Final Precursor Analysis

Accident Sequence Precursor Program --- Office of Nuclear Regulatory Research

Dresden Unit 3	Inoperable High Pressure Coolant Injection System After Water Hammer Event	
Event Date: 07/05/2001	**LER:** 249/02-005-01	**ΔCDP =** 3×10^{-6}

Condition Summary

Description. On July 5, 2001, a water hammer event had occurred during an automatic initiation of the Unit 3 High Pressure Coolant injection (HPCI) system. On July 19, 2001, DNPS personnel identified a HPCI discharge piping support in a degraded condition. An operability determination by DNPS was performed, which supported continued HPCI operability. Due to perceived low safety significance, the damaged support for the HPCI system was not immediately repaired by DNPS. The support was finally repaired, and the HPCI discharge piping was adequately vented on September 30, 2001, for return of HPCI to operability (Reference 1).

On November 16, 2001, the USNRC issued an Inspection Report (IR) which identified an Unresolved Item associated with the operability of the HPCI system with degraded pipe supports (Reference 2). In response to the IR, DNPS performed additional evaluations. Subsequently, DNPS was unable to demonstrate through analysis that the HPCI piping and supports would have met operating evaluation acceptance criteria following an additional automatic initiation. On October 4, 2002, DNPS concluded that the HPCI system was inoperable for the period following the water hammer event.

On June 23, 2003, Office of Enforcement issued a final significance determination letter to the licensee (Reference 3).

Cause. DNPS determined two root causes: 1. HPCI piping support failure due to water hammer event (which was due to inadequate venting of accumulated steam and air in the HPCI discharge piping system), and 2. failure of DNPS management to recognize and address the extent of the degraded pipe support conditions in a timely manner after the water hammer event on July 5, 2001. These two causes collectively resulted in failure to promptly implement corrective actions (immediately after July 19, 2001).

Condition duration. The operating condition involving inoperable HPCI system existed for a total of 87 days (2088 hours), covering the period 7/5/2001 thru 9/30/2001.

Recovery opportunity. After July 5, 2001, the HPCI system would have started on automatic initiation signals. However, the HPCI pump would have tripped since the system piping supports were sufficiently damaged to fail with system operating pressure. The operators would not have been able to restore the HPCI system due to damaged piping supports. Therefore, a non-recoverable failure probability of one is applied for the HPCI system failure probability to run.

Other related conditions or events during the condition period. No other overlapping condition was identified during the 87-day condition period.

Analysis Results

- **Importance**[1]

  The risk significance of inoperable HPCI system after water hammer event for a condition duration of 2088 hours was determined by subtracting the nominal core damage probability (point estimate) from the conditional core damage probability (point estimate):

Conditional core damage probability (CCDP) =	4E-6
Nominal core damage probability (CDP) =	1E-6
Importance (ΔCDP = CCDP - CDP) =	3E-6

  The estimated importance (CCDP-CDP) for the operating condition was 3E-6.

  A uncertainty analysis was conducted for the operating condition. The mean estimates for CCDP, CDP, and importance were 4.3E-6, 1.2E-6, and 3.1E-6 respectively.

- **Dominant sequence**

  A transient involving successful reactor scram, unavailable power conversion system, one safety relief valve (SRV) failing to close after lifting, failure of feed water injection, inoperable HPCI system due to water hammer event, and operator failing to depressurize the reactor in a timely manner. Sequence TRAN 56-31; Importance = 1.6 E-6. The events and important component failures in this sequence are as follows:

  - Transient- initiating event
  - Successful reactor scram
  - unavailable power conversion
  - one SRV fails to close after lifting due to vessel over pressurization
  - failure of Feed Water Injection
  - Inoperable HPCI system due to water hammer event with no recovery
  - operators fail to depressurize the reactor in a timely manner.
  - Onset of potential core damage

  Paths for dominant sequence TRAN 56-31 is shown in Figures 1A and 1B.

- **Results tables**

  – Table 1 provides the conditional probabilities for the dominant sequences.

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[1] Since this condition did not involve an actual initiating event, the parameter of interest is the measure of the incremental change between the conditional probability for the period in which the condition existed and the nominal probability for the same period but with the condition nonexistent and plant equipment available. This incremental change or "importance" is determined by subtracting the CDP from the CCDP. This measure is used to assess the risk significance of hardware unavailabilities especially for those operating conditions where the nominal CDP is high with respect to the incremental change of the conditional probability caused by the hardware unavailability.

- Table 2a provides the event tree sequence logic for the dominant sequences listed in Table 1.
- Table 2b provides the definitions of fault trees used in event tree logic listed in Table 2a.
- Table 3 provides the conditional (CCDP) cut sets for the dominant sequences.
- Table 4 provides the definitions and probabilities for added basic events and condition-affected basis events, and frequencies for initiating events.

Modeling Assumptions

- **Assessment summary**

  - ***Assessment type.*** A water hammer event in the discharge piping of the HPCI system occurred on 7/5/2001. After the event, the licensee inspected the piping and its support system (bolts and attachments) for structural and functional integrity and found that the piping supports were slightly damaged due to a water hammer event. For example, a portion of the discharge piping was hanging with some observed deflection due to loosened pipe supports. The licensee judged that the plant could be operated safely after the event. However, the plant was operated with potentially inoperable HPCI system. On 9/30/2001, inspection of the water hammer event by the USNRC inspection staff evaluated that the licensee was unable to demonstrate through standard and acceptable analysis that the degraded piping system and supports would have met operating evaluation acceptance criteria following an automatic engineered safety feature (ESF) actuation of the HPCI system. Both the licensee and the staff agreed and concluded that plant was operated with the inoperable HPCI system due to the water hammer event from 7/5/2001 thru 9/30/2001 (a total of 87 days).

    Therefore, the operating condition after the water hammer event on 7/5/2001 was assessed using a condition assessment for a plant condition in which the plant was operated with an inoperable HPCI system for a period of 87 days (2088 hours).

    During the 87 days, the HPCI pump would have started on ESF actuation demand. But, the pump would have tripped. Operators might not have been able to recover locally the tripped pump. Inoperability of the HPCI pump was set to unit probability by setting the ‘fail-run’ and ‘fail-to-recover run failures’ basic events to TRUE.

  - ***Model use.*** The Revision 3i Standardized Plant Analysis Risk (SPAR) model for Dresden Unit 2 & 3 (Reference 4) was used for this condition assessment.

    The Revision 3i SPAR model includes event trees for transients, loss of offsite power, small loss-of-coolant accident, loss of a support system (e.g., service water, a DC bus, instrument air), and other LOCA events (medium LOCA, large LOCA, interfacing system LOCAs). The Revision 3i SPAR plant model for Dresden includes fault tree models for many frontline systems (e.g., the HPCI system) and support systems modeled in the event trees, including the suppression pool cooling function.

- **Basic event probability changes**

Table 4 provides the basic events that were modeled and modified to reflect the operating condition being analyzed. Revision 3i SPAR plant model (Reference 4) modeled start-failures and run-failures of the HPCI system which would be affected by the operating condition. Since the HPCI pump would trip after the start and would not be recovered during the water hammer event, the fails-to-run event and operator fails-to-recover failure-to-run event of the HPCI system were set to TRUE in the condition assessment (current case). The basic events that were modified are:

- HCI-TDP-FR-TRAIN (HPCI pump train fails to run)
- HCI-XHE-XL-RUN (operator fails to recover HPCI failure to run)

- **Uncertainty analysis and range for total importance due to operating condition**

The parameter estimates and the uncertainties regarding the numerical estimates of the parameters used in the model (parameter uncertainty) are calculated. These data and uncertainty distributions are then propagated through the modified version of the Revision 3i SPAR model for DNPS (Reference 4) to produce statistical uncertainty estimates.

Uncertainty analysis of the operating condition along with parameters was performed using the SAPHIRE code (Version 6.75). Default distribution types for applicable initiating events (e.g. loss of offsite power, transients) and basic events for components were documented in the Revision 3i SPAR model for DNPS. These uncertainty estimates and uncertainty estimates for condition-affected basic events were used in estimating mean condition-CDP values and mean condition-CCDP values. Other statistical values such as point estimates, median estimates, 5% estimates, and 95% estimates were also calculated for CDP and CCDP analysis cases.
Uncertainty values of 5%, 95%, mean estimates for condition-importance were estimated based on uncertainty values of 5%, 95%, mean estimates for condition-CCDPs and condition-CDPs.

References

1. Excelon Nuclear, "LER 249-2002-005-01, High Pressure Coolant Injection System Inoperable Due to Water Hammer Event" dated February 14, 2003. (ADAMS Accession Number ML030590240)

2. USNRC, Region III, "Dresden Nuclear Power Station Units 2 and 3 - NRC Inspection Report 50-249/01-21 (DRS)" dated November 16, 2001. (ADAMS Accession Number ML013200525)

3. USNRC Office of Enforcement, "Notice of Violation and Proposed Imposition of Civil Penalty - $60,000, and Final Significance Determination for a White Finding [NRC Inspection Report No. 50-237/01-21(DRS); 50-249/01-21(DRS)] [NRC Office of Investigations Report No. 3-2001-054] - EA-02-264" dated June 23, 2003. (ADAMS Accession Number ML031740755)

4. John A. Schroeder, "Revision 3i Standardized Plant Analysis Risk (SPAR) Model for Dresden Units 2 & 3 (ASP BWR C)" by Idaho National Engineering and Environmental Laboratory, January 2002.

Table 1. Conditional probabilities (point values) for the dominant sequences

Event tree name	Sequence no.	Conditional core damage probability (CCDP)	Core damage probability (CDP)	Importance (CCDP - CDP)[2]
TRAN	56-31	1.7E-6	1.1E-7	1.6E-6
LOOP	40-27	1.0E-6	6.9E-8	9.8E-7
Total (all sequences)[1]		**4.1E-6**	**1.1E-6**	**3.0E-6**

Notes:
1. Total CCDP and CDP includes all sequences (including those not shown in this table).
2. Importance is calculated using the total CCDP and total CDP from all sequences of all applicable event trees. Sequence level importance measures are not additive.

Table 2a. Event tree sequence logic for dominant sequences

Event tree name	Sequence No.	Logic ("/" denotes success; see Table 2b for top event names)
TRAN	56-31	(IE-TRANS)*(/RPS)*(PCS)*(P1)*(MFW)*(HC1)*(DE2)
LOOP	40-27	(IE-LOOP)*(/RPS)*/(EPS)*(P1)*(HC1)*(DE2)

Table 2b. Definitions of fault trees used in event tree logic listed in Table 2a

IE-TRANS	Transients
IE-LOOP	Loss of Offsite Power
RPS	Reactor Shutdown Fails
HC1	High Pressure Coolant Injection Fails to Provide Sufficient Flow to Reactor Vessel
EPS	Emergency Power Is Unavailable
PCS	Power Conversion System Is Unavailable
P1	One SRV Fails to Close
MFW	Feed Water Injection Is Unavailable
DE2	Manual Depressurization (1 Stuck Open Relief Valve) Fault

Table 3a. CCDP cut sets for TRAN Sequence 56-31

CCDP	Percent contribution	Minimal cut sets[1]
Event Tree: TRAN, Sequence 56-31		
6.2E-7	37.9	PPR-SRV-OO-1VLV * CDS-SCRAM-NOCDS * ADS-XHE-XM-MDEP1
5.6E-7	34.2	ADS-SRV-CF-VALV1 *PPR-SRV-OO-1VLV * CDS-SCRAM-NOCDS
1.6E-6	Total[2]	

Notes
1. See Table 4 for definitions and probabilities for the basic events.
2. Total CCDP includes all cut sets (including those not shown in this table).

Table 3b. CCDP cut sets for LOOP Sequence 40-27

CCDP	Percent contribution	Minimal cut sets[1]
Event Tree: LOOP, Sequence 40-27		
5.4E-7	52.3	PPR-SRV-OO-1VLV * ADS-XHE-XM-MDEP1
5.0E-7	47.2	ADS-SRV-CF-VALV1 * PPR-SRV-OO-1VLV
9.8E-7	Total[2]	

Notes
1. See Table 4 for definitions and probabilities for the basic events.
2. Total CCDP includes all cut sets (including those not shown in this table).

Table 4. Definitions and probabilities for modified or dominant basic events.

Event name	Description	Probability/ Frequency	Modified
PPR-SRV-OO-1VLV	One SRV fails to close	8.8E-2	No
ADS-XHE-XM-MDEP1	Operator fails to depressurize the reactor	1.0E-3	No
CDS-SCRAM-NOCDS	Reactor trip occurs with a loss of condensate	3.4E-2	No
ADS-SRV-CF-VALV1	ADS valves fail from common cause	9.0E-4	No
HCI-TDP-FR-TRAIN	HPCI pump train fails to run	TRUE	Yes[1]
HCI-XHE-XL-RUN	Operator fails to recover HPCI failure to run	TRUE	Yes[1]

Notes
1. Basic event changed to reflect event being analyzed. See text.

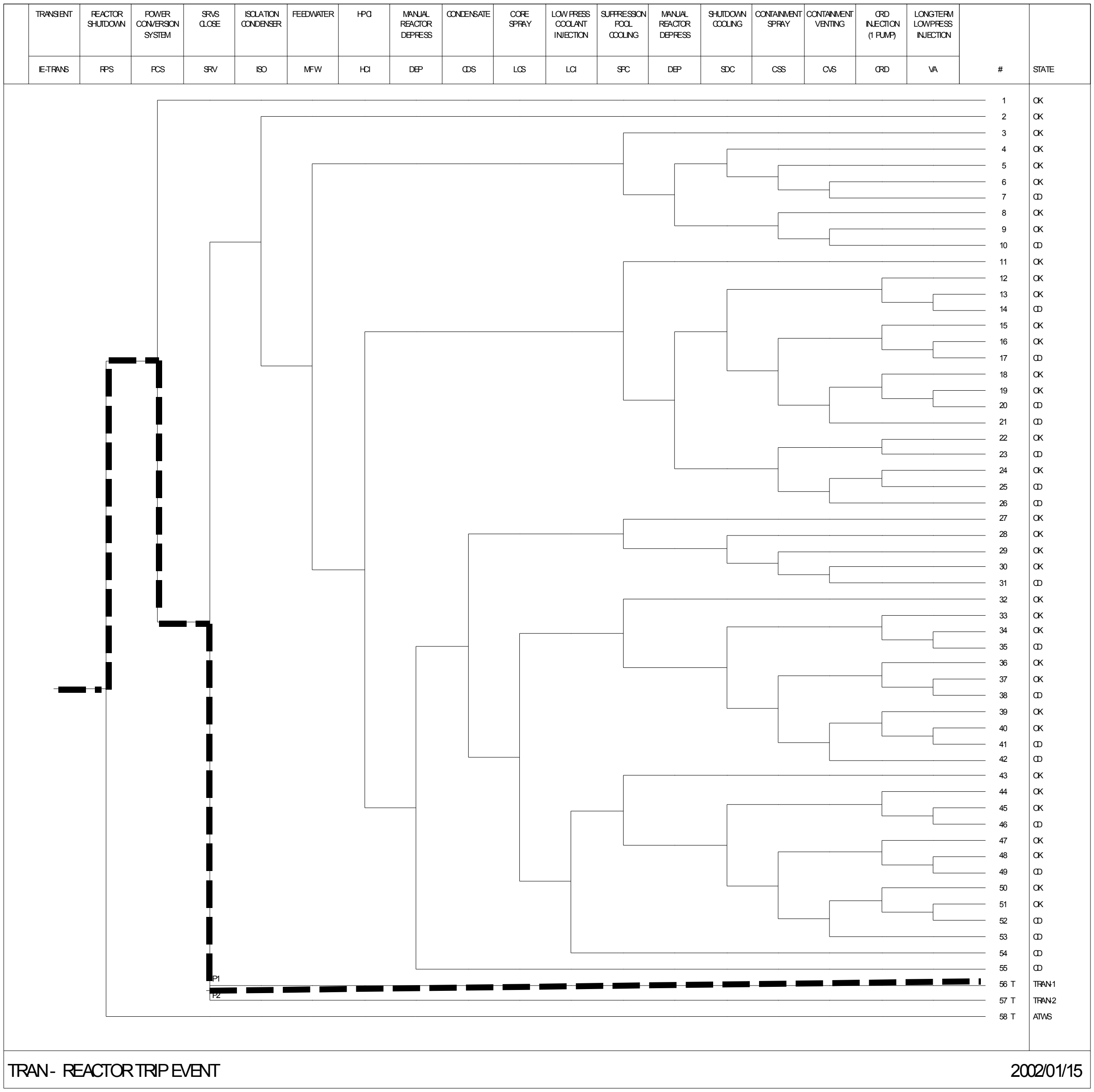

Figure 1A. Transient Event Tree (showing Sequence 56-31)

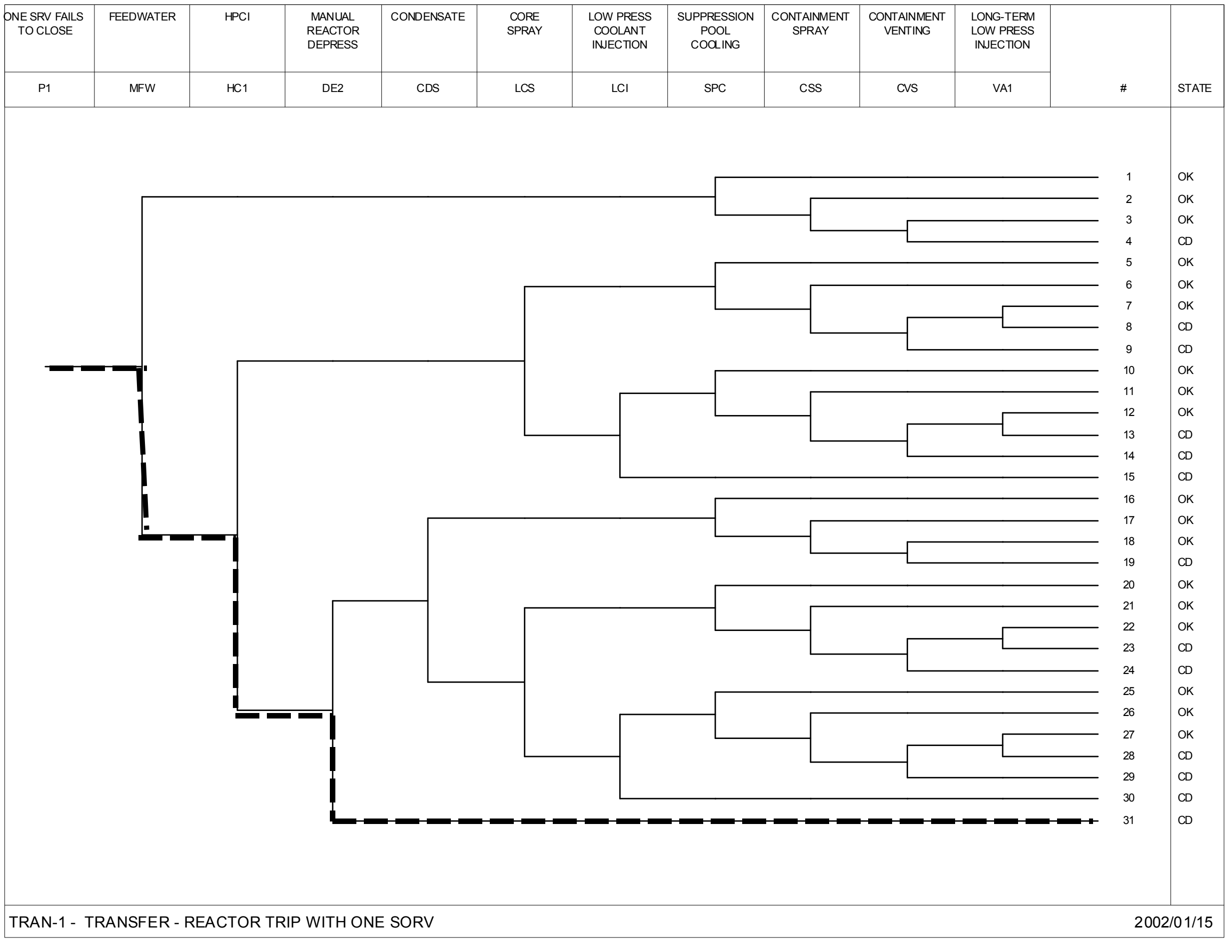

Figure 1B. Transient Event Tree showing Sequence 56-31 (Continued)