C.4 LER No. 237/94-021

Event Description: Long-Term Unavailability of High Pressure Coolant Injection

Date of Event: August 4, 1994

Plant: Dresden Unit 2

C.4.1 Summary

On August 4, 1994, at 1559 hours, with the plant at 99% power, the high pressure coolant injection (HPCI) turbine tripped due to high exhaust pressure during a monthly surveillance test. The cause of the high exhaust pressure was determined to be a failed check valve (No. 2-2301-74). The failure mechanism indicated that, since the last monthly surveillance test, the HPCI turbine would have tripped shortly after starting if the HPCI system had been needed to perform its safety function. The conditional core damage probability estimated for this event is 3.1×10^{-6}.

C.4.2 Event Description

On August 4, 1994, at 1559 hours, with the plant at 99% power, the HPCI turbine failed the monthly surveillance test. Prior to the automatic trip, the turbine was run up to 2500 rpm and manually tripped per the surveillance after running for approximately 5 min. The turbine was restarted and automatically tripped after 1 min due to high exhaust pressure (100 psig). An inspection of the turbine drain system was performed, and the rupture diaphragm was replaced. On August 7, 1994, the HPCI turbine was retested. When the turbine was started, the exhaust pressure increased at a higher than normal rate, and the turbine was manually tripped at an exhaust pressure of 30 psig to avoid an automatic trip. At this point, the turbine exhaust check valves were examined. A local leak rate test of the check valve volume was performed, and leakage that exceeded the technical specification limit was found. Since the HPCI exhaust line check valves could not be repaired on line, the reactor was shut down on August 8, 1994.

The two HPCI turbine exhaust valves (2-2301-45 and 2-2301-74) were disassembled and inspected (see Figure C.4.1). The valve seats for 2-2301-45 were found to be slightly worn due to normal valve operation. This condition did not affect the operation of the HPCI system. When valve 2-2301-74 was disassembled and inspected, the valve disk was not attached to the valve guide piston. Further inspection revealed that the four tack welds, which prevent the assembly from rotating, had broken recently due to fatigue. Exhaust pressure observed on previous tests was determined to have been normal, supporting the assumption that the tack welds failed during the most recent test run. Once the tack welds were broken and the valve disc was off the closed seat, the steam flow was able to rapidly rotate the valve disc on the valve stem, causing the valve to close by elongating the stem and valve disc assembly. This, in turn, caused the exhaust pressure to increase as observed in the last two tests.

C.4.3 Additional Event-Related Information

The HPCI system is designed to pump water into the reactor vessel under loss-of-coolant accident (LOCA) conditions that do not result in rapid depressurization of the reactor pressure vessel (RPV). The HPCI system is designed to pump 5600 gpm within an RPV pressure range of about 165 to 1135 psia. The size of the system is selected to provide sufficient core cooling to prevent clad melting until the RPV pressure decreases to the point where the core spray system and/or the low-pressure coolant injection (LPCI) subsystem become effective.

For medium-break LOCAs, RPV pressure decays away too slowly for the low-pressure injection pumps to inject and prevent core damage without operator action to depressurize. Therefore, following HPCI failure, the automatic depressurization system (ADS) is required to depressurize the RPV so that core spray and/or the LPCI subsystem become effective.

C.4.4 Modeling Assumptions

The event was modeled as a long-term nonrecoverable unavailability of HPCI. Once the tack welds broke, the exhaust check valve elongated itself closed in a matter of minutes (approximately 6 min during the failed surveillance). At this point, the exhaust pressure would increase to the turbine trip set point (unless the pump was manually tripped). It was assumed that any safety demand for the HPCI turbine, subsequent to the last successful monthly surveillance, would have resulted in several minutes of high pressure injection followed by a HPCI turbine trip. Therefore, the HPCI train was modeled as failed (HCI-TDP-FC-TRAIN set to TRUE). The difficulty encountered in identifying the root cause of the pump failure indicates that the failure would not have been recovered during an actual demand. Therefore, the failure was modeled as nonrecoverable (HCI-XHE-XE-NOREC set to TRUE). The HPCI system was considered unavailable for one surveillance period (i.e., 720 h) prior to the failed surveillance. The system was also unavailable for an additional 107 h following the failed surveillance prior to the unit shutdown. As a result, a total failure period of 827 h was modeled.

The run time involved in a successful surveillance of the HPCI turbine is less than the subsequent mission time that would be required in certain accident scenarios. If the running vibration of the turbine is considered to be a significant contributor to the tack weld failure mechanism, then previous tests could be viewed as consuming the remaining run time available prior to the tack weld failure. Under this scenario, the failure period could include several previous successful surveillances. If this were the case, the 827-h unavailability period would be increased to encompass these additional surveillance periods. However, this time period is difficult to estimate with the information available. Therefore, the 827-h failure period modeled was utilized, although this may be nonconservative.

A loss of the HPCI turbine leaves the plant more susceptible to core damage from a medium-break LOCA; therefore, a medium-break LOCA event tree was added to the model that is consistent with the event tree in the Dresden individual plant examination (IPE). The existing fault trees that are used in conjunction with the other event trees for Dresden were applied to the medium-break LOCA event tree. The medium-break LOCA initiating event frequency was modified to 8×10^{-4}/year, consistent with the value used in the Dresden IPE (Table 1.5.1-1). This was converted to a per hour frequency of 1.3×10^{-7} by dividing the 8×10^{-4}/year value by 6132 h, assuming a 70% plant availability [(365 days/year) (24 h/day) (0.7 unit availability)].

Two different values were used for the operator error prevents depressurization probability under different conditions.For medium-break LOCAs and transient-induced medium-break LOCAs (sequences 39 and 38–39), a probability of 0.01 was used. For conditions where a medium-break LOCA were not present, a value of 0.001 was used. These values were derived from a review of the individual plant examinations (IPEs) for a number of BWRs.

C.4.5 Analysis Results

The conditional core damage probability estimated for this event is 3.1×10^{-6}. The dominant sequence highlighted on the event tree in Figure C.4.2 involves a postulated medium-break LOCA, failure of HPCI, and failure of ADS.

For BWRs with isolation condensers (ICs) loss of HPCI under a medium-break LOCA (or transient-induced medium-break LOCA) requires the use of the ADS system to depressurize to allow injection of low-pressure systems. Medium-break LOCAs are defined as those that do not depressurize the system fast enough to allow low-pressure systems to be effective on their own. However, core damage will be minimal if depressurization fails because the break will eventually cause sufficient depressurization to allow low-pressure systems to inject. If HPCI works for a short period of time prior to failure, this will accelerate the depressurization such that ADS may not be required. The two medium-break LOCA sequences (39 and 38–39) contribute 63% of the overall conditional core damage probability for this event.

Definitions and probabilities for basic events are shown in Table C.4.1. The conditional probabilities associated with the highest probability sequences are shown in Table C.4.2. Table C.4.3 lists the sequence logic associated with the sequences listed in Table C.4.2. Table C.4.4 describes the system names associated with the dominant sequences. Cutsets associated with each sequence are shown in Table C.4.5.

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Figure C.4.1.Dresden 2 HPCI turbine exhaust check valve.

C.4.6 Reference

1. LER 237/94-021, "HPCI Turbine Tripped on High Exhaust Pressure Due to a Failed Exhaust Check Valve," September 2, 1994.

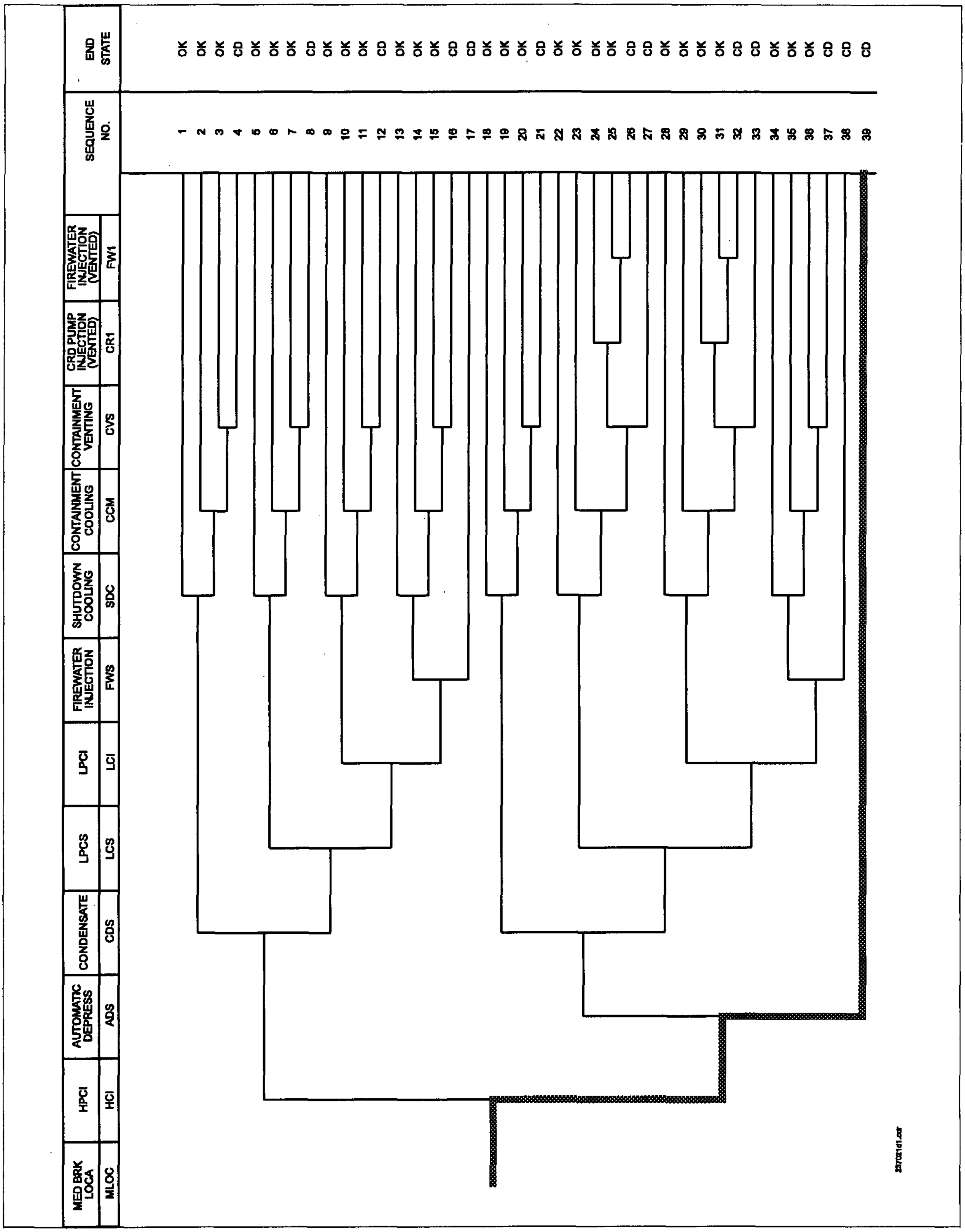

Figure C.4.2. Dominant core damage sequence for LER 237/94-021.

Table C.4.1. Definitions and probabilities for selected basic events for LER 237/94-021

Event name	Description	Base probability	Current probability	Type	Modified for this event
ADS-SRV-CC-VALVS	ADS Valves Fail to Open	3.7E-003	3.7E-003		N
ADS-XHE-XE-ERROR	Operator Error Prevents Depressurization	1.0E-002	1.0E-002*		N
ADS-XHE-XE-NOREC	Operator Fails to Recover ADS	7.1E-001	7.1E-001		N
CRD-MDP-FC-TRNA	Train A Failure	3.7E-003	3.7E-003		N
CRD-MDP-FC-TRNB	Train B Failure	3.7E-003	3.7E-003		N
CRD-XHE-XE-ERROR	Operator Fails to Align CRD	1.0E-002	1.0E-002		N
CRD-XHE-XE-NOREC	Operator Fails to Recover CRD	1.0E+000	1.0E+000		N
EPS-DGN-CF-DGNS	Common Cause Failure of Diesel Generators	1.4E-003	1.4E-003		N
EPS-DGN-FC-DG2	Unit 2 Generator Fails	7.8E-002	7.8E-002		N
EPS-DGN-FC-DG23	Swing Diesel Generator Fails	7.8E-002	7.8E-002		N
EPS-DGN-FC-DG3	Unit 3 Diesel Generator Failure	7.8E-002	7.8E-002		N
EPS-XHE-XE-NOREC	Operator Fails to Recover Emergency Power	8.0E-001	8.0E-001		N
HCI-TDP-FC-TRAIN	HPCI Train Level Failures	3.9E-002	1.0E+000	TRUE	Y
HCI-XHE-XE-NOREC	Operator Fails to Recover HPCI	7.1E-001	1.0E+000	TRUE	Y
IE-LOOP	Loss-of-Offsite Power Initiator	5.9E-006	4.9E-003		Y
IE-SLOCA	Small LOCA Initiator	1.7E-006	1.4E-003		Y
IE-TRAN	Transient Initiator	3.4E-004	2.8E-001		Y
IE-MLOCA	Medium-Break LOCA Initiator	1.3E-007	1.1E-004		Y
OEP-XHE-XE-NOREC	Operator Fails to Recover Offsite Power	6.6E-002	6.6E-002		N
PCS-SYS-VF-MISC	PCS Hardware Components Fail	1.7E-001	1.7E-001		N
PCS-XHE-XE-NOREC	Operator Fails to Recover PCS	1.0E+000	1.0E+000		N
PPR-SRV-OO-2VLVS	Two SRVs Fail to Close	1.3E-003	1.3E-003		N
PPR-SRV-OO-1VLV	One or Less SRVs Fail to Close	3.6E-002	3.6E-002		N

*0.01 used for MLOCA sequences, 0.001 used for other sequences.

Table C.4.2. Sequence conditional probabilities for LER 237/94-021

Event tree name	Sequence name	Conditional core damage probability (CCDP)	Core damage probability (CDP)	Importance (CCDP-CDP)	% Contribution
MLOCA	39	1.3E-006	1.5E-007	1.2E-006	43.0
TRAN	38-39	7.8E-007	8.9E-008	6.9E-007	25.3
LOOP	44	4.8E-007	4.8E-007	0.0E+000	15.6
LOOP	41	2.6E-007	2.9E-008	2.3E-007	8.2
Total (all sequences)		3.1E-006	8.3E-007	2.3E-006	

Table C.4.3. Sequence logic for dominant sequences for LER 237/94-021

Event tree name	Sequence name	Logic
IE-MLOCA	39	HCI, ADS
TRAN	38-39	/RPS, PCS, P2, HCI, ADS
LOOP	44	/RP1, EPS, OEP
LOOP	41	/RP1, EPS, /OEP, P1, HCI

Table C.4.4. System names for LER 237/94-021

System name	Description
ADS	Automatic Depressurization Fails
EPS	Emergency Power System Fails
HCI	HPCI Fails to Provide Sufficient Flow to Reactor Vessel
OEP	Offsite Power Recovery
P1	One or Less SRV Fail to Close
P2	Two SRVs Fail to Close
PCS	Power Conversion System
RP1	Reactor Shutdown Fails
RPS	Reactor Shutdown Fails

Table C.4.5. Conditional cut sets for higher probability sequences for LER 237/94-021

Cut set No.	% Contribution	Frequency	Cut sets
IE-MLOCA Sequence: 39		1.3E-006	
1	79.4	1.1E-006	ADS-XHE-XE-ERROR
2	20.8	2.8E-007	ADS-SRV-CC-VALVS, ADS-XHE-XE-NOREC
TRAN Sequence: 38-39		7.8E-007	
1	79.2	6.2E-007	ADS-XHE-XE-ERROR, PCS-SYS-VF-MISC, PCS-XHE-XE-NOREC, PPR-SRV-OO-2VLVS
2	20.8	1.7E-007	ADS-SRV-CC-VALVS, ADS-XHE-XE-NOREC, PCS-SYS-VF-MISC, PCS-XHE-XE-NOREC, PPR-SRV-OO-2VLVS
LOOP Sequence: 44		4.9E-007	
1	74.7	3.6E-007	EPS-DGN-CF-DGNS, EPS-XHE-XE-NOREC, OEP-XHE-XE-NOREC
2	25.3	1.2E-007	EPS-XHE-XE-NOREC, OEP-XHE-XE-NOREC, EPS-DGN-FC-DG23, EPS-DGN-FC-DG2, EPS-DGN-FC-DG3
LOOP Sequence: 41		2.7E-007	
1	74.7	2.0E-007	EPS-DGN-CF-DGNS, EPS-XHE-XE-NOREC, PPR-SRV-OO-1VLV
2	25.3	6.7E-008	EPS-XHE-XE-NOREC, PPR-SRV-OO-1VLV, EPS-DGN-FC-DG23, EPS-DGN-FC-DG2, EPS-DGN-FC-DG3
Total (all sequences)		3.1E-006	