B.8 LER No. 454/98-018

Event Description: Long-term unavailability (18 d) of an EDG

Date of Event: September 12, 1998

Plant: Byron Station, Unit 1

B.8.1 Event Summary

Byron Station, Unit 1 (Byron 1), had been in Mode 1 for 6 months following a refueling outage. During a monthly surveillance test on the 1A emergency diesel generator (EDG), the EDG tripped on a low lube oil pressure signal during the first minute of the test run. Personnel determined that the 1A EDG had been susceptible to tripping on a low lube oil pressure signal for at least 11 d until the EDG was repaired and tested satisfactorily. Because plant personnel could not precisely determine the actual failure point of the 1A EDG, for this analysis, the EDG was assumed to be unavailable for one-half of the 15-d interval between the last successful surveillance test and the point when the clogged strainers had the potential to be positively identified. Hence, this event was modeled as an 18-d (432 h) condition assessment with the 1A EDG failed. The core damage probability (CDP) at Byron 1 increased because of the increased susceptibility that would result from a loss of offsite power (LOOP) that progressed to a station blackout. The estimated increase in the CDP (i.e., the importance) for this event is 5.6×10^{-6}.

B.8.2 Event Description

On September 12, 1998, operators were starting the 1A EDG for the planned monthly surveillance test. The 1A EDG was started locally in the slow-start mode. The 1A EDG experienced a test-mode trip on an "engine lube oil pressure low" alarm during the first minute of the test run. Concurrent with this alarm were an "engine lube oil pressure low" alarm and a "turbo lube oil pressure low" alarm. An immediate inspection of the 1A EDG failed to reveal any leaks or obvious component failures; all piping components were in the correct configuration.[1]

Subsequent troubleshooting revealed that a fibrous material, consistent with that of the engine's main lube oil filter element medium, had clogged both lube oil strainers. The fibrous material was found to have covered the entire internal surface of the strainer element. An internal inspection of the lube oil filter housing unit showed that none of the filter elements had undergone a catastrophic failure. Regardless, the licensee decided to replace all 146 filter elements to perform a closer inspection of the removed elements. While replacing the filters, personnel noted that one filter element was missing its cartridge guide and many other filter elements were slightly crushed. A root-cause analysis determined that an inadequate maintenance practice was a factor in allowing a significant amount of unfiltered oil to bypass the filter elements and dislodge and transport the filter material to the lube oil strainers.[1]

B.8.3 Additional Event-Related Information

The lube oil circulating pump for each EDG runs continuously during standby conditions so that the internal engine parts remain lubricated. This facilitates a rapid start of the diesel engine. The EDGs at Byron are designed to trip on a low lube oil pressure condition when manually started or when the manual test mode switch is selected at the main control board. Although the 1A EDG should have successfully started in an emergency, the ability of the EDG to continue to perform its required function with a low lube oil pressure condition was questionable.[1]

No fibrous material was discovered in any other part of the 1A EDG lube oil system. Additionally, although no fibrous material was found in the lube oil filters on the turbocharger, the filters were replaced.[1]

The 1A EDG was returned to service on September 14, 1998. A review of the 1A EDG operating history revealed that the lube oil relief valve had lifted on September 3, 1998. The licensee subsequently determined that the relief valve had lifted because of the strainer blockage. Therefore, the 1A EDG was considered to be unavailable for at least 11 d—from September 3, 1998, until September 14, 1998, when the 1A EDG was returned to service. The licensee could not determine the actual point of failure before September 3, 1998. The last successful surveillance test on the 1A EDG was completed on August 19, 1998. Additionally, the 1A EDG operated without incident for ~12 h during a LOOP event on August 4, 1998.

The licensee verified that the 1B EDG was continually available between August 19, 1998, and September 14, 1998.[1]

B.8.4 Modeling Assumptions

After reviewing the 1A EDG records, the licensee considered the 1A EDG to be unavailable for the 11-day period between September 3, 1998, when the lube oil relief valve lifted, and September 14, 1998, when the EDG was returned to service. Because plant personnel could not precisely determine the actual failure point of the 1A EDG, for this analysis, the EDG was assumed to be unavailable for one-half of the 15-d interval between the last successful surveillance test (August 19, 1998) and the point when the clogged strainers had the potential to be positively identified (September 3, 1998). This 7.5-d window before the relief valve was noted to have lifted is in addition to the 11-d period that the 1A EDG was known to be failed. This results in a total unavailability of ~18.5 d. This event was modeled as an 18-d (432 h) condition assessment with the 1A EDG failed.

If the lube oil relief valve had not lifted and provided a reference failure point, the 1A EDG would have been presumed to be unavailable for half of the 26-d period since the last successful surveillance. A 13-d EDG unavailability was analyzed as a sensitivity study.

Because the ability to cross-tie the A and B emergency buses between Byron 1 and 2 exists, the EDGs from Unit 2 were added to the Integrated Reliability and Risk Analysis System (IRRAS) model for Unit 1. The probabilities that either of the opposite unit EDGs fails to start and run (basic events EPS-DGN-FC-2A and EPS-DGN-FC-2B) were set to the base probability of the Unit 1 EDGs (3.8×10^{-2}). The Byron/Braidwood Updated Final Safety Analysis Report indicates that a single EDG can provide sufficient ac power to safely shut down both units in

the event of a station blackout.[2] However, because operators must manually cross-tie the emergency buses between units, a basic event was added to reflect the probability that the operator fails to start and load the alternate EDG (basic event EPS-XHE-XM-OU). The probability for basic event EPS-XHE-XM-OU was set to 8.0×10^{-2} based on a human error analysis provided in the Byron individual plant examination (IPE).[3]

The common-cause failure probability of the emergency power system for the base case was revised to reflect the availability of four EDGs (two from each unit) and was developed using the data distributions contained in NUREG/CR-5497, *Common-Cause Failure Parameter Estimations* (Ref. 4, Table 5-9: alpha factor distribution summary – fail to start, CCCG = 4, $\alpha_{4S} = 0.0116$; and Table 5-12: alpha factor distribution summary – fail to run, CCCG = 4, $\alpha_{4R} = 0.0146$). Because α_4 is equivalent to the $\beta\gamma\delta$ factor of the multiple Greek letter (MGL) method used in the IRRAS models, the base case common-cause failure probability for four EDGs (basic event EPS-DGN-CF-ALL) is 4.6×10^{-4}.

LER No. 454/98-018 (p. 3) states that "other factors that contributed to the event were determined to be an inadequate maintenance procedure and inadequate maintenance practice." Both causes would transcend a single maintenance crew and the maintenance done on the 1A EDG was not presented as unique to just that EDG. Furthermore, crushed filter media degrades at variable rates. Therefore, the fact that this maintenance is not done simultaneously on multiple EDGs does not preclude this failure mechanism from simultaneously affecting more than one EDG. The common-cause failure probability for the EDGs is composed of failure to start and failure to run. The portion of the base case EDG common-cause failure probability for an engine to start was not altered because the low lube oil pressure trip is not in effect following an emergency start of an EDG. However, the portion of the base case EDG common-cause failure probability for failure to run for the mission time was adjusted based on the failure mechanism described. Because data specific to common-cause failures of the lube oil system was not available, aggregate EDG common-cause failure data were used in this analysis. However, it is not expected that this use of data introduces a significant error in the resulting estimate. Based on the failure of the 1A EDG with common-cause failure potential, basic event EPS-DGN-CF-ALL was adjusted for this event from 4.6×10^{-4} to 1.5×10^{-2} based on the MGL method (Ref. 4, Table 5-5 Summary of MGL Parameter Estimations – Fail to Run).

In the SBO sequences, the probabilities of a reactor coolant pump (RCP) seal loss-of-coolant accident (LOCA) and of failing to recover ac power at various points in time are calculated using a convolution approach that recognizes that all probabilities are a function of time. A Weibull distribution is used to predict the LOOP-related parameters applicable for Byron as defined in ORNL/NRC/LTR-89/11 (Ref. 5). Probabilities associated with the failure to recover ac power and the potential for an RCP seal LOCA are calculated given that ac power was not restored at specific points in time. Additionally, the probability for the operators' failure to restore emergency power is based on the assumption that the median repair time for an EDG is 4 h, as developed in NUREG-1032 (Ref. 6). The ac power non-recovery probabilities (typically valued at 0.8) in the Byron Integrated Reliability and Risk Analysis System (IRRAS) model are conditional probability values. These ac power non-recovery basic events represent the probability that an ac power source is not reestablished before core damage occurs *given* that power has not been restored at a particular reference point (i.e., battery failure or an RCP seal LOCA). Accounting for the conditional attributes of the ac power recovery basic events in the Byron IRRAS model, the 2-h and 8-h ac power non-recovery probability values can be approximated as 0.42 and 0.02, respectively, when

taken over the entire time interval. These values are not significantly different from the historically generated values used in the Byron PSA (0.32 and 0.03, respectively).

B.8.5 Analysis Results

The increase in the CDP (i.e., the importance) as the result of an 18-d failure of the 1A EDG with common-cause failure-to-run implications for this event is estimated to be 5.6×10^{-6}. The base probability over the same 18-d period (the CDP) for all sequences is 8.0×10^{-7}, resulting in a conditional core damage probability (CCDP) of 6.4×10^{-6}. As expected, station blackout (SBO) sequences dominate. The dominant core damage sequence for this event (Sequence 18 on Fig. B.8.1 and Sequence 18-9 on Fig. B.8.2) involves the following events:

- a LOOP,
- a successful reactor trip,
- a failure of the emergency power system,
- a successful initiation of auxiliary feedwater (AFW),
- successful control of reactor coolant system pressure such that the power-operated relief valves (PORVs) remain closed,
- a failure of the RCP seals, and
- a failure of the operators to restore ac power before core damage.

This sequence accounts for 24% of the total contribution to the increase in the CDP. A second SBO sequence where the RCP seals do not fail, but the operators fail to restore ac power before the batteries are depleted (Sequence 18-2), accounts for an additional 21% of the increase in the CDP. A third SBO sequence where the PORVs fail open accounts for 20% of the increase in the CDP (Sequence 18-20).

A sensitivity study on the length of time that the 1A EDG was unavailable was performed assuming the 1A EDG to be unavailable for just half of the 26-d surveillance period. Such a 13-d unavailability results in a calculated importance of 4.0×10^{-6}. This is similar to the importance calculated for the assumed 18-d unavailability. Therefore, the length of the unavailability does not significantly affect the importance calculation.

Definitions and probabilities for selected basic events are shown in Table B.8.1. The conditional probabilities associated with the highest probability sequences are shown in Table B.8.2. Table B.8.3 lists the sequence logic associated with the sequences listed in Table B.8.2. Table B.8.4 describes the system names associated with the dominant sequences. Minimal cut sets associated with the dominant sequences are shown in Table B.8.5.

B.8.6 References

1. LER 454/98-018, Rev. 0, "Inoperable Unit 1 Diesel Generator Due to Low Lube Oil Pressure Condition," October 9, 1998.

2. *ComEd Byron and Braidwood Stations Updated Final safety Analysis Report.*

3. *ComEd Byron and Braidwood Stations Individual Plant Examinations*, March 1997.

4. Marshall, Rasmuson, and Mosleh, *Common-Cause Failure Parameter Estimations*, NUREG/CR-5497, October 1998.

5. *Revised LOOP Recovery and PWR Seal LOCA Models*, ORNL/NRC/LTR-89/11, August 1989.

6. P. W. Baranowsky, *Evaluation of Station Blackout Accidents at Nuclear Power Plants*, NUREG-1032, U.S. Nuclear Regulatory Commission, June 1988.

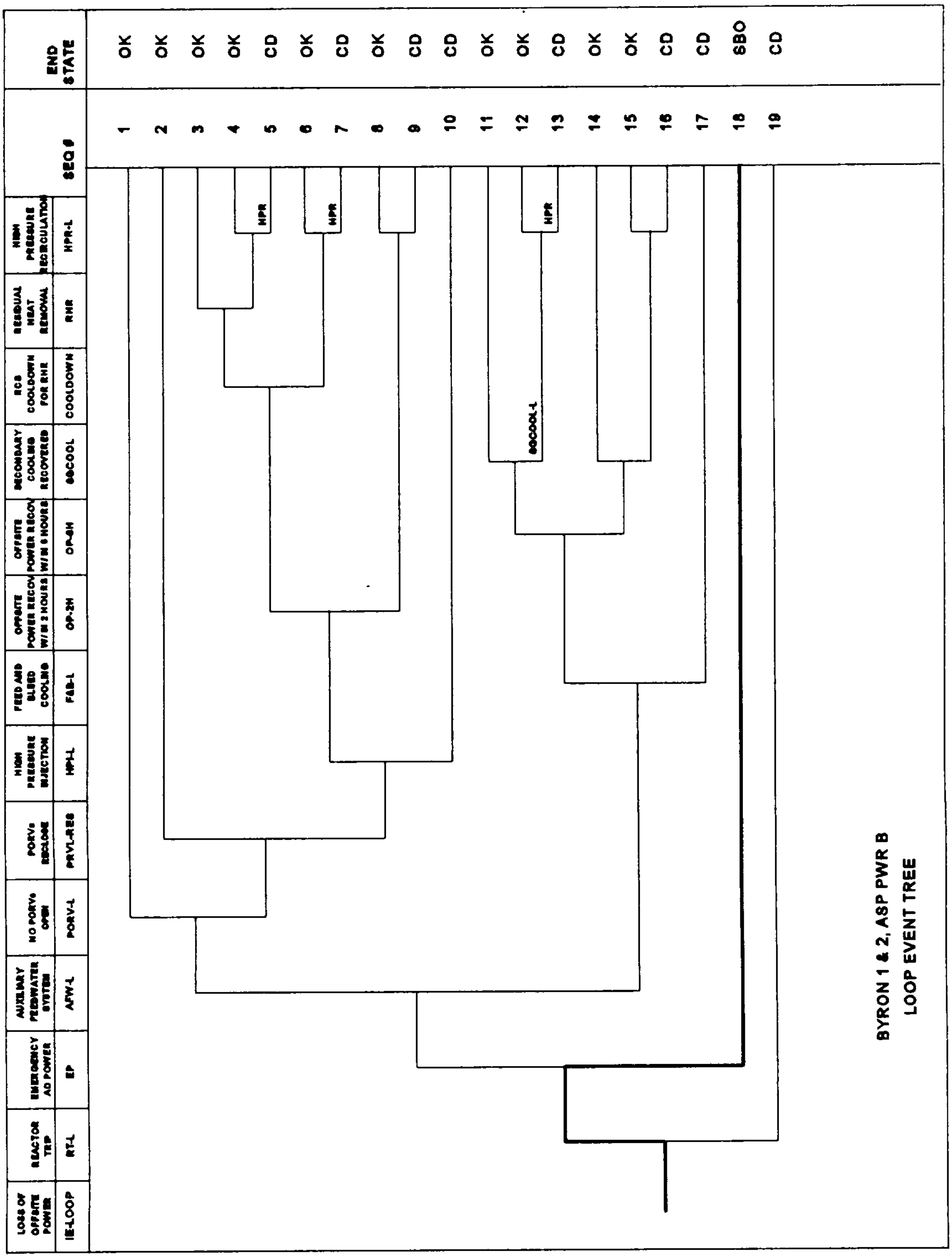

Fig. B.8.1. Dominant core damage sequence for LER No. 454/98-018.

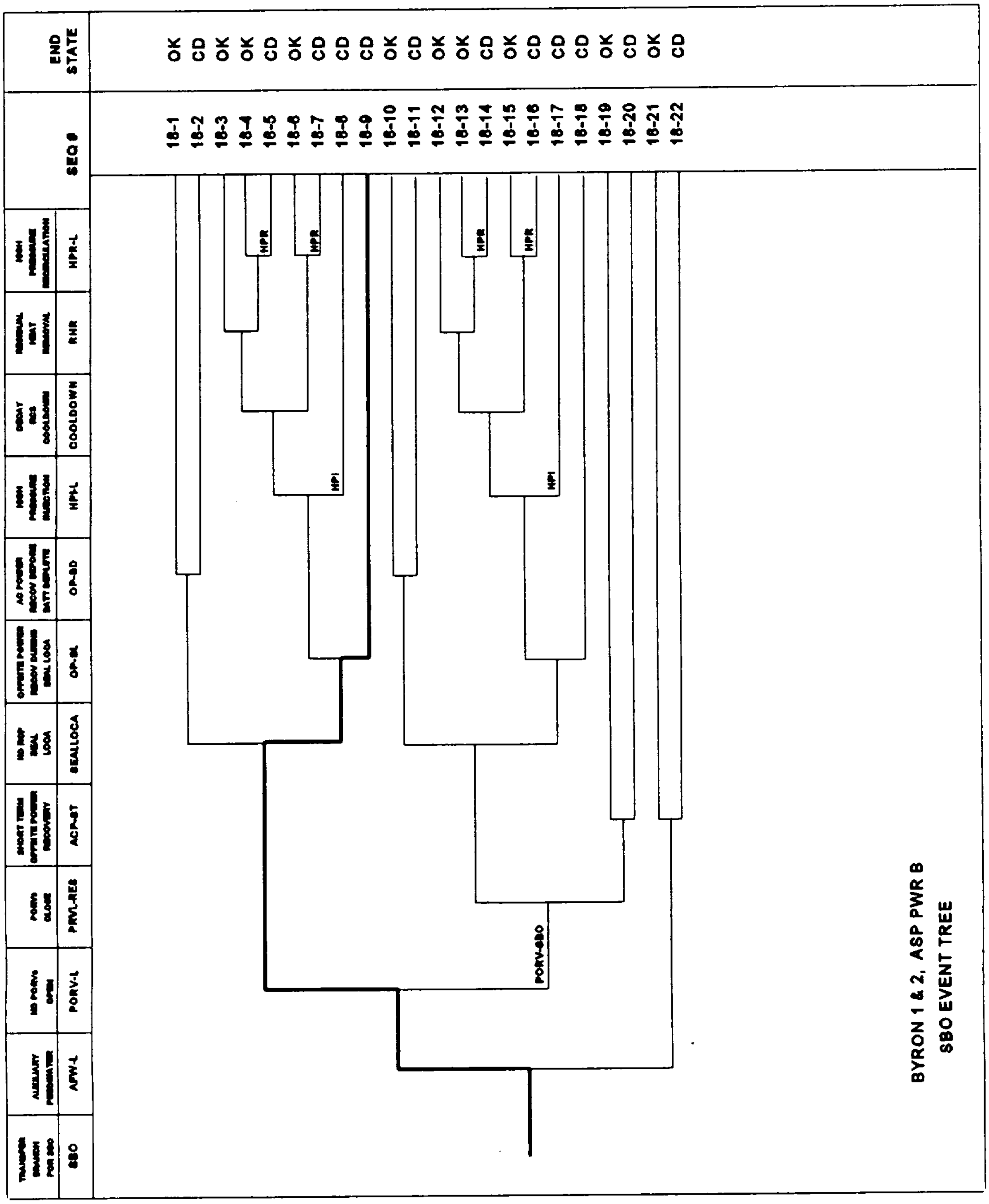

Fig. B.8.2. Dominant core damage sequence for LER No. 454/98-018.

Table B.8.1. Definitions and Probabilities for Selected Basic Events for LER No. 454/98-018

Event name	Description	Base probability	Current probability	Type	Modified for this event
IE-LOOP	Initiating Event–loss of offsite power (LOOP) (excludes the Probability of Recovering Offsite Power in the Short Term)	1.6 E-005	1.6 E-005		No
IE-SGTR	Initiating Event–Steam Generator Tube Rupture	1.6 E-006	1.6 E-006		No
IE-SLOCA	Initiating Event–Small-Break loss-of-coolant accident (LOCA)	2.3 E-006	2.3 E-006		No
IE-TRANS	Initiating Event–Transient	2.5 E-004	2.5 E-004		No
AFW-EDP-FC-1B	Auxiliary Feedwater (AFW) Diesel-Driven Pump Fails	2.0 E-002	2.0 E-002		No
AFW-MDP-FC-1A	AFW Motor-Driven Pump Fails	4.0 E-003	4.0 E-003		No
AFW-PMP-CF-ALL	Common-Cause Failure of AFW Pumps	2.1 E-004	2.1 E-004		No
EPS-DGN-CF-ALL	Common-Cause Failure of emergency diesel generators (EDGs)	4.6 E-004	1.5 E-002		Yes
EPS-DGN-FC-1A	EDG 1A Fails	3.8 E-002	1.0 E+000	TRUE	Yes
EPS-DGN-FC-1B	EDG 1B Fails	3.8 E-002	3.8 E-002		No
EPS-XHE-XM-OU	Operator Fails to Cross-Connect ESF Bus Without ac Power to Opposite Unit	8.0 E-002	8.0 E-002	NEW	No
HPI-MDP-CF-ALL	Common-Cause Failure of High-Pressure Injection (HPI) Pumps	7.8 E-004	7.8 E-004		No
HPI-MDP-FC-1B	HPI Motor-Driven Pump Fails	3.8 E-003	3.8 E-003		No
HPI-XHE-XM-FBL	Operator Fails to Initiate Feed-and-Bleed Cooling	1.0 E-002	1.0 E-002		No
LOOP-17-NREC	LOOP Sequence 17 Nonrecovery Probability – Failure to Recover AFW-L (0.26) and Feed-and-Bleed Cooling (0.8)	2.2 E-001	2.2 E-001		No

Table B.8.1. Definitions and Probabilities for Selected Basic Events for LER No. 454/98-018 (Continued)

Event name	Description	Base probability	Current probability	Type	Modified for this event
LOOP-18-02-NREC	LOOP Sequence 18-02 Nonrecovery Probability – Failure to Recover Electric Power (EP)	8.0 E-001	8.0 E-001		No
LOOP-18-11-NREC	LOOP Sequence 18-11 Nonrecovery Probability – Failure to Recover EP	8.0 E-001	8.0 E-001		No
LOOP-18-18-NREC	LOOP Sequence 18-18 Nonrecovery Probability – Failure to Recover EP	8.0 E-001	8.0 E-001		No
LOOP-18-20-NREC	LOOP Sequence 18-20 Nonrecovery Probability – Failure to Recover EP	8.0 E-001	8.0 E-001		No
LOOP-18-22-NREC	LOOP Sequence 18-22 Nonrecovery Probability – Failure to Recover EP (0.8) and AFW-L (0.34)	2.7 E-001	2.7 E-001		No
OEP-XHE-NOREC-BD	Operator Fails to Recover ac Power Before Battery Depletion	2.0 E-002	2.0 E-002		No
OEP-XHE-NOREC-SL	Operator Fails to Recover ac Power Before Core Damage Results From a Seal LOCA	6.3 E-001	6.3 E-001		No
OEP-XHE-NOREC-ST	Operator Fails to Recover ac Power in the Short Term	5.3 E-001	5.3 E-001		No
PPR-SRV-CC-PRV1	PORV 1 Fails to Open on Demand	6.3 E-003	6.3 E-003		No
PPR-SRV-CC-PRV2	PORV 2 Fails to Open on Demand	6.3 E-003	6.3 E-003		No
PPR-SRV-CO-SBO	Safety/Relief Valves Open During a Station Blackout (SBO)	3.7 E-001	3.7 E-001		No
PPR-SRV-OO-PRV1	PORV 1 Fails to Reseat	3.0 E-002	3.0 E-002		No
PPR-SRV-OO-PRV2	PORV 2 Fails to Reseat	3.0 E-002	3.0 E-002		No
RCS-MDP-LK-SEALS	Reactor Coolant Pump (RCP) Seals Fail without Cooling and Injection	3.5 E-002	3.5 E-002		No

Table B.8.2. Sequence Conditional Probabilities for LER No. 454/98-018

Event tree name	Sequence number	Conditional core damage probability (CCDP)	Core damage probability (CDP)	Importance (CCDP-CDP)	Percent contribution[a]
LOOP	18-09	1.4 E-006	4.4 E-008	1.3 E-006	24.1
LOOP	18-02	1.2 E-006	3.9 E-008	1.2 E-006	21.1
LOOP	18-20	1.2 E-006	3.8 E-008	1.1 E-006	20.4
LOOP	18-18	8.1 E-007	2.6 E-008	7.9 E-007	14.2
LOOP	18-11	7.1 E-007	2.3 E-008	6.9 E-007	12.4
LOOP	18-22	3.6 E-007	1.2 E-008	3.5 E-007	6.3
LOOP	17	7.8 E-008	1.4 E-008	6.4 E-008	1.1
Total (all sequences)		**6.4 E-006**	**8.0 E-007**	**5.6 E-006**	

[a]Percent contribution to the total importance.

Table B.8.3. Sequence Logic for Dominant Sequences for LER No. 454/98-018

Event tree name	Sequence number	Logic
LOOP	18-09	/RT-L, EP, /AFW-L, /PORV-SBO, SEALLOCA, OP-SL
LOOP	18-02	/RT-L, EP, /AFW-L, /PORV-SBO, /SEALLOCA, OP-BD
LOOP	18-20	/RT-L, EP, /AFW-L, PORV-SBO, PRVL-RES, ACP-ST
LOOP	18-18	/RT-L, EP, /AFW-L, PORV-SBO, /PRVL-RES, SEALLOCA, OP-SL
LOOP	18-11	/RT-L, EP, /AFW-L, PORV-SBO, /PRVL-RES, /SEALLOCA, OP-BD
LOOP	18-22	/RT-L, EP, AFW-L, ACP-ST
LOOP	17	/RT-L, /EP, AFW-L, F&B-L

Table B.8.4. System Names for LER No. 454/98-018

System name	Logic
ACP-ST	Offsite Power Recovered in Short Term
AFW-L	No or Insufficient AFW System Flow During LOOP
EP	Emergency Power System Fails
F&B-L	Failure to Provide Feed and Bleed Cooling
OP-BD	Operator Fails to Recover ac Power Before Battery Depletion
OP-SL	Operator Fails to Recover ac Power Before Core Damage Results Following an RCP Seal LOCA
PORV-SBO	PORVs Open During an SBO
PRVL-RES	PORVs and Block Valves Fail to Reclose
RT-L	Reactor Fails to Trip During a LOOP
SEALLOCA	RCP Seals Fail During a LOOP

Table B.8.5. Conditional Cut Sets for Higher Probability Sequences for LER No. 454/98-018

Cut set number	Percent contribution	CCDP[a]	Cut sets[b]
LOOP Sequence 18-09		1.4 E-006	
1	83.1	1.1 E-006	EPS-DGN-CF-ALL, /PPR-SRV-CO-SBO, RCS-MDP-LK-SEALS, OEP-XHE-NOREC-SL, LOOP-18-09-NREC
2	16.8	2.3 E-007	EPS-DGN-FC-1A, EPS-DGN-FC-1B, EPS-XHE-XM-OU, /PPR-SRV-CO-SBO, RCS-MDP-LK-SEALS, OEP-XHE-NOREC-SL, LOOP-18-09-NREC
LOOP Sequence 18-02		1.2 E-006	
1	83.1	1.0 E-006	EPS-DGN-CF-ALL, /PPR-SRV-CO-SBO, /RCS-MDP-LK-SEALS, OEP-XHE-NOREC-BD, LOOP-18-02-NREC
2	16.8	2.0 E-007	EPS-DGN-FC-1A, EPS-DGN-FC-1B, EPS-XHE-XM-OU, /PPR-SRV-CO-SBO, /RCS-MDP-LK-SEALS, OEP-XHE-NOREC-BD, LOOP-18-02-NREC
LOOP Sequence 18-20		1.2 E-006	
1	41.6	4.9 E-007	EPS-DGN-CF-ALL, PPR-SRV-CO-SBO, PPR-SRV-OO-PRV1, OEP-XHE-NOREC-ST, LOOP-18-20-NREC
2	41.6	4.9 E-007	EPS-DGN-CF-ALL, PPR-SRV-CO-SBO, PPR-SRV-OO-PRV2, OEP-XHE-NOREC-ST, LOOP-18-20-NREC
3	8.4	9.9 E-008	EPS-DGN-FC-1A, EPS-DGN-FC-1B, EPS-XHE-XM-OU, PPR-SRV-CO-SBO, PPR-SRV-OO-PRV2, OEP-XHE-NOREC-ST, LOOP-18-20-NREC
4	8.4	9.9 E-008	EPS-DGN-FC-1A, EPS-DGN-FC-1B, EPS-XHE-XM-OU, PPR-SRV-CO-SBO, PPR-SRV-OO-PRV2, OEP-XHE-NOREC-ST, LOOP-18-20-NREC
LOOP Sequence 18-18		8.1 E-007	
1	83.1	6.7 E-007	EPS-DGN-CF-ALL, PPR-SRV-CO-SBO, RCS-MDP-LK-SEALS, OEP-XHE-NOREC-SL, LOOP-18-18-NREC
2	16.8	1.4 E-007	EPS-DGN-FC-1A, EPS-DGN-FC-1B, EPS-XHE-XM-OU, PPR-SRV-CO-SBO, RCS-MDP-LK-SEALS, OEP-XHE-NOREC-SL, LOOP-18-18-NREC

Table B.8.5. Conditional Cut Sets for Higher Probability Sequences for LER No. 454/98-018 (continued)

Cut set number	Percent contribution	CCDP[a]	Cut sets[b]
LOOP Sequence 18-11		7.1 E-007	
1	83.1	5.9 E-007	EPS-DGN-CF-ALL, PPR-SRV-CO-SBO, /RCS-MDP-LK-SEALS, OEP-XHE-NOREC-BD, LOOP-18-11-NREC
2	16.8	1.2 E-007	EPS-DGN-FC-1A, EPS-DGN-FC-1B, EPS-XHE-XM-OU, PPR-SRV-CO-SBO, /RCS-MDP-LK-SEALS, OEP-XHE-NOREC-BD, LOOP-18-11-NREC
LOOP Sequence 18-22		3.6 E-007	
1	82.1	3.0 E-007	EPS-DGN-CF-ALL, AFW-EDP-FC-1B, OEP-XHE-NOREC-ST, LOOP-18-22-NREC
2	16.6	6.0 E-008	EPS-DGN-FC-1A, EPS-DGN-FC-1B, EPS-XHE-XM-OU, AFW-EDP-FC-1B, OEP-XHE-NOREC-ST, LOOP-18-22-NREC
LOOP Sequence 17		7.8 E-008	
1	31.1	2.4 E-008	EPS-DGN-FC-1A, EPS-XHE-XM-OU, AFW-EDP-FC-1B, HPI-XHE-XM-FBL, LOOP-17-NREC
2	19.6	1.5 E-008	EPS-DGN-FC-1A, EPS-XHE-XM-OU, AFW-EDP-FC-1B, PPR-SRV-CC-PRV1, LOOP-17-NREC
3	19.6	1.5 E-008	EPS-DGN-FC-1A, EPS-XHE-XM-OU, AFW-EDP-FC-1B, PPR-SRV-CC-PRV2, LOOP-17-NREC
4	11.8	9.2 E-009	EPS-DGN-FC-1A, EPS-XHE-XM-OU, AFW-EDP-FC-1B, HPI-MDP-FC-1B, LOOP-17-NREC
5	4.1	3.2 E-009	AFW-PMP-CF-ALL, HPI-XHE-XM-FBL, LOOP-17-NREC
6	2.6	2.0 E-009	AFW-PMP-CF-ALL, PPR-SRV-CC-PRV1, LOOP-17-NREC
7	2.6	2.0 E-009	AFW-PMP-CF-ALL, PPR-SRV-CC-PRV2, LOOP-17-NREC
8	2.4	1.9 E-009	EPS-DGN-FC-1A, EPS-XHE-XM-OU, AFW-EDP-FC-1B, HPI-MDP-CF-ALL, LOOP-17-NREC
9	1.6	1.2 E-009	AFW-EDP-FC-1B, AFW-MDP-FC-1A, HPI-XHE-XM-FBL, LOOP-17-NREC
Total (all sequences)		**6.4 E-006**	

[a]The change in conditional probability (importance) is determined by calculating the conditional probability for the period in which the condition existed and subtracting the conditional probability for the same period but with plant equipment assumed to be operating nominally. The conditional probability for each cut set within a sequence is determined by multiplying the probability that the portion of the sequence that makes the precursor visible (e.g., the system with a failure is demanded) will occur during the duration of the event by the probabilities of the remaining basic events in the minimal cut set. This can be approximated by $1 - e^{-p}$, where p is determined by multiplying the expected number of initiators that occur during the duration of the event by the probabilities of the basic events in that minimal cut set. The expected number of initiators is given by λt, where λ is the frequency of the initiating event (given on a per-hour basis) and t is the duration time of the event. This approximation is conservative for precursors made visible by the initiating event. The frequencies of interest for this event are $\lambda_{TRANS} = 2.5 \times 10^{-4}$/h, $\lambda_{LOOP} = 1.6 \times 10^{-5}$/h, $\lambda_{SLOCA} = 2.3 \times 10^{-6}$/h, and $\lambda_{SGTR} = 1.6 \times 10^{-6}$/h. The duration time for this event is 432 h.

[b]Basic event, EPS-DGN-FC-1A, is a TRUE type event that is not normally included in the output of fault tree reduction programs but has been added to aid in understanding the sequences to potential core damage associated with the event.