Final Precursor Analysis

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

Salem, Unit 2	4160 Vac switchgear rooms did not reach or maintain the required CO_2 concentration of 50% for Fire Suppression	
Date: 2/14/2000	**IR:** 50-311/99-10	ΔCDP = 1×10^{-6}

Condition Summary

Description On December 7, 1999, the NRC completed an inspection of selected areas of the Salem fire protection system. The team identified that the carbon dioxide (CO_2) concentration for the Unit 2 4160 Vac switchgear room did not reach or maintain the required CO_2 concentration of 50 percent during testing (Ref. 1). The CO_2 system also did not meet its design requirement, as stated in the final safety analysis report, which requires the CO_2 tanks to contain a sufficient supply of CO_2 for two full discharges into the largest protected areas. The installed tank was found to be only half full. This condition placed the CO_2 system in a degraded condition such that the system may not have been fully effective in extinguishing fires.

Duration The CO_2 system was in a degraded condition since the original construction in the 1970s. For the purposes of the Accident Sequence Precursor (ASP) analysis, this condition was modeled for a maximum period of one year.

Recovery Opportunity. Within the switchgear room, the 1B and 1C divisions of ac power are assumed failed with no recovery.

Analysis Results

- **Importance**[1]

  The risk significance of the CO_2 system being degraded and not effective, resulting in Division 1B and Division 1C 4160Vac power failing due to a postulated fire is determined by subtracting the nominal core damage probability from the conditional core damage probability for the point estimate $\Delta CDP = 1.5 \times 10^{-6}$ and a mean $\Delta CDP = 1.0 \times 10^{-6}$. This is an mean increase of 1.0×10^{-6} over the nominal CDP for the one year period where the Division 1B and Division 1C 4160Vac power was not available due to a postulated switchgear room fire. The uncertainty about the mean is: 5% bound, 9.4×10^{-9} and the 95% bound, 4.1×10^{-6}(see Figure 3).

  NOTE:

  The case where the fire does not propagate from Division 1B to Division 1C within the switchgear room was screened out, as the ΔCDP was less than the Accident Sequence Precursor (ASP) program acceptance threshold importance (ΔCDP) of 1×10^{-6}.

- **Dominant sequence**

  The initiating event is a postulated fire in the 4160V ac switchgear room. The dominant core damage sequence for this condition is Fire-Induced Transient – Sequence 20. The events and important component failures in this sequence (see Figure 2) include:

  – Reactor trips successfully
  – Failure of AFW
  – Failure of Main Feedwater system during transient
  – Successful bleed portion of feed and bleed
  – Failure of HPI system flow, resulting in core damage.

- **Results tables**

  – Table 1 provides the conditional probabilities for the dominant sequence.
  – Table 2a provides the event tree sequence logic for the dominant sequence.
  – Table 2b defines the event tree sequence logic elements listed in Table 2a.
  – Table 3 provides the conditional cut sets for the dominant sequence.
  – Table 4 provides the definitions and probabilities for modified and dominant basic events.

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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 increase 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 increase 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 cases where the nominal CDP is high with respect to the incremental increase of the conditional probability caused by the hardware unavailability.

Modeling Assumptions

- **Assessment Summary**

  The risk significance of the Division 1B and 1C 4160Vac cabinets/equipment is determined by performing an initiating event assessment using the revision 3.02 model for Salem with the transient initiating frequency replaced with the product of the switchgear room initiating fire frequency and the probability of nonsuppression. The current probability of basic events that are assumed failed (TRUE) are used in the analysis. This method is outlined in NUREG/CR-6544, "Development of a Methodology for Analyzing Precursors for Earthquake-Induced or Fire-Induced Accident Sequences," Section 3.7 (Ref. 2). For the case used in this analysis, the fire is assumed to propagate from Division 1B to Division 1C,

  The postulated fire in the 4160Vac switchgear room is assumed to fail both Division 1B and 1C electrical cabinets/equipment without recovery. However the fire is not assumed to propagate to Division 1A electrical cabinets/equipment because there are no cable/cable trays that traverse between the 1B/1C and 1A divisions (The case of a fire in Division 1A alone was determined to be of lower risk significance), adequate distance separation(approximately 20 feet between divisions), and no other basis for assuming propagation (see Fig. 1).

- **SPAR model used in the analysis**

  Revision 3.02 Standardized Plant Analysis Risk (SPAR) model for Salem Units 1 and 2 (Ref. 3) was used for this assessment. The transient initiating event (IE-TRANS) frequency is replaced (see below for details of fire-induced analysis considerations).

- **Fire induced analysis considerations**

  The fire-induced analysis is based on NUREG/CR-6544 (Ref. 2). For this analysis all 4160Vac Division 1B and Division 1C equipment is assumed failed and the product of the initiating fire frequency for the plant location (switchgear room) and the probability of nonsuppression replaced the transient initiating event frequency in the fire-induced initiating event assessment.

  – **Initiating Fire Frequency** – The initiating fire frequency (F_i) was developed from NRC Report RES/OERAB/S02-01 power operation fire event data for severe fires (fires with duration greater than 5 minutes that were not self-extinguished) in the Switchgear Room during the 1986–1999 period (Ref. 4) and updated with 2000-2001 fire data. For the Salem 2 switchgear room, the fire frequency (F_i) used was 3.2×10^{-3} based on the following:

Two switchgear room fire zones are assumed for this analysis: one for 4160 Vac divisions B and C and one for 4160 Vac division A.

$$F_i = \frac{\text{(No. of Severe Fire Events + Jeffreys Prior of 0.5 Fire Events)}}{\text{(No. of Switchgear Rooms x No. of Power Operation Reactor-Years)}}$$

$$F_i = \frac{(8 + 0.5)}{(2 \times 1311)} = \underline{3.2 \times 10^{-6}}$$

– **Probability of nonsuppression** – The assumption is that the fire will propagate between Division 1B and 1C, but not to Division 1A (see Assessment Summary, above).. Therefore, for this assumption, the probability of nonsuppression = 1.0.

- **Unique system and operational considerations**

All three divisions of the 4160 Vac switchgear are located in the 4160 Vac switchgear room (Fig. 1). Design characteristics include:

- The switchgear 4160Vac divisions are separated from each other by partial height, partial length marinite walls (Fig. 1). These walls form radiant heat shields and are not rated 1-hour fire barriers (Ref. 1.).

- Fire protection in the area is provided by a manually actuated CO_2 fire suppression system, smoke detectors, manual hose stations, and portable fire extinguishers. The room is accessible at opposite ends.

- Overhead cable trays associated with 4160 Vac divisions 1B and 1C are located in close proximity of each other. There are no intervening overhead cables and there is adequate distance separation between 1B/1C and 1A (Fig. 1).

- The 4160 Vac division 1A provides power to one train of safety systems, with the exception of intermediate pressure safety injection/CVCS pumps. These pumps are powered from 4160 Vac divisions 1B and1C. Reactor coolant pump seal cooling is accomplished by either the chemical and volume control system (CVCS) or the component cooling water system.

- **Modifications to event tree and fault tree models**

None

- **Initiating event frequency changes**

The transient initiating event (IE-TRANS) frequency was replaced by the product of the initiating fire frequency for the Switchgear Room and the probability of nonsuppression [$(3.2 \times 10^{-3}) \times 1.0 = 3.2 \times 10$-3]. Figure 2 shows the event tree for the fire-induced transient.

NOTE: Since the postulated fire is in the switchgear room (applicable to a transient), no other initiating event is considered as applicable to this analysis (Ref. 2 provides this basis for replacing IE-TRANS only).

- **Basic event probability changes**

  Table 4 provides the basic events that were modified to reflect the condition being analyzed.

  – **Division 1B AC power 4160 V bus fails (ACP-BAC-LP-1B) and Division 1C AC power 4160 V bus fails (ACP-BAC-LP-1C**). These basic events were set to "TRUE" (i.e., 1.0 failure probability) to reflect the worst case fire damage state due to the propagation of fire between the two electrical divisions via the cable trays.

  – **IE TRANS.** The transient initiating event was set to the product of the initiating fire frequency and the probability of nonsuppression (3.2×10^{-3}) to reflect the worst case fire damage state due to the propagation of fire between the two electrical divisions (B and C) via the cable trays.

  NOTE: For this analysis, IE FIRE replaces IE TRANS (see Fig. 2).

- **Model update**

  No updates were made to the revision 3.02 SPAR model for Salem.

  NOTE:
  The analysis assumes that high temperature seals were installed on all RCPs at the time of the event. For this analysis, the RCP seal LOCA is not applicable.

References

1. NRC Inspection Report, 272/1999-010, 311/1999-010, *Salem Generating Station - Final Significance Determination and Notice of Violation*, February 14, 2000 (ADAMS Accession Number: ML003683723).

2. R.W.Budnitz, et al., Development of a Met*hodology for Analyzing Precursors to Earthquake-Induced and Fire-Induced Accident Precursors,* NUREG/CR-6544, U.S. Nuclear Regulatory Commission, Washington, DC, April 1998.

3. J. K. Knudsen, et al., *Simplified Plant Analysis Risk (SPAR) Model for Salem Unit 1 & 2, Revision 2QA*, Idaho National Engineering and Environmental Laboratory, December 1997.

4. J.R. Houghton and D. M. Rasmuson, NRC Report RES/OERAB/S02-01, Fire Events — Update of U.S. Operating Experience, 1986–1999, U.S. Nuclear Regulatory Commission, Washington, DC, January 2002.

5. J. P. Poloski, et al., *Rates of Initiating Event at U.S. Nuclear Power Plants: 1987-1995*, NUREG/CR-5750, U.S. Nuclear Regulatory Commission, Washington, DC, February 1999.

6. C. L. Atwood, et al., *Evaluation of Loss of Offsite Power Events at Nuclear Power Plants: 1980-1996*, NUREG/CR-5496, U.S. Nuclear Regulatory Commission, Washington, DC November 1998.

7. J. P. Poloski, et al., *Reliability Study: Auxiliary Feedwater System,1987-1995*, NUREG/CR-5500, Vol. 1, U.S. Nuclear Regulatory Commission, Washington, DC, August 1998.

8. F. M. Marshall, et al., *Common-Cause Failure Parameter Estimations*, NUREG/CR-5497, U.S. Regulatory Commission, Washington, DC, October 1998.

9. G. M. Grant, et al., *Reliability Study: Emergency Diesel Generator Power System, 1987-1993*, NUREG/CR-5500, Vol. 5, U.S. Nuclear Regulatory Commission, Washington, DC, September 1999.

9. Public Service Electric and Gas company, *Salem Generating Station Individual Plant Examination for External Events,* January 1996.

Table 1. Conditional Probability of Dominating Sequences (Point Estimates)

Event Tree	Sequence	Conditional Core Damage probability (CCDP)
TRANS	20	6.5E-07
TOTAL	**All Sequences**	**1.5E-06**

Table 2a Event tree sequence logic for dominant sequence

Event Tree Name	Sequence no.	Logic (“/” denotes success; see Table 2b. for top event names
TRANS	20	/RT, AFW, MFW-T, /BLEEDS, HPI

Table 2b. Definitions of event tree sequence logic elements listed in Table 2a.

AFW	No or insufficient AFW flow
BLEED	Failure of Bleed portion of Bleed cooling
HPI	No or insufficient flow from HPI system
MFW-T	Failure of main feedwater system during transient
RT	Reactor fails to trip during transient

Table 3. Conditional cut sets for dominant sequence
Event tree: TRANS, Sequence 20

CCDP	Percent Contribution	Minimum cut sets[1]
9.8E-008/hr	15.0	MFW-XHE-NOREC MFW-SYS-UNAVAIL AFW-TDP-FR-13 SWS-MDP-TM-1SWE5
9.8E-008/hr	15.0	MFW-XHE-NOREC MFW-SYS-UNAVAIL AFW-TDP-FR-13 SWS-MDP-TM-1SWE6
7.8E-006/hr	12.0	MFW-SYS-TRIP MFW-XHE-ERROR AFW-TDP-FR-13 SWS-MDP-TM-1SWE5
7.8E-006/hr	12.0	MFW-SYS-TRIP MFW-XHE-ERROR AFW-TDP-FR-13 SWS-MDP-TM-1SWE6
6.5-007/hr	**Total[2]**	

NOTES:
1. See Table 4 for definitions and probabilities for the basoc events.
2. Total CCDP includes all other cut sets for this sequence (including those not shown in this table).

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

Event name	Description	Probability/ Frequency	Modified
IE-LOOP	LOSS OF OFFSITE POWER INITIATING EVENT	0.00	YES[1]
IE-SGTR	STEAM GENERATOR TUBE RAPTURE INIT. EVENT	0.00	YES[1]
IE-LDCA	LOSS OF DC BUS A INITIATING EVENT	0.00	YES[1]
IE-LOA	LOSS OF INSTRUMENT AIR INITIATING EVENT	0.00	YES[1]
IE-LLOSA	LARGE LOSS OF COOLANT ACCIDENT INIT. EVENT	0.00	YES[1]
IE-MLOCA	MEDIUM LOSS OF COOLANT ACCIDENT INIT. EVENT	0.00	YES[1]
IE-SLOCA	SMALL BREAK LOSS OF COOLANT ACCIDENT INIT. EVENT	0.00	YES[1]
IE-LOCCW	LOSS OF COMPONENT COOLING WATER INIT. EVENT	0.00	YES[1]
IE-LOSWS	LOSS OF SERVICE WATER INITIATING EVENT	0.00	YES[1]
IE-RHR-DIS-V	RHR DISCHARGE ISLOCA OCCURS INITIATING EVENT	0.00	YES[1]
IE-RHR-HL-V	RHR HOT LEG ISLOCA INITIATING EVENT	0.00	YES[1]
IE-RHR-SUC-V	RHR SUCTION ISLOCA INITIATING EVENT	0.00	YES[1]
IE-SI-CLDIS-V	SI COLD LEG ISLOCA INITIATING EVENT	0.00	YES[1]
IE-SI-HLDIS-V	SI HOT LEG ISLOCA INITIATING EVENT	0.00	YES[1]
IE-TRAN	INITIATING EVENT-TRANSIENT (FIRE-INDUCED)	3.2E-03	YES[2]
ACP-BAC-LP-1B	DIVISION 1B AC POWER 4160 V BUS FAILS	TRUE	YES[3]
ACP-BAC-LP-1C	DIVISION 1C AC POWER 4160 V BUS FAILS	TRUE	YES[3]

Notes:

1. All initiating events, except IE-TRANS were set to 0.00.
2. Transient initiating event frequency was revised to reflect the product of the initiating fire frequency and the probability of nonsuppression.
3. Basic event was changed to reflect condition being analyzed. TRUE has a failure probability of 1.0.

Figure 1 Salem 2 4160 VAC switchgear Room Simplified Diagram

Figure removed during SUNSI review.

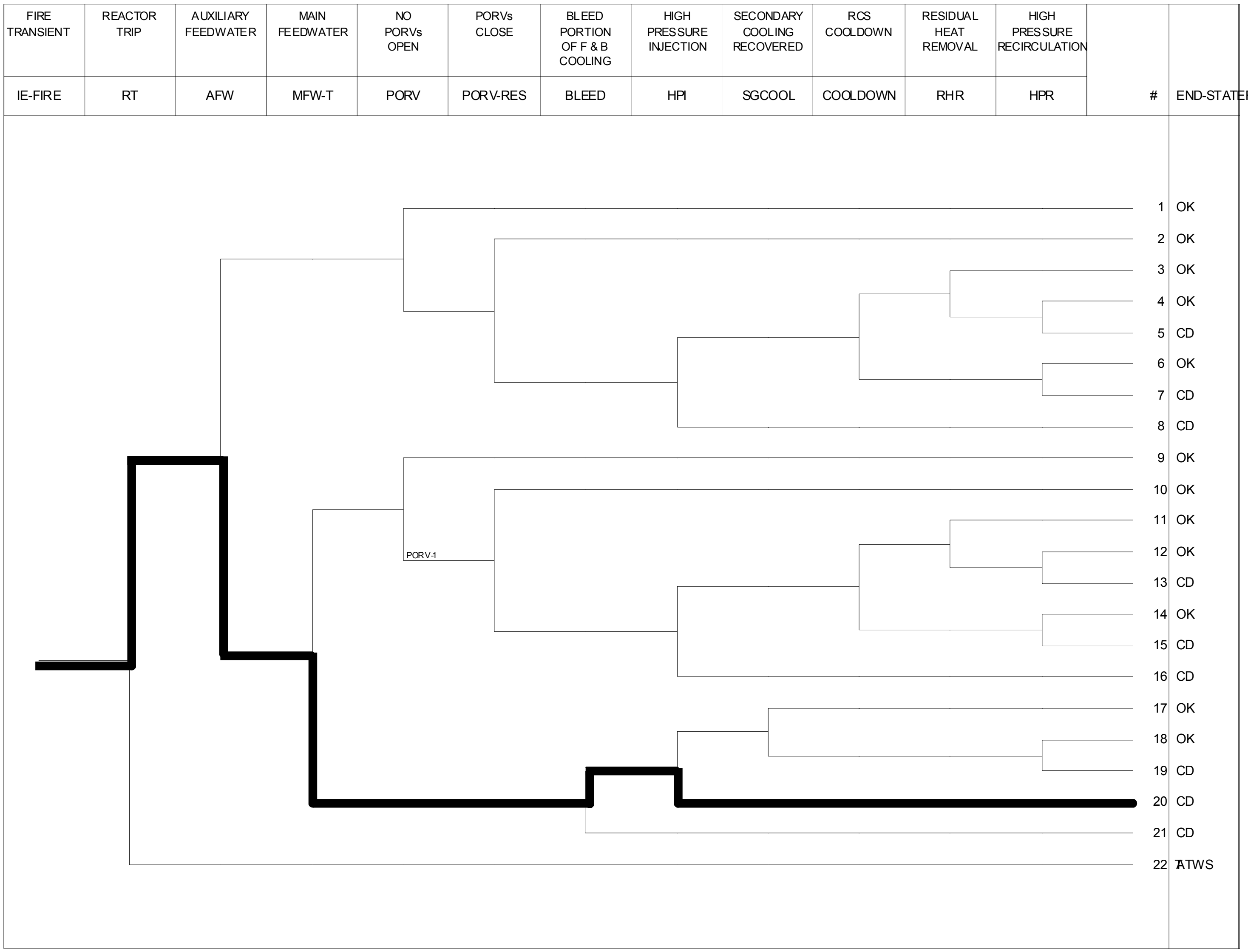

Figure 2 Fire-Induced Trans Sequence 20

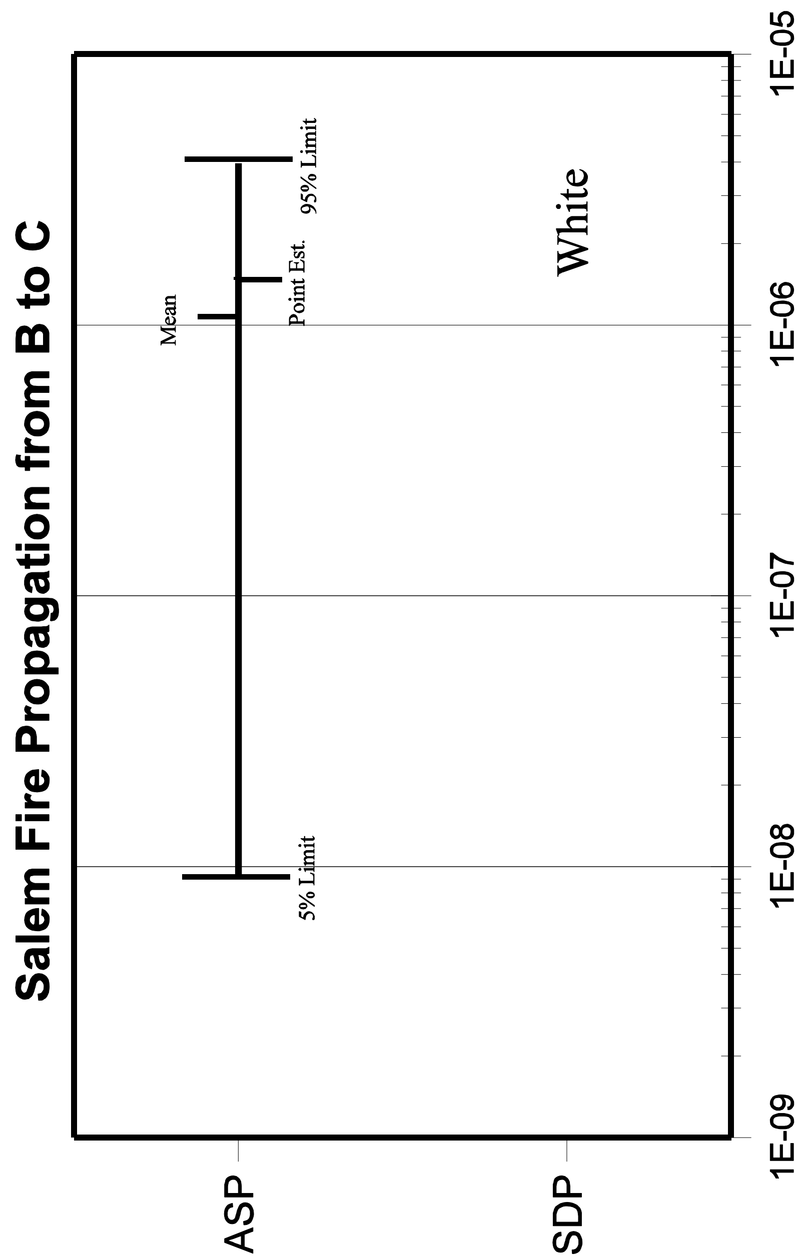

Figure 3 Uncertainty