A.6 LER No. 316/93-007

Event Description: Reactor Trip with Degraded Auxiliary Feedwater

Date of Event: August 2, 1993

Plant: Cook 2

A.6.1 Summary

Cook 2 tripped from 70% power because of a spurious high-temperature signal from the main turbine exhaust hood. The auxiliary feedwater (AFW) control valves for the east motor-driven AFW pump throttled further than expected, requiring operator action to restore proper flow from that pump. Operator action was also required to reopen two main steam isolation valves (MSIVs) that started drifting closed following the trip. The conditional core damage probability estimated for the event is 2.4×10^{-6}. The relative significance of this event compared to other postulated events at Cook 2 is shown in Fig. A.6.1.

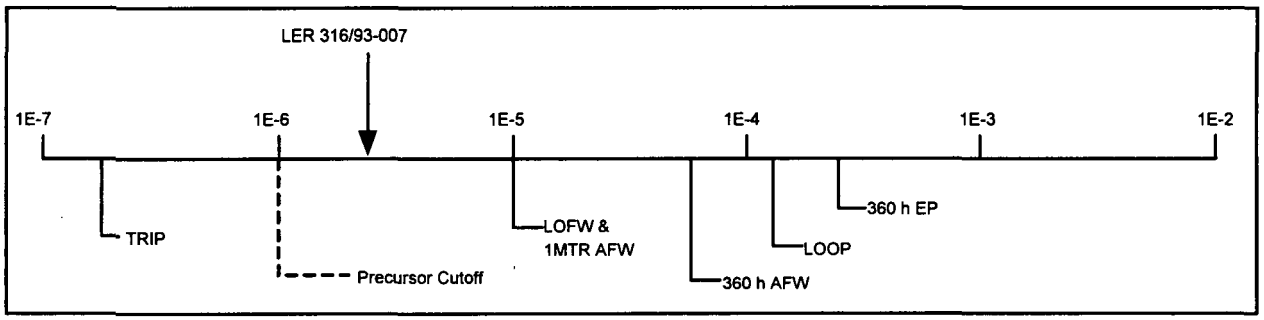

Fig. A.6.1 Relative event significance of LER 316/93-007 compared with other potential events at Cook 2

A.6.2 Event Description

On August 2, 1993, Cook 2 tripped from 70% power following a turbine trip caused by spurious actuation of the high-temperature switches on the turbine exhaust hood. Eight of the nine switch actuation set points were found to be significantly lower than the as-left condition recorded during the last calibration one year earlier.

Following the reactor trip, the AFW pumps started and provided flow to the steam generators. The feedwater control valves from the east motor-driven AFW pump throttled further than expected after receiving a flow retention signal, and operator action was required to maintain correct flow rates. AFW flow switches were subsequently recalibrated, and flow retention valve intermediate positions were reset to correct the problem.

Two MSIVs, which started to drift closed following the reactor trip, were reopened by the operators. The licensee stated that this drift was expected following a trip because of the valve actuator design.

A.6.3 Additional Event-Related Information

Cook 2 has three AFW pumps; two are motor-driven, and one is turbine-driven. The turbine-driven pump provides flow to all four SGs, and each motor-driven pump provides flow to two SGs. Flow retention valves control the flow from each pump to each SG; these valves can be controlled from the control room. A cross

connect exists that can provide flow from one motor-driven pump to the other unit. The cross-connect valves are manual and normally locked closed. The main feedwater (MFW) pumps are turbine-driven.

A.6.4 Modeling Assumptions

This event was modeled as a reactor trip with degraded AFW and MFW. To reflect the reduced flow from the east motor-driven AFW pump, one of the three AFW trains was assumed to be failed in the analysis. Consistent with other precursor analyses, the probability of not recovering the potentially failed AFW system was not revised because failures were not observed in the other two trains. The accident sequence precursor (ASP) model for MFW assumes that MFW is isolated following a trip but is potentially available in the event of a failure of AFW. If all four MSIVs had drifted closed and the operators had not promptly responded and reopened the MSIVs, steam to the MFW pump turbines would have been lost, rendering MFW unavailable. Because this recovery action could be performed in the control room and the observed MSIV response was apparently not unusual at Cook, a nonrecovery probability of 0.006 was added to the nominal MFW nonrecovery probability (0.07) to estimate the overall MFW nonrecovery used in the analysis (0.076). This probability considered the potential drift of the third and fourth MSIVs ($p = 0.3$ and 0.5, respectively) and the probability that the operators would fail to reopen the drifting-closed MSIVs ($p = 0.04$). The nonrecovery probabilities used in ASP analyses are described in Sect. A.3.2 of NUREG/CR-4674, Vol. 17, *Precursors to Potential Severe Core Damage Accidents: 1992, A Status Report.*

The potential use of the locked-closed cross-connect between both units' AFW systems was not addressed in the analysis.

A.6.5 Analysis Results

The conditional core damage probability estimated for this event is 2.4×10^{-6}. The dominant core damage sequences, highlighted on the event tree in Fig. A.6.2, involves a postulated failure of AFW and MFW following the trip and subsequent failure of feed-and-bleed cooling.

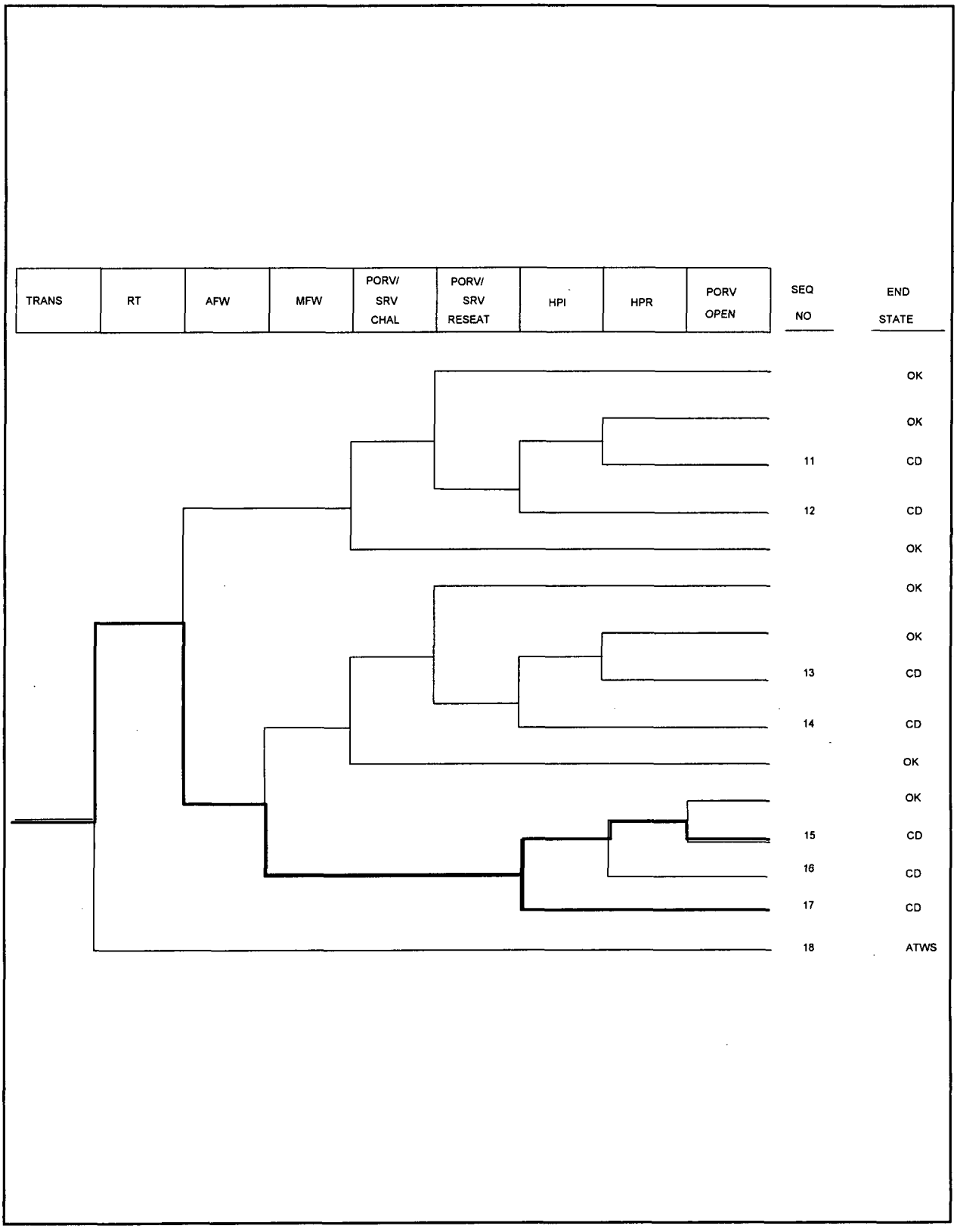

Fig. A.6.2 Dominant core damage sequence for LER 316/93-007

CONDITIONAL CORE DAMAGE PROBABILITY CALCULATIONS

Event Identifier: 316/93-007
Event Description: Reactor trip with degraded AFW
Event Date: August 2, 1993
Plant: Cook 2

INITIATING EVENT

NONRECOVERABLE INITIATING EVENT PROBABILITIES

TRANS	1.0E+00

SEQUENCE CONDITIONAL PROBABILITY SUMS

End State/Initiator	Probability
CD	
TRANS	2.4E-06
Total	2.4E-06
ATWS	
TRANS	3.4E-05
Total	3.4E-05

SEQUENCE CONDITIONAL PROBABILITIES (PROBABILITY ORDER)

	Sequence	End State	Prob	N Rec**
17	trans -rt AFW MFW hpi(f/b)	CD	1.1E-06	1.7E-02
15	trans -rt AFW MFW -hpi(f/b) -hpr/-hpi porv.open	CD	1.1E-06	2.0E-02
16	trans -rt AFW MFW -hpi(f/b) hpr/-hpi	CD	1.2E-07	2.0E-02
18	trans rt	ATWS	3.4E-05	1.2E-01

** nonrecovery credit for edited case

SEQUENCE CONDITIONAL PROBABILITIES (SEQUENCE ORDER)

	Sequence	End State	Prob	N Rec**
15	trans -rt AFW MFW -hpi(f/b) -hpr/-hpi porv.open	CD	1.1E-06	2.0E-02
16	trans -rt AFW MFW -hpi(f/b) hpr/-hpi	CD	1.2E-07	2.0E-02
17	trans -rt AFW MFW hpi(f/b)	CD	1.1E-06	1.7E-02
18	trans rt	ATWS	3.4E-05	1.2E-01

** nonrecovery credit for edited case

SEQUENCE MODEL: s:\asp\prog\models\pwrbseal.cmp
BRANCH MODEL: s:\asp\prog\models\cook.sl1
PROBABILITY FILE: s:\asp\prog\models\pwr_bsl1.pro
No Recovery Limit

BRANCH FREQUENCIES/PROBABILITIES

Branch	System	Non-Recov	Opr Fail
trans	3.4E-04	1.0E+00	
loop	1.6E-05	2.4E-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	3.8E-04 > 5.3E-03	2.6E-01	

Branch Model: 1.OF.3+ser			
Train 1 Cond Prob:	2.0E-02 > 1.0E+00		
Train 2 Cond Prob:	1.0E-01		
Train 3 Cond Prob:	5.0E-02		
Serial Component Prob:	2.8E-04		
afw/emerg.power	5.0E-02	3.4E-01	
MFW	1.0E+00 > 1.0E+00	7.0E-02 > 7.6E-02	
Branch Model: 1.OF.1			
Train 1 Cond Prob:	1.0E+00		
porv.or.srv.chall	4.0E-02	1.0E+00	
porv.or.srv.reseat	3.0E-02	1.1E-02	
porv.or.srv.reseat/emerg.power	3.0E-02	1.0E+00	
seal.loca	2.5E-01	1.0E+00	
ep.rec(sl)	6.9E-01	1.0E+00	
ep.rec	5.2E-02	1.0E+00	
hpi	1.0E-03	8.4E-01	
hpi(f/b)	1.0E-03	8.4E-01	1.0E-02
hpr/-hpi	1.5E-04	1.0E+00	1.0E-03
porv.open	1.0E-02	1.0E+00	4.0E-04

* branch model file
** forced