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-L	LLOCA During Shutdown State C (Note 1)	19B-1
SD LOCA-S	SLOCA During Shutdown State C (Note 1)	19B-2
SD LOCA D L	LOCA During Shutdown State D (Note 1)	19B-3
SD RHR C	Loss of RHR During State C (Note 1)	19B-4
SD RHR D	Loss of RHR During State D (Note 1)	19B-5
SD ULD CB	Uncontrolled Level Drop During Shutdown State CB (Note 1)	19B-6
SD ULD D	Uncontrolled Level Drop During Shutdown State D (Note 1)	19B-7
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 SD LOCA-L (Large): LLOCA During Shutdown State C

Event Tree Top Event		Success Criteria	Failure Event	Event Description
SD LOCA C L	LOCA (large) during shutdown state C	–	SD LOCA C L (consequence)	LOCA during shutdown state C (large)
MHSI	Medium-head safety injection available (Condition 1)	1 of 4 MHSI pumps supply flow	MHSI 4/4 (FT top gate)	Failure of 4 out of 4 MHSI trains
LHSI	LHSI available for feed-and-bleed cooling (Condition 1)	1 of 4 LHSI pumps available	LHSI INJ SD (FT top gate)	Failure of 4 out of 4 LHSI trains (injection mode only)
LTC	Long Term Cooling of IRWST via LHSI or SAHR (Condition 3)	1 of 4 LHSI trains (with Htx) available OR 1 of 1 SAHR pump available in recirculation mode	LTC (FT top gate)	Failure of IRWST Long Term Cooling (LHSI & SAHR)

Table 19B-2—Event Tree Headings for Initiating Event IE SD LOCA-S (Small): SLOCA During Shutdown State C
Sheet 1 of 2

Event Tree Top Event		Success Criteria	Failure Event	Event Description
SD LOCA C S	LOCA (small) during shutdown state C	–	SD LOCA C L (consequence)	LOCA during shutdown state C (large)
MHSI	Medium-head safety injection available (Condition 1)	1 of 4 MHSI pumps supply flow	MHSI 4/4 (FT top gate)	Failure of 4 out of 4 MHSI trains
OP RHR	Operator aligns and initiates RHR during shutdown (Condition 8)	Action taken	OPE-RHR-SD (basic event)	Failure of operator to start RHR
RHR	RHR available during shutdown (Condition 2)	1 out of 4 LHSI pumps available for RHR	RHR 4/4 SD (FT top gate)	Failure of 4 out of 4 LHSI trains for RHR (shutdown)
EFW	EFW available for manual cooldown (MSRVs only) (Condition 9)	1 out of 2 EFW trains available for manual cooldown	EFW SD (FT top gate)	Failure of EFW trains (with MSRVs) (during shutdown)
EFW INV	EFW maintains adequate inventory	All 4 EFW tanks cross tied (or refilled)	EFW INV (FT top gate)	Failure to provide adequate EFW Inventory
OP FB	Operator initiates feed-and-bleed cooling:	Initiation of feed-and-bleed		
	After a LOCA – MHSI failed or not asked (Condition 6)		OP FB 2 (FT top gate)	Operator fails to initiate feed & bleed after a LOCA – MHSI=F or n/a
	After a LOCA – MHSI success (Condition 8)		OP FB 3 (FT top gate)	Operator fails to initiate feed & bleed after a LOCA – MHSI=S
	After a LOCA – MHSI success and OP RHR failed (Condition 9)		OP FB 3D (FT top gate)	Operator fails to initiate feed & bleed after a LOCA – MHSI=S and OP RHR=F

Table 19B-2—Event Tree Headings for Initiating Event IE SD LOCA-S (Small): SLOCA During Shutdown State C
Sheet 2 of 2

Event Tree Top Event		Success Criteria	Failure Event	Event Description
PBL	Primary bleed available	3 of 3 PSVs or 1 of 2 PDVs and steam generator relief (4 SGs)	PBL (FT top gate)	Failure of a PSV and both PDVs or steam generator relief valves (MSRTs and safeties) on the steam generators
LHSI	LHSI available for feed-and-bleed cooling during shutdown (Condition 3)	1 of 4 LHSI pumps available	LHSI INJ SD (FT top gate)	Failure of 4 out of 4 LHSI trains (injection mode only) during shutdown
LTC	Long Term Cooling of IRWST via LHSI or SAHR (Condition 3)	1 of 4 LHSI trains (with Htx) available OR 1 of 1 SAHR pump available in recirculation mode	LTC SD (FT top gate)	Failure of IWRST Long Term Cooling (LHSI & SAHR) during shutdown

Table 19B-3—Event Tree Headings for Initiating Event IE SD LOCA (Large & Small): LOCA During Shutdown State D

Event Tree Top Event		Success Criteria	Failure Event	Event Description
SD LOCA D L*	Large LOCA during shutdown state D	–	SD LOCA D L (consequence)	LOCA during shutdown state D (large)
MHSI	Medium-head safety injection available (Condition 1)	1 of 4 MHSI pumps supply flow	MHSI 4/4 (FT top gate)	Failure of 4 out of 4 MHSI trains
LHSI	LHSI available for feed-and-bleed cooling during shutdown (Condition 3)	1 of 4 LHSI pumps available	LHSI INJ SD (FT top gate)	Failure of 4 out of 4 LHSI trains (injection mode only) during shutdown

*This tree structure also is applicable for initiators SD LOCA D S, SD LOCA E L and SD LOCA E S.

Table 19B-4—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	–	SD RHR C (consequence)	Loss of RHR during shutdown state C
TR LOCA	Transient induced LOCA does not occur	Seal injection with CVCS or seal cooling with CCWS or standstill seal actuation or seals withstand challenge AND pressurizer safety relief valves reclose	TR LOCA (FT top gate)	Transient induced LOCA
EFW	EFW available for manual cooldown (MSRVs only) (Condition 9)	1 out of 2 EFW trains available for manual cooldown	EFW SD (FT top gate)	Failure of EFW trains (with MSRVs) (during shutdown)
EFW INV	EFW maintains adequate inventory	All 4 EFW tanks cross tied (or refilled)	EFW INV (FT top gate)	Failure to provide adequate EFW Inventory
OP FB	Operator initiates feed-and-bleed cooling:	Initiation of feed-and-bleed		
	After a loss of RHR/EFW (Condition 5)		OP FB 1 (FT top gate)	Operator fails to initiate feed & bleed after a loss of RHR/EFW
	After a transient LOCA – MHSI failed or not asked (Condition 7)		OP FB 2L (FT top gate)	Operator fails to initiate feed & bleed after a transient LOCA – MHSI=F or n/a
PBL	Primary bleed available	3 of 3 PSVs or 1 of 2 PDVs and steam generator relief (4 SGs)	PBL (FT top gate)	Failure of a PSV and both PDVs or steam generator relief valves (MSRTs and safeties) on the steam generators
MHSI FB	MHSI available for feed-and-bleed cooling	1 of 4 MHSI pumps available	MHSI 4/4 (FT top gate)	Failure of 4 out of 4 MHSI trains

Table 19B-4—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
LHSI	LHSI available for feed-and-bleed cooling during shutdown (Condition 3)	1 of 4 LHSI pumps available	LHSI INJ SD (FT top gate)	Failure of 4 out of 4 LHSI trains (injection mode only) during shutdown
LTC	Long Term Cooling of IRWST via LHSI or SAHR (Condition 3)	1 of 4 LHSI trains (with Htx) available OR 1 of 1 SAHR pump available in recirculation mode	LTC SD (FT top gate)	Failure of IWRST Long Term Cooling (LHSI & SAHR) during shutdown

Table 19B-5—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	–	SD RHR D (consequence)	Loss of RHR during shutdown state D (large)
MHSI	Medium-head safety injection available (Condition 1)	1 of 4 MHSI pumps supply flow	MHSI 4/4 (FT top gate)	Failure of 4 out of 4 MHSI trains
LHSI	LHSI available for feed-and-bleed cooling during shutdown (Condition 3)	1 of 4 LHSI pumps available	LHSI INJ SD (FT top gate)	Failure of 4 out of 4 LHSI trains (injection mode only) during shutdown

Table 19B-6—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 CB	Uncontrolled level drop during shutdown state CB	–	SD ULD CB (consequence)	Uncontrolled level drop during shutdown state CB
ISO LPRS	Isolation of CVCS low pressure reducing station	Auto isolation of CVCS low pressure reducing station	ISO LPRS (FT top gate)	Failure to isolate the CVCS low pressure reducing station
MHSI	Medium-head safety injection available (Condition 1)	1 of 4 MHSI pumps supply flow	MHSI 4/4 (FT top gate)	Failure of 4 out of 4 MHSI trains
OP RHR	Operator aligns and initiates RHR during shutdown (Condition 8)	Action taken	OPE-RHR-SD (basic event)	Failure of operator to start RHR
RHR	RHR available during shutdown (Condition 2)	1 out of 4 LHSI pumps available for RHR	RHR 4/4 SD (FT top gate)	Failure of 4 out of 4 LHSI trains for RHR (shutdown)
EFW	EFW available for manual cooldown (MSRVs only) (Condition 9)	1 out of 2 EFW trains available for manual cooldown	EFW SD (FT top gate)	Failure of EFW trains (with MSRVs) (during shutdown)
EFW INV	EFW maintains adequate inventory	All 4 EFW tanks cross tied (or refilled)	EFW INV (FT top gate)	Failure to provide adequate EFW Inventory
OP FB	Operator initiates feed-and-bleed cooling:	Initiation of feed-and-bleed		
	After a LOCA – MHSI failed or not asked (Condition 6)		OP FB 2 (FT top gate)	Operator fails to initiate feed & bleed after a LOCA – MHSI=F or n/a
	After a LOCA – MHSI success (Condition 8)		OP FB 3 (FT top gate)	Operator fails to initiate feed & bleed after a LOCA – MHSI=S
	After a LOCA – MHSI success and OP RHR failed (Condition 9)		OP FB 3D (FT top gate)	Operator fails to initiate feed & bleed after a LOCA – MHSI=S and OP RHR=F

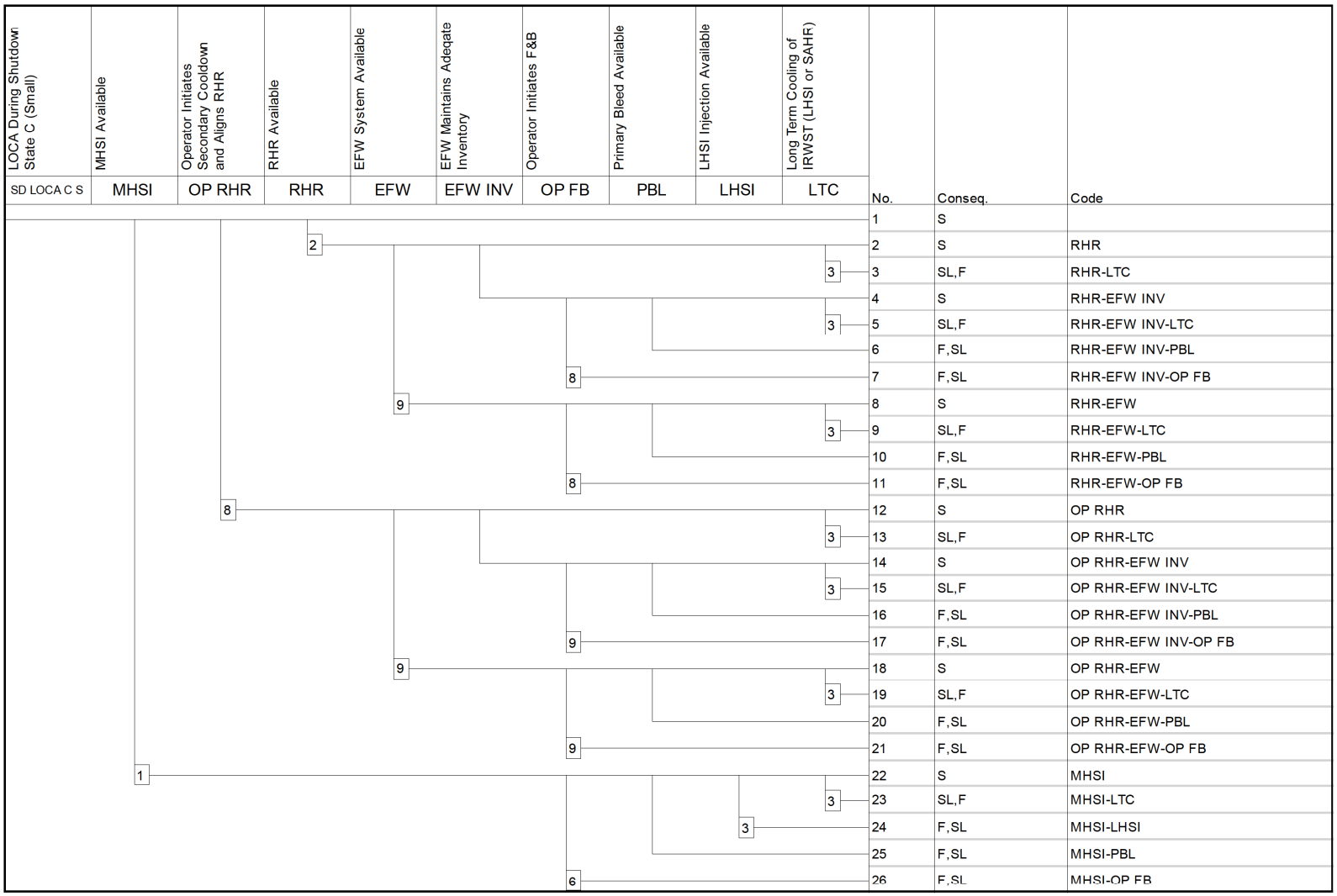
Table 19B-6—Event Tree Headings for Initiating Event IE ULD: Uncontrolled Level Drop During State CB
Sheet 2 of 2

Event Tree Top Event		Success Criteria	Failure Event	Event Description
PBL	Primary bleed available	3 of 3 PSVs or 1 of 2 PDVs and steam generator relief (4 SGs)	PBL (FT top gate)	Failure of a PSV and both PDVs or steam generator relief valves (MSRTs and safeties) on the steam generators
LHSI	LHSI available for feed-and-bleed cooling during shutdown (Condition 3)	1 of 4 LHSI pumps available	LHSI INJ SD (FT top gate)	Failure of 4 out of 4 LHSI trains (injection mode only) during shutdown
LTC	Long Term Cooling of IRWST via LHSI or SAHR (Condition 3)	1 of 4 LHSI trains (with Htx) available OR 1 of 1 SAHR pump available in recirculation mode	LTC SD (FT top gate)	Failure of IWRST Long Term Cooling (LHSI & SAHR) during shutdown
OP ISO LPRS	Operator isolates CVCS low pressure reducing station	Operator isolates CVCS low pressure reducing station	OPE-ISOCSLPRS (basic event)	Operator fails to isolate the CVCS low pressure reducing station

Table 19B-7—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	–	SD ULD D (consequence)	Uncontrolled level drop during shutdown state D
ISO LPRS	Isolation of CVCS low pressure reducing station	Auto isolation of CVCS low pressure reducing station	ISO LPRS (FT top gate)	Failure to isolate the CVCS low pressure reducing station
MHSI	Medium-head safety injection available (Condition 1)	1 of 4 MHSI pumps supply flow	MHSI 4/4 (FT top gate)	Failure of 4 out of 4 MHSI trains
LHSI	LHSI available for feed-and-bleed cooling during shutdown (Condition 3)	1 of 4 LHSI pumps available	LHSI INJ SD (FT top gate)	Failure of 4 out of 4 LHSI trains (injection mode only) during shutdown
OP ISO LPRS	Operator isolates CVCS low pressure reducing station	Operator isolates CVCS low pressure reducing station	OPE-ISOCSLPRS (basic event)	Operator fails to isolate the CVCS low pressure reducing station

Figure 19B-1—SLOCA During Shutdown State C



No.	Conseq.	Code
1	S	
2	S	RHR
3	SL,F	RHR-LTC
4	S	RHR-EFW INV
5	SL,F	RHR-EFW INV-LTC
6	F,SL	RHR-EFW INV-PBL
7	F,SL	RHR-EFW INV-OP FB
8	S	RHR-EFW
9	SL,F	RHR-EFW-LTC
10	F,SL	RHR-EFW-PBL
11	F,SL	RHR-EFW-OP FB
12	S	OP RHR
13	SL,F	OP RHR-LTC
14	S	OP RHR-EFW INV
15	SL,F	OP RHR-EFW INV-LTC
16	F,SL	OP RHR-EFW INV-PBL
17	F,SL	OP RHR-EFW INV-OP FB
18	S	OP RHR-EFW
19	SL,F	OP RHR-EFW-LTC
20	F,SL	OP RHR-EFW-PBL
21	F,SL	OP RHR-EFW-OP FB
22	S	MHSI
23	SL,F	MHSI-LTC
24	F,SL	MHSI-LHSI
25	F,SL	MHSI-PBL
26	F,SL	MHSI-OP FB

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

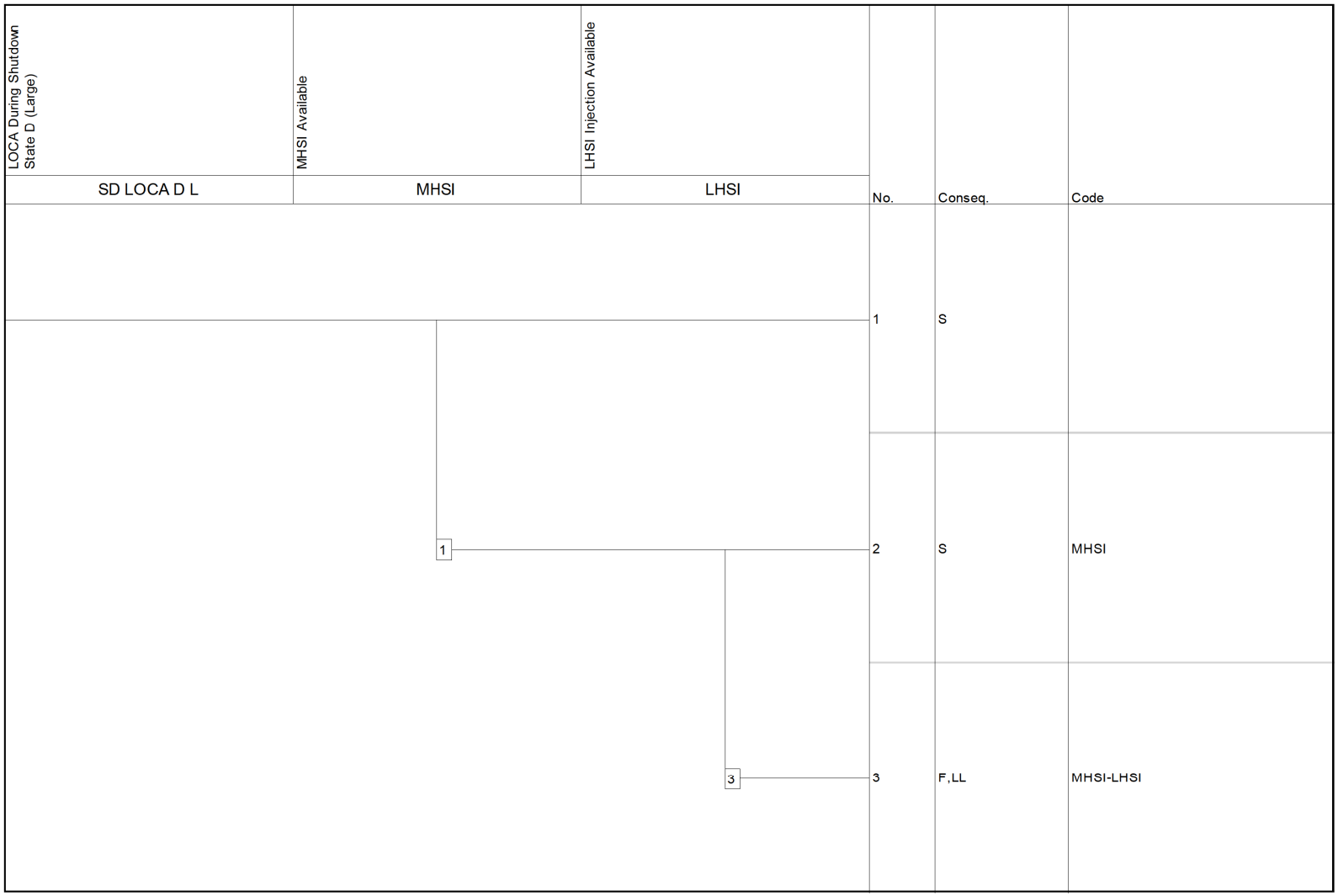

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Figure 19B-3—Loss of RHR During State C

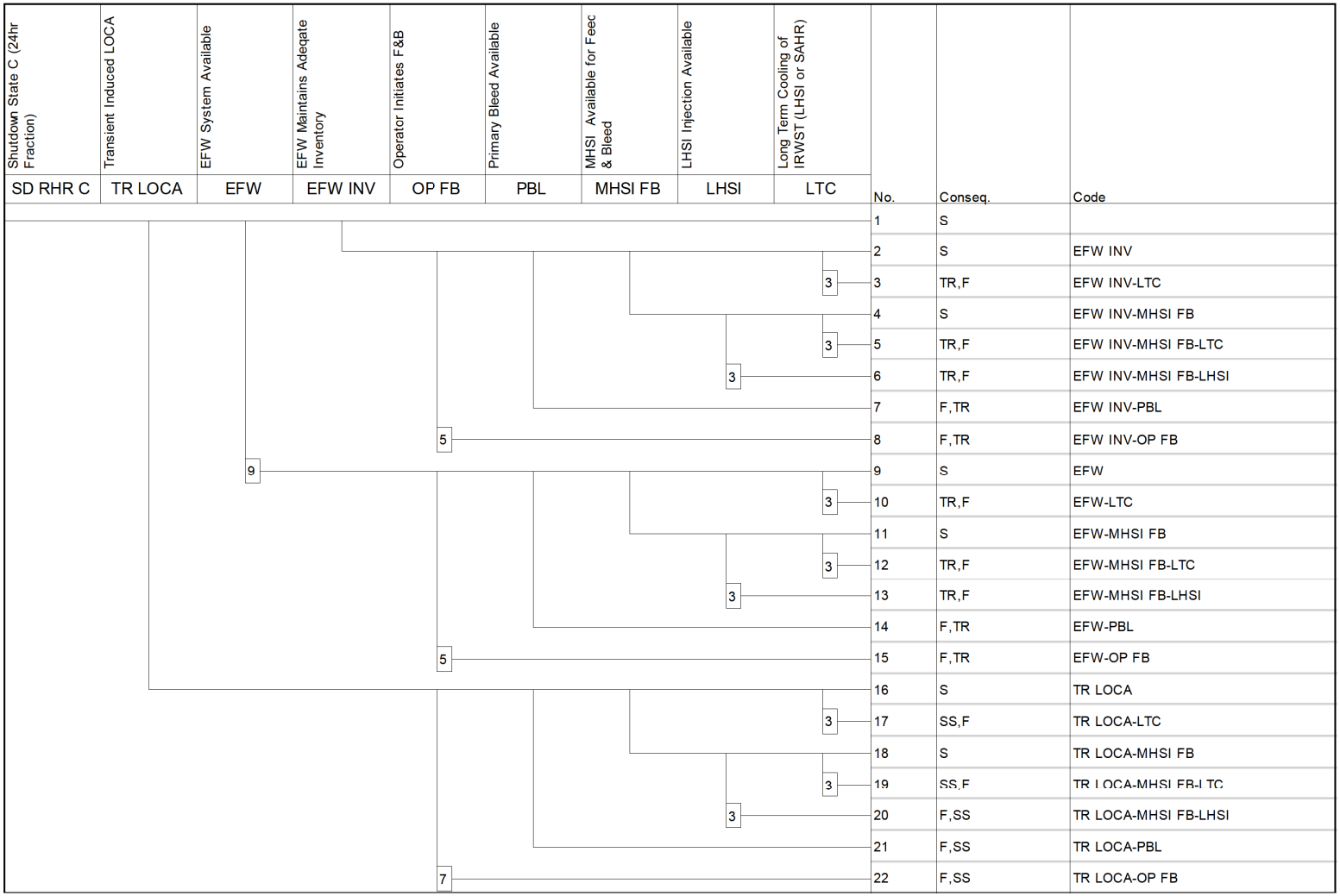

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Figure 19B-4—Loss of RHR During State D

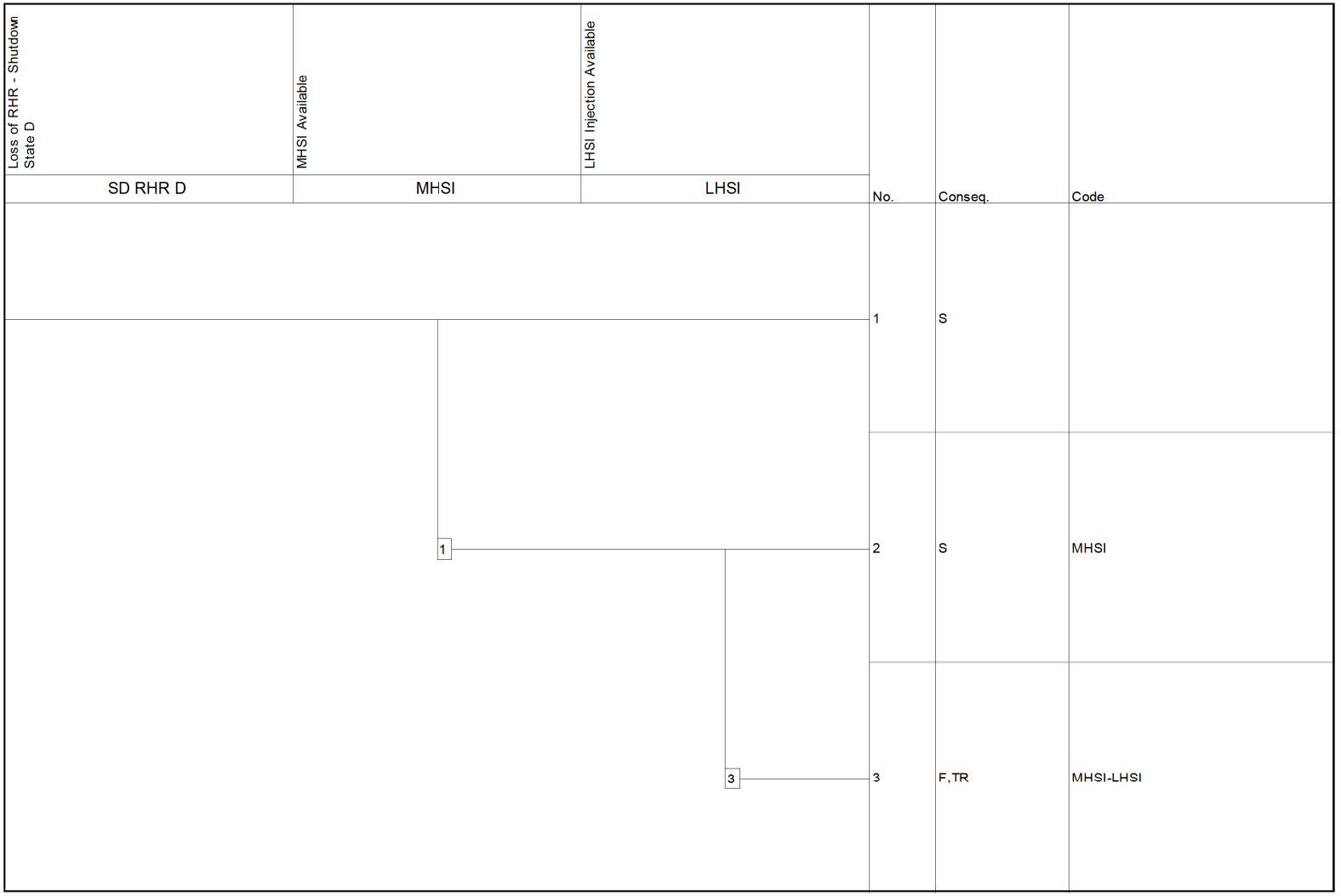

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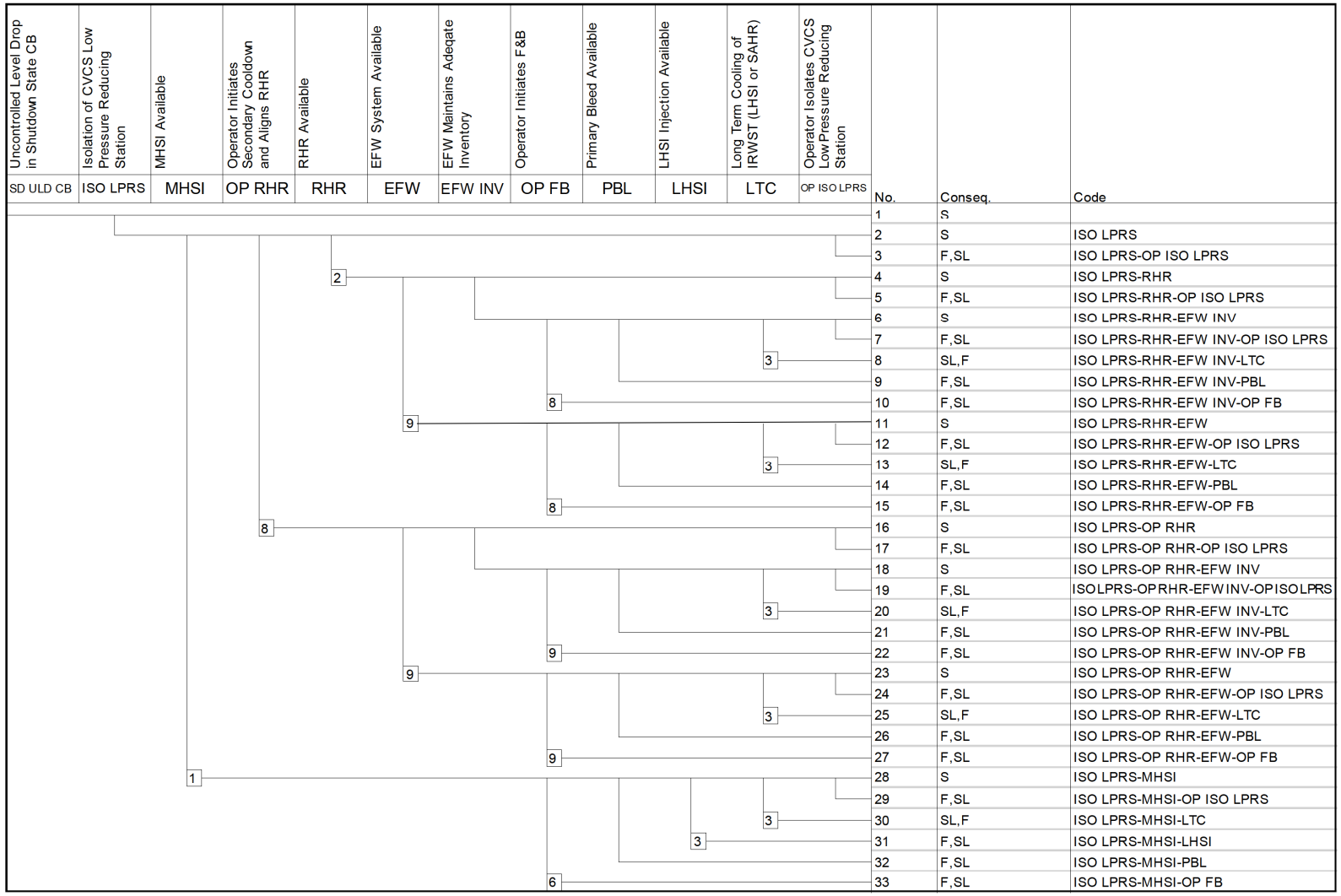
Figure 19B-5—Uncontrolled Level Drop During Shutdown State C



No.	Conseq.	Code
1	S	
2	S	ISO LPRS
3	F,SL	ISO LPRS-OP ISO LPRS
4	S	ISO LPRS-RHR
5	F,SL	ISO LPRS-RHR-OP ISO LPRS
6	S	ISO LPRS-RHR-EFW INV
7	F,SL	ISO LPRS-RHR-EFW INV-OP ISO LPRS
8	SL,F	ISO LPRS-RHR-EFW INV-LTC
9	F,SL	ISO LPRS-RHR-EFW INV-PBL
10	F,SL	ISO LPRS-RHR-EFW INV-OP FB
11	S	ISO LPRS-RHR-EFW
12	F,SL	ISO LPRS-RHR-EFW-OP ISO LPRS
13	SL,F	ISO LPRS-RHR-EFW-LTC
14	F,SL	ISO LPRS-RHR-EFW-PBL
15	F,SL	ISO LPRS-RHR-EFW-OP FB
16	S	ISO LPRS-OP RHR
17	F,SL	ISO LPRS-OP RHR-OP ISO LPRS
18	S	ISO LPRS-OP RHR-EFW INV
19	F,SL	ISO LPRS-OP RHR-EFW INV-OP ISO LPRS
20	SL,F	ISO LPRS-OP RHR-EFW INV-LTC
21	F,SL	ISO LPRS-OP RHR-EFW INV-PBL
22	F,SL	ISO LPRS-OP RHR-EFW INV-OP FB
23	S	ISO LPRS-OP RHR-EFW
24	F,SL	ISO LPRS-OP RHR-EFW-OP ISO LPRS
25	SL,F	ISO LPRS-OP RHR-EFW-LTC
26	F,SL	ISO LPRS-OP RHR-EFW-PBL
27	F,SL	ISO LPRS-OP RHR-EFW-OP FB
28	S	ISO LPRS-MHSI
29	F,SL	ISO LPRS-MHSI-OP ISO LPRS
30	SL,F	ISO LPRS-MHSI-LTC
31	F,SL	ISO LPRS-MHSI-LHSI
32	F,SL	ISO LPRS-MHSI-PBL
33	F,SL	ISO LPRS-MHSI-OP FB

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

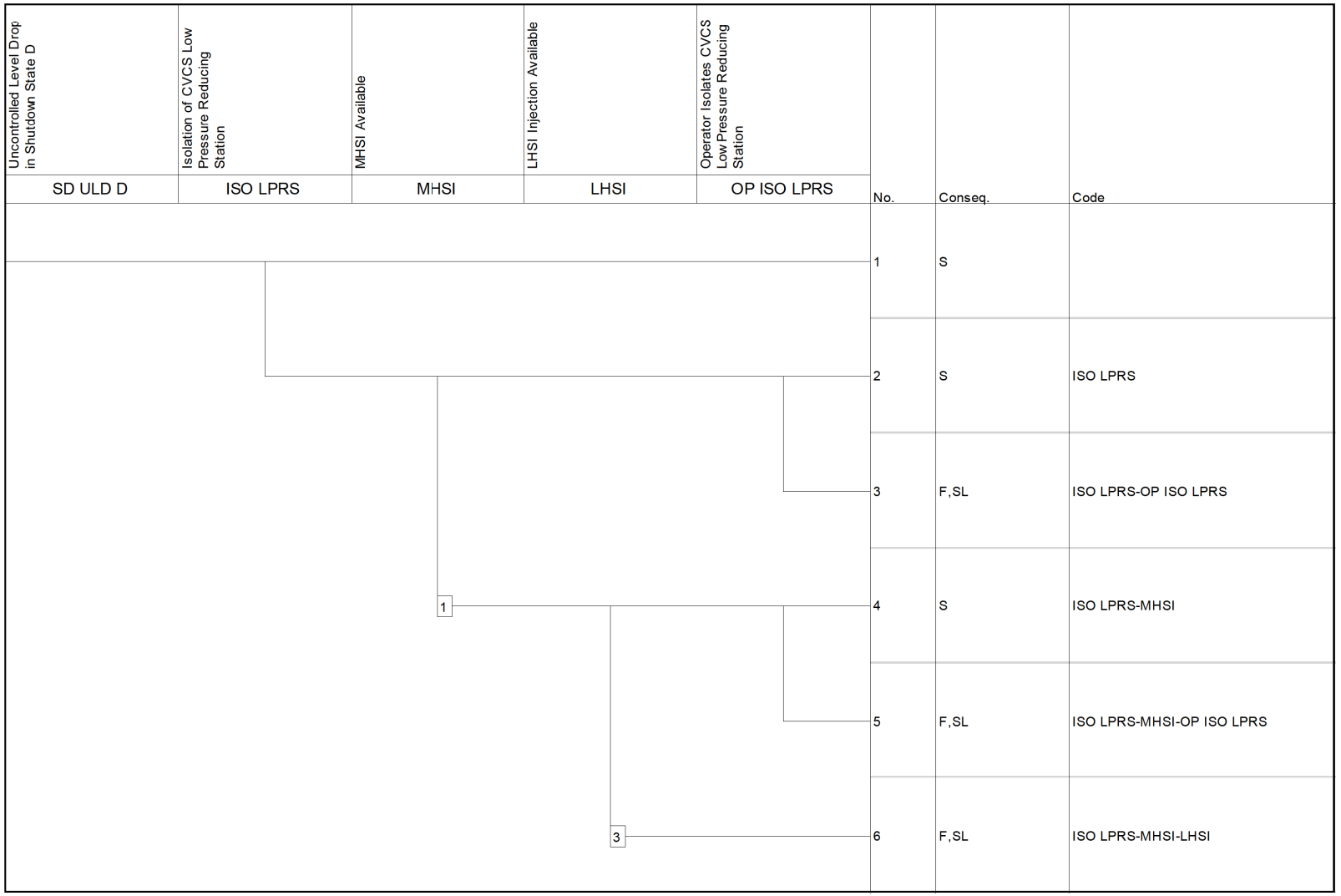

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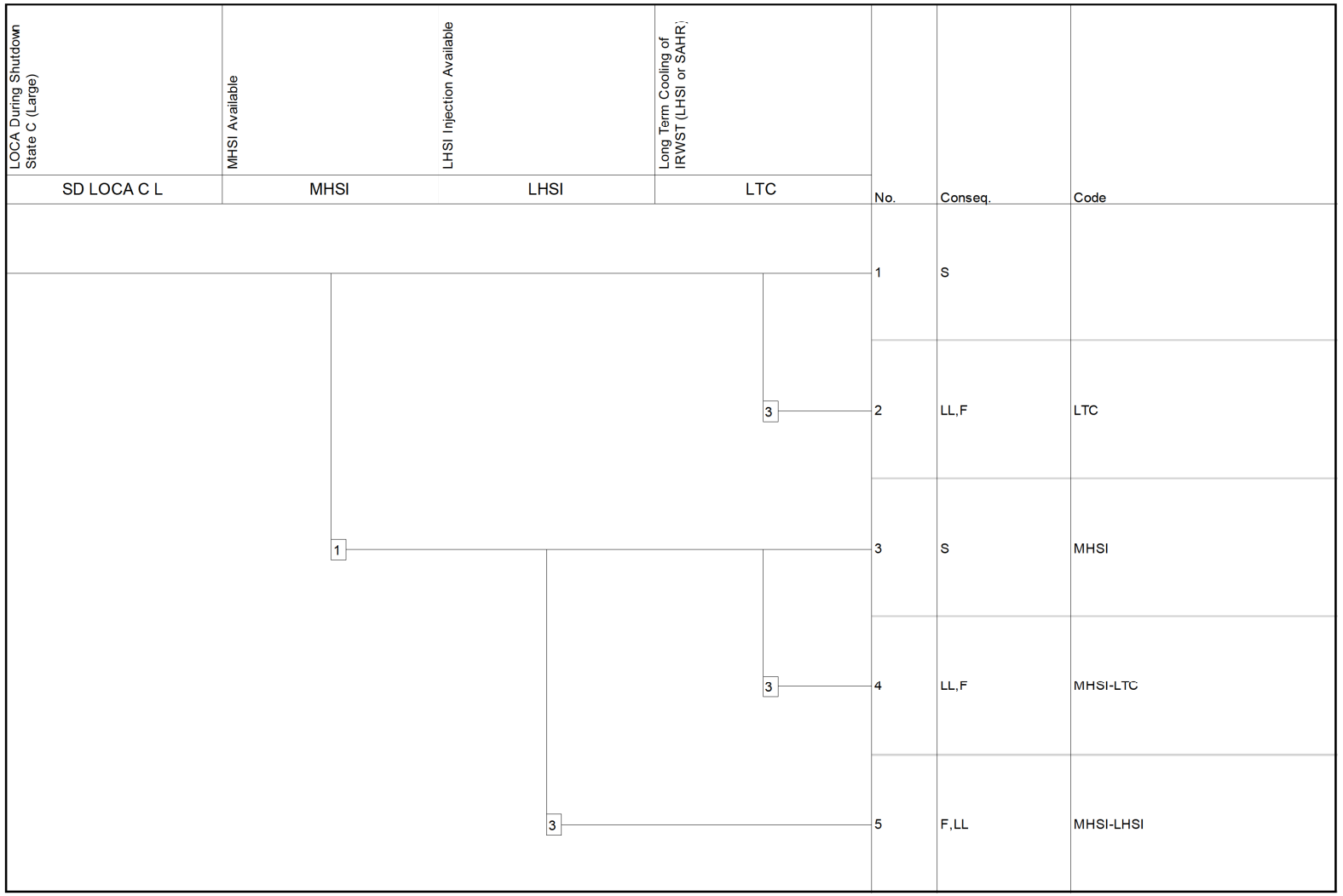
Figure 19B-7—LLOCA During Shutdown State C



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