ENCLOSURE 2

PLG Letter Report

EFFECTS OF CHANGING THE ALLOWED OUTAGE TIMES FOR VARIOUS EMERGENCY CORE COOLING SYSTEM COMPONENTS

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CONTENTS

1. INTRODUCTION

The purpose of this report is to present the effects of changing the allowed outage times (AOT) for components requiring maintenance in the emergency core cooling system (ECCS) at the Seabrook Nuclear Power Plant. The proposed changes involve Technical Specification 3.5.1.1, Accumulators (AOT increase from 1 hour to 8 hours), and Technical Specification 3.5.2, ECCS Subsystems (AOT increase from 72 hours to 7 days). The analysis examines the impact of these changes on system availability and on plant risk (core melt frequency).

Section 2 of this report describes the ECCS functions that have been quantified. Section 3 describes the base case equations that were developed in the Seabrook Station Probabilistic Safety Assessment (SSPSA). Section 4 describes the maintenance models used in this analysis, and Section 5 discusses the changes made to the maintenance models to evaluate the changes in AOT. Section 6 describes the data analysis that was done to support this study. Section 7 summarizes the results and lists the areas of conservatism. The Appendices contain the detailed results and systems equations.

2. ECCS FUNCTIONS QUANTIFIED

The ECCS subsystems are quantified by probabilistic methods similar to those used originally in the Seabrook Station Probabilistic Safety Assessment (SSPSA). The quantification is set up in a RISKMAN® format instead of the DPD format used in the initial assessment to allow the model to be inspected more easily. The equations for quantification, however, remain as originally defined in the system analysis (SSPSA, Appendix D.8), except for LLLPI and the boron injection tank (BIT) and BIT inlet valves as discussed below.

The ECCS functions, or top events, are analyzed under the boundary condition all support systems available. This limitation was made to simplify the analysis and is justified by the fact that the probability of occurrence of this boundary condition is much greater than for any other condition; e.g., electrical support unavailable. Of those top events with all support available, only those that have maintenance contributions are quantified; e.g., a function, such as cold-leg recirculation, is not considered because maintenance would not be scheduled during the recirculation phase. Hence, the following top events are quantified:

- Large LOCA - low pressure injection (LLLPI)
- Medium LOCA - high pressure injection (MLHPI)
- Medium LOCA - RHR miniflow recirculation (MLRHRM)
- Anticipated transient without scram (ATWS)
- Small LOCA - high pressure injection (SLHPI)
- Small LOCA - RHR miniflow recirculation (SLRHRM)

The top events are described in more detail in the system description (SSPSA, Appendix D.8) with the following changes:

- LLLPI is now broken down into two new top events in order to see directly the effect of maintenance on the accumulators. The two new top events are the accumulators (ACL), and LLLPI(new), where LLLPI(new) = LLLPI(old) - ACL.

- The boron injection tank (BIT) and BIT inlet valves are no longer in the system, and hence are no longer in the equations. This hardware change occurred after the SSPSA was published.

3. BASE CASE EQUATIONS

The new base case system equations, now in RISKMAN form, are defined in Appendix B. The common variables and data base variables are defined, with their means, in Appendix C. The results (in RISKMAN output form) of quantifying these equations are in Appendix D. The total for a top event is broken down into three or four categories of contributors: hardware, common cause, maintenance, and, when necessary, testing. Maintenance is further broken down, when possible, into its contributors. Also, hardware is further broken down into train (TRN) and block (BLK) contributors, as were defined in the functional diagrams of the system analysis. This detailed examination is done to assist in verification of the results.

The RISKMAN equations are written using variable names that serve as mnemonics so that the equations can be examined to understand how the system is modeled. For example, RHTRNA stands for RHR train A hardware contribution; RBLKA stands for RHR block A; PM stands for pump maintenance contribution; PSBR stands for the RHR pump start beta factor. The blocks refer to the reliability block diagram developed in the SSPSA. To understand what is modeled in each block, refer to the SSPSA.

Note that the RISKMAN equations are a convenient presentation of the system model but are not intended to stand alone. System descriptions, assumptions, boundary conditions, etc., are found in the SSPSA.

4. MAINTENANCE MODELS

4.1 ACCUMULATORS

The accumulators were modeled in the SSPSA system analysis as having an allowed outage time of 1 hour. The accumulator maintenance contributions were ignored in the original system analysis, however, due to the following two assumptions:

- o Significant maintenance could not be performed in the short time allowed; i.e., the AOT of 1 hour.
- o The effects of maintenance on accumulator unavailability would be insignificant when compared to other causes of failure.

In the new set of RISKMAN equations, a more detailed ACL model incorporates an accumulator maintenance contribution in order to evaluate the sensitivity of changes in AOT. The estimate of the frequency of accumulator maintenance is based upon a data review of accumulator licensee event reports (see Section 6). For the base case, this maintenance contribution is neglected and set to zero, as was done in the original analysis. For subsequent cases, the maintenance contribution is considered, with the maintenance duration conservatively assumed to be equal to the AOT.

The accumulator subsystem is modeled as being entirely unavailable during maintenance. This is conservative based on the following considerations. If the accumulator in maintenance happens to be on a cold leg which ruptures during a design basis accident (large LOCA), the accumulator system can still perform its function; i.e., three of the three accumulators discharge. This conservatism is not modeled in the accumulator analysis for this report.

4.2 ECCS SUBSYSTEMS

The other ECCS components that require maintenance were modeled in the original system analysis as follows:

- o The safety injection (SI) pumps, RHR pumps, and chemical and volume control system (CVCS) pumps were modeled as standby pumps tested monthly (mean frequency of maintenance is 8.42×10^{-5} per hour), with a 72-hour inoperability time limit (mean duration of 20.9 hours).
- o The refueling water storage tank (RWST) CVCS suction valves, the containment sump recirculation valves, and the BIT outlet valves were modeled as components requiring relatively infrequent maintenance (mean frequency of maintenance is 2.75×10^{-5} per hour) with a short duration outage time (mean duration of 10.8 hours).
- o The RHR heat exchanger (HEX) was modeled as a component requiring relatively infrequent maintenance (mean frequency of maintenance is 2.75×10^{-5} per hour) with a 72-hour inoperability time limit (mean duration of 20.9 hours).

The maintenance models and frequency distributions used in the original analysis are discussed in more detail in Section 6 and in the SSPSA (Section 6.2). Table 1 lists all the active components in ECCS and how the effects of maintenance are treated in this analysis.

TABLE 1. EMERGENCY CORE COOLING SYSTEM - ACTIVE COMPONENTS MAINTENANCE MODELING

Component Function	Component Identification	Effect of Maintenance	How Maintenance Is Modeled*
Pumps			
SI Pump A	SI-P-6A	Component function failed.	(a)
SI Pump B	SI-P-6B	Component function failed.	(a)
RHR Pump A	RH-P-8A	Component function failed.	(a)
RHR Pump B	RH-P-8B	Component function failed.	(a)
CVCS Pump A	CS-P-2A	Component function failed.	(a)
CVCS Pump B	CS-P-2B	Component function failed.	(a)
Accumulators			
Accumulator 1	SI-TK-9A	Component function failed.	(b)
Accumulator 2	SI-TK-9B	Component function failed.	(b)
Accumulator 3	SI-TK-9C	Component function failed.	(b)
Accumulator 4	SI-TK-9D	Component function failed.	(b)
Heat Exchangers			
Heat Exchanger A	RH-E-9A	Component function failed.	(c)
Heat Exchanger B	RH-E-9B	Component function failed.	(c)
Motor-Operated Valves			
SI RWST Suction Valve A	CBS-V47 (NO)	No effect, valve normally open.	(d)
SI RWST Suction Valve B	CBS-V51 (NO)	No effect, valve normally open.	(d)
SI Pump A Suction	CBS-V49 (NO)	No effect, valve normally open.	(d)
SI Pump B Suction	CBS-V53 (NO)	No effect, valve normally open.	(d)
SI Train A Crosstie	SI-V112 (NO)	No effect, valve normally open.	(d)
SI Train B Crosstie	SI-V111 (NO)	No effect, valve normally open.	(d)
SI Cold Leg Injection	SI-V114 (NO)	No effect, valve normally open.	(d)

*Footnotes with explanations are found on the last page of this table.

Legend: (NO) - Normally Open
(NC) - Normally Closed
(DO) - Deenergized Open
(DC) - Deenergized Closed

TABLE 1 (continued)

Component Function	Component Identification	Effect of Maintenance	How Maintenance Is Modeled*
Motor-Operated Valves			
CVCS-SI Pumps Suction Cross-Connection	CS-V460 (NC)	No effect, valve can be operated manually.	(d)
CVCS-SI Pumps Suction Cross-Connection	CS-V461 (NC)	No effect, valve can be operated manually.	(d)
CVCS-SI Pumps Suction Cross-Connection	CS-V475 (NO)	No effect, valve normally open.	(d)
SI Train A Hot Leg Injection	SI-V102 (NC)	No effect, valve can be operated manually.	(d)
SI Train B Hot Leg Injection	SI-V77 (NC)	No effect, valve can be operated manually.	(d)
SI Pump A Mini-Flow Isolation	SI-V90 (NO)	No effect, valve normally open.	(d)
SI Pump B Mini-Flow Isolation	SI-V89 (NO)	No effect, valve normally open.	(d)
SI Common Test Header Isolation	SI-V93 (NO)	No effect, valve normally open.	(d)
RHR A-CVCS Cross-connection	RH-V35 (NC)	No effect, valve can be operated manually.	(d)
RHR B-SI Cross-Connection	RH-V36 (NC)	No effect, valve can be operated manually.	(d)
Accumulator 1 Isolation Valve	SI-V3 (NO,DO)	No effect, valve normally open.	(d)
Accumulator 2 Isolation Valve	SI-V17 (NO,DO)	No effect, valve normally open.	(d)
Accumulator 3 Isolation Valve	SI-V32 (NO,DO)	No effect, valve normally open.	(d)
Accumulator 4 Isolation Valve	SI-V47 (NO,DO)	No effect, valve normally open.	(d)
RHR Suction Train A	CBS-V2 (NO)	No effect, valve normally open.	(d)
RHR Suction Train B	CBS-V5 (NO)	No effect, valve normally open.	(d)
RHR Crosstie Train A	RH-V22 (NO)	No effect, valve normally open.	(d)

*Footnotes with explanations are found on the last page of this table.

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TABLE 1 (continued)

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Component Function	Component Identification	Effect of Maintenance	How Maintenance Is Modeled*
Motor-Operated Valves			
RHR Crosstie Train B	RH-V21 (NO)	No effect, valve normally open.	(d)
RHR Cold Leg Injection A	RH-V14 (NO)	No effect, valve normally open.	(d)
RHR Cold Leg Injection B	RH-V26 (NO)	No effect, valve normally open.	(d)
RHR Hot Leg Injection A	RH-V70 (NC,DC)	No effect, valve can be opened manually.	(d)
RHR Hot Leg Injection B	RH-V32 (NC,DC)	No effect, valve can be opened manually.	(d)
RHR Miniflow Recirculation A	FCV-610 (NO)	No effect, valve normally open.	(d)
RHR Miniflow Recirculation B	FCV-611 (NO)	No effect, valve normally open.	(d)
RHR Hot Leg A Suction Valve A	RC-V23 (NC,DC)	No effect, valve can be opened manually.	(d)
RHR Hot Leg A Suction Valve B	RC-V22 (NC,DC)	No effect, valve can be opened manually.	(d)
RHR Hot Leg B Suction Valve A	RC-V88 (NC,DC)	No effect, valve can be opened manually.	(d)
RHR Hot Leg B Suction Valve B	RC-V87 (NC,DC)	No effect, valve can be opened manually.	(d)
RHR Heat Exchanger A - PCC Isolation	CC-V145 (NC)	No effect, valve can be opened manually.	(d)
RHR Heat Exchanger B - PCC Isolation	CC-V272 (NC)	No effect, valve can be opened manually.	(d)
Containment Sump Recirculation A	CBS-V8 (NC)	Component function failed.	(e)
Containment Sump Recirculation B	CBS-V14 (NC)	Component function failed.	(e)
CVCS Train A RWST Suction	LCV-112D (NC)	Component function failed.	(e)
CVCS Train B RWST Suction	LCV-112E (NC)	Component function failed.	(e)

*Footnotes with explanations are found on the last page of this table.

Legend: (NO) - Normally Open
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(DO) - Deenergized Open
(DC) - Deenergized Closed

TABLE 1 (continued)

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Component Function	Component Identification	Effect of Maintenance	How Maintenance Is Modeled
Motor-Operated Valves			
BIT Outlet Train A	SI-V138 (NC)	Component function failed.	(e)
BIT Outlet Train B	SI-V139 (NC)	Component function failed.	(e)
CVCS Pump A Miniflow	CS-V196 (NO)	No effect, valve normally open.	(d)
CVCS Pump B Miniflow	CS-V197 (NO)	No effect, valve normally open.	(d)
VCT Outlet Valve 1	LCV-112B (NO)	No effect, valve normally open.	(d)
VCT Outlet Valve 2	LCV-112C (NO)	No effect, valve normally open.	(d)
Normal Charging Valve A	CS-V142 (NO)	No effect, valve normally open.	(d)
Normal Charging Valve B	CS-V143 (NO)	No effect, valve normally open.	(d)

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a. Maintenance on each of the three pump types is modeled the same due to the similarity of the size and function. The maintenance frequency is estimated by the type 1 component distribution (see Section 6), with a mean of one maintenance outage per 1.4 years. The maintenance duration is varied from the base case (mean duration of 20.9 hours) to the 72-hour AOT (point value duration of 72 hours), to the 7-day AOT (point value duration of 7 days.)

b. Maintenance on each accumulator is modeled using the maintenance frequency given in Section 6 (mean frequency of 1.07×10^{-4} outages per hour). The maintenance duration is varied from the base case (no maintenance modeled) to the 1-hour AOT (point value duration of 1 hour) to the 8-hour AOT (point value duration of 8 hours).

c. Maintenance on the RHR heat exchangers is modeled using the maintenance frequency distribution estimated by type 4 component distribution (see Section 6) with a mean of one maintenance outage per 4.1 years. The duration of maintenance is varied from the base case (mean duration of 20.9 hours), to the 72-hour AOT (72 hours duration), and to the 7-day AOT (7 days duration).

d. These valves were modeled with no maintenance contribution because the maintenance can be done with the valve in its operable (failed safe) state or because the valve can easily be opened manually.

e. Maintenance on MOVs are modeled for those MOVs for which maintenance would require putting the valve in such a state that the system is no longer operable. For these valves, maintenance frequency is estimated by a type 4 component distribution (see Section 6), with a mean of one maintenance outage per 4.1 years. The duration of maintenance is varied from the base case (mean duration of 10.8 hours), to the 72-hour AOT (72-hour duration), and to the 7-day AOT (7-day duration).

5. CHANGING MAINTENANCE DURATIONS

To determine the impact of the maintenance durations on top event totals and core melt sequence totals, the maintenance durations are set to new point values (which, for the purposes of this report, are the AOTs to be implemented). The percentage change from the original (base case) top event totals can then be used to determine their sensitivity to the changes in the AOTs.

There are four maintenance duration changes implemented and quantified.

- For All ECCS Subsystems (except accumulators)
  - The maintenance durations are set to the maximum of the AOTs defined in the technical specifications of the system (i.e., 72 hours). The sensitivity is then calculated from the difference between the 72 hour results and the base case results. This sensitivity shows the effect of making the conservative assumption that the mean maintenance duration is the maximum of the AOT.
  - New 7-day AOTs are implemented in the equations. Again, the maintenance durations are set to the maximum AOT (i.e., 7 days) and the difference, or delta, between the 7-day results and the 72-hour results are calculated.
- For Accumulators
  - 1-hour AOTs are implemented in the ACL equations. The maintenance durations are set to 1 hour, and the delta between the 1-hour results and the base case results are calculated.
  - 8-hour AOTs are implemented in the ACL equations. The maintenance durations are set to 8 hours, and the delta between the 8-hour results and the 1-hour results are calculated.

The results of all RISKMAN quantifications are in Appendix D (in RISKMAN output form), and the sensitivities and deltas are in Appendix A.

Table A-1, Accumulators, shows that the assumption of no maintenance contribution in the base case has some effect on the total ACL system quantification, a 38% increase for the 1-hour maintenance assumption over the base case. The increase in system total from 1 hour to 8 hours is about a factor of 2. Although this is a significant change at the system level, it is judged to be a very conservative estimate of system unavailability with the 8-hour maintenance assumption. Thus, the best estimate of the delta system quantification is much smaller and is judged to be not significant. The delta sequence number is also judged to be very conservative, based on the system conservatism. It is judged that the best estimate of the delta system is less then 1.0×10^{-7}. The delta risk, considering all sequences with ACL, is judged to be insignificant.

Tables A-2 to A-7 give the delta system and delta sequence sensitivities for the ECCS subsystems. The delta between "72 hours" and the base case demonstrates the effect of making the conservative assumption that the maintenance duration is equal to the AOT. The system total and key sequence frequency increase between 8% and 60%, as the mean duration is increased from 20 hours (base case) to 72 hours. For all top events except SLRHRM, the delta between "7 days" and "72 hours" is very small, $\leq 1 \times 10^{-7}$. For SLRHRM, the increase for the key sequence is 4.80×10^{-6}, and, for all sequences with this top event, the delta is 6.04×10^{-6}. This delta is conservative for the reasons mentioned previously; i.e., the assumption that the maintenance duration is the same as the AOT. In addition, this top event is judged to be conservatively quantified because no human action has been modeled. In reality, when the RHR pumps began to heat up in the miniflow recirculation mode, the operators are very likely to shut off the pumps due to the presence of alarms. The frequency of this top event should be significantly smaller.

6. DATA ANALYSIS

6.1 ACCUMULATORS

In order to perform the sensitivity analysis of the effects of maintenance on the ECCS accumulators, the frequency of occurrence of accumulator maintenance had to be determined.

The publication, Nuclear Power Experience*, was reviewed to determine the number of applicable accumulator failures that had been reported by licensee event reports. One hundred and five applicable accumulator failure events were found and are summarized below.

37 Events - Boron Concentration out of Specification

20 Events - Pressure out of Specification

44 Events - Level out of Specification

4 Events - Other (valving error; outlet isolation valve operator breakers not sealed open; outlet isolation valves closed inadvertently due to faulty signal)

These data include failures in accumulators for the period, August 1974 to June 1985. These data exclude information for Yankee Rowe because of the differences in accumulator design.

Failure frequency for accumulators was estimated by dividing the number of reported events by the total number of pressurized reactor critical hours for the period, August 1974 to June 1985, 2.61×10^{6} hours.

A distribution was created for the frequency of accumulator maintenance by assuming that the total number of accumulator failures divided by the number of reactor critical hours was a median value and by assuming a range factor of 10 to determine the 95th and 5th percentiles of a lognormal distribution. The resulting mean value for accumulator maintenance frequency is 1.07×10^{-4} occurrences per reactor critical hour (with a 95th percentile value of 3.81×10^{-4} and a 5th percentile of 3.75×10^{-6}.)

This mean value is judged to be conservative for the following reasons:

- o No estimate was made for the total number of accumulators in the data base. If each pressurized water reactor in the data base had two accumulators, the resulting mean value of accumulator maintenance would be 5.36×10^{-5} occurrence per reactor critical hour.
- o Of the 101 out-of-specification events, it is estimated that approximately 90% involve only slightly out-of-specification

*Nuclear Power Experience, published by the S. M. Stoller Corporation.

conditions that were quickly corrected without taking the affected accumulator out of service.

6.2 ECCS SUBSYSTEMS

The maintenance frequencies assigned to ECCS components, other than accumulators, are taken from the Seabrook data base and are generic values based on similar equipment for which data are available.

Four types of maintenance frequencies were defined in the SSPSA. These types and their applicability to ECCS components are:

Maintenance Frequency Title	Description	Applicable To
Type 1	Distribution range indicates very light-duty components subject to relatively frequent starts, which would detect failures. A minimal preventive maintenance program is applied to these components due to their standby nature. Technical specification inoperability criteria applied to maintenance performed during noncold shutdown periods. (Mean = 8.42×10^{-5} events per hour.)	Residual heat removal pumps, safety injection pumps, and charging pumps.
Type 2	Distribution range indicates continuous service components with available installed spares. A nominal preventive maintenance frequency of one event every 12 months of component service time is included to account for the necessary inspections, routine repairs, and general overhauls typically performed on these components during noncold shutdown periods. (Mean = 1.26×10^{-4} events per hour.)	No ECCS components (typical of service water, and component cooling water pumps).
Type 3	Distribution range indicates components requiring relatively frequent routine maintenance. Components included are generally complex and subject to frequent testing and/or continuous operation. Unscheduled maintenance is required during noncold shutdown periods to repair coolant or lubrication leaks, adjust controls, and replace degraded subcomponents that contribute to impaired performance but may not cause total system failure. (Mean = 2.19×10^{-4} events per hour.)	No ECCS components (typical of diesel generators and turbine-driven pumps).

Maintenance Frequency Title	Description	Applicable To
Type 4	Range of this distribution indicates components requiring relatively infrequent maintenance, or components that can be maintained without affecting system operability during noncold shutdown periods. Components included are generally passive in nature, or require maintenance that can be performed with the system aligned normally. Also included are those components for which the total unavailability due to maintenance is small in relation to other components. (Mean = $2.75x10^{-5}$ events per hour.)	ECCS motor-operated valves that must be capable of changing position automatically.

A comparison of published data from operating plants for similar components are provided in Table 2.

The maintenance frequencies used for the emergency core cooling system components at Seabrook Station are comparable to the frequencies obtained from data at several similar operating pressurized water reactors and reflect the fact that Seabrook is not yet operating.

TABLE 2. COMPARISON OF THE FREQUENCY OF MAINTENANCE

Pumps	SSPSA			IPPS - IP2/IP3			Zion PSA		
	Mean*	95th Percentile	5th Percentile	Mean	95th Percentile	5th Percentile	Mean	95th Percentile	5th Percentile
CVCS	1.4	0.8	3.2	No Similar Component			0.8**	0.6	1.2
RHR	1.4	0.8	3.2	1.4/1.8	.85/1.1	2.5/3.4	1.9	1.2	3.0
SI	1.4	0.8	3.2	1.2/2.1	.8/1.3	2.0/3.8	2.8	1.8	4.8

*Values reported are the years between maintenance events.
**The centrifugal charging pumps at Zion were operated routinely as part of the volume control function. At the time of SSPSA, the station planned to operate the positive displacement charging pump exclusively and maintain the centrifugal charging pumps in standby.

7. SUMMARY AND CONCLUSIONS

7.1 SUMMARY

The delta risk values, due to changes in AOT from Appendix A, are summarized below.

Top Event	Delta Risk (Frequency)	Changes in AOT
ACL	6.1-7	1 hour to 8 hours
LLLPI	2.8-8	72 hours to 7 days
MLHPI	1.1-8	72 hours to 7 days
MLRHRM	1.3-7	72 hours to 7 days
ATWS	1.8-8	72 hours to 7 days
SLHPI	2.6-9	72 hours to 7 days
SLRHRM	5.97-6	72 hours to 7 days

NOTE: Exponential notation is indicated in abbreviated form; i.e., 6.1-7 = 6.1×10^{-7}.

7.2 CONCLUSIONS

The values given above are judged to be very conservative (i.e., the delta risk values are judged to be much smaller) due to the reasons listed below.

1. The conservative assumption was made for each top event that the maintenance duration is equal to the technical specification allowed outage time. In fact, the AOT is the upper bound of maintenance duration since the plant is required to begin shutting down at the end of the AOT. Thus, the system unavailability due to maintenance is actually an upper bound estimate with regard to duration. In general, such a conservative assumption is inappropriate for best estimate risk analyses because it tends to distort the importance of various contributors. This conservatism was used here because of the use of this analysis in the regulatory area.

2. The maintenance contribution to accumulator unavailability is overestimated due to the data used to compute the maintenance frequency. It is estimated that the frequency is overestimated by a factor of 10 due to inclusion of out-of-specification events for which the accumulators would still be available.

3. The 8-hour assumption of accumulator maintenance duration is very conservative. Extending the AOT beyond 1 hour will increase the mean maintenance duration, but most repairs/restoration actions will continue to be slight out-of-specification conditions, which can be restored within 1 to 2 hours. A best estimate of the mean duration of maintenance with the 8-hour AOT is 2 hours.

4. Top Events MLRHRM and SLRHRM are thus modeled conservatively. Both events involve failure of the RHR system during the miniflow recirculation. For SLOCA and MLOCA, the RHR system starts automatically, but since the RCS pressure is higher than the RHR pump discharge pressure, the pump flow is returned to the pump suction after being cooled by the RHR heat exchanger. If the RHR pumps fail in the miniflow recirculation mode, they will not be available for the sump recirculation phase of core cooling. In the modeling of this event, no operator action was modeled. In fact, in this event, the procedures instruct the operator to shut off the RHR pumps. In addition, temperature alarms on the pump would alert the operator to stop the pumps. Thus, inclusion of operator action would result in a considerable reduction in the failure frequency of these top events.

5. The plant damage states that contain the ECCS top events are 2A, 4A, and 8A, all states that are mapped to release category S5, 99% of the time. Release category S5 models a core melt release with containment intact. Thus, the health effects from this release are small and negligible compared to containment failed/bypassed categories. Thus, although the core melt delta frequency is small, the actual delta risk (health effects) is much smaller.

6. By increasing the AOT, several benefits are incurred that have not been modeled. These include:

   a. Increasing the AOT would decrease the likelihood of a forced shutdown due to reaching the AOT. Core melt initiating events have a greater likelihood of occurring while a plant is in a transient state. Thus, increasing the AOT would decrease the core melt risk from transient initiators.

   b. Increasing the AOT would allow components out of service due to maintenance be restored to the operating mode correctly and with greater likelihood.

   Both of these benefits are due to the judgment that human errors are less likely when the amount of time needed to perform a duty is increased.

Due to the above-mentioned conservatism, the best estimate total delta risk is judged to be considerably smaller than the values given in the summary section above and is judged to be an insignificant increase in core melt risk.

APPENDIX A

SENSITIVITY ANC DELTA RESULTS

TABLE A-1. TOP EVENT - ACL ACCUMULATORS

	AOT	Total System	Maintenance Contribution	Key Sequence Frequency
	Base	1.130-3	0.000	2.292-7
	1 Hour	1.561-3	4.272-4	3.169-7
	8 Hours	4.581-3	3.451-3	9.299-7
Delta (1 hour|base)		4.310-4	4.272-4	8.749-8
Percentage of Base		38.1%	-------	38.1%
Delta (8 hours|1 hour)		3.020-3	3.024-3	6.131-7
Percentage of 1 Hour		193.5%	707.8%	193.5%

Sequence Quantification Total

The key sequence is LLOCA*ACL (plant damage state 2A) in which LLOCA has a mean frequency of occurrence of 2.03-4 (from the Seabrook data base). There are no other ACL core melt sequences that have a frequency greater than 1.0-7. Thus, the delta risk for a change in AOT from 1 hour to 8 hours for accumulators is approximately 6.1-7.

NOTE: Exponential notation is indicated in abbreviated form; i.e., 1.130-3 = 1.130 x 10^{-3}.

TABLE A-2. TOP EVENT - LLLPI(new) - LOW PRESSURE INJECTION WITHOUT ACCUMULATORS

	AOT	Total System	Maintenance Contribution	Key Sequence Frequency
	Base	9.166-4	2.894-5	1.860-7
	72 Hours	9.843-4	1.033-4	1.998-7
	7 Days	1.122-3	2.410-4	2.278-7
Delta (72 hours|base)		6.770-5	7.436-5	1.380-8
Percentage of Base		7.4%	256.9%	7.4%
Delta (7 days|72 hours)		1.377-4	1.377-4	2.795-8
Percentage of 72 Hours		13.9%	133.3%	13.9%

Sequence Quantification Total

The key sequence is LLOCA*LA1*LBA (sequence 2A-1) in which LLOCA has a mean frequency of occurrence of 2.03-4 (from the Seabrook data base) and LA1*LBA = LLLPI(new). There are no other LLLPI core melt sequences that have a frequency of more than 1.0-7. Thus, the delta risk for a change in AOT from 72 hours to 7 days for LLLPI is approximately 2.8-8.

NOTE: Exponential notation is indicated in abbreviated form; i.e., 9.166-4 = 9.166×10^{-4}.

TABLE A-3. TOP EVENT - MLHPI - MLOCA HIGH PRESSURE INJECTION

	AOT	Total System	Maintenance Contribution	Key Sequence Frequency
	Base	2.670-5	5.310-6	1.241-8
	72 Hours	4.229-5	1.828-5	1.966-8
	7 Days	6.666-5	4.264-5	3.100-8
Delta (72 hours|base)		1.559-5	1.297-5	7.25-09
Percentage of Base		58.4%	244.3%	58.4%
Delta (7 days|72 hours)		2.437-5	2.436-5	1.134-8
Percentage of 72 Hours		57.6%	133.3%	57.7%

Sequence Quantification Total

The key sequence is MLOCA*MLHPI (plant damage state 2A) in which MLOCA has a mean frequency of occurrence of 4.65-4 (from the Seabrook data base).

There are no MLHPI sequences having a frequency of more than 1.0-7. Thus, the delta risk for a change in AOT from 72 hours to 7 days for MLHPI is approximately 1.1-8.

NOTE: Exponential notation is indicated in abbreviated form; i.e., 2.670-5 = 2.670 x 10^{-5}.

TABLE A-4. TOP EVENT - MLRHRM - MLOCA RHR MINIFLOW RECIRCULATION

	AOT	Total System	Maintenance Contribution	Key Sequence Frequency
	Base	5.482-4	5.960-5	2.549-7
	72 Hours	7.140-4	2.058-4	3.320-7
	7 Days	9.885-4	4.803-4	4.597-7
Delta (72 hour|base)		1.658-4	1.462-4	7.710-8
Percentage of Base		30.2%	245.3%	30.2%
Delta (7 days|72 hours)		2.745-4	2.745-4	1.277-7
Percentage of 72 Hours		38.4%	133.4%	38.4%

Sequence Quantification Total

*The key sequence is MLOCA*L11*L2A (sequence 2A-2) in which MLOCA has a mean frequency of occurrence of 4.65-4 (from the Seabrook data base) and L11*L2A = MLRHRM.

There are no other MLRHRM core melt sequences having a frequency of more than 1.0-7. Thus, the delta risk for a change in AOT from 72 hours to 7 days for MLRHRM is approximately 1.3-7.

NOTE: Exponential notation is indicated in abbreviated form; i.e., 5.482-4 = 5.482 x 10^{-4}.

TABLE A-5. TOP EVENT - ATWS

	AOT	Total System	Maintenance Contribution	Key Sequence Frequency
	Base	1.016-3	1.940-5	1.602-7
	72 Hours	1.131-3	8.481-5	1.781-7
	7 Days	1.244-3	1.979-4	1.959-7
Delta (72 hours|base)		1.150-4	6.481-5	1.81-8
Percentage of Base		11.3%	334.1%	11.3%
Delta (7 days|72 hours)		1.130-4	1.131-4	1.78-8
Percentage of 72 Hours		10.0%	133.4%	10.0%

Sequence Quantification Total

The key sequence is ATT*ATWS (plant damage state 4A) in which ATT equals TT (turbine trip : mean frequency of occurrence is 1.95 from the Seabrook data base) multiplied by RT (reactor trip with both SSPS signals present: mean frequency of occurrence is 8.0770-5 from the Seabrook Master Frequency File), which equals 1.575-4.

There are no other ATWS core melt sequences having a frequency of more than 1.0-7. Thus, the delta risk for a change in AOT from 72 hours to 7 days for ATWs is approximately 1.8-8.

NOTE: Exponential notation is indicated in abbreviated form; i.e., 1.016-3 = 1.016 x 10^{-3}.

TABLE A-6. TOP EVENT - SLHPI - SLOCA HIGH PRESSURE INJECTION

	AOT	Total System	Maintenance Contribution	Key Sequence Frequency
	Base	1.104-6	2.705-8	1.910-8
	72 Hours	1.224-6	1.109-7	2.118-8
	7 Days	1.372-6	2.588-7	2.374-8
Delta (72 hours|base)		1.200-7	8.385-8	2.08-9
Percentage of Base		10.9%	310.0%	10.9%
Delta (7 days|72 hours)		1.480-7	1.479-7	2.56-9
Percentage of 72 hours		12.1%	133.4%	12.1%

Sequence Quantification Total

The key sequence is SLOCA*SLHPI (plant damage state 8A) in which SLOCA has a mean frequency of occurrence of 1.73-2 (from the Seabrook data base).

There are no SLHPI core melt sequences having a frequency greater than 1.0-9. Thus, the delta risk for a change is AOT from 72 hours to 7 days for SLHPI is approximately 2.6-9.

NOTE: Exponential notation is indicated in abbreviated form; i.e., 1.104-6 = 1.104 x 10^{-6}.

TABLE A-7. TOP EVENT - SLRHRM - SLOCA RHR MINIFLOW RECIRCULATION

	AOT	Total System	Maintenance Contribution	Key Sequence Frequency
	Base	5.918-4	6.032-5	1.024-5
	72 hours	7.577-4	2.082-4	1.311-5
	7 days	1.035-3	4.857-4	1.791-5
Delta (72 hours|base)		1.659-4	1.479-4	2.87-6
Percentage of Base		28.0%	245.2%	28.0%
Delta (7 days|72 hours)		2.773-4	2.775-4	4.80-6
Percentage of 72 Hours		36.6%	133.3%	36.6%

Sequence Quantification Total

The key sequence is SLOCA*L13*L2C (sequence 8A-1) in which SLOCA has a mean frequency of occurrence of 1.73-2 (from the Seabrook data base) and L13*L2C = SLRHRM. The other SLRHRM core melt sequences that appear in the core melt equations (Sequences 8A-12, 8A-16, 8A-21, 8A-23, 8A-24) also change by the same percentage as the key sequence. The total change in core melt due to these sequences is 2.50-6 (base case).

The delta (7 days|72 hours) for these sequences is 1.17-6. There are no additional sequences with SLRHRM having a frequency of more than 1.0-7. Thus, the delta risk for a change in AOT from 72 hours to 7 days for SLRHRM is approximately 5.97-6.

NOTE: Exponential notation is indicated in abbreviated form; i.e., 5.918-4 = 5.918×10^{-4}.

APPENDIX B

ECCS RISKMAN® EQUATIONS

B.1 LLOCA: Low Pressure Injection--LLLPI

```
 1 LLLPI  = LLLPIH + LLLPIC + LLLPIM
 2 LLLPIH = RHTRNA*RHTRNB + RHRSYS
 3 LLLPIC = PSBR*PS + PRBR*PR*T1
 4 LLLPIM = 2*(PM + HEXM)*(RHTRNA + RBLKE + RBLKF*(RBLKG + RBLKH))
 5 RHRSYS = RSYS1 + RSYS2
 6 RSYS1  = 3*RBLKG*RBLKH + RBLKE + RBLKF*(RBLKG + RBLKH)
 7 RSYS2  = RHTRNA*RXTIE + RHTRNB*RXTIE*(RBLKE + RBLKG + RBLKH)
   RHTRNB = RHTRNA
 8 RHTRNA = RBLKA + RBLKC
 9 RXTIE  = RBLKK + RBLKL
   RBLKL  = RBLKK
10 RBLKK  = MOVT*(TTST2 + T1)
   RBLKI  = RBLKG
   RBLKH  = RBLKG
11 RBLKG  = CVO + CVT*T1 + MVT*(TTST2 + T1)
   RBLKF  = RBLKE
12 RBLKE  = MOVT*(TTST2 + T1)
13 RBLKC  = PS + CVO + (PR + CVT)*T1 + HEXL*T1 + RBLKC1
   RBLKC1 = 2*MVT*(TTST1 + T1) + AOVT*(TTST2 + T1)
14 RBLKA  = CVO + CVT*T1 + MVT*(TTST1 + T1)
```

B.2 MLOCA: High Pressure Injection--MLHPI

```
 1 MLHPI  = MLHPIH + MLHPIC + MLHPIM + MLHPIT
 2 MLHPIH = 2*SITRNA*CVTRNA*(SITRNB + CVTRNB) + MLH2
   MLH2   = SIOTHR*CVOTHR + 2*SITRNA*CVOTHR + 2*CVTRNA*SIOTHR
 3 MLHPIC = PS2*(2*CVTRNA + CVOTHR + 2*SITRNA + SIOTHR) + MLC2
   MLC2   = MOV2*(2*SITRNA + SIOTHR)
 4 MLHPIM = SIM + CVM + RWSTM + BOM
 5 SIM    = 2*PM*(CVCS + 2*SITRNA*CVTRNA)
 6 CVM    = 2*PM*(SI + 2*SITRNA*CVTRNA)
 7 RWSTM  = 2*MOVM*CBLKA*(2*SITRNA + SIOTHR)
 9 BOM    = 2*MOVM*CBLKH*(2*SITRNA + SIOTHR)
10 MLHPIT = 2*PT*(CVCS + 2*CVTRNA*SITRNA)
11 SI     = SITRNA*SITRNB + SIOTHR
   SITRNB = SITRNA
12 SITRNA = SBLKC + SBLKE
13 SIOTHR = SBLKA*SBLKB + SBLKG + SBLKL + 4*SBLKH*SBLKI*SBLKJ
14 SBLKL  = 4*CVSRL*T2
   SBLKJ  = SBLKH
   SBLKI  = SBLKH
15 SBLKH  = 2*(CVO + CVT*T2 + MVT*(TTST2 + T2))
16 SBLKG  = MOVT*(TTST2 + T2)
17 SBLKE  = PS + CVO + (PR + CVT)*T2 + SBLKE1
   SBLKE1 = 2*MVT*(T2 + TTST1) + (MVT + MOVT)*(T2 + TTST2)
18 SBLKC  = MOVT*(TTST1 + T2)
   SBLKB  = SBLKA
```

```
19 SBLKA  = MOVT*(TTST1 + T2) + CVO + CVT*T2
20 CVCS   = CVTRNA*CVTRNB + CVOTHR
   CVTRNB = CVTRNA
21 CVTRNA = CBLKC
22 CVOTHR = CBLKA*CBLKB + CBLKO + CVOTH1
   CVOTH1 = CBLKH*CBLKI + CBLKJ + 4*CBLKK*CBLKL*CBLKM
23 CBLKO  = MOVO*MOVO
   CBLKM  = CBLKK
   CBLKL  = CBLKK
24 CBLKK  = CVO + MVT*(TTST2 + T2) + CVT*T2
25 CBLKJ  = CVO + CVT*T2
   CBLKI  = CBLKH
26 CBLKH  = MOVO + MOVT*T2
29 CBLKC  = PS + CVO + (PR + CVT)*T2 + CBLKC1
   CBLKC1 = 3*MVT*(TTST1 + T2) + MVT*(TTST2 + T2)
   CBLKB  = CBLKA
30 CBLKA  = MOVO + CVO + (MOVT + CVT)*T2
31 PS2    = PSBC*PS + PRBC*PR*T2
32 MOV2   = (2/3)*MOVB*MOVO
```

B.3 MLOCA: RHR Miniflow--MLRHRM

```
 2 MLRHRM = MLRHMH + MLRHMC + MLRHMM
 3 MLRHMH = RHTRNA*RHTRNB
 4 MLRHMC = PSBR*PS + PRBR*PR*T2
 5 MLRHMM = 2*(HEXM + PM)*RHTRNA
   RHTRNB = RHTRNA
 6 RHTRNA = RBLKA + RBLKC + RBLKS + HBLKA
 7 RBLKS  = MOVT*(TTST1 + T2) + MOVO
 8 RBLKC  = PS + CVO + (PR + CVT + HEXL)*T2 + RBLKC1
   RBLKC1 = 2*MVT*(TTST1 + T2)
 9 RBLKA  = CVO + CVT*T2 + MVT*(TTST1 + T2)
10 HBLKA  = MOVO + MOVT*T2 + MVT*(TTST1 + T2)
```

B.4 ATWS: High Pressure Injection--ATWS

```
 1 ATWS   = ATWSH + ATWSC + ATWSM
 2 ATWSH  = CVCS
 3 ATWSC  = PS2 + MOV2
 4 ATWSM  = CVM + RWSTM + BOM
 5 CVM    = 2*PM*CVTRNA
 6 RWSTM  = 2*MOVM*CBLKA
 8 BOM    = 2*MOVM*CBLKH
 9 CVCS   = CVTRNA*CVTRNB + CVOTHR
   CVTRNB = CVTRNA
10 CVTRNA = CBLKC
11 CVOTHR = CBLKA*CBLKB + CBLKO + CVOTH1
   CVOTH1 = CBLKH*CBLKI + CBLKJ + 4*CBLKK*CBLKL*CBLKM
12 CBLKO  = MOVO*MOVO
```

```
   CBLKM  = CBLKK
   CBLKL  = CBLKK
13 CBLKK  = CVO + MVT*(TTST2 + T2) + CVT*T2
14 CBLKJ  = CVO + CVT*T2
   CBLKI  = CBLKH
15 CBLKH  = MOVO + MOVT*T2
18 CBLKC  = PS + CVO + (PR + CVT)*T2 + CBLKC1
   CBLKC1 = 3*MVT*(TTST1 + T2) + MVT*(TTST2 + T2)
   CBLKB  = CBLKA
19 CBLKA  = MOVO + CVO + (MOVT + CVT)*T2
20 PS2    = PSBC*PS + PRBC*PR*T2
21 MOV2   = (2/3)*MOVB*MOVO
```

B.5 SLOCA: High Pressure Injection--SLHPI

```
 1 SLHPI  = SLHPIH + SLHPIC + SLHPIM + SLHPIT
 2 SLHPIH = SI*CVCS
 3 SLHPIC = PS2*(CVCS + SI) + MOV2*SI + PS2*(PS2 + MOV2)
 4 SLHPIM = SIM + CVM + RWSTM + BOM
 5 SIM    = 2*PM*SITRNA*CVCS
 6 CVM    = 2*PM*CVTRNA*SI
 7 RWSTM  = 2*MOVM*CBLKA*SI
 9 BOM    = 2*MOVM*CBLKH*SI
10 SLHPIT = 2*PT*SITRNA*CVCS
11 SI     = SITRNA*SITRNB + SIOTHR
   SITRNB = SITRNA
12 SITRNA = SBLKC + SBLKE
13 SIOTHR = SBLKA*SBLKB + SBLKG + SBLKL + 4*SBLKH*SBLKI*SBLKJ
14 SBLKL  = 4*CVSRL*T6
   SBLKJ  = SBLKH
   SBLKI  = SBLKH
15 SBLKH  = 2*(CVO + CVT*T6 + MVT*(TTST2 + T6))
16 SBLKG  = MOVT*(TTST2 + T6)
17 SBLKE  = PS + CVO + (PR + CVT)*T6 + SBLKE1
   SBLKE1 = 2*MVT*(TTST1 + T6) + (MVT + MOVT)*(TTST2 + T6)
18 SBLKC  = MOVT*(TTST1 + T6)
   SBLKB  = SBLKA
19 SBLKA  = MOVT*(TTST1 + T6) + CVO + CVT*T6
20 CVCS   = CVTRNA*CVTRNB + CVOTHR
   CVTRNB = CVTRNA
21 CVTRNA = CBLKC
22 CVOTHR = CBLKA*CBLKB + CBLKO + CVOTH1
   CVOTH1 = CBLKH*CBLKI + CBLKJ + 4*CBLKK*CBLKL*CBLKM
23 CBLKO  = MOVO*MOVO
   CBLKM  = CBLKK
   CBLKL  = CBLKK
24 CBLKK  = CVO + MVT*(TTST2 + T6) + CVT*T6
25 CBLKJ  = CVO + CVT*T6
   CBLKI  = CBLKH
26 CBLKH  = MOVO + MOVT*T6
```

```
29 CBLKC  = PS + CVO + (PR + CVT)*T6 + CBLKC1
   CBLKC1 = 3*MVT*(TTST1 + T6) + MVT*(TTST2 + T6)
   CBLKB  = CBLKA
30 CBLKA  = MOVO + CVO + (MOVT + CVT)*T6
31 MOV2   = (2/3)*MOVB*MOVO
32 PS2    = PSBC*PS + PRBC*PR*T6
```

B.6 SLOCA: RHR Miniflow--SLRHRM

```
1 SLRHRM = SLRHMH + SLRHMC + SLRHMM
2 SLRHMH = RHTRNA*RHTRNB
3 SLRHMC = PSBR*PS + PRBR*PR*T6
4 SLRHMM = 2*(PM + HEXM)*RHTRNA
  RHTRNB = RHTRNA
5 RHTRNA = RBLKA + RBLKC + RBLKS + HBLKA
6 RBLKS  = MOVT*(TTST1 + T6) + MOVO
7 RBLKC  = PS + CVO + (PR + CVT)*T6 + RBLKC1
  RBLKC1 = 2*MVT*(TTST1 + T6) + HEXL*T6
8 RBLKA  = CVO + CVT*T6 + MVT*(TTST1 + T6)
9 HBLKA  = MOVO + MOVT*T6 + MVT*(TTST1 + T6)
```

B.7 Accumulators: Low Pressure Injection--ACL

```
1 ACL    = ACLH
2 ACLH   = ABLKAA + ABLKEE
3 ACLM   = 4*ACLM
4 ABLKAA = STP*T1 + MOVT*(TTST2 + T1) + CVO + CVT*T1
5 ABLKEE = CVO + CVT*T1
```

APPENDIX C

DEFINITIONS AND MEAN VALUES OF COMMON AND DATA BASE VARIABLES

Variable	Definition	Mean Values	
PS	- Standby pump, failure to start on demand.	3.290-3	(ZIPMSS)
PSBS	- Beta factor safety injection pumps - start.	5.879-2	(ZBPHPS)
PSBR	- Beta factor residual heat removal (RHR) pumps.	6.678-2	(ZBPDHS)
PSBC	- Beta factor charging (CVCS) pumps.	5.879-2	(ZBPHPS)
PR	- Standby pump, failure to run.	3.417-5	(ZIPMSR)
PRBS	- Beta factor for safety injection pumps.	6.402-2	(ZBPHPR)
PRBR	- Beta factor for RHR pumps.	2.757-1	(ZBPDHR)
PRBC	- Beta factor for CVCS pumps.	6.402-2	(ZBPHPR)
PM	- Pump unavailability due to maintenance.	1.758-3	(ZMGN1F*ZMGNBD)
PT	- Pump unavailability due to testing.	2.887-5	(FTEST*HERR1*HERR2*TDET)
FTEST	- Frequency of testing.	1.560-3	
HERR1	- Human error of tester.	4.700-3	(ZHE01B)
HERR2	- Human error of supervisor.	5.100-2	
TDET	- Time to detection.	7.720+1	
MOVO	- Motor operated valve (MOV) failure to operate on demand.	4.295-3	(ZIVMOD)
MOVT	- MOV transfer closed.	9.270-8	(ZIVMOT)
MOVOW	- MOV fail to operate while indicating operation.	1.070-4	(ZIVMOE)
MOVB	- Beta factor for MOV failure to open / close.	4.230-2	(ZBVMOD)
MOVM	- MOV maintenance unavailability.	2.966-4	(ZMGN4F*ZMGNAD)
AOVT	- Air operated valve (AOV) transfer closed.	2.667-7	(ZIVAOT)
AOVFTF	- AOV fail to transfer to failed position.	2.660-4	(ZIVAOF)
CVO	- Check valve fail to operate on demand.	2.691-4	(ZIVCOD)
CVT	- Check valve transfer close.	1.041-8	(ZIVCOP)
CVSRL	- Check valve severe reverse leakage.	5.358-7	(ZIVCOL)
MVT	- Manual valve transfer close.	4.197-8	(ZIVHOT)
HEXL	- Heat exchanger rupture / excessive leakage.	1.951-6	(ZIHXRB)
HEXM	- Heat exchanger maintenance.	5.735-4	(ZMGN4F*ZMGNBD)
STP	- Storage tank rupture / vent plugging.	2.664-8	(ZITK1B)
ACLM	- Accumulator maintenance.	0.000-1	(ACCMFR*TO)
TTST1	- Component test interval div 2.	3.600+2	
TTST2	- Component test interval div 2.	6.480+3	
ZMGNAD	- Mean duration of maintenance -- Type A.	1.080+1	
ZMGNBD	- Mean duration of maintenance -- Type B.	2.090+1	
ZMGN1F	- Maintenance frequency -- Type 1.	8.420-5	
ZMGN4F	- Maintenance frequency -- Type 4.	2.750-5	
ACCMFR	- Accumulator maintenance frequency.	1.070-4	

NOTE: Exponential notation is indicated in abbreviated form; i.e., 3.290-3 = 3.290×10^{-3}.

APPENDIX D

BASE CASE AND SENSITIVITY QUANTIFICATION RESULTS

APPENDIX D.1

ECCS TOP EVENT DEFINITIONS

Abbreviation	ECCS Function
SLHPI	SLOCA - High pressure injection.
ATWS	ATWS - MLOCA - High pressure injection.
MLHPI	MLOCA - High pressure injection.
LLLPI(new)	LLOCA - Low pressure injection without accumulators.
ACL	Accumulators.
MLRHRM	MLOCA - RHR - miniflow recirculation.
SLRHRM	SLOCA - RHR - miniflow recirculation.

APPENDIX D.2

ECCS RESULTS - BASE CASE

Top Event Split Fraction	Function	Cause	Results
SLHPI	1 SLHPI	SLOCA: HPI Total	1.104-6
	2 SLHPIH	Hardware Total	5.315-7
	3 SLHPIC	Common Cause Total	5.456-7
	4 SLHPIM	Maintenance Total	2.705-8
	5 SIM	SI Pump Maintenance	1.369-8
	6 CVM	CVCS Pump Maintenance	9.799-9
	7 RWSTM	RWST CVCS Pump Valve Maintenance	1.834-9
	9 BOM	BIT Outlet Valve Maintenance	1.729-9
	10 SLHPIT	Testing Total	1.952-0
	11 SI		6.654-4
	12 SITRNA		4.746-3
	13 SIOTHR		6.245-4
	14 SBLKL		1.225-5
	15 SBLKH		1.062-3
	16 SBLKG		6.120-4
	17 SBLKE		4.712-3
	18 SBLKC		3.454-5
	19 SBLKA		2.875-4
	20 CVCS		6.590-4
	21 CVTRNA		4.116-3
	22 CVOTHR		6.243-4
	23 CBLKO		3.846-5
	24 CBLKK		5.309-4
	25 CBLKJ		2.530-4
	26 CBLKH		4.356-3
	29 CBLKC		4.116-3
	30 CBLKA		4.609-3
	31 MOV 2		1.219-4
	32 P S2		2.074-4
ATWS	1 ATWS	ATWS: High Pressure Injection Total	1.016-3
	2 ATWSH	Hardware Total	6.813-4
	3 ATWSC	Common Cause Total	3.155-4
	4 ATWSM	Maintenance Total	1.940-5
	5 CVM	CVCS Pump Maintenance	1.409-5
	6 RWM	RWST CVCS Pump Maintenance	2.734-6

NOTE: Exponential notation is indicated in abbreviated form; i.e., 1.104-6 = 1.104 x 10^{-6}.

Sheet 2 of 4

Top Event Split Fraction	Function	Cause	Results
	8 BOM	BIT Outlet Valve Maintenance	2.577-6
	9 CVCS		6.813-4
	10 CVTRNA		3.917-3
	11 CVOTHR		6.496-4
	12 CBLKO		3.781-5
	13 CBLKK		5.477-4
	14 CBLKJ		2.666-4
	15 CBLKH		4.351-3
	18 CBLKC		3.917-3
	19 CBLKA		4.618-3
	20 PS2		1.919-4
	21 MOV2		1.236-4
MLHPI	1 MLHPI	MLOCA: HPI Total	2.670-5
	2 MLHPIH	Hardware Total	1.293-5
	3 MLHPIC	Common Cause Total	8.417-6
	4 MLHPIM	Maintenance Total	5.310-6
	5 SIM	SI Pump Maintenance	2.688-6
	6 CVM	CVCS Pump Maintenance	2.571-6
	7 RWSTM	RWST CVCS Pump Valve Maintenance	2.635-8
	9 BOM	BIT Outlet Valve Maintenance	2.476-8
	10 MLHPIT	Testing Total	4.461-8
	11 SI		6.395-4
	12 SITRNA		4.532-3
	13 SIOTHR		6.018-4
	14 SBLKL		4.179-6
	15 SBLKH		1.095-3
	16 SBLKG		5.974-4
	17 SBLKE		4.499-3
	18 SBLKC		3.336-5
	19 SBLKA		3.000-4
	20 CVCS		6.813-4
	21 CVTRNA		3.917-3
	22 CVOTHR		6.496-4
	23 CBLKO		3.781-5
	24 CBLKK		5.477-4
	25 CBLKJ		2.666-4
	26 CBLKH		4.351-3

NOTE: Exponential notation is indicated in abbreviated form; i.e., 2.577-6 = 2.577 x 10^{-6}.

Sheet 3 of 4

Top Event Split Fraction	Function	Cause	Results
	29 CBLKC 30 CBLKA 31 PS2 32 MOV2		3.917-3 4.618-3 1.919-4 1.236-4
LLLPI	1 LLLPI 2 LLLPIH 3 LLLPIC 4 LLLPIM 5 RHRSYS 6 RSYS1 7 RSYS2 8 RHTRNA 9 RXTIE 10 RBLKK 11 RBLKG 12 RBLKE 13 RBLKC 14 RBLKA	LLOCA: LPI Total Hardware Total Common Cause Total Maintenance Total	9.166-4 6.603-4 2.275-4 2.894-5 6.042-4 5.978-4 6.437-6 5.543-3 1.190-3 5.949-4 5.471-4 5.949-4 5.260-3 2.838-4
ACL	1 ACL 2 ACLH 3 ACLM 4 ABLKAA 5 ABLKEE	Accumulators Total Hardware Total Maintenance Total	1.130-3 1.130-3 0.000-1 8.639-4 2.666-4
MLRHRM	2 MLRHRM 3 MLRHMH 4 MLRHMC 5 MLRHMM 6 RHTRNA 7 RBLKS 8 RBLKC 9 RBLKA 10 HBLKA	MLOCA: RHR Miniflow Total Hardware Total Common Cause Total Maintenance Total	5.482-4 2.520-4 2.365-4 5.960-5 1.266-2 4.384-3 3.624-3 2.823-4 4.367-3

NOTE: Exponential notation is indicated in abbreviated form; i.e., 3.917-3 = 3.917×10^{-3}.

Sheet 4 of 4

Top Event Split Fraction	Function	Cause	Results
SLRHRM	1 SLRHRM	SLOCA: RHR Miniflow Total	5.918-4
	2 SLRHMH	Hardware Total	2.559-4
	3 SLRHMC	Common Cause Total	2.756-4
	4 SLRHMM	Maintenance Total	6.032-5
	5 RHTRNA		1.281-2
	6 RBLKS		4.385-3
	7 RBLKC		3.773-3
	8 RBLKA		2.825-4
	9 HBLKA		4.367-3

APPENDIX D.3

ECCS RESULTS - ACCUMULATOR - 1 HOUR

Top Event Split Fraction	Function	Cause	Results
ACL	1 ACL	Accumulators Total	1.561-3
	2 ACLH	Hardware Total	1.134-3
	3 ACLM	Maintenance Total	4.272-4
	4 ABLKAA		8.659-4
	5 ABLKEE		2.684-4

ECCS RESULTS - ACCUMULATOR - 8 HOURS

Top Event Split Fraction	Function	Cause	Results
ACL	1 ACL	Accumulators Total	4.581-3
	2 ACLH	Hardware Total	1.130-3
	3 ACLM	Maintenance Total	3.451-3
	4 ABLKAA		8.639-4
	5 ABLKEE		2.666-4

APPENDIX D.4

ECCS RESULTS - ALLOWABLE OUTAGE TIME AT 72 HOURS

Sheet 1 of 3

Top Event Split Fraction	Function	Cause	Results
SLHPI	1 SLHPI	SLOCA: HPI Total	1.224-6
	2 SLHPIH	Hardware Total	5.088-7
	3 SLHPIC	Common Cause Total	6.045-7
	4 SLHPIM	Maintenance Total	1.109-7
	5 SIM	SI Pump Maintenance	4.883-8
	6 CVM	CVCS Pump Maintenance	3.934-8
	7 RWSTM	RWST CVCS Pump Valve Maintenance	1.172-8
	9 BOM	BIT Outlet Valve Maintenance	1.103-8
	10 SLHPIT	Testing Total	2.271-0
	11 SI		6.308-4
	12 SITRNA		4.831-3
	13 SIOTHR		5.879-4
	14 SBLKL		1.303-5
	15 SBLKH		1.059-3
	16 SBLKG		5.746-4
	17 SBLKE		4.798-3
	18 SBLKC		3.243-5
	19 SBLKA		2.916-4
	20 CVCS		7.217-4
	21 CVTRNA		4.239-3
	22 CVOTHR		6.854-4
	23 CBLKO		3.942-5
	24 CBLKK		5.293-4
	25 CBLKJ		2.592-4
	26 CBLKH		4.385-3
	29 CBLKC		4.239-3
	30 CBLKA		4.644-3
	31 MOV2		1.104-4
	32 PS2		2.247-4
ATWS	1 ATWS	ATWS: High Pressure Injection Total	1.131-3
	2 ATWSH	Hardware Total	7.202-4
	3 ATWSC	Common Cause Total	3.260-4
	4 ATWSM	Maintenance Total	8.481-5
	5 CVM	CVCS Pump Maintenance	4.968-5
	6 RWM	RWST CVCS Pump Maintenance	1.808-5
	8 BOM	BIT Outlet Valve Maintenance	1.706-5
	9 CVCS		7.202-4
	10 CVTRNA		4.102-3

NOTE: Exponential notation is indicated in abbreviated form; i.e., 1.224-6 = 1.224×10^{-6}.

Sheet 2 of 3

Top Event Split Fraction	Function	Cause	Results
	11 CVOTHR		6.852-4
	12 CBLKO		3.942-5
	13 CBLKK		5.291-4
	14 CBLKJ		2.591-4
	15 CBLKH		4.385-3
	18 CBLKC		4.102-3
	19 CBLKA		4.644-3
	20 PS2		2.156-4
	21 MOV2		1.104-4
MLHPI	1 MLHPI	MLOCA: HPI Total	4.229-5
	2 MLHPIH	Hardware Total	1.448-5
	3 MLHPIC	Common Cause Total	9.495-6
	4 MLHPIM	Maintenance Total	1.828-5
	5 SIM	SI Pump Maintenance	9.531-6
	6 CVM	CVCS Pump Maintenance	8.390-6
	7 RWSTM	RWST CVCS Pump Valve Maintenance	1.827-7
	9 BOM	BIT Outlet Valve Maintenance	1.719-7
	10 MLHPIT	Testing Total	4.512-8
	11 SI		6.203-4
	12 SITRNA		4.693-3
	13 SIOTHR		5.788-4
	14 SBLKL		4.342-6
	15 SBLKH		1.058-3
	16 SBLKG		5.742-4
	17 SBLKE		4.661-3
	18 SBLKC		3.207-5
	19 SBLKA		2.912-4
	20 CVCS		7.202-4
	21 CVTRNA		4.102-3
	22 CVOTHR		6.852-4
	23 CBLKO		3.942-5
	24 CBLKK		5.291-4
	25 CBLKJ		2.591-4
	26 CBLKH		4.385-3
	29 CBLKC		4.102-3
	30 CBLKA		4.644-3
	31 PS2		2.156-4
	32 MOV2		1.104-4

NOTE: Exponential notation is indicated in abbreviated form; i.e., 6.852-6 = 6.852×10^{-6}.

Top Event Split Fraction	Function	Cause	Results
LLLPI	1 LLLPI	LLOCA: LPI Total	9.843-4
	2 LLLPIH	Hardware Total	6.487-4
	3 LLLPIC	Common Cause Total	2.323-4
	4 LLLPIM	Maintenance Total	1.033-4
	5 RHRSYS		5.840-4
	6 RSYS1		5.770-4
	7 RSYS2		7.058-6
	8 RHTRNA		5.877-3
	9 RXTIE		1.148-3
	10 RBLKK		5.742-4
	11 RBLKG		5.290-4
	12 RBLKE		5.742-4
	13 RBLKC		5.602-3
	14 RBLKA		2.741-4
MLRHRM	2 MLRHRM	MLOCA: RHR Miniflow Total	7.140-4
	3 MLRHMH	Hardware Total	2.665-4
	4 MLRHMC	Common Cause Total	2.417-4
	5 MLRHMM	Maintenance Total	2.058-4
	6 RHTRNA		1.291-2
	7 RBLKS		4.417-3
	8 RBLKC		3.821-3
	9 RBLKA		2.742-4
	10 HBLKA		4.400-3
SLRHRM	1 SLRHRM	SLOCA: RHR Miniflow Total	7.577-4
	2 SLRHMH	Hardware Total	2.704-4
	3 SLRHMC	Common Cause Total	2.791-4
	4 SLRHMM	Maintenance Total	2.082-4
	5 RHTRNA		1.306-2
	6 RBLKS		4.417-3
	7 RBLKC		3.966-3
	8 RBLKA		2.744-4
	9 HBLKA		4.400-3

NOTE: Exponential notation is indicated in abbreviated form; i.e., 9.843-4 = 9.843×10^{-4}.

Sheet 3 of 3

Top Event Split Fraction	Function	Cause	Results
LLLPI	1 LLLPI	LLOCA: LPI Total	1.122-3
	2 LLLPIH	Hardware Total	6.487-4
	3 LLLPIC	Common Cause Total	2.323-4
	4 LLLPIM	Maintenance Total	2.410-4
	5 RHRSYS		5.840-4
	6 RSYS1		5.770-4
	7 RSYS2		7.058-6
	8 RHTRNA		5.877-3
	9 RXTIE		1.148-3
	10 RBLKK		5.742-4
	11 RBLKG		5.290-4
	12 RBLKE		5.742-4
	13 RBLKC		5.602-3
	14 RBLKA		2.741-4
MLRHRM	2 MLRHRM	MLOCA: RHR Miniflow Total	9.885-4
	3 MLRHMH	Hardware Total	2.665-4
	4 MLRHMC	Common Cause Total	2.417-4
	5 MLRHMM	Maintenance Total	4.803-4
	6 RHTRNA		1.291-2
	7 RBLKS		4.417-3
	8 RBLKC		3.821-3
	9 RBLKA		2.742-4
	10 HBLKA		4.400-3
SLRHRM	1 SLRHRM	SLOCA: RHR Miniflow Total	1.035-3
	2 SLRHMH	Hardware Total	2.704-4
	3 SLRHMC	Common Cause Total	2.791-4
	4 SLRHMM	Maintenance Total	4.857-4
	5 RHTRNA		1.306-2
	6 RBLKS		4.417-3
	7 RBLKC		3.966-3
	8 RBLKA		2.744-4
	9 HBLKA		4.400-3

NOTE: Exponential notation is indicated in abbreviated form; i.e., 1.122-3 = 1.122 x 10^{-3}.

Sheet 2 of 3

Top Event Split Fraction	Function	Cause	Results
	11 CVOTHR		6.852-4
	12 CBLKO		3.942-5
	13 CBLKK		5.291-4
	14 CBLKJ		2.591-4
	15 CBLKH		4.385-3
	18 CBLKC		4.102-3
	19 CBLKA		4.644-3
	20 PS2		2.156-4
	21 MOV2		1.104-4
MLHPI	1 MLHPI	MLOCA: HPI Total	6.666-5
	2 MLHPIH	Hardware Total	1.448-5
	3 MLHPIC	Common Cause Total	9.495-6
	4 MLHPIM	Maintenance Total	4.264-5
	5 SIM	SI Pump Maintenance	2.224-5
	6 CVM	CVCS Pump Maintenance	1.958-5
	7 RWSTM	RWST CVCS Pump Valve Maintenance	4.262-7
	9 BOM	BIT Outlet Valve Maintenance	4.011-7
	10 MLHPIT	Testing Total	4.512-8
	11 SI		6.203-4
	12 SITRNA		4.693-3
	13 SIOTHR		5.788-4
	14 SBLKL		4.342-6
	15 SBLKH		1.058-3
	16 SBLKG		5.742-4
	17 SBLKE		4.661-3
	18 SBLKC		3.207-5
	19 SBLKA		2.912-4
	20 CVCS		7.202-4
	21 CVTRNA		4.102-3
	22 CVOTHR		6.852-4
	23 CBLKO		3.942-5
	24 CBLKK		5.291-4
	25 CBLKJ		2.591-4
	26 CBLKH		4.385-3
	29 CBLKC		4.102-3
	30 CBLKA		4.644-3
	31 PS2		2.156-4
	32 MOV2		1.104-4

NOTE: Exponential notation is indicated in abbreviated form; i.e., 6.852-4 = 6.852 x 10^{-4}.

APPENDIX D.5

ECCS RESULTS - ALLOWABLE OUTAGE TIME - 7 DAYS

Sheet 1 of 3

Top Event Split Fraction	Function	Cause	Results
SLHPI	1 SLHPI	SLOCA: HPI Total	1.372-6
	2 SLHPIH	Hardware Total	5.088-7
	3 SLHPIC	Common Cause Total	6.045-7
	4 SLHPIM	Maintenance Total	2.588-7
	5 SIM	SI Pump Maintenance	1.139-7
	6 CVM	CVCS Pump Maintenance	9.179-8
	7 RWSTM	RWST CVCS Pump Valve Maintenance	2.735-8
	9 BOM	BOT Outlet Valve Maintenance	2.573-8
	10 SLHPIT	Testing Total	2.271-0
	11 SI		6.308-4
	12 SITRNA		4.831-3
	13 SIOTHR		5.879-4
	14 SBLKL		1.303-5
	15 SBLKH		1.059-3
	16 SBLKG		5.746-4
	17 SBLKE		4.798-3
	18 SBLKC		3.243-5
	19 SBLKA		2.916-4
	20 CVCS		7.217-4
	21 CVTRNA		4.239-3
	22 CVOTHR		6.854-4
	23 CBLKO		3.942-5
	24 CBLKK		5.293-4
	25 CBLKJ		2.592-4
	26 CBLKH		4.385-3
	29 CBLKC		4.239-3
	30 CBLKA		4.644-3
	31 MOV2		1.104-4
	32 PS2		2.247-4
ATWS	1 ATWS	ATWS: High Pressure Injection Total	1.244-3
	2 ATWSH	Hardware Total	7.202-4
	3 ATWSC	Common Cause Total	3.260-4
	4 ATWSM	Maintenance Total	1.979-4
	5 CVM	CVCS Pump Maintenance	1.159-4
	6 RWM	RWST CVCS Pump Maintenance	4.218-5
	8 BOM	BIT Outlet Valve Maintenance	3.981-5
	9 CVCS		7.202-4
	10 CVTRNA		4.102-3

NOTE: Exponential notation is indicated in abbreviated form; i.e., 1.372-6 = 1.372 x 10^{-6}.