Final Precursor Analysis

Accident Sequence Precursor Program --- Office of Nuclear Regulatory Research

Brunswick Steam Electric Plant, Unit 2	Emergency Diesel Generator No. 3 Condition Prohibited by the Technical Specifications	
Event Date: 01/04/2004	**LER:** 325/04-001	**ΔCDP =** 2×10^{-6}

Condition Summary

Operating condition. During a monthly surveillance test and maintenance on EDG turbo charger #3 on January 4, 2004, 2003, when Brunswick Steam Electric Plant (BSEP), Unit 2 was at power, a jacket water cooling system piping leak with an estimated flow rate of one gallon per minute was identified by the licensee. The licensee determined that the volume of the identified leak rendered EDG #3 inoperable due to insufficient jacket water cooling (Reference 1). The licensee corrected the EDG #3 inoperability problem on January 7, 2004 and declared it to be operable.

Region II, USNRC inspectors found that a violation of 10 CFR PART 50, Appendix B, Criterion XVI, "failure to provide prompt corrective actions ", and documented their findings in inspection report 324/2003-006 (Reference 2). Then, Office of Enforcement issued a final significance determination process (SDP) White finding letter (Reference 3) for the same operating condition.

Cause. The licensee conducted a inoperability determination review of EDG 3 due to jacket water cooling failure at Brunswick, Unit 2. This review indicated: 1. A jacket water system pipe coupling was improperly installed during a pipe coupling gasket replacement activity performed during a maintenance on February 3, 2003, and 2. Tightening of the improperly installed coupling on December 8, 2003, resulted in coupling leakage at a rate which impacted EDG 3 operability until the leak was identified on January 4, 2004. At BSEP, work management procedure required functional verification following minor maintenance on EDG turbo chargers. However, post-maintenance functional verification for EDG 3 was not performed on February 3, 2003.

Condition duration. The licensee determined that the inoperability period for EDG 3 existed between December 8, 2003 thru January 7, 2004. This period included the duration which was needed to fix the EDG 3 support hardware problems. Thus, a condition duration of 30 days (720 hours) was estimated for the precursor assessment purposes.

Related event. None.

Recovery opportunity. Given a loss of offsite power and other initiating events (e.g., loss of a single AC bus, Division 2 bus), EDG 3 would have failed due to failure of water jacket, and the failure-to-run would not have been recovered to Division 1 bus.

Other related conditions or events. USNRC inspection report 324/2004-003 documented a task interface agreement related to a unresolved safety issue at Brunswick, Unit 2 which existed prior to January 7, 2004. This issue involves a design deficiency related to transfer of High Pressure Coolant Injection (HPCI) system suction from the condensate storage tank (CST) to suppression pool after CST level drops to low level. Due to vortexing phenomenon, HPCI suction transfer to the suppression pool from the CST might not have occurred on demand. This suction transfer failure might not have been recoverable in a timely manner.

A review of the licensee-issued LERs during a one year period prior to the failure event date indicates that no other significant operating conditions existed.

Analysis Results

- **Importance**[1]

  The risk significance of the inoperable EDG #3 due to its jacket water cooling failure for a condition duration of 720 Hours was determined by subtracting the nominal core damage probability (point estimate) from the conditional core damage probability (point estimate):

  Conditional core damage probability (CCDP) = 2.7E-6
  Nominal core damage probability (CDP) = 4.0E-7
  Importance (ΔCDP = CCDP - CDP) = 2.3E-6

  The estimated importance (CCDP-CDP) for the operating condition was 2.3E-6.

  A uncertainty analysis was conducted for the operating condition. The mean estimates for CCDP, CDP, and importance were 2.5E-06, 4.2E-07, and 2.1E-06 respectively.

- **Dominant sequence**

  Loss of offsite power (LOOP) event followed by successful reactor scram, failures of the Emergency Power system in Unit 2, failure of 4160 V bus cross-tie from Unit 1, successful closure of safety relief valves, successful Reactor Core Isolation Cooling system, successful manual vessel depressurization, successful fire water injection, and failure of AC power recovery in 2 hours.

  Sequence LOOP 52-03; Importance was estimated to be 1.8E-6. The events and important component failures in this sequence were as follows:

  - Initiating event (LOOP)
  - Mitigating system failures and successes
    - successful reactor scram

[1] Since this condition did not involve an actual initiating event, the parameter of interest is the measure of the incremental change between the conditional probability for the period in which the condition existed and the nominal probability for the same period but with the condition nonexistent and plant equipment available. This incremental change or “importance” is determined by subtracting the CDP from the CCDP. This measure is used to assess the risk significance of hardware unavailabilities especially for those operating conditions where the nominal CDP is high with respect to the incremental change of the conditional probability caused by the hardware unavailability.

- failures of the Emergency Power system in Unit 2,
- failure of 4160 V bus cross-tie from Unit 1,
- successful closure of safety relief valves,
- successful Reactor Core Isolation Cooling system,
- successful manual vessel depressurization,
- successful fire water injection, and
- recovery failure of both offsite AC power and emergency AC power in 2 hours.

- Onset of potential core damage

Paths for dominant sequence LOOP 52-03 is shown Figures 1 and 2.

- **Results tables**

  – Table 1 provides the conditional probabilities for 2 dominant sequences.
  – Table 2a provides the event tree sequence logic for the dominant sequences listed in Table 1.
  – Table 2b provides the definitions of fault trees used in event tree logic listed in Table 2a.
  – Table 3 provides the conditional (CCDP) cut sets for 2 dominant sequences.
  – Table 4 provides the definitions and probabilities for added basic events and condition-affected basis events.

Modeling Assumptions

- **Assessment summary**

  Assessment type

  During a period of 30 days, EDG #3 turbo charger was inoperable due to jacket cooling water failure. No other safety system failures were found during this operating period. During this operating period (reactor at power), EDG #3 might have failed to run on demand in earlier time frame (less than 30 minutes) from the timing of a challenging initiative event. So, a condition assessment involving EDG #3 failure-to-run event was conducted.

  Condition modeling and related assumptions

  1. EDG #3 would have tripped due to jacket water cooling failure due to pipe coupling leak. This failure-to-run could not have been recovered since the jacket water cooling failure might not have been corrected by operators in a timely manner (less than 6 hour period).

  Model use - The Revision 3.11 Standardized Plant Analysis Risk (SPAR) model for Brunswick Steam Electric Plant (Reference 4) was used for this condition assessment.

- Model update to Revision 3.11 SPAR model for Brunswick Steam Electric Plant

  No model change was performed to Revision 3.11 SPAR model for Brunswick Steam Electric Plant (December 31, 2004).
- Basic event probability changes

Table 4 provides the basic events that were modified to reflect the operating condition being analyzed. The bases for these changes are as follows:

EPS-DGN-FR-DG3 - This was set to TRUE to reflect the operating condition.

Table 4 also lists a description of all basic events involved in dominant cutsets for top 2 dominant sequences.

- Sensitivity analyses

No significant operating condition-related findings were found. So, no sensitivity analysis related to differences in operating conditions was performed.

However, one event-related recovery modeling assumption was considered. Although the plant operators declared EDG #3 was inoperable due to leak on the event date, EDG #3 run-failure could have been recovered by filling quality water to EDG cooling water supply tank, if EDG #3 would have tripped due to insufficient jacket cooling water. It is noted that at the time of the event, the plant did not have emergency operating procedures to refill the tank to makeup the jacket cooling water loss. A sensitivity analysis to incorporate some credit for this recovery was conducted. The increase in core damage frequency was about 1.6E-6.

- Uncertainty analysis and range for total importance due to operating condition

The parameter estimates and the uncertainties regarding the numerical estimates of the parameters used in the model (parameter uncertainty) are calculated. These data and uncertainty distributions are then propagated through the modified version of the Revision 3.11 SPAR model for Brunswick Steam Electric Plant (Reference 4) to produce uncertainty estimates.

Uncertainty analysis of the operating condition along with parameters was performed using the SAPHIRE code (Version 7.22). Default distribution types for applicable initiating events (e.g. loss of offsite power) and basic events for components were documented in the Revision 3.11 SPAR model for Brunswick Steam Electric Plant. These uncertainty estimates and uncertainty estimates for condition-affected basic events were used in estimating mean condition-CDP values and mean condition-CCDP values. Other statistical values such as point estimates, 5% estimates, and 95% estimates were also calculated for CDP and CCDP analysis cases. Estimated statistical values for the operating condition are shown in Table 5.

References

1. Progress Energy, “LER 325-2004-001-00, Emergency Diesel Generator No. 3 Condition Prohibited By the Technical Specifications” dated March 4, 2004. Adams accession number ML040780279.

2. USNRC, Region I, “Brunswick Steam Electric Plant, NRC integrated inspection report NOS. 05000324/2004002; Preliminary WHITE finding” dated April 19, 2004. Adams accession number ML041110073.

3. USNRC Office of Enforcement, “Final Significance Determination for a WHITE finding (NRC Inspection Report 05000324/2004002, Brunswick Steam Electric Plant) - EA-04-076” dated June 2, 2004. Adams accession number ML041590186.

4. Robert Buel, et al., “Standardized Plant Analysis Risk (SPAR) Model for Brunswick Steam Electric Plant - Revision 3.11” by Idaho National Engineering and Environmental Laboratory, 12/31/2004.

Table 1. Conditional probabilities (point values) for dominant sequences

Event tree name	Sequence no.	Conditional core damage probability (CCDP)	Core damage probability (CDP)	Importance (CCDP - CDP)[2]
LOOP	52-03	1.9E-6	5.5E-8	1.8E-6
LOOP	52-29	1.2E-7	3.5E-9	1.2E-7
Total (all sequences)[1]		2.7E-6	4.0E-7	2.3E-6

Notes:
1. Total CCDP and CDP includes all sequences (including those not shown in this table).
2. Importance is calculated using the total CCDP and total CDP from all sequences of all applicable event trees. Sequence level importance measures are not additive.

Table 2a. Event tree sequence logic for dominant sequences

Event tree name	Sequence No.	Logic ("/" denotes success; see Table 2b for top event names)
LOOP	52-03	(/RPS)*(EPS)*(/SRV)*((/RCI)*(BX)*(/DEP)*(/VA3)*(AC-02H)
LOOP	52-29	(/RPS)*(EPS)*(P2)*(/RCI)*(AC-01H)

Table 2b. Definitions of fault trees used in event tree logic listed in Table 2a

LOOP	LOSS OF OFFSITE POWER
RPS	REACTOR SHUTDOWN FAILS
EPS	ELECTRICAL POWER SYSTEM FAILS
/SRV	SRV's RECLOSE
RCI	REACTOR CORE ISOLATION COOLING SYSTEM FAILS
P2	TWO SRVs FAIL TO RECLOSE
AC-01-H	AC POWER RECOVERY IN ONE HOUR FAILS
AC-02H	AC POWER RECOVERY IN TWO HOURs FAILS
BX	4160 V CROSS-TIE FAILS
VA3	FIRE WATER INJECTION FAILS
DEP	MANUAL REACTOR DEPRESSURIZATION FAILS

Note:
1. "/" Indicates that top event is a success event in the event tree logic.

Table 3a. CCDP cut sets for LOOP Sequence 52-03

CCDP	Percent contribution	Minimal cut sets[1]
Event Tree: LOOP, Sequence 52-03		
7.973E-7	**42.20**	**OPR-XHE-XM-DIVXT * EPS-DGN-CF-RUN2 * EPS-XHE-XL-NR02H * OEP-XHE-XL-NR02H**
6.082E-7	**32.26**	**OPR-XHE-XM-DIVXT * EPS-DGN-FR-DG2 * EPS-XHE-XL-NR02H * OEP-XHE-XL-NR02H**
1.900E-6	Total[2]	

Table 3b. CCDP cut sets for LOOP Sequence 52-29

CCDP	Percent contribution	Minimal cut sets[1]
Event Tree: LOOP Sequence 52-29		
4.356E-8	**36.56**	**PPR-SRV-OO-2VLVS * EPS-DGN-CF-RUN2 * EPS-XHE-XL-NR01H * OEP-XHE-XL-NR01H**
3.370E-8	**27.95**	**PPR-SRV-OO-2VLVS * EPS-DGN-FR-DG2 * EPS-XHE-XL-NR01H * OEP-XHE-XL-NR01H**
1.200E-7	Total[2]	

Notes:
1. See Table 4 for definitions and probabilities for the basic events.
2. Total CCDP includes all cut sets (including those not shown in this table).

Table 4. Definitions and probabilities for added basic events and condition-affected basic events

Basic event name	Description	Prob.	Modified
OPR-XHE-XM-DIVXT	OPERATOR FAILS TO CROSS-TIE DIVISION BUSES	4.000E-2	NO
EPS-DGN-CF-RUN2	COMMON CAUSE FAILURE OF EDGS TO START	5.865E-4	NO
EPS-XHE-XL-NR02H	OPERATOR FAILS TO RECOVER EDG IN 2 HOURS	7.070E-1	NO
OEP-XHE-XL-NR02H	OPERATOR FAILS TO RECOVER OFFSITE POWER IN 2 HOURS	3.726E-1	NO
EPS-DGN-FR-DG2	DIESEL GENERATOR 2 FAILS TO RUN	2.117E-2	NO
PPR-SRV-OO-2VLVS	TWO SRVS FAIL TO CLOSE	1.300E-3	NO
EPS-XHE-XL-NR01H	OPERATOR FAILS TO RECOVER EDG IN 1 HOUR	8.410E-1	NO
OEP-XHE-XL-NR01H	OPERATOR FAILS TO RECOVER OFFSITE POWER IN 1 HOUR	5.286E-1	NO
LOOP	LOSS OF OFFSITE POWER	3.312E-2	NO
EPS-DGN-FR-DG1	DIESEL GENERATOR 1 FAILS TO RUN	TRUE	YES (Note 1)

Note:
1. Basic event probability was changed to reflect the operating condition. Bases for change was documented in Basic event probability changes section of this report.

Table 5. Uncertainty estimates for the operating condition

Plant: Brunswick Steam Electric Station, Unit 2
IR ID: 05000324/2004-002
LER ID: 324-2004-001-00
SDP: EA-04-076

Analysis type = Monte Carlo
Samples = 10000; Seeds = 97453

Initiating event (IE)	IE ID	Point estimate	mean estimate	5% estimate	50% estimate	95% estimate
All internal initiating events	CCDP for 1 year	3.222E-05	3.099E-05	1.995E-06	1.320E-05	1.130E-04
All internal initiating events	CDP for 1 year	4.854E-06	5.118E-06	5.007E-07	3.309E-06	1.554E-05
All internal initiating events	CCDP for 720 hours	2.648E-06	2.547E-06	1.640E-07	1.085E-06	9.288E-06
All internal initiating events	CDP for 720 hours	3.990E-07	4.207E-07	4.115E-08	2.720E-07	1.277E-06
All internal initiating events	Importance for 720 hours	2.249E-06	2.126E-06	1.228E-07	8.130E-07	8.010E-06

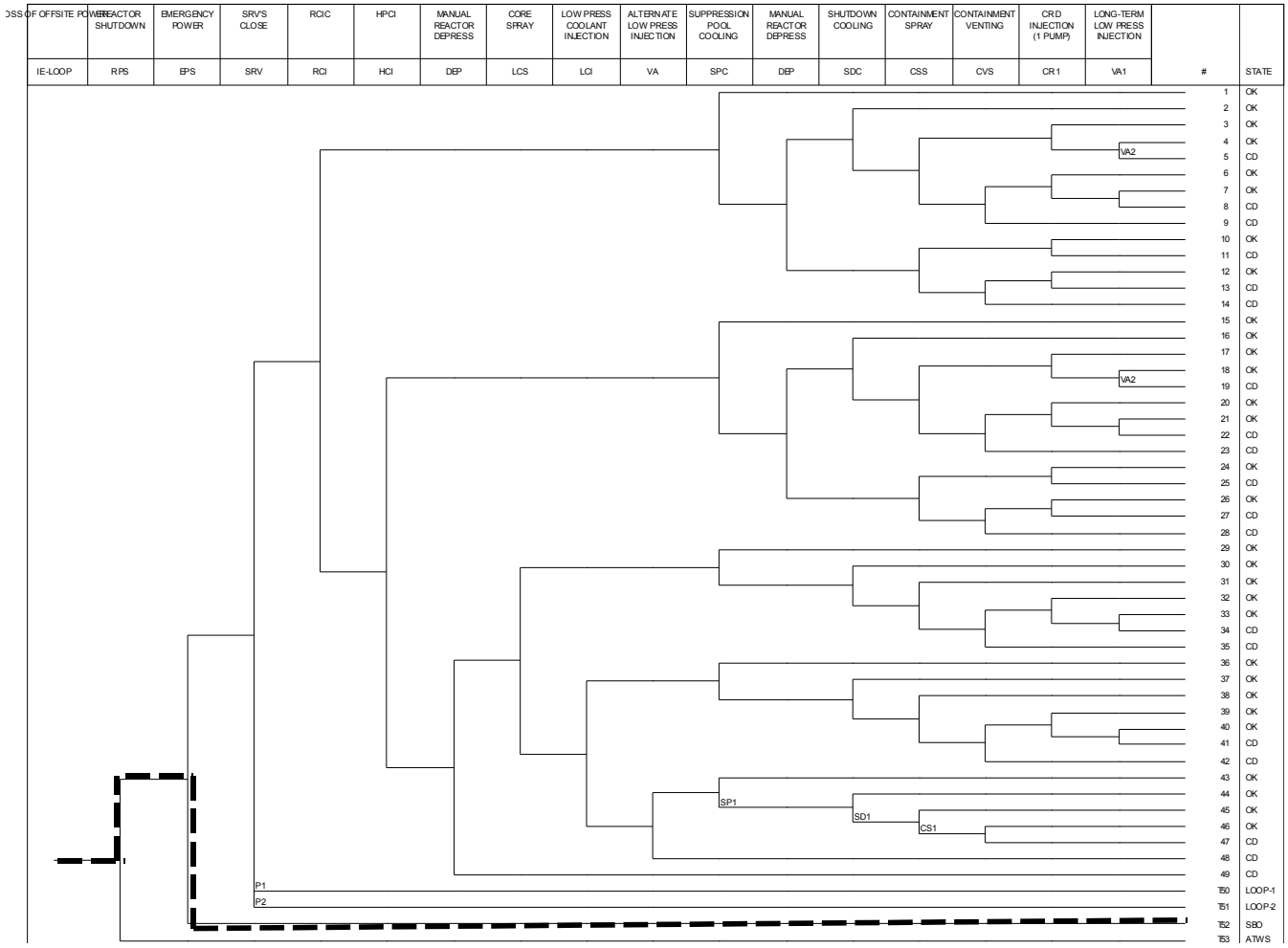

Figure 1. LOOP Event Tree Showing Sequence 52-03

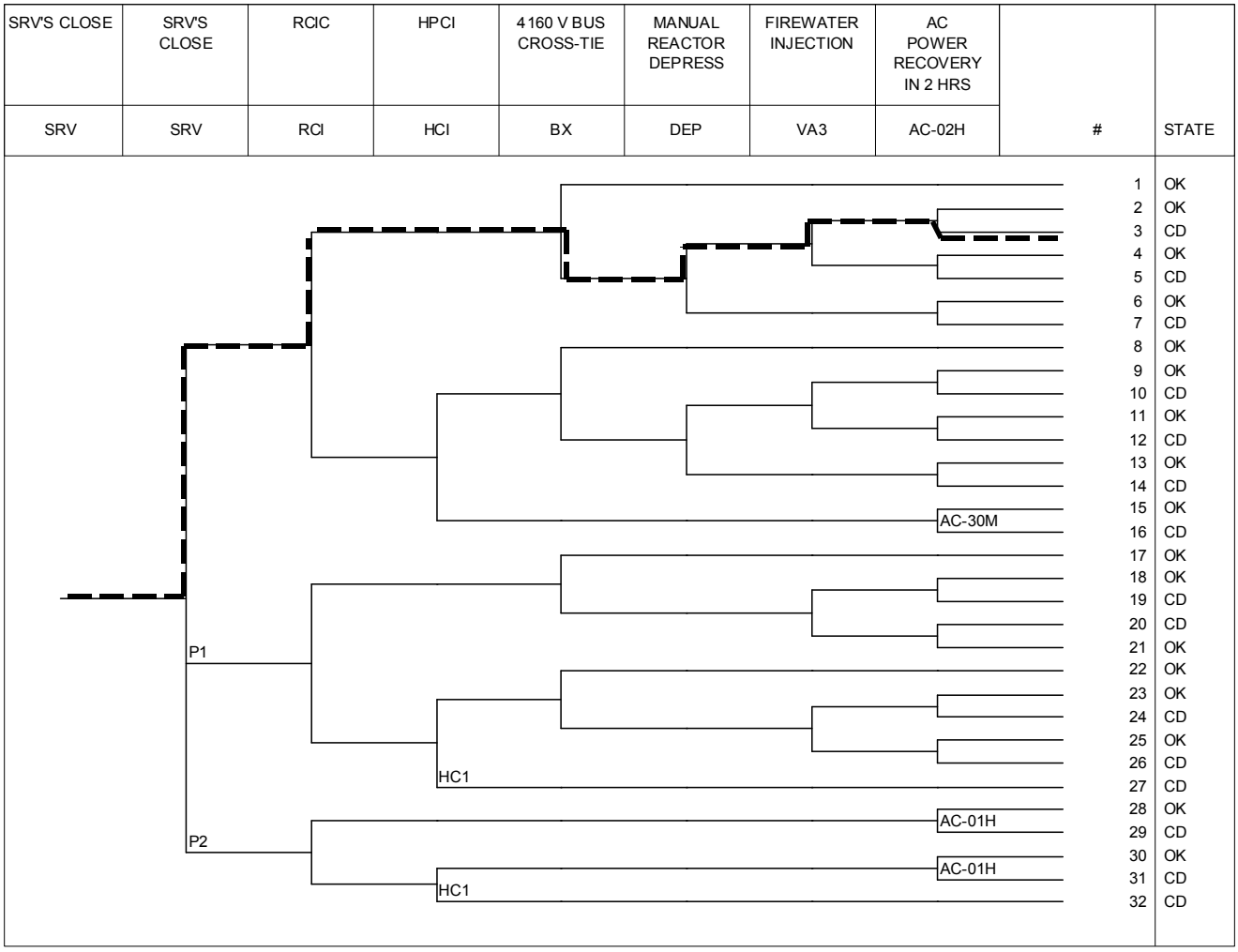

Figure 2. SBO Event Tree Showing Sequence 52-03