ACCIDENT SEQUENCE PRECURSOR PROGRAM EVENT ANALYSIS

Note: The following is an initial assessment of an event that occurred at cold shutdown. Event sequences were developed based on procedures in place at the time of the event. Information concerning the event was taken from preliminary notifications, verbal communications, etc., and may have been revised in the LER that formally documented the event.

Revised cold shutdown models are currently being developed in support of another NRC program. The operational event described herein will be re-analyzed when the new models are available. At that time, information contained in documentation that was received after the performance of this analysis will also be addressed. Because of this, the following analysis should be considered PRELIMINARY.

LER No.:	387/90-005
Event Description:	Loss of RPS bus "B" causes loss of shutdown cooling
Date of Event:	February 3, 1990
Plant:	Susquehanna 1

Summary

A ground fault resulted in the loss of reactor protection system (RPS) bus "B". The RPS buses provide power to the isolation control system, and the deenergization of RPS bus "B" resulted in the isolation of a shutdown cooling suction supply valve causing a loss of shutdown cooling.

Core cooling was maintained using safety relief valves, control rod drive pumps, and the suppression pool cooling mode of residual heat removal (RHR). The conditional probability of subsequent core damage associated with the event is conservatively estimated to be 4.1×10^{-5}.

Event Description

Susquehanna 1 was shut down on February 1, 1990, for maintenance. Two days later a test of the alternate power supply to RPS bus "B" was conducted. When the normal power supply was deenergized, the alternate supply failed to close in on the bus. Manual closure of the normal and alternate supplies was attempted, but they immediately tripped open. Subsequent investigation revealed that an insulator on a circuit breaker fed by RPS bus "B" had developed a crack, which resulted in a ground fault on the bus.

The RPS system provides power to the isolation control system. Loss of power on RPS

bus "B" resulted in isolation of certain valves controlled by this system, including an RHR system shutdown cooling suction supply valve. With shutdown cooling lost, reactor water temperature began to rise. Operators stemmed the coolant temperature rise at 252°F and 31 psia by opening three safety relief valves (SRVs) and providing makeup from the control rod drive system. Suppression pool cooling was used to remove the heat transferred to the suppression pool by the SRVs.

The defective circuit breaker was replaced and RPS bus "B" was reenergized. This permitted a return to shutdown cooling.

Event-Related Plant Information

There are two RPS buses for each unit, each of which is normally fed by a high-inertia motor-generator (MG) set. The MG sets are fed from 480-V boards and generate 120-V AC. There are alternate 120-V AC sources that may feed the RPS buses, but these are interlocked to ensure that no more than one bus is fed from its alternate supply at any given time. Interlocks also exist to ensure that the MG sets are not paralleled with the alternate supplies.

In addition to providing power for the reactor protection system, the RPS buses provide power to the isolation control system. This system operates valves as required to isolate the reactor vessel and/or primary containment to conserve coolant inventory and prevent the release of radioactive materials. Loss of power to RPS bus "B" de-energizes all "B" train logic in the isolation control system and results in the isolation of the reactor water cleanup system (RWCU) and the shutdown cooling supply to the RHR system.

The normal shutdown cooling flow path is from recirculation loop B, through inboard and outboard containment isolation valves, to either of two pairs of RHR pumps and thence to either of two RHR heat exchangers, which are cooled by RHR service water. The cooled water is then returned to the reactor vessel through either "A" or "B" recirculation loop. Isolation of either shutdown cooling supply valve renders the shutdown cooling system inoperable and other means of decay heat removal must be provided when the unit is shut down.

Susquehanna's "Loss of RHR Shutdown Cooling Mode" procedure required that operators provide for natural or forced reactor coolant circulation within the vessel, that they demonstrate operability of alternate methods of decay heat removal using RHR/low-pressure coolant injection (LPCI) system and core spray system, and that they reestablish cooling by one of several methods. These methods involve control rod drive cooling (CRD), condensate transfer through keepful and/or shutdown cooling flush, condensate,

RHR, core spray, RWCU recirculation/letdown, and SRV blowdown.

ASP Modeling Assumptions and Approach

An event tree model of sequences to core damage given a total loss of shutdown cooling was developed considering the potential unavailability of mitigating features described in Susquehanna procedure ON-149-001, Rev. 7, "Loss of RHR Shutdown Cooling Mode." This event tree, shown in Fig. 1, addresses reactor pressure vessel (RPV) makeup via the control rod drive, condensate, core spray, or LPCI systems. Heat removal and letdown is via the SRVs [to the suppression pool (SP)] or the RWCU system. If the SRVs are used, then suppression pooling cooling is also assumed required. If the RWCU system is utilized, then the model assumes that the condensate system is required for makeup. Both this assumption and the requirement for short-term suppression pool cooling are most likely conservative, considering the shutdown decay heat levels that exist during cold shutdown.

Additional conservatism exists in that not all makeup/letdown combinations identified in ON-149-001 are included in the model.

Fig. 1 includes the following core damage sequences:

Sequence	Description
1	Successful use of the SRVs and SP cooling for heat removal, but failure to provided RPV makeup via the CRD, condensate, core spray, and LPCI systems.
2	Failure of SP cooling following successful opening of the SRVs. RWCU is successful, but makeup via the condensate system fails.
3	Failure of SP cooling following successful opening of the SRVs. RWCU fails to provide letdown/heat removal.
4	Similar to sequence 2 except the SRVs fail to open.
5	Similar to sequence 3 except the SRVs fail to open.

The following branch probability values were utilized with the event tree.

Branch	Failure Probability
Failure of at least three SRVs to open. The SRV/ADS failure probability estimated from precursor data was utilized, with a nonrecovery estimate of 0.12, to take into account the long time period available for repair.	4.4×10^{-4}
Failure of SP cooling. A failure probability of 2×10^{-3} was assumed (this value is also used in the current at-power ASP models), with a nonrecovery estimate of 0.12.	2.4×10^{-4}
Unavailability of RWCU. A failure probability of 0.05 was assumed. RWCU is isolated upon loss of RPS bus "B." The containment isolation signal must be unblocked or the RWCU isolation valve manually opened. The failure probability for this was assumed to be 0.04. In addition, a failure probability of 0.01 for the RWCU system itself was also assumed.	5.0×10^{-2}
Unavailability of CRD cooling. *	1.0×10^{-2}
Unavailability of makeup via the condensate system. A failure probability of 0.01 was assumed.	1.0×10^{-2}
Unavailability of core spray. *	1.0×10^{-3}
Unavailability of LPCI. Given SP cooling success, failure of LPCI involves failure to open the series RPV injection valves in both trains. A failure probability of 0.002 was assumed.	2.0×10^{-3}

*Value currently used with current ASP models.

Failure to implement the loss of SDC procedure has not been specifically addressed in Fig. 1. Based on the long estimated time to core uncovery (~16 h based on simplified hand calculations) and the 2-yr operator training cycle at Susquehanna, the likelihood of operator error is low, and equipment failure is assumed to dominate the core damage probability estimate.

Analysis Results

Based on the model described above, a core damage probability of 4.1×10^{-5} is estimated. Because of the long response times associated with shutdown-related events and the potential for system unavailabilities during shutdown because of allowed maintenance, the uncertainty in the core damage probability estimate is high.

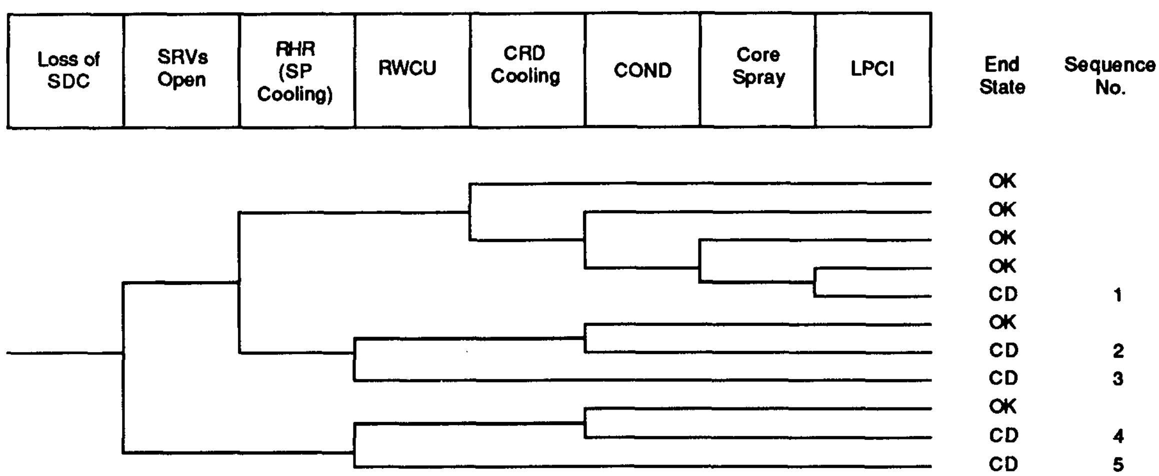

Fig. 1. Event Tree for Loss of Shutdown Cooling at Susquehanna 1 (LER 387/90-005)