

19B EVENT TREES FOR CORE DAMAGE SEQUENCES INITIATED DURING LOW POWER OPERATION

Appendix 19B presents the events trees that delineate the core-damage sequences for internal events initiated during low power operation. The event trees and summary of top events are provided in the following figures and tables, respectively:

Event Tree	Event Tree Description	Table and Figure Number
SD LOCA C	LOCA During Shutdown State C (Note 1)	19B-1
SD LOCA D E	LOCA During Shutdown State D or E (Note 1)	19.B-2
SD RHR C	Loss of RHR During State C (Note 1)	19.B-3
SD RHR D	Loss of RHR During State D (Note 1)	19.B-4
SD ULD C	Uncontrolled Level Drop During Shutdown State C (Note 1)	19.B-5
SD ULD D	Uncontrolled Level Drop During Shutdown State D (Note 1)	19.B-6
IE RHR ISLOCA	RHR ISLOCA (Note 2)	(Note 2)

1. There is also an initiating event tree for SD LOCA, SD RHR and SD ULD for every state. The initiating event tree is developed to quantify the initiating event frequency; it contains a fault tree which models the initiating event during 24 hours, which is multiplied by a specific POS duration (days/year).
2. The initiating event tree for IE RHR ISLOCA is transferred directly to core damage.

In each case, the summary tables provide the following information:

- The definition of the top event.
- The success criteria for the top event.
- The corresponding failure event (fault tree/gate) that is developed for purposes of evaluating the core-damage sequence.
- The description for the failure event.

Some of the top events may have different configurations for particular branch points. These configurations reflect conditions (e.g., different success criteria or timing) determined by the initiating event or by previous failures in the sequence. These conditional states are denoted by an integer at relevant branch points. These conditions are also identified in the tables.

Table 19B-1—Event-Tree Headings for Initiating Event IE LOCA: LOCA During Shutdown State C
Sheet 1 of 2

Event-Tree Top Event		Success Criteria	Failure Event	Event Description
SD LOCA C	LOCA during shutdown state C	—	IE LOCA (initiator)	LOCA during shutdown state C
MHSISD	MHSI available	1 of 4 MHSI pumps supply flow	MHSI SD (FT top gate)	Failure of 4 out of 4 MHSI trains
OP RHRSD	Operators initiate secondary cooldown and aligns RHRs	Initiation of RHR, different time windows for different POSs	OP RHRSD (Gate)	Operators fail to initiate RHR
RHRSD	RHR available	1 of 4 LHSI pumps available for RHR	RHR SD (FT top gate)	Failure of 4 of 4 LHSI trains for RHR
EFWSD	EFW system available	1 of 2 EFW trains available for decay heat removal	EFW SD (FT top gate)	Failure of EFW trains (with MSRVs)
EFW PBFSD	EFW maintains pressure boundary conditions	4 of 4 EFW storage pools maintain integrity OR operators isolate and maintain adequate inventory after a leak	EFW PBF SD (FT top gate)	Pressure boundary failure of EFW tanks and failure to isolate/ makeup

Table 19B-1—Event-Tree Headings for Initiating Event IE LOCA: LOCA During Shutdown State C
Sheet 2 of 2

Event-Tree Top Event		Success Criteria	Failure Event	Event Description
OP FBSD	Operators initiate feed-and-bleed cooling, given: MHSI failure (Condition 2) OP RHR Success (Condition 4) OP RHR Failure (Condition 5)	Initiation of feed-and-bleed, different time windows for different POSs	OP-FB2 (Gate) OPE-FB3 (Gate) OPE-FB 3D (Gate)	Operators fail to initiate feed-and-bleed
PBLSD	Primary bleed available	2 of 3 PSVs or 1 of 2 SADVs	PBL SD (FT top gate)	Failure of primary bleed
LHSISD	LHSI available for Injection only (Condition 1) Containment heat removal (Condition 2)	1 of 4 LHSI pumps available 1 of 4 LHSI pumps available with RHR heat exchangers	LHSI INJ SD (FT top gate) LHSI CHR SD (FT top gate)	Failure of 4 of 4 LHSI trains (injection) Failure of 4 of 4 LHSI trains (CHR mode)
SAHRSD	Severe accident heat removal available	1 of 1 SAHR pump available in recirculation mode	SAHR SD (FT top gate)	Failure of SAHRS to provide cooling to the IRWST

Table 19B-2—Event-Tree Headings for Initiating Event IE LOCA: LOCA During Shutdown State D or E

Event-Tree Top Event		Success Criteria	Failure Event	Event Description
SD LOCA D E	LOCA during shutdown state D or State E	—	IE LOCA (initiator)	LOCA during shutdown state D or E
MHSISD	MHSI available	1 of 4 MHSI pumps supply flow	MHSI SD (FT top gate)	Failure of 4 out of 4 MHSI trains
LHSISD	LHSI available for injection only (Condition 1)	1 of 4 LHSI pumps available	LHSI INJ SD (FT top gate)	Failure of 4 of 4 LHSI trains (injection)

Table 19B-3—Event-Tree Headings for Initiating Event IE RHR: Loss of RHR During Shutdown State C
Sheet 1 of 2

Event-Tree Top Event		Success Criteria	Failure Event	Event Description
SD RHR C	Loss of RHR during shutdown state C	—	IE RHR (initiator)	Loss of RHR during shutdown state C
TR LOCASD	Transient induced LOCA	LOCA induced by a loss of DHR in state C	TR LOCA (FT top gate)	Transient LOCA
EFWSD	EFW system available	1 of 4 EFW trains available for decay heat removal	EFW SD (FT top gate)	Failure of EFW trains (with MSRVs)
EFW PBFSD	EFW maintains pressure boundary conditions	4 of 4 EFW storage pools maintain integrity OR operators isolate and maintain adequate inventory after a leak	EFW PBF SD (FT top gate)	Pressure boundary failure of EFW tanks and failure to isolate/ makeup
OP FBSD	Operators initiate feed-and-bleed cooling' given No LOCA (Condition 1) LOCA (Condition 3)	Initiation of feed-and-bleed, different time windows for different POSs	OP-FB1 (Gate) OPE-FB 2L (Gate)	Operators fail to initiate feed-and-bleed
PBLSD	Primary bleed available	2 of 3 PSVs or 1 of 2 SADVs	PBL SD (FT top gate)	Failure of primary bleed
MHSISD	MHSI available	1 of 4 MHSI pumps supply flow	MHSI SD (FT top gate)	Failure of 4 out of 4 MHSI trains

Table 19B-3—Event-Tree Headings for Initiating Event IE RHR: Loss of RHR During Shutdown State C
Sheet 2 of 2

Event-Tree Top Event		Success Criteria	Failure Event	Event Description
LHSISD	LHSI available for Injection only (Condition 1)	1 of 4 LHSI pumps available	LHSI INJ SD (FT top gate)	Failure of 4 of 4 LHSI trains (injection)
	Containment heat removal (Condition 2)	1 of 4 LHSI pumps available with RHR heat exchangers	LHSI CHR SD (FT top gate)	Failure of 4 of 4 LHSI trains (CHR mode)
SAHRSD	Severe accident heat removal available	1 of 1 SAHR pump available in recirculation mode	SAHR SD (FT top gate)	Failure of SAHRS to provide cooling to the IRWST

Table 19B-4—Event-Tree Headings for Initiating Event IE RHR: Loss of RHR During Shutdown State D

Event-Tree Top Event		Success Criteria	Failure Event	Event Description
SD RHR D	Loss of RHR during shutdown state D	—	IE RHR (initiator)	Loss of RHR during shutdown state D
MHSISD	MHSI available	1 of 4 MHSI pumps supply flow	MHSI SD (FT top gate)	Failure of 4 out of 4 MHSI trains
LHSISD	LHSI available for injection only (Condition 1)	1 of 4 LHSI pumps available	LHSI INJ SD (FT top gate)	Failure of 4 of 4 LHSI trains (injection)

**Table 19B-5—Event-Tree Headings for Initiating Event IE ULD: Uncontrolled Level Drop During State CB
Sheet 1 of 2**

Event-Tree Top Event		Success Criteria	Failure Event	Event Description
SD ULD C	Uncontrolled level drop during shutdown state C	—	IE ULD (initiator)	Uncontrolled level drop during shutdown state C
ISOLSD	Isolation of CVCS low pressure reducing station	Auto isolation of CVCS low pressure reducing station letdown	ISOLSD (FT top gate)	Failure to isolate the CVCS low pressure reducing station
MHSISD	MHSI available	1 of 4 MHSI pumps supply flow	MHSI SD (FT top gate)	Failure of 4 out of 4 MHSI trains
OP RHRSD	Operators initiate secondary cooldown and aligns RHR	Initiation of RHR, different time windows for different POSs	OP RHRSD (Gate)	Operators fail to initiate RHR
RHRSD	RHR available	1 of 4 LHSI pumps available for RHR	RHR SD (FT top gate)	Failure of 4 of 4 LHSI trains for RHR
EFWSD	EFW system available	1 of 2 EFW trains available for decay heat removal	EFW SD (FT top gate)	Failure of EFW trains (with MSRVs)
EFW PBFSD	EFW maintains pressure boundary conditions	4 of 4 EFW storage pools maintain integrity OR operators isolate and maintain adequate inventory after a leak	EFW PBF SD (FT top gate)	Pressure boundary failure of EFW tanks and failure to isolate/ makeup

**Table 19B-5—Event-Tree Headings for Initiating Event IE ULD: Uncontrolled Level Drop During State CB
Sheet 2 of 2**

Event-Tree Top Event		Success Criteria	Failure Event	Event Description
OP FBSD	Operators initiate feed-and-bleed cooling, given: MHSI failure (Condition 2) OP RHR Success (Condition 4) OP RHR Failure (Condition 5)	Initiation of feed-and-bleed, different time windows for different POSs	OP-FB2 (Gate) OPE-FB3 (Gate) OPE-FB 3D (Gate)	Operators fail to initiate feed-and-bleed
PBLSD	Primary bleed available	2 of 3 PSVs or 1 of 2 SADVs	PBL SD (FT top gate)	Failure of primary bleed
LHSISD	LHSI available for Injection only (Condition 1) Containment heat removal (Condition 2)	1 of 4 LHSI pumps available 1 of 4 LHSI pumps available with RHR heat exchangers	LHSI INJ SD (FT top gate) LHSI CHR SD (FT top gate)	Failure of 4 of 4 LHSI trains (injection) Failure of 4 of 4 LHSI trains (CHR mode)
SAHRSD	Severe accident heat removal available	1 of 1 SAHR pump available in recirculation mode	SAHR SD (FT top gate)	Failure of SAHRS to provide cooling to the IRWST
OP ISOLSD	Operator isolates CVCS low pressure reducing station	Operator isolates letdown given auto isolation failure, over 8 hours available	OPE-ISOCSLPRS (basic event)	Operator fails to isolate the CVCS low pressure reducing station

Table 19B-6—Event-Tree Headings for Initiating Event IE ULD: Uncontrolled Level Drop During State D

Event Tree Top Event		Success Criteria	Failure Event	Event Description
SD ULD D	Uncontrolled level drop during shutdown state D	—	IE ULD (initiator)	Uncontrolled level drop during shutdown state D
ISOLSD	Isolation of CVCS low pressure reducing station	Auto isolation of CVCS low pressure reducing station letdown	ISOLSD (FT top gate)	Failure to isolate the CVCS low pressure reducing station
MHSISD	MHSI available	1 of 4 MHSI pumps supply flow	MHSI SD (FT top gate)	Failure of 4 out of 4 MHSI trains
LHSISD	LHSI available for injection only (Condition 1)	1 of 4 LHSI pumps available	LHSI INJ SD (FT top gate)	Failure of 4 of 4 LHSI trains (injection)
OP ISOLSD	Operator isolates CVCS low pressure reducing station	Operator isolates letdown, given auto isolation failure, over 8 hours available	OPE-ISOCSLPRS (basic event)	Operator fails to isolate letdown given auto isolation failure

Figure 19B-1—LOCA During Shutdown State C

LOCA During Shutdown State C	MHSI Available	Operator Initiates Secondary Cooldown and Aligns RHR	RHR Available	EFW System Available	EFW Maintains Pressure Boundary Conditions	Operator Initiates Feed & Bleed	Primary Bleed Available	LHSI Available (1) Injection 2) CHR	Severe Accident Heat Removal Available (1 of 2)	No.	Freq.	Conseq.	Code
SD LOCA C	MHSISD	OP RHRSD	RHRSD	EFWSD	EFW PBFSD	OP FBSD	PBLSD	LHSISD	SAHRSD				
										1		S	
								2		2		S	RHRSD
										3		S	RHRSD-LHSISD
										4		F	RHRSD-LHSISD-SAHRSD
										5		S	RHRSD-EFW PBFSD
								2		6		S	RHRSD-EFW PBFSD-LHSISD
										7		F	RHRSD-EFW PBFSD-LHSISD-SAHRSD
										8		F	RHRSD-EFW PBFSD-PBLSD
						4				9		F	RHRSD-EFW PBFSD-OP FBSD
										10		S	RHRSD-EFWSD
								2		11		S	RHRSD-EFWSD-LHSISD
										12		F	RHRSD-EFWSD-LHSISD-SAHRSD
						4				13		F	RHRSD-EFWSD-PBLSD
										14		F	RHRSD-EFWSD-OP FBSD
										15		S	OP RHRSD
								2		16		S	OP RHRSD-LHSISD
										17		F	OP RHRSD-LHSISD-SAHRSD
										18		S	OP RHRSD-EFW PBFSD
								2		19		S	OP RHRSD-EFW PBFSD-LHSISD
										20		F	OP RHRSD-EFW PBFSD-LHSISD-SAHRSD
						5				21		F	OP RHRSD-EFW PBFSD-PBLSD
										22		F	OP RHRSD-EFW PBFSD-OP FBSD
										23		S	OP RHRSD-EFWSD
								2		24		S	OP RHRSD-EFWSD-LHSISD
										25		F	OP RHRSD-EFWSD-LHSISD-SAHRSD
						5				26		F	OP RHRSD-EFWSD-PBLSD
										27		F	OP RHRSD-EFWSD-OP FBSD
										28		S	MHSISD
										29		F	MHSISD-SAHRSD
								1		30		F	MHSISD-LHSISD
										31		F	MHSISD-PBLSD
						2				32		F	MHSISD-OP FBSD

EPR6615 T2

Figure 19B-2—LOCA During Shutdown State D or E

LOCA During Shutdown State D or State E	MHSI Available	LHSI Available 1) Injection 2) CHR	No.	Freq.	Conseq.	Code
SD LOCA D E	MHSISD	LHSISD				
			1		S	
EPR6615 T2			2		S	MHSISD
			3		F	MHSISD-LHSISD

EPR6620 T2

Figure 19B-3—Loss of RHR During State C

Shutdown State C (24hr Fraction)	Transient Induced LOCA	EFW System Available	EFW Maintains Pressure Boundary Conditions	Operator Initiates Feed & Bleed	Primary Bleed Available	MHSI Available	LHSI Available (1) Injection 2) CHR	Severe Accident Heat Removal Available (1 of 2)	No.	Freq.	Conseq.	Code
SD RHR C	TR LOCASD	EFWSD	EFW PBFSD	OP FBSD	PBLSD	MHSISD	LHSISD	SAHRSD				
									1		S	
									2		S	EFW PBFSD
							2		3		S	EFW PBFSD-LHSISD
									4		F	EFW PBFSD-LHSISD-SAHRSD
							2		5		S	EFW PBFSD-MHSISD
									6		S	EFW PBFSD-MHSISD-LHSISD
									7		F	EFW PBFSD-MHSISD-LHSISD-SAHRSD
				1					8		F	EFW PBFSD-PBLSD
									9		F	EFW PBFSD-OP FBSD
									10		S	EFWSD
							EPR6615 T2		11		S	EFWSD-LHSISD
									12		F	EFWSD-LHSISD-SAHRSD
									13		S	EFWSD-MHSISD
							2		14		S	EFWSD-MHSISD-LHSISD
									15		F	EFWSD-MHSISD-LHSISD-SAHRSD
									16		F	EFWSD-PBLSD
				1					17		F	EFWSD-OP FBSD
									18		S	TR LOCASD
									19		S	TR LOCASD-LHSISD
									20		F	TR LOCASD-LHSISD-SAHRSD
									21		S	TR LOCASD-MHSISD
									22		F	TR LOCASD-MHSISD-SAHRSD
							1		23		F	TR LOCASD-MHSISD-LHSISD
									24		F	TR LOCASD-PBLSD
				3					25		F	TR LOCASD-OP FBSD

EPR6625 T2

Figure 19B-4—Loss of RHR During State D

Loss of RHR - Shutdown State D	MHSI Available	LHSI Available 1) Injection 2) CHR	No.	Freq.	Conseq.	Code
SD RHR D	MHSISD	LHSISD				
			1		S	
		EPR6615 T2	2		S	MHSISD
		1	3		F	MHSISD-LHSISD

EPR6630 T2

Figure 19B-5—Uncontrolled Level Drop During Shutdown State C

Uncontrolled Level Drop in Shutdown State CB	ISOLSD	MHSISD	OP RHRSD	RHRSD	EFWSD	EFW PBFSD	OP FBSD	PBLSD	LHSISD	SAHRSD	OP ISOLSD	No.	Freq.	Conseq.	Code
												1		S	
												2		S	ISOLSD
												3		F	ISOLSD-OP ISOLSD
												4		S	ISOLSD-RHRSD
												5		F	ISOLSD-RHRSD-OP ISOLSD
												6		S	ISOLSD-RHRSD-EFW PBFSD
												7		F	ISOLSD-RHRSD-EFW PBFSD-OP ISOLSD
									2			8		S	ISOLSD-RHRSD-EFW PBFSD-LHSISD
												9		F	ISOLSD-RHRSD-EFW PBFSD-LHSISD-OP ISOLSD
												10		F	ISOLSD-RHRSD-EFW PBFSD-LHSISD-SHRSD
							4					11		F	ISOLSD-RHRSD-EFW PBFSD-PBLSD
												12		F	ISOLSD-RHRSD-EFW PBFSD-OP FBSD
												13		S	ISOLSD-RHRSD-EFWS
									2			14		F	ISOLSD-RHRSD-EFWS-OP ISOLSD
												15		S	ISOLSD-RHRSD-EFWS-LHSISD
												16		F	ISOLSD-RHRSD-EFWS-LHSISD-OP ISOLSD
												17		F	ISOLSD-RHRSD-EFWS-LHSISD-SHRSD
							4					18		F	ISOLSD-RHRSD-EFWS-PBLSD
												19		F	ISOLSD-RHRSD-EFWS-OP FBSD
												20		S	ISOLSD-OP RHRSD
										EPR6615 T2		21		F	ISOLSD-OP RHRSD-OP ISOLSD
												22		S	ISOLSD-OP RHRSD-EFW PBFSD
									2			23		F	ISOLSD-OP RHRSD-EFW PBFSD-OP ISOLSD
												24		S	ISOLSD-OP RHRSD-EFW PBFSD-LHSISD
												25		F	ISOLSD-OP RHRSD-EFW PBFSD-LHSISD-OP ISOLSD
												26		F	ISOLSD-OP RHRSD-EFW PBFSD-LHSISD-SHRSD
							5					27		F	ISOLSD-OP RHRSD-EFW PBFSD-PBLSD
												28		F	ISOLSD-OP RHRSD-EFW PBFSD-OP FBSD
												29		S	ISOLSD-OP RHRSD-EFWS
									2			30		F	ISOLSD-OP RHRSD-EFWS-OP ISOLSD
												31		S	ISOLSD-OP RHRSD-EFWS-LHSISD
												32		F	ISOLSD-OP RHRSD-EFWS-LHSISD-OP ISOLSD
												33		F	ISOLSD-OP RHRSD-EFWS-LHSISD-SHRSD
							5					34		F	ISOLSD-OP RHRSD-EFWS-PBLSD
												35		F	ISOLSD-OP RHRSD-EFWS-OP FBSD
												36		S	ISOLSD-MHSISD
												37		F	ISOLSD-MHSISD-OP ISOLSD
									1			38		F	ISOLSD-MHSISD-SHRSD
												39		F	ISOLSD-MHSISD-LHSISD
							2					40		F	ISOLSD-MHSISD-PBLSD
												41		F	ISOLSD-MHSISD-OP FBSD

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Figure 19B-6—Uncontrolled Level Drop During Shutdown State D

Uncontrolled Level Drop in Shutdown State D	Isolation of CVCS Low Pressure Reducing Station	MHSI Available	LHST Available 1) Injection 2) CHR	Operator Isolates CVCS Low Pressure Reducing Station	No.	Freq.	Conseq.	Code
SD ULD D	ISOLSD	MHSISD	LHSISD	OP ISOLSD				
					1		S	
					2		S	ISOLSD
					3		F	ISOLSD-OP ISOLSD
					4		S	ISOLSD-MHSISD
					5		F	ISOLSD-MHSISD-OP ISOLSD
					6		F	ISOLSD-MHSISD-LHSISD

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