A.13 LER Nos. 440/93-011 and -010

Event Description: Clogged Suppression Pool Strainers and Service Water Flood

Date of Event: March 26, 1993

Plant: Perry

A.13.1 Summary

During a maintenance outage in January 1993, the Perry residual heat removal (RHR) suppression pool suction strainers were found to be deformed because of excessive differential pressure caused by strainer fouling during normal RHR pump operation. The suppression pool was partially inspected and cleaned, and the deformed strainers were replaced.

On March 26, 1993, the reactor was scrammed following a rupture in a 30-in. service water (SW) line. Condenser vacuum was lost, the main steam isolation valves (MSIVs) were closed, and cavitation problems were experienced with a control-rod drive (CRD) pump. The reactor core isolation cooling (RCIC) system was used for pressure vessel makeup. Water from the break entered numerous plant buildings, accumulating in the lowest level of the auxiliary building and control complex, where safety-related equipment is located. No safety-related equipment was impacted by the flood.

Three weeks later, the RHR suppression pool strainers were again inspected. One of the strainers was fouled and deformed. Excessive differential pressures across the RHR strainers from debris accumulation would have failed suppression pool cooling (SPC) if this mode of RHR was required to operate for long periods of time. The conditional core damage probability estimated for this event is 1.2×10^{-4}. The relative significance of this event compared to other postulated events at Perry is shown in Fig. A.13.1.

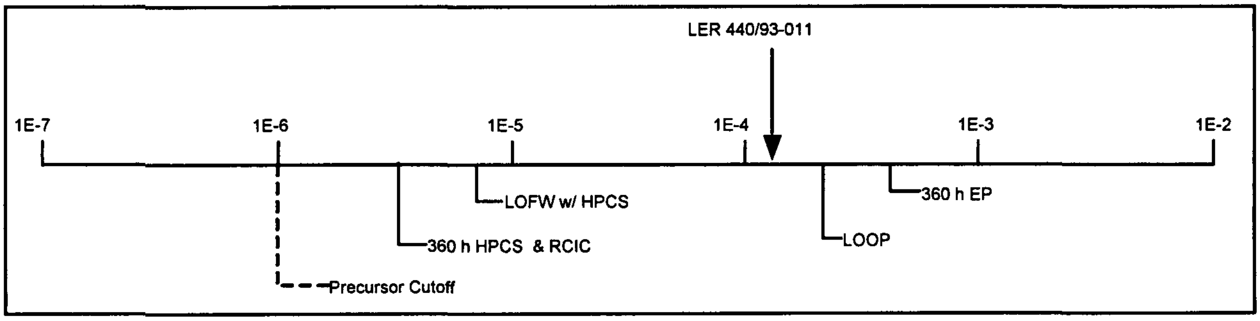

Fig. A.13.1 Relative event significance of LER 440/93-011 compared with other potential events at Perry

A.13.2 Event Description

When the Perry suppression pool was inspected in May 1992, an accumulation of dirt and debris was noticed on the suction strainers for RHR trains A and B. Strainer cleaning was scheduled for a later date, since RHR system performance was considered acceptable based on surveillance testing.

The suppression pool strainers were again inspected and cleaned during a maintenance outage in January 1993. RHR train A and B suction strainers were found to be deformed, with the area of the strainer surface between internal stiffeners partially collapsed inward, in the direction of system flow. It was

determined that the strainers were deformed by excessive differential pressure caused by strainer fouling during normal pump operation. Review of a videotape taken during the May 1992 inspection revealed evidence of deformation that had not been noticed at the time of the taping. The containment side of the suppression pool was inspected and cleaned in February 1993, and the deformed strainers were replaced.

On March 26, 1993, the reactor was scrammed at 1526 hours in response to a rupture in a 30-in. SW line. A leak of unknown origin had been detected at 1314 hours, coming from under concrete slabs south of the water treatment building. At 1522 hours, a low SW discharge pressure alarm annunciated in the control room and flow from the break increased substantially. An alert was declared at 1535 hours, about 12 min after the trip and about 16 min after the rupture probably occurred. The total break volume was approximately 1.7 million gal. Approximately 5% of the total leakage entered the auxiliary, intermediate, diesel, turbine, radwaste, and offgas buildings, as well as the control complex, via electrical manway number 1 at the northwest corner of the radwaste building and by flowing under roll-up and access doors on the west side of the plant. Water levels reached during the flood did not impact safety-related equipment.

Flooded building areas included:

Auxiliary Building. A maximum of 5 in. of standing water was reported on elevation 568 ft (lowest level). Water depths of less than 20 in. on this level will not compromise the operability of safety-related equipment. Flooding on elevation 599 ft resulted in leakage into the high-pressure core spray (HPCS) room through the ceiling hatch plugs. The water dripped on the HPCS pump motor, but the motor was not damaged.

Intermediate Building. Water levels of up to 5 in. were reported on elevation 574 ft. Due to the heavy silt content of the flood water, the drains in this building backed up.

Control Complex. Water levels up to 5 in. were reported on elevation 574 ft. Equipment required for safe shutdown and control room habitability is located at 22 in.

Emergency SW Pump House. The floor of this building was wet or covered with silt. Additionally, the motor-driven fire pump controller was wet but not damaged. Water was also found in an unused Unit 2 motor control center.

Condenser vacuum was lost following the shutdown of the SW system. This required closure of the MSIVs and the use of the safety relief valves (SRVs) for reactor pressure control. The RCIC was placed in service for reactor makeup, and both trains of the RHR system were started at 1552 hours for suppression pool cooling. At 2014 hours, shutdown cooling (SDC) was established using RHR train A. RHR train B continued to provide SPC for an additional 5 h. RCIC was secured and the CRD system was used for level control. The A CRD pump experienced minor cavitation due to loss of suction. The unit reached cold shutdown at 2210 hours.

On April 14, 1993, all emergency core cooling systems (ECCS) strainers were inspected using a high-powered light and video camera. The RHR train B strainer was fouled and deformed in a manner similar to that observed during the January inspection. The remaining strainers showed no signs of fouling. Without disturbing the debris on the strainer, a test run of RHR pump B was performed. The pump running suction pressure decreased to 0 psig after operating for 8 h, and the pump was secured.

The pump suction strainer was then inspected. The debris from the strainer was analyzed, and it was determined that the debris contained fibrous material and corrosion products. The predominant fibrous material was glass fiber from roughing filter material used in the drywell air cooler system. The RHR

strainer provided a structural framework for a uniform covering of the fibrous material, which in turn acted as a filter for suspended solids that would have otherwise passed through the strainer.

The licensee inspected and cleaned the containment following the discovery of the clogged strainers and did not identify large quantities of the fibrous material. Based on this, the licensee concluded that there was no chronic degradation of properly installed filter media. Instead, the licensee concluded that the fibrous material entered the suppression pool as intact pieces as a result of installation or maintenance activities (the roughing filters are normally replaced prior to startup from refueling outages). These pieces subsequently broke down to fibers once in the suppression pool. The actual time the material entered the suppression pool could not be determined.

The suppression pool was completely inspected and cleaned following the discovery of the clogged strainers. This was the first thorough inspection and cleaning since initial criticality in 1986. Previous inspection and cleanup efforts were limited to easily visible and accessible pool areas.

Additional information concerning this event are included in NRC Bulletin 93-02, Supplement 1, *Debris Plugging of Emergency Core Cooling Suction Strainers*, February 18, 1994, and Augmented Inspection Team (AIT) report 50-440/93006(DRS), *Perry Unit 1 Service Water Pipe Break*, April 15, 1993.

A.13.3 Additional Event-Related Information

Systems available at Perry for reactor vessel high-pressure makeup include RCIC, HPCS, and the CRD pumps, as well as main feedwater (MFW). In the event that these systems are unavailable, the automatic depressurization system (ADS) is used to depressurize the reactor to the point where low-pressure systems can provide makeup. Low-pressure systems include low-pressure core spray (LPCS) and low-pressure coolant injection (LPCI).

Two of the three LPCI trains include heat exchangers and piping to remove heat from the suppression pool (suppression pool cooling mode of RHR [RHR/SPC]) and directly from the core (shutdown cooling mode of RHR [RHR/SDC]). The strainers that were found clogged during this event were associated with the two LPCI trains that can be used for RHR.

In the event that RHR fails, the containment can be vented to remove decay heat and prevent overpressurization. To achieve this, the operator manually vents the suppression pool or the drywell. The steaming that will occur in the suppression pool may fail any injection source (such as LPCI) that draws from the suppression pool. Therefore, the feed operation associated with venting must come from an injection system that operates at low pressure and whose source of water is other than the suppression pool.

Flooding of the auxiliary building 568-ft basement level will not directly affect major ECCS components, as each of the RHR, HPCS, LPCS, and RCIC pumps are located in a separate room on the 574-ft level and protected by a watertight door. However, the local panels for all these pumps are mounted in the basement corridor (20 in. above the floor, based on information in the AIT report) except for the HPCS panel, which is at the 574-ft level. Flooding of the corridor will fail the ECCS pumps once water reaches the local panels. Flooding will also lead to loss of the ADS permissive; however, this can be bypassed by the operator in the control room.

Flooding of the control complex 574-ft elevation will result in loss of the instrument air compressors (12 in. above the floor), control complex chilled water pumps which provide ventilation cooling for the battery and switchgear rooms and control room (22 in. above the floor), and emergency closed cooling (ECC) system pumps (22 in. above the floor). The ECC system provides cooling water to the RCIC, LPCS, and RHR

pump room coolers and to the RHR pump seals, as well as to the control complex chillers. Although flooding did not reach 12 in. above the 574-ft elevation, instrument air was lost during the event.

A.13.4 Modeling Assumptions

Excessive differential pressure across the RHR strainers from debris accumulation would fail SPC and could fail LPCI if it was required to operate for long periods of time. The event was modeled as an unavailability of RHR/SPC following (1) postulated initiators in the 1-year period prior to discovery of the clogged strainers and (2) the reactor trip following the SW pipe rupture on March 26, 1993. The possibility of flooding damage to ECCS components was addressed in a sensitivity analysis.

Case 1. Unavailability of RHR/SPC cooling following postulated initiating events. The potential for plugging the suppression pool strainers existed prior to the May 1992 refueling outage. To estimate the relative significance of the event within a 1-year observation period (the interval between precursor reports), a 1-year observation period was used in the analysis (6132 hours, assuming the plant was critical or at hot shutdown 70% of the time). Based on the strainer deformation and clogging observed in 1992 and 1993, both trains of RHR/SPC were assumed to be failed and not recoverable for long-term decay heat removal. LPCI injection and short-term SPC prior to initiation of RHR/SDC were assumed to be operable (RHR train B suction pressure decreased to 0 psig after 17 h of operation following the SW flood). The unavailability of RHR/SPC affected sequences on each of the three ASP models: transient, loss-of-offsite power, and small-break loss of coolant accident. The reactor trip frequency utilized in the transient model was not reduced to reflect the trip following the SW pipe rupture analyzed in Case 2. A nominal reactor trip frequency was used in the analysis.

The existing ASP model was modified to include the potential use of containment venting for decay heat removal in the event that both RHR/SPC and RHR/SDC fail. This was done by revising the dominant sequences involving failure of both RHR cooling modes to also include failure to vent the containment. The probability of failing to vent was assumed to be dominated by human error. A probability of 0.01 was utilized for sequences in which the source of water for injection is separate from the suppression pool.

For sequences in which the injection source takes suction from the suppression pool (such as LPCS or LPCI), an alternate injection source, the CRD pumps or essential SW (RHRSW in the ASP models), must be aligned for injection following venting. Venting is considered much less reliable in such cases; an operator error probability of 0.5 was utilized (see NRR Daily Events Evaluation Manual, 1-275-03-336-01, January 31, 1992).

The current ASP models do not address the potential use of RCIC for reactor vessel (RV) injection in the event of a failed-open SRV. Thermal-hydraulic analyses performed in support of a number of contemporary probabilistic risk assessments indicate that RCIC can provide injection success provided only one SRV fails open. The conditional probabilities for sequences involving failed-open relief valves were revised to reflect the probability that RCIC must also fail or two or more SRVs must fail open before high-pressure RPV makeup fails. This probability was estimated as:

$$p(\text{RCIC}) + p(\text{2 or more SRVs fail open} \mid \text{1 or more SRVs fail open}).$$

This approximation assumes that sequences involving RCIC success avoid core damage if RHR is also successful. Since the probability of RHR failure is very small relative to the probability of failing RCIC, this approximation is valid. The failure probability for RCIC during this event was estimated at 0.042. A value of 0.024 was estimated for p(2 or more SRVs fail open | 1 or more SRVs fail open), based on an estimated probability for two or more SRVs failing open of 0.0015 (see NUREG/CR-4550, Vol. 1, Rev. 1,

Analysis of Core Damage Frequency: Internal Events Methodology, January 1990, pp. 6-10) and an estimated probability of one or more SRVs failing open of 0.0627 (this is developed in Appendix C of NUREG/CR-4674, Vol 1, *Precursors to Potential Severe Core Damage Accidents: 1985, A Status Report*, December 1986). The estimated probability of one or more SRVs failing open is dependent on the number of valves at a given plant and the probability of an SRV failing to close per demand. The probability of RCIC failure or more than one SRV failed open is then 0.042 + 0.024 = 0.066. RCIC can also provide makeup following a steam-side, small-break, loss-of-coolant accident (LOCA). Consistent with other ASP analyses, the probability of a steam-side LOCA was assumed to be 0.6. The probability of RCIC failing to provide RPV makeup following a small break LOCA is, therefore, (1-0.6) + 0.042 = 0.442.

Case 2. Reactor trip, effective loss of MFW, CRD pump problems, and unavailability of RHR/SPC. Following the reactor trip and SW system shutdown, condenser vacuum was lost and the MSIVs were closed. This resulted in unavailability of the power conversion system (PCS) for decay heat removal and the MFW and condensate systems for RV makeup. The CRD system was used for makeup after RCIC was secured; CRD pump A cavitated due to loss of suction. Because of the cavitation problems with the A pump, the CRD system was assumed to be unavailable for RV makeup in the short term (two-of-two CRD pumps are required for success) had it been needed in the event of failure of HPCS and RCIC. In addition, long-term RHR/SPC was also unavailable, as described in Case 1.

Analysis assumptions concerning the potential use of RCIC following a failed open SRV and containment venting were the same as for Case 1. Although CRD flow for short-term RV makeup was assumed unavailable because of cavitation problems with the pump A, CRD was assumed available for makeup following venting. One-of-two pumps provides success in this situation, since the decay heat load is lower.

If SW had not been secured, continued flooding of the auxiliary building and control complex could have resulted in damage to ECCS components. As described in Additional Event-Related Information, the LPCS, RHR, RCIC, and ECC system pumps would have been impacted had the water level reached 20-22 in. in these buildings (flood levels reached 5 in. during the actual event). The lack of detailed information concerning equipment locations and flood pathways prevents consideration of potential flooding effects in this analysis (operational events involving flooding are normally considered impractical to analyze in the ASP program because there is a lack of detailed information). However, a sensitivity analysis was performed to bound the potential effects of the flood.

The sensitivity analysis considered, in addition to the system unavailabilities described in Case 2, the unavailability of the RHR (LPCI and RHR/SDC as well as SPC already lost because of the suction strainer problems) and RCIC pumps if flooding reached 20-22 in. in the auxiliary building and control complex. To simplify the sensitivity analysis, these pumps were assumed unavailable and not recoverable if flooding reached this height. Based on information from the licensee, the LPCS pump was assumed to remain operable, although its room cooling would have been unavailable following the loss of the ECC pumps (this assumption has little affect on the sensitivity analysis results).

The probability of failing to secure SW prior to release of sufficient water to impact the RHR and RCIC pumps was estimated using the following assumptions:

- The rate of auxiliary building and control complex flooding was constant and therefore the time required before sufficient SW was released to reach 20-22 in. was approximately four times the actual flood duration. This assumption is subject to large uncertainties since details of the flooding pathways are not known.
- The compelling cue for SW shutdown was the observation of significant flooding of plant buildings at 1535 h, 14 min after the increase in break flowrate. The SW system was shut down 5 min later. Based on these times and the fact that water levels reached one-quarter of the height

required for damage, break flow must be terminated ~62 min following the cue to prevent damage to ECCS pump control panels in the auxiliary building basement corridor. Control panel flooding would fail RCIC. Damage to the ECC pumps in the control complex, which would impact RHR pump seal cooling and ECCS pump room cooling, would shortly follow.

- The observed time to secure SW (5 min) was assumed to be the median of a lognormal distribution with an error factor of 3.2 (see Dougherty and Fragola, *Human Reliability Analysis*, John Wiley and Sons, New York, 1988, Chapter 10). This is the error factor for time-reliability correlations (TRCs) for actions without hesitancy, which is considered appropriate based on the nature of the flood and the fact that the SW system is not safety-related at Perry. The resulting probability of failing to secure SW before RHR and RCIC pump impact is 1.9×10^{-4}.

During the actual event, the HPCS pump motor was wetted by water dripping from a ceiling hatch plug; however, the pump was not damaged. A separate sensitivity analysis was performed assuming the HPCS pump was unavailable and not recoverable during the actual event and during postulated flooding to understand the impact of such potential damage.

Five core damage probability calculation sheets document the analysis. Case 1 addresses unavailability of RHR/SPC for a 1-year period. Case 2 addresses the reactor trip, loss of condenser vacuum, and CRD problems following the SW pipe rupture. The conditional core damage probability for the event was estimated by modifying the sequence conditional probabilities to reflect the potential use of RCIC in the event of a single failed-open SRV and the use of containment venting for long-term decay heat removal (indicated in the notes at the end of each calculation sheet) and summing the conditional probabilities for the two cases. The three calculation sheets for the potential flooding-impacts and HPCS-unavailable sensitivity analyses are also included.

A.13.5 Analysis Results

The conditional core damage probability estimated for this event is 1.2×10^{-4}. The dominant core damage sequence, highlighted on the event tree shown in Fig. A.13.2, involves a scram with PCS and FW unavailable following the SW pipe rupture, HPCS success, failure of long-term decay heat removal via the RHR system, and failure to vent the containment.

The results of the sensitivity analysis to address potential flooding effects indicates a core damage probability of 2.5×10^{-6} given the rupture. This is small compared to the overall core damage probability for the event, indicating that potential flooding effects do not significantly contribute to the overall event, based on information available in the LER and AIT report. The flood is interesting, however, since it impacted multiple buildings that would typically be considered independent structures in an internal flooding risk analysis.

If the HPCS pump motor had been damaged by the water that dripped from the ceiling hatch, the estimated core damage probability would be 8.5×10^{-4} (including the suppression pool strainer unavailability), a much more significant event.

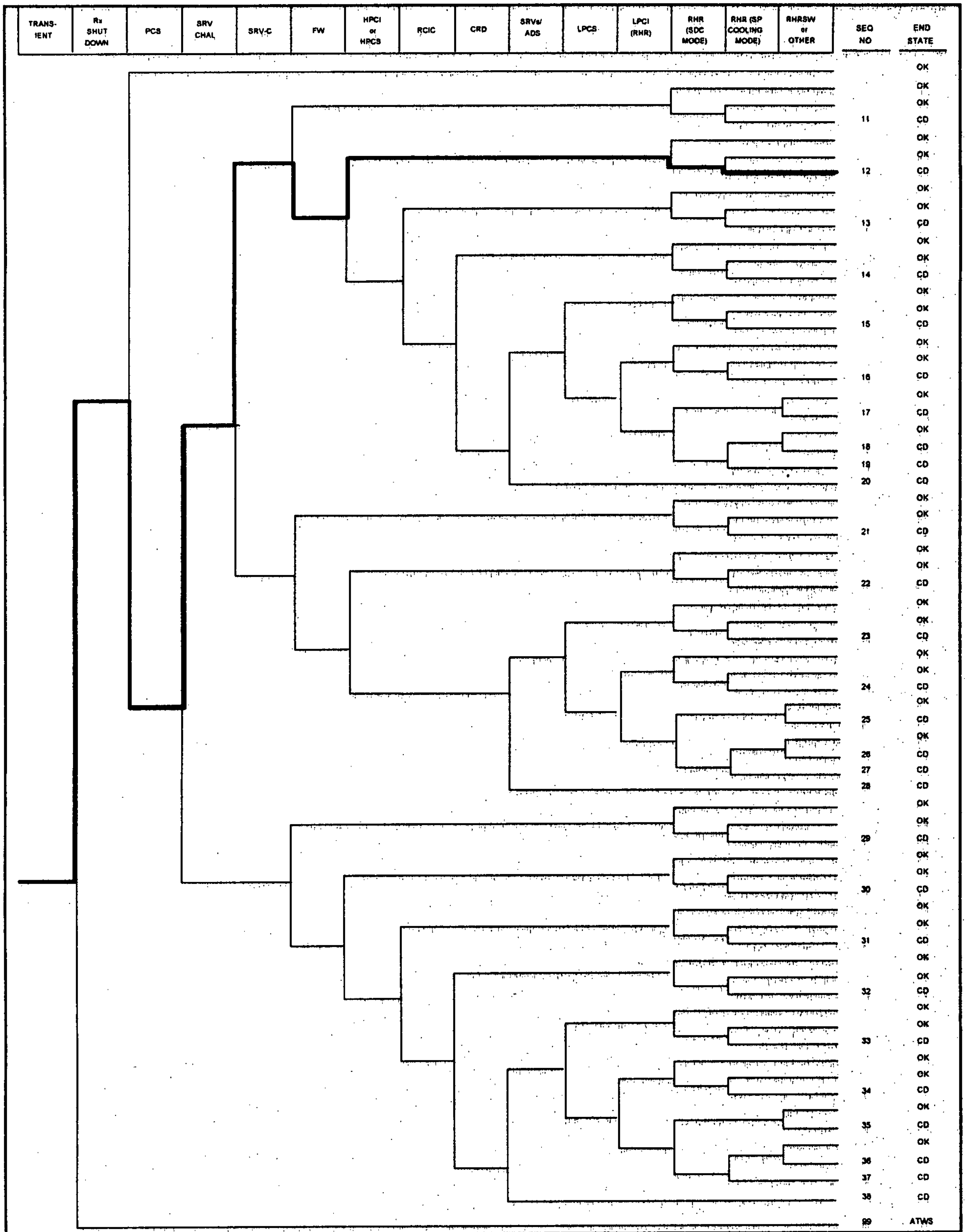

Fig. A.13.2 Dominant core damage sequence for LER 440/93-011

CONDITIONAL CORE DAMAGE PROBABILITY CALCULATIONS

Event Identifier: 440/93-011
Event Description: Unavailability of RHR suppression pool cooling (case 1)
Event Date: 03/26/93
Plant: Perry 1

UNAVAILABILITY, DURATION= 6132

NONRECOVERABLE INITIATING EVENT PROBABILITIES

TRANS	7.4E+00
LOOP	5.3E-02
LOCA	1.0E-02

SEQUENCE CONDITIONAL PROBABILITY SUMS

End State/Initiator	Probability
CD	
TRANS	2.0E-03(1)
LOOP	4.4E-04(1)
LOCA	8.8E-05(1)
Total	2.6E-03(1)
ATWS	
TRANS	0.0E+00
LOOP	0.0E+00
LOCA	0.0E+00
Total	0.0E+00

SEQUENCE CONDITIONAL PROBABILITIES (PROBABILITY ORDER)

	Sequence	End State	Prob	N Rec**
11	trans -rx.shutdown pcs/trans srv.chall/trans.-scram -srv.close -fw/pcs.trans rhr(sdc) RHR(SPCOOL)/RHR(SDC)	CD	1.7E-03(1)	3.2E-01
40	loop -emerg.power -rx.shutdown srv.chall/loop.-scram -srv.close -hpci rhr(sdc) RHR(SPCOOL)/RHR(SDC)	CD	4.1E-04(1)	1.8E-01
12	trans -rx.shutdown pcs/trans srv.chall/trans.-scram -srv.close fw/pcs.trans -hpci rhr(sdc) RHR(SPCOOL)/RHR(SDC)	CD	1.8E-04(1)	1.2E-01
21	trans -rx.shutdown pcs/trans srv.chall/trans.-scram srv.close -fw/pcs.trans rhr(sdc) RHR(SPCOOL)/RHR(SDC)	CD	1.1E-04(1)	3.2E-01
71	loca -rx.shutdown -hpci rhr(sdc) RHR(SPCOOL)/RHR(SDC)	CD	8.7E-05(1)	1.7E-01
49	loop -emerg.power -rx.shutdown srv.chall/loop.-scram srv.close -hpci rhr(sdc) RHR(SPCOOL)/RHR(SDC)	CD	2.8E-05(1)	1.8E-01
22	trans -rx.shutdown pcs/trans srv.chall/trans.-scram srv.close fw/pcs.trans -hpci rhr(sdc) RHR(SPCOOL)/RHR(SDC)	CD	1.2E-05(1)	1.2E-01
41	loop -emerg.power -rx.shutdown srv.chall/loop.-scram -srv.close hpci -rcic rhr(sdc) RHR(SPCOOL)/RHR(SDC)	CD	2.7E-06(1)	6.0E-02
13	trans -rx.shutdown pcs/trans srv.chall/trans.-scram -srv.close fw/pcs.trans hpci -rcic rhr(sdc) RHR(SPCOOL)/RHR(SDC)	CD	1.2E-06(1)	3.9E-02
65	loop emerg.power -rx.shutdown/ep -ep.rec srv.chall/loop.-scram -srv.close -hpci rhr(sdc)/-lpci RHR(SPCOOL)/-LPCI.RHR(SDC)	CD	6.9E-07(1)	1.4E-01
72	loca -rx.shutdown hpci -srv.ads -lpcs rhr(sdc) RHR(SPCOOL)/RH R(SDC)	CD	5.9E-07(1)	5.7E-02
50	loop -emerg.power -rx.shutdown srv.chall/loop.-scram srv.close hpci -srv.ads -lpcs rhr(sdc) RHR(SPCOOL)/RHR(SDC)	CD	1.8E-07(1)	6.1E-02

** nonrecovery credit for edited case

SEQUENCE CONDITIONAL PROBABILITIES (SEQUENCE ORDER)

	Sequence	End State	Prob	N Rec**
11	trans -rx.shutdown pcs/trans srv.chall/trans.-scram -srv.close -fw/pcs.trans rhr(sdc) RHR(SPCOOL)/RHR(SDC)	CD	1.7E-03(1)	3.2E-01
12	trans -rx.shutdown pcs/trans srv.chall/trans.-scram -srv.close fw/pcs.trans -hpci rhr(sdc) RHR(SPCOOL)/RHR(SDC)	CD	1.8E-04(1)	1.2E-01
13	trans -rx.shutdown pcs/trans srv.chall/trans.-scram -srv.close fw/pcs.trans hpci -rcic rhr(sdc) RHR(SPCOOL)/RHR(SDC)	CD	1.2E-06(1)	3.9E-02
21	trans -rx.shutdown pcs/trans srv.chall/trans.-scram srv.close -fw/pcs.trans rhr(sdc) RHR(SPCOOL)/RHR(SDC)	CD	1.1E-04(1)	3.2E-01
22	trans -rx.shutdown pcs/trans srv.chall/trans.-scram srv.close fw/pcs.trans -hpci rhr(sdc) RHR(SPCOOL)/RHR(SDC)	CD	1.2E-05(1)	1.2E-01
40	loop -emerg.power -rx.shutdown srv.chall/loop.-scram -srv.close -hpci rhr(sdc) RHR(SPCOOL)/RHR(SDC)	CD	4.1E-04(1)	1.8E-01
41	loop -emerg.power -rx.shutdown srv.chall/loop.-scram -srv.close hpci -rcic rhr(sdc) RHR(SPCOOL)/RHR(SDC)	CD	2.7E-06(1)	6.0E-02
49	loop -emerg.power -rx.shutdown srv.chall/loop.-scram srv.close -hpci rhr(sdc) RHR(SPCOOL)/RHR(SDC)	CD	2.8E-05(1)	1.8E-01
50	loop -emerg.power -rx.shutdown srv.chall/loop.-scram srv.close hpci -srv.ads -lpcs rhr(sdc) RHR(SPCOOL)/RHR(SDC)	CD	1.8E-07(1)	6.1E-02
65	loop emerg.power -rx.shutdown/ep -ep.rec srv.chall/loop.-scram -srv.close -hpci rhr(sdc)/-lpci RHR(SPCOOL)/-LPCI.RHR(SDC)	CD	6.9E-07(1)	1.4E-01
71	loca -rx.shutdown -hpci rhr(sdc) RHR(SPCOOL)/RHR(SDC)	CD	8.7E-05(1)	1.7E-01
72	loca -rx.shutdown hpci -srv.ads -lpcs rhr(sdc) RHR(SPCOOL)/RH R(SDC)	CD	5.9E-07(1)	5.7E-02

** nonrecovery credit for edited case

Note: For unavailabilities, conditional probability values are differential values which reflect the added risk due to failures associated with an event. Parenthetical values indicate a reduction in risk compared to a similar period without the existing failures.

SEQUENCE MODEL: s:\asp\prog\models\bwrcseal.cmp
BRANCH MODEL: s:\asp\prog\models\perry.sl1
PROBABILITY FILE: s:\asp\prog\models\bwr_csl1.pro

No Recovery Limit

BRANCH FREQUENCIES/PROBABILITIES

Branch	System	Non-Recov	Opr Fail
trans	1.2E-03	1.0E+00	
loop	1.6E-05	5.3E-01	
loca	3.3E-06	5.0E-01	
rx.shutdown	3.0E-05	1.0E+00	
rx.shutdown/ep	3.5E-04	1.0E+00	
pcs/trans	2.3E-01	1.0E+00	
srv.chall/trans.-scram	1.0E+00	1.0E+00	
srv.chall/loop.-scram	1.0E+00	1.0E+00	
srv.close	6.3E-02	1.0E+00	
emerg.power	2.9E-03	8.0E-01	
ep.rec	1.7E-01	1.0E+00	
fw/pcs.trans	2.8E-01	3.4E-01	
fw/pcs.loca	1.0E+00	3.4E-01	
hpci	2.0E-02	3.4E-01	
rcic	6.0E-02	7.0E-01	
crd	1.0E-02	1.0E+00	1.0E-02
srv.ads	3.7E-03	7.1E-01	1.0E-02
lpcs	2.0E-02	3.4E-01	
lpci(rhr)/lpcs	6.0E-04	7.1E-01	
rhr(sdc)	2.3E-02	3.4E-01	1.0E-03
rhr(sdc)/-lpci	2.0E-02	3.4E-01	1.0E-03
rhr(sdc)/lpci	1.0E+00	1.0E+00	1.0E-03
RHR(SPCOOL)/RHR(SDC)	2.0E-03 > 1.0E+00	3.4E-01 > 1.0E+00(2)	
Branch Model: 1.OF.1			
Train 1 Cond Prob:	2.0E-03 > Failed(2)		
RHR(SPCOOL)/-LPCI.RHR(SDC)	2.0E-03 > 1.0E+00	3.4E-01 > 1.0E+00(2)	
Branch Model: 1.OF.1			
Train 1 Cond Prob:	2.0E-03 > Failed(2)		
RHR(SPCOOL)/LPCI.RHR(SDC)	9.3E-02 > 1.0E+00	1.0E+00	

Branch Model: 1.OF.1			
Train 1 Cond Prob:	9.3E-02 > Failed(2)		
rhrsw	2.0E-02	3.4E-01	2.0E-03

* branch model file
** forced

Notes

1. Revised core damage probabilities reflecting the potential use of RCIC in the event of a single failed-open relief valve and containment venting for long-term decay heat removal.

Sequence	p(RCIC)	p(vent)	p(sequence)
11	n/a	0.01	1.7E-05
40	n/a	0.01	4.1E-06
12	n/a	0.01	1.8E-06
21	n/a	0.01	1.1E-06
71	n/a	0.01	8.7E-07
49	n/a	0.01	2.8E-07
22	n/a	0.01	1.2E-07
41	n/a	0.01	2.7E-08
13	n/a	0.01	1.2E-08
65	n/a	0.01	6.9E-09
72	0.466	0.5	1.4E-07
50	0.066	0.5	5.9E-09
		Total	2.5E-05

2. Nonrecoverable failure of long-term suppression pool cooling.

CONDITIONAL CORE DAMAGE PROBABILITY CALCULATIONS

Event Description: SW break with effective LOFW and CRD problems (case 2)
Event Date: 03/26/93
Plant: Perry 1

INITIATING EVENT

NONRECOVERABLE INITIATING EVENT PROBABILITIES

TRANS	1.0E+00

SEQUENCE CONDITIONAL PROBABILITY SUMS

End State/Initiator	Probability
CD	
TRANS	8.8E-03(1)
Total	8.8E-03(1)
ATWS	
TRANS	3.0E-05
Total	3.0E-05

SEQUENCE CONDITIONAL PROBABILITIES (PROBABILITY ORDER)

	Sequence	End State	Prob	N Rec**
12	trans -rx.shutdown PCS/TRANS srv.chall/trans.-scram -srv.close FW/PCS.TRANS -hpci rhr(sdc) RHR(SPCOOL)/RHR(SDC)	CD	8.2E-03(1)	3.4E-01
22	trans -rx.shutdown PCS/TRANS srv.chall/trans.-scram srv.close FW/PCS.TRANS -hpci rhr(sdc) RHR(SPCOOL)/RHR(SDC)	CD	5.5E-04(1)	3.4E-01
13	trans -rx.shutdown PCS/TRANS srv.chall/trans.-scram -srv.close FW/PCS.TRANS hpci -rcic rhr(sdc) RHR(SPCOOL)/RHR(SDC)	CD	5.4E-05(1)	1.1E-01
28	trans -rx.shutdown PCS/TRANS srv.chall/trans.-scram srv.close FW/PCS.TRANS hpci srv.ads	CD	5.4E-06(1)	2.4E-01
23	trans -rx.shutdown PCS/TRANS srv.chall/trans.-scram srv.close FW/PCS.TRANS hpci -srv.ads -lpcs rhr(sdc) RHR(SPCOOL)/RHR(SDC)	CD	3.7E-06(1)	1.1E-01
20	trans -rx.shutdown PCS/TRANS srv.chall/trans.-scram -srv.close FW/PCS.TRANS hpci rcic CRD srv.ads	CD	3.4E-06(1)	1.7E-01
15	trans -rx.shutdown PCS/TRANS srv.chall/trans.-scram -srv.close FW/PCS.TRANS hpci rcic CRD -srv.ads -lpcs rhr(sdc) RHR(SPCOOL)/RHR(SDC)	CD	2.3E-06(1)	8.0E-02
99	trans rx.shutdown	ATWS	3.0E-05	1.0E+00

** nonrecovery credit for edited case

SEQUENCE CONDITIONAL PROBABILITIES (SEQUENCE ORDER)

	Sequence	End State	Prob	N Rec**
12	trans -rx.shutdown PCS/TRANS srv.chall/trans.-scram -srv.close FW/PCS.TRANS -hpci rhr(sdc) RHR(SPCOOL)/RHR(SDC)	CD	8.2E-03(1)	3.4E-01
13	trans -rx.shutdown PCS/TRANS srv.chall/trans.-scram -srv.close FW/PCS.TRANS hpci -rcic rhr(sdc) RHR(SPCOOL)/RHR(SDC)	CD	5.4E-05(1)	1.1E-01
15	trans -rx.shutdown PCS/TRANS srv.chall/trans.-scram -srv.close FW/PCS.TRANS hpci rcic CRD -srv.ads -lpcs rhr(sdc) RHR(SPCOOL)/RHR(SDC)	CD	2.3E-06(1)	8.0E-02
20	trans -rx.shutdown PCS/TRANS srv.chall/trans.-scram -srv.close FW/PCS.TRANS hpci rcic CRD srv.ads	CD	3.4E-06(1)	1.7E-01
22	trans -rx.shutdown PCS/TRANS srv.chall/trans.-scram srv.close FW/PCS.TRANS -hpci rhr(sdc) RHR(SPCOOL)/RHR(SDC)	CD	5.5E-04(1)	3.4E-01

23	trans -rx.shutdown PCS/TRANS srv.chall/trans.-scram srv.close FW/PCS.TRANS hpci -srv.ads -lpcs rhr(sdc) RHR(SPCOOL)/RHR(SDC)	CD	3.7E-06(1)	1.1E-01
28	trans -rx.shutdown PCS/TRANS srv.chall/trans.-scram srv.close FW/PCS.TRANS hpci srv.ads	CD	5.4E-06(1)	2.4E-01
99	trans rx.shutdown	ATWS	3.0E-05	1.0E+00

** nonrecovery credit for edited case

SEQUENCE MODEL: s:\asp\prog\models\bwrcseal.cmp
BRANCH MODEL: s:\asp\prog\models\perry.sl1
PROBABILITY FILE: s:\asp\prog\models\bwr_csl1.pro

No Recovery Limit

BRANCH FREQUENCIES/PROBABILITIES

Branch	System	Non-Recov	Opr Fail
trans	1.2E-03	1.0E+00	
loop	1.6E-05	5.3E-01	
loca	3.3E-06	5.0E-01	
rx.shutdown	3.0E-05	1.0E+00	
rx.shutdown/ep	3.5E-04	1.0E+00	
PCS/TRANS	2.3E-01 > 1.0E+00	1.0E+00	
Branch Model: 1.OF.1			
Train 1 Cond Prob:	2.3E-01 > Unavailable(3)		
srv.chall/trans.-scram	1.0E+00	1.0E+00	
srv.chall/loop.-scram	1.0E+00	1.0E+00	
srv.close	6.3E-02	1.0E+00	
emerg.power	2.9E-03	8.0E-01	
ep.rec	1.7E-01	1.0E+00	
FW/PCS.TRANS	2.8E-01 > 1.0E+00	3.4E-01 > 1.0E+00(3)	
Branch Model: 1.OF.1			
Train 1 Cond Prob:	2.8E-01 > Unavailable(3)		
FW/PCS.LOCA	1.0E+00 > 1.0E+00	3.4E-01 > 1.0E+00(3)	
Branch Model: 1.OF.1			
Train 1 Cond Prob:	1.0E+00		
hpci	2.0E-02	3.4E-01	
rcic	6.0E-02	7.0E-01	
CRD	1.0E-02 > 1.0E+00	1.0E+00	1.0E-02
Branch Model: 1.OF.1+opr			
Train 1 Cond Prob:	1.0E-02 > Failed(4)		
srv.ads	3.7E-03	7.1E-01	1.0E-02
lpcs	2.0E-02	3.4E-01	
lpci(rhr)/lpcs	6.0E-04	7.1E-01	
rhr(sdc)	2.3E-02	3.4E-01	1.0E-03
rhr(sdc)/-lpci	2.0E-02	3.4E-01	1.0E-03
rhr(sdc)/lpci	1.0E+00	1.0E+00	1.0E-03
RHR(SPCOOL)/RHR(SDC)	2.0E-03 > 1.0E+00	3.4E-01 > 1.0E+00(2)	
Branch Model: 1.OF.1			
Train 1 Cond Prob:	2.0E-03 > Failed(2)		
RHR(SPCOOL)/-LPCI.RHR(SDC)	2.0E-03 > 1.0E+00	3.4E-01 > 1.0E+00(2)	
Branch Model: 1.OF.1			
Train 1 Cond Prob:	2.0E-03 > Failed(2)		
RHR(SPCOOL)/LPCI.RHR(SDC)	9.3E-02 > 1.0E+00	1.0E+00	
Branch Model: 1.OF.1			
Train 1 Cond Prob:	9.3E-02 > Failed(2)		
rhrsw	2.0E-02	3.4E-01	2.0E-03

* branch model file
** forced

Notes

1. Revised core damage probabilities reflecting the potential use of RCIC in the event of a single failed-open relief valve and containment venting for long-term decay heat removal.

Sequence	p(RCIC)	p(vent)	p(sequence)
12	n/a	0.01	8.2E-05
22	n/a	0.01	5.5E-06
13	n/a	0.01	5.4E-07
28	0.066	1.0	3.6E-07
23	0.066	0.5	1.2E-07
20	n/a	1.0	3.4E-06
15	n/a	0.5	1.2E-06
		Total	9.3E-05

2. Nonrecoverable failure of long-term suppression pool cooling.
3. These unavailabilities result from the loss of condenser vacuum and MSIV closure.
4. CRD pump "A" cavitation.

CONDITIONAL CORE DAMAGE PROBABILITY CALCULATIONS

Event Identifier: 440/93-011
Event Description: SW break with LOFW, CRD problems and flood impacts (sensitivity)
Event Date: 03/26/93
Plant: Perry 1

INITIATING EVENT

NONRECOVERABLE INITIATING EVENT PROBABILITIES

TRANS	1.9E-04

SEQUENCE CONDITIONAL PROBABILITY SUMS

End State/Initiator	Probability
CD	
TRANS	1.9E-04(1)
Total	1.9E-04(1)
ATWS	
TRANS	5.7E-09
Total	5.7E-09

SEQUENCE CONDITIONAL PROBABILITIES (PROBABILITY ORDER)

	Sequence	End State	Prob	N Rec**
12	TRANS -rx.shutdown PCS/TRANS srv.chall/trans.-scram -srv.close FW/PCS.TRANS -hpci RHR(SDC) RHR(SPCOOL)/RHR(SDC)	CD	1.8E-04(1)	1.9E-04
22	TRANS -rx.shutdown PCS/TRANS srv.chall/trans.-scram srv.close FW/PCS.TRANS -hpci RHR(SDC) RHR(SPCOOL)/RHR(SDC)	CD	1.2E-05(1)	1.9E-04
15	TRANS -rx.shutdown PCS/TRANS srv.chall/trans.-scram -srv.close FW/PCS.TRANS hpci RCIC CRD -srv.ads -lpcs RHR(SDC) RHR(SPCOOL)/RHR(SDC)	CD	1.2E-06(1)	6.4E-05
23	TRANS -rx.shutdown PCS/TRANS srv.chall/trans.-scram srv.close FW/PCS.TRANS hpci -srv.ads -lpcs RHR(SDC) RHR(SPCOOL)/RHR(SDC)	CD	7.9E-08(1)	6.4E-05
99	TRANS rx.shutdown	ATWS	5.7E-09	1.9E-04

** nonrecovery credit for edited case

SEQUENCE CONDITIONAL PROBABILITIES (SEQUENCE ORDER)

	Sequence	End State	Prob	N Rec**
12	TRANS -rx.shutdown PCS/TRANS srv.chall/trans.-scram -srv.close FW/PCS.TRANS -hpci RHR(SDC) RHR(SPCOOL)/RHR(SDC)	CD	1.8E-04(1)	1.9E-04
15	TRANS -rx.shutdown PCS/TRANS srv.chall/trans.-scram -srv.close FW/PCS.TRANS hpci RCIC CRD -srv.ads -lpcs RHR(SDC) RHR(SPCOOL)/RHR(SDC)	CD	1.2E-06(1)	6.4E-05
22	TRANS -rx.shutdown PCS/TRANS srv.chall/trans.-scram srv.close FW/PCS.TRANS -hpci RHR(SDC) RHR(SPCOOL)/RHR(SDC)	CD	1.2E-05(1)	1.9E-04
23	TRANS -rx.shutdown PCS/TRANS srv.chall/trans.-scram srv.close FW/PCS.TRANS hpci -srv.ads -lpcs RHR(SDC) RHR(SPCOOL)/RHR(SDC)	CD	7.9E-08(1)	6.4E-05
99	TRANS rx.shutdown	ATWS	5.7E-09	1.9E-04

** nonrecovery credit for edited case

SEQUENCE MODEL: s:\asp\prog\models\bwrcseal.cmp