Evaluation of Potential Severe Accidents During Low Power and Shutdown Operations at Surry, Unit 1

Analysis of Core Damage Frequency from
Internal Events During Mid-Loop Operations

Appendix E (Sections E.1-E.8)

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ABSTRACT

Traditionally, probabilistic risk assessments (PRA) of severe accidents in nuclear power plants have considered initiating events potentially occurring only during full power operation. Some previous screening analyses that were performed for other modes of operation suggested that risks during those modes were small relative to full power operation. However, more recent studies and operational experience have implied that accidents during low power and shutdown could be significant contributors to risk.

During 1989, the Nuclear Regulatory Commission (NRC) initiated an extensive program to carefully examine the potential risks during low power and shutdown operations. The program includes two parallel projects being performed by Brookhaven National Laboratory (BNL) and Sandia National Laboratories (SNL). Two plants, Surry (pressurized water reactor) and Grand Gulf (boiling water reactor), were selected as the plants to be studied.

The objectives of the program are to assess the risks of severe accidents initiated during plant operational states other than full power operation and to compare the estimated core damage frequencies, important accident sequences and other qualitative and quantitative results with those accidents initiated during full power operation as assessed in NUREG-1150. The scope of the program includes that of a level-3 PRA.

The objective of this volume of the report is to document the approach utilized in the level-1 internal events PRA for the Surry plant, and discuss the results obtained. A phased approach was used in the level-1 program. In phase 1, which was completed in Fall 1991, a coarse screening analysis examining accidents initiated by internal events (including internal fire and flood) was performed for all plant operational states (POSS). The objective of the phase 1 study was to identify potential vulnerable plant configurations, to characterize (on a high, medium, or low basis) the potential core damage accident scenarios, and to provide a foundation for a detailed phase 2 analysis.

In phase 2, mid-loop operation was selected as the plant configuration to be analyzed based on the results of the phase 1 study. The objective of the phase 2 study is to perform a detailed analysis of the potential accident scenarios that may occur during mid-loop operation, and compare the results with those of NUREG-1150. The scope of the level-1 study includes plant damage state analysis, and uncertainty analysis. Volume 1 summarizes the results of the study. Internal events analysis is documented in Volume 2. It also contains an appendix that documents the part of the phase 1 study that has to do with POSSs other than mid-loop operation. Internal fire and internal flood analyses are documented in Volumes 3 and 4. A separate study on seismic analysis, documented in Volume 5, was performed for the NRC by Future Resources Associates, Inc. Volume 6 documents the accident progression, source terms, and consequences analysis.

In the phase 2 study, system models applicable for shutdown conditions were developed and supporting thermal hydraulic analysis were performed to determine both the timing of the accidents and success criteria for systems. Initiating events that may occur during mid-loop operations were identified and accident sequence event trees were developed and quantified. In the preliminary quantification of the mid-loop accident sequences, it was found that the decay heat at which the accident initiating event occurs is an important parameter that determines both the success criteria for the mitigating functions and the time available for operator actions. In order to better account for the decay heat, a "time window" approach was

developed. In this approach, time windows after shutdown were defined based on the success criteria established for the various methods that can be used to mitigate the accident. Within each time window, the decay heat and accident sequence timing are more accurately defined and new event trees developed and quantified accordingly. Statistical analysis of the past outage data was performed to determine the time at which a mid-loop condition is reached, and the duration of the mid-loop operation. Past outage data were used to determine the probability that an accident initiating event occurs in each of the time windows. This probability is used in the quantification of the accident sequences.

The mean core damage frequency of the Surry plant due to internal events that may take place during mid-loop operations is $5\text{E-}06$ per year, and the 5th and 95th percentiles are $5\text{E-}07$ and $2\text{E-}05$ per year, respectively. This can be compared with the mean core damage frequency from internal events of $4\text{E-}05$ per year estimated in the NUREG-1150 study for full power operations.

Contents

Appendix E	Event Trees and Their Associated High Level Fault Trees
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FOREWORD

(NUREG/CR-6143 and 6144) Low Power and Shutdown Probabilistic Risk Assessment Program

Traditionally, probabilistic risk assessments (PRA) of severe accidents in nuclear power plants have considered initiating events potentially occurring only during full power operation. Some previous screening analysis that were performed for other modes of operation suggested that risks during those modes were small relative to full power operation. However, more recent studies and operational experience have implied that accidents during low power and shutdown could be significant contributors to risk.

During 1989, the Nuclear Regulatory Commission (NRC) initiated an extensive program to carefully examine the potential risks during low power and shutdown operations. The program includes two parallel projects performed by Brookhaven National Laboratory (BNL) and Sandia National Laboratories (SNL), with the seismic analysis performed by Future Resources Associates. Two plants, Surry (pressurized water reactor) and Grand Gulf (boiling water reactor), were selected as the plants to be studied.

The objectives of the program are to assess the risks of severe accidents due to internal events, internal fires, internal floods, and seismic events initiated during plant operational states other than full power operation and to compare the estimated core damage frequencies, important accident sequences and other qualitative and quantitative results with those accidents initiated during full power operation as assessed in NUREG-1150. The scope of the program includes that of a level-3 PRA.

The results of the program are documented in two reports, NUREG/CR-6143 and 6144. The reports are organized as follows:

For Grand Gulf:

NUREG/CR-6143 - Evaluation of Potential Severe Accidents during Low Power and Shutdown Operations at Grand Gulf, Unit 1

- Volume 1: Summary of Results
- Volume 2: Analysis of Core Damage Frequency from Internal Events for Operational State 5 During a Refueling Outage
 - Part 1: Main Report
 - Part 1A: Sections 1 - 9
 - Part 1B: Section 10
 - Part 1C: Sections 11 - 14
 - Part 2: Internal Events Appendices A to H
 - Part 3: Internal Events Appendices I and J
 - Part 4: Internal Events Appendices K to M
- Volume 3: Analysis of Core Damage Frequency from Internal Fire Events for Plant Operational State 5 During a Refueling Outage
- Volume 4: Analysis of Core Damage Frequency from Internal Flooding Events for Plant Operational State 5 During a Refueling Outage
- Volume 5: Analysis of Core Damage Frequency from Seismic Events for Plant Operational State 5 During a Refueling Outage

Foreword (continued)

- Volume 6: Evaluation of Severe Accident Risks for Plant Operational State 5
During a Refueling Outage
Part 1: Main Report
Part 2: Supporting MELCOR Calculations

For Surry:

NUREG/CR-6144- Evaluation of Potential Severe Accidents during Low Power and Shutdown
Operations at Surry Unit-1

- Volume 1: Summary of Results

- Volume 2: Analysis of Core Damage Frequency from Internal Events during
Mid-loop Operations
Part 1: Main Report
Part 1A: Chapters 1 - 6
Part 1B: Chapters 7 - 12
Part 2: Internal Events Appendices A to D
Part 3: Internal Events Appendix E
Part 3A: Sections E.1 - E.8
Part 3B: Sections E.9 - E.16

- Part 4: Internal Events Appendices F to H
Part 5: Internal Events Appendix I
Volume 3: Analysis of Core Damage Frequency from Internal Fires during
Mid-loop Operations
Part 1: Main Report
Part 2: Appendices
Volume 4: Analysis of Core Damage Frequency from Internal Floods during
Mid-loop Operations
Volume 5: Analysis of Core Damage Frequency from Seismic Events during
Mid-loop Operations
Volume 6: Evaluation of Severe Accident Risks during Mid-loop Operations
Part 1: Main Report
Part 2: Appendices

APPENDIX E

EVENT TREES AND THEIR ASSOCIATED HIGH LEVEL

FAULT TREES

APPENDIX E

EVENT TREES AND THEIR ASSOCIATED HIGH LEVEL

FAULT TREES

	Page
E.1 Event Trees and High Level Fault Trees for Over Draining to Mid-loop (RHR2A)	E-3
E.2 Event Trees and High Level Fault Trees for Loss of Inventory (RHR2B)	E-60
E.3 Event Trees and High Level Fault Trees for Non-Recoverable Loss of RHR (RHR3)	E-117
E.4 Event Trees and High Level Fault Trees for Loss of Operation Train of RHR (RHR4)	E-166
E.5 Event Trees and High Level Fault Trees for Recoverable Loss of RHR (RHR5)	E-219
E.6 Event Trees and High Level Fault Trees for Loss of Offsite Power (L1)	E-272
E.7 Event Trees and High Level Fault Trees for Loss of Offsite Power (L2)	E-368
E.8 Event Trees and High Level Fault Trees for Unit 1 Blackout (L3)	E-453
E.9 Event Trees and High Level Fault Trees for Two Unit Blackout (B1)	E-537
E.10 Event Trees and High Level Fault Trees for Two Unit Blackout (B2)	E-592
E.11 Event Trees and High Level Fault Trees for Loss of 4KV Bus (4K)	E-618
E.12 Event Trees and High Level Fault Trees for Loss of Vital Bus (VB)	E-701
E.13 Event Trees and High Level Fault Trees for Spurious Safety Injection Signal (SI)	E-784
E.14 Event Trees and High Level Fault Trees for Loss of Component Cooling Water (AR)	E-867
E.15 Event Trees and High Level Fault Trees for Loss of Instrument Air (CC)	E-910
E.16 Event Trees and High Level Fault Trees for Loss of Switchgear Room Cooling (SR)	E-967

Appendix E.1 Event Trees and High Level Fault trees for Over Draining to Mid-loop(RHR2A)

UNITY	IRAW1	MRAW1	RRAW1	VW1	SRAW1	FRAW1	GRAW1	CRAW1	SEQ #	END-STATE-
<p>RAWIR6 Event Tree</p>									1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18	OK OK OK CD CD CD OK OK CD CD OK CD CD CD OK OK CD CD

UNITY	IRAW1	MRAW1	RRAW1	FRAW1V	CRAW1V	SEQ #	END-STATE-NAMES
<div> <p>RAWID6 Event Tree</p> </div>							OK OK OK CD CD OK CD CD

1 | Top Event for Loss of Instrument Air in Window 1

RCS Makeup in Window 1

Restore RHR given RHR2B in Window 1

Safety Valves Not Removed in Window 1

Reflux Cooling in Window 1

RCS Loops Isolated to Cause Failure of Reflux in Window 1

Feed and Bleed the RCS in RHR2A, Window 1

Safety Valves Removed in Window 1

Feed and Bleed the RCS with V failed in RHR2A, Window 1

Gravity from RWST in RHR2A, Window 1

Failure of High Pressure Recirculation in Window 1

Failure of Recirculation Spray in Window 1—cause HPR failure

Failure of High Pressure Recirculation in Window 1

UNITY	IRAW2	MRAW2	RRAW2	SRAW2	FRAW2V	CRAW2V	SEQ #	END-STATE-NAMES
<p>RAW2D6 Event Tree</p>							1 2 3 4 5 6 7 8 9 10	OK OK OK OK CD CD OK OK CD CD

RCS Makeup in Window 2

Restore RHR given RHR2A in Window 2

Safety Valves Not Removed in Window 2

Reflux Cooling in Window 2

RCS Loops Isolated to Cause Failure of Reflux in Window 2

Feed and Bleed the RCS in RHR2A, Window 2

Safety Valves Removed in Window 2

Feed and Bleed the RCS with V failed in RHR2A, Window 2

Gravity from RWST in RHR2A, Window 2

Four of High
Pressure facies
in Window 2

Failure of Recirculation Spray in Window 2—cause HPR failure

Falls of High
Pressure Recirculation
In Window 2

UNITY	IRAW3	MRAW3	RRAW3	VW3	FRAW3	GRAW3	SEQ #	END-STATE-NAMES
<p style="text-align: center;">RAW3R6 Event Tree</p>								OK OK OK CD OK CD OK CD OK CD OK CD

UNITY	IRAW3	MRAW3	RRAW3	SRAW3	FRAW3V	SEQ #	END-STATE-NAMES
						1 2 3 4 5 6 7 8	OK OK OK OK CD OK OK CD
<p>RAW3D6 Event Tree</p>							

UNITY	IRAW3	MRAW3	RRAW3	VW3	PRAW3	GRAW3	SEQ #	END-STATE-NAMES
<p>RAW3R10 Event Tree</p>								OK OK OK CD CD OK CD OK CD CD OK CD

! top event for Over Draining
in window 3

RCS Makeup in Window 3

Restore RHR given RHR2A in Window 3

E-39

Safety Valves Not Removed in Window 3

Reflux Cooling in Window 3

RCS Loops Isolated to Cause Failure of Reflux in Window 3

Feed and Bleed the RCS in RHR2A, Window 3

Safety Valves Removed in Window 3

Feed and Bleed the RCS with V failed in RHR2A, Window 3

Gravity from RWST in RHR2A, Window 3

UNITY	IRAW4	MRAW4	RRAW4	VW4	SRAW4	FRAW4	GRAW4	SEQ #	END-STATE-NAMES
								1	OK
								2	OK
								3	OK
								4	OK
								5	CD
								6	OK
								7	OK
								8	CD
								9	OK
								10	OK
								11	CD
								12	OK
								13	OK
								14	CD

RAW4R6 Event Tree

UNITY	IRAW4	MRAW4	RRAW4	VW4	SRAW4	FRAW4	GRAW4	SEQ #	END - STATE - NAMES
								1 2 3 4 5 6 7 8 9 10 11 12 13 14	OK OK OK OK CD OK OK CD OK CD OK CD OK OK CD

RAW4R10 Event Tree

UNITY	IRAW4	MRAW4	RRAW4	SRAW4	FRAW4V	SEQ #	END-STATE-NAMES
<p>RAW4D6 Event Tree</p>							OK OK OK OK CD OK OK CD

1 top event for over Draining in window 4

RCS Makeup in Window 4

E-51

Restore RHR given RHR2A in Window 4

Safety Valves Not Removed in Window 4

Reflux Cooling in Window 4

RCS Loops Isolated to Cause Failure of Reflux in Window 4

Feed and Bleed the RCS in RHR2A Window 4

Safety Valves Removed in Window 4

Feed and Bleed the RCS with V failed in RHR2B, Window 4

Gravity from RWST in RHR2A, Window 4

Appendix E.2 Event trees and High Level Fault Trees for Loss of Inventory(RHR2B)

I Top Event for Loss of Inventory in Window 1

RCS Makeup in Window 1

Restore RHR given RHR2B in Window 1

Safety Valves Not Removed in Window 1

Reflux Cooling in Window 1

RCS Loops Isolated to Cause Failure of Reflux in Window 1

Feed and Bleed the RCS in RHR2B, Window 1

Safety Valves Removed in Window 1

Feed and Bleed the RCS with V failed in RHR2B, Window 1

Gravity from RWST in RHR2B, Window 1

E-73

1-cause HPR failure

1

UNITY	IRBW2	MRBW2	RRBW2	SRBW2	FRBW2V	CRBW2V	SEQ #	END-STATE-NAMES
<p style="text-align: center;">RBW2D6 Event Tree</p>								OK OK OK OK CD CD OK OK CD CD

Window 2

RCS Makeup in Window 2

Restore RHR given RHR2B in Window 2

Safety :Valves Not Removed in Window 2

Reflux Cooling in Window 2

RCS Loops Isolated to Cause Failure of Reflux in Window 2

Feed and Bleed the RCS in RHR2B, Window 2

Safety Valves Removed in Window 2

Feed and Bleed the RCS with V failed in RHR2B, Window 2

Gravity from RWST in RHR2B, Window 2

E-88

Failure of Recirculation Spray in Window 2—cause HPR failure

[illegible]

UNITY	IRBW3	MRBW3	RRBW3	VW3	FRBW3	GRBW3	SEQ #	END-STATE-NAMES
<p>RBW3R6 Event Tree</p>								OK OK OK CD CD OK OK OK CD CD OK CD

UNITY	IRBW3	MRBW3	RRBW3	VW3	FRBW3	GRBW3	SEQ #	END-STATE-NAMES
							1 2 3 4 5 6 7 8 9 10 11 12	OK OK OK CD CD CD OK OK OK CD CD OK CD

RBW3R10 Event Tree

UNITY	IRBW3	MRBW3	RRBW3	SRBW3	FRBW3V	SEQ #	END-STATE-NAMES
						1 2 3 4 5 6 7 8	OK OK OK CD OK OK CD

RBW3D6 Event Tree

1 Top Event for Loss of Inventory in Window 3

RCS Makeup in Window 3

Restore RHR given RHR2B in Window 3

Safety Valves Not Removed in Window 3

Reflux Cooling in Window 3

RCS Loops Isolated to Cause Failure of Reflux in Window 3

E-99

Feed and Bleed the RCS in RHR2B, Window 3

Safety Valves Removed in Window 3

Feed and Bleed the RCS with V failed in RHR2B, Window 3

Gravity from RWST in RHR2B, Window 3

UNITY	IRBW4	MRBW4	RRBW4	VW4	FRBW4	GRBW4	SEQ #	END-STATE-NAMES
<p>RBW4R6 Event Tree</p>								OK OK OK OK CD OK CD OK OK CD OK CD

UNITY	IRBW4	MRBW4	RRBW4	VW4	FRBW4	GRBW4	SEQ #	END-STATE-NAMES
<p style="text-align: center;">RBW4R10 Event Tree</p>								OK OK OK CD OK CD OK OK CD OK CD CD

I Top Event for Loss of Inventory in Window 4

RCS Makeup in Window 4

Restore RHR given RHR2B in Window 4

Safety Valves Not Removed in Window 4

Reflux Cooling in Window 4

RCS Loops Isolated to Cause Failure of Reflux in Window 4

Feed and Bleed the RCS in RHR2B, Window 4

Safety Valves Removed in Window 4

Feed and Bleed the RCS with V failed in RHR2B, Window 4

Gravity from RWST in RHR2B, Window 4

Appendix E.3 Event Tree and High Level Fault Trees for Non-recoverable Loss of RHR(RHR3)

UNITY	IR3W1	VW1	SR3W1	FR3W1	GR3W1	CR3W1	SEQ #	END-STATE-NAMES
<p style="text-align: center;">R3W1R6 Event Tree</p>								OK OK CD CD CD CD OK OK CD CD

UNITY	IR3W1	FR3W1V	CR3W1V	SEQ #	END-STATE-NAMES
				<div> <p>1 2 3 4</p> </div>	<div> <p>OK OK CD CD</p> </div> <div> <p>R3W1D6 Event Tree</p> </div>

1 Top Event for Loss of RHR – R3 in Window 1

Safety Valves Not Removed in Window 1

Reflux Cooling Given RHR3 in Window 1

RCS Loops Isolated to Cause Failure of Reflux in Window 1

Feed and Bleed the RCS in RHR3, Window 1

Safety Valves Removed in Window 1

Feed and Bleed the RCS with V failed in RHR3, Window 1

Gravity from RWST in RHR3, Window 1

1

Failure of Recirculation Spray in Window 1—cause HPR failure :

in Window 1

UNITY	IR3W2	VW2	SR3W2	FR3W2	GR3W2	CR3W2	SEQ #	END-STATE-NAMES
<p style="text-align: center;">R3W2R6 Event Tree</p>								OK OK CD CD CD OK OK CD CD

UNITY	IR3W2	SR3W2	FR3W2V	CR3W2V	SEQ #	END-STATE-NAMES
					1 2 3 4 5	OK OK OK CD CD
				R3W2D6 Event Tree

1 Top Event for Loss of RHR- R3 in Window 2

Safety Valves Not Removed in Window 2

Reflux Cooling Given RHR3 in Window 2

RCS Loops Isolated to Cause Failure of Reflux in Window 2

Feed and Bleed the RCS in RHR3, Window 2

Safety Valves Removed in Window 2

E-138

Feed and Bleed the RCS with V failed in RHR3, Window 2

Gravity from RWST in RHR3, Window 2

1
Failure of High
Pressure Packer
in Window 2

Failure of Recirculation Spray in Window 2—cause HPR failure for RHR3 Event

UNITY	IR3W3	VW3	FR3W3	GR3W3	SEQ #	END-STATE-NAMES
<p>R3W3R6 Event Tree</p>						OK OK CD CD OK CD

UNITY	IR3W3	VW3	FR3W3	GR3W3	SEQ #	END-STATE-NAMES
<div> <div> <div></div> <div></div> <div></div> <div></div> <div></div> <div></div> </div> <div> <div></div> <div></div> <div></div> <div></div> <div></div> <div></div> </div> <div> <div></div> <div></div> <div></div> <div></div> <div></div> <div></div> </div> <div> <div></div> <div></div> <div></div> <div></div> <div></div> <div></div> </div> <div> <div></div> <div></div> <div></div> <div></div> <div></div> <div></div> </div> <div> <div></div> <div></div> <div></div> <div></div> <div></div> <div></div> </div> </div>						OK OK CD CD OK OK CD

1 2 3 4 5 6

R3W3R10 Event Tree

UNITY	IR3W3	SR3W3	FR3W3	SEQ #	END-STATE-NAMES
<p>R3W3D6 Event Tree</p>					OK OK OK CD

Safety Valves Not Removed in Window 3

Reflux Cooling Given RHR3 in Window 3

RCS Loops Isolated to Cause Failure of Reflux in Window 3

Feed and Bleed the RCS in RHR3, Window 3

Safety Valves Removed in Window 3

Feed and Bleed the RCS with V failed in RHR3, Window 3

Gravity from RWST in RHR3, Window 3

UNITY	IR3W4	VW4	FR3W4	GR3W4	SEQ #	END-STATE-NAMES
<div> <pre> graph TD 1 --- 2 2 --- 3 3 --- 4 4 --- 5 4 --- 6 5 --- 6 </pre> </div> <div>R3W4R6 Event Tree</div>						OK OK OK CD OK CD

UNITY	IR3W4	VW4	FR3W4	GR3W4	SEQ #	END-STATE-NAMES
<p>R3W4R10 Event Tree</p>						OK OK OK CD OK CD

UNITY	IR3W4	SR3W4	FR3W4V	GR3W4	SEQ #	END-STATE-NAMES
					1 2 3 4	OK OK OK CD

R3W4D6 Event Tree

Safety Valves Not Removed in Window 4

Reflux Cooling Given RHR3 in Window 4

RCS Loops Isolated to Cause Failure of Reflux in Window 4

Feed and Bleed the RCS in RHR3, Window 4

Safety Valves Removed in Window 4

Feed and Bleed the RCS with V failed in RHR3, Window 4

Gravity from RWST in RHR3, Window 4

**Appendix E.4 Event Trees and High Level Fault Trees for Loss of Operation Train of
RHR(RHR4)**

UNITY	IR4W1	RR4W1	VW1	SR4W1	PR4W1	GR4W1	CR4W1	SEQ #	END-STATE-NAMES
<div> <p>R4W1R6 Event Tree</p> </div>									OK OK OK CD CD CD OK OK CD CD

UNITY	IR4W1	RR4W1	FR4W1V	CR4W1V	SEQ #	END-STATE-NAMES
					1 2 3 4 5	OK OK OK CD CD
<div> <div> <div></div> <div></div> <div></div> <div></div> <div></div> </div> <div> <div></div> <div></div> <div></div> <div></div> <div></div> </div> <div> <div></div> <div></div> <div></div> <div></div> <div></div> </div> <div> <div></div> <div></div> <div></div> <div></div> <div></div> </div> <div> <div></div> <div></div> <div></div> <div></div> <div></div> </div> </div> <div>R4W1D6 Event Tree</div>						

| top event for loss of RHR- R4 in Window 1 |

Restore RHR given RHR4 in Window 1

Safety Valves Not Removed in Window 1

Reflux Cooling in Window 1

RCS Loops Isolated to Cause Failure of Reflux in Window 1

Feed and Bleed the RCS in RHR4, Window 1

Safety Valves Removed in Window 1

Feed and Bleed the RCS with V failed in RHR4, Window 1

Gravity from RWST in RHR4, Window 1

Failure of High Pressure Recirculation in Window 1

Failure of Recirculation Spray in Window 1—cause HPR failure

Failure of High Pressure Recirculation in Window 1

UNITY	IR4W2	RR4W2	VW2	SR4W2	PR4W2	GR4W2	CR4W2	SEQ #	END-STATE-NAMES
<div> <div> <div> <div> <div>1</div> <div>2</div> <div>3</div> <div>4</div> <div>5</div> <div>6</div> <div>7</div> <div>8</div> <div>9</div> <div>10</div> </div> <div> <div>OK</div> <div>OK</div> <div>OK</div> <div>CD</div> <div>CD</div> <div>CD</div> <div>OK</div> <div>OK</div> <div>CD</div> <div>CD</div> </div> </div> <div> <div> <div> <div> <div>1</div> <div>2</div> <div>3</div> <div>4</div> <div>5</div> <div>6</div> <div>7</div> <div>8</div> <div>9</div> <div>10</div> </div> <div> <div>OK</div> <div>OK</div> <div>OK</div> <div>CD</div> <div>CD</div> <div>CD</div> <div>OK</div> <div>OK</div> <div>CD</div> <div>CD</div> </div> </div> </div> </div> <div>R4W2R6 Event Tree</div> </div></div>									

UNITY	IR4W2	RR4W2	SR4W2	PR4W2V	CR4W2V	SEQ #	END-STATE-NAMES
						1 2 3 4 5 6	OK OK OK OK CD CD

1
2
3
4
5
6

OK
OK
OK
OK
CD
CD

R4W2D6 Event Tree

1 Top Event for Loss of RHR- R4 in Window 2

Restore RHR given RHR4 in Window 2

Safety Valves Not Removed in Window 2

Reflux Cooling in Window 2

RCS Loops Isolated to Cause Failure of Reflux in Window 2

Feed and Bleed the RCS in RHR4, Window 2

Safety Valves Removed in Window 2

Feed and Bleed the RCS with V failed in RHR4, Window 2

Gravity from RWST in RHR4, Window 2

Failure of High Pressure Recirculation in Window 2

Failure of Recirculation Spray in Window 2—cause HPR failure

in Window 2

UNITY	IR4W3	RR4W3	VW3	FR4W3	GR4W3	SEQ #	END-STATE-NAMES
<p>R4W3R6 Event Tree</p>							OK OK OK CD CD OK CD

UNITY	IR4W3	RR4W3	VW3	FR4W3	GR4W3	SEQ #	END-STATE-NAMES
<p>R4W3R10 Event Tree</p>							OK OK OK CD CD OK CD

UNITY	IR4W3	RR4W3	SR4W3	FR4W3V	SEQ #	END-STATE-NAMES
<p>R4W3D6 Event Tree</p>						OK OK OK OK CD

I top event for loss of RHR-4 in window 3

Restore RHR given RHR4 in Window 3

Safety Valves Not Removed in Window 3

Reflux Cooling in Window 3

RCS Loops Isolated to Cause Failure of Reflux in Window 3

Feed and Bleed the RCS in RHR5, Window 3

Safety Valves Removed in Window 3

Feed and Bleed the RCS with V failed in RHR4, Window 3

Gravity from RWST in RHR4, Window 3

UNITY	IR4W4	RR4W4	VW4	FR4W4	GR4W4	SEQ #	END-STATE-NAMES
						1 2 3 4 5 6 7	OK OK OK CD OK OK CD

OK
OK
OK
CD
OK
OK
CD

1
2
3
4
5
6
7

R4W4R6 Event Tree

UNITY	IR4W4	RR4W4	VW4	FR4W4	GR4W4	SEQ #	END-STATE-NAMES
						1 2 3 4 5 6 7	OK OK OK OK CD OK CD

R4W4R10 Event Tree

UNITY	IR4W4	RR4W4	SR4W4	FR4W4V	SEQ #	END-STATE-NAMES
					1 2 3 4 5	OK OK OK OK CD
<p>R4W4D6 Event Tree</p>						

1 top event for loss of RHR-4 in window 4

Restore RHR given RHR4 in Window 4

Safety Valves Not Removed in Window 4

Reflux Cooling in Window 4

E-213

RCS Loops Isolated to Cause Failure of Reflux in Window 4

Feed and Bleed the RCS in RHR4, Window 4

Safety Valves Removed in Window 4

Feed and Bleed the RCS with V failed in RHR4, Window 4

Gravity from RWST in RHR4, Window 4

**Appendix E.5 Event Trees and High Level Fault Trees for Recoverable Loss of RHR
(RHR5)**

UNITY	IR5W1	RR5W1	VW1	SR5W1	FR5W1	GR5W1	CR5W1	SEQ #	END-STATE-NAMES
<div> <div> <div> <div> <div>1</div> <div>2</div> <div>3</div> <div>4</div> <div>5</div> <div>6</div> <div>7</div> <div>8</div> <div>9</div> <div>10</div> </div> <div> <div>OK</div> <div>OK</div> <div>OK</div> <div>CD</div> <div>CD</div> <div>CD</div> <div>OK</div> <div>OK</div> <div>CD</div> <div>CD</div> </div> </div> <div> <div> <div> <div> <div> <div>1</div> <div>2</div> <div>3</div> <div>4</div> <div>5</div> <div>6</div> <div>7</div> <div>8</div> <div>9</div> <div>10</div> </div> <div> <div>OK</div> <div>OK</div> <div>OK</div> <div>CD</div> <div>CD</div> <div>CD</div> <div>OK</div> <div>OK</div> <div>CD</div> <div>CD</div> </div> </div> </div> </div> </div> <div>R5W1R6 Event Tree</div> </div> </div>									

UNITY	IR5W1	RR5W1	FR5W1	GR5W1	CR5W1	SEQ #	END-STATE-NAMES
<p style="text-align: center;">R5W1D6 Event Tree</p>							OK OK OK CD CD

[illegible]

Restore RHR given RHR5 in Window 1

Safety Valves Not Removed in Window 1

Reflux Cooling Given RHR5 in Window 1

RCS Loops Isolated to Cause Failure of Reflux in Window 1

Feed and Bleed the RCS in RHR5, Window 1

Safety Valves Removed in Window 1

Feed and Bleed the RCS with V failed in RHR5, Window 1

Gravity from RWST in RHR5, Window 1

in Window 1

Failure of Recirculation Spray in Window 1-cause HPR failure for RHR5 Event

UNITY	IR5W2	RR5W2	SR5W2	FR5W2V	CR5W2V	SEQ #	END-STATE-NAMES
						1 2 3 4 5 6	OK OK OK OK CD CD
<p>R5W2D6 Event Tree</p>							

| Top Event for Loss of RHR— R5 in Window 2

Restore RHR given RHR5 in Window 2

Safety Valves Not Removed in Window 2

Reflux Cooling Given RHR5 in Window 2

RCS Loops Isolated to Cause Failure of Reflux in Window 2

Feed and Bleed the RCS in RHR5, Window 2

Safety Valves Removed in Window 2

Gravity from RWST in RHR5, Window 2

Failure of Recirculation Spray in Window 2-cause HPR failure for RHR5 Event

E-246

Faults of High Pressure Reactor in Window 2

UNITY	IR5W3	RR5W3	VW3	FR5W3	GR5W3	SEQ #	END-STATE-NAMES
<div> <p>R5W3R6 Event Tree</p> </div>							OK OK OK CD CD OK CD

UNITY	IR5W3	RR5W3	SR5W3	FR5W3V	SEQ #	END-STATE-NAMES
					<div> <p>1 2 3 4 5</p> </div>	<div> <p>OK OK OK OK CD</p> </div> <div> <p>R5W3D6 Event Tree</p> </div>

I Top Event for Loss of RHR- R5 in Window 3

E-251

Restore RHR given RHR5 in Window 3

Safety Valves Not Removed in Window 3

Reflux Cooling Given RHR5 in Window 3

RCS Loops Isolated to Cause Failure of Reflux in Window 3

Feed and Bleed the RCS in RHR5, Window 3

Safety Valves Removed in Window 3

Feed and Bleed the RCS with V failed in RHR5, Window 3

Gravity from RWST in RHR5, Window 3

UNITY	IR5W4	RR5W4	VW4	FR5W4	GR5W4	SEQ #	END-STATE-NAMES
<p>R5W4R6 Event Tree</p>							OK OK OK OK CD OK CD

UNITY	IR5W4	RR5W4	SR5W4	PR5W4V	SEQ #	END-STATE-NAMES
					1 2 3 4 5	OK OK OK OK CD
<div> <p>R5W4D6 Event Tree</p> </div>						

I Top Event for Loss of RHR-5 in Window 4

Restore RHR given RHR5 in Window 4

Safety Valves Not Removed in Window 4

E-265

Reflux Cooling Given RHR5 in Window 4

RCS Loops Isolated to Cause Failure of Reflux in Window 4

Feed and Bleed the RCS in RHR5, Window 4

Safety Valves Removed in Window 4

Feed and Bleed the RCS with V failed in RHR5, Window 4

Gravity from RWST in RHR5, Window 4

Appendix E.6 Event Trees and High Level Fault Trees for Loss of Offsite Power (L1)

UNITY	IL1W1	RL1W1	VW1	NL1W1	SL1W1	FL1W1	GL1W1	CLIW1	SEQ #	END-STATE-NAMES
L1WR6 -- LOSP L1, WINDOW W1, POS R6										
									1	@ @ @
									2	CD
									3	CD
									4	CD
									5	@
									6	CD
									7	CD
									8	CD
									9	CD
									10	@
									11	@
									12	CD
									13	CD
									14	@
									15	@
									16	CD
									17	CD
									18	CD

[illegible]

l top event for L1 LOSP – L1 in window 1

Restore RHR given L1 in POS 6 - Refueling

Safety valves Not Removed in Window 1

Non-Recovery of AC Power in 144 min. of LOOP

Reflux Cooling in window 1

Reflux Cooling in window 1

RCS Loops isolated to cause failure of reflux in window 1

Feed and Bleed the RCS in L1, Window 1

Feed and Bleed the RCS in L1, Window 1

Gravity from RWST in L1, Window 1

Gravity from RWST in L1, Window 1

Safety Valves Removed in Window 1

Failure of High Pressure Recirculation in Window 1

Failure of High Pressure Recirculation in Window 1

Failure of High Pressure Recirculation in Window 1

Failure of High Pressure Recirculation in Window 1

UNITY	IL1W2	RL1W2	NL1W2	SL1W2	FL1W2	CL1W2	SEQ #	END--STATI
L1W2D6 -- LOSP L1, WINDOW W2, POS D6								
								@ @ @ @ CD CD @ @ CD CD

1 top event for L1 in window 2

Restore RHR given L1 in POS 6 - Refueling

Safety valves Not Removed in Window 2

Non-Recovery of AC Power in W2

Reflux Cooling in window 2

Reflux Cooling in window 2

RCS Loops Isolated to Cause Failure of Reflux Cooling

ISO-W2

ISO-W2G6

ISO-W2G0

ISO-W2G8

POS-6 of a Drained Maintenance Outage

NO CLCS SIGNAL OPER OR AUTO TRIP A

POS-R10

ISO-W2G2

POS-6 of a Refueling Outage

ISO-W2-G10

POS-D6

Secondary Side of SCS Drained in POS 6 or 10 or Refueling

Secondary Side of SCS Drained in POS 6 or 10 or Refueling

Loops Isolated in Window 1 of D6

Loops Isolated in Window 1 of R6

Secondary Side of SCS Drained in POS 6 or 10 or Refueling

Loops Isolated in Window 1 of R6

SCS Loops Isolated to Cause Failure of Reflux Cooling

Feed and Bleed the RCS in L1, Window 2

Feed and Bleed the RCS in L1, Window 2

Gravity from RWST in L1, Window 2

Gravity from RWST in L1, Window 2

Safety Valves Removed in Window 2

Failure of High Pressure Recirculation in Window 2

Failure of High Pressure Recirculation in Window 2

Failure of High Pressure Recirculation in Window 2

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Failure of Recirculation Spray in Window 2-cause HPR failure

Failure of Recirculation Spray in Window 2—cause HPR failure

Failure of Recirculation Spray in Window 2—cause HPR failure

Failure of Recirculation Spray in Window 2—cause HPR failure

E-333

UNITY	IL1W3	RL1W3	VW3	NL1W3	FL1W3	GL1W3	SEQ #	END-STATE-NAMES
L1W3R6 -- LOSP L1, WINDOW W3, POS R6								
<div>1</div> <div>2</div> <div>3</div> <div>4</div> <div>5</div> <div>6</div> <div>7</div> <div>8</div> <div>9</div> <div>10</div> <div>11</div> <div>12</div>								<div>@</div> <div>@</div> <div>@</div> <div>CD</div> <div>CD</div> <div>@</div> <div>CD</div> <div>CD</div> <div>@</div> <div>CD</div> <div>@</div> <div>CD</div>

UNITY	IL1W3	RL1W3	NL1W3	SL1W3	FL1W3	SEQ #	END-STATE-NAMES
L1W3D6 -- LOSP L1, WINDOW W3, POS D6
1 2 3 4 5 6 7 8 @ @ @ @ CD @ @ @ CD

UNITY	ILIW3	RLIW3	VW3	NLIW3	FLIW3	GLIW3	SEQ #	END-STATE-NAMES
L1W3R10 --- LOSP L1, WINDOW W3, POS R10								
								@ @ @ CD CD @ CD CD @ CD @ CD

I top event for L1 in window 3

Restore RHR given L1

Safety valves Not Removed in Window 3

Non-Recovery of AC Power

Reflux Cooling in window 3

Reflux Cooling in window 3

RCS Loops isolated to cause failure of reflux in window 3

Feed and Bleed the RCS in L1, Window 3

Feed and Bleed the RCS in L1, Window 3

Safety Valves Removed in Window 3

Gravity from RWST in L1, Window 3

E-349

Gravity from RWST in L1, Window 3

UNITY	IL1W4	RL1W4	NL1W4	SL1W4	FL1W4	SEQ #	END-STATE-NAMES
L1W4D6 --- LOSP L1, WINDOW W4, POS D6
@ @ @ @ @ CD @ @ CD 1 2 3 4 5 6 7 8

UNITY	IL1W4	RL1W4	VW4	NLIW4	FL1W4	GL1W4	SEQ #	END--STATE--NAMES
L1W4R10 --- LOSP L1, WINDOW W4, POS R10								
								@ @ @ OK CD @ @ OK CD @ CD @ @ CD

Restore RHR given L1

E-355

Safety valves Not Removed in Window 4

Non-Recovery of AC Power

Reflux Cooling in window 4

Reflux Cooling in window 4

RCS Loops isolated to cause failure of reflux in window 4

Feed and Bleed the RCS in L1, Window 4

Feed and Bleed the RCS in L1, Window 4

Gravity from RWST in L1, Window 4

Gravity from RWST in L1, Window 4

Safety Valves Removed in Window 4

Appendix E.7 Event Trees and High Level Fault Trees for Loss of Offsite Power(L2)

UNITY	IL2W1	RL2W1	VW1	NL2W1	SL2W1	FL2W1	GL2W1	CL2W1	SEQ #	END-STATE-NAME
L2W1R6 --- LO SP L2, WINDOW W1, POS R6										
									1	@
									2	@
									3	@
									4	CD
									5	CD
									6	CD
									7	@
									8	CD
									9	CD
									10	CD
									11	@
									12	@
									13	CD
									14	CD
									15	@
									16	@
									17	CD
									18	CD

UNITY	IL2W1	RL2W1	NL2W1	FL2W1	CL2W1	SEQ #	END-STATE
L2W1D6 --- LOSP L2, WINDOW W1, DRAINED MAINT. POS 6							
						1	@
						2	@
						3	@
						4	CD
						5	CD
						6	@
						7	CD
						8	CD

1 top event for L2 LOSP - L2 in window 1

Restore RHR given L2 in POS 6 - Refueling

Non-Recovery of AC Power in 144 min. of LOOP

E-373

Reflux Cooling in window 1

Reflux Cooling in window 1

Feed and Bleed the RCS in L2, Window 1

Feed and Bleed the RCS in L2, Window 1

Gravity from RWST in L2, Window 1

Gravity from RWST in L2, Window 1

E-382

Failure of High Pressure Recirculation in Window 1

Failure of High Pressure Recirculation in Window 1

Failure of High Pressure Recirculation in Window 1

E-387

E-391

UNITY	IL2W2	RL2W2	VW2	NL2W2	SL2W2	FL2W2	GL2W2	CL2W2	SEQ #	END-STATE-NAMES
L2W2R6 --- LOSP L2, WINDOW W2, POS R6										
									1	e
									2	e
									3	e
									4	CD
									5	CD
									6	CD
									7	e
									8	CD
									9	CD
									10	CD
									11	e
									12	e
									13	CD
									14	CD
									15	e
									16	e
									17	CD
									18	CD

top event for L2 LOSP - L2 in window 2

Restore RHR given L2 in POS 6 - Refueling

E-397

Non-Recovery of AC Power in W2

Reflux Cooling in window 2

Reflux Cooling in window 2

Feed and Bleed the RCS in L2, Window 2

Feed and Bleed the RCS in L2, Window 2

Gravity from RWST in L2, Window 2

Gravity from RWST in L2, Window 2

Failure of High Pressure Recirculation in Window 2

Failure of High Pressure Recirculation in Window 2

Failure of High Pressure Recirculation in Window 2

Failure of High Pressure Recirculation in Window 2

Failure of Recirculation Spray in Window 2—cause HPR failure

Failure of Recirculation Spray in Window 2—cause HPR failure

Failure of Recirculation Spray in Window 2—cause HPR failure

Failure of Recirculation Spray in Window 2—cause HPR failure

E-415

E-421

E-422

E-423

UNITY	IL2W3	RL2W3	VW3	NL2W3	FL2W3	GL2W3	SEQ #	END-STATE-NAMES
L2W3R6 --- LO SP L2, WINDOW W3, POS R6								
							1	@
							2	@
							3	@
							4	CD
							5	CD
							6	@
							7	CD
							8	CD
							9	@
							10	CD
							11	@
							12	CD

UNITY	IL2W3	RL2W3	NL2W3	SL2W3	FL2W3	SEQ #	END-STATE-NAMES
L2W3D6 --- LOSP L2, WINDOW W3, POS D6
@ @ @ @ CD @ @ @ CD

UNITY	IL2W3	RL2W3	VW3	NL2W3	FL2W3	GL2W3	SEQ #	END-STATE-NAMES
L2W3R10 -- LOSP L2, WINDOW W3, POS R10								
								@ @ @ CD CD @ CD CD @ CD CD @ CD

| top event for L2 LOSP – L2 in window 3

Restore RHR given L2 in POS 6 - Refueling

Safety Valves Not Removed in Window 3

Non-Recovery of AC Power

Reflux Cooling in window 3

Reflux Cooling in window 3

E-432

Feed and Bleed the RCS in L2, Window 3

Feed and Bleed the RCS in L2, Window 3

Feed and Bleed the RCS in L2, Window 3

E-435

Feed and Bleed the RCS in L2, Window 3

Gravity from RWST in L2, Window 3

Gravity from RWST in L2, Window 3

UNITY	IL2W4	RL2W4	VW4	NL2W4	FL2W4	GL2W4	SEQ #	END--STATE--NAMES
L2W4R6 -- LOSP L2, WINDOW W4, POS R6								
								@ @ @ OK CD @ OK CD @ CD @ CD

UNITY	IL2W4	RL2W4	NL2W4	SL2W4	FL2W4	SEQ #	END-STATE-NAMES
L2W4D6 -- LO SP L2, WINDOW W4, POS D6
1	@
						2	@
						3	@
						4	@
						5	CD
						6	@
						7	@
						8	CD

UNITY	IL2W4	RL2W4	VW4	NL2W4	FL2W4	GL2W4	SEQ #	END-STATE-NAMES
L2W4R10 --- LO SP L2, WINDOW W4, POS R10
@ @ @ OK CD @ OK CD @ CD @ CD

I top event for L2 LOSP - L2 in window 4

Restore RHR given L2 in POS 6 - Refueling

E-443

Non-Recovery of AC Power

Reflux Cooling in window 4

E-445

Reflux Cooling in window 4

Feed and Bleed the RCS in L2, Window 4

Feed and Bleed the RCS in L2, Window 4

Feed and Bleed the RCS in L2, Window 4

E-449

Feed and Bleed the RCS in L2, Window 4

Gravity from RWST in L2, Window 4

Gravity from RWST in L2, Window 4

Appendix E.8 Event Trees and High Level Fault Trees for Unit 1 Blackout(L3)

UNITY	IL3W1	RL3W1	VW1	NL3W1	SL3W1	FL3W1	GL3W1	CL3W1	SEQ #	END-STATE-NAN
L3W1R6 --- LOSP L3, WINDOW W1, POS R6										
										@ @ @ CD CD CD @ CD CD CD @ @ CD CD @ @ CD CD
										1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18

UNITY	IL3W1	RL3W1	NL3W1	FL3W1	CL3W1	SEQ #	END-STATE
<div> <div>L3W1D6 -- LOSP L3, WINDOW W1, POS D6</div> </div>							<div> <div>1 2 3 4 5 6 7 8</div> <div>@ @ @ CD CD @ CD CD</div> </div>

1 | top event for L3 LOSP – L3 in window 1

Restore RHR given L3 in POS 6 - Refueling

E-457

Non-Recovery of AC Power in 144 min. of LOOP

Reflux Cooling in window 1

Reflux Cooling in window 1

Feed and Bleed the RCS in L3, Window 1

Feed and Bleed the RCS in L3, Window 1

Gravity from RWST in L3, Window 1

Gravity from RWST in L3, Window 1

Failure of High Pressure Recirculation in Window 1

Failure of High Pressure Recirculation in Window 1

Failure of High Pressure Recirculation in Window 1

Failure of High Pressure Recirculation in Window 1

E-475

E-476

E-477

E-478

UNITY	IL3W2	RL3W2	VW2	NL3W2	SL3W2	FL3W2	GL3W2	CL3W2	SEQ #	END-STATE-NAMES	
L3W2R6 -- LOSP L3, WINDOW W2, POS R6											
										1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18	@ @ @ CD CD CD @ CD CD CD @ @ CD CD @ @ CD CD

UNITY	IL3W2	RL3W2	NL3W2	SL3W2	FL3W2	CL3W2	SEQ #	END-STATI
L3W2D6 -- LOSP L3, WINDOW W2, POS D6
@ @ @ @ CD CD @ @ CD CD

l top event for L3 LOSP – L3 in window 2

Restore RHR given L3 in POS 6 - Refueling

Non-Recovery of AC Power in W2

Reflux Cooling in window 2

Reflux Cooling in window 2

Feed and Bleed the RCS in L3, Window 2

Feed and Bleed the RCS in L3, Window 2

E-489

Gravity from RWST in L3, Window 2

Gravity from RWST in L3, Window 2

Failure of High Pressure Recirculation in Window 2

Failure of High Pressure Recirculation in Window 2

Failure of High Pressure Recirculation in Window 2

Failure of High Pressure Recirculation in Window 2

Failure of Recirculation Spray in Window 2—cause HPR failure

Failure of Recirculation Spray in Window 2—cause HPR failure

Failure of Recirculation Spray in Window 2—cause HPR failure

Failure of Recirculation Spray in Window 2—cause HPR failure

E-500

E-505

E-508

UNITY	IL3W3	RL3W3	VW3	NL3W3	FL3W3	GL3W3	SEQ #	END-STATE-NAMES
L3W3R6 -- LOSP L3, WINDOW W3, POS R6								
								e e e CD CD e CD CD e CD e CD

UNITY	IL3W3	RL3W3	NL3W3	SL3W3	FL3W3	SEQ #	END--STATE--NAMES
L3W3D6 --- LOSP L3, WINDOW W3, POS D6							
							@ @ @ @ CD @ @ CD 1 2 3 4 5 6 7 8

UNITY	IL3W3	RL3W3	VW3	NL3W3	FL3W3	GL3W3	SEQ #	END-STATE-NAMES
<div> <div>L3W3R10 -- LOSP L3, WINDOW W3, POS R10</div> </div>								<div> <div> <div>1</div> <div>2</div> <div>3</div> <div>4</div> <div>5</div> <div>6</div> <div>7</div> <div>8</div> <div>9</div> <div>10</div> <div>11</div> <div>12</div> </div> <div> <div> <div>CD</div> <div>CD</div> <div>CD</div> <div>CD</div> <div>CD</div> <div>CD</div> <div>CD</div> <div>CD</div> <div>CD</div> <div>CD</div> <div>CD</div> <div>CD</div> </div> </div> </div>

1 top event for L3 LOSP - L3 in window 3

Restore RHR given L3 in POS 6 - Refueling

Non-Recovery of AC Power

Reflux Cooling in window 3

E-515

Reflux Cooling in window 3

Feed and Bleed the RCS in L3, Window 3

Feed and Bleed the RCS in L3, Window 3

Feed and Bleed the RCS in L3, Window 3

Feed and Bleed the RCS in L3, Window 3

Gravity from RWST in L3, Window 3

Gravity from RWST in L3, Window 3

UNITY	IL3W4	RL3W4	VW4	NL3W4	FL3W4	GL3W4	SEQ #	END-STATE-NAMES
L3W4R6 -- LOSP L3, WINDOW W4, POS R6								
							1	@
							2	@
							3	@
							4	OK
							5	CD
							6	@
							7	OK
							8	CD
							9	@
							10	CD
							11	@
							12	CD

E-523

UNITY	IL3W4	RL3W4	NL3W4	SL3W4	FL3W4	SEQ #	END--STATE--NAMES
L3W4D6 --- LO SP L3, WINDOW W4, POS D6
@ @ @ @ @ CD @ @ CD 1 2 3 4 5 6 7 8

UNITY	IL3W4	RL3W4	VW4	NL3W4	FL3W4	GL3W4	SEQ #	END-STATE-NAMES
L3W4R10 -- LOSP L3, WINDOW W4, POS R10								
							1	@
							2	@
							3	@
							4	OK
							5	CD
							6	@
							7	OK
							8	CD
							9	@
							10	CD
							11	@
							12	CD

1 top event for L3 LOSP - L3 in window 4

Restore RHR given L3 in POS 6 - Refueling

E-527

Non-Recovery of AC Power

Reflux Cooling in window 4

Reflux Cooling in window 4

Feed and Bleed the RCS in L3, Window 4

Feed and Bleed the RCS in L3, Window 4

Feed and Bleed the RCS in L3, Window 4

Feed and Bleed the RCS in L3, Window 4

Gravity from RWST in L3, Window 4

Gravity from RWST in L3, Window 4

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11. ABSTRACT (200 words or less)

During 1989, the Nuclear Regulatory Commission (NRC) initiated an extensive program to carefully examine the potential risks during low power and shutdown operations. The program includes two parallel projects being performed by Brookhaven National Laboratory (BNL) and Sandia National Laboratories (SNL). Two plants, Surry (pressurized water reactor) and Grand Gulf (boiling water reactor), were selected as the plants to be studied. The objectives of the program are to assess the risks of severe accidents initiated during plant operational states other than full power operation and to compare the estimated core damage frequencies, important accident sequences and other qualitative and quantitative results with those accidents initiated during full power operation as assessed in NUREG-1150. The objective of this report is to document the approach utilized in the Surry plant and discuss the results obtained. A parallel report for the Grand Gulf plant is prepared by SNL. This study shows that the core-damage frequency during mid-loop operation at the Surry plant is comparable to that of power operation. We recognize that there is very large uncertainty in the human error probabilities in this study. This study identified that only a few procedures are available for mitigating accidents that may occur during shutdown. Procedures written specifically for shutdown accidents would be useful.

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