

**B.10 LER No. 443/96-003**

Event Description: Turbine-driven emergency feedwater pump unavailable  
because of a mechanical seal failure

Date of Event: May 21, 1996

Plant: Seabrook

**B.10.1 Event Summary**

Seabrook was at 100% power when personnel were performing a scheduled operating test on the turbine-driven emergency feedwater (TDEFW) pump. The pump was manually tripped after sparks were observed coming out of its outboard mechanical seal. The sparks were ultimately attributed to the improper installation of the mechanical seal assembly during the previous refueling outage in November–December 1995 (Refs. 1, 2). This long-term unavailability of the TDEFW pump (3,875 h) would have affected the unit's response to a loss of offsite power (LOOP) or a transient event. The estimated increase in the core damage probability (CDP) over the 5-month period for this event (i.e., the importance) is  $4.6 \times 10^{-5}$ . The base probability of core damage (the CDP) for the same period is  $3.0 \times 10^{-5}$ .

**B.10.2 Event Description**

Seabrook was at 100% power on May 21, 1996, when personnel started the TDEFW pump for its scheduled quarterly surveillance test. The operator tripped the pump locally during the test after sparks were observed emanating from the outboard mechanical seal area of the pump. The mechanical seal was disassembled and inspected. The sparks were the result of mechanical interference within the seal assembly. The outboard seal gland was making contact with the top of the shaft sleeve and the throttle bushing inside diameter. The sparks were caused because the shaft sleeve rubbed against the inside diameter of the throttle bushing, causing a 0.0127 cm (0.005 in) gouge in the shaft sleeve and the chipping of the throttle bushing. The inboard seal gland had a 0.0178 cm (0.007 in) clearance between the top of the shaft sleeve and the throttle bushing inside diameter. Licensee personnel concluded that because of the improper installation of the seal, the TDEFW pump would not have been able to perform its safety function for the required mission time (24 h) since the November–December 1995 refueling outage. However, the exact time that the TDEFW pump became inoperable could not be conclusively determined since the pump had successfully completed two prior surveillance runs without any indications of problems related to the mechanical seal degradation.

After repairing the TDEFW pump, personnel inspected the mechanical seals of the motor-driven emergency feedwater (MDEFW) pump and discovered the outboard mechanical seal to have a similar position, along with the corresponding indications of mechanical rubbing. The MDEFW pump outboard mechanical seal gland had a 0.0089 cm (0.0035 in) clearance between the shaft sleeve and the top of the throttle bushing inside diameter. The MDEFW pump throttle bushing was not chipped like the throttle bushing was on the TDEFW pump. The inspection revealed that the burnishing identified on the outboard mechanical seal of the MDEFW pump was consistent with normal rubbing experienced during pump startup. The system

engineer concluded that the MDEFW pump was capable of performing its design function based on the review of the as-found clearance data.

The design clearances and tolerances of the TDEFW pump's mechanical seals were insufficient to prevent damage during operation unless the installation technique used noncustomary methods (i.e., use of dial indicators and feeler gauges). The design permitted the allowable tolerances to be greater than the available clearance. Hence, the design did not preclude the interference between the throttle bushing seal (secondary seal) and the shaft sleeve. There was never any contact with the primary seal. This design deficiency also applies to the MDEFW pump mechanical seals. Contributing to this event was the failure to adequately incorporate previous knowledge regarding seal installation into maintenance procedures or training. As a result, maintenance personnel were unaware of a prior seal failure (in 1987) or the need to take precision measurements to verify the proper installation of the seal assembly.

### **B.10.3 Additional Event-Related Information**

The emergency feedwater (EFW) system consists of two 100% capacity trains that feed a common discharge header.<sup>3</sup> One train uses the TDEFW pump, and the other train uses the MDEFW pump. All four steam generators can be fed by either EFW pump. The TDEFW pump is supplied steam from the A and B steam generators. The MDEFW pump is powered from 4160V emergency bus E6 supported by the B emergency diesel generator (EDG).

Seabrook also maintains a start-up feedwater pump with a capacity approximately equivalent to the combined capacity of both EFW pumps.<sup>3</sup> The start-up feedwater pump can be started from the control room, except during a LOOP. Two normally closed motor-operated valves (MOV's) must be opened to establish feedwater flow. Following a LOOP, the normal power source to the start-up feedwater pump is not supplied power from an emergency bus. Therefore, the normal breaker alignment for the start-up feedwater pump must be altered from 4160-V bus 4 to 4160-V emergency bus E5 (emergency bus E5 is powered by the A EDG). The normal and alternate start-up feedwater pump breakers are key-interlocked, requiring one breaker to be racked out before the interlock key can be removed. The interlock key is required to rack-in the alternate source breaker (from bus E5) to the start-up feedwater pump.

### **B.10.4 Modeling Assumptions**

Even though previous surveillance tests were successfully completed, the licensee concluded that the TDEFW pump would not have been able to perform its safety function for the required mission time (24 h) since the November–December 1995 refueling outage.<sup>1,2</sup> Hence, the TDEFW pump was considered inoperable, and its failure probability was adjusted to 1.0 (TRUE) for a 3,875-h condition assessment. The 3,875 h condition assessment is based on the TDEFW pump being required from the end of the outage on December 9, 1995, until the discovery of the mechanical seal failure on May 21, 1996. Two days (48 h) were subtracted from the total number of hours that the TDEFW pump was unavailable to account for a reactor trip in January.

The licensee indicated that the MDEFW pump would have performed its safety function for the required mission time. However, because the outboard mechanical seal on the MDEFW pump was (1) positioned similar to that of the TDEFW pump, (2) subject to the same design deficiency, and (3) subject to the same

inadequate maintenance procedure that resulted in the TDEFW pump failure, the potential for a common-cause EFW pump failure increased. The EFW common-cause factor was developed based on data distributions for mixed-pump types contained in INEL-94-0064, *Common-Cause Failure Data Collection and Analysis System* (Ref. 4, Table 9-19: Alpha Factor Distribution Summary – All AFW Types Fail to Start, CCCG = 2,  $\alpha_2 = 0.0884$ ). Because  $\alpha_2$  is equivalent to the  $\beta$  factor of the multiple Greek letter method used in the Integrated Reliability and Risk Analysis System (IRRAS) models, the common-cause failure probability of the EFW system pumps (EFW-PMP-CF-EFW) was adjusted from  $3.8 \times 10^{-4}$  to  $8.84 \times 10^{-2}$  based on the common-cause failure potential.

The utility has conducted computer simulations of a station blackout with a concurrent failure of EFW at Seabrook. This simulation has shown that under these conditions, the time to steam generator dryout is about 90 min. As a result, substantial time is available for electric power recovery. This potential was modeled by the addition of a basic event (OEP-XHE-NOREC-SB) that is considered under the OP-SBO top event (OP-2H) on the LOOP event tree (Fig. B.10.1). Top Event OP-SBO is substituted for the OP-2H top event whenever emergency power and EFW are failed.

The Seabrook individual plant examination (IPE) indicates that the start-up feedwater pump is a backup source of feedwater for the EFW system. To credit the use of the start-up feedwater pump, a basic event was added to the IRRAS model for the Seabrook plant based on the IPE value for a failure of the start-up feedwater pump to start and run (Ref. 5, Table 7.9-1) or a failure of the associated valves to open (basic event EFW-MDP-FC-SFP). Because an operator is required to open two normally closed MOVs to establish flow from the start-up feedwater system, another basic event was added to account for the failure of the operator to manipulate the required MOVs (EFW-XHE-XM-SFP). Finally, during a LOOP, an operator must realign the supply breaker for the start-up feedwater pump to the A EDG. A basic event was therefore added to represent the failure of an operator to complete this realignment (EFW-XHE-XM-BRKR). This last basic event was based on the assumption that it would take an operator approximately 15 min, following a LOOP, to perform the activity and that approximately 90 min were available before a steam generator dryout would occur, leading to core damage. A lognormal distribution was used to calculate the failure probability for EFW-XHE-XM-BRKR.

The operator nonrecovery probability for the EFW system during a LOOP (EFW-XHE-NOREC-L) was adjusted from 0.26 to 0.80 because this action is not independent from other operator actions. The operator must first realign the supply breaker for the start-up feedwater pump to the A EDG (EFW-XHE-XM-BRKR). If the operator fails to realign this breaker, the start-up feedwater pump would not be available in a LOOP scenario (LOOP sequence 17). Further, if the operator does indeed fail to realign this breaker, it is more likely that the operator will fail to recover the EFW system during a LOOP. Finally, during a station blackout (SBO), the only source of EFW is the TDEFW pump; therefore, with the TDEFW pump unavailable, there is no opportunity to recover EFW. Based on this, the operator nonrecovery factor during a SBO (EFW-XHE-NOREC-EP) was set to "TRUE" (recovery not possible).

### B.10.5 Analysis Results

The increase in the CDP during a 3,875-h period for this event is  $4.6 \times 10^{-5}$ . The nominal CDP for the same period is  $3.0 \times 10^{-5}$ . This is a conservative estimate because the TDEFW pump was satisfactorily tested twice (a total run time of ~1–2 h) during the unavailability period (3,875 h). Therefore, the TDEFW pump likely would have operated for a limited period (less than the mission time of 24 h) during the first part of the unavailability period, which would mitigate the calculated CDP. The dominant core damage sequence for this event (sequence 41 on Fig. B.10.1) involves

- a postulated LOOP,
- a successful reactor trip,
- a failure of emergency power,
- a failure of emergency feedwater, and
- a failure to restore electric power prior to steam generator dryout.

This SBO sequence (sequence 41 on Fig. B.10.1) accounts for 56% of the total contribution to the increase in the CDP. The next most dominant sequence (sequence 17 on Fig. B.10.1) contributes 22% to the total increase in the CDP. This sequence involves a LOOP with the success of emergency power, a failure of EFW, and a failure of feed-and-bleed decay heat removal.

An alternate study investigating the conditional core damage probability (CCDP) associated with the reactor trip that occurred in January with the unavailable TDEFW pump was conducted. The TDEFW pump failure probability (EFW-TDP-FC-1A) was set to TRUE (failed). Using the same material assumptions as those made for the previous condition assessment, the CCDP for this initiating event is  $4.0 \times 10^{-6}$ . The dominant core damage sequence involves a failure to trip the reactor and a failure of the EFW system.

Definitions and probabilities for selected basic events are shown in Table B.10.1. The conditional probabilities associated with the highest probability sequences are shown in Table B.10.2. Table B.10.3 lists the sequence logic associated with the sequences listed in Table B.10.2. Table B.10.4 describes the system names associated with the dominant sequences. Minimal cut sets associated with the dominant sequences are shown in Table B.10.5.

### B.10.6 References

1. LER 443/96-003, Rev. 0, "Emergency Feedwater Pump Mechanical Seal Failure," June 21, 1996.
2. LER 443/96-003, Rev. 1, "Emergency Feedwater Pump Mechanical Seal Failure," September 12, 1996.
3. Seabrook Nuclear Station, *Final Safety Analysis Report*.
4. Marshall and Rasmuson, *Common-Cause Failure Data Collection and Analysis System*, INEL-94/0064, December 1995.
5. Seabrook Nuclear Station, *Individual Plant Examination*.

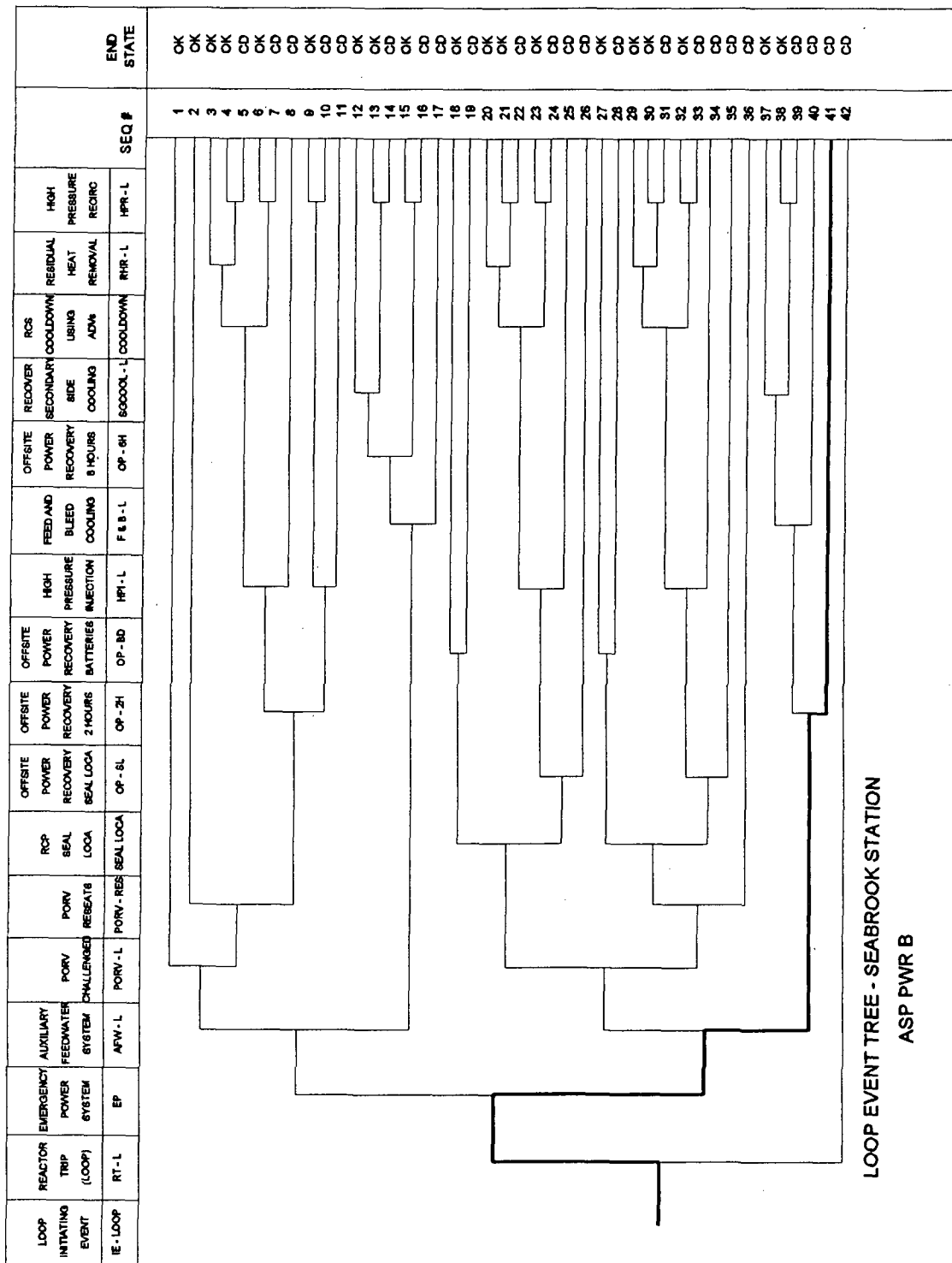


Fig. B.10.1 Dominant core damage sequence for LER No. 443/96-003.

Table B.10.1. Definitions and Probabilities for Selected Basic Events for LER No. 443/96-003

Event name	Description	Base probability	Current probability	Type	Modified for this event
IE-LOOP	Initiating Event-LOOP	8.6 E-006	8.6 E-006		No
IE-SGTR	Initiating Event-Steam Generator Tube Rupture	1.6 E-006	1.6 E-006		No
IE-SLOCA	Initiating Event-Small Loss-of-Coolant Accident (SLOCA)	1.0 E-006	1.0 E-006		No
IE-TRANS	Initiating Event-Transient (TRANS)	5.3 E-004	5.3 E-004		No
EFW-MDP-FC-1B	EFW Motor-Driven Pump Fails	3.9 E-003	3.9 E-003		No
EFW-MDP-FC-SFP	Start-up Feedwater Pump Fails	2.1 E-002	2.1 E-002	NEW	No
EFW-PMP-CF-EFW	Common-Cause Failure of EFW Pumps (Excludes Start-up Feedwater Pump)	3.8 E-004	8.8 E-002		Yes
EFW-TDP-FC-1A	EFW Turbine-Driven Pump Fails	3.9 E-002	1.0 E+000	TRUE	Yes
EFW-XHE-NOREC	Operator Fails to Recover EFW	2.6 E-001	2.6 E-001		No
EFW-XHE-NOREC-EP	Operator Fails to Recover EFW During a Station Blackout	3.4 E-001	1.0 E+000	TRUE	Yes
EFW-XHE-NOREC-L	Operator Fails to Recover EFW During a LOOP	2.6 E-001	8.0 E-001		Yes
EFW-XHE-NREC-ATW	Operator Fails to Recover EFW During an ATWS	1.0 E+000	1.0 E+000		No
EFW-XHE-XM-BRKR	Operator Fails to Realign Start-up Feedwater Pump Supply Breaker	5.6 E-002	5.6 E-002	NEW	No
EFW-XHE-XM-SFP	Operator Fails to Open Start-up Feedwater Pump MOVs	1.0 E-002	1.0 E-002	NEW	No
EPS-DGN-CF-ALL	Common-Cause Failure of EDGs	1.6 E-003	1.6 E-003		No
EPS-DGN-FC-1A	A EDG Fails	4.2 E-002	4.2 E-002		No
EPS-DGN-FC-1B	B EDG Fails	4.2 E-002	4.2 E-002		No
EPS-XHE-NOREC	Operator Fails to Recover Emergency Power	8.0 E-001	8.0 E-001		No
HPI-MDP-FC-1B	HPI Pump B Fails	3.9 E-003	3.9 E-003		No

**Table B.10.1. Definitions and Probabilities for Selected Basic Events for  
LER No. 443/96-003 (Continued)**

<b>Event name</b>	<b>Description</b>	<b>Base probability</b>	<b>Current probability</b>	<b>Type</b>	<b>Modified for this event</b>
HPI-XHE-NOREC-L	Operator Fails to Recover the HPI System During a LOOP	8.4 E-001	8.4 E-001		No
HPI-XHE-XM-FB	Operator Fails to Initiate Feed-and-Bleed	1.0 E-002	1.0 E-002		No
HPI-XHE-XM-FBL	Operator Fails to Initiate Feed-and-Bleed During LOOP	1.0 E-002	1.0 E-002		No
MFW-SYS-TRIP	Main Feedwater (MFW) System Trips	2.0 E-001	2.0 E-001		No
MFW-XHE-NOREC	Operator Fails to Recover MFW	3.4 E-001	3.4 E-001		No
OEP-XHE-NOREC-SB	Operator Fails to Recover Electric Power Before Steam Generator Dry out	2.9 E-001	2.9 E-001	NEW	No
PPR-SRV-CC-1	Power-Operated Relief Valve (PORV) 1 Fails to Open on Demand	6.3 E-003	6.3 E-003		No
PPR-SRV-CC-2	PORV 2 Fails to Open on Demand	6.3 E-003	6.3 E-003		No
RPS-NONREC	Nonrecoverable Reactor Protection System Failures	2.0 E-005	2.0 E-005		No
RPS-REC	Recoverable RCS Failures	4.0 E-005	4.0 E-005		No
RPS-XHE-XM-SCRAM	Operator Fails to Manually Trip the Reactor	1.0 E-002	1.0 E-002		No

Table B.10.2. Sequence Conditional Probabilities for LER No. 443/96-003

Event tree name	Sequence number	Conditional core damage probability (CCDP)	Core damage probability (CDP)	Importance (CCDP-CDP)	Percent contribution <sup>a</sup>
LOOP	41	2.6 E-005	3.4 E-007	2.5 E-005	55.6
LOOP	17	1.0 E-005	4.5 E-008	9.9 E-006	21.5
TRANS	21-8	5.1 E-006	7.7 E-008	5.0 E-006	10.9
TRANS	20	2.3 E-006	1.4 E-008	2.3 E-006	5.0
LOOP	40	2.0 E-006	2.6 E-008	2.0 E-006	4.3
Total (all sequences)		7.6 E-005	3.0 E-005	4.6 E-005	

<sup>a</sup>Percent contribution to the total importance.



Table B.10.3. Sequence Logic for Dominant Sequences for LER No. 443/96-003

Event tree name	Sequence number	Logic
LOOP	41	/RT-L, EP, EFW-L-EP, OP-SBO
LOOP	17	/RT-L, /EP, EFW-L, F&B-L
TRANS	21-8	RT, /RCSPRESS, EFW-ATWS
TRANS	20	/RT, EFW, MFW, F&B
LOOP	40	/RT-L, EP, EFW-L-EP, /OP-SBO, F&B

Table B.10.4. System Names for LER No. 443/96-003

System name	Logic
EFW	No or Insufficient EFW Flow
EFW-ATWS	No or Insufficient EFW Flow During an ATWS
EFW-L	No or Insufficient EFW Flow During a LOOP
EFW-L-EP	No or Insufficient EFW Flow During a Station Blackout
EP	Failure of Both Trains of Emergency Power
F&B	Failure to Provide Feed-and-Bleed Cooling
F&B-L	Failure to Provide Feed-and-Bleed Cooling During LOOP
MFW	Failure of the MFW System
OP-SBO	Operator Fails to Restore AC Power Before Steam Generator Dry out During a Station Blackout
RCSPRESS	Failure to Limit Reactor Coolant System Pressure to <3200 PSI
RT	Reactor Fails to Trip During Transient
RT-L	Reactor Fails to Trip During LOOP

Table B.10.5. Conditional Cut Sets for Higher Probability Sequences for LER No. 443/96-003

Cut set number	Percent contribution	CCDP <sup>a</sup>	Cut sets <sup>b</sup>
<b>LOOP Sequence 41</b>		2.6 E-005	
1	52.4	1.4 E-005	EPS-DGN-FC-1A, EPS-DGN-FC-1B, EPS-XHE-NOREC, EFW-TDP-FC-1A, EFW-XHE-NOREC-EP, OEP-XHE-NOREC-SB
2	47.6	1.2 E-005	EPS-DGN-CF-ALL, EPS-XHE-NOREC, EFW-TDP-FC-1A, EFW-XHE-NOREC-EP, OEP-XHE-NOREC-SB
<b>LOOP Sequence 17</b>		1.0 E-005	
1	13.2	1.3 E-006	EFW-TDP-FC-1A, EFW-PMP-CF-EFW, EFW-XHE-XM-BRKR, EFW-XHE-NOREC-L, HPI-XHE-XM-FBL
2	9.5	9.4 E-007	EPS-DGN-FC-1A, /EPS-DGN-FC-1B, EFW-TDP-FC-1A, EFW-PMP-CF-EFW, EFW-XHE-NOREC-L, HPI-XHE-XM-FBL
3	8.3	8.3 E-007	EFW-TDP-FC-1A, EFW-PMP-CF-EFW, EFW-XHE-XM-BRKR, EFW-XHE-NOREC-L, PPR-SRV-CC-1
4	8.3	8.3 E-007	EFW-TDP-FC-1A, EFW-PMP-CF-EFW, EFW-XHE-XM-BRKR, EFW-XHE-NOREC-L, PPR-SRV-CC-2
5	6.0	6.0 E-007	/EPS-DGN-FC-1A, EPS-DGN-FC-1B, EFW-TDP-FC-1A, EFW-XHE-XM-BRKR, EFW-XHE-NOREC-L, HPI-XHE-XM-FBL
6	6.0	5.9 E-007	EPS-DGN-FC-1A, /EPS-DGN-FC-1B, EFW-TDP-FC-1A, EFW-PMP-CF-EFW, EFW-XHE-NOREC-L, PPR-SRV-CC-2
7	6.0	5.9 E-007	EPS-DGN-FC-1A, /EPS-DGN-FC-1B, EFW-TDP-FC-1A, EFW-PMP-CF-EFW, EFW-XHE-NOREC-L, PPR-SRV-CC-1
8	5.0	4.9 E-007	EFW-TDP-FC-1A, EFW-PMP-CF-EFW, EFW-MDP-FC-SFP, EFW-XHE-NOREC-L, HPI-XHE-XM-FBL
9	3.8	3.8 E-007	/EPS-DGN-FC-1A, EPS-DGN-FC-1B, EFW-TDP-FC-1A, EFW-XHE-XM-BRKR, EFW-XHE-NOREC-L, PPR-SRV-CC-1
10	3.8	3.8 E-007	/EPS-DGN-FC-1A, EPS-DGN-FC-1B, EFW-TDP-FC-1A, EFW-XHE-XM-BRKR, EFW-XHE-NOREC-L, PPR-SRV-CC-2
11	3.1	3.1 E-007	EFW-TDP-FC-1A, EFW-PMP-CF-EFW, EFW-MDP-FC-SFP, EFW-XHE-NOREC-L, PPR-SRV-CC-1
12	3.1	3.1 E-007	EFW-TDP-FC-1A, EFW-PMP-CF-EFW, EFW-MDP-FC-SFP, EFW-XHE-NOREC-L, PPR-SRV-CC-2
13	3.1	3.1 E-007	EPS-DGN-FC-1A, /EPS-DGN-FC-1B, EFW-TDP-FC-1A, EFW-PMP-CF-EFW, EFW-XHE-NOREC-L, HPI-MDP-FC-1B, HPI-XHE-NOREC-L

**Table B.10.5. Conditional Cut Sets for Higher Probability Sequences for  
LER No. 443/96-003 (Continued)**

Cut set number	Percent contribution	CCDP <sup>a</sup>	Cut sets <sup>b</sup>
<b>TRANS Sequence 21-8</b>		5.1 E-006	
1	70.2	3.6 E-006	RPS-NONREC, EFW-TDP-FC-1A, EFW-PMP-CF-EFW, EFW-XHE-NREC-ATW
2	16.8	8.6 E-007	RPS-NONREC, EFW-TDP-FC-1A, EFW-MDP-FC-SFP, EFW-XHE-NREC-ATW
3	7.9	4.1 E-007	RPS-NONREC, EFW-TDP-FC-1A, EFW-XHE-XM-SFP, EFW-XHE-NREC-ATW
4	3.1	1.6 E-007	RPS-NONREC, EFW-TDP-FC-1A, EFW-MDP-FC-1B, EFW-XHE-NREC-ATW
5	1.4	7.2 E-008	RPS-REC, RPS-XHE-XM SCRAM, EFW-TDP-FC-1A, EFW-PMP-CF-EFW, EFW-XHE-NREC-ATW
<b>TRANS Sequence 20</b>		2.3 E-006	
1	28.7	6.7 E-007	EFW-TDP-FC-1A, EFW-PMP-CF-EFW, EFW-MDP-FC-SFP, EFW-XHE-NOREC, MFW-SYS-TRIP, MFW-XHE-NOREC, HPI-XHE-XM-FB
2	18.1	4.2 E-007	EFW-TDP-FC-1A, EFW-PMP-CF-EFW, EFW-MDP-FC-SFP, EFW-XHE-NOREC, MFW-SYS-TRIP, MFW-XHE-NOREC, PPR-SRV-CC-2
3	18.1	4.2 E-007	EFW-TDP-FC-1A, EFW-PMP-CF-EFW, EFW-MDP-FC-SFP, EFW-XHE-NOREC, MFW-SYS-TRIP, MFW-XHE-NOREC, PPR-SRV-CC-1
4	13.6	3.2 E-007	EFW-TDP-FC-1A, EFW-PMP-CF-EFW, EFW-XHE-XM-SFP, EFW-XHE-NOREC, MFW-SYS-TRIP, MFW-XHE-NOREC, HPI-XHE-XM-FB
5	8.6	2.0 E-007	EFW-TDP-FC-1A, EFW-PMP-CF-EFW, EFW-XHE-XM-SFP, EFW-XHE-NOREC, MFW-SYS-TRIP, MFW-XHE-NOREC, PPR-SRV-CC-2
6	8.6	2.0 E-007	EFW-TDP-FC-1A, EFW-PMP-CF-EFW, EFW-XHE-XM-SFP, EFW-XHE-NOREC, MFW-SYS-TRIP, MFW-XHE-NOREC, PPR-SRV-CC-1
7	1.3	3.0 E-008	EFW-TDP-FC-1A, EFW-MDP-FC-1B, EFW-MDP-FC-SFP, EFW-XHE-NOREC, MFW-SYS-TRIP, MFW-XHE-NOREC, HPI-XHE-XM-FB

**Table B.10.5. Conditional Cut Sets for Higher Probability Sequences for  
LER No. 443/96-003 (Continued)**

Cut set number	Percent contribution	CCDP <sup>a</sup>	Cut sets <sup>b</sup>
<b>LOOP Sequence 40</b>		2.0 E-006	
1	23.0	4.7 E-007	EPS-DGN-FC-1A, EPS-DGN-FC-1B, EPS-XHE-NOREC, EFW-TDP-FC-1A, EFW-XHE-NOREC-EP, HPI-XHE-XM-FBL
2	20.9	4.3 E-007	EPS-DGN-CF-ALL, EPS-XHE-NOREC, EFW-TDP-FC-1A, EFW-XHE-NOREC-EP, HPI-XHE-XM-FBL
3	14.5	3.0 E-007	EPS-DGN-FC-1A, EPS-DGN-FC-1B, EPS-XHE-NOREC, EFW-TDP-FC-1A, EFW-XHE-NOREC-EP, PPR-SRV-CC-1
4	14.5	3.0 E-007	EPS-DGN-FC-1A, EPS-DGN-FC-1B, EPS-XHE-NOREC, EFW-TDP-FC-1A, EFW-XHE-NOREC-EP, PPR-SRV-CC-2
5	13.2	2.7 E-007	EPS-DGN-CF-ALL, EPS-XHE-NOREC, EFW-TDP-FC-1A, EFW-XHE-NOREC-EP, PPR-SRV-CC-1
6	13.2	2.7 E-007	EPS-DGN-CF-ALL, EPS-XHE-NOREC, EFW-TDP-FC-1A, EFW-XHE-NOREC-EP, PPR-SRV-CC-2
<b>Total (all sequences)</b>		<b>7.6 E-005</b>	

<sup>a</sup>The CCDP 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  $\lambda t$ , where  $\lambda$  is the frequency of the initiating event (given on a per-hour basis), and  $t$  is the duration time of the event (3,875 h). This approximation is conservative for precursors made visible by the initiating event. The frequencies of interest for this event are  $\lambda_{\text{TRANS}} = 5.3 \times 10^{-4}/\text{h}$ ,  $\lambda_{\text{LOOP}} = 8.6 \times 10^{-6}/\text{h}$ . The importance is determined by subtracting the CDP for the same period but with plant equipment assumed to be operating nominally.

<sup>b</sup>Basic events EFW-TDP-FC-1A and EFW-XHE-NOREC-EP are type TRUE events. These type of events are not normally included in the output of the fault tree reduction process but have been added to aid in understanding the sequences to potential core damage associated with the event.