

Final Precursor Analysis

Accident Sequence Precursor Program – Office of Nuclear Regulatory Research

H. B. Robinson	Reactor Trip with a Loss of Main Feedwater and Pressurizer Power-Operated Relief Valve Opening on Demand	
Event Date: 9/9/2010	LER: 261/10-007 IRs: 50-261/10-05	CCDP = 3×10^{-6}

EVENT SUMMARY

Brief Event Description. At 1437 on September 9, 2010, with H. B. Robinson Steam Electric Plant, Unit 2, in Mode 1 at approximately 100% power, an automatic reactor trip occurred. The reactor trip signal was based on the over-temperature/differential temperature (OTΔT) reactor protection function. Due to the plant transient condition, the steam generator power operated relief valves (PORVs) opened and one pressurizer PORV cycled momentarily in response to pressure changes in the steam generators and pressurizer. The auxiliary feedwater system automatically actuated, as expected and provided feedwater to the steam generators. The main steam safety valves did not open during the event. Additional information is provided in References 1 and 2.

Key Event Details. The following details are important to the modeling of this event analysis:

- The reactor tripped and main feedwater (MFW) was lost due to the load rejection.
- A pressurizer PORV opened after the reactor trip and successfully closed after the demand.

ANALYSIS RESULTS

Conditional Core Damage Probability. The conditional core damage probability (CCDP) for this event is 3.0×10^{-6} .

The Accident Sequence Precursor (ASP) Program acceptance threshold is a CCDP of 1×10^{-6} or the CCDP equivalent of an uncomplicated reactor trip with a non-recoverable loss of secondary plant systems (e.g., feedwater and condensate), whichever is greater. This CCDP equivalent for H. B. Robinson is 2.7×10^{-6} .

Dominant Sequence. The dominant accident sequence, Loss of Main Feedwater (LOMFW) Sequence 13-16 (CCDP = 1.6×10^{-6}) contributes 55% of the total internal events CCDP. Additional sequences that contribute greater than 1% of the total internal events CCDP are provided in Appendix A.

The dominant sequence is shown graphically in Figure B-1 in Appendix B. The events and important component failures in LOMFW Sequence 13-16 are:

- Loss of MFW transient occurs,
- Reactor trip fails, and

- Reactor pressure increases above the reactor pressure vessel design pressure (the vessel fails).

SAPHIRE 8 Report. The SAPHIRE 8 Worksheets (Appendix A) provide the following:

- Modified basic events and initiating event frequencies, including base and change case probabilities/frequencies.
- Dominant sequences (including CCDPs).
- Sequence logic for all dominant sequences.
- Fault tree definitions.
- Sequence cutsets.
- Definitions and probabilities for key basic events

MODELING ASSUMPTIONS

Analysis Type. The Revision 8.16 of the Robinson Standardized Plant Analysis Risk (SPAR) Model created in September 2010 was used for this event analysis. This event was modeled as a loss of feedwater transient initiating event.

Analysis Rules. The ASP program uses Significance Determination Process results for degraded conditions when available. However, the ASP Program performs independent initiating event analysis when an initiator occurs.

Key Modeling Assumptions. The following modeling assumptions and associated basic event modifications were required for this event analysis:

- The initiating event was modeled as loss of main feedwater. The auxiliary feedwater system started automatically, when the main feed water was lost, due to a full load reject.
 - The frequency of IE-LOMFW (*Initiating Event- loss of feedwater*) was set to 1.0; all other initiating events frequencies were set to zero.
- The following basic event was modified due to the opening of a pressurizer PORV after the OTΔT reactor protection function initiated the reactor trip.
 - The probability of basic event PPR-SRV-CO-TRANS (*PORVs/SRVs open during transient*) was set to TRUE.
- The non-recoverability probability for basic event HPR-XHE-XM-RECIRC (*Operators fail to initiate high-pressure recirculation*) was set to 5×10^{-3} . This value was calculated using the SPAR-H Method (Reference 3).
 - This human failure event contains both diagnosis and action activities. Since operators would have enough time to perform the action, the nominal action human error probability of 1×10^{-3} was applied.
 - The following performance shaping factors (PSF) were adjusted. All other PSFs were determined to be nominal (i.e., $\times 1$).

PSF for Diagnosis	Multiplier	Notes
Time Available	0.1	Several hours exist for operators to initiate recirculation given a failure of RCS depressurization or shutdown cooling. Therefore, <i>Extra Time</i> (i.e., $\times 0.1$) was selected.
Stress	2	The PSF for diagnosis stress is assigned a value of <i>High Stress</i> (i.e., $\times 2$) due to the initiation of the event and multiple failures experienced during the postulated sequences.
Complexity	2	The PSF for diagnosis complexity is assigned a value of <i>Moderately Complex</i> (i.e., $\times 2$) due to the long procedure (41 pages) used to align recirculation and initiate sump recirculation.

Diagnosis HEP	4E-3
Action HEP	1E-3
Adjusted Total HEP	5E-3

REFERENCES

1. Progress Energy, "LER 261/10-007– Reactor Trip Due to a Degraded Connection on a Circuit Board in the Electro-Hydraulic Control Cabinet," dated January 17, 2011.
2. U.S. Nuclear Regulatory Commission, "H. B. Robinson Steam Electric Plant – NRC Integrated Inspection Report 05000261/2010005," dated January 28, 2011.
3. Idaho National Laboratory, "NUREG/CR-6883: The SPAR-H Human Reliability Analysis Method," dated August 2005.

Appendix A: SAPHIRE 8 Worksheets

Summary of Conditional Event Changes

Event	Description	Cond. Value	Nominal Value
HPR-XHE-XM-RECIRC	OPERATOR FAILS TO INITIATE HPR CL RECIRC	5.000E-3	2.000E-3
IE-LOMFW	LOSS OF MAIN FEEDWATER ^a	1.000E+0	1.000E-1
PPR-SRV-CO-TRAN	PORVs/SRVs OPEN DURING TRANSIENT	True	4.000E-2

a. All other initiating event frequencies set to zero.

Dominant Sequence Results

Only items contributing at least 1.0% to the total CCDP are displayed.

EVENT TREE	SEQUENCE	CCDP	% CONTRIBUTION	DESCRIPTION
LOMFW	13-16	1.627E-6	54.5%	RPS, RCSPRESS
LOMFW	12	8.023E-7	26.9%	/RPS, AFW, FAB
LOMFW	05	2.914E-7	9.8%	/RPS, /AFW, PORV, /HPI, /SSC, RHR, HPR
LOMFW	11	1.083E-7	3.6%	/RPS, AFW, /FAB, SSCR, HPR
LOMFW	13-07	1.045E-7	3.5%	RPS, /RCSPRESS, /MFW, BORATION
Total		3.406E-6	100.0%	

Referenced Fault Trees

Fault Tree	Description
AFW	AUXILIARY FEEDWATER AVAILABLE
BORATION	EMERGENCY BORATION
FAB	FEED AND BLEED
HPR	HPR PRESSURE RECIRC
PORV	PORV/SRVs ARE CLOSED
RCSPRESS	RCS PRESSURE LIMITED
RHR	RESIDUAL HEAT REMOVAL
RPS	REACTOR TRIP
SSCR	SECONDARY SIDE COOLING RECOVERED

Cutset Report - LOMFW 13-16

Only items contributing at least 1% to the total are displayed.

#	CCDP	TOTAL%	CUTSET
	1.627E-6	100	Displaying 62 of 62 Cutsets.
1	2.093E-7	12.87	IE-LOMFW,PPR-MOV-FC-535,RPS-BME-CF-RTBAB
2	2.093E-7	12.87	IE-LOMFW,PPR-MOV-FC-536,RPS-BME-CF-RTBAB
3	1.746E-7	10.73	IE-LOMFW,PPR-MOV-FC-535,/RPS-CCP-TM-CHA,RPS-TXX-CF-6OF8,RPS-XHE-XE-NSGNL
4	1.746E-7	10.73	IE-LOMFW,PPR-MOV-FC-536,/RPS-CCP-TM-CHA,RPS-TXX-CF-6OF8,RPS-XHE-XE-NSGNL
5	1.573E-7	9.67	IE-LOMFW,PPR-MOV-FC-535,RPS-ROD-CF-RCCAS
6	1.573E-7	9.67	IE-LOMFW,PPR-MOV-FC-536,RPS-ROD-CF-RCCAS
7	1.184E-7	7.28	IE-LOMFW,PPR-MOV-FC-535,/RPS-CCP-TM-CHA,RPS-CCX-CF-6OF8,RPS-XHE-XE-NSGNL
8	1.184E-7	7.28	IE-LOMFW,PPR-MOV-FC-536,/RPS-CCP-TM-CHA,RPS-CCX-CF-6OF8,RPS-XHE-XE-NSGNL
9	2.254E-8	1.39	IE-LOMFW,RCS-PHN-MODPOOR,RPS-BME-CF-RTBAB
10	1.881E-8	1.16	IE-LOMFW,RCS-PHN-MODPOOR,/RPS-CCP-TM-CHA,RPS-TXX-CF-6OF8,RPS-XHE-XE-NSGNL

#	CCDP	TOTAL%	CUTSET
11	1.694E-8	1.04	IE-LOMFW,RCS-PHN-MODPOOR,RPS-ROD-CF-RCCAS

Cutset Report - LOMFW 12

Only items contributing at least 1% to the total are displayed.

#	CCDP	TOTAL%	CUTSET
	8.023E-7	100	Displaying 1278 of 1278 Cutsets.
1	1.860E-7	23.19	IE-LOMFW,AFW-FCV-CF-REG,HPI-XHE-XM-FB
2	6.512E-8	8.12	IE-LOMFW,AFW-FCV-CF-REG,PPR-SRV-CC-455C
3	6.512E-8	8.12	IE-LOMFW,AFW-FCV-CF-REG,PPR-SRV-CC-456
4	2.533E-8	3.16	IE-LOMFW,AFW-FAN-CF-FR7AB,AFW-TDP-FS-SDP,HPI-XHE-XM-FB
5	1.809E-8	2.26	IE-LOMFW,AFW-FAN-CF-FR7AB,AFW-TDP-TM-SDP,HPI-XHE-XM-FB
6	1.739E-8	2.17	IE-LOMFW,AFW-FAN-CF-FS7AB,AFW-TDP-FS-SDP,HPI-XHE-XM-FB
7	1.484E-8	1.85	IE-LOMFW,AFW-FAN-CF-FR7AB,AFW-TDP-FR-SDP,HPI-XHE-XM-FB
8	1.242E-8	1.55	IE-LOMFW,AFW-FAN-CF-FS7AB,AFW-TDP-TM-SDP,HPI-XHE-XM-FB
9	1.155E-8	1.44	IE-LOMFW,AFW-MDP-CF-FSAB,AFW-TDP-FS-SDP,HPI-XHE-XM-FB
10	1.019E-8	1.27	IE-LOMFW,AFW-FAN-CF-FS7AB,AFW-TDP-FR-SDP,HPI-XHE-XM-FB
11	8.865E-9	1.1	IE-LOMFW,AFW-FAN-CF-FR7AB,AFW-TDP-FS-SDP,PPR-SRV-CC-455C
12	8.865E-9	1.1	IE-LOMFW,AFW-FAN-CF-FR7AB,AFW-TDP-FS-SDP,PPR-SRV-CC-456
13	8.250E-9	1.03	IE-LOMFW,AFW-MDP-CF-FSAB,AFW-TDP-TM-SDP,HPI-XHE-XM-FB

Cutset Report - LOMFW 05

Only items contributing at least 1% to the total are displayed.

#	CCDP	TOTAL%	CUTSET
	2.914E-7	100	Displaying 341 of 341 Cutsets.
1	8.450E-8	29	IE-LOMFW,HPR-XHE-XM-RECIRC,PPR-MOV-FC-535,PPR-MOV-FC-536,PPR-SRV-OO-551C
2	8.450E-8	29	IE-LOMFW,HPR-XHE-XM-RECIRC,PPR-MOV-FC-535,PPR-MOV-FC-536,PPR-SRV-OO-551A
3	8.450E-8	29	IE-LOMFW,HPR-XHE-XM-RECIRC,PPR-MOV-FC-535,PPR-MOV-FC-536,PPR-SRV-OO-551B
4	4.350E-9	1.49	IE-LOMFW,HPR-XHE-XM-RECIRC,/PPR-MOV-FC-536,PPR-MOV-OO-536,PPR-SRV-OO-455C
5	4.350E-9	1.49	IE-LOMFW,HPR-XHE-XM-RECIRC,/PPR-MOV-FC-536,PPR-SRV-OO-455C,PPR-XHE-XM-BLK
6	4.350E-9	1.49	IE-LOMFW,HPR-XHE-XM-RECIRC,/PPR-MOV-FC-535,PPR-MOV-OO-535,PPR-SRV-OO-456
7	4.350E-9	1.49	IE-LOMFW,HPR-XHE-XM-RECIRC,/PPR-MOV-FC-535,PPR-SRV-OO-456,PPR-XHE-XM-BLK

Cutset Report - LOMFW 11

Only items contributing at least 1% to the total are displayed.

#	CCDP	TOTAL%	CUTSET
	1.083E-7	100	Displaying 269 of 269 Cutsets.
1	4.651E-8	42.95	IE-LOMFW,AFW-FCV-CF-REG,HPR-XHE-XM-RECIRC
2	6.332E-9	5.85	IE-LOMFW,AFW-FAN-CF-FR7AB,AFW-TDP-FS-SDP,HPR-XHE-XM-RECIRC
3	4.523E-9	4.18	IE-LOMFW,AFW-FAN-CF-FR7AB,AFW-TDP-TM-SDP,HPR-XHE-XM-RECIRC
4	4.347E-9	4.01	IE-LOMFW,AFW-FAN-CF-FS7AB,AFW-TDP-FS-SDP,HPR-XHE-XM-RECIRC
5	3.710E-9	3.43	IE-LOMFW,AFW-FAN-CF-FR7AB,AFW-TDP-FR-SDP,HPR-XHE-XM-RECIRC
6	3.105E-9	2.87	IE-LOMFW,AFW-FAN-CF-FS7AB,AFW-TDP-TM-SDP,HPR-XHE-XM-RECIRC
7	2.888E-9	2.67	IE-LOMFW,AFW-MDP-CF-FSAB,AFW-TDP-FS-SDP,HPR-XHE-XM-RECIRC

#	CCDP	TOTAL%	CUTSET
8	2.547E-9	2.35	IE-LOMFW,AFW-FAN-CF-FS7AB,AFW-TDP-FR-SDP,HPR-XHE-XM-RECIRC
9	2.062E-9	1.9	IE-LOMFW,AFW-MDP-CF-FSAB,AFW-TDP-TM-SDP,HPR-XHE-XM-RECIRC
10	1.739E-9	1.61	IE-LOMFW,AFW-FCV-CF-142425,AFW-TDP-FS-SDP,HPR-XHE-XM-RECIRC
11	1.692E-9	1.56	IE-LOMFW,AFW-MDP-CF-FSAB,AFW-TDP-FR-SDP,HPR-XHE-XM-RECIRC
12	1.536E-9	1.42	IE-LOMFW,AFW-MOV-CF-1416ABC,HPR-XHE-XM-RECIRC
13	1.242E-9	1.15	IE-LOMFW,AFW-FCV-CF-142425,AFW-TDP-TM-SDP,HPR-XHE-XM-RECIRC
14	1.086E-9	1	IE-LOMFW,AFW-FAN-CF-FR7AB,AFW-FCV-CC-6416,HPR-XHE-XM-RECIRC

Cutset Report - LOMFW 13-07

Only items contributing at least 1% to the total are displayed.

#	CCDP	TOTAL%	CUTSET
	1.045E-7	100	Displaying 11 of 11 Cutsets.
1	3.220E-8	30.81	IE-LOMFW,CVC-XHE-XM-BOR,RPS-BME-CF-RTBAB
2	2.687E-8	25.7	IE-LOMFW,CVC-XHE-XM-BOR,/RPS-CCP-TM-CHA,RPS-TXX-CF-6OF8,RPS-XHE-XE-NSGNL
3	2.420E-8	23.15	IE-LOMFW,CVC-XHE-XM-BOR,RPS-ROD-CF-RCCAS
4	1.821E-8	17.42	IE-LOMFW,CVC-XHE-XM-BOR,/RPS-CCP-TM-CHA,RPS-CCX-CF-6OF8,RPS-XHE-XE-NSGNL
5	2.080E-9	1.99	IE-LOMFW,CVC-XHE-XM-BOR,RPS-UVL-CF-UVDAB,RPS-XHE-XE-SIGNL

Referenced Events

Event	Description	Probability
AFW-FAN-CF-FR7AB	CCF OF AFW HVAC HVH-7A&B TO RUN	1.809E-4
AFW-FAN-CF-FS7AB	CCF OF AFW HVAC HVH-7A&B TO START	1.242E-4
AFW-FCV-CC-6416	FAILURE OF AFW SDP DISCHARGE PATH HYDRAULIC VALVE 6416	1.200E-3
AFW-FCV-CF-142425	CCF OF AFW MDPS FCVs 1424 & 1425	4.968E-5
AFW-FCV-CF-REG	CCF OF AFW FEED REG VALVES	9.302E-6
AFW-MDP-CF-FSAB	CCF OF AFW MOTOR DRIVEN PUMPS TO START	8.250E-5
AFW-MOV-CF-1416ABC	CCF OF STEAM GENERATOR INLET MOVs	3.072E-7
AFW-TDP-FR-SDP	AFW TURBINE DRIVEN PUMP FAILS TO RUN	4.102E-3
AFW-TDP-FS-SDP	AFW TURBINE DRIVEN PUMP FAILS TO START	7.000E-3
AFW-TDP-TM-SDP	AFW TDP UNAVAILABLE DUE TO TEST AND MAINTENANCE	5.000E-3
CVC-XHE-XM-BOR	OPERATOR FAILS TO INITIATE EMERGENCY BORATION	2.000E-2
HPI-XHE-XM-FB	OPERATOR FAILS TO INITIATE FEED AND BLEED COOLING	2.000E-2
HPR-XHE-XM-RECIRC	OPERATOR FAILS TO INITIATE HPR CL RECIRC	5.000E-3
IE-LOMFW	LOSS OF MAIN FEEDWATER	1.000E+0
PPR-MOV-FC-535	BLOCK VALVE RC-535 FOR PORV PCV-456 CLOSED	1.300E-1
PPR-MOV-FC-536	BLOCK VALVE RC-536 FOR PORV PCV-455C CLOSED	1.300E-1
PPR-MOV-OO-535	BLOCK VALVE RC-535 FOR PORV PCV-456 FAILS TO CLOSE	1.000E-3
PPR-MOV-OO-536	BLOCK VALVE RC-536 FOR PORV PCV-455C FAILS TO CLOSE	1.000E-3
PPR-SRV-CC-455C	PORV PCV-455C FAILS TO OPEN ON DEMAND	7.000E-3
PPR-SRV-CC-456	PORV PCV-456 FAILS TO OPEN ON DEMAND	7.000E-3
PPR-SRV-OO-455C	PORV PCV-455C FAILS TO RECLOSE AFTER OPENING	1.000E-3
PPR-SRV-OO-456	PORV PCV-456 FAILS TO RECLOSE AFTER OPENING	1.000E-3
PPR-SRV-OO-551A	FAILURE OF SRV RC-551A TO RECLOSE	1.000E-3
PPR-SRV-OO-551B	FAILURE OF SRV RC-551B TO RECLOSE	1.000E-3
PPR-SRV-OO-551C	FAILURE OF SRV RC-551C TO RECLOSE	1.000E-3
PPR-XHE-XM-BLK	OPERATOR FAILS TO CLOSE BLOCK VALVE	1.000E-3

Event	Description	Probability
RCS-PHN-MODPOOR	MODERATOR TEMP COEFFICIENT NOT ENOUGH NEGATIVE	1.400E-2
RPS-BME-CF-RTBAB	CCF OF RTB-A AND RTB-B (MECHANICAL)	1.610E-6
RPS-CCX-CF-60F8	CCF 6 ANALOG PROCESS LOGIC MODULES IN 3 OF 4 CHANNELS	1.830E-6
RPS-ROD-CF-RCCAS	CCF 10 OR MORE RCCAS FAIL TO DROP	1.210E-6
RPS-TXX-CF-60F8	CCF 6 BISTABLES IN 3 OF 4 CHANNELS	2.700E-6
RPS-UVL-CF-UVDAB	CCF UV DRIVERS TRAINS A AND B (2 OF 2)	1.040E-5
RPS-XHE-XE-NSGNL	OPERATOR FAILS TO RESPOND WITH NO RPS SIGNAL PRESENT	5.000E-1
RPS-XHE-XE-SIGNL	OPERATOR FAILS TO RESPOND WITH RPS SIGNAL PRESENT	1.000E-2

Appendix B: Key Event Tree

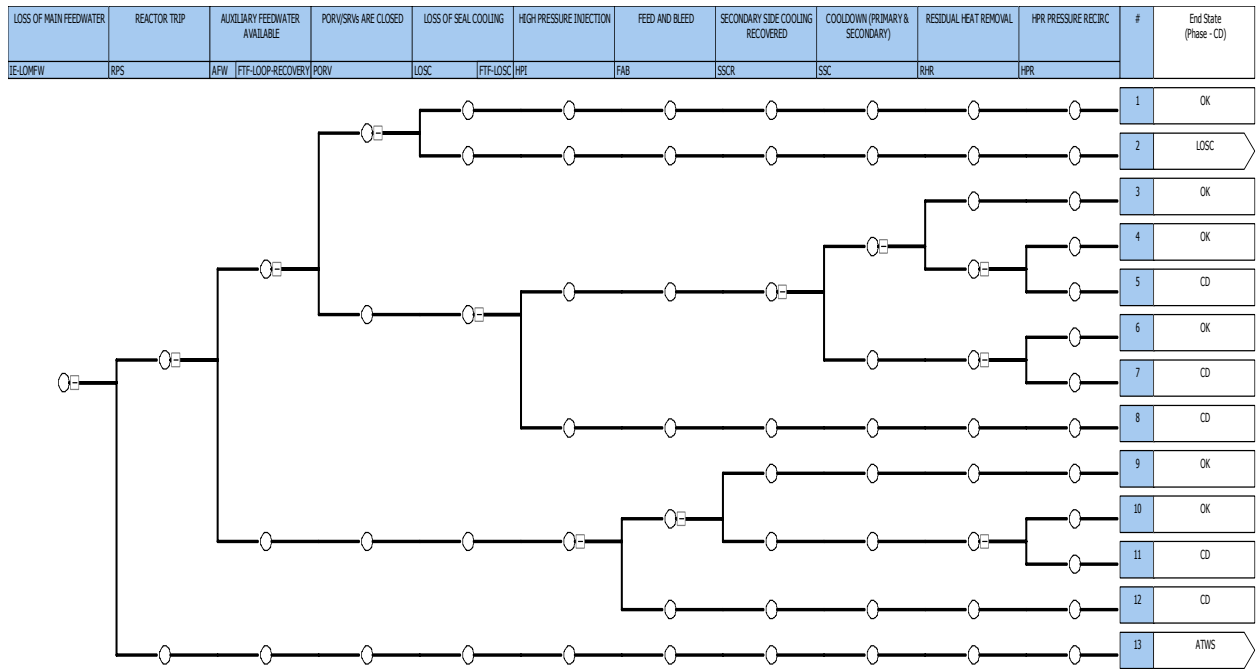


Figure B-1. H. B. Robinson LOMFW event tree.