A.5 LER No. 313/93-003

Event Description: Both Trains of Recirculation Inoperable for 14 h

Date of Event: September 30, 1993

Plant: Arkansas Nuclear One, Unit 1

A.5.1 Summary

On September 30, 1993, an engineering evaluation was completed at Arkansas Nuclear One, Unit 1, which indicated that the B decay heat removal/low-pressure injection (DHR/LPI) pump might have been incapable of performing its recirculation mode function following a loss-of-coolant accident (LOCA). This condition existed from May 24, 1993, while that plant was at power, until the plant shutdown on September 9, 1993. In addition, the A DHR/LPI pump was also inoperable for 14 h during this time period for routine maintenance and surveillance. The estimated conditional core damage probability for this event is 5.1×10^{-5}. The relative significance of this event compared to other postulated events at Arkansas Nuclear One, Unit 1, is shown in Fig. A.5.1.

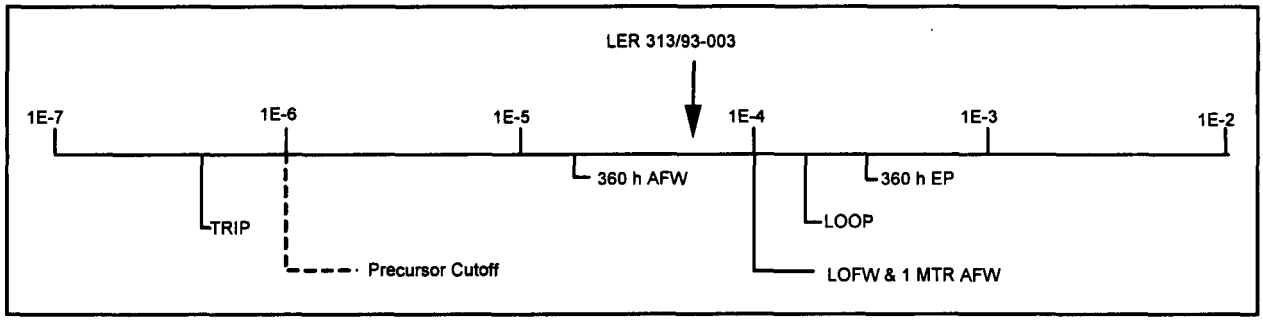

Fig. A.5.1 Relative event significance of LER 313/93-003 compared with other potential events at Arkansas Nuclear One, Unit 1

A.5.2 Event Description

On September 9, 1993, at 0432 hours, a routine plant shutdown was in progress to begin a refueling outage at Arkansas Nuclear One, Unit 1. With the reactor coolant system (RCS) temperature at 180°F, the B DHR/LPI pump was placed into service. At 0530 hours, the outboard motor bearing for the B DHR/LPI pump alarmed on high temperature, and the pump was secured. The A DHR/LPI pump remained in service. Following verification of the operation of the oil slinger and testing of the pump oil, the B pump was restarted at 1224 hours. The outboard motor bearing temperature again increased, and the pump was secured and declared inoperable at 1430 hours.

Troubleshooting efforts indicated that there was no bearing damage. However, the pump and the motor were not properly coupled. The coupling hub on the pump shaft was installed ~0.316 in. too far toward the motor. This condition caused the motor to be pushed off its magnetic center in the outward direction. Because the pump thrust bearing is on the opposite side of the pump from the motor, thermal expansion of the pump shaft while pumping hot fluids would push the shaft coupling farther in the outboard direction, creating increased thrust loading on the outboard motor bearing.

The outboard motor bearing temperature response during past surveillance tests was reviewed. Although the tests are terminated before the bearings reach stabilization temperature, the stabilization temperature can be determined from the strip chart data. This review indicated that higher than normal (but acceptable) bearing temperatures were observed after May 24, 1993. A review of maintenance records indicated that the B DHR/LPI pump coupling was greased during a system mini-outage on May 24, 1993.

The B DHR/LPI pump was considered capable of performing its LPI function throughout this period. However, from May 24, 1993, until the plant shutdown on September 9, 1993, the B pump was considered inoperable in the recirculation mode while pumping hot water from the reactor building sump. The A DHR/LPI pump was also inoperable for 14 h during this time period for routine maintenance and surveillance activities.

A.5.3 Additional Event-Related Information

The DHR/LPI pumps are used in three modes. The first is the DHR mode that is used during plant shutdowns, heatups, and outages. In this mode the pumps take suction from one of the RCS hot legs. After passing through the pumps and DHR coolers, cooled water is returned to the RCS cold legs. The B pump failed while operating in this mode. The second is the LPI mode; in this mode, the pumps take suction from the refueling water storage tank (RWST) and discharge it to the RCS loops. This LPI mode is automatically initiated following a safety injection signal. The third is the recirculation mode that is used following the depletion of the RWST. The pump suction is aligned to the containment sump. After passing through the pumps, the water is cooled in the DHR coolers. The discharge can then be aligned directly to the RCS, or if RCS pressure is above the DHR/LPI pump shutoff head, to the suction of the high-pressure injection (HPI) pumps for "piggyback" operation.

During the LPI mode, when the pumps take suction on the cooler water in the RWST, the licensee indicates that the B DHR/LPI pump will operate. However, when the warmer water from the containment sump passes through the pumps during the recirculation mode, the increased heat addition from the warmer water may cause the pump to fail due to the improper coupling of the motor.

A.5.4 Modeling Assumptions

Two cases were run. In the first case, both the A and B DHR/LPI pumps were assumed inoperable in the recirculation mode for 14 h. This calculation was performed because both trains of the system (high- and low-pressure recirculation) were inoperable. The B pump would have initially operated but would have subsequently failed as described above. The A pump was out-of-service for routine maintenance and surveillance testing. It was assumed that the A pump could potentially be recovered during the injection phase of a postulated LOCA event, making it available for the recirculation mode. A nonrecovery factor of 0.34 was assumed (NUREG/CR-4674, Vol.17, Sect. A.1.3, Recovery Class R2, failure appeared recoverable in the required period at the failed equipment, and the equipment was accessible; recovery from the control room did not appear possible).

The second case addresses the long-term unavailability of the B DHR/LPI pump. This calculation was performed because the long-term unavailability of a single train of recirculation significantly impacts the conditional core damage probability for the event. The pump was assumed to be inoperable in the recirculation mode for 3048 h (from May 5, 1993, to September 9, 1993). The A pump was considered operable during this period with nominal failure rates and nonrecovery values applied.

A.5.5 Analysis Results

The estimate of the conditional core damage probability for this event is 5.1×10^{-5}. This consists of a contribution of 4.9×10^{-6} for case 1 (both trains inoperable for 14 h) and 4.6×10^{-5} for case 2 (train B inoperable for 3048 h). The dominant core damage sequence for both cases, shown in Fig. A.5.2, involves a postulated LOCA, successful reactor trip, auxiliary feedwater, and HPI, followed by failure of high-pressure recirculation.

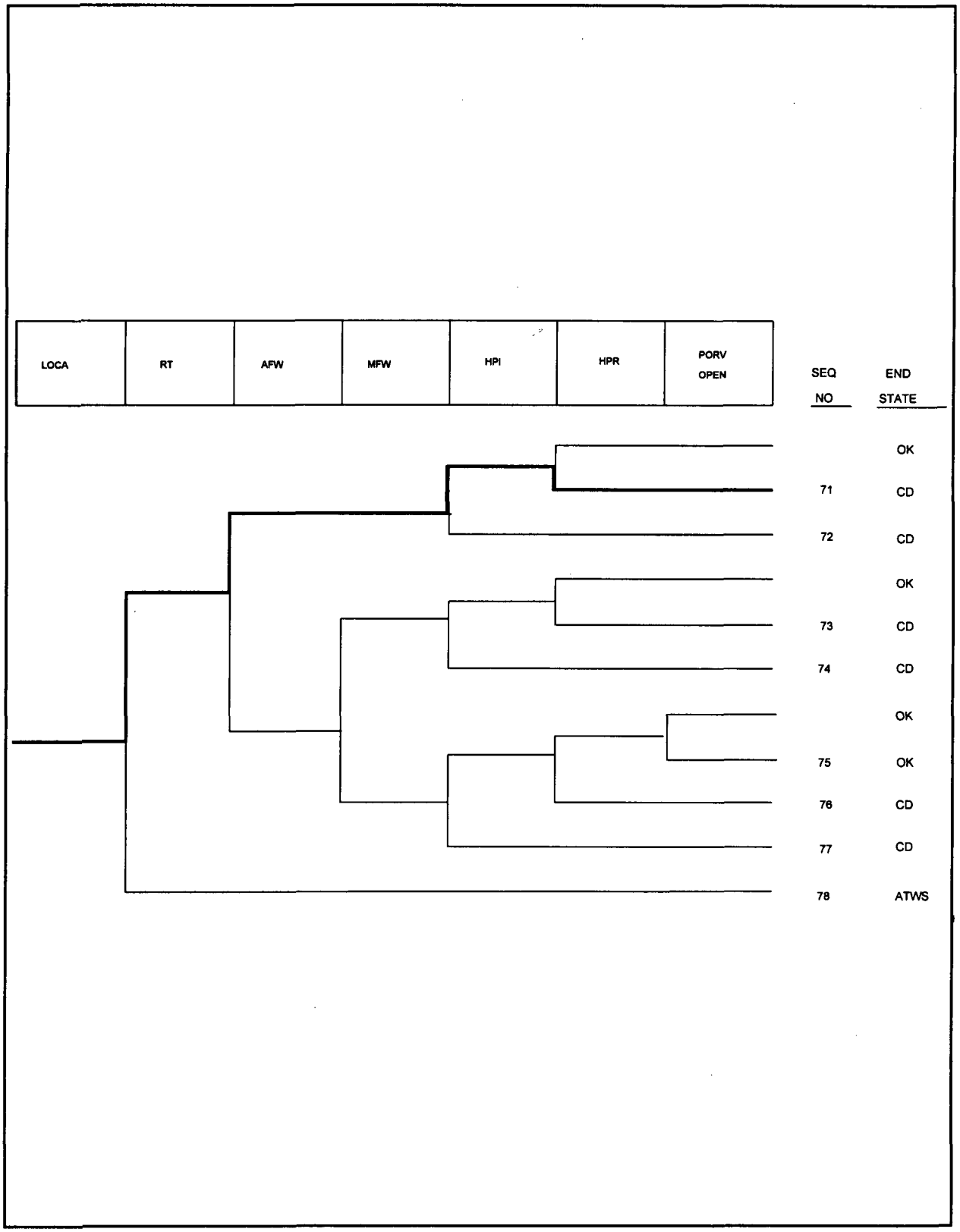

Fig. A.5.2 Dominant core damage sequence for LER 313/93-003

CONDITIONAL CORE DAMAGE PROBABILITY CALCULATIONS

Event Identifier: 313/93-003
Event Description: Both trains of recirc inoperable
Event Date: 09/30/93
Case: Case 1 - Both trains inoperable for 14 hours, A train recoverable
Plant: ANO - Unit 1

UNAVAILABILITY, DURATION= 14

NONRECOVERABLE INITIATING EVENT PROBABILITIES

LOCA	1.4E-05

SEQUENCE CONDITIONAL PROBABILITY SUMS

End State/Initiator	Probability
CD	
LOCA	4.9E-06
Total	4.9E-06
ATWS	
LOCA	0.0E+00
Total	0.0E+00

SEQUENCE CONDITIONAL PROBABILITIES (PROBABILITY ORDER)

	Sequence	End State	Prob	N Rec**
71	loca -rt -afw -hpi HPR/-HPI	CD	4.9E-06	1.5E-01

** nonrecovery credit for edited case

SEQUENCE CONDITIONAL PROBABILITIES (SEQUENCE ORDER)

	Sequence	End State	Prob	N Rec**
71	loca -rt -afw -hpi HPR/-HPI	CD	4.9E-06	1.5E-01

** 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\pwrdseal.cmp
BRANCH MODEL: s:\asp\prog\models\ano1.sl1
PROBABILITY FILE: s:\asp\prog\models\pwr_bsl1.pro

No Recovery Limit

BRANCH FREQUENCIES/PROBABILITIES

Branch	System	Nonrecov	Opr Fail
trans	1.4E-04	1.0E+00	
loop	1.6E-05	3.6E-01	
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	2.3E-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	4.0E-02	1.0E+00	
ep.rec(sl)	5.9E-01	1.0E+00	
ep.rec	1.5E-01	1.0E+00	
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+00 > 3.4E-01	1.0E-03
Branch Model: 1.0F.2+opr			
Train 1 Cond Prob:	1.0E-02 > Failed		
Train 2 Cond Prob:	1.5E-02 > Failed		

* branch model file
** forced

CONDITIONAL CORE DAMAGE PROBABILITY CALCULATIONS

Event Identifier: 313/93-003
Event Description: Both trains of recirc inoperable
Event Date: 09/30/93
Case: Case 2 - Long term inop of train B, Nominal values for A train
Plant: ANO - Unit 1

UNAVAILABILITY, DURATION= 3048

NONRECOVERABLE INITIATING EVENT PROBABILITIES

LOCA	3.1E-03

SEQUENCE CONDITIONAL PROBABILITY SUMS

End State/Initiator	Probability
CD	
LOCA	4.6E-05
Total	4.6E-05
ATWS	
LOCA	0.0E+00
Total	0.0E+00

SEQUENCE CONDITIONAL PROBABILITIES (PROBABILITY ORDER)

	Sequence	End State	Prob	N Rec**
71	loca -rt -afw -hpi HPR/-HPI	CD	4.6E-05	4.3E-01

** nonrecovery credit for edited case

SEQUENCE CONDITIONAL PROBABILITIES (SEQUENCE ORDER)

	Sequence	End State	Prob	N Rec**
71	loca -rt -afw -hpi HPR/-HPI	CD	4.6E-05	4.3E-01

** 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\pwrdseal.cmp
BRANCH MODEL: s:\asp\prog\models\ano1.sl1
PROBABILITY FILE: s:\asp\prog\models\pwr_bsl1.pro

No Recovery Limit

BRANCH FREQUENCIES/PROBABILITIES

Branch	System	Nonrecov	Opr Fail
trans	1.4E-04	1.0E+00	
loop	1.6E-05	3.6E-01	
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	2.3E-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	4.0E-02	1.0E+00	
ep.rec(sl)	5.9E-01	1.0E+00	
ep.rec	1.5E-01	1.0E+00	
hpi	3.0E-04	8.4E-01	
hpi(f/b)	3.0E-04	8.4E-01	1.0E-02
HPR/-HPI	1.5E-04 > 1.5E-02	1.0E+00	1.0E-03
Branch Model: 1.0F.2+opr			
Train 1 Cond Prob:	1.0E-02 > Failed		
Train 2 Cond Prob:	1.5E-02		

* branch model file
** forced