Final Precursor Analysis

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

Indian Point, Unit 2	Moderate degradation of control room west wall could allow smoke and gases to penetrate the control room in the event of a turbine building fire	
Date: July 19, 2002	**IR:** 50-247/02-10	**Mean ΔCDP =** 7.1×10^{-6}

Condition Summary

On July 19, 2002, the NRC completed an inspection of selected areas of the Indian Point Unit 2 facility (Ref. 1). The inspection identified a moderate degradation of the control room west wall fire prior to February 2002, in that there were passages in the wall that could allow smoke and gases to infiltrate into the control room in the event of a turbine building fire and could cause a control room evacuation and use of alternative safe shutdown systems (Ref. 1).

Cause The west wall did not conform to the 3-hour fire barrier design requirements.

Recovery Opportunity The postulated fire in the turbine building, applicable to the turbine generator lube oil system or the main feedwater pump lube oil system, could generate sufficient smoke to cause infiltration into the control room and its subsequent evacuation after a successful reactor trip/turbine trip. The recovery of one train of safe shutdown equipment using the alternate safe shutdown system (ASSS) would prevent core damage.

Analysis Results

- **Importance**

  The risk significance of the control room evacuation with the recovery of one train of safe shutdown equipment with the ASSS is determined using the SPAR Rev. 3i model for Indian Point 2 (Ref.2). The analyses was with the transient initiating frequency (IE-TRANS) replaced by the combined smoke frequency of the turbine generator lube oil fires and main feedwater pump lube oil fires. This method is similar to that outlined in NUREG/CR-6544, “Development of a Methodology for Analyzing Precursors for Earthquake-Induced or Fire-Induced Accident Sequences,” Section 3.7 (Ref. 3). For this analysis, the increase in point estimate change in conditional core damage probability (ΔCDP) is 7.4×10^{-6} and the mean ΔCDP is 7.1×10^{-6}. The uncertainty about the mean is: 5% bound, 1.3×10^{-7} and 95% bound, 2.8×10^{-5}.

  The Accident Sequence Precursor (ASP) program acceptance threshold is an importance (ΔCDP) of 1×10^{-6}.

- **Dominant sequence (TRANS)**

The dominant sequence is Transient Sequence 19. The events and important component failures in this sequence include:

– Reactor trips successfully during transient
– No or Insufficient AFW flow
– Failure of main feedwater system during transient
– Successful Bleed portion of feed and bleed
– Adequate flow from HPI system
– Failure of secondary cooling
– No or insufficient flow from HPR system

- **Results tables**

– Table 1 provides the importance values for the dominant sequences.
– Table 2a provides the event tree sequence logic for the dominant sequence.
– Table 2b defines the nomenclature used in Table 2a.
– Table 3 provides the additional cut sets for the dominant sequence.
– Table 4 provides the definitions and probabilities for selected events.

Modeling Assumptions

- **ASP analysis approach**

Condition duration. The control room west wall barrier was in a degraded condition since for a period greater than one year.

- **SPAR model used in the analysis**

The Revision 3i (interim) of the Indian Point 2 Standardized Plant Analysis Risk (SPAR) model (Ref. 2) was used for this assessment. For this initiating event analysis, the IE-TRANS frequency is replaced with the smoke frequency (5.6E-3) and all other initiating event frequencies are set to zero. External events are not included in this analysis.

- **Smoke-induced analysis considerations**

The smoke-induced analysis is based on NUREG/CR-6544 (Ref. 3). For this analysis the control room is assumed to be evacuated after successful reactor trip and one train of safe shutdown equipment is operated using the ASSS. The IE-TRANS frequency is replaced with the smoke frequency, based on smoke produced from turbine generator lube oil fires, severe smoke events resulting in turbine building evacuation, and smoke produced from main feedwater pump lube oil fires. These events were evaluated as severe enough to possibly result in smoke ingestion into the control room and subsequent control room evacuation.

– **Initiating Smoke Frequency** – The initiating smoke frequency (F_{is}) was developed from NRC Report RES/OERAB/S02-01 database (Ref. 4) for power operation fire events (1986-1999 with updates through 2001). For Indian Point 2, the smoke frequency (F_S) used was 5.6 x 10^{-3} based on:

F_{is} = (No. of Turbine Generator lube oil fires + No. Turbine Building smoke evacuation events + Jeffreys noninformative prior) ÷ No. Turbine Generators x No. of reactor-years of power operation for the period) + (No. of main feedwater pump lube oil fires ÷ No. Main feedwater pumps x No. of reactor-years of power operation for the period).

$$F_{is} = \frac{(5+1)}{(1 \times 1310)} + \frac{2}{(2.34)(1310)} + \text{Jeffrey's Prior} = \frac{8 + .5}{1529} = 5.6 \times 10^{-3}$$

Note: The number of smoke events in the numerator was maintained and the denominator (component-years) was adjusted/weighted before a Bayesian update was made using a Jeffreys noninformative prior (0.5 smoke events).

- **Unique system considerations**

  The plant design provides an alternate safe shutdown system to shut the plant down with one train of safe shutdown equipment in the event of control room evacuation.

- **Modifications to event tree and fault tree models**

  – The event trees were not modified.
  – The fault trees were modified to include/clarify the recovery of one train of safe shutdown equipment, as applicable, using the ASSS (see Figures 1A-1E).

- **Initiating event probability changes**

  The TRANS initiating event (IE-TRANS) frequency was replaced by the smoke frequency (5.6 x 10^{-3}). All other initiating events frequencies were set to zero. Figure 2 shows the event tree for the smoke-induced transient analysis dominant sequence.

- **Base event probability changes**

  Table 4 provides the basic events that were modified to reflect the event condition being analyzed. Equipment not controlled from the ASSS is assumed be inoperable and assigned a value of 1.0 in the model.

- **Initiating event assessment probability changes**

  – **AFW Motor-Driven Pump 23 Fails to Run (AFW-MDP-FR-23)**. This event was set to 1.0.
  – **AFW Motor-Driven Pump 23 Fails to Start (AFW-MDP-FS-23)**. This event was set to 1.0.

- **Operator Fails to Recover AFWMDP 23 (Fails to Run) (AFW-XHE-XL-MDP23).** This event was set to 1.0.
- **Failure of CCW MDP 22 (CCW-MDP-FC-22).** This event was set to 1.0.
- **Failure of CCW MDP-21 to Run (CCW-MDP-FR-MDP21). T**his event was set to 1.0.
- **Failure of CCW MDP 22 to Run (CCW-MDP-FR-MDP22).** This event was set to 1.0.
- **Failure of CCW MDP-21 to Start (CCW-MDP-FS-MDP21). T**his event was set to 1.0.
- **Failure of CCW MDP-22 to Start (CCW-MDP-FS-MDP22). T**his event was set to 1.0.
- **Failure of Positive Displacement Pump 22 (CVC-PDP-FC-22).** This event was set to 1.0.
- **Failure of Positive Displacement Pump 21 to Run (CVC-PDP-FR-21).** This event was set to 1.0.
- **Failure of Positive Displacement Pump 22 to Run (CVC-PDP-FR-22).** This event was set to 1.0.
- **Failure of Positive Displacement Pump 22 to Start (CVC- PDP-FS-22). T**his event was set to 1.0.
- **Failure of HPI MDP-22 (HPI-MDP-FC-22).** This event was set to 1.0.
- **Failure of HPI MDP-23 (HPI-MDP-FC-23). T**his event was set to 1.0.
- **Failure of HPI MDP-22 (HPI-MDP-FC-22). T**his event was set to 1.0.
- **RHR MDP-22 Fails (RHR-MDP-FC-22). T**his event was set to 1.0.
- **RHR MDP-22 Fails to Run (RHR-MDP-FR-22)**. This event was set to 1.0.
- **RHR MDP-22 Fails to Start (RHR-MDP-FS-22)**. This event was set to 1.0.
- **Failure of SWS MDP 21 to Run (SWS-MDP-FR-21).** This event was set to 1.0.
- **Failure of SWS MDP 22 to Run (SWS-MDP-FR-22).** This event was set to 1.0.
- **Failure of SWS MDP 25 to Run (SWS-MDP-FR-25).** This event was set to 1.0.
- **Failure of SWS MDP 26 to Run (SWS-MDP-FR-26).** This event was set to 1.0.
- **Failure of SWS MDP 21 to Run (SWS-MDP-FR-MDP21).** This event was set to 1.0.
- **Failure of SWS MDP 22 to Run (SWS-MDP-FR-MDP22).** This event was set to 1.0.
- **Failure of SWS MDP 25 to Run (SWS-MDP-FR-MDP25).** This event was set to 1.0.
- **Failure of SWS MDP 26 to Run (SWS-MDP-FR-MDP26).** This event was set to 1.0.
- **Failure of SWS MDP 21 to Start (SWS-MDP-FS-21).** This event was set to 1.0.
- **Failure of SWS MDP 22 to Start (SWS-MDP-FS-22).** This event was set to 1.0.
- **Failure of SWS MDP 25 to Start (SWS-MDP-FS-25).** This event was set to 1.0.
- **Failure of SWS MDP 26 to Start (SWS-MDP-FS-26).** This event was set to 1.0.
- **Failure to Align Alternate Safe Shutdown Power Supplies (SSS-XHE-XE-Align).** This event was set to 1.0E-002.
- **Transient Initiating Event (IE-TRANS).** This initiating event was set to 5.6E-003.
- All other initiating events were set to zero.

• **Model update**

No updates were made to the SPAR model, except clarification of fault trees for the alignment of the alternate safe shutdown system (see Figures 1A-1E) .

References

1. EA-02-162, *Indian Point Unit 2 - NRC Supplemental/Problem Identification and Resolution — Inspection Report No. 50-247/02-010n Number,* dated August 28, 2002.

2. J. K. Knudsen and R. F. Buell, *Standardized Plant Analysis Risk Model for Indian Point Unit 2, Revision 3i*, Idaho National Engineering and Environmental Laboratory, May 2002.

3. R.W.Budnitz, et al., Development of a Met*hodology for Analyzing Precursors to Earthquake-Induced and Fire-Induced Accident Precursors,* 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.

Table 1. Conditional Probability Associated with Highest Probability Sequence (Point Estimate)

Event Tree	**Sequence**	**Conditional Core Damage probability (CCDP)**
TRANS	19	6.7E-06
TOTAL	**All Sequences**	**7.4E-06**

Table 2a. Event tree sequence logic for dominant sequence

Event Tree Name	**Sequence no.**	**Logic (“/” denotes success; see Table 2b. for top event names**
TRANS	19	/RT, AFW, MFW-T, /BLEED, /HPI, SGCOOL, HPR

Table 2b. Definitions of sequence logic elements listed in Table 2a.

AFW	No or insufficient AFW flow
BLEED	Failure of Bleed portion of Feed and Bleed cooling
SGCOOL	Failure of secondary cooling
HPI	No or insufficient flow from HPI system
HPR	No or insufficient HPR flow
RHR	No or insufficient flow from RHR system
RT	Reactor fails to trip during transient

Table 3a. Conditional cut sets for dominant sequence (Point Estimate)
Event tree: TRANS Sequence 19

CCDP	**Percent Contribution**	**Minimum cut sets**[1]
1.6E-006	**23.5**	**PCS-XHE-XO-SEC SSS-XHE-XE-ALIGN AFW-MDP-FR-23 AFW-XHE-XL-MDPFR23 AFW-TDP-FR-22 SWS-MDP-FR-21 SWS-MDP-FR-22**
1.6E-006	**23.5**	**PCS-XHE-XO-SEC SSS-XHE-XE-ALIGN AFW-MDP-FR-22 AFW-XHE-XL-MDPFR23 AFW-TDP-FR-22 CCW-MDP-FR-MDP21 CCW-MDP-FC-MDP22**
6.7E-006	**Total**[2]	

NOTES:

1. **See Table 4 for definitions and probabilities for the base events.**
2. **Total ΔCDP includes all other 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
IE-LDC22	LOSS OF DC Bus 22 INITIATING EVENT FREQUENCY	0.00	YES1
IE-LLOCA	LARGE LOSS OF COOLANT ACCIDENT INITIATING EVENT	0.00	YES[1]
IE-LOCCW	LOSS OF COMPONENT COOLING WATER INITIATING EVENT	0.00	YES[1]
IE-LOop	LOSS OF OFFSITE POWER INITIATING EVENT	0.00	YES[1]
IE-LOSWS	LOSS OF SERVICE WATER INITIATING EVENT	0.00	YES[1]
IE-MLOCA	MEDIUM LOSS OF COOLANT ACCIDENT INITIATING EVENT	0.00	YES[1]
IE-RHR-DIS-V	RHR DISCHARGE ISLOCA OCCURS WITH REACTOR AT POWER OVER 1 YEAR	0.00	YES[1]
IE-RHR-SUC-V	RHR SUCTION ISLOCA INITIATING EVENT	0.00	YES[1]
IE-SGTR	STEAM GENERATOR TUBE RAPTURE	0.00	YES[1]
IE-SI-CLDIS-V	SI COLD LEG ISLOCA INITIATING EVENT	0.00	YES[1]
IE-SI-HLDIS-V	SI HOT LEG ISLOCA INITIATING EVENT	0.00	YES[1]
IE-SLOCA	SMALL BREAK LOSS OF COOLANT ACCIDENT INITIATING EVENT	0.00	YES[1]
IE-TRAN	INITIATING EVENT-TRANSIENT	5.6E-03	YES[1]
AFW-MDP-FR-23	AFW MOTOR-DRIVEN PUMP 23 FAILS TO RUN	1.00	YES[2]
AFW-MDP-FS-23	AFW MOTOR-DRIVEN PUMP 23 FAILS TO START	1.00	YES[2]
AFW-XHE-XL-MDPFR23	OPERATOR FAILS TO RECOVER MDP23	1.00	YES[2]
CCW-MDP-FC-MDP22	FAILURE OF CCW MDP22	1.00	YES[2]
CCW-MDP-FR-MDP21	FAILURE OF CCW MDP-21 TO RUN	1.00	YES[2]
CCW-MDP-FR-MDP22	FAILURE OF CCW MDP-22 TO RUN	1.00	YES[2]
CCW-MDP-FS-MDP21	FAILURE OF CCW MDP-21 TO START	1.00	YES[2]
CCW-MDP-FS-MDP22	FAILURE OF CCW MDP-22 TO START	1.00	YES[2]
CVC-PDP-FC-22	FAILURE OF POSITIVE DISPLACEMENT PUMP 22	1.00	YES[2]
CVC-PDP-FR-21	FAILURE OF POSITIVE DISPLACEMENT PUMP 21 TO RUN	1.00	YES[8]
CVC-PDP-FR-22	FAILURE OF POSITIVE DISPLACEMENT PUMP 22 TO RUN	1.00	YES[8]
CVC-PDP-FS-22	FAILURE OF POSITIVE DISPLACEMENT PUMP 22 TO START	1.00	YES[2]
HPI-MDP-FC-22	FAILURE OF HPI MDP-22	1.00	YES[2]
HPI-MDP-FC-23	FAILURE OF HPI MDP-23	1.00	YES[2]
RHR-MDP-FC-22	RHR MDP-22 FAILS	1.00	YES[2]
RHR-MDP-FR-22	RHR MDP-22 FAILS TO RUN	1.00	YES[2]

Event name	Description	Probability/ Frequency	Modified
RHR-MDP-FS-22	RHR MDP-22 FAILS TO START	1.00	YES[2]
SWS-MDP-FR-21	FAILURE OF SWS MDP-21 TO RUN	1.00	YES[2]
SWS-MDP-FR-22	FAILURE OF SWS MDP-22 TO RUN	1.00	YES[2]
SWS-MDP-FR-25	FAILURE OF SWS MDP-25 TO RUN	1.00	YES[2]
SWS-MDP-FR-26	FAILURE OF SWS MDP-26 TO RUN	1.00	YES[2]
SWS-MDP-FR-MDP21	FAILURE OF SWS MDP-21 TO RUN	1.00	YES[2]
SWS-MDP-FR-MDP22	FAILURE OF SWS MDP-22 TO RUN	1.00	YES[2]
SWS-MDP-FR-MDP25	FAILURE OF SWS MDP-25 TO RUN	1.00	YES[2]
SWS-MDP-FR-MDP26	FAILURE OF SWS MDP-26 TO RUN	1.00	YES[2]
SWS-MDP-FS21	FAILURE OF SWS MDP-21 TO START	1.00	YES[2]
SWS-MDP-FS22	FAILURE OF SWS MDP-22 TO START	1.00	YES[2]
SWS-MDP-FS25	FAILURE OF SWS MDP-25 TO START	1.00	YES[2]
SWS-MDP-FS26	FAILURE OF SWS MDP-26 TO START	1.00	YES[2]
SWS-XHE-XE-ALIGN	FAILURE TO ALIGN ALTERNATE SAFE SHUTDOWN SYSTEM	1.0E-02	YES[2]
AFW-TDP-FR-22	AFW TURBINE DRIVEN PUMP FAILS TO RUN	2.8E-02	NO
PCS-XHE-XO-SEC	OPERATOR FAILS TO ESTABLISH SECONDARY COOLING	2.0E-01	NO

Notes:

1. The TRANS initiating event frequency was replaced with the smoke frequency. All other initiating event frequencies were set to zero.
2. Basic events were changed to reflect condition being analyzed. .

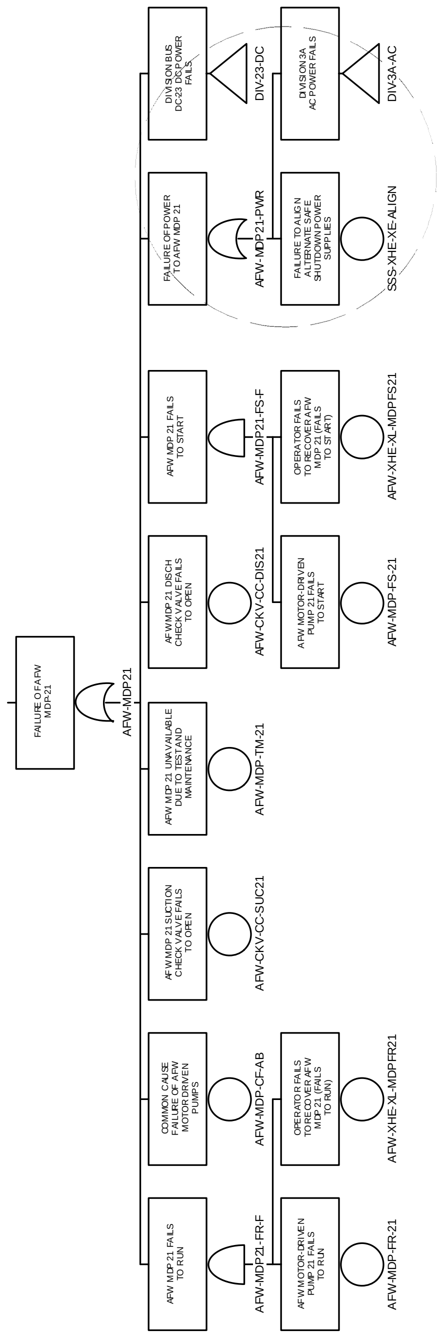
FAILURE OF AFW MDP-21
AFW-MDP21
AFW MDP 21 FAILS TO RUN
AFW-MDP21-FR-F
AFW MOTOR-DRIVEN PUMP 21 FAILS TO RUN
AFW-MDP-FR-21
COMMON CAUSE FAILURE OF AFW MOTOR DRIVEN PUMPS
AFW-MDP-CF-AB
OPERATOR FAILS TO RECOVER AFW MDP 21 (FAILS TO RUN)
AFW-XHE-XL-MDPFR21
AFW MDP 21 SUCTION CHECK VALVE FAILS TO OPEN
AFW-CKV-CC-SUC21
AFW MDP 21 UNAVAILABLE DUE TO TEST AND MAINTENANCE
AFW-MDP-TM-21
AFW MDP 21 DISCH CHECK VALVE FAILS TO OPEN
AFW-CKV-CC-DIS21
AFW MOTOR-DRIVEN PUMP 21 FAILS TO START
AFW-MDP-FS-21
AFW MDP 21 FAILS TO START
AFW-MDP21-FS-F
OPERATOR FAILS TO RECOVER AFW MDP 21 (FAILS TO START)
AFW-XHE-XL-MDPFS21
FAILURE OF POWER TO AFW MDP 21
AFW-MDP21-PWR
FAILURE TO ALIGN ALTERNATE SAFE SHUTDOWN POWER SUPPLIES
SSS-XHE-XE-ALIGN
DIVISION BUS DC23 DC POWER FAILS
DIV-23-DC
DIVISION 3A AC POWER FAILS
DIV3A-AC

FIGURE 1A

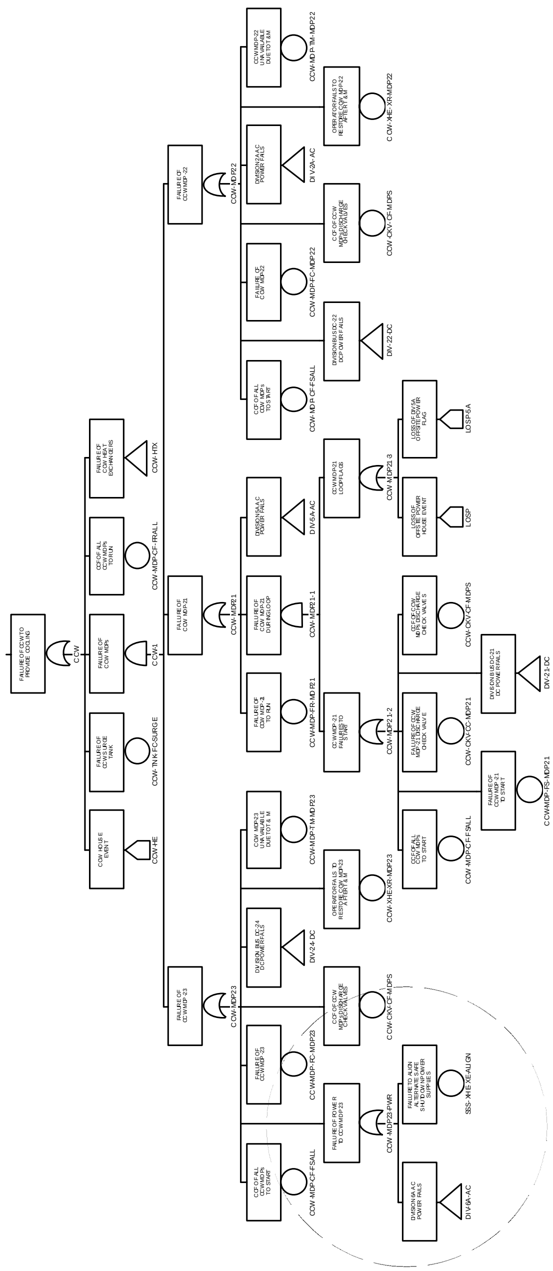

FIGURE 1B

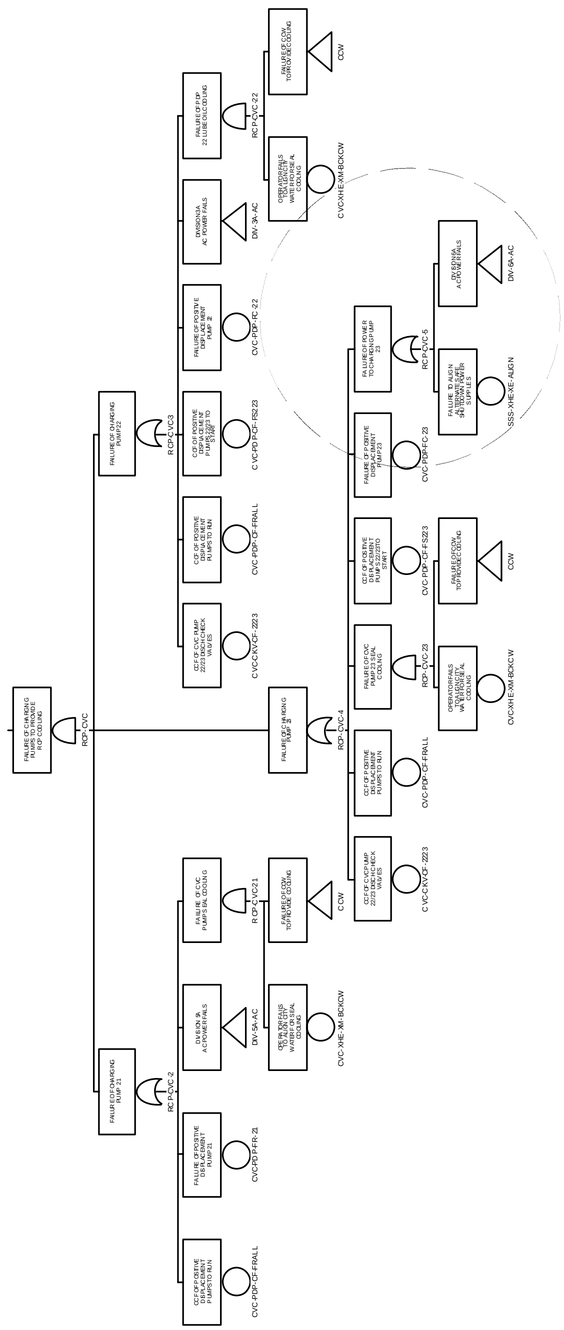

FIGURE 1C

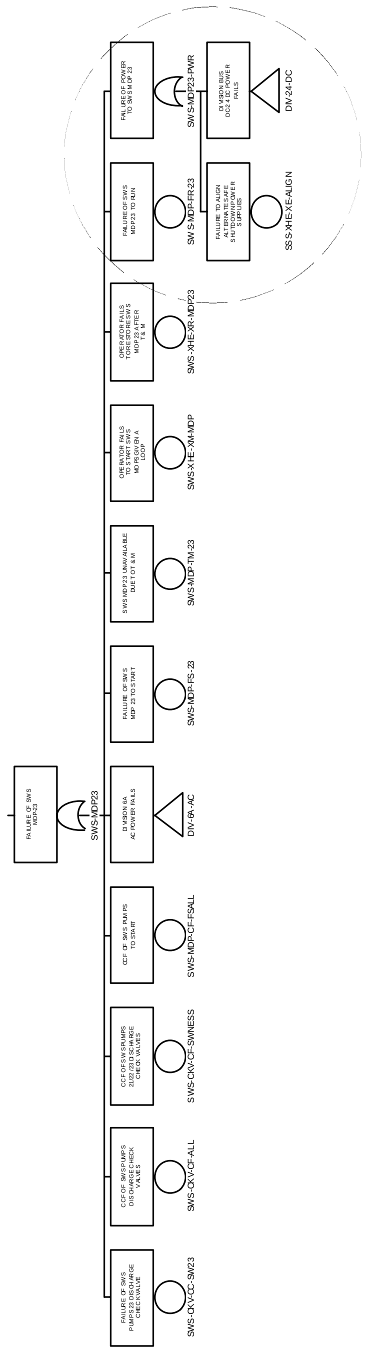
SWS-MDP23
DIV-6A-AC
SWS-MDP-FS-23
SWS-MDP-TM-23
SWS-XHE-XM-MDP
SWS-XHE-XR-MDP23
SWS-MDP-FR-23
SWS-MDP23-PWR
DIV-24-DC
SSS-XHE-XE-ALIGN
SWS-MDP-CF-FSALL
SWS-CKV-CF-SWNESS
SWS-CKV-CF-ALL
SWS-CKV-CC-SW23

FIGURE 1D

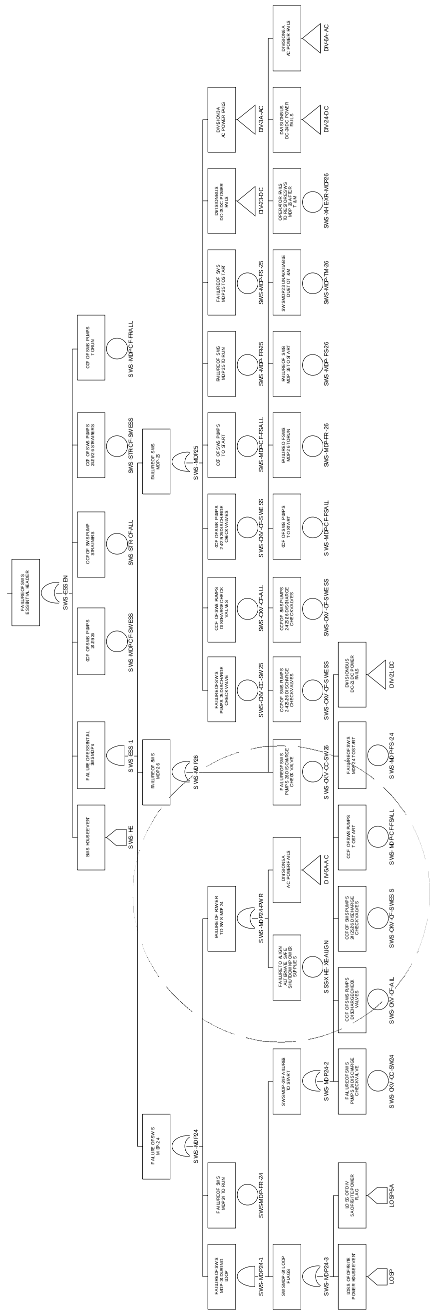

FIGURE 1E

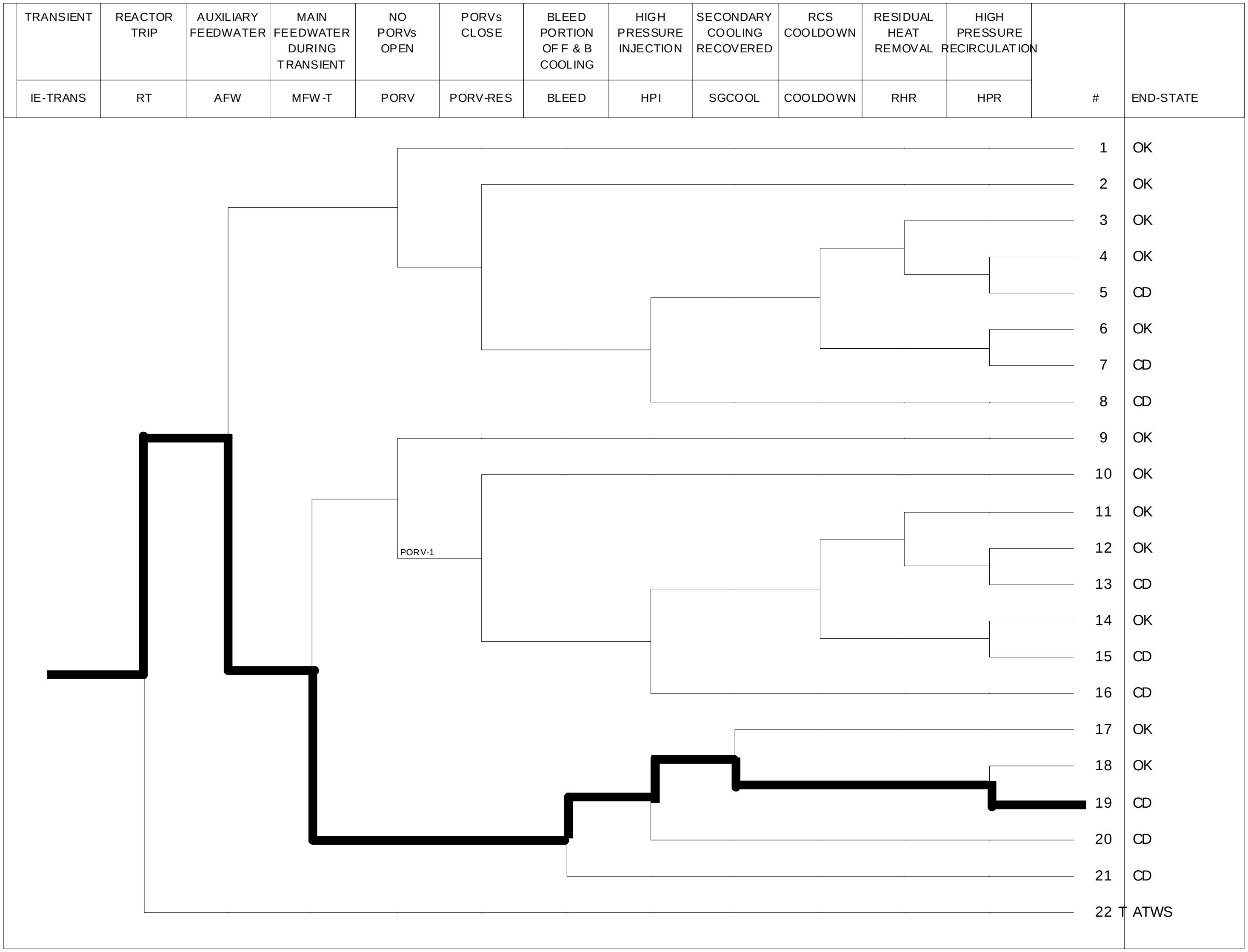

FIGURE 2 - TRANS SEQUENCE 19