

Final Precursor Analysis

Accident Sequence Precursor Program – Office of Nuclear Regulatory Research

Calvert Cliffs, Unit 2	Reactor Trip Due to a Partial Loss Offsite Power with a Subsequent Loss of Condenser Heat Sink and the Failure of an Emergency Diesel Generator.	
Event Date: 02/18/2010	LER: 318/10-001-01 IR: 50-318/10-06	CCDP = 2×10^{-5}

EVENT SUMMARY

Brief Event Description. On February 18, 2010, at 0824, ground over-current relay 2RY251 G/B-22-2 failed to actuate as designed, permitting the Unit 1 ground over-current condition to reach the associated 500kV/13kV transformer [P-13000-2]. Ground O/C protection for the P-13000-2 transformer actuated which deenergized the 500kV "Red Bus" offsite power supply, the Bus 22, and all four Unit 2 reactor coolant pumps (RCPs). The Unit 2 reactor automatically tripped from full reactor power in response to the associated reactor protection system trip on reactor coolant system (RCS) low flow. The P-13000-2 isolation also deenergized the 13 kV Bus 21, which deenergized the Unit 2 Safety Bus 24, and several Unit 2 non-safety 4 kV buses. Emergency Diesel Generator (EDG) 2B started, but tripped 15 seconds later due to a low lube oil pressure signal and Bus 24 remained deenergized.

At 0848, Unit 2 operators exited *Emergency Operating Procedure (EOP)-0, Reactor Trip* and entered *EOP-2, Loss of Flow and Loss of Offsite Power*. At 0857, operators reenergized the Bus 24 via the alternate feeder breaker. At 0900, Unit 2 operators restored RCS letdown and maintained appropriate pressurizer level control. At 1117, Unit 2 operators started the motor-driven Auxiliary Feedwater (AFW) Pump 23 and secured the turbine-driven AFW pump. At 1118, Unit 2 operators exited the EOPs and returned to normal operating procedures. At 1713, Unit 2 operators started RCPs 21B and 22A to restore forced RCS circulation.

On February 19, 2010, at 1205, operators verified two offsite power supplies were available, with the 13 kV Bus 21 energized from an alternate offsite source. On February 20, 2010, at 2231, repairs on EDG 2B were completed and the diesel generator was declared operable. On February 19, 2010, at 1205, operators verified two offsite power supplies were available. At 0538 on February 21, 2010, the 500kV "Red Bus" was restored at 0550. Unit 2 achieved cold shutdown at 0500 on February 22, 2010. Additional details are provided in References 1 and 2.

Key Event Details. The following event details are significant to the modeling of this event analysis:

- Loss of power to the Unit 2 non-safety related buses resulted in loss of the normal RCS heat removal path (i.e., main feedwater pumps, circulating water pumps, and condenser). Operators used the turbine driven auxiliary feedwater pump and atmospheric steam dump valves for decay heat removal.
- EDG 2B started, but tripped 15 seconds later due to a low lube oil pressure signal (due to a failed relay) and Bus 24 remained deenergized for approximately 33 minutes by

aligning power from Alternate Feeder Breaker 152-2414. EDG 2B was repaired and declared operable on February 20th at 2231.

ANALYSIS RESULTS

Change in Core Damage Probability. The calculated conditional core damage probability (CCDP) for this event is 1.8×10^{-5} .

The Accident Sequence Precursor (ASP) Program acceptance threshold is a CCDP of 1×10^{-6} or the CCDP equivalent of an uncomplicated reactor trip with a non-recoverable loss of secondary plant systems (e.g., feedwater and condensate), whichever is greater. This CCDP equivalent for Calvert Cliffs, Unit 2 is 1.5×10^{-5} .

Dominant Sequence. The dominant accident sequence for is Loss of Condenser Heat Sink (LOCHS) Sequence 14 which contributes 81% of the total internal events CCDP. Additional sequences that contribute greater than 1% of the total internal events CCDP are provided in Appendix A.

The dominant sequence is shown graphically in Figures B-1 in Appendix B. The events and important component failures in LOCHS Sequence 14 are:

- Loss of condenser heat sink transient occurs,
- Reactor trip succeeds,
- Steam generator cooling fails (AFW or MFW), and
- Once-through cooling (OTC) fails.

SAPHIRE 8 Report. The SAPHIRE 8 Worksheets (Appendix A) provide the following:

- Summary of conditional event changes, including base and change case probabilities/frequencies.
- Event tree dominant results
- Dominant sequences (including CCDPs).
- Sequence logic for all dominant sequences.
- Referenced fault trees (including definitions).
- Cutset report for each dominant sequence.
- Referenced events (including definitions and probabilities for key basic events)

MODELING ASSUMPTIONS

Analysis Type. The Revision 8.15 of the Calvert Cliffs, Unit 2 SPAR model (dated July 2010) was used for the analysis of this initiating event.

Analysis Rules. The ASP program uses Significance Determination Process results for degraded conditions when available. However, the ASP Program performs independent initiating event analysis when an initiator occurs.

Fault Tree Modifications. The following fault tree modifications were necessary to perform this event analysis:

- A new 'AND' gate and 'OR' were added to fault tree ACP-BUS-24 (*4kV Bus 24 fails*). The new 'AND' gate ACP-BUS24-ALL (*Offsite power to Bus 24 fails*) was added below gate ACP-BUS24-1 (*Loss of power to 4160kV Bus 24*). The 'OR' gate ACP-BUS-24-3 (*Loss of offsite power to 4kV Bus 24*) [and its associated events] was moved under this new 'AND' gate. In addition, a new 'OR' gate ACP-BUS24-ALT (*Alternate power to Bus 24 is unavailable*) was added under gate ACP-BUS24-ALL. A new basic event ACP-XHE-BUS24-RECOVERY (*Operators fail to recover offsite power to Bus 24*) was added to account for potential recovery of offsite power to Safety Bus 24. Along with this new basic event, a transfer gate ACP-13kVBUS-11 (*13kV Service Bus 11 fails*) was also added. See Figure B-2 in Appendix B for the modified fault tree.
- A new flag event was added to the fault tree LOSC (*Loss of RCP seal cooling*). The current logic was moved under a new 'OR' gate LOSC5 and the new flag event FLAG-LOSC (*Flag Event- Loss of seal cooling*) was inserted under the top event LOSC (*RCP seal integrity maintained*). See Figure B-3 in Appendix B for the modified fault tree.
 - This fault tree change (along with the following event tree post-processing rule) eliminates the potential credit for offsite power recovery to Safety Bus 24 during loss of RCP seal cooling sequences.


```
if FLAG-LOSC then
  DeleteEvent = ACP-XHE-BUS24-RECOVERY;
  AddEvent = ACP-XHE-BUS24-RECOVERY1;
endif
```

Key Modeling Assumptions. The following modeling assumptions and associated basic event modifications were required for this event analysis:

- The initiating event was modeled as loss condenser heat sink because the loss of power to the Unit 2 non-safety related buses resulted in loss of the normal RCS heat removal path (i.e., main feedwater pumps, circulating water pumps, and condenser).
 - The frequency of IE-LOCHS (*Initiating Event- Loss of Condenser Heat Sink*) was set to 1.0; all other initiating event frequencies were set to zero.
- Offsite power was lost to Safety Bus 24; the potential for recovery was credited. During the event, operators successfully recovered offsite power to Bus 24 in 33 minutes by closing Alternate Feeder Breaker 152-2414 (power is supplied to Bus 24 from the "Black" Bus through Service Transformer P-130000-1 and 13KV Service Bus 11).
 - The basic event was set ACP-BAC-LP-500KVR (*500 kV Red Bus Fails*) to TRUE to model the loss of offsite power to Safety Bus 24.
 - The basic event ACP-XHE-BUS24-RECOVERY was set to 5.0×10^{-3} . This value was calculated using the SPAR-H Method (Reference 3).
 - This human failure event contains both diagnosis and action activities. Since operators would have enough time to perform the action, the nominal action human error probability of 1×10^{-3} was applied.
 - The following performance shaping factors (PSFs) were adjusted. All other PSFs were determined to be *Nominal* (i.e., $\times 1$).

PSF for Diagnosis	Multiplier	Notes
Time Available	0.1	For the dominant and most time limiting sequence (LOCHS Sequence 14), approximately one hour is available for operators to restore offsite power to Safety Bus 24. With only Alternate Feeder Breaker 152-2414 needing to be shut to restore offsite power to Safety Bus 24, the action portion time for recovery of offsite power to a vital bus is minimal (< 5 minutes). Therefore, operators would have approximately 55 minutes to diagnose and go through the procedures. Thus, the diagnosis time available PSF was set to <i>Extra Time</i> (i.e., ×0.1).
Stress	2	The PSF for diagnosis stress is assigned a value of <i>High Stress</i> (i.e., ×2) because the failure to recover the power to the Safety Bus 24 could lead directly to core damage during the postulated sequences.
Complexity	2	The PSF for diagnosis complexity is assigned a value of <i>Moderately Complex</i> (i.e., ×2) because operators would have to deal with multiple equipment unavailabilities and the concurrent actions/multiple procedures.

Diagnosis HEP	4E-3
Action HEP	1E-3
Adjusted Total HEP	5E-3

- The basic events FLAG-LOSC and ACP-XHE-BUS24-RECOVERY1 (*Operators fail to recover offsite power to Bus 24 during LOSC*) were set to TRUE because operators wouldn't have enough time to restore offsite power during a loss of RCP seal cooling to prevent seal failure (i.e., approximately 13 minutes).
- The basic event EPS-DGN-FS-2B (*Diesel Generator 2B fails to start*) was set to TRUE because EDG 2B failed to start.
 - To ensure that the common cause failure probabilities were calculated within SAPHIRE, the following basic events were modified as following:
 - The basic event EPS-DGN-FR-2B (*Diesel Generator 2B fails to run*) was set to 1.0.
 - The basic event EPS-DGN-TM-2B (*Diesel Generator 2B unavailable due to test and maintenance*) was set to TRUE.
- All other safety systems responded as designed.

REFERENCES

1. Calvert Cliffs Nuclear Power Plant, Unit 2, "LER 318/10-001-01– Reactor Trip Due to Failure of Protective Relay Circuitry," dated May 27, 2010.
2. U.S. Nuclear Regulatory Commission, "Calvert Cliffs Nuclear Plant – NRC Special Inspection Report 05000317/2010006 and 05000318/2010006; Preliminary White Finding", dated June 14, 2010.
3. Idaho National Laboratory, "NUREG/CR-6883: The SPAR-H Human Reliability Analysis Method," dated August 2005.

Appendix A: SAPHIRE 8 Worksheets

Summary of Conditional Event Changes

Event	Description	Cond. Value	Nominal Value
ACP-BAC-LP-500KVR	500 kV RED BUS FAILS	TRUE	9.600E-6
ACP-XHE-BUS24-RECOVERY	OPERATORS FAIL TO RECOVER OFFSITE POWER TO BUS 24	5.000E-3	0.000E+0
ACP-XHE-BUS24-RECOVERY1	OPERATORS FAIL TO RECOVER OFFSITE POWER TO BUS 24	TRUE	TRUE
EPS-DGN-FR-2B	DIESEL GENERATOR 2B FAILS TO RUN	1.000E+0	2.118E-2
EPS-DGN-FS-2B	DIESEL GENERATOR 2B FAILS TO START	TRUE	5.000E-3
EPS-DGN-TM-2B	DIESEL GENERATOR 2B UNAVAILABLE DUE TO T&M	TRUE	1.200E-2
FLAG-LOSC	FLAG EVENT- LOSS OF SEAL COOLING	TRUE	1.000E+0
IE-LOCHS	LOSS OF CONDENSER HEAT SINK ^a	1.000E+0	8.000E-2
EPS-DGN-CF-ALL5FS	CCF OF ALL FIVE DIESEL GENERATORS TO START	6.232E-4	3.116E-6
EPS-DGN-CF-2AB0CFS	CCF OF DIESEL GENERATOR 2A, 2B AND SBO TO START	3.722E-3	1.861E-5
EPS-DGN-CF-2AB0CFR	CCF OF DIESEL GENERATOR 2A, 2B AND SBO TO RUN	6.665E-4	1.214E-4
EPS-DGN-CF-2ABFR	COMMON CAUSE FAILURE OF UNIT 2 DIESEL GENERATORS TO RUN	2.118E-2	3.282E-4
EPS-DGN-CF-2ABFS	COMMON CAUSE FAILURE OF UNIT 2 DIESEL GENERATORS TO START	1.150E-2	5.750E-5
EPS-DGN-CF-ALL5FR	CCF OF ALL FIVE DIESEL GENERATORS TO RUN	0.000E+0	2.002E-5
EPS-DGN-CF-1B2ABFR	CCF OF FAIRBANKS MORRIS DIESEL GENERATORS 1B, 2A & 2B TO RUN	6.665E-4	1.214E-4
EPS-DGN-CF-1B2ABFS	CCF OF FAIRBANKS MORRIS DIESEL GENERATORS 1B, 2A, & 2B TO START	3.722E-3	1.861E-5
DGS-OOS	DGS IN T&M	TRUE	4.714E-2

a. All other initiating frequencies set to zero.

Dominant Sequence Results

Only items contributing at least 1.0% to the total CCDP are displayed.

<u>EVENT TREE</u>	<u>SEQUENCE</u>	<u>CCDP</u>	<u>% CONTRIBUTION</u>	<u>DESCRIPTION</u>
LOCHS	14	1.454E-5	81.1%	/RPS, SGC, OTC
LOCHS	02-9-4	2.105E-6	11.7%	/RPS, /SGC, /PORV, LOSC, RCPT, HPI
LOCHS	15-09	5.920E-7	3.3%	RPS, /RCSPRESS, /SGC-A, /BORATION, PORV-A, HPI
LOCHS	02-8-4	4.969E-7	2.8%	/RPS, /SGC, /PORV, LOSC, /RCPT, CBO, RSUB, RCPSI04, HPI
Total		1.793E-5	100.0%	

Referenced Fault Trees

Fault Tree	Description
CBO	CONTROLLED BLEEDOFF ISOLATED
HPI	HIGH PRESSURE INJECTION
LOSC	RCP SEAL INTEGRITY MAINTAINED
OTC	ONCE THROUGH COOLING

Fault Tree	Description
PORV-A	PORVs AND SRVs ARE CLOSED
RCPSI04	RCP SEALS FROM LOSS OF ALL COOLING
RCPT	REACTOR COOLANT PUMPS TRIPPED
RPS	REACTOR TRIP
RSUB	REACTOR COOLANT SUBCOOLING MAINTAINED
SGC	STEAM GENERATOR COOLING (AFW or MFW)

Cutset Report - LOCHS 14

Only items contributing at least 1% to the total are displayed.

#	CCDP	TOTAL%	CUTSET
	1.454E-5	100	Displaying 2753 of 2753 Cutsets.
1	1.200E-5	82.55	IE-LOCHS,AFW-XHE-XM-HXNORM,AFW-XHE-XM-UQ
2	1.000E-6	6.88	IE-LOCHS,AFW-XHE-XM-F33,AFW-XHE-XM-F3WS
3	1.768E-7	1.22	IE-LOCHS,AFW-PIP-RP-5BCMNPIPE2,MFW-XHE-XM-LF
4	1.728E-7	1.19	IE-LOCHS,ACP-INV-FC-2Y01A1,AFW-XHE-XM-HX,AFW-XHE-XM-UQ
5	1.728E-7	1.19	IE-LOCHS,ACP-INV-FC-2Y02A1,AFW-XHE-XM-HX,AFW-XHE-XM-UQ
6	1.728E-7	1.19	IE-LOCHS,ACP-INV-FC-1Y01A1,AFW-XHE-XM-HX,AFW-XHE-XM-UQ

Cutset Report - LOCHS 02-9-4

Only items contributing at least 1% to the total are displayed.

#	CCDP	TOTAL%	CUTSET
	2.105E-6	100	Displaying 258 of 258 Cutsets.
1	4.800E-7	22.8	IE-LOCHS,CCW-HX21STBY-22OP,CCW-XHE-XM-KBI,EPS-XHE-XE-DG0C45,RCP-XHE-XM-TRIP,SWS-FLAG-23SB22IS
2	1.798E-7	8.54	IE-LOCHS,CCW-23RUN-2221STBY,CCW-MDP-TM-21,CCW-P23-FACB,EPS-XHE-XE-DG0C45,RCP-XHE-XM-TRIP
3	1.798E-7	8.54	IE-LOCHS,CCW-22RUN-2321STBY,CCW-MDP-TM-21,CCW-P23-FACB,EPS-XHE-XE-DG0C45,RCP-XHE-XM-TRIP
4	1.200E-7	5.7	IE-LOCHS,CCW-HX21STBY-22OP,CCW-XHE-XM-KBI,EPS-XHE-XE-DG0C45,RCP-XHE-XM-TRIP,SWS-FLAG-22SB23IS
5	8.471E-8	4.02	IE-LOCHS,CCW-HX21STBY-22OP,CCW-XHE-XM-KBI,EPS-DGN-FR-DG0C,RCP-XHE-XM-TRIP,SWS-FLAG-23SB22IS
6	8.250E-8	3.92	IE-LOCHS,CCW-HX22STBY-21OP,CCW-XHE-XM-KBI,RCP-XHE-XM-TRIP,SWS-HDR-TM-21
7	8.250E-8	3.92	IE-LOCHS,CCW-HX21STBY-22OP,CCW-XHE-XM-KBI,RCP-XHE-XM-TRIP,SWS-HDR-TM-22
8	6.988E-8	3.32	IE-LOCHS,CCW-HX22STBY-21OP,EPS-DGN-FR-DG0C,RCP-XHE-XM-TRIP,SWS-FLAG-23SB22IS,SWS-HDR-TM-21
9	6.988E-8	3.32	IE-LOCHS,CCW-HX21STBY-22OP,EPS-DGN-FR-DG0C,RCP-XHE-XM-TRIP,SWS-FLAG-23SB22IS,SWS-HDR-TM-21
10	6.000E-8	2.85	IE-LOCHS,CCW-HTX-TM-21,CCW-HX21STBY-22OP,EPS-XHE-XE-DG0C45,RCP-XHE-XM-TRIP,SWS-FLAG-23SB22IS
11	4.800E-8	2.28	IE-LOCHS,CCW-HX21STBY-22OP,CCW-XHE-XM-KBI,EPS-DGN-TM-DG0C,RCP-XHE-XM-TRIP,SWS-FLAG-23SB22IS
12	3.960E-8	1.88	IE-LOCHS,CCW-HX22STBY-21OP,EPS-DGN-TM-DG0C,RCP-XHE-XM-TRIP,SWS-FLAG-23SB22IS,SWS-HDR-TM-21
13	3.960E-8	1.88	IE-LOCHS,CCW-HX21STBY-22OP,EPS-DGN-TM-DG0C,RCP-XHE-XM-TRIP,SWS-FLAG-23SB22IS,SWS-HDR-TM-21
14	3.173E-8	1.51	IE-LOCHS,CCW-23RUN-2221STBY,CCW-MDP-TM-21,CCW-P23-FACB,EPS-DGN-FR-DG0C,RCP-XHE-XM-TRIP

#	CCDP	TOTAL%	CUTSET
15	3.173E-8	1.51	IE-LOCHS,CCW-22RUN-2321STBY,CCW-MDP-TM-21,CCW-P23-FACB,EPS-DGN-FR-DG0C,RCP-XHE-XM-TRIP
16	2.400E-8	1.14	IE-LOCHS,CCW-HX21STBY-22OP,CCW-XHE-XR-HTX21,EPS-XHE-XE-DG0C45,RCP-XHE-XM-TRIP,SWS-FLAG-23SB22IS
17	2.118E-8	1.01	IE-LOCHS,CCW-HX21STBY-22OP,CCW-XHE-XM-KBI,EPS-DGN-FR-DG0C,RCP-XHE-XM-TRIP,SWS-FLAG-22SB23IS

Cutset Report - LOCHS 15-09

Only items contributing at least 1% to the total are displayed.

#	CCDP	TOTAL%	CUTSET
Total	5.920E-7	100	Displaying 8 of 8 Cutsets.
1	1.200E-7	20.27	IE-LOCHS,PPR-SRV-OO-2RV200LIQ,RPS-VCF-FO-MECH
2	1.200E-7	20.27	IE-LOCHS,PPR-SRV-OO-2RV201LIQ,RPS-VCF-FO-MECH
3	1.200E-7	20.27	IE-LOCHS,PPR-SRV-OO-2ERV404LIQ,RPS-VCF-FO-MECH
4	1.200E-7	20.27	IE-LOCHS,PPR-SRV-OO-2ERV402LIQ,RPS-VCF-FO-MECH
5	2.800E-8	4.73	IE-LOCHS,PPR-SRV-OO-2RV200LIQ,RPS-VCF-FO-ELEC,RPS-XHE-XM-SCRAM
6	2.800E-8	4.73	IE-LOCHS,PPR-SRV-OO-2RV201LIQ,RPS-VCF-FO-ELEC,RPS-XHE-XM-SCRAM
7	2.800E-8	4.73	IE-LOCHS,PPR-SRV-OO-2ERV404LIQ,RPS-VCF-FO-ELEC,RPS-XHE-XM-SCRAM
8	2.800E-8	4.73	IE-LOCHS,PPR-SRV-OO-2ERV402LIQ,RPS-VCF-FO-ELEC,RPS-XHE-XM-SCRAM

Cutset Report - LOCHS 02-8-4

Only items contributing at least 1% to the total are displayed.

#	CCDP	TOTAL%	CUTSET
	4.969E-7	100	Displaying 56 of 56 Cutsets.
1	1.219E-7	24.54	IE-LOCHS,CCW-HX21STBY-22OP,CCW-XHE-XM-KBI,EPS-XHE-XE-DG0C45,RCS-MDP-LK-SEALS04,SWS-FLAG-23SB22IS
2	4.567E-8	9.19	IE-LOCHS,CCW-23RUN-2221STBY,CCW-MDP-TM-21,CCW-P23-FACB,EPS-XHE-XE-DG0C45,RCS-MDP-LK-SEALS04
3	4.567E-8	9.19	IE-LOCHS,CCW-22RUN-2321STBY,CCW-MDP-TM-21,CCW-P23-FACB,EPS-XHE-XE-DG0C45,RCS-MDP-LK-SEALS04
4	3.048E-8	6.13	IE-LOCHS,CCW-HX21STBY-22OP,CCW-XHE-XM-KBI,EPS-XHE-XE-DG0C45,RCS-MDP-LK-SEALS04,SWS-FLAG-22SB23IS
5	2.152E-8	4.33	IE-LOCHS,CCW-HX21STBY-22OP,CCW-XHE-XM-KBI,EPS-DGN-FR-DG0C,RCS-MDP-LK-SEALS04,SWS-FLAG-23SB22IS
6	2.096E-8	4.22	IE-LOCHS,CCW-HX22STBY-21OP,CCW-XHE-XM-KBI,RCS-MDP-LK-SEALS04,SWS-HDR-TM-21
7	2.096E-8	4.22	IE-LOCHS,CCW-HX21STBY-22OP,CCW-XHE-XM-KBI,RCS-MDP-LK-SEALS04,SWS-HDR-TM-22
8	1.775E-8	3.57	IE-LOCHS,CCW-HX22STBY-21OP,EPS-DGN-FR-DG0C,RCS-MDP-LK-SEALS04,SWS-FLAG-23SB22IS,SWS-HDR-TM-21
9	1.775E-8	3.57	IE-LOCHS,CCW-HX21STBY-22OP,EPS-DGN-FR-DG0C,RCS-MDP-LK-SEALS04,SWS-FLAG-23SB22IS,SWS-HDR-TM-21
10	1.524E-8	3.07	IE-LOCHS,CCW-HTX-TM-21,CCW-HX21STBY-22OP,EPS-XHE-XE-DG0C45,RCS-MDP-LK-SEALS04,SWS-FLAG-23SB22IS
11	1.219E-8	2.45	IE-LOCHS,CCW-HX21STBY-22OP,CCW-XHE-XM-KBI,EPS-DGN-TM-DG0C,RCS-MDP-LK-SEALS04,SWS-FLAG-23SB22IS
12	1.006E-8	2.02	IE-LOCHS,CCW-HX22STBY-21OP,EPS-DGN-TM-DG0C,RCS-MDP-LK-SEALS04,SWS-FLAG-23SB22IS,SWS-HDR-TM-21

#	CCDP	TOTAL%	CUTSET
13	1.006E-8	2.02	IE-LOCHS,CCW-HX21STBY-22OP, EPS-DGN-TM-DG0C,RCS-MDP-LK-SEALS04,SWS-FLAG-23SB22IS,SWS-HDR-TM-21
14	8.060E-9	1.62	IE-LOCHS,CCW-23RUN-2221STBY,CCW-MDP-TM-21,CCW-P23-FACB, EPS-DGN-FR-DG0C,RCS-MDP-LK-SEALS04
15	8.060E-9	1.62	IE-LOCHS,CCW-22RUN-2321STBY,CCW-MDP-TM-21,CCW-P23-FACB, EPS-DGN-FR-DG0C,RCS-MDP-LK-SEALS04
16	6.096E-9	1.23	IE-LOCHS,CCW-HX21STBY-22OP,CCW-XHE-XR-HTX21, EPS-XHE-XE-DG0C45,RCS-MDP-LK-SEALS04,SWS-FLAG-23SB22IS
17	5.379E-9	1.08	IE-LOCHS,CCW-HX21STBY-22OP,CCW-XHE-XM-KBI, EPS-DGN-FR-DG0C,RCS-MDP-LK-SEALS04,SWS-FLAG-22SB23IS
18	5.080E-9	1.02	IE-LOCHS,CCW-HX21STBY-22OP,CCW-XHE-XM-KBI, EPS-DGN-FS-DG0C,RCS-MDP-LK-SEALS04,SWS-FLAG-23SB22IS
19	5.075E-9	1.02	IE-LOCHS,CCW-23RUN-2221STBY,CCW-MDP-FS-21,CCW-P23-FACB, EPS-XHE-XE-DG0C45,RCS-MDP-LK-SEALS04
20	5.075E-9	1.02	IE-LOCHS,CCW-22RUN-2321STBY,CCW-MDP-FS-21,CCW-P23-FACB, EPS-XHE-XE-DG0C45,RCS-MDP-LK-SEALS04

Referenced Events

Event	DESCRIPTION	Probability
ACP-INV-FC-1Y01A1	INVERTER 1Y01A-1 FAILS DURING OPERATION	1.200E-4
ACP-INV-FC-2Y01A1	INVERTER 2Y01A-1 FAILS DURING OPERATION	1.200E-4
ACP-INV-FC-2Y02A1	INVERTER 2Y02A-1 FAILS DURING OPERATION	1.200E-4
AFW-PIP-RP-5BCMNPIPE2	2PIPECOMMON AFW - COMMON DISCH HDR EARLY PIPE BREAK (PSA)	4.420E-6
AFW-XHE-XM-F33	OPERATIONS ALIGNS LONG TERM AFW ON PUMP CAVITATION WITH INDICATION AVAILABLE	1.000E-3
AFW-XHE-XM-F3WS	OPERATIONS FAILS TO ALIGN LONG TERM AFW WITH ALL INDICATION AVAILABLE	1.000E-3
AFW-XHE-XM-HX	OP FAILS TO CONTROL AFW FLOW - SPAR	1.200E-1
AFW-XHE-XM-HXNORM	OP FAILS TO CONTROL AFW FLOW - SPAR	1.000E-3
AFW-XHE-XM-UQ	OPS ERRONEOUSLY UNDERFILLS S/G DURING LOSS OF FLOW CONTROL	1.200E-2
CCW-22RUN-2321STBY	CCW MDP-22 RUNNING 23&21 IN STANDBY	3.330E-1
CCW-23RUN-2221STBY	CCW MDP-23 RUNNING 21&22 IN STANDBY	3.330E-1
CCW-HTX-TM-21	CCW HEAT EXCHANGER 21 IN T & M	2.500E-3
CCW-HX21STBY-22OP	CCW HTX-21 IN STANDBY CCW HTX-22 IN OPERATION	5.000E-1
CCW-HX22STBY-21OP	CCW HTX-22 IN STANDBY CCW HTX-21 IN OPERATION	5.000E-1
CCW-MDP-FS-21	FAILURE OF CCW MDP-21 TO START	2.000E-3
CCW-MDP-TM-21	CCW MDP-21 UNAVAILABLE DUE TO T & M	1.800E-2
CCW-P23-FACB	CCW PUMP 23 ELECTRICALLY ALIGNED TO FACILITY B	5.000E-1
CCW-XHE-XM-KBI	OPS FAILS TO PLACE STANDBY CCW HX IN SERVICE W/IN 10 MINUTES OF HX FAILURE PRIOR TO TRIP	2.000E-2
CCW-XHE-XR-HTX21	OPERATOR FAILS TO RESTORE CCW HTX-21 AFTER T & M	1.000E-3
EPS-DGN-FR-DG0C	SBO DIESEL GENERATOR DG0C FAILS TO RUN	2.118E-2
EPS-DGN-FS-DG0C	SBO DIESEL GENERATOR DG0C FAILS TO START	5.000E-3
EPS-DGN-TM-DG0C	SBO DIESEL GENERATOR DG0C UNAVAILABLE DUE TO T & M	1.200E-2
EPS-XHE-XE-DG0C45	OPERATIONS ALIGN THE 0C DG IN 45 MINS	1.200E-1
IE-LOCHS	LOSS OF CONDENSER HEAT SINK	1.000E+0
MFW-XHE-XM-LF	OPER ESTABLISHES MANUAL ADV CTRL AND INIT LOW PRESS FEED USING CONDENSATE WITHIN 45 MIN OF LOSS	4.000E-2

Event	DESCRIPTION	Probability
PPR-SRV-OO-2ERV402LIQ	2ERV 402 FAILS TO RECLOSE AFTER PASSING LIQUID	1.000E-1
PPR-SRV-OO-2ERV404LIQ	2ERV 2 FAILS TO RECLOSE AFTER PASSING LIQUID	1.000E-1
PPR-SRV-OO-2RV200LIQ	SRV 2RV-200 FAILS TO RECLOSE AFTER PASSING LIQUID	1.000E-1
PPR-SRV-OO-2RV201LIQ	SRV RV-201 FAILS TO RECLOSE AFTER PASSING LIQUID	1.000E-1
RCP-XHE-XM-TRIP	OPERATIONS FAILS TO TRIP THE RCPS WHEN THE CCW PUMPS WERE NOT AVAIL FOR RECOVERY - ASA - U2 TRIP NEOP8	5.000E-4
RCS-MDP-LK-SEALS04	RCP SEALS FAIL W/O COOLING AND INJECTION	1.270E-4
RPS-VCF-FO-ELEC	ELECTRICAL (UV & ST) RPS FAILURE TO OPEN TRIP CIRCUIT BREAKERS	1.400E-5
RPS-VCF-FO-MECH	CONTROL ROD ASSEMBLIES FAIL TO INSERT	1.200E-6
RPS-XHE-XM-SCRAM	OPS FAILS TO MANUALLY TRIP THE RX WITHIN 5 MINUTES FOLLOWING THE FAILURE OF RPS AND DSS	2.000E-2
SWS-FLAG-22SB23IS	SW PUMP 23 IN-SERVICE WITH 22 IN STAND-BY (PSA)	2.000E-1
SWS-FLAG-23SB22IS	SW PUMP22 IN-SERVICE WITH 23 IN STAND-BY (PSA)	8.000E-1
SWS-HDR-TM-21	SW HDR 21 IS UNAVAILABLE WHEN UNIT 1 IS AT-POWER (PSA)	1.650E-2
SWS-HDR-TM-22	SW HDR 22 IS UNAVAILABLE WHEN UNIT 2 IS AT-POWER (PSA)	1.650E-2

Appendix B: Key Event Tree and Modified Fault Trees

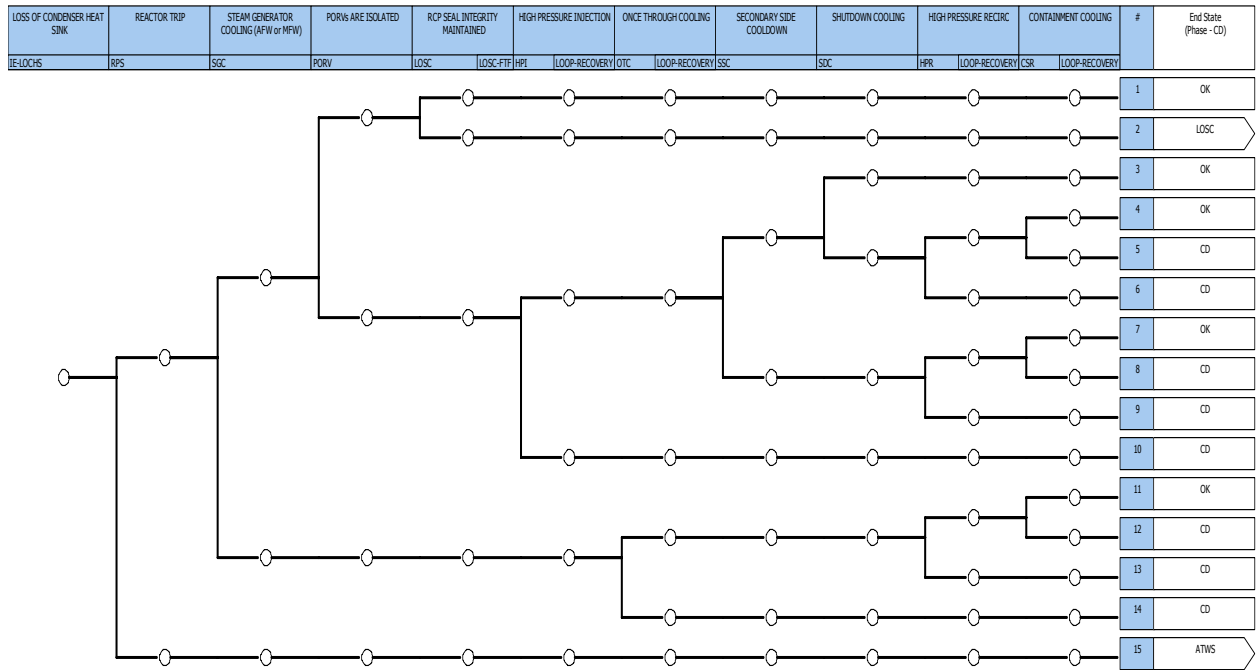


Figure B-1. Calvert Cliffs, Unit 2 LOCHS event tree.

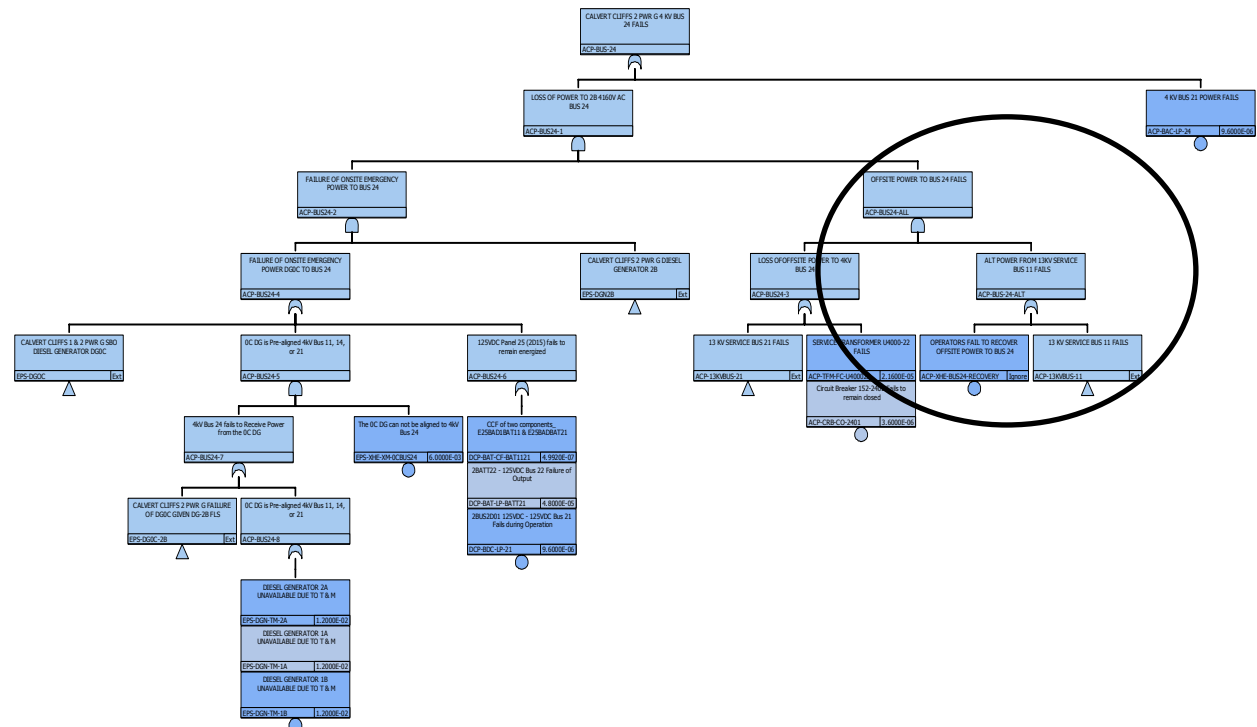


Figure B-2. Calvert Cliffs, Unit 2 modified ACP-BUS-24 fault tree.

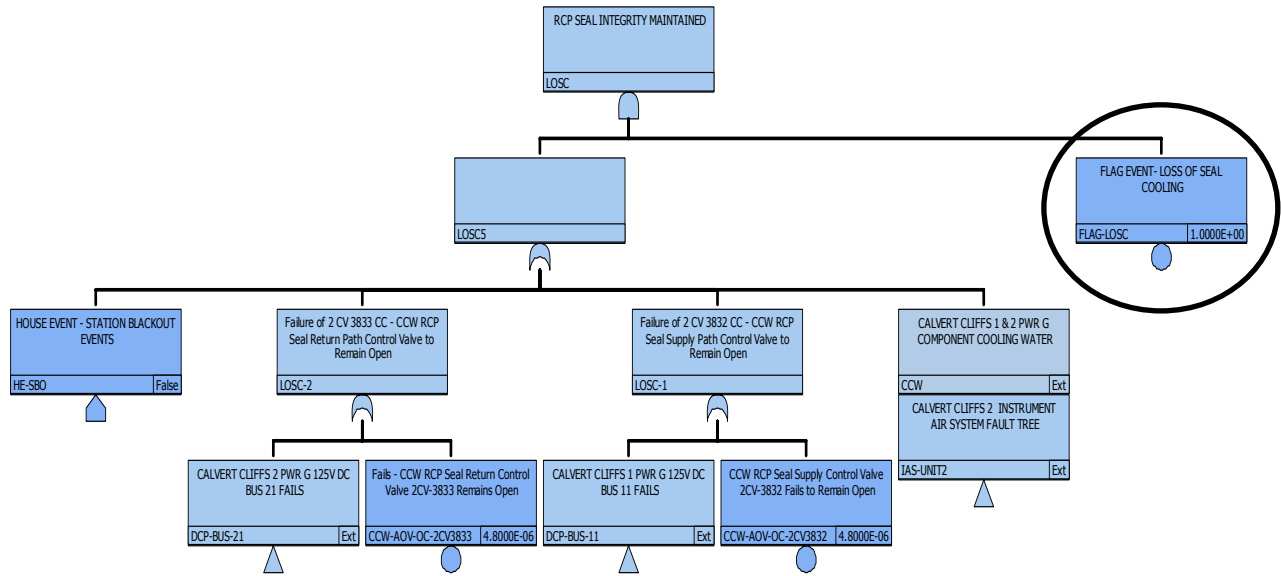


Figure B-3. Calvert Cliffs, Unit 2 modified LOSC fault tree.