ACCIDENT SEQUENCE PRECURSOR PROGRAM EVENT ANALYSIS

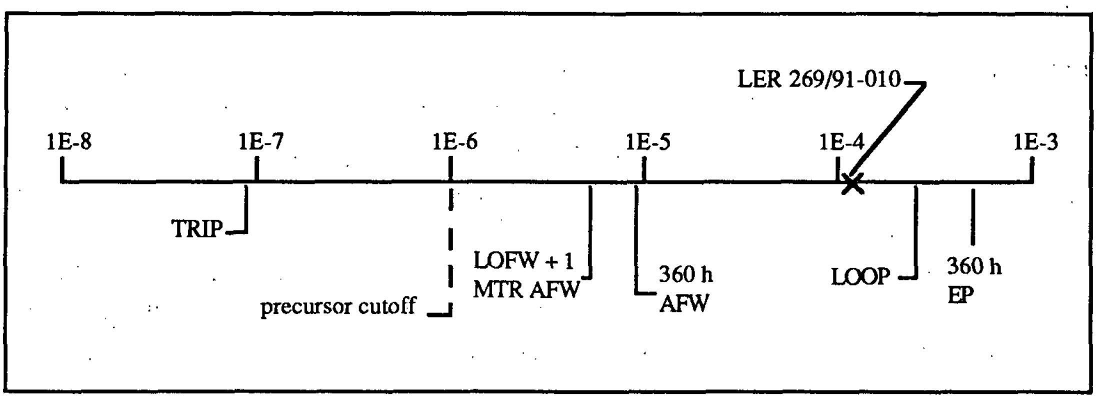
LER No.: 269/91-010, 270/91-003
Event Description: Potential for hydrogen entrainment in HPI pumps
Date of Event: September 19, 1991
Plant: Oconee 1, Oconee 2, and Oconee 3

Summary

During an analysis of the letdown storage tank (LDST) high-pressure alarm setpoint, it was determined that the potential existed for hydrogen entrainment in the high-pressure injection (HPI) pumps during small-break loss-of-coolant accident (LOCA) scenarios involving failure of either of the borated water storage tank (BWST) isolation valves to open.

LDST hydrogen overpressure is normally adjusted so that the BWST will provide flow to the HPI pumps during a safety actuation. In this situation, the higher BWST pressure seats the LDST outlet check valve and prevents hydrogen from expanding into the HPI pump suction piping. During review of a 1971 Babcock & Wilcox curve of maximum LDST pressure as a function of inventory, it was determined that the curve was based on an assumption that the LDST would be isolated within 6.5 min for certain scenarios. This action is not specified in the procedures. In addition, the single valve provided for this purpose is not safety-related nor is it provided with safety-related controls or power.

Subsequent analyses by the utility, which considered flow-related pressure drops, indicated that hydrogen entrainment would only occur if one of the BWST isolation valves failed to open. In this case, the additional pressure drop in the single operating line would allow hydrogen to expand into the HPI pump suction lines and damage the pumps. The conditional core damage probability estimated for this event is 1.2×10^{-4}. The relative significance of the event compared to other postulated events at Oconee 1 is shown below.



Event Description

On April 16, 1991, with Oconee 2 at full power, hydrogen was being added to the LDST. At the completion of this operation, a non-licensed operator observed that the hydrogen supply had not been isolated when the fill-line solenoid valve was closed. After manual isolation, the LDST pressure exceeded procedural limitations, and the excess pressure was vented. Both trains of HPI were declared inoperable for the duration of the overpressurization (~20 min) due to the potential for hydrogen to enter the HPI pump suctions following a LOCA and damage the pumps.

During a review of that event, it was observed that the setpoint for the control room alarm for high LDST pressure exceeded the highest procedurally specified LDST pressure, and a setpoint change was requested.

The setpoint review utilized a draft 1990 limit and precautions document, which included a copy of a 1971 curve developed by Babcock & Wilcox that specified the maximum LDST pressure as a function of BWST level. The curve was based on calculations that, for certain scenarios, assume the operator will isolate the LDST within 6.5 min by closing HP-23, the LDST outlet header isolation valve. HP-23 is not safety-related and does not have safety-related controls or power. Also, Oconee operating procedures did not require HP-23 to be closed.

The 1971 curve was based on calculations that addressed static head differences, but did not consider pressure drops due to flow. Calculations performed by the utility after this problem was discovered, which addressed flow-induced pressure drops, indicated the existing LDST hydrogen pressure curve was adequate for most scenarios without closure of HP-23.

The one exception was a small-break LOCA during which one of the two BWST isolation valves fails to open. In this case, all HPI injection flow would pass through one suction supply line, which would lead to higher pressure losses and lower pressure in the suction supply header, and would result in hydrogen entrainment from the LDST and HPI pump damage.

This problem applied to all three Oconee units. As a short-term corrective action, new pressure curves were developed that provided additional margin to assure hydrogen from the LDST would not expand into the HPI pump suction piping for all scenarios that do not involve a single failure of a valve in the lines from the BWST. In addition, new instructions were provided to the operators to align the HPI system for piggy-back operation (HPI pump suction flow provided by low-pressure injection pumps) if a single failure of a BWST line valve occurred. Use of the piggy-back mode would provide additional suction pressure at the HPI pumps and prevent hydrogen entrainment (provided a failed suction valve could be detected).

Additional Event-Related Information

The HPI system controls the reactor coolant system (RCS) inventory, provides seal water for the reactor coolant pumps, and recirculates RCS letdown for water quality maintenance and reactor coolant boric acid concentration control. The HPI system uses the LDST as a surge tank and normal suction source for the HPI pumps. During operation, a hydrogen atmosphere is maintained in the LDST to promote oxygen scavenging. Guidance for establishing and maintaining this hydrogen pressure is given in OP/1, 2, 3/A/1104/02, "High Pressure Injection System," which includes a graph of permissible hydrogen pressure versus LDST level.

The HPI system also serves to mitigate the consequences of a small-break LOCA. The HPI system, during emergency operation, supplies borated water to the RCS from the BWST. The HPI system has three parallel HPI pumps that take suction from the BWST and to discharge through two redundant flow paths into the RCS.

The suction lines from the LDST to the HPI pumps are normally isolated from the BWST supply lines by check valves (HP-101 and HP-102) and motor-operated valves (HP-24 and HP-25). In the event of a safety actuation, the motor-operated valves open, and the pressure due to elevation head in the BWST will overcome the pressure due to LDST level and hydrogen pressure, opening check valves HP-101 and HP-102, closing the LDST outlet header check valve (HP-97), and providing flow from the BWST to the HPI pumps. As BWST level drops, the available pressure from the LDST could exceed the available pressure from the BWST, allowing flow from the LDST as a check valve opens. The hydrogen gas in the LDST could then expand and fill the suction piping, resulting in damage to the HPI pumps. The procedural operating limit curve for LDST hydrogen pressure and volume is intended to assure that LDST pressure does not exceed available BWST pressure, even as BWST level is drawn down during a LOCA.

ASP Modeling Assumptions and Approach

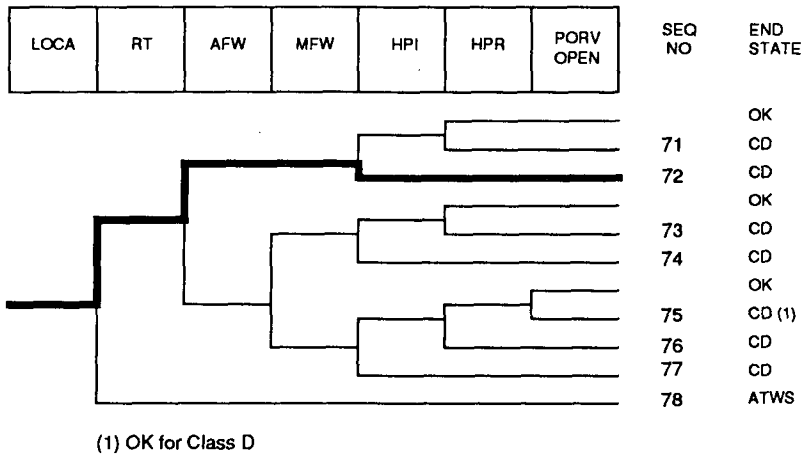
The event has been modeled as an unavailability of HPI and feed and bleed period for situations in which either of the two BWST-to-HPI-pump suction valves (HP-24 or HP-25) fail to open. The probability of HP-24 or HP-25 failing to open was assumed to be 0.02, based on the probability values typically used in ASP calculations.

The potential for hydrogen entrainment existed since initial criticality. To estimate the relative significance of the event within a 1-yr observation period (the interval between precursor reports), a 1-yr unavailability period was utilized in the analysis (6132 h, assuming the plant was critical or at hot shutdown 70% of the time).

Analysis Results

The conditional core damage probability for this event is estimated to be 1.2×10^{-4}. The dominant core damage sequence, highlighted on the following event tree, involves a postulated LOCA with failure of HPI.

If it is assumed that HPI would be failed for all small-break LOCA scenarios, independent of the status of the BWST valves, a conditional probability of 6.3×10^{-3} is estimated. This would be the case if flow-related pressure drops did not have the effect indicated in the utility analysis. Such an event would be considered very significant.



Dominant core damage sequence for LER 269/91-010

CONDITIONAL CORE DAMAGE PROBABILITY CALCULATIONS

Event Identifier: 269/91-010
Event Description: Potential for hydrogen entrainment in HPI pumps after a LOCA
Event Date: 09/19/91
Plant: Oconee 1

UNAVAILABILITY, DURATION= 6132

NON-RECOVERABLE INITIATING EVENT PROBABILITIES

TRANS	3.9E-01
LOOP	2.3E-02
LOCA	6.3E-03

SEQUENCE CONDITIONAL PROBABILITY SUMS

End State/Initiator	Probability
CD	
TRANS	9.9E-08
LOOP	4.6E-08
LOCA	1.2E-04
Total	1.2E-04
ATWS	
TRANS	0.0E+00
LOOP	0.0E+00
LOCA	0.0E+00
Total	0.0E+00

SEQUENCE CONDITIONAL PROBABILITIES (PROBABILITY ORDER)

	Sequence	End State	Prob	N Rec**
72	loca -rt -afw HPI	CD	1.2E-04	4.3E-01

** non-recovery credit for edited case

SEQUENCE CONDITIONAL PROBABILITIES (SEQUENCE ORDER)

	Sequence	End State	Prob	N Rec**
72	loca -rt -afw HPI	CD	1.2E-04	4.3E-01

** non-recovery 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: c:\asp\1989\pwrdseal.cmp
BRANCH MODEL: c:\asp\1989\oconee1.sl1
PROBABILITY FILE: c:\asp\1989\pwr_bsl1.pro

No Recovery Limit

Event Identifier: 269/91-010

BRANCH FREQUENCIES/PROBABILITIES

Branch	System	Non-Recov	Opr Fail
trans	6.4E-05	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	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	0.0E+00	1.0E+00	
ep.rec(sl)	0.0E+00	1.0E+00	
ep.rec	4.5E-01	1.0E+00	
HPI	3.0E-04 > 2.0E-02 **	8.4E-01 > 1.0E+00	
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		
HPI(F/B)	3.0E-04 > 2.0E-02 **	8.4E-01 > 1.0E+00	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		
hpr/-hpi	1.5E-04	1.0E+00	1.0E-03

* branch model file
** forced

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Event Identifier: 269/91-010