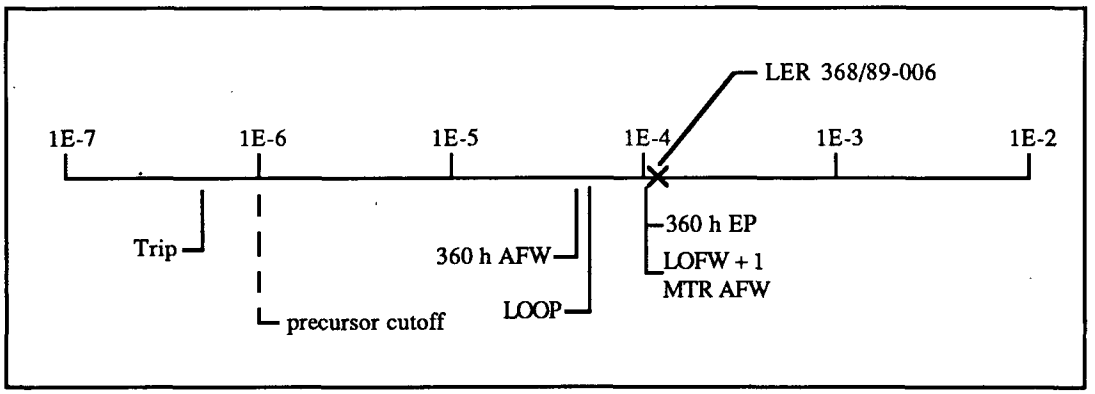
ACCIDENT SEQUENCE PRECURSOR PROGRAM EVENT ANALYSIS

LER No: 368/89-006
Event Description: High-pressure turbine extraction steam line rupture results in a reactor trip with unavailability of one train of auxiliary feedwater
Date of Event: April 18, 1989
Plant: Arkansas Nuclear One, Unit 2

Summary

One train of auxiliary feedwater was unavailable following the rupture of a high-pressure extraction steam line. The turbine-driven AFW pump tripped on overspeed because of a degraded ramp generator in the governor speed control circuit for the turbine. The conditional probability of core damage associated with this event is estimated to be 1.2×10^{-4}. The relative significance of this event compared with other potential events at Arkansas Nuclear One Unit 2 is shown below.



Event Description

On April 18, 1989, Arkansas Nuclear One, Unit 2 (ANO 2) was operating at 100% power when a 14-in. high-pressure turbine extraction steam line ruptured, resulting in a turbine generator trip followed by a reactor trip. Following the reactor trip, both trains of the auxiliary feedwater (AFW) system started, but the turbine-driven AFW pump tripped on overspeed 23 s later.

The main feedwater (MFW) pumps are automatically reduced to 5% flow following a reactor trip; however, the loop "A" MFW pump did not receive a signal to reduce flow, and as a result the "A" steam generator was overfilled slightly. Operators manually

tripped the "A" MFW pump 4 min after the reactor trip to stop the overfilling of the steam generator.

The ruptured extraction line caused a loss of condenser vacuum. Consequently, about 14 min after the reactor trip, the steam dump and bypass control system (SDBCS) sent close signals to the turbine bypass valves and open signals to the atmospheric dump valves (ADVs). One of the two ADVs downstream from the MSIVs failed to open on command from the SDBCS. Operators placed the controller for this valve in manual and again attempted to open the valve, but it still failed to open.

About 33 min after the reactor trip, the MSIVs were manually closed to ensure that the leak from the extraction steam line was isolated. The two ADVs upstream of the MSIVs were manually opened for decay heat removal. With a 20% open demand signal to one of the ADVs, the RCS temperature and steam generator pressure began to decrease abnormally. The rate of decrease indicated that the valve was full open rather than at the 20% level demanded, and a motor-operated isolation valve was used to isolate this ADV.

About 37 min after the pump tripped, operators manually reset, started, and realigned the turbine-driven AFW pump to feed the steam generators.

The cause of the extraction steam pipe rupture was erosion-corrosion of the inside diameter and was apparently due to high turbulence of steam flow in the pipe. The governor ramp generator signal converter module was replaced on the turbine-driven AFW pump. The failure of the MFW pump to reduce flow was caused by defective wiring in the reactor trip override circuitry; this wiring was replaced. The plug and stem of the downstream ADV that failed to open were replaced. No apparent cause could be determined for the upstream ADV valve to fail to close, and no corrective work was performed on this valve.

Additional Event-Related Information

The AFW system consists of two trains. Each train is capable of providing 100% of the feedwater necessary for safe shutdown. One train has a motor-driven pump, and one train has a turbine-driven pump.

The SDBCS consists of seven air-operated globe valves and associated instruments and controls. Three of these valves bypass directly to the condenser and the remaining four dump to the atmosphere. Two of the four valves that dump to the atmosphere are located upstream of the main steam isolation valves and may be used to remove reactor decay and

sensible heat in the absence of offsite power. During plant shutdown with offsite power available, one bypass valve can be remote manually positioned to reduce the reactor coolant temperature.

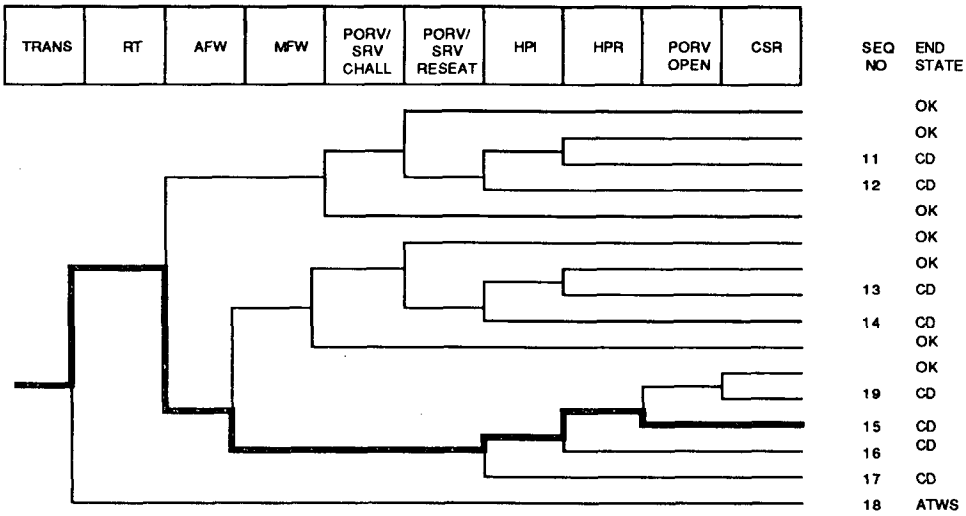
ASP Modeling Assumptions and Approach

The event has been modeled as an unavailability of one train of auxiliary feedwater followng an effective loss of feedwater.

Feed and bleed capability is provided on ANO 2 by feeding from the high-pressure injection pump and bleeding to atmosphere using a motor-operated valve (MOV) on the pressurizer that functions similarly to the power-operated function of a PORV. Only one such MOV is provided.

Analysis Results

The conditional probability of severe core damage estimated for this event is 1.2×10^{-4}. The dominant sequence leading to core damage for this event involved failure of the degraded AFW system and failure of the operator to initiate feed and bleed. This sequence is highlighted on the following event tree. Additional information is provided in LER 368/89–008.



Dominant core damage sequence for LER 368/89-006

CONDITIONAL CORE DAMAGE PROBABILITY CALCULATIONS

Event Identifier: 368/89-006
Event Description: Extraction steam line rupture and one train of AFW unavail
Event Date: 04/18/89
Plant: ANO - Unit 2

INITIATING EVENT

NON-RECOVERABLE INITIATING EVENT PROBABILITIES

TRANS	1.0E+00

SEQUENCE CONDITIONAL PROBABILITY SUMS

End State/Initiator	Probability
CD	
TRANS	1.2E-04
Total	1.2E-04
ATWS	
TRANS	3.4E-05
Total	3.4E-05

SEQUENCE CONDITIONAL PROBABILITIES (PROBABILITY ORDER)

	Sequence	End State	Prob	N Rec**
15	trans -rt AFW MFW -hpi(f/b) -hpr/-hpi porv.open	CD	5.4E-05	2.6E-01
17	trans -rt AFW MFW hpi(f/b)	CD	5.4E-05	2.2E-01
19	trans -rt AFW MFW -hpi(f/b) -hpr/-hpi -porv.open csr	CD	8.7E-06	8.8E-02
16	trans -rt AFW MFW -hpi(f/b) hpr/-hpi	CD	6.0E-06	2.6E-01
18	trans rt	ATWS	3.4E-05	1.2E-01

** non-recovery credit for edited case

SEQUENCE CONDITIONAL PROBABILITIES (SEQUENCE ORDER)

	Sequence	End State	Prob	N Rec**
19	trans -rt AFW MFW -hpi(f/b) -hpr/-hpi -porv.open csr	CD	8.7E-06	8.8E-02
15	trans -rt AFW MFW -hpi(f/b) -hpr/-hpi porv.open	CD	5.4E-05	2.6E-01
16	trans -rt AFW MFW -hpi(f/b) hpr/-hpi	CD	6.0E-06	2.6E-01
17	trans -rt AFW MFW hpi(f/b)	CD	5.4E-05	2.2E-01
18	trans rt	ATWS	3.4E-05	1.2E-01

** non-recovery credit for edited case

SEQUENCE MODEL: c:\asp\1989\pwrgseal.cmp
BRANCH MODEL: c:\asp\1989\ano2.sll
PROBABILITY FILE: c:\asp\1989\pwr_bsll.pro

No Recovery Limit

BRANCH FREQUENCIES/PROBABILITIES

Branch	System	Non-Recov	Opr Fail
trans	2.2E-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	1.3E-03 > 2.0E-02	2.6E-01	

Event Identifier: 368/89-006

Branch Model: 1.OF.2+ser			
Train 1 Cond Prob:	2.0E-02		
Train 2 Cond Prob:	5.0E-02 > Failed		
Serial Component Prob:	2.8E-04		
afw/emerg.power	5.0E-02	3.4E-01	
MFW	2.0E-01 > 1.0E+00	3.4E-01 > 1.0E+00	
Branch Model: 1.OF.1			
Train 1 Cond Prob:	2.0E-01 > Unavailable		
porv.or.srv.chall	2.0E-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	2.1E-02	1.0E+00	
hpi	3.0E-04	8.4E-01	
hpi(f/b)	3.0E-04	8.4E-01	1.0E-02
porv.open	1.0E-02	1.0E+00	4.0E-04
hpr/-hpi	1.5E-04	1.0E+00	
csr	2.0E-03	3.4E-01	

* branch model file
** forced

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