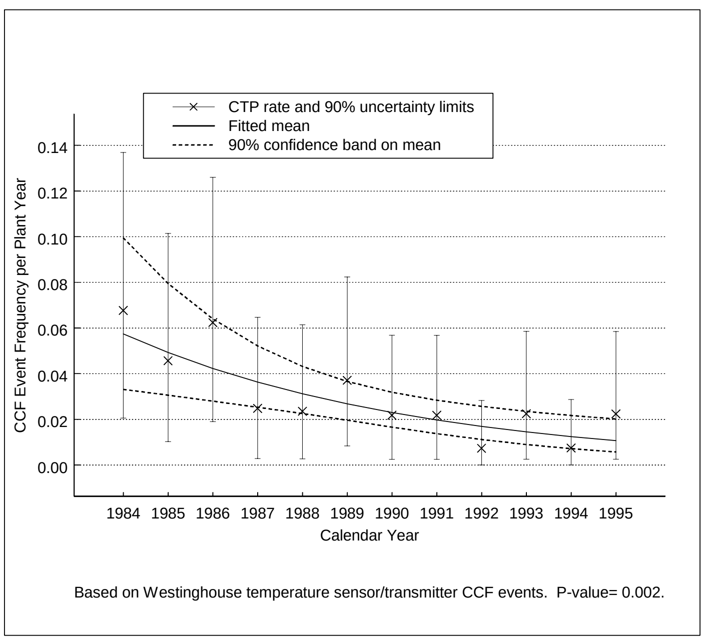


Figure 17. Temperature sensor/transmitter CCF event trend analysis.

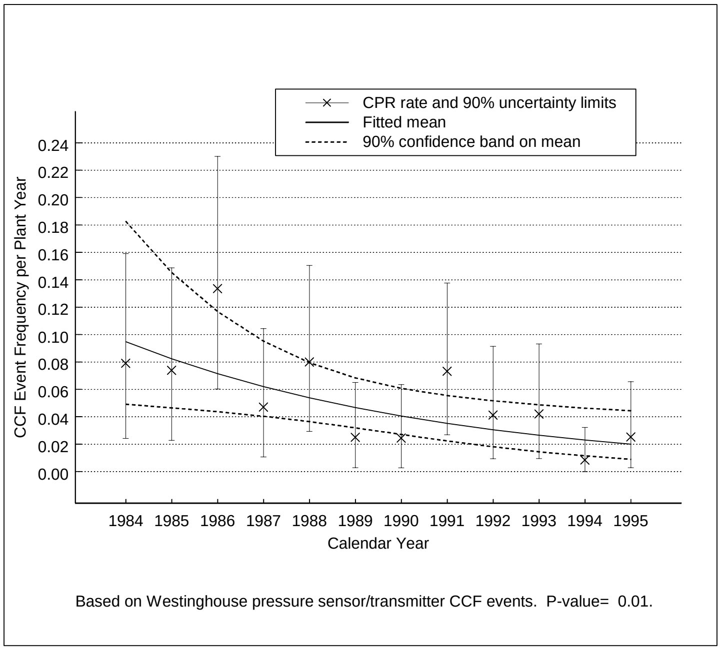


Figure 18. Pressure sensor/transmitter CCF event trend analysis.

are not fool-proof, because a single maintenance-induced card failure in 1991 was not detected when the plant returned to power. The card failure was detected following an unplanned reactor trip, when the post-reactor trip review indicated that one train of the RPS had failed.

Table B-2 in Appendix B lists 43 CCF events for bistables (CBI) during the period 1984 through 1995. Most of these CCF events involved degradation of the bistables, rather than actual failures. The CCFs involving actual bistable failures included gross setpoint calibration errors and bistable subcomponent failures. The events included only two bistables. Of the CCF events involving only degradation of the bistables (but not actual failure), one event included nine bistables and another included seven.

Another dominant contributor to RPS unavailability is CCF events involving both ΔT signal processing modules and pressurizer pressure signal processing modules. As Table B-2 in Appendix B indicates, there were 51 CCFs involving just ΔT signal processing modules (CDT). However, there were only two CCFs involving pressurizer pressure signal processing modules (CCP). For CCFs involving both types of processing modules, Table B-2 lists only five events (CCX). Three of these events involved degradation of the modules, rather than actual failures. The two events involving module failures included failed subcomponents within the modules. No trend over time was identified for these five CCF events.

Table B-2 in Appendix B lists one CCF event involving control rod drive mechanisms (CRD) and one CCF event for RCCAs (ROD). The fault tree for evaluating RPS unavailability combines both components into a single CCF basic event. Quantification of this basic event, failure of 10 or more rods (out of 50) to fully insert into the core, is discussed in Appendix E. The control rod drive mechanism CCF event involved only two failures, caused by faulty firing circuit cards. The RCCA CCF event involved the potential failure of two RCCAs, and observed degradation on other RCCAs. These two CCF events do not significantly impact the fault tree basic event probability.

Although trip breaker CCFs have historically been considered to be dominant contributors to RPS unavailability, only one such event (BME) is listed in Table B-2 in Appendix B for Westinghouse breakers. That CCF event involved only degradation of the breakers, and not actual failures. Therefore, the quantification of the trip breaker CCF basic events in the RPS fault tree relied mainly upon the CCF prior developed for this study. The two CCF events listed for the undervoltage coil (BUV) and shunt trip coil (BSN) in Table B-2 do not represent failures of the overall trip breakers, but failures of one of two diverse methods for opening the trip breakers. Also, both of these events involved degradation of the components, rather than actual failures.

The final type of CCF event to be discussed involves the train universal cards. Table B-2 in Appendix B lists six such events (TLC). All of these CCFs involved two or three card failures out of a group size of 32. No significant trend over time was observed for these failures.

4.3.2 Total Failure Probability Trends

All of the Q_T's for the 14 RPS components were analyzed for trends over time. Four of the component Q_T's had decreasing trends over time. The components with significant trends are the Eagle-21 channel processors, ΔT processing modules, processing modules (three types), and bistables. These are shown in Figures 19 through 22. None of the other components exhibited statistically significant trends over time over the period 1984 through 1995.

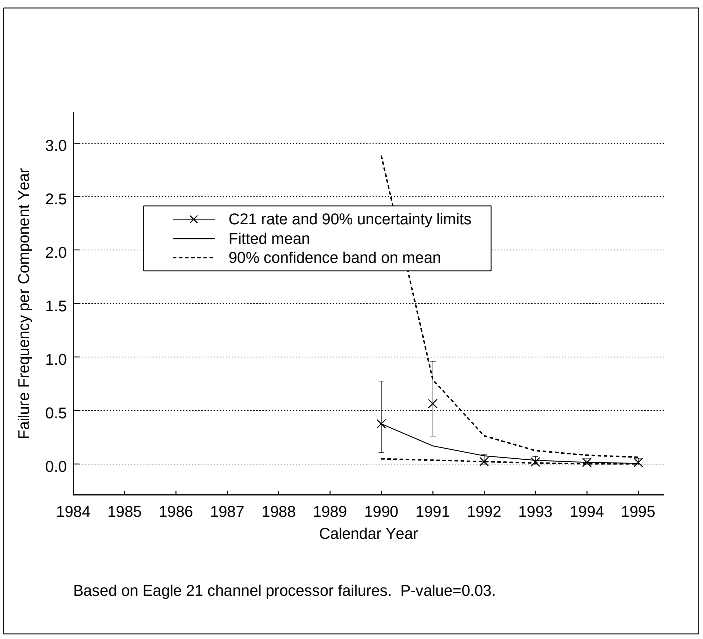


Figure 19. Eagle-21 channel processing module failure rate trend analysis.

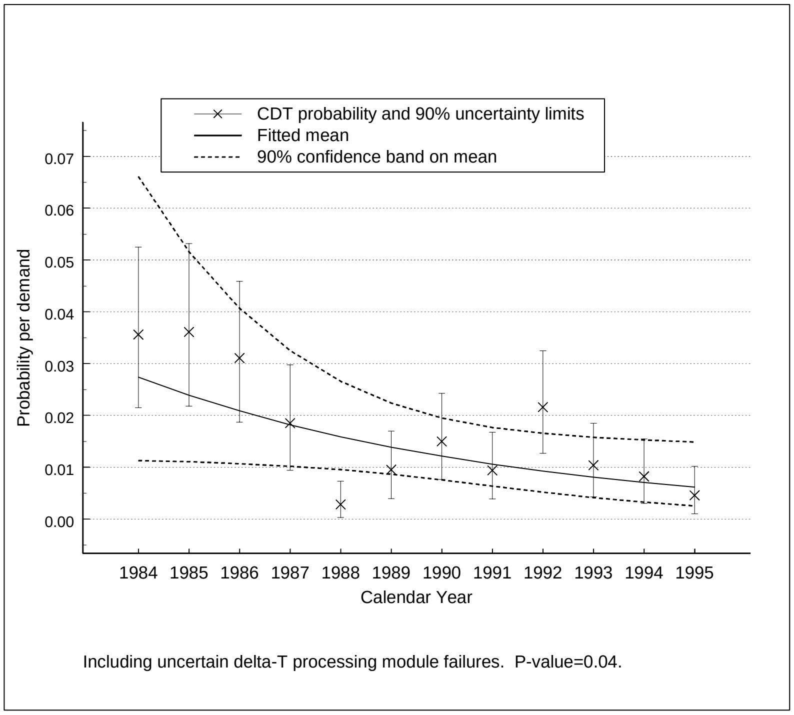


Figure 20. ΔT processing module failure probability trend analysis.

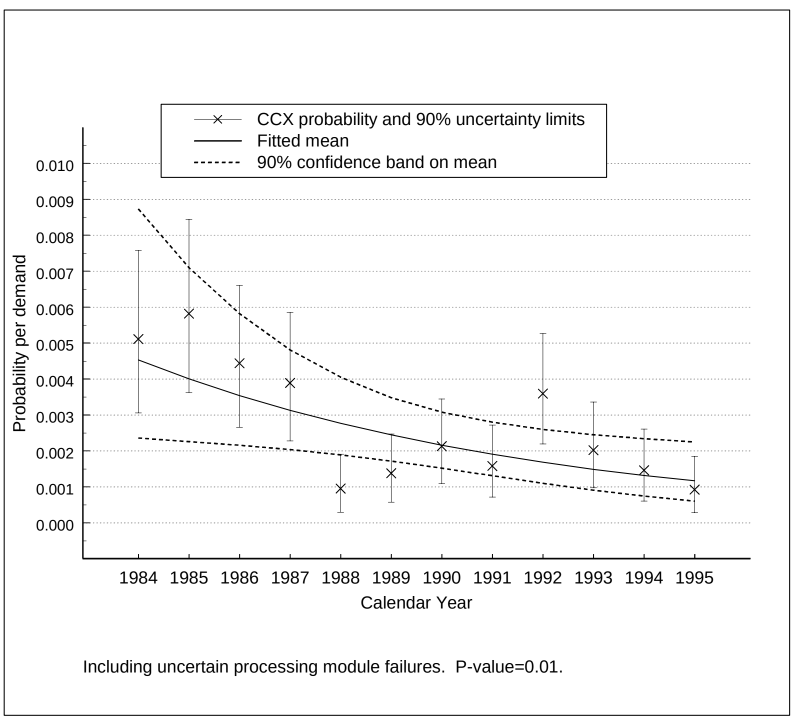


Figure 21. Signal processing module (three types) failure probability trend analysis.

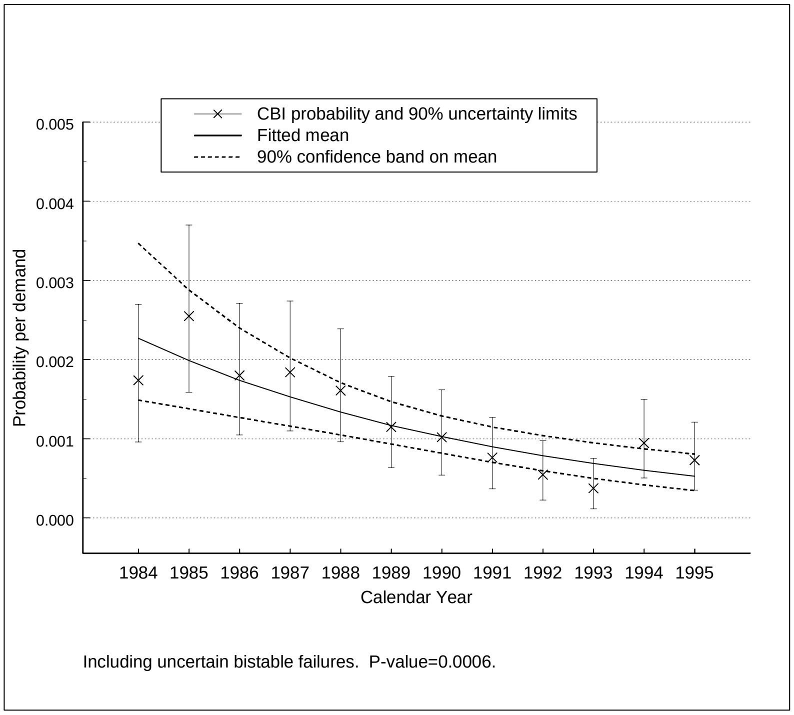


Figure 22. Bistable failure probability trend analysis.

5. SUMMARY AND CONCLUSIONS

Moderately detailed fault trees of the Westinghouse Analog Series 7300 and Eagle-21 RPS designs were developed and quantified using U.S. Westinghouse commercial reactor data from the period 1984 through 1995. The AMSAC ATWS mitigation system was not included in the fault tree model. The fault trees were developed for four-loop plants with SSPS trains, with quarterly testing of channels and staggered monthly testing of trains and reactor trip breakers. Also, for channel tests, the channel trip signal was assumed to be bypassed rather than tripped. Quantification of the fault tree models resulted in a mean unavailability (failure probability upon demand) of 2.2E-5 (with no credit for manual scram by the operator) for the Analog Series 7300 design. The lower 5^{th} percentile is 5.8E-6 and the upper 95^{th} percentile is 5.7E-5. Approximately 95% of the overall RPS unavailability is from CCF events. CCF of the two undervoltage driver cards (one per train) is the dominant contributor (46.1%) to RPS unavailability. Other important CCF events involve the channel bistables (11.5%), train universal cards (9.7%), channel signal processing modules (7.8%), reactor trip breakers (7.4%), and rods (5.5%). Results for the Eagle-21 RPS design are similar, with a mean unavailability of 2.0E-5.

The RPS fault trees were also quantified allowing credit for manual scram by the operator. The resulting mean unavailabilities are 5.5E-6 for the Analog Series 7300 design and 4.5E-6 for the Eagle-21 design. Operator action reduces the RPS unavailability by approximately 75%. This reduction is significant and occurs mainly because the manual scram signal bypasses the dominant undervoltage driver card failures. For the Analog Series 7300 design, CCF of the two reactor trip breakers is the dominant event, contributing 29.1% to the RPS unavailability. Other important CCF events involve the channel bistables (27.9%), rods (21.7%), and channel signal processing modules (18.9%). Contributors to the Eagle-21 unavailability are similar.

RPS unavailability estimates from Individual Plant Examinations (IPEs) and other sources range from approximately 1.0E-6 to 1.0E-4. Because of the lack of detailed information in the IPE submittals, it is not clear which estimates included credit for operator action. The IPE range of RPS unavailabilities covers the uncertainty ranges obtained in this study, based on the analysis of data from 1984 through 1995. However, most of these other sources estimated that the trip breaker CCF events would dominate the RPS unavailability. In this study, such events contribute less than 10% when no credit is taken for manual scram by the operator, and approximately 30% if credit is taken.

Quantification of the CCF events in the RPS fault trees is complex. The channel and train portions of the RPS fault trees contain component group sizes ranging from two to 16, and the rod portion was assumed to have a representative group size of 50. A prior was developed for the RPS CCF event quantifications. The prior was then updated using CCF data specific to the component in question. In many cases the component-specific CCF data were sparse, resulting in a strong influence by the prior.

Several general insights were obtained from this study:

1. Both the Analog Series 7300 and Eagle-21 RPS designs have a single undervoltage driver card in each of the two trains. Failure of both of these cards results in failure of RPS (unless manual scram is credited). This CCF event is the dominant contributor (almost 50%) to RPS unavailability. In 1989, a CCF event involving both driver cards occurred while the plant was shut down. The failures were caused by maintenance activities and were detected before the plant returned to power. Since then, the driver card design has been changed to minimize the chance of such maintenance activities causing such failures. Also, plant procedures for such maintenance have been improved. However, CCF of both of these cards is still predicted to be a dominant contributor to RPS unavailability.

2. Issues related to reactor trip breakers, arising during the early 1980s, are no longer dominant with respect to RPS unavailability. (This is true for both cases of RPS unavailabilities: without crediting operator action and crediting operator action.) Automatic actuation of the shunt trip mechanism within the reactor trip breakers and improved maintenance procedures have resulted in improved performance of these components.

3. The design of the manual scram feature of the Westinghouse RPS is especially effective. If credit is taken for manual scram by the operator, the predicted unavailability is reduced by approximately 75%. This occurs because the manual scram signal bypasses the train undervoltage driver cards. Therefore, operator action to actuate the manual scram switch is very effective in reducing RPS unavailability.

4. The Analog Series 7300 and Eagle-21 RPS designs have comparable unavailabilities. This occurs because the Eagle-21 design considered in this report involves only the channel processing portion of the RPS. The dominant contributors to RPS unavailability result from other portions of the RPS.

5. Not many significant Westinghouse RPS CCF events were identified from 1984 through 1995. Therefore, current practices appear to be effective in preventing such events.

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Appendix A

Data Collection and Analysis Methods

To characterize reactor protection system (RPS) performance, operational data pertaining to the RPS from U.S. commercial nuclear power plants from 1984 through 1995 were collected and reviewed. In this first study of the RPS, the fifty-three Westinghouse (W) pressurized water reactor (PWR) plants were considered. For these plants, reported inoperabilities and unplanned actuations were characterized and studied from the perspective of overall trends and the existence of patterns in the performance of a particular plant. Unlike other operational data-based system studies sponsored by AEOD at the INEEL, the inoperabilities were component failures. Redundancy in the RPS and interconnections between the RPS channels and the trip logic and breakers that deenergize and release the control rods requires a more detailed analysis rather than viewing the RPS even at a train level.

Descriptions of the methods for the basic data characterization and the estimation of unavailability are provided below. In addition to a discussion of the methods, the descriptions provide summaries of the quality assurance measures used and the reasoning behind the choice of methods. Probabilities coming from the common-cause data analysis are explained in Appendix E.

A-1. DATA COLLECTION AND CHARACTERIZATION

In subsections below, methods for acquiring the basic operational data used in this study are described. The data are inoperabilities and the associated demands and exposure time during which the events may occur.

A-1.1 Inoperabilities

Because RPS is a multiple-train system, most failures in RPS components are not required by 10 CFR 50.73 to be reported in Licensee Event Reports (LERs). Accordingly, the primary data source for RPS inoperabilities is the Nuclear Plant Reliability Data System (NPRDS). NPRDS failure data were downloaded for components in the RPS and control rod drive systems. Immediate/catastrophic and degraded events were included; incipient events were omitted.

For this study, events prior to 1984 were excluded for two reasons. First, nuclear power plant (NPP) industry changes related to the RPS occurred in response to the 1983 Salem Unit 1 low-power ATWS event. Second, the failure reporting system changed significantly with the January 1, 1984 institution of the current LER Rule (10 CFR 50.73). The LER rule shifted the emphasis in LER reporting away from single component failures to focus on significant events, leaving NPRDS to cover component failures. Failure reporting to NPRDS is voluntary. As manager of the NPRDS, the Institute for Nuclear Power Operations (INPO) has taken many measures to encourage complete failure reporting to the system since 1984. The NPP industry has relied on the NPRDS for the routine reporting of single component failures since 1984.

To ensure that the failure data set is as complete as possible, the Sequence Coding and Search System (SCSS) LER database was also searched for any RPS inoperabilities reported in LERs.

The NPRDS and SCSS data searches were used to identify events for screening. The major areas of evaluation to support the analysis in this report were as follows:

- What part of the RPS, if any, was affected. Some events pertained to the ATWS Mitigation System Actuation Circuitry (AMSAC), or to support systems that are not within the scope of the RPS. Other RPS events were in parts of the system not directly critical to the performance of its safety function, such as failures in indicators and recording devices. Such events were marked as non-failures and were not considered further.

- For events within the scope of RPS, the specific component affected by the event was indicated. For Westinghouse plants, the following distinctions were made (codes for the associated components are in parentheses):

  - Channels (instrumentation rack): sensors and transmitters [power (CPN), source (CSR), and intermediate range (CIR) neutron detectors, temperature sensor/transmitters (CTP), pressure sensor/transmitters (CPR), limit (CLT) and pressure (CPS) switches], power supplies (CPW); channel bistable relays or UV driver card relays (CRL); channel processing modules [ΔT processing modules (CDT), pressure processing modules (CCP), steam flow/feed flow mismatch processing modules (CMM), Eagle 21 solid state processing modules (C21)]; and bistables (BIS).

  - Trains (logic cabinet): SSPS universal cards (TLC), channel bistable or UV driver card relays (TLR), the SSPS undervoltage driver card (UVL), and the manual scram switch (MSW).

  - Trip breakers: AC breakers (mechanical/electrical) (BME) and the associated RTB undervoltage coil (BUV) and shunt trip (BSN) devices.

  - Rods: rod control cluster assemblies/control rod drive mechanisms (ROD).

- Whether the event contributed to a possible loss of the RPS's design safety function of shutting down the reactor. This distinction classifies each inoperability as either a failure, or just a fault. *Faults* are occurrences that might lead to spurious RPS actuation such as high-pressure set points that have drifted low. *Failures*, on the other hand, are losses at a component level that would contribute to loss of the safety function of RPS (i.e., a loss that would prevent the deenergizing and insertion of the control rods). For the RPS, another way of stating this distinction is that faults are inoperabilities that are fail-safe, while failures are those that are non-fail-safe. The RPS events were flagged as fail-safe (FS), non-fail-safe (NFS), or unknown (UNK). The latter designation applies, for example, when a failure report does not distinguish whether a failed transmitter monitors for high pressure or for low pressure.

- Whether the event was a common-cause failure (CCF). In this case, several other fields were encoded from the event record: CCF Number, CCF shock type, time delay factor, coupling strength, and a brief event description. These assessments are described further in Appendix B and Appendix E.

- Whether the failure was complete. Completeness is an issue, particularly for failed timing tests and cases where components are out of tolerance but might still perform their safety function if called upon. Completeness is also an issue when component boundary definitions differ and NPRDS reports the complete failure of a component that is a piece part with regard to the RPS fault tree model. The probability of the modeled RPS component functioning given the degradation reported in the LER or NRPDS was assessed as 1.0, 0.5, 0.1, or 0.01. In the basic failure analysis, the 0.5 assessed events were treated as unknown completeness, while the 0.1 and 0.01 assessed events were treated as nonfailures. These assessments were used in developing impact vectors for the common-cause assessment, as discussed in Appendix E.

- The method of discovery of the event [unplanned demand (i.e., reactor trip), surveillance test, other]. For the NPRDS data, "other" includes annunciated events. For surveillance tests, the test frequency was determined if it was clear from the event narrative. Failures discovered during reactor trips were identified from the LERs and from matching the reactor trip LERs (described in the next section) with the NPRDS failures. Narratives from the few matching records were reviewed. If the failure caused the reactor trip, it was flagged as a fail-safe fault discovered during operations. If it did not cause the reactor trip but was observed during the course of the reactor trip event, it was flagged as being discovered by the reactor trip.

- Plant operational state ("mode"): up or down. All unplanned reactor trip events that are reportable are for critical reactor trips; thus the plant is defined as up for these events. The test events may occur while the plant is up or while it is down. An issue is whether the failure occurrence probabilities (failures per demand) are the same for both situations, and which scenario is the most realistic for the unavailability analysis if they differ. The assessment of plant state for failures during testing and operation was based on the NPRDS and LER narratives, if possible. The data were compared with the outage information used in the NRC Performance Indicator Program to resolve plant state issues in some cases. When the plant state was unknown, it was treated as operating since the plants spend more time in an operating state than shut down.

- The plant and event date for each failure, as presented in the source databases, were preserved and used in the data analysis.

Other attributes were also considered, such as the event cause and failure mode. Some of these fields are described in Appendix B. The screening associated with the common-cause analysis is described further in Appendix E.

The RPS inoperability evaluation differs from previous NRC system operational unreliability studies (References A-1 through A-6) in several aspects. A greater emphasis on common-cause failure analysis applies due to the many redundant aspects of the system. The system redundancy also leads to the use of NPRDS data, since few unplanned reactor trips reveal problems within the RPS itself. That is, unlike the auxiliary feedwater system, the RPS does not have a sufficient failure data set for analysis from just the LERs from unplanned reactor trips. Given the use of NPRDS data and the focus on components rather than trains or segments, the completeness issue is more dynamic for the RPS. The inability to distinguish whether a failure is fail-safe adds additional uncertainty to the data evaluation. Unlike previous NRC system operational unreliability studies, the failure events were not screened to determine if the events were recoverable, since the RPS performs its mission on demand and has no extended mission time. The lack of a mission time means also that there is no need to evaluate the components based on different failure modes, such as starting and running.

The treatment of maintenance unavailability is also different for the RPS than for the previous system studies. Although the SCSS data search included timing codes such as "actual preexisting" and "potential," both previously detected and not previously detected, incidents of a channel of the RPS being out-of-service for maintenance or testing when demanded during an unplanned reactor trip are not routinely reported. The primary instances found in the data for such preexisting maintenance were when the maintenance contributed to causing a spurious reactor trip and was thus fail-safe. Thus, neither the NPRDS nor the LER data provide information on planned maintenance unavailabilities. Maintenance unavailabilities were included in the fault tree, with their associated impact on the RPS actuation logic. The fraction of time RPS channels, trains, and trip breakers are typically in maintenance was estimated directly from the operating procedures rather than from the failure data.

The data characterization for the events was based on reading the associated NPRDS event narratives and LER abstracts. Engineers with commercial power plant experience classified the data and reviewed each other's work for consistency. A final, focused review was performed by instrumentation and control and RPS experts on a subset of the approximately 15000 NPRDS and LER records.

Several additional checks and filters were applied to the RPS failure event data:

- For each plant, the data were constrained to lie between the plant's commercial operation date and its decommission date (if applicable). NPRDS data reporting for a plant begins with its commercial operation date.

- Events and operating time/demands during NRC-enforced *regulatory outages*, as defined in the NRC Performance Indicator (PI) Program, were excluded as being atypical. Among Westinghouse plants, this restriction removed Sequoyah 1 and 2 data for the last part of 1985 through mid-1988.

- Dates for RPS channel installation of Eagle 21 digital signal processors were estimated as follows: July 1, 1990 for the Sequoyah 1 and 2; January 1, 1992 for the Turkey Point 3 and 4; July 1, 1992 for Zion 1; October 1, 1992 for Zion 2; and January 1, 1994 for Diablo Canyon 1 and 2. For these eight plants, the data were checked to ensure that no analog channel calculator events or demands were counted after these dates, and no Eagle 21 events or demands before these dates.

- A second date check ensured that no control rod demands or events were counted after March 15, 1994, the date on which the NPRDS reporting scope changed to omit these components (among others) from the NPRDS.

- NPRDS and LER data were matched by plant, event date, and component, and checked to ensure that no event was counted twice.

Further details of the inoperability characterization and database structure are included in Appendix B.

A-1.2 Demands and Exposure Times

For the reliability estimation process, two models are typically used to estimate unavailability. The first is based simply on failures and demands. The probability of failure on demand is estimated simply as the number of failures divided by the number of demands. The resulting estimate is useful if the demands are complete and unbiased, and the counts of demands and failures are complete. This is the primary model used for the components in the RPS.

For the channel neutron monitors, pressure sensor/transmitters, temperature sensor/transmitters, power supplies and Eagle 21 module, however, failures occur other than the ones routinely monitored by testing. These failures are detected either by annunciators or during periodic walk-throughs by plant operators, and thus are not present during the cyclic surveillance tests. The method of discovery thus distinguishes these failures from the others. The downtime for discovering these failures and repairing them is small, typically eight hours or less. To ensure that this contribution to the unavailability is not overlooked, the non-testing failure rate in time is estimated for the subset of these components that appear in the fault tree. For each of the three components, a gamma uncertainty distribution for the rate is combined with an eight-hour downtime to obtain an unavailability. If this unavailability is much greater than the unavailability from the demand events, it is used in the fault model quantification. If, on the other hand, it is much smaller, the unavailability estimated from the failures on demand is used. If the two unavailabilities are comparable, they are summed for the fault model quantification.

In the engineering analysis portion of this study, general failure occurrence frequencies in time are estimated for the assessment of trends. These frequencies are based on all the failures and the associated calendar time for the components.

Estimation of both demands and operating times requires knowledge of the number of each type of RPS component at each plant. Estimates of component counts, demands, and operating times are discussed in the next three sections.

A-1.2.1 Component Counts

For each plant, the number of each type of RPS component listed in the second bullet in Section A-1.1 was estimated. These component counts are the exposed population of RPS system components installed at each plant that could fail. Table A-1 contains the results, as a function of the number of loops, for the components used in the fault trees. Note that these counts are estimates; exact information on each plant was not available. Plant-specific engineering records in the NPRDS are intended to provide a profile of the number of components for which failures are to be reported to the NPRDS system. These records were studied to identify component counts, but they were not directly useful because of differences in the component boundary definitions used for this study. Each channel processing module, for example, consists of a collection of NPRDS components.

A-1.2.2 Demands

For RPS, the demand count assessment for unavailability estimates based on failures per demand is more uncertain than in previous NRC system studies. In previous NRC system studies, possible sets of demands were considered, such as demands from unplanned actuations of the system and demands from various types of periodic surveillance tests (monthly, quarterly, or cyclic). Demands at plant start-up or shutdown might also be considered. The selection of the sets of events with particular system demands determines the set of failures to be considered in the reliability estimation (namely, the failures occurring during those demands).

In evaluating the possible sets of demands, the following criteria are sought:

1. An ability to count, or at least estimate, the number of demands

2. An ability to estimate the number of failures. Completeness is sought in the failures, so that they will not be underestimated. Conversely, the failures are to be matched with the demands, so that failures only on the type of demand being considered are counted. Then the number of successes on the type of demand being considered will not be underestimated.

3. The demands need to be complete and rigorous, like an unplanned demand on the system, so that all the relevant failure modes will be tested.

Table A-1. Counts per plant for components in Westinghouse fault trees.

Acronym	Definition	Count[a]
Channel parameter monitoring instruments		
CPR	Pressure sensor/transmitter	LoopM
CTP	Temperature sensor/transmitter	2*LoopM
Channel processing modules and bistable		
C21	Eagle 21 processing module	LoopM
CCP	Pressure processing module	5*LoopM
CDT	ΔT processing module	LoopM
CCX	Processing module (general; see Note b)	7*LoopM
CBI	Bistable	16*loopM
Trains		
TLC	SSPS universal card	2*16
TLR	Bistable or UV driver card relay	32*LoopM
UVL	Undervoltage driver card	2
Trip breakers		
BME	Breaker (mechanical/electrical)	4
BSN	RTB shunt trip device	4
BUV	RTB undervoltage coil	4
Rods		
ROD	RCCA/CRDM	Approx. 50 [c]

a. LoopM, the loop multiplier, is 3 for three-loop plants and 4 for two or four-loop plants.

b. CCX consists of CCP, CDT, and steam flow/feed flow mismatch processing modules (CMM). The count for CMM is assumed to be LoopM. Failures of CCP, CDT, or CMM were also counted as failures of CCX. CCX is needed for the common-cause analysis of processor failures.

c. Plant-specific control rod/control rod drive counts were used. They were taken from P. Lobner, C. Donahoe, and C. Cavallin, *Overview and Comparison of U.S. Commercial Nuclear Power Plants*, NUREG/CR-5640 (SAIC-89/1541), August 1990.

For the RPS, the requirement that the demand event set be *countable* is not always met. Although a fairly accurate count of unplanned reactor trips is available from the LERs since 1984, the reactor trips themselves do not exercise the complete RPS. Particularly for the channel components, different reactor trips come from different out-of-bound parameters. For example, the number of unplanned reactor trips for which the pressurizer low-pressure setpoint was exceeded is unknown. Unplanned reactor trip demand data are not used in this report for channel data since these demands are not countable. For the same reason, unplanned demands are also not used for SSPS universal cards and bistable/undervoltage driver card relays. Unplanned reactor trip demands are not used for the RTB shunt trip and undervoltage coils because these events demand at least one of these two components but not necessarily both.

Most of the estimates in this report are therefore based on test data. Bimonthly (six per year) tests apply for train (trip logic) components and breakers, quarterly tests apply for the channel calculator modules and bistables, and the sensor/transmitters are tested quarterly and calibrated during refueling outages and cyclic tests. The control rod assemblies and control rod drives are tested during cyclic tests associated with refueling. Based on calendar time and the number of installed components of each type in each plant, estimates for these demands are calculated in this report.

The completeness of the failure count for the RPS testing data depends on two attributes. First, the failures need to be reported, either through the LERs or NPRDS. In the August 7, 1991 NRC Policy Issue, SECY-91-244, the NRC staff estimated overall NPRDS completeness at 65 to 70%, based on a comparison of 1990 NPRDS failure data and component failures that were reported in LERs. As mentioned previously, the LERs themselves are not expected to be complete for RPS failures since single failures on testing are not required to be reported through the LER system. Thus, the failures may be undercounted.

The second attribute probably leads to an overcounting of the RPS testing failures. This attribute concerns the ability to distinguish whether a failure is detected during testing, or, more specifically, during the type of testing being considered. In this regard, the brief NPRDS failure narratives usually are insufficient to distinguish periodic surveillance tests from post-maintenance tests or other types of testing. Since the testing frequency often is not mentioned, no attempt is made in this study to restrict the set of testing failures to a particular type of test. An example of the influence of this uncertainty in the data is that all failures on testing for temperature sensor/transmitters are used in the unavailability analysis, although the quarterly testing occurs only four times per year and the calibration testing occurs on average only once every eighteen months. No attempt has been made in this study to associate the failure times with the plant refueling outage times. This source of uncertainty is not currently quantified.

The completeness of the periodic surveillance testing for RPS components is believed to be adequate, realistically mimicking the demand that an unplanned reactor trip using this portion of the RPS would place on the system. The demands are believed to be rigorous enough that successes as well as failures provide meaningful system performance information. However, in some of the data, differences have been noted between tests that are conducted while the plant is operating and tests conducted during shutdown periods. The failure probability in some cases is observed to be higher during the shutdown periods. This phenomena is attributed to the additional complications introduced by the maintenance being done during shutdowns, rather than to an inadequacy in the quarterly and bimonthly testing that occurs at power.

In the remaining subsections of this section, the methods for estimating the various types of demand counts are described.

A-1.2.2.1 Unplanned Demands. The NRC Performance Indicator (PI) databases maintained at the INEEL were used as the source for a list of unplanned actuations of the RPS. Unplanned reactor trips have been a reporting requirement for LERs since the 1984 LER rule. The PI databases have been maintained since 1985 and are a reliable source of LER reactor trip data. The databases include manual as well as automatic reactor trips, although only the latter are currently a performance indicator.

Reactor trip data for 1984 were obtained from the Sequence Coding and Search System. Nine LER number lists with associated event dates for 1984 were obtained. Seven corresponded to each combination of three attributes: required vs. spurious reactor trips, automatic vs. manual reactor trips, and during operation vs. during startup (there were no LERs for the combination of manual spurious reactor trips during startup). The other two files described automatic, spurious reactor trips. The eighth file was for LERs reporting reactor trips at a different unit at the site than the unit reporting the LER, and the ninth was for LERs reporting multiple reactor trips. These lists were consolidated, and records for a second unit's reactor trip were added for LERs reporting multiple reactor trips including reactor trips at another unit. The plant identifier field was adjusted to the unit with the reactor trip for LERs with single reactor trips at different units. Finally, records with multiple reactor trips at single units were examined. If multiple records were already present (e.g., reflecting a manual reactor trip and an automatic reactor trip on the same date), no changes were made. If no multiple records were present, the demand field (for number of reactor trips) was changed to two. Although uncertainties are associated with this process, since the SCSS did not provide a simple list of reactor trip dates and counts for each unit, the process is believed to be quite accurate.

The unplanned demands were used for four components in the fault tree: reactor trip breakers (the main breakers, not the bypass breakers), the undervoltage driver card, and the control rod assemblies and control rod drives. In each of these cases, for each plant and year, the number of reactor trips was multiplied by the assumed number of components to get the number of component demands.

A-1.2.2.2 Surveillance Tests. Bimonthly and quarterly test counts were estimated at a plant-year level by assuming four quarterly tests and six bimonthly tests per full plant year. On the year of the plant's commercial service date, and the year of the plant's decommission date (if any), the demands were reduced in proportion to the plant's in-service time.

Cyclic surveillance test demands at a plant level were counted using the NRC's *OUTINFO* database. This database is based on plant Monthly Operations Reports, and is maintained for the NRC PI program. It lists the starting and ending dates of all periods when the main generator is off-line for a period spanning at least two calendar days. Plausible test dates were estimated based on the ending dates for refueling outages. If the period from the startup after a refueling outage to the beginning of the next refueling outage exceeds 550 days (approximately 18 months), then a plausible date for a mid-cycle test is assigned. The resulting dates are summed by plant and year. For the 1984-1985 period for which the refueling outage information is not available, plausible testing dates are projected back in time from known refuelings.

For each type of periodic surveillance test, the estimated plant counts were pro-rated between plant operation time and plant shutdown time. For each plant and year, the outage time represented in the OUTINFO database, including the days on which outages started and ended, was summed. The down time was summed separately and excluded for the two instances among Westinghouse plants in the study period for which a regulatory-imposed outage occurred (Sequoyah 1 and 2, from mid-1985 to mid-1988). The remaining time between a plant's low power license date and its decommission date or the study end date was treated as operational (up) time. The demands were then prorated on a plant and year-specific basis; for example, the operational demands were taken to be the total demand, times the fraction of the year the plant was up, divided by the sum of the up fraction and the shut-down fraction.

For the current study, the time period covers 1984–1995. Outage data for the period prior to 1986, however, are not readily available. The OUTINFO database has gaps for periods prior to 1986. For periods in 1984 and 1985 between a plant's low power license date and the start of OUTINFO data on the plant, the outage and operational data split was estimated by summing the plant's operational and shut-down time from 1986–1995 and prorating the 1984 and 1985 time to reflect the same percentages.

The plant-year demands were multiplied by the number of components to obtain estimates of component demands. After this multiplication, the estimates for demands during shutdown and demands during operation were rounded up to whole numbers.

A-1.2.3 Operating Time

For failure rate assessments, outage time and operational time were estimated in fractions of calendar years for each plant and year, as discussed in the previous section. These fractions were multiplied by the estimated number of components for which failure data has been reported for each plant and year to obtain exposure times in years for operating and shut-down periods for each component type. As needed, these times were converted to hours.

A-2. ESTIMATION OF UNAVAILABILITY

In subsections below, statistical analysis for each separate component is described, then the combining of failure modes to characterize the total system unavailability and its uncertainty is addressed.

A-2.1 Estimates for Each Failure Mode

The RPS unavailability assessment is based on a fault tree with three general types of basic events: independent failures, common-cause failures (CCF), and miscellaneous maintenance/operator action events.

The CCF modes tend to contribute the most to the unavailability, because they affect multiple redundant components. With staggered testing, the estimation of each CCF probability is a product of a **total** failure event probability (Q_T), and one or more factors derived from the analysis of the failure events as explained in Appendix E.

Since every RPS component involved in the unavailability analysis is in a train whose function is also provided by at least one more train, every component occurs in the CCF events. Therefore, the focus in the individual component analysis for this report was on total failure probabilities rather than probabilities just for independent events. Separate independent estimates with the common-cause events removed were not evaluated. Nor were independent probabilities estimated as $\alpha_1 * Q_T$. The fault tree results were reviewed, and the use of Q_T in place of $\alpha_1 * Q_T$ for the independent events introduces less than three percent error.

This section addresses the estimation of the total failure probability and its uncertainty for virtually all of the RPS components appearing in the fault tree. For the RPS basic failure data analysis for the unavailability assessment, fourteen failure modes were identified, one for each of fourteen component types. Each is based on the non-fail-safe failures of a particular type of component. Component failure data from the NPRDS and LERs was not available for just one component, namely the 125 VDC power supply to the shunt trip coils (PWR). The power supply failures that were in the databases were fail-safe, tending to cause rather than prevent RPS actuation. Generic data were used for PWR failure estimates for the fault tree. The failure data also do not address the RPS maintenance unavailabilities.

The contribution of the operator is another aspect of the system operation that currently tends to fall outside the scope of the operational data analysis. At the system level, manual reactor trips are a form of recovery from failure of the automatic reactor trip function.

Table A-2 shows the components for which estimates were obtained. It also indicates which data sets might be applicable for each component. For the components marked in the table as operating, both a probability on demand and a rate were estimated. The demand probability was based on the number of tests and the failures discovered during testing, while the rate was based on the remaining failures in calendar time.

Table A-2. Possible data sets for components in Westinghouse fault trees.

Component	Unplanned Trips	Testing	Operating[a]
Channel parameter monitoring instruments			
Pressure sensor/transmitter (CPR)	Not used.[b]	Quarterly & cyclic	Yes.
Temperature sensor/transmitter (CTP)	Not used.	Quarterly & cyclic	Yes.
Channel processing modules and bistable			
Eagle 21 processing module (C21)	Not used.	Quarterly	Yes.
Pressure processing module (CCP)	Not used.	Quarterly	No.
ΔT processing module (CDT)	Not used.	Quarterly	No.
General processing module (CCX)[c]	Not used.	Quarterly	No.
Bistable (CBI)	Not used.	Quarterly	No.
Trains (trip logic)			
SSPS universal card (TLC)	Not used.	Bimonthly	No.
Bistable or UV driver card relay (TLR)	Not used.	Bimonthly	No.
Undervoltage driver card (UVL)	Automatic trips.	Bimonthly	No.
Trip breakers			
Breaker (mechanical/electrical) (BME)	Applicable.[d]	Bimonthly	No.
RTB shunt trip device (BSN)	Not used.	Bimonthly	No.
RTB undervoltage coil (BUV)	Not used.	Bimonthly	No.
Rods			
RCCA/CRDM (ROD)	Applicable.	Cyclic	No.

a. With failures in time that are annunciated or detected at shift change-overs, rather than by testing.

b. Failures detected in unplanned trips are not counted for components that may not be demanded in these trips.

c. CCX consists of CCP, CDT, and steam flow/feed flow mismatch processing modules (CMM). The count for CMM is assumed to be LoopM. Failures of CCP, CDT, or CMM were also counted as failures of CCX. CCX is needed for the common-cause analysis of processor failures.

d. For the main breakers, not the bypass breakers.

In subsections below, the processes of selecting particular data sets and estimating probability distributions that reflect uncertainty and variation in the data are described. Finally, a simulation method is described for quantifying the uncertainty regarding whether certain failures were complete losses of the component's safety function.

A-2.1.1 Data-Based Choice of Data Sets

To determine the most representative set of data for estimating each total failure probability or rate, statistical tests were performed to evaluate differences in the following attributes (as applicable):

- Differences in reactor trip data and testing data
- Differences in test results during operations and during shutdown periods (plant mode differences)
- Differences across time. In particular, the twelve-year time frame of the study was separated into two periods, from 1984 through 1989 and from 1990 through 1995, and differences were evaluated.

The plant operational mode during testing was considered because the duration of RPS maintenance outages during plant operations is limited by plant technical specifications. During plant outages, the technical specifications are much less restrictive, and the tests might be more detailed. Conversely, failure modes, if any, that can only occur during operations might be revealed in the tests conducted during operations.

All the unplanned demands occurred when the reactor was at power. Reactor trip signals passing through the system when the plant is not at power have not been reportable as LERs since mid-1993, and were never performance indicators. Thus, no analysis with regard to plant operating mode was performed for the unplanned demand data set.

The demand and failure data sets were obtained as described in Section A-1. Unlike other recent NRC system studies (References A-1 through A-6), there was no concern that failures of particular components would preclude demands on other components. The changes in demand counts that the few failures discovered in the unplanned demands might make on other RPS components is negligible compared with the total number of demands. In the testing data, failures of particular components would not preclude demands on other components because the tests are conducted on the components individually and are staggered across channels and breakers.

To determine which data to use in particular cases, each component failure probability and the associated 90% confidence interval was computed separately in each data set. For failures and demands, the confidence intervals assume binomial distributions for the number of failures observed in a fixed number of demands, with independent trials and a constant probability of failure in each data set. For failures and run times, the confidence intervals assume Poisson distributions for the number of failures observed in a fixed length of time, with a constant failure occurrence rate in each data set.

For each applicable failure mode, the hypothesis that the underlying probabilities were the same between the unplanned demand and testing data was tested. In addition, within the testing data sets the operational and shutdown data were compared. When exactly two groups of data with failures and demands were compared, as with these statistical tests, Fisher's exact test (described in many statistics references) was used. In other cases, chi-square tests were used to evaluate the null hypothesis of equal probabilities for a failure mode across data sets from different types of testing or from unplanned events.

As with Fisher's exact test, a premise for these tests is that variation between subgroups in the data be less than the sampling variation, so that the data can be treated as having constant probabilities of failure across the subgroups. When statistical evidence of differences across a grouping is identified, this hypothesis is not satisfied. For such data sets, confidence intervals based on overall pooled data are too narrow, not reflecting all the variability in the data. However, the additional between-subgroup variation is likely to inflate the likelihood of rejecting the hypothesis of no significant systematic variation between data sets, rather than to mask existing differences.

A further indication of differences among the data sets was whether empirical Bayes distributions were fitted for variation between the testing and unplanned demands or between the two plant modes or the two time periods. This topic is discussed further in the next section.

The following guidelines were used to select the data set for the unavailability analysis when differences were found:

1. Where unplanned demands were listed in Table A-2 for a component, they were used, since they were genuine demands on the RPS. However, when differences were observed, in every case the failure rate or probability associated with the unplanned demands was lower than the estimate associated with testing. Due to concerns about the adequacy of reporting the failures that might have been revealed in the reactor trips, applicable testing data were also used. That is, differences between the unplanned and testing data sets were noted but the data were pooled in spite of such differences.

2. Where differences were seen between the operational and shutdown testing data sets, and both were potentially applicable for the component, the operational data set was used. This is the set that corresponds to the goal of the unavailability analysis, which is to quantify RPS unavailability during operations.

3. When differences were found between the older and more recent data, the more recent data set was selected.

These evaluations were not performed in the common-cause analysis. The CCF analysis addresses the probability of multiple failures occurring, given a failure, rather than the actual occurrence rate of multiple failures. The occurrence of multiple failures among failures may be less sensitive to the type of demand, plant operational state, and time period than the incidence of failure itself. In any case, the CCF data are too sparse for such distinctions.

A-2.1.2 Estimation of Distributions Showing Variation in the Data

To further characterize the failure probability or rate estimates and their uncertainties, probabilities or rates and confidence bounds were computed in each data set for each year and each plant unit. The hypothesis of no differences across each of these groupings was tested in each data set, using the Pearson chi-square test. Often, the expected cell counts were small enough that the asymptotic chi-square distribution was not a good approximation for the distribution of the test statistic; therefore, the computed p-values were only rough approximations for the likelihood of observing as large a chi-square test statistic when no between-group differences exist. The tests are useful for screening, however. Variation in the rates or probabilities from plant to plant or from year to year is identified in order to describe the resulting variation in the unavailability estimates. Identifying the impact of particular plants or years on the estimates is useful in determining whether the results of the unavailability analysis are influenced by possible outliers. The existence of plant outliers is addressed in this report, although the identity of the plants is not since the NPRDS data are proprietary.

Three methods of modeling the failure/demand or failure in time data for the unavailability calculations were employed. They all use Bayesian tools, with the unknown probability or rate of failure for each failure mode represented by a probability distribution. An updated probability distribution, or *posterior* distribution, is formed by using the observed data to update an assumed *prior* distribution. One important reason for using Bayesian tools is that the resulting distributions for individual failure modes can be propagated easily, yielding an uncertainty distribution for the overall unavailability.

In all three methods, Bayes Theorem provides the mechanics for this process. Details are highlighted for probabilities and for rates in the next two subsections.

A-2.1.2.1 Estimation of Failure Probability Distributions Using Demands. The prior distribution describing failure probabilities is taken to be a beta distribution. The beta family of distributions provides a variety of distributions for quantities lying between 0 and 1, ranging from bell-shape distributions to J- and U-shaped distributions. Given a probability (p) sampled from this distribution, the number of failures in a fixed number of demands is taken to be binomially distributed. Use of the beta family of distributions for the prior on p is convenient because, with binomial data, the resulting output distribution is also beta. More specifically, if a and b are the parameters of a prior beta distribution, a plus the number of failures and b plus the number of successes are the parameters of the resulting posterior beta distribution. The posterior distribution thus combines the prior distribution and the observed data, both of which are viewed as relevant for the observed performance.

The three methods differ primarily in the selection of a prior distribution, as described below. After describing the basic methods, a summary section describes additional refinements that are applied in conjunction with these methods.

Simple Bayes Method. Where no significant differences were found between groups (such as plants), the data were pooled and modeled as arising from a binomial distribution with a failure probability *p*. The assumed prior distribution was taken to be the Jeffreys noninformative prior distribution.[A-7] More specifically, in accordance with the processing of binomially distributed data, the prior distribution was a beta distribution with parameters, a=0.5 and b=0.5. This distribution is diffuse, and has a mean of 0.5. Results from the use of noninformative priors are very similar to traditional confidence bounds. See Atwood[A-8] for further discussion.

In the simple Bayes method, the data were pooled, not because there were no differences between groups (such as years), but because the sampling variability within each group was so much larger than the variability between groups that the between-group variability could not be estimated. The dominant variability was the sampling variability, and this was quantified by the posterior distribution from the pooled data. Therefore, the simple Bayes method used a single posterior distribution for the failure probability. It was used both for any single group and as a generic distribution for industry results.

Empirical Bayes Method. When between-group variability could be estimated, the *empirical Bayes* method was employed.[A-9] Here, the prior beta (a, b) distribution is estimated directly from the data for a failure mode, and it models between-group variation. The model assumes that each group has its own probability of failure, *p*, drawn from this distribution, and that the number of failures from that group has a binomial distribution governed by the group's *p*. The likelihood function for the data is based on the observed number of failures and successes in each group and the assumed beta-binomial model. This function of a and b was maximized through an iterative search of the parameter space, using a SAS routine.[A-8] In order to avoid fitting a degenerate, spike-like distribution whose variance is less than the variance of the observed failure counts, the parameter space in this search was restricted to cases where the sum, a plus b, was less than the total number of observed demands. The a and b corresponding to the maximum likelihood were taken as estimates of the generic beta distribution parameters representing the observed data for the failure mode.

The empirical Bayes method uses the empirically estimated distribution for generic results, but it also can yield group-specific results. For this, the generic empirical distribution is used as a prior, which is updated by group-specific data to produce a group-specific posterior distribution. In this process, the generic distribution itself applies for modes and groups, if any, for which no demands occurred (such as plants with no unplanned demands).

A chi-square test was one method used to determine if there were significant differences between the groups. But because of concerns about the appropriateness and power of the chi-square test, discomfort at drawing a fixed line between significant and nonsignificant, and an engineering belief that there were real differences between the groups, an attempt was made for each failure mode to estimate an empirical Bayes prior distribution over years and plants. The fitting of a nondegenerate empirical Bayes distribution was used as the index of whether between-group variability could be estimated. The simple Bayes method was used only if no empirical Bayes distribution could be fitted, or if the empirical Bayes distribution was nearly degenerate, with smaller dispersion than the simple Bayes posterior distribution. Sometimes, an empirical Bayes distribution could be fitted even though the chi-square test did not find a between-group variation that was even close to statistically significant. In such a case, the empirical Bayes method was used, but the numerical results were almost the same as from the simple Bayes method.

If more than one empirical Bayes prior distribution was fitted for a failure mode, such as a distribution describing variation across plants and another one describing variation across years, the general principle was to select the distribution with the largest variability (highest 95th percentile). Exceptions to this rule were based on engineering judgment regarding the most logical and important sources of variation, or the needs of the application.

Alternate Method for Some Group-Specific Investigations. The data for each component were modeled by year to see if trends due to time existed. The above methods tend to mask any such trend. The simple Bayes method pools all the data, and thus yields a single generic posterior distribution. The empirical Bayes method typically does not apply to all of the failure modes, and so masks part of the variation. When empirical Bayes distributions are fitted, and year-specific updated distributions are obtained, the Bayes distribution may smooth the group-specific results and pull them towards the generic fitted distribution, thus masking trends.

It is natural, therefore, to update a prior distribution using only the data from the one group. The Jeffreys noninformative prior is suitably diffuse to allow the data to drive the posterior distribution toward any probability range between 0 and 1, if sufficient data exist. However, when the full data set is split into many groups, the groups often have sparse data and few demands. Any Bayesian update method pulls the posterior distribution toward the mean of the prior distribution. More specifically, with beta distributions and binomial data, the estimated posterior mean is $(a+f)/(a+b+d)$. The Jeffreys prior, with $a = b = 0.5$, thus pulls every failure probability toward 0.5. When the data are sparse, the pull toward 0.5 can be quite strong, and can result in every group having a larger estimated unavailability than the population as a whole. In the worst case of a group and failure mode having no demands, the posterior distribution mean is the same as that of the prior, 0.5, even though the overall industry experience may show that the probability for the particular failure mode is, for example, less than 0.1. Since industry experience is relevant for the performance of a particular group, a more practical prior distribution choice is a diffuse prior whose mean equals the estimated industry mean. Keeping the prior diffuse, and therefore somewhat noninformative, allows the data to strongly affect the posterior distribution; and using the industry mean avoids the bias introduced by the Jeffreys prior distribution when the data are sparse.

To do this, a generalization of the Jeffreys prior called the *constrained noninformative prior* was used. The constrained noninformative prior is defined in Reference A-10 and summarized here. The Jeffreys prior is defined by transforming the binomial data model so that the parameter p is transformed, approximately, to a location parameter, ϕ. The uniform distribution for ϕ is noninformative. The corresponding distribution for p is the Jeffreys noninformative prior. This process is generalized using the maximum entropy distribution[A-11] for ϕ, constrained so that the corresponding mean of p is the industry mean from the pooled data, $(f+0.5)/(d+1)$. The maximum entropy distribution for ϕ is, in a precise sense, as flat as possible subject to the constraint. Therefore, it is quite diffuse. The corresponding distribution for *p* is found. It does not have a convenient form, so the beta distribution for *p* having the same mean and variance is found. This beta distribution is referred to here as the constrained noninformative prior. It corresponds to an assumed mean for *p* but to no other prior information. For various assumed means of *p*, the noninformative prior beta distributions are tabulated in Reference A-10.

For each failure mode of interest, every group-specific failure probability was found by a Bayesian update of the constrained noninformative prior with the group-specific data. The resulting posterior distributions were pulled toward the industry mean instead of toward 0.5, but they were sensitive to the group-specific data because the prior distribution was so diffuse.

Additional Refinements in the Application of Group-Specific Bayesian Methods. For both the empirical Bayes distribution and the constrained noninformative prior distribution using pooled data, beta distribution parameters are estimated from the data. A minor adjustment[A-12] was made in the posterior beta distribution parameters for particular years to account for the fact that the prior parameters *a* and *b* are only estimated, not known. This adjustment increases the group-specific posterior variances somewhat.

Both group-specific failure probability distribution methods use a model, namely that the failure probability *p* varies between groups according to a beta distribution. In a second refinement, lack of fit to this model was investigated. Data from the most extreme groups (plants or years) were examined to see if the observed failure counts were consistent with the assumed model, or if they were so far in the tail of the beta-binomial distribution that the assumed model was hard to believe. The test consisted of computing the probability that as many or more than the observed number of failures for the group would occur given the beta posterior distribution and binomial sampling. If this probability was low, the results were flagged for further evaluation of whether the model adequately fit the data. This test was most important with the empirical Bayes method, since the empirical Bayes prior distribution might not be diffuse. See Atwood[A-8] for more details about this test.

Group-specific updates were not evaluated with the simple Bayes approach because this method is based on the hypothesis that significant differences in the groups do not exist.

Note that, for the RPS study, Westinghouse generic distributions were sought rather than distributions updated with plant-specific data. Plant-specific evaluations are not in the scope of this study.

A-2.1.2.2 Estimation of Failure Probability Distributions Using Operating Time.

Failure rates were estimated for the three operating components using the failures that occurred in time, excluding those detected in testing. Chi-square test statistics were computed and Bayesian methods similar to those described above for probabilities were used to characterize the variation in the rates. The analyses for rates are based on event counts from Poisson distributions, with gamma distributions that reflect the variation in the occurrence rate across subgroups of interest or across the industry. The simple Bayes procedure for rates results in a gamma distribution with shape parameter equal to 0.5+f, where f is the number of failures, and scale parameter 1/T, where T is the total pooled running time. An empirical Bayes method also exists. Here, gamma distribution shape and scale parameters are estimated by identifying the values that maximize the likelihood of the observed data. Finally, the constrained noninformative prior method was applied in a manner similar to the other failure modes but again resulting in a gamma distribution for rates. These methods are described further in References A-13 and A-10.

From the rates, failure probability distributions are estimated in the fault tree software. In addition to the gamma distribution for a rate, the software uses an estimate of the average downtime when a failure occurs. For the RPS components, this time is short since the failures are quickly detected and most corrective actions involve simple replacements and adjustments.

A-2.1.2.3 Estimation of Lognormal Failure Probability Distributions. For simplicity, the uncertainty distributions used in the fault tree analysis were lognormal distributions. These distributions produced more stable results in the fault tree simulations, since the lognormal densities are never J- or U-shaped. For both probabilities and rates, lognormal distributions were identified that had the same means and variances as the original uncertainty distributions.

A-2.1.3 Treatment of Uncertain Failures

In the statistical analysis of Section A-1.2.2, uncertainty is modeled by specifying probability distributions for each input failure probability or rate. These distributions account for known variations. For example, a simple event probability calculated from an observed number of events in an observed number of demands will vary as a result of the random nature of the events. The effect of this sampling variation on the system unavailability is modeled in the simple Bayes method.

For the RPS data, however, the number of events itself was difficult to determine from the often-vague NPRDS failure reports. Uncertain information for two particular aspects of the event records has been flagged. The first is whether the safety function was lost. Many of the failure reports for components such as calculators and sensors do not describe their exact usage. The reports often state how the component failed but not whether the nature of the failure would cause a reactor trip or delay a reactor trip. For example, failing high could have either impact depending on the particular process being monitored. In the failure data, the records were marked as safety function lost, not lost, or unknown.

The second source of uncertainty that has had a significant effect on the data for the RPS is whether the failure represents a total loss of function for the component. In the common-cause methodology, the data analyst assesses his or her confidence in whether a failure represents a total loss. The resulting completeness value represents the probability that, among similar events, the component's function would be completely lost. Assessed values of 1.0, 0.5, 0.1, and 0.01 were used in this field. For the uncertainty analysis, records with 1.0 were treated as complete, those with 0.5 were treated as unknown completeness, and those with lesser values were treated as not complete.

Since they were flagged in the data, these two sources of uncertainty in the RPS failure data were explicitly modeled in the RPS study. This section provides further details on the treatment of these uncertainties.

In the RPS modeling, each assessed common-cause fraction (alpha) was multiplied by the corresponding total failure probability for the component. This probability was based on the total number of failures (both independent and common cause) that represent complete losses of the safety function of the component. For each component, potentially nine sets of failures could be identified:

1. Complete, safety function lost, failures

2. Complete failures that were fail-safe (safety function not lost)

3. Complete failures for which the impact on the safety function (plant shutdown) is unknown

4. Incomplete failures that would result in the safety function being lost, if they were more severe

5. Incomplete failures that would be fail-safe if they were more severe

6. Incomplete failures with unknown impact on the safety function

7. Failures with unknown completeness that tend to prevent a trip (safety function lost)

8. Failures with unknown completeness that were fail-safe (safety function not lost)

9. Failures with unknown completeness and unknown impact on the safety function.

Failures in Categories 3, 7, and 9 were, potentially, complete failures with the safety function lost.

In past NRC system studies, uncertainties in data classification or the number of failures or demands have been modeled by explicitly assigning a probability for every possible scenario in the uncertain data. The data set for each scenario was analyzed, and the resulting output distributions were combined as a mixture distribution, weighted according to the assigned probabilities. This process was used to account for uncertain demands for system restart in the High Pressure Core Injection Study (Reference A-1), and to account for whether certain failures to run occurred in the early, middle, or late period in the Emergency Diesel Generator Study (Reference A-2). This method has recently become established in the literature (see References A-14 through A-16).

For each component in the RPS study, too many possible combinations of outcomes exist to separately enumerate each one. There are three types of uncertain data, and in some cases over 100 uncertain events for a component. Therefore, the well-known Monte Carlo simulation method was used to assess the impact of the uncertain failures. Probabilities were assigned for whether to treat each set of uncertain failures as complete failures with the safety function lost. After sampling from probability distributions based on the assigned probabilities, the failure probability or failure rate of the RPS component being studied was characterized as described in Section A-2.1.2. This process was repeated 1000 times, and the variation in the output was used to assess the overall uncertainty for the failure probability or failure rate. As with the previous NRC system uncertainty models, the resulting output distributions were combined as a mixture distribution. Since these distributions arise from simulations, they were equally weighted in forming the final output distribution.

More details on the selection of the probabilities, the nature of the simulations, and the combining of the output distributions are provided in subsections below.

A-2.1.3.1 Selection of Uncertainty Distributions. Three uncertainties were considered, corresponding to Categories 3, 7 and 9 in the list above. Probabilities for these events were developed using engineering judgment, as follows.

The average or best estimate of the probability that the safety function was lost was estimated from the data in each data set. Among complete failures, the ratio of the number of events with known safety function lost, to events with safety function either known to be lost or known to be fail-safe, was used for the probability of counting a complete event with uncertain safety function loss. Similarly, among failures with uncertain completeness, a probability of the safety function actually being lost in questionable cases was estimated by the ratio of the number of events with known safety function lost to events with safety function either known to be lost or known to be fail-safe, among events with uncertain completeness.

For the probability that an event with uncertain completeness would be a complete loss of the safety function of the component, 0.5 was the selected mean value. This choice corresponds to the assessments of the engineers reviewing the failure data. For the uncertain events under consideration, the assessment was that the probability of complete function loss among similar events is closer to 0.5 than to 1.0 or to a value less than or equal to 0.1.

In the simulations, beta distributions were used to model uncertainty in these probabilities. More specifically, the family of constrained noninformative distributions described under Alternate Methods in Section A-2.1.2 was selected. For both the probability of the safety function being lost and the probability of complete losses, the maximum entropy distribution constrained to have the specified mean probability was selected. The maximum entropy property results in a broad distribution; for the probability of an event with uncertain completeness being complete the 5th and 95th percentile bounds are, respectively, 0.006 and 0.994. Thus, these distributions model a range of probabilities for the uncertain data attributes.

For events in Category 9, for which both the safety function status and the completeness were unknown, the probability of complete failures with loss of the safety function was taken to be the product of the two separate probabilities. While the completeness and safety function loss status may not be completely independent among events with both attributes unknown, use of the product ensures that the modeled probability for these events will be as low, or lower, than the probability that the events with only one uncertain factor were complete losses of the safety function.

A-2.1.3.2 Nature of the Simulations. The simulations occurred in the context of the ordinary statistical analysis described in Sections A-2.1.1 and A-2.1.2. The first step in completing the analysis was to identify the best data subset, using the methods of Section A-2.1.1. The variation in the data was bounded by completing the analysis of Section A-2.1.1 using two cases:

- Lower bound case: counting no uncertain failures.
- Upper bound case: counting all uncertain failure (i.e., counting all the failures in Categories 3, 7, and 9 as complete losses of the safety function).

When differences were found between data sets in either of these bounding analyses, the differences were preserved for the simulation. That is, a subset was selected to best represent a RPS component's failure probability or failure rate for Westinghouse plants if the rules given in Section A-2.1.1 applied in either the upper bound or the lower bound case.

In the simulation, the selected data subset was analyzed using the simple Bayes method and also the empirical Bayes method for differences between plants and years. In each iteration, the data set itself differs according to the number of uncertain failures included. That is, for each selected set of data, the simulation proceeds as follows. First, a simulated number of failures was calculated for each combination of plant, year, plant mode, and method of discovery present in the data. Then, a simple Bayes or empirical Bayes distribution was sought. The results were saved and combined as described in the next subsection.

The calculation of the simulated number of failures was simple. Suppose a cell of data (plant/ year/plant operational mode/method-of-discovery combination) had f failures that were known to be complete losses of the safety function, s failures for which the impact on the safety function was unknown, c failures for which the completeness was unknown, and b failures for which both the safety function impact and completeness were unknown. In the simulation, a p_{sc} for complete failures with unknown safety function status and a p_{su} for unknown completeness failures with unknown safety function status were obtained by sampling from the beta distributions discussed above. A p_c was obtained by sampling from the beta distribution discussed above with mean 0.5. A simulated number of failures with the safety function lost among the *s* failures with unknown impact was obtained by sampling from a binomial distribution with parameters *s* and p_{sc}. Here, the first parameter of a binomial distribution is the number of opportunities for an outcome, and the second is the probability of the outcome of interest in each independent trial. Similarly, a simulated number of complete failures among the *c* failures with unknown completeness was obtained by sampling from a binomial distribution with parameters *c* and p_c. A simulated number of complete failures with safety function lost was generated from among the *b* failures with both uncertainties by sampling from a binomial distribution with parameters *b* and $p_{su}*p_c$. The total number of failures for the cell was *f* plus the values obtained from sampling from the three binomial distributions. This process was repeated for each cell of data.

A-2.1.3.3 Combining Output Distributions. The resulting beta or gamma distributions from the simulation cases were weighted equally and combined to produce distributions reflecting both the variation between plants or other specifically analyzed data sources, and the underlying uncertainty in the two attributes of the classification of the failure data. Two details of this process bear mention.

In some of the simulated data sets, empirical Bayes distributions were not fitted to the data; the maximum likelihood estimates of the empirical Bayes distribution parameters did not exist. An outcome of the simulation was the percentage of the iterations for which empirical Bayes distributions were found. When no empirical Bayes distribution was fit to the simulated data, the simulated data were treated as being homogenous. The simple Bayes method represented the data using the updated Jeffrey's non-informative prior distribution. The mean was taken to be the number of simulated failures plus 0.5, divided by the number of demands plus 1 (for probabilities) or by the exposure time (for rates). The resulting distribution goes into the mix along with the other distributions computed for the attribute under study in the simulations.

For each studied attribute, the simulation distributions were combined by matching moments. A lognormal distribution was obtained that has the same mean and variance as the mixture distribution arising from the simulation.

An option in the last step of this analysis would be to match the mean and the 95th percentile from the simulation instead of the mean and variance. Two lognormal distributions can generally be found that match a specified mean and upper 95th percentile (the error factors are roots of a quadratic equation). For the RPS data, the 95th percentiles from the simulation were relatively low, and the mean and upper bound match led to unrealistic error factors (generally less than 1.5 or greater than 100). Therefore, lognormal distributions that matched the means and variances of the simulation data were used rather than distributions based on the mean and 95th percentiles.

A-2.2 The Combination of Failure Modes

The failure mode probabilities were combined to obtain the unavailability. The primary tool in this assessment was the SAPHIRE analysis of the two fault trees (for plants with analog channels and for plants with the Eagle 21 design).

Algebraic methods, described briefly here, were used to compute overall common-cause failure probabilities and their associated uncertainties. The CCF probabilities were linear combinations of selected high-order CCF alpha factors, multiplied by the total failure probability or rate coming from the analysis of Section A-2.1. The CCF alpha factors, described in Appendix E, indicate the probability that, given a failure, a particular number of redundant components will fail by common-cause. For example, the probability of 6 of 8 components failing depends on the alpha factors for levels 6, 7, and 8. The linear combination of these terms was multiplied by Q_T, the total failure probability, to get the desired common-cause failure probability.

The following algebraic method is presented in more generality by Martz and Waller.[A-17] The CCF probability was an expression of the form

(aX+bY)*Z,

where X, Y, and Z are events or failure modes or alpha factors that each had an uncertainty distribution, and a and b are positive constants between 0 and 1 that reflect a subset of CCF events of a given order meeting the particular criterion of the RPS fault tree. A combined distribution was obtained by repeatedly rewriting the expression using the facts that

Prob(k*A*) = k Prob(*A*) for the subsetting operation,

Prob(*A**B*) = Prob(*A* and *B*) = Prob(*A*)*Prob(*B*), and

Prob(*A*+*B*) =Prob(*A* or *B*) = 1 - Prob(not *A*)*Prob(*not B*) = 1 - [1 - Prob(*A*)]*[1 - Prob(*B*)],

where *A* and *B* are any independent events. Because the resulting algebraic expressions were linear in each of the failure probabilities, the estimated mean and variance of the combination were obtained by propagating the failure probability means and variances. These means and variances were readily available from the beta distributions. Propagation of the means used the fact that the mean of a product is the product of the means, for independent random variables. Propagation of variances of independent factors was also readily accomplished, based on the fact that the variance of a random variable is the expected value of its square minus the square of its mean.

In practice, estimates were obtained by the following process:

- Compute the mean and variance of each beta distribution.
- Compute the mean and variance of the combination for each case using simple equations for expected values of sums for "or" operations and of products for "and" operations.
- Compute parameters for the lognormal distribution with the same mean and variance.
- Report the mean and the 5th and 95th percentiles of the fitted lognormal distribution.

The means and variances calculated from this process were exact. The 5th and 95th percentiles were only approximate, however, because they assume that the final distribution is a lognormal distribution. Monte Carlo simulation for the percentiles is more accurate than this method if enough Monte Carlo runs are performed, because the output uncertainty distribution is empirical and not required to be lognormal.

A-3. METHODS FOR THE TREND ANALYSIS

In addition to the analyses used to estimate system unavailability, the overall frequencies of unplanned demands (reactor trips), total failures for each component, and common-cause events for each component were analyzed by year to identify possible trends. Two specific analyses were performed for the three sets of occurrence frequencies. First, the frequencies were compared to determine whether significant differences exist among the calendar years. Frequencies and confidence bounds were computed for each type of frequency for each year. The hypotheses of simple Poisson distributions for the occurrences with no differences across the year groupings were tested using the Pearson chi-square test. The computed p-values were approximate since the expected cell counts were often small; however, they were useful for screening.

Regardless of whether particular years were identified as having different occurrence frequencies, the occurrence frequencies were also modeled by year to see if calendar trends exist. Least-squares regression analyses were used to assess the trends. A straight line was fitted to the frequency (shown as dots in the plot), and a straight line was also fitted to log(frequency). Thus, the analysis determined whether either the frequency or the log(frequency) was linear with regard to calendar time. The fit selected was the one that accounted for more of the variation, as measured by R^2 provided that it also produced a plot with regression confidence limits greater than zero. The regression-based confidence band shown as dashed lines on the plots applies to every point of the fitted line simultaneously; it is the band due to Working, Hotelling, and Scheffé, described in statistics books that treat linear regression. The paragraphs below describe certain analysis details associated with the frequency trend analyses.

With sparse data, estimated event frequencies (event counts divided by time) were often zero, and regression trend lines through such data often produced negative frequency estimates for certain groups (years). Since occurrence frequencies cannot be negative, log models were important in this analysis. However, an adjustment was needed in order to include frequencies that are zero in this model.

Using $0.5/t$ as a frequency estimate in such cases is not ideal. Such a method penalizes groups that have no failures, increasing only their estimated frequency. Furthermore, industry performance may show that certain events are very rare, so that $0.5/t$ is an unrealistically high estimate for a frequency. A method that adjusts the frequencies uniformly for all the grouping levels (years) and that uses the overall frequency information contained in the industry mean was needed for sparse data and rare events.

As explained in Section A-2.1.2.2, constrained noninformative priors can be formed for frequencies as well as for probabilities. This method met the requirements identified above. Because it also produced occurrence frequencies for each group (each year) in a way that was very sensitive to the data from that one group, it tended to preserve trends that were present in the unadjusted frequency data. The mean of the updated posterior distribution was used in the regression trending. This process effectively added 0.5 uniformly to each event count, and $T/(2N+1)$ to each group exposure time. The additional refinement explained in Section A-2.1.2.2 that adjusts the posterior gamma distribution parameters for particular years to account for the estimation of the prior distribution scale parameter was also applied.

A final trend analysis was performed on the total failure probabilities (Q_T) used in the risk assessment. Common-cause failure probabilities are largely driven by these probabilities, since the CCF probabilities are estimated by multiplying a function of the estimated alpha parameters (which are too sparse for trend analysis) and Q_T. For each component in the risk assessment, uncertainty distributions were estimated for each year using the constrained noninformative prior method. The failures and demands entering this calculation were from the subset used for the Q_T analysis, with the exception that the entire time period was used even for components for which the unreliability estimates were based on data from the 1990–1995 period. The means of the uncertainty distributions were trended, and significant trends were highlighted and plotted using the same regression methods as for the frequencies.

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Appendix B

Data Summary

This appendix is a summary of the data evaluated in the common-cause failure (CCF) data collection effort in support of the Westinghouse RPS study. Table B-1 lists independent failure counts by type of component from the source data files and is summarized on a yearly basis. Table B-2 lists the CCF failure event counts by type of component from the CCF file and is again summarized on a yearly basis. Table B-3 gives a detailed summary of the CCF events. The data presented in this appendix represent a subset of the data collected and analyzed for this study. The first screening was to exclude data prior to 1984 and to include only data from Westinghouse plants. The second screening separated out the components of interest for the RPS study. The following list shows the components that are included in this summary and a short description of each:

Component	**Component Description**
BME	Breaker mechanical
BSN	Breaker shunt trip coil
BUV	Breaker undervoltage coil
C21	Channel Eagle-21 processing module (solid state)
CBI	Channel bistables
CCP	Channel processing modules (analog) monitoring pressure/level/flow trip signals
CDT	Channel processing modules (analog) monitoring overpower and overtemperature ΔT trip signals
CCX	Channel processing modules (three types, analog)(note that this is a combination of three types of components: CDT, CCP, and CMM, which is a steam flow mismatch trip signal not explicitly modeled in the RPS fault tree)
CPR	Channel pressure sensor/transmitter
CRD	Control rod drive mechanism (one for each RCCA)
CTP	Channel temperature sensor/transmitter
ROD	Rod control cluster assembly (RCCA)
TLC	Train trip signal logic (universal) card (solid state)
TLR	Train trip module logic relay or undervoltage driver card shunt trip relay
UVL	Train undervoltage driver card

The third screening was for the safety function significance of the failure. The data collection classified failures into three categories: fail-safe (FS), which represents a failure that does not affect the component's safety function; non-fail-safe (NFS), which represents a failure of the component's safety function; and unknown (UKN), which represents a failure that cannot be classified as FS or NFS because of insufficient information concerning the failure. Only those failures designated as NFS or UKN are included in these attachments.

The fourth screening was for the failure completeness (degradation) value. Events were categorized as complete failures (CF)(P=1.0), non failures (NF)(P=0.1 or lower), or unknown completeness (UC)(P=0.5). Events with failure completeness (degradation) values less than 0.5 are excluded from the counts of independent events in Table B-1.

The Table B-3 headings are listed and described below:

Vendor	The vendor of the plant at which the event occurred. Only Westinghouse (WE) is considered in this report.
FM	Failure mode. The failure mode is a two-character designator describing the mode of failure. The following list shows the failure modes applicable to this report:

FM	Description
IO	Instrument inoperability
IS	Instrument setpoint drift
CO	Breaker fails to open
FO	Functionally failed (applies to RODs)

Completeness Value	This field indicates the extent of each component failure. The allowable values are decimal numbers from 0.0 to 1.0. Coding guidance for different values follows:

1.0 (CF)	The component has completely failed and will not perform its safety function.
0.5 (UC)	The completeness of the component failure is unknown.
0.1 (NF)	The component is only slightly degraded or failure is incipient.
0.01 (NF)	The component was considered inoperable in the failure report; however, the failure was so slight that failure did not seriously affect component function.
0.0	The component did not fail (given a CCF event).
--	No component exists for this group size.

Failures	The number of failure events included in the data record.
Date	The date of the event.
CCF Number	Unique identifier for each common-cause failure event. For this non-proprietary report, the docket number portion of the CCF number has been replaced with 'XXX'.
Description	The description field for the CCF.
Safety Function	Determination of the type of failure as related to the safety function. Allowable entries are NFS, UKN, or FS.
Shock Type	An indication of whether or not all components in a group can be expected to fail. Allowable entries: 'L' for lethal shock and 'NL' for non-lethal.

Time Delay Factor	The probability that two or more component failures separated in time represent a CCF. Allowable values are between 0.1 and 1.0. (Called the Timing Factor in Appendix E.)
Coupling Strength	The analyst's uncertainty about the existence of coupling among the failures of two or more components. Allowable values are between 0.1 and 1.0. (Called the Shared Cause Factor in Appendix E.)

Appendix B has been compiled from several database files that comprise the RPS study data. The file names and a short description are included here for reference:

RPS Data.mdb	LER, NPRDS, and CCF data files
CCF Analysis Code.mdb	Miscellaneous data tables and programs

Table B-1. Westinghouse RPS independent failure yearly summary, 1984 through 1995.

System	**Rod** Component	Safety Function	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	Total
	ROD	NFS	1												1
	BME	NFS				2		1							3
	BME	UKN						1						1	2
	BSN	NFS			1	3		1	1				1		7
	BSN	UKN			1										1
	BUV	NFS	2	1		1		1	1		1				7
	C21	NFS							3	7					10
	C21	UKN												1	1
	CBI	NFS	9	15	13	12	9	6	7	9	8	13	15	12	128
	CBI	UKN	7	8	13	12	16	14	7	9	2	4	1	4	97
	CCP	NFS		1	2	1		3	1	2	4	1	1		16
	CCP	UKN		3		2	2	1			2	1	1	2	14
	CDT	NFS	2	5	3	3	5	5	11	4	6	7	8	1	60
	CDT	UKN	19	24	18	17	8	14	22	12	14	7	8	4	167
	CPR	NFS		2	5	5	11	4	2	6	4	5	1		45
	CPR	UKN	1	2	2	3	3	3	3	6	3	6	5	4	41
	CTP	NFS	6	2	10	4	1	1	4	4	7	6	3	5	52
	CTP	UKN	8	4	7	8	5	1	4	4	2	1	1		45
	TLC	NFS		1				1	1	4	2	1	5	1	16
	TLC	UKN	2	1		1	1	1		1			1		8
	TLR	NFS	3	10		5	2	5	1	5	2	1	3	3	40
	TLR	UKN				1			1			1	2		5
	UVL	NFS	1	2		1			1	1					6
Study Total			61	81	75	81	63	63	70	74	57	54	56	38	772

Table B-2. Westinghouse RPS common-cause failure yearly summary, 1984 through 1995.

System	Rod Component	Safety Function	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	Total
	CRD	UKN		1											1
	ROD	NFS			1										1
	BME	UKN	1												1
	BSN	NFS		1											1
	BUV	NFS		1											1
	C21	NFS								1					1
	C21	UKN								1					1
	CBI	NFS	1	2	1	2	2	4	2	5	3		3	1	26
	CBI	UKN	4	1	5	1		1	2	1	1		1		17
	CCP	UKN	1								1				2
	CCX	NFS							1		1				2
	CCX	UKN		1		1	1								3
	CDT	NFS		2	3		1		3		1	4			14
	CDT	UKN	4	3	4	3	4	4	3	3	5	1	1	2	37
	CPR	NFS			2	1				3	1	2		1	10
	CPR	UKN	3	3	4	1	4	1	1	1	1				19
	CTP	NFS	1	1	1	1		2							6
	CTP	UKN	2	1	2		1		1	1		1		1	10
	TLC	NFS		1				1	2	1		1			6
	TLR	NFS		2		1	3							1	7
	TLR	UKN				1									1
	UVL	NFS						1							1
Study Total			17	20	23	12	16	14	15	17	14	9	5	6	168

Table B-3. Westinghouse RPS common-cause failure detailed summary, 1984 through 1995.

Component	Fail Mode	CCF Number	Event Year	Event Description	Safety Function	TDF	Coupling Strength	CCCG	Shock Type	Date	No. Failures[a]	Degraded Value
CRD	FO	N-XXX-85-1362-FO	1985	FAULTY FIRING CIRCUIT CARD	UKN	1.00	1.00	48	NL	9/16/85	1	1.00
										9/16/85	1	1.00
ROD	FO	N-XXX-86-1361-FO	1986	CLAD CRACKING SLIDE WEAR & GUIDE CARD WEAR ON RODLETS	NFS	1.00	1.00	48	NL	3/19/86	1	0.50
										3/19/86	1	0.50
BME	CC	L-XXX-84-1072-CC	1984	TRIP BREAKERS FOUND WITH DAMAGED COMPONENTS	UKN	1.00	0.50	4	NL	10/2/84	4	0.10
BSN	CO	N-XXX-85-1096-CO	1985	CLEARANCE BETWEEN SHUNT TRIP LEVER AND TRIP BAR TO BE OOS	NFS	1.00	1.00	4	NL	12/3/84	1	0.10
										12/3/85	1	0.10
BUV	CO	L-XXX-85-0557-CO	1985	2 BREAKERS FAILED THE FORCE MARGIN TEST AT THE 20 OUNCE LEVE	NFS	1.00	1.00	4	NL	11/7/85	2	0.10
C21	IS	N-XXX-91-1469-IS	1991	EAGLE 21 DIGITAL TO ANALOG CONVERTER CARD WAS FOUND OUT OF T	NFS	1.00	0.50	4	NL	11/30/91	1	0.10
										11/19/91	1	0.10
C21	IS	N-XXX-91-0418-IS	1991	5 VOLT OUTPUTS OUT OF TOLERANCE AND HAD EXCESSIVE AC RIPPLE	UKN	1.00	1.00	4	NL	5/5/91	1	0.10
										5/5/91	1	0.10
CBI	IO	L-XXX-84-0569-IO	1984	CHANNELS DEGRADED DUE TO MISSING JUMPERS	NFS	1.00	1.00	64	NL	11/26/84	2	1.00
CBI	IS	N-XXX-84-0395-IS	1984	WEAK CAPACITORS IN SIGNAL COMPARATORS	UKN	1.00	0.50	64	NL	11/9/84	1	0.10
										11/9/84	1	0.10
CBI	IS	N-XXX-84-0510-IS	1984	MODULES 00S	UKN	1.00	0.50	64	NL	2/29/84	1	0.10
										2/29/84	1	0.10
CBI	IS	N-XXX-84-0150-IS	1984	TRIP BISTABLE SETPOINTS FOUND OUT OF	UKN	0.10	0.50	64	NL	6/11/84	1	0.10
										5/9/84	1	0.10
CBI	IS	N-XXX-84-0081-IS	1984	COMPARATOR CARD OUT OF CALIBRATION	UKN	0.50	0.50	64	NL	2/23/85	1	0.10
										2/23/85	1	0.10
										2/23/85	1	0.10
										2/22/85	1	0.10
										2/22/85	1	0.10
										12/9/84	1	0.10
										11/21/84	1	0.10
										11/21/84	1	0.10
										10/22/84	1	0.10

Table B-3. (continued).

Component	Fail Mode	CCF Number	Event Year	Event Description	Safety Function	TDF	Coupling Strength	CCCG	Shock Type	Date	No. Failures[a]	Degraded Value
CBI	IS	N-XXX-85-0215-IS	1985	BISTABLES WOULD NOT TRIP AT THE DESIRED SETPOINT	NFS	1.00	0.50	64	NL	10/24/85 10/23/85	1 1	0.10 0.10
CBI	IS	N-XXX-85-0067-IS	1985	FAILURE OF THE COMPARATORS ATTRIBUTED TO NORMAL SETPOINT DRI	UKN	1.00	0.50	64	NL	10/30/85 10/30/85	1 1	0.10 0.10
CBI	IO	N-XXX-85-0049-IO	1985	BISTABLE FAILED TO ACTUATE	NFS	1.00	1.00	64	NL	7/11/85 7/11/85	1 1	1.00 1.00
CBI	IS	L-XXX-86-0577-IS	1986	(OTDT) TRIP SETPOINT HAD BEEN INCORRECTLY SET	UKN	1.00	1.00	64	NL	8/15/86	3	0.10
CBI	IS	N-XXX-86-0163-IS	1986	REACTOR TRIP BISTABLES FOUND OUT OF	UKN	1.00	0.50	64	NL	10/01/86 9/17/86 9/9/86	1 1 1	0.10 0.10 0.10
CBI	IS	N-XXX-86-1343-IS	1986	BISTABLE RELAY DRIVER CARD FOR THE ' P6 PERMISSIVE ' OOS	NFS	1.00	0.50	64	NL	8/4/86 8/4/86	1 1	0.10 0.10
CBI	IS	N-XXX-86-0050-IS	1986	OVER POWER TRIP DIRTY SWITCH CONTACTS AND POTENTIOMETERS	UKN	0.50	0.50	64	NL	5/15/86 4/29/86	1 1	0.10 0.10
CBI	IS	N-XXX-86-0068-IS	1986	FAILURE OF THE COMPARATORS ATTRIBUTED TO NORMAL SETPOINT DRI	UKN	1.00	0.50	64	NL	1/12/86 1/12/86 1/12/86 1/12/86 1/12/86	1 1 1 1 1	0.10 0.10 0.10 0.10 0.10
CBI	IO	N-XXX-86-0537-IO	1986	COMPARATOR AN ERRATIC OUTPUT	UKN	1.00	1.00	64	NL	6/16/86 6/16/86	1 1	1.00 1.00
CBI	IO	N-XXX-87-0075-IO	1987	BISTABLES FAILED TO OPERATE	NFS	0.50	0.50	64	NL	9/14/87 8/17/87	1 1	1.00 1.00
CBI	IS	L-XXX-87-0665-IS	1987	(OT DELTA T) SETPOINT BASED ON AXIAL FLUX DIFFERENCE SCALED	NFS	1.00	1.00	64	NL	6/25/87	4	0.10
CBI	IS	N-XXX-87-0073-IS	1987	TRIP BISTABLE WAS FOUND TO BE OUT OF TOLERANCE	UKN	1.00	0.50	64	NL	6/19/87 6/19/87	1 1	0.10 0.10
CBI	IO	L-XXX-88-0581-IS	1988	PROCEDURES WOULD ALLOW THE CHANNEL TO BE LEFT IN A NONCONSER	NFS	1.00	1.00	64	NL	1/29/88	4	0.10

Table B-3. (continued).

Component	Fail Mode	CCF Number	Event Year	Event Description	Safety Function	TDF	Coupling Strength	CCCG	Shock Type	Date	No. Failures[a]	Degraded Value
CBI	IO	N-XXX-88-0441-IO	1988	COMPARATOR TRIP CIRCUIT WOULD NOT TRIP	NFS	1.00	1.00	64	NL	7/28/88 7/28/88	1 1	1.00 1.00
CBI	IS	N-XXX-89-0425-IS	1989	LEVEL TRIP AND ROD STOP BISTABLE LIGHTS FOR BOTH CHANNELS WE	NFS	1.00	1.00	64	NL	5/5/89 5/5/89 5/5/89 5/5/89	1 1 1 1	0.10 0.10 0.10 0.10
CBI	IS	N-XXX-89-0283-IS	1989	BISTABLE RELAY DRIVER ASSEMBLY OUT OF	UKN	1.00	0.50	64	NL	3/3/89 3/3/89 3/3/89	1 1 1	0.10 0.10 0.10
CBI	IS	N-XXX-89-0414-IS	1989	OVERPOWER ROD STOP BISTABLES OUT OF TOLERANCE	NFS	1.00	0.50	64	NL	2/11/89 2/11/89	1 1	0.10 0.10
CBI	IO	L-XXX-89-0582-IO	1989	INCONSISTENCIES INTRODUCED A DEGREE OF NFS INTO THE OT DELTA	NFS	1.00	1.00	64	NL	4/10/89	4	1.00
CBI	IO	N-XXX-89-0444-IO	1989	COMPARATOR WOULD NOT TRIP	NFS	1.00	0.50	64	NL	8/29/89 8/13/89 8/9/89	1 1 1	1.00 1.00 1.00
CBI	IO	N-XXX-90-0525-IO	1990	REACTOR TRIP BISTABLE WOULD NOT CALIBRATE PROPERLY	UKN	1.00	0.50	64	NL	12/18/90 12/18/90	1 1	1.00 1.00
CBI	IO	N-XXX-90-0417-IO	1990	BISTABLES FOR POWER AND INTERMEDIATE RANGE INCORRECTLY CALIB	NFS	1.00	1.00	64	NL	6/8/90 6/8/90 6/8/90 6/8/90 6/1/90 6/1/90	1 1 1 1 1 1	1.00 1.00 1.00 1.00 1.00 1.00
CBI	IS	N-XXX-90-0426-IS	1990	TRIP BISTABLES HAD BEEN IMPROPERLY CALIBRATED	NFS	1.00	1.00	64	NL	11/17/90 11/17/90	1 1	0.10 0.10
CBI	IS	N-XXX-90-0077-IS	1990	LEVEL COMPARATOR WAS OUT OF SPECIFICATION LOW	UKN	1.00	0.50	64	NL	7/1/90 6/9/90 6/8/90	1 1 1	0.10 0.10 0.10
CBI	IS	N-XXX-91-0175-IS	1991	BISTABLE SETPOINT WAS DISCOVERED OUT OF SPEC	NFS	1.00	1.00	64	NL	6/6/91 6/6/91	1 1	0.10 0.10
CBI	IS	N-XXX-91-0515-IS	1991	SETPOINT BISTABLE OUT OF TOLERANCE HIGH	NFS	1.00	0.50	64	NL	11/3/91 11/3/91	1 1	0.10 0.10

Table B-3. (continued).

Component	Fail Mode	CCF Number	Event Year	Event Description	Safety Function	TDF	Coupling Strength	CCCG	Shock Type	Date	No. Failures[a]	Degraded Value
CBI	IS	N-XXX-91-0299-IS	1991	POWER RANGE NUCLEAR INSTRUMENTATION RELAY DriVER OOS	NFS	1.00	0.50	64	NL	11/7/91	1	0.10
										11/6/91	1	0.10
										11/6/91	1	0.10
										10/22/91	1	0.10
CBI	IS	N-XXX-91-0530-IS	1991	TRIP OUT OF TOLERANCE	NFS	1.00	0.50	64	NL	11/23/91	1	0.10
										11/23/91	1	0.10
CBI	IS	N-XXX-91-0173-IS	1991	INCREASED FLOW AFFECTED TRIP VALUES IN A NON-CONSERVATIVE DI	NFS	1.00	1.00	64	NL	5/17/91	1	0.10
										5/17/91	1	0.10
										5/17/91	1	0.10
										5/17/91	1	0.10
										5/17/91	1	0.10
										5/17/91	1	0.10
CBI	IS	N-XXX-91-0031-IS	1991	SIGNAL COMPARATOR OUTPUTS FOUND OOS	UKN	1.00	0.50	64	NL	7/16/91	1	0.10
										6/26/91	1	0.10
										6/26/91	1	0.10
										6/26/91	1	0.10
										6/10/91	1	0.10
										6/8/91	1	0.10
										5/28/91	1	0.10
CBI	IS	N-XXX-92-0364-IS	1992	PRESSURE INDICATING SWITCH DRIFTED HIGH OUT OF ALLOWABLE RAN	UKN	1.00	0.50	64	NL	10/28/92	1	0.10
										10/28/92	1	0.10
CBI	IS	N-XXX-92-0228-IS	1992	TRIP BISTABLES OOS	NFS	1.00	0.50	64	NL	7/3/92	1	0.10
										7/2/92	1	0.10
CBI	IO	N-XXX-92-0267-IO	1992	FAULTY CAPACITORS IN THE MODULE POWER SUPPLY	NFS	0.50	1.00	64	NL	2/6/92	1	1.00
										1/9/92	1	1.00
CBI	IS	N-XXX-92-0016-IS	1992	REACTOR TRIP BISTABLE ACTUATED AND RESET HIGH	NFS	1.00	0.50	64	NL	11/29/92	1	0.10
										11/29/92	1	0.10
CBI	IO	N-XXX-94-0470-IO	1994	TRIP AND RESET ERRATIC FOR BOTH OUTPUTS OF THE COMPARATOR	NFS	1.00	1.00	64	NL	6/20/94	1	1.00
										6/16/94	1	1.00
CBI	IS	N-XXX-94-0018-IS	1994	REACTOR TRIP SIGNAL COMPARATORS HIGH AC VOLTAGE ON OUTPUT	UKN	1.00	0.50	64	NL	4/16/94	1	0.10
										4/11/94	1	0.10
										4/6/94	1	0.10
CBI	IO	N-XXX-94-0199-IS	1994	ALL POWER RANGE BISTABLES WERE OUT OF TOLERANCE HIGH	NFS	1.00	1.00	64	NL	9/28/94	4	0.10

Table B-3. (continued).

Component	Fail Mode	CCF Number	Event Year	Event Description	Safety Function	TDF	Coupling Strength	CCCG	Shock Type	Date	No. Failures[a]	Degraded Value
CBI	IO	N-XXX-94-0362-IO	1994	BISTABLE CIRCUIT CARD FAILED TO TRIP REGARDLESS OF INPUT	NFS	1.00	0.50	64	NL	10/17/94	1	1.00
										10/17/94	1	1.00
CBI	IO	N-XXX-95-0363-IO	1995	BISTABLE CIRCUIT BOARD FAILED TO TRIP AT ITS SETPOINT	NFS	1.00	0.50	64	NL	6/13/95	1	1.00
										6/12/95	1	1.00
CCP	IS	N-XXX-84-0044-IS	1984	TRIP CALCULATOR WAS FOUND OUT OF	UKN	1.00	0.50	20	NL	9/7/84	1	0.10
										9/7/84	1	0.10
CCP	IO	N-XXX-92-1131-IO	1992	COMPUTATION MODULE ERRATIC OUTPUT	UKN	1.00	0.50	20	NL	8/19/92	1	1.00
										8/19/92	1	0.50
CCX	IO	N-XXX-85-0178-IO	1985	LEAD LAG DERIVATIVE CARD OUTPUT WAS RANDOMLY SPIKING	UKN	1.00	0.50	28	NL	6/7/85	1	0.50
										6/7/85	1	0.50
										6/7/85	1	0.50
										6/7/85	1	0.50
CCX	IS	N-XXX-87-0191-IS	1987	SUMMING AMPLIFIER WAS FOUND OUT OF CALIBRATION	UKN	1.00	0.50	20	NL	6/1/87	1	0.10
										5/19/87	1	0.10
										5/19/87	1	0.10
										5/19/87	1	0.10
CCX	IS	N-XXX-88-0226-IS	1988	MODULES DISCOVERED OUT OF SPECIFICATION	UKN	1.00	0.50	28	NL	10/15/88	1	0.10
										10/15/88	1	0.10
										10/15/88	1	0.10
										10/15/88	1	0.10
										10/15/88	1	0.10
CCX	IS	N-XXX-90-0524-IS	1990	7300 SERIES SUMMER/ AMPLIFIERS OUT-OF-TOLERANCE	NFS	1.00	0.50	28	NL	5/30/90	1	0.10
										4/28/90	1	0.10
										4/28/90	1	0.10
										4/24/90	1	0.10
										4/24/90	1	0.10
										4/24/90	1	0.10
CCX	IO	N-XXX-92-0197-IO	1992	SUMMING AMPLIFIER CARDS FOR CHANNEL 4 HAD FAILED	NFS	1.00	0.50	4	NL	3/6/92	1	1.00
										3/1/92	1	0.50
										2/28/92	1	0.50
CDT	IS	N-XXX-84-0043-IS	1984	DELTA-T CURRENT SOURCE WAS FOUND OUT OF SPECIFICATION	UKN	1.00	0.50	4	NL	8/30/84	1	0.10
										8/30/84	1	0.10
CDT	IS	N-XXX-84-0045-IS	1984	TRIP CALCULATOR WAS FOUND OUT OF	UKN	1.00	0.50	4	NL	10/6/84	1	0.10
										10/3/84	1	0.10
										10/3/84	1	0.10

Table B-3. (continued).

Component	Fail Mode	CCF Number	Event Year	Event Description	Safety Function	TDF	Coupling Strength	CCCG	Shock Type	Date	No. Failures[a]	Degraded Value
CDT	IS	N-XXX-84-0393-IS	1984	SUMMATORS OUT OF SPEC	UKN	0.50	0.50	4	NL	1/31/84	1	0.10
										1/10/84	1	0.10
CDT	IO	N-XXX-84-0006-IO	1984	HIGH A. C. RIPPLE WAS OBSERVED ON OUTPUT OF SIGNAL MODULES	UKN	1.00	0.50	3	NL	12/19/84	1	1.00
										12/18/84	1	1.00
CDT	IO	N-XXX-85-0224-IO	1985	LEAD LAG UNITS DISCOVERED WITH	UKN	1.00	1.00	4	NL	10/11/85	1	0.50
										10/11/85	1	0.50
										10/11/85	1	0.50
CDT	IS	N-XXX-85-0179-IS	1985	CALCULATOR CARDS OOS	NFS	1.00	0.50	4	NL	7/18/85	1	0.10
										7/18/85	1	0.10
										7/18/85	1	0.10
CDT	IS	N-XXX-85-0233-IS	1985	FLUX TILT CONTROLLERS FOUND OUT OF	UKN	1.00	0.50	4	NL	11/22/85	1	0.10
										11/22/85	1	0.10
CDT	IS	L-XXX-85-0570-IS	1985	JUMPERS NOT INSTALLED IN OT CIRCUITS	NFS	1.00	1.00	3	NL	8/28/85	3	0.50
CDT	IO	N-XXX-85-0452-IO	1985	SUMMATORS EXCESSIVE OUTPUT NOISE AND SPURIOUS LOW OUTPUT	UKN	1.00	1.00	3	NL	8/6/85	1	0.50
										7/30/85	1	0.50
CDT	IS	N-XXX-86-0355-IS	1986	COMPUTATION MODULE WAS OUT OF CALIBRATION	UKN	1.00	0.50	4	NL	11/28/86	1	0.10
										11/28/86	1	0.10
										11/28/86	1	0.10
CDT	IO	N-XXX-86-0461-IO	1986	SUMMATORS HAD AN EXCESSIVE BOW IN OUTPUT	UKN	1.00	1.00	3	NL	1/2/87	1	0.50
										12/31/86	1	0.50
CDT	IO	N-XXX-86-0458-IO	1986	SUMMATORS HAD AN EXCESSIVELY NOISY OUTPUT	UKN	1.00	1.00	3	NL	10/22/86	1	0.50
										10/8/86	1	0.50
										10/8/86	1	0.50
CDT	IS	L-XXX-86-0006-IS	1986	THREE OF THE FOUR F (DELTA I) FUNCTION SIGNALS OOS	NFS	1.00	0.50	4	NL	10/16/86	3	0.10
CDT	IO	N-XXX-86-0435-IO	1986	SUMMATORS WITH EXCESSIVE NOISE ON THE INPUT AND OUTPUT	NFS	1.00	1.00	3	NL	3/5/86	1	0.50
										2/21/86	1	0.50
										2/21/86	1	0.50
CDT	IS	N-XXX-86-0206-IS	1986	TEMPERATURE DIFFERENTIAL MODULES WITH A LOW OUTPUT SPAN	NFS	1.00	0.50	4	NL	4/16/86	1	0.10
										4/16/86	1	0.10
										4/16/86	1	0.10
										4/16/86	1	0.10

Table B-3. (continued).

Component	Fail Mode	CCF Number	Event Year	Event Description	Safety Function	TDF	Coupling Strength	CCCG	Shock Type	Date	No. Failures[a]	Degraded Value
CDT	IS	N-XXX-86-0097-IS	1986	SUMMING AMPLIFIER DELTA TEMPERATURE (T) – T AVERAGE OOS	UKN	1.00	0.50	3	NL	8/21/86 8/15/86	1 1	0.10 0.10
CDT	IS	N-XXX-87-0365-IS	1987	RESISTANCE TO VOLTAGE CONVERTER CARD HAD DRIFTED	UKN	1.00	0.50	4	NL	8/31/87 8/31/87	1 1	0.10 0.10
CDT	IS	N-XXX-87-0462-IS	1987	SUMMATORS HAD AN EXCESSIVE BOW IN OUTPUT AND DRIFT	UKN	1.00	1.00	3	NL	2/26/87 2/24/87	1 1	0.10 0.10
CDT	IO	N-XXX-87-0463-IO	1987	LOW LEVEL AMPLIFIERS ERRATIC OUTPUT	UKN	1.00	1.00	3	NL	8/30/87 8/15/87 8/14/87	1 1 1	0.50 0.50 0.50
CDT	IO	N-XXX-88-0438-IO	1988	SIGNAL ISOLATORS OUT OF ADJUSTMENT AND COULD NOT BE ADJUSTED	UKN	1.00	1.00	3	NL	4/20/88 4/15/88	1 1	0.50 0.50
CDT	IO	N-XXX-88-0464-IO	1988	SUMMATORS HAD AN ERRATIC/NOISY OUTPUT	UKN	1.00	1.00	3	NL	10/13/88 10/4/88 10/4/88	1 1 1	0.50 0.50 0.50
CDT	IS	N-XXX-88-0357-IS	1988	COMPUTATION MODULES OUT OF CALIBRATION	UKN	0.50	0.50	4	NL	7/18/88 7/18/88 6/22/88	1 1 1	0.10 0.10 0.10
CDT	IS	N-XXX-88-0514-IS	1988	LOOP LOW LEVEL AMPLIFIERS OUT OF	NFS	1.00	0.50	4	NL	11/19/88 11/12/88	1 1	0.10 0.10
CDT	IO	N-XXX-88-1423-IO	1988	SUMMATORS HAD AN ERRATIC/NOISY OUTPUT	UKN	1.00	1.00	3	NL	10/26/88 10/12/88 10/4/88	1 1 1	0.50 0.50 0.50
CDT	IS	N-XXX-89-1139-IS	1989	CIRCUIT SIGNAL SUMMATORS FOUND OUT OF	UKN	1.00	1.00	4	NL	6/4/89 5/24/89	1 1	0.10 0.10
CDT	IS	N-XXX-89-0481-IS	1989	DELTA-T LEAD/LAG AMPLIFIER OUT OF TECHNICAL SPECIFICATION	UKN	1.00	0.50	4	NL	2/28/89 2/28/89 2/20/89 2/20/89	1 1 1 1	0.10 0.10 0.10 0.10
CDT	IS	N-XXX-89-0519-IS	1989	SUMMER CARD OUT OF TOLERANCE	UKN	1.00	0.50	4	NL	11/20/89 10/24/89 10/21/89 10/19/89	1 1 1 1	0.10 0.10 0.10 0.10

Table B-3. (continued).

Component	Fail Mode	CCF Number	Event Year	Event Description	Safety Function	TDF	Coupling Strength	CCCG	Shock Type	Date	No. Failures[a]	Degraded Value
CDT	IO	N-XXX-89-0442-IO	1989	SIGNAL SUMMATORS HAD A NOISY OUTPUT	UKN	1.00	1.00	3	NL	5/31/89	1	0.50
										5/30/89	1	0.50
CDT	IS	N-XXX-90-0520-IS	1990	TEMPERATURE SENSING CARD WAS	NFS	1.00	0.50	4	NL	3/16/90	1	0.10
										3/15/90	1	0.10
										3/14/90	1	0.10
										3/13/90	1	0.10
CDT	IO	N-XXX-90-0257-IO	1990	LEAD-LAG CARDS FAILED	NFS	1.00	0.50	3	NL	10/24/90	1	1.00
										10/22/90	1	0.50
CDT	IO	N-XXX-90-0271-IO	1990	LEAD LAG CARD HAD NO OUTPUT	UKN	1.00	0.50	3	NL	10/24/90	1	0.50
										10/21/90	1	1.00
CDT	IS	N-XXX-90-0195-IS	1990	LEAD/LAG AMPLIFIER CARD WAS FOUND OUT OF CALIBRATION	UKN	1.00	0.50	4	NL	9/21/90	1	0.10
										9/19/90	1	0.10
CDT	IS	N-XXX-90-0493-IS	1990	OUTPUT FROM AMPLIFIERS FOR THE RTDS FOUND TO BE LOW	NFS	1.00	1.00	4	NL	10/23/90	1	0.10
										10/23/90	1	0.10
										10/23/90	1	0.10
CDT	IO	N-XXX-90-0264-IO	1990	TEMPERATURE SIGNAL LOW LEVEL AMPLIFIER MODULE FAULTS	UKN	1.00	1.00	3	NL	11/13/90	1	0.50
										11/13/90	1	0.50
CDT	IS	N-XXX-91-0109-IS	1991	SUMMING AMPLIFIER CARD WAS FOUND OUT OF CALIBRATION	UKN	1.00	0.50	3	NL	7/30/91	1	0.10
										7/28/91	1	0.10
CDT	IS	N-XXX-91-0059-IS	1991	LOOP DUAL CURRENT SOURCE FOR TEMPERATURE BRIDGE OOS	UKN	1.00	0.50	4	NL	4/18/91	1	0.10
										3/31/91	1	0.10
										3/31/91	1	0.10
CDT	IS	L-XXX-91-0666-IS	1991	OPDT AND OTDT SETPOINT FORMULA USED WRONG	UKN	1.00	1.00	3	NL	10/7/91	8	0.10
CDT	IO	N-XXX-92-0086-IO	1992	POTENTIOMETER WAS DEFECTIVE ON THE LEAD/LAG DERIVATIVE CAR	UKN	1.00	0.50	3	NL	6/9/92	1	0.50
										6/5/92	1	1.00
CDT	IO	N-XXX-92-1135-IO	1992	LEAD/LAG DERIVATIVE CARD OUTPUT WAS	UKN	1.00	0.50	3	NL	4/25/92	1	1.00
										4/25/92	1	0.10
CDT	IS	N-XXX-92-0087-IS	1992	SUMMING AMPLIFIER CARD WAS OUT OF TOLERANCE	UKN	1.00	0.50	3	NL	10/20/92	1	0.10
										10/20/92	1	0.10
										10/13/92	1	0.10

Table B-3. (continued).

Component	Fail Mode	CCF Number	Event Year	Event Description	Safety Function	TDF	Coupling Strength	CCCG	Shock Type	Date	No. Failures[a]	Degraded Value
CDT	IS	N-XXX-92-0196-IS	1992	SUMMING AMPLIFIER CARD ( ) WAS OUT OF TOLERANCE	NFS	1.00	0.50	4	NL	2/28/92	1	0.10
										2/25/92	1	0.10
CDT	IS	N-XXX-92-0070-IS	1992	SUMMATOR IN THE DELTA TEMPERATURE FOUND WITH AC RIPPLE	UKN	1.00	0.50	4	NL	7/19/92	1	0.10
										7/19/92	1	0.10
CDT	IS	N-XXX-92-0533-IS	1992	RESISTANCE TEMPERATURE DETECTOR AMPLIFIER OOS	UKN	1.00	0.50	4	NL	4/20/92	1	0.10
										4/14/92	1	0.10
CDT	IO	N-XXX-93-0354-IO	1993	ERRATIC OUTPUT FROM THE COMPUTATION MODULE	UKN	1.00	0.50	4	NL	11/20/93	1	0.50
										11/20/93	1	0.50
										10/12/93	1	0.50
										10/1/93	1	0.50
CDT	IS	N-XXX-93-1425-IS	1993	SUMMING AMPLIFIER OOS	NFS	1.00	1.00	4	NL	3/9/93	1	0.10
										3/9/93	1	0.10
										3/8/93	1	0.10
										3/8/93	1	0.10
CDT	IO	N-XXX-93-0321-IO	1993	HIGH FAILED OUTPUT OF SUMMING AMPLIFIER CARD	NFS	1.00	0.50	3	NL	6/25/93	1	1.00
										6/24/93	1	1.00
CDT	IS	N-XXX-93-0360-IS	1993	COMPUTATION MODULE OOS	NFS	1.00	0.50	4	NL	2/23/93	1	0.10
										2/23/93	1	0.10
CDT	IS	N-XXX-93-0221-IS	1993	NIS IMPROPERLY CALIBRATED	NFS	1.00	1.00	4	NL	2/4/93	1	0.10
										2/4/93	1	0.10
										2/4/93	1	0.10
										2/4/93	1	0.10
CDT	IO	N-XXX-94-0361-IO	1994	COMPUTATION MODULE WAS PRODUCING AN ERRATIC OUTPUT	UKN	1.00	0.50	4	NL	1/23/94	1	0.50
										1/22/94	1	0.50
CDT	IO	N-XXX-95-1137-IO	1995	OT/DT PROTECTION LOW LEVEL AMPLIFIER AC RIPPLE OUTPUT	UKN	1.00	0.50	3	NL	5/11/95	1	0.10
										5/8/95	1	0.10
CDT	IS	L-XXX-95-1140-IS	1995	DYNAMIC COMPENSATOR UNITS FOR THE DELTA-T FUNCTION OOS	UKN	1.00	1.00	4	NL	5/25/95	4	0.10
CPR	IS	N-XXX-84-1442-IS	1984	PRESSURIZER PRESSURE TRANSMITTER OUT OF CALIBRATION	UKN	1.00	0.50	3	NL	4/23/84	1	0.10
										4/23/84	1	0.10
CPR	IS	L-XXX-84-0559-IS	1984	TWO TRANSMITTERS WERE FOUND OUT OF SPEC	UKN	1.00	0.50	3	NL	9/28/84	2	0.10

Table B-3. (continued).

Component	Fail Mode	CCF Number	Event Year	Event Description	Safety Function	TDF	Coupling Strength	CCCG	Shock Type	Date	No. Failures[a]	Degraded Value
CPR	IS	N-XXX-84-0239-IS	1984	PRESSURE TRANSMITTERS OUT OF TOLERANCE	UKN	1.00	0.50	3	NL	6/19/84	1	0.10
										6/19/84	1	0.10
										6/4/84	1	0.10
CPR	IS	N-XXX-85-1436-IS	1985	PRESSURIZER PRESSURE TRANSMITTERS FOUND OUT OF CALIBRATION	UKN	1.00	0.50	4	NL	3/2/85	1	0.10
										3/2/85	1	0.10
										3/2/85	1	0.10
										3/2/85	1	0.10
CPR	IS	N-XXX-85-1347-IS	1985	PRESSURIZER PRESSURE CHANNELS FOUND OUT OF SPECIFICATION	UKN	1.00	0.50	3	NL	10/14/85	1	0.10
										10/14/85	1	0.10
CPR	IS	L-XXX-85-0561-IS	1985	PRESSURIZER TRANSMITTERS WERE INCORRECTLY CALIBRATED	UKN	1.00	1.00	3	NL	8/28/85	4	0.10
CPR	IS	N-XXX-86-1428-IS	1986	REACTOR COOLANT PRESSURE TRANSMITTERS OUT OF SPECIFICATIONS	UKN	1.00	0.50	4	NL	3/15/86	1	0.10
										3/15/86	1	0.10
										3/15/86	1	0.10
										3/15/86	1	0.10
CPR	IS	N-XXX-86-0161-IS	1986	PRESSURE TRANSMITTERS FOUND OUT OF	UKN	1.00	0.50	4	NL	3/27/86	1	0.10
										3/27/86	1	0.10
										3/27/86	1	0.10
										3/27/86	1	0.10
CPR	IS	N-XXX-86-0398-IS	1986	PRESSURE INSTRUMENT LOOP POWER SUPPLY MODULES DEFECTIVE	UKN	1.00	0.50	3	NL	8/11/86	1	0.10
										8/9/86	1	0.10
										8/9/86	1	0.10
CPR	IS	N-XXX-86-1454-IS	1986	PRESSURIZER PRESSURE TRANSMITTERS FOUND OUT OF CALIBRATION	UKN	1.00	0.50	3	NL	7/10/86	1	0.10
										7/8/86	1	0.10
										7/8/86	1	0.10
CPR	IO	N-XXX-86-1345-IO	1986	PRESSURIZER PRESSURE TRANSMITTERS WITH A LARGE ZERO SHIFT	NFS	1.00	0.50	3	NL	10/30/86	1	1.00
										10/21/86	1	1.00
CPR	IS	N-XXX-86-1443-IS	1986	PRESSURIZER PRESSURE TRANSMITTERS FOUND OUT OF TOLERANCE	NFS	1.00	0.50	3	NL	2/27/86	1	0.10
										2/22/86	1	0.10
										2/21/86	1	0.10
CPR	IS	L-XXX-87-0574-IS	1987	PZR PRESSURE DRIFTED OUT OF CALIBRATION	NFS	1.00	0.50	3	NL	9/14/87	3	0.10
CPR	IS	N-XXX-87-0423-IS	1987	PRESSURE TRANSMITTERS FOUND OUT OF TOLERANCE	UKN	1.00	0.50	3	NL	12/9/87	1	0.10
										12/9/87	1	01.0

Table B-3. (continued).

Component	Fail Mode	CCF Number	Event Year	Event Description	Safety Function	TDF	Coupling Strength	CCCG	Shock Type	Date	No. Failures[a]	Degraded Value
CPR	IS	N-XXX-88-1460-IS	1988	PRESSURE TRANSMITTERS FOUND OUT OF CALIBRATION	UKN	1.00	0.50	3	NL	7/5/88 7/2/88 7/2/88	1 1 1	0.10 0.10 0.10
CPR	IO	N-XXX-88-0084-IO	1988	PRESSURIZER PRESSURE PROTECTION LOOP LEAD/LAG CARD WAS OSC	UKN	1.00	1.00	3	NL	4/8/88 4/7/88	1 1	1.00 1.00
CPR	IS	N-XXX-88-0276-IS	1988	PRESSURIZER PRESSURE CHANNEL OUT OF	UKN	1.00	0.50	3	NL	10/29/88 10/29/88 10/29/88	1 1 1	0.10 0.10 0.10
CPR	IO	N-XXX-88-0327-IO	1988	BOURDON TUBE FAILURE RESULTING FROM POOR MANUFACTURING PROCE	UKN	0.10	1.00	3	NL	9/13/88 9/7/88 9/2/88	1 1 1	1.00 1.00 1.00
CPR	IS	N-XXX-89-1446-IS	1989	PRESSURIZER PRESSURE TRANSMITTERS FOUND OUT OF OPERATIONAL T	UKN	1.00	0.50	4	NL	2/13/89 2/9/89 2/3/89 2/2/89	1 1 1 1	0.10 0.10 0.10 0.10
CPR	IS	N-XXX-90-1462-IS	1990	PRESSURIZER PRESSURE TRANSMITTERS OUT OF TOLERANCE	UKN	1.00	0.50	3	NL	1/4/90 1/4/90 1/4/90	1 1 1	0.10 0.10 0.10
CPR	IS	N-XXX-91-1465-IS	1991	PRESSURIZER PRESSURE TRANSMITTER 00S	NFS	1.00	0.50	3	NL	10/29/91 10/27/91	1 1	0.10 01.0
CPR	IS	N-XXX-91-1427-IS	1991	PRESSURIZER PRESSURE TRANSMITTER OUT OF CALIBRATION	NFS	1.00	0.50	3	NL	10/26/91 10/25/91	1 1	0.10 0.10
CPR	IS	N-XXX-91-0294-IS	1991	PRESSURE TRANSMITTER OUTPUT WAS ABOVE ALLOWABLE TECHNINCAL SP	UKN	0.50	0.50	3	NL	4/3/91 3/24/91 3/2/91	1 1 1	0.10 0.10 0.10
CPR	IO	N-XXX-91-1461-IO	1991	PRESSURE TRANSMITTER FAILED HIGH	NFS	1.00	1.00	3	NL	5/28/91 5/28/91	1 1	1.00 1.00
CPR	IS	N-XXX-92-0531-IS	1992	PRESSURE TRANSMITTER WAS OUT OF CALIBRATION	NFS	1.00	0.50	3	NL	1/11/92 1/11/92	1 1	0.10 0.10
CPR	IS	N-XXX-92-1429-IS	1992	PRESSURIZER PRESSURE TRANSMITTER OUT OF TOLERANCE	UKN	1.00	0.50	3	NL	4/16/92 4/16/92	1 1	0.10 0.10
CPR	IS	N-XXX-93-0176-IS	1993	ALL THREE PRESSURIZER PRESSURE TRANSMITTERS WERE OUT OF SPEC	NFS	1.00	0.50	3	NL	3/8/93 3/8/93 3/8/93	1 1 1	0.10 0.10 0.10

Table B-3. (continued).

Component	Fail Mode	CCF Number	Event Year	Event Description	Safety Function	TDF	Coupling Strength	CCCG	Shock Type	Date	No. Failures[a]	Degraded Value
CPR	IS	N-XXX-93-0517-IS	1993	PRESSURE TRANSMITTERS OUT OF TOLERANCE LOW	NFS	1.00	0.50	3	NL	11/11/93	1	0.10
										11/11/93	1	0.10
CPR	IO	L-XXX-95-1359-IS	1995	THREE PRESSURIZER PRESSURE PROTECTION TRANSMITTERS OOS	NFS	1.00	1.00	3	NL	2/24/95	3	0.10
CTP	IS	N-XXX-84-0250-IS	1984	RESISTANCE TEMPERATURE DETECTOR (RTD) AMPLIFIER OOS	UKN	1.00	0.50	6	NL	11/8/84	1	0.10
										11/6/84	1	0.10
										11/6/84	1	0.10
CTP	IS	N-XXX-84-0040-IS	1984	T-AVG RTD DID NOT MEET AQCEPTANCE CRITERIA	NFS	1.00	0.50	8	NL	8/1/84	1	0.10
										8/1/84	1	0.10
										8/1/84	1	0.10
										8/1/84	1	0.10
										8/1/84	1	0.10
										8/1/84	1	0.10
										8/1/84	1	0.10
CTP	IS	N-XXX-84-0487-IS	1984	TEMPERATURE INSTRUMENT OOS	UKN	1.00	0.50	8	NL	2/28/84	1	0.10
										2/28/84	1	0.10
										2/28/84	1	0.10
										2/28/84	1	0.10
CTP	IO	N-XXX-85-0453-IO	1985	(RTD) FAILED	NFS	1.00	0.50	6	NL	10/15/85	1	1.00
										10/15/85	1	1.00
CTP	IS	N-XXX-85-0346-IS	1985	RESISTANCE TEMPERATURE DETECTOR (RTD)S FOUND TO BE OOS	UKN	1.00	0.50	8	NL	12/27/85	1	0.10
										12/27/85	1	0.10
										12/27/85	1	0.10
										12/27/85	1	0.10
										12/27/85	1	0.10
										12/27/85	1	0.10
CTP	IS	N-XXX-86-0243-IS	1986	RTD OUTPUT WAS OUT OF TOLERANCE DUE TO DRIFT	UKN	1.00	0.50	6	NL	1/6/86	1	0.10
										1/6/86	1	0.10
CTP	IO	N-XXX-86-0116-IO	1986	RESISTANCE TEMPERATURE DETECTOR COULD NOT BE CALIBRATED	NFS	1.00	1.00	8	NL	3/3/86	1	1.00
										3/3/86	1	1.00
										3/1/86	1	1.00
CTP	IS	N-XXX-86-0322-IS	1986	LOOP TEMPERATURE TRANSMITTERS FOUND OUT OF SPECIFICATION	UKN	1.00	0.50	8	NL	3/16/86	1	0.10
										3/16/86	1	0.10
CTP	IO	N-XXX-87-0437-IO	1987	RESISTANCE TEMPERATURE DETECTOR (RTD) WAS READING OPEN INS	NFS	1.00	0.50	6	NL	5/21/87	1	1.00
										5/19/87	1	1.00

Table B-3. (continued).

Component	Fail Mode	CCF Number	Event Year	Event Description	Safety Function	TDF	Coupling Strength	CCCG	Shock Type	Date	No. Failures[a]	Degraded Value
CTP	IS	N-XXX-88-0169-IS	1988	SETPOINT DRIFT OF RESISTANCE TO VOLTAGE CONVERTER	UKN	1.00	0.50	8	NL	5/4/88 5/4/88 5/4/88	1 1 1	0.10 0.10 0.10
CTP	IO	N-XXX-89-0218-IO	1989	RTDS READING LOW	NFS	1.00	1.00	8	NL	7/28/89 7/28/89	1 1	1.00 1.00
CTP	IO	L-XXX-89-0664-IO	1989	RTD THERMOWELLS FOUND WITH FATIGUE CRACKS	NFS	1.00	1.00	6	NL	2/11/89	3	1.00
CTP	IS	N-XXX-90-0292-IS	1990	TEMPERATURE TRANSMITTER OUT OF SPECIFICATION	UKN	1.00	1.00	8	NL	9/14/90 9/14/90 9/14/90 9/14/90 9/14/90 9/14/90	1 1 1 1 1 1	0.10 0.10 0.10 0.10 0.10 0.10
CTP	IO	N-XXX-91-0303-IO	1991	RESISTANCE TEMPERATURE DEVICE SPLICE RESISTANCE HIGH	UKN	1.00	1.00	8	NL	9/12/91 9/11/91 9/11/91	1 1 1	1.00 1.00 1.00
CTP	IO	N-XXX-93-0516-IO	1993	RTD WIRES WERE REVERSED DUE TO DESIGN DRAWING ERROR	UKN	1.00	1.00	8	NL	2/13/93 2/13/93	1 1	1.00 1.00
CTP	IS	N-XXX-95-0112-IS	1995	RESISTANCE TEMPERATURE DETECTOR AMPLIFIER CIRCUIT BOARDS OOS	UKN	1.00	0.50	6	NL	10/30/95 10/30/95 10/30/95	1 1 1	0.10 0.10 0.10
TLC	IO	N-XXX-85-0397-IO	1985	FAULTY UNIVERSAL PRINTED CIRCUIT BOARDS	NFS	1.00	1.00	32	NL	1/25/85 1/25/85 1/25/85	1 1 1	0.50 0.50 0.50
TLC	IO	N-XXX-89-1424-IO	1989	UNIVERSAL LOGIC BOARD FAILED TO OUTPUT A REACTOR TRIP SIGNAL	NFS	1.00	1.00	32	NL	8/31/89 8/28/89	1 1	1.00 1.00
TLC	IO	N-XXX-90-0367-IO	1990	STOP VALVE GENERATOR TRIP LOGIC CARD DID NOT PASS THE LOGIC	NFS	1.00	0.50	32	NL	11/4/90 11/4/90	1 1	1.00 1.00
TLC	IO	N-XXX-90-0194-IO	1990	UNIVERSAL LOGIC CIRCUIT CARD FAILED ITS LOGIC TEST	NFS	1.00	1.00	32	NL	7/31/90 7/31/90	1 1	1.00 1.00
TLC	IO	N-XXX-91-0335-IO	1991	TRIP LOGIC WERE FOUND DEFECTIVE	NFS	1.00	1.00	32	NL	4/8/91	3	1.00
TLC	IO	N-XXX-93-0184-IO	1993	UNIVERSAL LOGIC CARD FAILED ITS LOGIC TEST	NFS	1.00	1.00	32	NL	1/18/93 1/181/93	1 1	1.00 1.00

Table B-3. (continued).

Component	Fail Mode	CCF Number	Event Year	Event Description	Safety Function	TDF	Coupling Strength	CCCG	Shock Type	Date	No. Failures[a]	Degraded Value
TLR	RX	N-XXX-85-0324-RX	1985	REACTOR PROTECTION RELAY FAILED TO ACTUATE AS REQUIRED	NFS	1.00	0.50	130	NL	11/18/85 11/18/85	1 1	1.00 1.00
TLR	RO	L-XXX-85-0005-RO	1985	TRIP SETPOINTS THAT WERE NOT IN ACCORDANCE WITH TECHNICAL SP	NFS	1.00	1.00	156	NL	2/12/85	2	0.10
TLR	RO	N-XXX-87-0167-RO	1987	REACTOR PROTECTION RELAY TO BE SLOW ACTING ON DROP OUT	NFS	1.00	0.50	104	NL	10/27/87 10/27/87	1 1	0.50 0.50
TLR	RO	N-XXX-87-0377-RO	1987	FAILED RELAYS	UKN	1.00	1.00	130	NL	5/25/87 5/25/87	1 1	1.00 1.00
TLR	RO	N-XXX-88-0207-RO	1988	RELAYS WITH SLUGGISH PICKUP	NFS	1.00	1.00	104	NL	3/11/88 3/11/88 3/11/88 3/11/88	1 1 1 1	0.10 0.10 0.10 0.10
TLR	RO	N-XXX-88-0170-RO	1988	TRIP RELAY DID NOT FUNCTION AS DESIGNED	NFS	1.00	1.00	104	NL	6/1/88 6/1/88	1 1	1.00 1.00
TLR	RO	N-XXX-88-1368-RO	1988	MATRIX RELAYS FOUND TO BE STICKY/SLUGGISH	NFS	1.00	1.00	104	NL	3/22/88 3/22/88 3/22/88 3/22/88	1 1 1 1	0.10 1.00 1.00 1.00
TLR	RC	N-XXX-95-0496-RC	1995	RELAY TIMER CONTACTS WERE DIRTY FROM NORMAL WEAR	NFS	1.00	0.50	256	NL	9/18/95 9/18/95	1 1	1.00 1.00
UVL	IO	N-XXX-89-0482-IO	1989	TRAIN UNDERVOLTAGE OUTPUT BOARD OUTPUT FAILED TO DROP ON A	NFS	1.00	1.00	2	L	8/28/89 8/28/89	1 1	1.00 1.00

a. This value represents the number of failures in the event record that is part of the CCF event.

Appendix C

Quantitative Results of Basic Component Operational Data Analysis

Appendix C

QUANTITATIVE RESULTS OF BASIC COMPONENT OPERATIONAL DATA ANALYSIS

This appendix displays relevant RPS component counts and the estimated probability or rate for each failure mode, including distributions that characterize any variation observed between portions of the data. The analysis is based exclusively on data from Westinghouse plants during the period 1984 through 1995.

The quantitative analysis of the RPS failure data was influenced at each stage by the uncertainty in the number of complete failures for which the safety function of the associated component was lost. Table C-1 provides a breakdown of the component data, showing the number of events fully classified as known and complete failures, and the number of uncertain events within various subsets of the data. The table lists the failure modes in sequence across the RPS, beginning with the channel sensor/transmitters, then the channel processing modules and bistables, then the trip logic trains, breakers, and rods.

Within each component grouping, subsets in Table C-1 are based on the assessed method of discovery and the plant status (operations or shutdown) for each event (note that uncertainty in these two attributes of the data was not quantified in the data assessment). In addition, rows in Table C-1 show breakdowns for whether the failures occurred during the first half of the study period (1984–1989) or during the second half (1990–1995).

The choice of the most representative subset of data to use for each component for the fault tree was a major part of the statistical data analysis. Where operations and shutdown data differ significantly, the subset of operations data was selected since the risk assessment describes risk during operations. Similarly, when the newer data differed significantly from the data earlier in the study period, the newer data was used for the analysis. The analysis also considered whether the test data and data from unplanned scrams differ, for the limited number of components that are always demanded in a scram and whose failures would be detected. Rules for subset selection are discussed further in Section 2.1.1.

Table C-1 shows that the observed number of failures for each component potentially lies between two bounds: a lower bound that excludes all the uncertain failures, and an upper bound that includes them. The initial analysis of the RPS failure data, to select the subsets, was based on these two extreme cases. The next four tables provide information on how the subsets were selected using these two sets of data. Figure C-1 is an overview of the selection process and how the results feed into these tables.

As shown in Figure C-1, the analysis first considered the lower bound (LOB) case of no uncertain failures. These data correspond to the first failure count column in Table C-1. Table C-2 provides these counts for several subsets, along with the associated denominators and simple calculated probabilities or rates. It also gives confidence bounds for the estimates. Note that the confidence bounds do not consider any special sources of variation (e.g. year or plant). The maximum likelihood estimates and bounds are provided for simple comparisons. They are not used directly in the risk assessment.

Table C-3 summarizes the results from testing the hypothesis of constant probabilities or, as applicable, constant rates, across groupings for each basic component failure mode in the RPS fault trees having data. The table provides probability values (p-values) for the hypothesis tests, rounded to the

Table C-1. Summary of Westinghouse RPS total failure counts and weighted average total failures (independent and common-cause failures).

Basic Event (Component)	Data Set[a]	Lower Bound: Known Failures Only	Uncertain Failure Counts: Uncertain Loss of Safety Function	Uncertain Failure Counts: Uncertain Completeness	Uncertain Failure Counts: Both Uncertainties	Upper Bound: All Failures Counted	Total Failure Weighted Average[b]
Channel Parameter Monitoring Instruments							
Pressure sensor/transmitter (CPR)	Cyc. & qtr. tests	5	8	2	0	15	8.8
	—(op)	0	3	0	0	3	0.2
	—(s/d)	5	5	2	0	12	9.1
	(1984-1989)	4	6	1	0	11	7.5
	—(1984–1989 op)	0	2	0	0	2	0.3
	—(1984–1989 s/d)	4	4	1	0	9	7.5
	(1990–1995)	1	2	1	0	4	1.9
	—(1990–1995 op)	0	1	0	0	1	0.1
	—(1990–1995 s/d)	1	1	1	0	3	1.9
	Occurrences in time	25	34	17	2	78	45.2
	—(op)	20	32	10	0	62	34.8
	—(s/d)	5	2	7	2	16	10.2
	(1984–1989)	16	11	8	0	35	23.8
	—(1984–1989 op)	16	11	4	0	31	22.0
	—(1984–1989 s/d)	0	0	4	0	4	2.0
	(1990–1995)	9	23	9	2	43	21.1
	—(1990–1995 op)	4	21	6	0	31	11.1
	—(1990–1995 s/d)	5	2	3	2	12	8.3
Temperature sensor/ transmitter (CTP)	Cyc. & qtr. tests	25	14	0	0	39	33.1
	—(op)	6	5	0	0	11	8.2
	—(s/d)	19	9	0	0	28	24.9
	(1984–1989)	17	8	0	0	25	22.2
	—(1984–1989 op)	3	3	0	0	6	4.3
	—(1984–1989 s/d)	14	5	0	0	19	17.6
	(1990-1995)	8	6	0	0	14	10.8
	—(1990–1995 op)	3	2	0	0	5	3.9
	—(1990–1995 s/d)	5	4	0	0	9	7.0
	—Trips (op) (not used)[c]	1	0	0	0	1	1.0
	Occurrences in time	39	35	0	1	75	52.8
	—(op)	31	21	0	1	53	40.0
	—(s/d)	8	14	0	0	22	12.3
	(1984-1989)	18	24	0	1	43	26.6
	—(1984–1989 op)	16	15	0	1	32	22.2

Table C-1. (continued).

Basic Event (Component)	Data Set[a]	Lower Bound: Known Failures Only	Uncertain Failure Counts: Uncertain Loss of Safety Function	Uncertain Failure Counts: Uncertain Completeness	Uncertain Failure Counts: Both Uncertainties	Upper Bound: All Failures Counted	Total Failure Weighted Average[b]
Temperature sensor/transmitter (continued)	—(1984–1989 s/d)	2	9	0	0	11	3.9
	(1990–1995)	21	11	0	0	32	25.7
	—(1990–1995 op)	15	6	0	0	21	17.7
	—(1990–1995 s/d)	6	5	0	0	11	7.9
Eagle 21 processor (C21)	Qtr. Tests	0	0	0	0	0	0.0
	Occurrences in time (all 1990–1995 op)	10	1	0	0	11	10.6
Pressure processing module (CCP)	Qtr. Tests	2	4	2	6	14	5.6
	—(op)	1	2	2	5	10	3.9
	—(s/d)	1	2	0	1	4	2.0
	(1984–1989)	0	2	1	2	5	1.5
	—(1984–1989 op)	0	1	1	2	4	1.4
	—(1984–1989 s/d)	0	1	0	0	1	0.5
	(1990–1995)	2	2	1	4	9	4.1
	—(1990–1995 op)	1	1	1	3	6	2.5
	—(1990–1995 s/d)	1	1	0	1	3	1.6
	Occur. in time (not used)[c]	8	4	4	3	19	12.3
ΔT processing module (CDT)	Qtr. Tests	27	56	16	80	179	89.8
	—(op)	9	38	10	30	87	36.5
	—(s/d)	18	18	6	50	92	50.8
	(1984–1989)	6	37	12	49	104	39.9
	—(1984–1989 op)	2	27	9	13	51	16.9
	—(1984–1989 s/d)	4	10	3	36	53	20.5
	(1990-1995)	21	19	4	31	75	44.6
	—(1990–1995 op)	7	11	1	17	36	15.0
	—(1990–1995 s/d)	14	8	3	14	39	28.4
	Occur. in time (not used)	23	37	7	34	101	47.1

Table C-1. (continued).

Basic Event (Component)	Data Set[a]	Lower Bound: Known Failures Only	Uncertain Failure Counts: Uncertain Loss of Safety Function	Uncertain Completeness	Both Uncertainties	Upper Bound: All Failures Counted	Total Failure Weighted Average[b]
Processing module (CCX)	Qtr. Tests	33	62	20	92	207	99.8
	—(op)	11	41	13	37	102	40.8
	—(s/d)	22	21	7	55	105	56.4
	(1984–1989)	9	40	14	55	118	46.1
	—(1984–1989 op)	3	28	11	17	59	20.1
	—(1984–1989 s/d)	6	12	3	38	59	21.7
	(1990–1995)	24	22	6	37	89	50.3
	—(1990–1995 op)	8	13	2	20	43	17.3
	—(1990–1995 s/d)	16	9	4	17	46	32.4
	Occur. in time (not used)	40	48	19	40	147	76.2
Bistable (CBI)	Qtr. Tests	108	66	8	10	192	164.0
	—(op)	71	37	7	9	124	106.7
	—(s/d)	37	29	1	1	68	57.1
	(1984–1989)	59	46	5	10	120	99.2
	—(1984–1989 op)	43	23	5	9	80	66.4
	—(1984–1989 s/d)	16	23	0	1	40	31.4
	(1990–1995)	49	20	3	0	72	65.3
	—(1990–1995 op)	28	14	2	0	44	40.1
	—(1990–1995 s/d)	21	6	1	0	28	25.5
	—Trips (op) (not used)	1	0	0	0	1	1.0
	Occur. in time (not used)	36	24	2	1	63	41.7
Trains (Trip Logic)							
SSPS universal card (TLC)	Bimon. Tests	26	4	3	1	34	30.5
	—(op)	21	3	3	1	28	24.9
	—(s/d)	5	1	0	0	6	5.6
	(1984–1989)	4	3	3	0	10	6.7
	—(1984–1989 op)	2	2	3	0	7	4.1
	—(1984–1989 s/d)	2	1	0	0	3	2.6
	(1990–1995)	22	1	0	1	24	23.0
	—(1990–1995 op)	19	1	0	1	21	20.0

Table C-1. (continued).

Basic Event (Component)	Data Set[a]	Lower Bound: Known Failures Only	Uncertain Failure Counts: Uncertain Loss of Safety Function	Uncertain Failure Counts: Uncertain Completeness	Uncertain Failure Counts: Both Uncertainties	Upper Bound: All Failures Counted	Total Failure Weighted Average[b]
SSPS universal card (TLC) (continued)	—(1990–1995 s/d)	3	0	0	0	3	3.0
	Occur. in time (not used)	0	1	1	1	3	0.9
Bistable relay; undervoltage driver card relay (TLR)	Bimon. Tests	42	5	2	0	49	44.0
	—(op)	26	1	2	0	29	27.2
	—(s/d)	16	4	0	0	20	16.7
	(1984–1989)	27	2	2	0	31	28.4
	—(1984–1989 op)	20	0	2	0	22	21.0
	—(1984–1989 s/d)	7	2	0	0	9	7.3
	(1990–1995)	15	3	0	0	18	15.7
	—(1990–1995 op)	6	1	0	0	7	6.2
	—(1990–1995 s/d)	9	2	0	0	11	9.5
	—Trips (op) (not used)	1	0	0	0	1	1.0
	Occur. in time (not used)	6	0	0	1	7	6.3
SSPS undervoltage driver card (UVL)	Unplanned reactor trips	2	0	0	0	2	2.0
	—1984–1989	1	0	0	0	1	1.0
	—1990–1995	1	0	0	0	1	1.0
	Bimon. Tests (all s/d)	5	0	0	0	5	5.0
	—(1984–1989 s/d)	4	0	0	0	4	4.0
	—(1990–1995 s/d)	1	0	0	0	1	1.0
	Occur. in time (not used)	1	0	0	0	1	1.0
Reactor Trip Breakers							
Breaker (mechanical/ electrical) (BME)	Bimon. Tests (all s/d)	3	0	0	2	5	3.2
	—(1984–1989 s/d)	3	0	0	1	4	3.3
	—(1990–1995 s/d)	0	0	0	1	1	0.3
	Occur. in time (not used)	0	0	0	0	0	0.0
RTB shunt trip device (BSN)	Bimon. Tests	7	1	0	0	8	7.5
	—(op)	4	0	0	0	4	4.0
	—(s/d)	3	1	0	0	4	3.6
	(1984–1989)	5	1	0	0	6	5.5
	—(1984–1989 op)	3	0	0	0	3	3.0
	—(1984–1989 s/d)	2	1	0	0	3	2.5

Table C-1. (continued).

Basic Event (Component)	Data Set[a]	Lower Bound: Known Failures Only	Uncertain Failure Counts: Uncertain Loss of Safety Function	Uncertain Failure Counts: Uncertain Completeness	Uncertain Failure Counts: Both Uncertainties	Upper Bound: All Failures Counted	Total Failure Weighted Average[b]
RTB shunt trip device (BSN) (continued)	(1990–1995)	2	0	0	0	2	2.0
	—(1990–1995 op)	1	0	0	0	1	1.0
	—(1990–1995 s/d)	1	0	0	0	1	1.0
RTB undervoltage coil (BUV)	Bimon. Tests	6	0	1	0	7	6.5
	—(op)	2	0	0	0	2	2.0
	—(s/d)	4	0	1	0	5	4.5
	(1984–1989)	4	0	1	0	5	4.5
	—(1984–1989 op)	2	0	0	0	2	2.0
	—(1984–1989 s/d)	2	0	1	0	3	2.5
	(1990–1995) (all s/d)	2	0	0	0	2	2.0
Control Rod Drive and Rod							
RCCA/CRDM (RMA)	Cyc. & qtr. tests	0	2	2	0	4	2.0
	—(op)	0	2	0	0	2	1.0
	—(s/d)	0	0	2	0	2	1.0
	(1984–1989)	0	2	2	0	4	2.0
	—(1984–1989 op)	0	2	0	0	2	1.0
	—(1984–1989 s/d)	0	0	2	0	2	1.0
	Occur. in time (not used)	1	0	0	0	1	1.0

a. Testing frequency abbreviations: bimon., bimonthly; qtr., quarterly; cyclic, 18 months. The frequency of testing applies to the demand count estimations. The failure data are classified as being discovered on testing, unplanned demands, or observation (occurrences in time). Plant status abbreviations: op, operating; s/d, shut down.

b. The tabulated values are the means or weighted averages of the data. The uncertain events are analyzed using a simulation that in each iteration either counts or does not count them. In this column, 0.5 is the probability of events with uncertain completeness being counted. The ratio of the number of events with known safety function lost to events with safety function either known to be lost or known to be fail-safe, among complete events, was used for the probability of counting a complete event with uncertain safety function loss. For events with both uncertainties, 0.5 times the ratio of the number of events with known safety function lost to events with safety function either known to be lost or known to be fail-safe, among events with uncertain completeness, was used for the probability of counting an event.

c. Not used in the RPS fault tree unavailability analysis.

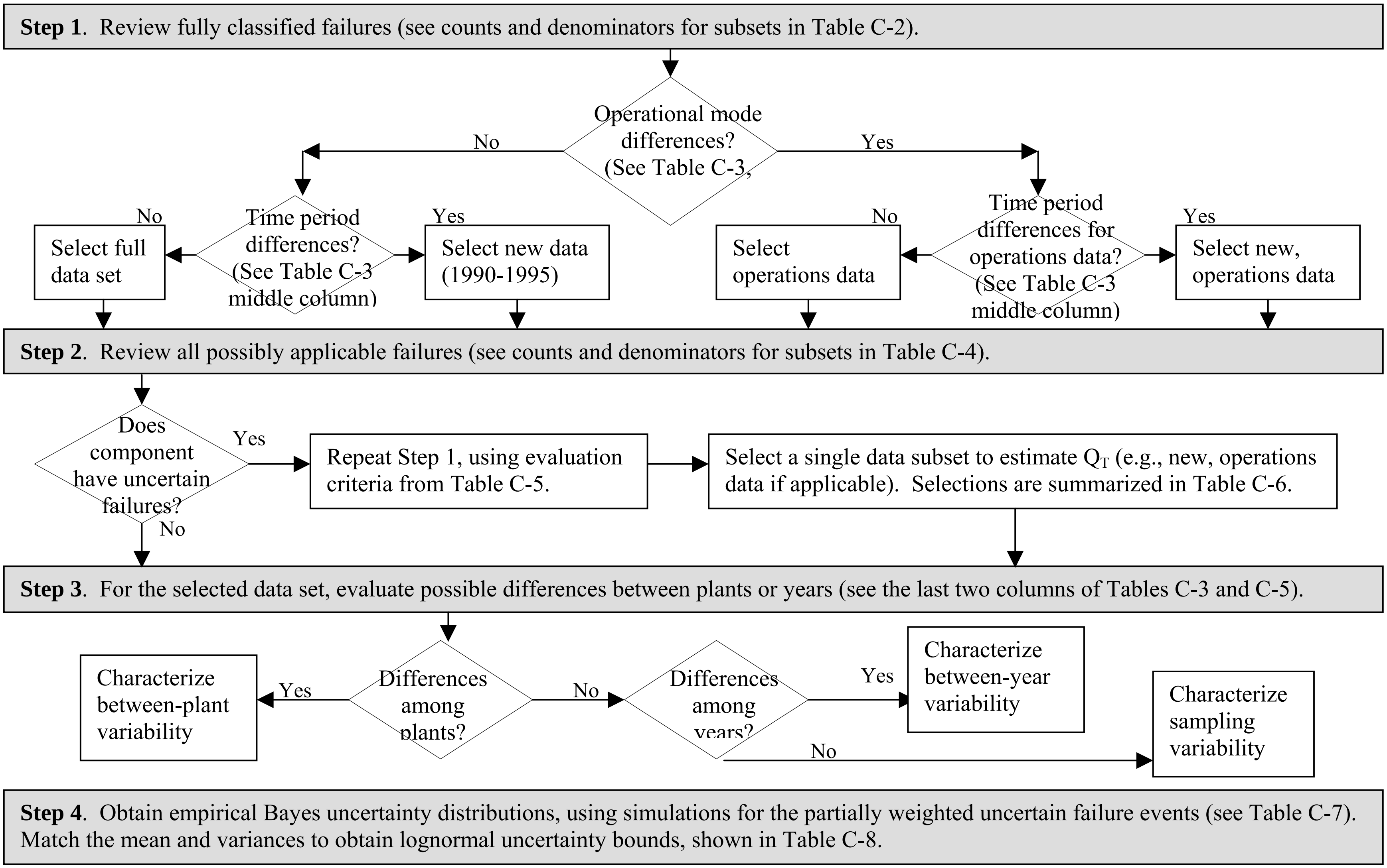


Figure C-1. Decision algorithm for uncertainty distribution selection (applied for each component).

Table C-2. Point estimates and confidence bounds for RPS total failure probabilities and rates (complete failures with safety function lost, only).

Failure Mode (Component)	Data Set	Failures f	Denominator d or T	Probability or Rate[a] and 90% Confidence Interval
Channel Parameter Monitoring Instruments				
Pressure sensor/ transmitter (CPR)	Cyclic tests	5	7700	(2.6E-04, 6.5E-04, 1.4E-03)
	Cyclic tests (op)[b]	**0**	**5832**	**(0.0E+00, 0.0E+00, 5.1E-04)**
	Cyclic tests (s/d)	5	1868	(1.1E-03, 2.7E-03, 5.6E-03)
	Occurrences in time	25	1631.1[c]	(1.1E-02, 1.5E-02, 2.1E-02)
	Occurrences in time, 1984–1989	16	721.4[c]	(1.4E-02, 2.2E-02, 3.3E-02)
	Occur. In time, 1990–1995	**9**	**909.7[c]**	**(5.2E-03, 9.9E-03, 1.7E-02)**
Temperature sensor/ transmitter (CTP)	Cyclic tests	25	19047	(9.1E-04, 1.3E-03, 1.8E-03)
	Cyclic tests (op)	**6**	**14423**	**(1.8E-04, 4.2E-04, 8.2E-04)**
	Cyclic tests (s/d)	19	4624	(2.7E-03, 4.1E-03, 6.0E-03)
	Cyc. Tests, 1984–1989 (s/d)	14	2227	(3.8E-03, 6.3E-03, 9.8E-03)
	Cyc. Tests, 1990–1995 (s/d)	5	2397	(8.2E-04, 2.1E-03, 4.4E-03)
	Occurrences in time	39	4034.2[c]	(7.3E-03, 9.7E-03, 1.3E-02)
Eagle 21 processor (C21)	**Quarterly tests**	**0**	**444**	**(0.0E+00, 0.0E+00, 6.7E-03)**
	Occurrences in time	**10**	**111.0[c]**	**(5.0E-02, 9.0E-02, 1.5E-01)**
	Occurrences in time (op)	10	82.8[c]	(6.7E-02, 1.2E-01, 2.0E-01)
	Occurrences in time (s/d)	0	28.2[c]	(0.0E+00, 0.0E+00, 1.0E-01)
Pressure processing module (CCP)	**Quarterly tests**	**2**	**38115**	**(9.3E-06, 5.2E-05, 1.7E-04)**
ΔT processing module (CDT)	Quarterly tests	27	7628	(2.5E-03, 3.5E-03, 4.9E-03)
	Quarterly tests (op)	9	5722	(8.2E-04, 1.6E-03, 2.7E-03)
	Quarterly tests (s/d)	18	1906	(6.1E-03, 9.4E-03, 1.4E-02)
	Qtr. Tests, 1984–1989 (s/d)	4	974	(1.4E-03, 4.1E-03, 9.4E-03)
	Qtr. Tests, 1990–1995 (s/d)	14	932	(9.1E-03, 1.5E-02, 2.3E-02)
Processing module (CCX)	Quarterly tests	33	53367	(4.5E-04, 6.2E-04, 8.3E-04)
	Quarterly tests (op)	11	40340	(1.5E-04, 2.7E-04, 4.5E-04)
	Quarterly tests (s/d)	22	13027	(1.1E-03, 1.7E-03, 2.4E-03)
	Qtr. Tests, 1984–1989 (s/d)	6	6712	(3.9E-04, 8.9E-04, 1.8E-03)
	Qtr. Tests, 1990–1995 (s/d)	16	6315	(1.6E-03, 2.5E-03, 3.8E-03)
Bistable (CBI)	Quarterly tests	108	129083	(7.1E-04, 8.4E-04, 9.8E-04)
	Quarterly tests (op)	71	97534	(5.9E-04, 7.3E-04, 8.9E-04)
	Qtr. Tests, 1984–1989 (op)	43	41299	(7.9E-04, 1.0E-03, 1.3E-03)
	Qtr. Tests, 1990–1995 (op)	**28**	**56235**	**(3.5E-04, 5.0E-04, 6.8E-04)**
	Quarterly tests (s/d)	37	31549	(8.7E-04, 1.2E-03, 1.5E-03)

Table C-2. (continued).

Failure Mode (Component)	Data Set	Failures *f*	Denominator *d* or *T*	Probability or Rate[a] and 90% Confidence Interval
Trains (Trip Logic)				
SSPS universal card (TLC)	Bi-monthly tests	26	104388	(1.7E-04, 2.5E-04, 3.5E-04)
	Bi-monthly tests, 1984–1989	4	46168	(3.0E-05, 8.7E-05, 2.0E-04)
	Bi-monthly tests, 1990–1995	**22**	**58220**	**(2.6E-04, 3.8E-04, 5.4E-04)**
Bistable relay; undervoltage driver card relay (TLR)	Bi-monthly tests	42	387260	(8.2E-05, 1.1E-04, 1.4E-04)
	Bi-monthly tests (op)	26	292578	(6.2E-05, 8.9E-05, 1.2E-04)
	Bimon. Tests, 1984–1989 (op)	20	123892	(1.1E-04, 1.6E-04, 2.3E-04)
	Bimon. Tests, 1990–1995 (op)	**6**	**168686**	**(1.5E-05, 3.6E-05, 7.0E-05)**
	Bi-monthly tests (s/d)	16	94682	(1.1E-04, 1.7E-04, 2.6E-04)
SSPS undervoltage driver card (UVL)	Unplanned trips	2	2490	(1.4E-04, 8.0E-04, 2.5E-03)
	Bi-monthly tests	5	6524	(3.0E-04, 7.7E-04, 1.6E-03)
	Bi-monthly tests (op)	0	4934	(0.0E+00, 0.0E+00, 6.1E-04)
	Bi-monthly tests (s/d)	5	1590	(1.2E-03, 3.1E-03, 6.6E-03)
	Pooled trips & tests	7	9014	(3.6E-04, 7.8E-04, 1.5E-03)
	Pooled trips & tests (op)	**2**	**7424**	**(4.8E-05, 2.7E-04, 8.5E-04)**
Reactor Trip Breakers				
Breaker (mechanical/ electrical) (BME)	Unplanned trips	0	3690	(0.0E+00, 0.0E+00, 8.1E-04)
	Bi-monthly tests	3	13048	(6.3E-05, 2.3E-04, 5.9E-04)
	Bi-monthly tests (op)	0	9856	(0.0E+00, 0.0E+00, 3.0E-04)
	Bi-monthly tests (s/d)	3	3192	(2.6E-04, 9.4E-04, 2.4E-03)
	Bimon. Tests, 1984-1989 (s/d)	3	1587	(5.2E-04, 1.9E-03, 4.9E-03)
	Bimon. Tests, 1990-1995 (s/d)	0	1605	(0.0E+00, 0.0E+00, 1.9E-03)
	Pooled trips & tests	3	16738	(4.9E-05, 1.8E-04, 4.6E-04)
	Pooled trips & tests (op)	**0**	**13546**	**(0.0E+00, 0.0E+00, 2.2E-04)**
	Pooled trips & tests, 1984–1989	3	8472	(9.7E-05, 3.5E-04, 9.1E-04)
	Pooled trips & tests, 1990–1995	0	8266	(0.0E+00, 0.0E+00, 3.6E-04)
RTB shunt trip device (BSN)	**Bi-monthly tests**	**7**	**13048**	**(2.5E-04, 5.4E-04, 1.0E-03)**
RTB undervoltage coil (BUV)	Bi-monthly tests	6	13048	(2.0E-04, 4.6E-04, 9.1E-04)
	Bi-monthly tests (op)	**2**	**9856**	**(3.6E-05, 2.0E-04, 6.4E-04)**
	Bi-monthly tests (s/d)	4	3192	(4.3E-04, 1.3E-03, 2.9E-03)

Table C-2. (continued).

Failure Mode (Component)	Data Set	Failures *f*	Denominator *d* or *T*	Probability or Rate[a] and 90% Confidence Interval
Control Rod Drive and Rod				
RCCA/CRDM (RMA)	Unplanned trips	0	89885	(0.0E+00, 0.0E+00, 3.3E-05)
	Cyclic tests	0	16346	(0.0E+00, 0.0E+00, 1.8E-04)
	Pooled trips & tests	**0**	**106231**	**(0.0E+00, 0.0E+00, 2.8E-05)**

a. The middle number is the point estimate, *f/d*, or f/T, and the two end numbers form a 90% confidence interval. For demands, the interval is based on a binomial distribution for the occurrence of failures, while it is based on a Poisson distribution for the rates. Rates are identified from the "occurrences in time" data set, and a footnote in the denominator column. Note that these maximum likelihood estimates may be zero, and are not used directly in the risk assessment.

b. Highlighted rows show the data sets selected for the unavailability analysis. In sections where no row is highlighted, see Table C-4.

c. Component years. The associated rates are failures per component year.

Table C-3. Evaluation of differences between groups for RPS failure modes (based only on complete failures with safety function lost).[a]

		P-Values for Test of Variation[c]				
Failure Mode (Component)	Data Set[b]	Rx. Trip vs. Tests	In Plant Modes	In Time Periods	In Plant Units	In Years
Channel Parameter Monitoring Instruments						
Pressure sensor/ transmitter (CPR)	Cyclic tests	—	**0.001** (E)	0.176	0.321 (E)	0.293
	Cyclic tests (op)	—	—	0 F	0 F	0 F
	Cyclic tests (s/d)	—	—	0.374	**0.001** (E)	0.401
	Occurrences in time	—	0.603	**0.047** (E)	**0.000** (E)	**0.007** (E)
	Occur. in time, 1984–1989	—		—	**0.000** (E)	**0.032** (E)
	Occur. in time, 1990–1995	—		—	0.123 (E)	0.278
Temperature sensor/ transmitter (CTP)	Cyclic tests	—	**0.000** (E)	**0.015** (E)	**0.001** (E)	**0.022** (E)
	Cyclic tests (op)	—	—	0.701	0.335 (E)	0.535
	Cyclic tests (s/d)	—	—	**0.036** (E)	**0.001** (E)	**0.027** (E)
	Cyc. tests, 1984–1989 (s/d)	—	—	—	**0.007** (E)	0.097 (E)
	Cyc. tests, 1990–1995 (s/d)	—	—	—	**0.048** (E)	0.437
	Occurrences in time	—	0.567	0.775	**0.001** (E)	**0.008** (E)
Eagle 21 processor (C21)	Quarterly tests	—	0 F	0 F	0 F	0 F
	Occurrences in time	—	0.065 (E)	-NA—	**0.033** (E)	**0.000** (E)
	Occurrences in time (op)	—	—	-NA—	**0.016** (E)	**0.000** (E)
	Occurrences in time (s/d)	—	—	0 F	0 F	0 F
Pressure processing module (CCP)	Quarterly tests	—	0.428	0.503	0.158	0.604

Table C-3. (continued).

Failure Mode (Component)	Data Set[b]	P-Values for Test of Variation[c]				
		Rx. Trip vs. Tests	In Plant Modes	In Time Periods	In Plant Units	In Years
ΔT processing module (CDT)	Quarterly tests	—	**0.000** (E)	**0.012** (E)	0.228 (E)	**0.037** (E)
	Quarterly tests (op)	—	—	0.200	0.667	0.393
	Quarterly tests (s/d)	—	—	**0.017** (E)	0.120 (E)	0.311 (E)
	Qtr. tests, 1984–1989 (s/d)	—	—	—	0.906	0.873
	Qtr. tests, 1990–1995 (s/d)	—	—	—	0.073 (E)	0.591
Processing module (CCX)	Quarterly tests	—	**0.000** (E)	**0.035** (E)	0.111 (E)	0.101 (E)
	Quarterly tests (op)	—	—	0.365	0.641	0.713
	Quarterly tests (s/d)	—	—	**0.031** (E)	0.346	0.207 (E)
	Qtr. tests, 1984–1989 (s/d)	—	—	—	0.974	0.457
	Qtr. tests, 1990–1995 (s/d)	—	—	—	0.096 (E)	0.473
Bistable (CBI)	Quarterly tests	—	**0.024** (E)	**0.026** (E)	**0.001** (E)	0.435
	Quarterly tests (op)	—	—	**0.002** (E)	**0.001** (E)	0.046 (E)
	Qtr. tests, 1984–1989 (op)	—	—	—	**0.001** (E)	0.505
	Qtr. tests, 1990–1995 (op)	—	—	—	**0.001** (E)	0.309
	Quarterly tests (s/d)	—	—	0.622	**0.001** (E)	0.968
Trains (Trip Logic)						
SSPS universal card (TLC)	Bi-monthly tests	—	0.652	**0.003** (E)	**0.001** (E)	**0.020** (E)
	Bi-monthly tests, 1984–1989	—		—	**0.001** (E)	0.121 (E)
	Bi-monthly tests, 1990–1995	—		—	**0.001** (E)	0.210 (E)
Bistable relay; undervoltage driver card relay (TLR)	Bi-monthly tests	—	**0.048** (E)	**0.012** (E)	**0.001** (E)	**0.001** (E)
	Bi-monthly tests (op)	—	—	**0.000** (E)	**0.001** (E)	**0.001** (E)
	Bimon. tests, 1984–1989 (op)	—	—	—	**0.006** (E)	**0.001** (E)
	Bimon. tests, 1990–1995 (op)	—	—	—	0.554	0.576
	Bi-monthly tests (s/d)	—	—	0.805	**0.001** (E)	**0.026** (E)
SSPS undervoltage driver card (UVL)	Unplanned trips	—	—	0.524	0.457	0.527
	Bi-monthly tests	—	**0.001** (E)	0.177	**0.001** (E)	0.366
	Bi-monthly tests (op)	—	—	0 F	0 F	0 F
	Bi-monthly tests (s/d)	—	—	0.374	**0.001** (E)	0.507
	Pooled trips & tests	1.000	**0.003** (E)	0.454	**0.001** (E)	0.710
	Pooled trips & tests (op)	0.112	—	1.000	0.415	0.545

Table C-3. (continued).

Failure Mode (Component)	Data Set[b]	P-Values for Test of Variation[c]				
		Rx. Trip vs. Tests	In Plant Modes	In Time Periods	In Plant Units	In Years
Reactor Trip Breakers						
Breaker (mechanical/ electrical) (BME)	Unplanned trips	—	0 F	0 F	0 F	0 F
	Bi-monthly tests	—	**0.015** (E)	0.086 (E)	0.823	0.071 (E)
	Bi-monthly tests (op)	—	—	0 F	0 F	0 F
	Bi-monthly tests (s/d)	—	—	0.123 (E)	0.376	0.163 (E)
	Bimon. tests, 1984–1989 (s/d)	—	—	—	0.500	0.289
	Bimon. tests, 1990–1995 (s/d)	—	—	—	0 F	0 F
	Pooled trips & tests	1.000	**0.007** (E)	0.250 (E)	0.806	0.070 (E)
	Pooled trips & tests (op)	0 F	—	0 F	0 F	0 F
	Pooled trips & tests, 1984–1989	0.556		—	0.854	0.162 (E)
	Pooled trips & tests, 1990–1995	0 F	0 F	—	0 F	0 F
RTB shunt trip device (BSN)	Bi-monthly tests	—	0.373	0.253	0.799	0.111 (E)
RTB undervoltage coil (BUV)	Bi-monthly tests	—	**0.035** (E)	0.416	0.293 (E)	0.801
	Bi-monthly tests (op)	—	—	0.180	0.229	0.259
	Bi-monthly tests (s/d)	—	—	1.000	0.940	0.712
Control Rod Drive and Rod						
RCCA/CRDM (RMA)	Unplanned trips	—	0 F	0 F	0 F	0 F
	Cyclic tests	—	0 F	0 F	0 F	0 F
	Pooled trips & tests	0 F	0 F	0 F	0 F	0 F

a. This table describes components in the fault tree whose failure probability or rate was estimated from the RPS data. Unplanned demands are considered for some components as indicated in Table A-2. Additional rows for subsets based on plant status or time period appear if significant differences in these attributes were found in the larger groups of data.

b. —, a subset of the test data for the component based on plant state (operating or shut down) and/or year.

c. —, not applicable; 0 F, no failures (thus, no test); All F, no successes (thus, no test); **0.000**, less than 5E-4; NE, not evaluated. P-values less than or equal to 0.05 are in a bold font. For the evaluation columns other than "Rx. trip vs. tests," an "E" is in parentheses after the p-value if and only if an empirical Bayes distribution was found accounting for variations in groupings. Low p-values and the fitting of empirical Bayes distributions are indications of variability between the groupings considered in the column.

nearest 0.001. When the hypothesis is rejected, the data show evidence of variation. The tests are for possible differences based on method of discovery or data source (unplanned reactor trips or testing), on plant mode (operations or shutdown), on the time period (1984–1989 versus 1990–1995), on different plant units, and on different calendar years. Like Table C-2, Table C-3 applies to the LOB data. The results in every case are subdivided according to the method of discovery, if applicable. In the table, finding empirical Bayes distributions for differences in plant mode resulted in the generation of lines describing the operational and shutdown data separately. Similarly, a finding of an empirical Bayes distribution in the time period data groupings produced additional separate evaluations of the older and more recent data.

In Table C-3, low p-values point to variation and lack of homogeneity in the associated data groupings. For example, in Table C-3 the 0.001 p-value for pressure sensor/transmitter differences in cyclic tests by plant mode shows that, when the operational failures and demands are pooled and compared with the corresponding total failures and demands during shutdowns, the likelihood of the observed difference or a more extreme difference if the groups did have the same failure probability is 0.1 percent. Either a “rare” (probability 0.001) situation occurred, or the two pooled sets of failures and demands have different failure probabilities. Throughout these tables, p-values that are less than or equal to 0.05 are highlighted. The tables show many cases where differences in plant unit reporting were observed.

In each of the first three evaluation columns in Table C-3, two entities or data groupings are being compared (reactor trips versus tests, operational versus shutdown, and older versus more recent). In the first column, where applicable, the testing versus reactor trip data were compared. This evaluation is for information only; both sets of data were pooled for the risk assessment.

The second and third evaluations in Table C-3 also reflect the comparison of pairs of attributes. Step 1 in Figure C-1 shows how the plant operating mode and time period evaluations are used in the selection of a subset of data for analysis. The selections were also dictated by the allowed component combinations listed in Table A-2.

Step 2 in the data selection process is to repeat Step 1 using the upper bound (UPB) data from the fifth data column in Table C-1. Table C-4 is similar to Table C-2, and gives denominators, probabilities or rates, and confidence intervals. Table C-5 shows the p-values computed for the tests of differences in groups for the UPB data.

The subset selection results for the LOB and UPB cases agreed for several of the components. In the overall analysis described below, subsets were used if either of the bounding analyses showed a need for them. This point is explained in the last Step 2 box in Figure C-1. In both Tables C-2 and C-4, lines are highlighted corresponding to the subsets selected. Table C-6 provides a concise summary of the data in the selected subsets.

Within each selected subset, the next evaluation focused on the two remaining attributes for study of data variation, namely differences between plants and between calendar years. Tables C-3 and C-5 include results from these evaluations in the last two columns. These evaluations are used in Step 3 in Figure 1. In nearly every instance where a significant p-value appears in these columns, empirical Bayes distributions reflect the associated variability. The single exception to this finding is for control rod/control rod drive data during operating periods in Table C-5. At a Westinghouse plant in 1985, a common-cause event occurred involving two control rod drive failures that were discovered in testing. These failures, the only failures within the selected data subset, were assessed as complete but with unknown loss of the safety function. Since both failures occurred at one plant (having approximately

Table C-4. Point estimates and confidence bounds for RPS total failure probabilities and rates (including all failures with unknown completeness and/or unknown loss of the safety function).

Failure Mode (Component)	Data Set	Failures *f*	Denominator *d* or *T*	Probability or Rate[a] and 90% Confidence Interval
Channel Parameter Monitoring Instruments				
Pressure sensor/ transmitter (CPR)	Cyclic tests	15	7700	(1.2E-03, 1.9E-03, 3.0E-03)
	Cyclic tests (op)[b]	**3**	**5832**	**(1.4E-04, 5.1E-04, 1.3E-03)**
	Cyclic tests (s/d)	12	1868	(3.7E-03, 6.4E-03, 1.0E-02)
	Cyclic tests, 1984–1989	11	3381	(1.8E-03, 3.3E-03, 5.4E-03)
	Cyclic tests, 1990–1995	4	4319	(3.2E-04, 9.3E-04, 2.1E-03)
	Occurrences in time	78	1631.1[c]	(3.9E-02, 4.8E-02, 5.7E-02)
Temperature sensor/ transmitter (CTP)	Cyclic tests	39	19047	(1.5E-03, 2.0E-03, 2.7E-03)
	Cyclic tests (op)	**11**	**14423**	**(4.3E-04, 7.6E-04, 1.3E-03)**
	Cyclic tests (s/d)	28	4624	(4.3E-03, 6.1E-03, 8.3E-03)
	Cyc. tests, 1984–1989 (s/d)	19	2227	(5.6E-03, 8.5E-03, 1.2E-02)
	Cyc. tests, 1990–1995 (s/d)	9	2397	(2.0E-03, 3.8E-03, 6.5E-03)
	Occurrences in time	75	4034.2[c]	(1.5E-02, 1.9E-02, 2.2E-02)
	Occurrences in time, 1984–1989	43	1770.1[c]	(1.9E-02, 2.4E-02, 3.1E-02)
	Occurrences in time, 1990–1995	**32**	**2264.1[c]**	**(1.0E-02, 1.4E-02, 1.9E-02)**
Eagle 21 processor (C21)	Quarterly tests—See Note d	**—**	—	—
	Occurrences in time	**11**	**111.0[c]**	**(5.7E-02, 9.9E-02, 1.6E-01)**
	Occurrences in time (op)	11	82.8[c]	(7.6E-02, 1.3E-01, 2.1E-01)
	Occurrences in time (s/d)	0	28.2[c]	(0.0E+00, 0.0E+00, 1.0E-01)
Pressure processing module (CCP)	**Quarterly tests**	**14**	**38115**	**(2.2E-04, 3.7E-04, 5.7E-04)**
ΔT processing module (CDT)	Quarterly tests	179	7628	(2.1E-02, 2.3E-02, 2.7E-02)
	Quarterly tests (op)	87	5722	(1.3E-02, 1.5E-02, 1.8E-02)
	Qtr. tests, 1984–1989 (op)	51	2565	(1.6E-02, 2.0E-02, 2.5E-02)
	Qtr. tests, 1990–1995 (op)	**36**	**3157**	**(8.5E-03, 1.1E-02, 1.5E-02)**
	Quarterly tests (s/d)	92	1906	(4.0E-02, 4.8E-02, 5.7E-02)
Processing module (CCX)	Quarterly tests	207	53367	(3.4E-03, 3.9E-03, 4.4E-03)
	Quarterly tests (op)	102	40340	(2.1E-03, 2.5E-03, 3.0E-03)
	Qtr. tests, 1984–1989 (op)	59	18068	(2.6E-03, 3.3E-03, 4.1E-03)
	Qtr. tests, 1990–1995 (op)	**43**	**22272**	**(1.5E-03, 1.9E-03, 2.5E-03)**
	Quarterly tests (s/d)	105	13027	(6.8E-03, 8.1E-03, 9.5E-03)
Bistable (CBI)	Quarterly tests	192	129083	(1.3E-03, 1.5E-03, 1.7E-03)
	Quarterly tests (op)	124	97534	(1.1E-03, 1.3E-03, 1.5E-03)
	Qtr. tests, 1984–1989 (op)	80	41299	(1.6E-03, 1.9E-03, 2.3E-03)
	Qtr. tests, 1990–1995 (op)	**44**	**56235**	**(6.0E-04, 7.8E-04, 1.0E-03)**
	Quarterly tests (s/d)	68	31549	(1.7E-03, 2.2E-03, 2.6E-03)

Table C-4. (continued)

Failure Mode (Component)	Data Set	Failures *f*	Denominator *d* or *T*	Probability or Rate[a] and 90% Confidence Interval
Trains (Trip Logic)[d]				
SSPS universal card (TLC)	**Bi-monthly tests**	**34**	**104388**	**(2.4E-04, 3.3E-04, 4.3E-04)**
Bistable relay; undervoltage driver card relay (TLR)	Bi-monthly tests	49	387260	(9.8E-05, 1.3E-04, 1.6E-04)
	Bi-monthly tests (op)	29	292578	(7.1E-05, 9.9E-05, 1.4E-04)
	Bimon. tests, 1984–1989 (op)	22	123892	(1.2E-04, 1.8E-04, 2.5E-04)
	Bimon. tests, 1990–1995 (op)	**7**	**168686**	**(1.9E-05, 4.1E-05, 7.8E-05)**
	Bi-monthly tests (s/d)	20	94682	(1.4E-04, 2.1E-04, 3.1E-04)
SSPS undervoltage driver card (UVL)	Pooled trips & tests (op)—See Note d	—	—	—
Reactor Trip Breakers				
Breaker (mechanical/ electrical) (BME)	Unplanned trips	0	3690	(0.0E+00, 0.0E+00, 8.1E-04)
	Bi-monthly tests	5	13048	(1.5E-04, 3.8E-04, 8.1E-04)
	Bi-monthly tests (op)	0	9856	(0.0E+00, 0.0E+00, 3.0E-04)
	Bi-monthly tests (s/d)	5	3192	(6.2E-04, 1.6E-03, 3.3E-03)
	Pooled trips & tests	5	16738	(1.2E-04, 3.0E-04, 6.3E-04)
	Pooled trips & tests (op)	**0**	**13546**	**(0.0E+00, 0.0E+00, 2.2E-04)**
RTB shunt trip device (BSN)	**Bi-monthly tests**	**8**	**13048**	**(3.1E-04, 6.1E-04, 1.1E-03)**
RTB undervoltage coil (BUV)	Bi-monthly tests	7	13048	(2.5E-04, 5.4E-04, 1.0E-03)
	Bi-monthly tests (op)	**2**	**9856**	**(3.6E-05, 2.0E-04, 6.4E-04)**
	Bi-monthly tests (s/d)	5	3192	(6.2E-04, 1.6E-03, 3.3E-03)
Control Rod Drive and Rod				
RCCA/CRDM (RMA)	Unplanned trips	0	89885	(0.0E+00, 0.0E+00, 3.3E-05)
	Cyclic tests	4	16346	(8.4E-05, 2.4E-04, 5.6E-04)
	Cyclic tests, 1984–1989	4	8132	(1.7E-04, 4.9E-04, 1.1E-03)
	Cyclic tests, 1990–1995	0	8214	(0.0E+00, 0.0E+00, 3.6E-04)
	Pooled trips & tests	4	106231	(1.3E-05, 3.8E-05, 8.6E-05)
	Pooled trips & tests (op)	**2**	**102088**	**(3.5E-06, 2.0E-05, 6.2E-05)**

a. The middle number is the point estimate, *f/d*, or f/T, and the two end numbers form a 90% confidence interval. For demands, the interval is based on a binomial distribution for the occurrence of failures, while it is based on a Poisson distribution for the rates. Rates are identified from the "occurrences in time" data set, and a footnote in the denominator column. Note that these maximum likelihood estimates may be zero, and are not used directly in the risk assessment.

b. Highlighted rows show the data sets selected for the unavailability analysis. No rows are highlighted among the occurrences in time because the unavailability associated with each rate and an 8-hour per year down time is two orders of magnitude lower than the unavailability computed from the test data.

c. Component years. The associated rates are failures per component year.

d. See Table C-2. There were no uncertain failures for these components in the specified data set.

Table C-5. Evaluation of differences between groups for RPS failure modes, including failures with unknown completeness and/or unknown loss of safety function.[a]

Failure Mode (Component)	Data Set[b]	P-Values for Test Variation[c]: Rx. Trip vs. Tests	In Plant Modes	In time Periods	In Plant Units	In Years
Channel Parameter Monitoring Instruments						
Pressure sensor/ transmitter (CPR)	Cyclic tests	—	**0.000** (E)	**0.034** (E)	**0.006** (E)	**0.030** (E)
	Cyclic tests (op)	—	—	0.576	**0.001** (E)	0.470
	Cyclic tests (s/d)	—	—	0.145	**0.001** (E)	**0.030** (E)
	Cyclic tests, 1984–1989	—		—	**0.003** (E)	0.143 (E)
	Cyclic tests, 1990–1995	—		—	0.698	0.427
	Occurrences in time	—	0.416	0.909	**0.000** (E)	**0.004** (E)
Temperature sensor/ transmitter (CTP)	Cyclic tests	—	**0.000** (E)	**0.014** (E)	**0.001** (E)	**0.014** (E)
	Cyclic tests (op)	—	—	0.543	0.273 (E)	0.177
	Cyclic tests (s/d)	—	—	**0.038** (E)	**0.001** (E)	**0.041** (E)
	Cyc. tests, 1984–1989 (s/d)	—	—	—	**0.012** (E)	0.081 (E)
	Cyc. tests, 1990–1995 (s/d)	—	—	—	**0.001** (E)	0.632
	Occurrences in time	—	0.326	**0.019** (E)	**0.001** (E)	**0.001** (E)
	Occurrences in time, 1984–1989	—		—	**0.000** (E)	**0.005** (E)
	Occurrences in time, 1990–1995	—		—	**0.000** (E)	0.365
Eagle 21 processor (C21)	Quarterly tests—See Note d	—	—	—	—	—
	Occurrences in time	—	0.053 (E)	-NA—	0.081 (E)	**0.000** (E)
	Occurrences in time (op)	—	—	-NA—	**0.041** (E)	**0.000** (E)
	Occurrences in time (s/d)	—	—	0 F	0 F	0 F
Pressure processing module (CCP)	Quarterly tests	—	0.756	0.594	**0.002** (E)	0.514
ΔT processing module (CDT)	Quarterly tests	—	**0.000** (E)	**0.002** (E)	**0.001** (E)	**0.001** (E)
	Quarterly tests (op)	—	—	**0.012** (E)	**0.001** (E)	**0.001** (E)
	Qtr. tests, 1984–1989 (op)	—	—	—	**0.001** (E)	**0.001** (E)
	Qtr. tests, 1990–1995 (op)	—	—	—	**0.003** (E)	0.091 (E)
	Quarterly tests (s/d)	—	—	0.240	**0.001** (E)	**0.014** (E)
Processing module (CCX)	Quarterly tests	—	**0.000** (E)	**0.003** (E)	**0.001** (E)	**0.001** (E)
	Quarterly tests (op)	—	—	**0.009** (E)	**0.001** (E)	**0.001** (E)
	Qtr. tests, 1984–1989 (op)	—	—	—	**0.001** (E)	**0.001** (E)
	Qtr. tests, 1990–1995 (op)	—	—	—	**0.007** (E)	0.108 (E)
	Quarterly tests (s/d)	—	—	0.378	**0.001** (E)	**0.032** (E)
Bistable (CBI)	Quarterly tests	—	**0.001** (E)	**0.000** (E)	**0.001** (E)	**0.001** (E)
	Quarterly tests (op)	—	—	**0.000** (E)	**0.001** (E)	**0.001** (E)
	Qtr. tests, 1984–1989 (op)	—	—	—	**0.001** (E)	0.604
	Qtr. tests, 1990–1995 (op)	—	—	—	**0.001** (E)	**0.021** (E)
	Quarterly tests (s/d)	—	—	0.114	**0.001** (E)	0.374

Table C-5. (continued)

Failure Mode (Component)	Data Set[b]	P-Values for Test Variation[c]				
		Rx. Trip vs. Tests	In Plant Modes	In time Periods	In Plant Units	In Years
Trains (Trip Logic)						
SSPS universal card (TLC)	Bi-monthly tests	—	0.429	0.087	**0.001** (E)	**0.021** (E)
Bistable relay; undervoltage driver card relay (TLR)	Bi-monthly tests	—	**0.012** (E)	**0.009** (E)	**0.001** (E)	**0.001** (E)
	Bi-monthly tests (op)	—	—	**0.000** (E)	**0.001** (E)	**0.001** (E)
	Bimon. tests, 1984–1989 (op)	—	—	—	**0.001** (E)	**0.001** (E)
	Bimon. tests, 1990–1995 (op)	—	—	—	**0.008** (E)	0.803
	Bi-monthly tests (s/d)	—	—	0.825	**0.001** (E)	0.096 (E)
SSPS undervoltage driver card (UVL)	Pooled trips & tests (op)—See Note d	—	—	—	—	—
Reactor Trip Breakers						
Breaker (mechanical/ electrical) (BME)	Unplanned trips	—	0 F	0 F	0 F	0 F
	Bi-monthly tests	—	**0.001** (E)	0.177	0.706	0.117 (E)
	Bi-monthly tests (op)	—	—	0 F	0 F	0 F
	Bi-monthly tests (s/d)	—	—	0.216	0.487	0.176 (E)
	Pooled trips & tests	0.593	**0.000** (E)	0.375	0.676	0.094 (E)
	Pooled trips & tests (op)	0 F	—	0 F	0 F	0 F
RTB shunt trip device (BSN)	Bi-monthly tests	—	0.106	0.150	0.846	0.075 (E)
RTB undervoltage coil (BUV)	Bi-monthly tests	—	**0.012** (E)	0.253	0.085 (E)	0.426
	Bi-monthly tests (op)	—	—	0.180	0.229	0.259
	Bi-monthly tests (s/d)	—	—	0.686	**0.026** (E)	0.245
Control Rod Drive and Rod						
RCCA/CRDM (RMA)	Unplanned trips	—	0 F	0 F	0 F	0 F
	Cyclic tests	—	0.268	0.061 (E)	**0.001** (E)	0.058 (E)
	Cyclic tests, 1984–1989	—		—	**0.001** (E)	0.232 (E)
	Cyclic tests, 1990–1995	—	0 F	—	0 F	0 F
	Pooled trips & tests	**0.001**	**0.009** (E)	0.579	**0.001** (E)	0.143 (E)
	Pooled trips & tests (op)	**0.014**	—	1.000	**0.001**	0.081

a. This table describes components in the fault tree whose failure probability or rate was estimated from the RPS data including uncertain failures. Unplanned demands are considered for some components as indicated in Table A-2. Additional rows for subsets based on plant status or time period appear if significant differences in these attributes were found in the larger groups of data.

b. —, a subset of the test data for the component based on plant state (operating or shut down) and/or year.

c. —, not applicable; 0 F, no failures (thus, no test); All F, no successes (thus, no test); **0.000**, less than 5E-4, NE, not evaluated. P-values less than or equal to 0.05 are in a bold font. For the evaluation columns other than "Rx. trip vs. tests," an "E" is in parentheses after the p-value if and only if an empirical Bayes distribution was found accounting for variations in groupings. Low p-values and the fitting of empirical Bayes distributions are indications of variability between the groupings considered in the column.

d. See Table C-3. There were no failures with unknown completeness and/or unknown loss of safety function for these components in the specified data set.

Table C-6. Point estimates of failure probabilities and rates for RPS risk assessment.

Basic Event (Component)	Data Set (Westinghouse Data Only)	No Uncertain Failures	Failure Count with Uncertain Failures Included	Probability Applied to Uncertainty in Whether the Safety Function is Lost[b]: Among Complete Failures	Probability Applied to Uncertainty in Whether the Safety Function is Lost[b]: Among Uncertain Completeness Failures	Weighted Average Total Failures	Denominator (Demands or Hours)	Failures per Demand or Hour	Update of Jeffreys Noninformative Prior[a]
Channel Parameter Monitoring Instruments									
Pressure sensor/ transmitter (CPR)	Cyc. & qtr. tests (op)	0	3	0.063	—	0.2	5832	3.2E-05	1.2E-04
Pressure sensor/ transmitter (CPR)	Occurrences in time, 1990–1995	9	43	0.297	0.731	21.1	7968990	2.6E-06	2.7E-06
Temperature sensor/ transmitter (CTP)	Cyc. & qtr. tests (op)	6	11	0.433	—	8.2	14423	5.7E-04	6.0E-04
Temperature sensor/ transmitter (CTP)	Occurrences in time, 1990–1995	21	32	0.430	—	25.7	19833043	1.3E-06	1.3E-06
Eagle 21 processor (C21)	Qtr. tests	0	0	—	—	0.0	444	0.0E+00	1.1E-03
Eagle 21 processor (C21)	Occurrences in time	10	11	0.618	—	10.6	972577	1.1E-05	1.1E-05
Pressure processing module (CCP)	Qtr. tests	2	14	0.192	0.625	5.6	38115	1.5E-04	1.6E-04
ΔT processing module (CDT)	Qtr. tests, 1990–1995 (op)	7	36	0.395	0.375	15.0	3157	4.8E-03	4.9E-03
Processing module (CCX)	Qtr. Tests, 1990–1995 (op)	8	43	0.315	0.417	17.3	22272	7.7E-04	8.0E-04
Bistable (CBI)	Qtr. Tests, 1990–1995 (op)	28	44	0.792	—	40.1	56235	7.1E-04	7.2E-04

Table C-6. (continued).

Basic Event (Component)	Data Set (Westinghouse Data Only)	No Uncertain Failures	Failure Count with Uncertain Failures Included	Probability Applied to Uncertainty in Whether the Safety Function is Lost[b]: Among Complete Failures	Probability Applied to Uncertainty in Whether the Safety Function is Lost[b]: Among Uncertain Completeness Failures	Weighted Average Total Failures	Denominator (Demands or Hours)	Failures per Demand or Hour	Update of Jeffreys Noninformative Prior[a]
Trains (Trip Logic)									
SSPS universal card (TLC)	Bimon. tests, 1990–1995	22	24	0.726	0.500	23.0	58220	3.9E-04	4.0E-04
Bistable relay; undervoltage driver card relay (TLR)	Bimon. tests, 1990–1995 (op)	6	7	0.224	—	6.2	168686	3.7E-05	4.0E-05
SSPS undervoltage driver card (UVL)	Unplanned scrams & bimon. test (op)	2	2	—	—	2.0	7424	2.7E-04	3.4E-04
Reactor Trip Breakers									
Breaker (mechanical/ electrical) (BME)	Unplanned scrams & bimon. test (op)	0	0	—	—	0.0	13546	0.0E+0 0	3.7E-05
RTB shunt trip device (BSN)	Bimon. tests	7	8	0.469	—	7.5	13048	5.7E-04	6.1E-04
RTB undervoltage coil (BUV)	Bimon. tests (op)	2	2	—	—	2.0	9856	2.0E-04	2.5E-04
Control Rod Drive and Rod									
RCCA/CRDM (RMA)	Unpl. scr. & cyc. tests (op)	0	2	0.500	—	1.0	102088	9.8E-06	1.5E-05

a. (Failures + 0.5)/(Denominator+1) for probabilities; (Failures + 0.5)/Denominator for rates.

b. "—" when there were no applicable uncertain events. The probability applied for uncertainty in completeness is 0.5.

1.2% of the demands), the plant stands out. However, the data were too sparse for the estimation of an empirical Bayes distribution.

In the Table C-5 data just discussed, the rod and control rod drive component shows a higher probability from testing failures than from trips (p-value=0.014). Zero failures were found in nearly 90,000 trip demands, and the two possible failures were identified in an estimated 12,000 operational cyclic tests. The trip data are directly relevant to the study of operational reliability, but confidence in the detection of all failures occurring during trips is not as high as for the periodic testing failures. The tests are also believed to be complete. Pooling the two data sets is conservative.

The upper and lower bound empirical Bayes analyses included tests of goodness of fit for the resulting beta-binomial model for probabilities or the associated gamma-Poisson model for rates. Each grouping level (each plant or each year) was evaluated to see if it was a high outlier compared with the fitted GE model for each component. For the subsets of data used in the unreliability analysis, no outliers were found.

Within each selected subset for which differences exist in the LOB and UPB data, a simulation was conducted to observe the variation in the composite data that includes the fully classified failures and a fraction of the uncertain failures. This evaluation, referenced in Step 4 of Figure 1, also focused on the two attributes for study of data variation that remain after considering the data subsets, namely differences between plants and between calendar years. In the simulation, the probability of being complete failures for events whose completeness was unknown was determined by a fixed distribution with a mean of 0.5. The probability that events with unknown safety function status were losses of the safety function was estimated based on the failure data within each subset, including the events (not shown in Table C-1) that were assessed as fail-safe. The last column of Table C-1 shows the weighted average of the events that would be complete losses of the safety function.

Table C-7 gives the final results of the basic quantitative component data analysis, most of which come from the simulation. Table C-7 describes the Bayes distributions initially selected to describe the statistical variability in the data used to model the basic RPS events. Table C-7 differs from Tables C-2 and C-4 because it gives Bayes distributions and intervals, not confidence intervals. This choice allows the results for the failure modes to be combined to give an uncertainty distribution on the unavailability. When distributions were fit for both plant variation and year variation, the distribution for differences between plants had greater variability and was selected. Where empirical Bayes distributions were not found, the simple Bayes method was used to obtain uncertainty distributions.

In the unreliability analysis, the means and variances of the generic Bayes distributions were fitted to lognormal distributions, listed in Table C-8. As applicable, these distributions describe the total failure probabilities (Q_T) associated with the common-cause fault tree events.

Table C-7. Results of uncertainty analysis.

Failure Mode (Component)	Failures[a]	Denominator[b]	Modeled Variation[c]	Distribution[d]	Bayes Mean and Interval[e]
Channel Parameter Monitoring Instruments					
Pressure sensor/ transmitter (CPR)	0.2	5832	Sampling	Beta(0.5,4735.0)	(7.21E-07,1.16E-04,4.30E-04)
	20.9	909.7[f,g]	Between plant	Gamma(0.9,40.0)	(9.50E-04,2.30E-02,7.09E-02)
Temperature sensor/ transmitter (CTP)	8.1	14423	Between plant	Beta(0.7,1174.1)	(7.86E-06,5.62E-04,1.95E-03)
	25.7	2264.0 [f,g]	Between plant	Gamma(0.3,30.6)	(3.42E-06,1.11E-02,4.87E-02)
Eagle 21 processor (C21)	0	444[h]	Sampling (only)[i]	Beta(0.5,444.5)	(4.43E-06,1.12E-03,4.31E-03)
	10.6	111.0[f]	Between plant	Gamma(0.6,7.8)	(4.85E-04,7.14E-02,2.64E-01)
Pressure processing module (CCP)	5.6	38115	Between plant	Beta(0.4,2343.5)	(9.16E-08,1.57E-04,6.72E-04)
ΔT processing module (CDT)	15.1	3157	Between plant	Beta(2.3,470.8)	(1.01E-03,4.83E-03,1.10E-02)
Processing module (CCX)	17.2	22272	Between plant	Beta(3.1,3907.2)	(2.16E-04,7.81E-04,1.63E-03)
Bistable (CBI)	40.0	56235	Between plant	Beta(0.4,504.7)	(5.10E-07,7.46E-04,3.16E-03)
Trains (Trip Logic)					
SSPS universal card (TLC)	23.0	58220	Between plant	Beta(0.2,412.4)	(1.00E-09,3.83E-04,2.09E-03)
Bistable relay; undervoltage driver card relay (TLR)	6.2	168686	Between plant	Beta(1.8,44492)	(5.85E-06,3.94E-05,9.74E-05)
SPSS undervoltage driver card (UVL)	2	7424	Sampling (only)[i]	Beta(2.5,7422.5)	(7.72E-05,3.37E-04,7.45E-04)
Reactor Trip Breakers					
Breaker (mechanical/ electrical) (BME)	0	13546	Sampling (only)[i]	Beta(0.5,13547)	(1.45E-07,3.69E-05,1.42E-04)
RTB shunt trip device (BSN)	7.5	13048	Between year	Beta(1.4,2481.3)	(6.40E-05,5.81E-04,1.53E-03)
RTB undervoltage coil (BUV)	2	9856	Sampling (only)[i]	Beta(2.5,9854.5)	(5.81E-05,2.54E-04,5.61E-04)
Control Rod Drive and Rod					
RCCA/CRDM (RMA)	1.0	102088	Sampling	Beta(1.0,67504)	(7.13E-07,1.45E-05,4.39E-05)

a. Number of failures, averaged over 1000 simulation iterations, each of which had an integral number of failures.

b. Estimated number of demands or exposure time, based on the selected data sets or subsets shown in Table C-6.

c. In addition to variation from unknown completeness and/or from unknown loss of safety function.

d. Beta distributions for probabilities and gamma distributions for rates. The simple and empirical Bayes distributions are initially either beta or gamma distributions. See Table C-8 for lognormal bounds.

e. Aggregate of Bayes distributions from simulation, unless otherwise noted. Obtained by matching the mean and variance of the simulation output distribution. If the variation is not just sampling, empirical Bayes distributions were found in each simulated iteration, except for the following: CTP probability, 98.6% of the time; CPR rates, 96.3%; CCP, 51.6%; CDT, 47.7%; CCX, 42.7%, and TLR, 21.9% of the time. Sampling variation (from the simple Bayes method) entered the simulation mixture when EB distributions were not found.

f. Component years rather than demands. Also, the rates in the Bayes mean column are per year.

g. Rate not used in fault tree assessment, because the unavailability associated with the failure rate was much lower than the unavailability estimated from the testing data.

h. Probability not used in fault tree assessment, because the data are very sparse and there were no failures detected in testing. The estimate is believed to be too conservative.

i. Simple Bayes distribution not based on the simulations. No uncertain events were in the selected subsets.

Table C-8. Lognormal uncertainty distributions used for total failure probabilities (Q_T).

Failure Mode (Component)	Median	Error Factor[a]	Lognormal Distribution Mean and Interval[b]
Channel Parameter Monitoring Instruments			
Pressure sensor/ transmitter (CPR)	6.9E-05	5.3	(1.3E-05, 1.2E-04, 3.7E-04)
Temperature sensor/ transmitter (CTP)	5.6E-04	1.8	(3.1E-04, 6.0E-04, 1.0E-03)
Eagle 21 processor (C21)[c]	4.9E-06	5.3	(9.2E-07, 8.2E-06, 2.6E-05)
Pressure processing module (CCP)	8.2E-05	6.6	(1.2E-05, 1.6E-04, 5.4E-04)
ΔT processing mod (CDT)	4.0E-03	2.7	(1.5E-03, 4.8E-03, 1.1E-02)
Processing module (CCX)	6.8E-04	2.4	(2.8E-04, 7.8E-04, 1.6E-03)
Bistable (CBI)	3.9E-04	6.5	(6.0E-05, 7.5E-04, 2.5E-03)
Trains (Trip Logic)			
SSPS universal card (TLC)	1.4E-04	10.2	(1.4E-05, 3.8E-04, 1.4E-03)
Bistable relay; undervoltage driver card relay (TLR)	3.1E-05	3.0	(1.0E-05, 3.9E-05, 9.5E-05)
SPSS undervoltage driver card (UVL)	2.8E-04	2.6	(1.1E-04, 3.4E-04, 7.4E-04)
Reactor Trip Breakers			
Breaker (mechanical/ electrical) (BME)	2.1E-05	5.6	(3.8E-06, 3.7E-05, 1.2E-04)
RTB shunt trip device (BSN)	4.5E-04	3.3	(1.4E-04, 5.8E-04, 1.5E-03)
Control Rod Drive and Rod			
RTB undervoltage coil (BUV)	2.1E-04	2.6	(8.3E-05, 2.5E-04, 5.6E-04)
RCCA/CRDM (RMA)	1.0E-05	4.0	(2.6E-06, 1.5E-05, 4.1E-05)

a. Lognormal error factor corresponding to 5% and 95% bounds.

b. Mean and lognormal distribution 5th and 95th percentiles. Obtained by matching the mean and variance of the distributions from Table C-7 that are used in the unreliability analysis.

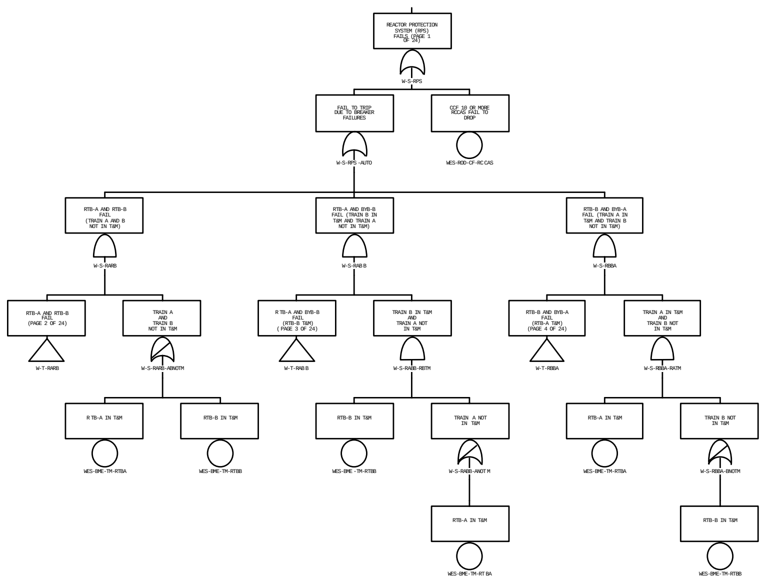
c. Failure rate per hour, rather than probability of failure.

Appendix D

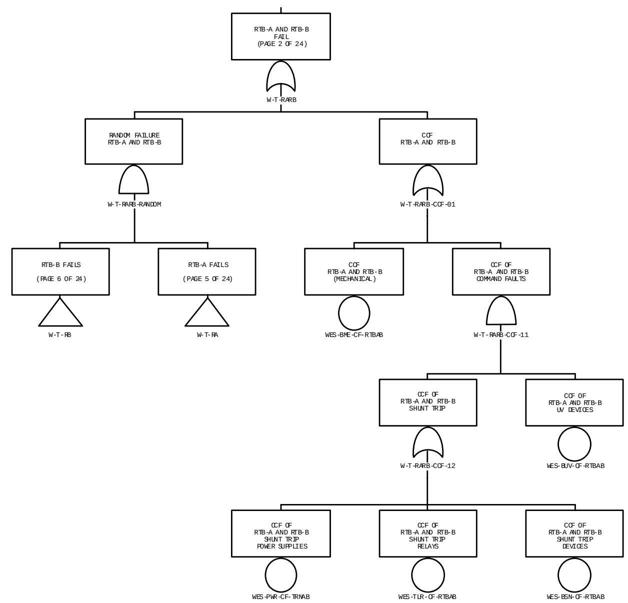
Fault Tree

This appendix contains the Westinghouse reactor protection system fault tree used for both the Analog Series 7300 and Eagle-21 RPS designs. A house event is used to switch between the two designs.

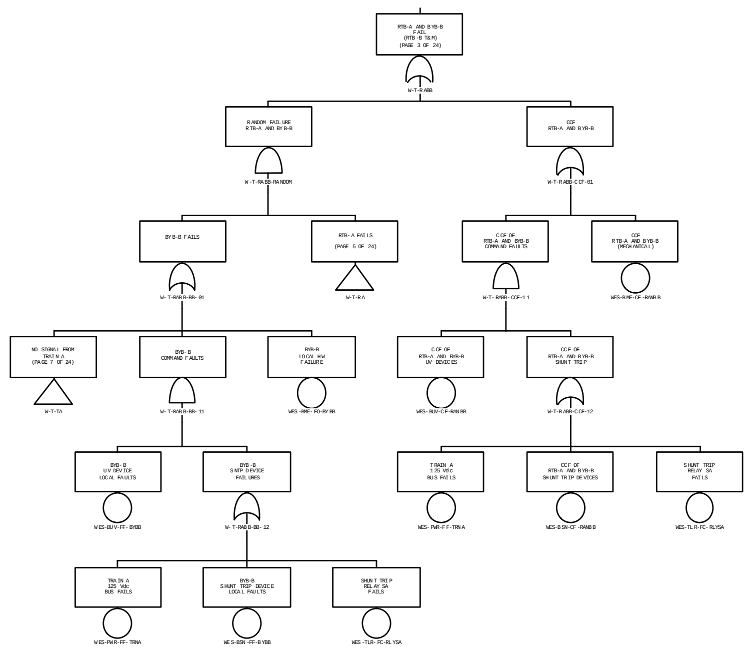
REACTOR PROTECTION SYSTEM (RPS) FAILS
(PAGE 1 OF 24)



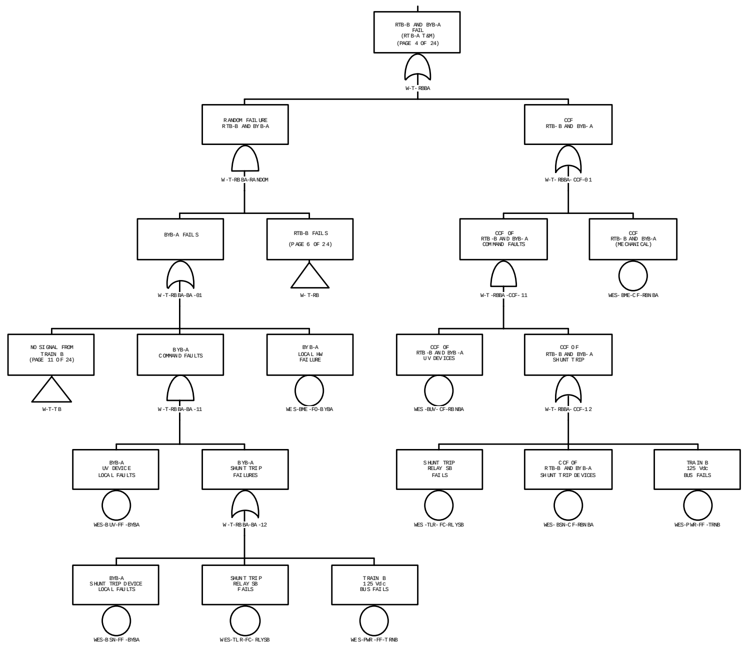
RTB-A AND RTB-B FAIL
(PAGE 2 OF 24)



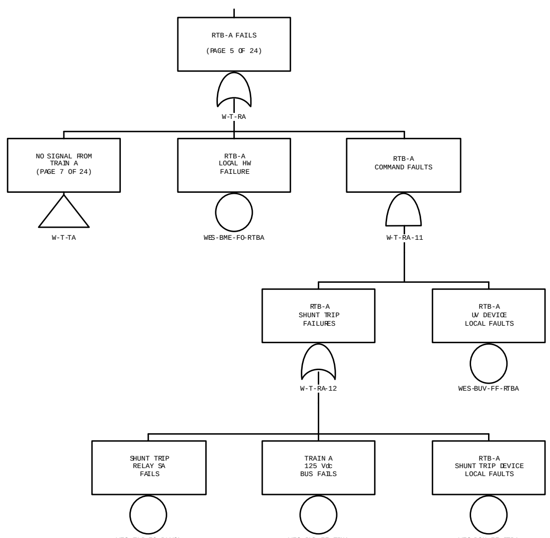
RTB-A AND BYB-B FAIL (RTB-B IN T&M)
(PAGE 3 OF 24)



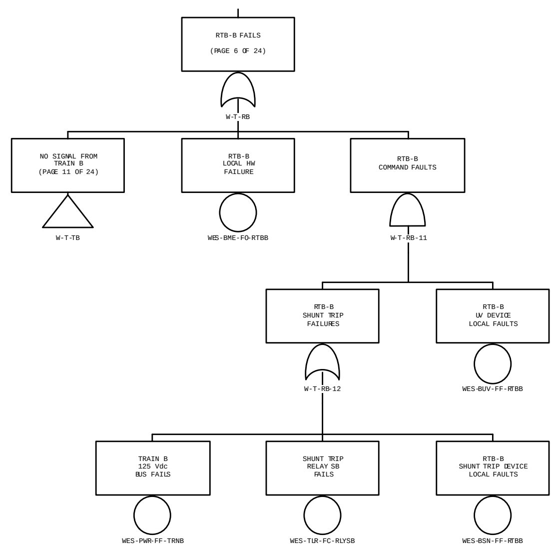
RTB-B AND BYB-A FAIL (RTB-A IN T&M)
(PAGE 4 OF 24)



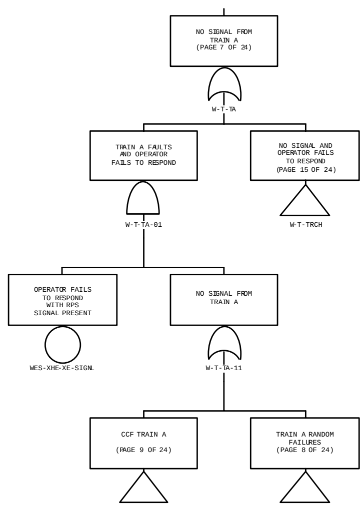
RTB-A FAILS
(PAGE 5 OF 24)



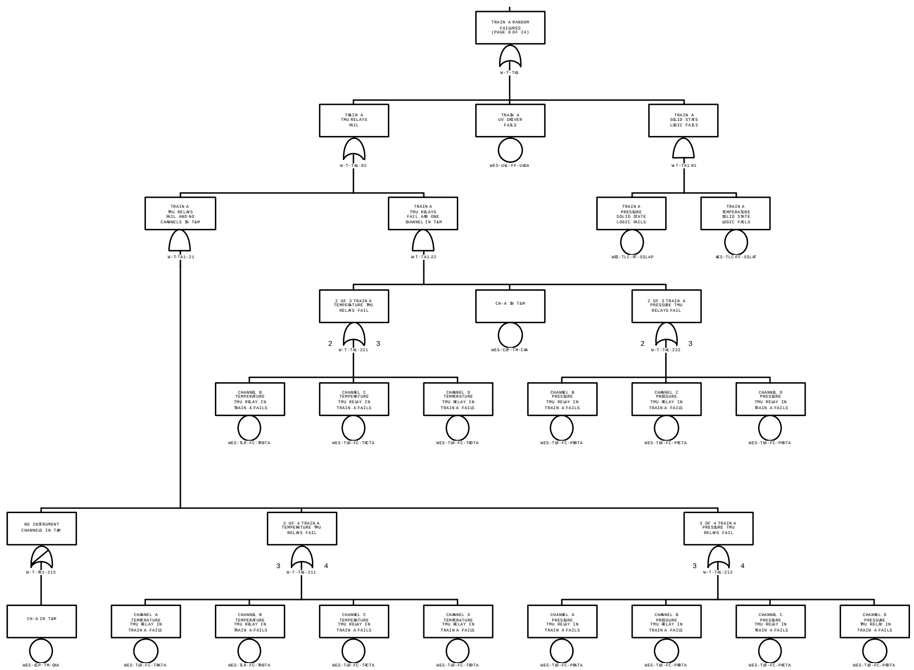
RTB-B FAILS
(PAGE 6 OF 24)



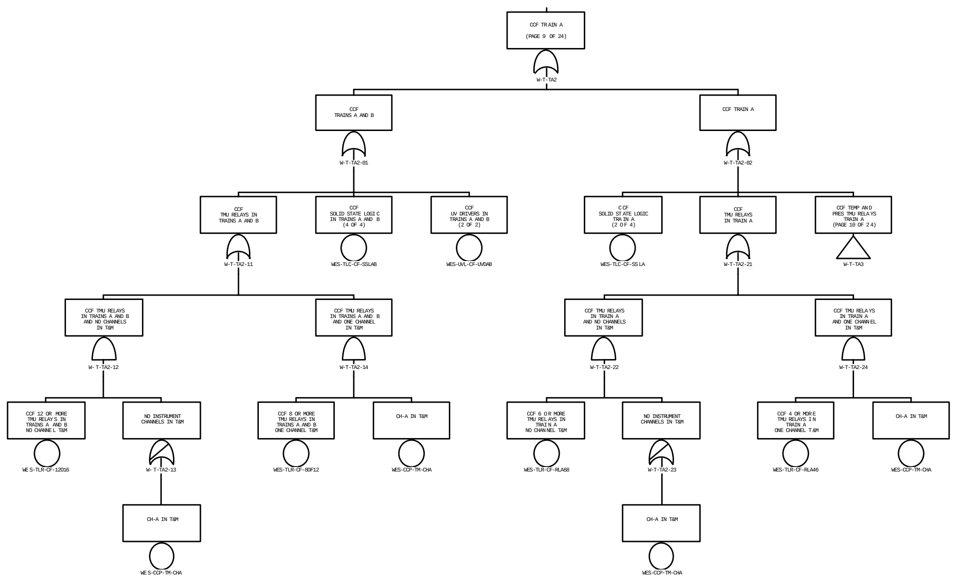
NO SIGNAL FROM TRAIN A
(PAGE 7 OF 24)



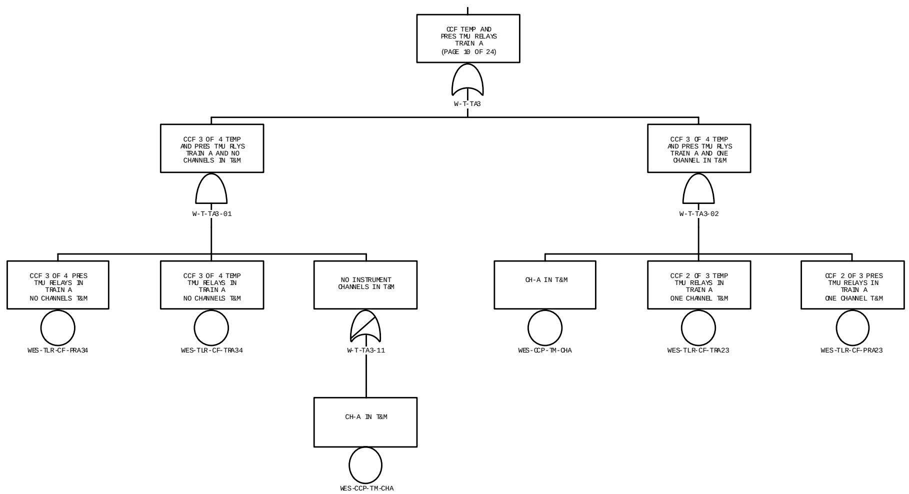
TRAIN A RANDOM FAILURES
(PAGE 8 OF 24)



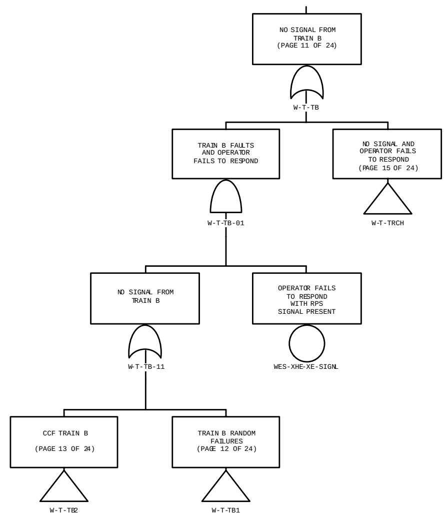
CCF TRAIN A
(PAGE 9 OF 24)



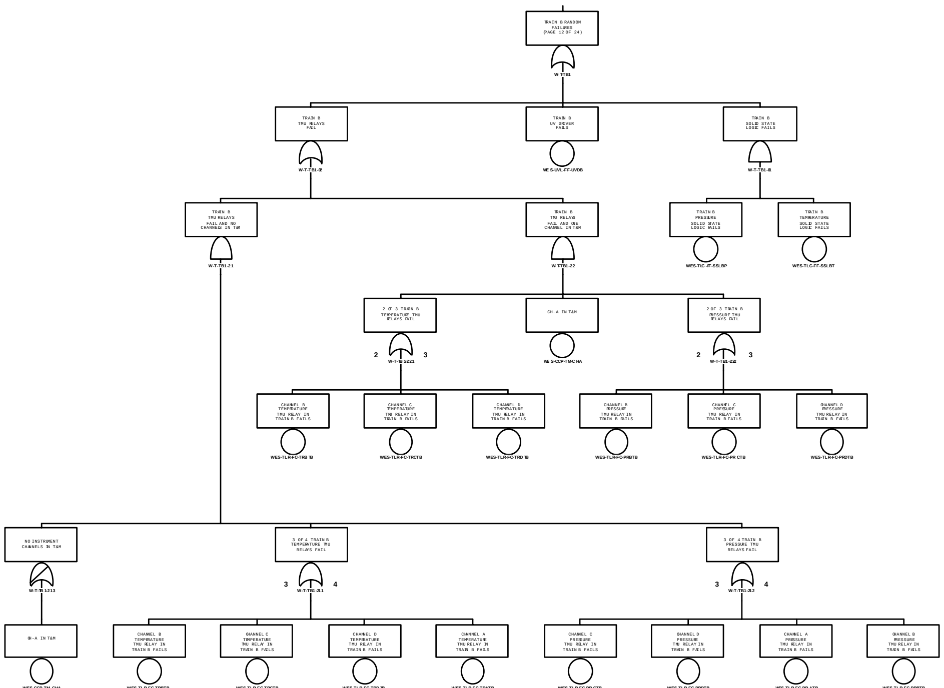
CCF TEMP AND PRES TMU RELAYS TRAIN A
(PAGE 10 OF 24)



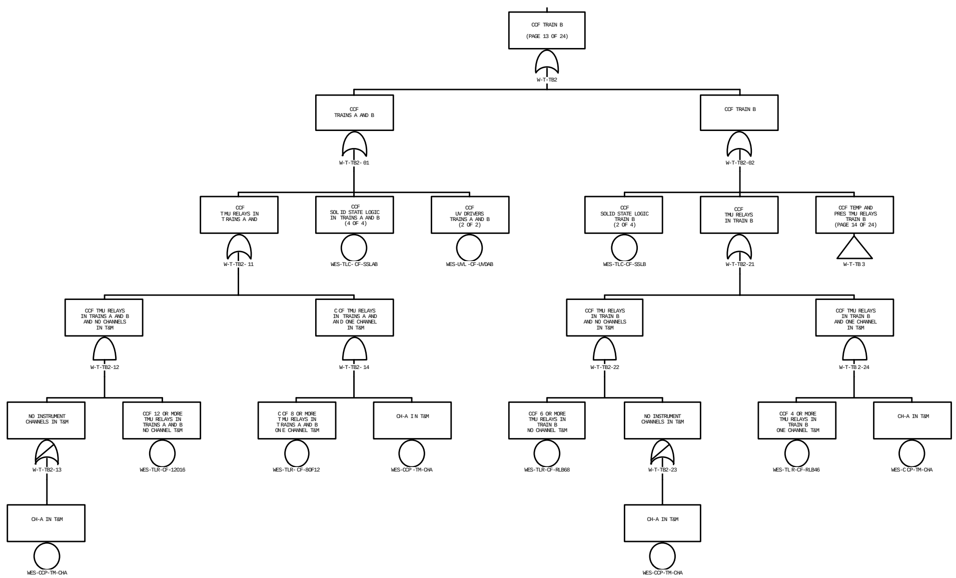
NO SIGNAL FROM TRAIN B
(PAGE 11 OF 24)



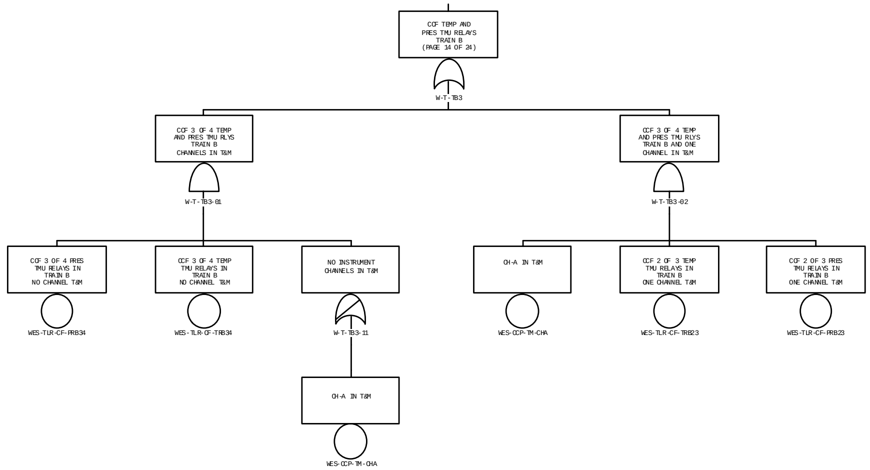
TRAIN B RANDOM FAILURES
(PAGE 12 OF 24)



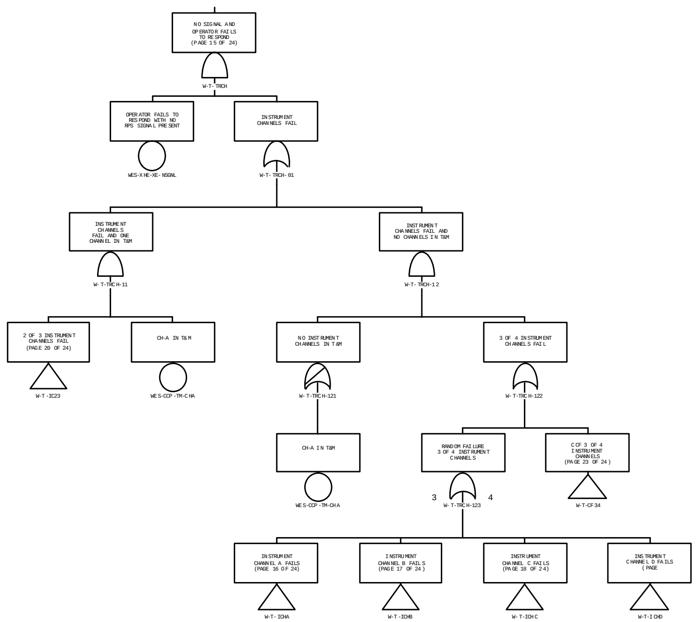
CCF TRAIN B
(PAGE 13 OF 24)

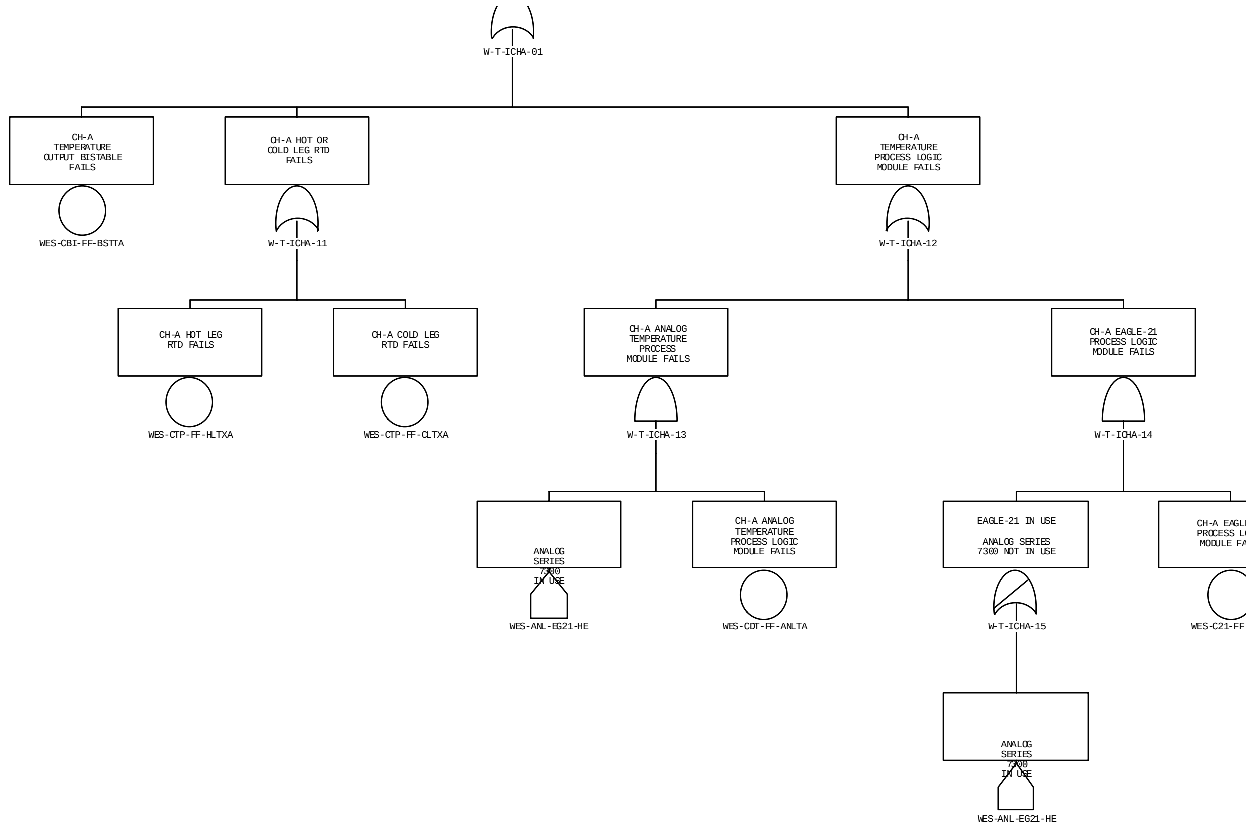


CCF TEMP AND PRES TMU RELAYS TRAIN B
(PAGE 14 OF 24)

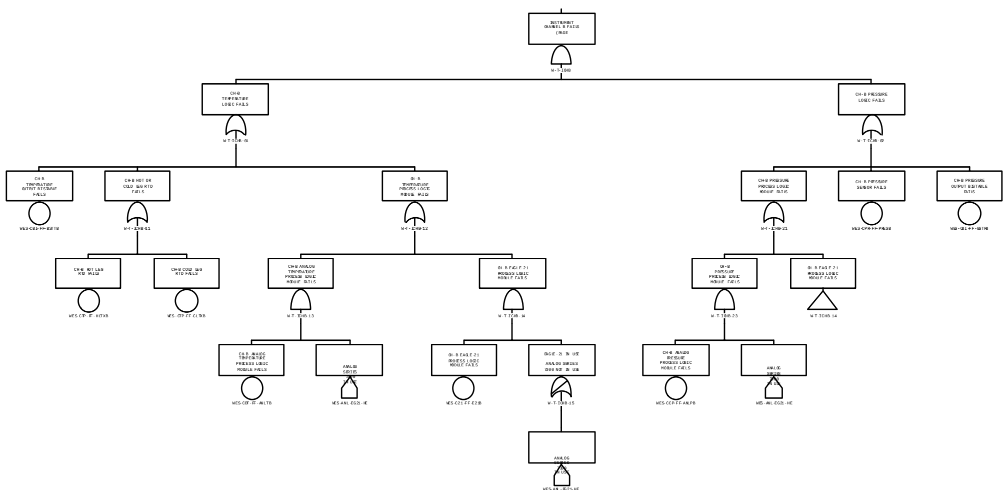


NO SIGNAL AND OPERATOR FAILS TO RESPOND
(PAGE 15 OF 24)

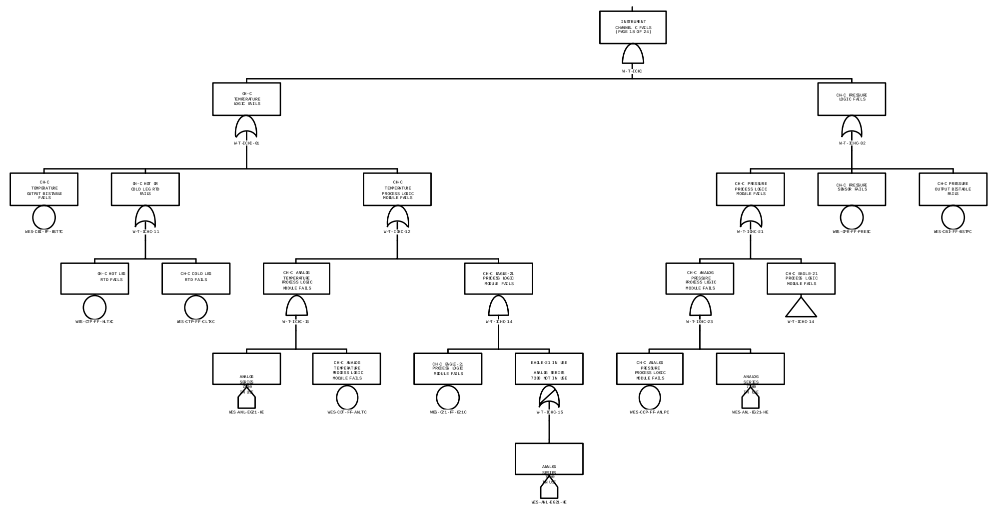



W-T-ICHA-01
CH-A TEMPERATURE OUTPUT BISTABLE FAILS
WES-CBI-FF-BSTTA
CH-A HOT OR COLD LEG RTD FAILS
W-T-ICHA-11
CH-A TEMPERATURE PROCESS LOGIC MODULE FAILS
W-T-ICHA-12
CH-A HOT LEG RTD FAILS
WES-CTP-FF-HLTXA
CH-A COLD LEG RTD FAILS
WES-CTP-FF-CLTXA
CH-A ANALOG TEMPERATURE PROCESS MODULE FAILS
W-T-ICHA-13
CH-A EAGLE-21 PROCESS LOGIC MODULE FAILS
W-T-ICHA-14
ANALOG SERIES 7300 IN USE
WES-ANL-EG21-HE
CH-A ANALOG TEMPERATURE PROCESS LOGIC MODULE FAILS
WES-CDT-FF-ANLTA
EAGLE-21 IN USE
ANALOG SERIES 7300 NOT IN USE
W-T-ICHA-15
CH-A EAGL
PROCESS L
MODULE FA
WES-C21-FF
ANALOG SERIES 7300 IN USE
WES-ANL-EG21-HE

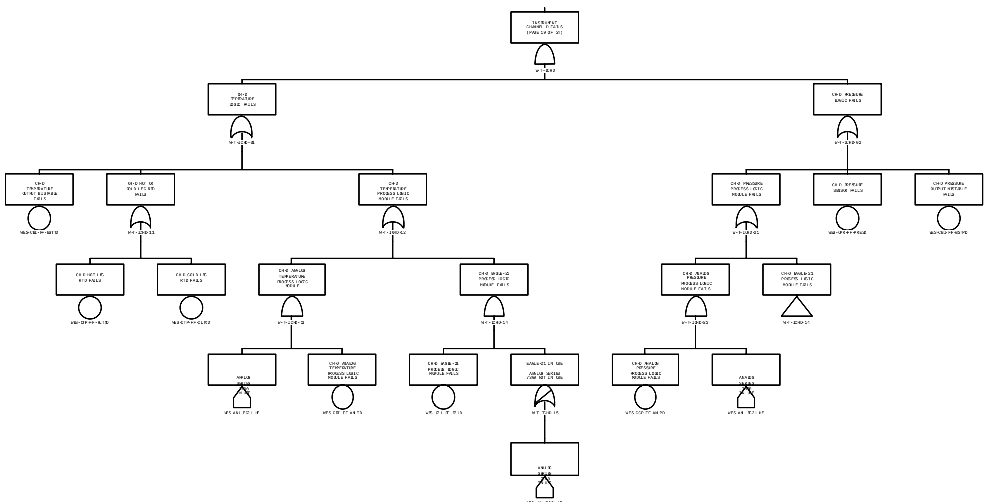
INSTRUMENT CHANNEL B FAILS
(PAGE 17 OF 24)



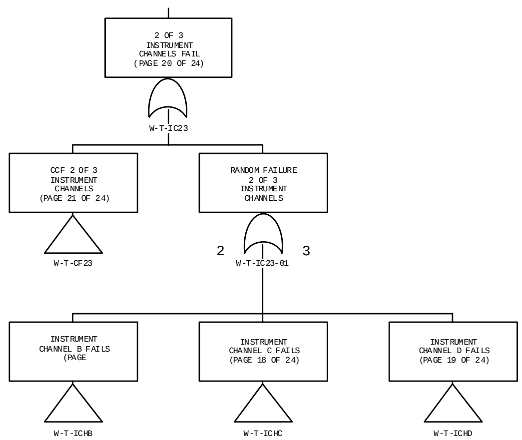
INSTRUMENT CHANNEL C FAILS
(PAGE 18 OF 24)



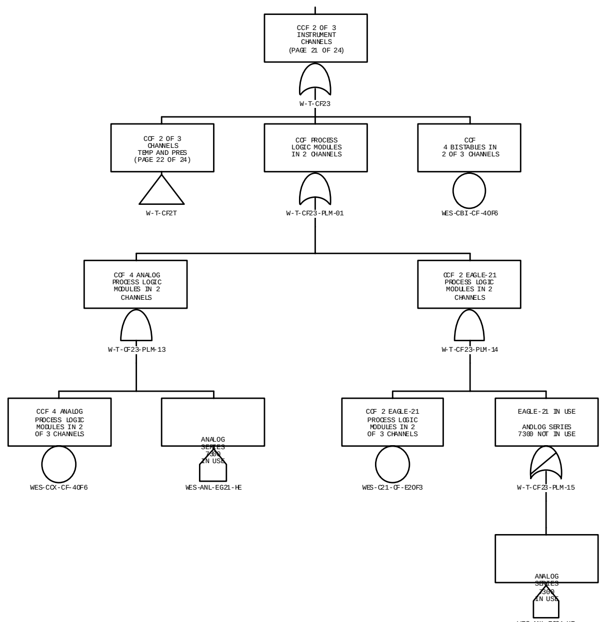
INSTRUMENT CHANNEL D FAILS
(PAGE 19 OF 24)



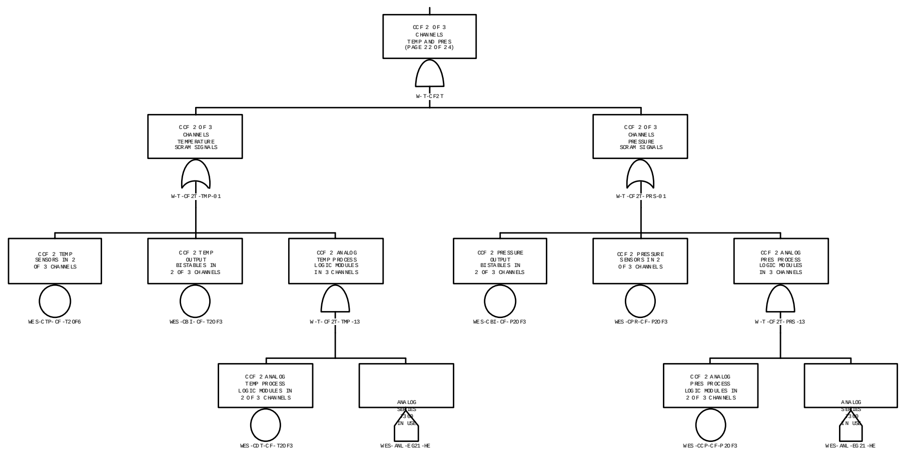
2 OF 3 INSTRUMENT CHANNELS FAIL
(PAGE 20 OF 24)



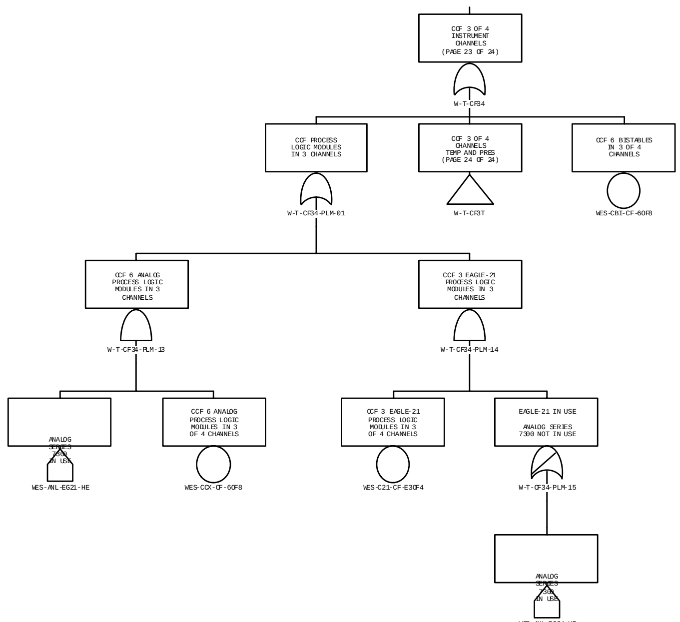
CCF 2 OF 3 INSTRUMENT CHANNELS (PAGE 21 OF 24)



CCF 2 OF 3 CHANNELS TEMP AND PRES
(PAGE 22 OF 24)



CCF 3 OF 4 INSTRUMENT CHANNELS
(PAGE 23 OF 24)



CCF 3 OF 4 CHANNELS TEMP AND PRES
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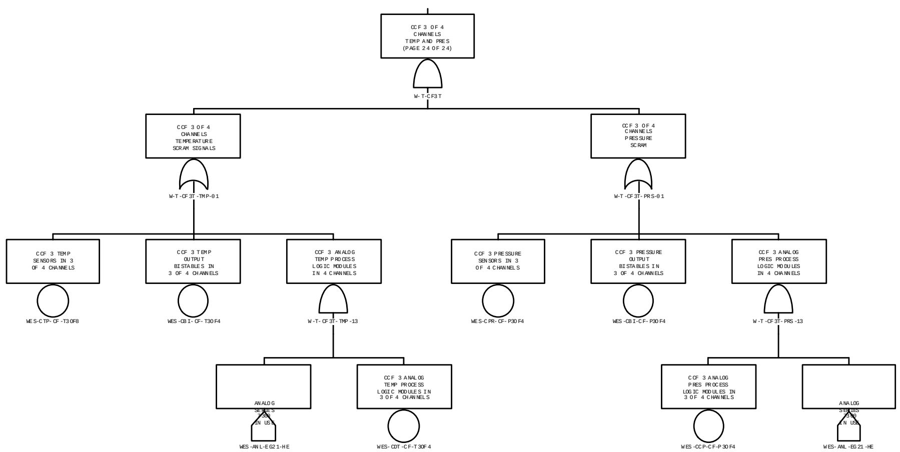

Appendix E

Common Cause Failure Analysis

E-1. INTRODUCTION

This appendix presents general information on the subject of common-cause failure (CCF) and special techniques developed for the reactor protection system (RPS) study. Included are sections that discuss background, methodology, the RPS CCF database, the prior, special software developed for this study, calculation of CCF basic event (BE) probabilities, sensitivities, and a special section on the rod BE probabilities. Throughout this section, component codes (e.g., CCX) are used when referring to components used in the RPS study. These codes are defined in the acronym list at the beginning of this report.

E-1.1 CCF Event Definition

A CCF event consists of component failures that meet four criteria: (1) two or more individual components fail or are degraded, including failures during demand, in-service testing, or deficiencies that would have resulted in a failure if a demand signal had been received; (2) components fail within a selected period of time, such that success of the probabilistic risk assessment (PRA) mission would be uncertain; (3) component failures result from a single shared cause and coupling mechanism; and (4) component failures are not due to failures of equipment outside the established component boundary.

Two data sources are used to select equipment failure reports to be reviewed for CCF event identification. The first is the Nuclear Plant Reliability Data System (NPRDS), which contains component failure information. The second one is the Sequence Coding and Search System (SCSS), which contains Licensee Event Reports (LERs).

The CCF event identification process includes a review of failure data to identify CCF events and independent failure event counts. The identification process allows the analyst to consistently screen failures and identify CCF events. The CCF event coding process provides guidance for the analyst to consistently code CCF events. Sufficient information is recorded to ensure accuracy and consistency. Additionally, the CCF events are stored in a format that allows PRA analysts to review the events and develop an understanding of CCF phenomenology.

E-1.2 Approach

The calculation of a CCF BE probability is a multi-step process. The fault trees developed for the RPS study identified CCF events that contributed to the possible failure of the RPS to successfully initiate a reactor trip. The data review and calculation of those CCF BE probabilities was driven by those needs. Figure E-1 shows a process flow diagram outlining the steps necessary to calculate a CCF BE probability. The step involving analysis of failure events is discussed in Appendices A and C. Fault tree development, defining CCF BE criteria, and component boundary definitions are discussed in Section 2 of the main body of this report.

A brief review of the CCF calculations is presented in this appendix to familiarize the reader with the terminology. More information can be found in the report *Common-Cause Failure Data Collection and Analysis System Volume 2—Definition and Classification of Common-Cause Failure Events*.[E-1]

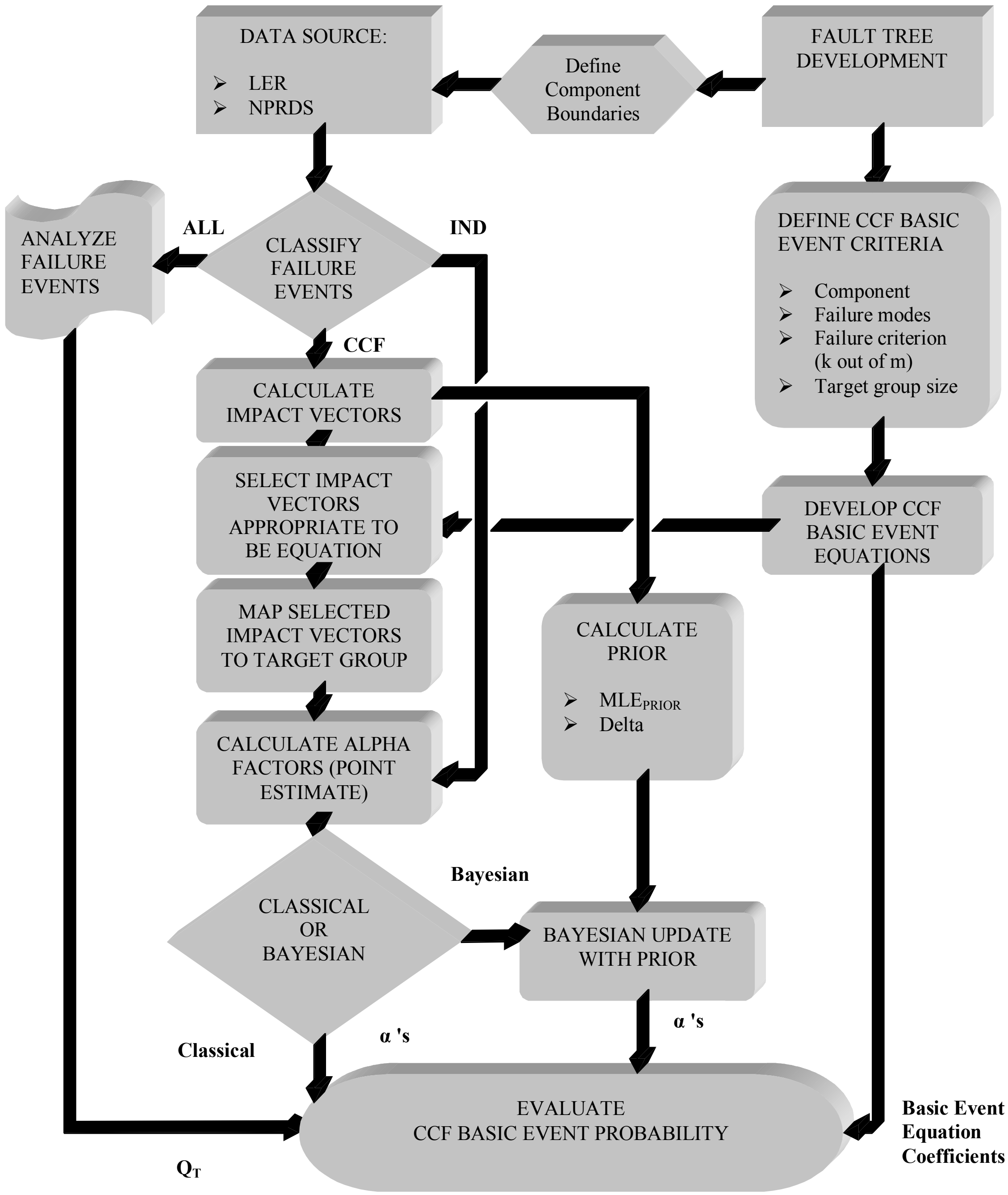

Figure E-1. CCF process flow diagram.

E-2. CCF MODEL

This section provides information on the type of CCF model used in this study and describes the process of developing the CCF BE equation.

E-2.1 Alpha Model

In order to provide estimates of the probability of a common-cause event involving *k* specific components in a common-cause component group (CCCG) of size *m*, a model needed to be selected from among the available models. The available models include the Basic Parameter model, the Beta model, the Multiple Greek Letter (MGL) model, and the Alpha Factor model.

The parametric Alpha Factor model was chosen. Reasons for this choice are that the alpha factor model 1) is a multi-parameter model, which can handle any redundancy level, 2) is based on ratios of failure rates which makes the assessment of its parameters easier when no statistical data are available, and 3) has a simpler statistical model, and produces more accurate point estimates as well as uncertainty distributions compared to other parametric models which have the above two properties.

The alpha factor model estimates CCF frequencies from a set of ratios of failures and the total component failure rate. The parameters of the model are:

Q_T = total failure frequency of each component (includes independent and common cause events)

$\alpha^{(m)}_k$ = fraction of the total frequency of failure events that occur in the system involving the failure of *k* components in a system of *m* components due to a common cause.

E-2.2 CCF Basic Event Equation Development

Two types of failure criterion are used in the GE RPS study. The first is one-out-of-two-twice logic. This type of logic is used throughout the RPS instrumentation logic. The second type is any k of m combinations. This type is used in the ROD model.

E-2.2.1 Specific Failure Criterion

In terms of the alpha factor model, the BE probability for *k* failures out of a system of *m* components (assuming a staggered testing scheme) is shown in Equation E-1.

$$BE_{CCF} = Q_T \sum_{i=k}^{m} C_i \frac{(m-i)!(i-1)!}{(m-1)!} \alpha_i^{(m)} \qquad \text{E-1}$$

where:

C_i = number of combinations of *k* component failures that will fail the system

A *specific failure criterion* is represented by the C_i term in Equation E-1. An example of a specific failure criterion is shown in Figure E-2. This example applies to the 6/8 CBI CCF event used in the fault trees. In this example, the failure criterion is described in shorthand as 6/8. This is based on specific criteria of failure of two of two components to fail a channel and failure of at least three of four channels to fail the system or function. Some of the combinations of six component failures will fail three channels e.g., those combinations where two failures are in each of three channels). Some combinations of six will fail only two channels, e.g., those combinations that have less than two failures in a channel.

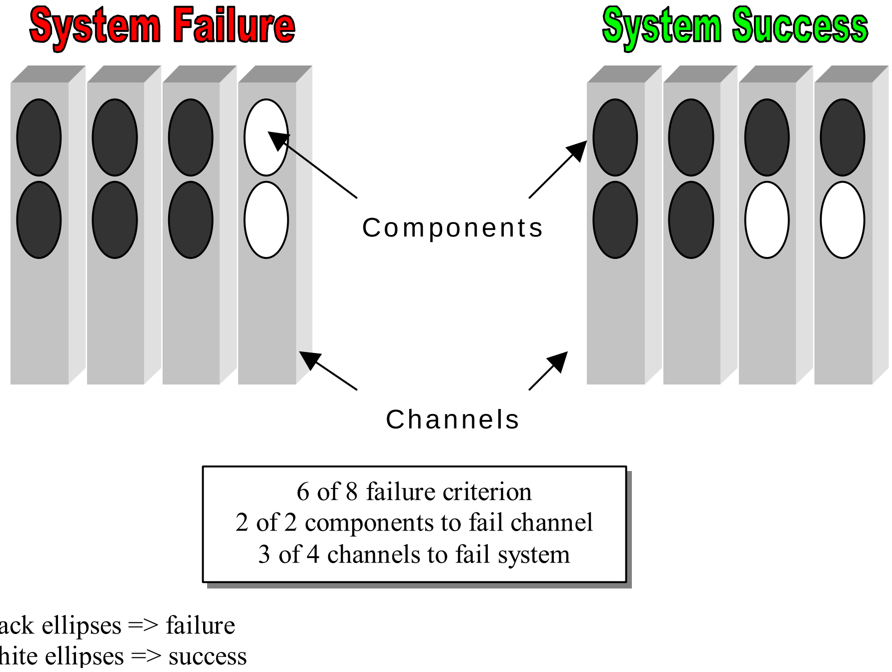

Figure E-2. Example of a specific failure criterion.

The valid failure combinations are counted and the sum becomes the C_i term in the BE equation. When a channel is taken out of service for maintenance, it is placed in a non-tripped status. The criteria then become two of two components and two or more of the remaining three channels. This maintenance event is described in shorthand as 4/6 |8.

E-2.2.2 Any k of m Combinations

The form of the CCF BE equation for any *k* out of *m* components failing is given by Equation E-2, for staggered testing:

$$Q_{CCF} = Q_T \sum_{i=k}^{m} \frac{\binom{m}{i}}{\binom{m-1}{i-1}} \alpha_i = Q_T \sum_{i=k}^{m} \frac{m}{i} \alpha_i \qquad \text{E-2}$$

where:

α_i = the ratio of *i* and only *i* CCF failures to total failures

m = the number of total rods in the component group

k = the failure criteria for a number of rod failures in the component group

Q_T = the random failure rate (Total)

Q_{CCF} = the failure probability of *k* and greater than *k* components due to CCF

Table E-1 shows the CCF BE probability equations used in the RPS study. All of the equations are based on staggered testing.

Table E-1. Failure criteria and basic event equation table.

Failure Criteria			
Channel or Train Level	Component (within channel or train)	Shorthand Criterion[a]	Basic Event Probability Equations
2/2	1/1	2/2	$\alpha_2 * Q_T$
2/2	1/2	2/3 |4	$(\alpha_4 + 4\alpha_3/3 + \alpha_2) * Q_T$
2/2	1/2	2/4	$(\alpha_4 + 4/3\ \alpha_3 + 2/3\ \alpha_2) * Q_T$
¾	1/1	3/4	$(\alpha_4 + 4\alpha_3/3\ ) * Q_T$
2/2	2/2	4/4	$\alpha_4 * Q_T$
2/2	3/3	6/6	$\alpha_6 * Q_T$
3/4	1/2	3/8	$(\alpha_8 + 8\alpha_7/7 + 28\alpha_6/21 + 56\alpha_5/35 + 64\alpha_4/35 + 32\alpha_3/21) * Q_T$
2/3	1/2	2/6 |8	$(\alpha_8 + 8\alpha_7/7 + 28\alpha_6/21 + 56\alpha_5/35 + 67\alpha_4/35 + 44\alpha_3/21 + 12\alpha_2/7) * Q_T$
1/1	4/6	4/6 |8	$(\alpha_8 + 8\alpha_7/7 + 28\alpha_6/21 + 3\alpha_5/35 + 3\alpha_4/35) * Q_T$
1/1	6/8	6/8	$(\alpha_8 + 8\alpha_7/7 + 4\alpha_6/21) * Q_T$
3/4	3/3	9/12	$(\alpha_{12} + 12\alpha_{11}/11 + 12\alpha_{10}/55 + 4\alpha_9/165) * Q_T$
2/3	3/3	6/9 |12	$(\alpha_{12} + 12\alpha_{11}/11 + 39\alpha_{10}/55 + 58\alpha_9/165 + 45\alpha_8/330 + 18\alpha_7/462 + 3\alpha_6/462) * Q_T$
2/2	4/6	8/12 |16	$(\alpha_{16} +16\alpha_{15}/15 + 72\alpha_{14}/105 + 160\alpha_{13}/455 + 208\alpha_{12}/1365 + 168\alpha_{11}/3003 + 84\alpha_{10}/5005 + 24\alpha_9/6435 + 3\alpha_8/6435) * Q_T$
2/2	6/8	12/16	$(\alpha_{16} +16\alpha_{15}/15 + 24\alpha_{14}/105 + 16\alpha_{13}/455 + 4\alpha_{12}/1365) * Q_T$
10/50	1/1	10/50	Equation E-2

a. Shorthand criteria with the form x/y |z are maintenance events involving one channel or train taken out of service due to maintenance.

E-3. CCF PARAMETER DEVELOPMENT

This section provides detailed discussions of the parameters, tools, and treatments developed specifically for the RPS study. Specifically, it describes the development of a Westinghouse RPS-specific prior, how CCF BE probabilities are calculated, application of the safety function knowledge, and special application of the Bayesian update process.

E-3.1 CCF Calculation Methodology

Three techniques are discussed in this section. These techniques are used to facilitate the estimation of plant-specific CCF probabilities from industry experience. One technique is the *impact vector* method, which is used to classify events according to the level of impact of common-cause events and the associated uncertainties in numerical terms. The second is impact vector specialization, in which impact vectors are modified to reflect the likelihood of the occurrence of the event in the specific system of interest. This technique is called *mapping*. The third technique is the estimation of alpha factors from the mapped impact vectors. Each technique is described briefly.

E-3.1.1 Impact Vector

An impact vector is a numerical representation of a CCF event. For a CCCG of size m, an impact vector has m+1 elements. The k+1 element, denoted by F_k, equals one if failure of exactly k components occurred, and zero otherwise. This applies to those situations where the component degradation values equal 1.0 and the time delay and coupling strength are 1.0. For those cases where these parameters are less than 1.0, the following techniques are used to develop an impact vector.

E-3.1.1.1 Impact Vector Equations. The values of the different elements (F_k) of the impact vector can be calculated based on the possible combinations of failures and non-failures. Equation E-3 shows, in general, how an element of the impact vector is calculated based on a degraded component state.

$$F_k^{(m)} = \sum_{l=0}^{\binom{m}{k}} \prod_{i=0}^{k} (p_i) \prod_{j=0}^{m-k} (1 - p_j) \qquad \text{E-3}$$

where:

m	=	the number of elements in the group
k	=	the number of failures out of the group of m
i	=	the failure elements of the l^{th} combination of k out of m failures
j	=	the non-failure elements of the l^{th} combination of k out of m failures
p	=	the weight or probability of the failure of each component (component degradation value)

Two additional parameters are coded with each CCF event: q represents the timing factor, and c represents the shared cause factor. The impact vector is then modified, see Equation E-4, to reflect these parameters in the following manner:

$$\begin{aligned} I_{CCF} &= \left[cqF_0^{(m)}, cqF_1^{(m)}, \ldots, cqF_m^{(m)}\right] \\ I_{c_1} &= \left[(1-cq)(1-p_1), (1-cq)p_1, 0, \ldots, 0\right] \\ &\vdots \\ I_{c_m} &= \left[(1-cq)(1-p_m), (1-cq)p_m, 0, \ldots, 0\right] \end{aligned} \qquad \text{E-4}$$

where:

c	=	shared cause factor
q	=	timing factor

Finally, the average impact vector is obtained by adding I_{CCF} and the I_c's, element by element.

E-3.1.1.2 Treatment of Uncertainty in Determining the Loss of Component Safety Function. During the review of the NPRDS and LER data for the RPS study there was some uncertainty about whether the safety function of the piece of equipment under scrutiny was compromised due to the failure mechanism. The uncertainty in this judgment is due to either: 1) unclear text in the event narrative, or 2) the component could be required to perform in different modes in the fault trees. For example, if a temperature detector fails high, it could either cause a spurious trip or contribute to preventing a trip depending on the parameter being measured.

To document the safety function impact, an additional field (FM2) was added to the database. When the analyst was uncertain about the status of the safety function, UKN (unknown) was entered in this field. Otherwise the field was coded FS for a fail-safe failure mode or NFS for a non-fail-safe failure mode.

This information was used in estimating component failure rates or Q_T's in Appendix C. The method is to calculate a ratio (NFS Ratio) of the failures identified as NFS to those that are identified as either FS or NFS. The NFS ratio was then applied by multiplying the count of UKN events by the NFS ratio and adding that to the NFS count.

The CCF data were treated in a similar manner. The method chosen to implement this treatment is to multiply each element of the average impact vector (for those CCF events designated as UKN) by the NFS ratio the same as the treatment of coupling strength and time delay. This effectively provides consistency between the CCF alpha parameter calculation and the Q_T calculation. A list of the component-specific ratios is given in Table E-2.

Table E-2. Component NFS ratios.

CCF Component Code	FS	NFS	Ratio
BME	130	11	0.08
BSN	8	10	0.55
BUV	31	28	0.47
C21	15	20	0.57
CBI	348	354	0.50
CCP	69	47	0.41
CDT	317	198	0.38
CPR	184	234	0.56
CTP	132	109	0.45
ROD	1	8	0.85
TLC	37	47	0.56
TLR	272	86	0.24
UVL	6	13	0.68

E-3.1.2 Mapping of Data

E-3.1.2.1 Exposed Population versus Component Group Size. There is a difference between the concepts of exposed population and the CCCG size. The exposed population is a data analysis concept, and CCCG size is a modeling concept. An example of the difference is provided in the context of the RPS study.

PWR plants contain from 20 to 64 bistables. The actual number of bistables in a particular plant represents the exposed population and remains the same for a given plant. Table A-1 shows the exposed population counts used in this study. For a given trip scenario, one or more bistables are required to function in each channel. The CCCG size is the number of bistables required per channel times the number of channels. This varies as the number of modeled trip parameters changes, depending upon the channel design. Therefore, it is possible to have events with in-plant populations of 20 to 64 components, and the modeled events have a CCCG from two to the exposed population. In the case of a maintenance event, one channel's worth of components is removed from the CCCG.

An impact vector represents a CCF in a specific group of components of exposed population size *m*. A collection of impact vectors used to calculate the CCF BE probability for a particular component may contain impact vectors of many different exposed population sizes (e.g., events that occur in different plants or different systems). In this case, the impact vectors are mapped to the CCCG size of interest.

E-3.1.2.2 Mapping Techniques. An impact vector will be mapped up, mapped down, or unchanged depending upon the relationship between the original system and the target system CCCG. The process for determining the equations for mapping has been written into a program to allow mapping from any size system to any other size system. The equations that describe the mapping process are discussed below.

There are three general routines for mapping, depending on the relationship between the original impact vectors and the system of interest. Mapping down is performed when the impact vector exposed population size is larger than the target group size, and mapping up is performed when the impact vector exposed population size is smaller than the target group size. In the special case where the impact vector has been coded as a "lethal shock," the impact vector for the new system of *m* components contains a 1.0 in the F_m position. To illustrate the mapping process, mapping down and mapping up equations are presented for CCCGs of three and five in Equations E-5 and E-6.

Mapping Down (5 ⇒ 3)

$$\begin{aligned} F_1^{(3)} &= 3/5F_1^{(5)} + 3/5F_2^{(5)} + 3/10F_3^{(5)} \\ F_2^{(3)} &= 3/10F_2^{(5)} + 3/5F_3^{(5)} + 3/5F_4^{(5)} \\ F_3^{(3)} &= 1/10F_3^{(5)} + 2/5F_4^{(5)} + F_5^{(5)} \end{aligned} \qquad \text{E-5}$$

Mapping Up (3 ⇒ 5)

$$\begin{aligned} F_1^{(5)} &= 5/3(1-\rho)^2 F_1^{(3)} \\ F_2^{(5)} &= 7/3\rho(1-\rho)^1 F_1^{(3)} + (1-\rho)^2 F_2^{(3)} \\ F_3^{(5)} &= \rho^2 F_1^{(3)} + 2\rho(1-\rho)^1 F_2^{(3)} + (1-\rho)^2 F_3^{(3)} \\ F_4^{(5)} &= \rho^2 F_2^{(3)} + 2\rho(1-\rho)^1 F_3^{(3)} \\ F_5^{(5)} &= \rho^2 F_3^{(3)} \end{aligned} \qquad \text{E-6}$$

The parameter ρ in Equation E-6 is called the *mapping up* parameter. It is the probability that the non-lethal shock or cause would have failed a single component added to the system. One method of estimating ρ is given in Equation E-7.

$$\rho = \sum_{i=1}^{m} \frac{i}{m} f_i \qquad \text{E-7}$$

and:

m = the number of elements in the group (CCCG)

f_i = the $i^{\underline{th}}$ element of the generic impact vector

This method works well when the system sizes are close to one another (e.g., mapping from size 2 to size 3 or 4) or when at least one of the component degradation values is less than 1.0. When all of the component degradation values are equal to 1.0, ρ is also equal to 1.0. When used in the *mapping up* equations for the RPS data, this method tends to overestimate the probability that additional components added to a system will exhibit the same lethal shock-like behavior. Examination of trends in the unmapped RPS data shows that as the number of components in a system increases, the likelihood of lethal behavior in that group of components decreases rapidly. Based on these observed trends, a limit of 0.85 was established for ρ.

E-3.1.3 Estimation of CCF Alpha Factors

Once the impact vectors are calculated for the target group, the number of events in each impact category (n_k), Equation E-8, can be calculated by adding the corresponding elements of the impact vectors. That is, with n CCF events,

$$n_k = \sum_{j=1}^{n} \overline{F}_k(j) \qquad \text{E-8}$$

where:

$F_k(i)$ = the k^{th} element of the impact vector for event i

The parameters of the alpha-factor model, Equation E-9, can be estimated using the following maximum likelihood estimators (MLE):

$$\alpha_k = \frac{n_k}{\sum_{k=1}^{m} n_k} \qquad \text{E-9}$$

E-3.2 Development of an RPS-Specific Prior

E-3.2.1 Background

The Bayesian approach utilizes the concept of a prior distribution. The prior reflects the analyst's degree of belief about the parameter before the evidence. The prior distribution is based on a generic data source, and updating the prior with a specific data set has the effect of specializing the prior to the specific application. The updated data set is known as the posterior distribution. The posterior represents the degree of belief about the parameter after incorporating the evidence.

E-3.2.2 RPS CCF Prior Event Population

The Westinghouse RPS CCF events comprise a suitably large volume of data to use as the prior population for this study. The prior data set contains 259 CCF events, based on the components used in this study. The weighted count of independent data is 1944.

E-3.2.3 Prior Results

The Westinghouse CCF data were repeatedly mapped to CCCGs of 2 to 16 and 50, and a data set representing a generic distribution for each CCCG was created. The results are shown in Table E-3 and Table E-4. Table E-3 shows the sums of each element (n_k) of the impact vectors for each CCCG, which are the results of the mapping. Table E-4 shows the prior maximum likelihood estimators (MLE) for each component CCCG. The MLE is represented by Equation E-10:

$$MLE_i = \frac{n_i}{\sum_{j=1}^{m} n_j} \qquad \text{E-10}$$

where:

m	=	CCCG
n_k	=	the sum of the k^{th} element of the impact vector, over the 491 events
n_1	=	sum of the first element and the Adjusted Independent
Adjusted Independent	=	(Ind. Event Count * Mapped CCCG)/Average CCCG

The CCF prior distribution for RPS, derived from the complete set of Westinghouse RPS data, provides an initial estimate for each $\alpha^{(m)}{}_k$ by mapping the data to each CCCG of interest, summing the impact vector elements for each CCF event, adding the number of independent events for the CCCG being considered to the $\alpha^{(m)}{}_1$ term, and normalizing across the alphas for the CCCG so that they add up to one. These estimates are taken to be the prior distribution mean values for each uncertainty distribution.

E-3.3 Bayesian Update Process

This section presents specific methods used to complete the Bayesian update calculation of CCF BEs in the RPS study.

E-3.3.1 Bayesian Update Methodology

In accordance with the methods explained in Section A-2.1.2.1, the distributions of the prior α_k are assumed to have a beta distribution form. When the prior α_k has a beta distribution for the probability of an occurrence, and occurrence data are generated from a binomial distribution with this probability, the posterior distribution from a Bayesian update is also a beta distribution. Thus, beta distributions are conjugate prior distributions for binomial data, and are a natural choice for the uncertainty in the CCF alpha parameters. The mean of the posterior uncertainty distribution (Equation E-11) that results from updating a beta prior distribution with the observed data is a weighted average of the mean of the prior distribution and the maximum likelihood estimate from the data, as follows:

$$\alpha_{CCF} = \alpha_{\mathrm{Pr}\,ior} * \frac{\delta}{\delta + d} + \frac{f}{d} * \frac{d}{d + \delta} \qquad \text{E-11}$$

Table E-3. Sums of impact vector elements for Westinghouse RPS prior.

Group Size	Adjusted Independent	Σn_k Vector
2	78.01	[5.56e+01, 8.01e+00]
3	117.01	[6.81e+01, 1.55e+01, 2.76e+00]
4	156.01	[6.55e+01, 2.78e+01, 7.33e+00, 2.08e+00]
5	195.02	[6.20e+01, 2.93e+01, 1.76e+01, 4.58e+00, 1.65e+00]
6	234.02	[6.07e+01, 2.84e+01, 1.96e+01, 1.20e+01, 3.19e+00, 1.36e+00]
7	273.02	[6.05e+01, 2.69e+01, 2.01e+01, 1.36e+01, 9.32e+00, 2.31e+00, 1.14e+00]
8	312.03	[6.11e+01, 2.52e+01, 1.99e+01, 1.47e+01, 1.05e+01, 7.28e+00, 1.80e+00, 9.70e-01]
9	351.03	[6.17e+01, 2.48e+01, 1.80e+01, 1.57e+01, 1.20e+01, 7.69e+00, 6.14e+00, 1.46e+00, 8.28e-01]
10	390.03	[6.25e+01, 2.46e+01, 1.65e+01, 1.52e+01, 1.30e+01, 9.67e+00, 5.74e+00, 5.35e+00, 1.22e+00, 7.09e-01]
11	429.04	[6.34e+01, 2.47e+01, 1.54e+01, 1.42e+01, 1.32e+01, 1.09e+01, 7.70e+00, 4.35e+00, 4.80e+00, 1.05e+00, 6.10e-01]
12	468.04	[6.43e+01, 2.51e+01, 1.45e+01, 1.30e+01, 1.28e+01, 1.15e+01, 9.06e+00, 6.13e+00, 3.35e+00, 4.41e+00, 9.20e-01, 5.26e-01]
13	507.04	[6.52e+01, 2.57e+01, 1.40e+01, 1.19e+01, 1.21e+01, 1.16e+01, 9.89e+00, 7.51e+00, 4.89e+00, 2.61e+00, 4.14e+00, 8.16e-01, 4.55e-01]
14	546.05	[6.60e+01, 2.65e+01, 1.37e+01, 1.09e+01, 1.11e+01, 1.12e+01, 1.03e+01, 8.46e+00, 6.21e+00, 3.91e+00, 2.07e+00, 3.94e+00, 7.30e-01, 3.95e-01]
15	585.05	[6.66e+01, 2.74e+01, 1.36e+01, 1.01e+01, 1.02e+01, 1.06e+01, 1.03e+01, 9.04e+00, 7.20e+00, 5.14e+00, 3.14e+00, 1.67e+00, 3.79e+00, 6.56e-01, 3.44e-01]
16	624.05	[6.72e+01, 2.83e+01, 1.38e+01, 9.53e+00, 9.32e+00, 9.90e+00, 1.00e+01, 9.30e+00, 7.89e+00, 6.12e+00, 4.25e+00, 2.54e+00, 1.37e+00, 3.68e+00, 5.91e-01, 3.01e-01]
50	1950.17	[6.34e+01, 3.33e+01, 2.51e+01, 2.08e+01, 1.53e+01, 9.97e+00, 5.85e+00, 3.37e+00, 2.10e+00, 1.65e+00, 1.67e+00, 1.89e+00, 2.19e+00, 2.47e+00, 2.69e+00, 2.84e+00, 2.93e+00, 2.99e+00, 3.08e+00, 3.24e+00, 3.48e+00, 3.76e+00, 3.99e+00, 4.08e+00, 3.98e+00, 3.69e+00, 3.29e+00, 2.88e+00, 2.54e+00, 2.33e+00, 2.21e+00, 2.13e+00, 2.01e+00, 1.80e+00, 1.51e+00, 1.16e+00, 8.27e-01, 5.52e-01, 3.72e-01, 2.88e-01, 2.80e-01, 3.08e-01, 3.30e-01, 3.14e-01, 2.53e-01, 1.67e-01, 8.62e-02, 2.86e+00, 8.07e-03, 5.69e-02]

Table E-4. Maximum likelihood estimators of α_k for Westinghouse RPS prior.

Group Size	MLE Vector
2	[9.43e-01, 5.66e-02]
3	[9.10e-01, 7.60e-02, 1.36e-02]
4	[8.56e-01, 1.07e-01, 2.83e-02, 8.06e-03]
5	[8.29e-01, 9.44e-02, 5.67e-02, 1.48e-02, 5.34e-03]
6	[8.20e-01, 7.90e-02, 5.45e-02, 3.35e-02, 8.89e-03, 3.78e-03]
7	[8.20e-01, 6.61e-02, 4.94e-02, 3.34e-02, 2.29e-02, 5.67e-03, 2.81e-03]
8	[8.23e-01, 5.55e-02, 4.40e-02, 3.24e-02, 2.31e-02, 1.60e-02, 3.97e-03, 2.14e-03]
9	[8.26e-01, 4.96e-02, 3.61e-02, 3.14e-02, 2.41e-02, 1.54e-02, 1.23e-02, 2.92e-03, 1.66e-03]
10	[8.31e-01, 4.52e-02, 3.04e-02, 2.79e-02, 2.39e-02, 1.78e-02, 1.05e-02, 9.82e-03, 2.24e-03, 1.30e-03]
11	[8.36e-01, 4.20e-02, 2.61e-02, 2.40e-02, 2.25e-02, 1.85e-02, 1.31e-02, 7.38e-03, 8.14e-03, 1.78e-03, 1.03e-03]
12	[8.40e-01, 3.96e-02, 2.30e-02, 2.05e-02, 2.02e-02, 1.81e-02, 1.43e-02, 9.67e-03, 5.28e-03, 6.96e-03, 1.45e-03, 8.30e-04]
13	[8.44e-01, 3.80e-02, 2.06e-02, 1.75e-02, 1.78e-02, 1.70e-02, 1.46e-02, 1.11e-02, 7.21e-03, 3.85e-03, 6.10e-03, 1.20e-03, 6.72e-04]
14	[8.48e-01, 3.67e-02, 1.90e-02, 1.51e-02, 1.54e-02, 1.55e-02, 1.42e-02, 1.17e-02, 8.61e-03, 5.42e-03, 2.87e-03, 5.46e-03, 1.01e-03, 5.48e-04]
15	[8.52e-01, 3.58e-02, 1.78e-02, 1.33e-02, 1.33e-02, 1.39e-02, 1.35e-02, 1.18e-02, 9.42e-03, 6.71e-03, 4.10e-03, 2.18e-03, 4.96e-03, 8.58e-04, 4.50e-04]
16	[8.55e-01, 3.50e-02, 1.70e-02, 1.18e-02, 1.15e-02, 1.22e-02, 1.24e-02, 1.15e-02, 9.76e-03, 7.58e-03, 5.26e-03, 3.14e-03, 1.69e-03, 4.56e-03, 7.31e-04, 3.73e-04]
50	[9.12e-01, 1.51e-02, 1.14e-02, 9.41e-03, 6.91e-03, 4.52e-03, 2.65e-03, 1.53e-03, 9.53e-04, 7.49e-04, 7.54e-04, 8.57e-04, 9.90e-04, 1.12e-03, 1.22e-03, 1.29e-03, 1.33e-03, 1.35e-03, 1.39e-03, 1.47e-03, 1.58e-03, 1.70e-03, 1.81e-03, 1.85e-03, 1.80e-03, 1.67e-03, 1.49e-03, 1.30e-03, 1.15e-03, 1.05e-03, 1.00e-03, 9.63e-04, 9.09e-04, 8.16e-04, 6.83e-04, 5.27e-04, 3.75e-04, 2.50e-04, 1.68e-04, 1.31e-04, 1.27e-04, 1.40e-04, 1.49e-04, 1.42e-04, 1.15e-04, 7.56e-05, 3.90e-05, 1.30e-03, 3.65e-06, 2.58e-05]

where:

α_{CCF} = posterior alpha

α_{Prior} = prior alpha

δ ≡ $\alpha + \beta$, parameters of the beta distribution of the prior

f = the sum of the i^{th} impact vector elements for the component, CCCG, and degree of CCF loss under consideration

d = the sum of all the impact vector elements for the CCCG and component under consideration

E-3.3.2 Uncertainty in the Prior Alpha Factors

To characterize the uncertainty in the common-cause alpha factors for the RPS, a distribution was associated with each alpha factor in the equation used to estimate each CCF probability (Table E-1). To complete the uncertainty analysis, distributions were needed for the alpha factors, $\alpha^{(m)}_{k}, \ldots \alpha^{(m)}_{m}$.

The particular beta distribution for each alpha parameter remains to be determined. With the means based on estimates from the data, just a single beta distribution parameter remains to be determined. The δ in Equation E-11 is a convenient choice. As δ increases, the variance of the uncertainty distribution decreases. Two basic approaches were used to estimate the prior distribution delta parameter, as discussed in subsections below.

E-3.3.2.1 Constrained Noninformative Distributions for CCF Factors. The first approach was to fit a constrained noninformative (CN) prior distribution for each $\alpha^{(m)}_{i}$, for i = 2, …, m. In this approach, the variance of the selected beta distribution maximizes the entropy, subject to the constraint that the mean matches the estimated probability of loss of i of m components by common cause. In practice, knowledge of the constrained mean leads to an estimate of the alpha parameter of the desired beta distribution. When the fixed mean is very small (i.e., less than 0.001), the alpha parameter of the fitted CN distribution is approximately 0.50. The beta parameter is selected so that $\alpha/(\alpha + \beta)=\alpha/\delta$, which equals the mean. Further details of the method are found in the "Alternate Method" subsection of Section A-2.1.2.1. Figure E-3 shows the relationship between the fixed mean and the alpha parameter of the beta distribution about the mean.

Application of the CN method treats each $\alpha^{(m)}_{k}$ independently. It results in a generally different prior distribution delta for each CCF $\alpha^{(m)}_{k}$. As a result, the sum of the $\alpha^{(m)}_{k}$ from 1 to m does not equal 1.0. Since the sum of the CCF $\alpha^{(m)}_{k}$ from 1 to m must equal 1.0, the independent failure probability term, $\alpha^{(m)}_{1}$, is obtained by subtraction.

Also, since the prior δ parameters differ, the weighting between the prior distribution and the data for a particular component [see Equation (2)] differs as the level of loss of redundancy (k in the subscript $\alpha^{(m)}_{k}$) changes across a CCCG. The results of the calculation of the prior δ are shown in Table E-5.

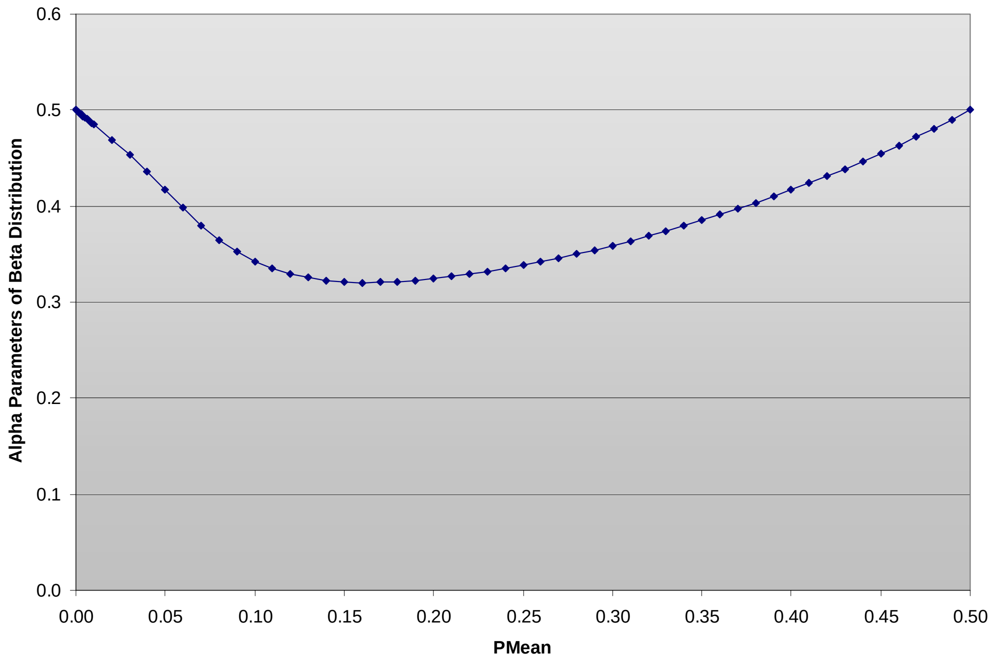

Figure E-3. Constrained non-informative prior alpha calculation.

E-3.3.2.2 Dirichlet Distributions for CCF Factors. In the CCF analysis methodology, an underlying assumption is that, among the failure events, the number (k_1) of events with just one failure and no CCF loss, together with the number (k_2) of events with exactly two components lost by CCF, and the number (k_3) with exactly 3 components lost, and so forth, up to m components lost by CCF (k_m), form a joint multinomial probability distribution. Each event independently provides an increment for one of the k_i. The CCF $\alpha^{(m)}_k$ are the conditional probabilities that describe the likelihood for each level of component loss. The Dirichlet distribution is the multinomial counterpart to a beta distribution function in which the parameters ($\alpha_1,\ldots, \alpha_m$) sum to one and represent the probability of exactly k failures out of m components in one event. Equation E-12 shows the Dirichlet distribution function:

$$\pi(\alpha_1,\ldots,\alpha_m) = \frac{\Gamma(A_1 + A_2 + \ldots, + A_m)}{\Gamma(A_1)\ldots\Gamma(A_m)} \alpha_1^{A_1 - 1} \alpha_2^{A_2 - 1} \ldots \alpha_m^{A_m - 1} \qquad \text{E-12}$$

The A_k's [$k = 1,\ldots, m$] are the parameters of the distribution and act like the count of events with k failures in the data.

When the set of alpha parameters { $\alpha^{(m)}_k$ }, for $k = 1,\ldots, m$ has a joint Dirichlet distribution, the marginal distributions are beta distributions with a common $\delta = (\alpha + \beta)$ parameter. That is, the mean of each common-cause α parameter is expressed as α_i/δ, for an appropriate alpha parameter α_i, and the corresponding beta parameter of the marginal beta distribution for each common-cause alpha is $\delta - \alpha_i$. Given the mean values and δ, the marginal beta distributions are fixed: $a_i = \delta$ * *the mean*, and $b_i = \delta - \alpha_i$. The Dirichlet uncertainty distribution depends on just the choice of the common δ, given the basic CCF alpha estimates.

When the Dirichlet prior distributions are updated with component-specific data, the posterior common-cause parameters will automatically sum to one. This is shown in Equation E-11, where both *d* from the data and δ from the prior distribution remain constant as the level of redundancy lost increases from 1 to m. In addition, with the Dirichlet distribution choice, the weighting between the prior and the data shown in Equation E-11 no longer depends on the level of redundancy of the alpha parameter. The treatment is thus more even-handed.

A reasonable choice for the δ is the geometric mean of the δ parameters computed in the CN distribution method. If the orders of magnitude between the estimated CCF alphas are not large, this average will result in uncertainty distributions that are not too skewed. Since the prior common-cause mean is α_i / δ, the beta distribution alpha parameter α_i is the mean times δ. From Figure E-3, low mean values lead to α_i parameters around 0.5. Since the chosen δ was calculated from the CN δ's, the resulting α_i parameters will center around 0.5, which is generally not too small. Small values for the alpha parameter of a beta distribution must be avoided, since they result in extremely skewed distributions.

E-3.3.3 Data

Data were selected from the RPS CCF database to match the criteria of each defined CCF BE used in the fault trees. Data for the component of interest included events in which the Safety Function is either NFS or UKN. The associated component independent failure count was extracted from the database and was selected using the same criteria as the CCF data.

E-3.4 CCF Basic Event Probability Results

E-3.4.1 Bayesian Update Results

Table E-6 shows the results of the CCF BE calculations with the Dirichlet prior for those components modeled in the fault trees. The Failure Criterion designation for each component points to an equation in Table E-1. The α_k's are only listed to α_8 to conserve space.

Error propagation using the beta distributions described in Section E-3.3.2 leads to uncertainty distributions on the estimated BE probabilities. The process, leading to lognormal distributions, is explained in Section A-2.2. Table E-7 shows the lognormal uncertainty parameters for the CCF BEs.

E-3.4.2 Classical Results

The classical or no prior influence results are shown in Table E-8. The results of the classical method show that, in general, the CCF results updated with a prior are higher. This method does not produce uncertainty distributions.

Table E-5. RPS prior, constrained non-informative δ and the geometric mean of δ.

Group Size	Delta Vector	Average	Geometric Mean
2	[7.26e+00, 7.26e+00]	7.26	7.26
3	[4.07e+00, 4.92e+00, 3.50e+01]	14.67	8.88
4	[2.24e+00, 3.17e+00, 1.65e+01, 6.04e+01]	20.56	9.16
5	[1.88e+00, 3.67e+00, 7.25e+00, 3.23e+01, 9.21e+01]	27.43	10.82
6	[1.78e+00, 4.79e+00, 7.46e+00, 1.32e+01, 5.48e+01, 1.31e+02]	35.50	13.50
7	[1.79e+00, 5.92e+00, 8.79e+00, 1.32e+01, 2.00e+01, 8.68e+01, 1.77e+02]	44.75	16.79
8	[1.81e+00, 7.36e+00, 9.66e+00, 1.36e+01, 1.98e+01, 2.98e+01, 1.25e+02, 2.32e+02]	54.85	20.39
9	[1.85e+00, 8.77e+00, 1.24e+01, 1.40e+01, 1.91e+01, 3.10e+01, 3.85e+01, 1.70e+02, 3.00e+02]	66.24	24.56
10	[1.90e+00, 9.44e+00, 1.44e+01, 1.67e+01, 1.92e+01, 2.71e+01, 4.46e+01, 4.95e+01, 2.21e+02, 3.82e+02]	78.58	28.97
11	[1.95e+00, 1.00e+01, 1.77e+01, 1.91e+01, 2.04e+01, 2.61e+01, 3.63e+01, 6.62e+01, 5.98e+01, 2.80e+02, 4.80e+02]	92.47	33.89
12	[2.01e+00, 1.14e+01, 1.99e+01, 2.21e+01, 2.24e+01, 2.66e+01, 3.33e+01, 5.02e+01, 9.31e+01, 7.05e+01, 3.43e+02, 6.02e+02]	108.01	39.32
13	[2.06e+00, 1.18e+01, 2.20e+01, 2.74e+01, 2.71e+01, 2.82e+01, 3.26e+01, 4.25e+01, 6.77e+01, 1.29e+02, 8.02e+01, 4.13e+02, 7.43e+02]	125.12	45.26
14	[2.11e+00, 1.22e+01, 2.54e+01, 3.15e+01, 3.10e+01, 3.07e+01, 3.34e+01, 4.03e+01, 5.66e+01, 9.07e+01, 1.73e+02, 9.01e+01, 4.91e+02, 9.11e+02]	144.26	51.60
15	[2.18e+00, 1.25e+01, 2.70e+01, 3.58e+01, 3.56e+01, 3.42e+01, 3.53e+01, 4.00e+01, 5.15e+01, 7.30e+01, 1.20e+02, 2.28e+02, 9.96e+01, 5.83e+02, 1.11e+03]	165.72	58.21
16	[2.23e+00, 1.27e+01, 2.82e+01, 4.00e+01, 4.09e+01, 3.86e+01, 3.81e+01, 4.10e+01, 4.98e+01, 6.45e+01, 9.34e+01, 1.58e+02, 2.94e+02, 1.08e+02, 6.83e+02, 1.34e+03]	189.51	65.26
50	[4.11e+00, 3.17e+01, 4.14e+01, 5.16e+01, 7.10e+01, 1.09e+02, 1.88e+02, 3.26e+02, 5.25e+02, 6.67e+02, 6.62e+02, 5.83e+02, 5.05e+02, 4.45e+02, 4.08e+02, 3.86e+02, 3.75e+02, 3.67e+02, 3.57e+02, 3.39e+02, 3.16e+02, 2.93e+02, 2.76e+02, 2.70e+02, 2.76e+02, 2.98e+02, 3.34e+02, 3.82e+02, 4.32e+02, 4.72e+02, 5.00e+02, 5.19e+02, 5.50e+02, 6.12e+02, 7.31e+02, 9.47e+02, 1.33e+03, 1.99e+03, 2.96e+03, 3.82e+03, 3.93e+03, 3.57e+03, 3.34e+03, 3.51e+03, 4.35e+03, 6.59e+03, 1.28e+04, 3.83e+02, 1.36e+05, 1.93e+04]	4360.31	609.11

Table E-6. Bayesian update CCF basic event results.

Basic Event Name	Failure Criterion	Q_T Mean	CCF Basic Event Failure Probability	Alpha Vector	Event Description
WES-BME-CF-RANBB	2/2	3.69E-05	1.61E-06	[9.56e-01, 4.37e-02]	Breaker RTB-A and BYB-B fail to open due to a mechanical failure
WES-BME-CF-RBNBA	2/2	3.69E-05	1.61E-06	[9.56e-01, 4.37e-02]	Breaker RTB-A and BYB-A fail to open due to a mechanical failure
WES-BME-CF-RTBAB	2/2	3.69E-05	1.61E-06	[9.56e-01, 4.37e-02]	Breaker RTB-A and RTB-B fail to open due to a mechanical failure
WES-BSN-CF-RANBB	2/2	5.81E-04	2.10E-05	[9.64e-01, 3.61e-02]	Breaker RTB-A and BYB-B fail to open due to a shunt trip failure
WES-BSN-CF-RBNBA	2/2	5.81E-04	2.10E-05	[9.64e-01, 3.61e-02]	Breaker RTB-B and BYB-A fail to open due to a shunt trip failure
WES-BSN-CF-RTBAB	2/2	5.81E-04	2.10E-05	[9.64e-01, 3.61e-02]	Breaker RTB-A and RTB-B fail to open due to a shunt trip failure
WES-BUV-CF-RANBB	2/2	2.54E-04	9.73E-06	[9.62e-01, 3.83e-02]	Breaker RTB-A and BYB-B fail to open due to a undervoltage trip unit failure
WES-BUV-CF-RBNBA	2/2	2.54E-04	9.73E-06	[9.62e-01, 3.83e-02]	Breaker RTB-B and BYB-A fail to open due to a undervoltage trip unit failure
WES-BUV-CF-RTBAB	2/2	2.54E-04	9.73E-06	[9.62e-01, 3.83e-02]	Breaker RTB-A and RTB-B fail to open due to a undervoltage trip unit failure
WES-C21-CF-E2OF3	2/3 |4	8.16E-06	5.07E-07	[9.42e-01, 4.37e-02, 1.14e-02, 3.25e-03]	2 of 3 Eagle 21 logic modules fail to function
WES-C21-CF-E3OF4	3/4	8.16E-06	1.51E-07	[9.42e-01, 4.37e-02, 1.14e-02, 3.25e-03]	3 of 4 Eagle 21 logic modules fail to function
WES-CBI-CF-4OF6	4/6 |8	7.46E-04	8.21E-06	[9.28e-01, 2.65e-02, 1.68e-02, 1.21e-02, 8.60e-03, 5.97e-03, 1.47e-03, 7.95e-04]	4 of 6 analog bistables fail to function
WES-CBI-CF-6OF8	6/8	7.46E-04	2.70E-06	[9.28e-01, 2.65e-02, 1.68e-02, 1.21e-02, 8.60e-03, 5.97e-03, 1.47e-03, 7.95e-04]	6 of 8 analog bistables fail to function
WES-CBI-CF-6OF9	6/9 |12	7.46E-04	3.62E-06	[9.22e-01, 2.44e-02, 1.09e-02, 9.00e-03, 8.78e-03, 7.86e-03, 6.20e-03, 4.19e-03, 2.29e-03, 3.02e-03, 6.29e-04, 3.60e-04]	6 of 9 analog bistables fail to function
WES-CBI-CF-9OF12	9/12	7.46E-04	1.31E-06	[9.22e-01, 2.44e-02, 1.09e-02, 9.00e-03, 8.78e-03, 7.86e-03, 6.20e-03, 4.19e-03, 2.29e-03, 3.02e-03, 6.29e-04, 3.60e-04]	9 of 12 analog bistables fail to function

Table E-6. (continued).

Basic Event Name	Failure Criterion	Q_T Mean	CCF Basic Event Failure Probability	Alpha Vector	Event Description
WES-CBI-CF-P2OF3	2/3 |4	7.46E-04	4.19E-05	[9.47e-01, 4.02e-02, 9.88e-03, 2.79e-03]	2 of 3 bistables fail to function
WES-CBI-CF-P3OF4	3/4	7.46E-04	1.19E-05	[9.47e-01, 4.02e-02, 9.88e-03, 2.79e-03]	3 of 4 bistables fail to function
WES-CBI-CF-T2OF3	2/3 |4	7.46E-04	4.19E-05	[9.47e-01, 4.02e-02, 9.88e-03, 2.79e-03]	2 of 3 bistables fail to function
WES-CBI-CF-T3OF4	3/4	7.46E-04	1.19E-05	[9.47e-01, 4.02e-02, 9.88e-03, 2.79e-03]	3 of 4 bistables fail to function
WES-CCP-CF-P2OF3	2/3 |4	1.57E-04	1.50E-05	[9.10e-01, 6.71e-02, 1.76e-02, 5.02e-03]	2 of 3 pressure process logic modules fail to function
WES-CCP-CF-P3OF4	3/4	1.57E-04	4.48E-06	[9.10e-01, 6.71e-02, 1.76e-02, 5.02e-03]	3 of 4 pressure process logic modules fail to function
WES-CCX-CF-4OF6	4/6 |8	7.81E-04	6.33E-06	[9.43e-01, 1.70e-02, 1.59e-02, 1.18e-02, 7.07e-03, 4.06e-03, 9.62e-04, 4.73e-04]	4 of 6 analog process logic modules fail to function
WES-CCX-CF-6OF8	6/8	7.81E-04	1.83E-06	[9.43e-01, 1.70e-02, 1.59e-02, 1.18e-02, 7.07e-03, 4.06e-03, 9.62e-04, 4.73e-04]	6 of 8 analog process logic modules fail to function
WES-CCX-CF-6OF9	6/9 |12	7.81E-04	2.55E-06	[9.44e-01, 1.16e-02, 7.55e-03, 7.95e-03, 8.44e-03, 7.43e-03, 5.36e-03, 3.23e-03, 1.60e-03, 1.91e-03, 3.94e-04, 2.24e-04]	6 of 9 analog process logic modules fail to function
WES-CCX-CF-9OF12	9/12	7.81E-04	8.66E-07	[9.44e-01, 1.16e-02, 7.55e-03, 7.95e-03, 8.44e-03, 7.43e-03, 5.36e-03, 3.23e-03, 1.60e-03, 1.91e-03, 3.94e-04, 2.24e-04]	9 of 12 analog process logic modules fail to function
WES-CDT-CF-T2OF3	2/3 |4	4.83E-03	2.50E-04	[9.51e-01, 4.02e-02, 7.77e-03, 1.13e-03]	2 of 3 delta temperature process logic modules fail to function
WES-CDT-CF-T3OF4	3/4	4.83E-03	5.55E-05	[9.51e-01, 4.02e-02, 7.77e-03, 1.13e-03]	3 of 4 delta temperature process logic modules fail to function
WES-CPR-CF-P2OF3	2/3 |4	1.16E-04	7.71E-06	[[9.38e-01, 4.87e-02, 1.26e-02, 9.91e-04]	2 of 3 pressure sensors in 4 channels fail to function
WES-CPR-CF-P3OF4	3/4	1.16E-04	2.06E-06	[9.38e-01, 4.87e-02, 1.26e-02, 9.91e-04]	3 of 4 pressure sensors in 4 channels fail to function
WES-CTP-CF-T2OF6	2/6 |8	5.98E-04	7.46E-05	[9.32e-01, 2.88e-02, 2.24e-02, 8.68e-03, 4.91e-03, 2.23e-03, 5.51e-04, 2.97e-04]	2 of 6 temperature sensors fail to function
WES-CTP-CF-T3OF8	3/8	5.98E-04	3.70E-05	[9.32e-01, 2.88e-02, 2.24e-02, 8.68e-03, 4.91e-03, 2.23e-03, 5.51e-04, 2.97e-04]	3 of 8 temperature sensors fail to function

Table E-6. (continued).

Basic Event Name	Failure Criterion	Q_T Mean	CCF Basic Event Failure Probability	Alpha Vector	Event Description
WES-ROD-CF-RCCAS	10/50	1.45E-05	1.21E-06	[9.12e-01, 1.54e-02, 1.14e-02, 9.39e-03, 6.89e-03, 4.50e-03, 2.64e-03, 1.52e-03, 9.50e-04, 7.47e-04, 7.52e-04, 8.55e-04, 9.87e-04, 1.11e-03, 1.21e-03, 1.28e-03, 1.32e-03, 1.35e-03, 1.39e-03, 1.46e-03, 1.57e-03, 1.70e-03, 1.80e-03, 1.84e-03, 1.80e-03, 1.67e-03, 1.49e-03, 1.30e-03, 1.15e-03, 1.05e-03, 9.97e-04, 9.60e-04, 9.06e-04, 8.14e-04, 6.81e-04, 5.26e-04, 3.73e-04, 2.49e-04, 1.68e-04, 1.30e-04, 1.26e-04, 1.39e-04, 1.49e-04, 1.42e-04, 1.14e-04, 7.54e-05, 3.89e-05, 1.29e-03, 3.64e-06, 2.57e-05]	Any 10 of 50 RCCAs fail to insert
WES-TLC-CF-SSL-3	6/6	3.83E-04	9.83E-07	[8.67e-01, 6.40e-02, 3.72e-02, 2.27e-02, 6.04e-03, 2.57e-03]	Solid state logic Train A & B (6 of 6)
WES-TLC-CF-SSLA	2/2	3.83E-04	1.72E-05	[9.55e-01, 4.50e-02]	CCF solid state logic Train A (2 of 2)
WES-TLC-CF-SSLAB	4/4	3.83E-04	2.10E-06	[8.96e-01, 7.94e-02, 1.93e-02, 5.48e-03]	Solid state logic Train A & B (4 of 4)
WES-TLC-CF-SSLB	2/2	3.83E-04	1.72E-05	[9.55e-01, 4.50e-02]	CCF solid state logic Train B (2 of 2)
WES-TLR-CF-12O16	12/16	3.94E-05	8.07E-08	[8.68e-01, 3.31e-02, 1.55e-02, 1.07e-02, 1.04e-02, 1.11e-02, 1.12e-02, 1.04e-02, 8.84e-03, 6.86e-03, 4.76e-03, 2.84e-03, 1.53e-03, 4.13e-03, 6.62e-04, 3.37e-04]	12 of 16 trip logic relays fail to function
WES-TLR-CF-8OF12	8/12 |16	3.94E-05	2.07E-07	[8.68e-01, 3.31e-02, 1.55e-02, 1.07e-02, 1.04e-02, 1.11e-02, 1.12e-02, 1.04e-02, 8.84e-03, 6.86e-03, 4.76e-03, 2.84e-03, 1.53e-03, 4.13e-03, 6.62e-04, 3.37e-04]	8 of 12 trip logic relays fail to function
WES-TLR-CF-PRA23	2/3 |4	3.94E-05	5.10E-06	[8.78e-01, 9.09e-02, 2.38e-02, 6.78e-03]	CCF 2 of 3 pressure relays in Train A
WES-TLR-CF-PRA34	3/4	3.94E-05	1.52E-06	[8.78e-01, 9.09e-02, 2.38e-02, 6.78e-03]	CCF 3 of 4 pressure relays in Train A
WES-TLR-CF-PRB23	2/3 |4	3.94E-05	5.10E-06	[8.78e-01, 9.09e-02, 2.38e-02, 6.78e-03]	CCF 2 of 3 pressure relays in Train B
WES-TLR-CF-PRB34	3/4	3.94E-05	1.52E-06	[8.78e-01, 9.09e-02, 2.38e-02, 6.78e-03]	CCF 3 of 4 pressure relays in Train B
WES-TLR-CF-RLA46	4/6 |8	3.94E-05	9.98E-07	[8.47e-01, 4.86e-02, 3.76e-02, 2.78e-02, 1.98e-02, 1.37e-02, 3.39e-03, 1.83e-03]	CCF 4 or more TMU relays in Train A
WES-TLR-CF-RLA68	6/8	3.94E-05	3.28E-07	[8.47e-01, 4.86e-02, 3.76e-02, 2.78e-02, 1.98e-02, 1.37e-02, 3.39e-03, 1.83e-03]	CCF 6 or more TMU relays in Train A

Table E-6. (continued).

Basic Event Name	Failure Criterion	Q_T Mean	CCF Basic Event Failure Probability	Alpha Vector	Event Description
WES-TLR-CF-RLB46	4/6 |8	3.94E-05	9.98E-07	[8.47e-01, 4.86e-02, 3.76e-02, 2.78e-02, 1.98e-02, 1.37e-02, 3.39e-03, 1.83e-03]	CCF 4 or more TMU relays in Train B
WES-TLR-CF-RLB68	6/8	3.94E-05	3.28E-07	[8.47e-01, 4.86e-02, 3.76e-02, 2.78e-02, 1.98e-02, 1.37e-02, 3.39e-03, 1.83e-03]	CCF 6 or more TMU relays in Train B
WES-TLR-CF-RTBAB	2/2	3.94E-05	2.00E-06	[9.49e-01, 5.07e-02]	Shunt trip relays fail to function
WES-TLR-CF-TRA23	2/3 |4	3.94E-05	5.10E-06	[8.78e-01, 9.09e-02, 2.38e-02, 6.78e-03]	CCF 2 of 3 temperature relays in Train A
WES-TLR-CF-TRA34	3/4	3.94E-05	1.52E-06	[8.78e-01, 9.09e-02, 2.38e-02, 6.78e-03]	CCF 3 of 4 temperature relays in Train A
WES-TLR-CF-TRB23	2/3 |4	3.94E-05	5.10E-06	[8.78e-01, 9.09e-02, 2.38e-02, 6.78e-03]	CCF 2 of 3 temperature relays in Train B
WES-TLR-CF-TRB34	3/4	3.94E-05	1.52E-06	[8.78e-01, 9.09e-02, 2.38e-02, 6.78e-03]	CCF 3 of 4 temperature relays in Train B
WES-UVL-CF-UVDAB	2/2	3.37E-04	1.04E-05	[9.69e-01, 3.07e-02]	RTB-A & B undervoltage device drivers fail to function

Table E-7. Lognormal uncertainty distributions for CCF events.

Basic Event Name	Median	EF	CCF Failure Rate Low [a]	CCF Failure Rate Mean [a]	CCF Failure Rate Upper [a]
WES-BME-CF-RANBB	5.30E-07	11.63	4.56E-08	1.61E-06	6.17E-06
WES-BME-CF-RBNBA	5.30E-07	11.63	4.56E-08	1.61E-06	6.17E-06
WES-BME-CF-RTBAB	5.30E-07	11.63	4.56E-08	1.61E-06	6.17E-06
WES-BSN-CF-RANBB	9.09E-06	8.40	1.08E-06	2.10E-05	7.64E-05
WES-BSN-CF-RBNBA	9.09E-06	8.40	1.08E-06	2.10E-05	7.64E-05
WES-BSN-CF-RTBAB	9.09E-06	8.40	1.08E-06	2.10E-05	7.64E-05
WES-BUV-CF-RANBB	4.65E-06	7.38	6.30E-07	9.73E-06	3.43E-05
WES-BUV-CF-RBNBA	4.65E-06	7.38	6.30E-07	9.73E-06	3.43E-05
WES-BUV-CF-RTBAB	4.65E-06	7.38	6.30E-07	9.73E-06	3.43E-05
WES-C21-CF-E2OF3	2.33E-07	7.80	2.98E-08	5.07E-07	1.81E-06
WES-C21-CF-E3OF4	4.58E-08	12.65	3.62E-09	1.51E-07	5.79E-07
WES-CBI-CF-4OF6	3.00E-06	10.34	2.90E-07	8.21E-06	3.10E-05
WES-CBI-CF-6OF8	6.32E-07	16.48	3.84E-08	2.70E-06	1.04E-05
WES-CBI-CF-6OF9	1.23E-06	11.20	1.10E-07	3.62E-06	1.38E-05
WES-CBI-CF-9OF12	2.96E-07	17.09	1.73E-08	1.31E-06	5.06E-06
WES-CBI-CF-P2OF3	1.70E-05	9.12	1.86E-06	4.19E-05	1.55E-04
WES-CBI-CF-P3OF4	3.17E-06	14.52	2.19E-07	1.19E-05	4.61E-05
WES-CBI-CF-T2OF3	1.70E-05	9.12	1.86E-06	4.19E-05	1.55E-04
WES-CBI-CF-T3OF4	3.17E-06	14.52	2.19E-07	1.19E-05	4.61E-05
WES-CCP-CF-P2OF3	6.00E-06	9.29	6.46E-07	1.50E-05	5.57E-05
WES-CCP-CF-P3OF4	1.19E-06	14.54	8.19E-08	4.48E-06	1.73E-05
WES-CCX-CF-4OF6	4.07E-06	4.68	8.71E-07	6.33E-06	1.91E-05
WES-CCX-CF-6OF8	7.37E-07	9.21	8.00E-08	1.83E-06	6.79E-06
WES-CCX-CF-6OF9	1.48E-06	5.53	2.68E-07	2.55E-06	8.22E-06
WES-CCX-CF-9OF12	3.25E-07	9.99	3.25E-08	8.66E-07	3.25E-06
WES-CDT-CF-T2OF3	2.01E-04	2.94	6.84E-05	2.50E-04	5.93E-04
WES-CDT-CF-T3OF4	3.90E-05	3.98	9.80E-06	5.55E-05	1.55E-04
WES-CPR-CF-P2OF3	4.35E-06	5.81	7.49E-07	7.71E-06	2.53E-05
WES-CPR-CF-P3OF4	9.88E-07	7.35	1.34E-07	2.06E-06	7.27E-06
WES-CTP-CF-T2OF6	6.69E-05	2.16	3.10E-05	7.46E-05	1.44E-04
WES-CTP-CF-T3OF8	3.21E-05	2.40	1.34E-05	3.70E-05	7.69E-05
WES-ROD-CF-RCCAS	8.27E-07	4.19	1.98E-07	1.21E-06	3.46E-06
WES-TLC-CF-SSL-3	8.21E-08	39.08	2.10E-09	9.83E-07	3.21E-06
WES-TLC-CF-SSLA	3.66E-06	18.10	2.02E-07	1.72E-05	6.62E-05
WES-TLC-CF-SSLAB	2.11E-07	34.00	6.20E-09	2.10E-06	7.17E-06
WES-TLC-CF-SSLB	3.66E-06	18.10	2.02E-07	1.72E-05	6.62E-05
WES-TLR-CF-12O16	2.81E-08	10.90	2.58E-09	8.07E-08	3.07E-07

Table E-7. (continued).

Basic Event Name	Median	EF	CCF Failure Rate Low [a]	CCF Failure Rate Mean [a]	CCF Failure Rate Upper [a]
WES-TLR-CF-8OF12	1.02E-07	7.08	1.44E-08	2.07E-07	7.24E-07
WES-TLR-CF-PRA23	3.17E-06	4.99	6.35E-07	5.10E-06	1.58E-05
WES-TLR-CF-PRA34	6.29E-07	8.89	7.08E-08	1.52E-06	5.59E-06
WES-TLR-CF-PRB23	3.17E-06	4.99	6.35E-07	5.10E-06	1.58E-05
WES-TLR-CF-PRB34	6.29E-07	8.89	7.08E-08	1.52E-06	5.59E-06
WES-TLR-CF-RLA46	5.58E-07	5.90	9.46E-08	9.98E-07	3.29E-06
WES-TLR-CF-RLA68	1.18E-07	10.49	1.13E-08	3.28E-07	1.24E-06
WES-TLR-CF-RLB46	5.58E-07	5.90	9.46E-08	9.98E-07	3.29E-06
WES-TLR-CF-RLB68	1.18E-07	10.49	1.13E-08	3.28E-07	1.24E-06
WES-TLR-CF-RTBAB	9.12E-07	7.84	1.16E-07	2.00E-06	7.15E-06
WES-TLR-CF-TRA23	3.17E-06	4.99	6.35E-07	5.10E-06	1.58E-05
WES-TLR-CF-TRA34	6.29E-07	8.89	7.08E-08	1.52E-06	5.59E-06
WES-TLR-CF-TRB23	3.17E-06	4.99	6.35E-07	5.10E-06	1.58E-05
WES-TLR-CF-TRB34	6.29E-07	8.89	7.08E-08	1.52E-06	5.59E-06
WES-UVL-CF-UVDAB	4.90E-06	7.49	6.54E-07	1.04E-05	3.67E-05

a. Fifth percentile, mean, and 95th percentile of lognormal distribution found by propagating the means and variances of the Bayesian updated alpha terms from Table E-6 through the equations in Table E-1. The means and variances of the Q_T terms used in this calculation are the means and variances of the distributions listed in Table C-7.

Table E-8. Classical method CCF basic event results.

Basic Event Name	Failure Criterion	Q_T Mean	CCF Basic Event Failure Probability	Alpha Vector	Event Description
WES-BME-CF-RANBB	2/2	3.69E-05	8.22E-08	[9.98e-01, 2.23e-03]	Breaker RTB-A and BYB-B fail to open due to a mechanical failure
WES-BME-CF-RBNBA	2/2	3.69E-05	8.22E-08	[9.98e-01, 2.23e-03]	Breaker RTB-B and BYB-A fail to open due to a mechanical failure
WES-BME-CF-RTBAB	2/2	3.69E-05	8.22E-08	[9.98e-01, 2.23e-03]	Breaker RTB-A and RTB-B fail to open due to a mechanical failure
WES-BSN-CF-RANBB	2/2	5.81E-04	2.65E-07	[1.00e+00, 4.57e-04]	Breaker RTB-A and BYB-B fail to open due to a shunt trip failure
WES-BSN-CF-RBNBA	2/2	5.81E-04	2.65E-07	[1.00e+00, 4.57e-04]	Breaker RTB-B and BYB-A fail to open due to a shunt trip failure
WES-BSN-CF-RTBAB	2/2	5.81E-04	2.65E-07	[1.00e+00, 4.57e-04]	Breaker RTB-A and RTB-B fail to open due to a shunt trip failure
WES-BUV-CF-RANBB	2/2	2.54E-04	1.21E-07	[1.00e+00, 4.76e-04]	Breaker RTB-A and BYB-B fail to open due to a undervoltage trip unit failure
WES-BUV-CF-RBNBA	2/2	2.54E-04	1.21E-07	[1.00e+00, 4.76e-04]	Breaker RTB-B and BYB-A fail to open due to a undervoltage trip unit failure
WES-BUV-CF-RTBAB	2/2	2.54E-04	1.21E-07	[1.00e+00, 4.76e-04]	Breaker RTB-A and RTB-B fail to open due to a undervoltage trip unit failure
WES-C21-CF-E2OF3	2/3 |4	8.16E-06	6.42E-09	[9.99e-01, 7.87e-04, 0.00e+00, 0.00e+00]	2 of 3 Eagle 21 logic modules fail to function
WES-C21-CF-E3OF4	3/4	8.16E-06	<1.0e-10	[9.99e-01, 7.87e-04, 0.00e+00, 0.00e+00]	3 of 4 Eagle 21 logic modules fail to function
WES-CBI-CF-4OF6	4/6 |8	7.46E-04	3.19E-09	[9.90e-01, 9.38e-03, 7.67e-04, 4.50e-05, 1.21e-06, 1.08e-08, …the rest of the alpha vector elements are < 1.0e-10]	4 of 6 analog bistables fail to function
WES-CBI-CF-6OF8	6/8	7.46E-04	<1.0e-10	[9.90e-01, 9.38e-03, 7.67e-04, 4.50e-05, 1.21e-06, 1.08e-08, …the rest of the alpha vector elements are < 1.0e-10]	6 of 8 analog bistables fail to function
WES-CBI-CF-6OF9	6/9 |12	7.46E-04	<1.0e-10	[9.85e-01, 1.27e-02, 1.67e-03, 1.86e-04, 1.07e-05, 2.40e-07, …the rest of the alpha vector elements are < 1.0e-10]	6 of 9 analog bistables fail to function
WES-CBI-CF-9OF12	9/12	7.46E-04	<1.0e-10	[9.85e-01, 1.27e-02, 1.67e-03, 1.86e-04, 1.07e-05, 2.40e-07, …the rest of the alpha vector elements are < 1.0e-10]	9 of 12 analog bistables fail to function
WES-CBI-CF-P2OF3	2/3 |4	7.46E-04	3.63E-06	[9.95e-01, 4.70e-03, 1.30e-04, 1.45e-06]	2 of 3 bistables fail to function
WES-CBI-CF-P3OF4	3/4	7.46E-04	1.31E-07	[9.95e-01, 4.70e-03, 1.30e-04, 1.45e-06]	3 of 4 bistables fail to function
WES-CBI-CF-T2OF3	2/3 |4	7.46E-04	3.63E-06	[9.95e-01, 4.70e-03, 1.30e-04, 1.45e-06]	2 of 3 bistables fail to function
WES-CBI-CF-T3OF4	3/4	7.46E-04	1.31E-07	[9.95e-01, 4.70e-03, 1.30e-04, 1.45e-06]	3 of 4 bistables fail to function

Table E-8. (continued).

Basic Event Name	Failure Criterion	Q_T Mean	CCF Basic Event Failure Probability	Alpha Vector	Event Description
WES-CCP-CF-P2OF3	2/3 |4	1.57E-04	9.23E-08	[9.99e-01, 5.88e-04, 0.00e+00, 0.00e+00]	2 of 3 pressure process logic modules fail to function
WES-CCP-CF-P3OF4	3/4	1.57E-04	<1.0e-10	[9.99e-01, 5.88e-04, 0.00e+00, 0.00e+00]	3 of 4 pressure process logic modules fail to function
WES-CCX-CF-4OF6	4/6 |8	7.81E-04	1.55E-06	[9.77e-01, 6.03e-03, 7.87e-03, 5.91e-03, 2.50e-03, 6.53e-04, 1.09e-04, 0.00e+00]	4 of 6 analog process logic modules fail to function
WES-CCX-CF-6OF8	6/8	7.81E-04	1.94E-07	[9.77e-01, 6.03e-03, 7.87e-03, 5.91e-03, 2.50e-03, 6.53e-04, 1.09e-04, 0.00e+00]	6 of 8 analog process logic modules fail to function
WES-CCX-CF-6OF9	6/9 |12	7.81E-04	2.67E-07	[9.83e-01, 1.21e-03, 1.88e-03, 3.32e-03, 4.10e-03, 3.49e-03, 2.07e-03, 8.52e-04, 2.43e-04, 4.58e-05, 4.58e-06, 0.00e+00]	6 of 9 analog process logic modules fail to function
WES-CCX-CF-9OF12	9/12	7.81E-04	1.63E-08	[9.83e-01, 1.21e-03, 1.88e-03, 3.32e-03, 4.10e-03, 3.49e-03, 2.07e-03, 8.52e-04, 2.43e-04, 4.58e-05, 4.58e-06, 0.00e+00]	9 of 12 analog process logic modules fail to function
WES-CDT-CF-T2OF3	2/3 |4	4.83E-03	2.33E-04	[9.54e-01, 3.78e-02, 7.05e-03, 8.91e-04]	2 of 3 delta temperature process logic modules fail to function
WES-CDT-CF-T3OF4	3/4	4.83E-03	4.97E-05	[9.54e-01, 3.78e-02, 7.05e-03, 8.91e-04]	3 of 4 delta temperature process logic modules fail to function
WES-CPR-CF-P2OF3	2/3 |4	1.16E-04	1.82E-06	[9.44e-01, 4.43e-02, 1.14e-02, 4.62e-04]	2 of 3 pressure sensors in 4 channels fail to function
WES-CPR-CF-P3OF4	3/4	1.16E-04	5.63E-05	[[9.44e-01, 4.43e-02, 1.14e-02, 4.62e-04]	3 of 4 pressure sensors in 4 channels fail to function
WES-CTP-CF-T2OF6	2/6 |8	5.98E-04	5.63E-05	[9.50e-01, 2.45e-02, 1.89e-02, 4.85e-03, 1.98e-03, 3.03e-08, 3.96e-10, 0.00e+00]	2 of 6 temperature sensors fail to function
WES-CTP-CF-T3OF8	3/8	5.98E-04	2.45E-05	[9.50e-01, 2.45e-02, 1.89e-02, 4.85e-03, 1.98e-03, 3.03e-08, 3.96e-10, 0.00e+00]	3 of 8 temperature sensors fail to function
WES-ROD-CF-RCCAS	10/50	1.45E-05	<1.0e-10	[8.51e-01, 1.44e-01, 5.75e-03, 5.99e-05, 0.00e+00]	Any 10 of 50 RCCAs fail to insert
WES-TLC-CF-SSL-3	6/6	3.83E-04	<1.0e-10	[9.67e-01, 3.22e-02, 7.10e-04, 0.00e+00, 0.00e+00, 0.00e+00]	Solid state logic Train A & B (6 of 6)
WES-TLC-CF-SSLA	2/2	3.83E-04	2.56E-06	[9.93e-01, 6.69e-03]	CCF solid state logic Train A (2 of 2)
WES-TLC-CF-SSLAB	4/4	3.83E-04	<1.0e-10	[9.80e-01, 1.97e-02, 2.10e-04, 0.00e+00]	Solid state logic Train A & B (4 of 4)

Table E-8. (continued).

Basic Event Name	Failure Criterion	Q_T Mean	CCF Basic Event Failure Probability	Alpha Vector	Event Description
WES-TLC-CF-SSLB	2/2	3.83E-04	2.56E-06	[9.93e-01, 6.69e-03]	CCF solid state logic Train B (2 of 2)
WES-TLR-CF-12O16	12/16	3.94E-05	<1.0e-10	[9.85e-01, 1.49e-02, 5.65e-04, 5.82e-06, 0.00e+00, 0.00e+00, 0.00e+00, 0.00e+00, 0.00e+00, 0.00e+00, 0.00e+00, 0.00e+00, 0.00e+00, 0.00e+00, 0.00e+00, 0.00e+00]	12 of 16 trip logic relays fail to function
WES-TLR-CF-8OF12	8/12 |16	3.94E-05	<1.0e-10	[9.85e-01, 1.49e-02, 5.65e-04, 5.82e-06, 0.00e+00, 0.00e+00, 0.00e+00, 0.00e+00, 0.00e+00, 0.00e+00, 0.00e+00, 0.00e+00, 0.00e+00, 0.00e+00, 0.00e+00, 0.00e+00]	8 of 12 trip logic relays fail to function
WES-TLR-CF-PRA23	2/3 |4	3.94E-05	1.28E-07	[9.97e-01, 3.23e-03, 1.66e-05, 1.26e-08]	CCF 2 of 3 pressure relays in Train A
WES-TLR-CF-PRA34	3/4	3.94E-05	8.70E-10	[9.97e-01, 3.23e-03, 1.66e-05, 1.26e-08]	CCF 3 of 4 pressure relays in Train A
WES-TLR-CF-PRB23	2/3 |4	3.94E-05	1.28E-07	[9.97e-01, 3.23e-03, 1.66e-05, 1.26e-08]	CCF 2 of 3 pressure relays in Train B
WES-TLR-CF-PRB34	3/4	3.94E-05	8.70E-10	[9.97e-01, 3.23e-03, 1.66e-05, 1.26e-08]	CCF 3 of 4 pressure relays in Train B
WES-TLR-CF-RLA46	4/6 |8	3.94E-05	<1.0e-10	[9.93e-01, 7.33e-03, 1.15e-04, 4.44e-07, 0.00e+00, 0.00e+00, 0.00e+00, 0.00e+00]	CCF 4 or more TMU relays in Train A
WES-TLR-CF-RLA68	6/8	3.94E-05	<1.0e-10	[9.93e-01, 7.33e-03, 1.15e-04, 4.44e-07, 0.00e+00, 0.00e+00, 0.00e+00, 0.00e+00]	CCF 6 or more TMU relays in Train A
WES-TLR-CF-RLB46	4/6 |8	3.94E-05	<1.0e-10	[9.93e-01, 7.33e-03, 1.15e-04, 4.44e-07, 0.00e+00, 0.00e+00, 0.00e+00, 0.00e+00]	CCF 4 or more TMU relays in Train B
WES-TLR-CF-RLB68	6/8	3.94E-05	<1.0e-10	[9.93e-01, 7.33e-03, 1.15e-04, 4.44e-07, 0.00e+00, 0.00e+00, 0.00e+00, 0.00e+00]	CCF 6 or more TMU relays in Train B
WES-TLR-CF-RTBAB	2/2	3.94E-05	4.29E-08	[9.99e-01, 1.09e-03]	Shunt trip relays fail to function
WES-TLR-CF-TRA23	2/3 |4	3.94E-05	1.28E-07	[9.97e-01, 3.23e-03, 1.66e-05, 1.26e-08]	CCF 2 of 3 temperature relays in Train A
WES-TLR-CF-TRA34	3/4	3.94E-05	8.70E-10	[9.97e-01, 3.23e-03, 1.66e-05, 1.26e-08]	CCF 3 of 4 temperature relays in Train A
WES-TLR-CF-TRB23	2/3 |4	3.94E-05	1.28E-07	[9.97e-01, 3.23e-03, 1.66e-05, 1.26e-08]	CCF 2 of 3 temperature relays in Train B
WES-TLR-CF-TRB34	3/4	3.94E-05	8.70E-10	[9.97e-01, 3.23e-03, 1.66e-05, 1.26e-08]	CCF 3 of 4 temperature relays in Train B
WES-UVL-CF-UVDAB	2/2	3.37E-04	<1.0e-10	[1.00e+00, 0.00e+00]	RTB-A & B undervoltage device drivers fail to function

E-4. RPS ROD CCF STUDY

The Westinghouse RPS fault tree includes an event that represents the CCF of the rods to insert, given that the trip breaker(s) have opened. The components included in this failure are the rod control cluster assemblies (RCCAs) and the control rod drive mechanisms (CRDs). One BE has been assigned to the supercomponent, ROD. Westinghouse cores contain approximately 50 rods. This section describes the definition of the failure criterion, the calculation of this BE probability, and the sensitivity of the BE probability to the assumed failure criterion.

E-4.1 Rod Failure Criteria

The probability of failure of sufficient rods to insert and shut down the reactor due to ROD or CRD common-cause failure is expected to be very small. This event has never occurred in the operating history of commercial PWR nuclear power plants. The calculated common-cause failure probability depends on the number of rods required to insert. For most transients, the insertion of a few rods is sufficient to shut down the reactor, e.g., less than ten for a mild transient. For others, it requires more rods to insert. In rare cases, insertion of all of the rods will not guarantee successful shut down of the reactor.

In SECY 83-297[E-2], Appendix A, a special definition of scram success was adopted based on overpressurization of a PWR primary loop or the overheating of a BWR suppression pool for the purposes of evaluating ATWS events. It was assumed that about half the rods were needed to safely shutdown the reactor for an overpressure transient. Moreover, these rods should insert in a somewhat checkerboard pattern. This success criteria is compatible with the ATWS event trees used by the ATWS task force to analyze the reactor's tolerance to an ATWS event. It is further stated that PWR overpressurization can be prevented by a *relatively few* control rods successfully inserting whereas suppression pool overheating in a BWR requires half the control rods in the checkerboard pattern.

Theoretically, it is possible to create expressions to calculate the probability of specific combinations of 25 rods out 50 failing to insert on demand in a checkerboard pattern. However, the computations would require an extremely long time to perform. Furthermore, the validity of such an answer should be questioned since there are common-cause mechanisms at work in large exposed populations that are not well understood and the expressions would not consider these mechanisms. To provide an upper bound to the probability, the following assumptions were made:

- Failure of any 10 rods to insert results in a loss of shutdown capability. This assumption is conservative since it is more likely to have 10 rods fail due to common cause than 25.

- Westinghouse cores contain an average of 50 rods.

- It does not matter which 10 rods fail to insert. They can be in a tight group or evenly distributed.

From 1984 through 1995, only two common-cause failure events were observed. In the first event, two rods were observed to have clad cracking and guide wear. The other 46 rods were assigned a degradation value of 0.1 due to the design flaw nature of the fault. In the other event, two control rod drives out of 48 exhibited faulty firing circuits. Thus, the operating experience is very sparse.

E-4.2 Rod CCF BE Failure Probability Sensitivity Results

Figure E-4 shows the resulting Q_{CCF} for each k out of m failure criterion based on a ROD/CRD random failure rate of 1.5E-5 per demand. The rod CCF BE probability ranges from approximately 7.7E-6 for 3 or more of 50 rods failing to insert to approximately 6.6E-7 for 20 or more of 50 rods failing to insert. The failure probability for 10 or more of 50 rods is 1.2E-6. This reflects a conservative yet practical estimate of the event.

When the uncertainty methods discussed in Section E-3.1.1.2 are applied to the rod data, the lognormal uncertainty bounds are 2.0E-7 and 3.5E-6. The median is 8.3E-7 and the error factor is 4.2.

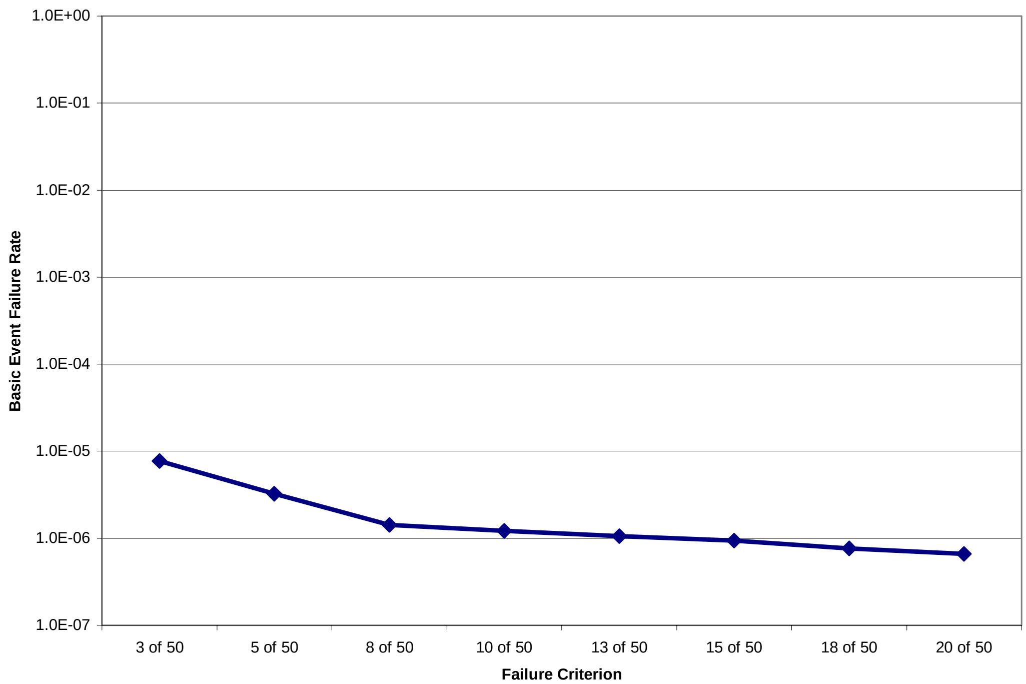

Figure E-4. Rod basic event sensitivity to failure criterion.

E-5. REFERENCES

E-1 H. M. Stromberg et. al., *Common-Cause Failure Data Collection and Analysis System Volume 2—Definition and Classification of Common-Cause Failure Events,* INEEL-94/0064, December 1995.

E-2. SECY-83-293, *Amendments to 10 CFR 50 Related to Anticipated Transients Without Scram (ATWS) Events*, U.S. Nuclear Regulatory Commission, July 19, 1983.

Appendix F

Fault Tree Quantification Results

Appendix F

Fault Tree Quantification Results

This appendix contains the SAPHIRE cut sets, importance rankings, and basic event reports from the quantification of the RPS fault trees for the Westinghouse Analog Series 7300 and Eagle-21 RPS designs. Two separate cases of results are presented for the Analog Series 7300 and Eagle-21 RPS designs. The first case of results presented for each RPS design assumes a value of 1.0 for both the operator failing to respond with no RPS signal present (WES-XHE-XE-NSGNL) and the operator failing to respond with RPS signal present (WES-XHE-XE-SIGNL). Tables F-1, F-2, F-3, and F-4 contain the cut sets and importance measures sorted by Fussell-Vesely, Risk Increase Ratio, and Birnbaum, respectively, for the Analog Series 7300 design for this case. Tables F-5, F-6, F-7, and F-8 contain the cut sets and importance measures sorted by Fussell-Vesely, Risk Increase Ratio, and Birnbaum, respectively, for the Eagle-21 design for this case.

The second case of results presented for each RPS design assumes a value of 0.5 and 0.01 for the operator failing to respond with no RPS signal present (WES-XHE-XE-NSGNL) and the operator failing to respond with RPS signal present (WES-XHE-XE-SIGNL), respectively. Tables F-9, F-10, F-11 and F-12 contain the cut sets and importance measures sorted by Fussell-Vesely, Risk Increase Ratio, and Birnbaum, respectively, for the Analog Series 7300 design for this case. Tables F-13, F-14, F-15, and F-16 contain the cut sets and importance measures sorted by Fussell-Vesely, Risk Increase Ratio, and Birnbaum, respectively, for the Eagle-21 design for this case.

The RPS fault tree cut sets for the Analog Series 7300 and Eagle-21 designs for the two cases were generated with no truncation level specified. Table F-17 provides a listing of the basic events used in the RPS fault tree along with their respective failure probability, uncertainty data, and description.

The cut sets that are shown in Tables F-1, F-5, F-9, and F-13 contain some basic events with a "/" in front of them. A "/" as the first character in a basic event name indicates a complemented event (Success = 1 - Failure). For example, the basic event for reactor trip breaker train A (RTB-A) in test and maintenance (T&M) is WES-BME-TM-RTBA (Failure = 1.40E-03). Thus, the basic event name for RTB-A not in T&M is /WES-BME-TM-RTBA (Success = 9.986E-01). The event description for complemented events remains the same as the description used for the failure event.

Table F-1. RPS Analog design top 100 cut sets (operator actions = 1.0) mincut = 2.2E-5.

Cut Set	Cut Set Percent	Cut Set Prob.	Basic Event[a]	Description	Prob.
1	47.9	1.0E-05	/WES-BME-TM-RTBA	RTB-A IN T&M	1.0E+0
			/WES-BME-TM-RTBB	RTB-B IN T&M	1.0E+0
			WES-UVL-CF-UVDAB	CCF UV DRIVERS TRAINS A AND B (2 OF 2)	1.0E-5
			WES-XHE-XE-SIGNL	OPERATOR FAILS TO RESPOND WITH RPS SIGNAL PRESENT	1.0E+0
2	11.7	2.5E-06	/WES-BME-TM-RTBA	RTB-A IN T&M	1.0E+0
			/WES-BME-TM-RTBB	RTB-B IN T&M	1.0E+0
			WES-CBI-CF-6OF8	CCF 6 BISTABLES IN 3 OF 4 CHANNELS	2.7E-6
			/WES-CCP-TM-CHA	CH-A IN T&M	9.4E-1
			WES-XHE-XE-NSGNL	OPERATOR FAILS TO RESPOND WITH NO RPS SIGNAL PRESENT	1.0E+0
3	9.7	2.1E-06	/WES-BME-TM-RTBA	RTB-A IN T&M	1.0E+0
			/WES-BME-TM-RTBB	RTB-B IN T&M	1.0E+0
			WES-TLC-CF-SSLAB	CCF SOLID STATE LOGIC IN TRAINS A AND B (4 OF 4)	2.1E-6
			WES-XHE-XE-SIGNL	OPERATOR FAILS TO RESPOND WITH RPS SIGNAL PRESENT	1.0E+0
4	7.9	1.7E-06	/WES-BME-TM-RTBA	RTB-A IN T&M	1.0E+0
			/WES-BME-TM-RTBB	RTB-B IN T&M	1.0E+0
			/WES-CCP-TM-CHA	CH-A IN T&M	9.4E-1
			WES-CCX-CF-6OF8	CCF 6 ANALOG PROCESS LOGIC MODULES IN 3 OF 4 CHANNELS	1.8E-6
			WES-XHE-XE-NSGNL	OPERATOR FAILS TO RESPOND WITH NO RPS SIGNAL PRESENT	1.0E+0
5	7.4	1.6E-06	WES-BME-CF-RTBAB	CCF RTB-A AND RTB-B (MECHANICAL)	1.6E-6
			/WES-BME-TM-RTBA	RTB-A IN T&M	1.0E+0
			/WES-BME-TM-RTBB	RTB-B IN T&M	1.0E+0
6	5.6	1.2E-06	WES-ROD-CF-RCCAS	CCF 10 OR MORE RCCAS FAIL TO DROP	1.2E-6
7	2.2	4.8E-07	/WES-BME-TM-RTBA	RTB-A IN T&M	1.0E+0
			/WES-BME-TM-RTBB	RTB-B IN T&M	1.0E+0
			WES-CBI-CF-4OF6	CCF 4 BISTABLES IN 2 OF 3 CHANNELS	8.2E-6
			WES-CCP-TM-CHA	CH-A IN T&M	5.8E-2
			WES-XHE-XE-NSGNL	OPERATOR FAILS TO RESPOND WITH NO RPS SIGNAL PRESENT	1.0E+0
8	2.2	4.7E-07	WES-BME-TM-RTBA	RTB-A IN T&M	1.4E-3
			/WES-BME-TM-RTBB	RTB-B IN T&M	1.0E+0
			WES-UVL-FF-UVDB	TRAIN B UV DRIVER FAILS	3.4E-4
			WES-XHE-XE-SIGNL	OPERATOR FAILS TO RESPOND WITH RPS SIGNAL PRESENT	1.0E+0
9	2.2	4.7E-07	/WES-BME-TM-RTBA	RTB-A IN T&M	1.0E+0
			WES-BME-TM-RTBB	RTB-B IN T&M	1.4E-3
			WES-UVL-FF-UVDA	TRAIN A UV DRIVER FAILS	3.4E-4
			WES-XHE-XE-SIGNL	OPERATOR FAILS TO RESPOND WITH RPS SIGNAL PRESENT	1.0E+0
10	1.7	3.7E-07	/WES-BME-TM-RTBA	RTB-A IN T&M	1.0E+0
			/WES-BME-TM-RTBB	RTB-B IN T&M	1.0E+0
			WES-CCP-TM-CHA	CH-A IN T&M	5.8E-2
			WES-CCX-CF-4OF6	CCF 4 ANALOG PROCESS LOGIC MODULES IN 2 OF 3 CHANNELS	6.3E-6
			WES-XHE-XE-NSGNL	OPERATOR FAILS TO RESPOND WITH NO RPS SIGNAL PRESENT	1.0E+0
11	0.5	1.1E-07	/WES-BME-TM-RTBA	RTB-A IN T&M	1.0E+0
			/WES-BME-TM-RTBB	RTB-B IN T&M	1.0E+0
			WES-UVL-FF-UVDA	TRAIN A UV DRIVER FAILS	3.4E-4
			WES-UVL-FF-UVDB	TRAIN B UV DRIVER FAILS	3.4E-4
			WES-XHE-XE-SIGNL	OPERATOR FAILS TO RESPOND WITH RPS SIGNAL PRESENT	1.0E+0
12	0.4	7.6E-08	/WES-BME-TM-RTBA	RTB-A IN T&M	1.0E+0
			/WES-BME-TM-RTBB	RTB-B IN T&M	1.0E+0
			/WES-CCP-TM-CHA	CH-A IN T&M	9.4E-1
			WES-TLR-CF-12O16	CCF 12 OR MORE TMU RELAYS IN TRAINS A AND B NO CHANNEL T&M	8.1E-8
			WES-XHE-XE-SIGNL	OPERATOR FAILS TO RESPOND WITH RPS SIGNAL PRESENT	1.0E+0
13	0.1	2.4E-08	WES-BME-TM-RTBA	RTB-A IN T&M	1.4E-3
			/WES-BME-TM-RTBB	RTB-B IN T&M	1.0E+0
			WES-TLC-CF-SSLB	CCF SOLID STATE LOGIC TRAIN B (2 OF 4)	1.7E-5
			WES-XHE-XE-SIGNL	OPERATOR FAILS TO RESPOND WITH RPS SIGNAL PRESENT	1.0E+0
14	0.1	2.4E-08	/WES-BME-TM-RTBA	RTB-A IN T&M	1.0E+0
			WES-BME-TM-RTBB	RTB-B IN T&M	1.4E-3
			WES-TLC-CF-SSLA	CCF SOLID STATE LOGIC TRAIN A (2 OF 4)	1.7E-5
			WES-XHE-XE-SIGNL	OPERATOR FAILS TO RESPOND WITH RPS SIGNAL PRESENT	1.0E+0
15	0.1	1.5E-08	WES-BME-TM-RTBA	RTB-A IN T&M	1.4E-3
			/WES-BME-TM-RTBB	RTB-B IN T&M	1.0E+0
			WES-UVL-CF-UVDAB	CCF UV DRIVERS TRAINS A AND B (2 OF 2)	1.0E-5
			WES-XHE-XE-SIGNL	OPERATOR FAILS TO RESPOND WITH RPS SIGNAL PRESENT	1.0E+0
16	0.1	1.5E-08	/WES-BME-TM-RTBA	RTB-A IN T&M	1.0E+0
			WES-BME-TM-RTBB	RTB-B IN T&M	1.4E-3
			WES-UVL-CF-UVDAB	CCF UV DRIVERS TRAINS A AND B (2 OF 2)	1.0E-5
			WES-XHE-XE-SIGNL	OPERATOR FAILS TO RESPOND WITH RPS SIGNAL PRESENT	1.0E+0
17	0.1	1.2E-08	WES-BME-FO-RTBA	RTB-A LOCAL HW FAILURE	3.7E-5
			/WES-BME-TM-RTBA	RTB-A IN T&M	1.0E+0
			/WES-BME-TM-RTBB	RTB-B IN T&M	1.0E+0
			WES-UVL-FF-UVDB	TRAIN B UV DRIVER FAILS	3.4E-4
			WES-XHE-XE-SIGNL	OPERATOR FAILS TO RESPOND WITH RPS SIGNAL PRESENT	1.0E+0
18	0.1	1.2E-08	WES-BME-FO-RTBB	RTB-B LOCAL HW FAILURE	3.7E-5
			/WES-BME-TM-RTBA	RTB-A IN T&M	1.0E+0
			/WES-BME-TM-RTBB	RTB-B IN T&M	1.0E+0
			WES-UVL-FF-UVDA	TRAIN A UV DRIVER FAILS	3.4E-4
			WES-XHE-XE-SIGNL	OPERATOR FAILS TO RESPOND WITH RPS SIGNAL PRESENT	1.0E+0
19	0.1	1.2E-08	/WES-BME-TM-RTBA	RTB-A IN T&M	1.0E+0
			/WES-BME-TM-RTBB	RTB-B IN T&M	1.0E+0

Table F-1. (continued).

Cut Set	Cut Set Percent	Cut Set Prob.	Basic Event[a]	Description	Prob.
			WES-CCP-TM-CHA	CH-A IN T&M	5.8E-2
			WES-TLR-CF-8OF12	CCF 8 OR MORE TMU RELAYS IN TRAINS A AND B ONE CHANNEL T&M	2.1E-7
			WES-XHE-XE-SIGNL	OPERATOR FAILS TO RESPOND WITH RPS SIGNAL PRESENT	1.0E+0
20	0.0	5.8E-09	/WES-BME-TM-RTBA	RTB-A IN T&M	1.0E+0
			/WES-BME-TM-RTBB	RTB-B IN T&M	1.0E+0
			WES-TLC-CF-SSLA	CCF SOLID STATE LOGIC TRAIN A (2 OF 4)	1.7E-5
			WES-UVL-FF-UVDB	TRAIN B UV DRIVER FAILS	3.4E-4
			WES-XHE-XE-SIGNL	OPERATOR FAILS TO RESPOND WITH RPS SIGNAL PRESENT	1.0E+0
21	0.0	5.8E-09	/WES-BME-TM-RTBA	RTB-A IN T&M	1.0E+0
			/WES-BME-TM-RTBB	RTB-B IN T&M	1.0E+0
			WES-TLC-CF-SSLB	CCF SOLID STATE LOGIC TRAIN B (2 OF 4)	1.7E-5
			WES-UVL-FF-UVDA	TRAIN A UV DRIVER FAILS	3.4E-4
			WES-XHE-XE-SIGNL	OPERATOR FAILS TO RESPOND WITH RPS SIGNAL PRESENT	1.0E+0
22	0.0	3.6E-09	WES-BME-TM-RTBA	RTB-A IN T&M	1.4E-3
			/WES-BME-TM-RTBB	RTB-B IN T&M	1.0E+0
			WES-CBI-CF-6OF8	CCF 6 BISTABLES IN 3 OF 4 CHANNELS	2.7E-6
			/WES-CCP-TM-CHA	CH-A IN T&M	9.4E-1
			WES-XHE-XE-NSGNL	OPERATOR FAILS TO RESPOND WITH NO RPS SIGNAL PRESENT	1.0E+0
23	0.0	3.6E-09	/WES-BME-TM-RTBA	RTB-A IN T&M	1.0E+0
			WES-BME-TM-RTBB	RTB-B IN T&M	1.4E-3
			WES-CBI-CF-6OF8	CCF 6 BISTABLES IN 3 OF 4 CHANNELS	2.7E-6
			/WES-CCP-TM-CHA	CH-A IN T&M	9.4E-1
			WES-XHE-XE-NSGNL	OPERATOR FAILS TO RESPOND WITH NO RPS SIGNAL PRESENT	1.0E+0
24	0.0	2.9E-09	WES-BME-TM-RTBA	RTB-A IN T&M	1.4E-3
			/WES-BME-TM-RTBB	RTB-B IN T&M	1.0E+0
			WES-TLC-CF-SSLAB	CCF SOLID STATE LOGIC IN TRAINS A AND B (4 OF 4)	2.1E-6
			WES-XHE-XE-SIGNL	OPERATOR FAILS TO RESPOND WITH RPS SIGNAL PRESENT	1.0E+0
25	0.0	2.9E-09	/WES-BME-TM-RTBA	RTB-A IN T&M	1.0E+0
			WES-BME-TM-RTBB	RTB-B IN T&M	1.4E-3
			WES-TLC-CF-SSLAB	CCF SOLID STATE LOGIC IN TRAINS A AND B (4 OF 4)	2.1E-6
			WES-XHE-XE-SIGNL	OPERATOR FAILS TO RESPOND WITH RPS SIGNAL PRESENT	1.0E+0
26	0.0	2.4E-09	WES-BME-TM-RTBA	RTB-A IN T&M	1.4E-3
			/WES-BME-TM-RTBB	RTB-B IN T&M	1.0E+0
			/WES-CCP-TM-CHA	CH-A IN T&M	9.4E-1
			WES-CCX-CF-6OF8	CCF 6 ANALOG PROCESS LOGIC MODULES IN 3 OF 4 CHANNELS	1.8E-6
			WES-XHE-XE-NSGNL	OPERATOR FAILS TO RESPOND WITH NO RPS SIGNAL PRESENT	1.0E+0
27	0.0	2.4E-09	/WES-BME-TM-RTBA	RTB-A IN T&M	1.0E+0
			WES-BME-TM-RTBB	RTB-B IN T&M	1.4E-3
			/WES-CCP-TM-CHA	CH-A IN T&M	9.4E-1
			WES-CCX-CF-6OF8	CCF 6 ANALOG PROCESS LOGIC MODULES IN 3 OF 4 CHANNELS	1.8E-6
			WES-XHE-XE-NSGNL	OPERATOR FAILS TO RESPOND WITH NO RPS SIGNAL PRESENT	1.0E+0
28	0.0	2.3E-09	WES-BME-CF-RANBB	CCF RTB-A AND BYB-B (MECHANICAL)	1.6E-6
			/WES-BME-TM-RTBA	RTB-A IN T&M	1.0E+0
			WES-BME-TM-RTBB	RTB-B IN T&M	1.4E-3
29	0.0	2.3E-09	WES-BME-CF-RBNBA	CCF RTB-B AND BYB-A (MECHANICAL)	1.6E-6
			WES-BME-TM-RTBA	RTB-A IN T&M	1.4E-3
			/WES-BME-TM-RTBB	RTB-B IN T&M	1.0E+0
30	0.0	1.4E-09	WES-BME-FO-RTBA	RTB-A LOCAL HW FAILURE	3.7E-5
			WES-BME-FO-RTBB	RTB-B LOCAL HW FAILURE	3.7E-5
			/WES-BME-TM-RTBA	RTB-A IN T&M	1.0E+0
			/WES-BME-TM-RTBB	RTB-B IN T&M	1.0E+0
31	0.0	6.7E-10	WES-BME-TM-RTBA	RTB-A IN T&M	1.4E-3
			/WES-BME-TM-RTBB	RTB-B IN T&M	1.0E+0
			WES-CBI-CF-4OF6	CCF 4 BISTABLES IN 2 OF 3 CHANNELS	8.2E-6
			WES-CCP-TM-CHA	CH-A IN T&M	5.8E-2
			WES-XHE-XE-NSGNL	OPERATOR FAILS TO RESPOND WITH NO RPS SIGNAL PRESENT	1.0E+0
32	0.0	6.7E-10	/WES-BME-TM-RTBA	RTB-A IN T&M	1.0E+0
			WES-BME-TM-RTBB	RTB-B IN T&M	1.4E-3
			WES-CBI-CF-4OF6	CCF 4 BISTABLES IN 2 OF 3 CHANNELS	8.2E-6
			WES-CCP-TM-CHA	CH-A IN T&M	5.8E-2
			WES-XHE-XE-NSGNL	OPERATOR FAILS TO RESPOND WITH NO RPS SIGNAL PRESENT	1.0E+0
33	0.0	6.3E-10	WES-BME-FO-RTBA	RTB-A LOCAL HW FAILURE	3.7E-5
			/WES-BME-TM-RTBA	RTB-A IN T&M	1.0E+0
			/WES-BME-TM-RTBB	RTB-B IN T&M	1.0E+0
			WES-TLC-CF-SSLB	CCF SOLID STATE LOGIC TRAIN B (2 OF 4)	1.7E-5
			WES-XHE-XE-SIGNL	OPERATOR FAILS TO RESPOND WITH RPS SIGNAL PRESENT	1.0E+0
34	0.0	6.3E-10	WES-BME-FO-RTBB	RTB-B LOCAL HW FAILURE	3.7E-5

Cut Set	Cut Set Percent	Cut Set Prob.	Basic Event[a]	Description	Prob.
			/WES-BME-TM-RTBA	RTB-A IN T&M	1.0E+0
			/WES-BME-TM-RTBB	RTB-B IN T&M	1.0E+0
			WES-TLC-CF-SSLA	CCF SOLID STATE LOGIC TRAIN A (2 OF 4)	1.7E-5
			WES-XHE-XE-SIGNL	OPERATOR FAILS TO RESPOND WITH RPS SIGNAL PRESENT	1.0E+0
35	0.0	6.2E-10	/WES-BME-TM-RTBA	RTB-A IN T&M	1.0E+0
			/WES-BME-TM-RTBB	RTB-B IN T&M	1.0E+0
			WES-CBI-CF-P3OF4	CCF 3 PRESSURE OUTPUT BISTABLES IN 3 OF 4 CHANNELS	1.2E-5
			/WES-CCP-TM-CHA	CH-A IN T&M	9.4E-1
			WES-CDT-CF-T3OF4	CCF 3 ANALOG TEMP PROCESS LOGIC MODULES IN 3 OF 4 CHANNELS	5.6E-5
			WES-XHE-XE-NSGNL	OPERATOR FAILS TO RESPOND WITH NO RPS SIGNAL PRESENT	1.0E+0
36	0.0	6.1E-10	/WES-BME-TM-RTBA	RTB-A IN T&M	1.0E+0
			/WES-BME-TM-RTBB	RTB-B IN T&M	1.0E+0
			WES-CBI-CF-P2OF3	CCF 2 PRESSURE OUTPUT BISTABLES IN 2 OF 3 CHANNELS	4.2E-5
			WES-CCP-TM-CHA	CH-A IN T&M	5.8E-2
			WES-CDT-CF-T2OF3	CCF 2 ANALOG TEMP PROCESS LOGIC MODULES IN 2 OF 3 CHANNELS	2.5E-4
			WES-XHE-XE-NSGNL	OPERATOR FAILS TO RESPOND WITH NO RPS SIGNAL PRESENT	1.0E+0
37	0.0	5.1E-10	WES-BME-TM-RTBA	RTB-A IN T&M	1.4E-3
			/WES-BME-TM-RTBB	RTB-B IN T&M	1.0E+0
			WES-CCP-TM-CHA	CH-A IN T&M	5.8E-2
			WES-CCX-CF-4OF6	CCF 4 ANALOG PROCESS LOGIC MODULES IN 2 OF 3 CHANNELS	6.3E-6
			WES-XHE-XE-NSGNL	OPERATOR FAILS TO RESPOND WITH NO RPS SIGNAL PRESENT	1.0E+0
38	0.0	5.1E-10	/WES-BME-TM-RTBA	RTB-A IN T&M	1.0E+0
			WES-BME-TM-RTBB	RTB-B IN T&M	1.4E-3
			WES-CCP-TM-CHA	CH-A IN T&M	5.8E-2
			WES-CCX-CF-4OF6	CCF 4 ANALOG PROCESS LOGIC MODULES IN 2 OF 3 CHANNELS	6.3E-6
			WES-XHE-XE-NSGNL	OPERATOR FAILS TO RESPOND WITH NO RPS SIGNAL PRESENT	1.0E+0
39	0.0	4.3E-10	WES-BME-TM-RTBA	RTB-A IN T&M	1.4E-3
			/WES-BME-TM-RTBB	RTB-B IN T&M	1.0E+0
			/WES-CCP-TM-CHA	CH-A IN T&M	9.4E-1
			WES-TLR-CF-RLB68	CCF 6 OR MORE TMU RELAYS IN TRAIN B NO CHANNEL T&M	3.3E-7
			WES-XHE-XE-SIGNL	OPERATOR FAILS TO RESPOND WITH RPS SIGNAL PRESENT	1.0E+0
40	0.0	4.3E-10	/WES-BME-TM-RTBA	RTB-A IN T&M	1.0E+0
			WES-BME-TM-RTBB	RTB-B IN T&M	1.4E-3
			/WES-CCP-TM-CHA	CH-A IN T&M	9.4E-1
			WES-TLR-CF-RLA68	CCF 6 OR MORE TMU RELAYS IN TRAIN A NO CHANNEL T&M	3.3E-7
			WES-XHE-XE-SIGNL	OPERATOR FAILS TO RESPOND WITH RPS SIGNAL PRESENT	1.0E+0
41	0.0	4.1E-10	/WES-BME-TM-RTBA	RTB-A IN T&M	1.0E+0
			/WES-BME-TM-RTBB	RTB-B IN T&M	1.0E+0
			WES-CBI-CF-P3OF4	CCF 3 PRESSURE OUTPUT BISTABLES IN 3 OF 4 CHANNELS	1.2E-5
			/WES-CCP-TM-CHA	CH-A IN T&M	9.4E-1
			WES-CTP-CF-T3OF8	CCF 3 TEMP SENSORS IN 3 OF 4 CHANNELS	3.7E-5
			WES-XHE-XE-NSGNL	OPERATOR FAILS TO RESPOND WITH NO RPS SIGNAL PRESENT	1.0E+0
42	0.0	3.0E-10	/WES-BME-TM-RTBA	RTB-A IN T&M	1.0E+0
			/WES-BME-TM-RTBB	RTB-B IN T&M	1.0E+0
			WES-TLC-CF-SSLA	CCF SOLID STATE LOGIC TRAIN A (2 OF 4)	1.7E-5
			WES-TLC-CF-SSLB	CCF SOLID STATE LOGIC TRAIN B (2 OF 4)	1.7E-5
			WES-XHE-XE-SIGNL	OPERATOR FAILS TO RESPOND WITH RPS SIGNAL PRESENT	1.0E+0
43	0.0	2.3E-10	/WES-BME-TM-RTBA	RTB-A IN T&M	1.0E+0
			/WES-BME-TM-RTBB	RTB-B IN T&M	1.0E+0
			WES-CCP-CF-P3OF4	CCF 3 ANALOG PRES PROCESS LOGIC MODULES IN 3 OF 4 CHANNELS	4.5E-6
			/WES-CCP-TM-CHA	CH-A IN T&M	9.4E-1
			WES-CDT-CF-T3OF4	CCF 3 ANALOG TEMP PROCESS LOGIC MODULES IN 3 OF 4 CHANNELS	5.6E-5
			WES-XHE-XE-NSGNL	OPERATOR FAILS TO RESPOND WITH NO RPS SIGNAL PRESENT	1.0E+0
44	0.0	2.2E-10	/WES-BME-TM-RTBA	RTB-A IN T&M	1.0E+0
			/WES-BME-TM-RTBB	RTB-B IN T&M	1.0E+0
			WES-CCP-CF-P2OF3	CCF 2 ANALOG PRES PROCESS LOGIC MODULES IN 2 OF 3 CHANNELS	1.5E-5
			WES-CCP-TM-CHA	CH-A IN T&M	5.8E-2
			WES-CDT-CF-T2OF3	CCF 2 ANALOG TEMP PROCESS LOGIC MODULES IN 2 OF 3 CHANNELS	2.5E-4
			WES-XHE-XE-NSGNL	OPERATOR FAILS TO RESPOND WITH NO RPS SIGNAL PRESENT	1.0E+0
45	0.0	2.1E-10	WES-BME-TM-RTBA	RTB-A IN T&M	1.4E-3
			/WES-BME-TM-RTBB	RTB-B IN T&M	1.0E+0
			WES-TLC-FF-SSLBP	TRAIN B PRESSURE SOLID STATE LOGIC FAILS	3.8E-4
			WES-TLC-FF-SSLBT	TRAIN B TEMPERATURE SOLID STATE LOGIC FAILS	3.8E-4
			WES-XHE-XE-SIGNL	OPERATOR FAILS TO RESPOND WITH RPS SIGNAL PRESENT	1.0E+0
46	0.0	2.1E-10	/WES-BME-TM-RTBA	RTB-A IN T&M	1.0E+0
			WES-BME-TM-RTBB	RTB-B IN T&M	1.4E-3
			WES-TLC-FF-SSLAP	TRAIN A PRESSURE SOLID STATE LOGIC FAILS	3.8E-4
			WES-TLC-FF-SSLAT	TRAIN A TEMPERATURE SOLID STATE LOGIC FAILS	3.8E-4
			WES-XHE-XE-SIGNL	OPERATOR FAILS TO RESPOND WITH RPS SIGNAL PRESENT	1.0E+0
47	0.0	2.0E-10	/WES-BME-TM-RTBA	RTB-A IN T&M	1.0E+0

Table F-1. (continued).

Cut Set	Cut Set Percent	Cut Set Prob.	Basic Event[a]	Description	Prob.
			/WES-BME-TM-RTBB	RTB-B IN T&M	1.0E+0
			WES-BSN-CF-RTBAB	CCF OF RTB-A AND RTB-B SHUNT TRIP DEVICES	2.1E-5
			WES-BUV-CF-RTBAB	CCF OF RTB-A AND RTB-B UV DEVICES	9.7E-6
48	0.0	1.8E-10	/WES-BME-TM-RTBA	RTB-A IN T&M	1.0E+0
			/WES-BME-TM-RTBB	RTB-B IN T&M	1.0E+0
			WES-CBI-CF-P2OF3	CCF 2 PRESSURE OUTPUT BISTABLES IN 2 OF 3 CHANNELS	4.2E-5
			WES-CCP-TM-CHA	CH-A IN T&M	5.8E-2
			WES-CTP-CF-T2OF6	CCF 2 TEMP SENSORS IN 2 OF 3 CHANNELS	7.5E-5
			WES-XHE-XE-NSGNL	OPERATOR FAILS TO RESPOND WITH NO RPS SIGNAL PRESENT	1.0E+0
49	0.0	1.6E-10	/WES-BME-TM-RTBA	RTB-A IN T&M	1.0E+0
			/WES-BME-TM-RTBB	RTB-B IN T&M	1.0E+0
			WES-CCP-CF-P3OF4	CCF 3 ANALOG PRES PROCESS LOGIC MODULES IN 3 OF 4 CHANNELS	4.5E-6
			/WES-CCP-TM-CHA	CH-A IN T&M	9.4E-1
			WES-CTP-CF-T3OF8	CCF 3 TEMP SENSORS IN 3 OF 4 CHANNELS	3.7E-5
			WES-XHE-XE-NSGNL	OPERATOR FAILS TO RESPOND WITH NO RPS SIGNAL PRESENT	1.0E+0
50	0.0	1.3E-10	/WES-BME-TM-RTBA	RTB-A IN T&M	1.0E+0
			/WES-BME-TM-RTBB	RTB-B IN T&M	1.0E+0
			WES-CBI-CF-P3OF4	CCF 3 PRESSURE OUTPUT BISTABLES IN 3 OF 4 CHANNELS	1.2E-5
			WES-CBI-CF-T3OF4	CCF 3 TEMP OUTPUT BISTABLES IN 3 OF 4 CHANNELS	1.2E-5
			/WES-CCP-TM-CHA	CH-A IN T&M	9.4E-1
			WES-XHE-XE-NSGNL	OPERATOR FAILS TO RESPOND WITH NO RPS SIGNAL PRESENT	1.0E+0
51	0.0	1.1E-10	/WES-BME-TM-RTBA	RTB-A IN T&M	1.0E+0
			/WES-BME-TM-RTBB	RTB-B IN T&M	1.0E+0
			WES-CCP-TM-CHA	CH-A IN T&M	5.8E-2
			WES-CDT-CF-T2OF3	CCF 2 ANALOG TEMP PROCESS LOGIC MODULES IN 2 OF 3 CHANNELS	2.5E-4
			WES-CPR-CF-P2OF3	CCF 2 PRESSURE SENSORS IN 2 OF 3 CHANNELS	7.7E-6
			WES-XHE-XE-NSGNL	OPERATOR FAILS TO RESPOND WITH NO RPS SIGNAL PRESENT	1.0E+0
52	0.0	1.1E-10	/WES-BME-TM-RTBA	RTB-A IN T&M	1.0E+0
			/WES-BME-TM-RTBB	RTB-B IN T&M	1.0E+0
			/WES-CCP-TM-CHA	CH-A IN T&M	9.4E-1
			WES-CDT-CF-T3OF4	CCF 3 ANALOG TEMP PROCESS LOGIC MODULES IN 3 OF 4 CHANNELS	5.6E-5
			WES-CPR-CF-P3OF4	CCF 3 PRESSURE SENSORS IN 3 OF 4 CHANNELS	2.1E-6
			WES-XHE-XE-NSGNL	OPERATOR FAILS TO RESPOND WITH NO RPS SIGNAL PRESENT	1.0E+0
53	0.0	1.1E-10	WES-BME-TM-RTBA	RTB-A IN T&M	1.4E-3
			/WES-BME-TM-RTBB	RTB-B IN T&M	1.0E+0
			/WES-CCP-TM-CHA	CH-A IN T&M	9.4E-1
			WES-TLR-CF-12O16	CCF 12 OR MORE TMU RELAYS IN TRAINS A AND B NO CHANNEL T&M	8.1E-8
			WES-XHE-XE-SIGNL	OPERATOR FAILS TO RESPOND WITH RPS SIGNAL PRESENT	1.0E+0
54	0.0	1.1E-10	/WES-BME-TM-RTBA	RTB-A IN T&M	1.0E+0
			WES-BME-TM-RTBB	RTB-B IN T&M	1.4E-3
			/WES-CCP-TM-CHA	CH-A IN T&M	9.4E-1
			WES-TLR-CF-12O16	CCF 12 OR MORE TMU RELAYS IN TRAINS A AND B NO CHANNEL T&M	8.1E-8
			WES-XHE-XE-SIGNL	OPERATOR FAILS TO RESPOND WITH RPS SIGNAL PRESENT	1.0E+0
55	0.0	1.0E-10	/WES-BME-TM-RTBA	RTB-A IN T&M	1.0E+0
			/WES-BME-TM-RTBB	RTB-B IN T&M	1.0E+0
			/WES-CCP-TM-CHA	CH-A IN T&M	9.4E-1
			WES-TLR-CF-RLA68	CCF 6 OR MORE TMU RELAYS IN TRAIN A NO CHANNEL T&M	3.3E-7
			WES-UVL-FF-UVDB	TRAIN B UV DRIVER FAILS	3.4E-4
			WES-XHE-XE-SIGNL	OPERATOR FAILS TO RESPOND WITH RPS SIGNAL PRESENT	1.0E+0
56	0.0	1.0E-10	/WES-BME-TM-RTBA	RTB-A IN T&M	1.0E+0
			/WES-BME-TM-RTBB	RTB-B IN T&M	1.0E+0
			/WES-CCP-TM-CHA	CH-A IN T&M	9.4E-1
			WES-TLR-CF-RLB68	CCF 6 OR MORE TMU RELAYS IN TRAIN B NO CHANNEL T&M	3.3E-7
			WES-UVL-FF-UVDA	TRAIN A UV DRIVER FAILS	3.4E-4
			WES-XHE-XE-SIGNL	OPERATOR FAILS TO RESPOND WITH RPS SIGNAL PRESENT	1.0E+0
57	0.0	1.0E-10	/WES-BME-TM-RTBA	RTB-A IN T&M	1.0E+0
			/WES-BME-TM-RTBB	RTB-B IN T&M	1.0E+0
			WES-CBI-CF-P2OF3	CCF 2 PRESSURE OUTPUT BISTABLES IN 2 OF 3 CHANNELS	4.2E-5
			WES-CBI-CF-T2OF3	CCF 2 TEMP OUTPUT BISTABLES IN 2 OF 3 CHANNELS	4.2E-5
			WES-CCP-TM-CHA	CH-A IN T&M	5.8E-2
			WES-XHE-XE-NSGNL	OPERATOR FAILS TO RESPOND WITH NO RPS SIGNAL PRESENT	1.0E+0
58	0.0	8.1E-11	WES-BME-TM-RTBA	RTB-A IN T&M	1.4E-3
			/WES-BME-TM-RTBB	RTB-B IN T&M	1.0E+0
			WES-CCP-TM-CHA	CH-A IN T&M	5.8E-2
			WES-TLR-CF-RLB46	CCF 4 OR MORE TMU RELAYS IN TRAIN B ONE CHANNEL T&M	1.0E-6
			WES-XHE-XE-SIGNL	OPERATOR FAILS TO RESPOND WITH RPS SIGNAL PRESENT	1.0E+0
59	0.0	8.1E-11	/WES-BME-TM-RTBA	RTB-A IN T&M	1.0E+0

Cut Set	Cut Set Percent	Cut Set Prob.	Basic Event[a]	Description	Prob.
			WES-BME-TM-RTBB	RTB-B IN T&M	1.4E-3
			WES-CCP-TM-CHA	CH-A IN T&M	5.8E-2
			WES-TLR-CF-RLA46	CCF 4 OR MORE TMU RELAYS IN TRAIN A ONE CHANNEL T&M	1.0E-6
			WES-XHE-XE-SIGNL	OPERATOR FAILS TO RESPOND WITH RPS SIGNAL PRESENT	1.0E+0
60	0.0	7.2E-11	/WES-BME-TM-RTBA	RTB-A IN T&M	1.0E+0
			/WES-BME-TM-RTBB	RTB-B IN T&M	1.0E+0
			/WES-CCP-TM-CHA	CH-A IN T&M	9.4E-1
			WES-CPR-CF-P3OF4	CCF 3 PRESSURE SENSORS IN 3 OF 4 CHANNELS	2.1E-6
			WES-CTP-CF-T3OF8	CCF 3 TEMP SENSORS IN 3 OF 4 CHANNELS	3.7E-5
			WES-XHE-XE-NSGNL	OPERATOR FAILS TO RESPOND WITH NO RPS SIGNAL PRESENT	1.0E+0
61	0.0	6.5E-11	/WES-BME-TM-RTBA	RTB-A IN T&M	1.0E+0
			/WES-BME-TM-RTBB	RTB-B IN T&M	1.0E+0
			WES-CCP-CF-P2OF3	CCF 2 ANALOG PRES PROCESS LOGIC MODULES IN 2 OF 3 CHANNELS	1.5E-5
			WES-CCP-TM-CHA	CH-A IN T&M	5.8E-2
			WES-CTP-CF-T2OF6	CCF 2 TEMP SENSORS IN 2 OF 3 CHANNELS	7.5E-5
			WES-XHE-XE-NSGNL	OPERATOR FAILS TO RESPOND WITH NO RPS SIGNAL PRESENT	1.0E+0
62	0.0	5.0E-11	/WES-BME-TM-RTBA	RTB-A IN T&M	1.0E+0
			/WES-BME-TM-RTBB	RTB-B IN T&M	1.0E+0
			WES-CBI-CF-T3OF4	CCF 3 TEMP OUTPUT BISTABLES IN 3 OF 4 CHANNELS	1.2E-5
			WES-CCP-CF-P3OF4	CCF 3 ANALOG PRES PROCESS LOGIC MODULES IN 3 OF 4 CHANNELS	4.5E-6
			/WES-CCP-TM-CHA	CH-A IN T&M	9.4E-1
			WES-XHE-XE-NSGNL	OPERATOR FAILS TO RESPOND WITH NO RPS SIGNAL PRESENT	1.0E+0
63	0.0	5.0E-11	/WES-BME-TM-RTBA	RTB-A IN T&M	1.0E+0
			/WES-BME-TM-RTBB	RTB-B IN T&M	1.0E+0
			WES-BSN-FF-RTBA	RTB-A SHUNT TRIP DEVICE LOCAL FAULTS	5.8E-4
			WES-BUV-FF-RTBA	RTB-A UV DEVICE LOCAL FAULTS	2.5E-4
			WES-UVL-FF-UVDB	TRAIN B UV DRIVER FAILS	3.4E-4
			WES-XHE-XE-SIGNL	OPERATOR FAILS TO RESPOND WITH RPS SIGNAL PRESENT	1.0E+0
64	0.0	5.0E-11	/WES-BME-TM-RTBA	RTB-A IN T&M	1.0E+0
			/WES-BME-TM-RTBB	RTB-B IN T&M	1.0E+0
			WES-BSN-FF-RTBB	RTB-B SHUNT TRIP DEVICE LOCAL FAULTS	5.8E-4
			WES-BUV-FF-RTBB	RTB-B UV DEVICE LOCAL FAULTS	2.5E-4
			WES-UVL-FF-UVDA	TRAIN A UV DRIVER FAILS	3.4E-4
			WES-XHE-XE-SIGNL	OPERATOR FAILS TO RESPOND WITH RPS SIGNAL PRESENT	1.0E+0
65	0.0	4.9E-11	/WES-BME-TM-RTBA	RTB-A IN T&M	1.0E+0
			/WES-BME-TM-RTBB	RTB-B IN T&M	1.0E+0
			WES-TLC-FF-SSLAP	TRAIN A PRESSURE SOLID STATE LOGIC FAILS	3.8E-4
			WES-TLC-FF-SSLAT	TRAIN A TEMPERATURE SOLID STATE LOGIC FAILS	3.8E-4
			WES-UVL-FF-UVDB	TRAIN B UV DRIVER FAILS	3.4E-4
			WES-XHE-XE-SIGNL	OPERATOR FAILS TO RESPOND WITH RPS SIGNAL PRESENT	1.0E+0
66	0.0	4.9E-11	/WES-BME-TM-RTBA	RTB-A IN T&M	1.0E+0
			/WES-BME-TM-RTBB	RTB-B IN T&M	1.0E+0
			WES-TLC-FF-SSLBP	TRAIN B PRESSURE SOLID STATE LOGIC FAILS	3.8E-4
			WES-TLC-FF-SSLBT	TRAIN B TEMPERATURE SOLID STATE LOGIC FAILS	3.8E-4
			WES-UVL-FF-UVDA	TRAIN A UV DRIVER FAILS	3.4E-4
			WES-XHE-XE-SIGNL	OPERATOR FAILS TO RESPOND WITH RPS SIGNAL PRESENT	1.0E+0
67	0.0	3.6E-11	/WES-BME-TM-RTBA	RTB-A IN T&M	1.0E+0
			/WES-BME-TM-RTBB	RTB-B IN T&M	1.0E+0
			WES-CBI-CF-T2OF3	CCF 2 TEMP OUTPUT BISTABLES IN 2 OF 3 CHANNELS	4.2E-5
			WES-CCP-CF-P2OF3	CCF 2 ANALOG PRES PROCESS LOGIC MODULES IN 2 OF 3 CHANNELS	1.5E-5
			WES-CCP-TM-CHA	CH-A IN T&M	5.8E-2
			WES-XHE-XE-NSGNL	OPERATOR FAILS TO RESPOND WITH NO RPS SIGNAL PRESENT	1.0E+0
68	0.0	3.3E-11	/WES-BME-TM-RTBA	RTB-A IN T&M	1.0E+0
			/WES-BME-TM-RTBB	RTB-B IN T&M	1.0E+0
			WES-CCP-TM-CHA	CH-A IN T&M	5.8E-2
			WES-CPR-CF-P2OF3	CCF 2 PRESSURE SENSORS IN 2 OF 3 CHANNELS	7.7E-6
			WES-CTP-CF-T2OF6	CCF 2 TEMP SENSORS IN 2 OF 3 CHANNELS	7.5E-5
			WES-XHE-XE-NSGNL	OPERATOR FAILS TO RESPOND WITH NO RPS SIGNAL PRESENT	1.0E+0
69	0.0	3.3E-11	/WES-BME-TM-RTBA	RTB-A IN T&M	1.0E+0
			/WES-BME-TM-RTBB	RTB-B IN T&M	1.0E+0
			WES-BUV-CF-RTBAB	CCF OF RTB-A AND RTB-B UV DEVICES	9.7E-6
			WES-PWR-CF-TRNAB	CCF OF RTB-A AND RTB-B SHUNT TRIP POWER SUPPLIES	3.4E-6
70	0.0	2.3E-11	/WES-BME-TM-RTBA	RTB-A IN T&M	1.0E+0
			/WES-BME-TM-RTBB	RTB-B IN T&M	1.0E+0
			WES-CBI-CF-T3OF4	CCF 3 TEMP OUTPUT BISTABLES IN 3 OF 4 CHANNELS	1.2E-5
			/WES-CCP-TM-CHA	CH-A IN T&M	9.4E-1
			WES-CPR-CF-P3OF4	CCF 3 PRESSURE SENSORS IN 3 OF 4 CHANNELS	2.1E-6
			WES-XHE-XE-NSGNL	OPERATOR FAILS TO RESPOND WITH NO RPS SIGNAL PRESENT	1.0E+0
71	0.0	2.0E-11	/WES-BME-TM-RTBA	RTB-A IN T&M	1.0E+0
			/WES-BME-TM-RTBB	RTB-B IN T&M	1.0E+0

Table F-1. (continued).

Cut Set	Cut Set Percent	Cut Set Prob.	Basic Event[a]	Description	Prob.
			WES-CCP-TM-CHA	CH-A IN T&M	5.8E-2
			WES-TLR-CF-RLA46	CCF 4 OR MORE TMU RELAYS IN TRAIN A ONE CHANNEL T&M	1.0E-6
			WES-UVL-FF-UVDB	TRAIN B UV DRIVER FAILS	3.4E-4
			WES-XHE-XE-SIGNL	OPERATOR FAILS TO RESPOND WITH RPS SIGNAL PRESENT	1.0E+0
72	0.0	2.0E-11	/WES-BME-TM-RTBA	RTB-A IN T&M	1.0E+0
			/WES-BME-TM-RTBB	RTB-B IN T&M	1.0E+0
			WES-CCP-TM-CHA	CH-A IN T&M	5.8E-2
			WES-TLR-CF-RLB46	CCF 4 OR MORE TMU RELAYS IN TRAIN B ONE CHANNEL T&M	1.0E-6
			WES-UVL-FF-UVDA	TRAIN A UV DRIVER FAILS	3.4E-4
			WES-XHE-XE-SIGNL	OPERATOR FAILS TO RESPOND WITH RPS SIGNAL PRESENT	1.0E+0
73	0.0	1.9E-11	/WES-BME-TM-RTBA	RTB-A IN T&M	1.0E+0
			/WES-BME-TM-RTBB	RTB-B IN T&M	1.0E+0
			WES-BUV-CF-RTBAB	CCF OF RTB-A AND RTB-B UV DEVICES	9.7E-6
			WES-TLR-CF-RTBAB	CCF OF RTB-A AND RTB-B SHUNT TRIP RELAYS	2.0E-6
74	0.0	1.9E-11	/WES-BME-TM-RTBA	RTB-A IN T&M	1.0E+0
			/WES-BME-TM-RTBB	RTB-B IN T&M	1.0E+0
			WES-CBI-CF-T2OF3	CCF 2 TEMP OUTPUT BISTABLES IN 2 OF 3 CHANNELS	4.2E-5
			WES-CCP-TM-CHA	CH-A IN T&M	5.8E-2
			WES-CPR-CF-P2OF3	CCF 2 PRESSURE SENSORS IN 2 OF 3 CHANNELS	7.7E-6
			WES-XHE-XE-NSGNL	OPERATOR FAILS TO RESPOND WITH NO RPS SIGNAL PRESENT	1.0E+0
75	0.0	1.7E-11	WES-BME-TM-RTBA	RTB-A IN T&M	1.4E-3
			/WES-BME-TM-RTBB	RTB-B IN T&M	1.0E+0
			WES-CCP-TM-CHA	CH-A IN T&M	5.8E-2
			WES-TLR-CF-8OF12	CCF 8 OR MORE TMU RELAYS IN TRAINS A AND B ONE CHANNEL T&M	2.1E-7
			WES-XHE-XE-SIGNL	OPERATOR FAILS TO RESPOND WITH RPS SIGNAL PRESENT	1.0E+0
76	0.0	1.7E-11	/WES-BME-TM-RTBA	RTB-A IN T&M	1.0E+0
			WES-BME-TM-RTBB	RTB-B IN T&M	1.4E-3
			WES-CCP-TM-CHA	CH-A IN T&M	5.8E-2
			WES-TLR-CF-8OF12	CCF 8 OR MORE TMU RELAYS IN TRAINS A AND B ONE CHANNEL T&M	2.1E-7
			WES-XHE-XE-SIGNL	OPERATOR FAILS TO RESPOND WITH RPS SIGNAL PRESENT	1.0E+0
77	0.0	1.1E-11	WES-BME-FO-RTBA	RTB-A LOCAL HW FAILURE	3.7E-5
			/WES-BME-TM-RTBA	RTB-A IN T&M	1.0E+0
			/WES-BME-TM-RTBB	RTB-B IN T&M	1.0E+0
			/WES-CCP-TM-CHA	CH-A IN T&M	9.4E-1
			WES-TLR-CF-RLB68	CCF 6 OR MORE TMU RELAYS IN TRAIN B NO CHANNEL T&M	3.3E-7
			WES-XHE-XE-SIGNL	OPERATOR FAILS TO RESPOND WITH RPS SIGNAL PRESENT	1.0E+0
78	0.0	1.1E-11	WES-BME-FO-RTBB	RTB-B LOCAL HW FAILURE	3.7E-5
			/WES-BME-TM-RTBA	RTB-A IN T&M	1.0E+0
			/WES-BME-TM-RTBB	RTB-B IN T&M	1.0E+0
			/WES-CCP-TM-CHA	CH-A IN T&M	9.4E-1
			WES-TLR-CF-RLA68	CCF 6 OR MORE TMU RELAYS IN TRAIN A NO CHANNEL T&M	3.3E-7
			WES-XHE-XE-SIGNL	OPERATOR FAILS TO RESPOND WITH RPS SIGNAL PRESENT	1.0E+0
79	0.0	5.4E-12	WES-BME-FO-RTBA	RTB-A LOCAL HW FAILURE	3.7E-5
			/WES-BME-TM-RTBA	RTB-A IN T&M	1.0E+0
			/WES-BME-TM-RTBB	RTB-B IN T&M	1.0E+0
			WES-BSN-FF-RTBB	RTB-B SHUNT TRIP DEVICE LOCAL FAULTS	5.8E-4
			WES-BUV-FF-RTBB	RTB-B UV DEVICE LOCAL FAULTS	2.5E-4
80	0.0	5.4E-12	WES-BME-FO-RTBB	RTB-B LOCAL HW FAILURE	3.7E-5
			/WES-BME-TM-RTBA	RTB-A IN T&M	1.0E+0
			/WES-BME-TM-RTBB	RTB-B IN T&M	1.0E+0
			WES-BSN-FF-RTBA	RTB-A SHUNT TRIP DEVICE LOCAL FAULTS	5.8E-4
			WES-BUV-FF-RTBA	RTB-A UV DEVICE LOCAL FAULTS	2.5E-4
81	0.0	5.4E-12	WES-BME-FO-RTBA	RTB-A LOCAL HW FAILURE	3.7E-5
			/WES-BME-TM-RTBA	RTB-A IN T&M	1.0E+0
			/WES-BME-TM-RTBB	RTB-B IN T&M	1.0E+0
			WES-TLC-FF-SSLBP	TRAIN B PRESSURE SOLID STATE LOGIC FAILS	3.8E-4
			WES-TLC-FF-SSLBT	TRAIN B TEMPERATURE SOLID STATE LOGIC FAILS	3.8E-4
			WES-XHE-XE-SIGNL	OPERATOR FAILS TO RESPOND WITH RPS SIGNAL PRESENT	1.0E+0
82	0.0	5.4E-12	WES-BME-FO-RTBB	RTB-B LOCAL HW FAILURE	3.7E-5
			/WES-BME-TM-RTBA	RTB-A IN T&M	1.0E+0
			/WES-BME-TM-RTBB	RTB-B IN T&M	1.0E+0
			WES-TLC-FF-SSLAP	TRAIN A PRESSURE SOLID STATE LOGIC FAILS	3.8E-4
			WES-TLC-FF-SSLAT	TRAIN A TEMPERATURE SOLID STATE LOGIC FAILS	3.8E-4
			WES-XHE-XE-SIGNL	OPERATOR FAILS TO RESPOND WITH RPS SIGNAL PRESENT	1.0E+0
83	0.0	5.3E-12	/WES-BME-TM-RTBA	RTB-A IN T&M	1.0E+0
			/WES-BME-TM-RTBB	RTB-B IN T&M	1.0E+0
			/WES-CCP-TM-CHA	CH-A IN T&M	9.4E-1

Cut Set	Cut Set Percent	Cut Set Prob.	Basic Event[a]	Description	Prob.
			WES-TLC-CF-SSLA	CCF SOLID STATE LOGIC TRAIN A (2 OF 4)	1.7E-5
			WES-TLR-CF-RLB68	CCF 6 OR MORE TMU RELAYS IN TRAIN B NO CHANNEL T&M	3.3E-7
			WES-XHE-XE-SIGNL	OPERATOR FAILS TO RESPOND WITH RPS SIGNAL PRESENT	1.0E+0
84	0.0	5.3E-12	/WES-BME-TM-RTBA	RTB-A IN T&M	1.0E+0
			/WES-BME-TM-RTBB	RTB-B IN T&M	1.0E+0
			/WES-CCP-TM-CHA	CH-A IN T&M	9.4E-1
			WES-TLC-CF-SSLB	CCF SOLID STATE LOGIC TRAIN B (2 OF 4)	1.7E-5
			WES-TLR-CF-RLA68	CCF 6 OR MORE TMU RELAYS IN TRAIN A NO CHANNEL T&M	3.3E-7
			WES-XHE-XE-SIGNL	OPERATOR FAILS TO RESPOND WITH RPS SIGNAL PRESENT	1.0E+0
85	0.0	5.1E-12	/WES-BME-TM-RTBA	RTB-A IN T&M	1.0E+0
			/WES-BME-TM-RTBB	RTB-B IN T&M	1.0E+0
			WES-BUV-FF-RTBA	RTB-A UV DEVICE LOCAL FAULTS	2.5E-4
			WES-PWR-FF-TRNA	TRAIN A 125 VDC BUS FAILS	6.0E-5
			WES-UVL-FF-UVDB	TRAIN B UV DRIVER FAILS	3.4E-4
			WES-XHE-XE-SIGNL	OPERATOR FAILS TO RESPOND WITH RPS SIGNAL PRESENT	1.0E+0
86	0.0	5.1E-12	/WES-BME-TM-RTBA	RTB-A IN T&M	1.0E+0
			/WES-BME-TM-RTBB	RTB-B IN T&M	1.0E+0
			WES-BUV-FF-RTBB	RTB-B UV DEVICE LOCAL FAULTS	2.5E-4
			WES-PWR-FF-TRNB	TRAIN B 125 VDC BUS FAILS	6.0E-5
			WES-UVL-FF-UVDA	TRAIN A UV DRIVER FAILS	3.4E-4
			WES-XHE-XE-SIGNL	OPERATOR FAILS TO RESPOND WITH RPS SIGNAL PRESENT	1.0E+0
87	0.0	3.4E-12	/WES-BME-TM-RTBA	RTB-A IN T&M	1.0E+0
			/WES-BME-TM-RTBB	RTB-B IN T&M	1.0E+0
			WES-BUV-FF-RTBA	RTB-A UV DEVICE LOCAL FAULTS	2.5E-4
			WES-TLR-FC-RLYSA	SHUNT TRIP RELAY SA FAILS	3.9E-5
			WES-UVL-FF-UVDB	TRAIN B UV DRIVER FAILS	3.4E-4
			WES-XHE-XE-SIGNL	OPERATOR FAILS TO RESPOND WITH RPS SIGNAL PRESENT	1.0E+0
88	0.0	3.4E-12	/WES-BME-TM-RTBA	RTB-A IN T&M	1.0E+0
			/WES-BME-TM-RTBB	RTB-B IN T&M	1.0E+0
			WES-BUV-FF-RTBB	RTB-B UV DEVICE LOCAL FAULTS	2.5E-4
			WES-TLR-FC-RLYSB	SHUNT TRIP RELAY SB FAILS	3.9E-5
			WES-UVL-FF-UVDA	TRAIN A UV DRIVER FAILS	3.4E-4
			WES-XHE-XE-SIGNL	OPERATOR FAILS TO RESPOND WITH RPS SIGNAL PRESENT	1.0E+0
89	0.0	2.5E-12	/WES-BME-TM-RTBA	RTB-A IN T&M	1.0E+0
			/WES-BME-TM-RTBB	RTB-B IN T&M	1.0E+0
			WES-BSN-FF-RTBA	RTB-A SHUNT TRIP DEVICE LOCAL FAULTS	5.8E-4
			WES-BUV-FF-RTBA	RTB-A UV DEVICE LOCAL FAULTS	2.5E-4
			WES-TLC-CF-SSLB	CCF SOLID STATE LOGIC TRAIN B (2 OF 4)	1.7E-5
			WES-XHE-XE-SIGNL	OPERATOR FAILS TO RESPOND WITH RPS SIGNAL PRESENT	1.0E+0
90	0.0	2.5E-12	/WES-BME-TM-RTBA	RTB-A IN T&M	1.0E+0
			/WES-BME-TM-RTBB	RTB-B IN T&M	1.0E+0
			WES-BSN-FF-RTBB	RTB-B SHUNT TRIP DEVICE LOCAL FAULTS	5.8E-4
			WES-BUV-FF-RTBB	RTB-B UV DEVICE LOCAL FAULTS	2.5E-4
			WES-TLC-CF-SSLA	CCF SOLID STATE LOGIC TRAIN A (2 OF 4)	1.7E-5
			WES-XHE-XE-SIGNL	OPERATOR FAILS TO RESPOND WITH RPS SIGNAL PRESENT	1.0E+0
91	0.0	2.5E-12	/WES-BME-TM-RTBA	RTB-A IN T&M	1.0E+0
			/WES-BME-TM-RTBB	RTB-B IN T&M	1.0E+0
			WES-TLC-CF-SSLA	CCF SOLID STATE LOGIC TRAIN A (2 OF 4)	1.7E-5
			WES-TLC-FF-SSLBP	TRAIN B PRESSURE SOLID STATE LOGIC FAILS	3.8E-4
			WES-TLC-FF-SSLBT	TRAIN B TEMPERATURE SOLID STATE LOGIC FAILS	3.8E-4
			WES-XHE-XE-SIGNL	OPERATOR FAILS TO RESPOND WITH RPS SIGNAL PRESENT	1.0E+0
92	0.0	2.5E-12	/WES-BME-TM-RTBA	RTB-A IN T&M	1.0E+0
			/WES-BME-TM-RTBB	RTB-B IN T&M	1.0E+0
			WES-TLC-CF-SSLB	CCF SOLID STATE LOGIC TRAIN B (2 OF 4)	1.7E-5
			WES-TLC-FF-SSLAP	TRAIN A PRESSURE SOLID STATE LOGIC FAILS	3.8E-4
			WES-TLC-FF-SSLAT	TRAIN A TEMPERATURE SOLID STATE LOGIC FAILS	3.8E-4
			WES-XHE-XE-SIGNL	OPERATOR FAILS TO RESPOND WITH RPS SIGNAL PRESENT	1.0E+0
93	0.0	2.1E-12	WES-BME-FO-RTBA	RTB-A LOCAL HW FAILURE	3.7E-5
			/WES-BME-TM-RTBA	RTB-A IN T&M	1.0E+0
			/WES-BME-TM-RTBB	RTB-B IN T&M	1.0E+0
			WES-CCP-TM-CHA	CH-A IN T&M	5.8E-2
			WES-TLR-CF-RLB46	CCF 4 OR MORE TMU RELAYS IN TRAIN B ONE CHANNEL T&M	1.0E-6
			WES-XHE-XE-SIGNL	OPERATOR FAILS TO RESPOND WITH RPS SIGNAL PRESENT	1.0E+0
94	0.0	2.1E-12	WES-BME-FO-RTBB	RTB-B LOCAL HW FAILURE	3.7E-5
			/WES-BME-TM-RTBA	RTB-A IN T&M	1.0E+0
			/WES-BME-TM-RTBB	RTB-B IN T&M	1.0E+0
			WES-CCP-TM-CHA	CH-A IN T&M	5.8E-2
			WES-TLR-CF-RLA46	CCF 4 OR MORE TMU RELAYS IN TRAIN A ONE CHANNEL T&M	1.0E-6
			WES-XHE-XE-SIGNL	OPERATOR FAILS TO RESPOND WITH RPS SIGNAL PRESENT	1.0E+0
95	0.0	1.9E-12	WES-BME-FO-BYBA	BYB-A LOCAL HW FAILURE	3.7E-5

Table F-1. (continued).

Cut Set	Cut Set Percent	Cut Set Prob.	Basic Event[a]	Description	Prob.
			WES-BME-FO-RTBB	RTB-B LOCAL HW FAILURE	3.7E-5
			WES-BME-TM-RTBA	RTB-A IN T&M	1.4E-3
			/WES-BME-TM-RTBB	RTB-B IN T&M	1.0E+0
96	0.0	1.9E-12	WES-BME-FO-BYBB	BYB-B LOCAL HW FAILURE	3.7E-5
			WES-BME-FO-RTBA	RTB-A LOCAL HW FAILURE	3.7E-5
			/WES-BME-TM-RTBA	RTB-A IN T&M	1.0E+0
			WES-BME-TM-RTBB	RTB-B IN T&M	1.4E-3
97	0.0	9.9E-13	/WES-BME-TM-RTBA	RTB-A IN T&M	1.0E+0
			/WES-BME-TM-RTBB	RTB-B IN T&M	1.0E+0
			WES-CCP-TM-CHA	CH-A IN T&M	5.8E-2
			WES-TLC-CF-SSLA	CCF SOLID STATE LOGIC TRAIN A (2 OF 4)	1.7E-5
			WES-TLR-CF-RLB46	CCF 4 OR MORE TMU RELAYS IN TRAIN B ONE CHANNEL T&M	1.0E-6
			WES-XHE-XE-SIGNL	OPERATOR FAILS TO RESPOND WITH RPS SIGNAL PRESENT	1.0E+0
98	0.0	9.9E-13	/WES-BME-TM-RTBA	RTB-A IN T&M	1.0E+0
			/WES-BME-TM-RTBB	RTB-B IN T&M	1.0E+0
			WES-CCP-TM-CHA	CH-A IN T&M	5.8E-2
			WES-TLC-CF-SSLB	CCF SOLID STATE LOGIC TRAIN B (2 OF 4)	1.7E-5
			WES-TLR-CF-RLA46	CCF 4 OR MORE TMU RELAYS IN TRAIN A ONE CHANNEL T&M	1.0E-6
			WES-XHE-XE-SIGNL	OPERATOR FAILS TO RESPOND WITH RPS SIGNAL PRESENT	1.0E+0
99	0.0	8.7E-13	WES-BME-TM-RTBA	RTB-A IN T&M	1.4E-3
			/WES-BME-TM-RTBB	RTB-B IN T&M	1.0E+0
			WES-CBI-CF-P3OF4	CCF 3 PRESSURE OUTPUT BISTABLES IN 3 OF 4 CHANNELS	1.2E-5
			/WES-CCP-TM-CHA	CH-A IN T&M	9.4E-1
			WES-CDT-CF-T3OF4	CCF 3 ANALOG TEMP PROCESS LOGIC MODULES IN 3 OF 4 CHANNELS	5.6E-5
			WES-XHE-XE-NSGNL	OPERATOR FAILS TO RESPOND WITH NO RPS SIGNAL PRESENT	1.0E+0
100	0.0	8.7E-13	/WES-BME-TM-RTBA	RTB-A IN T&M	1.0E+0
			WES-BME-TM-RTBB	RTB-B IN T&M	1.4E-3
			WES-CBI-CF-P3OF4	CCF 3 PRESSURE OUTPUT BISTABLES IN 3 OF 4 CHANNELS	1.2E-5
			/WES-CCP-TM-CHA	CH-A IN T&M	9.4E-1
			WES-CDT-CF-T3OF4	CCF 3 ANALOG TEMP PROCESS LOGIC MODULES IN 3 OF 4 CHANNELS	5.6E-5
			WES-XHE-XE-NSGNL	OPERATOR FAILS TO RESPOND WITH NO RPS SIGNAL PRESENT	1.0E+0

a. A / as the first character in a basic event name indicates a complemented event (Success = 1 - Failure). For example, the basic event for reactor trip breaker train A (RTB-A) in test and maintenance (T&M) is WES-BME-TM-RTBA (Failure = 1.40E-03). Thus, the basic event name for RTB-A not in T&M is /WES-BME-TM-RTBA (Success = 9.986E-01). The event description for complemented events remains the same as the description used for the failure event.

Table F-2. Importance measures sorted on Fussell-Vesely for case with RPS mincut = 2.2E-5.

Basic Event	Number of Occur.	Prob. of Failure	Fussell-Vesely Importance	Risk Reduction Ratio	Risk Increase Ratio	Birnbaum Importance
WES-XHE-XE-SIGNL	960	1.00E+0	6.338E-01	2.730	1.000E+0	1.373E-05
WES-UVL-CF-UVDAB	3	1.04E-5	4.800E-01	1.923	4.603E+4	9.972E-01
WES-XHE-XE-NSGNL	22098	1.00E+0	2.360E-01	1.309	1.000E+0	5.114E-06
WES-CBI-CF-6OF8	3	2.70E-6	1.174E-01	1.133	4.336E+4	9.395E-01
WES-TLC-CF-SSLAB	3	2.10E-6	9.692E-02	1.107	4.603E+4	9.972E-01
WES-CCX-CF-6OF8	3	1.83E-6	7.956E-02	1.086	4.336E+4	9.395E-01
WES-BME-CF-RTBAB	1	1.61E-6	7.410E-02	1.080	4.603E+4	9.972E-01
WES-ROD-CF-RCCAS	1	1.21E-6	5.585E-02	1.059	4.615E+4	1.000E+00
WES-UVL-FF-UVDA	37	3.37E-4	2.782E-02	1.029	8.350E+1	1.788E-03
WES-UVL-FF-UVDB	37	3.37E-4	2.782E-02	1.029	8.350E+1	1.788E-03
WES-CCP-TM-CHA	23013	5.80E-2	2.720E-02	1.028	1.442E+0	1.016E-05
WES-BME-TM-RTBA	23106	1.40E-3	2.284E-02	1.023	1.729E+1	3.535E-04
WES-BME-TM-RTBB	23106	1.40E-3	2.284E-02	1.023	1.729E+1	3.535E-04
WES-CBI-CF-4OF6	3	8.21E-6	2.198E-02	1.023	2.677E+3	5.799E-02
WES-CCX-CF-4OF6	3	6.33E-6	1.694E-02	1.017	2.677E+3	5.799E-02
WES-TLR-CF-12O16	3	8.07E-8	3.509E-03	1.004	4.336E+4	9.395E-01
WES-TLC-CF-SSLA	37	1.72E-5	1.420E-03	1.001	8.353E+1	1.788E-03
WES-TLC-CF-SSLB	37	1.72E-5	1.420E-03	1.001	8.353E+1	1.788E-03
WES-BME-FO-RTBA	40	3.69E-5	6.655E-04	1.001	1.903E+1	3.907E-04
WES-BME-FO-RTBB	40	3.69E-5	6.655E-04	1.001	1.903E+1	3.907E-04
WES-TLR-CF-8OF12	3	2.07E-7	5.541E-04	1.001	2.677E+3	5.799E-02
WES-BME-CF-RANBB	1	1.61E-6	1.039E-04	1.000	6.552E+1	1.398E-03
WES-BME-CF-RBNBA	1	1.61E-6	1.039E-04	1.000	6.552E+1	1.398E-03
WES-CBI-CF-P3OF4	9	1.19E-5	5.401E-05	1.000	5.539E+0	9.834E-05
WES-CDT-CF-T3OF4	9	5.55E-5	4.449E-05	1.000	1.802E+0	1.737E-05
WES-CDT-CF-T2OF3	9	2.50E-4	4.324E-05	1.000	1.173E+0	3.747E-06
WES-CBI-CF-P2OF3	9	4.19E-5	4.111E-05	1.000	1.981E+0	2.126E-05
WES-CTP-CF-T3OF8	9	3.70E-5	2.966E-05	1.000	1.802E+0	1.737E-05
WES-TLR-CF-RLA68	26	3.28E-7	2.551E-05	1.000	7.874E+1	1.684E-03
WES-TLR-CF-RLB68	26	3.28E-7	2.551E-05	1.000	7.874E+1	1.684E-03
WES-CCP-CF-P3OF4	9	4.48E-6	2.033E-05	1.000	5.539E+0	9.834E-05
WES-CCP-CF-P2OF3	9	1.50E-5	1.472E-05	1.000	1.981E+0	2.126E-05
WES-CTP-CF-T2OF6	9	7.46E-5	1.290E-05	1.000	1.173E+0	3.747E-06
WES-TLC-FF-SSLAP	37	3.83E-4	1.211E-05	1.000	1.032E+0	6.851E-07
WES-TLC-FF-SSLAT	37	3.83E-4	1.211E-05	1.000	1.032E+0	6.851E-07
WES-TLC-FF-SSLBP	37	3.83E-4	1.211E-05	1.000	1.032E+0	6.851E-07
WES-TLC-FF-SSLBT	37	3.83E-4	1.211E-05	1.000	1.032E+0	6.851E-07
WES-BUV-CF-RTBAB	3	9.73E-6	1.182E-05	1.000	2.215E+0	2.633E-05
WES-CBI-CF-T3OF4	9	1.19E-5	9.540E-06	1.000	1.802E+0	1.737E-05
WES-BSN-CF-RTBAB	1	2.10E-5	9.404E-06	1.000	1.448E+0	9.703E-06
WES-CPR-CF-P3OF4	9	2.06E-6	9.350E-06	1.000	5.539E+0	9.834E-05
WES-CPR-CF-P2OF3	9	7.71E-6	7.564E-06	1.000	1.981E+0	2.126E-05
WES-CBI-CF-T2OF3	9	4.19E-5	7.247E-06	1.000	1.173E+0	3.747E-06
WES-TLR-CF-RLA46	19	9.98E-7	4.780E-06	1.000	5.790E+0	1.038E-04
WES-TLR-CF-RLB46	19	9.98E-7	4.780E-06	1.000	5.790E+0	1.038E-04
WES-BUV-FF-RTBA	114	2.54E-4	3.117E-06	1.000	1.012E+0	2.659E-07
WES-BUV-FF-RTBB	114	2.54E-4	3.117E-06	1.000	1.012E+0	2.659E-07
WES-BSN-FF-RTBA	38	5.81E-4	2.661E-06	1.000	1.005E+0	9.925E-08
WES-BSN-FF-RTBB	38	5.81E-4	2.661E-06	1.000	1.005E+0	9.925E-08
WES-PWR-CF-TRNAB	1	3.40E-6	1.523E-06	1.000	1.448E+0	9.703E-06
WES-TLR-CF-RTBAB	1	2.00E-6	8.956E-07	1.000	1.448E+0	9.703E-06
WES-PWR-FF-TRNA	40	6.00E-5	3.128E-07	1.000	1.005E+0	1.130E-07
WES-PWR-FF-TRNB	40	6.00E-5	3.128E-07	1.000	1.005E+0	1.130E-07
WES-TLR-FC-RLYSA	40	3.94E-5	2.054E-07	1.000	1.005E+0	1.130E-07
WES-TLR-FC-RLYSB	40	3.94E-5	2.054E-07	1.000	1.005E+0	1.130E-07
WES-CBI-FF-BSTPB	5472	7.46E-4	1.864E-07	1.000	1.000E+0	5.422E-09
WES-CBI-FF-BSTPC	5472	7.46E-4	1.864E-07	1.000	1.000E+0	5.422E-09
WES-CBI-FF-BSTPD	5472	7.46E-4	1.864E-07	1.000	1.000E+0	5.422E-09
WES-CDT-FF-ANLTB	4104	4.83E-3	1.816E-07	1.000	1.000E+0	8.158E-10
WES-CDT-FF-ANLTC	4104	4.83E-3	1.816E-07	1.000	1.000E+0	8.158E-10
WES-CDT-FF-ANLTD	4104	4.83E-3	1.816E-07	1.000	1.000E+0	8.158E-10
WES-BME-FO-BYBA	4	3.69E-5	8.827E-08	1.000	1.002E+0	5.183E-08
WES-BME-FO-BYBB	4	3.69E-5	8.827E-08	1.000	1.002E+0	5.183E-08
WES-BUV-CF-RANBB	3	9.73E-6	7.559E-08	1.000	1.008E+0	1.683E-07
WES-BUV-CF-RBNBA	3	9.73E-6	7.559E-08	1.000	1.008E+0	1.683E-07
WES-CCP-FF-ANLPB	5472	1.57E-4	3.917E-08	1.000	1.000E+0	5.422E-09
WES-CCP-FF-ANLPC	5472	1.57E-4	3.917E-08	1.000	1.000E+0	5.422E-09
WES-CCP-FF-ANLPD	5472	1.57E-4	3.917E-08	1.000	1.000E+0	5.422E-09

Table F-2. (continued).

Basic Event	Number of Occur.	Prob. of Failure	Fussell-Vesely Importance	Risk Reduction Ratio	Risk Increase Ratio	Birnbaum Importance
WES-CPR-FF-PRESB	5472	1.16E-4	2.889E-08	1.000	1.000E+0	5.422E-09
WES-CPR-FF-PRESC	5472	1.16E-4	2.889E-08	1.000	1.000E+0	5.422E-09
WES-CPR-FF-PRESD	5472	1.16E-4	2.889E-08	1.000	1.000E+0	5.422E-09
WES-CBI-FF-BSTTB	4104	7.46E-4	2.798E-08	1.000	1.000E+0	8.158E-10
WES-CBI-FF-BSTTC	4104	7.46E-4	2.798E-08	1.000	1.000E+0	8.158E-10
WES-CBI-FF-BSTTD	4104	7.46E-4	2.798E-08	1.000	1.000E+0	8.158E-10
WES-CTP-FF-CLTXB	4104	5.98E-4	2.244E-08	1.000	1.000E+0	8.158E-10
WES-CTP-FF-CLTXC	4104	5.98E-4	2.244E-08	1.000	1.000E+0	8.158E-10
WES-CTP-FF-CLTXD	4104	5.98E-4	2.244E-08	1.000	1.000E+0	8.158E-10
WES-CTP-FF-HLTXB	4104	5.98E-4	2.244E-08	1.000	1.000E+0	8.158E-10
WES-CTP-FF-HLTXC	4104	5.98E-4	2.244E-08	1.000	1.000E+0	8.158E-10
WES-CTP-FF-HLTXD	4104	5.98E-4	2.244E-08	1.000	1.000E+0	8.158E-10
WES-BSN-CF-RANBB	1	2.10E-5	1.318E-08	1.000	1.001E+0	1.360E-08
WES-BSN-CF-RBNBA	1	2.10E-5	1.318E-08	1.000	1.001E+0	1.360E-08
WES-BUV-FF-BYBA	6	2.54E-4	8.301E-10	1.000	1.000E+0	7.052E-11
WES-BUV-FF-BYBB	6	2.54E-4	8.301E-10	1.000	1.000E+0	7.052E-11
WES-BSN-FF-BYBA	2	5.81E-4	3.536E-10	1.000	1.000E+0	1.316E-11
WES-BSN-FF-BYBB	2	5.81E-4	3.536E-10	1.000	1.000E+0	1.316E-11
WES-TLR-CF-PRA34	26	1.52E-6	1.793E-10	1.000	1.000E+0	2.561E-09
WES-TLR-CF-PRB34	26	1.52E-6	1.793E-10	1.000	1.000E+0	2.561E-09
WES-TLR-CF-TRA34	26	1.52E-6	1.793E-10	1.000	1.000E+0	2.561E-09
WES-TLR-CF-TRB34	26	1.52E-6	1.793E-10	1.000	1.000E+0	2.561E-09
WES-TLR-CF-PRA23	19	5.10E-6	1.230E-10	1.000	1.000E+0	5.293E-10
WES-TLR-CF-PRB23	19	5.10E-6	1.230E-10	1.000	1.000E+0	5.293E-10
WES-TLR-CF-TRA23	19	5.10E-6	1.230E-10	1.000	1.000E+0	5.293E-10
WES-TLR-CF-TRB23	19	5.10E-6	1.230E-10	1.000	1.000E+0	5.293E-10
WES-CBI-FF-BSTPA	5184	7.46E-4	+0.000E+00	1.000	1.000E+0	8.939E-13
WES-CBI-FF-BSTTA	3888	7.46E-4	+0.000E+00	1.000	1.000E+0	1.252E-13
WES-CCP-FF-ANLPA	5184	1.57E-4	+0.000E+00	1.000	1.000E+0	8.939E-13
WES-CDT-FF-ANLTA	3888	4.83E-3	+0.000E+00	1.000	1.000E+0	1.252E-13
WES-CPR-FF-PRESA	5184	1.16E-4	+0.000E+00	1.000	1.000E+0	8.939E-13
WES-CTP-FF-CLTXA	3888	5.98E-4	+0.000E+00	1.000	1.000E+0	1.252E-13
WES-CTP-FF-HLTXA	3888	5.98E-4	+0.000E+00	1.000	1.000E+0	1.252E-13
WES-TLR-FC-PRATA	312	3.94E-5	+0.000E+00	1.000	1.000E+0	+0.000E+00
WES-TLR-FC-PRATB	312	3.94E-5	+0.000E+00	1.000	1.000E+0	+0.000E+00
WES-TLR-FC-PRBTA	426	3.94E-5	+0.000E+00	1.000	1.000E+0	+0.000E+00
WES-TLR-FC-PRBTB	426	3.94E-5	+0.000E+00	1.000	1.000E+0	+0.000E+00
WES-TLR-FC-PRCTA	426	3.94E-5	+0.000E+00	1.000	1.000E+0	+0.000E+00
WES-TLR-FC-PRCTB	426	3.94E-5	+0.000E+00	1.000	1.000E+0	+0.000E+00
WES-TLR-FC-PRDTA	426	3.94E-5	+0.000E+00	1.000	1.000E+0	+0.000E+00
WES-TLR-FC-PRDTB	426	3.94E-5	+0.000E+00	1.000	1.000E+0	+0.000E+00
WES-TLR-FC-TRATA	312	3.94E-5	+0.000E+00	1.000	1.000E+0	+0.000E+00
WES-TLR-FC-TRATB	312	3.94E-5	+0.000E+00	1.000	1.000E+0	+0.000E+00
WES-TLR-FC-TRBTA	426	3.94E-5	+0.000E+00	1.000	1.000E+0	+0.000E+00
WES-TLR-FC-TRBTB	426	3.94E-5	+0.000E+00	1.000	1.000E+0	+0.000E+00
WES-TLR-FC-TRCTA	426	3.94E-5	+0.000E+00	1.000	1.000E+0	+0.000E+00
WES-TLR-FC-TRCTB	426	3.94E-5	+0.000E+00	1.000	1.000E+0	+0.000E+00
WES-TLR-FC-TRDTA	426	3.94E-5	+0.000E+00	1.000	1.000E+0	+0.000E+00
WES-TLR-FC-TRDTB	426	3.94E-5	+0.000E+00	1.000	1.000E+0	+0.000E+00

Table F-3. Importance measures sorted on Risk Increase for case with RPS mincut = 2.2E-5.

Basic Event	Number of Occur.	Prob. of Failure	Fussell-Vesely Importance	Risk Reduction Ratio	Risk Increase Ratio	Birnbaum Importance
WES-ROD-CF-RCCAS	1	1.21E-6	5.585E-02	1.059	4.615E+4	1.000E+00
WES-BME-CF-RTBAB	1	1.61E-6	7.410E-02	1.080	4.603E+4	9.972E-01
WES-TLC-CF-SSLAB	3	2.10E-6	9.692E-02	1.107	4.603E+4	9.972E-01
WES-UVL-CF-UVDAB	3	1.04E-5	4.800E-01	1.923	4.603E+4	9.972E-01
WES-CBI-CF-6OF8	3	2.70E-6	1.174E-01	1.133	4.336E+4	9.395E-01
WES-CCX-CF-6OF8	3	1.83E-6	7.956E-02	1.086	4.336E+4	9.395E-01
WES-TLR-CF-12O16	3	8.07E-8	3.509E-03	1.004	4.336E+4	9.395E-01
WES-CBI-CF-4OF6	3	8.21E-6	2.198E-02	1.023	2.677E+3	5.799E-02
WES-CCX-CF-4OF6	3	6.33E-6	1.694E-02	1.017	2.677E+3	5.799E-02
WES-TLR-CF-8OF12	3	2.07E-7	5.541E-04	1.001	2.677E+3	5.799E-02
WES-TLC-CF-SSLA	37	1.72E-5	1.420E-03	1.001	8.353E+1	1.788E-03
WES-TLC-CF-SSLB	37	1.72E-5	1.420E-03	1.001	8.353E+1	1.788E-03
WES-UVL-FF-UVDA	37	3.37E-4	2.782E-02	1.029	8.350E+1	1.788E-03
WES-UVL-FF-UVDB	37	3.37E-4	2.782E-02	1.029	8.350E+1	1.788E-03
WES-TLR-CF-RLA68	26	3.28E-7	2.551E-05	1.000	7.874E+1	1.684E-03
WES-TLR-CF-RLB68	26	3.28E-7	2.551E-05	1.000	7.874E+1	1.684E-03
WES-BME-CF-RANBB	1	1.61E-6	1.039E-04	1.000	6.552E+1	1.398E-03
WES-BME-CF-RBNBA	1	1.61E-6	1.039E-04	1.000	6.552E+1	1.398E-03
WES-BME-FO-RTBA	40	3.69E-5	6.655E-04	1.001	1.903E+1	3.907E-04
WES-BME-FO-RTBB	40	3.69E-5	6.655E-04	1.001	1.903E+1	3.907E-04
WES-BME-TM-RTBA	23106	1.40E-3	2.284E-02	1.023	1.729E+1	3.535E-04
WES-BME-TM-RTBB	23106	1.40E-3	2.284E-02	1.023	1.729E+1	3.535E-04
WES-TLR-CF-RLA46	19	9.98E-7	4.780E-06	1.000	5.790E+0	1.038E-04
WES-TLR-CF-RLB46	19	9.98E-7	4.780E-06	1.000	5.790E+0	1.038E-04
WES-CBI-CF-P3OF4	9	1.19E-5	5.401E-05	1.000	5.539E+0	9.834E-05
WES-CCP-CF-P3OF4	9	4.48E-6	2.033E-05	1.000	5.539E+0	9.834E-05
WES-CPR-CF-P3OF4	9	2.06E-6	9.350E-06	1.000	5.539E+0	9.834E-05
WES-BUV-CF-RTBAB	3	9.73E-6	1.182E-05	1.000	2.215E+0	2.633E-05
WES-CBI-CF-P2OF3	9	4.19E-5	4.111E-05	1.000	1.981E+0	2.126E-05
WES-CCP-CF-P2OF3	9	1.50E-5	1.472E-05	1.000	1.981E+0	2.126E-05
WES-CPR-CF-P2OF3	9	7.71E-6	7.564E-06	1.000	1.981E+0	2.126E-05
WES-CBI-CF-T3OF4	9	1.19E-5	9.540E-06	1.000	1.802E+0	1.737E-05
WES-CDT-CF-T3OF4	9	5.55E-5	4.449E-05	1.000	1.802E+0	1.737E-05
WES-CTP-CF-T3OF8	9	3.70E-5	2.966E-05	1.000	1.802E+0	1.737E-05
WES-BSN-CF-RTBAB	1	2.10E-5	9.404E-06	1.000	1.448E+0	9.703E-06
WES-PWR-CF-TRNAB	1	3.40E-6	1.523E-06	1.000	1.448E+0	9.703E-06
WES-TLR-CF-RTBAB	1	2.00E-6	8.956E-07	1.000	1.448E+0	9.703E-06
WES-CCP-TM-CHA	23013	5.80E-2	2.720E-02	1.028	1.442E+0	1.016E-05
WES-CBI-CF-T2OF3	9	4.19E-5	7.247E-06	1.000	1.173E+0	3.747E-06
WES-CDT-CF-T2OF3	9	2.50E-4	4.324E-05	1.000	1.173E+0	3.747E-06
WES-CTP-CF-T2OF6	9	7.46E-5	1.290E-05	1.000	1.173E+0	3.747E-06
WES-TLC-FF-SSLAP	37	3.83E-4	1.211E-05	1.000	1.032E+0	6.851E-07
WES-TLC-FF-SSLAT	37	3.83E-4	1.211E-05	1.000	1.032E+0	6.851E-07
WES-TLC-FF-SSLBP	37	3.83E-4	1.211E-05	1.000	1.032E+0	6.851E-07
WES-TLC-FF-SSLBT	37	3.83E-4	1.211E-05	1.000	1.032E+0	6.851E-07
WES-BUV-FF-RTBA	114	2.54E-4	3.117E-06	1.000	1.012E+0	2.659E-07
WES-BUV-FF-RTBB	114	2.54E-4	3.117E-06	1.000	1.012E+0	2.659E-07
WES-BUV-CF-RANBB	3	9.73E-6	7.559E-08	1.000	1.008E+0	1.683E-07
WES-BUV-CF-RBNBA	3	9.73E-6	7.559E-08	1.000	1.008E+0	1.683E-07
WES-BSN-FF-RTBA	38	5.81E-4	2.661E-06	1.000	1.005E+0	9.925E-08
WES-BSN-FF-RTBB	38	5.81E-4	2.661E-06	1.000	1.005E+0	9.925E-08
WES-PWR-FF-TRNA	40	6.00E-5	3.128E-07	1.000	1.005E+0	1.130E-07
WES-PWR-FF-TRNB	40	6.00E-5	3.128E-07	1.000	1.005E+0	1.130E-07
WES-TLR-FC-RLYSA	40	3.94E-5	2.054E-07	1.000	1.005E+0	1.130E-07
WES-TLR-FC-RLYSB	40	3.94E-5	2.054E-07	1.000	1.005E+0	1.130E-07
WES-BME-FO-BYBA	4	3.69E-5	8.827E-08	1.000	1.002E+0	5.183E-08
WES-BME-FO-BYBB	4	3.69E-5	8.827E-08	1.000	1.002E+0	5.183E-08
WES-BSN-CF-RANBB	1	2.10E-5	1.318E-08	1.000	1.001E+0	1.360E-08
WES-BSN-CF-RBNBA	1	2.10E-5	1.318E-08	1.000	1.001E+0	1.360E-08
WES-BSN-FF-BYBA	2	5.81E-4	3.536E-10	1.000	1.000E+0	1.316E-11
WES-BSN-FF-BYBB	2	5.81E-4	3.536E-10	1.000	1.000E+0	1.316E-11
WES-BUV-FF-BYBA	6	2.54E-4	8.301E-10	1.000	1.000E+0	7.052E-11
WES-BUV-FF-BYBB	6	2.54E-4	8.301E-10	1.000	1.000E+0	7.052E-11
WES-CBI-FF-BSTPA	5184	7.46E-4	+0.000E+00	1.000	1.000E+0	8.939E-13
WES-CBI-FF-BSTPB	5472	7.46E-4	1.864E-07	1.000	1.000E+0	5.422E-09
WES-CBI-FF-BSTPC	5472	7.46E-4	1.864E-07	1.000	1.000E+0	5.422E-09
WES-CBI-FF-BSTPD	5472	7.46E-4	1.864E-07	1.000	1.000E+0	5.422E-09
WES-CBI-FF-BSTTA	3888	7.46E-4	+0.000E+00	1.000	1.000E+0	1.252E-13

Table F-3. (continued).

Basic Event	Number of Occur.	Prob. of Failure	Fussell-Vesely Importance	Risk Reduction Ratio	Risk Increase Ratio	Birnbaum Importance
WES-CBI-FF-BSTTB	4104	7.46E-4	2.798E-08	1.000	1.000E+0	8.158E-10
WES-CBI-FF-BSTTC	4104	7.46E-4	2.798E-08	1.000	1.000E+0	8.158E-10
WES-CBI-FF-BSTTD	4104	7.46E-4	2.798E-08	1.000	1.000E+0	8.158E-10
WES-CCP-FF-ANLPA	5184	1.57E-4	+0.000E+00	1.000	1.000E+0	8.939E-13
WES-CCP-FF-ANLPB	5472	1.57E-4	3.917E-08	1.000	1.000E+0	5.422E-09
WES-CCP-FF-ANLPC	5472	1.57E-4	3.917E-08	1.000	1.000E+0	5.422E-09
WES-CCP-FF-ANLPD	5472	1.57E-4	3.917E-08	1.000	1.000E+0	5.422E-09
WES-CDT-FF-ANLTA	3888	4.83E-3	+0.000E+00	1.000	1.000E+0	1.252E-13
WES-CDT-FF-ANLTB	4104	4.83E-3	1.816E-07	1.000	1.000E+0	8.158E-10
WES-CDT-FF-ANLTC	4104	4.83E-3	1.816E-07	1.000	1.000E+0	8.158E-10
WES-CDT-FF-ANLTD	4104	4.83E-3	1.816E-07	1.000	1.000E+0	8.158E-10
WES-CPR-FF-PRESA	5184	1.16E-4	+0.000E+00	1.000	1.000E+0	8.939E-13
WES-CPR-FF-PRESB	5472	1.16E-4	2.889E-08	1.000	1.000E+0	5.422E-09
WES-CPR-FF-PRESC	5472	1.16E-4	2.889E-08	1.000	1.000E+0	5.422E-09
WES-CPR-FF-PRESD	5472	1.16E-4	2.889E-08	1.000	1.000E+0	5.422E-09
WES-CTP-FF-CLTXA	3888	5.98E-4	+0.000E+00	1.000	1.000E+0	1.252E-13
WES-CTP-FF-CLTXB	4104	5.98E-4	2.244E-08	1.000	1.000E+0	8.158E-10
WES-CTP-FF-CLTXC	4104	5.98E-4	2.244E-08	1.000	1.000E+0	8.158E-10
WES-CTP-FF-CLTXD	4104	5.98E-4	2.244E-08	1.000	1.000E+0	8.158E-10
WES-CTP-FF-HLTXA	3888	5.98E-4	+0.000E+00	1.000	1.000E+0	1.252E-13
WES-CTP-FF-HLTXB	4104	5.98E-4	2.244E-08	1.000	1.000E+0	8.158E-10
WES-CTP-FF-HLTXC	4104	5.98E-4	2.244E-08	1.000	1.000E+0	8.158E-10
WES-CTP-FF-HLTXD	4104	5.98E-4	2.244E-08	1.000	1.000E+0	8.158E-10
WES-TLR-CF-PRA23	19	5.10E-6	1.230E-10	1.000	1.000E+0	5.293E-10
WES-TLR-CF-PRA34	26	1.52E-6	1.793E-10	1.000	1.000E+0	2.561E-09
WES-TLR-CF-PRB23	19	5.10E-6	1.230E-10	1.000	1.000E+0	5.293E-10
WES-TLR-CF-PRB34	26	1.52E-6	1.793E-10	1.000	1.000E+0	2.561E-09
WES-TLR-CF-TRA23	19	5.10E-6	1.230E-10	1.000	1.000E+0	5.293E-10
WES-TLR-CF-TRA34	26	1.52E-6	1.793E-10	1.000	1.000E+0	2.561E-09
WES-TLR-CF-TRB23	19	5.10E-6	1.230E-10	1.000	1.000E+0	5.293E-10
WES-TLR-CF-TRB34	26	1.52E-6	1.793E-10	1.000	1.000E+0	2.561E-09
WES-TLR-FC-PRATA	312	3.94E-5	+0.000E+00	1.000	1.000E+0	+0.000E+00
WES-TLR-FC-PRATB	312	3.94E-5	+0.000E+00	1.000	1.000E+0	+0.000E+00
WES-TLR-FC-PRBTA	426	3.94E-5	+0.000E+00	1.000	1.000E+0	+0.000E+00
WES-TLR-FC-PRBTB	426	3.94E-5	+0.000E+00	1.000	1.000E+0	+0.000E+00
WES-TLR-FC-PRCTA	426	3.94E-5	+0.000E+00	1.000	1.000E+0	+0.000E+00
WES-TLR-FC-PRCTB	426	3.94E-5	+0.000E+00	1.000	1.000E+0	+0.000E+00
WES-TLR-FC-PRDTA	426	3.94E-5	+0.000E+00	1.000	1.000E+0	+0.000E+00
WES-TLR-FC-PRDTB	426	3.94E-5	+0.000E+00	1.000	1.000E+0	+0.000E+00
WES-TLR-FC-TRATA	312	3.94E-5	+0.000E+00	1.000	1.000E+0	+0.000E+00
WES-TLR-FC-TRATB	312	3.94E-5	+0.000E+00	1.000	1.000E+0	+0.000E+00
WES-TLR-FC-TRBTA	426	3.94E-5	+0.000E+00	1.000	1.000E+0	+0.000E+00
WES-TLR-FC-TRBTB	426	3.94E-5	+0.000E+00	1.000	1.000E+0	+0.000E+00
WES-TLR-FC-TRCTA	426	3.94E-5	+0.000E+00	1.000	1.000E+0	+0.000E+00
WES-TLR-FC-TRCTB	426	3.94E-5	+0.000E+00	1.000	1.000E+0	+0.000E+00
WES-TLR-FC-TRDTA	426	3.94E-5	+0.000E+00	1.000	1.000E+0	+0.000E+00
WES-TLR-FC-TRDTB	426	3.94E-5	+0.000E+00	1.000	1.000E+0	+0.000E+00
WES-XHE-XE-NSGNL	22098	1.00E+0	2.360E-01	1.309	1.000E+0	5.114E-06
WES-XHE-XE-SIGNL	960	1.00E+0	6.338E-01	2.730	1.000E+0	1.373E-05

Table F-4. Importance measures sorted on Birnbaum for case with RPS mincut = 2.2E-5.

Basic Event	Number of Occur.	Prob. of Failure	Fussell-Vesely Importance	Risk Reduction Ratio	Risk Increase Ratio	Birnbaum Importance
WES-ROD-CF-RCCAS	1	1.21E-6	5.585E-02	1.059	4.615E+4	1.000E+00
WES-BME-CF-RTBAB	1	1.61E-6	7.410E-02	1.080	4.603E+4	9.972E-01
WES-TLC-CF-SSLAB	3	2.10E-6	9.692E-02	1.107	4.603E+4	9.972E-01
WES-UVL-CF-UVDAB	3	1.04E-5	4.800E-01	1.923	4.603E+4	9.972E-01
WES-CBI-CF-6OF8	3	2.70E-6	1.174E-01	1.133	4.336E+4	9.395E-01
WES-CCX-CF-6OF8	3	1.83E-6	7.956E-02	1.086	4.336E+4	9.395E-01
WES-TLR-CF-12O16	3	8.07E-8	3.509E-03	1.004	4.336E+4	9.395E-01
WES-CBI-CF-4OF6	3	8.21E-6	2.198E-02	1.023	2.677E+3	5.799E-02
WES-CCX-CF-4OF6	3	6.33E-6	1.694E-02	1.017	2.677E+3	5.799E-02
WES-TLR-CF-8OF12	3	2.07E-7	5.541E-04	1.001	2.677E+3	5.799E-02
WES-TLC-CF-SSLA	37	1.72E-5	1.420E-03	1.001	8.353E+1	1.788E-03
WES-TLC-CF-SSLB	37	1.72E-5	1.420E-03	1.001	8.353E+1	1.788E-03
WES-UVL-FF-UVDA	37	3.37E-4	2.782E-02	1.029	8.350E+1	1.788E-03
WES-UVL-FF-UVDB	37	3.37E-4	2.782E-02	1.029	8.350E+1	1.788E-03
WES-TLR-CF-RLA68	26	3.28E-7	2.551E-05	1.000	7.874E+1	1.684E-03
WES-TLR-CF-RLB68	26	3.28E-7	2.551E-05	1.000	7.874E+1	1.684E-03
WES-BME-CF-RANBB	1	1.61E-6	1.039E-04	1.000	6.552E+1	1.398E-03
WES-BME-CF-RBNBA	1	1.61E-6	1.039E-04	1.000	6.552E+1	1.398E-03
WES-BME-FO-RTBA	40	3.69E-5	6.655E-04	1.001	1.903E+1	3.907E-04
WES-BME-FO-RTBB	40	3.69E-5	6.655E-04	1.001	1.903E+1	3.907E-04
WES-BME-TM-RTBA	23106	1.40E-3	2.284E-02	1.023	1.729E+1	3.535E-04
WES-BME-TM-RTBB	23106	1.40E-3	2.284E-02	1.023	1.729E+1	3.535E-04
WES-TLR-CF-RLA46	19	9.98E-7	4.780E-06	1.000	5.790E+0	1.038E-04
WES-TLR-CF-RLB46	19	9.98E-7	4.780E-06	1.000	5.790E+0	1.038E-04
WES-CBI-CF-P3OF4	9	1.19E-5	5.401E-05	1.000	5.539E+0	9.834E-05
WES-CCP-CF-P3OF4	9	4.48E-6	2.033E-05	1.000	5.539E+0	9.834E-05
WES-CPR-CF-P3OF4	9	2.06E-6	9.350E-06	1.000	5.539E+0	9.834E-05
WES-BUV-CF-RTBAB	3	9.73E-6	1.182E-05	1.000	2.215E+0	2.633E-05
WES-CBI-CF-P2OF3	9	4.19E-5	4.111E-05	1.000	1.981E+0	2.126E-05
WES-CCP-CF-P2OF3	9	1.50E-5	1.472E-05	1.000	1.981E+0	2.126E-05
WES-CPR-CF-P2OF3	9	7.71E-6	7.564E-06	1.000	1.981E+0	2.126E-05
WES-CBI-CF-T3OF4	9	1.19E-5	9.540E-06	1.000	1.802E+0	1.737E-05
WES-CDT-CF-T3OF4	9	5.55E-5	4.449E-05	1.000	1.802E+0	1.737E-05
WES-CTP-CF-T3OF8	9	3.70E-5	2.966E-05	1.000	1.802E+0	1.737E-05
WES-XHE-XE-SIGNL	960	1.00E+0	6.338E-01	2.730	1.000E+0	1.373E-05
WES-CCP-TM-CHA	23013	5.80E-2	2.720E-02	1.028	1.442E+0	1.016E-05
WES-BSN-CF-RTBAB	1	2.10E-5	9.404E-06	1.000	1.448E+0	9.703E-06
WES-PWR-CF-TRNAB	1	3.40E-6	1.523E-06	1.000	1.448E+0	9.703E-06
WES-TLR-CF-RTBAB	1	2.00E-6	8.956E-07	1.000	1.448E+0	9.703E-06
WES-XHE-XE-NSGNL	22098	1.00E+0	2.360E-01	1.309	1.000E+0	5.114E-06
WES-CBI-CF-T2OF3	9	4.19E-5	7.247E-06	1.000	1.173E+0	3.747E-06
WES-CDT-CF-T2OF3	9	2.50E-4	4.324E-05	1.000	1.173E+0	3.747E-06
WES-CTP-CF-T2OF6	9	7.46E-5	1.290E-05	1.000	1.173E+0	3.747E-06
WES-TLC-FF-SSLAP	37	3.83E-4	1.211E-05	1.000	1.032E+0	6.851E-07
WES-TLC-FF-SSLAT	37	3.83E-4	1.211E-05	1.000	1.032E+0	6.851E-07
WES-TLC-FF-SSLBP	37	3.83E-4	1.211E-05	1.000	1.032E+0	6.851E-07
WES-TLC-FF-SSLBT	37	3.83E-4	1.211E-05	1.000	1.032E+0	6.851E-07
WES-BUV-FF-RTBA	114	2.54E-4	3.117E-06	1.000	1.012E+0	2.659E-07
WES-BUV-FF-RTBB	114	2.54E-4	3.117E-06	1.000	1.012E+0	2.659E-07
WES-BUV-CF-RANBB	3	9.73E-6	7.559E-08	1.000	1.008E+0	1.683E-07
WES-BUV-CF-RBNBA	3	9.73E-6	7.559E-08	1.000	1.008E+0	1.683E-07
WES-PWR-FF-TRNA	40	6.00E-5	3.128E-07	1.000	1.005E+0	1.130E-07
WES-PWR-FF-TRNB	40	6.00E-5	3.128E-07	1.000	1.005E+0	1.130E-07
WES-TLR-FC-RLYSA	40	3.94E-5	2.054E-07	1.000	1.005E+0	1.130E-07
WES-TLR-FC-RLYSB	40	3.94E-5	2.054E-07	1.000	1.005E+0	1.130E-07
WES-BSN-FF-RTBA	38	5.81E-4	2.661E-06	1.000	1.005E+0	9.925E-08
WES-BSN-FF-RTBB	38	5.81E-4	2.661E-06	1.000	1.005E+0	9.925E-08
WES-BME-FO-BYBA	4	3.69E-5	8.827E-08	1.000	1.002E+0	5.183E-08
WES-BME-FO-BYBB	4	3.69E-5	8.827E-08	1.000	1.002E+0	5.183E-08
WES-BSN-CF-RANBB	1	2.10E-5	1.318E-08	1.000	1.001E+0	1.360E-08
WES-BSN-CF-RBNBA	1	2.10E-5	1.318E-08	1.000	1.001E+0	1.360E-08
WES-CBI-FF-BSTPB	5472	7.46E-4	1.864E-07	1.000	1.000E+0	5.422E-09
WES-CBI-FF-BSTPC	5472	7.46E-4	1.864E-07	1.000	1.000E+0	5.422E-09
WES-CBI-FF-BSTPD	5472	7.46E-4	1.864E-07	1.000	1.000E+0	5.422E-09
WES-CCP-FF-ANLPB	5472	1.57E-4	3.917E-08	1.000	1.000E+0	5.422E-09
WES-CCP-FF-ANLPC	5472	1.57E-4	3.917E-08	1.000	1.000E+0	5.422E-09
WES-CCP-FF-ANLPD	5472	1.57E-4	3.917E-08	1.000	1.000E+0	5.422E-09
WES-CPR-FF-PRESB	5472	1.16E-4	2.889E-08	1.000	1.000E+0	5.422E-09

Table F-4. (continued).

Basic Event	Number of Occur.	Prob. of Failure	Fussell-Vesely Importance	Risk Reduction Ratio	Risk Increase Ratio	Birnbaum Importance
WES-CPR-FF-PRESC	5472	1.16E-4	2.889E-08	1.000	1.000E+0	5.422E-09
WES-CPR-FF-PRESD	5472	1.16E-4	2.889E-08	1.000	1.000E+0	5.422E-09
WES-TLR-CF-PRA34	26	1.52E-6	1.793E-10	1.000	1.000E+0	2.561E-09
WES-TLR-CF-PRB34	26	1.52E-6	1.793E-10	1.000	1.000E+0	2.561E-09
WES-TLR-CF-TRA34	26	1.52E-6	1.793E-10	1.000	1.000E+0	2.561E-09
WES-TLR-CF-TRB34	26	1.52E-6	1.793E-10	1.000	1.000E+0	2.561E-09
WES-CBI-FF-BSTTB	4104	7.46E-4	2.798E-08	1.000	1.000E+0	8.158E-10
WES-CBI-FF-BSTTC	4104	7.46E-4	2.798E-08	1.000	1.000E+0	8.158E-10
WES-CBI-FF-BSTTD	4104	7.46E-4	2.798E-08	1.000	1.000E+0	8.158E-10
WES-CDT-FF-ANLTB	4104	4.83E-3	1.816E-07	1.000	1.000E+0	8.158E-10
WES-CDT-FF-ANLTC	4104	4.83E-3	1.816E-07	1.000	1.000E+0	8.158E-10
WES-CDT-FF-ANLTD	4104	4.83E-3	1.816E-07	1.000	1.000E+0	8.158E-10
WES-CTP-FF-CLTXB	4104	5.98E-4	2.244E-08	1.000	1.000E+0	8.158E-10
WES-CTP-FF-CLTXC	4104	5.98E-4	2.244E-08	1.000	1.000E+0	8.158E-10
WES-CTP-FF-CLTXD	4104	5.98E-4	2.244E-08	1.000	1.000E+0	8.158E-10
WES-CTP-FF-HLTXB	4104	5.98E-4	2.244E-08	1.000	1.000E+0	8.158E-10
WES-CTP-FF-HLTXC	4104	5.98E-4	2.244E-08	1.000	1.000E+0	8.158E-10
WES-CTP-FF-HLTXD	4104	5.98E-4	2.244E-08	1.000	1.000E+0	8.158E-10
WES-TLR-CF-PRA23	19	5.10E-6	1.230E-10	1.000	1.000E+0	5.293E-10
WES-TLR-CF-PRB23	19	5.10E-6	1.230E-10	1.000	1.000E+0	5.293E-10
WES-TLR-CF-TRA23	19	5.10E-6	1.230E-10	1.000	1.000E+0	5.293E-10
WES-TLR-CF-TRB23	19	5.10E-6	1.230E-10	1.000	1.000E+0	5.293E-10
WES-BUV-FF-BYBA	6	2.54E-4	8.301E-10	1.000	1.000E+0	7.052E-11
WES-BUV-FF-BYBB	6	2.54E-4	8.301E-10	1.000	1.000E+0	7.052E-11
WES-BSN-FF-BYBA	2	5.81E-4	3.536E-10	1.000	1.000E+0	1.316E-11
WES-BSN-FF-BYBB	2	5.81E-4	3.536E-10	1.000	1.000E+0	1.316E-11
WES-CBI-FF-BSTPA	5184	7.46E-4	+0.000E+00	1.000	1.000E+0	8.939E-13
WES-CCP-FF-ANLPA	5184	1.57E-4	+0.000E+00	1.000	1.000E+0	8.939E-13
WES-CPR-FF-PRESA	5184	1.16E-4	+0.000E+00	1.000	1.000E+0	8.939E-13
WES-CBI-FF-BSTTA	3888	7.46E-4	+0.000E+00	1.000	1.000E+0	1.252E-13
WES-CDT-FF-ANLTA	3888	4.83E-3	+0.000E+00	1.000	1.000E+0	1.252E-13
WES-CTP-FF-CLTXA	3888	5.98E-4	+0.000E+00	1.000	1.000E+0	1.252E-13
WES-CTP-FF-HLTXA	3888	5.98E-4	+0.000E+00	1.000	1.000E+0	1.252E-13
WES-TLR-FC-PRATA	312	3.94E-5	+0.000E+00	1.000	1.000E+0	+0.000E+00
WES-TLR-FC-PRATB	312	3.94E-5	+0.000E+00	1.000	1.000E+0	+0.000E+00
WES-TLR-FC-PRBTA	426	3.94E-5	+0.000E+00	1.000	1.000E+0	+0.000E+00
WES-TLR-FC-PRBTB	426	3.94E-5	+0.000E+00	1.000	1.000E+0	+0.000E+00
WES-TLR-FC-PRCTA	426	3.94E-5	+0.000E+00	1.000	1.000E+0	+0.000E+00
WES-TLR-FC-PRCTB	426	3.94E-5	+0.000E+00	1.000	1.000E+0	+0.000E+00
WES-TLR-FC-PRDTA	426	3.94E-5	+0.000E+00	1.000	1.000E+0	+0.000E+00
WES-TLR-FC-PRDTB	426	3.94E-5	+0.000E+00	1.000	1.000E+0	+0.000E+00
WES-TLR-FC-TRATA	312	3.94E-5	+0.000E+00	1.000	1.000E+0	+0.000E+00
WES-TLR-FC-TRATB	312	3.94E-5	+0.000E+00	1.000	1.000E+0	+0.000E+00
WES-TLR-FC-TRBTA	426	3.94E-5	+0.000E+00	1.000	1.000E+0	+0.000E+00
WES-TLR-FC-TRBTB	426	3.94E-5	+0.000E+00	1.000	1.000E+0	+0.000E+00
WES-TLR-FC-TRCTA	426	3.94E-5	+0.000E+00	1.000	1.000E+0	+0.000E+00
WES-TLR-FC-TRCTB	426	3.94E-5	+0.000E+00	1.000	1.000E+0	+0.000E+00
WES-TLR-FC-TRDTA	426	3.94E-5	+0.000E+00	1.000	1.000E+0	+0.000E+00
WES-TLR-FC-TRDTB	426	3.94E-5	+0.000E+00	1.000	1.000E+0	+0.000E+00

Table F-5. (continued).

Table F-5. RPS Eagle-21 design top 100 cut sets (operator actions = 0.01) mincut = 2.0E-5.

Cut Set	Cut Set Percent	Cut Set Prob.	Basic Event[a]	Description	Prob.
1	53.0	1.0E-05	/WES-BME-TM-RTBA	RTB-A IN T&M	1.0E+0
			/WES-BME-TM-RTBB	RTB-B IN T&M	1.0E+0
			WES-UVL-CF-UVDAB	CCF UV DRIVERS TRAINS A AND B (2 OF 2)	1.0E-5
			WES-XHE-XE-SIGNL	OPERATOR FAILS TO RESPOND WITH RPS SIGNAL PRESENT	1.0E+0
2	13.4	2.6E-06	/WES-BME-TM-RTBA	RTB-A IN T&M	1.0E+0
			/WES-BME-TM-RTBB	RTB-B IN T&M	1.0E+0
			WES-CBI-CF-6OF8	CCF 6 BISTABLES IN 3 OF 4 CHANNELS	2.7E-6
			/WES-CCP-TM-CHA	CH-A IN T&M	9.7E-1
			WES-XHE-XE-NSGNL	OPERATOR FAILS TO RESPOND WITH NO RPS SIGNAL PRESENT	1.0E+0
3	10.7	2.1E-06	/WES-BME-TM-RTBA	RTB-A IN T&M	1.0E+0
			/WES-BME-TM-RTBB	RTB-B IN T&M	1.0E+0
			WES-TLC-CF-SSLAB	CCF SOLID STATE LOGIC IN TRAINS A AND B (4 OF 4)	2.1E-6
			WES-XHE-XE-SIGNL	OPERATOR FAILS TO RESPOND WITH RPS SIGNAL PRESENT	1.0E+0
4	8.2	1.6E-06	WES-BME-CF-RTBAB	CCF RTB-A AND RTB-B (MECHANICAL)	1.6E-6
			/WES-BME-TM-RTBA	RTB-A IN T&M	1.0E+0
			/WES-BME-TM-RTBB	RTB-B IN T&M	1.0E+0
5	6.2	1.2E-06	WES-ROD-CF-RCCAS	CCF 10 OR MORE RCCAS FAIL TO DROP	1.2E-6
6	2.4	4.7E-07	WES-BME-TM-RTBA	RTB-A IN T&M	1.4E-3
			/WES-BME-TM-RTBB	RTB-B IN T&M	1.0E+0
			WES-UVL-FF-UVDB	TRAIN B UV DRIVER FAILS	3.4E-4
			WES-XHE-XE-SIGNL	OPERATOR FAILS TO RESPOND WITH RPS SIGNAL PRESENT	1.0E+0
7	2.4	4.7E-07	/WES-BME-TM-RTBA	RTB-A IN T&M	1.0E+0
			WES-BME-TM-RTBB	RTB-B IN T&M	1.4E-3
			WES-UVL-FF-UVDA	TRAIN A UV DRIVER FAILS	3.4E-4
			WES-XHE-XE-SIGNL	OPERATOR FAILS TO RESPOND WITH RPS SIGNAL PRESENT	1.0E+0
8	1.2	2.4E-07	/WES-BME-TM-RTBA	RTB-A IN T&M	1.0E+0
			/WES-BME-TM-RTBB	RTB-B IN T&M	1.0E+0
			WES-CBI-CF-4OF6	CCF 4 BISTABLES IN 2 OF 3 CHANNELS	8.2E-6
			WES-CCP-TM-CHA	CH-A IN T&M	2.9E-2
			WES-XHE-XE-NSGNL	OPERATOR FAILS TO RESPOND WITH NO RPS SIGNAL PRESENT	1.0E+0
9	0.8	1.5E-07	/WES-BME-TM-RTBA	RTB-A IN T&M	1.0E+0
			/WES-BME-TM-RTBB	RTB-B IN T&M	1.0E+0
			WES-C21-CF-E3OF4	CCF 3 EAGLE-21 PROCESS LOGIC MODULES IN 3 OF 4 CHANNELS	1.5E-7
			/WES-CCP-TM-CHA	CH-A IN T&M	9.7E-1
			WES-XHE-XE-NSGNL	OPERATOR FAILS TO RESPOND WITH NO RPS SIGNAL PRESENT	1.0E+0
10	0.6	1.1E-07	/WES-BME-TM-RTBA	RTB-A IN T&M	1.0E+0
			/WES-BME-TM-RTBB	RTB-B IN T&M	1.0E+0
			WES-UVL-FF-UVDA	TRAIN A UV DRIVER FAILS	3.4E-4
			WES-UVL-FF-UVDB	TRAIN B UV DRIVER FAILS	3.4E-4
			WES-XHE-XE-SIGNL	OPERATOR FAILS TO RESPOND WITH RPS SIGNAL PRESENT	1.0E+0
11	0.4	7.8E-08	/WES-BME-TM-RTBA	RTB-A IN T&M	1.0E+0
			/WES-BME-TM-RTBB	RTB-B IN T&M	1.0E+0
			/WES-CCP-TM-CHA	CH-A IN T&M	9.7E-1
			WES-TLR-CF-12O16	CCF 12 OR MORE TMU RELAYS IN TRAINS A AND B NO CHANNEL T&M	8.1E-8
			WES-XHE-XE-SIGNL	OPERATOR FAILS TO RESPOND WITH RPS SIGNAL PRESENT	1.0E+0
12	0.1	2.4E-08	WES-BME-TM-RTBA	RTB-A IN T&M	1.4E-3
			/WES-BME-TM-RTBB	RTB-B IN T&M	1.0E+0
			WES-TLC-CF-SSLB	CCF SOLID STATE LOGIC TRAIN B (2 OF 4)	1.7E-5
			WES-XHE-XE-SIGNL	OPERATOR FAILS TO RESPOND WITH RPS SIGNAL PRESENT	1.0E+0
13	0.1	2.4E-08	/WES-BME-TM-RTBA	RTB-A IN T&M	1.0E+0
			WES-BME-TM-RTBB	RTB-B IN T&M	1.4E-3
			WES-TLC-CF-SSLA	CCF SOLID STATE LOGIC TRAIN A (2 OF 4)	1.7E-5
			WES-XHE-XE-SIGNL	OPERATOR FAILS TO RESPOND WITH RPS SIGNAL PRESENT	1.0E+0
14	0.1	1.5E-08	/WES-BME-TM-RTBA	RTB-A IN T&M	1.0E+0
			/WES-BME-TM-RTBB	RTB-B IN T&M	1.0E+0
			WES-C21-CF-E2OF3	CCF 2 EAGLE-21 PROCESS LOGIC MODULES IN 2 OF 3 CHANNELS	5.1E-7
			WES-CCP-TM-CHA	CH-A IN T&M	2.9E-2
			WES-XHE-XE-NSGNL	OPERATOR FAILS TO RESPOND WITH NO RPS SIGNAL PRESENT	1.0E+0
15	0.1	1.5E-08	WES-BME-TM-RTBA	RTB-A IN T&M	1.4E-3
			/WES-BME-TM-RTBB	RTB-B IN T&M	1.0E+0
			WES-UVL-CF-UVDAB	CCF UV DRIVERS TRAINS A AND B (2 OF 2)	1.0E-5
			WES-XHE-XE-SIGNL	OPERATOR FAILS TO RESPOND WITH RPS SIGNAL PRESENT	1.0E+0
16	0.1	1.5E-08	/WES-BME-TM-RTBA	RTB-A IN T&M	1.0E+0
			WES-BME-TM-RTBB	RTB-B IN T&M	1.4E-3
			WES-UVL-CF-UVDAB	CCF UV DRIVERS TRAINS A AND B (2 OF 2)	1.0E-5
			WES-XHE-XE-SIGNL	OPERATOR FAILS TO RESPOND WITH RPS SIGNAL PRESENT	1.0E+0

Table F-5. (continued).

Cut Set	Cut Set Percent	Cut Set Prob.	Basic Event[a]	Description	Prob.
17	0.1	1.2E-08	WES-BME-FO-RTBA	RTB-A LOCAL HW FAILURE	3.7E-5
			/WES-BME-TM-RTBA	RTB-A IN T&M	1.0E+0
			/WES-BME-TM-RTBB	RTB-B IN T&M	1.0E+0
			WES-UVL-FF-UVDB	TRAIN B UV DRIVER FAILS	3.4E-4
			WES-XHE-XE-SIGNL	OPERATOR FAILS TO RESPOND WITH RPS SIGNAL PRESENT	1.0E+0
18	0.1	1.2E-08	WES-BME-FO-RTBB	RTB-B LOCAL HW FAILURE	3.7E-5
			/WES-BME-TM-RTBA	RTB-A IN T&M	1.0E+0
			/WES-BME-TM-RTBB	RTB-B IN T&M	1.0E+0
			WES-UVL-FF-UVDA	TRAIN A UV DRIVER FAILS	3.4E-4
			WES-XHE-XE-SIGNL	OPERATOR FAILS TO RESPOND WITH RPS SIGNAL PRESENT	1.0E+0
19	0.0	6.0E-09	/WES-BME-TM-RTBA	RTB-A IN T&M	1.0E+0
			/WES-BME-TM-RTBB	RTB-B IN T&M	1.0E+0
			WES-CCP-TM-CHA	CH-A IN T&M	2.9E-2
			WES-TLR-CF-8OF12	CCF 8 OR MORE TMU RELAYS IN TRAINS A AND B ONE CHANNEL T&M	2.1E-7
			WES-XHE-XE-SIGNL	OPERATOR FAILS TO RESPOND WITH RPS SIGNAL PRESENT	1.0E+0
20	0.0	5.8E-09	/WES-BME-TM-RTBA	RTB-A IN T&M	1.0E+0
			/WES-BME-TM-RTBB	RTB-B IN T&M	1.0E+0
			WES-TLC-CF-SSLA	CCF SOLID STATE LOGIC TRAIN A (2 OF 4)	1.7E-5
			WES-UVL-FF-UVDB	TRAIN B UV DRIVER FAILS	3.4E-4
			WES-XHE-XE-SIGNL	OPERATOR FAILS TO RESPOND WITH RPS SIGNAL PRESENT	1.0E+0
21	0.0	5.8E-09	/WES-BME-TM-RTBA	RTB-A IN T&M	1.0E+0
			/WES-BME-TM-RTBB	RTB-B IN T&M	1.0E+0
			WES-TLC-CF-SSLB	CCF SOLID STATE LOGIC TRAIN B (2 OF 4)	1.7E-5
			WES-UVL-FF-UVDA	TRAIN A UV DRIVER FAILS	3.4E-4
			WES-XHE-XE-SIGNL	OPERATOR FAILS TO RESPOND WITH RPS SIGNAL PRESENT	1.0E+0
22	0.0	3.7E-09	WES-BME-TM-RTBA	RTB-A IN T&M	1.4E-3
			/WES-BME-TM-RTBB	RTB-B IN T&M	1.0E+0
			WES-CBI-CF-6OF8	CCF 6 BISTABLES IN 3 OF 4 CHANNELS	2.7E-6
			/WES-CCP-TM-CHA	CH-A IN T&M	9.7E-1
			WES-XHE-XE-NSGNL	OPERATOR FAILS TO RESPOND WITH NO RPS SIGNAL PRESENT	1.0E+0
23	0.0	3.7E-09	/WES-BME-TM-RTBA	RTB-A IN T&M	1.0E+0
			WES-BME-TM-RTBB	RTB-B IN T&M	1.4E-3
			WES-CBI-CF-6OF8	CCF 6 BISTABLES IN 3 OF 4 CHANNELS	2.7E-6
			/WES-CCP-TM-CHA	CH-A IN T&M	9.7E-1
			WES-XHE-XE-NSGNL	OPERATOR FAILS TO RESPOND WITH NO RPS SIGNAL PRESENT	1.0E+0
24	0.0	2.9E-09	WES-BME-TM-RTBA	RTB-A IN T&M	1.4E-3
			/WES-BME-TM-RTBB	RTB-B IN T&M	1.0E+0
			WES-TLC-CF-SSLAB	CCF SOLID STATE LOGIC IN TRAINS A AND B (4 OF 4)	2.1E-6
			WES-XHE-XE-SIGNL	OPERATOR FAILS TO RESPOND WITH RPS SIGNAL PRESENT	1.0E+0
25	0.0	2.9E-09	/WES-BME-TM-RTBA	RTB-A IN T&M	1.0E+0
			WES-BME-TM-RTBB	RTB-B IN T&M	1.4E-3
			WES-TLC-CF-SSLAB	CCF SOLID STATE LOGIC IN TRAINS A AND B (4 OF 4)	2.1E-6
			WES-XHE-XE-SIGNL	OPERATOR FAILS TO RESPOND WITH RPS SIGNAL PRESENT	1.0E+0
26	0.0	2.3E-09	WES-BME-CF-RANBB	CCF RTB-A AND BYB-B (MECHANICAL)	1.6E-6
			/WES-BME-TM-RTBA	RTB-A IN T&M	1.0E+0
			WES-BME-TM-RTBB	RTB-B IN T&M	1.4E-3
27	0.0	2.3E-09	WES-BME-CF-RBNBA	CCF RTB-B AND BYB-A (MECHANICAL)	1.6E-6
			WES-BME-TM-RTBA	RTB-A IN T&M	1.4E-3
			/WES-BME-TM-RTBB	RTB-B IN T&M	1.0E+0
28	0.0	1.4E-09	WES-BME-FO-RTBA	RTB-A LOCAL HW FAILURE	3.7E-5
			WES-BME-FO-RTBB	RTB-B LOCAL HW FAILURE	3.7E-5
			/WES-BME-TM-RTBA	RTB-A IN T&M	1.0E+0
			/WES-BME-TM-RTBB	RTB-B IN T&M	1.0E+0
29	0.0	6.3E-10	WES-BME-FO-RTBA	RTB-A LOCAL HW FAILURE	3.7E-5
			/WES-BME-TM-RTBA	RTB-A IN T&M	1.0E+0
			/WES-BME-TM-RTBB	RTB-B IN T&M	1.0E+0
			WES-TLC-CF-SSLB	CCF SOLID STATE LOGIC TRAIN B (2 OF 4)	1.7E-5
			WES-XHE-XE-SIGNL	OPERATOR FAILS TO RESPOND WITH RPS SIGNAL PRESENT	1.0E+0
30	0.0	6.3E-10	WES-BME-FO-RTBB	RTB-B LOCAL HW FAILURE	3.7E-5
			/WES-BME-TM-RTBA	RTB-A IN T&M	1.0E+0
			/WES-BME-TM-RTBB	RTB-B IN T&M	1.0E+0
			WES-TLC-CF-SSLA	CCF SOLID STATE LOGIC TRAIN A (2 OF 4)	1.7E-5
			WES-XHE-XE-SIGNL	OPERATOR FAILS TO RESPOND WITH RPS SIGNAL PRESENT	1.0E+0
31	0.0	4.5E-10	WES-BME-TM-RTBA	RTB-A IN T&M	1.4E-3
			/WES-BME-TM-RTBB	RTB-B IN T&M	1.0E+0
			/WES-CCP-TM-CHA	CH-A IN T&M	9.7E-1
			WES-TLR-CF-RLB68	CCF 6 OR MORE TMU RELAYS IN TRAIN B NO CHANNEL T&M	3.3E-7

Table F-5. (continued).

Cut Set	Cut Set Percent	Cut Set Prob.	Basic Event[a]	Description	Prob.
			WES-XHE-XE-SIGNL	OPERATOR FAILS TO RESPOND WITH RPS SIGNAL PRESENT	1.0E+0
32	0.0	4.5E-10	/WES-BME-TM-RTBA	RTB-A IN T&M	1.0E+0
			WES-BME-TM-RTBB	RTB-B IN T&M	1.4E-3
			/WES-CCP-TM-CHA	CH-A IN T&M	9.7E-1
			WES-TLR-CF-RLA68	CCF 6 OR MORE TMU RELAYS IN TRAIN A NO CHANNEL T&M	3.3E-7
			WES-XHE-XE-SIGNL	OPERATOR FAILS TO RESPOND WITH RPS SIGNAL PRESENT	1.0E+0
33	0.0	4.3E-10	/WES-BME-TM-RTBA	RTB-A IN T&M	1.0E+0
			/WES-BME-TM-RTBB	RTB-B IN T&M	1.0E+0
			WES-CBI-CF-P3OF4	CCF 3 PRESSURE OUTPUT BISTABLES IN 3 OF 4 CHANNELS	1.2E-5
			/WES-CCP-TM-CHA	CH-A IN T&M	9.7E-1
			WES-CTP-CF-T3OF8	CCF 3 TEMP SENSORS IN 3 OF 4 CHANNELS	3.7E-5
			WES-XHE-XE-NSGNL	OPERATOR FAILS TO RESPOND WITH NO RPS SIGNAL PRESENT	1.0E+0
34	0.0	3.3E-10	WES-BME-TM-RTBA	RTB-A IN T&M	1.4E-3
			/WES-BME-TM-RTBB	RTB-B IN T&M	1.0E+0
			WES-CBI-CF-4OF6	CCF 4 BISTABLES IN 2 OF 3 CHANNELS	8.2E-6
			WES-CCP-TM-CHA	CH-A IN T&M	2.9E-2
			WES-XHE-XE-NSGNL	OPERATOR FAILS TO RESPOND WITH NO RPS SIGNAL PRESENT	1.0E+0
35	0.0	3.3E-10	/WES-BME-TM-RTBA	RTB-A IN T&M	1.0E+0
			WES-BME-TM-RTBB	RTB-B IN T&M	1.4E-3
			WES-CBI-CF-4OF6	CCF 4 BISTABLES IN 2 OF 3 CHANNELS	8.2E-6
			WES-CCP-TM-CHA	CH-A IN T&M	2.9E-2
			WES-XHE-XE-NSGNL	OPERATOR FAILS TO RESPOND WITH NO RPS SIGNAL PRESENT	1.0E+0
36	0.0	3.0E-10	/WES-BME-TM-RTBA	RTB-A IN T&M	1.0E+0
			/WES-BME-TM-RTBB	RTB-B IN T&M	1.0E+0
			WES-TLC-CF-SSLA	CCF SOLID STATE LOGIC TRAIN A (2 OF 4)	1.7E-5
			WES-TLC-CF-SSLB	CCF SOLID STATE LOGIC TRAIN B (2 OF 4)	1.7E-5
			WES-XHE-XE-SIGNL	OPERATOR FAILS TO RESPOND WITH RPS SIGNAL PRESENT	1.0E+0
37	0.0	2.1E-10	WES-BME-TM-RTBA	RTB-A IN T&M	1.4E-3
			/WES-BME-TM-RTBB	RTB-B IN T&M	1.0E+0
			WES-TLC-FF-SSLBP	TRAIN B PRESSURE SOLID STATE LOGIC FAILS	3.8E-4
			WES-TLC-FF-SSLBT	TRAIN B TEMPERATURE SOLID STATE LOGIC FAILS	3.8E-4
			WES-XHE-XE-SIGNL	OPERATOR FAILS TO RESPOND WITH RPS SIGNAL PRESENT	1.0E+0
38	0.0	2.1E-10	/WES-BME-TM-RTBA	RTB-A IN T&M	1.0E+0
			WES-BME-TM-RTBB	RTB-B IN T&M	1.4E-3
			WES-TLC-FF-SSLAP	TRAIN A PRESSURE SOLID STATE LOGIC FAILS	3.8E-4
			WES-TLC-FF-SSLAT	TRAIN A TEMPERATURE SOLID STATE LOGIC FAILS	3.8E-4
			WES-XHE-XE-SIGNL	OPERATOR FAILS TO RESPOND WITH RPS SIGNAL PRESENT	1.0E+0
39	0.0	2.1E-10	WES-BME-TM-RTBA	RTB-A IN T&M	1.4E-3
			/WES-BME-TM-RTBB	RTB-B IN T&M	1.0E+0
			WES-C21-CF-E3OF4	CCF 3 EAGLE-21 PROCESS LOGIC MODULES IN 3 OF 4 CHANNELS	1.5E-7
			/WES-CCP-TM-CHA	CH-A IN T&M	9.7E-1
			WES-XHE-XE-NSGNL	OPERATOR FAILS TO RESPOND WITH NO RPS SIGNAL PRESENT	1.0E+0
40	0.0	2.1E-10	/WES-BME-TM-RTBA	RTB-A IN T&M	1.0E+0
			WES-BME-TM-RTBB	RTB-B IN T&M	1.4E-3
			WES-C21-CF-E3OF4	CCF 3 EAGLE-21 PROCESS LOGIC MODULES IN 3 OF 4 CHANNELS	1.5E-7
			/WES-CCP-TM-CHA	CH-A IN T&M	9.7E-1
			WES-XHE-XE-NSGNL	OPERATOR FAILS TO RESPOND WITH NO RPS SIGNAL PRESENT	1.0E+0
41	0.0	2.0E-10	/WES-BME-TM-RTBA	RTB-A IN T&M	1.0E+0
			/WES-BME-TM-RTBB	RTB-B IN T&M	1.0E+0
			WES-BSN-CF-RTBAB	CCF OF RTB-A AND RTB-B SHUNT TRIP DEVICES	2.1E-5
			WES-BUV-CF-RTBAB	CCF OF RTB-A AND RTB-B UV DEVICES	9.7E-6
42	0.0	1.4E-10	/WES-BME-TM-RTBA	RTB-A IN T&M	1.0E+0
			/WES-BME-TM-RTBB	RTB-B IN T&M	1.0E+0
			WES-CBI-CF-P3OF4	CCF 3 PRESSURE OUTPUT BISTABLES IN 3 OF 4 CHANNELS	1.2E-5
			WES-CBI-CF-T3OF4	CCF 3 TEMP OUTPUT BISTABLES IN 3 OF 4 CHANNELS	1.2E-5
			/WES-CCP-TM-CHA	CH-A IN T&M	9.7E-1
			WES-XHE-XE-NSGNL	OPERATOR FAILS TO RESPOND WITH NO RPS SIGNAL PRESENT	1.0E+0
43	0.0	1.2E-10	/WES-BME-TM-RTBA	RTB-A IN T&M	1.0E+0
			/WES-BME-TM-RTBB	RTB-B IN T&M	1.0E+0
			WES-C21-FF-E21B	CH-B EAGLE-21 PROCESS LOGIC MODULE FAILS	6.5E-5
			WES-C21-FF-E21C	CH-C EAGLE-21 PROCESS LOGIC MODULE FAILS	6.5E-5
			WES-CCP-TM-CHA	CH-A IN T&M	2.9E-2
			WES-XHE-XE-NSGNL	OPERATOR FAILS TO RESPOND WITH NO RPS SIGNAL PRESENT	1.0E+0
44	0.0	1.2E-10	/WES-BME-TM-RTBA	RTB-A IN T&M	1.0E+0
			/WES-BME-TM-RTBB	RTB-B IN T&M	1.0E+0
			WES-C21-FF-E21B	CH-B EAGLE-21 PROCESS LOGIC MODULE FAILS	6.5E-5
			WES-C21-FF-E21D	CH-D EAGLE-21 PROCESS LOGIC MODULE FAILS	6.5E-5
			WES-CCP-TM-CHA	CH-A IN T&M	2.9E-2
			WES-XHE-XE-NSGNL	OPERATOR FAILS TO RESPOND WITH NO RPS SIGNAL PRESENT	1.0E+0
45	0.0	1.2E-10	/WES-BME-TM-RTBA	RTB-A IN T&M	1.0E+0
			/WES-BME-TM-RTBB	RTB-B IN T&M	1.0E+0
			WES-C21-FF-E21C	CH-C EAGLE-21 PROCESS LOGIC MODULE FAILS	6.5E-5
			WES-C21-FF-E21D	CH-D EAGLE-21 PROCESS LOGIC MODULE FAILS	6.5E-5
			WES-CCP-TM-CHA	CH-A IN T&M	2.9E-2
			WES-XHE-XE-NSGNL	OPERATOR FAILS TO RESPOND WITH NO RPS SIGNAL PRESENT	1.0E+0
46	0.0	1.1E-10	WES-BME-TM-RTBA	RTB-A IN T&M	1.4E-3
			/WES-BME-TM-RTBB	RTB-B IN T&M	1.0E+0
			/WES-CCP-TM-CHA	CH-A IN T&M	9.7E-1
			WES-TLR-CF-12O16	CCF 12 OR MORE TMU RELAYS IN TRAINS A AND B NO CHANNEL T&M	8.1E-8
			WES-XHE-XE-SIGNL	OPERATOR FAILS TO RESPOND WITH RPS SIGNAL PRESENT	1.0E+0
47	0.0	1.1E-10	/WES-BME-TM-RTBA	RTB-A IN T&M	1.0E+0
			WES-BME-TM-RTBB	RTB-B IN T&M	1.4E-3
			/WES-CCP-TM-CHA	CH-A IN T&M	9.7E-1
			WES-TLR-CF-12O16	CCF 12 OR MORE TMU RELAYS IN TRAINS A AND B NO CHANNEL T&M	8.1E-8
			WES-XHE-XE-SIGNL	OPERATOR FAILS TO RESPOND WITH RPS SIGNAL PRESENT	1.0E+0
48	0.0	1.1E-10	/WES-BME-TM-RTBA	RTB-A IN T&M	1.0E+0
			/WES-BME-TM-RTBB	RTB-B IN T&M	1.0E+0
			/WES-CCP-TM-CHA	CH-A IN T&M	9.7E-1

Table F-5. (continued).

Cut Set	Cut Set Percent	Cut Set Prob.	Basic Event[a]	Description	Prob.
			WES-TLR-CF-RLA68	CCF 6 OR MORE TMU RELAYS IN TRAIN A NO CHANNEL T&M	3.3E-7
			WES-UVL-FF-UVDB	TRAIN B UV DRIVER FAILS	3.4E-4
			WES-XHE-XE-SIGNL	OPERATOR FAILS TO RESPOND WITH RPS SIGNAL PRESENT	1.0E+0
49	0.0	1.1E-10	/WES-BME-TM-RTBA	RTB-A IN T&M	1.0E+0
			/WES-BME-TM-RTBB	RTB-B IN T&M	1.0E+0
			/WES-CCP-TM-CHA	CH-A IN T&M	9.7E-1
			WES-TLR-CF-RLB68	CCF 6 OR MORE TMU RELAYS IN TRAIN B NO CHANNEL T&M	3.3E-7
			WES-UVL-FF-UVDA	TRAIN A UV DRIVER FAILS	3.4E-4
			WES-XHE-XE-SIGNL	OPERATOR FAILS TO RESPOND WITH RPS SIGNAL PRESENT	1.0E+0
50	0.0	9.0E-11	/WES-BME-TM-RTBA	RTB-A IN T&M	1.0E+0
			/WES-BME-TM-RTBB	RTB-B IN T&M	1.0E+0
			WES-CBI-CF-P2OF3	CCF 2 PRESSURE OUTPUT BISTABLES IN 2 OF 3 CHANNELS	4.2E-5
			WES-CCP-TM-CHA	CH-A IN T&M	2.9E-2
			WES-CTP-CF-T2OF6	CCF 2 TEMP SENSORS IN 2 OF 3 CHANNELS	7.5E-5
			WES-XHE-XE-NSGNL	OPERATOR FAILS TO RESPOND WITH NO RPS SIGNAL PRESENT	1.0E+0
51	0.0	7.4E-11	/WES-BME-TM-RTBA	RTB-A IN T&M	1.0E+0
			/WES-BME-TM-RTBB	RTB-B IN T&M	1.0E+0
			/WES-CCP-TM-CHA	CH-A IN T&M	9.7E-1
			WES-CPR-CF-P3OF4	CCF 3 PRESSURE SENSORS IN 3 OF 4 CHANNELS	2.1E-6
			WES-CTP-CF-T3OF8	CCF 3 TEMP SENSORS IN 3 OF 4 CHANNELS	3.7E-5
			WES-XHE-XE-NSGNL	OPERATOR FAILS TO RESPOND WITH NO RPS SIGNAL PRESENT	1.0E+0
52	0.0	5.1E-11	/WES-BME-TM-RTBA	RTB-A IN T&M	1.0E+0
			/WES-BME-TM-RTBB	RTB-B IN T&M	1.0E+0
			WES-CBI-CF-P2OF3	CCF 2 PRESSURE OUTPUT BISTABLES IN 2 OF 3 CHANNELS	4.2E-5
			WES-CBI-CF-T2OF3	CCF 2 TEMP OUTPUT BISTABLES IN 2 OF 3 CHANNELS	4.2E-5
			WES-CCP-TM-CHA	CH-A IN T&M	2.9E-2
			WES-XHE-XE-NSGNL	OPERATOR FAILS TO RESPOND WITH NO RPS SIGNAL PRESENT	1.0E+0
53	0.0	5.0E-11	/WES-BME-TM-RTBA	RTB-A IN T&M	1.0E+0
			/WES-BME-TM-RTBB	RTB-B IN T&M	1.0E+0
			WES-BSN-FF-RTBA	RTB-A SHUNT TRIP DEVICE LOCAL FAULTS	5.8E-4
			WES-BUV-FF-RTBA	RTB-A UV DEVICE LOCAL FAULTS	2.5E-4
			WES-UVL-FF-UVDB	TRAIN B UV DRIVER FAILS	3.4E-4
			WES-XHE-XE-SIGNL	OPERATOR FAILS TO RESPOND WITH RPS SIGNAL PRESENT	1.0E+0
54	0.0	5.0E-11	/WES-BME-TM-RTBA	RTB-A IN T&M	1.0E+0
			/WES-BME-TM-RTBB	RTB-B IN T&M	1.0E+0
			WES-BSN-FF-RTBB	RTB-B SHUNT TRIP DEVICE LOCAL FAULTS	5.8E-4
			WES-BUV-FF-RTBB	RTB-B UV DEVICE LOCAL FAULTS	2.5E-4
			WES-UVL-FF-UVDA	TRAIN A UV DRIVER FAILS	3.4E-4
			WES-XHE-XE-SIGNL	OPERATOR FAILS TO RESPOND WITH RPS SIGNAL PRESENT	1.0E+0
55	0.0	4.9E-11	/WES-BME-TM-RTBA	RTB-A IN T&M	1.0E+0
			/WES-BME-TM-RTBB	RTB-B IN T&M	1.0E+0
			WES-TLC-FF-SSLAP	TRAIN A PRESSURE SOLID STATE LOGIC FAILS	3.8E-4
			WES-TLC-FF-SSLAT	TRAIN A TEMPERATURE SOLID STATE LOGIC FAILS	3.8E-4
			WES-UVL-FF-UVDB	TRAIN B UV DRIVER FAILS	3.4E-4
			WES-XHE-XE-SIGNL	OPERATOR FAILS TO RESPOND WITH RPS SIGNAL PRESENT	1.0E+0
56	0.0	4.9E-11	/WES-BME-TM-RTBA	RTB-A IN T&M	1.0E+0
			/WES-BME-TM-RTBB	RTB-B IN T&M	1.0E+0
			WES-TLC-FF-SSLBP	TRAIN B PRESSURE SOLID STATE LOGIC FAILS	3.8E-4
			WES-TLC-FF-SSLBT	TRAIN B TEMPERATURE SOLID STATE LOGIC FAILS	3.8E-4
			WES-UVL-FF-UVDA	TRAIN A UV DRIVER FAILS	3.4E-4
			WES-XHE-XE-SIGNL	OPERATOR FAILS TO RESPOND WITH RPS SIGNAL PRESENT	1.0E+0
57	0.0	4.1E-11	WES-BME-TM-RTBA	RTB-A IN T&M	1.4E-3
			/WES-BME-TM-RTBB	RTB-B IN T&M	1.0E+0
			WES-CCP-TM-CHA	CH-A IN T&M	2.9E-2
			WES-TLR-CF-RLB46	CCF 4 OR MORE TMU RELAYS IN TRAIN B ONE CHANNEL T&M	1.0E-6
			WES-XHE-XE-SIGNL	OPERATOR FAILS TO RESPOND WITH RPS SIGNAL PRESENT	1.0E+0
58	0.0	4.1E-11	/WES-BME-TM-RTBA	RTB-A IN T&M	1.0E+0
			WES-BME-TM-RTBB	RTB-B IN T&M	1.4E-3
			WES-CCP-TM-CHA	CH-A IN T&M	2.9E-2
			WES-TLR-CF-RLA46	CCF 4 OR MORE TMU RELAYS IN TRAIN A ONE CHANNEL T&M	1.0E-6
			WES-XHE-XE-SIGNL	OPERATOR FAILS TO RESPOND WITH RPS SIGNAL PRESENT	1.0E+0
59	0.0	3.3E-11	/WES-BME-TM-RTBA	RTB-A IN T&M	1.0E+0
			/WES-BME-TM-RTBB	RTB-B IN T&M	1.0E+0
			WES-BUV-CF-RTBAB	CCF OF RTB-A AND RTB-B UV DEVICES	9.7E-6
			WES-PWR-CF-TRNAB	CCF OF RTB-A AND RTB-B SHUNT TRIP POWER SUPPLIES	3.4E-6
60	0.0	2.4E-11	/WES-BME-TM-RTBA	RTB-A IN T&M	1.0E+0
			/WES-BME-TM-RTBB	RTB-B IN T&M	1.0E+0
			WES-CBI-CF-T3OF4	CCF 3 TEMP OUTPUT BISTABLES IN 3 OF 4 CHANNELS	1.2E-5
			/WES-CCP-TM-CHA	CH-A IN T&M	9.7E-1
			WES-CPR-CF-P3OF4	CCF 3 PRESSURE SENSORS IN 3 OF 4 CHANNELS	2.1E-6
			WES-XHE-XE-NSGNL	OPERATOR FAILS TO RESPOND WITH NO RPS SIGNAL PRESENT	1.0E+0
61	0.0	2.1E-11	WES-BME-TM-RTBA	RTB-A IN T&M	1.4E-3
			/WES-BME-TM-RTBB	RTB-B IN T&M	1.0E+0
			WES-C21-CF-E2OF3	CCF 2 EAGLE-21 PROCESS LOGIC MODULES IN 2 OF 3 CHANNELS	5.1E-7
			WES-CCP-TM-CHA	CH-A IN T&M	2.9E-2
			WES-XHE-XE-NSGNL	OPERATOR FAILS TO RESPOND WITH NO RPS SIGNAL PRESENT	1.0E+0
62	0.0	2.1E-11	/WES-BME-TM-RTBA	RTB-A IN T&M	1.0E+0
			WES-BME-TM-RTBB	RTB-B IN T&M	1.4E-3
			WES-C21-CF-E2OF3	CCF 2 EAGLE-21 PROCESS LOGIC MODULES IN 2 OF 3 CHANNELS	5.1E-7
			WES-CCP-TM-CHA	CH-A IN T&M	2.9E-2
			WES-XHE-XE-NSGNL	OPERATOR FAILS TO RESPOND WITH NO RPS SIGNAL PRESENT	1.0E+0
63	0.0	1.9E-11	/WES-BME-TM-RTBA	RTB-A IN T&M	1.0E+0
			/WES-BME-TM-RTBB	RTB-B IN T&M	1.0E+0
			WES-BUV-CF-RTBAB	CCF OF RTB-A AND RTB-B UV DEVICES	9.7E-6
			WES-TLR-CF-RTBAB	CCF OF RTB-A AND RTB-B SHUNT TRIP RELAYS	2.0E-6
64	0.0	1.7E-11	/WES-BME-TM-RTBA	RTB-A IN T&M	1.0E+0
			/WES-BME-TM-RTBB	RTB-B IN T&M	1.0E+0
			WES-CCP-TM-CHA	CH-A IN T&M	2.9E-2
			WES-CPR-CF-P2OF3	CCF 2 PRESSURE SENSORS IN 2 OF 3 CHANNELS	7.7E-6
			WES-CTP-CF-T2OF6	CCF 2 TEMP SENSORS IN 2 OF 3 CHANNELS	7.5E-5

Table F-5. (continued).

Cut Set	Cut Set Percent	Cut Set Prob.	Basic Event[a]	Description	Prob.
			WES-XHE-XE-NSGNL	OPERATOR FAILS TO RESPOND WITH NO RPS SIGNAL PRESENT	1.0E+0
65	0.0	1.2E-11	WES-BME-FO-RTBA	RTB-A LOCAL HW FAILURE	3.7E-5
			/WES-BME-TM-RTBA	RTB-A IN T&M	1.0E+0
			/WES-BME-TM-RTBB	RTB-B IN T&M	1.0E+0
			/WES-CCP-TM-CHA	CH-A IN T&M	9.7E-1
			WES-TLR-CF-RLB68	CCF 6 OR MORE TMU RELAYS IN TRAIN B NO CHANNEL T&M	3.3E-7
			WES-XHE-XE-SIGNL	OPERATOR FAILS TO RESPOND WITH RPS SIGNAL PRESENT	1.0E+0
66	0.0	1.2E-11	WES-BME-FO-RTBB	RTB-B LOCAL HW FAILURE	3.7E-5
			/WES-BME-TM-RTBA	RTB-A IN T&M	1.0E+0
			/WES-BME-TM-RTBB	RTB-B IN T&M	1.0E+0
			/WES-CCP-TM-CHA	CH-A IN T&M	9.7E-1
			WES-TLR-CF-RLA68	CCF 6 OR MORE TMU RELAYS IN TRAIN A NO CHANNEL T&M	3.3E-7
			WES-XHE-XE-SIGNL	OPERATOR FAILS TO RESPOND WITH RPS SIGNAL PRESENT	1.0E+0
67	0.0	9.7E-12	/WES-BME-TM-RTBA	RTB-A IN T&M	1.0E+0
			/WES-BME-TM-RTBB	RTB-B IN T&M	1.0E+0
			WES-CCP-TM-CHA	CH-A IN T&M	2.9E-2
			WES-TLR-CF-RLA46	CCF 4 OR MORE TMU RELAYS IN TRAIN A ONE CHANNEL T&M	1.0E-6
			WES-UVL-FF-UVDB	TRAIN B UV DRIVER FAILS	3.4E-4
			WES-XHE-XE-SIGNL	OPERATOR FAILS TO RESPOND WITH RPS SIGNAL PRESENT	1.0E+0
68	0.0	9.7E-12	/WES-BME-TM-RTBA	RTB-A IN T&M	1.0E+0
			/WES-BME-TM-RTBB	RTB-B IN T&M	1.0E+0
			WES-CCP-TM-CHA	CH-A IN T&M	2.9E-2
			WES-TLR-CF-RLB46	CCF 4 OR MORE TMU RELAYS IN TRAIN B ONE CHANNEL T&M	1.0E-6
			WES-UVL-FF-UVDA	TRAIN A UV DRIVER FAILS	3.4E-4
			WES-XHE-XE-SIGNL	OPERATOR FAILS TO RESPOND WITH RPS SIGNAL PRESENT	1.0E+0
69	0.0	9.3E-12	/WES-BME-TM-RTBA	RTB-A IN T&M	1.0E+0
			/WES-BME-TM-RTBB	RTB-B IN T&M	1.0E+0
			WES-CBI-CF-T2OF3	CCF 2 TEMP OUTPUT BISTABLES IN 2 OF 3 CHANNELS	4.2E-5
			WES-CCP-TM-CHA	CH-A IN T&M	2.9E-2
			WES-CPR-CF-P2OF3	CCF 2 PRESSURE SENSORS IN 2 OF 3 CHANNELS	7.7E-6
			WES-XHE-XE-NSGNL	OPERATOR FAILS TO RESPOND WITH NO RPS SIGNAL PRESENT	1.0E+0
70	0.0	8.4E-12	WES-BME-TM-RTBA	RTB-A IN T&M	1.4E-3
			/WES-BME-TM-RTBB	RTB-B IN T&M	1.0E+0
			WES-CCP-TM-CHA	CH-A IN T&M	2.9E-2
			WES-TLR-CF-8OF12	CCF 8 OR MORE TMU RELAYS IN TRAINS A AND B ONE CHANNEL T&M	2.1E-7
			WES-XHE-XE-SIGNL	OPERATOR FAILS TO RESPOND WITH RPS SIGNAL PRESENT	1.0E+0
71	0.0	8.4E-12	/WES-BME-TM-RTBA	RTB-A IN T&M	1.0E+0
			WES-BME-TM-RTBB	RTB-B IN T&M	1.4E-3
			WES-CCP-TM-CHA	CH-A IN T&M	2.9E-2
			WES-TLR-CF-8OF12	CCF 8 OR MORE TMU RELAYS IN TRAINS A AND B ONE CHANNEL T&M	2.1E-7
			WES-XHE-XE-SIGNL	OPERATOR FAILS TO RESPOND WITH RPS SIGNAL PRESENT	1.0E+0
72	0.0	5.5E-12	/WES-BME-TM-RTBA	RTB-A IN T&M	1.0E+0
			/WES-BME-TM-RTBB	RTB-B IN T&M	1.0E+0
			/WES-CCP-TM-CHA	CH-A IN T&M	9.7E-1
			WES-TLC-CF-SSLA	CCF SOLID STATE LOGIC TRAIN A (2 OF 4)	1.7E-5
			WES-TLR-CF-RLB68	CCF 6 OR MORE TMU RELAYS IN TRAIN B NO CHANNEL T&M	3.3E-7
			WES-XHE-XE-SIGNL	OPERATOR FAILS TO RESPOND WITH RPS SIGNAL PRESENT	1.0E+0
73	0.0	5.5E-12	/WES-BME-TM-RTBA	RTB-A IN T&M	1.0E+0
			/WES-BME-TM-RTBB	RTB-B IN T&M	1.0E+0
			/WES-CCP-TM-CHA	CH-A IN T&M	9.7E-1
			WES-TLC-CF-SSLB	CCF SOLID STATE LOGIC TRAIN B (2 OF 4)	1.7E-5
			WES-TLR-CF-RLA68	CCF 6 OR MORE TMU RELAYS IN TRAIN A NO CHANNEL T&M	3.3E-7
			WES-XHE-XE-SIGNL	OPERATOR FAILS TO RESPOND WITH RPS SIGNAL PRESENT	1.0E+0
74	0.0	5.4E-12	WES-BME-FO-RTBA	RTB-A LOCAL HW FAILURE	3.7E-5
			/WES-BME-TM-RTBA	RTB-A IN T&M	1.0E+0
			/WES-BME-TM-RTBB	RTB-B IN T&M	1.0E+0
			WES-BSN-FF-RTBB	RTB-B SHUNT TRIP DEVICE LOCAL FAULTS	5.8E-4
			WES-BUV-FF-RTBB	RTB-B UV DEVICE LOCAL FAULTS	2.5E-4
75	0.0	5.4E-12	WES-BME-FO-RTBB	RTB-B LOCAL HW FAILURE	3.7E-5
			/WES-BME-TM-RTBA	RTB-A IN T&M	1.0E+0
			/WES-BME-TM-RTBB	RTB-B IN T&M	1.0E+0
			WES-BSN-FF-RTBA	RTB-A SHUNT TRIP DEVICE LOCAL FAULTS	5.8E-4
			WES-BUV-FF-RTBA	RTB-A UV DEVICE LOCAL FAULTS	2.5E-4
76	0.0	5.4E-12	WES-BME-FO-RTBA	RTB-A LOCAL HW FAILURE	3.7E-5
			/WES-BME-TM-RTBA	RTB-A IN T&M	1.0E+0
			/WES-BME-TM-RTBB	RTB-B IN T&M	1.0E+0
			WES-TLC-FF-SSLBP	TRAIN B PRESSURE SOLID STATE LOGIC FAILS	3.8E-4
			WES-TLC-FF-SSLBT	TRAIN B TEMPERATURE SOLID STATE LOGIC FAILS	3.8E-4
			WES-XHE-XE-SIGNL	OPERATOR FAILS TO RESPOND WITH RPS SIGNAL PRESENT	1.0E+0
77	0.0	5.4E-12	WES-BME-FO-RTBB	RTB-B LOCAL HW FAILURE	3.7E-5
			/WES-BME-TM-RTBA	RTB-A IN T&M	1.0E+0
			/WES-BME-TM-RTBB	RTB-B IN T&M	1.0E+0
			WES-TLC-FF-SSLAP	TRAIN A PRESSURE SOLID STATE LOGIC FAILS	3.8E-4
			WES-TLC-FF-SSLAT	TRAIN A TEMPERATURE SOLID STATE LOGIC FAILS	3.8E-4
			WES-XHE-XE-SIGNL	OPERATOR FAILS TO RESPOND WITH RPS SIGNAL PRESENT	1.0E+0
78	0.0	5.1E-12	/WES-BME-TM-RTBA	RTB-A IN T&M	1.0E+0
			/WES-BME-TM-RTBB	RTB-B IN T&M	1.0E+0
			WES-BUV-FF-RTBA	RTB-A UV DEVICE LOCAL FAULTS	2.5E-4
			WES-PWR-FF-TRNA	TRAIN A 125 VDC BUS FAILS	6.0E-5
			WES-UVL-FF-UVDB	TRAIN B UV DRIVER FAILS	3.4E-4
			WES-XHE-XE-SIGNL	OPERATOR FAILS TO RESPOND WITH RPS SIGNAL PRESENT	1.0E+0
79	0.0	5.1E-12	/WES-BME-TM-RTBA	RTB-A IN T&M	1.0E+0
			/WES-BME-TM-RTBB	RTB-B IN T&M	1.0E+0
			WES-BUV-FF-RTBB	RTB-B UV DEVICE LOCAL FAULTS	2.5E-4
			WES-PWR-FF-TRNB	TRAIN B 125 VDC BUS FAILS	6.0E-5
			WES-UVL-FF-UVDA	TRAIN A UV DRIVER FAILS	3.4E-4
			WES-XHE-XE-SIGNL	OPERATOR FAILS TO RESPOND WITH RPS SIGNAL PRESENT	1.0E+0
80	0.0	3.4E-12	/WES-BME-TM-RTBA	RTB-A IN T&M	1.0E+0
			/WES-BME-TM-RTBB	RTB-B IN T&M	1.0E+0
			WES-BUV-FF-RTBA	RTB-A UV DEVICE LOCAL FAULTS	2.5E-4

Table F-5. (continued).

Cut Set	Cut Set Percent	Cut Set Prob.	Basic Event[a]	Description	Prob.
			WES-TLR-FC-RLYSA	SHUNT TRIP RELAY SA FAILS	3.9E-5
			WES-UVL-FF-UVDB	TRAIN B UV DRIVER FAILS	3.4E-4
			WES-XHE-XE-SIGNL	OPERATOR FAILS TO RESPOND WITH RPS SIGNAL PRESENT	1.0E+0
81	0.0	3.4E-12	/WES-BME-TM-RTBA	RTB-A IN T&M	1.0E+0
			/WES-BME-TM-RTBB	RTB-B IN T&M	1.0E+0
			WES-BUV-FF-RTBB	RTB-B UV DEVICE LOCAL FAULTS	2.5E-4
			WES-TLR-FC-RLYSB	SHUNT TRIP RELAY SB FAILS	3.9E-5
			WES-UVL-FF-UVDA	TRAIN A UV DRIVER FAILS	3.4E-4
			WES-XHE-XE-SIGNL	OPERATOR FAILS TO RESPOND WITH RPS SIGNAL PRESENT	1.0E+0
82	0.0	2.5E-12	/WES-BME-TM-RTBA	RTB-A IN T&M	1.0E+0
			/WES-BME-TM-RTBB	RTB-B IN T&M	1.0E+0
			WES-BSN-FF-RTBA	RTB-A SHUNT TRIP DEVICE LOCAL FAULTS	5.8E-4
			WES-BUV-FF-RTBA	RTB-A UV DEVICE LOCAL FAULTS	2.5E-4
			WES-TLC-CF-SSLB	CCF SOLID STATE LOGIC TRAIN B (2 OF 4)	1.7E-5
			WES-XHE-XE-SIGNL	OPERATOR FAILS TO RESPOND WITH RPS SIGNAL PRESENT	1.0E+0
83	0.0	2.5E-12	/WES-BME-TM-RTBA	RTB-A IN T&M	1.0E+0
			/WES-BME-TM-RTBB	RTB-B IN T&M	1.0E+0
			WES-BSN-FF-RTBB	RTB-B SHUNT TRIP DEVICE LOCAL FAULTS	5.8E-4
			WES-BUV-FF-RTBB	RTB-B UV DEVICE LOCAL FAULTS	2.5E-4
			WES-TLC-CF-SSLA	CCF SOLID STATE LOGIC TRAIN A (2 OF 4)	1.7E-5
			WES-XHE-XE-SIGNL	OPERATOR FAILS TO RESPOND WITH RPS SIGNAL PRESENT	1.0E+0
84	0.0	2.5E-12	/WES-BME-TM-RTBA	RTB-A IN T&M	1.0E+0
			/WES-BME-TM-RTBB	RTB-B IN T&M	1.0E+0
			WES-TLC-CF-SSLA	CCF SOLID STATE LOGIC TRAIN A (2 OF 4)	1.7E-5
			WES-TLC-FF-SSLBP	TRAIN B PRESSURE SOLID STATE LOGIC FAILS	3.8E-4
			WES-TLC-FF-SSLBT	TRAIN B TEMPERATURE SOLID STATE LOGIC FAILS	3.8E-4
			WES-XHE-XE-SIGNL	OPERATOR FAILS TO RESPOND WITH RPS SIGNAL PRESENT	1.0E+0
85	0.0	2.5E-12	/WES-BME-TM-RTBA	RTB-A IN T&M	1.0E+0
			/WES-BME-TM-RTBB	RTB-B IN T&M	1.0E+0
			WES-TLC-CF-SSLB	CCF SOLID STATE LOGIC TRAIN B (2 OF 4)	1.7E-5
			WES-TLC-FF-SSLAP	TRAIN A PRESSURE SOLID STATE LOGIC FAILS	3.8E-4
			WES-TLC-FF-SSLAT	TRAIN A TEMPERATURE SOLID STATE LOGIC FAILS	3.8E-4
			WES-XHE-XE-SIGNL	OPERATOR FAILS TO RESPOND WITH RPS SIGNAL PRESENT	1.0E+0
86	0.0	1.9E-12	WES-BME-FO-BYBA	BYB-A LOCAL HW FAILURE	3.7E-5
			WES-BME-FO-RTBB	RTB-B LOCAL HW FAILURE	3.7E-5
			WES-BME-TM-RTBA	RTB-A IN T&M	1.4E-3
			/WES-BME-TM-RTBB	RTB-B IN T&M	1.0E+0
87	0.0	1.9E-12	WES-BME-FO-BYBB	BYB-B LOCAL HW FAILURE	3.7E-5
			WES-BME-FO-RTBA	RTB-A LOCAL HW FAILURE	3.7E-5
			/WES-BME-TM-RTBA	RTB-A IN T&M	1.0E+0
			WES-BME-TM-RTBB	RTB-B IN T&M	1.4E-3
88	0.0	1.1E-12	WES-BME-FO-RTBA	RTB-A LOCAL HW FAILURE	3.7E-5
			/WES-BME-TM-RTBA	RTB-A IN T&M	1.0E+0
			/WES-BME-TM-RTBB	RTB-B IN T&M	1.0E+0
			WES-CCP-TM-CHA	CH-A IN T&M	2.9E-2
			WES-TLR-CF-RLB46	CCF 4 OR MORE TMU RELAYS IN TRAIN B ONE CHANNEL T&M	1.0E-6
			WES-XHE-XE-SIGNL	OPERATOR FAILS TO RESPOND WITH RPS SIGNAL PRESENT	1.0E+0
89	0.0	1.1E-12	WES-BME-FO-RTBB	RTB-B LOCAL HW FAILURE	3.7E-5
			/WES-BME-TM-RTBA	RTB-A IN T&M	1.0E+0
			/WES-BME-TM-RTBB	RTB-B IN T&M	1.0E+0
			WES-CCP-TM-CHA	CH-A IN T&M	2.9E-2
			WES-TLR-CF-RLA46	CCF 4 OR MORE TMU RELAYS IN TRAIN A ONE CHANNEL T&M	1.0E-6
			WES-XHE-XE-SIGNL	OPERATOR FAILS TO RESPOND WITH RPS SIGNAL PRESENT	1.0E+0
90	0.0	1.1E-12	/WES-BME-TM-RTBA	RTB-A IN T&M	1.0E+0
			/WES-BME-TM-RTBB	RTB-B IN T&M	1.0E+0
			WES-C21-FF-E21B	CH-B EAGLE-21 PROCESS LOGIC MODULE FAILS	6.5E-5
			WES-CBI-FF-BSTPC	CH-C PRESSURE OUTPUT BISTABLE FAILS	7.5E-4
			WES-CBI-FF-BSTTC	CH-C TEMPERATURE OUTPUT BISTABLE FAILS	7.5E-4
			WES-CCP-TM-CHA	CH-A IN T&M	2.9E-2
			WES-XHE-XE-NSGNL	OPERATOR FAILS TO RESPOND WITH NO RPS SIGNAL PRESENT	1.0E+0
91	0.0	1.1E-12	/WES-BME-TM-RTBA	RTB-A IN T&M	1.0E+0
			/WES-BME-TM-RTBB	RTB-B IN T&M	1.0E+0
			WES-C21-FF-E21B	CH-B EAGLE-21 PROCESS LOGIC MODULE FAILS	6.5E-5
			WES-CBI-FF-BSTPD	CH-D PRESSURE OUTPUT NISTABLE FAILS	7.5E-4
			WES-CBI-FF-BSTTD	CH-D TEMPERATURE OUTPUT BISTABLE FAILS	7.5E-4
			WES-CCP-TM-CHA	CH-A IN T&M	2.9E-2
			WES-XHE-XE-NSGNL	OPERATOR FAILS TO RESPOND WITH NO RPS SIGNAL PRESENT	1.0E+0
92	0.0	1.1E-12	/WES-BME-TM-RTBA	RTB-A IN T&M	1.0E+0
			/WES-BME-TM-RTBB	RTB-B IN T&M	1.0E+0
			WES-C21-FF-E21C	CH-C EAGLE-21 PROCESS LOGIC MODULE FAILS	6.5E-5
			WES-CBI-FF-BSTPB	CH-B PRESSURE OUTPUT BISTABLE FAILS	7.5E-4
			WES-CBI-FF-BSTTB	CH-B TEMPERATURE OUTPUT BISTABLE FAILS	7.5E-4
			WES-CCP-TM-CHA	CH-A IN T&M	2.9E-2
			WES-XHE-XE-NSGNL	OPERATOR FAILS TO RESPOND WITH NO RPS SIGNAL PRESENT	1.0E+0
93	0.0	1.1E-12	/WES-BME-TM-RTBA	RTB-A IN T&M	1.0E+0
			/WES-BME-TM-RTBB	RTB-B IN T&M	1.0E+0
			WES-C21-FF-E21C	CH-C EAGLE-21 PROCESS LOGIC MODULE FAILS	6.5E-5
			WES-CBI-FF-BSTPD	CH-D PRESSURE OUTPUT NISTABLE FAILS	7.5E-4
			WES-CBI-FF-BSTTD	CH-D TEMPERATURE OUTPUT BISTABLE FAILS	7.5E-4
			WES-CCP-TM-CHA	CH-A IN T&M	2.9E-2
			WES-XHE-XE-NSGNL	OPERATOR FAILS TO RESPOND WITH NO RPS SIGNAL PRESENT	1.0E+0
94	0.0	1.1E-12	/WES-BME-TM-RTBA	RTB-A IN T&M	1.0E+0
			/WES-BME-TM-RTBB	RTB-B IN T&M	1.0E+0
			WES-C21-FF-E21D	CH-D EAGLE-21 PROCESS LOGIC MODULE FAILS	6.5E-5
			WES-CBI-FF-BSTPB	CH-B PRESSURE OUTPUT BISTABLE FAILS	7.5E-4
			WES-CBI-FF-BSTTB	CH-B TEMPERATURE OUTPUT BISTABLE FAILS	7.5E-4
			WES-CCP-TM-CHA	CH-A IN T&M	2.9E-2
			WES-XHE-XE-NSGNL	OPERATOR FAILS TO RESPOND WITH NO RPS SIGNAL PRESENT	1.0E+0
95	0.0	1.1E-12	/WES-BME-TM-RTBA	RTB-A IN T&M	1.0E+0
			/WES-BME-TM-RTBB	RTB-B IN T&M	1.0E+0

Table F-5. (continued).

Cut Set	Cut Set Percent	Cut Set Prob.	Basic Event[a]	Description	Prob.
			WES-C21-FF-E21D	CH-D EAGLE-21 PROCESS LOGIC MODULE FAILS	6.5E-5
			WES-CBI-FF-BSTPC	CH-C PRESSURE OUTPUT BISTABLE FAILS	7.5E-4
			WES-CBI-FF-BSTTC	CH-C TEMPERATURE OUTPUT BISTABLE FAILS	7.5E-4
			WES-CCP-TM-CHA	CH-A IN T&M	2.9E-2
			WES-XHE-XE-NSGNL	OPERATOR FAILS TO RESPOND WITH NO RPS SIGNAL PRESENT	1.0E+0
96	0.0	8.4E-13	/WES-BME-TM-RTBA	RTB-A IN T&M	1.0E+0
			/WES-BME-TM-RTBB	RTB-B IN T&M	1.0E+0
			WES-C21-FF-E21B	CH-B EAGLE-21 PROCESS LOGIC MODULE FAILS	6.5E-5
			WES-CBI-FF-BSTPC	CH-C PRESSURE OUTPUT BISTABLE FAILS	7.5E-4
			WES-CCP-TM-CHA	CH-A IN T&M	2.9E-2
			WES-CTP-FF-CLTXC	CH-C COLD LEG RTD FAILS	6.0E-4
			WES-XHE-XE-NSGNL	OPERATOR FAILS TO RESPOND WITH NO RPS SIGNAL PRESENT	1.0E+0
97	0.0	8.4E-13	/WES-BME-TM-RTBA	RTB-A IN T&M	1.0E+0
			/WES-BME-TM-RTBB	RTB-B IN T&M	1.0E+0
			WES-C21-FF-E21B	CH-B EAGLE-21 PROCESS LOGIC MODULE FAILS	6.5E-5
			WES-CBI-FF-BSTPC	CH-C PRESSURE OUTPUT BISTABLE FAILS	7.5E-4
			WES-CCP-TM-CHA	CH-A IN T&M	2.9E-2
			WES-CTP-FF-HLTXC	CH-C HOT LEG RTD FAILS	6.0E-4
			WES-XHE-XE-NSGNL	OPERATOR FAILS TO RESPOND WITH NO RPS SIGNAL PRESENT	1.0E+0
98	0.0	8.4E-13	/WES-BME-TM-RTBA	RTB-A IN T&M	1.0E+0
			/WES-BME-TM-RTBB	RTB-B IN T&M	1.0E+0
			WES-C21-FF-E21B	CH-B EAGLE-21 PROCESS LOGIC MODULE FAILS	6.5E-5
			WES-CBI-FF-BSTPD	CH-D PRESSURE OUTPUT NISTABLE FAILS	7.5E-4
			WES-CCP-TM-CHA	CH-A IN T&M	2.9E-2
			WES-CTP-FF-CLTXD	CH-D COLD LEG RTD FAILS	6.0E-4
			WES-XHE-XE-NSGNL	OPERATOR FAILS TO RESPOND WITH NO RPS SIGNAL PRESENT	1.0E+0
99	0.0	8.4E-13	/WES-BME-TM-RTBA	RTB-A IN T&M	1.0E+0
			/WES-BME-TM-RTBB	RTB-B IN T&M	1.0E+0
			WES-C21-FF-E21B	CH-B EAGLE-21 PROCESS LOGIC MODULE FAILS	6.5E-5
			WES-CBI-FF-BSTPD	CH-D PRESSURE OUTPUT NISTABLE FAILS	7.5E-4
			WES-CCP-TM-CHA	CH-A IN T&M	2.9E-2
			WES-CTP-FF-HLTXD	CH-D HOT LEG RTD FAILS	6.0E-4
			WES-XHE-XE-NSGNL	OPERATOR FAILS TO RESPOND WITH NO RPS SIGNAL PRESENT	1.0E+0
100	0.0	8.4E-13	/WES-BME-TM-RTBA	RTB-A IN T&M	1.0E+0
			/WES-BME-TM-RTBB	RTB-B IN T&M	1.0E+0
			WES-C21-FF-E21C	CH-C EAGLE-21 PROCESS LOGIC MODULE FAILS	6.5E-5
			WES-CBI-FF-BSTPB	CH-B PRESSURE OUTPUT BISTABLE FAILS	7.5E-4
			WES-CCP-TM-CHA	CH-A IN T&M	2.9E-2
			WES-CTP-FF-CLTXB	CH-B COLD LEG RTD FAILS	6.0E-4
			WES-XHE-XE-NSGNL	OPERATOR FAILS TO RESPOND WITH NO RPS SIGNAL PRESENT	1.0E+0

a. A / as the first character in a basic event name indicates a complemented event (Success = 1 - Failure). For example, the basic event for reactor trip breaker train A (RTB-A) in test and maintenance (T&M) is WES-BME-TM-RTBA (Failure = 1.40E-03). Thus, the basic event name for RTB-A not in T&M is /WES-BME-TM-RTBA (Success = 9.986E-01). The event description for complemented events remains the same as the description used for the failure event.

Table F-6. (continued).

Table F-6. Importance measures sorted on Fussell-Vesely for case with RPS mincut = 2.0E-5.

Basic Event	Number of Occur.	Prob. of Failure	Fussell-Vesely Importance	Risk Reduction Ratio	Risk Increase Ratio	Birnbaum Importance
WES-XHE-XE-SIGNL	960	1.00E+0	7.014E-01	3.349	1.000E+0	1.373E-05
WES-UVL-CF-UVDAB	3	1.04E-5	5.314E-01	2.134	5.095E+4	9.972E-01
WES-XHE-XE-NSGNL	4593	1.00E+0	1.544E-01	1.183	1.000E+0	3.022E-06
WES-CBI-CF-6OF8	3	2.70E-6	1.340E-01	1.155	4.948E+4	9.684E-01
WES-TLC-CF-SSLAB	3	2.10E-6	1.073E-01	1.120	5.095E+4	9.972E-01
WES-BME-CF-RTBAB	1	1.61E-6	8.203E-02	1.089	5.095E+4	9.972E-01
WES-ROD-CF-RCCAS	1	1.21E-6	6.182E-02	1.066	5.109E+4	1.000E+00
WES-UVL-FF-UVDA	37	3.37E-4	3.080E-02	1.032	9.233E+1	1.788E-03
WES-UVL-FF-UVDB	37	3.37E-4	3.080E-02	1.032	9.233E+1	1.788E-03
WES-BME-TM-RTBA	5601	1.40E-3	2.529E-02	1.026	1.904E+1	3.535E-04
WES-BME-TM-RTBB	5601	1.40E-3	2.529E-02	1.026	1.904E+1	3.535E-04
WES-CBI-CF-4OF6	3	8.21E-6	1.217E-02	1.012	1.483E+3	2.900E-02
WES-CCP-TM-CHA	5508	2.90E-2	8.910E-03	1.009	1.298E+0	6.013E-06
WES-C21-CF-E3OF4	3	1.51E-7	7.491E-03	1.008	4.948E+4	9.684E-01
WES-TLR-CF-12O16	3	8.07E-8	4.004E-03	1.004	4.948E+4	9.684E-01
WES-TLC-CF-SSLA	37	1.72E-5	1.572E-03	1.002	9.236E+1	1.788E-03
WES-TLC-CF-SSLB	37	1.72E-5	1.572E-03	1.002	9.236E+1	1.788E-03
WES-C21-CF-E2OF3	3	5.07E-7	7.512E-04	1.001	1.483E+3	2.900E-02
WES-BME-FO-RTBA	40	3.69E-5	7.367E-04	1.001	2.096E+1	3.907E-04
WES-BME-FO-RTBB	40	3.69E-5	7.367E-04	1.001	2.096E+1	3.907E-04
WES-TLR-CF-8OF12	3	2.07E-7	3.067E-04	1.000	1.483E+3	2.900E-02
WES-BME-CF-RANBB	1	1.61E-6	1.150E-04	1.000	7.243E+1	1.398E-03
WES-BME-CF-RBNBA	1	1.61E-6	1.150E-04	1.000	7.243E+1	1.398E-03
WES-TLR-CF-RLA68	26	3.28E-7	2.911E-05	1.000	8.971E+1	1.736E-03
WES-TLR-CF-RLB68	26	3.28E-7	2.911E-05	1.000	8.971E+1	1.736E-03
WES-CBI-CF-P3OF4	6	1.19E-5	2.887E-05	1.000	3.426E+0	4.748E-05
WES-CTP-CF-T3OF8	6	3.70E-5	2.563E-05	1.000	1.693E+0	1.356E-05
WES-TLC-FF-SSLAP	37	3.83E-4	1.341E-05	1.000	1.035E+0	6.851E-07
WES-TLC-FF-SSLAT	37	3.83E-4	1.341E-05	1.000	1.035E+0	6.851E-07
WES-TLC-FF-SSLBP	37	3.83E-4	1.341E-05	1.000	1.035E+0	6.851E-07
WES-TLC-FF-SSLBT	37	3.83E-4	1.341E-05	1.000	1.035E+0	6.851E-07
WES-BUV-CF-RTBAB	3	9.73E-6	1.309E-05	1.000	2.345E+0	2.633E-05
WES-C21-FF-E21B	483	6.52E-5	1.296E-05	1.000	1.199E+0	3.892E-06
WES-C21-FF-E21C	483	6.52E-5	1.296E-05	1.000	1.199E+0	3.892E-06
WES-C21-FF-E21D	483	6.52E-5	1.296E-05	1.000	1.199E+0	3.892E-06
WES-BSN-CF-RTBAB	1	2.10E-5	1.041E-05	1.000	1.496E+0	9.703E-06
WES-CBI-CF-T3OF4	6	1.19E-5	8.242E-06	1.000	1.693E+0	1.356E-05
WES-CBI-CF-P2OF3	6	4.19E-5	7.233E-06	1.000	1.173E+0	3.378E-06
WES-CTP-CF-T2OF6	6	7.46E-5	5.484E-06	1.000	1.074E+0	1.439E-06
WES-CPR-CF-P3OF4	6	2.06E-6	4.998E-06	1.000	3.426E+0	4.748E-05
WES-BUV-FF-RTBA	114	2.54E-4	3.451E-06	1.000	1.014E+0	2.659E-07
WES-BUV-FF-RTBB	114	2.54E-4	3.451E-06	1.000	1.014E+0	2.659E-07
WES-CBI-CF-T2OF3	6	4.19E-5	3.080E-06	1.000	1.074E+0	1.439E-06
WES-BSN-FF-RTBA	38	5.81E-4	2.946E-06	1.000	1.005E+0	9.924E-08
WES-BSN-FF-RTBB	38	5.81E-4	2.946E-06	1.000	1.005E+0	9.924E-08
WES-TLR-CF-RLA46	19	9.98E-7	2.646E-06	1.000	3.651E+0	5.189E-05
WES-TLR-CF-RLB46	19	9.98E-7	2.646E-06	1.000	3.651E+0	5.189E-05
WES-PWR-CF-TRNAB	1	3.40E-6	1.686E-06	1.000	1.496E+0	9.703E-06
WES-CPR-CF-P2OF3	6	7.71E-6	1.331E-06	1.000	1.173E+0	3.378E-06
WES-TLR-CF-RTBAB	1	2.00E-6	9.915E-07	1.000	1.496E+0	9.703E-06
WES-PWR-FF-TRNA	40	6.00E-5	3.463E-07	1.000	1.006E+0	1.130E-07
WES-PWR-FF-TRNB	40	6.00E-5	3.463E-07	1.000	1.006E+0	1.130E-07
WES-CBI-FF-BSTPB	1449	7.46E-4	2.880E-07	1.000	1.000E+0	7.558E-09
WES-CBI-FF-BSTPC	1449	7.46E-4	2.880E-07	1.000	1.000E+0	7.558E-09
WES-CBI-FF-BSTPD	1449	7.46E-4	2.880E-07	1.000	1.000E+0	7.558E-09
WES-TLR-FC-RLYSA	40	3.94E-5	2.274E-07	1.000	1.006E+0	1.130E-07
WES-TLR-FC-RLYSB	40	3.94E-5	2.274E-07	1.000	1.006E+0	1.130E-07
WES-CBI-FF-BSTTB	966	7.46E-4	1.279E-07	1.000	1.000E+0	3.355E-09
WES-CBI-FF-BSTTC	966	7.46E-4	1.279E-07	1.000	1.000E+0	3.355E-09
WES-CBI-FF-BSTTD	966	7.46E-4	1.279E-07	1.000	1.000E+0	3.355E-09
WES-CTP-FF-CLTXB	966	5.98E-4	1.025E-07	1.000	1.000E+0	3.355E-09
WES-CTP-FF-CLTXC	966	5.98E-4	1.025E-07	1.000	1.000E+0	3.355E-09
WES-CTP-FF-CLTXD	966	5.98E-4	1.025E-07	1.000	1.000E+0	3.355E-09
WES-CTP-FF-HLTXB	966	5.98E-4	1.025E-07	1.000	1.000E+0	3.355E-09
WES-CTP-FF-HLTXC	966	5.98E-4	1.025E-07	1.000	1.000E+0	3.355E-09
WES-CTP-FF-HLTXD	966	5.98E-4	1.025E-07	1.000	1.000E+0	3.355E-09
WES-BME-FO-BYBA	4	3.69E-5	9.772E-08	1.000	1.003E+0	5.183E-08
WES-BME-FO-BYBB	4	3.69E-5	9.772E-08	1.000	1.003E+0	5.183E-08
WES-BUV-CF-RANBB	3	9.73E-6	8.368E-08	1.000	1.009E+0	1.683E-07
WES-BUV-CF-RBNBA	3	9.73E-6	8.368E-08	1.000	1.009E+0	1.683E-07
WES-CPR-FF-PRESB	1449	1.16E-4	4.482E-08	1.000	1.000E+0	7.558E-09
WES-CPR-FF-PRESC	1449	1.16E-4	4.482E-08	1.000	1.000E+0	7.558E-09
WES-CPR-FF-PRESD	1449	1.16E-4	4.482E-08	1.000	1.000E+0	7.558E-09
WES-C21-FF-E21A	441	6.52E-5	4.341E-08	1.000	1.001E+0	1.303E-08
WES-BSN-CF-RANBB	1	2.10E-5	1.460E-08	1.000	1.001E+0	1.360E-08
WES-BSN-CF-RBNBA	1	2.10E-5	1.460E-08	1.000	1.001E+0	1.360E-08
WES-CBI-FF-BSTPA	1323	7.46E-4	9.360E-10	1.000	1.000E+0	2.529E-11
WES-BUV-FF-BYBA	6	2.54E-4	9.190E-10	1.000	1.000E+0	7.052E-11
WES-BUV-FF-BYBB	6	2.54E-4	9.190E-10	1.000	1.000E+0	7.052E-11
WES-CBI-FF-BSTTA	882	7.46E-4	4.084E-10	1.000	1.000E+0	1.123E-11
WES-BSN-FF-BYBA	2	5.81E-4	3.914E-10	1.000	1.000E+0	1.316E-11
WES-BSN-FF-BYBB	2	5.81E-4	3.914E-10	1.000	1.000E+0	1.316E-11
WES-CTP-FF-CLTXA	882	5.98E-4	3.404E-10	1.000	1.000E+0	1.123E-11
WES-CTP-FF-HLTXA	882	5.98E-4	3.404E-10	1.000	1.000E+0	1.123E-11
WES-TLR-CF-PRA34	26	1.52E-6	2.042E-10	1.000	1.000E+0	2.640E-09
WES-TLR-CF-PRB34	26	1.52E-6	2.042E-10	1.000	1.000E+0	2.640E-09
WES-TLR-CF-TRA34	26	1.52E-6	2.042E-10	1.000	1.000E+0	2.640E-09
WES-TLR-CF-TRB34	26	1.52E-6	2.042E-10	1.000	1.000E+0	2.640E-09
WES-CPR-FF-PRESA	1323	1.16E-4	1.532E-10	1.000	1.000E+0	2.529E-11
WES-TLR-CF-PRA23	19	5.10E-6	6.240E-11	1.000	1.000E+0	2.646E-10

Table F-6. (continued).

Basic Event	Number of Occur.	Prob. of Failure	Fussell-Vesely Importance	Risk Reduction Ratio	Risk Increase Ratio	Birnbaum Importance
WES-TLR-CF-PRB23	19	5.10E-6	6.240E-11	1.000	1.000E+0	2.646E-10
WES-TLR-CF-TRA23	19	5.10E-6	6.240E-11	1.000	1.000E+0	2.646E-10
WES-TLR-CF-TRB23	19	5.10E-6	6.240E-11	1.000	1.000E+0	2.646E-10
WES-TLR-FC-PRATA	312	3.94E-5	+0.000E+00	1.000	1.000E+0	+0.000E+00
WES-TLR-FC-PRATB	312	3.94E-5	+0.000E+00	1.000	1.000E+0	+0.000E+00
WES-TLR-FC-PRBTA	426	3.94E-5	+0.000E+00	1.000	1.000E+0	+0.000E+00
WES-TLR-FC-PRBTB	426	3.94E-5	+0.000E+00	1.000	1.000E+0	+0.000E+00
WES-TLR-FC-PRCTA	426	3.94E-5	+0.000E+00	1.000	1.000E+0	+0.000E+00
WES-TLR-FC-PRCTB	426	3.94E-5	+0.000E+00	1.000	1.000E+0	+0.000E+00
WES-TLR-FC-PRDTA	426	3.94E-5	+0.000E+00	1.000	1.000E+0	+0.000E+00
WES-TLR-FC-PRDTB	426	3.94E-5	+0.000E+00	1.000	1.000E+0	+0.000E+00
WES-TLR-FC-TRATA	312	3.94E-5	+0.000E+00	1.000	1.000E+0	+0.000E+00
WES-TLR-FC-TRATB	312	3.94E-5	+0.000E+00	1.000	1.000E+0	+0.000E+00
WES-TLR-FC-TRBTA	426	3.94E-5	+0.000E+00	1.000	1.000E+0	+0.000E+00
WES-TLR-FC-TRBTB	426	3.94E-5	+0.000E+00	1.000	1.000E+0	+0.000E+00
WES-TLR-FC-TRCTA	426	3.94E-5	+0.000E+00	1.000	1.000E+0	+0.000E+00
WES-TLR-FC-TRCTB	426	3.94E-5	+0.000E+00	1.000	1.000E+0	+0.000E+00
WES-TLR-FC-TRDTA	426	3.94E-5	+0.000E+00	1.000	1.000E+0	+0.000E+00
WES-TLR-FC-TRDTB	426	3.94E-5	+0.000E+00	1.000	1.000E+0	+0.000E+00

Table F-7. (continued).

Table F-7. Importance measures sorted on Risk Increase for case with RPS mincut = 2.0E-5.

Basic Event	Number of Occur.	Prob. of Failure	Fussell-Vesely Importance	Risk Reduction Ratio	Risk Increase Ratio	Birnbaum Importance
WES-ROD-CF-RCCAS	1	1.21E-6	6.182E-02	1.066	5.109E+4	1.000E+00
WES-BME-CF-RTBAB	1	1.61E-6	8.203E-02	1.089	5.095E+4	9.972E-01
WES-TLC-CF-SSLAB	3	2.10E-6	1.073E-01	1.120	5.095E+4	9.972E-01
WES-UVL-CF-UVDAB	3	1.04E-5	5.314E-01	2.134	5.095E+4	9.972E-01
WES-C21-CF-E3OF4	3	1.51E-7	7.491E-03	1.008	4.948E+4	9.684E-01
WES-CBI-CF-6OF8	3	2.70E-6	1.340E-01	1.155	4.948E+4	9.684E-01
WES-TLR-CF-12O16	3	8.07E-8	4.004E-03	1.004	4.948E+4	9.684E-01
WES-C21-CF-E2OF3	3	5.07E-7	7.512E-04	1.001	1.483E+3	2.900E-02
WES-CBI-CF-4OF6	3	8.21E-6	1.217E-02	1.012	1.483E+3	2.900E-02
WES-TLR-CF-8OF12	3	2.07E-7	3.067E-04	1.000	1.483E+3	2.900E-02
WES-TLC-CF-SSLA	37	1.72E-5	1.572E-03	1.002	9.236E+1	1.788E-03
WES-TLC-CF-SSLB	37	1.72E-5	1.572E-03	1.002	9.236E+1	1.788E-03
WES-UVL-FF-UVDA	37	3.37E-4	3.080E-02	1.032	9.233E+1	1.788E-03
WES-UVL-FF-UVDB	37	3.37E-4	3.080E-02	1.032	9.233E+1	1.788E-03
WES-TLR-CF-RLA68	26	3.28E-7	2.911E-05	1.000	8.971E+1	1.736E-03
WES-TLR-CF-RLB68	26	3.28E-7	2.911E-05	1.000	8.971E+1	1.736E-03
WES-BME-CF-RANBB	1	1.61E-6	1.150E-04	1.000	7.243E+1	1.398E-03
WES-BME-CF-RBNBA	1	1.61E-6	1.150E-04	1.000	7.243E+1	1.398E-03
WES-BME-FO-RTBA	40	3.69E-5	7.367E-04	1.001	2.096E+1	3.907E-04
WES-BME-FO-RTBB	40	3.69E-5	7.367E-04	1.001	2.096E+1	3.907E-04
WES-BME-TM-RTBA	5601	1.40E-3	2.529E-02	1.026	1.904E+1	3.535E-04
WES-BME-TM-RTBB	5601	1.40E-3	2.529E-02	1.026	1.904E+1	3.535E-04
WES-TLR-CF-RLA46	19	9.98E-7	2.646E-06	1.000	3.651E+0	5.189E-05
WES-TLR-CF-RLB46	19	9.98E-7	2.646E-06	1.000	3.651E+0	5.189E-05
WES-CBI-CF-P3OF4	6	1.19E-5	2.887E-05	1.000	3.426E+0	4.748E-05
WES-CPR-CF-P3OF4	6	2.06E-6	4.998E-06	1.000	3.426E+0	4.748E-05
WES-BUV-CF-RTBAB	3	9.73E-6	1.309E-05	1.000	2.345E+0	2.633E-05
WES-CBI-CF-T3OF4	6	1.19E-5	8.242E-06	1.000	1.693E+0	1.356E-05
WES-CTP-CF-T3OF8	6	3.70E-5	2.563E-05	1.000	1.693E+0	1.356E-05
WES-BSN-CF-RTBAB	1	2.10E-5	1.041E-05	1.000	1.496E+0	9.703E-06
WES-PWR-CF-TRNAB	1	3.40E-6	1.686E-06	1.000	1.496E+0	9.703E-06
WES-TLR-CF-RTBAB	1	2.00E-6	9.915E-07	1.000	1.496E+0	9.703E-06
WES-CCP-TM-CHA	5508	2.90E-2	8.910E-03	1.009	1.298E+0	6.013E-06
WES-C21-FF-E21B	483	6.52E-5	1.296E-05	1.000	1.199E+0	3.892E-06
WES-C21-FF-E21C	483	6.52E-5	1.296E-05	1.000	1.199E+0	3.892E-06
WES-C21-FF-E21D	483	6.52E-5	1.296E-05	1.000	1.199E+0	3.892E-06
WES-CBI-CF-P2OF3	6	4.19E-5	7.233E-06	1.000	1.173E+0	3.378E-06
WES-CPR-CF-P2OF3	6	7.71E-6	1.331E-06	1.000	1.173E+0	3.378E-06
WES-CBI-CF-T2OF3	6	4.19E-5	3.080E-06	1.000	1.074E+0	1.439E-06
WES-CTP-CF-T2OF6	6	7.46E-5	5.484E-06	1.000	1.074E+0	1.439E-06
WES-TLC-FF-SSLAP	37	3.83E-4	1.341E-05	1.000	1.035E+0	6.851E-07
WES-TLC-FF-SSLAT	37	3.83E-4	1.341E-05	1.000	1.035E+0	6.851E-07
WES-TLC-FF-SSLBP	37	3.83E-4	1.341E-05	1.000	1.035E+0	6.851E-07
WES-TLC-FF-SSLBT	37	3.83E-4	1.341E-05	1.000	1.035E+0	6.851E-07
WES-BUV-FF-RTBA	114	2.54E-4	3.451E-06	1.000	1.014E+0	2.659E-07
WES-BUV-FF-RTBB	114	2.54E-4	3.451E-06	1.000	1.014E+0	2.659E-07
WES-BUV-CF-RANBB	3	9.73E-6	8.368E-08	1.000	1.009E+0	1.683E-07
WES-BUV-CF-RBNBA	3	9.73E-6	8.368E-08	1.000	1.009E+0	1.683E-07
WES-PWR-FF-TRNA	40	6.00E-5	3.463E-07	1.000	1.006E+0	1.130E-07
WES-PWR-FF-TRNB	40	6.00E-5	3.463E-07	1.000	1.006E+0	1.130E-07
WES-TLR-FC-RLYSA	40	3.94E-5	2.274E-07	1.000	1.006E+0	1.130E-07
WES-TLR-FC-RLYSB	40	3.94E-5	2.274E-07	1.000	1.006E+0	1.130E-07
WES-BSN-FF-RTBA	38	5.81E-4	2.946E-06	1.000	1.005E+0	9.924E-08
WES-BSN-FF-RTBB	38	5.81E-4	2.946E-06	1.000	1.005E+0	9.924E-08
WES-BME-FO-BYBA	4	3.69E-5	9.772E-08	1.000	1.003E+0	5.183E-08
WES-BME-FO-BYBB	4	3.69E-5	9.772E-08	1.000	1.003E+0	5.183E-08
WES-BSN-CF-RANBB	1	2.10E-5	1.460E-08	1.000	1.001E+0	1.360E-08
WES-BSN-CF-RBNBA	1	2.10E-5	1.460E-08	1.000	1.001E+0	1.360E-08
WES-C21-FF-E21A	441	6.52E-5	4.341E-08	1.000	1.001E+0	1.303E-08
WES-BSN-FF-BYBA	2	5.81E-4	3.914E-10	1.000	1.000E+0	1.316E-11
WES-BSN-FF-BYBB	2	5.81E-4	3.914E-10	1.000	1.000E+0	1.316E-11
WES-BUV-FF-BYBA	6	2.54E-4	9.190E-10	1.000	1.000E+0	7.052E-11
WES-BUV-FF-BYBB	6	2.54E-4	9.190E-10	1.000	1.000E+0	7.052E-11
WES-CBI-FF-BSTPA	1323	7.46E-4	9.360E-10	1.000	1.000E+0	2.529E-11
WES-CBI-FF-BSTPB	1449	7.46E-4	2.880E-07	1.000	1.000E+0	7.558E-09
WES-CBI-FF-BSTPC	1449	7.46E-4	2.880E-07	1.000	1.000E+0	7.558E-09
WES-CBI-FF-BSTPD	1449	7.46E-4	2.880E-07	1.000	1.000E+0	7.558E-09
WES-CBI-FF-BSTTA	882	7.46E-4	4.084E-10	1.000	1.000E+0	1.123E-11
WES-CBI-FF-BSTTB	966	7.46E-4	1.279E-07	1.000	1.000E+0	3.355E-09
WES-CBI-FF-BSTTC	966	7.46E-4	1.279E-07	1.000	1.000E+0	3.355E-09
WES-CBI-FF-BSTTD	966	7.46E-4	1.279E-07	1.000	1.000E+0	3.355E-09
WES-CPR-FF-PRESA	1323	1.16E-4	1.532E-10	1.000	1.000E+0	2.529E-11
WES-CPR-FF-PRESB	1449	1.16E-4	4.482E-08	1.000	1.000E+0	7.558E-09
WES-CPR-FF-PRESC	1449	1.16E-4	4.482E-08	1.000	1.000E+0	7.558E-09
WES-CPR-FF-PRESD	1449	1.16E-4	4.482E-08	1.000	1.000E+0	7.558E-09
WES-CTP-FF-CLTXA	882	5.98E-4	3.404E-10	1.000	1.000E+0	1.123E-11
WES-CTP-FF-CLTXB	966	5.98E-4	1.025E-07	1.000	1.000E+0	3.355E-09
WES-CTP-FF-CLTXC	966	5.98E-4	1.025E-07	1.000	1.000E+0	3.355E-09
WES-CTP-FF-CLTXD	966	5.98E-4	1.025E-07	1.000	1.000E+0	3.355E-09
WES-CTP-FF-HLTXA	882	5.98E-4	3.404E-10	1.000	1.000E+0	1.123E-11
WES-CTP-FF-HLTXB	966	5.98E-4	1.025E-07	1.000	1.000E+0	3.355E-09
WES-CTP-FF-HLTXC	966	5.98E-4	1.025E-07	1.000	1.000E+0	3.355E-09
WES-CTP-FF-HLTXD	966	5.98E-4	1.025E-07	1.000	1.000E+0	3.355E-09
WES-TLR-CF-PRA23	19	5.10E-6	6.240E-11	1.000	1.000E+0	2.646E-10
WES-TLR-CF-PRA34	26	1.52E-6	2.042E-10	1.000	1.000E+0	2.640E-09
WES-TLR-CF-PRB23	19	5.10E-6	6.240E-11	1.000	1.000E+0	2.646E-10
WES-TLR-CF-PRB34	26	1.52E-6	2.042E-10	1.000	1.000E+0	2.640E-09
WES-TLR-CF-TRA23	19	5.10E-6	6.240E-11	1.000	1.000E+0	2.646E-10
WES-TLR-CF-TRA34	26	1.52E-6	2.042E-10	1.000	1.000E+0	2.640E-09
WES-TLR-CF-TRB23	19	5.10E-6	6.240E-11	1.000	1.000E+0	2.646E-10
WES-TLR-CF-TRB34	26	1.52E-6	2.042E-10	1.000	1.000E+0	2.640E-09

Appendix F

Table F-7. (continued).

Basic Event	Number of Occur.	Prob. of Failure	Fussell-Vesely Importance	Risk Reduction Ratio	Risk Increase Ratio	Birnbaum Importance
WES-TLR-FC-PRATA	312	3.94E-5	+0.000E+00	1.000	1.000E+0	+0.000E+00
WES-TLR-FC-PRATB	312	3.94E-5	+0.000E+00	1.000	1.000E+0	+0.000E+00
WES-TLR-FC-PRBTA	426	3.94E-5	+0.000E+00	1.000	1.000E+0	+0.000E+00
WES-TLR-FC-PRBTB	426	3.94E-5	+0.000E+00	1.000	1.000E+0	+0.000E+00
WES-TLR-FC-PRCTA	426	3.94E-5	+0.000E+00	1.000	1.000E+0	+0.000E+00
WES-TLR-FC-PRCTB	426	3.94E-5	+0.000E+00	1.000	1.000E+0	+0.000E+00
WES-TLR-FC-PRDTA	426	3.94E-5	+0.000E+00	1.000	1.000E+0	+0.000E+00
WES-TLR-FC-PRDTB	426	3.94E-5	+0.000E+00	1.000	1.000E+0	+0.000E+00
WES-TLR-FC-TRATA	312	3.94E-5	+0.000E+00	1.000	1.000E+0	+0.000E+00
WES-TLR-FC-TRATB	312	3.94E-5	+0.000E+00	1.000	1.000E+0	+0.000E+00
WES-TLR-FC-TRBTA	426	3.94E-5	+0.000E+00	1.000	1.000E+0	+0.000E+00
WES-TLR-FC-TRBTB	426	3.94E-5	+0.000E+00	1.000	1.000E+0	+0.000E+00
WES-TLR-FC-TRCTA	426	3.94E-5	+0.000E+00	1.000	1.000E+0	+0.000E+00
WES-TLR-FC-TRCTB	426	3.94E-5	+0.000E+00	1.000	1.000E+0	+0.000E+00
WES-TLR-FC-TRDTA	426	3.94E-5	+0.000E+00	1.000	1.000E+0	+0.000E+00
WES-TLR-FC-TRDTB	426	3.94E-5	+0.000E+00	1.000	1.000E+0	+0.000E+00
WES-XHE-XE-NSGNL	4593	1.00E+0	1.544E-01	1.183	1.000E+0	3.022E-06
WES-XHE-XE-SIGNL	960	1.00E+0	7.014E-01	3.349	1.000E+0	1.373E-05

Table F-8. (continued).

Table F-8. Importance measures sorted on Birnbaum for case with RPS mincut = 2.0E-5.

Basic Event	Number of Occur.	Prob. of Failure	Fussell-Vesely Importance	Risk Reduction Ratio	Risk Increase Ratio	Birnbaum Importance
WES-ROD-CF-RCCAS	1	1.21E-6	6.182E-02	1.066	5.109E+4	1.000E+00
WES-BME-CF-RTBAB	1	1.61E-6	8.203E-02	1.089	5.095E+4	9.972E-01
WES-TLC-CF-SSLAB	3	2.10E-6	1.073E-01	1.120	5.095E+4	9.972E-01
WES-UVL-CF-UVDAB	3	1.04E-5	5.314E-01	2.134	5.095E+4	9.972E-01
WES-C21-CF-E3OF4	3	1.51E-7	7.491E-03	1.008	4.948E+4	9.684E-01
WES-CBI-CF-6OF8	3	2.70E-6	1.340E-01	1.155	4.948E+4	9.684E-01
WES-TLR-CF-12O16	3	8.07E-8	4.004E-03	1.004	4.948E+4	9.684E-01
WES-C21-CF-E2OF3	3	5.07E-7	7.512E-04	1.001	1.483E+3	2.900E-02
WES-CBI-CF-4OF6	3	8.21E-6	1.217E-02	1.012	1.483E+3	2.900E-02
WES-TLR-CF-8OF12	3	2.07E-7	3.067E-04	1.000	1.483E+3	2.900E-02
WES-TLC-CF-SSLA	37	1.72E-5	1.572E-03	1.002	9.236E+1	1.788E-03
WES-TLC-CF-SSLB	37	1.72E-5	1.572E-03	1.002	9.236E+1	1.788E-03
WES-UVL-FF-UVDA	37	3.37E-4	3.080E-02	1.032	9.233E+1	1.788E-03
WES-UVL-FF-UVDB	37	3.37E-4	3.080E-02	1.032	9.233E+1	1.788E-03
WES-TLR-CF-RLA68	26	3.28E-7	2.911E-05	1.000	8.971E+1	1.736E-03
WES-TLR-CF-RLB68	26	3.28E-7	2.911E-05	1.000	8.971E+1	1.736E-03
WES-BME-CF-RANBB	1	1.61E-6	1.150E-04	1.000	7.243E+1	1.398E-03
WES-BME-CF-RBNBA	1	1.61E-6	1.150E-04	1.000	7.243E+1	1.398E-03
WES-BME-FO-RTBA	40	3.69E-5	7.367E-04	1.001	2.096E+1	3.907E-04
WES-BME-FO-RTBB	40	3.69E-5	7.367E-04	1.001	2.096E+1	3.907E-04
WES-BME-TM-RTBA	5601	1.40E-3	2.529E-02	1.026	1.904E+1	3.535E-04
WES-BME-TM-RTBB	5601	1.40E-3	2.529E-02	1.026	1.904E+1	3.535E-04
WES-TLR-CF-RLA46	19	9.98E-7	2.646E-06	1.000	3.651E+0	5.189E-05
WES-TLR-CF-RLB46	19	9.98E-7	2.646E-06	1.000	3.651E+0	5.189E-05
WES-CBI-CF-P3OF4	6	1.19E-5	2.887E-05	1.000	3.426E+0	4.748E-05
WES-CPR-CF-P3OF4	6	2.06E-6	4.998E-06	1.000	3.426E+0	4.748E-05
WES-BUV-CF-RTBAB	3	9.73E-6	1.309E-05	1.000	2.345E+0	2.633E-05
WES-XHE-XE-SIGNL	960	1.00E+0	7.014E-01	3.349	1.000E+0	1.373E-05
WES-CBI-CF-T3OF4	6	1.19E-5	8.242E-06	1.000	1.693E+0	1.356E-05
WES-CTP-CF-T3OF8	6	3.70E-5	2.563E-05	1.000	1.693E+0	1.356E-05
WES-BSN-CF-RTBAB	1	2.10E-5	1.041E-05	1.000	1.496E+0	9.703E-06
WES-PWR-CF-TRNAB	1	3.40E-6	1.686E-06	1.000	1.496E+0	9.703E-06
WES-TLR-CF-RTBAB	1	2.00E-6	9.915E-07	1.000	1.496E+0	9.703E-06
WES-CCP-TM-CHA	5508	2.90E-2	8.910E-03	1.009	1.298E+0	6.013E-06
WES-C21-FF-E21B	483	6.52E-5	1.296E-05	1.000	1.199E+0	3.892E-06
WES-C21-FF-E21C	483	6.52E-5	1.296E-05	1.000	1.199E+0	3.892E-06
WES-C21-FF-E21D	483	6.52E-5	1.296E-05	1.000	1.199E+0	3.892E-06
WES-CBI-CF-P2OF3	6	4.19E-5	7.233E-06	1.000	1.173E+0	3.378E-06
WES-CPR-CF-P2OF3	6	7.71E-6	1.331E-06	1.000	1.173E+0	3.378E-06
WES-XHE-XE-NSGNL	4593	1.00E+0	1.544E-01	1.183	1.000E+0	3.022E-06
WES-CBI-CF-T2OF3	6	4.19E-5	3.080E-06	1.000	1.074E+0	1.439E-06
WES-CTP-CF-T2OF6	6	7.46E-5	5.484E-06	1.000	1.074E+0	1.439E-06
WES-TLC-FF-SSLAP	37	3.83E-4	1.341E-05	1.000	1.035E+0	6.851E-07
WES-TLC-FF-SSLAT	37	3.83E-4	1.341E-05	1.000	1.035E+0	6.851E-07
WES-TLC-FF-SSLBP	37	3.83E-4	1.341E-05	1.000	1.035E+0	6.851E-07
WES-TLC-FF-SSLBT	37	3.83E-4	1.341E-05	1.000	1.035E+0	6.851E-07
WES-BUV-FF-RTBA	114	2.54E-4	3.451E-06	1.000	1.014E+0	2.659E-07
WES-BUV-FF-RTBB	114	2.54E-4	3.451E-06	1.000	1.014E+0	2.659E-07
WES-BUV-CF-RANBB	3	9.73E-6	8.368E-08	1.000	1.009E+0	1.683E-07
WES-BUV-CF-RBNBA	3	9.73E-6	8.368E-08	1.000	1.009E+0	1.683E-07
WES-PWR-FF-TRNA	40	6.00E-5	3.463E-07	1.000	1.006E+0	1.130E-07
WES-PWR-FF-TRNB	40	6.00E-5	3.463E-07	1.000	1.006E+0	1.130E-07
WES-TLR-FC-RLYSA	40	3.94E-5	2.274E-07	1.000	1.006E+0	1.130E-07
WES-TLR-FC-RLYSB	40	3.94E-5	2.274E-07	1.000	1.006E+0	1.130E-07
WES-BSN-FF-RTBA	38	5.81E-4	2.946E-06	1.000	1.005E+0	9.924E-08
WES-BSN-FF-RTBB	38	5.81E-4	2.946E-06	1.000	1.005E+0	9.924E-08
WES-BME-FO-BYBA	4	3.69E-5	9.772E-08	1.000	1.003E+0	5.183E-08
WES-BME-FO-BYBB	4	3.69E-5	9.772E-08	1.000	1.003E+0	5.183E-08
WES-BSN-CF-RANBB	1	2.10E-5	1.460E-08	1.000	1.001E+0	1.360E-08
WES-BSN-CF-RBNBA	1	2.10E-5	1.460E-08	1.000	1.001E+0	1.360E-08
WES-C21-FF-E21A	441	6.52E-5	4.341E-08	1.000	1.001E+0	1.303E-08
WES-CBI-FF-BSTPB	1449	7.46E-4	2.880E-07	1.000	1.000E+0	7.558E-09
WES-CBI-FF-BSTPC	1449	7.46E-4	2.880E-07	1.000	1.000E+0	7.558E-09
WES-CBI-FF-BSTPD	1449	7.46E-4	2.880E-07	1.000	1.000E+0	7.558E-09
WES-CPR-FF-PRESB	1449	1.16E-4	4.482E-08	1.000	1.000E+0	7.558E-09
WES-CPR-FF-PRESC	1449	1.16E-4	4.482E-08	1.000	1.000E+0	7.558E-09
WES-CPR-FF-PRESD	1449	1.16E-4	4.482E-08	1.000	1.000E+0	7.558E-09
WES-CBI-FF-BSTTB	966	7.46E-4	1.279E-07	1.000	1.000E+0	3.355E-09
WES-CBI-FF-BSTTC	966	7.46E-4	1.279E-07	1.000	1.000E+0	3.355E-09
WES-CBI-FF-BSTTD	966	7.46E-4	1.279E-07	1.000	1.000E+0	3.355E-09
WES-CTP-FF-CLTXB	966	5.98E-4	1.025E-07	1.000	1.000E+0	3.355E-09
WES-CTP-FF-CLTXC	966	5.98E-4	1.025E-07	1.000	1.000E+0	3.355E-09
WES-CTP-FF-CLTXD	966	5.98E-4	1.025E-07	1.000	1.000E+0	3.355E-09
WES-CTP-FF-HLTXB	966	5.98E-4	1.025E-07	1.000	1.000E+0	3.355E-09
WES-CTP-FF-HLTXC	966	5.98E-4	1.025E-07	1.000	1.000E+0	3.355E-09
WES-CTP-FF-HLTXD	966	5.98E-4	1.025E-07	1.000	1.000E+0	3.355E-09
WES-TLR-CF-PRA34	26	1.52E-6	2.042E-10	1.000	1.000E+0	2.640E-09
WES-TLR-CF-PRB34	26	1.52E-6	2.042E-10	1.000	1.000E+0	2.640E-09
WES-TLR-CF-TRA34	26	1.52E-6	2.042E-10	1.000	1.000E+0	2.640E-09
WES-TLR-CF-TRB34	26	1.52E-6	2.042E-10	1.000	1.000E+0	2.640E-09
WES-TLR-CF-PRA23	19	5.10E-6	6.240E-11	1.000	1.000E+0	2.646E-10

Table F-8. (continued).

Basic Event	Number of Occur.	Prob. of Failure	Fussell-Vesely Importance	Risk Reduction Ratio	Risk Increase Ratio	Birnbaum Importance
WES-TLR-CF-PRB23	19	5.10E-6	6.240E-11	1.000	1.000E+0	2.646E-10
WES-TLR-CF-TRA23	19	5.10E-6	6.240E-11	1.000	1.000E+0	2.646E-10
WES-TLR-CF-TRB23	19	5.10E-6	6.240E-11	1.000	1.000E+0	2.646E-10
WES-BUV-FF-BYBA	6	2.54E-4	9.190E-10	1.000	1.000E+0	7.052E-11
WES-BUV-FF-BYBB	6	2.54E-4	9.190E-10	1.000	1.000E+0	7.052E-11
WES-CBI-FF-BSTPA	1323	7.46E-4	9.360E-10	1.000	1.000E+0	2.529E-11
WES-CPR-FF-PRESA	1323	1.16E-4	1.532E-10	1.000	1.000E+0	2.529E-11
WES-BSN-FF-BYBA	2	5.81E-4	3.914E-10	1.000	1.000E+0	1.316E-11
WES-BSN-FF-BYBB	2	5.81E-4	3.914E-10	1.000	1.000E+0	1.316E-11
WES-CBI-FF-BSTTA	882	7.46E-4	4.084E-10	1.000	1.000E+0	1.123E-11
WES-CTP-FF-CLTXA	882	5.98E-4	3.404E-10	1.000	1.000E+0	1.123E-11
WES-CTP-FF-HLTXA	882	5.98E-4	3.404E-10	1.000	1.000E+0	1.123E-11
WES-TLR-FC-PRATA	312	3.94E-5	+0.000E+00	1.000	1.000E+0	+0.000E+00
WES-TLR-FC-PRATB	312	3.94E-5	+0.000E+00	1.000	1.000E+0	+0.000E+00
WES-TLR-FC-PRBTA	426	3.94E-5	+0.000E+00	1.000	1.000E+0	+0.000E+00
WES-TLR-FC-PRBTB	426	3.94E-5	+0.000E+00	1.000	1.000E+0	+0.000E+00
WES-TLR-FC-PRCTA	426	3.94E-5	+0.000E+00	1.000	1.000E+0	+0.000E+00
WES-TLR-FC-PRCTB	426	3.94E-5	+0.000E+00	1.000	1.000E+0	+0.000E+00
WES-TLR-FC-PRDTA	426	3.94E-5	+0.000E+00	1.000	1.000E+0	+0.000E+00
WES-TLR-FC-PRDTB	426	3.94E-5	+0.000E+00	1.000	1.000E+0	+0.000E+00
WES-TLR-FC-TRATA	312	3.94E-5	+0.000E+00	1.000	1.000E+0	+0.000E+00
WES-TLR-FC-TRATB	312	3.94E-5	+0.000E+00	1.000	1.000E+0	+0.000E+00
WES-TLR-FC-TRBTA	426	3.94E-5	+0.000E+00	1.000	1.000E+0	+0.000E+00
WES-TLR-FC-TRBTB	426	3.94E-5	+0.000E+00	1.000	1.000E+0	+0.000E+00
WES-TLR-FC-TRCTA	426	3.94E-5	+0.000E+00	1.000	1.000E+0	+0.000E+00
WES-TLR-FC-TRCTB	426	3.94E-5	+0.000E+00	1.000	1.000E+0	+0.000E+00
WES-TLR-FC-TRDTA	426	3.94E-5	+0.000E+00	1.000	1.000E+0	+0.000E+00
WES-TLR-FC-TRDTB	426	3.94E-5	+0.000E+00	1.000	1.000E+0	+0.000E+00

Table F-9. (continued).

Table F-9. RPS Analog design top 100 cut sets (SIGNL 0.01, NSGNL 0.5) mincut 5.5E-6.

Cut Set	Cut Set Percent	Cut Set Prob.	Basic Event[a]	Description	Prob.
1	29.1	1.6E-06	WES-BME-CF-RTBAB	CCF RTB-A AND RTB-B (MECHANICAL)	1.6E-6
			/WES-BME-TM-RTBA	RTB-A IN T&M	1.0E+0
			/WES-BME-TM-RTBB	RTB-B IN T&M	1.0E+0
2	23.0	1.3E-06	/WES-BME-TM-RTBA	RTB-A IN T&M	1.0E+0
			/WES-BME-TM-RTBB	RTB-B IN T&M	1.0E+0
			WES-CBI-CF-6OF8	CCF 6 BISTABLES IN 3 OF 4 CHANNELS	2.7E-6
			/WES-CCP-TM-CHA	CH-A IN T&M	9.4E-1
			WES-XHE-XE-NSGNL	OPERATOR FAILS TO RESPOND WITH NO RPS SIGNAL PRESENT	5.0E-1
3	21.9	1.2E-06	WES-ROD-CF-RCCAS	CCF 10 OR MORE RCCAS FAIL TO DROP	1.2E-6
4	15.6	8.6E-07	/WES-BME-TM-RTBA	RTB-A IN T&M	1.0E+0
			/WES-BME-TM-RTBB	RTB-B IN T&M	1.0E+0
			/WES-CCP-TM-CHA	CH-A IN T&M	9.4E-1
			WES-CCX-CF-6OF8	CCF 6 ANALOG PROCESS LOGIC MODULES IN 3 OF 4 CHANNELS	1.8E-6
			WES-XHE-XE-NSGNL	OPERATOR FAILS TO RESPOND WITH NO RPS SIGNAL PRESENT	5.0E-1
5	4.3	2.4E-07	/WES-BME-TM-RTBA	RTB-A IN T&M	1.0E+0
			/WES-BME-TM-RTBB	RTB-B IN T&M	1.0E+0
			WES-CBI-CF-4OF6	CCF 4 BISTABLES IN 2 OF 3 CHANNELS	8.2E-6
			WES-CCP-TM-CHA	CH-A IN T&M	5.8E-2
			WES-XHE-XE-NSGNL	OPERATOR FAILS TO RESPOND WITH NO RPS SIGNAL PRESENT	5.0E-1
6	3.3	1.8E-07	/WES-BME-TM-RTBA	RTB-A IN T&M	1.0E+0
			/WES-BME-TM-RTBB	RTB-B IN T&M	1.0E+0
			WES-CCP-TM-CHA	CH-A IN T&M	5.8E-2
			WES-CCX-CF-4OF6	CCF 4 ANALOG PROCESS LOGIC MODULES IN 2 OF 3 CHANNELS	6.3E-6
			WES-XHE-XE-NSGNL	OPERATOR FAILS TO RESPOND WITH NO RPS SIGNAL PRESENT	5.0E-1
7	1.9	1.0E-07	/WES-BME-TM-RTBA	RTB-A IN T&M	1.0E+0
			/WES-BME-TM-RTBB	RTB-B IN T&M	1.0E+0
			WES-UVL-CF-UVDAB	CCF UV DRIVERS TRAINS A AND B (2 OF 2)	1.0E-5
			WES-XHE-XE-SIGNL	OPERATOR FAILS TO RESPOND WITH RPS SIGNAL PRESENT	1.0E-2
8	0.4	2.1E-08	/WES-BME-TM-RTBA	RTB-A IN T&M	1.0E+0
			/WES-BME-TM-RTBB	RTB-B IN T&M	1.0E+0
			WES-TLC-CF-SSLAB	CCF SOLID STATE LOGIC IN TRAINS A AND B (4 OF 4)	2.1E-6
			WES-XHE-XE-SIGNL	OPERATOR FAILS TO RESPOND WITH RPS SIGNAL PRESENT	1.0E-2
9	0.1	4.7E-09	WES-BME-TM-RTBA	RTB-A IN T&M	1.4E-3
			/WES-BME-TM-RTBB	RTB-B IN T&M	1.0E+0
			WES-UVL-FF-UVDB	TRAIN B UV DRIVER FAILS	3.4E-4
			WES-XHE-XE-SIGNL	OPERATOR FAILS TO RESPOND WITH RPS SIGNAL PRESENT	1.0E-2
10	0.1	4.7E-09	/WES-BME-TM-RTBA	RTB-A IN T&M	1.0E+0
			WES-BME-TM-RTBB	RTB-B IN T&M	1.4E-3
			WES-UVL-FF-UVDA	TRAIN A UV DRIVER FAILS	3.4E-4
			WES-XHE-XE-SIGNL	OPERATOR FAILS TO RESPOND WITH RPS SIGNAL PRESENT	1.0E-2
11	0.0	2.3E-09	WES-BME-CF-RANBB	CCF RTB-A AND BYB-B (MECHANICAL)	1.6E-6
			/WES-BME-TM-RTBA	RTB-A IN T&M	1.0E+0
			WES-BME-TM-RTBB	RTB-B IN T&M	1.4E-3
12	0.0	2.3E-09	WES-BME-CF-RBNBA	CCF RTB-B AND BYB-A (MECHANICAL)	1.6E-6
			WES-BME-TM-RTBA	RTB-A IN T&M	1.4E-3
			/WES-BME-TM-RTBB	RTB-B IN T&M	1.0E+0
13	0.0	1.8E-09	WES-BME-TM-RTBA	RTB-A IN T&M	1.4E-3
			/WES-BME-TM-RTBB	RTB-B IN T&M	1.0E+0
			WES-CBI-CF-6OF8	CCF 6 BISTABLES IN 3 OF 4 CHANNELS	2.7E-6
			/WES-CCP-TM-CHA	CH-A IN T&M	9.4E-1
			WES-XHE-XE-NSGNL	OPERATOR FAILS TO RESPOND WITH NO RPS SIGNAL PRESENT	5.0E-1
14	0.0	1.8E-09	/WES-BME-TM-RTBA	RTB-A IN T&M	1.0E+0
			WES-BME-TM-RTBB	RTB-B IN T&M	1.4E-3
			WES-CBI-CF-6OF8	CCF 6 BISTABLES IN 3 OF 4 CHANNELS	2.7E-6
			/WES-CCP-TM-CHA	CH-A IN T&M	9.4E-1
			WES-XHE-XE-NSGNL	OPERATOR FAILS TO RESPOND WITH NO RPS SIGNAL PRESENT	5.0E-1
15	0.0	1.4E-09	WES-BME-FO-RTBA	RTB-A LOCAL HW FAILURE	3.7E-5
			WES-BME-FO-RTBB	RTB-B LOCAL HW FAILURE	3.7E-5
			/WES-BME-TM-RTBA	RTB-A IN T&M	1.0E+0
			/WES-BME-TM-RTBB	RTB-B IN T&M	1.0E+0
16	0.0	1.2E-09	WES-BME-TM-RTBA	RTB-A IN T&M	1.4E-3
			/WES-BME-TM-RTBB	RTB-B IN T&M	1.0E+0
			/WES-CCP-TM-CHA	CH-A IN T&M	9.4E-1
			WES-CCX-CF-6OF8	CCF 6 ANALOG PROCESS LOGIC MODULES IN 3 OF 4 CHANNELS	1.8E-6
			WES-XHE-XE-NSGNL	OPERATOR FAILS TO RESPOND WITH NO RPS SIGNAL PRESENT	5.0E-1
17	0.0	1.2E-09	/WES-BME-TM-RTBA	RTB-A IN T&M	1.0E+0
			WES-BME-TM-RTBB	RTB-B IN T&M	1.4E-3
			/WES-CCP-TM-CHA	CH-A IN T&M	9.4E-1
			WES-CCX-CF-6OF8	CCF 6 ANALOG PROCESS LOGIC MODULES IN 3 OF 4 CHANNELS	1.8E-6
			WES-XHE-XE-NSGNL	OPERATOR FAILS TO RESPOND WITH NO RPS SIGNAL PRESENT	5.0E-1
18	0.0	1.1E-09	/WES-BME-TM-RTBA	RTB-A IN T&M	1.0E+0
			/WES-BME-TM-RTBB	RTB-B IN T&M	1.0E+0
			WES-UVL-FF-UVDA	TRAIN A UV DRIVER FAILS	3.4E-4
			WES-UVL-FF-UVDB	TRAIN B UV DRIVER FAILS	3.4E-4
			WES-XHE-XE-SIGNL	OPERATOR FAILS TO RESPOND WITH RPS SIGNAL PRESENT	1.0E-2
19	0.0	7.6E-10	/WES-BME-TM-RTBA	RTB-A IN T&M	1.0E+0
			/WES-BME-TM-RTBB	RTB-B IN T&M	1.0E+0
			/WES-CCP-TM-CHA	CH-A IN T&M	9.4E-1
			WES-TLR-CF-12O16	CCF 12 OR MORE TMU RELAYS IN TRAINS A AND B NO CHANNEL T&M	8.1E-8
			WES-XHE-XE-SIGNL	OPERATOR FAILS TO RESPOND WITH RPS SIGNAL PRESENT	1.0E-2

Table F-9. (continued).

Cut Set	Cut Set Percent	Cut Set Prob.	Basic Event[a]	Description	Prob.
20	0.0	3.3E-10	WES-BME-TM-RTBA	RTB-A IN T&M	1.4E-3
			/WES-BME-TM-RTBB	RTB-B IN T&M	1.0E+0
			WES-CBI-CF-4OF6	CCF 4 BISTABLES IN 2 OF 3 CHANNELS	8.2E-6
			WES-CCP-TM-CHA	CH-A IN T&M	5.8E-2
			WES-XHE-XE-NSGNL	OPERATOR FAILS TO RESPOND WITH NO RPS SIGNAL PRESENT	5.0E-1
21	0.0	3.3E-10	/WES-BME-TM-RTBA	RTB-A IN T&M	1.0E+0
			WES-BME-TM-RTBB	RTB-B IN T&M	1.4E-3
			WES-CBI-CF-4OF6	CCF 4 BISTABLES IN 2 OF 3 CHANNELS	8.2E-6
			WES-CCP-TM-CHA	CH-A IN T&M	5.8E-2
			WES-XHE-XE-NSGNL	OPERATOR FAILS TO RESPOND WITH NO RPS SIGNAL PRESENT	5.0E-1
22	0.0	3.1E-10	/WES-BME-TM-RTBA	RTB-A IN T&M	1.0E+0
			/WES-BME-TM-RTBB	RTB-B IN T&M	1.0E+0
			WES-CBI-CF-P3OF4	CCF 3 PRESSURE OUTPUT BISTABLES IN 3 OF 4 CHANNELS	1.2E-5
			/WES-CCP-TM-CHA	CH-A IN T&M	9.4E-1
			WES-CDT-CF-T3OF4	CCF 3 ANALOG TEMP PROCESS LOGIC MODULES IN 3 OF 4 CHANNELS	5.6E-5
			WES-XHE-XE-NSGNL	OPERATOR FAILS TO RESPOND WITH NO RPS SIGNAL PRESENT	5.0E-1
23	0.0	3.0E-10	/WES-BME-TM-RTBA	RTB-A IN T&M	1.0E+0
			/WES-BME-TM-RTBB	RTB-B IN T&M	1.0E+0
			WES-CBI-CF-P2OF3	CCF 2 PRESSURE OUTPUT BISTABLES IN 2 OF 3 CHANNELS	4.2E-5
			WES-CCP-TM-CHA	CH-A IN T&M	5.8E-2
			WES-CDT-CF-T2OF3	CCF 2 ANALOG TEMP PROCESS LOGIC MODULES IN 2 OF 3 CHANNELS	2.5E-4
			WES-XHE-XE-NSGNL	OPERATOR FAILS TO RESPOND WITH NO RPS SIGNAL PRESENT	5.0E-1
24	0.0	2.6E-10	WES-BME-TM-RTBA	RTB-A IN T&M	1.4E-3
			/WES-BME-TM-RTBB	RTB-B IN T&M	1.0E+0
			WES-CCP-TM-CHA	CH-A IN T&M	5.8E-2
			WES-CCX-CF-4OF6	CCF 4 ANALOG PROCESS LOGIC MODULES IN 2 OF 3 CHANNELS	6.3E-6
			WES-XHE-XE-NSGNL	OPERATOR FAILS TO RESPOND WITH NO RPS SIGNAL PRESENT	5.0E-1
25	0.0	2.6E-10	/WES-BME-TM-RTBA	RTB-A IN T&M	1.0E+0
			WES-BME-TM-RTBB	RTB-B IN T&M	1.4E-3
			WES-CCP-TM-CHA	CH-A IN T&M	5.8E-2
			WES-CCX-CF-4OF6	CCF 4 ANALOG PROCESS LOGIC MODULES IN 2 OF 3 CHANNELS	6.3E-6
			WES-XHE-XE-NSGNL	OPERATOR FAILS TO RESPOND WITH NO RPS SIGNAL PRESENT	5.0E-1
26	0.0	2.4E-10	WES-BME-TM-RTBA	RTB-A IN T&M	1.4E-3
			/WES-BME-TM-RTBB	RTB-B IN T&M	1.0E+0
			WES-TLC-CF-SSLB	CCF SOLID STATE LOGIC TRAIN B (2 OF 4)	1.7E-5
			WES-XHE-XE-SIGNL	OPERATOR FAILS TO RESPOND WITH RPS SIGNAL PRESENT	1.0E-2
27	0.0	2.4E-10	/WES-BME-TM-RTBA	RTB-A IN T&M	1.0E+0
			WES-BME-TM-RTBB	RTB-B IN T&M	1.4E-3
			WES-TLC-CF-SSLA	CCF SOLID STATE LOGIC TRAIN A (2 OF 4)	1.7E-5
			WES-XHE-XE-SIGNL	OPERATOR FAILS TO RESPOND WITH RPS SIGNAL PRESENT	1.0E-2
28	0.0	2.1E-10	/WES-BME-TM-RTBA	RTB-A IN T&M	1.0E+0
			/WES-BME-TM-RTBB	RTB-B IN T&M	1.0E+0
			WES-CBI-CF-P3OF4	CCF 3 PRESSURE OUTPUT BISTABLES IN 3 OF 4 CHANNELS	1.2E-5
			/WES-CCP-TM-CHA	CH-A IN T&M	9.4E-1
			WES-CTP-CF-T3OF8	CCF 3 TEMP SENSORS IN 3 OF 4 CHANNELS	3.7E-5
			WES-XHE-XE-NSGNL	OPERATOR FAILS TO RESPOND WITH NO RPS SIGNAL PRESENT	5.0E-1
29	0.0	2.0E-10	/WES-BME-TM-RTBA	RTB-A IN T&M	1.0E+0
			/WES-BME-TM-RTBB	RTB-B IN T&M	1.0E+0
			WES-BSN-CF-RTBAB	CCF OF RTB-A AND RTB-B SHUNT TRIP DEVICES	2.1E-5
			WES-BUV-CF-RTBAB	CCF OF RTB-A AND RTB-B UV DEVICES	9.7E-6
30	0.0	1.5E-10	WES-BME-TM-RTBA	RTB-A IN T&M	1.4E-3
			/WES-BME-TM-RTBB	RTB-B IN T&M	1.0E+0
			WES-UVL-CF-UVDAB	CCF UV DRIVERS TRAINS A AND B (2 OF 2)	1.0E-5
			WES-XHE-XE-SIGNL	OPERATOR FAILS TO RESPOND WITH RPS SIGNAL PRESENT	1.0E-2
31	0.0	1.5E-10	/WES-BME-TM-RTBA	RTB-A IN T&M	1.0E+0
			WES-BME-TM-RTBB	RTB-B IN T&M	1.4E-3
			WES-UVL-CF-UVDAB	CCF UV DRIVERS TRAINS A AND B (2 OF 2)	1.0E-5
			WES-XHE-XE-SIGNL	OPERATOR FAILS TO RESPOND WITH RPS SIGNAL PRESENT	1.0E-2
32	0.0	1.2E-10	WES-BME-FO-RTBA	RTB-A LOCAL HW FAILURE	3.7E-5
			/WES-BME-TM-RTBA	RTB-A IN T&M	1.0E+0
			/WES-BME-TM-RTBB	RTB-B IN T&M	1.0E+0
			WES-UVL-FF-UVDB	TRAIN B UV DRIVER FAILS	3.4E-4
			WES-XHE-XE-SIGNL	OPERATOR FAILS TO RESPOND WITH RPS SIGNAL PRESENT	1.0E-2
33	0.0	1.2E-10	WES-BME-FO-RTBB	RTB-B LOCAL HW FAILURE	3.7E-5
			/WES-BME-TM-RTBA	RTB-A IN T&M	1.0E+0
			/WES-BME-TM-RTBB	RTB-B IN T&M	1.0E+0
			WES-UVL-FF-UVDA	TRAIN A UV DRIVER FAILS	3.4E-4
			WES-XHE-XE-SIGNL	OPERATOR FAILS TO RESPOND WITH RPS SIGNAL PRESENT	1.0E-2
34	0.0	1.2E-10	/WES-BME-TM-RTBA	RTB-A IN T&M	1.0E+0
			/WES-BME-TM-RTBB	RTB-B IN T&M	1.0E+0
			WES-CCP-TM-CHA	CH-A IN T&M	5.8E-2
			WES-TLR-CF-8OF12	CCF 8 OR MORE TMU RELAYS IN TRAINS A AND B ONE CHANNEL T&M	2.1E-7
			WES-XHE-XE-SIGNL	OPERATOR FAILS TO RESPOND WITH RPS SIGNAL PRESENT	1.0E-2
35	0.0	1.2E-10	/WES-BME-TM-RTBA	RTB-A IN T&M	1.0E+0
			/WES-BME-TM-RTBB	RTB-B IN T&M	1.0E+0
			WES-CCP-CF-P3OF4	CCF 3 ANALOG PRES PROCESS LOGIC MODULES IN 3 OF 4 CHANNELS	4.5E-6
			/WES-CCP-TM-CHA	CH-A IN T&M	9.4E-1
			WES-CDT-CF-T3OF4	CCF 3 ANALOG TEMP PROCESS LOGIC MODULES IN 3 OF 4 CHANNELS	5.6E-5
			WES-XHE-XE-NSGNL	OPERATOR FAILS TO RESPOND WITH NO RPS SIGNAL PRESENT	5.0E-1
36	0.0	1.1E-10	/WES-BME-TM-RTBA	RTB-A IN T&M	1.0E+0
			/WES-BME-TM-RTBB	RTB-B IN T&M	1.0E+0

Table F-9. (continued).

Cut Set	Cut Set Percent	Cut Set Prob.	Basic Event[a]	Description	Prob.
			WES-CCP-CF-P2OF3	CCF 2 ANALOG PRES PROCESS LOGIC MODULES IN 2 OF 3 CHANNELS	1.5E-5
			WES-CCP-TM-CHA	CH-A IN T&M	5.8E-2
			WES-CDT-CF-T2OF3	CCF 2 ANALOG TEMP PROCESS LOGIC MODULES IN 2 OF 3 CHANNELS	2.5E-4
			WES-XHE-XE-NSGNL	OPERATOR FAILS TO RESPOND WITH NO RPS SIGNAL PRESENT	5.0E-1
37	0.0	9.0E-11	/WES-BME-TM-RTBA	RTB-A IN T&M	1.0E+0
			/WES-BME-TM-RTBB	RTB-B IN T&M	1.0E+0
			WES-CBI-CF-P2OF3	CCF 2 PRESSURE OUTPUT BISTABLES IN 2 OF 3 CHANNELS	4.2E-5
			WES-CCP-TM-CHA	CH-A IN T&M	5.8E-2
			WES-CTP-CF-T2OF6	CCF 2 TEMP SENSORS IN 2 OF 3 CHANNELS	7.5E-5
			WES-XHE-XE-NSGNL	OPERATOR FAILS TO RESPOND WITH NO RPS SIGNAL PRESENT	5.0E-1
38	0.0	7.8E-11	/WES-BME-TM-RTBA	RTB-A IN T&M	1.0E+0
			/WES-BME-TM-RTBB	RTB-B IN T&M	1.0E+0
			WES-CCP-CF-P3OF4	CCF 3 ANALOG PRES PROCESS LOGIC MODULES IN 3 OF 4 CHANNELS	4.5E-6
			/WES-CCP-TM-CHA	CH-A IN T&M	9.4E-1
			WES-CTP-CF-T3OF8	CCF 3 TEMP SENSORS IN 3 OF 4 CHANNELS	3.7E-5
			WES-XHE-XE-NSGNL	OPERATOR FAILS TO RESPOND WITH NO RPS SIGNAL PRESENT	5.0E-1
39	0.0	6.7E-11	/WES-BME-TM-RTBA	RTB-A IN T&M	1.0E+0
			/WES-BME-TM-RTBB	RTB-B IN T&M	1.0E+0
			WES-CBI-CF-P3OF4	CCF 3 PRESSURE OUTPUT BISTABLES IN 3 OF 4 CHANNELS	1.2E-5
			WES-CBI-CF-T3OF4	CCF 3 TEMP OUTPUT BISTABLES IN 3 OF 4 CHANNELS	1.2E-5
			/WES-CCP-TM-CHA	CH-A IN T&M	9.4E-1
			WES-XHE-XE-NSGNL	OPERATOR FAILS TO RESPOND WITH NO RPS SIGNAL PRESENT	5.0E-1
40	0.0	5.8E-11	/WES-BME-TM-RTBA	RTB-A IN T&M	1.0E+0
			/WES-BME-TM-RTBB	RTB-B IN T&M	1.0E+0
			WES-TLC-CF-SSLA	CCF SOLID STATE LOGIC TRAIN A (2 OF 4)	1.7E-5
			WES-UVL-FF-UVDB	TRAIN B UV DRIVER FAILS	3.4E-4
			WES-XHE-XE-SIGNL	OPERATOR FAILS TO RESPOND WITH RPS SIGNAL PRESENT	1.0E-2
41	0.0	5.8E-11	/WES-BME-TM-RTBA	RTB-A IN T&M	1.0E+0
			/WES-BME-TM-RTBB	RTB-B IN T&M	1.0E+0
			WES-TLC-CF-SSLB	CCF SOLID STATE LOGIC TRAIN B (2 OF 4)	1.7E-5
			WES-UVL-FF-UVDA	TRAIN A UV DRIVER FAILS	3.4E-4
			WES-XHE-XE-SIGNL	OPERATOR FAILS TO RESPOND WITH RPS SIGNAL PRESENT	1.0E-2
42	0.0	5.6E-11	/WES-BME-TM-RTBA	RTB-A IN T&M	1.0E+0
			/WES-BME-TM-RTBB	RTB-B IN T&M	1.0E+0
			WES-CCP-TM-CHA	CH-A IN T&M	5.8E-2
			WES-CDT-CF-T2OF3	CCF 2 ANALOG TEMP PROCESS LOGIC MODULES IN 2 OF 3 CHANNELS	2.5E-4
			WES-CPR-CF-P2OF3	CCF 2 PRESSURE SENSORS IN 2 OF 3 CHANNELS	7.7E-6
			WES-XHE-XE-NSGNL	OPERATOR FAILS TO RESPOND WITH NO RPS SIGNAL PRESENT	5.0E-1
43	0.0	5.4E-11	/WES-BME-TM-RTBA	RTB-A IN T&M	1.0E+0
			/WES-BME-TM-RTBB	RTB-B IN T&M	1.0E+0
			/WES-CCP-TM-CHA	CH-A IN T&M	9.4E-1
			WES-CDT-CF-T3OF4	CCF 3 ANALOG TEMP PROCESS LOGIC MODULES IN 3 OF 4 CHANNELS	5.6E-5
			WES-CPR-CF-P3OF4	CCF 3 PRESSURE SENSORS IN 3 OF 4 CHANNELS	2.1E-6
			WES-XHE-XE-NSGNL	OPERATOR FAILS TO RESPOND WITH NO RPS SIGNAL PRESENT	5.0E-1
44	0.0	5.1E-11	/WES-BME-TM-RTBA	RTB-A IN T&M	1.0E+0
			/WES-BME-TM-RTBB	RTB-B IN T&M	1.0E+0
			WES-CBI-CF-P2OF3	CCF 2 PRESSURE OUTPUT BISTABLES IN 2 OF 3 CHANNELS	4.2E-5
			WES-CBI-CF-T2OF3	CCF 2 TEMP OUTPUT BISTABLES IN 2 OF 3 CHANNELS	4.2E-5
			WES-CCP-TM-CHA	CH-A IN T&M	5.8E-2
			WES-XHE-XE-NSGNL	OPERATOR FAILS TO RESPOND WITH NO RPS SIGNAL PRESENT	5.0E-1
45	0.0	3.6E-11	/WES-BME-TM-RTBA	RTB-A IN T&M	1.0E+0
			/WES-BME-TM-RTBB	RTB-B IN T&M	1.0E+0
			/WES-CCP-TM-CHA	CH-A IN T&M	9.4E-1
			WES-CPR-CF-P3OF4	CCF 3 PRESSURE SENSORS IN 3 OF 4 CHANNELS	2.1E-6
			WES-CTP-CF-T3OF8	CCF 3 TEMP SENSORS IN 3 OF 4 CHANNELS	3.7E-5
			WES-XHE-XE-NSGNL	OPERATOR FAILS TO RESPOND WITH NO RPS SIGNAL PRESENT	5.0E-1
46	0.0	3.3E-11	/WES-BME-TM-RTBA	RTB-A IN T&M	1.0E+0
			/WES-BME-TM-RTBB	RTB-B IN T&M	1.0E+0
			WES-BUV-CF-RTBAB	CCF OF RTB-A AND RTB-B UV DEVICES	9.7E-6
			WES-PWR-CF-TRNAB	CCF OF RTB-A AND RTB-B SHUNT TRIP POWER SUPPLIES	3.4E-6
47	0.0	3.2E-11	/WES-BME-TM-RTBA	RTB-A IN T&M	1.0E+0
			/WES-BME-TM-RTBB	RTB-B IN T&M	1.0E+0
			WES-CCP-CF-P2OF3	CCF 2 ANALOG PRES PROCESS LOGIC MODULES IN 2 OF 3 CHANNELS	1.5E-5
			WES-CCP-TM-CHA	CH-A IN T&M	5.8E-2
			WES-CTP-CF-T2OF6	CCF 2 TEMP SENSORS IN 2 OF 3 CHANNELS	7.5E-5
			WES-XHE-XE-NSGNL	OPERATOR FAILS TO RESPOND WITH NO RPS SIGNAL PRESENT	5.0E-1
48	0.0	2.9E-11	WES-BME-TM-RTBA	RTB-A IN T&M	1.4E-3
			/WES-BME-TM-RTBB	RTB-B IN T&M	1.0E+0
			WES-TLC-CF-SSLAB	CCF SOLID STATE LOGIC IN TRAINS A AND B (4 OF 4)	2.1E-6
			WES-XHE-XE-SIGNL	OPERATOR FAILS TO RESPOND WITH RPS SIGNAL PRESENT	1.0E-2
49	0.0	2.9E-11	/WES-BME-TM-RTBA	RTB-A IN T&M	1.0E+0
			WES-BME-TM-RTBB	RTB-B IN T&M	1.4E-3
			WES-TLC-CF-SSLAB	CCF SOLID STATE LOGIC IN TRAINS A AND B (4 OF 4)	2.1E-6
			WES-XHE-XE-SIGNL	OPERATOR FAILS TO RESPOND WITH RPS SIGNAL PRESENT	1.0E-2
50	0.0	2.5E-11	/WES-BME-TM-RTBA	RTB-A IN T&M	1.0E+0
			/WES-BME-TM-RTBB	RTB-B IN T&M	1.0E+0
			WES-CBI-CF-T3OF4	CCF 3 TEMP OUTPUT BISTABLES IN 3 OF 4 CHANNELS	1.2E-5
			WES-CCP-CF-P3OF4	CCF 3 ANALOG PRES PROCESS LOGIC MODULES IN 3 OF 4 CHANNELS	4.5E-6
			/WES-CCP-TM-CHA	CH-A IN T&M	9.4E-1
			WES-XHE-XE-NSGNL	OPERATOR FAILS TO RESPOND WITH NO RPS SIGNAL PRESENT	5.0E-1
51	0.0	1.9E-11	/WES-BME-TM-RTBA	RTB-A IN T&M	1.0E+0

Table F-9. (continued).

Cut Set	Cut Set Percent	Cut Set Prob.	Basic Event[a]	Description	Prob.
			/WES-BME-TM-RTBB	RTB-B IN T&M	1.0E+0
			WES-BUV-CF-RTBAB	CCF OF RTB-A AND RTB-B UV DEVICES	9.7E-6
			WES-TLR-CF-RTBAB	CCF OF RTB-A AND RTB-B SHUNT TRIP RELAYS	2.0E-6
52	0.0	1.8E-11	/WES-BME-TM-RTBA	RTB-A IN T&M	1.0E+0
			/WES-BME-TM-RTBB	RTB-B IN T&M	1.0E+0
			WES-CBI-CF-T2OF3	CCF 2 TEMP OUTPUT BISTABLES IN 2 OF 3 CHANNELS	4.2E-5
			WES-CCP-CF-P2OF3	CCF 2 ANALOG PRES PROCESS LOGIC MODULES IN 2 OF 3 CHANNELS	1.5E-5
			WES-CCP-TM-CHA	CH-A IN T&M	5.8E-2
			WES-XHE-XE-NSGNL	OPERATOR FAILS TO RESPOND WITH NO RPS SIGNAL PRESENT	5.0E-1
53	0.0	1.7E-11	/WES-BME-TM-RTBA	RTB-A IN T&M	1.0E+0
			/WES-BME-TM-RTBB	RTB-B IN T&M	1.0E+0
			WES-CCP-TM-CHA	CH-A IN T&M	5.8E-2
			WES-CPR-CF-P2OF3	CCF 2 PRESSURE SENSORS IN 2 OF 3 CHANNELS	7.7E-6
			WES-CTP-CF-T2OF6	CCF 2 TEMP SENSORS IN 2 OF 3 CHANNELS	7.5E-5
			WES-XHE-XE-NSGNL	OPERATOR FAILS TO RESPOND WITH NO RPS SIGNAL PRESENT	5.0E-1
54	0.0	1.2E-11	/WES-BME-TM-RTBA	RTB-A IN T&M	1.0E+0
			/WES-BME-TM-RTBB	RTB-B IN T&M	1.0E+0
			WES-CBI-CF-T3OF4	CCF 3 TEMP OUTPUT BISTABLES IN 3 OF 4 CHANNELS	1.2E-5
			/WES-CCP-TM-CHA	CH-A IN T&M	9.4E-1
			WES-CPR-CF-P3OF4	CCF 3 PRESSURE SENSORS IN 3 OF 4 CHANNELS	2.1E-6
			WES-XHE-XE-NSGNL	OPERATOR FAILS TO RESPOND WITH NO RPS SIGNAL PRESENT	5.0E-1
55	0.0	9.3E-12	/WES-BME-TM-RTBA	RTB-A IN T&M	1.0E+0
			/WES-BME-TM-RTBB	RTB-B IN T&M	1.0E+0
			WES-CBI-CF-T2OF3	CCF 2 TEMP OUTPUT BISTABLES IN 2 OF 3 CHANNELS	4.2E-5
			WES-CCP-TM-CHA	CH-A IN T&M	5.8E-2
			WES-CPR-CF-P2OF3	CCF 2 PRESSURE SENSORS IN 2 OF 3 CHANNELS	7.7E-6
			WES-XHE-XE-NSGNL	OPERATOR FAILS TO RESPOND WITH NO RPS SIGNAL PRESENT	5.0E-1
56	0.0	6.3E-12	WES-BME-FO-RTBA	RTB-A LOCAL HW FAILURE	3.7E-5
			/WES-BME-TM-RTBA	RTB-A IN T&M	1.0E+0
			/WES-BME-TM-RTBB	RTB-B IN T&M	1.0E+0
			WES-TLC-CF-SSLB	CCF SOLID STATE LOGIC TRAIN B (2 OF 4)	1.7E-5
			WES-XHE-XE-SIGNL	OPERATOR FAILS TO RESPOND WITH RPS SIGNAL PRESENT	1.0E-2
57	0.0	6.3E-12	WES-BME-FO-RTBB	RTB-B LOCAL HW FAILURE	3.7E-5
			/WES-BME-TM-RTBA	RTB-A IN T&M	1.0E+0
			/WES-BME-TM-RTBB	RTB-B IN T&M	1.0E+0
			WES-TLC-CF-SSLA	CCF SOLID STATE LOGIC TRAIN A (2 OF 4)	1.7E-5
			WES-XHE-XE-SIGNL	OPERATOR FAILS TO RESPOND WITH RPS SIGNAL PRESENT	1.0E-2
58	0.0	5.4E-12	WES-BME-FO-RTBA	RTB-A LOCAL HW FAILURE	3.7E-5
			/WES-BME-TM-RTBA	RTB-A IN T&M	1.0E+0
			/WES-BME-TM-RTBB	RTB-B IN T&M	1.0E+0
			WES-BSN-FF-RTBB	RTB-B SHUNT TRIP DEVICE LOCAL FAULTS	5.8E-4
			WES-BUV-FF-RTBB	RTB-B UV DEVICE LOCAL FAULTS	2.5E-4
59	0.0	5.4E-12	WES-BME-FO-RTBB	RTB-B LOCAL HW FAILURE	3.7E-5
			/WES-BME-TM-RTBA	RTB-A IN T&M	1.0E+0
			/WES-BME-TM-RTBB	RTB-B IN T&M	1.0E+0
			WES-BSN-FF-RTBA	RTB-A SHUNT TRIP DEVICE LOCAL FAULTS	5.8E-4
			WES-BUV-FF-RTBA	RTB-A UV DEVICE LOCAL FAULTS	2.5E-4
60	0.0	4.3E-12	WES-BME-TM-RTBA	RTB-A IN T&M	1.4E-3
			/WES-BME-TM-RTBB	RTB-B IN T&M	1.0E+0
			/WES-CCP-TM-CHA	CH-A IN T&M	9.4E-1
			WES-TLR-CF-RLB68	CCF 6 OR MORE TMU RELAYS IN TRAIN B NO CHANNEL T&M	3.3E-7
			WES-XHE-XE-SIGNL	OPERATOR FAILS TO RESPOND WITH RPS SIGNAL PRESENT	1.0E-2
61	0.0	4.3E-12	/WES-BME-TM-RTBA	RTB-A IN T&M	1.0E+0
			WES-BME-TM-RTBB	RTB-B IN T&M	1.4E-3
			/WES-CCP-TM-CHA	CH-A IN T&M	9.4E-1
			WES-TLR-CF-RLA68	CCF 6 OR MORE TMU RELAYS IN TRAIN A NO CHANNEL T&M	3.3E-7
			WES-XHE-XE-SIGNL	OPERATOR FAILS TO RESPOND WITH RPS SIGNAL PRESENT	1.0E-2
62	0.0	3.0E-12	/WES-BME-TM-RTBA	RTB-A IN T&M	1.0E+0
			/WES-BME-TM-RTBB	RTB-B IN T&M	1.0E+0
			WES-TLC-CF-SSLA	CCF SOLID STATE LOGIC TRAIN A (2 OF 4)	1.7E-5
			WES-TLC-CF-SSLB	CCF SOLID STATE LOGIC TRAIN B (2 OF 4)	1.7E-5
			WES-XHE-XE-SIGNL	OPERATOR FAILS TO RESPOND WITH RPS SIGNAL PRESENT	1.0E-2
63	0.0	2.1E-12	WES-BME-TM-RTBA	RTB-A IN T&M	1.4E-3
			/WES-BME-TM-RTBB	RTB-B IN T&M	1.0E+0
			WES-TLC-FF-SSLBP	TRAIN B PRESSURE SOLID STATE LOGIC FAILS	3.8E-4
			WES-TLC-FF-SSLBT	TRAIN B TEMPERATURE SOLID STATE LOGIC FAILS	3.8E-4
			WES-XHE-XE-SIGNL	OPERATOR FAILS TO RESPOND WITH RPS SIGNAL PRESENT	1.0E-2
64	0.0	2.1E-12	/WES-BME-TM-RTBA	RTB-A IN T&M	1.0E+0
			WES-BME-TM-RTBB	RTB-B IN T&M	1.4E-3
			WES-TLC-FF-SSLAP	TRAIN A PRESSURE SOLID STATE LOGIC FAILS	3.8E-4
			WES-TLC-FF-SSLAT	TRAIN A TEMPERATURE SOLID STATE LOGIC FAILS	3.8E-4
			WES-XHE-XE-SIGNL	OPERATOR FAILS TO RESPOND WITH RPS SIGNAL PRESENT	1.0E-2
65	0.0	1.9E-12	WES-BME-FO-BYBA	BYB-A LOCAL HW FAILURE	3.7E-5
			WES-BME-FO-RTBB	RTB-B LOCAL HW FAILURE	3.7E-5
			WES-BME-TM-RTBA	RTB-A IN T&M	1.4E-3
			/WES-BME-TM-RTBB	RTB-B IN T&M	1.0E+0
66	0.0	1.9E-12	WES-BME-FO-BYBB	BYB-B LOCAL HW FAILURE	3.7E-5
			WES-BME-FO-RTBA	RTB-A LOCAL HW FAILURE	3.7E-5
			/WES-BME-TM-RTBA	RTB-A IN T&M	1.0E+0
			WES-BME-TM-RTBB	RTB-B IN T&M	1.4E-3
67	0.0	1.1E-12	WES-BME-TM-RTBA	RTB-A IN T&M	1.4E-3

Table F-9. (continued).

Cut Set	Cut Set Percent	Cut Set Prob.	Basic Event[a]	Description	Prob.
			/WES-BME-TM-RTBB	RTB-B IN T&M	1.0E+0
			/WES-CCP-TM-CHA	CH-A IN T&M	9.4E-1
			WES-TLR-CF-12O16	CCF 12 OR MORE TMU RELAYS IN TRAINS A AND B NO CHANNEL T&M	8.1E-8
			WES-XHE-XE-SIGNL	OPERATOR FAILS TO RESPOND WITH RPS SIGNAL PRESENT	1.0E-2
68	0.0	1.1E-12	/WES-BME-TM-RTBA	RTB-A IN T&M	1.0E+0
			WES-BME-TM-RTBB	RTB-B IN T&M	1.4E-3
			/WES-CCP-TM-CHA	CH-A IN T&M	9.4E-1
			WES-TLR-CF-12O16	CCF 12 OR MORE TMU RELAYS IN TRAINS A AND B NO CHANNEL T&M	8.1E-8
			WES-XHE-XE-SIGNL	OPERATOR FAILS TO RESPOND WITH RPS SIGNAL PRESENT	1.0E-2
69	0.0	1.0E-12	/WES-BME-TM-RTBA	RTB-A IN T&M	1.0E+0
			/WES-BME-TM-RTBB	RTB-B IN T&M	1.0E+0
			/WES-CCP-TM-CHA	CH-A IN T&M	9.4E-1
			WES-TLR-CF-RLA68	CCF 6 OR MORE TMU RELAYS IN TRAIN A NO CHANNEL T&M	3.3E-7
			WES-UVL-FF-UVDB	TRAIN B UV DRIVER FAILS	3.4E-4
			WES-XHE-XE-SIGNL	OPERATOR FAILS TO RESPOND WITH RPS SIGNAL PRESENT	1.0E-2
70	0.0	1.0E-12	/WES-BME-TM-RTBA	RTB-A IN T&M	1.0E+0
			/WES-BME-TM-RTBB	RTB-B IN T&M	1.0E+0
			/WES-CCP-TM-CHA	CH-A IN T&M	9.4E-1
			WES-TLR-CF-RLB68	CCF 6 OR MORE TMU RELAYS IN TRAIN B NO CHANNEL T&M	3.3E-7
			WES-UVL-FF-UVDA	TRAIN A UV DRIVER FAILS	3.4E-4
			WES-XHE-XE-SIGNL	OPERATOR FAILS TO RESPOND WITH RPS SIGNAL PRESENT	1.0E-2
71	0.0	8.2E-13	WES-BME-TM-RTBA	RTB-A IN T&M	1.4E-3
			/WES-BME-TM-RTBB	RTB-B IN T&M	1.0E+0
			WES-BUV-CF-RBNBA	CCF OF RTB-B AND BYB-A UV DEVICES	9.7E-6
			WES-PWR-FF-TRNB	TRAIN B 125 VDC BUS FAILS	6.0E-5
72	0.0	8.2E-13	/WES-BME-TM-RTBA	RTB-A IN T&M	1.0E+0
			WES-BME-TM-RTBB	RTB-B IN T&M	1.4E-3
			WES-BUV-CF-RANBB	CCF OF RTB-A AND BYB-B UV DEVICES	9.7E-6
			WES-PWR-FF-TRNA	TRAIN A 125 VDC BUS FAILS	6.0E-5
73	0.0	8.1E-13	WES-BME-TM-RTBA	RTB-A IN T&M	1.4E-3
			/WES-BME-TM-RTBB	RTB-B IN T&M	1.0E+0
			WES-CCP-TM-CHA	CH-A IN T&M	5.8E-2
			WES-TLR-CF-RLB46	CCF 4 OR MORE TMU RELAYS IN TRAIN B ONE CHANNEL T&M	1.0E-6
			WES-XHE-XE-SIGNL	OPERATOR FAILS TO RESPOND WITH RPS SIGNAL PRESENT	1.0E-2
74	0.0	8.1E-13	/WES-BME-TM-RTBA	RTB-A IN T&M	1.0E+0
			WES-BME-TM-RTBB	RTB-B IN T&M	1.4E-3
			WES-CCP-TM-CHA	CH-A IN T&M	5.8E-2
			WES-TLR-CF-RLA46	CCF 4 OR MORE TMU RELAYS IN TRAIN A ONE CHANNEL T&M	1.0E-6
			WES-XHE-XE-SIGNL	OPERATOR FAILS TO RESPOND WITH RPS SIGNAL PRESENT	1.0E-2
75	0.0	5.6E-13	WES-BME-FO-RTBA	RTB-A LOCAL HW FAILURE	3.7E-5
			/WES-BME-TM-RTBA	RTB-A IN T&M	1.0E+0
			/WES-BME-TM-RTBB	RTB-B IN T&M	1.0E+0
			WES-BUV-FF-RTBB	RTB-B UV DEVICE LOCAL FAULTS	2.5E-4
			WES-PWR-FF-TRNB	TRAIN B 125 VDC BUS FAILS	6.0E-5
76	0.0	5.6E-13	WES-BME-FO-RTBB	RTB-B LOCAL HW FAILURE	3.7E-5
			/WES-BME-TM-RTBA	RTB-A IN T&M	1.0E+0
			/WES-BME-TM-RTBB	RTB-B IN T&M	1.0E+0
			WES-BUV-FF-RTBA	RTB-A UV DEVICE LOCAL FAULTS	2.5E-4
			WES-PWR-FF-TRNA	TRAIN A 125 VDC BUS FAILS	6.0E-5
77	0.0	5.4E-13	WES-BME-TM-RTBA	RTB-A IN T&M	1.4E-3
			/WES-BME-TM-RTBB	RTB-B IN T&M	1.0E+0
			WES-BUV-CF-RBNBA	CCF OF RTB-B AND BYB-A UV DEVICES	9.7E-6
			WES-TLR-FC-RLYSB	SHUNT TRIP RELAY SB FAILS	3.9E-5
78	0.0	5.4E-13	/WES-BME-TM-RTBA	RTB-A IN T&M	1.0E+0
			WES-BME-TM-RTBB	RTB-B IN T&M	1.4E-3
			WES-BUV-CF-RANBB	CCF OF RTB-A AND BYB-B UV DEVICES	9.7E-6
			WES-TLR-FC-RLYSA	SHUNT TRIP RELAY SA FAILS	3.9E-5
79	0.0	5.0E-13	/WES-BME-TM-RTBA	RTB-A IN T&M	1.0E+0
			/WES-BME-TM-RTBB	RTB-B IN T&M	1.0E+0
			WES-BSN-FF-RTBA	RTB-A SHUNT TRIP DEVICE LOCAL FAULTS	5.8E-4
			WES-BUV-FF-RTBA	RTB-A UV DEVICE LOCAL FAULTS	2.5E-4
			WES-UVL-FF-UVDB	TRAIN B UV DRIVER FAILS	3.4E-4
			WES-XHE-XE-SIGNL	OPERATOR FAILS TO RESPOND WITH RPS SIGNAL PRESENT	1.0E-2
80	0.0	5.0E-13	/WES-BME-TM-RTBA	RTB-A IN T&M	1.0E+0
			/WES-BME-TM-RTBB	RTB-B IN T&M	1.0E+0
			WES-BSN-FF-RTBB	RTB-B SHUNT TRIP DEVICE LOCAL FAULTS	5.8E-4
			WES-BUV-FF-RTBB	RTB-B UV DEVICE LOCAL FAULTS	2.5E-4
			WES-UVL-FF-UVDA	TRAIN A UV DRIVER FAILS	3.4E-4
			WES-XHE-XE-SIGNL	OPERATOR FAILS TO RESPOND WITH RPS SIGNAL PRESENT	1.0E-2
81	0.0	4.9E-13	/WES-BME-TM-RTBA	RTB-A IN T&M	1.0E+0
			/WES-BME-TM-RTBB	RTB-B IN T&M	1.0E+0
			WES-TLC-FF-SSLAP	TRAIN A PRESSURE SOLID STATE LOGIC FAILS	3.8E-4
			WES-TLC-FF-SSLAT	TRAIN A TEMPERATURE SOLID STATE LOGIC FAILS	3.8E-4
			WES-UVL-FF-UVDB	TRAIN B UV DRIVER FAILS	3.4E-4
			WES-XHE-XE-SIGNL	OPERATOR FAILS TO RESPOND WITH RPS SIGNAL PRESENT	1.0E-2
82	0.0	4.9E-13	/WES-BME-TM-RTBA	RTB-A IN T&M	1.0E+0
			/WES-BME-TM-RTBB	RTB-B IN T&M	1.0E+0
			WES-TLC-FF-SSLBP	TRAIN B PRESSURE SOLID STATE LOGIC FAILS	3.8E-4
			WES-TLC-FF-SSLBT	TRAIN B TEMPERATURE SOLID STATE LOGIC FAILS	3.8E-4
			WES-UVL-FF-UVDA	TRAIN A UV DRIVER FAILS	3.4E-4
			WES-XHE-XE-SIGNL	OPERATOR FAILS TO RESPOND WITH RPS SIGNAL PRESENT	1.0E-2

Table F-9. (continued).

Cut Set	Cut Set Percent	Cut Set Prob.	Basic Event[a]	Description	Prob.
83	0.0	4.4E-13	WES-BME-TM-RTBA	RTB-A IN T&M	1.4E-3
			/WES-BME-TM-RTBB	RTB-B IN T&M	1.0E+0
			WES-CBI-CF-P3OF4	CCF 3 PRESSURE OUTPUT BISTABLES IN 3 OF 4 CHANNELS	1.2E-5
			/WES-CCP-TM-CHA	CH-A IN T&M	9.4E-1
			WES-CDT-CF-T3OF4	CCF 3 ANALOG TEMP PROCESS LOGIC MODULES IN 3 OF 4 CHANNELS	5.6E-5
			WES-XHE-XE-NSGNL	OPERATOR FAILS TO RESPOND WITH NO RPS SIGNAL PRESENT	5.0E-1
84	0.0	4.4E-13	/WES-BME-TM-RTBA	RTB-A IN T&M	1.0E+0
			WES-BME-TM-RTBB	RTB-B IN T&M	1.4E-3
			WES-CBI-CF-P3OF4	CCF 3 PRESSURE OUTPUT BISTABLES IN 3 OF 4 CHANNELS	1.2E-5
			/WES-CCP-TM-CHA	CH-A IN T&M	9.4E-1
			WES-CDT-CF-T3OF4	CCF 3 ANALOG TEMP PROCESS LOGIC MODULES IN 3 OF 4 CHANNELS	5.6E-5
			WES-XHE-XE-NSGNL	OPERATOR FAILS TO RESPOND WITH NO RPS SIGNAL PRESENT	5.0E-1
85	0.0	4.3E-13	WES-BME-TM-RTBA	RTB-A IN T&M	1.4E-3
			/WES-BME-TM-RTBB	RTB-B IN T&M	1.0E+0
			WES-CBI-CF-P2OF3	CCF 2 PRESSURE OUTPUT BISTABLES IN 2 OF 3 CHANNELS	4.2E-5
			WES-CCP-TM-CHA	CH-A IN T&M	5.8E-2
			WES-CDT-CF-T2OF3	CCF 2 ANALOG TEMP PROCESS LOGIC MODULES IN 2 OF 3 CHANNELS	2.5E-4
			WES-XHE-XE-NSGNL	OPERATOR FAILS TO RESPOND WITH NO RPS SIGNAL PRESENT	5.0E-1
86	0.0	4.3E-13	/WES-BME-TM-RTBA	RTB-A IN T&M	1.0E+0
			WES-BME-TM-RTBB	RTB-B IN T&M	1.4E-3
			WES-CBI-CF-P2OF3	CCF 2 PRESSURE OUTPUT BISTABLES IN 2 OF 3 CHANNELS	4.2E-5
			WES-CCP-TM-CHA	CH-A IN T&M	5.8E-2
			WES-CDT-CF-T2OF3	CCF 2 ANALOG TEMP PROCESS LOGIC MODULES IN 2 OF 3 CHANNELS	2.5E-4
			WES-XHE-XE-NSGNL	OPERATOR FAILS TO RESPOND WITH NO RPS SIGNAL PRESENT	5.0E-1
87	0.0	3.8E-13	/WES-BME-TM-RTBA	RTB-A IN T&M	1.0E+0
			/WES-BME-TM-RTBB	RTB-B IN T&M	1.0E+0
			WES-CBI-FF-BSTPB	CH-B PRESSURE OUTPUT BISTABLE FAILS	7.5E-4
			WES-CBI-FF-BSTPC	CH-C PRESSURE OUTPUT BISTABLE FAILS	7.5E-4
			WES-CCP-TM-CHA	CH-A IN T&M	5.8E-2
			WES-CDT-FF-ANLTB	CH-B ANALOG TEMPERATURE PROCESS LOGIC MODULE FAILS	4.8E-3
			WES-CDT-FF-ANLTC	CH-C ANALOG TEMPERATURE PROCESS LOGIC MODULE FAILS	4.8E-3
			WES-XHE-XE-NSGNL	OPERATOR FAILS TO RESPOND WITH NO RPS SIGNAL PRESENT	5.0E-1
88	0.0	3.8E-13	/WES-BME-TM-RTBA	RTB-A IN T&M	1.0E+0
			/WES-BME-TM-RTBB	RTB-B IN T&M	1.0E+0
			WES-CBI-FF-BSTPB	CH-B PRESSURE OUTPUT BISTABLE FAILS	7.5E-4
			WES-CBI-FF-BSTPD	CH-D PRESSURE OUTPUT NISTABLE FAILS	7.5E-4
			WES-CCP-TM-CHA	CH-A IN T&M	5.8E-2
			WES-CDT-FF-ANLTB	CH-B ANALOG TEMPERATURE PROCESS LOGIC MODULE FAILS	4.8E-3
			WES-CDT-FF-ANLTD	CH-D ANALOG TEMPERATURE PROCESS LOGIC MODULE FAILS	4.8E-3
			WES-XHE-XE-NSGNL	OPERATOR FAILS TO RESPOND WITH NO RPS SIGNAL PRESENT	5.0E-1
89	0.0	3.8E-13	/WES-BME-TM-RTBA	RTB-A IN T&M	1.0E+0
			/WES-BME-TM-RTBB	RTB-B IN T&M	1.0E+0
			WES-CBI-FF-BSTPC	CH-C PRESSURE OUTPUT BISTABLE FAILS	7.5E-4
			WES-CBI-FF-BSTPD	CH-D PRESSURE OUTPUT NISTABLE FAILS	7.5E-4
			WES-CCP-TM-CHA	CH-A IN T&M	5.8E-2
			WES-CDT-FF-ANLTC	CH-C ANALOG TEMPERATURE PROCESS LOGIC MODULE FAILS	4.8E-3
			WES-CDT-FF-ANLTD	CH-D ANALOG TEMPERATURE PROCESS LOGIC MODULE FAILS	4.8E-3
			WES-XHE-XE-NSGNL	OPERATOR FAILS TO RESPOND WITH NO RPS SIGNAL PRESENT	5.0E-1
90	0.0	3.7E-13	WES-BME-FO-RTBA	RTB-A LOCAL HW FAILURE	3.7E-5
			/WES-BME-TM-RTBA	RTB-A IN T&M	1.0E+0
			/WES-BME-TM-RTBB	RTB-B IN T&M	1.0E+0
			WES-BUV-FF-RTBB	RTB-B UV DEVICE LOCAL FAULTS	2.5E-4
			WES-TLR-FC-RLYSB	SHUNT TRIP RELAY SB FAILS	3.9E-5
91	0.0	3.7E-13	WES-BME-FO-RTBB	RTB-B LOCAL HW FAILURE	3.7E-5
			/WES-BME-TM-RTBA	RTB-A IN T&M	1.0E+0
			/WES-BME-TM-RTBB	RTB-B IN T&M	1.0E+0
			WES-BUV-FF-RTBA	RTB-A UV DEVICE LOCAL FAULTS	2.5E-4
			WES-TLR-FC-RLYSA	SHUNT TRIP RELAY SA FAILS	3.9E-5
92	0.0	2.9E-13	WES-BME-TM-RTBA	RTB-A IN T&M	1.4E-3
			/WES-BME-TM-RTBB	RTB-B IN T&M	1.0E+0
			WES-CBI-CF-P3OF4	CCF 3 PRESSURE OUTPUT BISTABLES IN 3 OF 4 CHANNELS	1.2E-5
			/WES-CCP-TM-CHA	CH-A IN T&M	9.4E-1
			WES-CTP-CF-T3OF8	CCF 3 TEMP SENSORS IN 3 OF 4 CHANNELS	3.7E-5
			WES-XHE-XE-NSGNL	OPERATOR FAILS TO RESPOND WITH NO RPS SIGNAL PRESENT	5.0E-1
93	0.0	2.9E-13	/WES-BME-TM-RTBA	RTB-A IN T&M	1.0E+0
			WES-BME-TM-RTBB	RTB-B IN T&M	1.4E-3
			WES-CBI-CF-P3OF4	CCF 3 PRESSURE OUTPUT BISTABLES IN 3 OF 4 CHANNELS	1.2E-5
			/WES-CCP-TM-CHA	CH-A IN T&M	9.4E-1
			WES-CTP-CF-T3OF8	CCF 3 TEMP SENSORS IN 3 OF 4 CHANNELS	3.7E-5
			WES-XHE-XE-NSGNL	OPERATOR FAILS TO RESPOND WITH NO RPS SIGNAL PRESENT	5.0E-1
94	0.0	2.9E-13	WES-BME-TM-RTBA	RTB-A IN T&M	1.4E-3
			/WES-BME-TM-RTBB	RTB-B IN T&M	1.0E+0
			WES-BSN-CF-RBNBA	CCF OF RTB-B AND BYB-A SHUNT TRIP DEVICES	2.1E-5
			WES-BUV-CF-RBNBA	CCF OF RTB-B AND BYB-A UV DEVICES	9.7E-6
95	0.0	2.9E-13	/WES-BME-TM-RTBA	RTB-A IN T&M	1.0E+0
			WES-BME-TM-RTBB	RTB-B IN T&M	1.4E-3
			WES-BSN-CF-RANBB	CCF OF RTB-A AND BYB-B SHUNT TRIP DEVICES	2.1E-5
			WES-BUV-CF-RANBB	CCF OF RTB-A AND BYB-B UV DEVICES	9.7E-6
96	0.0	2.0E-13	/WES-BME-TM-RTBA	RTB-A IN T&M	1.0E+0
			/WES-BME-TM-RTBB	RTB-B IN T&M	1.0E+0
			WES-CCP-TM-CHA	CH-A IN T&M	5.8E-2

Table F-9. (continued).

Cut Set	Cut Set Percent	Cut Set Prob.	Basic Event[a]	Description	Prob.
			WES-TLR-CF-RLA46	CCF 4 OR MORE TMU RELAYS IN TRAIN A ONE CHANNEL T&M	1.0E-6
			WES-UVL-FF-UVDB	TRAIN B UV DRIVER FAILS	3.4E-4
			WES-XHE-XE-SIGNL	OPERATOR FAILS TO RESPOND WITH RPS SIGNAL PRESENT	1.0E-2
97	0.0	2.0E-13	/WES-BME-TM-RTBA	RTB-A IN T&M	1.0E+0
			/WES-BME-TM-RTBB	RTB-B IN T&M	1.0E+0
			WES-CCP-TM-CHA	CH-A IN T&M	5.8E-2
			WES-TLR-CF-RLB46	CCF 4 OR MORE TMU RELAYS IN TRAIN B ONE CHANNEL T&M	1.0E-6
			WES-UVL-FF-UVDA	TRAIN A UV DRIVER FAILS	3.4E-4
			WES-XHE-XE-SIGNL	OPERATOR FAILS TO RESPOND WITH RPS SIGNAL PRESENT	1.0E-2
98	0.0	1.7E-13	WES-BME-TM-RTBA	RTB-A IN T&M	1.4E-3
			/WES-BME-TM-RTBB	RTB-B IN T&M	1.0E+0
			WES-CCP-TM-CHA	CH-A IN T&M	5.8E-2
			WES-TLR-CF-8OF12	CCF 8 OR MORE TMU RELAYS IN TRAINS A AND B ONE CHANNEL T&M	2.1E-7
			WES-XHE-XE-SIGNL	OPERATOR FAILS TO RESPOND WITH RPS SIGNAL PRESENT	1.0E-2
99	0.0	1.7E-13	/WES-BME-TM-RTBA	RTB-A IN T&M	1.0E+0
			WES-BME-TM-RTBB	RTB-B IN T&M	1.4E-3
			WES-CCP-TM-CHA	CH-A IN T&M	5.8E-2
			WES-TLR-CF-8OF12	CCF 8 OR MORE TMU RELAYS IN TRAINS A AND B ONE CHANNEL T&M	2.1E-7
			WES-XHE-XE-SIGNL	OPERATOR FAILS TO RESPOND WITH RPS SIGNAL PRESENT	1.0E-2
100	0.0	1.6E-13	WES-BME-TM-RTBA	RTB-A IN T&M	1.4E-3
			/WES-BME-TM-RTBB	RTB-B IN T&M	1.0E+0
			WES-CCP-CF-P3OF4	CCF 3 ANALOG PRES PROCESS LOGIC MODULES IN 3 OF 4 CHANNELS	4.5E-6
			/WES-CCP-TM-CHA	CH-A IN T&M	9.4E-1
			WES-CDT-CF-T3OF4	CCF 3 ANALOG TEMP PROCESS LOGIC MODULES IN 3 OF 4 CHANNELS	5.6E-5
			WES-XHE-XE-NSGNL	OPERATOR FAILS TO RESPOND WITH NO RPS SIGNAL PRESENT	5.0E-1

a. A / as the first character in a basic event name indicates a complemented event (Success = 1 - Failure). For example, the basic event for reactor trip breaker train A (RTB-A) in test and maintenance (T&M) is WES-BME-TM-RTBA (Failure = 1.40E-03). Thus, the basic event name for RTB-A not in T&M is /WES-BME-TM-RTBA (Success = 9.986E-01). The event description for complemented events remains the same as the description used for the failure event.

Table F-10. Importance measures sorted on Fussell-Vesely for case with RPS mincut = 5.5E-6.

Basic Event	Number of Occur.	Prob. of Failure	Fussell-Vesely Importance	Risk Reduction Ratio	Risk Increase Ratio	Birnbaum Importance
WES-XHE-XE-NSGNL	22098	5.00E-1	4.636E-01	1.864	1.464E+0	5.114E-06
WES-BME-CF-RTBAB	1	1.61E-6	2.911E-01	1.411	1.808E+5	9.972E-01
WES-CBI-CF-6OF8	3	2.70E-6	2.306E-01	1.300	8.528E+4	4.704E-01
WES-ROD-CF-RCCAS	1	1.21E-6	2.194E-01	1.281	1.813E+5	1.000E+00
WES-CCX-CF-6OF8	3	1.83E-6	1.563E-01	1.185	8.528E+4	4.704E-01
WES-CCP-TM-CHA	23013	5.80E-2	5.276E-02	1.056	1.857E+0	5.017E-06
WES-CBI-CF-4OF6	3	8.21E-6	4.317E-02	1.045	5.258E+3	2.900E-02
WES-CCX-CF-4OF6	3	6.33E-6	3.328E-02	1.034	5.258E+3	2.900E-02
WES-XHE-XE-SIGNL	960	1.00E-2	2.490E-02	1.026	3.465E+0	1.373E-05
WES-UVL-CF-UVDAB	3	1.04E-5	1.886E-02	1.019	1.814E+3	1.000E-02
WES-TLC-CF-SSLAB	3	2.10E-6	3.807E-03	1.004	1.814E+3	1.000E-02
WES-UVL-FF-UVDA	37	3.37E-4	1.093E-03	1.001	4.242E+0	1.789E-05
WES-UVL-FF-UVDB	37	3.37E-4	1.093E-03	1.001	4.242E+0	1.789E-05
WES-BME-TM-RTBA	23106	1.40E-3	8.961E-04	1.001	1.639E+0	3.531E-06
WES-BME-TM-RTBB	23106	1.40E-3	8.961E-04	1.001	1.639E+0	3.531E-06
WES-BME-CF-RANBB	1	1.61E-6	4.081E-04	1.000	2.545E+2	1.398E-03
WES-BME-CF-RBNBA	1	1.61E-6	4.081E-04	1.000	2.545E+2	1.398E-03
WES-BME-FO-RTBA	40	3.69E-5	2.713E-04	1.000	8.353E+0	4.056E-05
WES-BME-FO-RTBB	40	3.69E-5	2.713E-04	1.000	8.353E+0	4.056E-05
WES-TLR-CF-12O16	3	8.07E-8	1.378E-04	1.000	1.709E+3	9.420E-03
WES-CBI-CF-P3OF4	9	1.19E-5	1.061E-04	1.000	9.915E+0	4.917E-05
WES-CDT-CF-T3OF4	9	5.55E-5	8.739E-05	1.000	2.575E+0	8.685E-06
WES-CDT-CF-T2OF3	9	2.50E-4	8.492E-05	1.000	1.340E+0	1.874E-06
WES-CBI-CF-P2OF3	9	4.19E-5	8.074E-05	1.000	2.927E+0	1.063E-05
WES-CTP-CF-T3OF8	9	3.70E-5	5.826E-05	1.000	2.575E+0	8.685E-06
WES-TLC-CF-SSLA	37	1.72E-5	5.578E-05	1.000	4.243E+0	1.789E-05
WES-TLC-CF-SSLB	37	1.72E-5	5.578E-05	1.000	4.243E+0	1.789E-05
WES-BUV-CF-RTBAB	3	9.73E-6	4.644E-05	1.000	5.773E+0	2.633E-05
WES-CCP-CF-P3OF4	9	4.48E-6	3.994E-05	1.000	9.915E+0	4.917E-05
WES-BSN-CF-RTBAB	1	2.10E-5	3.694E-05	1.000	2.759E+0	9.703E-06
WES-CCP-CF-P2OF3	9	1.50E-5	2.890E-05	1.000	2.927E+0	1.063E-05
WES-CTP-CF-T2OF6	9	7.46E-5	2.534E-05	1.000	1.340E+0	1.874E-06
WES-TLR-CF-8OF12	3	2.07E-7	2.177E-05	1.000	1.062E+2	5.800E-04
WES-CBI-CF-T3OF4	9	1.19E-5	1.874E-05	1.000	2.575E+0	8.685E-06
WES-CPR-CF-P3OF4	9	2.06E-6	1.836E-05	1.000	9.915E+0	4.917E-05
WES-CPR-CF-P2OF3	9	7.71E-6	1.486E-05	1.000	2.927E+0	1.063E-05
WES-CBI-CF-T2OF3	9	4.19E-5	1.423E-05	1.000	1.340E+0	1.874E-06
WES-PWR-CF-TRNAB	1	3.40E-6	5.981E-06	1.000	2.759E+0	9.703E-06
WES-TLR-CF-RTBAB	1	2.00E-6	3.518E-06	1.000	2.759E+0	9.703E-06
WES-BUV-FF-RTBA	114	2.54E-4	1.272E-06	1.000	1.005E+0	2.763E-08
WES-BUV-FF-RTBB	114	2.54E-4	1.272E-06	1.000	1.005E+0	2.763E-08
WES-BSN-FF-RTBA	38	5.81E-4	1.085E-06	1.000	1.002E+0	1.030E-08
WES-BSN-FF-RTBB	38	5.81E-4	1.085E-06	1.000	1.002E+0	1.030E-08
WES-TLR-CF-RLA68	26	3.28E-7	1.002E-06	1.000	4.055E+0	1.685E-05
WES-TLR-CF-RLB68	26	3.28E-7	1.002E-06	1.000	4.055E+0	1.685E-05
WES-TLC-FF-SSLAP	37	3.83E-4	4.757E-07	1.000	1.001E+0	6.851E-09
WES-TLC-FF-SSLAT	37	3.83E-4	4.757E-07	1.000	1.001E+0	6.851E-09
WES-TLC-FF-SSLBP	37	3.83E-4	4.757E-07	1.000	1.001E+0	6.851E-09
WES-TLC-FF-SSLBT	37	3.83E-4	4.757E-07	1.000	1.001E+0	6.851E-09
WES-CBI-FF-BSTPB	5472	7.46E-4	3.668E-07	1.000	1.001E+0	2.711E-09
WES-CBI-FF-BSTPC	5472	7.46E-4	3.668E-07	1.000	1.001E+0	2.711E-09
WES-CBI-FF-BSTPD	5472	7.46E-4	3.668E-07	1.000	1.001E+0	2.711E-09
WES-CDT-FF-ANLTB	4104	4.83E-3	3.572E-07	1.000	1.000E+0	4.079E-10
WES-CDT-FF-ANLTC	4104	4.83E-3	3.572E-07	1.000	1.000E+0	4.079E-10
WES-CDT-FF-ANLTD	4104	4.83E-3	3.572E-07	1.000	1.000E+0	4.079E-10
WES-BME-FO-BYBA	4	3.69E-5	3.467E-07	1.000	1.009E+0	5.183E-08
WES-BME-FO-BYBB	4	3.69E-5	3.467E-07	1.000	1.009E+0	5.183E-08
WES-BUV-CF-RANBB	3	9.73E-6	2.969E-07	1.000	1.031E+0	1.683E-07
WES-BUV-CF-RBNBA	3	9.73E-6	2.969E-07	1.000	1.031E+0	1.683E-07
WES-PWR-FF-TRNA	40	6.00E-5	2.611E-07	1.000	1.004E+0	2.401E-08
WES-PWR-FF-TRNB	40	6.00E-5	2.611E-07	1.000	1.004E+0	2.401E-08
WES-TLR-CF-RLA46	19	9.98E-7	1.878E-07	1.000	1.188E+0	1.038E-06
WES-TLR-CF-RLB46	19	9.98E-7	1.878E-07	1.000	1.188E+0	1.038E-06
WES-TLR-FC-RLYSA	40	3.94E-5	1.715E-07	1.000	1.004E+0	2.401E-08
WES-TLR-FC-RLYSB	40	3.94E-5	1.715E-07	1.000	1.004E+0	2.401E-08
WES-CCP-FF-ANLPB	5472	1.57E-4	7.725E-08	1.000	1.001E+0	2.711E-09
WES-CCP-FF-ANLPC	5472	1.57E-4	7.725E-08	1.000	1.001E+0	2.711E-09
WES-CCP-FF-ANLPD	5472	1.57E-4	7.725E-08	1.000	1.001E+0	2.711E-09

Table F-10. (continued).

Basic Event	Number of Occur.	Prob. of Failure	Fussell-Vesely Importance	Risk Reduction Ratio	Risk Increase Ratio	Birnbaum Importance
WES-CPR-FF-PRESB	5472	1.16E-4	5.704E-08	1.000	1.001E+0	2.711E-09
WES-CPR-FF-PRESC	5472	1.16E-4	5.704E-08	1.000	1.001E+0	2.711E-09
WES-CPR-FF-PRESD	5472	1.16E-4	5.704E-08	1.000	1.001E+0	2.711E-09
WES-CBI-FF-BSTTB	4104	7.46E-4	5.527E-08	1.000	1.000E+0	4.079E-10
WES-CBI-FF-BSTTC	4104	7.46E-4	5.527E-08	1.000	1.000E+0	4.079E-10
WES-CBI-FF-BSTTD	4104	7.46E-4	5.527E-08	1.000	1.000E+0	4.079E-10
WES-BSN-CF-RANBB	1	2.10E-5	5.179E-08	1.000	1.003E+0	1.360E-08
WES-BSN-CF-RBNBA	1	2.10E-5	5.179E-08	1.000	1.003E+0	1.360E-08
WES-CTP-FF-CLTXB	4104	5.98E-4	4.428E-08	1.000	1.000E+0	4.079E-10
WES-CTP-FF-CLTXC	4104	5.98E-4	4.428E-08	1.000	1.000E+0	4.079E-10
WES-CTP-FF-CLTXD	4104	5.98E-4	4.428E-08	1.000	1.000E+0	4.079E-10
WES-CTP-FF-HLTXB	4104	5.98E-4	4.428E-08	1.000	1.000E+0	4.079E-10
WES-CTP-FF-HLTXC	4104	5.98E-4	4.428E-08	1.000	1.000E+0	4.079E-10
WES-CTP-FF-HLTXD	4104	5.98E-4	4.428E-08	1.000	1.000E+0	4.079E-10
WES-BUV-FF-BYBA	6	2.54E-4	3.261E-09	1.000	1.000E+0	7.052E-11
WES-BUV-FF-BYBB	6	2.54E-4	3.261E-09	1.000	1.000E+0	7.052E-11
WES-BSN-FF-BYBA	2	5.81E-4	1.389E-09	1.000	1.000E+0	1.316E-11
WES-BSN-FF-BYBB	2	5.81E-4	1.389E-09	1.000	1.000E+0	1.316E-11
WES-CBI-FF-BSTPA	5184	7.46E-4	+0.000E+00	1.000	1.000E+0	4.496E-13
WES-CBI-FF-BSTTA	3888	7.46E-4	+0.000E+00	1.000	1.000E+0	5.929E-14
WES-CCP-FF-ANLPA	5184	1.57E-4	+0.000E+00	1.000	1.000E+0	4.496E-13
WES-CDT-FF-ANLTA	3888	4.83E-3	+0.000E+00	1.000	1.000E+0	5.929E-14
WES-CPR-FF-PRESA	5184	1.16E-4	+0.000E+00	1.000	1.000E+0	4.496E-13
WES-CTP-FF-CLTXA	3888	5.98E-4	+0.000E+00	1.000	1.000E+0	5.929E-14
WES-CTP-FF-HLTXA	3888	5.98E-4	+0.000E+00	1.000	1.000E+0	5.929E-14
WES-TLR-CF-PRA23	19	5.10E-6	+0.000E+00	1.000	1.000E+0	5.293E-12
WES-TLR-CF-PRA34	26	1.52E-6	+0.000E+00	1.000	1.000E+0	2.561E-11
WES-TLR-CF-PRB23	19	5.10E-6	+0.000E+00	1.000	1.000E+0	5.293E-12
WES-TLR-CF-PRB34	26	1.52E-6	+0.000E+00	1.000	1.000E+0	2.561E-11
WES-TLR-CF-TRA23	19	5.10E-6	+0.000E+00	1.000	1.000E+0	5.293E-12
WES-TLR-CF-TRA34	26	1.52E-6	+0.000E+00	1.000	1.000E+0	2.561E-11
WES-TLR-CF-TRB23	19	5.10E-6	+0.000E+00	1.000	1.000E+0	5.293E-12
WES-TLR-CF-TRB34	26	1.52E-6	+0.000E+00	1.000	1.000E+0	2.561E-11
WES-TLR-FC-PRATA	312	3.94E-5	+0.000E+00	1.000	1.000E+0	+0.000E+00
WES-TLR-FC-PRATB	312	3.94E-5	+0.000E+00	1.000	1.000E+0	+0.000E+00
WES-TLR-FC-PRBTA	426	3.94E-5	+0.000E+00	1.000	1.000E+0	+0.000E+00
WES-TLR-FC-PRBTB	426	3.94E-5	+0.000E+00	1.000	1.000E+0	+0.000E+00
WES-TLR-FC-PRCTA	426	3.94E-5	+0.000E+00	1.000	1.000E+0	+0.000E+00
WES-TLR-FC-PRCTB	426	3.94E-5	+0.000E+00	1.000	1.000E+0	+0.000E+00
WES-TLR-FC-PRDTA	426	3.94E-5	+0.000E+00	1.000	1.000E+0	+0.000E+00
WES-TLR-FC-PRDTB	426	3.94E-5	+0.000E+00	1.000	1.000E+0	+0.000E+00
WES-TLR-FC-TRATA	312	3.94E-5	+0.000E+00	1.000	1.000E+0	+0.000E+00
WES-TLR-FC-TRATB	312	3.94E-5	+0.000E+00	1.000	1.000E+0	+0.000E+00
WES-TLR-FC-TRBTA	426	3.94E-5	+0.000E+00	1.000	1.000E+0	+0.000E+00
WES-TLR-FC-TRBTB	426	3.94E-5	+0.000E+00	1.000	1.000E+0	+0.000E+00
WES-TLR-FC-TRCTA	426	3.94E-5	+0.000E+00	1.000	1.000E+0	+0.000E+00
WES-TLR-FC-TRCTB	426	3.94E-5	+0.000E+00	1.000	1.000E+0	+0.000E+00
WES-TLR-FC-TRDTA	426	3.94E-5	+0.000E+00	1.000	1.000E+0	+0.000E+00
WES-TLR-FC-TRDTB	426	3.94E-5	+0.000E+00	1.000	1.000E+0	+0.000E+00

Table F-11. Importance measures sorted on Risk Increase for case with RPS mincut = 5.5E-6.

Basic Event	Number of Occur.	Prob. of Failure	Fussell-Vesely Importance	Risk Reduction Ratio	Risk Increase Ratio	Birnbaum Importance
WES-ROD-CF-RCCAS	1	1.21E-6	2.194E-01	1.281	1.813E+5	1.000E+00
WES-BME-CF-RTBAB	1	1.61E-6	2.911E-01	1.411	1.808E+5	9.972E-01
WES-CBI-CF-6OF8	3	2.70E-6	2.306E-01	1.300	8.528E+4	4.704E-01
WES-CCX-CF-6OF8	3	1.83E-6	1.563E-01	1.185	8.528E+4	4.704E-01
WES-CBI-CF-4OF6	3	8.21E-6	4.317E-02	1.045	5.258E+3	2.900E-02
WES-CCX-CF-4OF6	3	6.33E-6	3.328E-02	1.034	5.258E+3	2.900E-02
WES-TLC-CF-SSLAB	3	2.10E-6	3.807E-03	1.004	1.814E+3	1.000E-02
WES-UVL-CF-UVDAB	3	1.04E-5	1.886E-02	1.019	1.814E+3	1.000E-02
WES-TLR-CF-12O16	3	8.07E-8	1.378E-04	1.000	1.709E+3	9.420E-03
WES-BME-CF-RANBB	1	1.61E-6	4.081E-04	1.000	2.545E+2	1.398E-03
WES-BME-CF-RBNBA	1	1.61E-6	4.081E-04	1.000	2.545E+2	1.398E-03
WES-TLR-CF-8OF12	3	2.07E-7	2.177E-05	1.000	1.062E+2	5.800E-04
WES-CBI-CF-P3OF4	9	1.19E-5	1.061E-04	1.000	9.915E+0	4.917E-05
WES-CCP-CF-P3OF4	9	4.48E-6	3.994E-05	1.000	9.915E+0	4.917E-05
WES-CPR-CF-P3OF4	9	2.06E-6	1.836E-05	1.000	9.915E+0	4.917E-05
WES-BME-FO-RTBA	40	3.69E-5	2.713E-04	1.000	8.353E+0	4.056E-05
WES-BME-FO-RTBB	40	3.69E-5	2.713E-04	1.000	8.353E+0	4.056E-05
WES-BUV-CF-RTBAB	3	9.73E-6	4.644E-05	1.000	5.773E+0	2.633E-05
WES-TLC-CF-SSLA	37	1.72E-5	5.578E-05	1.000	4.243E+0	1.789E-05
WES-TLC-CF-SSLB	37	1.72E-5	5.578E-05	1.000	4.243E+0	1.789E-05
WES-UVL-FF-UVDA	37	3.37E-4	1.093E-03	1.001	4.242E+0	1.789E-05
WES-UVL-FF-UVDB	37	3.37E-4	1.093E-03	1.001	4.242E+0	1.789E-05
WES-TLR-CF-RLA68	26	3.28E-7	1.002E-06	1.000	4.055E+0	1.685E-05
WES-TLR-CF-RLB68	26	3.28E-7	1.002E-06	1.000	4.055E+0	1.685E-05
WES-XHE-XE-SIGNL	960	1.00E-2	2.490E-02	1.026	3.465E+0	1.373E-05
WES-CBI-CF-P2OF3	9	4.19E-5	8.074E-05	1.000	2.927E+0	1.063E-05
WES-CCP-CF-P2OF3	9	1.50E-5	2.890E-05	1.000	2.927E+0	1.063E-05
WES-CPR-CF-P2OF3	9	7.71E-6	1.486E-05	1.000	2.927E+0	1.063E-05
WES-BSN-CF-RTBAB	1	2.10E-5	3.694E-05	1.000	2.759E+0	9.703E-06
WES-PWR-CF-TRNAB	1	3.40E-6	5.981E-06	1.000	2.759E+0	9.703E-06
WES-TLR-CF-RTBAB	1	2.00E-6	3.518E-06	1.000	2.759E+0	9.703E-06
WES-CBI-CF-T3OF4	9	1.19E-5	1.874E-05	1.000	2.575E+0	8.685E-06
WES-CDT-CF-T3OF4	9	5.55E-5	8.739E-05	1.000	2.575E+0	8.685E-06
WES-CTP-CF-T3OF8	9	3.70E-5	5.826E-05	1.000	2.575E+0	8.685E-06
WES-CCP-TM-CHA	23013	5.80E-2	5.276E-02	1.056	1.857E+0	5.017E-06
WES-BME-TM-RTBA	23106	1.40E-3	8.961E-04	1.001	1.639E+0	3.531E-06
WES-BME-TM-RTBB	23106	1.40E-3	8.961E-04	1.001	1.639E+0	3.531E-06
WES-XHE-XE-NSGNL	22098	5.00E-1	4.636E-01	1.864	1.464E+0	5.114E-06
WES-CBI-CF-T2OF3	9	4.19E-5	1.423E-05	1.000	1.340E+0	1.874E-06
WES-CDT-CF-T2OF3	9	2.50E-4	8.492E-05	1.000	1.340E+0	1.874E-06
WES-CTP-CF-T2OF6	9	7.46E-5	2.534E-05	1.000	1.340E+0	1.874E-06
WES-TLR-CF-RLA46	19	9.98E-7	1.878E-07	1.000	1.188E+0	1.038E-06
WES-TLR-CF-RLB46	19	9.98E-7	1.878E-07	1.000	1.188E+0	1.038E-06
WES-BUV-CF-RANBB	3	9.73E-6	2.969E-07	1.000	1.031E+0	1.683E-07
WES-BUV-CF-RBNBA	3	9.73E-6	2.969E-07	1.000	1.031E+0	1.683E-07
WES-BME-FO-BYBA	4	3.69E-5	3.467E-07	1.000	1.009E+0	5.183E-08
WES-BME-FO-BYBB	4	3.69E-5	3.467E-07	1.000	1.009E+0	5.183E-08
WES-BUV-FF-RTBA	114	2.54E-4	1.272E-06	1.000	1.005E+0	2.763E-08
WES-BUV-FF-RTBB	114	2.54E-4	1.272E-06	1.000	1.005E+0	2.763E-08
WES-PWR-FF-TRNA	40	6.00E-5	2.611E-07	1.000	1.004E+0	2.401E-08
WES-PWR-FF-TRNB	40	6.00E-5	2.611E-07	1.000	1.004E+0	2.401E-08
WES-TLR-FC-RLYSA	40	3.94E-5	1.715E-07	1.000	1.004E+0	2.401E-08
WES-TLR-FC-RLYSB	40	3.94E-5	1.715E-07	1.000	1.004E+0	2.401E-08
WES-BSN-CF-RANBB	1	2.10E-5	5.179E-08	1.000	1.003E+0	1.360E-08
WES-BSN-CF-RBNBA	1	2.10E-5	5.179E-08	1.000	1.003E+0	1.360E-08
WES-BSN-FF-RTBA	38	5.81E-4	1.085E-06	1.000	1.002E+0	1.030E-08
WES-BSN-FF-RTBB	38	5.81E-4	1.085E-06	1.000	1.002E+0	1.030E-08
WES-CBI-FF-BSTPB	5472	7.46E-4	3.668E-07	1.000	1.001E+0	2.711E-09
WES-CBI-FF-BSTPC	5472	7.46E-4	3.668E-07	1.000	1.001E+0	2.711E-09
WES-CBI-FF-BSTPD	5472	7.46E-4	3.668E-07	1.000	1.001E+0	2.711E-09
WES-CCP-FF-ANLPB	5472	1.57E-4	7.725E-08	1.000	1.001E+0	2.711E-09
WES-CCP-FF-ANLPC	5472	1.57E-4	7.725E-08	1.000	1.001E+0	2.711E-09
WES-CCP-FF-ANLPD	5472	1.57E-4	7.725E-08	1.000	1.001E+0	2.711E-09
WES-CPR-FF-PRESB	5472	1.16E-4	5.704E-08	1.000	1.001E+0	2.711E-09
WES-CPR-FF-PRESC	5472	1.16E-4	5.704E-08	1.000	1.001E+0	2.711E-09
WES-CPR-FF-PRESD	5472	1.16E-4	5.704E-08	1.000	1.001E+0	2.711E-09
WES-TLC-FF-SSLAP	37	3.83E-4	4.757E-07	1.000	1.001E+0	6.851E-09
WES-TLC-FF-SSLAT	37	3.83E-4	4.757E-07	1.000	1.001E+0	6.851E-09

Table F-11. (continued).

Basic Event	Number of Occur.	Prob. of Failure	Fussell-Vesely Importance	Risk Reduction Ratio	Risk Increase Ratio	Birnbaum Importance
WES-TLC-FF-SSLBP	37	3.83E-4	4.757E-07	1.000	1.001E+0	6.851E-09
WES-TLC-FF-SSLBT	37	3.83E-4	4.757E-07	1.000	1.001E+0	6.851E-09
WES-BSN-FF-BYBA	2	5.81E-4	1.389E-09	1.000	1.000E+0	1.316E-11
WES-BSN-FF-BYBB	2	5.81E-4	1.389E-09	1.000	1.000E+0	1.316E-11
WES-BUV-FF-BYBA	6	2.54E-4	3.261E-09	1.000	1.000E+0	7.052E-11
WES-BUV-FF-BYBB	6	2.54E-4	3.261E-09	1.000	1.000E+0	7.052E-11
WES-CBI-FF-BSTPA	5184	7.46E-4	+0.000E+00	1.000	1.000E+0	4.496E-13
WES-CBI-FF-BSTTA	3888	7.46E-4	+0.000E+00	1.000	1.000E+0	5.929E-14
WES-CBI-FF-BSTTB	4104	7.46E-4	5.527E-08	1.000	1.000E+0	4.079E-10
WES-CBI-FF-BSTTC	4104	7.46E-4	5.527E-08	1.000	1.000E+0	4.079E-10
WES-CBI-FF-BSTTD	4104	7.46E-4	5.527E-08	1.000	1.000E+0	4.079E-10
WES-CCP-FF-ANLPA	5184	1.57E-4	+0.000E+00	1.000	1.000E+0	4.496E-13
WES-CDT-FF-ANLTA	3888	4.83E-3	+0.000E+00	1.000	1.000E+0	5.929E-14
WES-CDT-FF-ANLTB	4104	4.83E-3	3.572E-07	1.000	1.000E+0	4.079E-10
WES-CDT-FF-ANLTC	4104	4.83E-3	3.572E-07	1.000	1.000E+0	4.079E-10
WES-CDT-FF-ANLTD	4104	4.83E-3	3.572E-07	1.000	1.000E+0	4.079E-10
WES-CPR-FF-PRESA	5184	1.16E-4	+0.000E+00	1.000	1.000E+0	4.496E-13
WES-CTP-FF-CLTXA	3888	5.98E-4	+0.000E+00	1.000	1.000E+0	5.929E-14
WES-CTP-FF-CLTXB	4104	5.98E-4	4.428E-08	1.000	1.000E+0	4.079E-10
WES-CTP-FF-CLTXC	4104	5.98E-4	4.428E-08	1.000	1.000E+0	4.079E-10
WES-CTP-FF-CLTXD	4104	5.98E-4	4.428E-08	1.000	1.000E+0	4.079E-10
WES-CTP-FF-HLTXA	3888	5.98E-4	+0.000E+00	1.000	1.000E+0	5.929E-14
WES-CTP-FF-HLTXB	4104	5.98E-4	4.428E-08	1.000	1.000E+0	4.079E-10
WES-CTP-FF-HLTXC	4104	5.98E-4	4.428E-08	1.000	1.000E+0	4.079E-10
WES-CTP-FF-HLTXD	4104	5.98E-4	4.428E-08	1.000	1.000E+0	4.079E-10
WES-TLR-CF-PRA23	19	5.10E-6	+0.000E+00	1.000	1.000E+0	5.293E-12
WES-TLR-CF-PRA34	26	1.52E-6	+0.000E+00	1.000	1.000E+0	2.561E-11
WES-TLR-CF-PRB23	19	5.10E-6	+0.000E+00	1.000	1.000E+0	5.293E-12
WES-TLR-CF-PRB34	26	1.52E-6	+0.000E+00	1.000	1.000E+0	2.561E-11
WES-TLR-CF-TRA23	19	5.10E-6	+0.000E+00	1.000	1.000E+0	5.293E-12
WES-TLR-CF-TRA34	26	1.52E-6	+0.000E+00	1.000	1.000E+0	2.561E-11
WES-TLR-CF-TRB23	19	5.10E-6	+0.000E+00	1.000	1.000E+0	5.293E-12
WES-TLR-CF-TRB34	26	1.52E-6	+0.000E+00	1.000	1.000E+0	2.561E-11
WES-TLR-FC-PRATA	312	3.94E-5	+0.000E+00	1.000	1.000E+0	+0.000E+00
WES-TLR-FC-PRATB	312	3.94E-5	+0.000E+00	1.000	1.000E+0	+0.000E+00
WES-TLR-FC-PRBTA	426	3.94E-5	+0.000E+00	1.000	1.000E+0	+0.000E+00
WES-TLR-FC-PRBTB	426	3.94E-5	+0.000E+00	1.000	1.000E+0	+0.000E+00
WES-TLR-FC-PRCTA	426	3.94E-5	+0.000E+00	1.000	1.000E+0	+0.000E+00
WES-TLR-FC-PRCTB	426	3.94E-5	+0.000E+00	1.000	1.000E+0	+0.000E+00
WES-TLR-FC-PRDTA	426	3.94E-5	+0.000E+00	1.000	1.000E+0	+0.000E+00
WES-TLR-FC-PRDTB	426	3.94E-5	+0.000E+00	1.000	1.000E+0	+0.000E+00
WES-TLR-FC-TRATA	312	3.94E-5	+0.000E+00	1.000	1.000E+0	+0.000E+00
WES-TLR-FC-TRATB	312	3.94E-5	+0.000E+00	1.000	1.000E+0	+0.000E+00
WES-TLR-FC-TRBTA	426	3.94E-5	+0.000E+00	1.000	1.000E+0	+0.000E+00
WES-TLR-FC-TRBTB	426	3.94E-5	+0.000E+00	1.000	1.000E+0	+0.000E+00
WES-TLR-FC-TRCTA	426	3.94E-5	+0.000E+00	1.000	1.000E+0	+0.000E+00
WES-TLR-FC-TRCTB	426	3.94E-5	+0.000E+00	1.000	1.000E+0	+0.000E+00
WES-TLR-FC-TRDTA	426	3.94E-5	+0.000E+00	1.000	1.000E+0	+0.000E+00
WES-TLR-FC-TRDTB	426	3.94E-5	+0.000E+00	1.000	1.000E+0	+0.000E+00

Table F-12. Importance measures sorted on Birnbaum for case with RPS mincut = 5.5E-5.

Basic Event	Number of Occur.	Prob. of Failure	Fussell-Vesely Importance	Risk Reduction Ratio	Risk Increase Ratio	Birnbaum Importance
WES-ROD-CF-RCCAS	1	1.21E-6	2.194E-01	1.281	1.813E+5	1.000E+00
WES-BME-CF-RTBAB	1	1.61E-6	2.911E-01	1.411	1.808E+5	9.972E-01
WES-CBI-CF-6OF8	3	2.70E-6	2.306E-01	1.300	8.528E+4	4.704E-01
WES-CCX-CF-6OF8	3	1.83E-6	1.563E-01	1.185	8.528E+4	4.704E-01
WES-CBI-CF-4OF6	3	8.21E-6	4.317E-02	1.045	5.258E+3	2.900E-02
WES-CCX-CF-4OF6	3	6.33E-6	3.328E-02	1.034	5.258E+3	2.900E-02
WES-TLC-CF-SSLAB	3	2.10E-6	3.807E-03	1.004	1.814E+3	1.000E-02
WES-UVL-CF-UVDAB	3	1.04E-5	1.886E-02	1.019	1.814E+3	1.000E-02
WES-TLR-CF-12O16	3	8.07E-8	1.378E-04	1.000	1.709E+3	9.420E-03
WES-BME-CF-RANBB	1	1.61E-6	4.081E-04	1.000	2.545E+2	1.398E-03
WES-BME-CF-RBNBA	1	1.61E-6	4.081E-04	1.000	2.545E+2	1.398E-03
WES-TLR-CF-8OF12	3	2.07E-7	2.177E-05	1.000	1.062E+2	5.800E-04
WES-CBI-CF-P3OF4	9	1.19E-5	1.061E-04	1.000	9.915E+0	4.917E-05
WES-CCP-CF-P3OF4	9	4.48E-6	3.994E-05	1.000	9.915E+0	4.917E-05
WES-CPR-CF-P3OF4	9	2.06E-6	1.836E-05	1.000	9.915E+0	4.917E-05
WES-BME-FO-RTBA	40	3.69E-5	2.713E-04	1.000	8.353E+0	4.056E-05
WES-BME-FO-RTBB	40	3.69E-5	2.713E-04	1.000	8.353E+0	4.056E-05
WES-BUV-CF-RTBAB	3	9.73E-6	4.644E-05	1.000	5.773E+0	2.633E-05
WES-TLC-CF-SSLA	37	1.72E-5	5.578E-05	1.000	4.243E+0	1.789E-05
WES-TLC-CF-SSLB	37	1.72E-5	5.578E-05	1.000	4.243E+0	1.789E-05
WES-UVL-FF-UVDA	37	3.37E-4	1.093E-03	1.001	4.242E+0	1.789E-05
WES-UVL-FF-UVDB	37	3.37E-4	1.093E-03	1.001	4.242E+0	1.789E-05
WES-TLR-CF-RLA68	26	3.28E-7	1.002E-06	1.000	4.055E+0	1.685E-05
WES-TLR-CF-RLB68	26	3.28E-7	1.002E-06	1.000	4.055E+0	1.685E-05
WES-XHE-XE-SIGNL	960	1.00E-2	2.490E-02	1.026	3.465E+0	1.373E-05
WES-CBI-CF-P2OF3	9	4.19E-5	8.074E-05	1.000	2.927E+0	1.063E-05
WES-CCP-CF-P2OF3	9	1.50E-5	2.890E-05	1.000	2.927E+0	1.063E-05
WES-CPR-CF-P2OF3	9	7.71E-6	1.486E-05	1.000	2.927E+0	1.063E-05
WES-BSN-CF-RTBAB	1	2.10E-5	3.694E-05	1.000	2.759E+0	9.703E-06
WES-PWR-CF-TRNAB	1	3.40E-6	5.981E-06	1.000	2.759E+0	9.703E-06
WES-TLR-CF-RTBAB	1	2.00E-6	3.518E-06	1.000	2.759E+0	9.703E-06
WES-CBI-CF-T3OF4	9	1.19E-5	1.874E-05	1.000	2.575E+0	8.685E-06
WES-CDT-CF-T3OF4	9	5.55E-5	8.739E-05	1.000	2.575E+0	8.685E-06
WES-CTP-CF-T3OF8	9	3.70E-5	5.826E-05	1.000	2.575E+0	8.685E-06
WES-XHE-XE-NSGNL	22098	5.00E-1	4.636E-01	1.864	1.464E+0	5.114E-06
WES-CCP-TM-CHA	23013	5.80E-2	5.276E-02	1.056	1.857E+0	5.017E-06
WES-BME-TM-RTBA	23106	1.40E-3	8.961E-04	1.001	1.639E+0	3.531E-06
WES-BME-TM-RTBB	23106	1.40E-3	8.961E-04	1.001	1.639E+0	3.531E-06
WES-CBI-CF-T2OF3	9	4.19E-5	1.423E-05	1.000	1.340E+0	1.874E-06
WES-CDT-CF-T2OF3	9	2.50E-4	8.492E-05	1.000	1.340E+0	1.874E-06
WES-CTP-CF-T2OF6	9	7.46E-5	2.534E-05	1.000	1.340E+0	1.874E-06
WES-TLR-CF-RLA46	19	9.98E-7	1.878E-07	1.000	1.188E+0	1.038E-06
WES-TLR-CF-RLB46	19	9.98E-7	1.878E-07	1.000	1.188E+0	1.038E-06
WES-BUV-CF-RANBB	3	9.73E-6	2.969E-07	1.000	1.031E+0	1.683E-07
WES-BUV-CF-RBNBA	3	9.73E-6	2.969E-07	1.000	1.031E+0	1.683E-07
WES-BME-FO-BYBA	4	3.69E-5	3.467E-07	1.000	1.009E+0	5.183E-08
WES-BME-FO-BYBB	4	3.69E-5	3.467E-07	1.000	1.009E+0	5.183E-08
WES-BUV-FF-RTBA	114	2.54E-4	1.272E-06	1.000	1.005E+0	2.763E-08
WES-BUV-FF-RTBB	114	2.54E-4	1.272E-06	1.000	1.005E+0	2.763E-08
WES-PWR-FF-TRNA	40	6.00E-5	2.611E-07	1.000	1.004E+0	2.401E-08
WES-PWR-FF-TRNB	40	6.00E-5	2.611E-07	1.000	1.004E+0	2.401E-08
WES-TLR-FC-RLYSA	40	3.94E-5	1.715E-07	1.000	1.004E+0	2.401E-08
WES-TLR-FC-RLYSB	40	3.94E-5	1.715E-07	1.000	1.004E+0	2.401E-08
WES-BSN-CF-RANBB	1	2.10E-5	5.179E-08	1.000	1.003E+0	1.360E-08
WES-BSN-CF-RBNBA	1	2.10E-5	5.179E-08	1.000	1.003E+0	1.360E-08
WES-BSN-FF-RTBA	38	5.81E-4	1.085E-06	1.000	1.002E+0	1.030E-08
WES-BSN-FF-RTBB	38	5.81E-4	1.085E-06	1.000	1.002E+0	1.030E-08
WES-TLC-FF-SSLAP	37	3.83E-4	4.757E-07	1.000	1.001E+0	6.851E-09
WES-TLC-FF-SSLAT	37	3.83E-4	4.757E-07	1.000	1.001E+0	6.851E-09
WES-TLC-FF-SSLBP	37	3.83E-4	4.757E-07	1.000	1.001E+0	6.851E-09
WES-TLC-FF-SSLBT	37	3.83E-4	4.757E-07	1.000	1.001E+0	6.851E-09
WES-CBI-FF-BSTPB	5472	7.46E-4	3.668E-07	1.000	1.001E+0	2.711E-09
WES-CBI-FF-BSTPC	5472	7.46E-4	3.668E-07	1.000	1.001E+0	2.711E-09
WES-CBI-FF-BSTPD	5472	7.46E-4	3.668E-07	1.000	1.001E+0	2.711E-09
WES-CCP-FF-ANLPB	5472	1.57E-4	7.725E-08	1.000	1.001E+0	2.711E-09
WES-CCP-FF-ANLPC	5472	1.57E-4	7.725E-08	1.000	1.001E+0	2.711E-09
WES-CCP-FF-ANLPD	5472	1.57E-4	7.725E-08	1.000	1.001E+0	2.711E-09
WES-CPR-FF-PRESB	5472	1.16E-4	5.704E-08	1.000	1.001E+0	2.711E-09

Table F-12. (continued).

Basic Event	Number of Occur.	Prob. of Failure	Fussell-Vesely Importance	Risk Reduction Ratio	Risk Increase Ratio	Birnbaum Importance
WES-CPR-FF-PRESC	5472	1.16E-4	5.704E-08	1.000	1.001E+0	2.711E-09
WES-CPR-FF-PRESD	5472	1.16E-4	5.704E-08	1.000	1.001E+0	2.711E-09
WES-CBI-FF-BSTTB	4104	7.46E-4	5.527E-08	1.000	1.000E+0	4.079E-10
WES-CBI-FF-BSTTC	4104	7.46E-4	5.527E-08	1.000	1.000E+0	4.079E-10
WES-CBI-FF-BSTTD	4104	7.46E-4	5.527E-08	1.000	1.000E+0	4.079E-10
WES-CDT-FF-ANLTB	4104	4.83E-3	3.572E-07	1.000	1.000E+0	4.079E-10
WES-CDT-FF-ANLTC	4104	4.83E-3	3.572E-07	1.000	1.000E+0	4.079E-10
WES-CDT-FF-ANLTD	4104	4.83E-3	3.572E-07	1.000	1.000E+0	4.079E-10
WES-CTP-FF-CLTXB	4104	5.98E-4	4.428E-08	1.000	1.000E+0	4.079E-10
WES-CTP-FF-CLTXC	4104	5.98E-4	4.428E-08	1.000	1.000E+0	4.079E-10
WES-CTP-FF-CLTXD	4104	5.98E-4	4.428E-08	1.000	1.000E+0	4.079E-10
WES-CTP-FF-HLTXB	4104	5.98E-4	4.428E-08	1.000	1.000E+0	4.079E-10
WES-CTP-FF-HLTXC	4104	5.98E-4	4.428E-08	1.000	1.000E+0	4.079E-10
WES-CTP-FF-HLTXD	4104	5.98E-4	4.428E-08	1.000	1.000E+0	4.079E-10
WES-BUV-FF-BYBA	6	2.54E-4	3.261E-09	1.000	1.000E+0	7.052E-11
WES-BUV-FF-BYBB	6	2.54E-4	3.261E-09	1.000	1.000E+0	7.052E-11
WES-TLR-CF-PRA34	26	1.52E-6	+0.000E+00	1.000	1.000E+0	2.561E-11
WES-TLR-CF-PRB34	26	1.52E-6	+0.000E+00	1.000	1.000E+0	2.561E-11
WES-TLR-CF-TRA34	26	1.52E-6	+0.000E+00	1.000	1.000E+0	2.561E-11
WES-TLR-CF-TRB34	26	1.52E-6	+0.000E+00	1.000	1.000E+0	2.561E-11
WES-BSN-FF-BYBA	2	5.81E-4	1.389E-09	1.000	1.000E+0	1.316E-11
WES-BSN-FF-BYBB	2	5.81E-4	1.389E-09	1.000	1.000E+0	1.316E-11
WES-TLR-CF-PRA23	19	5.10E-6	+0.000E+00	1.000	1.000E+0	5.293E-12
WES-TLR-CF-PRB23	19	5.10E-6	+0.000E+00	1.000	1.000E+0	5.293E-12
WES-TLR-CF-TRA23	19	5.10E-6	+0.000E+00	1.000	1.000E+0	5.293E-12
WES-TLR-CF-TRB23	19	5.10E-6	+0.000E+00	1.000	1.000E+0	5.293E-12
WES-CBI-FF-BSTPA	5184	7.46E-4	+0.000E+00	1.000	1.000E+0	4.496E-13
WES-CCP-FF-ANLPA	5184	1.57E-4	+0.000E+00	1.000	1.000E+0	4.496E-13
WES-CPR-FF-PRESA	5184	1.16E-4	+0.000E+00	1.000	1.000E+0	4.496E-13
WES-CBI-FF-BSTTA	3888	7.46E-4	+0.000E+00	1.000	1.000E+0	5.929E-14
WES-CDT-FF-ANLTA	3888	4.83E-3	+0.000E+00	1.000	1.000E+0	5.929E-14
WES-CTP-FF-CLTXA	3888	5.98E-4	+0.000E+00	1.000	1.000E+0	5.929E-14
WES-CTP-FF-HLTXA	3888	5.98E-4	+0.000E+00	1.000	1.000E+0	5.929E-14
WES-TLR-FC-PRATA	312	3.94E-5	+0.000E+00	1.000	1.000E+0	+0.000E+00
WES-TLR-FC-PRATB	312	3.94E-5	+0.000E+00	1.000	1.000E+0	+0.000E+00
WES-TLR-FC-PRBTA	426	3.94E-5	+0.000E+00	1.000	1.000E+0	+0.000E+00
WES-TLR-FC-PRBTB	426	3.94E-5	+0.000E+00	1.000	1.000E+0	+0.000E+00
WES-TLR-FC-PRCTA	426	3.94E-5	+0.000E+00	1.000	1.000E+0	+0.000E+00
WES-TLR-FC-PRCTB	426	3.94E-5	+0.000E+00	1.000	1.000E+0	+0.000E+00
WES-TLR-FC-PRDTA	426	3.94E-5	+0.000E+00	1.000	1.000E+0	+0.000E+00
WES-TLR-FC-PRDTB	426	3.94E-5	+0.000E+00	1.000	1.000E+0	+0.000E+00
WES-TLR-FC-TRATA	312	3.94E-5	+0.000E+00	1.000	1.000E+0	+0.000E+00
WES-TLR-FC-TRATB	312	3.94E-5	+0.000E+00	1.000	1.000E+0	+0.000E+00
WES-TLR-FC-TRBTA	426	3.94E-5	+0.000E+00	1.000	1.000E+0	+0.000E+00
WES-TLR-FC-TRBTB	426	3.94E-5	+0.000E+00	1.000	1.000E+0	+0.000E+00
WES-TLR-FC-TRCTA	426	3.94E-5	+0.000E+00	1.000	1.000E+0	+0.000E+00
WES-TLR-FC-TRCTB	426	3.94E-5	+0.000E+00	1.000	1.000E+0	+0.000E+00
WES-TLR-FC-TRDTA	426	3.94E-5	+0.000E+00	1.000	1.000E+0	+0.000E+00
WES-TLR-FC-TRDTB	426	3.94E-5	+0.000E+00	1.000	1.000E+0	+0.000E+00

Table F-13. (continued).

Table F-13. RPS Eagle-21 design top 100 cut sets (SIGNL 0.01, NSGNL 0.5) mincut 4.5E-6.

Cut Set	Cut Set Percent	Cut Set Prob.	Basic Event[a]	Description	Prob.
1	35.9	1.6E-06	WES-BME-CF-RTBAB	CCF RTB-A AND RTB-B (MECHANICAL)	1.6E-6
			/WES-BME-TM-RTBA	RTB-A IN T&M	1.0E+0
			/WES-BME-TM-RTBB	RTB-B IN T&M	1.0E+0
2	29.2	1.3E-06	/WES-BME-TM-RTBA	RTB-A IN T&M	1.0E+0
			/WES-BME-TM-RTBB	RTB-B IN T&M	1.0E+0
			WES-CBI-CF-6OF8	CCF 6 BISTABLES IN 3 OF 4 CHANNELS	2.7E-6
			/WES-CCP-TM-CHA	CH-A IN T&M	9.7E-1
			WES-XHE-XE-NSGNL	OPERATOR FAILS TO RESPOND WITH NO RPS SIGNAL PRESENT	5.0E-1
3	27.1	1.2E-06	WES-ROD-CF-RCCAS	CCF 10 OR MORE RCCAS FAIL TO DROP	1.2E-6
4	2.7	1.2E-07	/WES-BME-TM-RTBA	RTB-A IN T&M	1.0E+0
			/WES-BME-TM-RTBB	RTB-B IN T&M	1.0E+0
			WES-CBI-CF-4OF6	CCF 4 BISTABLES IN 2 OF 3 CHANNELS	8.2E-6
			WES-CCP-TM-CHA	CH-A IN T&M	2.9E-2
			WES-XHE-XE-NSGNL	OPERATOR FAILS TO RESPOND WITH NO RPS SIGNAL PRESENT	5.0E-1
5	2.3	1.0E-07	/WES-BME-TM-RTBA	RTB-A IN T&M	1.0E+0
			/WES-BME-TM-RTBB	RTB-B IN T&M	1.0E+0
			WES-UVL-CF-UVDAB	CCF UV DRIVERS TRAINS A AND B (2 OF 2)	1.0E-5
			WES-XHE-XE-SIGNL	OPERATOR FAILS TO RESPOND WITH RPS SIGNAL PRESENT	1.0E-2
6	1.6	7.3E-08	/WES-BME-TM-RTBA	RTB-A IN T&M	1.0E+0
			/WES-BME-TM-RTBB	RTB-B IN T&M	1.0E+0
			WES-C21-CF-E3OF4	CCF 3 EAGLE-21 PROCESS LOGIC MODULES IN 3 OF 4 CHANNELS	1.5E-7
			/WES-CCP-TM-CHA	CH-A IN T&M	9.7E-1
			WES-XHE-XE-NSGNL	OPERATOR FAILS TO RESPOND WITH NO RPS SIGNAL PRESENT	5.0E-1
7	0.5	2.1E-08	/WES-BME-TM-RTBA	RTB-A IN T&M	1.0E+0
			/WES-BME-TM-RTBB	RTB-B IN T&M	1.0E+0
			WES-TLC-CF-SSLAB	CCF SOLID STATE LOGIC IN TRAINS A AND B (4 OF 4)	2.1E-6
			WES-XHE-XE-SIGNL	OPERATOR FAILS TO RESPOND WITH RPS SIGNAL PRESENT	1.0E-2
8	0.2	7.3E-09	/WES-BME-TM-RTBA	RTB-A IN T&M	1.0E+0
			/WES-BME-TM-RTBB	RTB-B IN T&M	1.0E+0
			WES-C21-CF-E2OF3	CCF 2 EAGLE-21 PROCESS LOGIC MODULES IN 2 OF 3 CHANNELS	5.1E-7
			WES-CCP-TM-CHA	CH-A IN T&M	2.9E-2
			WES-XHE-XE-NSGNL	OPERATOR FAILS TO RESPOND WITH NO RPS SIGNAL PRESENT	5.0E-1
9	0.1	4.7E-09	WES-BME-TM-RTBA	RTB-A IN T&M	1.4E-3
			/WES-BME-TM-RTBB	RTB-B IN T&M	1.0E+0
			WES-UVL-FF-UVDB	TRAIN B UV DRIVER FAILS	3.4E-4
			WES-XHE-XE-SIGNL	OPERATOR FAILS TO RESPOND WITH RPS SIGNAL PRESENT	1.0E-2
10	0.1	4.7E-09	/WES-BME-TM-RTBA	RTB-A IN T&M	1.0E+0
			WES-BME-TM-RTBB	RTB-B IN T&M	1.4E-3
			WES-UVL-FF-UVDA	TRAIN A UV DRIVER FAILS	3.4E-4
			WES-XHE-XE-SIGNL	OPERATOR FAILS TO RESPOND WITH RPS SIGNAL PRESENT	1.0E-2
11	0.1	2.3E-09	WES-BME-CF-RANBB	CCF RTB-A AND BYB-B (MECHANICAL)	1.6E-6
			/WES-BME-TM-RTBA	RTB-A IN T&M	1.0E+0
			WES-BME-TM-RTBB	RTB-B IN T&M	1.4E-3
12	0.1	2.3E-09	WES-BME-CF-RBNBA	CCF RTB-B AND BYB-A (MECHANICAL)	1.6E-6
			WES-BME-TM-RTBA	RTB-A IN T&M	1.4E-3
			/WES-BME-TM-RTBB	RTB-B IN T&M	1.0E+0
13	0.0	1.8E-09	WES-BME-TM-RTBA	RTB-A IN T&M	1.4E-3
			/WES-BME-TM-RTBB	RTB-B IN T&M	1.0E+0
			WES-CBI-CF-6OF8	CCF 6 BISTABLES IN 3 OF 4 CHANNELS	2.7E-6
			/WES-CCP-TM-CHA	CH-A IN T&M	9.7E-1
			WES-XHE-XE-NSGNL	OPERATOR FAILS TO RESPOND WITH NO RPS SIGNAL PRESENT	5.0E-1
14	0.0	1.8E-09	/WES-BME-TM-RTBA	RTB-A IN T&M	1.0E+0
			WES-BME-TM-RTBB	RTB-B IN T&M	1.4E-3
			WES-CBI-CF-6OF8	CCF 6 BISTABLES IN 3 OF 4 CHANNELS	2.7E-6
			/WES-CCP-TM-CHA	CH-A IN T&M	9.7E-1
			WES-XHE-XE-NSGNL	OPERATOR FAILS TO RESPOND WITH NO RPS SIGNAL PRESENT	5.0E-1
15	0.0	1.4E-09	WES-BME-FO-RTBA	RTB-A LOCAL HW FAILURE	3.7E-5
			WES-BME-FO-RTBB	RTB-B LOCAL HW FAILURE	3.7E-5
			/WES-BME-TM-RTBA	RTB-A IN T&M	1.0E+0
			/WES-BME-TM-RTBB	RTB-B IN T&M	1.0E+0
16	0.0	1.1E-09	/WES-BME-TM-RTBA	RTB-A IN T&M	1.0E+0
			/WES-BME-TM-RTBB	RTB-B IN T&M	1.0E+0
			WES-UVL-FF-UVDA	TRAIN A UV DRIVER FAILS	3.4E-4
			WES-UVL-FF-UVDB	TRAIN B UV DRIVER FAILS	3.4E-4
			WES-XHE-XE-SIGNL	OPERATOR FAILS TO RESPOND WITH RPS SIGNAL PRESENT	1.0E-2
17	0.0	7.8E-10	/WES-BME-TM-RTBA	RTB-A IN T&M	1.0E+0
			/WES-BME-TM-RTBB	RTB-B IN T&M	1.0E+0
			/WES-CCP-TM-CHA	CH-A IN T&M	9.7E-1
			WES-TLR-CF-12O16	CCF 12 OR MORE TMU RELAYS IN TRAINS A AND B NO CHANNEL T&M	8.1E-8
			WES-XHE-XE-SIGNL	OPERATOR FAILS TO RESPOND WITH RPS SIGNAL PRESENT	1.0E-2
18	0.0	2.4E-10	WES-BME-TM-RTBA	RTB-A IN T&M	1.4E-3
			/WES-BME-TM-RTBB	RTB-B IN T&M	1.0E+0
			WES-TLC-CF-SSLB	CCF SOLID STATE LOGIC TRAIN B (2 OF 4)	1.7E-5
			WES-XHE-XE-SIGNL	OPERATOR FAILS TO RESPOND WITH RPS SIGNAL PRESENT	1.0E-2

Table F-13. (continued).

Cut Set	Cut Set Percent	Cut Set Prob.	Basic Event[a]	Description	Prob.
19	0.0	2.4E-10	/WES-BME-TM-RTBA	RTB-A IN T&M	1.0E+0
			WES-BME-TM-RTBB	RTB-B IN T&M	1.4E-3
			WES-TLC-CF-SSLA	CCF SOLID STATE LOGIC TRAIN A (2 OF 4)	1.7E-5
			WES-XHE-XE-SIGNL	OPERATOR FAILS TO RESPOND WITH RPS SIGNAL PRESENT	1.0E-2
20	0.0	2.1E-10	/WES-BME-TM-RTBA	RTB-A IN T&M	1.0E+0
			/WES-BME-TM-RTBB	RTB-B IN T&M	1.0E+0
			WES-CBI-CF-P3OF4	CCF 3 PRESSURE OUTPUT BISTABLES IN 3 OF 4 CHANNELS	1.2E-5
			/WES-CCP-TM-CHA	CH-A IN T&M	9.7E-1
			WES-CTP-CF-T3OF8	CCF 3 TEMP SENSORS IN 3 OF 4 CHANNELS	3.7E-5
			WES-XHE-XE-NSGNL	OPERATOR FAILS TO RESPOND WITH NO RPS SIGNAL PRESENT	5.0E-1
21	0.0	2.0E-10	/WES-BME-TM-RTBA	RTB-A IN T&M	1.0E+0
			/WES-BME-TM-RTBB	RTB-B IN T&M	1.0E+0
			WES-BSN-CF-RTBAB	CCF OF RTB-A AND RTB-B SHUNT TRIP DEVICES	2.1E-5
			WES-BUV-CF-RTBAB	CCF OF RTB-A AND RTB-B UV DEVICES	9.7E-6
22	0.0	1.7E-10	WES-BME-TM-RTBA	RTB-A IN T&M	1.4E-3
			/WES-BME-TM-RTBB	RTB-B IN T&M	1.0E+0
			WES-CBI-CF-4OF6	CCF 4 BISTABLES IN 2 OF 3 CHANNELS	8.2E-6
			WES-CCP-TM-CHA	CH-A IN T&M	2.9E-2
			WES-XHE-XE-NSGNL	OPERATOR FAILS TO RESPOND WITH NO RPS SIGNAL PRESENT	5.0E-1
23	0.0	1.7E-10	/WES-BME-TM-RTBA	RTB-A IN T&M	1.0E+0
			WES-BME-TM-RTBB	RTB-B IN T&M	1.4E-3
			WES-CBI-CF-4OF6	CCF 4 BISTABLES IN 2 OF 3 CHANNELS	8.2E-6
			WES-CCP-TM-CHA	CH-A IN T&M	2.9E-2
			WES-XHE-XE-NSGNL	OPERATOR FAILS TO RESPOND WITH NO RPS SIGNAL PRESENT	5.0E-1
24	0.0	1.5E-10	WES-BME-TM-RTBA	RTB-A IN T&M	1.4E-3
			/WES-BME-TM-RTBB	RTB-B IN T&M	1.0E+0
			WES-UVL-CF-UVDAB	CCF UV DRIVERS TRAINS A AND B (2 OF 2)	1.0E-5
			WES-XHE-XE-SIGNL	OPERATOR FAILS TO RESPOND WITH RPS SIGNAL PRESENT	1.0E-2
25	0.0	1.5E-10	/WES-BME-TM-RTBA	RTB-A IN T&M	1.0E+0
			WES-BME-TM-RTBB	RTB-B IN T&M	1.4E-3
			WES-UVL-CF-UVDAB	CCF UV DRIVERS TRAINS A AND B (2 OF 2)	1.0E-5
			WES-XHE-XE-SIGNL	OPERATOR FAILS TO RESPOND WITH RPS SIGNAL PRESENT	1.0E-2
26	0.0	1.2E-10	WES-BME-FO-RTBA	RTB-A LOCAL HW FAILURE	3.7E-5
			/WES-BME-TM-RTBA	RTB-A IN T&M	1.0E+0
			/WES-BME-TM-RTBB	RTB-B IN T&M	1.0E+0
			WES-UVL-FF-UVDB	TRAIN B UV DRIVER FAILS	3.4E-4
			WES-XHE-XE-SIGNL	OPERATOR FAILS TO RESPOND WITH RPS SIGNAL PRESENT	1.0E-2
27	0.0	1.2E-10	WES-BME-FO-RTBB	RTB-B LOCAL HW FAILURE	3.7E-5
			/WES-BME-TM-RTBA	RTB-A IN T&M	1.0E+0
			/WES-BME-TM-RTBB	RTB-B IN T&M	1.0E+0
			WES-UVL-FF-UVDA	TRAIN A UV DRIVER FAILS	3.4E-4
			WES-XHE-XE-SIGNL	OPERATOR FAILS TO RESPOND WITH RPS SIGNAL PRESENT	1.0E-2
28	0.0	1.0E-10	WES-BME-TM-RTBA	RTB-A IN T&M	1.4E-3
			/WES-BME-TM-RTBB	RTB-B IN T&M	1.0E+0
			WES-C21-CF-E3OF4	CCF 3 EAGLE-21 PROCESS LOGIC MODULES IN 3 OF 4 CHANNELS	1.5E-7
			/WES-CCP-TM-CHA	CH-A IN T&M	9.7E-1
			WES-XHE-XE-NSGNL	OPERATOR FAILS TO RESPOND WITH NO RPS SIGNAL PRESENT	5.0E-1
29	0.0	1.0E-10	/WES-BME-TM-RTBA	RTB-A IN T&M	1.0E+0
			WES-BME-TM-RTBB	RTB-B IN T&M	1.4E-3
			WES-C21-CF-E3OF4	CCF 3 EAGLE-21 PROCESS LOGIC MODULES IN 3 OF 4 CHANNELS	1.5E-7
			/WES-CCP-TM-CHA	CH-A IN T&M	9.7E-1
			WES-XHE-XE-NSGNL	OPERATOR FAILS TO RESPOND WITH NO RPS SIGNAL PRESENT	5.0E-1
30	0.0	6.9E-11	/WES-BME-TM-RTBA	RTB-A IN T&M	1.0E+0
			/WES-BME-TM-RTBB	RTB-B IN T&M	1.0E+0
			WES-CBI-CF-P3OF4	CCF 3 PRESSURE OUTPUT BISTABLES IN 3 OF 4 CHANNELS	1.2E-5
			WES-CBI-CF-T3OF4	CCF 3 TEMP OUTPUT BISTABLES IN 3 OF 4 CHANNELS	1.2E-5
			/WES-CCP-TM-CHA	CH-A IN T&M	9.7E-1
			WES-XHE-XE-NSGNL	OPERATOR FAILS TO RESPOND WITH NO RPS SIGNAL PRESENT	5.0E-1
31	0.0	6.2E-11	/WES-BME-TM-RTBA	RTB-A IN T&M	1.0E+0
			/WES-BME-TM-RTBB	RTB-B IN T&M	1.0E+0
			WES-C21-FF-E21B	CH-B EAGLE-21 PROCESS LOGIC MODULE FAILS	6.5E-5
			WES-C21-FF-E21C	CH-C EAGLE-21 PROCESS LOGIC MODULE FAILS	6.5E-5
			WES-CCP-TM-CHA	CH-A IN T&M	2.9E-2
			WES-XHE-XE-NSGNL	OPERATOR FAILS TO RESPOND WITH NO RPS SIGNAL PRESENT	5.0E-1
32	0.0	6.2E-11	/WES-BME-TM-RTBA	RTB-A IN T&M	1.0E+0
			/WES-BME-TM-RTBB	RTB-B IN T&M	1.0E+0
			WES-C21-FF-E21B	CH-B EAGLE-21 PROCESS LOGIC MODULE FAILS	6.5E-5
			WES-C21-FF-E21D	CH-D EAGLE-21 PROCESS LOGIC MODULE FAILS	6.5E-5
			WES-CCP-TM-CHA	CH-A IN T&M	2.9E-2
			WES-XHE-XE-NSGNL	OPERATOR FAILS TO RESPOND WITH NO RPS SIGNAL PRESENT	5.0E-1
33	0.0	6.2E-11	/WES-BME-TM-RTBA	RTB-A IN T&M	1.0E+0
			/WES-BME-TM-RTBB	RTB-B IN T&M	1.0E+0
			WES-C21-FF-E21C	CH-C EAGLE-21 PROCESS LOGIC MODULE FAILS	6.5E-5
			WES-C21-FF-E21D	CH-D EAGLE-21 PROCESS LOGIC MODULE FAILS	6.5E-5
			WES-CCP-TM-CHA	CH-A IN T&M	2.9E-2

Table F-13. (continued).

Cut Set	Cut Set Percent	Cut Set Prob.	Basic Event[a]	Description	Prob.
			WES-XHE-XE-NSGNL	OPERATOR FAILS TO RESPOND WITH NO RPS SIGNAL PRESENT	5.0E-1
34	0.0	6.0E-11	/WES-BME-TM-RTBA	RTB-A IN T&M	1.0E+0
			/WES-BME-TM-RTBB	RTB-B IN T&M	1.0E+0
			WES-CCP-TM-CHA	CH-A IN T&M	2.9E-2
			WES-TLR-CF-8OF12	CCF 8 OR MORE TMU RELAYS IN TRAINS A AND B ONE CHANNEL T&M	2.1E-7
			WES-XHE-XE-SIGNL	OPERATOR FAILS TO RESPOND WITH RPS SIGNAL PRESENT	1.0E-2
35	0.0	5.8E-11	/WES-BME-TM-RTBA	RTB-A IN T&M	1.0E+0
			/WES-BME-TM-RTBB	RTB-B IN T&M	1.0E+0
			WES-TLC-CF-SSLA	CCF SOLID STATE LOGIC TRAIN A (2 OF 4)	1.7E-5
			WES-UVL-FF-UVDB	TRAIN B UV DRIVER FAILS	3.4E-4
			WES-XHE-XE-SIGNL	OPERATOR FAILS TO RESPOND WITH RPS SIGNAL PRESENT	1.0E-2
36	0.0	5.8E-11	/WES-BME-TM-RTBA	RTB-A IN T&M	1.0E+0
			/WES-BME-TM-RTBB	RTB-B IN T&M	1.0E+0
			WES-TLC-CF-SSLB	CCF SOLID STATE LOGIC TRAIN B (2 OF 4)	1.7E-5
			WES-UVL-FF-UVDA	TRAIN A UV DRIVER FAILS	3.4E-4
			WES-XHE-XE-SIGNL	OPERATOR FAILS TO RESPOND WITH RPS SIGNAL PRESENT	1.0E-2
37	0.0	4.5E-11	/WES-BME-TM-RTBA	RTB-A IN T&M	1.0E+0
			/WES-BME-TM-RTBB	RTB-B IN T&M	1.0E+0
			WES-CBI-CF-P2OF3	CCF 2 PRESSURE OUTPUT BISTABLES IN 2 OF 3 CHANNELS	4.2E-5
			WES-CCP-TM-CHA	CH-A IN T&M	2.9E-2
			WES-CTP-CF-T2OF6	CCF 2 TEMP SENSORS IN 2 OF 3 CHANNELS	7.5E-5
			WES-XHE-XE-NSGNL	OPERATOR FAILS TO RESPOND WITH NO RPS SIGNAL PRESENT	5.0E-1
38	0.0	3.7E-11	/WES-BME-TM-RTBA	RTB-A IN T&M	1.0E+0
			/WES-BME-TM-RTBB	RTB-B IN T&M	1.0E+0
			/WES-CCP-TM-CHA	CH-A IN T&M	9.7E-1
			WES-CPR-CF-P3OF4	CCF 3 PRESSURE SENSORS IN 3 OF 4 CHANNELS	2.1E-6
			WES-CTP-CF-T3OF8	CCF 3 TEMP SENSORS IN 3 OF 4 CHANNELS	3.7E-5
			WES-XHE-XE-NSGNL	OPERATOR FAILS TO RESPOND WITH NO RPS SIGNAL PRESENT	5.0E-1
39	0.0	3.3E-11	/WES-BME-TM-RTBA	RTB-A IN T&M	1.0E+0
			/WES-BME-TM-RTBB	RTB-B IN T&M	1.0E+0
			WES-BUV-CF-RTBAB	CCF OF RTB-A AND RTB-B UV DEVICES	9.7E-6
			WES-PWR-CF-TRNAB	CCF OF RTB-A AND RTB-B SHUNT TRIP POWER SUPPLIES	3.4E-6
40	0.0	2.9E-11	WES-BME-TM-RTBA	RTB-A IN T&M	1.4E-3
			/WES-BME-TM-RTBB	RTB-B IN T&M	1.0E+0
			WES-TLC-CF-SSLAB	CCF SOLID STATE LOGIC IN TRAINS A AND B (4 OF 4)	2.1E-6
			WES-XHE-XE-SIGNL	OPERATOR FAILS TO RESPOND WITH RPS SIGNAL PRESENT	1.0E-2
41	0.0	2.9E-11	/WES-BME-TM-RTBA	RTB-A IN T&M	1.0E+0
			WES-BME-TM-RTBB	RTB-B IN T&M	1.4E-3
			WES-TLC-CF-SSLAB	CCF SOLID STATE LOGIC IN TRAINS A AND B (4 OF 4)	2.1E-6
			WES-XHE-XE-SIGNL	OPERATOR FAILS TO RESPOND WITH RPS SIGNAL PRESENT	1.0E-2
42	0.0	2.5E-11	/WES-BME-TM-RTBA	RTB-A IN T&M	1.0E+0
			/WES-BME-TM-RTBB	RTB-B IN T&M	1.0E+0
			WES-CBI-CF-P2OF3	CCF 2 PRESSURE OUTPUT BISTABLES IN 2 OF 3 CHANNELS	4.2E-5
			WES-CBI-CF-T2OF3	CCF 2 TEMP OUTPUT BISTABLES IN 2 OF 3 CHANNELS	4.2E-5
			WES-CCP-TM-CHA	CH-A IN T&M	2.9E-2
			WES-XHE-XE-NSGNL	OPERATOR FAILS TO RESPOND WITH NO RPS SIGNAL PRESENT	5.0E-1
43	0.0	1.9E-11	/WES-BME-TM-RTBA	RTB-A IN T&M	1.0E+0
			/WES-BME-TM-RTBB	RTB-B IN T&M	1.0E+0
			WES-BUV-CF-RTBAB	CCF OF RTB-A AND RTB-B UV DEVICES	9.7E-6
			WES-TLR-CF-RTBAB	CCF OF RTB-A AND RTB-B SHUNT TRIP RELAYS	2.0E-6
44	0.0	1.2E-11	/WES-BME-TM-RTBA	RTB-A IN T&M	1.0E+0
			/WES-BME-TM-RTBB	RTB-B IN T&M	1.0E+0
			WES-CBI-CF-T3OF4	CCF 3 TEMP OUTPUT BISTABLES IN 3 OF 4 CHANNELS	1.2E-5
			/WES-CCP-TM-CHA	CH-A IN T&M	9.7E-1
			WES-CPR-CF-P3OF4	CCF 3 PRESSURE SENSORS IN 3 OF 4 CHANNELS	2.1E-6
			WES-XHE-XE-NSGNL	OPERATOR FAILS TO RESPOND WITH NO RPS SIGNAL PRESENT	5.0E-1
45	0.0	1.0E-11	WES-BME-TM-RTBA	RTB-A IN T&M	1.4E-3
			/WES-BME-TM-RTBB	RTB-B IN T&M	1.0E+0
			WES-C21-CF-E2OF3	CCF 2 EAGLE-21 PROCESS LOGIC MODULES IN 2 OF 3 CHANNELS	5.1E-7
			WES-CCP-TM-CHA	CH-A IN T&M	2.9E-2
			WES-XHE-XE-NSGNL	OPERATOR FAILS TO RESPOND WITH NO RPS SIGNAL PRESENT	5.0E-1
46	0.0	1.0E-11	/WES-BME-TM-RTBA	RTB-A IN T&M	1.0E+0
			WES-BME-TM-RTBB	RTB-B IN T&M	1.4E-3
			WES-C21-CF-E2OF3	CCF 2 EAGLE-21 PROCESS LOGIC MODULES IN 2 OF 3 CHANNELS	5.1E-7
			WES-CCP-TM-CHA	CH-A IN T&M	2.9E-2
			WES-XHE-XE-NSGNL	OPERATOR FAILS TO RESPOND WITH NO RPS SIGNAL PRESENT	5.0E-1
47	0.0	8.3E-12	/WES-BME-TM-RTBA	RTB-A IN T&M	1.0E+0
			/WES-BME-TM-RTBB	RTB-B IN T&M	1.0E+0
			WES-CCP-TM-CHA	CH-A IN T&M	2.9E-2
			WES-CPR-CF-P2OF3	CCF 2 PRESSURE SENSORS IN 2 OF 3 CHANNELS	7.7E-6
			WES-CTP-CF-T2OF6	CCF 2 TEMP SENSORS IN 2 OF 3 CHANNELS	7.5E-5
			WES-XHE-XE-NSGNL	OPERATOR FAILS TO RESPOND WITH NO RPS SIGNAL PRESENT	5.0E-1
48	0.0	6.3E-12	WES-BME-FO-RTBA	RTB-A LOCAL HW FAILURE	3.7E-5
			/WES-BME-TM-RTBA	RTB-A IN T&M	1.0E+0
			/WES-BME-TM-RTBB	RTB-B IN T&M	1.0E+0

Table F-13. (continued).

Cut Set	Cut Set Percent	Cut Set Prob.	Basic Event[a]	Description	Prob.
			WES-TLC-CF-SSLB	CCF SOLID STATE LOGIC TRAIN B (2 OF 4)	1.7E-5
			WES-XHE-XE-SIGNL	OPERATOR FAILS TO RESPOND WITH RPS SIGNAL PRESENT	1.0E-2
49	0.0	6.3E-12	WES-BME-FO-RTBB	RTB-B LOCAL HW FAILURE	3.7E-5
			/WES-BME-TM-RTBA	RTB-A IN T&M	1.0E+0
			/WES-BME-TM-RTBB	RTB-B IN T&M	1.0E+0
			WES-TLC-CF-SSLA	CCF SOLID STATE LOGIC TRAIN A (2 OF 4)	1.7E-5
			WES-XHE-XE-SIGNL	OPERATOR FAILS TO RESPOND WITH RPS SIGNAL PRESENT	1.0E-2
50	0.0	5.4E-12	WES-BME-FO-RTBA	RTB-A LOCAL HW FAILURE	3.7E-5
			/WES-BME-TM-RTBA	RTB-A IN T&M	1.0E+0
			/WES-BME-TM-RTBB	RTB-B IN T&M	1.0E+0
			WES-BSN-FF-RTBB	RTB-B SHUNT TRIP DEVICE LOCAL FAULTS	5.8E-4
			WES-BUV-FF-RTBB	RTB-B UV DEVICE LOCAL FAULTS	2.5E-4
51	0.0	5.4E-12	WES-BME-FO-RTBB	RTB-B LOCAL HW FAILURE	3.7E-5
			/WES-BME-TM-RTBA	RTB-A IN T&M	1.0E+0
			/WES-BME-TM-RTBB	RTB-B IN T&M	1.0E+0
			WES-BSN-FF-RTBA	RTB-A SHUNT TRIP DEVICE LOCAL FAULTS	5.8E-4
			WES-BUV-FF-RTBA	RTB-A UV DEVICE LOCAL FAULTS	2.5E-4
52	0.0	4.7E-12	/WES-BME-TM-RTBA	RTB-A IN T&M	1.0E+0
			/WES-BME-TM-RTBB	RTB-B IN T&M	1.0E+0
			WES-CBI-CF-T2OF3	CCF 2 TEMP OUTPUT BISTABLES IN 2 OF 3 CHANNELS	4.2E-5
			WES-CCP-TM-CHA	CH-A IN T&M	2.9E-2
			WES-CPR-CF-P2OF3	CCF 2 PRESSURE SENSORS IN 2 OF 3 CHANNELS	7.7E-6
			WES-XHE-XE-NSGNL	OPERATOR FAILS TO RESPOND WITH NO RPS SIGNAL PRESENT	5.0E-1
53	0.0	4.5E-12	WES-BME-TM-RTBA	RTB-A IN T&M	1.4E-3
			/WES-BME-TM-RTBB	RTB-B IN T&M	1.0E+0
			/WES-CCP-TM-CHA	CH-A IN T&M	9.7E-1
			WES-TLR-CF-RLB68	CCF 6 OR MORE TMU RELAYS IN TRAIN B NO CHANNEL T&M	3.3E-7
			WES-XHE-XE-SIGNL	OPERATOR FAILS TO RESPOND WITH RPS SIGNAL PRESENT	1.0E-2
54	0.0	4.5E-12	/WES-BME-TM-RTBA	RTB-A IN T&M	1.0E+0
			WES-BME-TM-RTBB	RTB-B IN T&M	1.4E-3
			/WES-CCP-TM-CHA	CH-A IN T&M	9.7E-1
			WES-TLR-CF-RLA68	CCF 6 OR MORE TMU RELAYS IN TRAIN A NO CHANNEL T&M	3.3E-7
			WES-XHE-XE-SIGNL	OPERATOR FAILS TO RESPOND WITH RPS SIGNAL PRESENT	1.0E-2
55	0.0	3.0E-12	/WES-BME-TM-RTBA	RTB-A IN T&M	1.0E+0
			/WES-BME-TM-RTBB	RTB-B IN T&M	1.0E+0
			WES-TLC-CF-SSLA	CCF SOLID STATE LOGIC TRAIN A (2 OF 4)	1.7E-5
			WES-TLC-CF-SSLB	CCF SOLID STATE LOGIC TRAIN B (2 OF 4)	1.7E-5
			WES-XHE-XE-SIGNL	OPERATOR FAILS TO RESPOND WITH RPS SIGNAL PRESENT	1.0E-2
56	0.0	2.1E-12	WES-BME-TM-RTBA	RTB-A IN T&M	1.4E-3
			/WES-BME-TM-RTBB	RTB-B IN T&M	1.0E+0
			WES-TLC-FF-SSLBP	TRAIN B PRESSURE SOLID STATE LOGIC FAILS	3.8E-4
			WES-TLC-FF-SSLBT	TRAIN B TEMPERATURE SOLID STATE LOGIC FAILS	3.8E-4
			WES-XHE-XE-SIGNL	OPERATOR FAILS TO RESPOND WITH RPS SIGNAL PRESENT	1.0E-2
57	0.0	2.1E-12	/WES-BME-TM-RTBA	RTB-A IN T&M	1.0E+0
			WES-BME-TM-RTBB	RTB-B IN T&M	1.4E-3
			WES-TLC-FF-SSLAP	TRAIN A PRESSURE SOLID STATE LOGIC FAILS	3.8E-4
			WES-TLC-FF-SSLAT	TRAIN A TEMPERATURE SOLID STATE LOGIC FAILS	3.8E-4
			WES-XHE-XE-SIGNL	OPERATOR FAILS TO RESPOND WITH RPS SIGNAL PRESENT	1.0E-2
58	0.0	1.9E-12	WES-BME-FO-BYBA	BYB-A LOCAL HW FAILURE	3.7E-5
			WES-BME-FO-RTBB	RTB-B LOCAL HW FAILURE	3.7E-5
			WES-BME-TM-RTBA	RTB-A IN T&M	1.4E-3
			/WES-BME-TM-RTBB	RTB-B IN T&M	1.0E+0
59	0.0	1.9E-12	WES-BME-FO-BYBB	BYB-B LOCAL HW FAILURE	3.7E-5
			WES-BME-FO-RTBA	RTB-A LOCAL HW FAILURE	3.7E-5
			/WES-BME-TM-RTBA	RTB-A IN T&M	1.0E+0
			WES-BME-TM-RTBB	RTB-B IN T&M	1.4E-3
60	0.0	1.1E-12	WES-BME-TM-RTBA	RTB-A IN T&M	1.4E-3
			/WES-BME-TM-RTBB	RTB-B IN T&M	1.0E+0
			/WES-CCP-TM-CHA	CH-A IN T&M	9.7E-1
			WES-TLR-CF-12O16	CCF 12 OR MORE TMU RELAYS IN TRAINS A AND B NO CHANNEL T&M	8.1E-8
			WES-XHE-XE-SIGNL	OPERATOR FAILS TO RESPOND WITH RPS SIGNAL PRESENT	1.0E-2
61	0.0	1.1E-12	/WES-BME-TM-RTBA	RTB-A IN T&M	1.0E+0
			WES-BME-TM-RTBB	RTB-B IN T&M	1.4E-3
			/WES-CCP-TM-CHA	CH-A IN T&M	9.7E-1
			WES-TLR-CF-12O16	CCF 12 OR MORE TMU RELAYS IN TRAINS A AND B NO CHANNEL T&M	8.1E-8
			WES-XHE-XE-SIGNL	OPERATOR FAILS TO RESPOND WITH RPS SIGNAL PRESENT	1.0E-2
62	0.0	1.1E-12	/WES-BME-TM-RTBA	RTB-A IN T&M	1.0E+0
			/WES-BME-TM-RTBB	RTB-B IN T&M	1.0E+0
			/WES-CCP-TM-CHA	CH-A IN T&M	9.7E-1
			WES-TLR-CF-RLA68	CCF 6 OR MORE TMU RELAYS IN TRAIN A NO CHANNEL T&M	3.3E-7
			WES-UVL-FF-UVDB	TRAIN B UV DRIVER FAILS	3.4E-4
			WES-XHE-XE-SIGNL	OPERATOR FAILS TO RESPOND WITH RPS SIGNAL PRESENT	1.0E-2
63	0.0	1.1E-12	/WES-BME-TM-RTBA	RTB-A IN T&M	1.0E+0
			/WES-BME-TM-RTBB	RTB-B IN T&M	1.0E+0
			/WES-CCP-TM-CHA	CH-A IN T&M	9.7E-1

Table F-13. (continued).

Cut Set	Cut Set Percent	Cut Set Prob.	Basic Event[a]	Description	Prob.
			WES-TLR-CF-RLB68	CCF 6 OR MORE TMU RELAYS IN TRAIN B NO CHANNEL T&M	3.3E-7
			WES-UVL-FF-UVDA	TRAIN A UV DRIVER FAILS	3.4E-4
			WES-XHE-XE-SIGNL	OPERATOR FAILS TO RESPOND WITH RPS SIGNAL PRESENT	1.0E-2
64	0.0	8.2E-13	WES-BME-TM-RTBA	RTB-A IN T&M	1.4E-3
			/WES-BME-TM-RTBB	RTB-B IN T&M	1.0E+0
			WES-BUV-CF-RBNBA	CCF OF RTB-B AND BYB-A UV DEVICES	9.7E-6
			WES-PWR-FF-TRNB	TRAIN B 125 VDC BUS FAILS	6.0E-5
65	0.0	8.2E-13	/WES-BME-TM-RTBA	RTB-A IN T&M	1.0E+0
			WES-BME-TM-RTBB	RTB-B IN T&M	1.4E-3
			WES-BUV-CF-RANBB	CCF OF RTB-A AND BYB-B UV DEVICES	9.7E-6
			WES-PWR-FF-TRNA	TRAIN A 125 VDC BUS FAILS	6.0E-5
66	0.0	5.6E-13	WES-BME-FO-RTBA	RTB-A LOCAL HW FAILURE	3.7E-5
			/WES-BME-TM-RTBA	RTB-A IN T&M	1.0E+0
			/WES-BME-TM-RTBB	RTB-B IN T&M	1.0E+0
			WES-BUV-FF-RTBB	RTB-B UV DEVICE LOCAL FAULTS	2.5E-4
			WES-PWR-FF-TRNB	TRAIN B 125 VDC BUS FAILS	6.0E-5
67	0.0	5.6E-13	WES-BME-FO-RTBB	RTB-B LOCAL HW FAILURE	3.7E-5
			/WES-BME-TM-RTBA	RTB-A IN T&M	1.0E+0
			/WES-BME-TM-RTBB	RTB-B IN T&M	1.0E+0
			WES-BUV-FF-RTBA	RTB-A UV DEVICE LOCAL FAULTS	2.5E-4
			WES-PWR-FF-TRNA	TRAIN A 125 VDC BUS FAILS	6.0E-5
68	0.0	5.4E-13	WES-BME-TM-RTBA	RTB-A IN T&M	1.4E-3
			/WES-BME-TM-RTBB	RTB-B IN T&M	1.0E+0
			WES-BUV-CF-RBNBA	CCF OF RTB-B AND BYB-A UV DEVICES	9.7E-6
			WES-TLR-FC-RLYSB	SHUNT TRIP RELAY SB FAILS	3.9E-5
69	0.0	5.4E-13	/WES-BME-TM-RTBA	RTB-A IN T&M	1.0E+0
			WES-BME-TM-RTBB	RTB-B IN T&M	1.4E-3
			WES-BUV-CF-RANBB	CCF OF RTB-A AND BYB-B UV DEVICES	9.7E-6
			WES-TLR-FC-RLYSA	SHUNT TRIP RELAY SA FAILS	3.9E-5
70	0.0	5.3E-13	/WES-BME-TM-RTBA	RTB-A IN T&M	1.0E+0
			/WES-BME-TM-RTBB	RTB-B IN T&M	1.0E+0
			WES-C21-FF-E21B	CH-B EAGLE-21 PROCESS LOGIC MODULE FAILS	6.5E-5
			WES-CBI-FF-BSTPC	CH-C PRESSURE OUTPUT BISTABLE FAILS	7.5E-4
			WES-CBI-FF-BSTTC	CH-C TEMPERATURE OUTPUT BISTABLE FAILS	7.5E-4
			WES-CCP-TM-CHA	CH-A IN T&M	2.9E-2
			WES-XHE-XE-NSGNL	OPERATOR FAILS TO RESPOND WITH NO RPS SIGNAL PRESENT	5.0E-1
71	0.0	5.3E-13	/WES-BME-TM-RTBA	RTB-A IN T&M	1.0E+0
			/WES-BME-TM-RTBB	RTB-B IN T&M	1.0E+0
			WES-C21-FF-E21B	CH-B EAGLE-21 PROCESS LOGIC MODULE FAILS	6.5E-5
			WES-CBI-FF-BSTPD	CH-D PRESSURE OUTPUT NISTABLE FAILS	7.5E-4
			WES-CBI-FF-BSTTD	CH-D TEMPERATURE OUTPUT BISTABLE FAILS	7.5E-4
			WES-CCP-TM-CHA	CH-A IN T&M	2.9E-2
			WES-XHE-XE-NSGNL	OPERATOR FAILS TO RESPOND WITH NO RPS SIGNAL PRESENT	5.0E-1
72	0.0	5.3E-13	/WES-BME-TM-RTBA	RTB-A IN T&M	1.0E+0
			/WES-BME-TM-RTBB	RTB-B IN T&M	1.0E+0
			WES-C21-FF-E21C	CH-C EAGLE-21 PROCESS LOGIC MODULE FAILS	6.5E-5
			WES-CBI-FF-BSTPB	CH-B PRESSURE OUTPUT BISTABLE FAILS	7.5E-4
			WES-CBI-FF-BSTTB	CH-B TEMPERATURE OUTPUT BISTABLE FAILS	7.5E-4
			WES-CCP-TM-CHA	CH-A IN T&M	2.9E-2
			WES-XHE-XE-NSGNL	OPERATOR FAILS TO RESPOND WITH NO RPS SIGNAL PRESENT	5.0E-1
73	0.0	5.3E-13	/WES-BME-TM-RTBA	RTB-A IN T&M	1.0E+0
			/WES-BME-TM-RTBB	RTB-B IN T&M	1.0E+0
			WES-C21-FF-E21C	CH-C EAGLE-21 PROCESS LOGIC MODULE FAILS	6.5E-5
			WES-CBI-FF-BSTPD	CH-D PRESSURE OUTPUT NISTABLE FAILS	7.5E-4
			WES-CBI-FF-BSTTD	CH-D TEMPERATURE OUTPUT BISTABLE FAILS	7.5E-4
			WES-CCP-TM-CHA	CH-A IN T&M	2.9E-2
			WES-XHE-XE-NSGNL	OPERATOR FAILS TO RESPOND WITH NO RPS SIGNAL PRESENT	5.0E-1
74	0.0	5.3E-13	/WES-BME-TM-RTBA	RTB-A IN T&M	1.0E+0
			/WES-BME-TM-RTBB	RTB-B IN T&M	1.0E+0
			WES-C21-FF-E21D	CH-D EAGLE-21 PROCESS LOGIC MODULE FAILS	6.5E-5
			WES-CBI-FF-BSTPB	CH-B PRESSURE OUTPUT BISTABLE FAILS	7.5E-4
			WES-CBI-FF-BSTTB	CH-B TEMPERATURE OUTPUT BISTABLE FAILS	7.5E-4
			WES-CCP-TM-CHA	CH-A IN T&M	2.9E-2
			WES-XHE-XE-NSGNL	OPERATOR FAILS TO RESPOND WITH NO RPS SIGNAL PRESENT	5.0E-1
75	0.0	5.3E-13	/WES-BME-TM-RTBA	RTB-A IN T&M	1.0E+0
			/WES-BME-TM-RTBB	RTB-B IN T&M	1.0E+0
			WES-C21-FF-E21D	CH-D EAGLE-21 PROCESS LOGIC MODULE FAILS	6.5E-5
			WES-CBI-FF-BSTPC	CH-C PRESSURE OUTPUT BISTABLE FAILS	7.5E-4
			WES-CBI-FF-BSTTC	CH-C TEMPERATURE OUTPUT BISTABLE FAILS	7.5E-4
			WES-CCP-TM-CHA	CH-A IN T&M	2.9E-2
			WES-XHE-XE-NSGNL	OPERATOR FAILS TO RESPOND WITH NO RPS SIGNAL PRESENT	5.0E-1
76	0.0	5.0E-13	/WES-BME-TM-RTBA	RTB-A IN T&M	1.0E+0
			/WES-BME-TM-RTBB	RTB-B IN T&M	1.0E+0
			WES-BSN-FF-RTBA	RTB-A SHUNT TRIP DEVICE LOCAL FAULTS	5.8E-4
			WES-BUV-FF-RTBA	RTB-A UV DEVICE LOCAL FAULTS	2.5E-4

Table F-13. (continued).

Cut Set	Cut Set Percent	Cut Set Prob.	Basic Event[a]	Description	Prob.
			WES-UVL-FF-UVDB	TRAIN B UV DRIVER FAILS	3.4E-4
			WES-XHE-XE-SIGNL	OPERATOR FAILS TO RESPOND WITH RPS SIGNAL PRESENT	1.0E-2
77	0.0	5.0E-13	/WES-BME-TM-RTBA	RTB-A IN T&M	1.0E+0
			/WES-BME-TM-RTBB	RTB-B IN T&M	1.0E+0
			WES-BSN-FF-RTBB	RTB-B SHUNT TRIP DEVICE LOCAL FAULTS	5.8E-4
			WES-BUV-FF-RTBB	RTB-B UV DEVICE LOCAL FAULTS	2.5E-4
			WES-UVL-FF-UVDA	TRAIN A UV DRIVER FAILS	3.4E-4
			WES-XHE-XE-SIGNL	OPERATOR FAILS TO RESPOND WITH RPS SIGNAL PRESENT	1.0E-2
78	0.0	4.9E-13	/WES-BME-TM-RTBA	RTB-A IN T&M	1.0E+0
			/WES-BME-TM-RTBB	RTB-B IN T&M	1.0E+0
			WES-TLC-FF-SSLAP	TRAIN A PRESSURE SOLID STATE LOGIC FAILS	3.8E-4
			WES-TLC-FF-SSLAT	TRAIN A TEMPERATURE SOLID STATE LOGIC FAILS	3.8E-4
			WES-UVL-FF-UVDB	TRAIN B UV DRIVER FAILS	3.4E-4
			WES-XHE-XE-SIGNL	OPERATOR FAILS TO RESPOND WITH RPS SIGNAL PRESENT	1.0E-2
79	0.0	4.9E-13	/WES-BME-TM-RTBA	RTB-A IN T&M	1.0E+0
			/WES-BME-TM-RTBB	RTB-B IN T&M	1.0E+0
			WES-TLC-FF-SSLBP	TRAIN B PRESSURE SOLID STATE LOGIC FAILS	3.8E-4
			WES-TLC-FF-SSLBT	TRAIN B TEMPERATURE SOLID STATE LOGIC FAILS	3.8E-4
			WES-UVL-FF-UVDA	TRAIN A UV DRIVER FAILS	3.4E-4
			WES-XHE-XE-SIGNL	OPERATOR FAILS TO RESPOND WITH RPS SIGNAL PRESENT	1.0E-2
80	0.0	4.2E-13	/WES-BME-TM-RTBA	RTB-A IN T&M	1.0E+0
			/WES-BME-TM-RTBB	RTB-B IN T&M	1.0E+0
			WES-C21-FF-E21B	CH-B EAGLE-21 PROCESS LOGIC MODULE FAILS	6.5E-5
			WES-CBI-FF-BSTPC	CH-C PRESSURE OUTPUT BISTABLE FAILS	7.5E-4
			WES-CCP-TM-CHA	CH-A IN T&M	2.9E-2
			WES-CTP-FF-CLTXC	CH-C COLD LEG RTD FAILS	6.0E-4
			WES-XHE-XE-NSGNL	OPERATOR FAILS TO RESPOND WITH NO RPS SIGNAL PRESENT	5.0E-1
81	0.0	4.2E-13	/WES-BME-TM-RTBA	RTB-A IN T&M	1.0E+0
			/WES-BME-TM-RTBB	RTB-B IN T&M	1.0E+0
			WES-C21-FF-E21B	CH-B EAGLE-21 PROCESS LOGIC MODULE FAILS	6.5E-5
			WES-CBI-FF-BSTPC	CH-C PRESSURE OUTPUT BISTABLE FAILS	7.5E-4
			WES-CCP-TM-CHA	CH-A IN T&M	2.9E-2
			WES-CTP-FF-HLTXC	CH-C HOT LEG RTD FAILS	6.0E-4
			WES-XHE-XE-NSGNL	OPERATOR FAILS TO RESPOND WITH NO RPS SIGNAL PRESENT	5.0E-1
82	0.0	4.2E-13	/WES-BME-TM-RTBA	RTB-A IN T&M	1.0E+0
			/WES-BME-TM-RTBB	RTB-B IN T&M	1.0E+0
			WES-C21-FF-E21B	CH-B EAGLE-21 PROCESS LOGIC MODULE FAILS	6.5E-5
			WES-CBI-FF-BSTPD	CH-D PRESSURE OUTPUT NISTABLE FAILS	7.5E-4
			WES-CCP-TM-CHA	CH-A IN T&M	2.9E-2
			WES-CTP-FF-CLTXD	CH-D COLD LEG RTD FAILS	6.0E-4
			WES-XHE-XE-NSGNL	OPERATOR FAILS TO RESPOND WITH NO RPS SIGNAL PRESENT	5.0E-1
83	0.0	4.2E-13	/WES-BME-TM-RTBA	RTB-A IN T&M	1.0E+0
			/WES-BME-TM-RTBB	RTB-B IN T&M	1.0E+0
			WES-C21-FF-E21B	CH-B EAGLE-21 PROCESS LOGIC MODULE FAILS	6.5E-5
			WES-CBI-FF-BSTPD	CH-D PRESSURE OUTPUT NISTABLE FAILS	7.5E-4
			WES-CCP-TM-CHA	CH-A IN T&M	2.9E-2
			WES-CTP-FF-HLTXD	CH-D HOT LEG RTD FAILS	6.0E-4
			WES-XHE-XE-NSGNL	OPERATOR FAILS TO RESPOND WITH NO RPS SIGNAL PRESENT	5.0E-1
84	0.0	4.2E-13	/WES-BME-TM-RTBA	RTB-A IN T&M	1.0E+0
			/WES-BME-TM-RTBB	RTB-B IN T&M	1.0E+0
			WES-C21-FF-E21C	CH-C EAGLE-21 PROCESS LOGIC MODULE FAILS	6.5E-5
			WES-CBI-FF-BSTPB	CH-B PRESSURE OUTPUT BISTABLE FAILS	7.5E-4
			WES-CCP-TM-CHA	CH-A IN T&M	2.9E-2
			WES-CTP-FF-CLTXB	CH-B COLD LEG RTD FAILS	6.0E-4
			WES-XHE-XE-NSGNL	OPERATOR FAILS TO RESPOND WITH NO RPS SIGNAL PRESENT	5.0E-1
85	0.0	4.2E-13	/WES-BME-TM-RTBA	RTB-A IN T&M	1.0E+0
			/WES-BME-TM-RTBB	RTB-B IN T&M	1.0E+0
			WES-C21-FF-E21C	CH-C EAGLE-21 PROCESS LOGIC MODULE FAILS	6.5E-5
			WES-CBI-FF-BSTPB	CH-B PRESSURE OUTPUT BISTABLE FAILS	7.5E-4
			WES-CCP-TM-CHA	CH-A IN T&M	2.9E-2
			WES-CTP-FF-HLTXB	CH-B HOT LEG RTD FAILS	6.0E-4
			WES-XHE-XE-NSGNL	OPERATOR FAILS TO RESPOND WITH NO RPS SIGNAL PRESENT	5.0E-1
86	0.0	4.2E-13	/WES-BME-TM-RTBA	RTB-A IN T&M	1.0E+0
			/WES-BME-TM-RTBB	RTB-B IN T&M	1.0E+0
			WES-C21-FF-E21C	CH-C EAGLE-21 PROCESS LOGIC MODULE FAILS	6.5E-5
			WES-CBI-FF-BSTPD	CH-D PRESSURE OUTPUT NISTABLE FAILS	7.5E-4
			WES-CCP-TM-CHA	CH-A IN T&M	2.9E-2
			WES-CTP-FF-CLTXD	CH-D COLD LEG RTD FAILS	6.0E-4
			WES-XHE-XE-NSGNL	OPERATOR FAILS TO RESPOND WITH NO RPS SIGNAL PRESENT	5.0E-1
87	0.0	4.2E-13	/WES-BME-TM-RTBA	RTB-A IN T&M	1.0E+0
			/WES-BME-TM-RTBB	RTB-B IN T&M	1.0E+0
			WES-C21-FF-E21C	CH-C EAGLE-21 PROCESS LOGIC MODULE FAILS	6.5E-5
			WES-CBI-FF-BSTPD	CH-D PRESSURE OUTPUT NISTABLE FAILS	7.5E-4
			WES-CCP-TM-CHA	CH-A IN T&M	2.9E-2
			WES-CTP-FF-HLTXD	CH-D HOT LEG RTD FAILS	6.0E-4

Table F-13. (continued).

Cut Set	Cut Set Percent	Cut Set Prob.	Basic Event[a]	Description	Prob.
			WES-XHE-XE-NSGNL	OPERATOR FAILS TO RESPOND WITH NO RPS SIGNAL PRESENT	5.0E-1
88	0.0	4.2E-13	/WES-BME-TM-RTBA	RTB-A IN T&M	1.0E+0
			/WES-BME-TM-RTBB	RTB-B IN T&M	1.0E+0
			WES-C21-FF-E21D	CH-D EAGLE-21 PROCESS LOGIC MODULE FAILS	6.5E-5
			WES-CBI-FF-BSTPB	CH-B PRESSURE OUTPUT BISTABLE FAILS	7.5E-4
			WES-CCP-TM-CHA	CH-A IN T&M	2.9E-2
			WES-CTP-FF-CLTXB	CH-B COLD LEG RTD FAILS	6.0E-4
			WES-XHE-XE-NSGNL	OPERATOR FAILS TO RESPOND WITH NO RPS SIGNAL PRESENT	5.0E-1
89	0.0	4.2E-13	/WES-BME-TM-RTBA	RTB-A IN T&M	1.0E+0
			/WES-BME-TM-RTBB	RTB-B IN T&M	1.0E+0
			WES-C21-FF-E21D	CH-D EAGLE-21 PROCESS LOGIC MODULE FAILS	6.5E-5
			WES-CBI-FF-BSTPB	CH-B PRESSURE OUTPUT BISTABLE FAILS	7.5E-4
			WES-CCP-TM-CHA	CH-A IN T&M	2.9E-2
			WES-CTP-FF-HLTXB	CH-B HOT LEG RTD FAILS	6.0E-4
			WES-XHE-XE-NSGNL	OPERATOR FAILS TO RESPOND WITH NO RPS SIGNAL PRESENT	5.0E-1
90	0.0	4.2E-13	/WES-BME-TM-RTBA	RTB-A IN T&M	1.0E+0
			/WES-BME-TM-RTBB	RTB-B IN T&M	1.0E+0
			WES-C21-FF-E21D	CH-D EAGLE-21 PROCESS LOGIC MODULE FAILS	6.5E-5
			WES-CBI-FF-BSTPC	CH-C PRESSURE OUTPUT BISTABLE FAILS	7.5E-4
			WES-CCP-TM-CHA	CH-A IN T&M	2.9E-2
			WES-CTP-FF-CLTXC	CH-C COLD LEG RTD FAILS	6.0E-4
			WES-XHE-XE-NSGNL	OPERATOR FAILS TO RESPOND WITH NO RPS SIGNAL PRESENT	5.0E-1
91	0.0	4.2E-13	/WES-BME-TM-RTBA	RTB-A IN T&M	1.0E+0
			/WES-BME-TM-RTBB	RTB-B IN T&M	1.0E+0
			WES-C21-FF-E21D	CH-D EAGLE-21 PROCESS LOGIC MODULE FAILS	6.5E-5
			WES-CBI-FF-BSTPC	CH-C PRESSURE OUTPUT BISTABLE FAILS	7.5E-4
			WES-CCP-TM-CHA	CH-A IN T&M	2.9E-2
			WES-CTP-FF-HLTXC	CH-C HOT LEG RTD FAILS	6.0E-4
			WES-XHE-XE-NSGNL	OPERATOR FAILS TO RESPOND WITH NO RPS SIGNAL PRESENT	5.0E-1
92	0.0	4.1E-13	WES-BME-TM-RTBA	RTB-A IN T&M	1.4E-3
			/WES-BME-TM-RTBB	RTB-B IN T&M	1.0E+0
			WES-CCP-TM-CHA	CH-A IN T&M	2.9E-2
			WES-TLR-CF-RLB46	CCF 4 OR MORE TMU RELAYS IN TRAIN B ONE CHANNEL T&M	1.0E-6
			WES-XHE-XE-SIGNL	OPERATOR FAILS TO RESPOND WITH RPS SIGNAL PRESENT	1.0E-2
93	0.0	4.1E-13	/WES-BME-TM-RTBA	RTB-A IN T&M	1.0E+0
			WES-BME-TM-RTBB	RTB-B IN T&M	1.4E-3
			WES-CCP-TM-CHA	CH-A IN T&M	2.9E-2
			WES-TLR-CF-RLA46	CCF 4 OR MORE TMU RELAYS IN TRAIN A ONE CHANNEL T&M	1.0E-6
			WES-XHE-XE-SIGNL	OPERATOR FAILS TO RESPOND WITH RPS SIGNAL PRESENT	1.0E-2
94	0.0	3.7E-13	WES-BME-FO-RTBA	RTB-A LOCAL HW FAILURE	3.7E-5
			/WES-BME-TM-RTBA	RTB-A IN T&M	1.0E+0
			/WES-BME-TM-RTBB	RTB-B IN T&M	1.0E+0
			WES-BUV-FF-RTBB	RTB-B UV DEVICE LOCAL FAULTS	2.5E-4
			WES-TLR-FC-RLYSB	SHUNT TRIP RELAY SB FAILS	3.9E-5
95	0.0	3.7E-13	WES-BME-FO-RTBB	RTB-B LOCAL HW FAILURE	3.7E-5
			/WES-BME-TM-RTBA	RTB-A IN T&M	1.0E+0
			/WES-BME-TM-RTBB	RTB-B IN T&M	1.0E+0
			WES-BUV-FF-RTBA	RTB-A UV DEVICE LOCAL FAULTS	2.5E-4
			WES-TLR-FC-RLYSA	SHUNT TRIP RELAY SA FAILS	3.9E-5
96	0.0	3.0E-13	WES-BME-TM-RTBA	RTB-A IN T&M	1.4E-3
			/WES-BME-TM-RTBB	RTB-B IN T&M	1.0E+0
			WES-CBI-CF-P3OF4	CCF 3 PRESSURE OUTPUT BISTABLES IN 3 OF 4 CHANNELS	1.2E-5
			/WES-CCP-TM-CHA	CH-A IN T&M	9.7E-1
			WES-CTP-CF-T3OF8	CCF 3 TEMP SENSORS IN 3 OF 4 CHANNELS	3.7E-5
			WES-XHE-XE-NSGNL	OPERATOR FAILS TO RESPOND WITH NO RPS SIGNAL PRESENT	5.0E-1
97	0.0	3.0E-13	/WES-BME-TM-RTBA	RTB-A IN T&M	1.0E+0
			WES-BME-TM-RTBB	RTB-B IN T&M	1.4E-3
			WES-CBI-CF-P3OF4	CCF 3 PRESSURE OUTPUT BISTABLES IN 3 OF 4 CHANNELS	1.2E-5
			/WES-CCP-TM-CHA	CH-A IN T&M	9.7E-1
			WES-CTP-CF-T3OF8	CCF 3 TEMP SENSORS IN 3 OF 4 CHANNELS	3.7E-5
			WES-XHE-XE-NSGNL	OPERATOR FAILS TO RESPOND WITH NO RPS SIGNAL PRESENT	5.0E-1
98	0.0	2.9E-13	WES-BME-TM-RTBA	RTB-A IN T&M	1.4E-3
			/WES-BME-TM-RTBB	RTB-B IN T&M	1.0E+0
			WES-BSN-CF-RBNBA	CCF OF RTB-B AND BYB-A SHUNT TRIP DEVICES	2.1E-5
			WES-BUV-CF-RBNBA	CCF OF RTB-B AND BYB-A UV DEVICES	9.7E-6
99	0.0	2.9E-13	/WES-BME-TM-RTBA	RTB-A IN T&M	1.0E+0
			WES-BME-TM-RTBB	RTB-B IN T&M	1.4E-3
			WES-BSN-CF-RANBB	CCF OF RTB-A AND BYB-B SHUNT TRIP DEVICES	2.1E-5
			WES-BUV-CF-RANBB	CCF OF RTB-A AND BYB-B UV DEVICES	9.7E-6
100	0.0	1.3E-13	/WES-BME-TM-RTBA	RTB-A IN T&M	1.0E+0
			/WES-BME-TM-RTBB	RTB-B IN T&M	1.0E+0
			WES-C21-FF-E21A	CH-A EAGLE-21 PROCESS LOGIC MODULE FAILS	6.5E-5
			WES-C21-FF-E21B	CH-B EAGLE-21 PROCESS LOGIC MODULE FAILS	6.5E-5
			WES-C21-FF-E21C	CH-C EAGLE-21 PROCESS LOGIC MODULE FAILS	6.5E-5
			/WES-CCP-TM-CHA	CH-A IN T&M	9.7E-1

Table F-13. (continued).

Cut Set	Cut Set Percent	Cut Set Prob.	Basic Event[a]	Description	Prob.
			WES-XHE-XE-NSGNL	OPERATOR FAILS TO RESPOND WITH NO RPS SIGNAL PRESENT	5.0E-1

a. A / as the first character in a basic event name indicates a complemented event (Success = 1 - Failure). For example, the basic event for reactor trip breaker train A (RTB-A) in test and maintenance (T&M) is WES-BME-TM-RTBA (Failure = 1.40E-03). Thus, the basic event name for RTB-A not in T&M is /WES-BME-TM-RTBA (Success = 9.986E-01). The event description for complemented events remains the same as the description used for the failure event.

Table F-14. Importance measures sorted on Fussell-Vesely for case with RPS mincut = 4.5E-6.

Basic Event	Number of Occur.	Prob. of Failure	Fussell-Vesely Importance	Risk Reduction Ratio	Risk Increase Ratio	Birnbaum Importance
WES-BME-CF-RTBAB	1	1.61E-6	3.592E-01	1.561	2.231E+5	9.972E-01
WES-XHE-XE-NSGNL	4593	5.00E-1	3.381E-01	1.511	1.338E+0	3.022E-06
WES-CBI-CF-6OF8	3	2.70E-6	2.933E-01	1.415	1.085E+5	4.848E-01
WES-ROD-CF-RCCAS	1	1.21E-6	2.707E-01	1.371	2.237E+5	1.000E+00
WES-XHE-XE-SIGNL	960	1.00E-2	3.071E-02	1.032	4.040E+0	1.373E-05
WES-CBI-CF-4OF6	3	8.21E-6	2.663E-02	1.027	3.245E+3	1.450E-02
WES-UVL-CF-UVDAB	3	1.04E-5	2.327E-02	1.024	2.238E+3	1.000E-02
WES-CCP-TM-CHA	5508	2.90E-2	1.910E-02	1.020	1.639E+0	2.944E-06
WES-C21-CF-E3OF4	3	1.51E-7	1.640E-02	1.017	1.085E+5	4.848E-01
WES-TLC-CF-SSLAB	3	2.10E-6	4.698E-03	1.005	2.238E+3	1.000E-02
WES-C21-CF-E2OF3	3	5.07E-7	1.645E-03	1.002	3.245E+3	1.450E-02
WES-UVL-FF-UVDA	37	3.37E-4	1.349E-03	1.001	5.000E+0	1.789E-05
WES-UVL-FF-UVDB	37	3.37E-4	1.349E-03	1.001	5.000E+0	1.789E-05
WES-BME-TM-RTBA	5601	1.40E-3	1.106E-03	1.001	1.789E+0	3.532E-06
WES-BME-TM-RTBB	5601	1.40E-3	1.106E-03	1.001	1.789E+0	3.532E-06
WES-BME-CF-RANBB	1	1.61E-6	5.035E-04	1.001	3.138E+2	1.398E-03
WES-BME-CF-RBNBA	1	1.61E-6	5.035E-04	1.001	3.138E+2	1.398E-03
WES-BME-FO-RTBA	40	3.69E-5	3.348E-04	1.000	1.007E+1	4.056E-05
WES-BME-FO-RTBB	40	3.69E-5	3.348E-04	1.000	1.007E+1	4.056E-05
WES-TLR-CF-12O16	3	8.07E-8	1.753E-04	1.000	2.173E+3	9.710E-03
WES-TLC-CF-SSLA	37	1.72E-5	6.883E-05	1.000	5.001E+0	1.789E-05
WES-TLC-CF-SSLB	37	1.72E-5	6.883E-05	1.000	5.001E+0	1.789E-05
WES-CBI-CF-P3OF4	6	1.19E-5	6.320E-05	1.000	6.311E+0	2.374E-05
WES-BUV-CF-RTBAB	3	9.73E-6	5.730E-05	1.000	6.889E+0	2.633E-05
WES-CTP-CF-T3OF8	6	3.70E-5	5.610E-05	1.000	2.516E+0	6.778E-06
WES-BSN-CF-RTBAB	1	2.10E-5	4.558E-05	1.000	3.171E+0	9.703E-06
WES-C21-FF-E21B	483	6.52E-5	2.838E-05	1.000	1.435E+0	1.946E-06
WES-C21-FF-E21C	483	6.52E-5	2.838E-05	1.000	1.435E+0	1.946E-06
WES-C21-FF-E21D	483	6.52E-5	2.838E-05	1.000	1.435E+0	1.946E-06
WES-CBI-CF-T3OF4	6	1.19E-5	1.804E-05	1.000	2.516E+0	6.778E-06
WES-CBI-CF-P2OF3	6	4.19E-5	1.583E-05	1.000	1.378E+0	1.689E-06
WES-TLR-CF-8OF12	3	2.07E-7	1.343E-05	1.000	6.588E+1	2.900E-04
WES-CTP-CF-T2OF6	6	7.46E-5	1.201E-05	1.000	1.161E+0	7.193E-07
WES-CPR-CF-P3OF4	6	2.06E-6	1.094E-05	1.000	6.311E+0	2.374E-05
WES-PWR-CF-TRNAB	1	3.40E-6	7.380E-06	1.000	3.171E+0	9.703E-06
WES-CBI-CF-T2OF3	6	4.19E-5	6.743E-06	1.000	1.161E+0	7.193E-07
WES-TLR-CF-RTBAB	1	2.00E-6	4.341E-06	1.000	3.171E+0	9.703E-06
WES-CPR-CF-P2OF3	6	7.71E-6	2.914E-06	1.000	1.378E+0	1.689E-06
WES-BUV-FF-RTBA	114	2.54E-4	1.570E-06	1.000	1.006E+0	2.763E-08
WES-BUV-FF-RTBB	114	2.54E-4	1.570E-06	1.000	1.006E+0	2.763E-08
WES-BSN-FF-RTBA	38	5.81E-4	1.339E-06	1.000	1.002E+0	1.030E-08
WES-BSN-FF-RTBB	38	5.81E-4	1.339E-06	1.000	1.002E+0	1.030E-08
WES-TLR-CF-RLA68	26	3.28E-7	1.274E-06	1.000	4.885E+0	1.737E-05
WES-TLR-CF-RLB68	26	3.28E-7	1.274E-06	1.000	4.885E+0	1.737E-05
WES-CBI-FF-BSTPB	1449	7.46E-4	6.303E-07	1.000	1.001E+0	3.779E-09
WES-CBI-FF-BSTPC	1449	7.46E-4	6.303E-07	1.000	1.001E+0	3.779E-09
WES-CBI-FF-BSTPD	1449	7.46E-4	6.303E-07	1.000	1.001E+0	3.779E-09
WES-TLC-FF-SSLAP	37	3.83E-4	5.870E-07	1.000	1.002E+0	6.851E-09
WES-TLC-FF-SSLAT	37	3.83E-4	5.870E-07	1.000	1.002E+0	6.851E-09
WES-TLC-FF-SSLBP	37	3.83E-4	5.870E-07	1.000	1.002E+0	6.851E-09
WES-TLC-FF-SSLBT	37	3.83E-4	5.870E-07	1.000	1.002E+0	6.851E-09
WES-BME-FO-BYBA	4	3.69E-5	4.279E-07	1.000	1.012E+0	5.183E-08
WES-BME-FO-BYBB	4	3.69E-5	4.279E-07	1.000	1.012E+0	5.183E-08
WES-BUV-CF-RANBB	3	9.73E-6	3.664E-07	1.000	1.038E+0	1.683E-07
WES-BUV-CF-RBNBA	3	9.73E-6	3.664E-07	1.000	1.038E+0	1.683E-07
WES-PWR-FF-TRNA	40	6.00E-5	3.222E-07	1.000	1.005E+0	2.401E-08
WES-PWR-FF-TRNB	40	6.00E-5	3.222E-07	1.000	1.005E+0	2.401E-08
WES-CBI-FF-BSTTB	966	7.46E-4	2.799E-07	1.000	1.000E+0	1.677E-09
WES-CBI-FF-BSTTC	966	7.46E-4	2.799E-07	1.000	1.000E+0	1.677E-09
WES-CBI-FF-BSTTD	966	7.46E-4	2.799E-07	1.000	1.000E+0	1.677E-09
WES-CTP-FF-CLTXB	966	5.98E-4	2.243E-07	1.000	1.000E+0	1.677E-09
WES-CTP-FF-CLTXC	966	5.98E-4	2.243E-07	1.000	1.000E+0	1.677E-09
WES-CTP-FF-CLTXD	966	5.98E-4	2.243E-07	1.000	1.000E+0	1.677E-09
WES-CTP-FF-HLTXB	966	5.98E-4	2.243E-07	1.000	1.000E+0	1.677E-09
WES-CTP-FF-HLTXC	966	5.98E-4	2.243E-07	1.000	1.000E+0	1.677E-09
WES-CTP-FF-HLTXD	966	5.98E-4	2.243E-07	1.000	1.000E+0	1.677E-09
WES-TLR-FC-RLYSA	40	3.94E-5	2.116E-07	1.000	1.005E+0	2.401E-08
WES-TLR-FC-RLYSB	40	3.94E-5	2.116E-07	1.000	1.005E+0	2.401E-08

Table F-14. (continued).

Basic Event	Number of Occur.	Prob. of Failure	Fussell-Vesely Importance	Risk Reduction Ratio	Risk Increase Ratio	Birnbaum Importance
WES-TLR-CF-RLA46	19	9.98E-7	1.158E-07	1.000	1.116E+0	5.189E-07
WES-TLR-CF-RLB46	19	9.98E-7	1.158E-07	1.000	1.116E+0	5.189E-07
WES-CPR-FF-PRESB	1449	1.16E-4	9.816E-08	1.000	1.001E+0	3.779E-09
WES-CPR-FF-PRESC	1449	1.16E-4	9.816E-08	1.000	1.001E+0	3.779E-09
WES-CPR-FF-PRESD	1449	1.16E-4	9.816E-08	1.000	1.001E+0	3.779E-09
WES-C21-FF-E21A	441	6.52E-5	9.485E-08	1.000	1.002E+0	6.514E-09
WES-BSN-CF-RANBB	1	2.10E-5	6.391E-08	1.000	1.003E+0	1.360E-08
WES-BSN-CF-RBNBA	1	2.10E-5	6.391E-08	1.000	1.003E+0	1.360E-08
WES-BUV-FF-BYBA	6	2.54E-4	4.024E-09	1.000	1.000E+0	7.052E-11
WES-BUV-FF-BYBB	6	2.54E-4	4.024E-09	1.000	1.000E+0	7.052E-11
WES-CBI-FF-BSTPA	1323	7.46E-4	1.937E-09	1.000	1.000E+0	1.265E-11
WES-BSN-FF-BYBA	2	5.81E-4	1.714E-09	1.000	1.000E+0	1.316E-11
WES-BSN-FF-BYBB	2	5.81E-4	1.714E-09	1.000	1.000E+0	1.316E-11
WES-CBI-FF-BSTTA	882	7.46E-4	8.941E-10	1.000	1.000E+0	5.614E-12
WES-CTP-FF-CLTXA	882	5.98E-4	6.706E-10	1.000	1.000E+0	5.614E-12
WES-CTP-FF-HLTXA	882	5.98E-4	6.706E-10	1.000	1.000E+0	5.614E-12
WES-CPR-FF-PRESA	1323	1.16E-4	2.980E-10	1.000	1.000E+0	1.265E-11
WES-TLR-CF-PRA23	19	5.10E-6	+0.000E+00	1.000	1.000E+0	2.646E-12
WES-TLR-CF-PRA34	26	1.52E-6	+0.000E+00	1.000	1.000E+0	2.640E-11
WES-TLR-CF-PRB23	19	5.10E-6	+0.000E+00	1.000	1.000E+0	2.646E-12
WES-TLR-CF-PRB34	26	1.52E-6	+0.000E+00	1.000	1.000E+0	2.640E-11
WES-TLR-CF-TRA23	19	5.10E-6	+0.000E+00	1.000	1.000E+0	2.646E-12
WES-TLR-CF-TRA34	26	1.52E-6	+0.000E+00	1.000	1.000E+0	2.640E-11
WES-TLR-CF-TRB23	19	5.10E-6	+0.000E+00	1.000	1.000E+0	2.646E-12
WES-TLR-CF-TRB34	26	1.52E-6	+0.000E+00	1.000	1.000E+0	2.640E-11
WES-TLR-FC-PRATA	312	3.94E-5	+0.000E+00	1.000	1.000E+0	+0.000E+00
WES-TLR-FC-PRATB	312	3.94E-5	+0.000E+00	1.000	1.000E+0	+0.000E+00
WES-TLR-FC-PRBTA	426	3.94E-5	+0.000E+00	1.000	1.000E+0	+0.000E+00
WES-TLR-FC-PRBTB	426	3.94E-5	+0.000E+00	1.000	1.000E+0	+0.000E+00
WES-TLR-FC-PRCTA	426	3.94E-5	+0.000E+00	1.000	1.000E+0	+0.000E+00
WES-TLR-FC-PRCTB	426	3.94E-5	+0.000E+00	1.000	1.000E+0	+0.000E+00
WES-TLR-FC-PRDTA	426	3.94E-5	+0.000E+00	1.000	1.000E+0	+0.000E+00
WES-TLR-FC-PRDTB	426	3.94E-5	+0.000E+00	1.000	1.000E+0	+0.000E+00
WES-TLR-FC-TRATA	312	3.94E-5	+0.000E+00	1.000	1.000E+0	+0.000E+00
WES-TLR-FC-TRATB	312	3.94E-5	+0.000E+00	1.000	1.000E+0	+0.000E+00
WES-TLR-FC-TRBTA	426	3.94E-5	+0.000E+00	1.000	1.000E+0	+0.000E+00
WES-TLR-FC-TRBTB	426	3.94E-5	+0.000E+00	1.000	1.000E+0	+0.000E+00
WES-TLR-FC-TRCTA	426	3.94E-5	+0.000E+00	1.000	1.000E+0	+0.000E+00
WES-TLR-FC-TRCTB	426	3.94E-5	+0.000E+00	1.000	1.000E+0	+0.000E+00
WES-TLR-FC-TRDTA	426	3.94E-5	+0.000E+00	1.000	1.000E+0	+0.000E+00
WES-TLR-FC-TRDTB	426	3.94E-5	+0.000E+00	1.000	1.000E+0	+0.000E+00

Table F-15. Importance measures sorted on Risk Increase for case with RPS mincut = 4.5E-6.

Basic Event	Number of Occur.	Prob. of Failure	Fussell-Vesely Importance	Risk Reduction Ratio	Risk Increase Ratio	Birnbaum Importance
WES-ROD-CF-RCCAS	1	1.21E-6	2.707E-01	1.371	2.237E+5	1.000E+00
WES-BME-CF-RTBAB	1	1.61E-6	3.592E-01	1.561	2.231E+5	9.972E-01
WES-C21-CF-E3OF4	3	1.51E-7	1.640E-02	1.017	1.085E+5	4.848E-01
WES-CBI-CF-6OF8	3	2.70E-6	2.933E-01	1.415	1.085E+5	4.848E-01
WES-C21-CF-E2OF3	3	5.07E-7	1.645E-03	1.002	3.245E+3	1.450E-02
WES-CBI-CF-4OF6	3	8.21E-6	2.663E-02	1.027	3.245E+3	1.450E-02
WES-TLC-CF-SSLAB	3	2.10E-6	4.698E-03	1.005	2.238E+3	1.000E-02
WES-UVL-CF-UVDAB	3	1.04E-5	2.327E-02	1.024	2.238E+3	1.000E-02
WES-TLR-CF-12O16	3	8.07E-8	1.753E-04	1.000	2.173E+3	9.710E-03
WES-BME-CF-RANBB	1	1.61E-6	5.035E-04	1.001	3.138E+2	1.398E-03
WES-BME-CF-RBNBA	1	1.61E-6	5.035E-04	1.001	3.138E+2	1.398E-03
WES-TLR-CF-8OF12	3	2.07E-7	1.343E-05	1.000	6.588E+1	2.900E-04
WES-BME-FO-RTBA	40	3.69E-5	3.348E-04	1.000	1.007E+1	4.056E-05
WES-BME-FO-RTBB	40	3.69E-5	3.348E-04	1.000	1.007E+1	4.056E-05
WES-BUV-CF-RTBAB	3	9.73E-6	5.730E-05	1.000	6.889E+0	2.633E-05
WES-CBI-CF-P3OF4	6	1.19E-5	6.320E-05	1.000	6.311E+0	2.374E-05
WES-CPR-CF-P3OF4	6	2.06E-6	1.094E-05	1.000	6.311E+0	2.374E-05
WES-TLC-CF-SSLA	37	1.72E-5	6.883E-05	1.000	5.001E+0	1.789E-05
WES-TLC-CF-SSLB	37	1.72E-5	6.883E-05	1.000	5.001E+0	1.789E-05
WES-UVL-FF-UVDA	37	3.37E-4	1.349E-03	1.001	5.000E+0	1.789E-05
WES-UVL-FF-UVDB	37	3.37E-4	1.349E-03	1.001	5.000E+0	1.789E-05
WES-TLR-CF-RLA68	26	3.28E-7	1.274E-06	1.000	4.885E+0	1.737E-05
WES-TLR-CF-RLB68	26	3.28E-7	1.274E-06	1.000	4.885E+0	1.737E-05
WES-XHE-XE-SIGNL	960	1.00E-2	3.071E-02	1.032	4.040E+0	1.373E-05
WES-BSN-CF-RTBAB	1	2.10E-5	4.558E-05	1.000	3.171E+0	9.703E-06
WES-PWR-CF-TRNAB	1	3.40E-6	7.380E-06	1.000	3.171E+0	9.703E-06
WES-TLR-CF-RTBAB	1	2.00E-6	4.341E-06	1.000	3.171E+0	9.703E-06
WES-CBI-CF-T3OF4	6	1.19E-5	1.804E-05	1.000	2.516E+0	6.778E-06
WES-CTP-CF-T3OF8	6	3.70E-5	5.610E-05	1.000	2.516E+0	6.778E-06
WES-BME-TM-RTBA	5601	1.40E-3	1.106E-03	1.001	1.789E+0	3.532E-06
WES-BME-TM-RTBB	5601	1.40E-3	1.106E-03	1.001	1.789E+0	3.532E-06
WES-CCP-TM-CHA	5508	2.90E-2	1.910E-02	1.020	1.639E+0	2.944E-06
WES-C21-FF-E21B	483	6.52E-5	2.838E-05	1.000	1.435E+0	1.946E-06
WES-C21-FF-E21C	483	6.52E-5	2.838E-05	1.000	1.435E+0	1.946E-06
WES-C21-FF-E21D	483	6.52E-5	2.838E-05	1.000	1.435E+0	1.946E-06
WES-CBI-CF-P2OF3	6	4.19E-5	1.583E-05	1.000	1.378E+0	1.689E-06
WES-CPR-CF-P2OF3	6	7.71E-6	2.914E-06	1.000	1.378E+0	1.689E-06
WES-XHE-XE-NSGNL	4593	5.00E-1	3.381E-01	1.511	1.338E+0	3.022E-06
WES-CBI-CF-T2OF3	6	4.19E-5	6.743E-06	1.000	1.161E+0	7.193E-07
WES-CTP-CF-T2OF6	6	7.46E-5	1.201E-05	1.000	1.161E+0	7.193E-07
WES-TLR-CF-RLA46	19	9.98E-7	1.158E-07	1.000	1.116E+0	5.189E-07
WES-TLR-CF-RLB46	19	9.98E-7	1.158E-07	1.000	1.116E+0	5.189E-07
WES-BUV-CF-RANBB	3	9.73E-6	3.664E-07	1.000	1.038E+0	1.683E-07
WES-BUV-CF-RBNBA	3	9.73E-6	3.664E-07	1.000	1.038E+0	1.683E-07
WES-BME-FO-BYBA	4	3.69E-5	4.279E-07	1.000	1.012E+0	5.183E-08
WES-BME-FO-BYBB	4	3.69E-5	4.279E-07	1.000	1.012E+0	5.183E-08
WES-BUV-FF-RTBA	114	2.54E-4	1.570E-06	1.000	1.006E+0	2.763E-08
WES-BUV-FF-RTBB	114	2.54E-4	1.570E-06	1.000	1.006E+0	2.763E-08
WES-PWR-FF-TRNA	40	6.00E-5	3.222E-07	1.000	1.005E+0	2.401E-08
WES-PWR-FF-TRNB	40	6.00E-5	3.222E-07	1.000	1.005E+0	2.401E-08
WES-TLR-FC-RLYSA	40	3.94E-5	2.116E-07	1.000	1.005E+0	2.401E-08
WES-TLR-FC-RLYSB	40	3.94E-5	2.116E-07	1.000	1.005E+0	2.401E-08
WES-BSN-CF-RANBB	1	2.10E-5	6.391E-08	1.000	1.003E+0	1.360E-08
WES-BSN-CF-RBNBA	1	2.10E-5	6.391E-08	1.000	1.003E+0	1.360E-08
WES-BSN-FF-RTBA	38	5.81E-4	1.339E-06	1.000	1.002E+0	1.030E-08
WES-BSN-FF-RTBB	38	5.81E-4	1.339E-06	1.000	1.002E+0	1.030E-08
WES-C21-FF-E21A	441	6.52E-5	9.485E-08	1.000	1.002E+0	6.514E-09
WES-TLC-FF-SSLAP	37	3.83E-4	5.870E-07	1.000	1.002E+0	6.851E-09
WES-TLC-FF-SSLAT	37	3.83E-4	5.870E-07	1.000	1.002E+0	6.851E-09
WES-TLC-FF-SSLBP	37	3.83E-4	5.870E-07	1.000	1.002E+0	6.851E-09
WES-TLC-FF-SSLBT	37	3.83E-4	5.870E-07	1.000	1.002E+0	6.851E-09
WES-CBI-FF-BSTPB	1449	7.46E-4	6.303E-07	1.000	1.001E+0	3.779E-09
WES-CBI-FF-BSTPC	1449	7.46E-4	6.303E-07	1.000	1.001E+0	3.779E-09
WES-CBI-FF-BSTPD	1449	7.46E-4	6.303E-07	1.000	1.001E+0	3.779E-09
WES-CPR-FF-PRESB	1449	1.16E-4	9.816E-08	1.000	1.001E+0	3.779E-09
WES-CPR-FF-PRESC	1449	1.16E-4	9.816E-08	1.000	1.001E+0	3.779E-09
WES-CPR-FF-PRESD	1449	1.16E-4	9.816E-08	1.000	1.001E+0	3.779E-09
WES-BSN-FF-BYBA	2	5.81E-4	1.714E-09	1.000	1.000E+0	1.316E-11

Table F-15. (continued).

Basic Event	Number of Occur.	Prob. of Failure	Fussell-Vesely Importance	Risk Reduction Ratio	Risk Increase Ratio	Birnbaum Importance
WES-BSN-FF-BYBB	2	5.81E-4	1.714E-09	1.000	1.000E+0	1.316E-11
WES-BUV-FF-BYBA	6	2.54E-4	4.024E-09	1.000	1.000E+0	7.052E-11
WES-BUV-FF-BYBB	6	2.54E-4	4.024E-09	1.000	1.000E+0	7.052E-11
WES-CBI-FF-BSTPA	1323	7.46E-4	1.937E-09	1.000	1.000E+0	1.265E-11
WES-CBI-FF-BSTTA	882	7.46E-4	8.941E-10	1.000	1.000E+0	5.614E-12
WES-CBI-FF-BSTTB	966	7.46E-4	2.799E-07	1.000	1.000E+0	1.677E-09
WES-CBI-FF-BSTTC	966	7.46E-4	2.799E-07	1.000	1.000E+0	1.677E-09
WES-CBI-FF-BSTTD	966	7.46E-4	2.799E-07	1.000	1.000E+0	1.677E-09
WES-CPR-FF-PRESA	1323	1.16E-4	2.980E-10	1.000	1.000E+0	1.265E-11
WES-CTP-FF-CLTXA	882	5.98E-4	6.706E-10	1.000	1.000E+0	5.614E-12
WES-CTP-FF-CLTXB	966	5.98E-4	2.243E-07	1.000	1.000E+0	1.677E-09
WES-CTP-FF-CLTXC	966	5.98E-4	2.243E-07	1.000	1.000E+0	1.677E-09
WES-CTP-FF-CLTXD	966	5.98E-4	2.243E-07	1.000	1.000E+0	1.677E-09
WES-CTP-FF-HLTXA	882	5.98E-4	6.706E-10	1.000	1.000E+0	5.614E-12
WES-CTP-FF-HLTXB	966	5.98E-4	2.243E-07	1.000	1.000E+0	1.677E-09
WES-CTP-FF-HLTXC	966	5.98E-4	2.243E-07	1.000	1.000E+0	1.677E-09
WES-CTP-FF-HLTXD	966	5.98E-4	2.243E-07	1.000	1.000E+0	1.677E-09
WES-TLR-CF-PRA23	19	5.10E-6	+0.000E+00	1.000	1.000E+0	2.646E-12
WES-TLR-CF-PRA34	26	1.52E-6	+0.000E+00	1.000	1.000E+0	2.640E-11
WES-TLR-CF-PRB23	19	5.10E-6	+0.000E+00	1.000	1.000E+0	2.646E-12
WES-TLR-CF-PRB34	26	1.52E-6	+0.000E+00	1.000	1.000E+0	2.640E-11
WES-TLR-CF-TRA23	19	5.10E-6	+0.000E+00	1.000	1.000E+0	2.646E-12
WES-TLR-CF-TRA34	26	1.52E-6	+0.000E+00	1.000	1.000E+0	2.640E-11
WES-TLR-CF-TRB23	19	5.10E-6	+0.000E+00	1.000	1.000E+0	2.646E-12
WES-TLR-CF-TRB34	26	1.52E-6	+0.000E+00	1.000	1.000E+0	2.640E-11
WES-TLR-FC-PRATA	312	3.94E-5	+0.000E+00	1.000	1.000E+0	+0.000E+00
WES-TLR-FC-PRATB	312	3.94E-5	+0.000E+00	1.000	1.000E+0	+0.000E+00
WES-TLR-FC-PRBTA	426	3.94E-5	+0.000E+00	1.000	1.000E+0	+0.000E+00
WES-TLR-FC-PRBTB	426	3.94E-5	+0.000E+00	1.000	1.000E+0	+0.000E+00
WES-TLR-FC-PRCTA	426	3.94E-5	+0.000E+00	1.000	1.000E+0	+0.000E+00
WES-TLR-FC-PRCTB	426	3.94E-5	+0.000E+00	1.000	1.000E+0	+0.000E+00
WES-TLR-FC-PRDTA	426	3.94E-5	+0.000E+00	1.000	1.000E+0	+0.000E+00
WES-TLR-FC-PRDTB	426	3.94E-5	+0.000E+00	1.000	1.000E+0	+0.000E+00
WES-TLR-FC-TRATA	312	3.94E-5	+0.000E+00	1.000	1.000E+0	+0.000E+00
WES-TLR-FC-TRATB	312	3.94E-5	+0.000E+00	1.000	1.000E+0	+0.000E+00
WES-TLR-FC-TRBTA	426	3.94E-5	+0.000E+00	1.000	1.000E+0	+0.000E+00
WES-TLR-FC-TRBTB	426	3.94E-5	+0.000E+00	1.000	1.000E+0	+0.000E+00

Table F-16. Importance measures sorted on Birnbaum for case with RPS mincut = 4.5E-6.

Basic Event	Number of Occur.	Prob. of Failure	Fussell-Vesely Importance	Risk Reduction Ratio	Risk Increase Ratio	Birnbaum Importance
WES-ROD-CF-RCCAS	1	1.21E-6	2.707E-01	1.371	2.237E+5	1.000E+00
WES-BME-CF-RTBAB	1	1.61E-6	3.592E-01	1.561	2.231E+5	9.972E-01
WES-C21-CF-E3OF4	3	1.51E-7	1.640E-02	1.017	1.085E+5	4.848E-01
WES-CBI-CF-6OF8	3	2.70E-6	2.933E-01	1.415	1.085E+5	4.848E-01
WES-C21-CF-E2OF3	3	5.07E-7	1.645E-03	1.002	3.245E+3	1.450E-02
WES-CBI-CF-4OF6	3	8.21E-6	2.663E-02	1.027	3.245E+3	1.450E-02
WES-TLC-CF-SSLAB	3	2.10E-6	4.698E-03	1.005	2.238E+3	1.000E-02
WES-UVL-CF-UVDAB	3	1.04E-5	2.327E-02	1.024	2.238E+3	1.000E-02
WES-TLR-CF-12O16	3	8.07E-8	1.753E-04	1.000	2.173E+3	9.710E-03
WES-BME-CF-RANBB	1	1.61E-6	5.035E-04	1.001	3.138E+2	1.398E-03
WES-BME-CF-RBNBA	1	1.61E-6	5.035E-04	1.001	3.138E+2	1.398E-03
WES-TLR-CF-8OF12	3	2.07E-7	1.343E-05	1.000	6.588E+1	2.900E-04
WES-BME-FO-RTBA	40	3.69E-5	3.348E-04	1.000	1.007E+1	4.056E-05
WES-BME-FO-RTBB	40	3.69E-5	3.348E-04	1.000	1.007E+1	4.056E-05
WES-BUV-CF-RTBAB	3	9.73E-6	5.730E-05	1.000	6.889E+0	2.633E-05
WES-CBI-CF-P3OF4	6	1.19E-5	6.320E-05	1.000	6.311E+0	2.374E-05
WES-CPR-CF-P3OF4	6	2.06E-6	1.094E-05	1.000	6.311E+0	2.374E-05
WES-TLC-CF-SSLA	37	1.72E-5	6.883E-05	1.000	5.001E+0	1.789E-05
WES-TLC-CF-SSLB	37	1.72E-5	6.883E-05	1.000	5.001E+0	1.789E-05
WES-UVL-FF-UVDA	37	3.37E-4	1.349E-03	1.001	5.000E+0	1.789E-05
WES-UVL-FF-UVDB	37	3.37E-4	1.349E-03	1.001	5.000E+0	1.789E-05
WES-TLR-CF-RLA68	26	3.28E-7	1.274E-06	1.000	4.885E+0	1.737E-05
WES-TLR-CF-RLB68	26	3.28E-7	1.274E-06	1.000	4.885E+0	1.737E-05
WES-XHE-XE-SIGNL	960	1.00E-2	3.071E-02	1.032	4.040E+0	1.373E-05
WES-BSN-CF-RTBAB	1	2.10E-5	4.558E-05	1.000	3.171E+0	9.703E-06
WES-PWR-CF-TRNAB	1	3.40E-6	7.380E-06	1.000	3.171E+0	9.703E-06
WES-TLR-CF-RTBAB	1	2.00E-6	4.341E-06	1.000	3.171E+0	9.703E-06
WES-CBI-CF-T3OF4	6	1.19E-5	1.804E-05	1.000	2.516E+0	6.778E-06
WES-CTP-CF-T3OF8	6	3.70E-5	5.610E-05	1.000	2.516E+0	6.778E-06
WES-BME-TM-RTBA	5601	1.40E-3	1.106E-03	1.001	1.789E+0	3.532E-06
WES-BME-TM-RTBB	5601	1.40E-3	1.106E-03	1.001	1.789E+0	3.532E-06
WES-XHE-XE-NSGNL	4593	5.00E-1	3.381E-01	1.511	1.338E+0	3.022E-06
WES-CCP-TM-CHA	5508	2.90E-2	1.910E-02	1.020	1.639E+0	2.944E-06
WES-C21-FF-E21B	483	6.52E-5	2.838E-05	1.000	1.435E+0	1.946E-06
WES-C21-FF-E21C	483	6.52E-5	2.838E-05	1.000	1.435E+0	1.946E-06
WES-C21-FF-E21D	483	6.52E-5	2.838E-05	1.000	1.435E+0	1.946E-06
WES-CBI-CF-P2OF3	6	4.19E-5	1.583E-05	1.000	1.378E+0	1.689E-06
WES-CPR-CF-P2OF3	6	7.71E-6	2.914E-06	1.000	1.378E+0	1.689E-06
WES-CBI-CF-T2OF3	6	4.19E-5	6.743E-06	1.000	1.161E+0	7.193E-07
WES-CTP-CF-T2OF6	6	7.46E-5	1.201E-05	1.000	1.161E+0	7.193E-07
WES-TLR-CF-RLA46	19	9.98E-7	1.158E-07	1.000	1.116E+0	5.189E-07
WES-TLR-CF-RLB46	19	9.98E-7	1.158E-07	1.000	1.116E+0	5.189E-07
WES-BUV-CF-RANBB	3	9.73E-6	3.664E-07	1.000	1.038E+0	1.683E-07
WES-BUV-CF-RBNBA	3	9.73E-6	3.664E-07	1.000	1.038E+0	1.683E-07
WES-BME-FO-BYBA	4	3.69E-5	4.279E-07	1.000	1.012E+0	5.183E-08
WES-BME-FO-BYBB	4	3.69E-5	4.279E-07	1.000	1.012E+0	5.183E-08
WES-BUV-FF-RTBA	114	2.54E-4	1.570E-06	1.000	1.006E+0	2.763E-08
WES-BUV-FF-RTBB	114	2.54E-4	1.570E-06	1.000	1.006E+0	2.763E-08
WES-PWR-FF-TRNA	40	6.00E-5	3.222E-07	1.000	1.005E+0	2.401E-08
WES-PWR-FF-TRNB	40	6.00E-5	3.222E-07	1.000	1.005E+0	2.401E-08
WES-TLR-FC-RLYSA	40	3.94E-5	2.116E-07	1.000	1.005E+0	2.401E-08
WES-TLR-FC-RLYSB	40	3.94E-5	2.116E-07	1.000	1.005E+0	2.401E-08
WES-BSN-CF-RANBB	1	2.10E-5	6.391E-08	1.000	1.003E+0	1.360E-08
WES-BSN-CF-RBNBA	1	2.10E-5	6.391E-08	1.000	1.003E+0	1.360E-08
WES-BSN-FF-RTBA	38	5.81E-4	1.339E-06	1.000	1.002E+0	1.030E-08
WES-BSN-FF-RTBB	38	5.81E-4	1.339E-06	1.000	1.002E+0	1.030E-08
WES-TLC-FF-SSLAP	37	3.83E-4	5.870E-07	1.000	1.002E+0	6.851E-09
WES-TLC-FF-SSLAT	37	3.83E-4	5.870E-07	1.000	1.002E+0	6.851E-09
WES-TLC-FF-SSLBP	37	3.83E-4	5.870E-07	1.000	1.002E+0	6.851E-09
WES-TLC-FF-SSLBT	37	3.83E-4	5.870E-07	1.000	1.002E+0	6.851E-09
WES-C21-FF-E21A	441	6.52E-5	9.485E-08	1.000	1.002E+0	6.514E-09
WES-CBI-FF-BSTPB	1449	7.46E-4	6.303E-07	1.000	1.001E+0	3.779E-09
WES-CBI-FF-BSTPC	1449	7.46E-4	6.303E-07	1.000	1.001E+0	3.779E-09
WES-CBI-FF-BSTPD	1449	7.46E-4	6.303E-07	1.000	1.001E+0	3.779E-09
WES-CPR-FF-PRESB	1449	1.16E-4	9.816E-08	1.000	1.001E+0	3.779E-09
WES-CPR-FF-PRESC	1449	1.16E-4	9.816E-08	1.000	1.001E+0	3.779E-09
WES-CPR-FF-PRESD	1449	1.16E-4	9.816E-08	1.000	1.001E+0	3.779E-09
WES-CBI-FF-BSTTB	966	7.46E-4	2.799E-07	1.000	1.000E+0	1.677E-09

Table F-16. (continued).

Basic Event	Number of Occur.	Prob. of Failure	Fussell-Vesely Importance	Risk Reduction Ratio	Risk Increase Ratio	Birnbaum Importance
WES-CBI-FF-BSTTC	966	7.46E-4	2.799E-07	1.000	1.000E+0	1.677E-09
WES-CBI-FF-BSTTD	966	7.46E-4	2.799E-07	1.000	1.000E+0	1.677E-09
WES-CTP-FF-CLTXB	966	5.98E-4	2.243E-07	1.000	1.000E+0	1.677E-09
WES-CTP-FF-CLTXC	966	5.98E-4	2.243E-07	1.000	1.000E+0	1.677E-09
WES-CTP-FF-CLTXD	966	5.98E-4	2.243E-07	1.000	1.000E+0	1.677E-09
WES-CTP-FF-HLTXB	966	5.98E-4	2.243E-07	1.000	1.000E+0	1.677E-09
WES-CTP-FF-HLTXC	966	5.98E-4	2.243E-07	1.000	1.000E+0	1.677E-09
WES-CTP-FF-HLTXD	966	5.98E-4	2.243E-07	1.000	1.000E+0	1.677E-09
WES-BUV-FF-BYBA	6	2.54E-4	4.024E-09	1.000	1.000E+0	7.052E-11
WES-BUV-FF-BYBB	6	2.54E-4	4.024E-09	1.000	1.000E+0	7.052E-11
WES-TLR-CF-PRA34	26	1.52E-6	+0.000E+00	1.000	1.000E+0	2.640E-11
WES-TLR-CF-PRB34	26	1.52E-6	+0.000E+00	1.000	1.000E+0	2.640E-11
WES-TLR-CF-TRA34	26	1.52E-6	+0.000E+00	1.000	1.000E+0	2.640E-11
WES-TLR-CF-TRB34	26	1.52E-6	+0.000E+00	1.000	1.000E+0	2.640E-11
WES-BSN-FF-BYBA	2	5.81E-4	1.714E-09	1.000	1.000E+0	1.316E-11
WES-BSN-FF-BYBB	2	5.81E-4	1.714E-09	1.000	1.000E+0	1.316E-11
WES-CBI-FF-BSTPA	1323	7.46E-4	1.937E-09	1.000	1.000E+0	1.265E-11
WES-CPR-FF-PRESA	1323	1.16E-4	2.980E-10	1.000	1.000E+0	1.265E-11
WES-CBI-FF-BSTTA	882	7.46E-4	8.941E-10	1.000	1.000E+0	5.614E-12
WES-CTP-FF-CLTXA	882	5.98E-4	6.706E-10	1.000	1.000E+0	5.614E-12
WES-CTP-FF-HLTXA	882	5.98E-4	6.706E-10	1.000	1.000E+0	5.614E-12
WES-TLR-CF-PRA23	19	5.10E-6	+0.000E+00	1.000	1.000E+0	2.646E-12
WES-TLR-CF-PRB23	19	5.10E-6	+0.000E+00	1.000	1.000E+0	2.646E-12
WES-TLR-CF-TRA23	19	5.10E-6	+0.000E+00	1.000	1.000E+0	2.646E-12
WES-TLR-CF-TRB23	19	5.10E-6	+0.000E+00	1.000	1.000E+0	2.646E-12
WES-TLR-FC-PRATA	312	3.94E-5	+0.000E+00	1.000	1.000E+0	+0.000E+00
WES-TLR-FC-PRATB	312	3.94E-5	+0.000E+00	1.000	1.000E+0	+0.000E+00
WES-TLR-FC-PRBTA	426	3.94E-5	+0.000E+00	1.000	1.000E+0	+0.000E+00
WES-TLR-FC-PRBTB	426	3.94E-5	+0.000E+00	1.000	1.000E+0	+0.000E+00
WES-TLR-FC-PRCTA	426	3.94E-5	+0.000E+00	1.000	1.000E+0	+0.000E+00
WES-TLR-FC-PRCTB	426	3.94E-5	+0.000E+00	1.000	1.000E+0	+0.000E+00
WES-TLR-FC-PRDTA	426	3.94E-5	+0.000E+00	1.000	1.000E+0	+0.000E+00
WES-TLR-FC-PRDTB	426	3.94E-5	+0.000E+00	1.000	1.000E+0	+0.000E+00
WES-TLR-FC-TRATA	312	3.94E-5	+0.000E+00	1.000	1.000E+0	+0.000E+00
WES-TLR-FC-TRATB	312	3.94E-5	+0.000E+00	1.000	1.000E+0	+0.000E+00
WES-TLR-FC-TRBTA	426	3.94E-5	+0.000E+00	1.000	1.000E+0	+0.000E+00
WES-TLR-FC-TRBTB	426	3.94E-5	+0.000E+00	1.000	1.000E+0	+0.000E+00
WES-TLR-FC-TRCTA	426	3.94E-5	+0.000E+00	1.000	1.000E+0	+0.000E+00
WES-TLR-FC-TRCTB	426	3.94E-5	+0.000E+00	1.000	1.000E+0	+0.000E+00
WES-TLR-FC-TRDTA	426	3.94E-5	+0.000E+00	1.000	1.000E+0	+0.000E+00
WES-TLR-FC-TRDTB	426	3.94E-5	+0.000E+00	1.000	1.000E+0	+0.000E+00

Table F-17. (continued).

Table F-17. Failure probability and uncertainty data for RPS basic events.

	Basic Event Name	Prob.	Distr. Type	Uncert. Value[a]	Correlation Class	Basic Event Description
1	WES-ANL-EG21-HE	TRUE	-	-	-	ANALOG SERIES 7300 IN USE Parameters for Analog Series 7300 design
	WES-ANL-EG21-HE	FALSE	-	-	-	ANALOG SERIES 7300 IN USE Parameters for Eagle-21 design
2	WES-BME-CF-RANBB	1.61E-6	Lognormal	1.163E+1	BME3	CCF RTB-A AND BYB-B (MECHANICAL)
3	WES-BME-CF-RBNBA	1.61E-6	Lognormal	1.163E+1	BME3	CCF RTB-B AND BYB-A (MECHANICAL)
4	WES-BME-CF-RTBAB	1.61E-6	Lognormal	1.163E+1	BME3	CCF RTB-A AND RTB-B (MECHANICAL)
5	WES-BME-FO-BYBA	3.69E-5	Lognormal	5.600E+0	BME1	BYB-A LOCAL HW FAILURE
6	WES-BME-FO-BYBB	3.69E-5	Lognormal	5.600E+0	BME1	BYB-B LOCAL HW FAILURE
7	WES-BME-FO-RTBA	3.69E-5	Lognormal	5.600E+0	BME1	RTB-A LOCAL HW FAILURE
8	WES-BME-FO-RTBB	3.69E-5	Lognormal	5.600E+0	BME1	RTB-B LOCAL HW FAILURE
9	WES-BME-TM-RTBA	1.40E-3	Uniform	2.800E-3	BME2	RTB-A IN T&M
10	WES-BME-TM-RTBB	1.40E-3	Uniform	2.800E-3	BME2	RTB-B IN T&M
11	WES-BSN-CF-RANBB	2.10E-5	Lognormal	8.400E+0	BSN2	CCF OF RTB-A AND BYB-B SHUNT TRIP DEVICES
12	WES-BSN-CF-RBNBA	2.10E-5	Lognormal	8.400E+0	BSN2	CCF OF RTB-B AND BYB-A SHUNT TRIP DEVICES
13	WES-BSN-CF-RTBAB	2.10E-5	Lognormal	8.400E+0	BSN2	CCF OF RTB-A AND RTB-B SHUNT TRIP DEVICES
14	WES-BSN-FF-BYBA	5.81E-4	Lognormal	3.300E+0	BSN1	BYB-A SHUNT TRIP DEVICE LOCAL FAULTS
15	WES-BSN-FF-BYBB	5.81E-4	Lognormal	3.300E+0	BSN1	BYB-B SHUNT TRIP DEVICE LOCAL FAULTS
16	WES-BSN-FF-RTBA	5.81E-4	Lognormal	3.300E+0	BSN1	RTB-A SHUNT TRIP DEVICE LOCAL FAULTS
17	WES-BSN-FF-RTBB	5.81E-4	Lognormal	3.300E+0	BSN1	RTB-B SHUNT TRIP DEVICE LOCAL FAULTS
18	WES-BUV-CF-RANBB	9.73E-6	Lognormal	7.380E+0	BUV2	CCF OF RTB-A AND BYB-B UV DEVICES
19	WES-BUV-CF-RBNBA	9.73E-6	Lognormal	7.380E+0	BUV2	CCF OF RTB-B AND BYB-A UV DEVICES
20	WES-BUV-CF-RTBAB	9.73E-6	Lognormal	7.380E+0	BUV2	CCF OF RTB-A AND RTB-B UV DEVICES
21	WES-BUV-FF-BYBA	2.54E-4	Lognormal	2.600E+0	BUV1	BYB-A UV DEVICE LOCAL FAULTS
22	WES-BUV-FF-BYBB	2.54E-4	Lognormal	2.600E+0	BUV1	BYB-B UV DEVICE LOCAL FAULTS
23	WES-BUV-FF-RTBA	2.54E-4	Lognormal	2.600E+0	BUV1	RTB-A UV DEVICE LOCAL FAULTS
24	WES-BUV-FF-RTBB	2.54E-4	Lognormal	2.600E+0	BUV1	RTB-B UV DEVICE LOCAL FAULTS
25	WES-C21-CF-E2OF3	5.07E-7	Lognormal	7.800E+0	-	CCF 2 EAGLE-21 PROCESS LOGIC MODULES IN 2 OF 3 CHANNELS
26	WES-C21-CF-E3OF4	1.51E-7	Lognormal	1.265E+1	-	CCF 3 EAGLE-21 PROCESS LOGIC MODULES IN 3 OF 4 CHANNELS
27	WES-C21-FF-E21A	6.52E-5	Lognormal	5.300E+0	C211	CH-A EAGLE-21 PROCESS LOGIC MODULE FAILS
28	WES-C21-FF-E21B	6.52E-5	Lognormal	5.300E+0	C211	CH-B EAGLE-21 PROCESS LOGIC MODULE FAILS
29	WES-C21-FF-E21C	6.52E-5	Lognormal	5.300E+0	C211	CH-C EAGLE-21 PROCESS LOGIC MODULE FAILS
30	WES-C21-FF-E21D	6.52E-5	Lognormal	5.300E+0	C211	CH-D EAGLE-21 PROCESS LOGIC MODULE FAILS
31	WES-CBI-CF-4OF6	8.21E-6	Lognormal	1.034E+1	-	CCF 4 BISTABLES IN 2 OF 3 CHANNELS
32	WES-CBI-CF-6OF8	2.70E-6	Lognormal	1.648E+1	-	CCF 6 BISTABLES IN 3 OF 4 CHANNELS
33	WES-CBI-CF-P2OF3	4.19E-5	Lognormal	9.120E+0	CBI3	CCF 2 PRESSURE OUTPUT BISTABLES IN 2 OF 3 CHANNELS
34	WES-CBI-CF-P3OF4	1.19E-5	Lognormal	1.452E+1	CBI2	CCF 3 PRESSURE OUTPUT BISTABLES IN 3 OF 4 CHANNELS
35	WES-CBI-CF-T2OF3	4.19E-5	Lognormal	9.120E+0	CBI3	CCF 2 TEMP OUTPUT BISTABLES IN 2 OF 3 CHANNELS
36	WES-CBI-CF-T3OF4	1.19E-5	Lognormal	1.452E+1	CBI2	CCF 3 TEMP OUTPUT BISTABLES IN 3 OF 4 CHANNELS
37	WES-CBI-FF-BSTPA	7.46E-4	Lognormal	6.500E+0	CBI1	CH-A PRESSURE OUTPUT BISTABLE FAILS
38	WES-CBI-FF-BSTPB	7.46E-4	Lognormal	6.500E+0	CBI1	CH-B PRESSURE OUTPUT BISTABLE FAILS
39	WES-CBI-FF-BSTPC	7.46E-4	Lognormal	6.500E+0	CBI1	CH-C PRESSURE OUTPUT BISTABLE FAILS
40	WES-CBI-FF-BSTPD	7.46E-4	Lognormal	6.500E+0	CBI1	CH-D PRESSURE OUTPUT NISTABLE FAILS
41	WES-CBI-FF-BSTTA	7.46E-4	Lognormal	6.500E+0	CBI1	CH-A TEMPERATURE OUTPUT BISTABLE FAILS
42	WES-CBI-FF-BSTTB	7.46E-4	Lognormal	6.500E+0	CBI1	CH-B TEMPERATURE OUTPUT BISTABLE FAILS
43	WES-CBI-FF-BSTTC	7.46E-4	Lognormal	6.500E+0	CBI1	CH-C TEMPERATURE OUTPUT BISTABLE FAILS
44	WES-CBI-FF-BSTTD	7.46E-4	Lognormal	6.500E+0	CBI1	CH-D TEMPERATURE OUTPUT BISTABLE FAILS
45	WES-CCP-CF-P2OF3	1.50E-5	Lognormal	9.290E+0	-	CCF 2 ANALOG PRES PROCESS LOGIC MODULES IN 2 OF 3 CHANNELS
46	WES-CCP-CF-P3OF4	4.48E-6	Lognormal	1.454E+1	-	CCF 3 ANALOG PRES PROCESS LOGIC MODULES IN 3 OF 4 CHANNELS
47	WES-CCP-FF-ANLPA	1.57E-4	Lognormal	6.600E+0	CCP1	CH-A ANALOG PRESSURE PROCESS LOGIC MODULE FAILS
48	WES-CCP-FF-ANLPB	1.57E-4	Lognormal	6.600E+0	CCP1	CH-B ANALOG PRESSURE PROCESS LOGIC MODULE FAILS
49	WES-CCP-FF-ANLPC	1.57E-4	Lognormal	6.600E+0	CCP1	CH-C ANALOG PRESSURE PROCESS LOGIC MODULE FAILS
50	WES-CCP-FF-ANLPD	1.57E-4	Lognormal	6.600E+0	CCP1	CH-D ANALOG PRESSURE PROCESS LOGIC MODULE FAILS
51	WES-CCP-TM-CHA	5.80E-2	Uniform	1.160E-1	-	CH-A IN T&M Parameters for Analog Series 7300 design

Table F-17. (continued).

	Basic Event Name	Prob.	Distr. Type	Uncert. Value[a]	Correlation Class	Basic Event Description
	WES-CCP-TM-CHA	2.90E-2	Uniform	5.800E-2	-	CH-A IN T&M Parameters for Eagle 21 design
52	WES-CCX-CF-4OF6	6.33E-6	Lognormal	4.680E+0	-	CCF 4 ANALOG PROCESS LOGIC MODULES IN 2 OF 3 CHANNELS
53	WES-CCX-CF-6OF8	1.83E-6	Lognormal	9.210E+0	-	CCF 6 ANALOG PROCESS LOGIC MODULES IN 3 OF 4 CHANNELS
54	WES-CDT-CF-T2OF3	2.50E-4	Lognormal	2.940E+0	-	CCF 2 ANALOG TEMP PROCESS LOGIC MODULES IN 2 OF 3 CHANNELS
55	WES-CDT-CF-T3OF4	5.55E-5	Lognormal	3.980E+0	-	CCF 3 ANALOG TEMP PROCESS LOGIC MODULES IN 3 OF 4 CHANNELS
56	WES-CDT-FF-ANLTA	4.83E-3	Lognormal	2.700E+0	CDT1	CH-A ANALOG TEMPERATURE PROCESS LOGIC MODULE FAILS
57	WES-CDT-FF-ANLTB	4.83E-3	Lognormal	2.700E+0	CDT1	CH-B ANALOG TEMPERATURE PROCESS LOGIC MODULE FAILS
58	WES-CDT-FF-ANLTC	4.83E-3	Lognormal	2.700E+0	CDT1	CH-C ANALOG TEMPERATURE PROCESS LOGIC MODULE FAILS
59	WES-CDT-FF-ANLTD	4.83E-3	Lognormal	2.700E+0	CDT1	CH-D ANALOG TEMPERATURE PROCESS LOGIC MODULE FAILS
60	WES-CPR-CF-P2OF3	7.71E-6	Lognormal	5.810E+0	-	CCF 2 PRESSURE SENSORS IN 2 OF 3 CHANNELS
61	WES-CPR-CF-P3OF4	2.06E-6	Lognormal	7.350E+0	-	CCF 3 PRESSURE SENSORS IN 3 OF 4 CHANNELS
62	WES-CPR-FF-PRESA	1.16E-4	Lognormal	5.300E+0	CPR1	CH-A PRESSURE SENSOR FAILS
63	WES-CPR-FF-PRESB	1.16E-4	Lognormal	5.300E+0	CPR1	CH-B PRESSURE SENSOR FAILS
64	WES-CPR-FF-PRESC	1.16E-4	Lognormal	5.300E+0	CPR1	CH-C PRESSURE SENSOR FAILS
65	WES-CPR-FF-PRESD	1.16E-4	Lognormal	5.300E+0	CPR1	CH-D PRESSURE SENSOR FAILS
66	WES-CTP-CF-T2OF6	7.46E-5	Lognormal	2.160E+0	-	CCF 2 TEMP SENSORS IN 2 OF 3 CHANNELS
67	WES-CTP-CF-T3OF8	3.70E-5	Lognormal	2.400E+0	-	CCF 3 TEMP SENSORS IN 3 OF 4 CHANNELS
68	WES-CTP-FF-CLTXA	5.98E-4	Lognormal	1.800E+0	CTP1	CH-A COLD LEG RTD FAILS
69	WES-CTP-FF-CLTXB	5.98E-4	Lognormal	1.800E+0	CTP1	CH-B COLD LEG RTD FAILS
70	WES-CTP-FF-CLTXC	5.98E-4	Lognormal	1.800E+0	CTP1	CH-C COLD LEG RTD FAILS
71	WES-CTP-FF-CLTXD	5.98E-4	Lognormal	1.800E+0	CTP1	CH-D COLD LEG RTD FAILS
72	WES-CTP-FF-HLTXA	5.98E-4	Lognormal	1.800E+0	CTP1	CH-A HOT LEG RTD FAILS
73	WES-CTP-FF-HLTXB	5.98E-4	Lognormal	1.800E+0	CTP1	CH-B HOT LEG RTD FAILS
74	WES-CTP-FF-HLTXC	5.98E-4	Lognormal	1.800E+0	CTP1	CH-C HOT LEG RTD FAILS
75	WES-CTP-FF-HLTXD	5.98E-4	Lognormal	1.800E+0	CTP1	CH-D HOT LEG RTD FAILS
76	WES-PWR-CF-TRNAB	3.40E-6	Lognormal	1.790E+1	-	CCF OF RTB-A AND RTB-B SHUNT TRIP POWER SUPPLIES
77	WES-PWR-FF-TRNA	6.00E-5	Lognormal	1.000E+1	PWR1	TRAIN A 125 Vdc BUS FAILS
78	WES-PWR-FF-TRNB	6.00E-5	Lognormal	1.000E+1	PWR1	TRAIN B 125 Vdc BUS FAILS
79	WES-ROD-CF-RCCAS	1.21E-6	Lognormal	4.190E+0	-	CCF 10 OR MORE RCCAS FAIL TO DROP
80	WES-TLC-CF-SSLA	1.72E-5	Lognormal	1.810E+1	TLC2	CCF SOLID STATE LOGIC TRAIN A (2 OF 4)
81	WES-TLC-CF-SSLAB	2.10E-6	Lognormal	3.400E+1	-	CCF SOLID STATE LOGIC IN TRAINS A AND B (4 OF 4)
82	WES-TLC-CF-SSLB	1.72E-5	Lognormal	1.810E+1	TLC2	CCF SOLID STATE LOGIC TRAIN B (2 OF 4)
83	WES-TLC-FF-SSLAP	3.83E-4	Lognormal	1.020E+1	TLC1	TRAIN A PRESSURE SOLID STATE LOGIC FAILS
84	WES-TLC-FF-SSLAT	3.83E-4	Lognormal	1.020E+1	TLC1	TRAIN A TEMPERATURE SOLID STATE LOGIC FAILS
85	WES-TLC-FF-SSLBP	3.83E-4	Lognormal	1.020E+1	TLC1	TRAIN B PRESSURE SOLID STATE LOGIC FAILS
86	WES-TLC-FF-SSLBT	3.83E-4	Lognormal	1.020E+1	TLC1	TRAIN B TEMPERATURE SOLID STATE LOGIC FAILS
87	WES-TLR-CF-12O16	8.07E-8	Lognormal	1.090E+1	-	CCF 12 OR MORE TMU RELAYS IN TRAINS A AND B NO CHANNEL T&M
88	WES-TLR-CF-8OF12	2.07E-7	Lognormal	7.080E+0	-	CCF 8 OR MORE TMU RELAYS IN TRAINS A AND B ONE CHANNEL T&M
89	WES-TLR-CF-PRA23	5.10E-6	Lognormal	4.990E+0	TLR3	CCF 2 OF 3 PRES TMU RELAYS IN TRAIN A ONE CHANNEL T&M
90	WES-TLR-CF-PRA34	1.52E-6	Lognormal	8.890E+0	TLR2	CCF 3 OF 4 PRES TMU RELAYS IN TRAIN A NO CHANNELS T&M
91	WES-TLR-CF-PRB23	5.10E-6	Lognormal	4.990E+0	TLR3	CCF 2 OF 3 PRES TMU RELAYS IN TRAIN B ONE CHANNEL T&M
92	WES-TLR-CF-PRB34	1.52E-6	Lognormal	8.890E+0	TLR2	CCF 3 OF 4 PRES TMU RELAYS IN TRAIN B NO CHANNEL T&M
93	WES-TLR-CF-RLA46	9.98E-7	Lognormal	5.900E+0	TLR4	CCF 4 OR MORE TMU RELAYS IN TRAIN A ONE CHANNEL T&M
94	WES-TLR-CF-RLA68	3.28E-7	Lognormal	1.049E+1	TLR5	CCF 6 OR MORE TMU RELAYS IN TRAIN A NO CHANNEL T&M
95	WES-TLR-CF-RLB46	9.98E-7	Lognormal	5.900E+0	TLR4	CCF 4 OR MORE TMU RELAYS IN TRAIN B ONE CHANNEL T&M
96	WES-TLR-CF-RLB68	3.28E-7	Lognormal	1.049E+1	TLR5	CCF 6 OR MORE TMU RELAYS IN TRAIN B NO CHANNEL T&M
97	WES-TLR-CF-RTBAB	2.00E-6	Lognormal	7.840E+0	-	CCF OF RTB-A AND RTB-B SHUNT TRIP RELAYS

Table F-17. (continued).

	Basic Event Name	Prob.	Distr. Type	Uncert. Value[a]	Correlation Class	Basic Event Description
98	WES-TLR-CF-TRA23	5.10E-6	Lognormal	4.990E+0	TLR3	CCF 2 OF 3 TEMP TMU RELAYS IN TRAIN A ONE CHANNEL T&M
99	WES-TLR-CF-TRA34	1.52E-6	Lognormal	8.890E+0	TLR2	CCF 3 OF 4 TEMP TMU RELAYS IN TRAIN A NO CHANNELS T&M
100	WES-TLR-CF-TRB23	5.10E-6	Lognormal	4.990E+0	TLR3	CCF 2 OF 3 TEMP TMU RELAYS IN TRAIN B ONE CHANNEL T&M
101	WES-TLR-CF-TRB34	1.52E-6	Lognormal	8.890E+0	TLR2	CCF 3 OF 4 TEMP TMU RELAYS IN TRAIN B NO CHANNEL T&M
102	WES-TLR-FC-PRATA	3.94E-5	Lognormal	3.000E+0	TLR1	CHANNEL A PRESSURE TMU RELAY IN TRAIN A FAILS
103	WES-TLR-FC-PRATB	3.94E-5	Lognormal	3.000E+0	TLR1	CHANNEL A PRESSURE TMU RELAY IN TRAIN B FAILS
104	WES-TLR-FC-PRBTA	3.94E-5	Lognormal	3.000E+0	TLR1	CHANNEL B PRESSURE TMU RELAY IN TRAIN A FAILS
105	WES-TLR-FC-PRBTB	3.94E-5	Lognormal	3.000E+0	TLR1	CHANNEL B PRESSURE TMU RELAY IN TRAIN B FAILS
106	WES-TLR-FC-PRCTA	3.94E-5	Lognormal	3.000E+0	TLR1	CHANNEL C PRESSURE TMU RELAY IN TRAIN A FAILS
107	WES-TLR-FC-PRCTB	3.94E-5	Lognormal	3.000E+0	TLR1	CHANNEL C PRESSURE TMU RELAY IN TRAIN B FAILS
108	WES-TLR-FC-PRDTA	3.94E-5	Lognormal	3.000E+0	TLR1	CHANNEL D PRESSURE TMU RELAY IN TRAIN A FAILS
109	WES-TLR-FC-PRDTB	3.94E-5	Lognormal	3.000E+0	TLR1	CHANNEL D PRESSURE TMU RELAY IN TRAIN B FAILS
110	WES-TLR-FC-RLYSA	3.94E-5	Lognormal	3.000E+0	TLR1	SHUNT TRIP RELAY SA FAILS
111	WES-TLR-FC-RLYSB	3.94E-5	Lognormal	3.000E+0	TLR1	SHUNT TRIP RELAY SB FAILS
112	WES-TLR-FC-TRATA	3.94E-5	Lognormal	3.000E+0	TLR1	CHANNEL A TEMPERATURE TMU RELAY IN TRAIN A FAILS
113	WES-TLR-FC-TRATB	3.94E-5	Lognormal	3.000E+0	TLR1	CHANNEL A TEMPERATURE TMU RELAY IN TRAIN B FAILS
114	WES-TLR-FC-TRBTA	3.94E-5	Lognormal	3.000E+0	TLR1	CHANNEL B TEMPERATURE TMU RELAY IN TRAIN A FAILS
115	WES-TLR-FC-TRBTB	3.94E-5	Lognormal	3.000E+0	TLR1	CHANNEL B TEMPERATURE TMU RELAY IN TRAIN B FAILS
116	WES-TLR-FC-TRCTA	3.94E-5	Lognormal	3.000E+0	TLR1	CHANNEL C TEMPERATURE TMU RELAY IN TRAIN A FAILS
117	WES-TLR-FC-TRCTB	3.94E-5	Lognormal	3.000E+0	TLR1	CHANNEL C TEMPERATURE TMU RELAY IN TRAIN B FAILS
118	WES-TLR-FC-TRDTA	3.94E-5	Lognormal	3.000E+0	TLR1	CHANNEL D TEMPERATURE TMU RELAY IN TRAIN A FAILS
119	WES-TLR-FC-TRDTB	3.94E-5	Lognormal	3.000E+0	TLR1	CHANNEL D TEMPERATURE TMU RELAY IN TRAIN B FAILS
120	WES-UVL-CF-UVDAB	1.04E-5	Lognormal	7.490E+0	-	CCF UV DRIVERS TRAINS A AND B (2 OF 2)
121	WES-UVL-FF-UVDA	3.37E-4	Lognormal	2.600E+0	UVL1	TRAIN A UV DRIVER FAILS
122	WES-UVL-FF-UVDB	3.37E-4	Lognormal	2.600E+0	UVL1	TRAIN B UV DRIVER FAILS
123	WES-XHE-XE-NSGNL	1.00E+0	-	-	-	OPERATOR FAILS TO RESPOND WITH NO RPS SIGNAL PRESENT
	WES-XHE-XE-NSGNL	5.00E-1	Lognormal	2.000E+0	-	OPERATOR FAILS TO RESPOND WITH NO RPS SIGNAL PRESENT
124	WES-XHE-XE-SIGNL	1.00E+0	-	-	-	OPERATOR FAILS TO RESPOND WITH RPS SIGNAL PRESENT
	WES-XHE-XE-SIGNL	1.00E-2	Lognormal	1.000E+1	-	OPERATOR FAILS TO RESPOND WITH RPS SIGNAL PRESENT

a. The uncertainty (Uncert.) value is the parameter that is used to describe the uncertainty distribution for the associated basic event. The lognormal and uniform distributions are the only two distributions used for the RPS basic events. The lognormal distribution is described by the mean and the upper 95% error factor. The uniform distribution is described by the mid point (mean probability) and the upper endpoint (Uncert. Value).

Appendix G

Sensitivity Analysis

Sensitivity analyses were performed on the Westinghouse RPS in the areas of CCF modeling and quantification, component independent failure rates, and channel modeling. For CCF modeling and quantification, three issues were addressed: choice of prior distribution for CCF calculations, including or excluding certain CCF events, and the failure criterion for rods segment of the RPS. The prior used in the CCF calculations was generated from all of the Westinghouse RPS CCF data collected for the period 1984 through 1995. An alternative approach to calculating CCF event probabilities is to not use a prior when calculating component-specific probabilities. This approach is termed the classical approach to CCF parameter estimation. Details of both approaches are presented in Appendix E. The classical approach relies solely on the available Westinghouse CCF data for the component in question. This method generally results in lower CCF event probabilities; however, it is very sensitive to the exclusion or inclusion of specific CCF data for components with few or no CCF data. Also, such an approach predicts a zero probability of a CCF event if no data exist for the period 1984 through 1995. Westinghouse RPS fault tree quantification using the classical CCF event probabilities resulted in an RPS unavailability of 1.4E-6 for the Analog Series 7300 design, compared with the base case result of 2.2E-5. For the Eagle-21 design, the classical CCF result is 1.2E-6, compared with the base case result of 2.0E-5.

The data analysis for the undervoltage driver card indicated that failure data obtained while a plant is at power are different from failure data obtained while a plant is down. When such a difference was seen in the data analysis, the approach was to use the data obtained while the plants are at power. This approach was taken because additional maintenance activities may be causing component failures that would not occur while the plants are at power. The only potential undervoltage driver card CCF occurred while a plant was shut down. This CCF event occurred in 1989. Maintenance activities resulted in shorting out both undervoltage driver cards. However, the failures were detected before the plant returned to power. Therefore, this CCF event was not included in the RPS quantification. As a sensitivity case, the Westinghouse RPS fault tree was requantified using this CCF event. For the Analog Series 7300 design, the RPS unavailability increased from 2.2E-5 to 3.5E-5 (62% increase), all because of an increase in the train failure contribution. For the Eagle-21 design, the RPS unavailability increased from 2.0E-5 to 3.3E-5 (69% increase).

The failure criterion for the rods segment of the Westinghouse RPS is the final CCF issue. The failure criterion assumed for this study is 10 or more RCCAs fail to insert fully into the core upon demand. CCF calculations outlined in Appendix E indicate that the rods segment contribution to the RPS unavailability ranges from 7.7E-6 for three or more of 50 RCCAs failing to insert to 9.4E-7 for 15 or more RCCAs failing to insert. The choice of 10 or more RCCAs failing to insert results in an unavailability contribution of 1.2E-6. If 15 or more out of 50 is chosen, then the Analog Series 7300 RPS unavailability drops from 2.2E-5 to 2.1E-5 (1% decrease). If the failure criterion of 3 or more out of 50 is chosen, then the RPS unavailability increases from 2.2E-5 to 2.8E-5 (30% increase). The percentage changes are similar for the Eagle-21 design.

The second category of sensitivity calculations involves the quantification of the component failure rates, or Q_T's (Table 2). Note that these failure rates also impact the CCF event probabilities. As discussed in Appendix A, the recommended Q_T's were obtained from a weighted average of the data in four of the nine possible data bins. One bin contains the events that are known to be non-fail safe with complete component failure. However, three of the other data bins might also contain such events, but incomplete knowledge results in uncertainty as to which specific events in these other three data bins are actually non-fail-safe and complete failures. Two sensitivity cases were analyzed to bound these failure rates. The lower bound used only the data in the NFS-CF bin (non-fail-safe, complete failures), while the upper bound used the data from all four data bins, weighted equally. Using only the lower bound data, the Analog Series 7300 RPS unavailability decreases from 2.2E-5 to 1.9E-5 (11% decrease). Using the upper bound data increased the RPS unavailability from 2.2E-5 to 2.6E-5 (19% increase). Again, the Eagle-21 results are similar.

An additional uncertainty in the channel component failure rates involves the estimated number of demands. The base case quantification assumed quarterly testing of the channel components during the entire period 1984 through 1995. However, is it not known when each Westinghouse plant switched from monthly testing to quarterly testing. Therefore, the RPS unavailablility was recalculated assuming monthly test demands for these components over the entire period. The resulting unavailability decreased from 2.1E-5 to 2.0E-5 (7% decrease). The Eagle-21 results are similar.

The final category of sensitivity calculations deals with the issue of modeling only two trip signals in the RPS fault tree. For most plant upset conditions requiring a scram, at least three trip signals are available. If three trip signals were to be included in the fault tree, then calculations of several of the CCF events would be impacted. Referring to Table 3 in the main body of this report, some of the logic cabinet (SSPS) TLC and TLR CCF events would change to higher order events; e.g., four of four changes to six of six for the TLC CCF. Also, in the channels, the CCX and CBI CCF events would change to higher order; e.g., nine of 12 rather than six of eight. The results of such changes on the RPS unavailability were estimated by recalculating the CCF event probabilities of the affected CCF events. Assuming three trip signals, the Analog Series 7300 RPS unavailability drops from 2.2E-5 to 1.9E-5 (13% decrease).

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11. ABSTRACT (200 words or less)
This report documents an analysis of the safety-related performance of the reactor protection system (RPS) at U.S. Westinghouse commercial reactors during the period 1984 through 1995. Westinghouse RPS designs analyzed in this report include those with solid state protection system trains and Analog Series 7300 or Eagle-21 channels. The analysis is based on a four-loop plant design. RPS operational data were collected for all U.S. Westinghouse commercial reactors from the Nuclear Plant Reliability Data System and Licensee Event Reports. A risk-based analysis was performed on the data to estimate the observed unavailability of the RPS, based on a fault tree model of the system. An engineering analysis of trends and patterns was also performed on the data to provide additional insights into RPS performance. RPS unavailability results obtained from the data were compared with existing unavailability estimates from Individual Plant Examinations and other reports.

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