Final Precursor Analysis

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

Shearon Harris	Design Deficiency involving Inadequate Fire Protection and Suppression System for Switchgear Room B and Auxiliary Control Panel Room	
Inspection Report Date: 12/18/2001	**Inspection Report:** 50-400/00-09	Δ**CDP =** 6×10^{-6}

Condition Summary

The inspection report 50-400/2000-09 (Ref. 1) indicated that the licensee stated that fire endurance testing demonstrated that the Thermo-Lag walls, which serve as part of the fire area separation barriers between Switchgear Room B and the Auxiliary Control Panel (ACP) room, would provide a 1 hour and 48 minutes barrier for a 3-hour fire loading area with no automatic suppression. Further, the licensee's fire brigade had not practiced in the area for over seven years.

Cause. The cause of this event is changes made to the Updated Final Safety Analysis Report (UFSAR) under 10 CFR 50.59 to revise the fire rating of the Thermo-Lag fire barrier between the Switchgear Room B and ACP room from a Safety Evaluation Report (SER) approved 3-hour fire barrier to a lesser rated fire barrier without prior Commission approval. This involved a change to the approved fire protection program. The change to the Thermo-Lag barrier fire rating represented a degradation (derating) of the margin of fire resistance from that established in the approved fire protection program. The fire barrier rating has been estimated to be as low as one hour by U.S. Nuclear Regulatory Commission (NRC) staff.

Recovery opportunity. A postulated fire in fire Switchgear Room B is assumed to propagate to the ACP Room unless successfully suppressed by the fire brigade within one hour . In this case, all train B safety-related equipment and the AFW turbine-driven pump, including the steam generator B power operated relief valves (ADVs) and some train A power cables in the ACP room (for A and C steam generator ADVs, AFW motor-driven pump A, and the heating, ventilation and air conditioning (HVAC) system for train A equipment) are considered failed with no recovery. Recovery of failed HVAC system function is assumed by installation of portable fans to provide equipment cooling in Switchgear Room A. The Switchgear Room B area has no fixed suppression system, but does have a detection system that uses ionization smoke detectors. Response by the fire brigade may have been impaired throughout the years, as seen in several Condition Reports written concerning equipment and the lack of fire brigade training in the switchgear rooms.

In summary, the B train is lost completely due to a fire in Switchgear Room B and through propagation to ACP Room, the AFWMDPA pump and AFWTDP flow control portions of the A train are also lost. Equipment lost is as follows:

Switchgear Room B

- B Train Motor-driven auxiliary feedwater (MDAFW) pump, suction valves from condensate storage tank (CST) & essential service water (ESW), and AFW discharge valves to steam generators (SGs).
- B Train charging/safety injection pumps (CSIPs), suction valves from the volume control tank (VCT), low pressure safety injection (LPSI) pump and refueling water storage tank (RWST) & discharge valves to the reactor vessel from high pressure safety injection pump (EIHP) and high pressure recirculation (HPR).
- B Train LPSI pumps, suction & discharge valves from the RWST and the containment sump [support train to HPR]
- B Train component cooling water (CCW), a support train to HPR.
- B Train ESW, a support train to HPR, EIHP, AFW.
- Turbine-driven AFW pump steam inlet valve (train B power).
- B Train emergency diesel generator (EDG), emergency AC system (EAC).
- SG B PORV (ADV)
- Division 1B AC power
- Division 1B 125VDC power

ACP Room

- Train A MDAFW pump.
- SG A and C PORVs [automatic discharge valve (ADV) portion of cool down].
- AFWTDP steam inlet valve and flow control valves (recovered, see below).
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Although there are “energetic” 6.9kV switchgear and bus ducts in the switchgear room, there is greater than 50 feet separation between the closest 6.9kV bus duct and the fire barrier for the ACP room (see Figure 1).

Recovery of AFW Turbine-Driven (TDAFW) pump

In order to operate the TDAFW pump with the loss of alternating current (AC) power and direct current (DC) control, the discharge SG motor-operated valve (MOV) must be opened and the flow control air-operated valve (AOV) fails full open. The flow control has been set via speed control and local control change to speed to speed control, can be used to throttle the flow.

Analysis Results

- **Importance**

  Base Case

  For the base case, the fire is assumed to be contained within the Switchgear Room B (see Fig. 1. The risk significance of train B equipment and the TDAFW pump being unavailable for automatic initiation is determined by performing an conditional assessment using the 3i model for Shearon Harris. For this case, the transient initiating event frequency replaced by the product of the Switchgear Room B initiating fire frequency and the probability of nonsuppression. For this case, current probability of the base events that are assumed failed (TRUE or FALSE, as applicable) are used in the analysis. This method is outlined in NUREG/CR-6544, "Development of a Methodology for Analyzing Precursors to Earthquake-Initiated or Fire-Initiated Accident Sequences," Section 3.7 (Ref. 2). The conditional core damage probability (CCDP) is 8.5×10^{-7}.

  Current Case

  For the current case, the fire is assumed to propagate to the ACP Room with a probability of nonsuppression of 0.5 (see Modeling Assumptions below for details). In addition to the equipment failed in the base case, the AFW MDP A pump is failed and the other steam inlet valve and flow control valves to the AFWTDP are failed, but recovered. The current case CCDP is 6.5×10^{-6}.

  Increase in Core Damage Probability

  The increase in core damage probability (ΔCDP) is the difference between the current case and the base case: $6.5 \times 10^{-6} - 8.5 \times 0^{-7} = 5.6 \times 10^{-6}$.

  The Accident Sequence Precursor (ASP) Program acceptance threshold is an importance (ΔCDP) of 1×0^{-6}.

- **Dominant sequence (Current Case)**

  The Fire Event tree includes the transfer of Fire initiating event to Transient Sequence 21 (see Figures 2).

  TRANS (Sequence 21)

  The events and important component failures in TRANS Sequence 21 include:

- Reactor trips successfully during transient
- Failure of AFW system
- Failure of main feedwater system during transient
- Failure to provide bleed portion of feed and bleed

- **Results tables**

  - Table 1 provides the importance values for some dominant sequences.
  - Table 2a provides the event tree sequence logic for the dominant sequences.
  - Table 2b defines the nomenclature used in Table 2a.
  - Table 3 provides the conditional cut sets for the dominant sequences.
  - Table 4 provides the definitions and probabilities for the modified and dominant basic events

Modeling Assumptions

- **Assessment summary**

  Condition duration. Due to the fire barrier being degraded for more than one year, a maximum time of one year is normally the duration in a conditional assessment. However, this analysis was made as an initiating event assessment, with degraded fire barriers for 1 year, with a postulated fire occurring in Switchgear Room B and propagating to the adjacent Auxiliary Control Panel (ACP) room.

- **SPAR model used in the analysis**

  The Revision 3i of the Harris Standardized Plant Analysis Risk (SPAR) Model (Ref. 2) was used for this assessment. The SPAR Revision 3i model includes event trees for transients (TRANS), Loss of Offsite Power (LOOP), steam generator tube rupture (SGTR), and small Loss of coolant accident (SLOCA). For this conditional assessment all initiating events, other than TRANS are not applicable. Since the fire is not caused by these initiating events, therefore, these frequencies are set to zero. The transient initiating event (IE-TRANS) frequency is replaced (see below for details of fire-Induced analysis considerations).

- **Recovery of TDAFW Pump**

  Recovery of the TDAFW pump is assumed for this analysis (see fault tree, Fig. 3A).

- **Fire-induced analysis methodology**

  The fire-induced analysis is based on NUREG/CR-6544 (Ref. 3), For this analysis, all equipment in Switchgear Room B (the fire zone) is assumed failed and the fire propagates

to the ACP room and causes failure to certain train A equipment cables. The product of the initiating fire frequency and the probability of nonsuppression replaces the transient event frequency in the conditional assessment.

– **Initiating Fire Frequency -** The initiating fire frequency (F_i) was developed from NRC Report RES/OERAB/S02-01 power operation fire event data for severe fires (fires with duration greater than 5 minutes and were not self-extinguished) in the switchgear room during the 1986–1999 period (Ref. 4), with updated data for 2000-2001. The Switchgear Room B fire frequency is 3.2E-3, based on:

$$F_i = \frac{\text{(No. Of Severe Fires + Jeffreys Prior)}}{\text{(No. Of Switchgear Rooms x No. Power Operation Reactor-Years)}}$$

$$F_i = \frac{(8 + 0.5)}{(2 \times 1311)} = 3.2E\text{-}3$$

– **Probability of nonsuppression**

Fire Barrier. The licensee's position that the fire barrier rating of 1 hour and 48 minutes was sufficient to meet the intent of the Appendix R requirement for a 3-hour fire barrier was challenged by NRC staff because the testing documentation was not substantiated in an exemption request or provided for NRC review. However, a best estimate of a 1 hour fire rating was considered conservative for the fire analysis, based on discussion with NRC fire protection staff (NRR/DSSA/SPLB) and used in this analysis.

Manual Fire Suppression. Due to the several Condition Reports written concerning equipment and performance, the fire brigade was considered below optimum in performance. An earlier NRC Inspection Report documented NRC inspector observations that no fire drills were scheduled in the switchgear rooms and, no fire drill had been conducted in these areas for at least seven years. For this analysis, the lesser trained fire brigade was assumed to be on station in 30 minutes (10 minutes later than nominal). For the current case, with an assumed one-hour fire barrier, this leaves 30 minutes for suppression of the fir and a probability of nonsuppression = 5E-1, based on the EPRI Fire Guide.

For the base case, the fire, does not propagate to the ACP room and the probability of nonsuppression is 1.0 within the Switchgear Room.

- **Modifications to fault trees**

For the current case, the recovery of the AFWTDP is added by base event AFW-XHE-XE-TDP1X (See Figure 3A).

For the current case, the probability of failure of AFWMDPA by propagation to the ACP Room is added by the base event FIRE-PROPAGATION-ACP (see Figure 3B),

- **Basic event probability changes**

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

- **Probability changes (Current Case)**

  - **Division 1B AC Power 6.9kV Bus Fails (ACP-BAC-LP-1B).** This value was set to TRUE..
  - **AFW Motor Driven Pump 1B Fails to Run (AFW-MDP-FR-1B).** The value was set to TRUE.
  - **AFW Motor Driven Pump 1B Fails to Start (AFW-MDP-FS-1B).** The value was set to TRUE.
  - **Operator fails to Recover AFW Turbine Driven Pump (AFW-TDP-XHE-TDP1X).** This value was set to 4.0E-02.
  - **Operator Fails to Recover Motor-Driven Pump B (AFW-XHE-XL-MDPFSB).** This value is set to TRUE.
  - **CCW MDP 1B Fails to Run (CCW-MDP-FR-1B).** This value was set to TRUE.
  - **CCW MDP 1B Fails to Start (CCW-MDP-FS-1B).** This value was set to TRUE.
  - **Division 1B 125VDC Bus DP-1B Fails (DCP-BDC-LP-1B).** This value is TRUE.
  - **Diesel Generator B Fails to Run (EPS-DGN-FR-1B).** The value was set to TRUE.
  - **Diesel Generator B Fails to Start (EPS-DGN-FS-1B).** This value was set to TRUE.
  - **ESW MDP 1 B Fails to Run (ESW-MDP-FR-1B).** This value was set to TRUE.
  - **ESW MDP 1 B Fails to Start (ESW-MDP-FS-1B).** This value was set to TRUE.
  - **Probability that the Fire Propagates to the ACP (FIRE-PROPAGATION-ACP).** This value was set to 5.0E-01.
  - **HPI MDP 1B Fails to Run (HPI-MDP-FR-1B).** This value was set to TRUE.
  - **HPI MDP 1B Fails to Start (HPI-MDP-FS-1B).** This value was set to TRUE.
  - **RHR MDP 1B Fails to Run (RHR-MDP-FR-1B).** This value was set to TRUE.
  - **RHR MDP 1B Fails to Start (RHR-MDP-FS-1B).** This value was set to TRUE.
  - **Transient Initiating Event (IE-TRANS).** This value was set to the fire frequency value, 3.2E-3.

  All other initiating events were set to zero.

- **Model update**

The SPAR model for Harris was not updated.

Differences with Licensee's individual plant examination for external events (IPEEE)

The licensee's IPEEE (Ref. 5.) assumed that a switchgear room fire would cause failure of all equipment within the room and resulted in a CDF for this scenario (same as base case) of 2.8E-6. The IPEEE assumed no barrier degradation and no propagation, while this analysis assumed propagation in the current case. This ASP analysis does not include external events.

References

1. EA-00-022/EA-01-310, NRC Inspection Report 50-400/2000-09, dated 12/18/2001

2. K. Knudsen, et al., *Standardized Plant Analysis Risk Model for Shearon Harris (ASP PWR B)*, Revision 31, Idaho National Engineering and Environmental Laboratory, October 2000.

3. R. J. Budnitz, et al., *Development of a Methodology for Analyzing Precursors to Earthquake-Induced and Fire-Induced Accident Sequences*, NUREG/CR-6544, U.S. Nuclear Regulatory Commission, Washington, DC, April 1998.

4. J. R. Houghton and D. M. Rasmuson, NRC Report RES/OERAB/S02-01, *Fire Events — Update of U.S. Operating Experience. 1986–1999,* U. S. Nuclear Regulatory Commission, Washington DC, January 2002.

5. Carolina Power & Light letter to USNRC, Serial: HNP -95-01, *Individual Plant Examination for External Events Submittal – Final Report,* June 1995

Table 1. Conditional Probabilities Associated with Highest Probability Sequences (Importance)

Event tree name	Sequence Number	Conditional core damage probability (CCDP)
TRANS	21	3.3E-006
Total (all sequences)		**6.5E-006**

Table 2a. Event Tree Sequence Logic for Dominant Sequence

Event tree name	Sequence no.	Logic ("/" denotes success; see Table 4b for top event names)
TRANS	21	/RT, AFW, MFW-T, BLEED

Table 2b. Definitions of Fault Trees Listed in Table 2a

/RT	REACTOR Trips Successfully During Transient
AFW	No or insufficient AFW flow
MFW-T	Failure of Main Feedwater System During Transient
BLEED	Failure to provide bleed portion of fill and bleed

Table 3. Conditional cut sets for Dominant TRANS Sequence

Event Tree: TRANS, Sequence 21			
CCDP	Percent contribution	Minimal cut sets[1]	
1.1E-006	34.5	AFW-MDP-CF-AB	MFW-SYS-UNAVAIL
		MFW-XHE-NOREC	FIRE-PROPAGATION-ACP
		AFW-XHE-XL-TDPFR	AFW-TDP-FR-1X
9.0E-007	27.6	AFW-MDP-CF-AB	MFW-SYS-TRIP
		FIRE-PROPAGATION-ACP	AFW-XHE-XL-TDPFR
		MFW-XHE-ERROR	MFW-SYS-UNAVAIL
3.3E-006	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 modified and dominant basic events

Event name	Description	Probability/Frequency	Modified
ACP-BAC-LP-1A	DIVISION 1B AC POWER 6.9KV BUS FAILURE PROB.	TRUE	YES[3]
AFW-MDP-FR-1B	AFW MDP 1B FAILS TO RUN FAILURE PROBABILITY	TRUE	YES[1]
AFW-MDP-FS-1B	AFW MDP 1B FAILS TO START FAILURE PROBABILITY	TRUE	YES[1]
AFW-XHE-XE-TDP1X	OPERATOR FAILS TO RECOVER AFW TDP	4.0E-02	YES[2]
AFW-xHE-XE-MDPFSB	OPERATOR FAILS TO RECOVER AFW MDP B	TRUE	YES[1]
CCW-MDP-FR-1B	CCW MDP 1B FAILS TO RUN	TRUE	YES[1]
CCW-MDP-FS-1B	CCW MDP 1B FAILS TO START	TRUE	YES[1]
DCP-BDC-LP-1B	DIVISION 1B 125VDC BUS DP-1B FAILS	TRUE	YES[1]
EPS-DGN-FR-1B	DIESEL GENERATOR B FAILS TO RUN	TRUE	YES[1]
EPS-DGN-FS-1B	DIESEL GENERATOR B FAILS TO START	TRUE	YES[1]
ESW-MDP-FR-1B	ESW MDP 1B FAILS TO RUN	TRUE	YES[1]
ESW-MDP-FS-1B	ESW MDP 1B FAILS TO START	TRUE	YES[1]
FIRE-PROPAGATION-ACP	PROBABILITY THAT FIRE PROPAGATES TO ACP ROOM	5.0E-01	YES[3]
HPI-MDP-FR-1B	HPI MDP 1B FAILS TO RUN	TRUE	YES[1]
HPI-MDP-FS-1B	HPI MDP 1B FAILS TO START	TRUE	YES[1]
RHR-MDP-FR-1B	RHR MDP 1B FAILS TO RUN	TRUE	YES[1]
RHR-MDP-FS-1B	RHR MDP 1B FAILS TO START	TRUE	YES[1]
IE-LDCA	Loss of DC POWER BUS 1A INITIATING EVENT	0.00	YES[4]
IE-LLOCA	LARGE LOSS OF COOLANT ACCIDENT INITIAT. EVENT	0.00	YES[4]
IE-LOCCW	LOSS OF COMPONENT COOLING WATER INITIAT. EVENT	0.00	YES[4]
IE-LOESW	LOSS OF EMERGENCY COOLING WATER INITIAT. EVENT	0.00	YES[4]
IE-LOOP	LOSS OF OFFSITE POWER INITIATING EVENT	0.00	YES[4]
IE-MLOCA	MEDIUM LOSS OF COOLANT ACCIDENT INITIAT. EVENT	0.00	YES[4]
IE-RHR-DIS-V	RHR DISCHARGE ISLOCA OCCURS	0.00	YES[4]
IE-RHR-HL-V	RHR HOT LEG ISLOCA INITIATING EVENT	0.00	YES[4]
IE-RHR-SUC-V	RHR SUCTION ISLOCA INITIATING EVENT	0.00	YES[4]
IE-SGTR	STEAM GENERATOR TUBE RUPTURE INITIATING EVENT	0.00	YES[4]
IE-SI-CLDIS-V	SI COLD LEG ISLOCA OCCURS	0.00	YES[4]
IE-SI-HLDIS-V	SI HOT LEG ISLOCA OCCURS	0.00	YES[4]
IE-SLOCA	SMALL LOSS OF COOLANT ACCIDENT INITIATING EVENT	0.00	YES[4]
IE-TRANS	TRANSIENT INITIATING EVENT (FIRE)	3.2E-03	YES[5]
AFW-MDP-CF-AB	CCF FAILURES OF AFW MDPS	9.9E-02	NO[6]
MFW-SYS-TRIP	MAIN FEEDWATER SYSTEM UNAVAILABLE GIVEN REACTOR TRIPS	8.0E-01	NO[6]

Event name	Description	Probability/Frequency	Modified
MFW-SYS-UNAVAIL	MAIN FEEDWATER SYTEM UNAVAILABLE GIVEN AN ATWS EVENT	2.0e-01	NO[6]
MFW-XHE-NOREC	OPERATOR FAILS TO RECOVER MAIN FEEDWATER	2.0E-01	NO[6]
MFW-XHE-ERROR	OPERATOR FAILS TO RESTORE MAIN FEEDWATER FLOW	4.0E-02	NO[6]

Notes:

1. Base events set to TRUE reflect the failed position, if applicable, for this analysis.
2. The probability was determined from human factors work sheets.
3. The probability for nonsuppression (cuurent case) was derived from the time for the fire brigade on station and the time available to suppress the fire given a one-hour fire barrier.
4. Initiating event frequencies set to zero for this analysis.
5. Transient initiating event frequency revised to reflect the product of the initiating fire frequency and the probability of nonsuppression.
6. Identifies dominant sequence cutset base events that were not revised.

Figure removed during SUNSI review

Figure1 Simplified Equipment Layout Switchgear Room B and ACP room

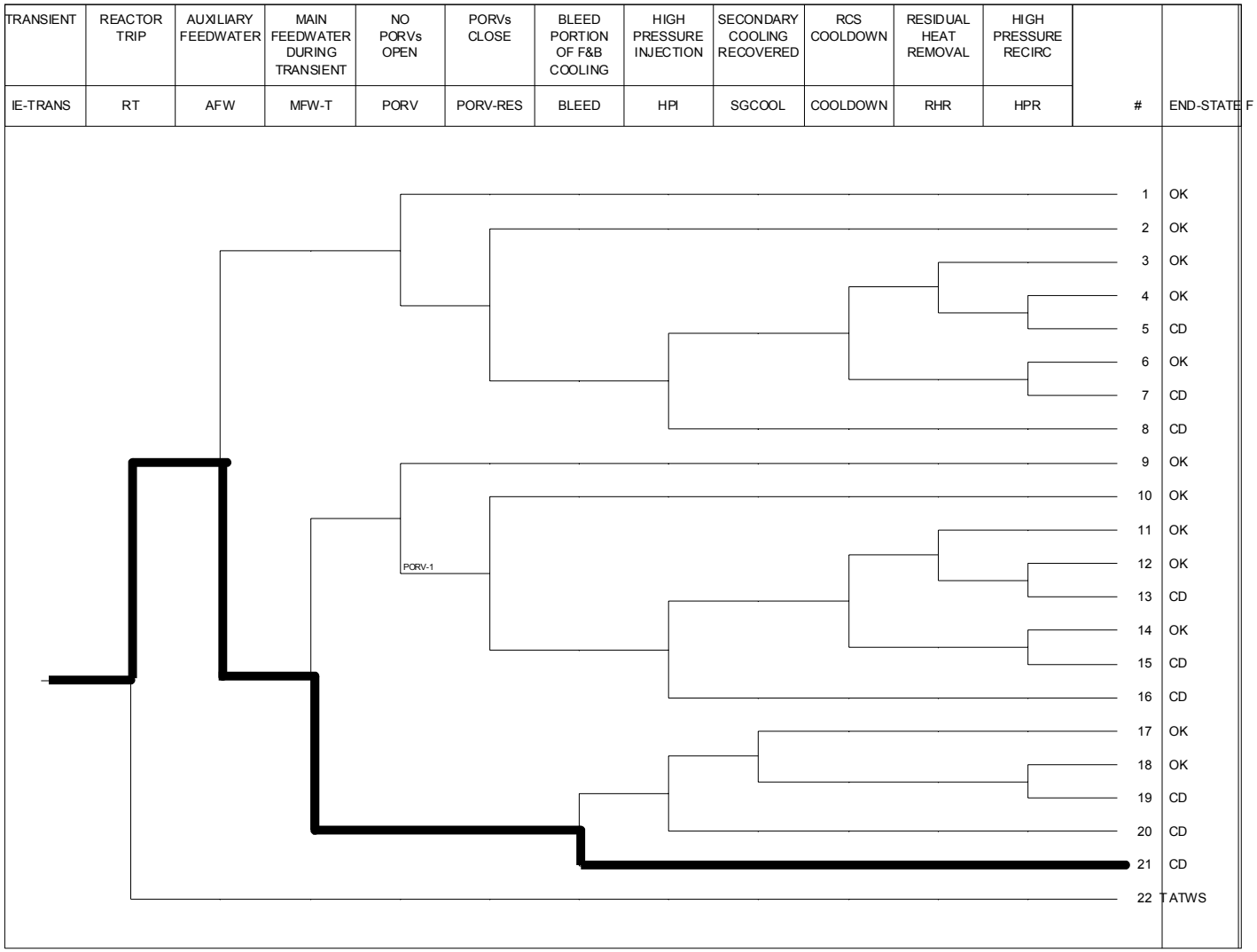

Figure 2 Trans Sequence 21

AFW MDP TRAIN A FAILURES
AFW-MDPA
AFW MDP TRAIN A FAILURES
PROBABILITY THAT FIRE PROPAGATE TO ACP
AFW-MDPA-1
FIRE-PROPAGATION-ACP
FAILURE TO ST ART AFW MOTOR DRIVEN PUMP 1A
AFW MDP 1A UNAVAILBLE DUE TO TEST AND MAINTENANCE
DIVISION 1A DC POWER BUS FAILS
AFW MDP 1A SUCTION CHECK VALVE 1CE-38 FAILS TO OPEN
AFW MDP 1A DISCH HYDRAULIC V ALVE 1AF-19 FAILS TO REMAIN OPEN
CCF FAILURE OF AFW MDPs
FAILURE OF AFW MOTOR DRIVEN PUMP 1A TO RUN
OP FAILS TO RESTORE AFW MDP 1A AFTER T&M
DIVISION 1A AC POWER FAILS
AFW MDP 1A DISCHARGE CHECK VALVE 1AF-16 FAILS TO OPEN
AFW-MDP-TM-1A
DIV-A-DC
DIV-A-AC
AFW-CKV-CC-36
AFW-HDV-OC-19
AFW-MDP-CF-AB
AFW-CKV-CC-16
AFW-XHE-XR-MDP1A
AFW-MDPA-FR-F
AFW-MDPA-FS-F
APW MDP 1A FAILS TO ST ART
OPERATOR FAILS TO RECOVER AFW MDP 1A (FAILS TO START)
OPERATOR FAILS TO RECOVER AFW MDP 1A (FAILS TO RUN)
AF W MDP 1AFAILS TO RUN
AFW-MDP-FS-1A
AFW-XHE-XL-MDPFSA
AFW-MDP-FR-1A
AFW-XHE-XL-MDPFRA

Figure 3 A

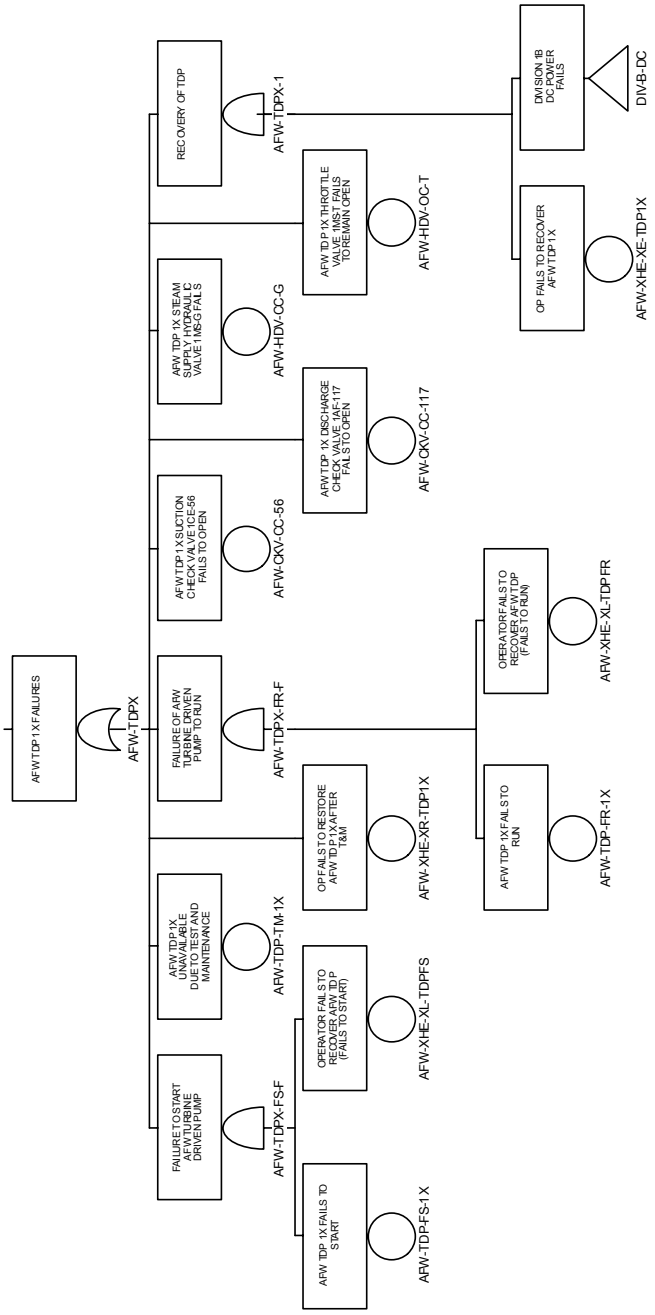
AFW TDP 1X FAILURES
AFW-TDPX
FAILURE OF AFW TURBINE DRIVEN PUMP TO RUN
AFW-TDPX-FR-F
AFW TDP 1X SUCTION CHECK VALVE 1CE-56 FAILS TO OPEN
AFW-CKV-CC-56
AFW TDP 1X DISCHARGE CHECK VALVE 1CE-117 FAILS TO OPEN
AFW-CKV-CC-117
AFW TDP 1X STEAM SUPPLY HYDRAULIC VALVE 1MS-G FAILS
AFW-HDV-CC-G
AFW TDP 1X THROTTLE VALVE 1MS-135 FAILS TO REMAIN OPEN
AFW-HDV-OC-T
RECOVERY OF TDP
AFW-TDPX-1
DIVISION 1B DC POWER FAILS
DIV-B-DC
OP FAILS TO RECOVER AFW TDP 1X
AFW-XHE-XE-TDP1X
OPERATOR FAILS TO RECOVER AFW TDP (FAILS TO RUN)
AFW-XHE-XL-TDPFR
AFW TDP 1X FAILS TO RUN
AFW-TDP-FR-1X
OP FAILS TO RESTORE AFW TDP 1X AFTER T&M
AFW-XHE-XR-TDP1X
AFW TDP 1X UNAVAILABLE DUE TO TEST AND MAINTENANCE
AFW-TDP-TM-1X
OPERATOR FAILS TO RECOVER AFW TDP (FAILS TO START)
AFW-XHE-XL-TDPFS
FAILURE TO START AFW TURBINE DRIVEN PUMP
AFW-TDPX-FS-F
AFW TDP 1X FAILS TO START
AFW-TDP-FS-1X

Figure 3B