B.4 LER No. 315/95-011

Event Description: One safety injection pump unavailable for 6 months

Date of Event: September 12, 1995

Plant: D. C. Cook, Unit 1

B.4.1 Event Summary

As the result of a surveillance test performed while the unit was shut down in Mode 6, personnel determined that the West Centrifugal Charging Pump (CCP) had been inoperable for about 6 months. The pump was inoperable because a relay calibration had been performed incorrectly 6 months earlier. The unavailability of the West CCP primarily affects the unit's response to a small-break loss-of-coolant accident (SLOCA) event. The estimated *increase* in core damage probability (CDP) for this event (i.e., the importance) is 7.7×10^{-6} above a base probability of core damage (the CDP) for the same period of 2.9×10^{-5}.

B.4.2 Event Description

On September 12, 1995, the plant was shut down in Mode 6 when the West CCP was started to perform the emergency core cooling system (ECCS) full flow test surveillance. The West CCP provides injection flow on the receipt of a safety injection (SI) signal. After operating at full flow for 7 min, the pump tripped on motor overcurrent. Personnel determined that the pump tripped because the 1-51-TA8 time overcurrent relay was set incorrectly. It was determined that this relay was last calibrated on March 15, 1995, 180 days before the full-flow test. The West CCP was rendered inoperable for the preceding 6 months.

During the event review, the Instrumentation and Control (I&C) technicians involved in calibrating the relays demonstrated the way they typically determine the relay pick-up current. Because their technique was incorrect, the relays were miscalibrated. Both I&C technicians involved in the relay calibration were trained and qualified in the D. C. Cook Nuclear Plant relay training program. However, a significant amount of time had elapsed between the end of the training program and the time the 1-51-TA8 time overcurrent relay on the West CCP breaker was calibrated incorrectly.

B.4.3 Additional Event-Related Information

During normal plant operation, both charging pumps (East and West) are configured for their charging function. One charging pump is sufficient to supply full charging flow and reactor coolant pump seal injection during normal leakage and normal letdown conditions. A third positive displacement charging pump is available but is not normally used. On receipt of a valid SI signal, the CCPs operate in the high pressure injection (HPI) mode.

D. C. Cook also has a separate SI system. The system, with two pumps operating in parallel, runs in an intermediate pressure injection mode. The two SI pumps deliver flow from the Refueling Water Storage Tank

(RWST) at a maximum injection pressure of approximately 7.6 MPa (1100 psig). The residual heat removal (RHR) pumps can be aligned for recirculation from the containment sump to the suction of either the SI pumps or the CCPs.

The licensee indicated that the East CCP had been inoperable for less than 18 h during the 6-month period that the West CCP was unavailable. Additionally, the emergency diesel generator (EDG) supporting the East CCP was unavailable for less than 50 h during the 6-month period that the West CCP was unavailable.

B.4.4 Modeling Assumptions

This event was modeled as a long term (4320 hours, 180 days × 24 h/day) unavailability of the West CCP. The event model was broken into three cases based on reported equipment availability. The first case modeled only the West CCP as being unavailable for 4252 hours. The second case took into account that the opposite train EDG was periodically unavailable for time periods totaling 50 hours while the West CCP was unavailable. Finally, the third case accounted for the report that both CCPs were simultaneously unavailable for various maintenance periods totaling 18 hours.

Loss-of-offsite power (LOOP) sequences are prominent in the second case when only one EDG was available. LOOP probabilities for short-term and long-term off-site power recovery and the probability of a reactor coolant pump (RCP) seal LOCA following a postulated station blackout were developed based on data distributions contained in NUREG 1032, *Evaluation of Station Blackout Accidents at Nuclear Power Plants*. The RCP seal LOCA models were developed as part of the NUREG-1150 PRA efforts. These probabilities and models are described in *Revised LOOP Recovery and PWR Seal LOCA Models*, ORNL/NRC/LTR-89/11, August 1989.

The CCPs were subject to common-cause failure during this 6-month period resulting from incorrect maintenance practices. Because the success criterion in the Integrated Reliability and Risk Analysis System (IRRAS) model assumes both CCPs are required for success of the CCP portion of the HPI function in response to either an SLOCA or a steam generator tube rupture (SGTR), no changes were required to model the increased potential for common-cause failure. Success of one of the two SI pumps also ensures success of the HPI function in the IRRAS model, independent of the success of the CCPs. This assumption is not as stringent as that of the plant Individual Plant Examination, which is that one of two CCPs and one of two SI pumps are required in response to an SLOCA.

The IRRAS response to an SGTR was modified. Previously, a loss of the HPI function lead directly to core damage. The possibility of lowering RCS pressure below the steam generator safety valve set point within 30 min was allowed following the loss of HPI capability by adding a basic event PCS-XHE-DEPRES. Based on the operator burden under a short time constraint, a failure probability of 0.1 was assigned to the new basic event, PCS-XHE-DEPRES.

B.4.5 Analysis Results

Determining the overall increase in the CDP required determining the increase in the CDP for the three different cases and then summing the cases. The three cases are:

Case 1	the increase in the CDP due to the long-term unavailability of the West CCP (4252 h).
Case 2	the increase in the CDP from the opposite train EDG being unavailable periodically while the West CCP was unavailable (50 h).
Case 3	the increase in the CDP due to the time that the CCPs were simultaneously unavailable because of various maintenance activities (18 h).

Combining the probability estimates for the three cases results in an overall increase of 7.7×10^{-6} in the CDP for the 180-day period. This is above a base probability for core damage (the CDP) for the same period of 2.9×10^{-5}. Most of the increase (56%) is driven by the long-term unavailability of the West CCP (Case 1). An additional 44% of the increase in CDP is added by Case 2. The dominant core damage sequence, highlighted as sequence number 6 on the event tree in Fig. B.4.1, contributes approximately 44% to the combined increase in the CDP estimate for all three modeled cases. Sequence number 6 involves:

- an SLOCA,
- the successful trip of the reactor,
- the successful operation of the Auxiliary Feedwater (AFW) system, and
- the failure of the HPI system to provide sufficient cooling flow.

The next most dominant sequence involves a LOOP and contributes approximately 13% to the combined increase in the CDP estimate for all three modeled cases.

The nominal CDP over a 6-month period estimated using the Accident Sequence Precursor (ASP) models for D. C. Cook is approximately 2.9×10^{-5}. The failed West CCP increased this probability by 28% to 3.7×10^{-5}. This latter value (3.7×10^{-5}) is the conditional core damage probability (CCDP) for the 6-month period in which the West CCP was inoperable.

For most ASP analyses of conditions (equipment failures over a period of time during which postulated initiating events could have occurred), sequences and cut sets associated with the observed failure dominate the CCDP (i.e., the probability of core damage over the unavailability period, given the observed failures). The increase in CDP because of the failures is, therefore, essentially the same as the CCDP, and the CCDP can be considered a reasonable measure of the significance of the observed failures. However, for this event, sequences unrelated to the failure of the West CCP dominated the CCDP estimate. The increase in CDP given the West CCP inoperability, 7.7×10^{-6}, is, therefore, a better measure of the significance of the failure of the West CCP.

Definitions and probabilities for selected basic events are shown in Table B.4.1. The conditional probabilities associated with the highest probability sequences for the condition assessment are shown in Table B.4.2. The sequence logic associated with the sequences listed in Table B.4.2 are given in Table B.4.3. Table B.4.4 lists

the system names associated with the dominant sequences for the condition assessment. Minimal cut sets associated with the dominant sequences for the condition assessment are shown in Table B.4.5.

B.4.6 References

1. LER 315/95-011, Rev 0, "West Centrifugal Charging Pump Inoperable due to Inability to Meet Design Basis Requirements for Six Months as a Result of Personnel Error During Relay Calibration," November 20, 1995.

2. Indiana Michigan Power Company, *Donald C. Cook Nuclear Plant Individual Plant Examination Summary Report.*

3. Indiana Michigan Power Company, *Donald C. Cook Nuclear Plant Final Safety Analysis Report.*

4. *Evaluation of Station Blackout Accidents at Nuclear Power Plants,* NUREG-1032.

5. *Revised LOOP Recovery and PWR Seal LOCA Models*, ORNL/NRC/LTR-89/11, August 1989.

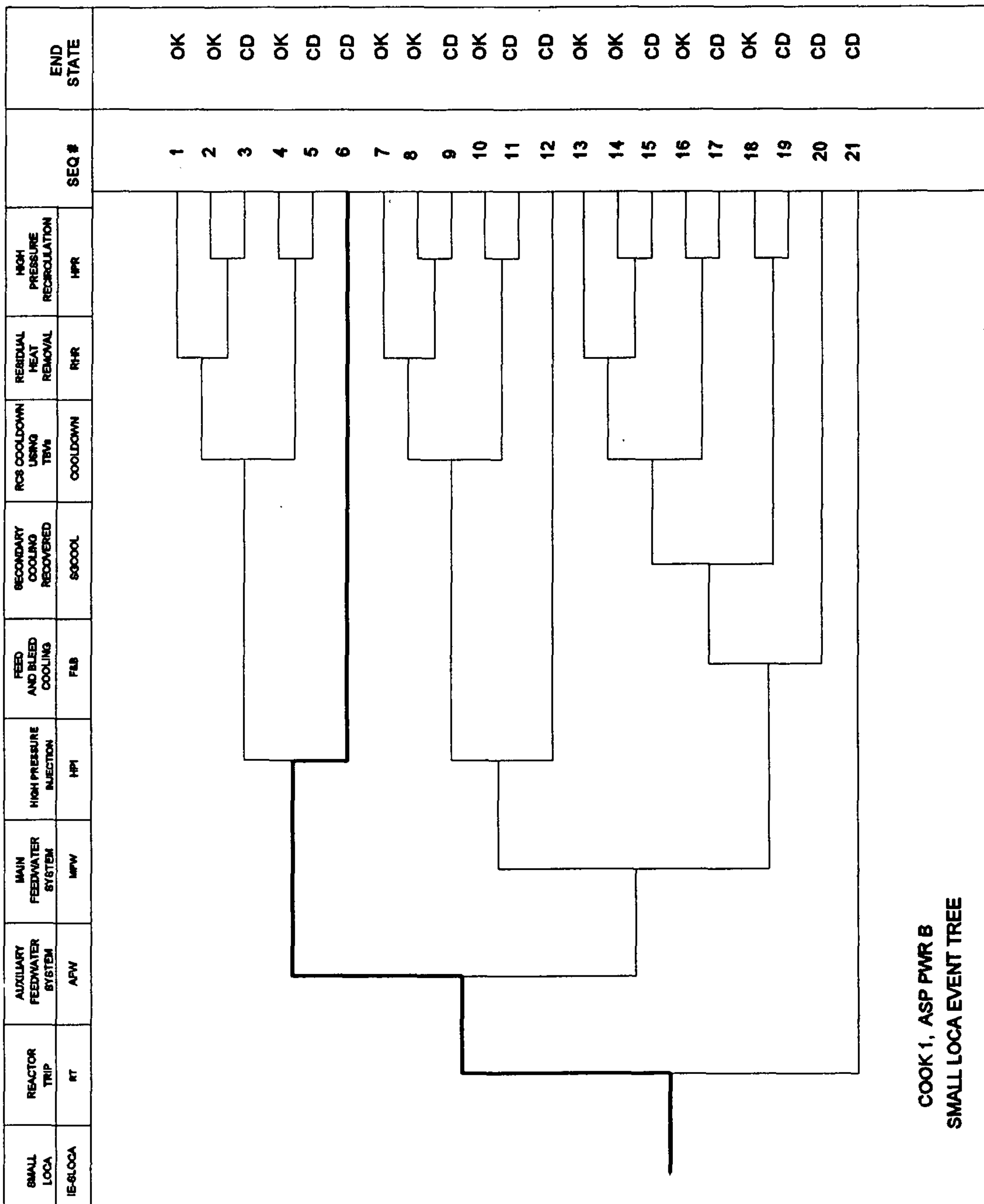

Fig. B.4.1. Dominant core damage sequence given a small LOCA for LER 315/95-011.

Table B.4.1. Definitions and Probabilities for Selected Basic Events for LER No. 315/95-011

Event name	Description	Base probability	Current probability	Type	Modified for this event
CVC-MDP-FC-1A	Failure of Charging Pump A	9.0E-004	1.0E+000	TRUE	Yes
HPI-MDP-CF-ALL	HPI Motor-Driven Pump Common-Cause Failures	7.8E-004	7.8E-004		No
HPI-MDP-FC-1A	HPI Motor-Driven Pump A Fails	3.9E-003	3.9E-003		No
HPI-MDP-FC-1B	HPI Motor-Driven Pump B Fails	3.9E-003	3.9E-003		No
HPI-MOV-OC-SUC	HPI Serial Component Failures	1.4E-004	1.4E-004		No
HPI-MOV-OO-RWST	Failure to Isolate the RWST From the HPI System	3.0E-003	3.0E-003		No
HPI-XHE-NOREC	Operator Fails to Recover the HPI System	8.4E-001	8.4E-001		No
HPR-XHE-NOREC	Operator Fails to Recover the High Pressure Recirculation (HPR) System	1.0E+000	1.0E+000		No
PCS-XHE-DEPRES	Failure to Depressurize the RCS Within 30 Minutes	1.0E-001	1.0E-001	NEW	No
RHR-MDP-CF-ALL	RHR Pump Common-Cause Failures	4.5E-004	4.5E-004		No
RHR-MDP-FC-1A	RHR Motor-Driven Pump 1A Fails	4.1E-003	4.1E-003		No
RHR-MDP-FC-1B	RHR Motor-Driven Pump 1B Fails	4.1E-003	4.1E-003		No
RHR-MOV-CC-SUC1	Failure of RHR Hot Leg Suction Motor-Operated Valve (MOV) A	3.0E-003	3.0E-003		No
RHR-MOV-CC-SUC2	Failure of RHR Hot Leg Suction MOV B	3.0E-003	3.0E-003		No
RHR-MOV-OO-RWST	Failure to Isolate the RWST During RHR	3.0E-003	3.0E-003		No
RHR-XHE-NOREC	Operator Fails to Recover the RHR System	1.0E+000	1.0E+000		No

Table B.4.2. Sequence Conditional Probabilities for LER No. 315/95-011

Event tree name	Sequence name	Conditional core damage probability (CCDP)	Core damage probability (CDP)	Importance (CCDP–CDP)	Percent contribution[d]
SLOCA	06	3.3E-006	2.9E-008	3.3E-006	77.2
SGTR	08	5.4E-007	4.8E-009	5.4E-007	12.5
SLOCA	03	2.2E-008	2.0E-006	1.5E-007	3.7
Subtotal Case 1 (shown)[a]		3.3E-005	2.9E-005	4.3E-006	
Subtotal Case 2[b]		3.7E-006	3.4E-007	3.4E-006	
Subtotal Case 3[c]		1.4E-007	1.2E-007	1.8E-008	
Total (all sequences)		**3.7E-005**	**2.9E-005**	**7.7E-006**	

[a] Case 1 represents the increase in the core damage probability due to the long-term unavailability of the West CCP (4252 h).

[b] Case 2 represents the increase in the CDP from the opposite train EDG being unavailable periodically while the West CCP was unavailable (50 h).

[c] Case 3 represents the increase in the core damage probability due to the time that the CCPs were simultaneously unavailable because of various maintenance activities (18 h).

[d] Percent contribution to the total importance.

Table B.4.3. Sequence Logic for Dominant Sequences for LER No. 315/95-011 (Case 1 only)

Event tree name	Sequence name	Logic
SLOCA	06	/RT, /AFW, HPI
SGTR	08	/RT, /AFW, HPI, RCS-SG-H
SLOCA	03	/RT, /AFW, /HPI, /COOLDOWN, RHR, HPR

Table B.4.4. System Names for LER No. 315/95-011 (Case 1 only)

System name	Logic
AFW	No or Insufficient AFW Flow
COOLDOWN	RCS Cooldown to RHR Pressure Using Turbine-Bypass Valves, etc.
HPI	No or Insufficient Flow From HPI System
HPR	No or Insufficient HPR Flow
RHR	No or Insufficient Flow From RHR System
RCS-SG-H	Failure to Depressurize the RCS Below the Steam Generator Safety Valve Setpoint Without HPI
RT	Reactor Fails to Trip During Transient

Table B.4.5. Conditional Cut Sets for Higher Probability Sequences for LER No. 315/95-011

Cut set no.	Percent contribution	Change in CCDP (Importance)[a]	Cut sets[e]
SLOCA Sequence 06		3.3E-006	
1	83.1	2.8E-006	CVC-MDP-FC-1A, HPI-MDP-CF-ALL, HPI-XHE-NOREC
2	14.9	5.0E-007	CVC-MDP-FC-1A, HPI-MOV-OC-SUC, HPI-XHE-NOREC
3	1.6	5.4E-008	CVC-MDP-FC-1A, HPI-MDP-FC-1A, HPI-MDP-FC-1B, HPI-XHE-NOREC
SGTR Sequence 08		5.4E-007	
1	83.1	4.5E-007	CVC-MDP-FC-1A, HPI-MDP-CF-ALL, HPI-XHE-NOREC, PCS-XHE-DEPRES
2	14.9	8.0E-008	CVC-MDP-FC-1A, HPI-MOV-OC-SUC, HPI-XHE-NOREC, PCS-XHE-DEPRES
3	1.6	8.6E-009	CVC-MDP-FC-1A, HPI-MDP-FC-1A, HPI-MDP-FC-1B, HPI-XHE-NOREC, PCS-XHE-DEPRES
SLOCA Sequence 03		1.6E-007	
1	86.4	1.5E-007	RHR-MDP-CF-ALL, RHR-XHE-NOREC, HPR-XHE-NOREC
2	3.2	6.2E-009	RHR-MDP-FC-1A, RHR-MDP-FC-1B, RHR-XHE-NOREC, HPR-XHE-NOREC
3	1.7	3.6E-009	CVC-MDP-FC-1A, HPI-MOV-OO-RWST, RHR-MOV-CC-SUC2, RHR-XHE-NOREC, HPR-XHE-NOREC
4	1.7	3.6E-009	CVC-MDP-FC-1A, HPI-MOV-OO-RWST, RHR-MOV-OO-RWST, RHR-XHE-NOREC, HPR-XHE-NOREC
5	1.7	3.6E-009	CVC-MDP-FC-1A, HPI-MOV-OO-RWST, RHR-MOV-CC-SUC1, RHR-XHE-NOREC, HPR-XHE-NOREC
Subtotal Case 1[b] (shown above)		**4.3E-006**	
Subtotal Case 2[c]		**3.4E-006**	
Subtotal Case 3[d]		**1.8E-008**	
Total (all sequences)		**7.7E-006**	

[a] The change in conditional probability (importance) is determined by calculating the conditional probability for the period in which the condition existed, and subtracting the conditional probability for the same period but with plant equipment assumed to be operating nominally. The conditional probability for each cut set within a sequence is determined by multiplying the probability that the portion of the sequence that makes the precursor visible (e.g., the system with a failure is demanded) will occur during the duration of the event by the probabilities of the remaining basic events in the minimal cut set. This can be approximated by $1 - e^{-p}$, where p is determined by multiplying the expected number of initiators that occur during the duration of the event by the probabilities of the basic events in that minimal cut set. The expected number of initiators is given by λt, where λ is the frequency of the initiating event (given on a per-hour basis), and t is the duration time of the event. This approximation is conservative for precursors made visible by the initiating event. The frequencies of interest for this event are:

$\lambda_{TRANS} = 5.3 \times 10^{-4}$/h, $\lambda_{LOOP} = 3.8 \times 10^{-6}$/h, $\lambda_{SLOCA} = 1.0 \times 10^{-6}$/h, and $\lambda_{SGTR} = 1.6 \times 10^{-6}$/h.

[b] Case 1 represents the increase in the core damage probability due to the long term unavailability of the West CCP (4252 h).

[c] Case 2 represents the increase in the CDP from the opposite train EDG being unavailable periodically while the West CCP was unavailable (50 h).

[d] Case 3 represents the increase in the core damage probability due to the time that the CCPs were simultaneously unavailable because of various maintenance activities (18 h).

[e] Basic event, CVC-MDP-FC-1A, is a TRUE type event which is not normally included in the output of fault tree reduction programs. This event has been added to aid in understanding the sequences to potential core damage associated with the event.