B.18 LER Number 302/92-001 and 302/92-002

Event Description: Loss of Offsite Power with Inoperable Vital Bus Inverter

Date of Event: March 27, 1992

Plant: Crystal River, Unit 3

B.18.1 Summary

Maintenance work on a vital bus inverter resulted in the loss of the inverter, loss of offsite power (LOOP) to the two safeguards busses, and a plant trip. Following the start of the emergency diesel generators (EDGs), an existing leak in the 3B EDG jacket cooling system increased. After partial restoration of offsite power to the safeguards busses, the 3B EDG was declared inoperable because of the jacket system leakage. The conditional core damage probability for this event is estimated to be 1.7×10^{-5}. The relative significance of this event compared to other postulated events at Crystal River, Unit 3, is shown in Fig. B.36.

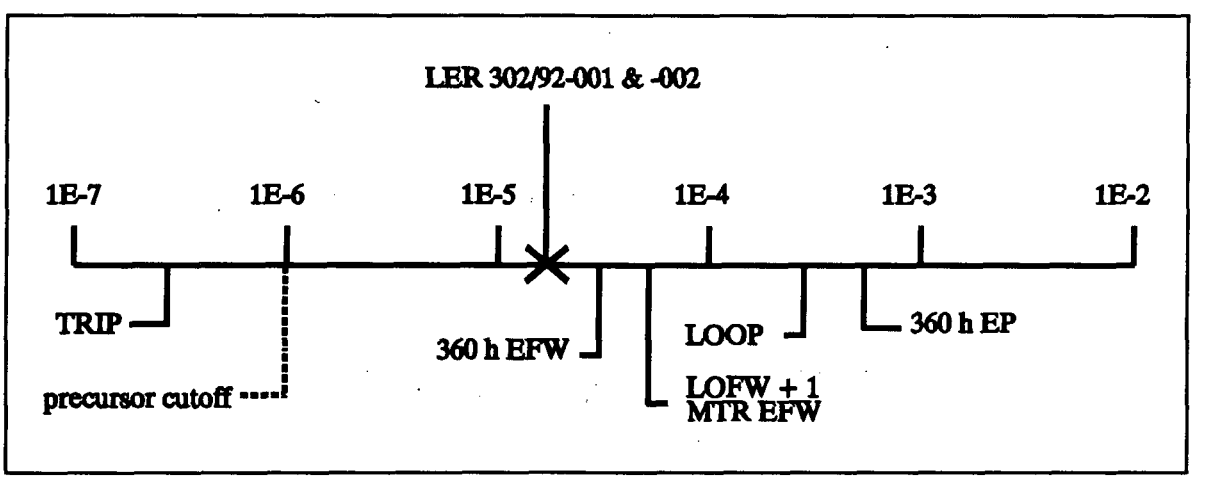

Fig. B.36. Relative event significance of LER 302/92-001 and 302/92-002 compared with other potential events at Crystal River 3.

B.18.2 Event Description

Maintenance was in progress on the C vital bus inverter (see Fig. B.37). The inverter was removed from service, and the C vital bus was being powered by the 480-Vac/120-Vac regulating transformer. When the inverter was repowered from the dc bus at 1308 hours as part of the troubleshooting effort, incomplete isolation of the inverter from the 480-Vac supply resulted in ac voltage swings on the 125-Vdc bus. The voltage swings caused the relays for the Offsite Power Transformer (OPT) to actuate, resulting in the opening of the OPT supply breakers (4900 and 4902). As a result, offsite power to the safeguards busses (ES-3A and ES-3B) was lost. This caused the C vital bus to lose power because the inverter was

Figure removed during SUNSI review.

Fig. B.37. Electrical distribution system for Crystal River 3

out of service. Both EDGs started and loaded as expected. The reactor tripped (rods inserted) because of loss of power to the control rod drive (CRD) motors. The reactor coolant pumps did not trip because nonsafeguards busses 3A and 3B were unaffected, and the turbine did not trip because a reactor trip setpoint had not been reached yet. When the operator pushed the manual reactor trip button, the CRD motor breakers and the turbine both tripped.

Post trip reactor coolant system (RCS) temperature was lower than expected because of the temporary mismatch between primary heat production and secondary heat removal. The reactor was effectively tripped when all the control rods were inserted and resulted in a sharp decrease in primary heat production. The turbine remained on-line for a brief period after the rods were inserted and was drawing 100% steam flow during this time. This resulted in more heat removal following the trip than would be normal. As a result, post-trip RCS temperature was lower than expected.

LER NO: 302/92-001 and -002

A leak of 1 gph was present on the 3B EDG jacket water-cooling system pump seal prior to the transient. Following the starting and loading of the EDG the leakage from the pump seal increased to 2 – 3 gpm. With the EDG running, it was difficult to maintain jacket cooling water inventory through manual makeup. At this point the operability of the EDG was questioned by the licensee. At 1538 hours, the 4160-V bus ES-3B was repowered from the OPT. Following shutdown of the 3B EDG, the leakage decreased but remained above pretrip levels. At 1918 hours, the 4160-V bus ES-3A was repowered from the OPT. At 2330 hours, 7 h and 52 min after it was shut down, the 3B EDG was declared out of service as a result of the jacket system leakage. With the 3B EDG and the C vital bus inverter both out of service, Technical Specifications required the plant to proceed to cold shutdown.

B.18.3 Additional Event-Related Information

The in-plant ac distribution system consists of six ac busses: two 6900-V nonsafeguards busses (3A and 3B) that supply the reactor coolant pumps, two nonsafeguards 4160-V busses (3A and 3B), and two safeguards 4160-V busses (ES-3A and ES-3B). Busses ES-3A and ES-3B normally receive power from the OPT. The startup and auxiliary transformers will not close in on the safeguards busses following a loss of the OPT; however, they can be aligned manually to the busses. On loss of the feed from the OPT, the EDGs automatically supply power to the safeguards busses. Although it is not explicitly stated in the Licensee Event Report (LER), two alternate sources of power (the startup and auxiliary transformers) were apparently available throughout the event because the four nonsafeguards busses remained energized by offsite power throughout the event.

The vital ac and dc distribution system consists of two 250-/125-Vdc busses and four vital 120-Vac busses (3A, 3B, 3C, and 3D). Normally the dc busses are supplied by the battery chargers, but a backup supply is available from the safeguards batteries. The 125-Vdc system provides primary control power to the OPT feeder breakers. Normally, the vital dc busses are supplied by their associated 480-V bus via an inverter. On loss of the 480-V input, the inverter automatically transfers to the 125-Vdc input. If the inverter is out of service (e.g., as it was during the troubleshooting of the C inverter), the bus can be powered from the 480-V bus via a regulating transformer.

B.18.4 Modeling Assumptions

The event was modeled as a plant centered LOOP. Two bounding cases were initially run: one with the B EDG and its associated equipment operable throughout the event (case 1) and another with the B EDG and its associated equipment inoperable throughout the event (case 2). These two cases determine the upper and lower bounds of the estimated core damage probability. For these cases, the probabilities for LOOP nonrecovery (short term), failure to recover ac power prior to battery depletion, and reactor coolant pump seal LOCAs were revised to reflect values associated with a plant-centered LOOP (see ORNL/NRC/LTR-89/11, *Revised LOOP Recovery and PWR Seal LOCA Models,* August 1989).

A point estimate calculation was then performed assuming that the "B" EDG would not have been able to function beyond 2.5 h. The event tree was modified to include the failure of the "B" EDG 2.5 h into the event. The modified tree is shown in Fig. B.38. The following sections describe the basis for the event tree probabilities.

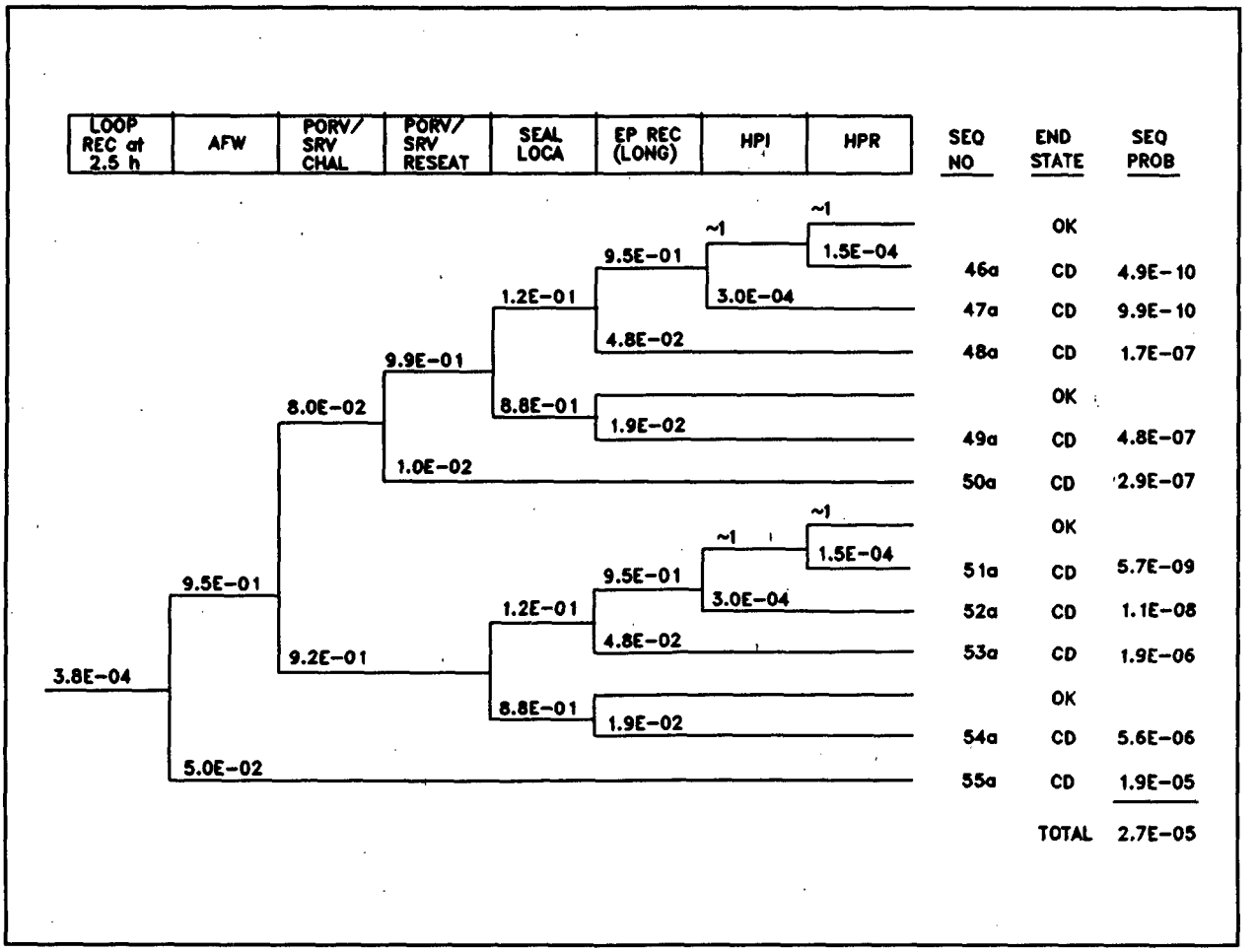

Fig. B.38. Modification to event tree to account for failure of EDG "B" at 2.5 hours.

AC Power Recovery Values

The probabilities for ac nonrecovery were estimated using a Weibull-based distribution (see ORNL/NRC/LTR-89/11, *Revised LOOP Recovery and PWR Seal LOCA Models*, August 1989). This distribution is based on data from NUREG-1032, *Evaluation of Station Blackout Accidents at Nuclear Power Plants*. In this case, the frequency of a LOOP of duration greater than time t is given by:

$$\lambda(t) = 0.0797\ e^{-3.3136t^{0.7837}}$$

where t is in hours. Table B.10 provides values from this equation for times of interest in this event.

LOOP Recovery at 0.5 h. The ac power recovery for the first 0.5 h of the event is included in the LOOP nonrecovery value. From Table B.10, this value is 0.146 which is approximately equal to 0.15.

Table B.10. Probabilities for nonrecovery of emergency power for 302/92-001 and -002.

Time (in hours)	Description	p(nonrecovery of ac)
0.5	Recovery to this time addressed in LOOP frequency	1.46E−01
2.5	EDG "B" failure	1.12E−03
4.0	Core uncovery given seal LOCA	5.43E−05
4.5	Core damage given battery depletion	2.10E−05

LOOP Recovery at 2.5 h. It was assumed that the "B" EDG would not operate beyond 2.5 h. Therefore, the probability of failure of emergency power at 2.5 h is the probability that the "A" EDG has failed and offsite power recovery has not been successful. This is given by:

= p(ac power not recovered at 2.5 h) × p(DG A failed to start and run)
= p(ac power not recovered at 2.5 h | ac power not recovered at 0.5 h) × p(DG A failed to start and run)
= (1.12E-03 / 1.46E-01) × 0.05 = 3.8E-04

LOOP Recovery at 4.0 h. It is assumed that seal failure will occur 1.0 h after seal cooling is lost (1.0 h after emergency power is lost) and core uncovery will occur 0.5 h after the seal LOCA. If power is lost at 2.5 h, then core uncovery will occur at 4.0 h (2.5 + 1.0 + 0.5) given a seal LOCA. The probability of not recovering offsite power at 4.0 h is given by:

= p(ac power not recovered at 4.0 h | ac power not recovered at 2.5 h)
= 5.43E-05 / 1.12E-03 = 4.8E-02

LOOP Recovery at 4.5 h. If a seal failure does not occur, then core damage will occur when battery depletion occurs. The battery lifetime, as stated in the Crystal River Final Safety Analysis Report (FSAR), is 2.0 h. Therefore core damage will occur at 4.5 h (2.0 + 2.5). The probability of not recovering offsite power at 4.5 h is given by:

= p(ac power not recovered at 4.5 h | ac power not recovered at 2.5 h)
= 2.10E-05 / 1.12E-03 = 1.9E-02

Seal LOCA probability

The seal LOCA is assumed to occur 1.0 h after the loss of seal cooling with a probability of 0.12 (see ORNL/NRC/LTR-89/11, *Revised LOOP Recovery and PWR Seal LOCA Models*, August 1989). This is the minimum time period for failure and the maximum failure probability given in the reference document.

PORV/SRV Reseat

Assume that power for the PORV block valve is unavailable. The resulting failure to reseat probability is 0.01.

Other Values

The remaining values are the same as those typically used for Crystal River 3. These values are also found in the computer model calculations.

PORV/SRV Challenge Rate	8.0E-02
HPI (Given Offsite Power Recovery)	3.0E-04
HPR (Given HPI success and Offsite Power Recovery)	1.5E-04

Sequence Probabilities

The total conditional core damage probability for the sequences in the event tree in Fig. B.38 is found by multiplying the total value of the tree by the conditional events as follows:

= p(LOOP) × p(-RT/LOOP) × p(-EP) × p(total for tree in Fig. B.38)
= 0.15 × (1.0 - 0.0) × (1.0 - 2.3E-03) × (2.7E-05) = 4.1E-06

The sequences where EP fails, sequences 46 − 55, are unaffected by the modification made to the original event tree. Therefore, values for these branches can be read directly from the output of the existing ASP model for case 1. For those sequences where EP succeeds throughout the event (initially and after 2.5 h), sequences 41 − 45, the results of the ASP model for case 1 are multiplied by the probability of success for EP at 2.5 h. This value is $1.0 - 3.8 \times 10^{-4} = 0.9996$. This is close enough to 1.0 that these values can also be read directly from the output of case 1.

Therefore, the conditional core damage probability for this event is obtained by adding the results of case 1 to the results of the tree as just calculated.

B.18.5 Analysis Results

The conditional core damage probability for this event is estimated to be 1.7×10^{-5}. Two cases were run to examine the sensitivity of the results to the operability of the 3B EDG. Case 1 assumes that the 3B train of equipment is not degraded and is operable throughout the event and results in a value of 1.3×10^{-5}. Case 2 assumes that the 3B train of equipment is inoperable throughout the event and results in a value of 2.6×10^{-4}. The dominant core damage sequence, highlighted on the event tree in Fig. B.39, involves a reactor trip, a postulated failure of on-site emergency power, and a postulated failure of auxiliary feedwater.

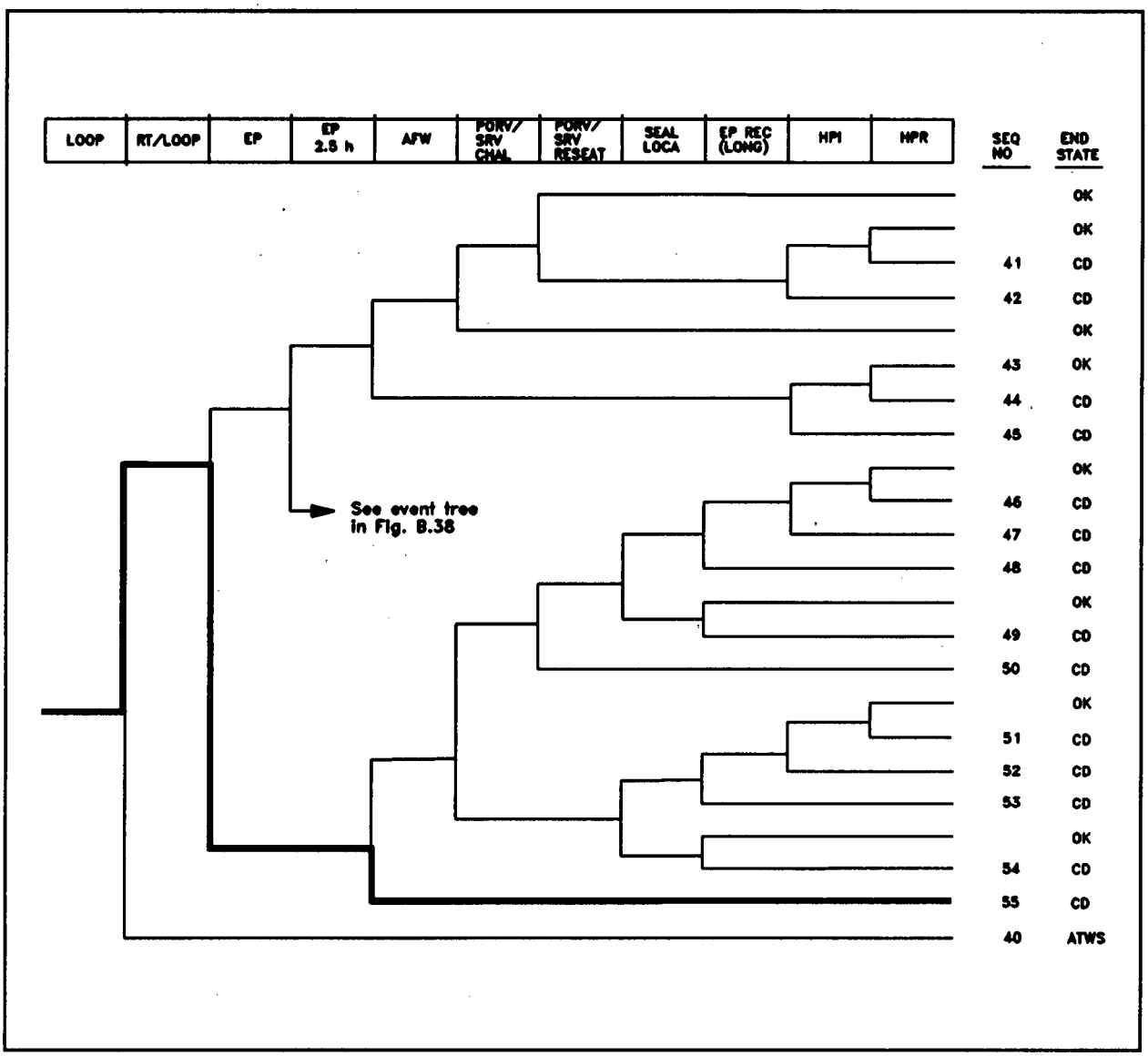

Fig. B.39. Dominant core damage sequences for LER 302/92-001 and 302/92-002

CONDITIONAL CORE DAMAGE PROBABILITY CALCULATIONS

Event Identifier: 302/92-001
Event Description: LOOP from loss of vital bus (EDG B & Assoc Equip Operable) (Case 1 - Lower Bound)
Event Date: 03/27/92
Plant: Crystal River 3

INITIATING EVENT

NON-RECOVERABLE INITIATING EVENT PROBABILITIES

LOOP	1.5E-01

SEQUENCE CONDITIONAL PROBABILITY SUMS

End State/Initiator	Probability
CD	
LOOP	1.3E-05'
Total	1.3E-05'
ATWS	
LOOP	0.0E+00
Total	0.0E+00

SEQUENCE CONDITIONAL PROBABILITIES (PROBABILITY ORDER)

	Sequence	End State	Prob	N Rec**
55	LOOP -rt/loop emerg.power afw/emerg.power	CD	5.8E-06	4.1E-02
54	LOOP -rt/loop emerg.power -afw/emerg.power -porv.or.srv.chall - SEAL.LOCA EP.REC	CD	4.9E-06	1.2E-01
53	LOOP -rt/loop emerg.power -afw/emerg.power -porv.or.srv.chall SEAL.LOCA EP.REC(SL)	CD	1.3E-06	1.2E-01
45	LOOP -rt/loop -emerg.power afw hpi(f/b)	CD	5.1E-07	3.3E-02
49	LOOP -rt/loop emerg.power -afw/emerg.power porv.or.srv.chall - porv.or.srv.reseat/emerg.power -SEAL.LOCA EP.REC	CD	4.2E-07	1.2E-01
50	LOOP -rt/loop emerg.power -afw/emerg.power porv.or.srv.chall porv.or.srv.reseat/emerg.power	CD	2.7E-07	1.2E-01

** non-recovery credit for edited case

SEQUENCE CONDITIONAL PROBABILITIES (SEQUENCE ORDER)

	Sequence	End State	Prob	N Rec**
45	LOOP -rt/loop -emerg.power afw hpi(f/b)	CD	5.1E-07	3.3E-02
49	LOOP -rt/loop emerg.power -afw/emerg.power porv.or.srv.chall - porv.or.srv.reseat/emerg.power -SEAL.LOCA EP.REC	CD	4.2E-07	1.2E-01
50	LOOP -rt/loop emerg.power -afw/emerg.power porv.or.srv.chall porv.or.srv.reseat/emerg.power	CD	2.7E-07	1.2E-01
53	LOOP -rt/loop emerg.power -afw/emerg.power -porv.or.srv.chall SEAL.LOCA EP.REC(SL)	CD	1.3E-06	1.2E-01
54	LOOP -rt/loop emerg.power -afw/emerg.power -porv.or.srv.chall - SEAL.LOCA EP.REC	CD	4.9E-06	1.2E-01
55	LOOP -rt/loop emerg.power afw/emerg.power	CD	5.8E-06	4.1E-02

** non-recovery credit for edited case

Event Identifier: 302/92-001

SEQUENCE MODEL: c:\asppra\models\pwrdseal.cmp
BRANCH MODEL: c:\asppra\models\crystal3.sl1
PROBABILITY FILE: c:\asppra\models\pwr_bsl1.pro

No Recovery Limit

BRANCH FREQUENCIES/PROBABILITIES

Branch	System	Non-Recov	Opr Fail
trans	3.9E-04	1.0E+00	
LOOP	1.8E-05 > 1.8E-05	3.3E-01 > 1.5E-01	
Branch Model: INITOR			
Initiator Freq:	1.8E-05		
loca	2.4E-06	4.3E-01	
rt	2.8E-04	1.2E-01	
rt/loop	0.0E+00	1.0E+00	
emerg.power	2.9E-03	8.0E-01	
afw	1.3E-03	2.6E-01	
afw/emerg.power	5.0E-02	3.4E-01	
mfw	2.0E-01	3.4E-01	
porv.or.srv.chall	8.0E-02	1.0E+00	
porv.or.srv.reseat	1.0E-02	1.1E-02	
porv.or.srv.reseat/emerg.power	1.0E-02	1.0E+00	
SEAL.LOCA	6.0E-02 > 1.5E-02	1.0E+00	
Branch Model: 1.OF.1			
Train 1 Cond Prob:	6.0E-02 > 1.5E-02		
EP.REC(SL)	7.6E-01 > 2.8E-01	1.0E+00	
Branch Model: 1.OF.1			
Train 1 Cond Prob:	7.6E-01 > 2.8E-01		
EP.REC	3.1E-01 > 1.6E-02	1.0E+00	
Branch Model: 1.OF.1			
Train 1 Cond Prob:	3.1E-01 > 1.6E-02		
hpi	3.0E-04	8.4E-01	
hpi(f/b)	3.0E-04	8.4E-01	1.0E-02
hpr/-hpi	1.5E-04	1.0E+00	1.0E-03

* branch model file
** forced

Notes:
'This value was modified to obtain the point estimate for the event. See Modeling Assumptions section for a description of the modifications made.

CONDITIONAL CORE DAMAGE PROBABILITY CALCULATIONS

Event Identifier: 302/92-001
Event Description: LOOP from loss of vital equip bus (EDG B & Assoc Equip OOS) (CASE 2 - Upper Bound)
Event Date: 03/27/92
Plant: Crystal River 3

INITIATING EVENT

NON-RECOVERABLE INITIATING EVENT PROBABILITIES

LOOP	1.5E-01

SEQUENCE CONDITIONAL PROBABILITY SUMS

End State/Initiator	Probability
CD	
LOOP	2.6E-04
Total	2.6E-04
ATWS	
LOOP	0.0E+00
Total	0.0E+00

SEQUENCE CONDITIONAL PROBABILITIES (PROBABILITY ORDER)

	Sequence	End State	Prob	N Rec**
55	LOOP -rt/loop EMERG.POWER afw/emerg.power	CD	1.2E-04	4.1E-02
54	LOOP -rt/loop EMERG.POWER -afw/emerg.power -porv.or.srv.chall - SEAL.LOCA EP.REC	CD	9.7E-05	1.2E-01
53	LOOP -rt/loop EMERG.POWER -afw/emerg.power -porv.or.srv.chall SEAL.LOCA EP.REC(SL)	CD	2.6E-05	1.2E-01
49	LOOP -rt/loop EMERG.POWER -afw/emerg.power porv.or.srv.chall - porv.or.srv.reseat/emerg.power -SEAL.LOCA EP.REC	CD	8.4E-06	1.2E-01
50	LOOP -rt/loop EMERG.POWER -afw/emerg.power porv.or.srv.chall porv.or.srv.reseat/emerg.power	CD	5.4E-06	1.2E-01

** non-recovery credit for edited case

SEQUENCE CONDITIONAL PROBABILITIES (SEQUENCE ORDER)

	Sequence	End State	Prob	N Rec**
49	LOOP -rt/loop EMERG.POWER -afw/emerg.power porv.or.srv.chall - porv.or.srv.reseat/emerg.power -SEAL.LOCA EP.REC	CD	8.4E-06	1.2E-01
50	LOOP -rt/loop EMERG.POWER -afw/emerg.power porv.or.srv.chall porv.or.srv.reseat/emerg.power	CD	5.4E-06	1.2E-01
53	LOOP -rt/loop EMERG.POWER -afw/emerg.power -porv.or.srv.chall SEAL.LOCA EP.REC(SL)	CD	2.6E-05	1.2E-01
54	LOOP -rt/loop EMERG.POWER -afw/emerg.power -porv.or.srv.chall - SEAL.LOCA EP.REC	CD	9.7E-05	1.2E-01
55	LOOP -rt/loop EMERG.POWER afw/emerg.power	CD	1.2E-04	4.1E-02

** non-recovery credit for edited case

Event Identifier: 302/92-001

```
SEQUENCE MODEL:      c:\asppra\models\pwrdseal.cmp
BRANCH MODEL:        c:\asppra\models\crystal3.sl1
PROBABILITY FILE:    c:\asppra\models\pwr_bs11.pro

No Recovery Limit

BRANCH FREQUENCIES/PROBABILITIES

Branch                              System                    Non-Recov          Opr Fail

trans                               3.9E-04                   1.0E+00
LOOP                                1.8E-05 > 1.8E-05         3.3E-01 > 1.5E-01
    Branch Model:  INITOR
    Initiator Freq:                 1.8E-05
loca                                2.4E-06                   4.3E-01
rt                                  2.8E-04                   1.2E-01
rt/loop                             0.0E+00                   1.0E+00
EMERG.POWER                         2.9E-03 > 5.7E-02         8.0E-01
    Branch Model:  1.OF.2
    Train 1  Cond Prob:             5.0E-02 > Failed
    Train 2  Cond Prob:             5.7E-02
afw                                 1.3E-03                   2.6E-01
afw/emerg.power                     5.0E-02                   3.4E-01
mfw                                 2.0E-01                   3.4E-01
porv.or.srv.chall                   8.0E-02                   1.0E+00
porv.or.srv.reseat                  1.0E-02                   1.1E-02
porv.or.srv.reseat/emerg.power      1.0E-02                   1.0E+00
SEAL.LOCA                           6.0E-02 > 1.5E-02         1.0E+00
    Branch Model:  1.OF.1
    Train 1  Cond Prob:             6.0E-02 > 1.5E-02
EP.REC(SL)                          7.6E-01 > 2.8E-01         1.0E+00
    Branch Model:  1.OF.1
    Train 1  Cond Prob:             7.6E-01 > 2.8E-01
EP.REC                              3.1E-01 > 1.6E-02         1.0E+00
    Branch Model:  1.OF.1
    Train 1  Cond Prob:             3.1E-01 > 1.6E-02
HPI                                 3.0E-04 > 1.0E-03         8.4E-01
    Branch Model:  1.OF.3
    Train 1  Cond Prob:             1.0E-02
    Train 2  Cond Prob:             1.0E-01
    Train 3  Cond Prob:             3.0E-01 > Unavailable
HPI(F/B)                            3.0E-04 > 1.0E-03         8.4E-01          1.0E-02
    Branch Model:  1.OF.3+opr
    Train 1  Cond Prob:             1.0E-02
    Train 2  Cond Prob:             1.0E-01
    Train 3  Cond Prob:             3.0E-01 > Unavailable
HPR/-HPI                            1.5E-04 > 1.0E-02         1.0E+00          1.0E-03
    Branch Model:  1.OF.2+opr
    Train 1  Cond Prob:             1.0E-02
    Train 2  Cond Prob:             1.5E-02 > Unavailable

*  branch model file
** forced



Event Identifier: 302/92-001
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