B.7 LER No. 361/98-003

Event Description: Inoperable sump recirculation valve

Date of Event: February 5, 1998

Plant: San Onofre, Unit 2

B.7.1 Event Summary

San Onofre, Unit 2, was in a mid-cycle outage when personnel discovered that the linestarter for the containment emergency sump outlet valve was jammed because of grit in the sliding cam. The grit would have prevented the valve from opening on a recirculation actuation signal (RAS). This would result in one inoperable train while in the recirculation mode of the Emergency Core Cooling System (ECCS) and the Containment Spray (CS) system. This condition existed for ~18 d until the unit shut down for a mid-cycle outage. The core damage probability (CDP) at San Onofre 2 increased during these 18 d because of the increased susceptibility that would result from any loss-of-coolant accident (LOCA) that progressed to the recirculation phase. The estimated increase in the CDP (i.e., the importance) for this event is 7.2×10^{-6}.

B.7.2 Event Description

On February 5, 1998, utility electricians were replacing Square D linestarters as part of planned maintenance. The electricians discovered the mechanical interlock on the linestarter for the Train A containment emergency sump outlet valve (HV-9305) jammed. The sump outlet valve was in the closed position at the time the failure was discovered, fulfilling the containment isolation function of the valve (Fig. B.7.1). However, the as-found condition of the linestarter would have prevented valve HV-9305 from opening. Consequently, the recirculation function for Train A of High Pressure Safety Injection (HPSI) and CS could not be fulfilled without some recovery action. The Train A containment emergency sump outlet valve was last cycled open and closed on January 6, 1998. San Onofre, Unit 2, was shut down for the mid-cycle outage on January 24, 1998. Therefore, from the nature of the failure, the licensee considered the Train A containment emergency sump outlet valve inoperable for approximately 18 d before it was no longer required by Technical Specifications. Consequently, the ECCS Train A and CS Train A were inoperable for ~18 d.[1]

B.7.3 Additional Event-Related Information

The licensee had been programmatically replacing all of the Square D linestarters—60 of 86 linestarters in Unit 2, and 61 of 86 linestarters in Unit 3 had already been replaced. All remaining old linestarters (26 at Unit 2 and 25 at Unit 3) were replaced; no additional failures were discovered.[1]

The grit that caused the linestarter for the Train A containment emergency sump outlet valve to jam was identified as Portland cement particles.[2] No grit was discovered on or around other switchgear room components or in the ventilation ducts. However, some grit was found in other 480-V ac motor control center buckets, but it had not

affected the operation of the associated linestarters. The grit was assumed to have been introduced before plant startup and was known not to migrate after being deposited.[1]

The HPSI system has three centrifugal pumps divided among two trains (Fig. B.7.1). Pump P-017 is in Train A and pump P-019 is in Train B. The third pump, P-018, is a swing pump and can be aligned to either train on the suction or discharge side. P-018 is normally aligned to Train A. Because the HPSI pumps do not automatically stop in response to an RAS signal, operators are directed to stop the pumps before the water level in the refueling water storage tank (RWST) decreases below 5%.[3]

While the recirculation phase of ECCS Train A was compromised between January 6, 1998, and January 24, 1998, the opposite train—ECCS Train B—was inoperable six times during this same period. These six occasions were for

1. 1 h, 43 min to perform an in-service test of an HPSI pump (January 12, 1998),
2. 27 h, 5 min to repair a Component Cooling Water (CCW) heat exchanger tube leak (January 13, 1998) (CCW is required to support ECCS.),
3. 6 h, 36 min to perform heat treatment of the main condenser (January 16, 1998). (This treatment process increases the heat load on the salt water cooling (SWC) system, which is required to support ECCS.),
4. 19 min to swap the in-service SWC pump to the opposite train (January 22, 1998),
5. 5 h, 45 min to perform maintenance work on the Train B RWST outlet valve's breaker-position indicating light replacement (January 23, 1998), and
6. 5 h, 31 min to perform an additional heat treatment of the main condenser (January 24, 1998).

B.7.4 Modeling Assumptions

This event was modeled as an 18-d (432-h) condition assessment with the Train A containment emergency sump outlet valve failed (valve HV-9305). The CCW heat exchanger maintenance (27 h, 5 min) was included in the modeling because of the time required to back out of the maintenance. The maintenance period with the unavailable RWST outlet valve (5 h, 45 min) was not included in the event model because the valve was deenergized in the open position, making Train B available during the injection phase of an accident. Time was considered available to manually close the RWST outlet valve before recirculation or to discontinue repairs and make the valve available remotely. Likewise, the two periods involving heat treatment of the main condenser (6 h, 36 min and 5 h, 31 min) were not included in the model of this event because any heat treatment would likely be terminated quickly by the operator. Even if this were not done, a turbine trip initiated by a LOCA would self-limit any added heat loads on the SWC system. The in-service test of the Train B HPSI pump (1 h, 43 min) was not modeled because of operator staffing for the test, the ability to restore the normal lineup quickly, and the limited time the pump was unavailable. The time required to swap pumps (19 min) was not modeled because of the limited time required to perform the task. Therefore, two distinct cases, totaling 432 h (18 d), were modeled as part of this event.

Case 1. 404 h, 55 min with only the Train A containment emergency sump outlet valve failed (valve HV-9305).
Case 2. 27 h, 5 min with the Train A containment emergency sump outlet valve failed (valve HV-9305) and CCW Train B unavailable.

The CS pumps are not represented in the Integrated Reliability and Risk Analysis System (IRRAS) model for San Onofre. However, because Train B of the CS system and all of the containment emergency fan coolers were available throughout the 18-d event, no attempt was made to incorporate the unavailability of one train of CS into the IRRAS model for San Onofre. This is estimated to have an insignificant impact on the calculated importance of this event because CS impacts containment pressure and not core cooling.

The failed Train A containment emergency sump outlet valve was modeled by setting basic event HPR-SMP-FC-UMPA (Containment Sump A Failure) failure probability from 6.1×10^{-3} to TRUE (i.e., probability = 1.0 that the valve would fail on demand). Because of multiple locations which were discovered with grit, previous operational success of the linestarters does not preclude the grit failure mechanism from simultaneously affecting more than one linestarter. In fact, multiple safety components are affected by this failure mechanism; however, most of the affected equipment is not identified. Therefore, only the sump isolation motor-operated valves were considered for adjustment of the common-cause treatment. No supporting evidence was available which would suggest that the failure of the Train A containment emergency sump outlet valve linestarter was unique to just this one linestarter. Therefore, the associated common-cause failure basic event (HPR-MOV-CF-SUMP) was adjusted from 1.1×10^{-3} to the β factor of the Multiple Greek Letter method used in the IRRAS models (8.8×10^{-2}) based on the failure of the Train A containment emergency sump outlet valve.
It was assumed that the operators would correctly follow procedures and secure the HPSI pumps before the RWST level decreases below 5%. Therefore, this was not modeled in the analysis.

An evaluation of this event,[4] prepared by the licensee, estimated that if a small-break LOCA (SLOCA) (3/8–2 in. pipe diameter) occurred, 250 min would be available to recover a recirculation flow path before the onset of core damage. Operators would initiate recirculation flow about 118 min after an SLOCA occurred. Although other CE plants consider depressurization an option, simulator exercises at San Onofre 2 showed that operating crews would not attempt to cool down and depressurize the plant for a leak size in this range. Conversely, it was not expected that small-small-break LOCAs (SSLOCAs) (<3/8 in. pipe diameter) would proceed to the recirculation phase because sufficient time was assumed to be available to cool down and depressurize the primary system. This differentiation required the IRRAS model for San Onofre 2 to be adjusted to reflect the different operator responses expected following an SSLOCA and an SLOCA. Because the importance of medium-break and large-break LOCAs calculated by the licensee using a methodology which parallels the IRRAS development was less than 1.0×10^{-6}, these larger LOCAs were not specifically modeled (i.e., the contribution to the overall importance of the event from these events is small).

Recovery from the CCW heat exchanger maintenance could begin at the time a LOCA event was recognized because the operating staff was aware of the maintenance being performed from pre-shift briefings. By similar reasoning, planning for recovery from the RWST Train B outlet valve maintenance could also begin at the time a LOCA event was recognized. The RWST Train B outlet valve was open for the injection mode and would not be required to change position for 118 min. It was assumed that this was ample time to plan and execute a desired course of action for this RWST valve.

The recovery from the train B CCW heat exchanger maintenance to repair a tube leak was expected to require 200 min.[4] This assumes 15 min for operators to recognize that an SLOCA occurred and to order the restoration of the CCW heat exchanger, 120 min for maintenance personnel to reassemble the CCW heat exchanger, 60 min

for operators to realign the system valves correctly, and 5 min to restore power and start the appropriate CCW pump. These time estimates made by the licensee are conservative, yet still leave an additional 50 min before core damage would occur following an SLOCA. Performance shaping factors considered that the process would be governed by a maintenance procedure and performed under stress outside the control room by a skilled crew.[4] Based on this, the licensee estimated a 60% probability of success in restoring the CCW heat exchanger within 250 min. In addition, one HPSI pump and one residual heat removal (RHR) pump were affected by the maintenance on the CCW heat exchanger. Because the CCW system is not directly modeled by the San Onofre IRRAS model, a basic event was added to several fault trees to represent the CCW system failure probability during the ~27 h maintenance period. The new basic event (CCW-TRNB-FAIL) was added such that a failure to return the train B CCW heat exchanger to service would cause the affected pumps (HPI-MDP-FC-P019 and RHR-MDP-FC-P016) to be failed during the ~27 h CCW maintenance period. The probability of basic event CCW-TRNB-FAIL was adjusted to 0.4 for Case 2; for Case 1, the probability of this basic event occurring was zero.

Two viable options exist to recover from the Train A containment emergency sump outlet valve failing closed.[3] First, the failure of the valve could be traced to the breaker linestarter and replacement could be initiated. Secondly, it is possible to cross-connect the HPSI Train A suction to the Train B suction. In either case, 132 min (250 - 118 min) would be available before the onset of core damage following an SLOCA. Because operator training and emergency operating procedures focus attention on the correct entry into the recirculation mode, it is assumed that the operators would quickly notice the failure of the train A sump valve to open. Recognition and correction of the breaker failure were assumed to require 40 min.[4] This would allow an additional 92 min (132 - 40 min) to complete repairs before the onset of core damage. Performance shaping factors considered that the breaker repair process would not be governed by a maintenance procedure and would be performed under stress outside the control room by a skilled crew.[4] Based on this, the licensee estimated a 50% probability of success in restoring the linestarter and opening the train A sump valve within 132 min of RAS. A new basic event (HPR-SMPA-XHE-NRE) was added to the High-Pressure Recirculation (HPR) fault tree to represent the probability (0.5) that electricians would fail to repair the breaker linestarter. Recognition of the failure and cross-connecting the HPSI pump suctions were assumed to require 20 min. This action would allow an additional 112 min (132 - 20 min) to complete realignment before the onset of core damage. Performance shaping factors considered that the breaker repair process would be governed by an operating procedure and performed under stress outside the control room by a skilled crew.[4] Based on this, the licensee estimated an 80% probability of success in cross-connecting the HPSI pump suction if there were an SLOCA. A new basic event (HPR-XCONN-XHE-NR) was added to the HPR fault tree to represent the probability (0.2) that operators fail to cross-connect the HPSI pump suctions within 132 min of RAS. Because these two new events involve separate groups of plant personnel (electricians and operators), the basic events were considered to be independent. Independence was also assumed when these two new basic events were compared with the effort to restore the CCW heat exchanger, which would involve mechanics.

B.7.5 Analysis Results

Determining the overall increase in the CDP required determining the increase in the CDP for the two different cases, and then summing the results. The cases are

Case 1. 404 h, 55 min with only the Train A containment emergency sump outlet valve failed (valve HV-9305).
Case 2. 27 h, 5 min with the Train A containment emergency sump outlet valve failed (valve HV-9305) and CCW Train B unavailable.

The combined increase in the CDP from this 432-h event (i.e., the importance) is 7.2×10^{-6}. This increase is above a base-case probability for the 432-h period (the CDP) of 3.9×10^{-5} and credits the possible recovery actions discussed in Ref. 2. The resulting conditional core damage probability (CCDP) for the 432-h period in which the linestarter was failed is 4.6×10^{-5}. Most of the increase above the CDP (90%) is driven by Case 1. As expected, the common-cause failure of the containment sump valve shows up most often in the cut sets of the most significant sequences because it is driven by the initial sump valve failure. Potential recovery actions and the CCW train B failure are more conspicuous in Case 2. However, the dominant core damage sequence in both cases of this event (Sequence 2 on Fig. B.7.2) involves

- an SLOCA,
- a successful reactor trip,
- a successful initiation of emergency feedwater,
- a successful initiation of high pressure injection, and
- a failure of high pressure recirculation.

The SLOCA sequences account for ~80% of the overall increase in the CDP for this event. The next most dominant sequence among both cases involves an SSLOCA with a failure to cool down the plant before requiring HPR (SSLOCA Sequence 3). This sequence contributes 5% to the overall importance of this event.

Definitions and probabilities for selected basic events are shown in Table B.7.1. The conditional probabilities associated with the highest probability sequences are shown in Table B.7.2. Table B.7.3 lists the sequence logic associated with the sequences listed in Table B.7.2. Table B.7.4 describes the system names associated with the dominant sequences. Minimal cut sets associated with the dominant sequences are shown in Table B.7.5.

B.7.6 References

1. LER No. 361/98-003, Rev. 1, "Inoperable Valve Due to Grit in Linestarter Mechanism," March 17, 1998.

2. Letter from Dwight E. Nunn, Vice President, to U. S. Nuclear Regulatory Commission, "Response to NRC Inspection Report 98-05 Regarding Linestarters San Onofre Nuclear Generating Station, Units 2 and 3," June 22, 1998.

3. San Onofre, *Final Safety Analysis Report (Updated Version)*.

4. Letter from Dwight E. Nunn, Vice President, San Onofre Nuclear Generating Station, to U. S. Nuclear Regulatory Commission, "Linestarter and AFW Supplemental Information," April 7, 1998.

Figure removed during SUNSI review.

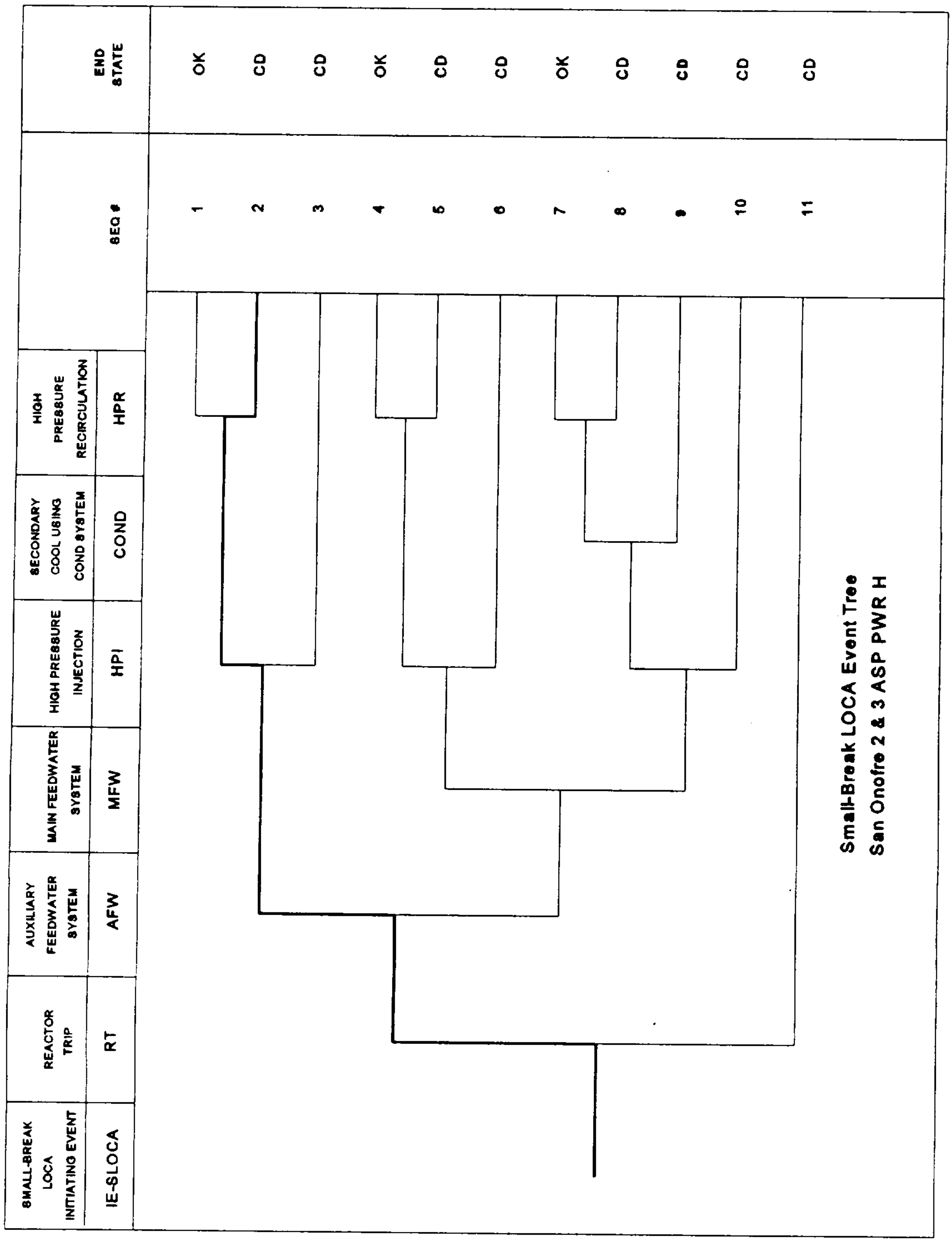

Fig. B.7.2 Dominant core damage sequence for LER No. 361/98-003.

Table B.7.1. Definitions and Probabilities for Selected Basic Events for LER No. 361/98-003

Event name	Description	Base probability	Current probability	Type	Modified for this event
IE-LOOP	Initiating Event–loss of offsite power (LOOP) (Includes the Probability of Recovering Offsite Power in the Short Term)	1.1 E-005	1.1 E-005		No
IE-SGTR	Initiating Event–Steam Generator Tube Rupture (SGTR)	2.1 E-006	2.1 E-006		No
IE-SLOCA	Initiating Event–SLOCA	1.6 E-007	1.6 E-007		Yes
IE-SSLOCA	Initiating Event–SSLOCA	2.1 E-006	2.1 E-006	NEW	Yes
IE-TRANS	Initiating Event–Transient (TRANS)	6.2 E-004	6.2 E-004		No
CCW-TRNB-FAIL	Train B CCW Heat Exchanger is not Returned to Service	0.0 E+000	4.0 E-001	NEW	Yes (Case 2)
HPR-MOV-CF-SUMP	Common-Cause Failure of Sump Isolation Motor-Operated Valves (MOVs)	1.1 E-003	8.8 E-002		Yes
HPR-SMP-FC-SUMPA	Containment Sump Train A Failure (Valve HV-9305 Stuck Closed)	6.1 E-003	1.0 E+000	TRUE	Yes
HPR-XCONN-XHE-NR	Operator Fails to Cross-Connect HPSI Suction from Train B to Train A	2.0 E-001	2.0 E-001	NEW	No
HPR-XHE-NOREC	Operator Fails to Recover the HPR System	1.0 E+000	1.0 E+000		No
HPR-XHE-XM-HLEG	Operator Fails to Initiate Hot-Leg Recirculation	1.0 E-003	1.0 E-003		No
PCS-VCF-HW	Failure of Equipment Required for Plant Cooldown	1.0 E-003	1.0 E-003		No
PCS-XHE-XM-CDOWN	Operator Fails to Initiate Cooldown	1.0 E-003	1.0 E-003		No
PPR-SRV-CO-TRAN	Safety/Relief Valves (SRVs) Open During a Transient	2.0 E-002	2.0 E-002		No
PPR-SRV-OO-1	SRV 1 Fails to Reseat	1.6 E-002	1.6 E-002		No
PPR-SRV-OO-2	SRV 2 Fails to Reseat	1.6 E-002	1.6 E-002		No

Table B.7.1. Definitions and Probabilities for Selected Basic Events for LER No. 361/98-003 (Continued)

Event name	Description	Base probability	Current probability	Type	Modified for this event
RHR-MDP-CF-AB	Common-Cause Failure of RHR Motor-Driven Pumps	5.6 E-004	5.6 E-004		No
RHR-MOV-CF-HX	Common-Cause Failure of RHR Heat Exchanger Isolation MOVs	1.1 E-003	1.1 E-003		No
RHR-MOV-CF-SUC	Common-Cause Failure of RHR Suction MOVs	1.3 E-003	1.3 E-003		No
RHR-PSF-VF-BYP	Flow Diverted From Heat Exchangers or Reactor Vessel	9.0 E-003	9.0 E-003		No
RHR-XHE-NOREC	Operator Fails to Recover the RHR System	3.4 E-001	3.4 E-001		No
RHR-XHE-XM	Operator Fails to Actuate the RHR System	1.0 E-003	1.0 E-003		No

Table B.7.2. Sequence Conditional Probabilities for LER No. 361/98-003

Event tree name	Sequence number	Conditional core damage probability (CCDP)	Core damage probability (CDP)	Importance (CCDP-CDP)	Percent contribution[c]
SLOCA	02	6.0 E-006	1.9 E-007	5.8 E-006	89.4
SSLOCA	03	4.0 E-007	1.3 E-008	3.9 E-007	6.0
SSLOCA	05	1.6 E-007	4.8 E-009	1.5 E-007	2.3
TRANS	05	7.6 E-008	2.4 E-009	7.3 E-008	1.1
Subtotal Case 1 (shown)[a]		4.3 E-005	3.7 E-005	6.5 E-006	
Subtotal Case 2[b]		3.2 E-006	2.4 E-006	7.0 E-007	
Total (all sequences)		**4.6 E-005**	**3.9 E-005**	**7.2 E-006**	

[a]Case 1 represents the increase in the CDP because of the long-term unavailability of the Train A containment emergency sump outlet valve HV-9305 (404.9 h).

[b]Case 2 represents the increase in the CDP because of maintenance being performed on the Train B CCW heat exchanger while the Train A containment emergency sump outlet valve HV-9305 was unavailable (27.1 h).

[c]Because case 1 presents the largest contribution to the total importance, the reported dominant sequences are ordered according to the importance of case 1.

Table B.7.3. Sequence Logic for Dominant Sequences for LER No. 361/98-003 (Case 1 Only)

Event tree name	Sequence number	Logic
SLOCA	02	/RT, /AFW, /HPI, HPR
SSLOCA	03	/RT,/AFW, /HPI, /COOLDOWN, RHR, HPR
SSLOCA	05	/RT,/AFW, /HPI, COOLDOWN, HPR
TRANS	05	/RT, /AFW, SRV, SRV-RES, /HPI, /COOLDOWN, RHR, HPR

Table B.7.4. System Names for LER No. 361/98-003 (Case 1 Only)

System name	Logic
AFW	No or Insufficient Auxiliary Feedwater System Flow
COOLDOWN	Reactor Coolant System Cooldown to RHR Decay Heat Removal Mode of Operation
HPI	No or Insufficient HPSI Flow
HPR	No or Insufficient HPR Flow
RHR	No or Insufficient RHR System Flow
RT	Reactor Fails to Trip
SRV	SRVs Open During a Transient
SRV-RES	SRVs Fail to Reseat

Table B.7.5. Conditional Cut Sets for Higher Probability Sequences for LER No. 361/98-003

Cut set number	Percent contribution	CCDP[a]	Cut sets[d]
SLOCA Sequence 02		6.0 E-006	
1	96.6	5.7 E-006	HPR-MOV-CF-SUMP, HPR-XHE-NOREC
2	1.1	6.5 E-008	HPR-SMP-FC-SUMPA, HPR-XHE-XM-HLEG
SSLOCA Sequence 03		4.0 E-07	
1	57.2	2.3 E-007	RHR-PSF-VF-BYP, RHR-XHE-NOREC, HPR-MOV-CF-SUMP, HPR-XHE-NOREC
2	18.7	7.4 E-008	RHR-XHE-XM, HPR-MOV-CF-SUMP, HPR-XHE-NOREC
3	8.4	3.3 E-008	RHR-MOV-CF-SUC, RHR-XHE-NOREC, HPR-MOV-CF-SUMP, HPR-XHE-NOREC
4	6.7	2.8 E-008	RHR-MOV-CF-HX, RHR-XHE-NOREC, HPR-MOV-CF-SUMP, HPR-XHE-NOREC
5	3.6	1.4 E-008	RHR-MDP-CF-AB, RHR-XHE-NOREC, HPR-MOV-CF-SUMP, HPR-XHE-NOREC
SSLOCA Sequence 05		1.6 E-007	
1	48.1	7.4 E-008	PCS-XHE-XM-CDOWN, HPR-MOV-CF-SUMP, HPR-XHE-NOREC
2	48.1	7.4 E-008	PCS-VCF-HW, HPR-MOV-CF-SUMP, HPR-XHE-NOREC
TRANS Sequence 05		7.6 E-008	
1	28.6	2.1 E-008	PPR-SRV-CO-TRAN, PPR-SRV-OO-1, RHR-PSF-VF-BYP, RHR-XHE-NOREC, HPR-MOV-CF-SUMP, HPR-XHE-NOREC
2	28.6	2.1 E-008	PPR-SRV-CO-TRAN, PPR-SRV-OO-2, RHR-PSF-VF-BYP, RHR-XHE-NOREC, HPR-MOV-CF-SUMP, HPR-XHE-NOREC
3	9.3	7.0 E-009	PPR-SRV-CO-TRAN, PPR-SRV-OO-1, RHR-XHE-XM, HPR-MOV-CF-SUMP, HPR-XHE-NOREC
4	9.3	7.0 E-009	PPR-SRV-CO-TRAN, PPR-SRV-OO-2, RHR-XHE-XM, HPR-MOV-CF-SUMP, HPR-XHE-NOREC
5	4.2	3.1 E-009	PPR-SRV-CO-TRAN, PPR-SRV-OO-1, RHR-MOV-CF-SUC, RHR-XHE-NOREC, HPR-MOV-CF-SUMP, HPR-XHE-NOREC

Table B.7.5. Conditional Cut Sets for Higher Probability Sequences for LER No. 361/98-003 (continued)

Cut set number	Percent contribution	CCDP[a]	Cut sets[d]
6	4.2	3.1 E-009	PPR-SRV-CO-TRAN, PPR-SRV-OO-2, RHR-MOV-CF-SUC, RHR-XHE-NOREC, HPR-MOV-CF-SUMP, HPR-XHE-NOREC
7	3.4	2.6 E-009	PPR-SRV-CO-TRAN, PPR-SRV-OO-1, RHR-MOV-CF-HX, RHR-XHE-NOREC, HPR-MOV-CF-SUMP, HPR-XHE-NOREC
8	3.4	2.6 E-009	PPR-SRV-CO-TRAN, PPR-SRV-OO-2, RHR-MOV-CF-HX, RHR-XHE-NOREC, HPR-MOV-CF-SUMP, HPR-XHE-NOREC
9	1.8	1.3 E-009	PPR-SRV-CO-TRAN, PPR-SRV-OO-1, RHR-MDP-CF-AB, RHR-XHE-NOREC, HPR-MOV-CF-SUMP, HPR-XHE-NOREC
10	1.8	1.3 E-009	PPR-SRV-CO-TRAN, PPR-SRV-OO-2, RHR-MDP-CF-AB, RHR-XHE-NOREC, HPR-MOV-CF-SUMP, HPR-XHE-NOREC
Subtotal Case 1[b] (shown above)		**4.2 E-005**	
Subtotal Case 2[c]		**3.2 E-006**	
Total (all sequences)		**4.6 E-005**	

[a]The change in conditional probability (importance) is determined by calculating the conditional probability for the period in which the condition existed, and subtracting the conditional probability for the same period but with plant equipment assumed to be operating nominally. The conditional probability for each cut set within a sequence is determined by multiplying the probability that the portion of the sequence that makes the precursor visible (e.g., the system with a failure is demanded) will occur during the duration of the event by the probabilities of the remaining basic events in the minimal cut set. This can be approximated by $1 - e^{-p}$, where p is determined by multiplying the expected number of initiators that occur during the duration of the event by the probabilities of the basic events in that minimal cut set. The expected number of initiators is given by λt, where λ is the frequency of the initiating event (given on a per-hour basis), and t is the duration time of the event. This approximation is conservative for precursors made visible by the initiating event. The frequencies of interest for this event are $\lambda_{TRANS} = 6.2 \times 10^{-4}$/h, $\lambda_{LOOP} = 1.1 \times 10^{-5}$/h, $\lambda_{SLOCA} = 1.6 \times 10^{-7}$/h, $\lambda_{SSLOCA} = 2.1 \times 10^{-6}$/h, and $\lambda_{SGTR} = 2.1 \times 10^{-6}$/h.

[b]Case 1 represents the increase in the CDP because of the long-term unavailability of the Train A containment emergency sump outlet valve (404.9 h).

[c]Case 2 represents the increase in the CDP because of Train B CCW heat exchanger maintenance while the Train A containment emergency sump outlet valve was unavailable (27.1 h).

[d]Basic event HPR-SMP-FC-SUMPA is a TRUE type event which is not normally included in the output of fault tree reduction programs but has been added to aid in understanding the sequences to potential core damage associated with the event.