A.4 LER No. 293/93-004

Event Description: Weather-Induced Loss-of-offsite Power, Vessel Pressure/Temperature Limits Violated

Date of Event: March 13, 1993

Plant: Pilgrim

A.4.1 Summary

Pilgrim was operating at 100% power when a severe coastal storm caused a loss-of-load scram and subsequent loss of the normal power supply to the plant. Difficulties were experienced during cooldown, when the reactor repressurized to at least 820 psig, with vessel bottom head temperature declining to ~110° F. The conditional core damage probability estimated for this event is 4.6×10^{-6}. The relative significance of this event compared to other postulated events at Pilgrim is shown in Fig. A.4.1.

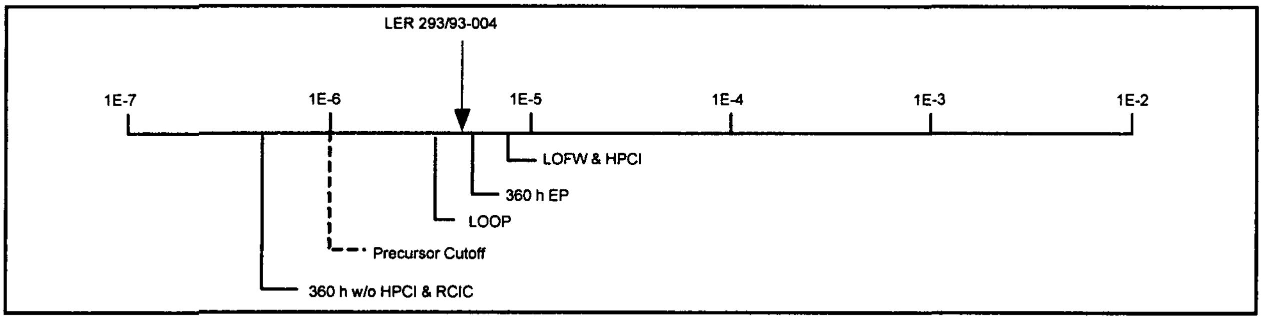

Fig. A.4.1 Relative event significance of LER 293/93-004 compared with other potential events at Pilgrim.

A.4.2 Event Description

On March 13, 1993, at 1628 hours, Pilgrim experienced a load rejection from 100% power. Wind-driven snow and ice accumulated on switchyard insulators, causing a fault that resulted in the automatic opening of switchyard circuit breakers 104 and 105 (see Fig. A.4.2). This action isolated the main transformer from the switchyard and initiated automatic turbine-generator and reactor trips. The loss of the main generator resulted in the loss of the unit auxiliary transformer (UAT). Most loads fed from the UAT fast-transferred to the alternate source, the start-up transformer (SUT). However, a breaker control failure prevented 4160-V ac bus A3 from transferring. Loads fed from bus A3, including the A recirculation pump motor-generator set, the A circulating water pump, the A main turbine auxiliary oil pump, and the 480-V ac bus B3, were deenergized. Deenergization of 480-V ac bus B3, in turn, removed power from reactor protection system (RPS) bus A.

The loss of the A main turbine auxiliary oil pump resulted in the closure of the turbine bypass valves. With these valves closed, two of the main steam relief valves opened briefly for pressure relief. Protective breakers for 120-V ac safeguards buses A and B tripped due to improper trip settings. As a result, the auto starts for pumps in the salt service water (SSW) system and the reactor building closed-cooling-water (RBCCW) system were disabled. Manual operation of these pumps was not affected.

Twelve minutes after the trip, at 1640 hours, switchyard circuit breaker 102 opened automatically due to a flashover of the energized side of switchyard circuit breaker 105. The flashover initiated an isolation and deenergization of line 355.

At 1650 hours, bus A3 was reenergized from the SUT by manually closing breaker 304. This reenergized the A turbine auxiliary lube oil pump, which enabled the turbine bypass valves to open. At 1655 hours, emergency diesel generators (EDGs) 1 and 2 were started and loaded onto their respective buses. Over the next 10 min, 120-V ac safeguards buses A and B were reenergized.

At 1710 hours, the remaining switchyard circuit breaker (105) opened, which deenergized the SUT. Buses A1, A2, A3, and A4 were deenergized. Buses A5 and A6 continued to be fed from the EDGs. At 2155 hours, switchyard breaker 103 was reclosed. The closing of breaker 103 reenergized the SUT from offsite power. Buses A3 and A4 were then realigned to the SUT. Buses A5 and A6 remained aligned to the EDGs.

By 2300 hours, the reactor coolant system (RCS) had been isolated. The main steam isolation valves (MSIVs) had been closed in response to a loss of condensate flow. The reactor-core-isolation cooling (RCIC) and high-pressure coolant injection (HPCI) systems were returned to standby service. HPCI had been providing RCS pressure control. With the RCS isolated, pressure began to rise at ~10 psig/min. By 2330 hours, the reactor vessel (RV) pressure was 510 psig, and the bottom head temperature was 110°F. It was determined 6 d later that this condition violated Technical Specifications. The RV water level was at 48 in. This is above the high-level trip set point for HPCI and RCIC; therefore, they could not be placed into service. At 2336 hours, an RPS scram signal was generated when RV pressure reached 572 psig with the MSIVs closed.

Between 0015 and 0100 hours, the operating staff discussed the use of the main steam relief valves to reduce RV pressure. During this time period, RV pressure gradually rose to 820 psig. At 0100 hours, four of the main steam relief valves were opened for about 5 min to reduce RV pressure. This also reduced RV water level below the HPCI and RCIC trip set points. By 0121 hours, HPCI had been placed into service for RV pressure control, and RCIC was placed into service for RV level control. At 0245 hours, the technical specification pressure-temperature limit for the RV was no longer exceeded. RV pressure was 345 psig, and bottom head temperature was 92°F.

At 0322 and 0345 hours, buses A5 and A6 were realigned to the SUT, and their respective EDGs were returned to standby service.

A.4.3 Additional Event-Related Information

Pilgrim has four nonsafety-related 4160-V ac buses (see Fig. A.4.2). Each of these nonsafety-related buses can be powered from the UAT, which is energized by the main generator output, or the SUT, which is connected to two offsite 345-kV lines. Upon loss of the UAT, the nonsafety-related buses are automatically fast-transferred to the SUT. The two safety-related 4160-V ac buses can also receive power from the UAT and SUT. In addition, they can be powered from a 23-kV offsite line or from the blackout diesel generator (BODG). The BODG is a nonsafety-related supply that is not dependent on any other onsite systems for its operation. It can be started manually from the control room and is capable of providing power to one of the two safeguards buses and associated loads for blackout events without a concurrent loss-of-coolant accident (LOCA) event. Upon the loss of the UAT, the safety-related buses are fast-transferred to the SUT. If the SUT is lost, the buses automatically load onto the safeguards EDGs. If an EDG fails, the breaker for the 23-kV line automatically closes 2 s later. If this should fail, the BODG can be manually aligned to one of the safeguards buses and loaded as required.

A.4.4 Modeling Assumptions

Typically the Accident Sequence Precursor (ASP) Program has selected events for analysis as a loss-of-offsite power (LOOP) event if the LOOP required the EDGs to be relied on for safeguards power for an extended period of time. In this event, only the preferred offsite power source was lost; the 23-kV line was available throughout the event. Although the 23-kV line was available, it was not used because it only closes in if an EDG fails. The plant response was typical of what most plants would experience during a total LOOP. The ASP event tree for a LOOP was used with one modification; the 23-kV line was treated as another source of emergency power.

As with all ASP Program analyses, only the observed failures were included in the modeling of the event. The observed successes were not credited. Equipment that was observed to successfully operate was modeled with nominal failure rates. This is consistent with the program objective of determining the decrease in core damage margin due to the observed events or conditions. As noted in Chap. 2, the data utilized in this analysis are not specific to the Pilgrim unit but are representative of all units of similar design. Application of plant-specific data to the model may result in an increase or decrease in the calculated conditional core damage probability.

This event was modeled as a severe-weather-induced LOOP because it was caused by a widespread ice storm. This is consistent with the categorization of LOOPs in NUREG-1032, *Evaluation of Station Blackout Accidents at Nuclear Power Plants*. The values for the short-term LOOP nonrecovery probability and the long-term nonrecovery of emergency power probability were both modified using the models described in *Revised LOOP Recovery and PWR Seal LOCA Models*, ORNL/NRC/LTR-89-11, August 1989. These models are based on the results of the data distributions contained in NUREG-1032. The output of this program is a short-term LOOP nonrecovery (within the first 30 min) and long-term nonrecovery (before battery depletion). These values are based on the typical duration of a LOOP caused by a severe weather condition. This results in a short-term nonrecovery of 0.9 and a long-term nonrecovery of 5.5×10^{-2}.

The BODG described in the previous section was included in the modeling. According to information provided by the licensee, the failure rate of the BODG is 0.075; this accounts for the operator failure rate to align the BODG. However, this does not account for all of the common cause failures of the two EDGs and the BODG. A calculation that incorporates all potential common cause failures results in a total failure rate for all of the DGs of 2.7×10^{-4}. To determine the failure rate for the BODG, the total failure (2.7×10^{-4}) is divided by the failure rate of the EDGs ($0.05 \times 0.057 = 2.9 \times 10^{-3}$). This results in a failure rate for the BODG of 0.093 ($2.7 \times 10^{-4}/2.9 \times 10^{-3}$). This rate is slightly higher than the value provided by the licensee, and is similar to the typical value of 0.1 used by the ASP Program.

Procedures direct the operators to place the BODG into service if the EDGs fail. It is unlikely that the operators would be able to recover the EDGs within the first half-hour after the LOOP if the BODG failed to be loaded. Therefore, the standard emergency power nonrecovery value was changed from 0.8 to 1.0.

The 23-kV line is unusual because it is used following the failure of the EDGs to start. The Pilgrim IPE indicates that 18 failures of the 345-kV lines occurred between September 13, 1975, and February 21, 1989. Of these 18 LOOPs, 7 were caused by severe weather. In three of these severe-weather-induced LOOPs, the 23-kV line was also lost. Therefore, the conditional probability that the 23-kV line is lost, given that the 345-kV lines were lost due to a severe-weather-induced LOOP, was set to 0.43 (3/7). Because the 23-kV line would close in automatically following the failure of the EDGs, the EDG nonrecovery value was modified to include the 23-kV line. Breaker failures and control system failures were assumed to be not

significant given the high unavailability of the line under these conditions. The nonrecovery value for the EDGs was multiplied by 0.43 to incorporate the 23-kV line.

Although the EDGs were started and loaded 10 min before the actual loss of the 345-kV lines, the EDG probabilities were left at their nominal values. This was done because the same basic failure mechanisms are in place regardless of whether the EDGs are started before or immediately after the LOOP. In either case, the EDG has to start. The only difference between the manual start and the potential automatic start from the LOOP is the elimination of the potential failure of the automatic signal. It was assumed that this did not significantly affect the EDG failure probability. It was also assumed that insufficient time was available between the time that the EDGs were started and when the LOOP occurred (15 min) for significant recovery actions to be performed. As a result, the mean-time-to-repair of the EDGs was assumed to be unaffected by the 15-min period. Had the EDGs been started early enough that significant recovery actions could have been performed before the LOOP event, a modification of the EDG mean-time-to-repair could have decreased the conditional core damage probability for the event. However, the potential for the trip of the running and paralleled EDGs at the time of the LOOP would also need to be considered.

The loss of the A and B safeguards buses resulted in the loss of the automatic start of the SSW and the RBCCW. However, power was restored to these buses within 28 min. If power had not been restored before these two systems were needed, manual starting of the pumps would have been required. Considering the time period available to start the pumps, the operator failure probability was not modified.

The existing ASP model was modified to include the potential use of containment venting for decay heat removal if both residual heat removal (RHR)/suppression pool cooling (SPC) and RHR/shutdown cooling (SDC) fail. This was done by revising the dominant sequences involving failure of both the 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 used for sequences in which the injection source operates at low pressure and uses a source of water that 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 control rod drive pump or the 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 used (see *NRR Daily Events Evaluation Manual*, 1-275-03-336-01, January 31, 1992).

The licensee has performed a Modular Accident Analysis Program (MAAP) analysis of a trip with one stuck-open SRV and all HPI systems inoperable. The results of this analysis indicate that the RV will depressurize rapidly enough to allow LPI systems to inject and, as a result, prevent core damage. Because one or more stuck-open SRVs will perform the same function as the automatic depressurization system (ADS) system, the ADS failure rate for sequences 49 through 55 was set to zero.

The dominant core damage sequences from the calculation sheets were modified as follows to incorporate suppression pool venting and depressurization via a stuck-open SRV.

Sequence	p(sequence from calculation sheets)	p(ADS)	p(vent)	p(sequence)
40	4.8×10^{-6}	1.0	0.01	4.8×10^{-8}
48	1.9×10^{-7}	1.0	1.0	1.9×10^{-7}
55	3.0×10^{-6}	0.0	1.0	0
67	9.2×10^{-7}	1.0	1.0	9.2×10^{-7}
69	2.9×10^{-7}	1.0	1.0	2.9×10^{-7}
83	3.2×10^{-6}	1.0	1.0	3.2×10^{-6}
			Total	4.6×10^{-6}

No analytical evaluation was made of potential consequences of the RV repressurization that occurred during this event.

A.4.5 Analysis Results

The conditional core damage probability estimated for this event is 4.6×10^{-6}. The dominant core damage sequence is highlighted on the event tree in Fig. A.4.3. Sequence 83 involves a failure to recover power from the EDGs or 23-kV line following the LOOP, and failure to recover offsite power before battery depletion.

Inclusion of the BODG and the 23-kV lines in the model reduces the conditional core damage probability for the event. Inclusion of only the BODG results in a reduction of the conditional core damage probability by a factor of 7.5. Inclusion of only the 23-kV line results in a reduction of the conditional core damage probability by a factor of 2.2.

Incorporation of suppression pool venting reduces the conditional core damage probability by a factor of 1.2. It only impacts sequence 40.

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Fig. A.4.2 Simplified diagram of the Pilgrim electrical distribution system

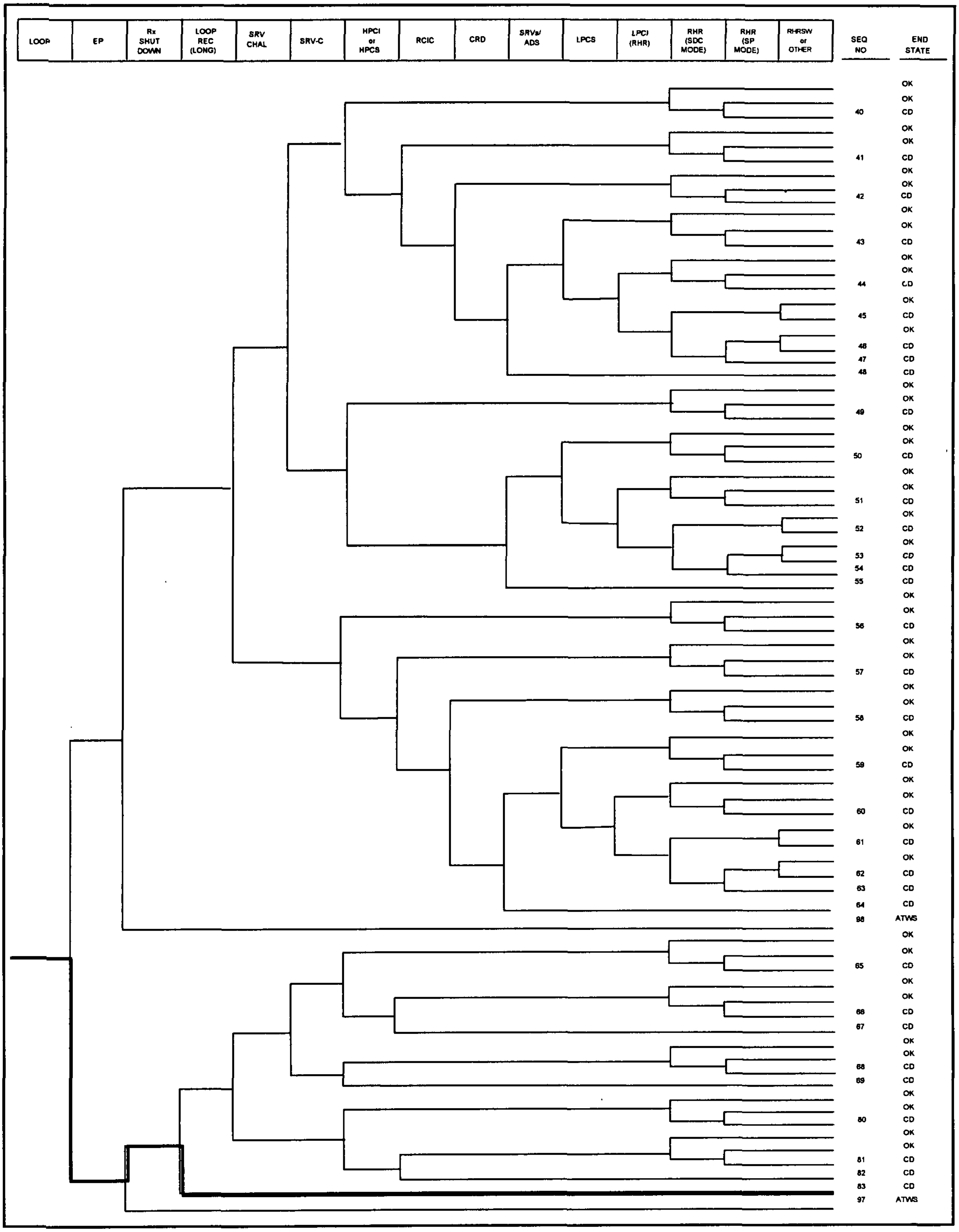

Fig. A.4.3 Dominant core damage sequence for LER 293/93-004

CONDITIONAL CORE DAMAGE PROBABILITY CALCULATIONS

Event Identifier: 293/93-004
Event Description: Severe Weather Induced LOOP
Event Date: 03/13/93
Case: Includes BODG and 23-kV line
Plant: Pilgrim 1

INITIATING EVENT

NONRECOVERABLE INITIATING EVENT PROBABILITIES

LOOP	9.0E-01

SEQUENCE CONDITIONAL PROBABILITY SUMS

End State/Initiator	Probability
CD	
LOOP	1.3E-05 (1)
Total	1.3E-05 (1)
ATWS	
LOOP	2.7E-05
Total	2.7E-05

SEQUENCE CONDITIONAL PROBABILITIES (PROBABILITY ORDER)

	Sequence	End State	Prob	N Rec**
40	LOOP -EMERG.POWER -rx.shutdown srv.chall/loop.-scram -srv.close -hpci rhr(sdc) rhr(spcool)/rhr(sdc)	CD	4.8E-06(1)	1.0E-01
83	LOOP EMERG.POWER -rx.shutdown/ep EP.REC	CD	3.2E-06	3.6E-02
55	LOOP -EMERG.POWER -rx.shutdown srv.chall/loop.-scram srv.close hpci srv.ads	CD	3.0E-06(1)	4.5E-01
67	LOOP EMERG.POWER -rx.shutdown/ep -EP.REC srv.chall/loop.-scram -srv.close hpci rcic	CD	9.2E-07	1.9E-01
69	LOOP EMERG.POWER -rx.shutdown/ep -EP.REC srv.chall/loop.-scram srv.close hpci	CD	2.9E-07	2.7E-01
48	LOOP -EMERG.POWER -rx.shutdown srv.chall/loop.-scram -srv.close hpci rcic crd srv.ads	CD	1.9E-07	3.1E-01
98	LOOP -EMERG.POWER rx.shutdown	ATWS	2.7E-05	9.0E-01

** nonrecovery credit for edited case

SEQUENCE CONDITIONAL PROBABILITIES (SEQUENCE ORDER)

	Sequence	End State	Prob	N Rec**
40	LOOP -EMERG.POWER -rx.shutdown srv.chall/loop.-scram -srv.close -hpci rhr(sdc) rhr(spcool)/rhr(sdc)	CD	4.8E-06(1)	1.0E-01
48	LOOP -EMERG.POWER -rx.shutdown srv.chall/loop.-scram -srv.close hpci rcic crd srv.ads	CD	1.9E-07	3.1E-01
55	LOOP -EMERG.POWER -rx.shutdown srv.chall/loop.-scram srv.close hpci srv.ads	CD	3.0E-06(1)	4.5E-01
98	LOOP -EMERG.POWER rx.shutdown	ATWS	2.7E-05	9.0E-01
67	LOOP EMERG.POWER -rx.shutdown/ep -EP.REC srv.chall/loop.-scram -srv.close hpci rcic	CD	9.2E-07	1.9E-01
69	LOOP EMERG.POWER -rx.shutdown/ep -EP.REC srv.chall/loop.-scram	CD	2.9E-07	2.7E-01

	srv.close hpci			
83	LOOP EMERG.POWER -rx.shutdown/ep EP.REC	CD	3.2E-06	3.6E-02

** nonrecovery credit for edited case

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

No Recovery Limit

BRANCH FREQUENCIES/PROBABILITIES

Branch	System	Nonrecov	Opr Fail
trans	5.5E-04	1.0E+00	
LOOP	2.0E-05 > 2.0E-05	4.3E-01 > 9.0E-01	
Branch Model: INITOR			
Initiator Freq:	2.0E-05		
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	1.7E-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	1.3E-02	1.0E+00	
EMERG.POWER	2.9E-03 > 2.9E-03	8.0E-01 > 4.34E-01 (2)	
Branch Model: 1.OF.2			
Train 1 Cond Prob:	5.0E-02		
Train 2 Cond Prob:	5.7E-02		
EP.REC	3.1E-02 > 3.1E-02	1.0E+00 > 9.3E-02 (3)	
Branch Model: 1.OF.1			
Train 1 Cond Prob:	3.1E-02		
fw/pcs.trans	2.9E-01	3.4E-01	
fw/pcs.loca	4.0E-02	3.4E-01	
hpci	2.9E-02	7.0E-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	3.0E-03	3.4E-01	
lpci(rhr)/lpcs	1.0E-03	7.1E-01	
rhr(sdc)	2.1E-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	3.4E-01	
rhr(spcool)/-lpci.rhr(sdc)	2.0E-03	3.4E-01	
rhr(spcool)/lpci.rhr(sdc)	9.3E-02	1.0E+00	
rhrsw	2.0E-02	3.4E-01	2.0E-03

* branch model file
** forced

NOTES
(1) See Modeling Assumptions section for modifications of these values based on suppression pool venting and depressurization of the RV with one or more stuck open SRVs.
(2)Includes 23-kV line.
(3)Includes BODG.