19B Event Trees for Core Damage Sequences Initiated During Low Power Operation

Appendix 19B presents the event 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
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

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
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-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

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
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
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

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
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)	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
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

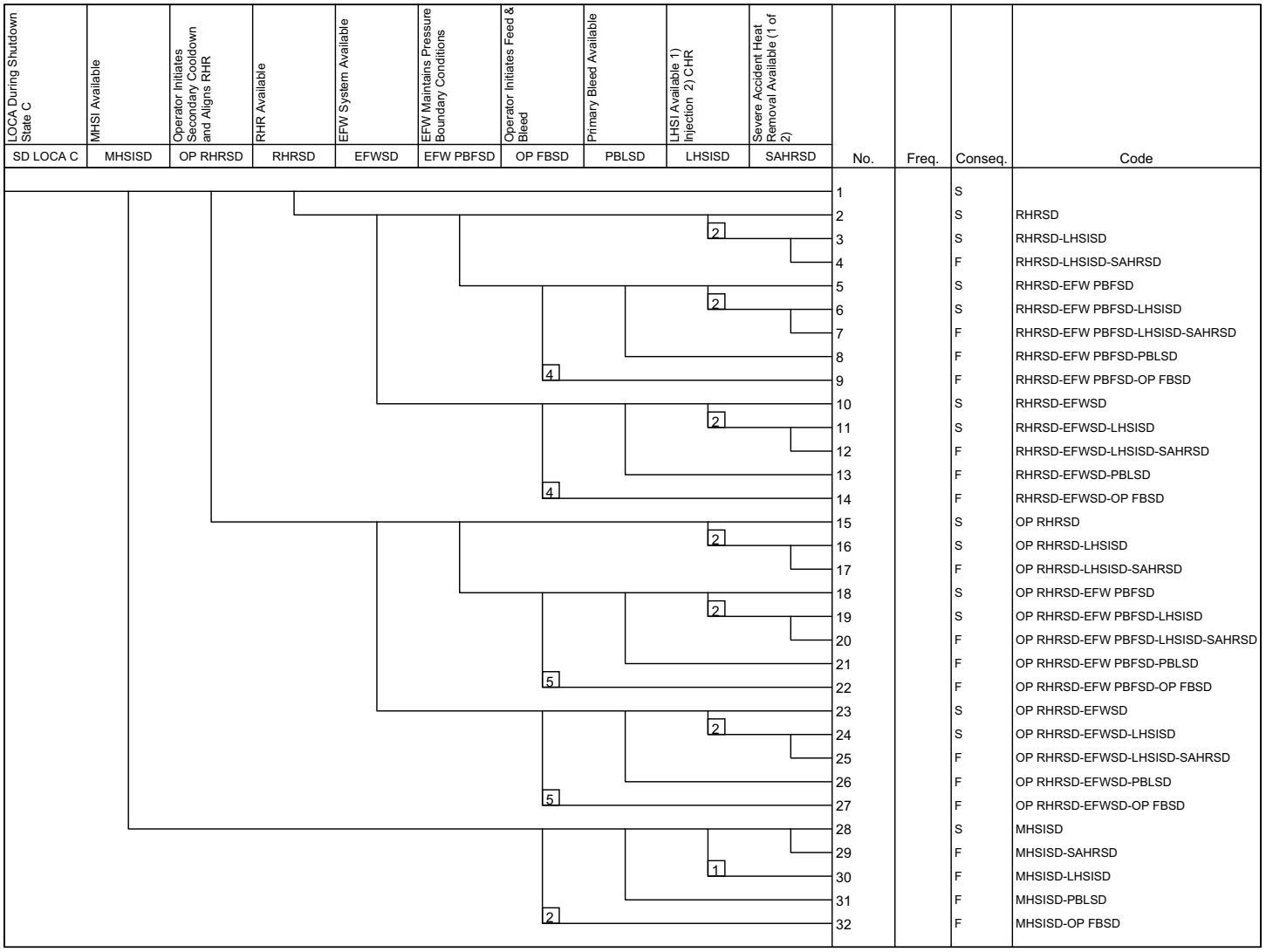


Figure 19B-2—LOCA During Shutdown State D or E

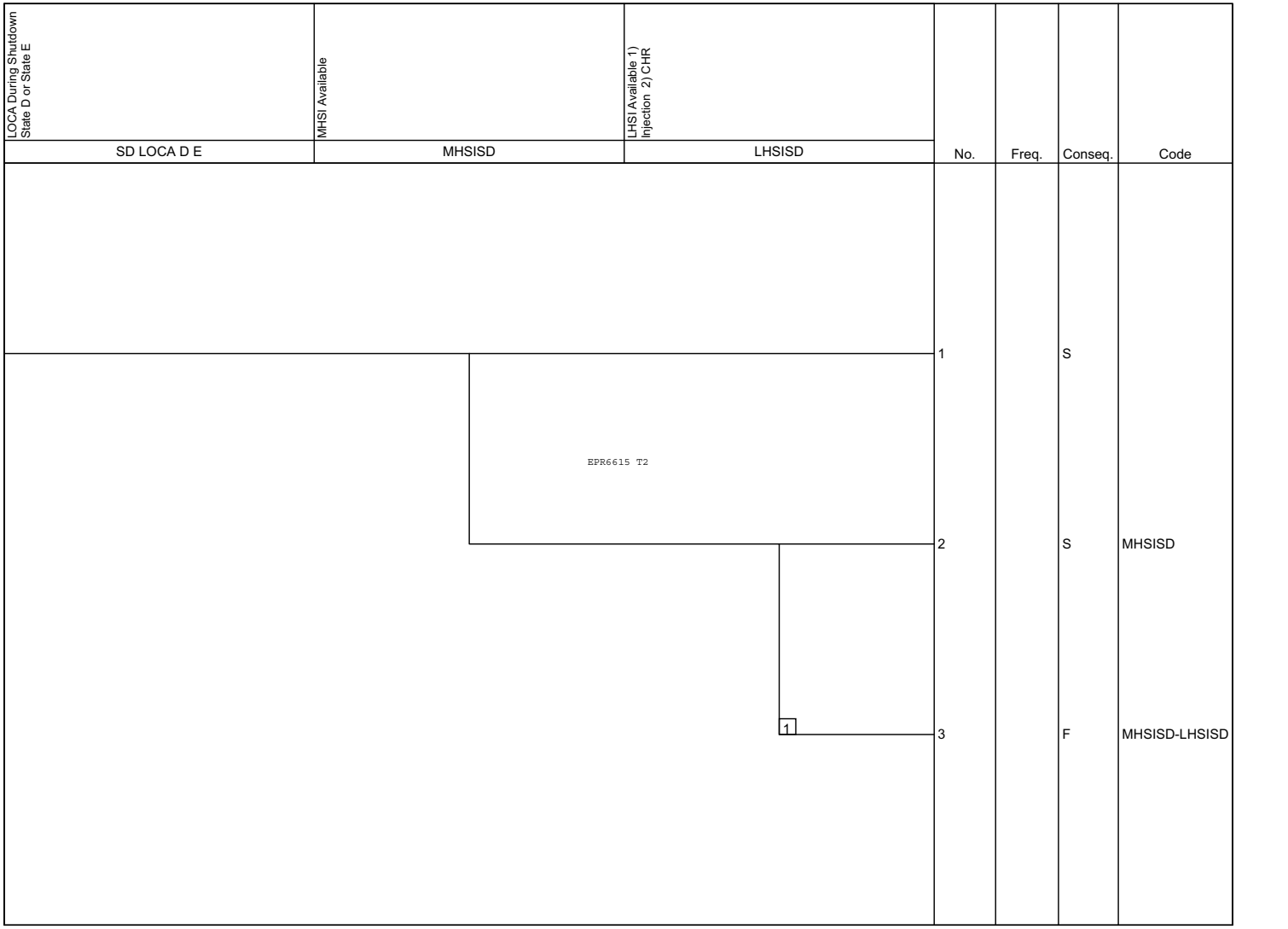


Figure 19B-3—Loss of RHR During State C

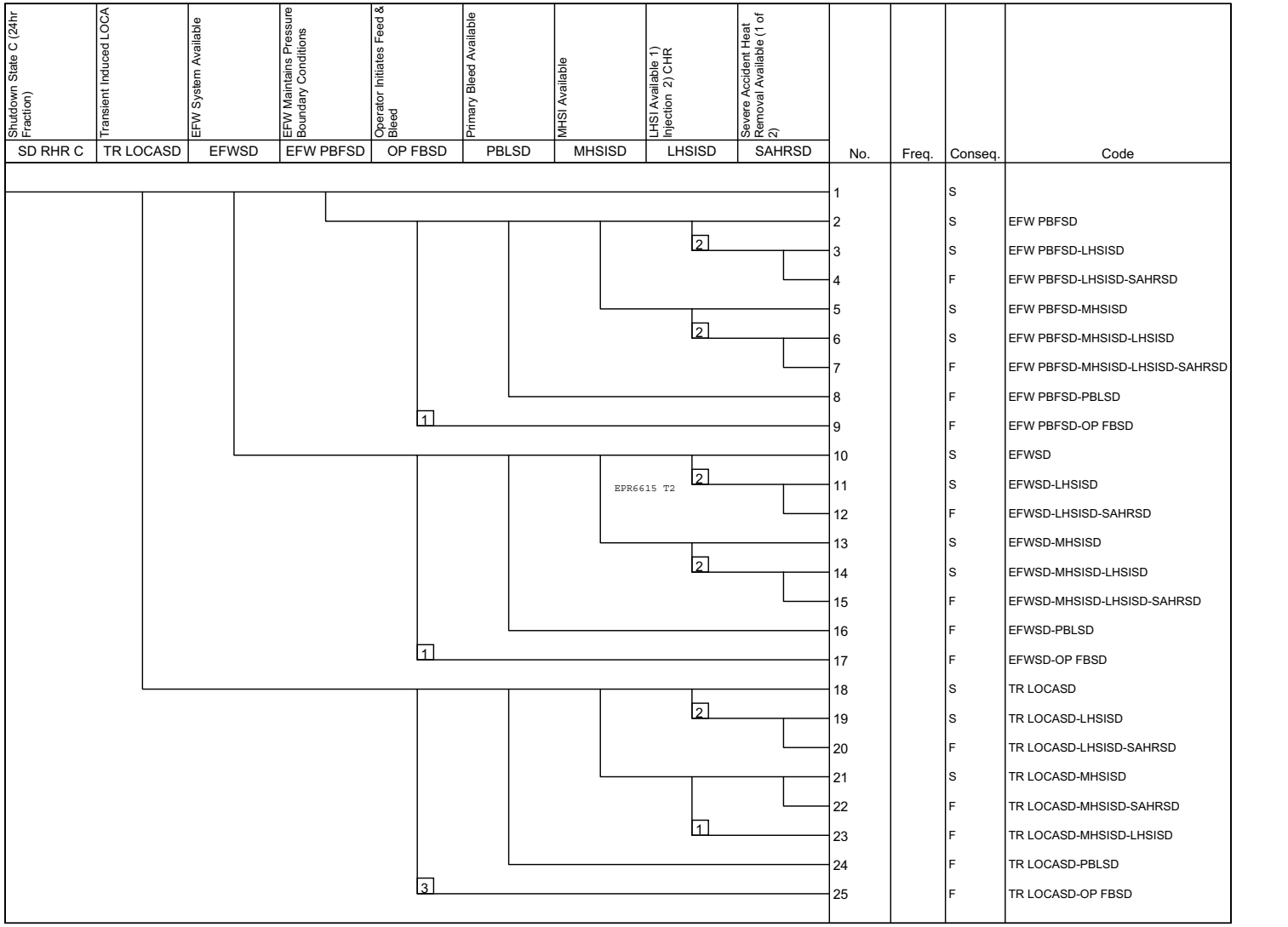


Figure 19B-4—Loss of RHR During State D

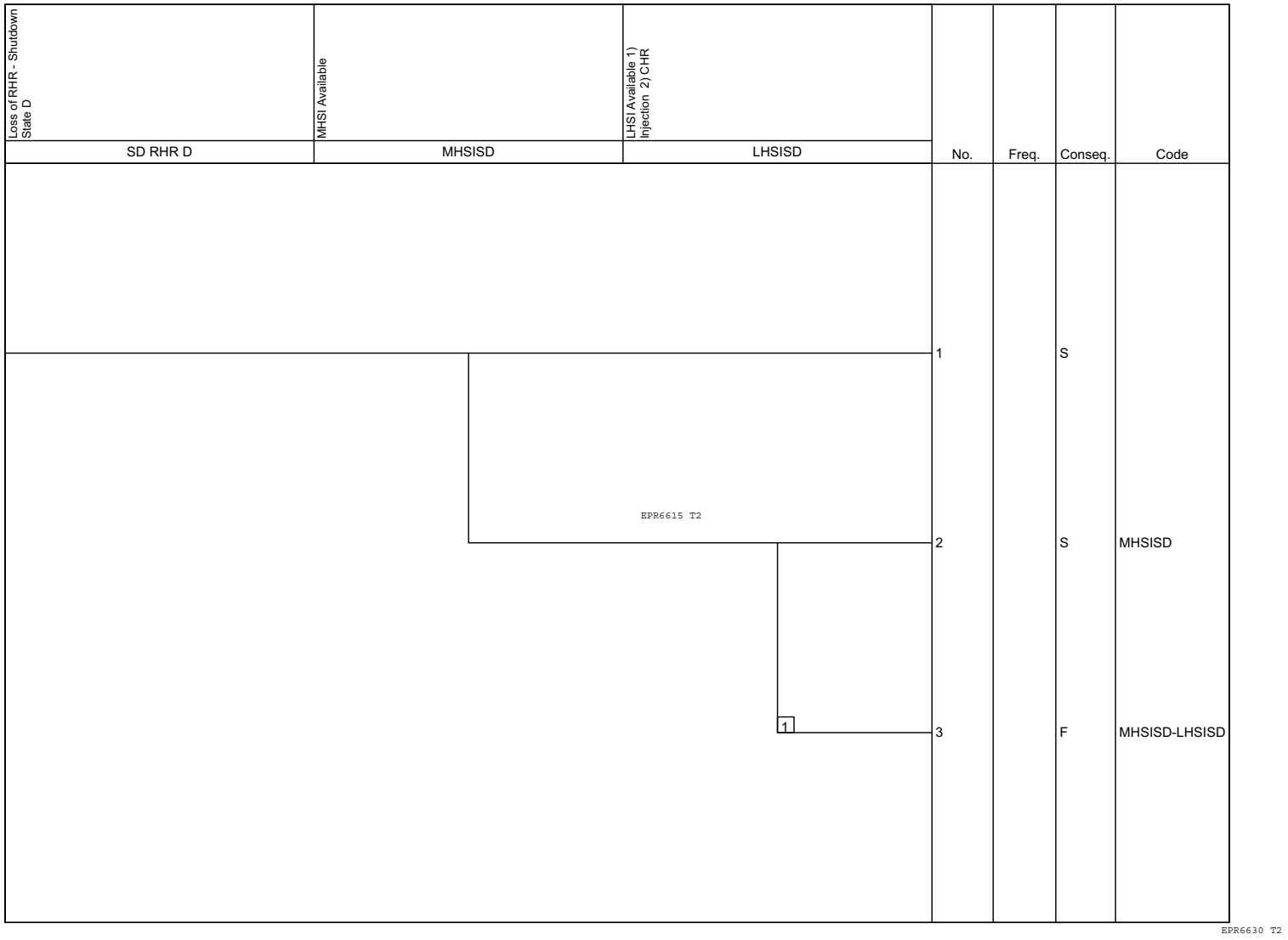


Figure 19B-5—Uncontrolled Level Drop During Shutdown State C

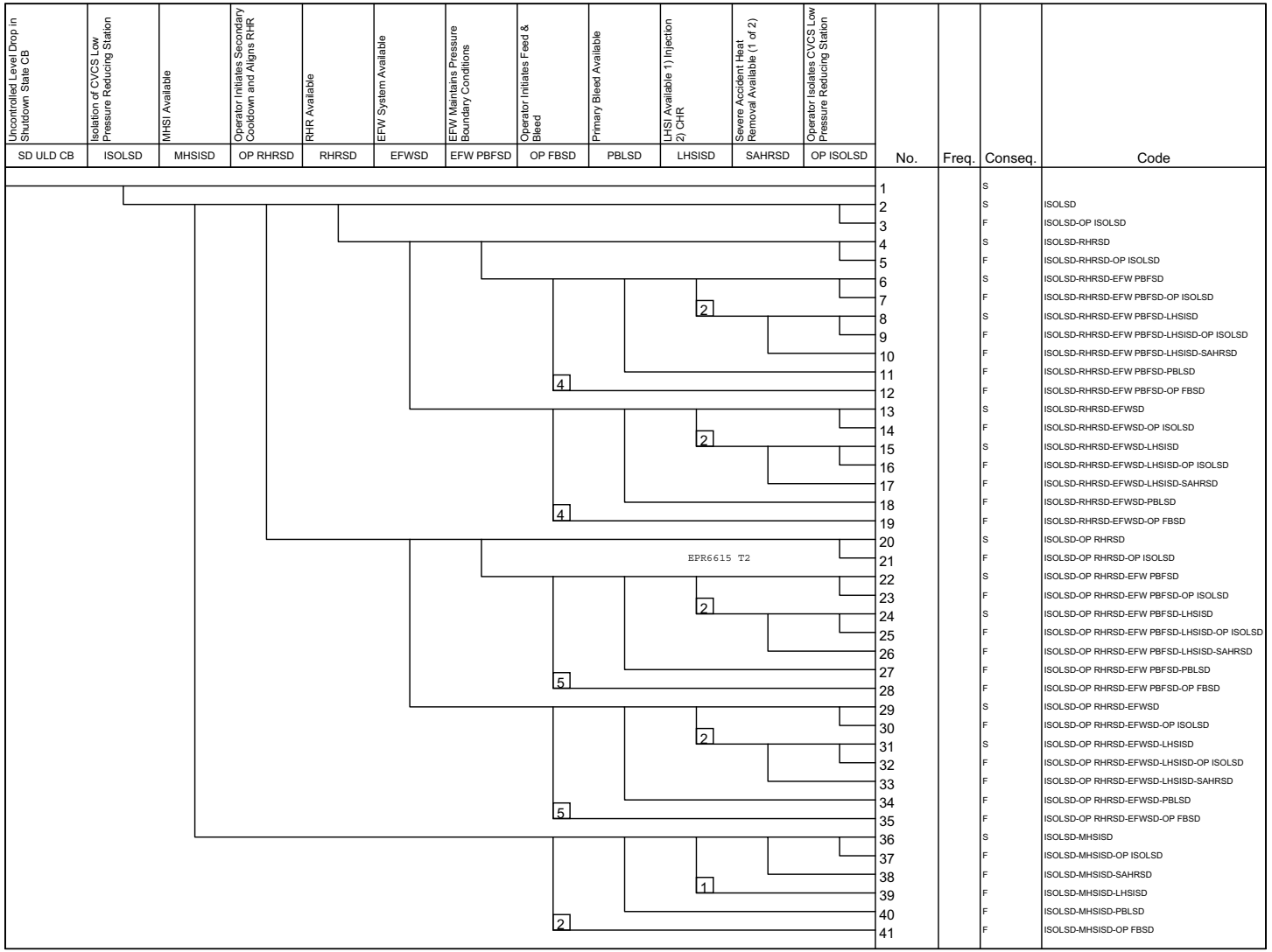
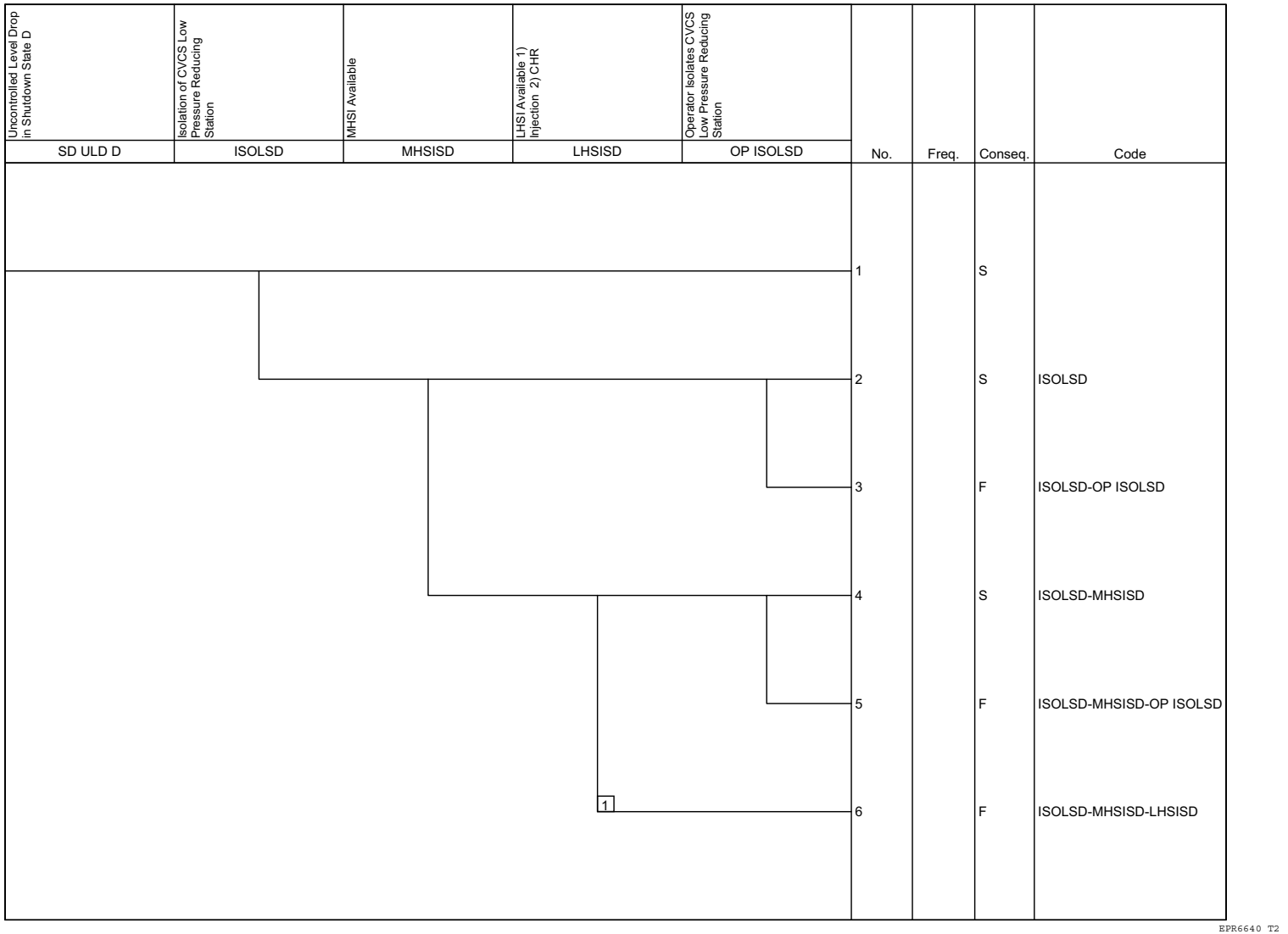


Figure 19B-6—Uncontrolled Level Drop During Shutdown State D



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