## B.7 LER No. 370/96-002

Event Description: 2B EDG inoperable due to slow instrumentation response

Date of Event: March 6, 1996

Plant: McGuire Unit 2

### B.7.1 Event Summary

McGuire Unit 2 was at 100% power when the 2B Emergency Diesel Generator (EDG), which was undergoing a scheduled operating test, tripped on a false low lube oil pressure signal shortly after starting.[1] The test failure was the result of air entrainment into the instrument line for the lube oil piping combined with low room temperature. Personnel determined that these conditions (air ingress and cold room temperature), which were deemed sufficient to cause the 2B EDG to trip, existed for a combined total of 540 h. (The 540-h total was distributed over four separate occasions where the 72-h single EDG outage allowed by Technical Specifications was exceeded.) This long-term unavailability of the 2B EDG could have affected the unit's response to a loss of offsite power (LOOP). The estimated increase in the core damage probability (CDP) over the 540-h period for this event (i.e., the importance) is $1.8 \times 10^{-6}$. The base probability of core damage (the CDP) for the same period is $1.2 \times 10^{-6}$.

### B.7.2 Event Description

Unit 2 was at 100% power on February 6, 1996. The 2B EDG was scheduled for a non-prelubricated start test. The 2B EDG reached 95% of rated speed in 9 s.[2] The 2B EDG tripped on a low lube oil pressure signal 30 s later (39 s after starting the EDG). Indicated pressure was 0.10–0.14 MPa (15–20 psig) and decreasing; normal operating pressure is 0.28 MPa (40 psig). However, personnel determined that the low lube oil pressure indication was false. The low pressure indication resulted from a slow instrument response due to air entrainment in the instrument line for the lube oil piping, coupled with the low EDG room temperature. (An inadequate design of the instrument lines allowed for air to be introduced into the system. The lube oil pressure switch impulse line for the 2B EDG is ~21.3 m (70 ft) long. The licensee indicated in the LER that this length is excessive.) The cool EDG room temperature added to the slow instrument response by increasing the viscosity of the oil in the instrument line. Because the low lube oil pressure trip signal is not bypassed on an emergency start of the EDGs, the failure was classified as a valid test failure.

The lowest recorded EDG room temperature in the 7 d preceding the EDG failure to start was 16.7°C (62°F). EDG room temperature was 20°C (68°F) just before the test. On March 6, 1996, the licensee determined that the 2B EDG should be considered inoperable with the current instrument line configuration when the EDG room temperature is < 71°F and the before and after (B&A) lube oil pump is not running. Based on these criteria, all other station EDGs were determined to be operable at the time the 2B EDG failed its operating test. Based on a review of the log books containing the EDG room temperature readings, the licensee calculated that the 2B EDG was susceptible to this type of failure for a total of 666 h. Because the B&A lube oil pump runs for 15 min during each hour, the licensee estimated that the 2B EDG was susceptible to this

type of failure only 75% of the time–a total of 499.5 h. Nuclear Regulatory Commission (NRC) inspectors, in NRC Inspection Report 50-370/96-02,[2] noted that previous EDG trips occurred while the B&A lube oil pump was running. Therefore, the NRC inspectors discounted the assumption that running a B&A lube oil pump at the time of a start demand with the EDG room temperature below 21.7°C (71°F) would have prevented this type of failure of the EDG to start. The 2B EDG was susceptible to these failure conditions on numerous separate occasions through the winter (for a total of 666 h); however, there were only four occurrences of the potential failure conditions that exceeded the EDG Technical Specification Action Statement limit of 72 h. The NRC inspection report[2] tallied the total amount of time for the four occurrences that the room temperature dropped below 21.7°C (71°F) and determined that the four susceptibility periods totaled 540 h.

## B.7.3 Additional Event-Related Information

McGuire Nuclear Station maintains a Safe Shutdown Facility (SSF) designed to provide an alternate and independent means to achieve and maintain hot standby conditions.[3] The facility includes an EDG that can be used to operate a positive displacement pump to supply seal injection water to the reactor coolant pump (RCP) seals, preventing an RCP seal loss-of-coolant accident (LOCA). Credit for the SSF is included in the ASP models via a separate top event in the LOOP event tree.

The most important recovery action with respect to this condition assessment is the possibility of restoring ac power to Unit 2 from Unit 1 via a cross-tie, given a station blackout at Unit 2. Because procedures exist detailing this operation, it is considered a viable option. Recovery via the cross-tie is included as a basic event imbedded in several LOOP event fault trees.

There was a brief period (5.3 h) when both EDGs were technically out of service due to maintenance activities on Motor Control Center 1EMXH-1, which affected ventilation. The 2A EDG was functionally available and would have performed its design function. Technical Specifications allow both EDGs to be out of service for up to 8 h.

## B.7.4 Modeling Assumptions

Similar to the licensee's analysis of this event,[1] the failure probability of the 2B EDG was set to 1.0 (TRUE) for this condition assessment. The duration was set to 540 h per the NRC inspection report since previous EDG trips occurred while the B&A fuel oil pump was running. Sensitivity studies are examined for the total time (666 h) the 2B EDG was determined to meet the low temperature criteria and the discounted time (499.5 h) the 2B EDG was determined to be unavailable based on the hourly B&A pump operation.

The licensee suggested that if an actual failure to start occurred under circumstances similar to the conditions that existed since February 6, then a second start attempt would likely be successful.[1] Therefore, the emergency power nonrecovery probability (EPS-XHE-NOREC) was adjusted from 1.0 to 0.34, as shown in Table B.7.1, to reflect the fact that the equipment appeared recoverable and was accessible (Recovery Class 2).

The 2B EDG failure appears to be a failure mode unique to the physical setup of the lube oil pressure instrumentation lines on the 2B EDG. A similar failure of the 2A EDG was documented by special report 25 months earlier.[4] The length of time between events and, consequently, the number of successful surveillance tests between events indicates that the two failures were random rather than having any common-cause effects. Consequently, the common-cause failure probability for the EDGs was not adjusted from the nominal value of $1.1 \times 10^{-3}$ shown in Table B.7.1.

During the 5-h period that both EDGs were declared unavailable, the 2A EDG was functionally available and would have performed its design function. This 5-h period was not considered separately when calculating the increase in the CDP over the entire 540-h period because the importance (i.e., the increase in the CDP) is less than the ASP cut-off value of $1.0 \times 10^{-6}$.

Credit for the SSF at McGuire was accounted for by adding a fault tree at the SSF branch point in the LOOP event tree shown in Fig. B.7.1. The nominal probability of SSF failure is 0.36 based on information in the plant's *Individual Plant Examination*.[5] The nominal SSF failure probability is derived from the failure probabilities, listed in Table B.7.1, for the basic events *SSF EDG Fails* (SSF-DGN-FC-1), *Operator Fails to Start SSF EDG Within 10 Minutes* (SSF-XHE-XM-DGN), and *SSF Unavailable Due to Maintenance* (SSF-XHE-MAINT).

Additionally, ac power to the emergency buses was recoverable by implementing a cross-tie to Unit 1. Based on a telephone conversation with the licensee,[6] it was assumed that personnel could cross-tie the power buses at Unit 1 with the buses at Unit 2 in less than 1 h 50% of the time, and within 2 h 95% of the time. The recovery of power by implementing a cross-tie to Unit 1 was modeled by adding the basic event *Failure to Cross-Tie Emergency Power Within 90 Min* (OEP-XHE-XTIE) to the McGuire fault trees for failure to recover power before the core uncovering given an RCP seal LOCA (OP-SL) and before battery depletion given no seal LOCA (OP-BD). Failure to cross-tie to Unit 1 was modeled as a time-reliability correlation (TRC) as described in Ref. 7. The probability distribution for this TRC is lognormal, with an error factor of 2.0 based on the licensee time estimates.[6] The median response time of 60 min was assumed to include any delays in initiating the cross-tie procedure. Without power, a seal LOCA was assumed to occur after 60 min, and the core would begin to uncover in an additional 30 min. The probability of crew failure at 90 min, estimated using this TRC and response time, is 0.17.

The actions to man the SSF and to cross-tie emergency power were assumed to be independent for this analysis. This assumption would have to be confirmed for an event occurring outside the day shift because it is unknown if sufficient personnel would be available during the period between 5:00 p.m. and 8:00 a.m. to perform all the necessary actions in parallel.

## B.7.5 Analysis Results

The increase in the CDP (i.e., the importance) over a 540-h period for this event is $1.8 \times 10^{-6}$. This is an increase over the nominal CDP of $1.2 \times 10^{-6}$. The dominant core damage sequence for this event (sequence 41 on Fig. B.7.1) involves

- a postulated LOOP,

- a successful reactor trip,
- failure of emergency power, and
- failure of the auxiliary feedwater (AFW) system.

This sequence accounts for 38% of the total contribution to the increase in the CDP. Sequences 29 and 39 are similar, but LOOP sequence 39 involves a power-operated relief valve (PORV) lift and successful reclosure. Combined, these two sequences account for an additional 36% of the total contribution to the increase in the CDP (Table B.7.2). Core damage in these two sequences (29 and 39) is the result of a failure of the SSF and a resulting seal LOCA. Core damage results from battery depletion in two additional sequences (16% of the increase in the CDP) and results from a failure of a PORV to reclose in one other sequence (8% of the increase in the CDP).

The increase in the CDP over a 666-h period for this event is $2.2 \times 10^{-6}$ if the 2B EDG is assumed to be inoperable for the collective total time the 2B EDG room temperature was below 21.7°C (71°F) as reported by the licensee. This is an increase over the nominal CDP for 666 h of $1.5 \times 10^{-6}$. The dominant core damage sequence for this sensitivity case study is the same as it is for the 540-h analysis. Similarly, if a 499.5-h period is assumed (as the licensee contends is the most appropriate period when the operation of the B&A pump is considered), the increase in the CDP is $1.6 \times 10^{-6}$ over the nominal CDP for 499.5 h of $1.1 \times 10^{-6}$. These sensitivity studies show that there is not much difference with respect to the CDP between an unavailability of 499.5, 540, and 666 h.

Definitions and probabilities for selected basic events are shown in Table B.7.1. The conditional probabilities associated with the highest probability sequences are shown in Table B.7.2. Table B.7.3 lists the sequence logic associated with the sequences listed in Table B.7.2. Table B.7.4 describes the system names associated with the dominant sequences. Minimal cut sets associated with the dominant sequences are shown in Table B.7.5.

## B.7.6 References

1. LER 370/96-002, Rev. 0, "Past Inoperability of Emergency Diesel Generator 2B Due to Low Lube Oil Pressure Caused by Unanticipated Interaction of Systems and Components," March 29, 1996.

2. NRC Inspection Report No. 50-370/96-02, Inspection Conducted: March 11 – April 1, 1996.

3. *Final Safety Analysis Report*, McGuire Nuclear Station.

4. Duke Power Company, *Diesel Generator Special Report, McGuire Nuclear Station*, Special Report 94-01 (PIP 2-M94-0242), March 15, 1994.

5. McGuire Nuclear Station, *Individual Plant Examination*.

6. Conference call with McGuire licensing and probabilistic risk assessment staff, September 11, 1997.

7. E. M. Dougherty and J. R. Fragola, *Human Reliability Analysis*, John Wiley and Sons, New York, 1988.

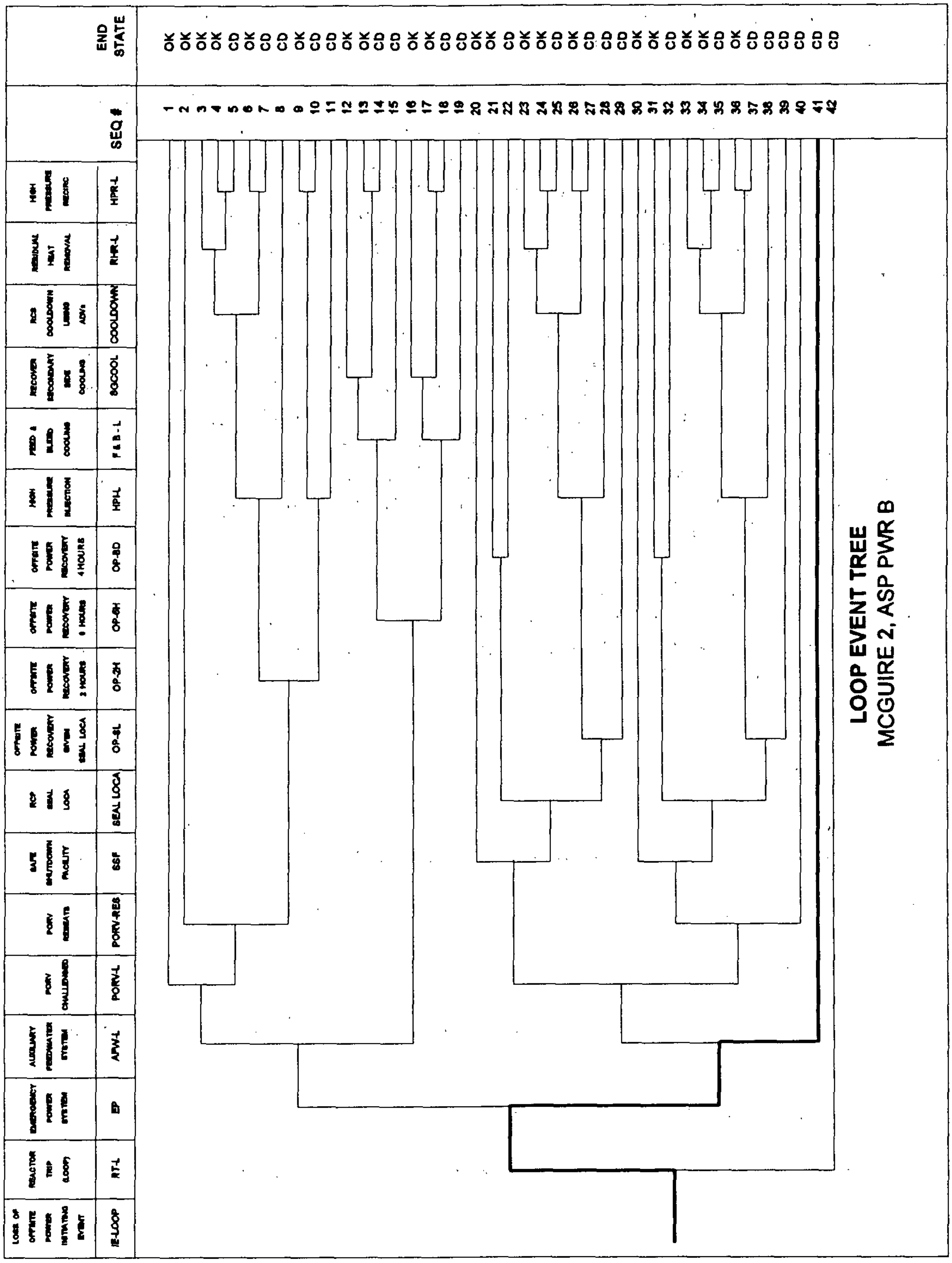


Fig. B.7.1. Dominant core damage sequence for LER No. 370/96-002.

**Table B.7.1. Definitions and Probabilities for Selected Basic Events for LER No. 370/96-002**

| Event name | Description | Base probability | Current probability | Type | Modified for this event |
|---|---|---|---|---|---|
| IE-LOOP | Initiating Event–LOOP | 9.3 E-006 | 9.3 E-006 | | No |
| IE-SGTR | Initiating Event–Steam Generator Tube Rupture | 1.6 E-006 | 1.6 E-006 | | No |
| IE-SLOCA | Initiating Event–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 |
| AFW-TDP-FC-1A | Turbine-Driven AFW Pump Fails | 3.2 E-002 | 3.2 E-002 | | No |
| AFW-XHE-NOREC-EP | Operator Fails to Recover AFW During a Station Blackout (SBO) | 3.4 E-001 | 3.4 E-001 | | No |
| EPS-DGN-CF-ALL | Common-Cause Failure of EDGs | 1.1 E-003 | 1.1 E-003 | | No |
| EPS-DGN-FC-1A | EDG A Fails | 4.2 E-002 | 4.2 E-002 | | No |
| EPS-DGN-FC-1B | EDG B Fails | 4.2 E-002 | 1.0 E+000 | TRUE | Yes |
| EPS-XHE-NOREC | Operator Fails to Recover Emergency Power | 1.0 E+000 | 3.4 E-001 | | Yes |
| OEP-XHE-NOREC-BD | Operator Fails to Recover Offsite Power Before Battery Depletion | 9.7 E-002 | 9.7 E-002 | | No |
| OEP-XHE-NOREC-SL | Operator Fails to Recover Offsite Power During a Seal LOCA | 7.4 E-001 | 7.4 E-001 | | No |
| OEP-XHE-XTIE | Failure to Cross-Tie ac Power From the Opposite Unit | 1.7 E-001 | 1.7 E-001 | NEW | No |
| PPR-SRV-CO-SBO | PORVs Open During an SBO | 3.7 E-001 | 3.7 E-001 | | No |
| PPR-SRV-OO-PRV1 | PORV 1 Fails to Reclose | 2.0 E-003 | 2.0 E-003 | | No |
| PPR-SRV-OO-PRV2 | PORV 2 Fails to Reclose | 2.0 E-003 | 2.0 E-003 | | No |
| PPR-SRV-OO-PRV3 | PORV 3 Fails to Reclose | 2.0 E-003 | 2.0 E-003 | | No |
| RCS-MDP-LK-SEALS | RCP Seals Fail Without Cooling and Injection Water | 2.3 E-001 | 2.3 E-001 | | No |
| SSF-DGN-FC-1 | SSF EDG Fails | 2.0 E-001 | 2.0 E-001 | NEW | No |
| SSF-XHE-MAINT | SSF Unavailable Due to Maintenance | 6.1 E-002 | 6.1 E-002 | NEW | No |
| SSF-XHE-XM-DGN | Operator Fails to Start SSF EDG Within 10 Min | 1.0 E-001 | 1.0 E-001 | NEW | No |

**Table B.7.2. Sequence Conditional Probabilities for LER No. 370/96-002**

| Event tree name | Sequence number | Conditional core damage probability (CCDP) | Core damage probability (CDP) | Importance (CCDP-CDP) | Percent contribution[a] |
|---|---|---|---|---|---|
| LOOP | 41 | 8.0 E-007 | 1.2 E-007 | 6.7 E-007 | 38.3 |
| LOOP | 29 | 4.8 E-007 | 7.6 E-008 | 4.0 E-007 | 23.0 |
| LOOP | 39 | 2.8 E-007 | 4.4 E-008 | 2.3 E-007 | 13.4 |
| LOOP | 22 | 2.1 E-007 | 3.3 E-008 | 1.7 E-007 | 10.1 |
| LOOP | 40 | 1.6 E-007 | 2.5 E-008 | 1.3 E-007 | 7.7 |
| LOOP | 32 | 1.2 E-007 | 1.9 E-008 | 1.0 E-007 | 5.9 |
| **Total (all sequences)** | | **3.0 E-006** | **1.2 E-006** | **1.8 E-006** | |

[a]Percent contribution to the total importance.

Table B.7.3. Sequence Logic for Dominant Sequences for LER No. 370/96-002

| Event tree name | Sequence number | Logic |
|---|---|---|
| LOOP | 41 | /RT-L, EP, AFW-L-EP |
| LOOP | 29 | /RT-L, EP, /AFW-L-EP, /PORV-SBO, SSF, SEALLOCA, OP-SL |
| LOOP | 39 | /RT-L, EP, /AFW-L-EP, PORV-SBO, /PORV-EP, SSF, SEALLOCA, OP-SL |
| LOOP | 22 | /RT-L, EP, /AFW-L-EP, /PORV-SBO, SSF, /SEALLOCA, OP-BD |
| LOOP | 40 | /RT-L, EP, /AFW-L-EP, PORV-SBO, PORV-EP |
| LOOP | 32 | /RT-L, EP, /AFW-L-EP, PORV-SBO, /PORV-EP, SSF, /SEALLOCA, OP-BD |

Table B.7.4. System Names for LER No. 370/96-002

| System name | Logic |
|---|---|
| AFW-L-EP | No or Insufficient AFW Flow During a Station Blackout |
| EP | Failure of Both Trains of Emergency Power |
| OP-BD | Operator Fails to Recover Offsite Power Before Battery Depletion |
| OP-SL | Operator Fails to Recover Offsite Power During a Seal LOCA |
| PORV-EP | PORVs Fail to Reclose (No Electric Power) |
| PORV-SBO | PORVs Open During a Station Blackout |
| RT-L | Reactor Fails to Trip During a LOOP |
| SEALLOCA | RCP Seals Fail During a LOOP |
| SSF | Safe Shutdown Facility Failure |

Table B.7.5. Conditional Cut Sets for Higher Probability Sequences for LER No. 370/96-002

| Cut set number | Percent contribution | CCDP[a] | Cut sets[b] |
|---|---|---|---|
| LOOP Sequence 41 | | 8.0 E-007 | |
| 1 | 96.8 | 7.8 E-007 | EPS-DGN-FC-1A, EPS-DGN-FC-1B, EPS-XHE-NOREC, AFW-TDP-FC-1A, AFW-XHE-NOREC-EP |
| 2 | 2.6 | 2.0 E-008 | EPS-DGN-CF-ALL, EPS-XHE-NOREC, AFW-TDP-FC-1A, AFW-XHE-NOREC-EP |
| LOOP Sequence 29 | | 4.8 E-007 | |
| 1 | 53.9 | 2.6 E-007 | EPS-DGN-FC-1A, EPS-DGN-FC-1B, EPS-XHE-NOREC, /PPR-SRV-CO-SBO, SSF-DGN-FC-1, RCS-MDP-LK-SEALS, OEP-XHE-NOREC-SL, OEP-XHE-XTIE |
| 2 | 27.0 | 1.3 E-007 | EPS-DGN-FC-1A, EPS-DGN-FC-1B, EPS-XHE-NOREC, /PPR-SRV-CO-SBO, SSF-XHE-XM-DGN, RCS-MDP-LK-SEALS, OEP-XHE-NOREC-SL, OEP-XHE-XTIE |
| 3 | 16.5 | 8.0 E-008 | EPS-DGN-FC-1A, EPS-DGN-FC-1B, EPS-XHE-NOREC, /PPR-SRV-CO-SBO, SSF-XHE-MAINT, RCS-MDP-LK-SEALS, OEP-XHE-NOREC-SL, OEP-XHE-XTIE |
| LOOP Sequence 39 | | 2.8 E-007 | |
| 1 | 53.9 | 1.5 E-007 | EPS-DGN-FC-1A, EPS-DGN-FC-1B, EPS-XHE-NOREC, PPR-SRV-CO-SBO, SSF-DGN-FC-1, RCS-MDP-LK-SEALS, OEP-XHE-NOREC-SL, OEP-XHE-XTIE |
| 2 | 27.0 | 7.6 E-008 | EPS-DGN-FC-1A, EPS-DGN-FC-1B, EPS-XHE-NOREC, PPR-SRV-CO-SBO, SSF-XHE-XM-DGN, RCS-MDP-LK-SEALS, OEP-XHE-NOREC-SL, OEP-XHE-XTIE |
| 3 | 16.5 | 4.6 E-008 | EPS-DGN-FC-1A, EPS-DGN-FC-1B, EPS-XHE-NOREC, PPR-SRV-CO-SBO, SSF-XHE-MAINT, RCS-MDP-LK-SEALS, OEP-XHE-NOREC-SL, OEP-XHE-XTIE |
| LOOP Sequence 22 | | 2.1 E-007 | |
| 1 | 53.9 | 1.1 E-007 | EPS-DGN-FC-1A, EPS-DGN-FC-1B, EPS-XHE-NOREC, /PPR-SRV-CO-SBO, SSF-DGN-FC-1, /RCS-MDP-LK-SEALS, OEP-XHE-NOREC-BD, OEP-XHE-XTIE |
| 2 | 27.0 | 5.7 E-008 | EPS-DGN-FC-1A, EPS-DGN-FC-1B, EPS-XHE-NOREC, /PPR-SRV-CO-SBO, SSF-XHE-XM-DGN, /RCS-MDP-LK-SEALS, OEP-XHE-NOREC-BD, OEP-XHE-XTIE |

**Table B.7.5. Conditional Cut Sets for Higher Probability Sequences for LER No. 370/96-002 (Continued)**

| Cut set number | Percent contribution | CCDP[a] | Cut sets[b] |
|---|---|---|---|
| 3 | 16.5 | 3.5 E-008 | EPS-DGN-FC-1A, EPS-DGN-FC-1B, EPS-XHE-NOREC, /PPR-SRV-CO-SBO, SSF-XHE-MAINT, /RCS-MDP-LK-SEALS, OEP-XHE-NOREC-BD, OEP-XHE-XTIE |
| LOOP Sequence 40 | | 1.6 E-007 | |
| 1 | 32.5 | 5.3 E-008 | EPS-DGN-FC-1A, EPS-DGN-FC-1B, EPS-XHE-NOREC, PPR-SRV-CO-SBO, PPR-SRV-OO-PRV1 |
| 2 | 32.5 | 5.3 E-008 | EPS-DGN-FC-1A, EPS-DGN-FC-1B, EPS-XHE-NOREC, PPR-SRV-CO-SBO, PPR-SRV-OO-PRV2 |
| 3 | 32.5 | 5.3 E-008 | EPS-DGN-FC-1A, EPS-DGN-FC-1B, EPS-XHE-NOREC, PPR-SRV-CO-SBO, PPR-SRV-OO-PRV3 |
| LOOP Sequence 32 | | 1.2 E-007 | |
| 1 | 32.5 | 6.7 E-008 | EPS-DGN-FC-1A, EPS-DGN-FC-1B, EPS-XHE-NOREC, PPR-SRV-CO-SBO, SSF-DGN-FC-1, /RCS-MDP-LK-SEALS, OEP-XHE-NOREC-BD, OEP-XHE-XTIE |
| 2 | 32.5 | 3.3 E-008 | EPS-DGN-FC-1A, EPS-DGN-FC-1B, EPS-XHE-NOREC, PPR-SRV-CO-SBO, SSF-XHE-XM-DGN, /RCS-MDP-LK-SEALS, OEP-XHE-NOREC-BD, OEP-XHE-XTIE |
| 3 | 32.5 | 2.0 E-008 | EPS-DGN-FC-1A, EPS-DGN-FC-1B, EPS-XHE-NOREC, PPR-SRV-CO-SBO, SSF-XHE-MAINT, RCS-MDP-LK-SEALS, OEP-XHE-NOREC-SL, OEP-XHE-XTIE |
| **Total (all sequences)** | | **3.0 E-006** | |

[a]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 (540 h). This approximation is conservative for precursors made visible by the initiating event. The frequency of interest for this event is $\lambda_{LOOP} = 9.3 \times 10^{-6}$/h. The importance is determined by subtracting the CDP for the same period but with plant equipment assumed to be operating nominally.

[b]Basic event EPS-DGN-FC-1B is a type TRUE event. This type of event is not normally included in the output of the fault tree reduction process but has been added to aid in understanding the sequences to potential core damage associated with the event.