Detailed Discussion of Aspects in Shutdown SDP

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Detailed Discussion of Aspects in Shutdown SDP

- POS Groups (PGs), Time Windows (TWs), and Initiating Events (IEs)
- Likelihood Ratings of IEs
- Available or Outage-Specific Mitigation Capability
- SDP Worksheets and Event Trees

Definition of Plant Operational States

- The RHR System Is Initially Operating. The shutdown conditions in which steam generators are normally used to remove heat are covered by full power model.
- Whether or Not RCS is Filled or Vented (PWRs)
- Whether or Not Vessel Head Is On or Off (BWRs)
- Time Window After Shutdown: Before, During, or After Refueling

Characterization of Plant Operational States

- Defines the Initial Conditions for Developing PRA Model and SDP Model
- Use of 35-day Outage Schedule to Determine Maintenance Unavailability
- Determination of Time Available for Operator Action and Success Criteria

PWR Shutdown SDP - Definition and Characterization of POSs

POS Group (corresponding POS in reg. Ana.)	Normal Method of Heat Removal	Plant Operational States Defined in NUREG/CR-6144	Tech. Spec. Mode	Characterization	Initiating Events
I (1,4)[1]	RHR System	3,4,12,13	4. Hot Shutdown 5. Cold shutdown	RCS is closed. Boron concentration is maintained at that of cold shutdown. The RHR system is running to remove decay heat. Low temperature over pressurization protection is in operation.. Charging and RHR letdown is operating. Steam generators are available for decay heat removal. Before refueling, train A is down for maintenance. After refueling, train B is down for maintenance.	Loss of RHR (LORHR), loss of offsite power(LOOP), Loss of Inventory (ILORI)
II (2)[2]	RHR System-Reduced Inventory	5,6,7,9,10,11	5. Cold shutdown	RCS is vented at a high point such as at the pressurizer (PORVs opened, safety valves removed, man way removed) to prevent nozzle dam failure. Vessel level is at or below the vessel flange. The stand pipe level instrumenation provides vessel level information. RCS may be isolated from the SGs by closed loop stop valves or nozzle dams. All RCPs are tripped. RHR is running to remove decay heat. Before refueling, train A is down for maintenance. After refueling, train B is down for maintenance.	LORHR, LOOP, ILORI, Loss of Level Control (LOLC)
III (3)	RHR System-Refueling	8	6. Refueling	Vessel head and upper internal are removed. The cavity seal is installed and the refueling cavity is filled. RHR is operating to remove decay heat. Either train A or train B is down for maintenance.	LORHR, LOOP

1. There is not a separate POS for hot shutdown which has different TS requirements.
2. The RCS level/inventory may vary significantly.

Representative PWR Accident Timing and Success Criteria

POS Group (Assumed Decay Heat Level)	Time to Boiling[1] (NUREG/CR 5718, 6144)	Time to SG Dry Out (Assumed Wet Layup, NUREG/CR-5718)	Time to Core Damage (NUREG/CR 5718, 6144)	Recirculation after Successful Feed and Bleed (Requires capability to take suction from sump)	Credit for Operator actions [2]	SG Makeup
I-E (2 days after shutdown)	3 hours	14 hours	4 hours	yes	base HEP	yes
I-L (12 days after shutdown)	6 hours	24 hours	8 hours	no	base HEP +1	no
II-E (2 days after shutdown)	15 min.	-	2 hours	yes	base HEP	-
II-L (12 days after shutdown)	27 min.	-	3 hours	no	base HEP +1	-

1. It depends on the initial RCS temperature and pressure. For a higher initial temperature, the timing should be much shorter.

2. The credit for operator actions needs to be estimated for the early time window. It is proposed to give an extra credit to all operator actions in the late time window.

BWR Shutdown SDP - Definition of POSs

POS (corresponding POS in reg. Ana.)	Normal Method of Heat Removal	Plant Operational States Defined in NUREG/CR-6143	Tech. Spec. Mode	Characterization	Important Initiating Events
I (1,2,4)	RHR System	4, 5	3. Hot Shutdown (partial) 4. Cold shutdown	Vessel head on, recirculation on low speed, RCS pressure below 135 psig, MSIVs closed, RCS level at low level 3 (requiring recirculation pump running)	LORHR, LOOP, ILORI
II (2,4)	RHR System	6	5. Refueling (partial)	Vessel head off, RCS level at main steam lines, MSIV closed	LORHR, LOOP, ILORI
III (3)	RHR System	7	5. Refueling	Vessel head off, RCS level at 23'	LORHR, LOOP, ILORI

1. NSAC-175 states that Grand Gulf reduced suppression pool level by 100,000 gallon in mode 4 by transferring water to radwaste holding tank. In mode 3, containment is required to be closed, but not mode 4. In modes 4 and 5 pressure suppression capability is not required, and upper pool has to be drained before RPV disassembly.

2. NSACV-175 states that in mode 4 Grand Gulf keeps level at 231 " above TAF (366.3"), steam separator turn around point, to enhance natural circulation, while CR-6143 states that level has to be at measured 82" (actual 63") above instrument zero (533"). Therefore, in mode 4, they do not have to have recirculation pumps. In a LOOP, this determines if makeup is required to support RHR operation.

Representative BWR Accident Timing and Success Criteria

POS Group (Assumed Decay Heat Level)	Remove Decay Heat with Steaming (CR-6143 screening)	Time to RHR Rupture in a SBO (CR-6143, volume 6	Time to Core Uncovery due to Low Pressure Steaming (CR-6143)	Time to Core Uncovery due to High Pressure Boil Off (CR-6143)	Credit for Operator actions (2)
I-E (7 hours)	249 gpm	3 hours	2.8ours	7 hours	base HEP
I-L	44 gpm (30 days)	- (40 days)	6.5 hours (40 days)	> 24 hours (40 days)	base HEP +1
II-E (Before refueling)					base HEP
II-L (after refueling)					base HEP +1

1. It depends on the initial RCS temperature and pressure. For a higher initial temperature, the timing should be much shorter.

2. The credit for operator actions needs to be estimated for the early time window. It is proposed to give an extra credit to all operator actions in the late time window.

Relating Inspections Findings to POSs, TWs, and TS Modes

- Shutdown periods are divided into

  - different plant operating states (POSs), and
  - different time windows (TWs)

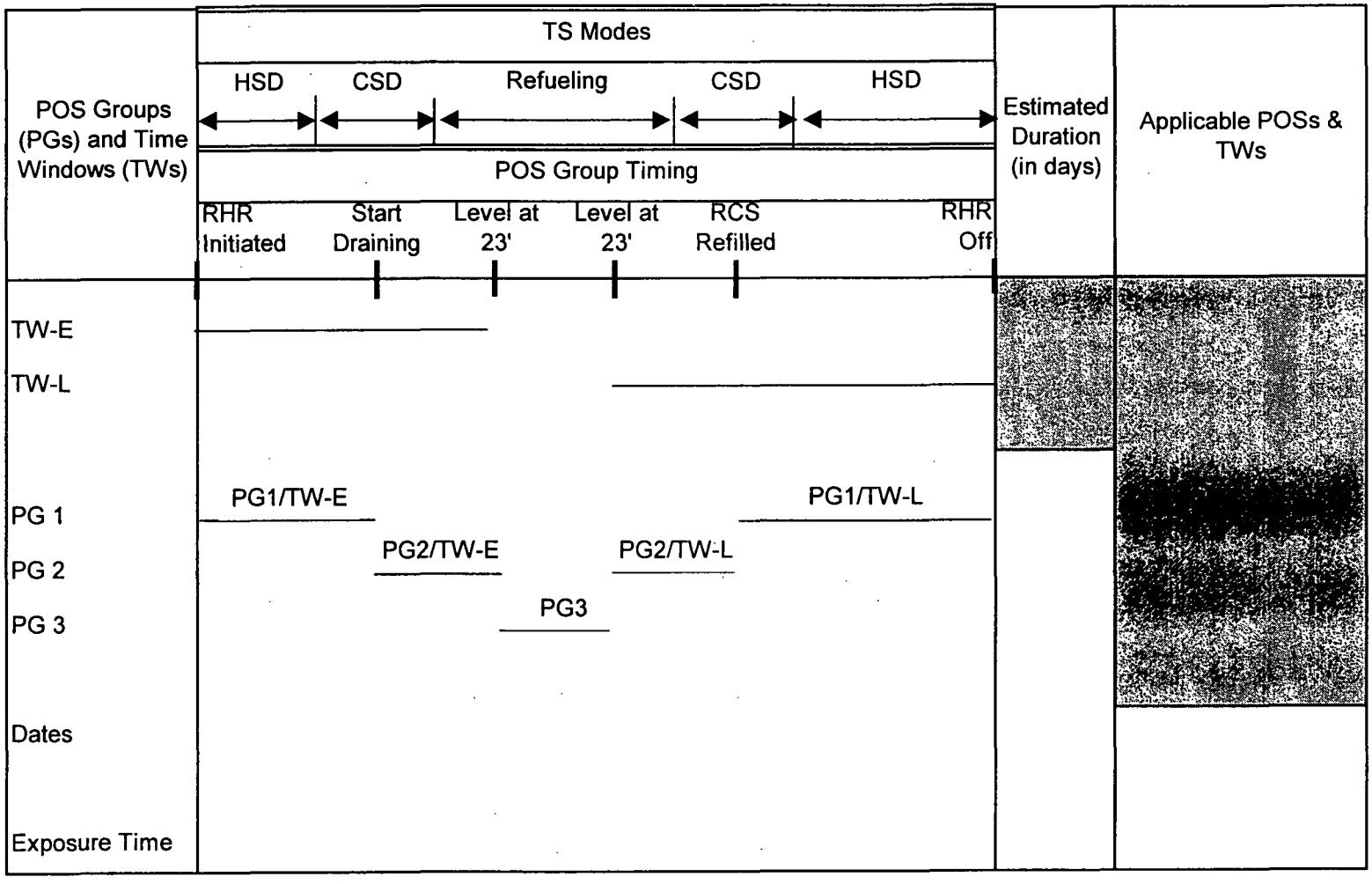
  to account for different risk implications for different periods during a shutdown

- Inspection findings may relate to part of or the entire shutdown. Assessment of an inspection finding may involve a single POS for a specific TW or multiple POSs involving both the TWs.

- Relating to the exposure time of an inspection finding, the applicable POSs and TWs for which evaluations should be conducted need to be defined

- SDP worksheets to include a table for inspectors to define the applicable POS and TW combinations using the time (from the outage schedule) at which different operating conditions are initiated and an assessment of the exposure time for the inspection findings

Identifying PGs and TWs for Inspection Findings (PWRs)



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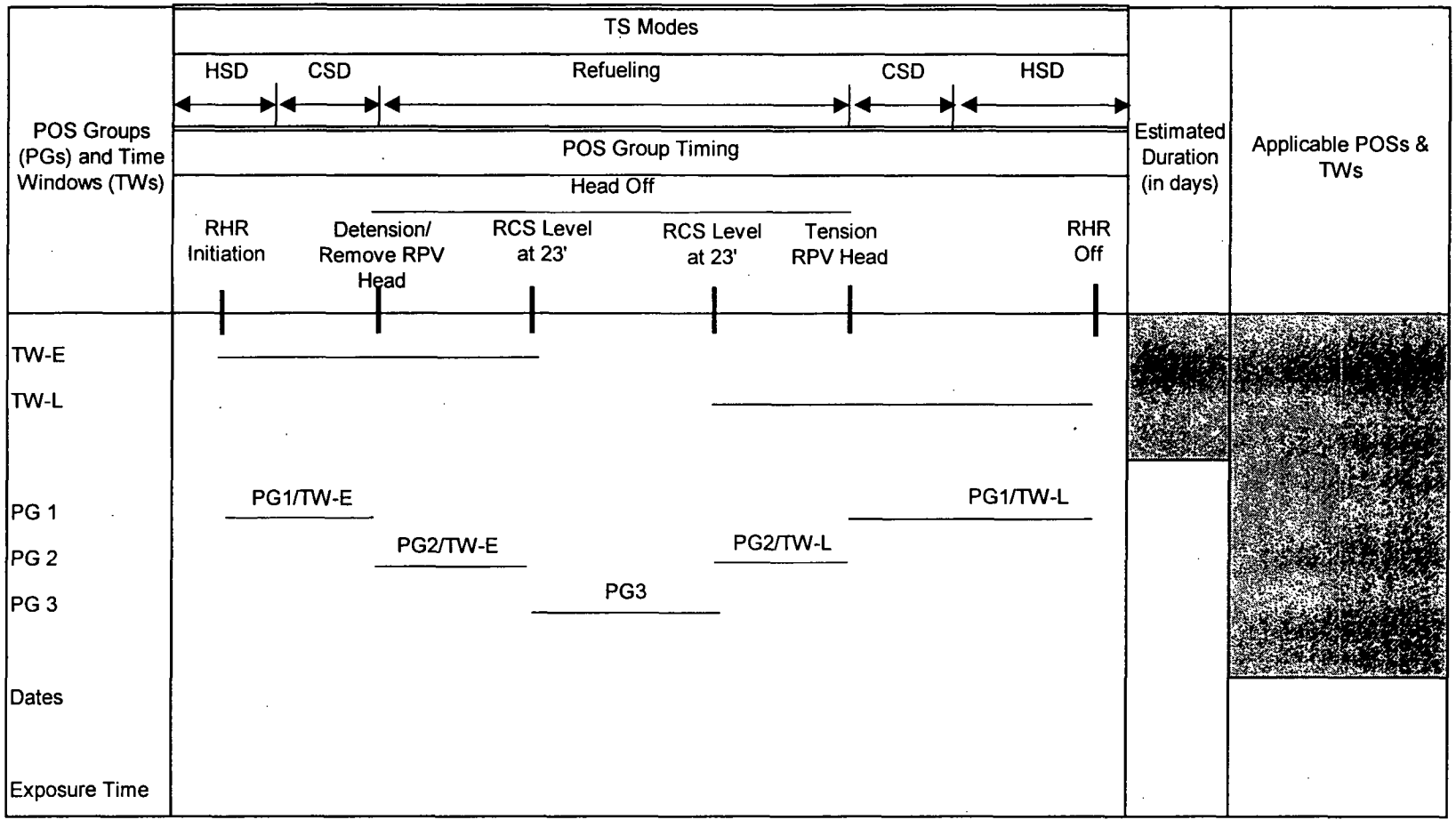


Defining Initiating Event Categories for Shutdown Significant Determination Process (SSDP)

- Shutdown IE is calculated on a yearly basis to assess the core damage frequency on a yearly basis
- The duration and frequency of the POS is taken into consideration in estimating the yearly IE frequency
- Conditional frequency of an IE during shutdown (i.e., IE frequency given that the plant is in shutdown) is assumed same across the POSs. (Small data set does not justify calculation of conditional POS-specific frequency.)
- The POS durations are different which results in different POS-specific yearly frequency for an initiating event

Defining IE Categories for Shutdown SDP

- Similar to full power SDPs, order of magnitude categorization is needed
- Since the yearly frequency is POS-specific, then POS-specific categorization is included
- Since POS duration for an inspection finding has implication for the risk color, then likelihood ratings are provided for expected ranges of POS durations
- Inspector uses the estimated exposure time for degraded condition identified by the inspection finding and the POS duration to obtain a likelihood rating for the initiating event as provided in the table.

Estimating IE Frequency for Different POSs

- LER search by Houghton (July 2000) is used to obtain the number of occurrence of different IEs categorized by the shutdown SDP POS Group definitions

- The conditional IE frequency is obtained by dividing the number of occurrences by the amount of time the population of reactors spent in the applicable POSs.

- The yearly frequency is obtained by multiplying the conditional frequency and the fraction of time the spends in the POS (in unit of a year)

Uncertainties in Estimating Average POS Durations

- A typical refueling outage of 35 days at 18-month interval is considered to define the POS durations
- The applicable POS durations from the typical outage is adjusted to obtain estimated POS duration per year
- The industry average capacity factor is used to adjust the POS durations to account for the average time spent in shutdown conditions
- The above process involves assumptions resulting in uncertainty in the estimated "average" POS duration; also, POS duration may vary significantly from one outage to another

Categorization of IE Frequencies forShutdown SDP Process

- Ranges of POS durations are defined to cover the expected durations that may be observed in different outages
- "Nominal" frequency calculated using the estimated "average" duration is used to assign the IE categorization corresponding to the range of POS duration
- IE categorization for other (order of magnitude difference) POS durations and exposure time for degraded conditions are proportionally defined

Advantages in Using the Proposed Shutdown IE Categorization Table

- Allows incorporation of POS duration in obtaining risk colors directly
- Large uncertainty in POS durations are treated through assignment of ranges for POS durations and the time spent in the POS is accounted avoiding the uncertainty in POS durations
- Inspector's use of the Table is direct based on the data in the refueling schedule and his findings; it does not require any separate calculations

Calculation of Initiating Event Frequency Using LERs

- Results of LER Search of 1992-1998

POS Group	LOOP	LORHR	ILORI	LOLC	Fraction of a Calendar Year
I	12	11	1	no	6%
II	yes	3	1	1	3%
III	3	1	no	no	5%
Total	15	15	2	1	14%

yes: The initiating event is applicable to the POS, however, no event was found in the LER search
no: The initiating event is not applicable to the POS.

- Conditional initiating event frequency = number of events / number of years the plants or sites spent in the applicable POSs

POS Group	LOOP	LORHR	ILORI	LOLC
I	0.37	0.22	4.65E-2	no
II	0.37	0.22	4.65E-2	7.22E-2
III	0.37	0.22	No	no

- Initiating Event Frequency = Conditional Initiating Event Frequency * Fraction of Time the Plant Spent in the POS

POS Group	Fraction of Year	LOOP	LORHR	ILORI	LOLC
I	6%	2.3E-2	1.3E-2	2.9E-3	no
II	3%	1.1E-2	6.4E-3	1.4E-3	2.1E-3
III	5%	1.9E-2	1.1E-2	no	no

- The above table is used as the anchoring point for determining the initiating event likelihood rating

Table 1 Categories of POS Group I Initiating Events for PWRs

Row	Approximate Frequency	Example Event Type	Estimated Likelihood Rating				
			POS Group I Durations				
			> 30 days		3 to 30 days		< 3 days
I	> 1 per 1-10 yr						
II	1 per 10-10^2 yr	Loss of offsite power (LOOP), Loss of RHR (LORHR)	A	B	B	C	C
III	1 per 10^2 - 10^3 yr	Loss of Inventory (ILORI)	B	C	C	D	D
IV	1 per 10^3 - 10^4 yr						
			> 30 days	3-30 days	3-30 days	< 3 days	< 3 days
			Exposure Time for Degraded Condition				

Table 1.1 Categories of POS Group I Initiating Events for a BWR Plant

Row	Approximate Frequency	Example Event Type	Estimated Likelihood Rating				
			POS Group I Durations				
			> 30 days		3 to 30 days		< 3 days
I	> 1 per 1-10 yr	Loss of RHR (LORHR)	A+	A	A	B	B
II	1 per 10-10^2 yr	Loss of offsite power (LOOP)	A	B	B	C	C
III	1 per 10^2 - 10^3 yr	Loss of Inventory (ILORI)	B	C	C	D	D
IV	1 per 10^3 - 10^4 yr						
			> 30 days	3-30 days	3-30 days	< 3 days	< 3 days
			Exposure Time for Degraded Condition				

Table 1.2 Categories of POS Group II Initiating Events for a BWR Plant

Row	Approximate Frequency	Example Event Type	Estimated Likelihood Rating		
			POS Group II Durations		
			3 to 30 days		< 3 days
I	> 1 per 1-10 yr		A	B	B
II	1 per 10-10^2 yr	Loss of RHR (LORHR)	A	B	B
III	1 per 10^2 - 10^3 yr	Loss of offsite power (LOOP)	B	C	C
IV	1 per 10^3 - 10^4 yr	Loss of Inventory (ILORI)	C	D	D
			3-30 days	< 3 days	< 3 days
			Exposure Time for Degraded Condition		

Table 1.3 Categories of POS Group III Initiating Events for a BWR Plant

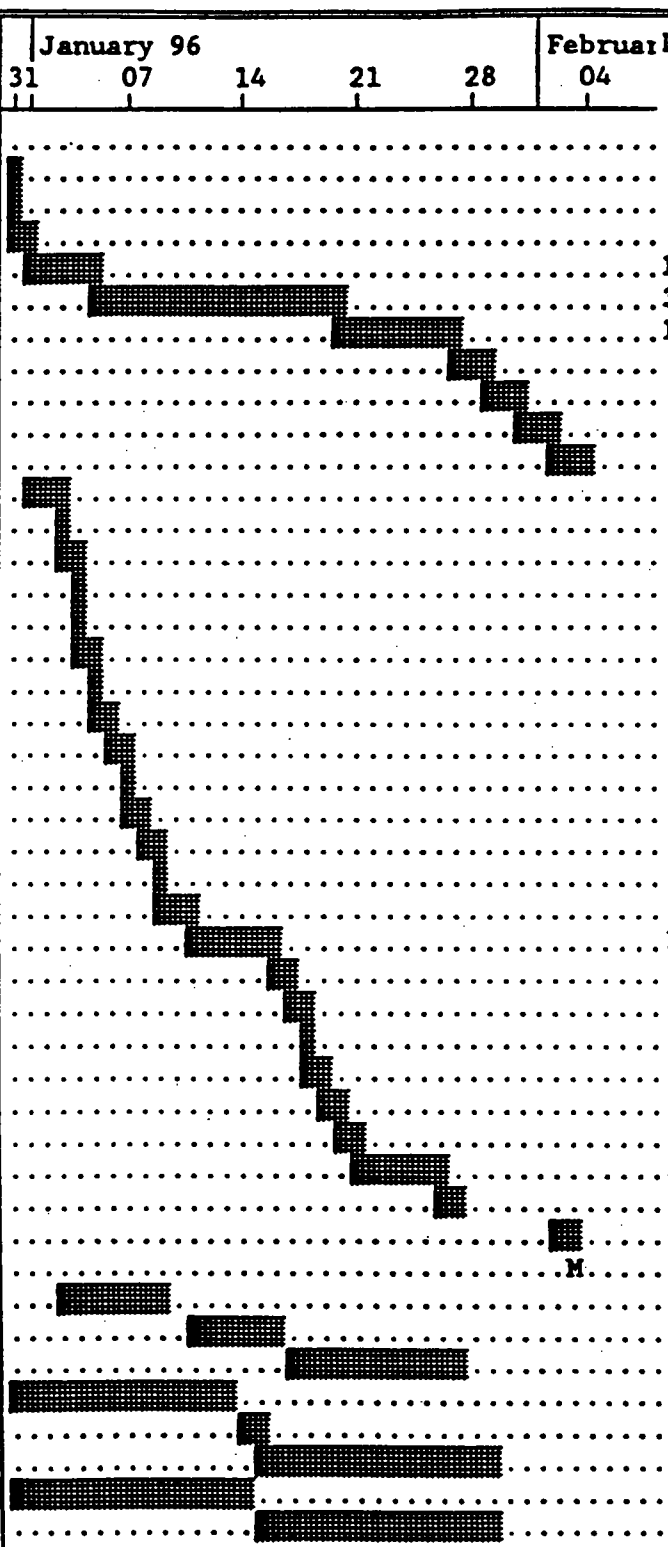
Row	Approximate Frequency	Example Event Type	Estimated Likelihood Rating				
			POS Group III Durations				
			> 30 days		3 to 30 days		< 3 days
I	> 1 per 1-10 yr	Loss of RHR (LORHR)	A+	A	A	B	B
II	1 per 10-10^2 yr	Loss of offsite power (LOOP)	A	B	B	C	C
III	1 per 10^2 - 10^3 yr		B	C	C	D	D
IV	1 per 10^3 - 10^4 yr						
			> 30 days	3-30 days	3-30 days	< 3 days	< 3 days
			Exposure Time for Degraded Condition				

Outage Specific Mitigation Capability for the Inspection Findings

- The available mitigation capability may vary from one outage to another and also, from one portion of shutdown to another
- Usually, the mitigation capability is more than that required by the TS, but less than the full capability because of the scheduled activities defined in the outage plan (e.g, one division of ECCS may be unavailable for the entire shutdown)
- To allow for proper consideration of the available mitigation capability in assessing the inspection findings, the available mitigation capability is delineated based on the outage plan.
- SDP worksheet provides a table for specifying the mitigation capability for the shutdown being inspected
- The mitigation capability strictly needs to be completed for the exposure time covering POSs and TWS of the inspection findings
- The purpose of the outage specific mitigation capability table is to address the planned significant limitations in the mitigation capability, and not the short duration corrective maintenance that may be undertaken as needed.

PWR Base Case - Refueling Outage

ID	Day Per Symbol Heading/Task	Resource	Dur	Schd Start	Schd Finish
P1	BASE-PWR.PJ		35D	12-31-95<	02-03-96
001	MODE 2-1		1h	12-31-95<	12-31-95
002	MODE 3-1		9h	12-31-95	12-31-95
003	MODE 4-1		19h	12-31-95	01-01-96
004	MODE 5-1		100h	01-01-96	01-05-96
005	MODE 6		363h	01-05-96	01-20-96
006	MODE 5-2		169h	01-20-96	01-27-96
007	MODE 4-2		35h	01-27-96	01-29-96
008	MODE 3-2		41h	01-29-96	01-31-96
009	MODE 2-2		54h	01-31-96	02-02-96
010	MODE 1		2D	02-02-96	02-03-96
011	MISC OPERATIONS		46h	01-01-96	01-03-96
012	OPEN RCS VENT		6h	01-03-96	01-03-96
013	DRAIN TO RED INV		10h	01-03-96	01-04-96
014	DRAIN TO MIDLOOP		8h	01-04-96	01-04-96
015	MISC OPERATIONS		12h	01-04-96	01-04-96
016	OPEN SG MANWAYS		8h	01-04-96	01-05-96
017	INSTALL NOZ DAMS		10h	01-05-96	01-05-96
018	INSTALL NOZ DAMS		30h	01-05-96	01-06-96
019	FILL TO RED INVE		20h	01-06-96	01-07-96
020	FILL TO FLANGE		4h	01-07-96	01-07-96
021	MISC OPERATIONS		16h	01-07-96	01-08-96
	23', HEAD LIFT		16h	01-08-96	01-09-96
023	REMOVE INTERNALS		8h	01-09-96	01-09-96
024	FUEL OFFLOAD		48h	01-09-96	01-11-96
025	DEFUELED WINDOW		120h	01-11-96	01-16-96
026	FUEL ON-LOAD		26h	01-16-96	01-17-96
027	PLACE INTERNALS		8'	01-17-96	01-18-96
028	0', HEAD SET		19h	01-18-96	01-18-96
029	DRAIN TO MIDLOOP		8h	01-18-96	01-19-96
030	REMOVE NOZ DAMS		40h	01-19-96	01-20-96
031	RCS FILL & VENT		25h	01-20-96	01-21-96
032	MISC OPERATIONS		100h	01-21-96	01-26-96
033	RCS HEAT * PRESS		44h	01-26-96	01-27-96
034	MISC OPERATIONS		24h	02-02-96	02-03-96
035	CLOSE BREAKERS		0	02-03-96	02-03-96
036	CONTAINMENT OPEN		148h	01-03-96	01-09-96
037	CONTAINMENT OPEN		120h	01-11-96	01-16-96
038	CONTAINMENT OPEN		244h	01-17-96	01-27-96
039	DG A MAIN WINDOW		14D	12-31-95	01-14-96
040	MISC OPERATIONS		24h	01-14-96	01-15-96
041	DG B MAIN WINDOW		14D	01-15-96	01-29-96
042	SI A MAIN WINDOW		14D	12-31-95	01-14-96
043	SI B MAIN WINDOW		14D	01-15-96	01-29-96



Non Critical m Milestone »»» Float/Delay ___ Interrupt
Critical M Critical MS >>> Free Float

PWR - Available Mitigation Capability During an Outage

Equipment	Available Equipment based on Tech Specs., GL 88-17, NUMARC 91-06, and 35-day Outage Schedule				
	PWR POS Groups				
	I-E (before refueling)	**I-L (after refueling)**	**II-E (before refueling)**	**II-L (after refueling)**	**III (refueling)**
RHR	Two RHR Trains with Support Systems and SGs Available for Decay Heat Removal		Two RHR Trains with Support Systems		One Trains of RHR with Support Systems
Systems [1]	Train B (AFW, PORVs, Charging, SI, EDGs and Support Systems, RWST, containment sump)	Train A (AFW, PORVs, Charging, SI, EDGs and Support Systems, RWST, containment sump)	Train B (Charging, SI, EDGs and Support Systems, RWST, containment sump)	Train A (Charging, SI, EDGs and Support Systems, RWST, containment sump)	Train A or B (Charging, SI, EDGs and Support Systems, RWST, containment sump)
Offsite Power	Available				
Core Heat Removal Instrumentation	(1) DHR heat exchanger inlet/outlet temperature and DHR flow indication in the control room with flow hi/low alarm. (2) 2 core exit thermocouples with readout and hi alarm in the control room.		(1) DHR heat exchanger inlet/outlet temperature, DHR flow indication with hi/low flow alarm, and DHR pump motor current with alarm. (GL 88-17) (2) At least two core exit thermocouples with control room readout and hi alarm until must be removed for preparations for vessel head removal (GL 88-17).		(1) DHR heat exchanger inlet/outlet temperature and DHR flow indication in the control room with flow hi/low alarm. (2) Two sources of vessel temperature instrumentation (as soon as practical during vessel head re-installation).

Inventory Control Instrumentation	2 independent pressurizer level instruments with a Hi/Lo alarm or level deviation annunciator.	(1)2 sources of pressurizer level instrumentation with hi/low alarm or level deviation in control room when inventory in pressurizer. (2) Two sources of level continuous level instrumentation with pressurizer empty. Monitoring performed by an operator in the control room or from a location other than the control room with a provision for providing immediate water level values to an operator in the control room if significant changes occur. (GL 88-17)	Two sources of level instrumentation system with low level setpoint alarm with level < 23 ' above reactor vessel flange. One source of level instrumentation with refueling cavity flooded.

1. Based on the 35-day refueling outage.

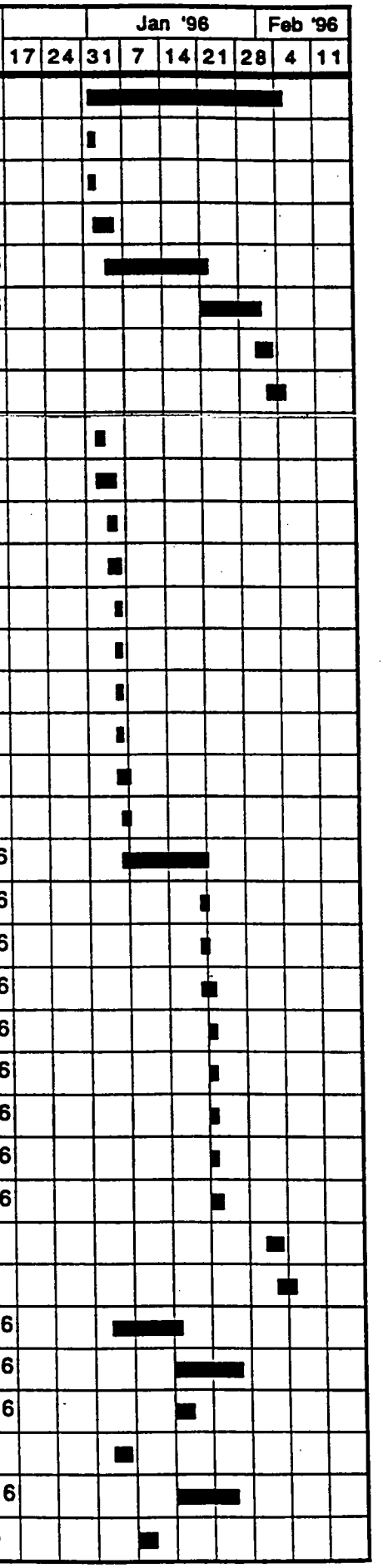
BWR - Available Mitigation Capability During an Outage

Equipment	Available Equipment Based on Tech. Specs., GL 88-17, NUMARC-91-06, and 35-day Refueling Shcedule				
	BWR POS Groups				
	I-E	I-L	II-E	II-L	III
RHR [1]	2 RHR sub-systems				
ECCS System (not HPCI) [2]	Division 1/3	Division 2/4	Division 1/3	Division 2/4	Division 1/3 or 2/4
CRD, HPSW, Condensate and RWST Transfer System [3]	Yes				
SRVs and Suppression Pool [1]	at least 2/11 SRVs and SP Cooling		SP		-
EDGs [2]	1,3,4	1,2,4	1,3,4	1,2,4	2,4 or 1,3
Core Heat Removal and Inventory Control Instrumentation [1]	(1) DHR heat exchanger inlet/outlet temperature and DHR flow indication in the control room with hi/low flow alarm. (2) Two Sources of vessel level instrumentation				
RHR Auto- Isolation on Low Level [1]	Yes				

Notes:
1. Based on voluntary case requirement
2. Based on 35-day refueling outage
3. Other systems that may be available

BWR Base Case - Refueling Outage

Heading/Task	Duration	Schd Start	Schd Finish
BASE - BWR	35 days	1/1/96	2/4/96
MODE 2 - Hot Standby	8 hrs	1/1/96	1/1/96
MODE 3 - Hot Shutdown	16 hrs	1/1/96	1/1/96
MODE 4 - Cold Shutdown	3 days	1/2/96	1/4/96
MODE 5 - Refueling	17 days	1/4/96	1/21/96
MODE 4 - Cold Shutdown	10 days	1/21/96	1/31/96
MODE 2 - Startup	2 days	1/31/96	2/2/96
MODE 1 - Gen. Synch.	2 days	2/2/96	2/4/96
Refuel Floor Plug Remove	12 hrs	1/2/96	1/2/96
Detension/Removal of D/W Head	55 hrs	1/2/96	1/4/96
Prep for RPV Head Detension	3 hrs	1/4/96	1/4/96
Detension RPV Head	4 hrs	1/4/96	1/5/96
Remove RPV Head	8 hrs	1/5/96	1/5/96
Floodup over RPV Flange, Leak Check	5 hrs	1/5/96	1/5/96
Remove RPV Dryer, F/P Gates	5 hrs	1/5/96	1/5/96
Install MSL Plugs	5 hrs	1/5/96	1/5/96
Unlatch/remove Separator	5 hrs	1/5/96	1/6/96
Final RPV Prep	5 hrs	1/6/96	1/6/96
Core Alterations	14 day	1/6/96	1/20/96
Cavity Preparations	6 hrs	1/20/96	1/20/96
Install Separator	11 hrs	1/20/96	1/20/96
Remove MSL Plugs	6 hrs	1/20/96	1/21/96
Install Dryer and F/P Gates	7 hrs	1/21/96	1/21/96
Reactor Cavity Drain Down	3 hrs	1/21/96	1/21/96
Install RPV Head	6 hrs	1/21/96	1/21/96
Tension RPV Head	5 hrs	1/21/96	1/21/96
Mirror Insulation	6 hrs	1/21/96	1/22/96
Startup and Heatup	48 hrs	1/31/96	2/2/96
Power Ops to Synchronize	2 days	2/2/96	2/4/96
ECCS Outage Window: Div 2/4	11 days	1/3/96	1/14/96
ECCS Outage Window: Div 1/3	11 days	1/14/96	1/25/96
DG Outage Window: Div 1	2 days	1/14/96	1/16/96
DG Outage Window: Div 2	2 days	1/3/96	1/5/96
DG Outage Window: Div 3	10 days	1/14/96	1/24/96
DG Outage Window: Div 4	2 days	1/7/96	1/9/96



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SDP Worksheets

- SDP worksheets are developed similar to full power operation to assess the inspection findings
- SDP worksheets define the full mitigation capability and provides provision for incorporating the available mitigation capability for the shutdown in consideration
- Inspectors use the outage specific mitigation capability table to define the available mitigation capability for the applicable safety functions
- Inspection findings are then imposed to assess the available credits for the remaining mitigation capability in significance determination

PWR SDP Worksheet Development

- Loss of RHR event tree developed for POS group I-E
- Event Tree is expected to be applicable to Westinghouse 4 Loop plants; Byron system/function information is used.
- Modeling uses insights included in SD regulator analysis and Surry study
- Overpressurization scenarios were evaluated and excluded.
- Mitigation capability is expected to be plant-specific and possibly outage specific, modifications will be needed.
- Level of detail in the modeling allows for "full" mitigation capability and remaining mitigation capability is defined considering applicable credits

Table 5.1 SDP Worksheet for a Westinghouse 4-Loop Plant Loss of RHR in POS I (LORHR-I)

Estimated Frequency (Table 1 Row) _____ **Exposure Time** _____
Table 1 Result (circle): A B C D E F G H

Safety Functions Needed:	**Full Creditable Mitigation Capability for Each Safety Function:**	**Important Instrumentation**
RHR Recoverability (RECOVERA)	Probability that RHR is recoverable (1 multi-train system) [1]	DHR temp, DHR flow, CET,
Short Term Recovery of RHR (RHR-S)	Operator recovers RHR before RCS boiling (operator action = 2) [2]	DHR temp, DHR flow, CET,
SG Cooling (SG)	Operator initiates SG cooling before core recovery with 1/1 MDAFW pump or 1/1 diesel-driven pump and 1/4 SG PORVs (operator action = 3) [3]	SG level, SG pressure,
RCS Injection (FEED)	Operator initiates injection before CD with 1/2 charging pumps (1multi-train system) or 1/2 SI pumps [4] (operator action = 4)	PZR pressure, CET, Aux. building sump level,
RHR Recovery (RHR-R)	Operator fills RCS, vents RHR pumps, and restarts RHR system before RWST depletion (operator action = 3) [5]	DHR temp, DHR flow, CET, CTMT level, RWST level
Vent Path for Feed and Bleed (BLEED)	Operator opens 1/2 PORVs (operator action = 3) [6]	
Long Term RHR Recovery/Recirculation (RHR-L)	Operator recovers RHR before CD or initiate recirc given RHR cooling has failed or operator establish RWST make up (operator action = 2) [7]	DHR temp, DHR flow, CET, CTMT level, RWST level
Borated Water Makeup (RWSTMU)	Operator Establishes RWST Makeup with boric acid transfer pumps and primary grade water (operator action = 2) [8]	CTMT level, RWST level

Available Mitigation Capability for Each Safety Function:	Important Instrumentation
RHR Recoverability (RECOVERA) Short Term Recovery of RHR (RHR-S) SG Cooling (SG) RCS Injection (FEED) RHR Recovery (RHR-R) Vent Path for Feed and Bleed (BLEED) Long Term RHR Recovery/Recirculation (RHR-L) Borated Water Makeup (RWSTMU)	

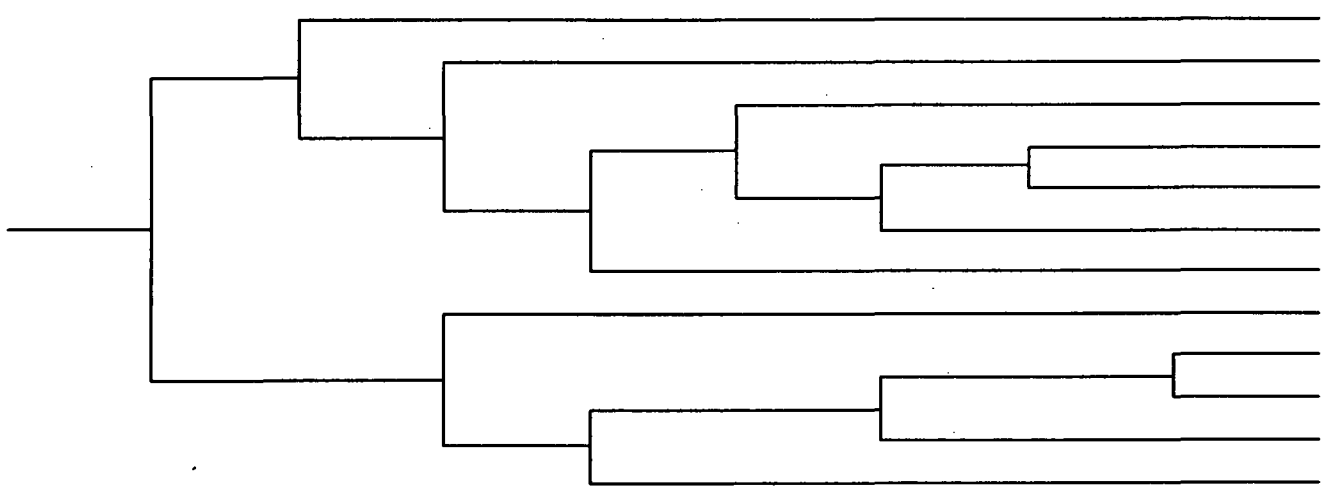
Circle Affected Functions	Recovery of Failed Train	Remaining Mitigation Sequence Capability Rating for Each Affected Sequence	Color			
1 LORHR-I - RHR-S - SG - FEED (7)						
2 LORHR-I - RHR-S - SG - RHR-R - BLEED (6)						
3 LORHR-I - RHR-S - SG - RHR-R - RHR-L (5)						
4 LORHR-I - RECOVERA - RWSTMU (10)						
5 LORHR-I - RECOVERA - BLEED (11)						

6 LORHR-I - RECOBERA - FEED (12)						
Identify any operator recovery actions that are credited to directly restore the degraded equipment or initiating event: If operator actions are required to credit placing mitigation equipment in service or for recovery actions, such credit should be given only if the following criteria are met: 1) sufficient time is available to implement these actions, 2) environmental conditions allow access where needed, 3) procedures exist, 4) training is conducted on the existing procedures under conditions similar to the scenario assumed, and 5) any equipment needed to complete these actions is available and ready for use.						

Notes:

6. Need to account for loss of RHR that can not be recovered in 24 hours. Look at operating experience,
7. Need to develop guidance on how the credit for operator actions can be determined based on the time after shutdown, training, procedures, and instrumentation. The failure likelihood index method probably can be used.
8. Need to develop guidance/rules on how dependence among the operator actions in the same sequence should be accounted for.
9. Based on the weighted recoverability of different contributors to loss of RHR.
10. Based on HEP of NRC draft work sheet.
11. Based on HEP of NRC draft work sheet.
12. Based on HEP of NRC draft work sheet.
13. Based on HEP of NRC draft work sheet

LORHR-I	RECOVER	RHR-S	SG	FEED	RHR-R	BLEED	RHR-L	RWSTMU	#	STATUS



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4	OK
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6	CD
7	CD
8	OK
9	OK
10	CD
11	CD
12	CD

Plant Name Abbrev.: BYRN

Table 3.1 SDP Worksheet for a Westinghouse 4-Loop Plant — Loss of RHR in POS I (LORHR-I)

Estimated Frequency (Table 1 Row) _____ Exposure Time _____ Table 1 Result (circle): A B C D E F G H		Important Instrumentation
Safety Functions Needed:	**Full Creditable Mitigation Capability for Each Safety Function:**	
RHR Recoverability (RECOVERA)	Probability that RHR is recoverable (1 multi-train system) [1]	DHR temp, DHR flow, CET
Short Term Recovery of RHR (RHR-S)	Operator recovers RHR before RCS boiling (operator action = 2) [2]	DHR temp, DHR flow, CET
SG Cooling (SG)	Operator initiates SG cooling before core recovery with 1/1 MDAFW pump or 1/1 diesel-driven pump and 1/4 SG PORVs (Operator action = 3) [3]	SG level, SG pressure
RCS Injection (FEED)	Operator initiates injection before CD with 1/2 charging pumps (1multi-train system) or 1/2 SI pumps [4] (operator action = 4)	PZR Level, DHR temp, DHR flow, CET
RHR Recovery (RHR-R)	Operator fills RCS, vents RHR pumps, and restarts RHR system before RWST depletion (operator action = 3) [5]	DHR temp, DHR flow, CET
Vent Path for Feed and Bleed (BLEED)	Operator opens 1/2 PORVs (operator action = 3) [6]	
Long Term RHR Recovery/Recirculation (RHR-L)	Operator recovers RHR before CD or initiate recirc given RHR cooling has failed or operator establish RWST make up (operator action = 2) [7]	CTMT level, RWST level
Borated Water Makeup (RWSTMU)	Operator establishes RWST Makeup with boric acid transfer pumps and primary grade water (operator action = 2) [8]	CTMT level, RWST level

Available Mitigation Capability for Each Safety Function:

RHR Recoverability (RECOVERA)

Short Term Recovery of RHR (RHR-S)

SG Cooling (SG)

RCS Injection (FEED)

RHR Recovery (RHR-R)

Vent Path for Feed and Bleed (BLEED)

Long Term RHR Recovery/Recirculation (RHR-L)

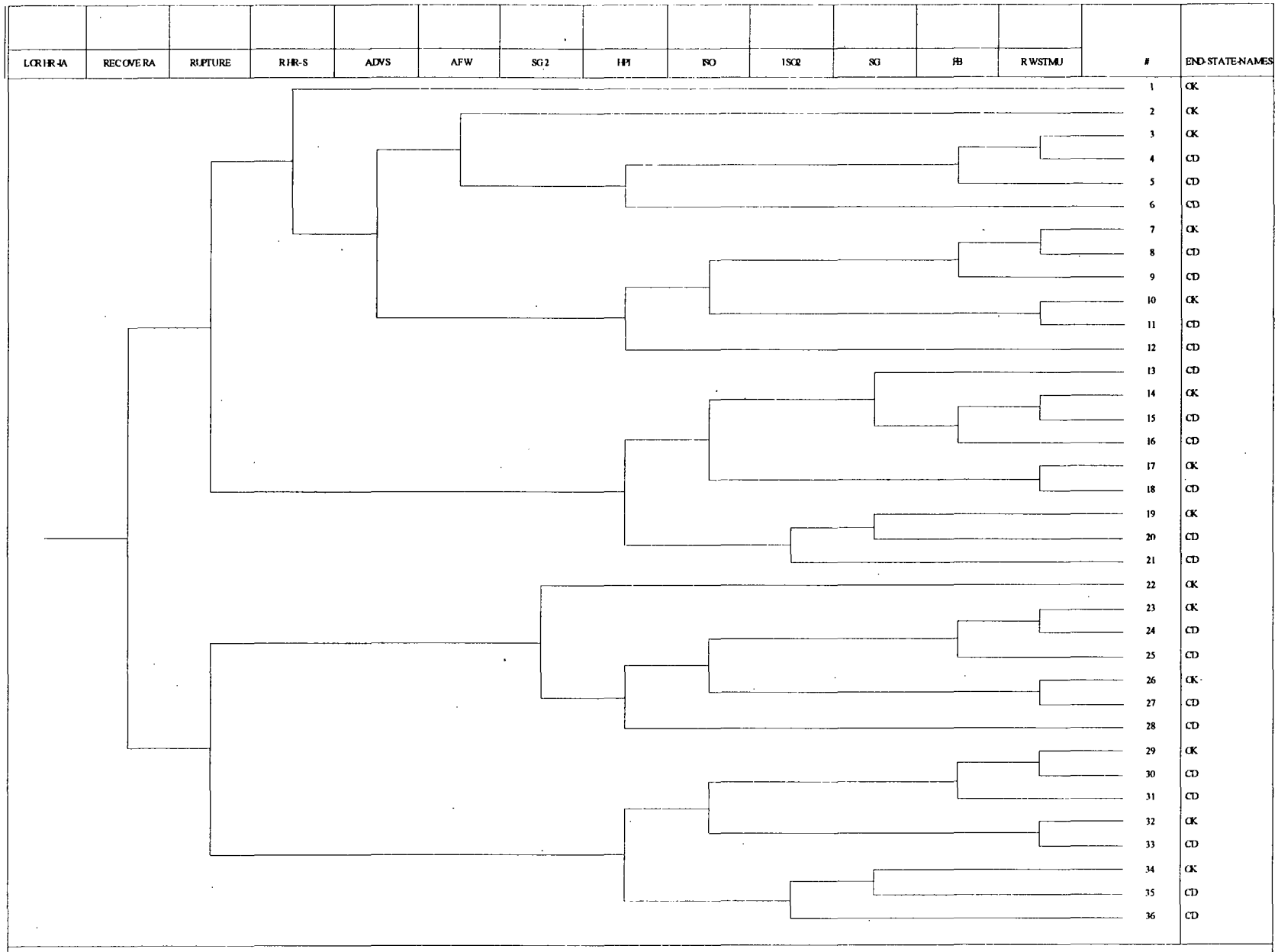
Borated Water Makeup (RWSTMU)

Circle Affected Functions	Recovery of Failed Train	Remaining Mitigation Capability Rating for Each Affected Sequence	Sequence Color			
1 LORHR-I - RHR-S - SG - FEED (7)						
2 LORHR-I - RHR-S - SG - RHR-R - BLEED (6)						
3 LORHR-I - RHR-S - SG - RHR-R - RHR-L (5)						

4 LORHR-I - RECOVERA - RWSTMU (10)						
5 LORHR-I - RECOVERA - BLEED (11)						
6 LORHR-I - RECOBERA - FEED (12)						
Identify any operator recovery actions that are credited to directly restore the degraded equipment or initiating event: If operator actions are required to credit placing mitigation equipment in service or for recovery actions, such credit should be given only if the following criteria are met: 1) sufficient time is available to implement these actions, 2) environmental conditions allow access where needed, 3) procedures exist, 4) training is conducted on the existing procedures under conditions similar to the scenario assumed, and 5) any equipment needed to complete these actions is available and ready for use.						

Notes:

1. Need to account for loss of RHR that can not be recovered in 24 hours. Look at operating experience,
2. Need to develop guidance on how the credit for operator actions can be determined based on the time after shutdown, training, procedures, and instrumentation. The failure likelihood index method probably can be used.
3. Need to develop guidance/rules on how dependence among the operator actions in the same sequence should be accounted for.
4. Based on the weighted recoverability of different contributors to loss of RHR.
5. Based on HEP of NRC draft work sheet.
6. Based on HEP of NRC draft work sheet.
7. Based on HEP of NRC draft work sheet.
8. Based on HEP of NRC draft work sheet


LOR HR-IA
RECOVERA
RUPTURE
RHR-S
ADVS
AFW
SG2
HPI
ISO
ISO2
SG
FB
RWSTMU
#
END-STATE-NAMES
1 OK
2 OK
3 OK
4 CD
5 CD
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36 CD

Modeling of Operator Actions in Shutdown SDP

- During shutdown, all mitigating functions require operator actions. Therefore, multiple operator actions would have to be modeled in the core damage sequences. In addition, the influence of the varying amount of time available for operator actions needs to be accounted for. It is also desirable to account for the influence of instrumentations, operator training and procedures. At the same time, we still have to be able to capture the importance of hardware.

Ideas on Assigning Credits for Operator Actions

- The credits in the worksheets is the base case representing early time window of the POS. The credits given to the individual actions should have accounted for the preceding operator failures. Therefore, coloring of the sequences is the same as before.

- For a later time window, give one extra credit to each operator action.

- Findings associated with training, procedures, and instrumentation can be modeled by determining their impacts on initiating event frequency, and mitigating capability.

- The impact on initiating event frequency can be reflected by modifying the frequency in table 1 of the notebook.

- The impacted operator actions are identified and the credits given to the operator actions are adjusted accordingly.

BWR SDP Worksheet Development

- LOOP worksheet developed for applicable PGs and Tws
- Event Tree is expected to be applicable to BWR4s; Peach Bottom system/function information is used
- Mitigation capability is expected to be plant-specific and modifications will be needed for plant-specific application
- Modeling uses insights from analyses included in the SD Regulatory analysis, Grand Gulf study, and other available publications relating to shutdown
- Level of detail in the modeling allows for "full" mitigation capability and remaining mitigation capability is defined considering applicable credits

Table 5.1 Shutdown SDP Worksheet for BWR (Peach Bottom) — Loss of Offsite Power (LOOP), PG1, TW-E

Estimated Frequency (Table 1 Row) _____ **Exposure Time** _____ **Table 1 Result (circle): A B C D E F G H**

Safety Functions Needed:	**Full Creditable Mitigation Capability for Each Safety Function:**
Emergency Power (EAC)	1/4 EDGs per unit (1 multi-train system)
Shutdown Cooling (SDC)	1/4 RHR pumps with 1/4 RHR HXs in 1/2 trains (1 multi-train system)
Control Rod Drive (CRD)	1/2 CRD pumps (operator action = 2)
Alternate Coolant Injection (ACI)	1/2 firewater pump (operator action = 1)
Recovery of LOOP in 2 hrs (RLOOP2)	(operator action = 1)
Recovery of LOOP in 20 hrs (RLOOP20)	(operator action = 2)
Depressurization (DEP)	1/6 SRVs manually opened (operator action = 2)
Low Pressure Injection (LPI)	1/4 RHR pumps in 1/2 trains in LPCI Mode or 1/4 LPCS pumps in 1/2 trains (operator action = 2) or condensate and RWST transfer system or 1/4 HPSW pumps injection through RHR/HPSW crosstie (operator action = 2)
Low Pressure Injection or ACI (LP/ACI)	1/4 LPCS pumps in 1/2 trains or 1/4 HPSW trains (operator action = 2) or 1/2 fire pumps (operator action = 1)
Safety Functions Needed:	**Available Creditable Mitigation Capability for Each Safety Function:**
Emergency Power (EAC)	
Shutdown Cooling (SDC)	
Control Rod Drive (CRD)	
Alternate Coolant Injection (ACI)	
Recovery of LOOP in 2 hrs (RLOOP1)	
Recovery of LOOP in 20 hrs (RLOOP20)	
Depressurization (DEP)	
Low Pressure Injection (LPI)	
Low Pressure Injection or ACI (LP/ACI)	

Circle Affected Functions	Recovery of Failed Train	Remaining Mitigation Capability Rating for Each Affected Sequence	Sequence Color
1 LOOP - SDC - CRD - LP/ACI (4)			
2 LOOP - SDC - CRD - DEP (5)			
3 LOOP - EAC - LPI (7, 11)			
4 LOOP - EAC - RLOOP20 (8)			
5 LOOP - EAC - DEP (9, 12)			
6 LOOP - EAC - ACI - RLOOP2 (13)			

Identify any operator recovery actions that are credited to directly restore the degraded equipment or initiating event:

If operator actions are required to credit placing mitigation equipment in service or for recovery actions, such credit should be given only if the following criteria are met: 1) sufficient time is available to implement these actions, 2) environmental conditions allow access where needed, 3) procedures exist, 4) training is conducted on the existing procedures under conditions similar to the scenario assumed, and 5) any equipment needed to complete these actions is available and ready for use.

Notes:

1. The recovery of AC at 5 hours has HEPs in the 0.1 to 1.0 range.

2. On a LOOP, one EDG is required for each Unit making a total of 2 EDGs. PB also takes credit for additional offsite power received from the Conowingo tie line.

3. The PB HEP in the full power PRA, for late injection using HPSW pumps injecting through the RHR/HPSW crosstie, is 6 E-2. An operator action credit of 1 is assigned in this worksheet considering the full power PRA assessment.

Table 5.2 Shutdown SDP Worksheet for BWR (Peach Bottom) — Loss of Offsite Power (LOOP), PG1, TW-L

Estimated Frequency (Table 1 Row) _____ **Exposure Time** _____ **Table 1 Result (circle): A B C D E F G H**

Safety Functions Needed:	**Full Creditable Mitigation Capability for Each Safety Function:**
Emergency Power (EAC)	1/4 EDGs per unit (1 multi-train system)
Shutdown Cooling (SDC)	1/4 RHR pumps with 1/4 RHR HXs in 1/ 2 trains (1 multi-train system)
Control Rod Drive (CRD)	1/2 CRD pumps (operator action = 2)
Alternate Coolant Injection (ACI)	1/2 firewater pump (operator action =1)
Recovery of LOOP in 6 hrs (RLOOP6)	(operator action = 2)
Depressurization (DEP)	1/6 SRVs manually opened (operator action = 2)
Low Pressure Injection (LPI)	1/4 RHR pumps in 1/2 trains in LPCI Mode or 1/4 LPCS pumps in 1/2 trains (operator action = 2) or condensate and RWST transfer system or 1/4 HPSW pumps injection through RHR/HPSW crosstie (operator action = 2)
Low Pressure Injection or ACI (LP/ACI)	1/4 LPCS pumps in 1/2 trains or 1/4 HPSW pumps (operator action = 2) or 1/2 fire pumps (operator action = 1)
Safety Functions Needed:	**Available Creditable Mitigation Capability for Each Safety Function:**
Emergency Power (EAC)	
Shutdown Cooling (SDC)	
Control Rod Drive (CRD)	
Alternate Coolant Injection (ACI)	
Recovery of LOOP in 6 hrs (RLOOP6)	
Depressurization (DEP)	
Low Pressure Injection (LPI)	
Low Pressure Injection or ACI (LP/ACI)	

Circle Affected Functions	**Recovery of Failed Train**	**Remaining Mitigation Capability Rating for Each Affected Sequence**	**Sequence Color**
1 LOOP - SDC - CRD - LPCS/ACI (4)			

2 LOOP - SDC - CRD - DEP (5)			
3 LOOP - EAC - ACI - LPI (8)			
4 LOOP - EAC - ACI - DEP (9)			
5 LOOP - EAC - ACI - RLOOP6 (10)			

Identify any operator recovery actions that are credited to directly restore the degraded equipment or initiating event:

If operator actions are required to credit placing mitigation equipment in service or for recovery actions, such credit should be given only if the following criteria are met: 1) sufficient time is available to implement these actions, 2) environmental conditions allow access where needed, 3) procedures exist, 4) training is conducted on the existing procedures under conditions similar to the scenario assumed, and 5) any equipment needed to complete these actions is available and ready for use.

Notes:

1. The recovery of AC at 5 hours has HEPs in the 0.1 to 1.0 range.

2. On a LOOP, one EDG is required for each Unit making a total of 2 EDGs. PB also takes credit for additional offsite power received from the Conowingo tie line.

3. The PB HEP in the full power PRA, for late injection using HPSW pumps injecting through the RHR/HPSW crosstie, is 6 E-2. An operator action credit of 1 is assigned in this worksheet considering the full power PRA assessment.

Table 5.3 Shutdown SDP Worksheet for BWR (Peach Bottom) — Loss of Offsite Power (LOOP), PG2, TW-E

Estimated Frequency (Table 1 Row) _____ **Exposure Time** _____ **Table 1 Result (circle): A B C D E F G H**

Safety Functions Needed:	**Full Creditable Mitigation Capability for Each Safety Function:**
Emergency Power (EAC)	1/4 EDGs per unit (1 multi-train system)
Shutdown Cooling (SDC)	1/4 RHR pumps with 1/4 RHR HXs in 1/2 trains (1 multi-train system)
Alternate Coolant Injection (ACI)	1/2 firewater pump (operator action = 1)
Recovery of LOOP in 8 hrs (RLOOP8)	(operator action = 2)
Low Pressure Injection (LPI)	1/4 RHR pumps in 1/2 trains in LPCI Mode or 1/4 LPCS pumps in 1/2 trains (operator action = 2) or condensate and RWST transfer system or 1/4 HPSW pumps injection through RHR/HPSW crosstie (operator action = 2)
Low Pressure Injection or ACI (LP/ACI)	1/4 LPCS pumps in 1/2 trains or 1/4 HPSW pumps (operator action = 2) or 1/2 fire pumps (operator action = 1)
Safety Functions Needed:	**Available Creditable Mitigation Capability for Each Safety Function:**
Emergency Power (EAC)	
Shutdown Cooling (SDC)	
Alternate Coolant Injection (ACI)	
Recovery of LOOP in 8 hrs (RLOOP8)	
Low Pressure Injection (LPI)	
Low Pressure Injection or ACI (LP/ACI)	

Circle Affected Functions	**Recovery of Failed Train**	**Remaining Mitigation Capability Rating for Each Affected Sequence**	**Sequence Color**
1 LOOP - SDC - LPCS/ACI (3)			
2 LOOP - EAC - ACI - LPI (6)			

3 LOOP - EAC - ACI - RLOOP8 (7)			

Identify any operator recovery actions that are credited to directly restore the degraded equipment or initiating event:

If operator actions are required to credit placing mitigation equipment in service or for recovery actions, such credit should be given only if the following criteria are met: 1) sufficient time is available to implement these actions, 2) environmental conditions allow access where needed, 3) procedures exist, 4) training is conducted on the existing procedures under conditions similar to the scenario assumed, and 5) any equipment needed to complete these actions is available and ready for use.

Notes:

1. The recovery of AC at 5 hours has HEPs in the 0.1 to 1.0 range.

2. On a LOOP, one EDG is required for each Unit making a total of 2 EDGs. PB also takes credit for additional offsite power received from the Conowingo tie line.

3. The PB HEP in the full power PRA, for late injection using HPSW pumps injecting through the RHR/HPSW crosstie, is 6 E-2. An operator action credit of 1 is assigned in this worksheet considering the full power PRA assessment.

Table 5.4 Shutdown SDP Worksheet for BWR (Peach Bottom) — Loss of Offsite Power (LOOP), PG2, TW-L

Estimated Frequency (Table 1 Row) _____ **Exposure Time** _____ **Table 1 Result (circle): A B C D E F G H**

Safety Functions Needed:	**Full Creditable Mitigation Capability for Each Safety Function:**
Emergency Power (EAC)	1/4 EDGs per unit (1 multi-train system)
Shutdown Cooling (SDC)	1/4 RHR pumps with 1/4 RHR HXs in 1/2 trains (1 multi-train system)
Alternate Coolant Injection (ACI)	1/2 firewater pump (operator action = 1)
Recovery of LOOP in 16 hrs (RLOOP16)	(operator action = 2)
Low Pressure Injection (LPI)	1/4 RHR pumps in 1/2 trains in LPCI Mode or 1/4 LPCS pumps in 1/2 trains (operator action = 2) or condensate and RWST transfer system or 1/4 HPSW pumps injection through RHR/HPSW crosstie (operator action = 2)
Low Pressure Injection or ACI (LP/ACI)	1/4 LPCS pumps in 1/2 trains or 1/4 HPSW pumps (operator action = 2) or 1/2 fire pumps (operator action = 1)
Safety Functions Needed:	**Available Creditable Mitigation Capability for Each Safety Function:**
Emergency Power (EAC)	
Shutdown Cooling (SDC)	
Alternate Coolant Injection (ACI)	
Recovery of LOOP in 16 hrs (RLOOP16)	
Low Pressure Injection (LPI)	
Low Pressure Injection or ACI (LP/ACI)	

Circle Affected Functions	**Recovery of Failed Train**	**Remaining Mitigation Capability Rating for Each Affected Sequence**	**Sequence Color**
1 LOOP - SDC - LPCS/ACI (3)			
2 LOOP - EAC - ACI - LPI (6)			

3 LOOP - EAC - ACI - RLOOP16 (7)			

Identify any operator recovery actions that are credited to directly restore the degraded equipment or initiating event:

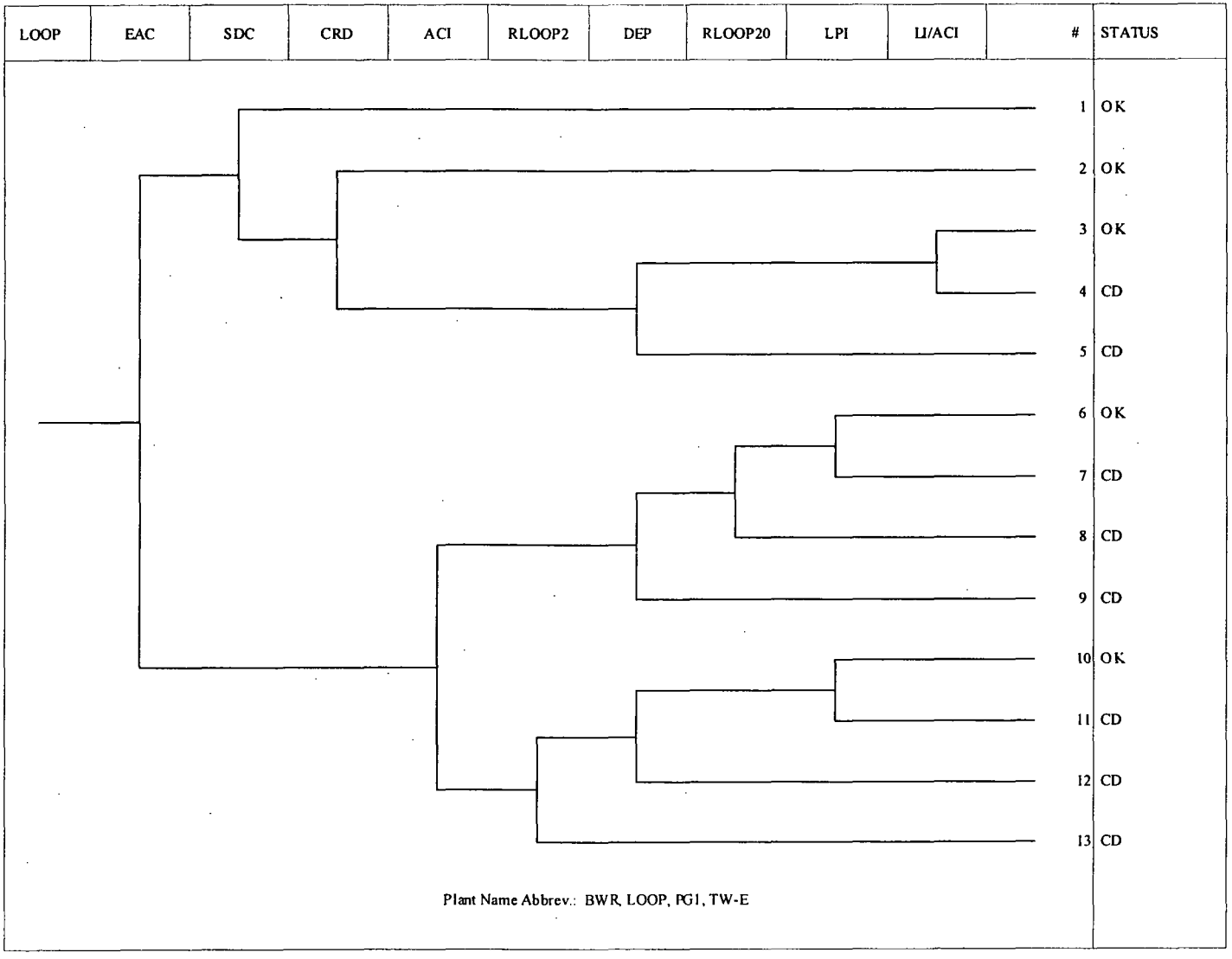
If operator actions are required to credit placing mitigation equipment in service or for recovery actions, such credit should be given only if the following criteria are met: 1) sufficient time is available to implement these actions, 2) environmental conditions allow access where needed, 3) procedures exist, 4) training is conducted on the existing procedures under conditions similar to the scenario assumed, and 5) any equipment needed to complete these actions is available and ready for use.

Notes:

1. The recovery of AC at 5 hours has HEPs in the 0.1 to 1.0 range.

2. On a LOOP, one EDG is required for each Unit making a total of 2 EDGs. PB also takes credit for additional offsite power received from the Conowingo tie line.

3. The PB HEP in the full power PRA, for late injection using HPSW pumps injecting through the RHR/HPSW crosstie, is 6 E-2. An operator action credit of 1 is assigned in this worksheet considering the full power PRA assessment.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DEP
RLOOP20
LPI
LI/ACI
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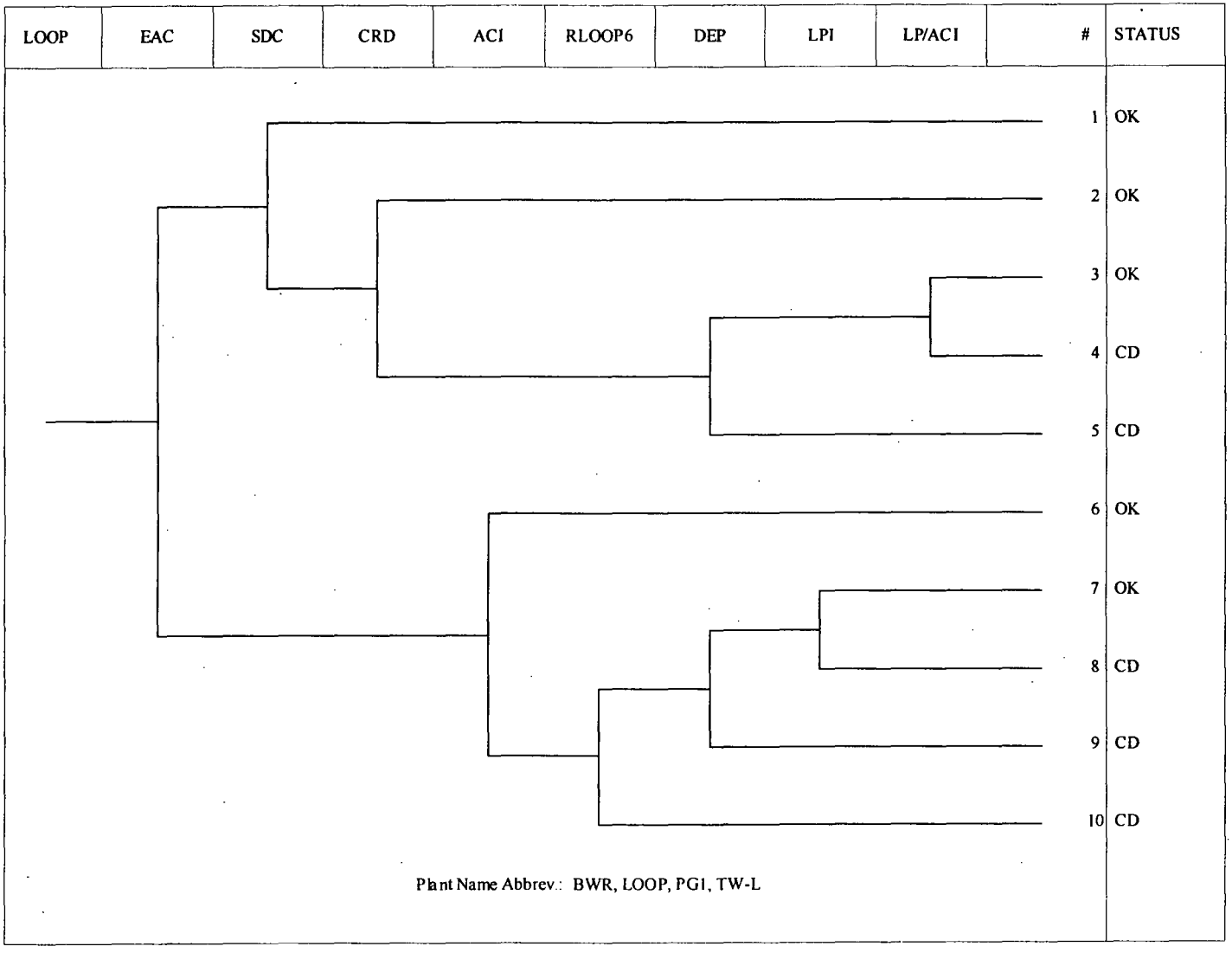
Plant Name Abbrev.: BWR, LOOP, PG1, TW-E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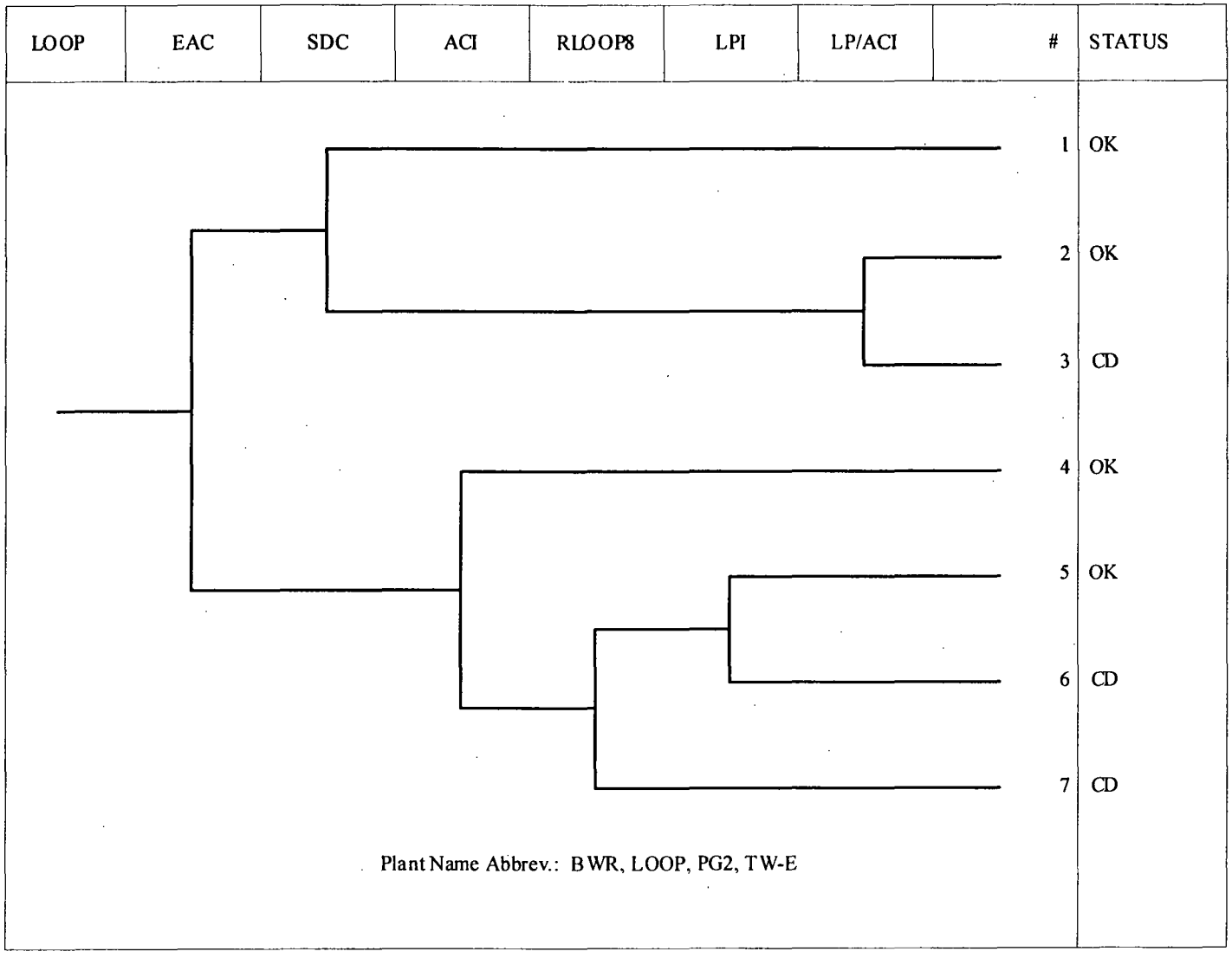
Plant Name Abbrev.: BWR, LOOP, PG1, TW-L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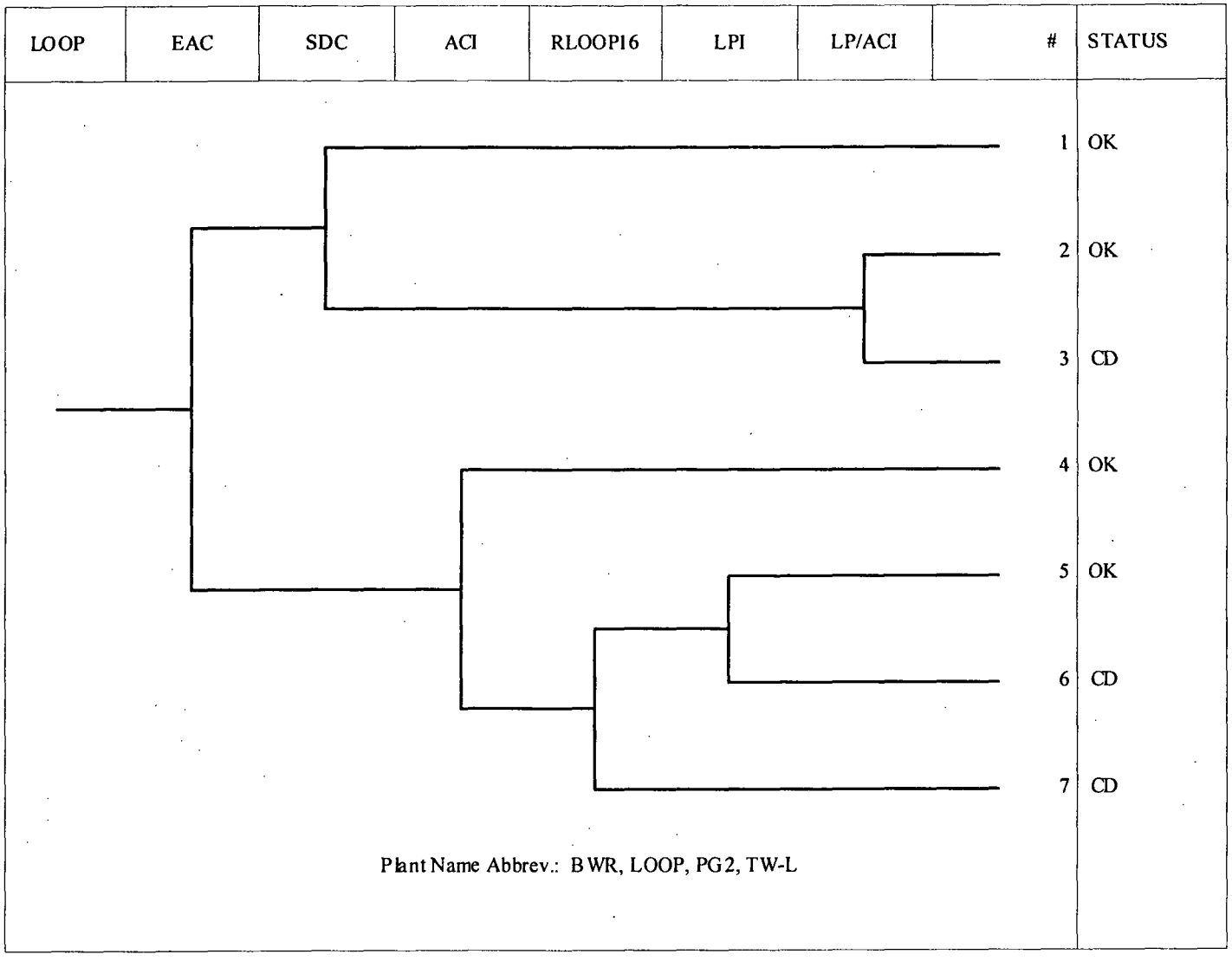
Plant Name Abbrev.: BWR, LOOP, PG2, TW-E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STATUS
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3 CD
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6 CD
7 CD
Plant Name Abbrev.: BWR, LOOP, PG2, TW-L