



UNITED STATES
NUCLEAR REGULATORY COMMISSION
WASHINGTON, D.C. 20555-0001

May 11, 2023

Mr. James Barstow
Vice President, Nuclear Regulatory Affairs
and Support Services
Tennessee Valley Authority
1101 Market Street, LP 4A-C
Chattanooga, TN 37402-2801

SUBJECT: SEQUOYAH NUCLEAR PLANT, UNIT 1 - TRANSMITTAL OF FINAL ACCIDENT
SEQUENCE PRECURSOR REPORT REGARDING CENTRIFUGAL
CHARGING PUMP 1B-B (EPID L-2019-PMP-0032)

Dear Mr. Barstow:

By letter dated September 15, 2022, (Agencywide Documents Access and Management System (ADAMS) Accession No. ML22258A065), Tennessee Valley Authority submitted licensee event report (LER) No. 50-327/2022-001-00 to the U.S. Nuclear Regulatory Commission (NRC) staff pursuant to Title 10 of the *Code of Federal Regulations* (10 CFR) Section 50.73. As part of the Accident Sequence Precursor (ASP) Program, the NRC staff reviewed the event to identify potential precursors and to determine the probability of the event leading to a core damage state. The results of the analysis are provided in the enclosure to this letter.

The NRC does not request a formal analysis review, in accordance with Regulatory Issue Summary 2006-24, "Revised Review and Transmittal Process for Accident Sequence Precursor Analyses," (ML060900007), because the analysis resulted in an increase in core damage probability (Δ CDP) of less than 1×10^{-4} .

Final ASP Analysis Summary. A brief summary of the final ASP analysis, including the results, is provided below.

Failure of Unit 1, 1B-B Centrifugal Charging Pump Results in Condition Prohibited by Technical Specifications. This event is documented in LER 50-327/2022-001-00 and Inspection Report 05000327/2022004 (ML23041A069).

Executive Summary. On July 18, 2022, main control room (MCR) operators determined the centrifugal charging pump (CCP) '1B-B' was unable to maintain pressurizer level with downstream charging flow control valve fully open. A subsequent MCR alarm was received for low flow to the reactor coolant pump (RCP) '1' seal. RCP seal flow was adjusted, and the alarm cleared. Approximately 1 hour later, the low pressurizer level alarm was received in the MCR. Operators manually started CCP '1A-A' to recover pressurizer level. The CCP '1B-B' was declared inoperable, and the plant entered Technical Specification (TS) Limiting Condition for Operation 3.5.2, "Emergency Core Cooling Systems," Condition A. Licensee troubleshooting

activities revealed the degradation of CCP '1B-B' was caused by severe wear of multiple impellers.

The estimated repair time associated with CCP '1B-B' was expected to exceed the TS 72-hour allowed outage time. On July 21, 2022, the licensee requested a notice of enforcement discretion for 69 hours additional hours to repair the pump, which the NRC approved. Repairs were completed and CCP '1B-B' was declared operable on July 24, 2022.

The mean Δ CDP for this event is 2×10^{-6} and, therefore, this event is a precursor. The dominant hazard for this ASP analysis is internal fires, which contribute approximately 64 percent of the total Δ CDP. The risk from internal events is approximately 24 percent, seismic events contribute approximately 10 percent, and internal floods contribute approximately 2 percent. External floods and high winds (including and tornados) are minimal contributors to the total Δ CDP for this analysis.

Summary of Analysis Results. This operational event resulted in a best estimate of Δ CDP of 2×10^{-6} . The detailed ASP analysis can be found in the enclosure.

If you have any questions, please contact the Project Manager, Perry Buckberg at 301-415-1383 or via email at Perry.Buckberg@nrc.gov.

Sincerely,

/RA/

Perry Buckberg, Senior Project Manager
Plant Licensing Branch II-2
Division of Operating Reactor Licensing
Office of Nuclear Reactor Regulation

Docket No. 50-327

Enclosure:
Failure of 1B-B Centrifugal Charging Pump Results in
Condition Prohibited by Technical Specifications

cc: Listserv



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NUCLEAR REGULATORY COMMISSION**
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ENCLOSURE

Final Accident Sequence Precursor Analysis
Sequoyah Nuclear Plant, Unit 1 - Failure of 1B-B Centrifugal Charging Pump Results in
Condition Prohibited by Technical Specifications

Final ASP Analysis – Precursor

Accident Sequence Precursor Program – Office of Nuclear Regulatory Research		
Sequoyah Nuclear Plant, Unit 1	Failure of 1B-B Centrifugal Charging Pump Results in Condition Prohibited by Technical Specifications	
Event Date: 7/22/2022	LER: 327-2022-001 IR: 05000327/2022004	ΔCDP = 2×10 ⁻⁶
Plant Type:	Westinghouse Four-Loop Pressurized Water Reactor with Wet, Ice Condenser Containment	
Plant Operating Mode (Reactor Power Level):	Mode 1 (100% Reactor Power)	
Analyst: Christopher Hunter	Reviewer: Mehdi Reisi Fard	Completion Date: 4/19/2023

1 EXECUTIVE SUMMARY

On July 18, 2022, main control room (MCR) operators determined the centrifugal charging pump (CCP) ‘1B-B’ was unable to maintain pressurizer level with downstream charging flow control valve fully open. A subsequent MCR alarm was received for low flow to the reactor coolant pump (RCP) ‘1’ seal. RCP seal flow was adjusted, and the alarm cleared. Approximately 1 hour later, the low pressurizer level alarm was received in the MCR. Operators manually started CCP ‘1A-A’ to recover pressurizer level. The CCP ‘1B-B’ was declared inoperable, and the plant entered Technical Specification (TS) Limiting Condition for Operation (LCO) 3.5.2, “Emergency Core Cooling Systems (ECCS),” Condition A. Licensee troubleshooting activities revealed the degradation of CCP ‘1B-B’ was caused by severe wear of multiple impellers.

The estimated repair time associated with CCP ‘1B-B’ was expected to exceed the TS 72-hour allowed outage time (AOT). On July 21st, the licensee requested a notice of enforcement discretion (NOED) for 69 hours additional hours to repair the pump, which the U.S. Nuclear Regulatory Commission (NRC) approved. Repairs were completed and CCP ‘1B-B’ was declared operable on July 24th.

The mean core damage probability (ΔCDP) for this event is 2×10⁻⁶ and, therefore, this event is a precursor. The dominant hazard for this accident sequence precursor (ASP) analysis is internal fires, which contribute approximately 64 percent of the total ΔCDP. The risk from internal events is approximately 24 percent, seismic events contribute approximately 10 percent, and internal floods contribute approximately 2 percent. External floods and high winds (including and tornados) are minimal contributors to the total ΔCDP for this analysis.

2 EVENT DETAILS

2.1 Event Description

On July 18, 2022, MCR operators determined the CCP ‘1B-B’ was unable to maintain pressurizer level with downstream charging flow control valve fully open. A subsequent MCR alarm was received for low flow to the RCP ‘1’ seal. RCP seal flow was adjusted, and the alarm cleared. Approximately 1 hour later, the low pressurizer level alarm was received in the MCR. Operators manually started CCP ‘1A-A’ to recover pressurizer level. The CCP ‘1B-B’ was

declared inoperable, and the plant entered TS LCO 3.5.2, "ECCS," Condition A. Licensee troubleshooting activities revealed the degradation of CCP '1B-B' was caused by severe wear of multiple impellers.

The estimated repair time associated with CCP '1B-B' was expected to exceed the TS 72-hour AOT. On July 21st, the licensee requested a NOED for 69 hours additional hours to repair the pump, which the U.S. NRC approved. Repairs were completed and CCP '1B-B' was declared operable on July 24th. Additional information is provided in licensee event report (LER) 327-2022-001, "Failure of 1B-B Centrifugal Charging Pump Results in Condition Prohibited by Technical Specifications," ([ML22258A065](#)) and inspection report (IR) 05000327/2022004, "Sequoyah, Units 1 and 2 – Integrated Inspection Report 05000327/2022004 and 05000328/2022004," ([ML23041A069](#)).

2.2 Cause

The CCP '1B-B' impellers showed significant wear, which is indicative of bowing of the pump shaft. A dye penetrant examination of the shaft revealed a crack in the split-ring keeper key groove at the 11th stage impeller. The most likely cause of the failure is low-stress, high-cycle fatigue.

3 MODELING

3.1 Basis for ASP Analysis

The [ASP Program](#) uses SDP results for degraded conditions when available (and applicable). No licensee performance deficiency associated with this condition was identified. The LER was reviewed and closed in IR 05000327/2022004 ([ML23041A069](#)). Therefore, an independent ASP analysis was performed because there was no performance deficiency identified and its potential risk significance. A search of Sequoyah Nuclear Plant (Unit 1) LERs did not reveal any "windowed" events.

3.2 Analysis Type

A condition assessment event analysis was performed using a test and limited use (TLU) of the version 8.80 standardized plant analysis risk (SPAR) model for Sequoyah Nuclear Plant (Unit 1) created on April 5, 2022. This SPAR model includes the following hazards:

- Internal events,
- Internal fires,
- Internal floods,
- External floods,
- Seismic events, and
- High winds (including tornados).

3.3 SPAR Model Modifications

No modifications were made to the TLU version of the base SPAR model to support this analysis.

3.4 Exposure Time

The following table provides the key dates and times associated with the failure of CCP '1B-B':

Table 1. Key Dates and Time Associated with the Failure of CCP '1B-B'

Date	Time	Description
June 9, 2022	—	Surveillance test of the ECCS function for CCP '1B-B' is completed satisfactorily. With the exception of a 2-hour period surveillance test on CCP '1A-A', CCP '1B-B' is running until the failure experienced on July 18 th .
July 18, 2022	2130	MCR alarm received for low RCP seal '1' flow. Operators manually adjust RCP seal flow to restore adequate flow.
July 18, 2022	2230	MCR alarm received for lowering pressurizer level. Operators start CCP '1A-A' and restore pressurizer level to normal. CCP '1B-B' is declared inoperable, and the plant entered TS LCO 3.5.2, Condition A.
July 24, 2022	1635	Repairs completed; CCP '1B-B' declared operable.

Based on this information, the following two exposure times were identified for this condition analysis:

- **Exposure Time 1.** This period represents the time from when the observed failure CCP '1B-B' occurred on July 18th until repairs were completed on July 24th, which is approximately 139 hours. During this period, CCP '1B-B' was unable to fulfil both its RCP seal injection and ECCS functions.
- **Exposure Time 2.** This period represents the time from when the ECCS TS surveillance was completed on June 9th until the observed failure CCP '1B B' on July 18th, which is approximately 39 days. During this period, CCP '1B-B' was assumed to be unable to fulfil its ECCS functions only. Since the exact time when CCP '1B-B' was unable to perform its safety function is unknown, the 39-day time period is divided by two, which results in an exposure time of 468 hours. The assumption that CCP '1B-B' was unable to fulfil its ECCS function during this exposure time is potentially conservative and is a key uncertainty for this analysis, which is discussed further in [Section 4.4](#).

3.5 Analysis Assumptions

The following modeling assumptions were required to reflect the plant status and event circumstances for this condition assessment:

- Basic event CVC-MDP-FR-1B (*CVC MDP train B failure to run*) was set to TRUE for Exposure Time 1 due to the failure of CCP '1B-B' on July 18th. This basic event fails both the RCP seal injection and ECCS functions for the pump.
- Basic events CVC-MDP-AP-RUN1A (*CVC pump 1A-A is normally running*) was set to TRUE and CVC-MDP-AP-RUN1B (*CVC pump 1B-B is normally running*) was set to FALSE to account for operating status (i.e., which pump was running) during Exposure Time 1.
- Housed event HE-TLU-SENS (*house event – TLU sensitivity*) was set to TRUE to activation the fault tree logic that allows to failure ECCS high-pressure injection function for CCP '1B-B' only.
- Basic event CVC-MDP-FR-1B-TLU (*CVC MDP train B failure to run – TLU sensitivity*) was set to TRUE for Exposure Time 2. This basic event only fails the ECCS function for the pump.

- Basic events CVC-MDP-AP-RUN1A (*CVC pump 1A-A is normally running*) was set to FALSE and CVC-MDP-AP-RUN1B (*CVC pump 1B-B is normally running*) was set to TRUE to account for operating status (i.e., which pump was running) during Exposure Time 2.

4 ANALYSIS RESULTS

4.1 Results

The overall mean Δ CDP for this analysis is calculated to be 1.7×10^{-6} , which is the sum of the two exposure times. The ASP Program threshold is 1×10^{-6} for degraded conditions; therefore, this event is a precursor. The parameter uncertainty results for both exposure times of this analysis are provided below:

Table 2. Parameter Uncertainty Results for Exposure Times 1 and 2

Exposure Time	5%	Median	Point Estimate	Mean	95%
1	8.4×10^{-8}	5.5×10^{-7}	9.4×10^{-7}	1.1×10^{-6}	3.9×10^{-6}
2	1.3×10^{-7}	4.4×10^{-7}	5.6×10^{-7}	6.0×10^{-7}	1.6×10^{-6}

4.2 Dominant Hazards¹

The dominant hazard for this analysis is internal fires (Δ CDP = 9.6×10^{-7}), which contribute approximately 64 percent of the total Δ CDP. Internal events contribute approximately 24 percent (Δ CDP = 3.6×10^{-7}), seismic events contribute approximately 10 percent (Δ CDP = 1.5×10^{-7}), and internal floods contribute approximately 2 percent (Δ CDP = 2.6×10^{-8}). External floods and high winds (including and tornados) are minimal contributors to the total Δ CDP for this analysis.

4.3 Dominant Sequences

The dominant accident sequence is FRI-ERCW-1A 2-2-2-4 (Δ CDP = 5.0×10^{-7}), which contributes approximately 33 percent of the total Δ CDP. The sequences that contribute at least 5 percent to the total Δ CDP are provided in the following table. These dominant sequences are shown graphically in Figures A-1 though and A-4 of [Appendix A](#).

¹ The Δ CDPs provided in Sections 4.2 and 4.3 are point estimates.

Table 3. Dominant Sequences

Sequence	Δ CDP	%	Description
FRI-ERCW-1A 2-2-2-4	5.0×10^{-7}	33.3%	Fire in the emergency raw cooling water (ERCW) building results in a loss in ERCW train 'A' initiating event; auxiliary feedwater (AFW) is successful; RCP seal cooling fails; operators successfully trip the RCPs, but the stage 2 seals fail resulting in a small loss-of-coolant accident (SLCOA); high-pressure injection is successful; operators successfully cooldown and depressurize the reactor coolant system (RCS); shutdown cooling fails; and cold leg recirculation fails resulting in core damage.
LOERCW-A 4-2-4	1.3×10^{-7}	8.4%	A loss of ERCW train 'A' initiating event occurs; AFW is successful; RCP seal cooling fails; operators successfully trip the RCPs, but the stage 2 seals fail resulting in a SLCOA; high-pressure injection is successful; operators successfully cooldown and depressurize the RCS; shutdown cooling fails; and cold leg recirculation fails resulting in core damage.

4.4 Key Uncertainties

The following are the key uncertainties of this ASP analysis.

- Loss of ECCS Function of CCP '1B-B' Prior to Observed Failure.*** The CCPs have two safety-related functions. First, they provide RCP seal injection flow. In addition, they provide an ECCS source of high-pressure injection. CCP '1B-B' failed on July 18th resulting in a loss of both functions for the pump. This analysis also assumed that the high-pressure injection function was lost prior to the observed failure. This assumption is potentially conservative; however, due to the different system dynamics between the two functions (i.e., different flow rates, temperatures, etc.) the high-pressure injection function for CCP '1B-B' could have been unavailable since the last successful surveillance test completed on June 9th. Since the exact time that the high-pressure injection was potentially lost is unknown, the Exposure Time 2 in this analysis used the $t/2$ approximation. Although this assumption is still potentially conservative (i.e., CCP '1B-B' could have maintained its high-pressure injection function until the observed failure on July 18th), the Δ CDP for this condition still exceeds the precursor threshold if the high-pressure injection function is assumed to be available.

Appendix A: Key Event Trees

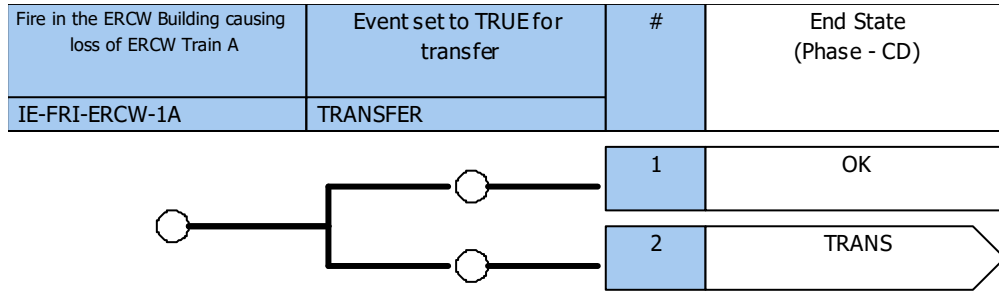


Figure A-1. IE-FRI-ERCW-1A Event Tree

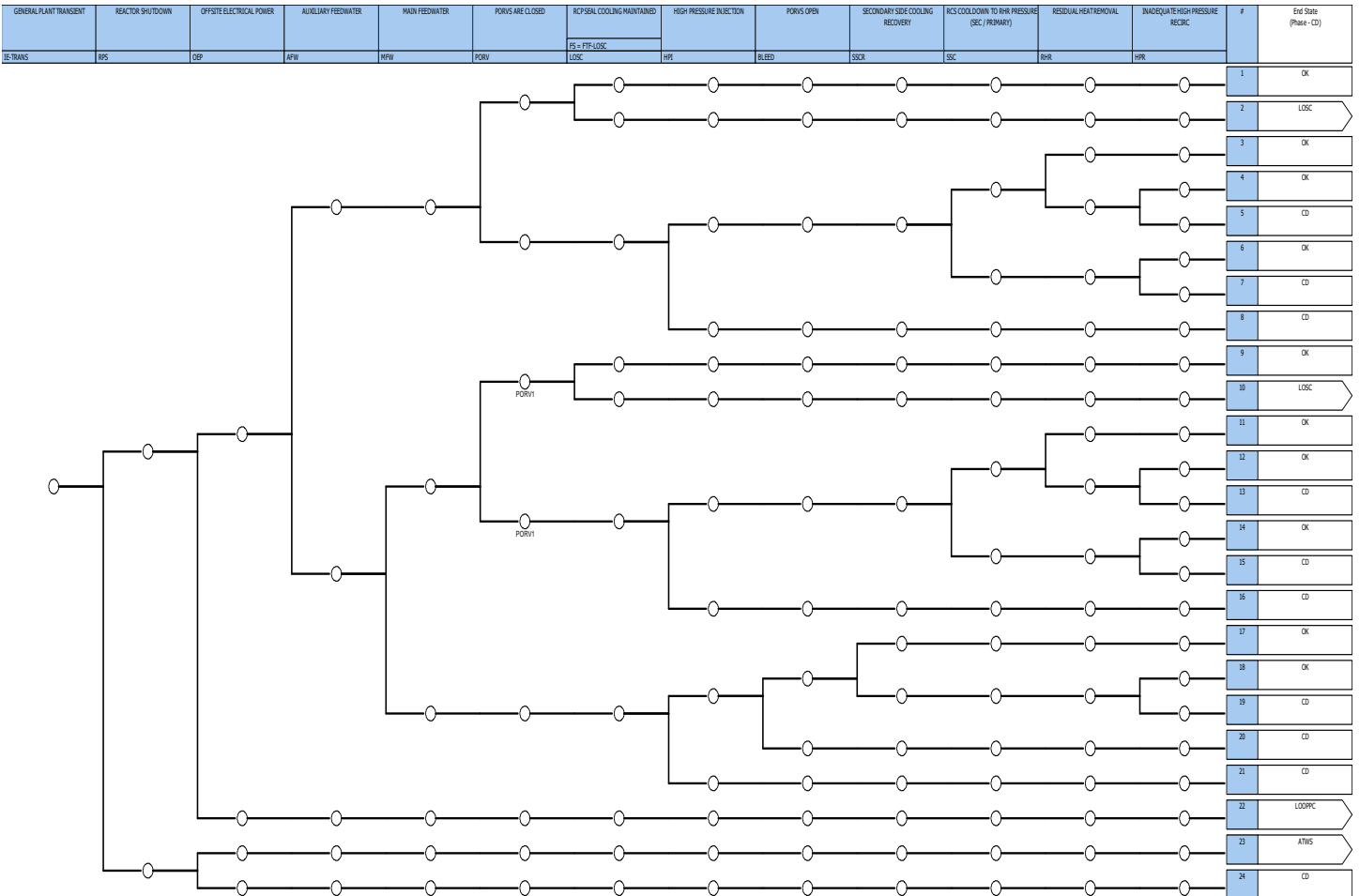


Figure A-2. TRANS Event Tree

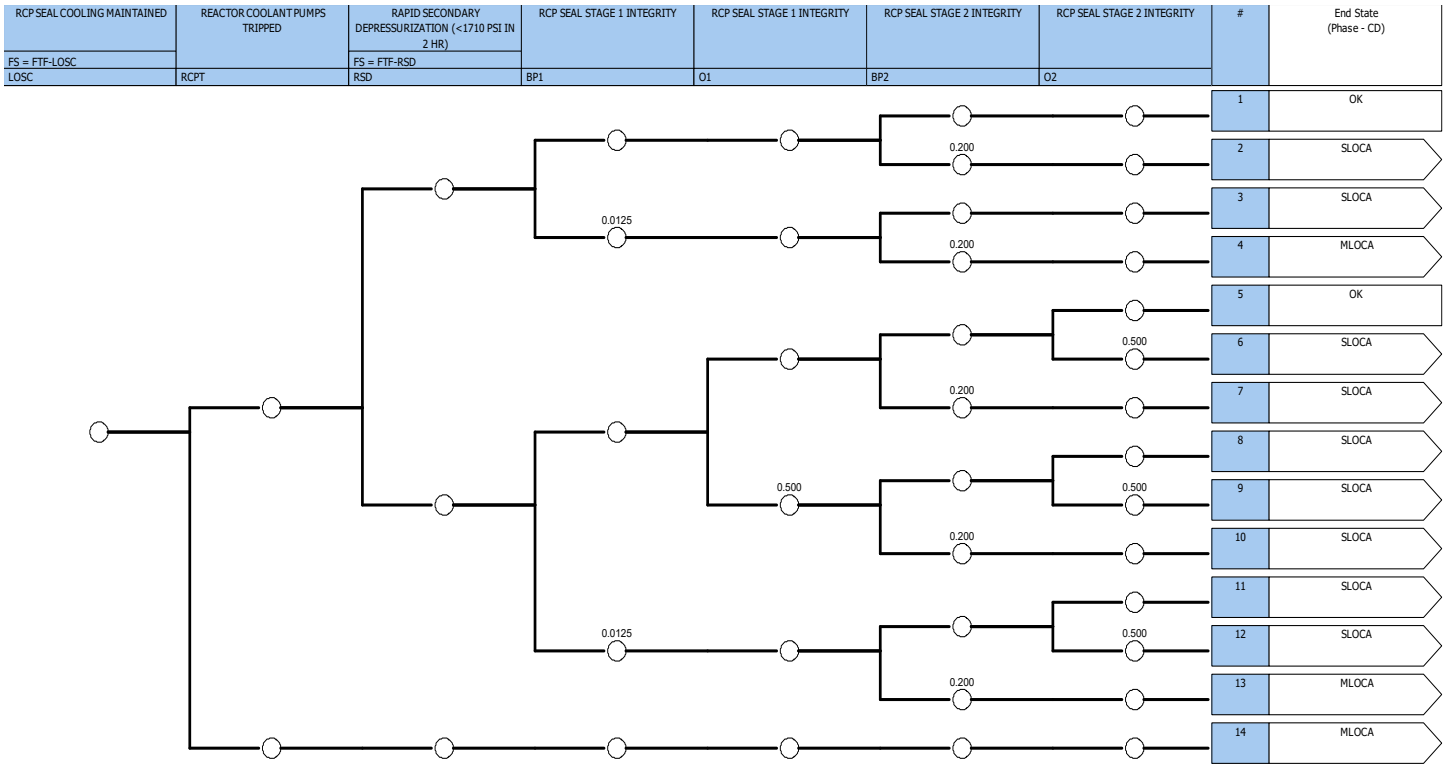


Figure A-3. LOSC Event Tree

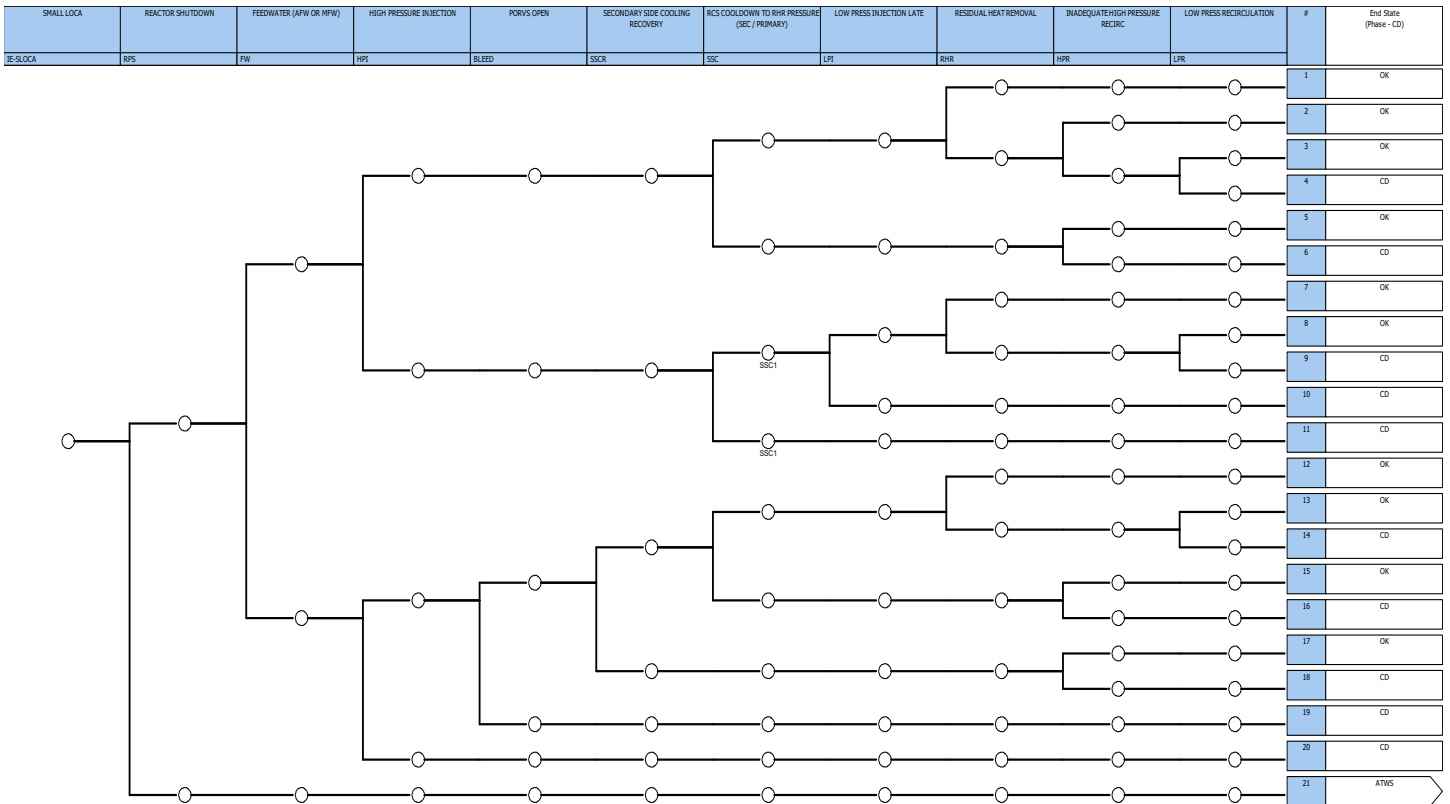


Figure A-4. SLOCA Event Tree

Final Accident Sequence Precursor - Sequoyah Nuclear Nuclear Plant (Unit 1), Failure of 1B-B CCP
 Results in Condition Prohibited by TS (LER 327-2022-001) - Precursor DATE April 19, 2023

ADAMS Accession No.: ML23104A013; ML23104A013

OFFICE	RES/DRA/PRB	RES/DRA		
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DATE	Apr 14, 2023	Apr 19, 2023		

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