Contents

List of Tables

List of Illustrations

11A THERMAL HYDRAULIC SENSITIVITY

The purpose of this appendix is to provide the results of the thermal hydraulic sensitivity of the ESBWR model using the thermal hydraulic code developed by EPRI Modular Accident Analysis Program (MAAP) 4.0.6. The thermal hydraulic sensitivity was performed to address issues and further knowledge related to the function and operation of the ESBWR passive systems. Because of the limiting nature of the LOCA scenarios, the thermal hydraulic sensitivities were performed for large break LOCA (LLOCA), medium break LOCA (MLOCA) and inadvertently open relief valve (IORV) scenarios to provide the greatest challenge to the passive system analyses.

The MAAP runs conducted for the thermal hydraulic sensitivity analysis were evaluated for success against one primary criteria, peak clad temperature. The peak clad temperature is calculated to be the single peak centerline fuel clad temperature within one of 65 cladding nodes in the ESBWR MAAP model. Additionally, the reactor water level was used to establish the timing and extent of core uncovery. The thermal hydraulic sensitivity analyses were grouped based on scope and are discussed in the remaining sections.

11A.1 LOCA ANALYSIS

LOCA scenarios were identified from Table 2.2-3 from NEDO 33201, Rev. 2. For the purpose of the TH sensitivity, small LOCA scenarios were not included in the LOCA analysis, because these scenarios are bounded by the larger break LOCA. Types of scenarios considered in the LOCA sensitivity analyses include large break LOCA, medium break LOCA and inadvertently opened relief valves.

11A.1.1 Large Break LOCA

For the ESBWR, large break LOCA scenarios are considered to be 12-inches in diameter or greater. Five LLOCA were identified and evaluated for this portion of the TH sensitivity. It should be noted that analysis of a feedwater (FW) line break as identified in Table 2.2-3 from NEDO 33201, Rev. 2 was not included in the LLOCA analysis. Due to the size and location of this break, the RWCU break bounds the FW break. Included in the LLOCA analysis are breaks associated with the safety relief valves (SRVs) and differential pressure valves (DPVs). It should be noted that a single SRV or DPV break is not considered a LLOCA. However, for the purpose of this analysis, both single and multiple breaks in the SRVs and DPVs were considered.

The LLOCA analysis was conducted for a success scenario (LL-S003) where GDCS injection provides inventory control and a combination of the PCCS and vacuum breakers are available for heat removal. The results of the LLOCA sensitivity analysis are shown in Table A.11-1.

The LLOCA resulting from a break in the RWCU line was identified as the limiting LLOCA case. The selection of the RWCU LLOCA as the limiting case was based on the early core uncovery and challenge to both RPV and shroud water levels. Figures A.11-1 through A.11-12 graphically depict the LLOCA results. Future LLOCA analyses were all based on the large break of the RWCU line.

11A.1.2 Medium Break LOCA

Based on Table 2.3-2 from NEDO 33201, Rev. 2, five medium break LOCA scenarios (MLOCA) were considered. For the ESBWR, MLOCA are considered less than 12-inches in diameter and greater than 1-inch in diameter for liquid breaks.

The MLOCA analysis was conducted for a success scenario (ML-S003) where GDCS injection provides inventory control and a combination of the ADS valves, PCCS and vacuum breakers are available for heat removal. The results of the MLOCA sensitivity analysis are shown in Table A.11-2.

The MLOCA resulting from a break in the SLCS line was identified as the limiting MLOCA case. The selection of the SLCS MLOCA as the limiting case was based on the early core uncovery and challenge to both RPV and shroud water levels. Figures A.11-13 through A.11-20 graphically depict the MLOCA results. Future MLOCA analyses were all based on the medium break of the SLCS line.

11A.2 PASSIVE SYSTEM PERFORMANCE

A passive system performance evaluation was conducted to test the operational performance of the passive systems with the ESBWR MAAP code and to evaluate potential margin for the existing system.

Passive systems evaluated as part of the TH sensitivity included the short-term gravity drainage cooling system (GDCS) for injection, the long-term GDCS for equalization, automatic depressurization system (ADS), isolation condenser system (ICS) and passive containment cooling system (PCCS). The sensitivities conducted for each of the passive systems are discussed in the following sections.

11A.2.1 GDCS Injection

The GDCS injection was evaluated for LLOCA and MLOCA to determine the number and size of injection lines required to meet the TH objectives. Because IORVs act as LOCAs, GDCS injection was evaluated for an IORV success scenario as well.

The LLOCA and MLOCA GDCS injection sensitivity analysis was conducted using the limiting LOCA cases identified in Section A.11.2. A scenario (T-IORV017), similar to the scenarios used for the LLOCA and MLOCA, was selected for the IORV GDCS Injection sensitivity. The IORV scenario for GDCS injection provides inventory control and a combination of the ADS valves, PCCS and vacuum breakers are available for heat removal. The results of the GDCS Injection sensitivity analysis are shown in Table A.11-1 for LLOCA, Table A.11-2 for MLOCA and A.11-3 for IORV.

The results from the GDCS injection sensitivity showed that a single GDCS injection line was successful in maintaining core coverage and peak clad temperatures within acceptable limits. Figures A.11-21 through A.11-25 graphically depict the GDCS injection results for LLOCA, Figures A.11-26 through A.11-30 for MLOCA and A.11-31 through A.11-35 for IORV.

To further evaluate the limits of the GDCS injection system, additional MAAP runs were performed to evaluate the size limitations of the GDCS injection line with respect to maintaining peak clad temperatures within acceptable limits. Results from these analyses show that a single

GDCS injection line with a flow capacity of about 66% for LLOCA, 75% for MLOCA and 66% for IORV is capable of meeting the peak clad temperature limits.

The results of the GDCS injection sensitivity show that a single GDCS valve capable of delivering more than 75% of its design flow as per the MAAP TH model is successful in maintaining core coverage and peak clad temperature with acceptable limits.

11A.2.2 GDCS Equalization

A sensitivity of the GDCS equalization was evaluated for LLOCA and MLOCA to determine the number and size of injection lines required to meet the TH objectives. Because IORV act as LOCA, GDCS equalization was evaluated for an IORV success scenario as well.

The LLOCA and MLOCA GDCS equalization sensitivity analysis was conducted using the limiting LOCA cases identified in Section A.11.2. A scenario (T-IORV017), similar to the scenarios used for the LLOCA and MLOCA, was selected for the IORV GDCS Injection sensitivity. The IORV scenario for GDCS equalization provides inventory control from GDCS and a combination of the ADS valves, PCCS and vacuum breakers are available for heat removal. The results of the GDCS equalization sensitivity analysis are shown in Table A.11-1 for LLOCA, Table A.11-2 for MLOCA and Table A.11-3 for IORV.

The GDCS equalization results showed that GDCS equalization did not impact the LOCA scenarios from the selected scenario. It should be noted that for the scenario analyzed, both GDCS injection and PCCS were also available. The availability of these systems would likely facilitate recirculation of steam generated by decay heat. Figures A.11-36 through A.11-39 graphically depict the GDCS equalization results for LLOCA, Figures A.11-40 through A.11-43 for MLOCA and A.11-44 through A.11-47 for IORV.

11A.2.3 Automatic Depressurization System

The GDCS injection was evaluated for MLOCA to determine the number and size of ADS valves lines required to meet the TH objectives. Because of the nature of LLOCA breaks, additional depressurization via the ADS valves is not required. Because IORV act as LOCA, ADS was evaluated for an IORV success scenario as well.

The MLOCA and IORV ADS sensitivity analysis was conducted using the limiting LOCA cases identified in Section A.11.2. A scenario (T-IORV017), similar to the scenarios used for the MLOCA, was selected for the IORV ADS sensitivity. The IORV scenario for ADS provides inventory control and a combination of the ADS valves, PCCS and vacuum breakers are available for heat removal. The results of the ADS sensitivity analysis are shown in Table A.11-2 for MLOCA and Table A.11-3 for IORV.

The results from the ADS sensitivity showed that three ADS valves were successful in maintaining core coverage and peak clad temperatures within acceptable limits. Figures A.11-48 through A.11-51 graphically depict the ADS results for MLOCA and Figures A.11-52 through A.11-55 for IORV.

To further evaluate the limits of the ADS system, additional MAAP runs were performed to evaluate the size limitations of the ADS valves with respect to maintaining peak clad temperatures within acceptable limits. Results from these analyses show that three ADS valves each with a flow capacity of about 75% MLOCA were capable of meeting the peak clad temperature limits. The IORV was able to meet the peak clad temperature with only two ADS valve with a flow capacity of about 85% each.

The results of the ADS sensitivity show that a three ADS valves capable of delivering more than 75% of its design flow as per the MAAP TH model is successful in maintaining core coverage and peak clad temperature with acceptable limits.

11A.2.4 Isolation Condenser System

A sensitivity of the ICS was evaluated for LLOCA and MLOCA to determine the number of units required to meet the TH objectives.

The LLOCA and MLOCA ICS sensitivity analysis was conducted using the limiting LOCA cases identified in Section A.11.2. The results of the ICS sensitivity analysis are shown in Table A.11-1 for LLOCA and A.11-2 for MLOCA.

The ICS results showed that the number of ICS of units did not impact the success in meeting the peak clad temperature limits. A review of the data does indicate that challenges to water levels in the RPV and clad temperatures decrease inversely with increased number of ICS units. Figures A.11-56 through A.11-59 graphically depict the ICS results for LLOCA and Figures A.11-60 through A.11-63 for MLOCA.

11A.2.5 Passive Containment Cooling System

A sensitivity of the PCCS was evaluated for LLOCA and MLOCA to determine the number of units required to meet the TH objectives.

The LLOCA and MLOCA PCCS sensitivity analysis was conducted using the limiting LOCA cases identified in Section A.11.2. The results of the PCCS sensitivity analysis are shown in Table A.11-1 for LLOCA and Table A.11-2 for MLOCA.

The PCCS results showed that the number of PCCS of units did not impact the success in meeting the peak clad temperature limits. A review of the data does indicate that challenges to water levels in the RPV and clad temperatures are increased proportionally with increased number of PCCS units. The effect is the result of higher drywell pressures associated with the operation of more PCCS units which delay the GDCS injection. Figures A.11-64 through A.11-67 graphically depict the PCCS results for LLOCA and Figures A.11-68 through A.11-71 for MLOCA.

11A.3 MAAP PARAMETER ANALYSIS

An evaluation was conducted to test selected parameters in the MAAP code on the passive ESBWR systems. The MAAP parameters evaluated as part of the TH sensitivity included break LOCA parameters and natural circulation parameters. The sensitivities of each parameter are discussed in the following sections.

11A.3.1 Break LOCA Parameters

Break LOCA parameters in the MAAP code evaluated as part of the MAAP parameter analysis include:

- FCDBRK - discharge coefficient for flows through BWR generalized openings and BWR vessel failures.
- FELOCA - fraction of water break flow entrained as suspended water into containment atmosphere.

The break LOCA parameter sensitivity analysis was conducted using the limiting LOCA cases identified in Section A.11.2. The results of the break LOCA sensitivity parameter analysis are shown in Table A.11-1 for LLOCA.

For the break flow sensitivity, the success in meeting the peak clad temperature limits were shown to be impacted by changes in these break flow parameter FCDBRK. The current ESBWR parameter file uses a value of 0.75 for FCDBRK. Results indicate that the peak clad temperature limits are challenged with lower values of the FCDBRK discharge coefficient. This impact was shown to be 0.66 for LLOCA. Figures A.11-72 through A.11-75 graphically depict the break flow sensitivity results.

11A.3.2 NATURAL CIRCULATION PARAMETERS

Natural circulation parameters in the MAAP code evaluated as part of the MAAP parameter analysis include:

- FFRICX - gas cross-flow friction coefficient in the core for the in-vessel natural circulation model.
- FNCBP - reactor vessel natural circulation flow path selection for return to outer assembly or down to outer bypass.

The natural circulation parameter sensitivity analysis was conducted using the limiting large break LOCA case identified in Section A.11.2. The results of the natural circulation break parameter analysis are shown in Table A.11-1 for LLOCA.

For the natural circulation sensitivity, changes in these natural circulation parameters for the LLOCA scenarios did not impact the success in meeting the peak clad temperature limits. Figures A.11-76 through A.11-79 graphically depict the break flow results.

11A.4 THERMAL HYDRAULIC SENSITIVITY INSIGHTS

The following insights were obtained from results generated from the TH sensitivity.

- The large break LOCA is bounded by a 12-inch liquid break of one of two RWCU lines.
- The medium break LOCA is bounded by a 2-inch liquid break of one of two SLCS lines.
- GDCS Injection was found to be successful with 1 of 8 GDCS valves open at 75% of the flow capacity; current GDCS injection success criteria requires 2 of 8 GDCS valves for success.
- ADS was found to be successful with 3 of 8 ADS valves open at 75% of the flow capacity; current ADS success criteria requires 4 of 8 ADS valves for success.
- The break flow parameter FCDBRK has the potential to impact the TH results of values less than 0.66; the current value of FDCBRK is 0.75.

Table 11A-1

LLOCA – Thermal Hydraulic Sensitivity Results

Parameter	Run Name	Minimum RPV Water Level (m)		Max Fuel Clad Temp	Time to Blowdown (sec)		Time to Core Uncovery	Time of Core Recovery	RPV Failure	Containment Failure	Comments
		Core[1]	Shroud[2]	(K)	INJ[3]	EQU[4]	(sec)	(sec)	(sec)	(sec)	
Type of LOCA	LL_RWCU[5]	5.24	4.57	795	320	1971	1619	2036	---	---	LLOCA at RWCU tap
	LL_MSL	21.82	6.54	< 750	270	---	---	---	---	---	LLOCA on main steam line
	LL_DPVIC	10.91	6.14	< 750	287	1937	---	---	---	---	LLOCA at DPV common line
	LL_DPV1	4.10	4.07	2700	585	2235	2340	4482	---	---	LLOCA at DPV
	LL_DPV2	4.38	4.30	2784	464	2113	2049	3000	---	---	LLOCA at 2 DPVs
	LL_DPV3	4.83	4.54	852	377	2028	1948	2471	---	---	LLOCA at 3 DPVs
	LL_DPV4	6.81	4.92	< 750	337	1988	1888	2099	---	---	LLOCA at 4 DPVs
	LL_SRV1	4.11	4.11	2403	671	2321	2810	---	---	---	LLOCA at SRV
	LL_SRV2	4.10	4.05	2426	581	2232	2329	4430	---	---	LLOCA at 2 SRVs
	LL_SRV4	4.40	4.32	2787	459	2109	2044	2961	---	---	LLOCA at 4 SRVs
	LL_SRV6	4.87	4.53	826	374	2024	1944	2434	---	---	LLOCA at 6 SRVs
	LL_SRV8	7.05	4.99	< 750	335	1985	1884	2118	---	---	LLOCA at 8 SRVs
	LL_SRV10	8.57	5.71	< 750	311	1961	---	---	---	---	LLOCA at 10 SRVs
	LL_SRV12	9.51	5.96	< 750	298	1948	---	---	---	---	LLOCA at 12 SRVs
	LL_SRV14	10.51	6.09	< 750	289	1940	---	---	---	---	LLOCA at 14 SRVs
	LL_SRV16	10.99	6.18	< 750	284	1934	---	---	---	---	LLOCA at 16 SRVs
	LL_SRV18	10.92	6.18	< 750	280	1930	---	---	---	---	LLOCA at 18 SRVs
	LL_RWCU2	8.83	5.69	< 750	259	1909	---	---	---	---	LLOCA at RWCU tap x2
	LL_MSL2	9.42	5.77	< 750	230	---	---	---	---	---	LLOCA on main steam line x2
	LL_DPVIC2	21.82	6.51	< 750	270	---	---	---	---	---	LLOCA at DPV common line x2
Break Parameters; FCDBRK, FELOCA	LL_BF1a	3.96	3.94	> 7500	523	2173	2144	4296	---	---	FCDBRK = 0.25
	LL_BF1b	4.41	4.34	3117	395	2045	1787	2605	---	---	FCDBRK = 0.50
	LL_BF1c	4.50	4.42	1020	341	1991	1670	2222	---	---	FCDBRK = 0.66
	LL_BF1d	6.98	4.94	677	290	1941	1507	1714	---	---	FCDBRK = 0.99
	LL_BF1e	7.07	4.96	677	289	1939	1504	1661	---	---	FCDBRK = 1.00
	LL_BF1f	4.71	4.50	830	331	1982	1647	2106	---	---	FCDBRK = 0.70
	LL_BF1g	5.61	4.66	764	313	1964	1594	1976	---	---	FCDBRK = 0.80
	LL_BF2a	5.24	4.57	793	321	1971	1619	2034	---	---	FELOCA = 0.1
GDCS Injection: AGO(1), N_GDCS_VALVES	LL_VI1	4.71	4.49	1075	320	1971	1619	2169	---	---	1 of 8 GDCS valves
	LL_VI1a	4.57	4.43	1102	320	1971	1619	2192	---	---	1 GDCS valve @ 0.95 flow area
	LL_VI1b	4.59	4.42	1333	320	1971	1619	2306	---	---	1 GDCS valve @ 0.75 flow area
	LL_VI1c	4.35	4.28	4373	320	1971	1619	2364	---	---	1 GDCS valve @ 0.50 flow area
	LL_VI1d	4.06	4.00	> 7500	320	1971	1619	2522	---	---	1 GDCS valve @ 0.25 flow area
	LL_VI1e	4.49	4.39	1462	320	1971	1619	2186	---	---	1 GDCS valve @ 0.66 flow area
	LL_VI2	5.24	4.57	795	320	1971	1619	2036	---	---	2 of 8 GDCS valves
	LL_VI4	5.37	4.59	< 750	320	1971	1619	1994	---	---	4 of 8 GDCS valves
	LL_VI6	5.40	4.60	< 750	320	1971	1619	1982	---	---	6 of 8 GDCS valves
	LL_VI8	5.39	4.60	< 750	320	1971	1619	1977	---	---	8 of 8 GDCS valves
GDCS Equalization: N_EQU_VALVES	LL_VE0	5.24	4.57	< 750	273	---	1619	2036	---	---	0 of 4 EQU valves
	LL_VE1	5.24	4.57	< 750	273	1923	1619	2036	---	---	1 of 4 EQU valves
	LL_VE2	5.24	4.57	< 750	273	1923	1619	2036	---	---	2 of 4 EQU valves
	LL_VE3	5.24	4.57	< 750	273	1923	1619	2036	---	---	3 of 4 EQU valves
	LL_VE4	5.24	4.57	< 750	273	1923	1619	2036	---	---	4 of 4 EQU valves

Parameter	Run Name	Minimum RPV Water Level (m)		Max Fuel Clad Temp	Time to Blowdown (sec)		Time to Core Uncovery	Time of Core Recovery	RPV Failure	Containment Failure	Comments
		Core[1]	Shroud[2]	(K)	INJ[3]	EQU[4]	(sec)	(sec)	(sec)	(sec)	
Passive Containment Cooling System: NIC(2)	LL_WP0	4.76	4.51	< 750	322	1971	1580	1582	---	---	NIC(2)=0
	LL_WP1	5.27	4.57	778	321	1971	1618	2016	---	---	NIC(2)=1
	LL_WP2	5.26	4.57	782	320	1971	1618	2020	---	---	NIC(2)=2
	LL_WP3	5.26	4.57	786	321	1971	1619	2026	---	---	NIC(2)=3
	LL_WP4	5.24	4.57	794	320	1971	1619	2036	---	---	NIC(2)=4
	LL_WP5	4.80	4.52	807	321	1971	1619	2051	---	---	NIC(2)=5
	LL_WP6	4.77	4.51	822	321	1970	1619	2068	---	---	NIC(2)=6
Isolation Condenser System: NIC(1)	LL_IC0	5.24	4.57	795	320	1971	1619	2036	---	---	NIC(1)=0
	LL_IC1	8.92	6.23	< 750	563	2213	---	---	---	---	NIC(1)=1
	LL_IC2	10.24	6.60	< 750	577	2227	---	---	---	---	NIC(1)=2
	LL_IC3	11.49	6.95	< 750	592	2241	---	---	---	---	NIC(1)=3
	LL_IC4	21.14	7.45	< 750	610	2260	---	---	---	---	NIC(1)=4
Natural Circulation Parameters; FFRICX, FNCBP	LL_NC1a	5.24	4.57	795	320	1971	1619	2036	---	---	FFRICX = 0
	LL_NC1b	5.24	4.57	795	320	1971	1619	2036	---	---	FFRICX = 1.0
	LL_NC2a	5.24	4.57	795	320	1971	1619	2036	---	---	FNCBP = 0
	LL_NC2b	5.24	4.57	795	320	1971	1619	2036	---	---	FNCBP = 1.0

1 The core minimum RPV water level represents the MAAP parameter, XWCOR. The value shown in this column reflects the minimum value derived from the data plotfile, D86.

2 The minimum water level in the shroud is represented by the MAAP parameter, XWSH. The value shown in this column reflects the minimum value derived from the data plotfile, D86.

3 The timing indicated in this column represents the time for the GDCS injection area to become positive.

4 The timing indicated in this column represents the time for the GDCS equalization area to become positive.

5 All subsequent runs were based on the selection of this scenario as the limiting LLOCA

Table 11A-2

MLOCA – Thermal Hydraulic Sensitivity Results

Sensitivity	Parameter	Run Name	Minimum RPV Water Level (m)		Max Fuel Clad Temp	Time to Blowdown (sec)		Time to Core Uncovery	Time of Core Recovery	RPV Failure	Containment Failure	Comments
			Core[1]	Shroud[2]	(K)	INJ[3]	EQU[3]	(sec)	(sec)	(sec)	(sec)	
LOCA - Medium Break	Type of LOCA	ML_EQU	4.41	4.35	< 750	381	---	693	941	---	---	MLOCA at equalization line
		ML_GDCS	5.51	4.59	< 750	278	---	772	954	---	---	MLOCA at GDCS injection line
		ML_IC	10.83	5.82	< 750	384	---	---	---	---	---	MLOCA at IC return tap
		ML_RWCU	4.41	4.33	754	497	---	865	1097	---	---	MLOCA at RWCU tap
		ML_SLCS[4]	5.39	4.58	< 750	510	---	994	1206	---	---	MLOCA at SLCS inlet
		ML_EQU2	8.50	5.34	< 750	287	---	---	---	---	---	MLOCA at equalization line x2
		ML_GDCS2	8.64	5.42	< 750	289	---	---	---	---	---	MLOCA at GDCS injection line x2
		ML_IC2	11.23	5.79	< 750	293	---	---	---	---	---	MLOCA at IC return tap x2
		ML_RWCU2	8.23	5.17	< 750	361	---	---	---	---	---	MLOCA at RWCU tap x2
		ML_SLCS2	4.77	4.44	< 750	383	---	787	1013	---	---	MLOCA at SLCS inlet x2
	GDCS Injection: AGO(1), N_GDCS_VALVES	ML_VI0	3.96	3.95	3920	---	2164	995	2361	---	---	0 of 8 GDCS valves
		ML_VI1	4.50	4.39	1084	510	2161	995	1356	---	---	1 of 8 GDCS valves
		ML_VI2	4.95	4.50	< 750	510	2160	995	1243	---	---	2 of 8 GDCS valves
		ML_VI4	5.38	4.53	< 750	510	2160	995	1224	---	---	4 of 8 GDCS valves
		ML_VI6	5.38	4.56	< 750	510	---	995	1213	---	---	6 of 8 GDCS valves
		ML_VI8	4.47	4.37	< 750	510	---	995	1207	---	---	8 of 8 GDCS valves
		ML_VI1a	4.47	4.37	1101	510	2161	994	1369	---	---	Flow area of 90%
		ML_VI1b	4.38	4.30	1394	510	2160	995	1463	---	---	Flow area of 75%
		ML_VI1c	4.36	4.30	3116	510	2161	995	1547	---	---	Flow area of 50%
		ML_VI1d	4.05	4.00	>7500	510	2162	995	1607	---	---	Flow area of 25%
		ML_VI1e	4.40	4.31	1525	510	2161	995	1492	---	---	Flow area of 70%
	GDCS Equalization: AGO(2), N_EQU_VALVES	ML_VE4	4.93	4.49	< 750	511	2162	996	1243	---	---	4 of 4 EQU valves
		ML_VE3	4.93	4.49	< 750	511	2162	996	1243	---	---	3 of 4 EQU valves
		ML_VE2	4.93	4.49	< 750	511	2162	996	1243	---	---	2 of 4 EQU valves
		ML_VE1	4.93	4.49	< 750	511	2162	996	1243	---	---	1 of 4 EQU valves
		ML_VE0	4.93	4.49	< 750	511	---	996	1243	---	---	0 of 4 EQU valves
	ADS Parameters: #_DPV	ML_XD1	3.96	3.94	> 7500	510	2161	1218	2738	---	---	1 of 8 DPVs
		ML_XD2	4.29	4.24	1513	511	2160	1089	1759	---	---	2 of 8 DPVs
		ML_XD3	4.42	4.36	1086	510	2161	1022	1407	---	---	3 of 8 DPVs
		ML_XD3a	4.35	4.30	1427	511	2161	1069	1623	---	---	Flow area of 75%
		ML_XD3b	4.34	4.30	1175	511	2161	1029	1446	---	---	Flow area of 95%
		ML_XD4	4.95	4.50	< 750	510	2160	995	1243	---	---	4 of 8 DPVs
	Passive Containment Cooling System: NIC(2)	ML_WP0	4.89	4.51	< 750	515	2168	964	965	---	---	NIC(2)=0 w/ Pool 1
		ML_WP1	4.89	4.49	< 750	510	2160	994	1230	---	---	NIC(2)=1 w/ Pool 1
		ML_WP2	4.90	4.49	< 750	511	2161	995	1237	---	---	NIC(2)=2 w/ Pool 1
		ML_WP3	4.94	4.50	< 750	511	2161	994	1242	---	---	NIC(2)=3 w/ Pool 1
		ML_WP4	4.95	4.50	< 750	510	2160	995	1243	---	---	NIC(2)=4 w/ Pool 1
		ML_WP5	4.94	4.49	< 750	511	2161	994	1244	---	---	NIC(2)=5 w/ Pool 1
		ML_WP6	4.93	4.49	< 750	510	2160	994	1244	---	---	NIC(2)=6 w/ Pool 1
	Isolation Condenser System: NIC(1)	ML_IC0	4.95	4.50	< 750	510	2160	995	1243	---	---	NIC(1)=0 w/ Pool 1
		ML_IC1	8.22	5.45	< 750	712	2361	---	---	---	---	NIC(1)=1 w/ Pool 1
		ML_IC2	8.87	5.88	< 750	743	2393	---	---	---	---	NIC(1)=2 w/ Pool 1
		ML_IC3	10.10	6.20	< 750	930	2580	---	---	---	---	NIC(1)=3 w/ Pool 1
		ML_IC4	12.07	6.64	< 750	1656	3306	---	---	---	---	NIC(1)=4 w/ Pool 1

1 The core minimum RPV water level represents the MAAP parameter, XWCOR. The value shown in this column reflects the minimum value derived from the data plotfile, D86.
2 The minimum water level in the shroud is represented by the MAAP parameter, XWSH. The value shown in this column reflects the minimum value derived from the data plotfile, D86.
3 The timing indicated in this column represents the time for the GDCS injection area or equalization area to become positive.
4 All subsequent runs were based on the selection of this scenario as the limiting MLOCA

Table 11A-3

IORV – Thermal Hydraulic Sensitivity Results

Sensitivity	Parameter	Run Name	Minimum RPV Water Level (m)		Max Fuel Clad Temp (K)	Time to Blowdown (sec)		Time to Core Uncovery (sec)	Time of Core Recovery (sec)	RPV Failure (sec)	Containment Failure (sec)	Comments
			Core[1]	Shroud[2]		INJ[3]	EQU[4]					
IORV-Inadvertantly Stuck Open Relief Valve	GDCS Injection: AGO(1), N_GDCS_VALVES	IORV_VI0	4.04	3.98	> 7500	---	2023	926	2252	---	---	0 of 8 GDCS valves
		IORV_VI1	5.18	4.52	< 750	372	2022	926	1203	---	---	1 of 8 GDCS valves
		IORV_VI1a	4.48	4.38	1064	372	2021	926	1381	---	---	1 GDCS valve @ 0.75 flow area
		IORV_VI1b	4.40	4.31	1778	372	2022	926	1609	---	---	1 GDCS valve @ 0.50 flow area
		IORV_VI1c	4.38	4.29	1335	372	2022	926	1335	---	---	1 GDCS valve @ 0.66 flow area
		IORV_VI2	6.17	4.67	< 750	372	2022	926	1097	---	---	2 of 8 GDCS valves
		IORV_VI4	6.33	4.72	< 750	372	2022	926	1073	---	---	4 of 8 GDCS valves
		IORV_VI6	6.34	4.74	< 750	372	---	926	1058	---	---	6 of 8 GDCS valves
		IORV_VI8	6.34	4.75	< 750	372	---	926	1050	---	---	8 of 8 GDCS valves
	GDCS Equalization: N_EQU_VALVES	IORV_VE0	6.17	4.67	< 750	372	---	926	1097	---	---	0 of 4 EQU valves
		IORV_VE1	6.17	4.67	< 750	372	2022	926	1097	---	---	1 of 4 EQU valves
		IORV_VE2	6.17	4.67	< 750	372	2022	926	1097	---	---	2 of 4 EQU valves
		IORV_VE3	6.17	4.67	< 750	372	2022	926	1097	---	---	3 of 4 EQU valves
		IORV_VE4	6.17	4.67	< 750	372	2022	926	1096	---	---	4 of 4 EQU valves
	ADS Parameters: #_DPV	IORV_XD1	4.24	4.22	> 7500	372	2022	992	1949	---	---	1 of 8 DPVs
		IORV_XD2	4.36	4.31	1294	372	2021	948	1446	---	---	2 of 8 DPVs
		IORV_XD2_75	4.33	4.28	1626	372	2022	969	1599	---	---	Flow area of 75%
		IORV_XD2_85	4.36	4.30	1449	372	2022	961	1576	---	---	Flow area of 85%
		IORV_XD2_90	4.36	4.30	1362	372	2022	954	1525	---	---	Flow area of 90%
		IORV_XD3	4.72	4.44	777	372	2022	928	1228	---	---	3 of 8 DPVs
		IORV_XD4	6.17	4.67	676	372	2022	926	1097	---	---	4 of 8 DPVs

1 The core minimum RPV water level represents the MAAP parameter, XWCOR. The value shown in this column reflects the minimum value derived from the data plotfile, D86.

2 The minimum water level in the shroud is represented by the MAAP parameter, XWSH. The value shown in this column reflects the minimum value derived from the data plotfile, D86.

3 The timing indicated in this column represents the time for the GDCS injection area to become positive.

4 The timing indicated in this column represents the time for the GDCS equalization area to become positive.

5 All subsequent runs were based on the selection of this scenario as the limiting LLOCA

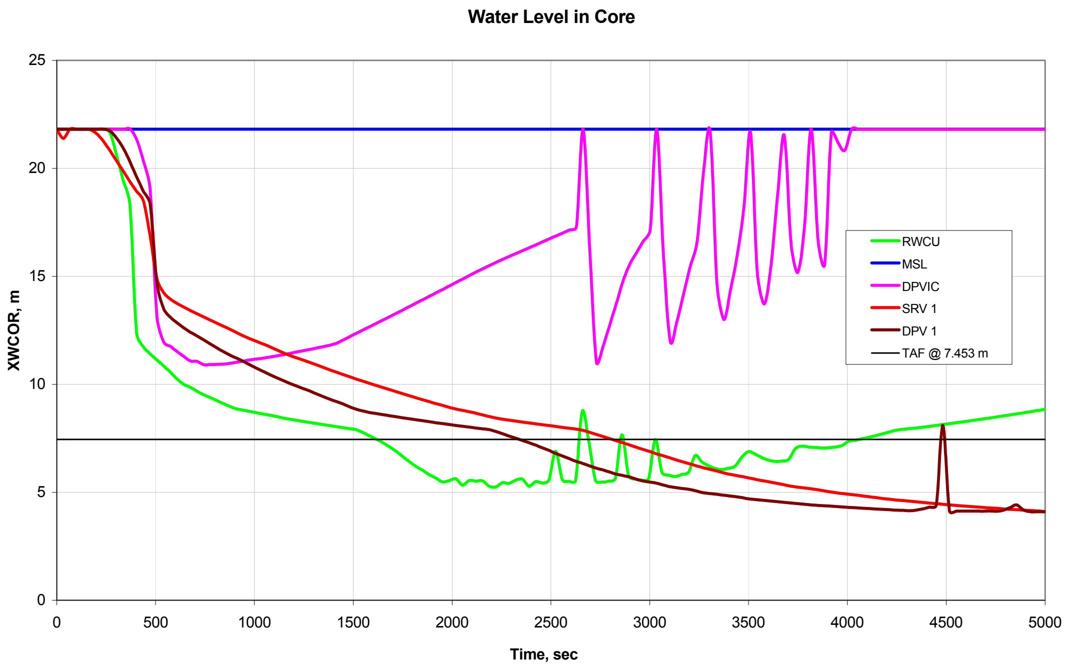

Figure 11A-1. LOCA Sensitivity – Level Profile of XWCOR for LOCA

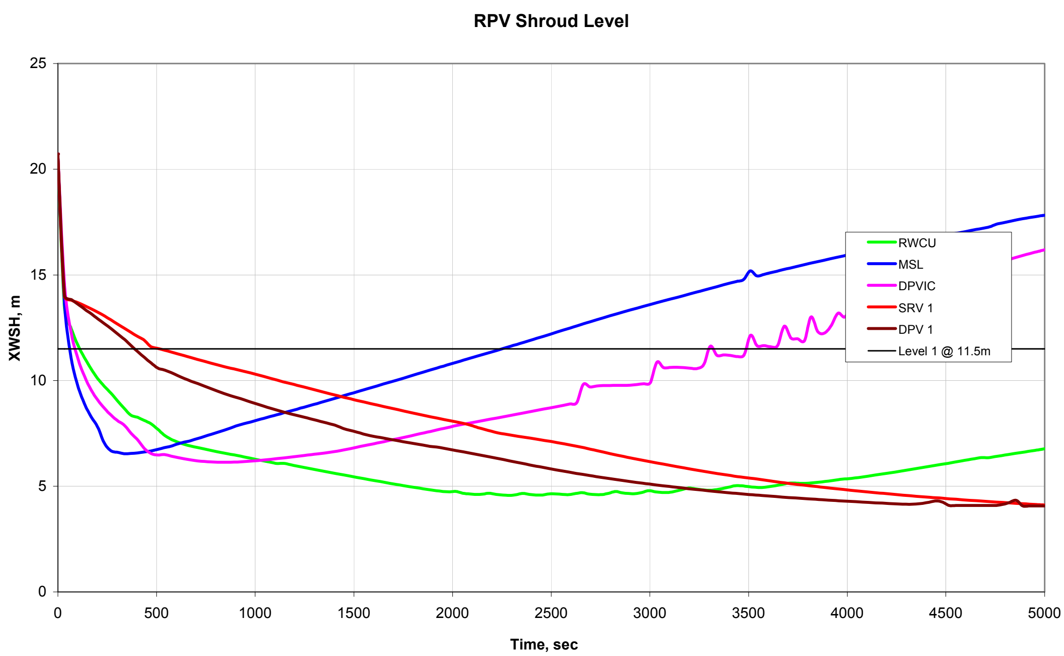

Figure 11A-2. LOCA Sensitivity – Level Profile of XWSH for LOCA

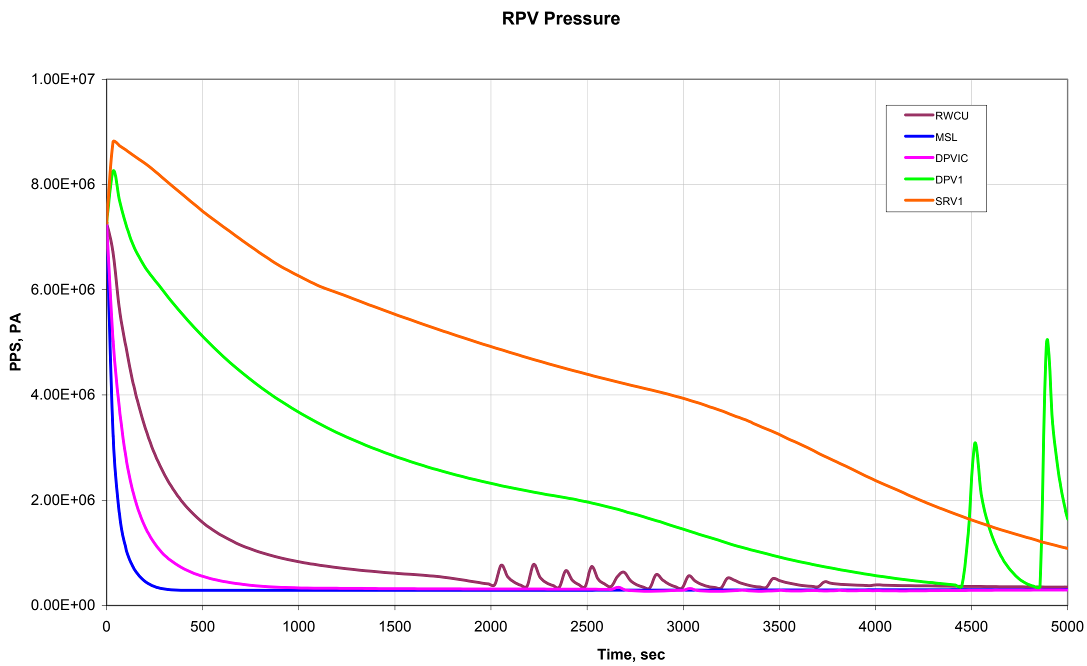

Figure 11A-3. LOCA Sensitivity – Pressure Profile of PPS for LOCA

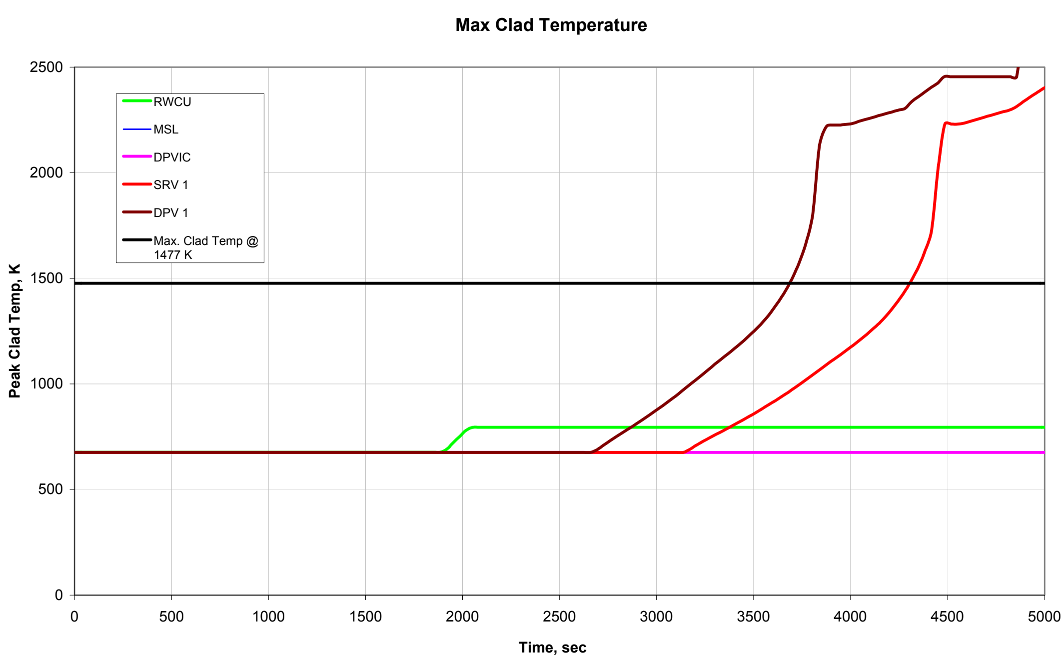

Figure 11A-4. LOCA Sensitivity – Temperature Profile of Max Clad Temp for LOCA

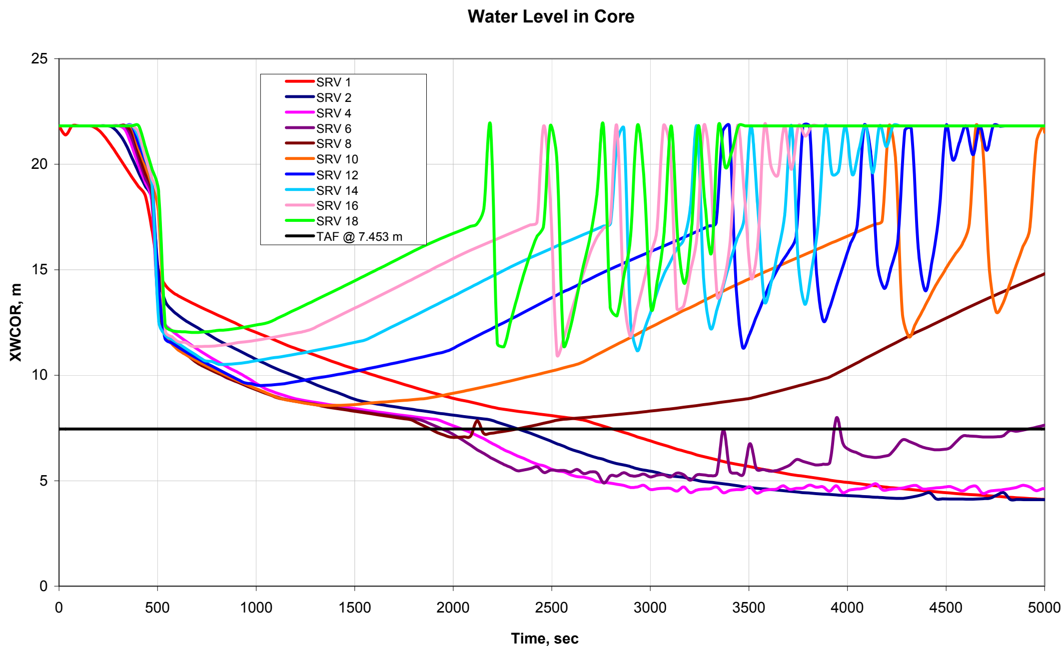

Figure 11A-5. LOCA Sensitivity – Level Profile of XWCOR for SRVs

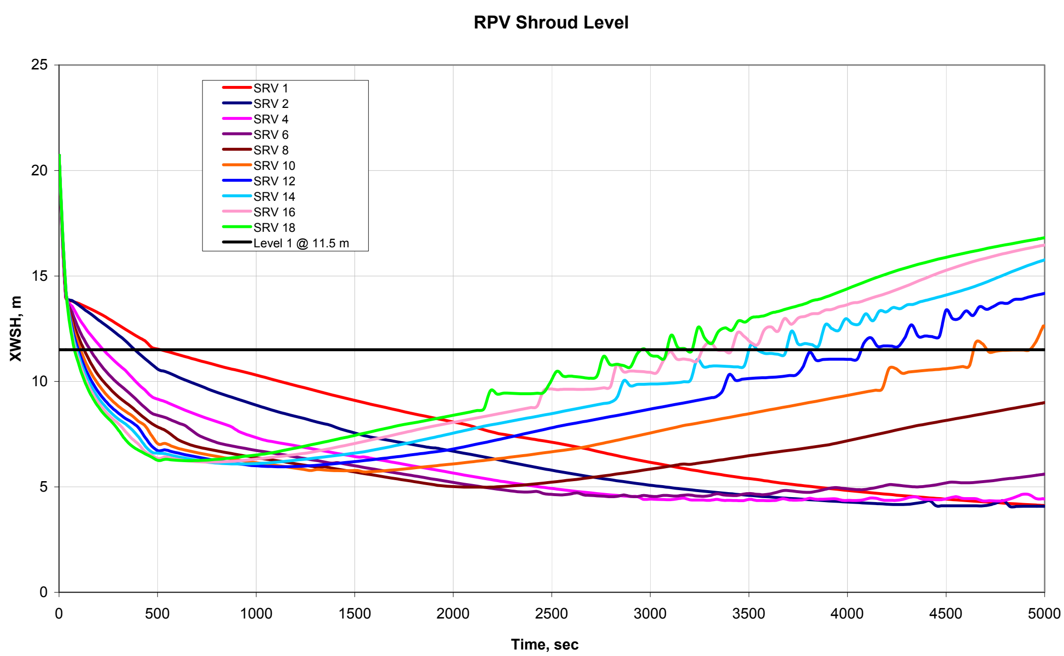

Figure 11A-6. LOCA Sensitivity – Level Profile of XWSH for SRVs

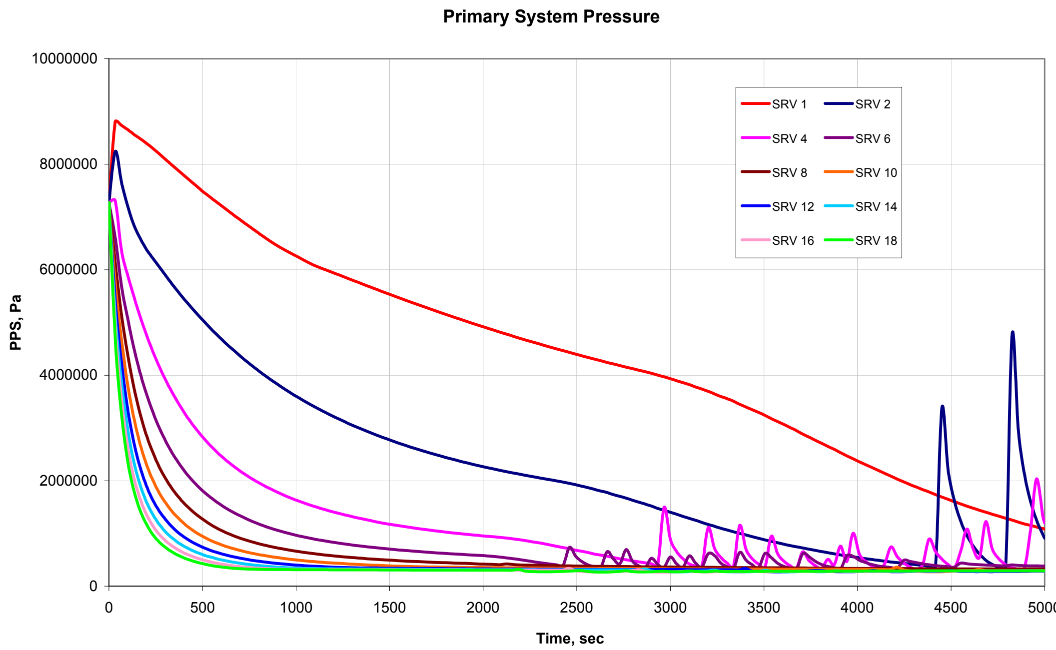

Figure 11A-7. LOCA Sensitivity – Pressure Profile of PPS for SRVs

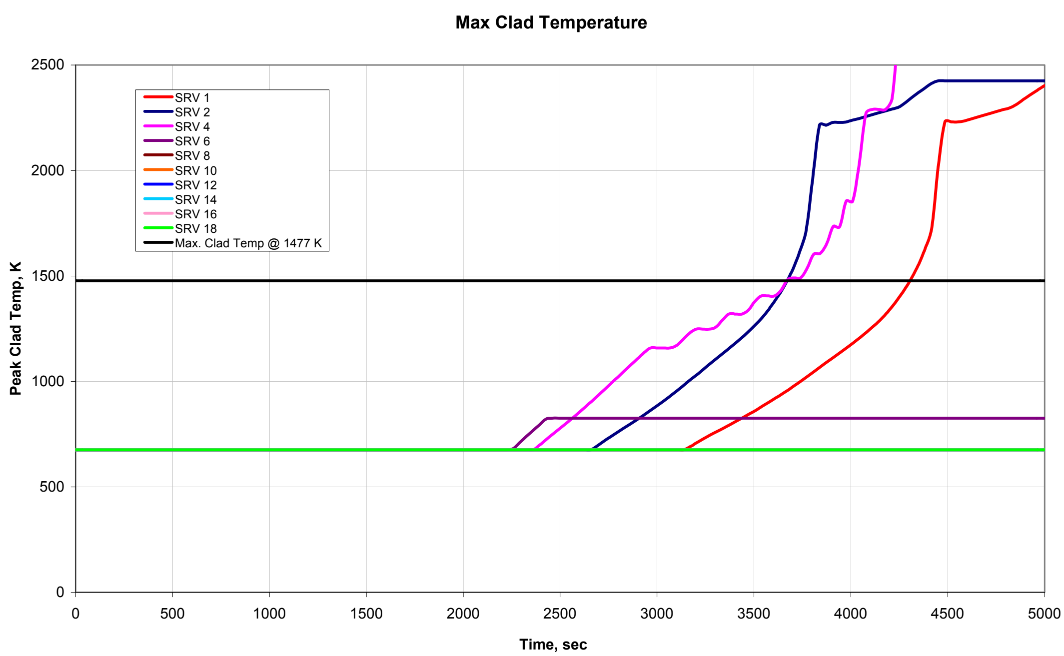

Figure 11A-8. LOCA Sensitivity – Temperature Profile of Max Clad Temp for SRVs

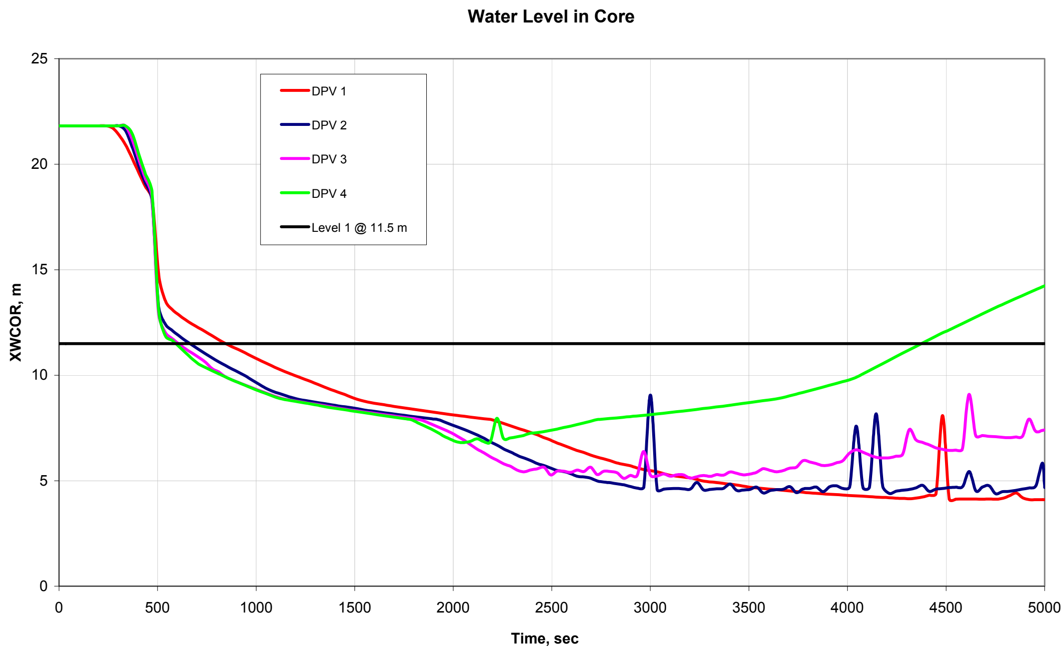

Figure 11A-9. LOCA Sensitivity – Level Profile of XWCOR for DPVs

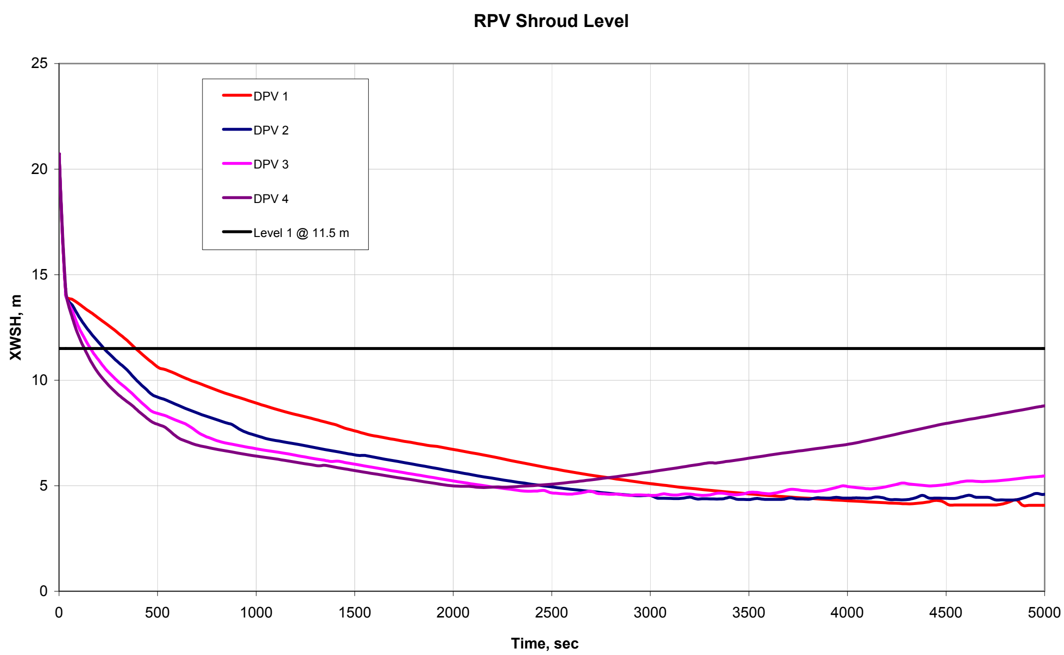

Figure 11A-10. LOCA Sensitivity – Level Profile of XWSH for DPVs

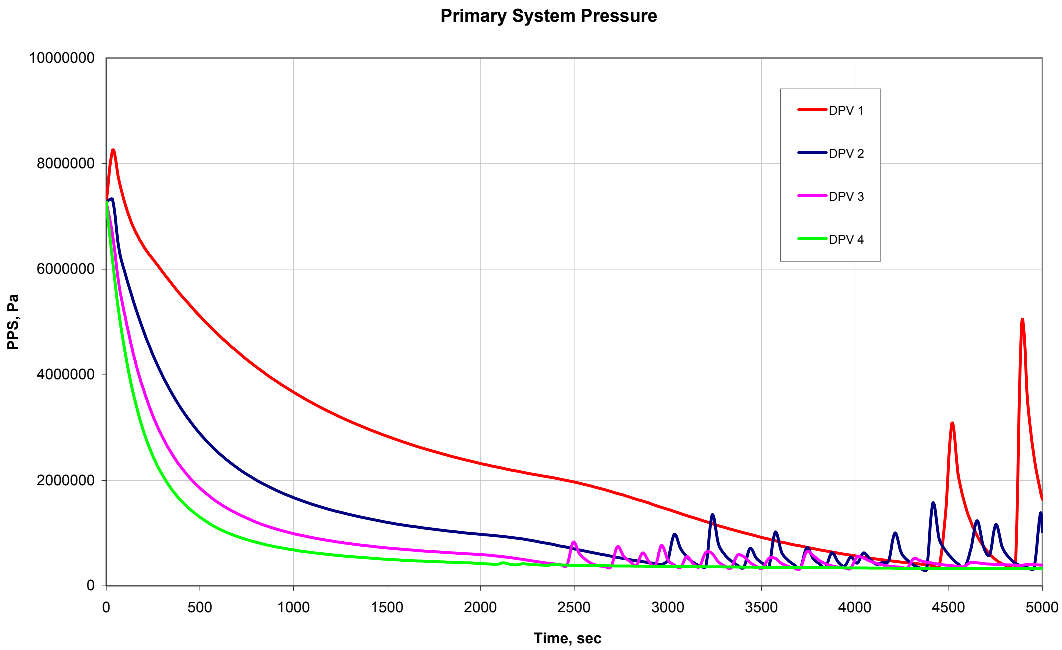

Figure 11A-11. LOCA Sensitivity – Pressure Profile of PPS for DPVs

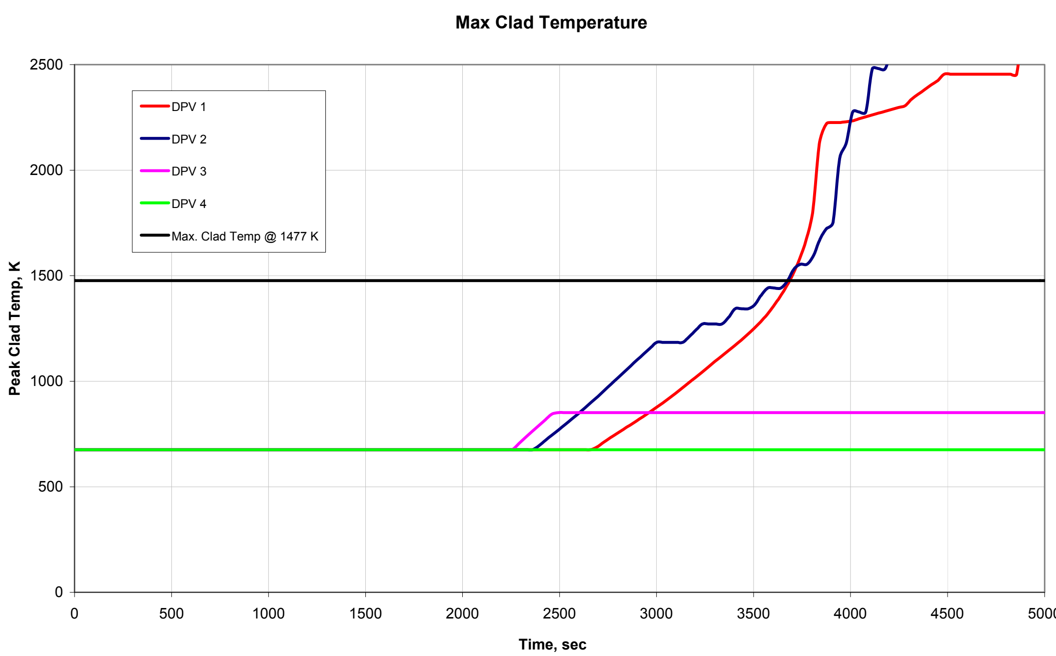

Figure 11A-12. LOCA Sensitivity – Temperature Profile of Max Clad Temp for DPVs

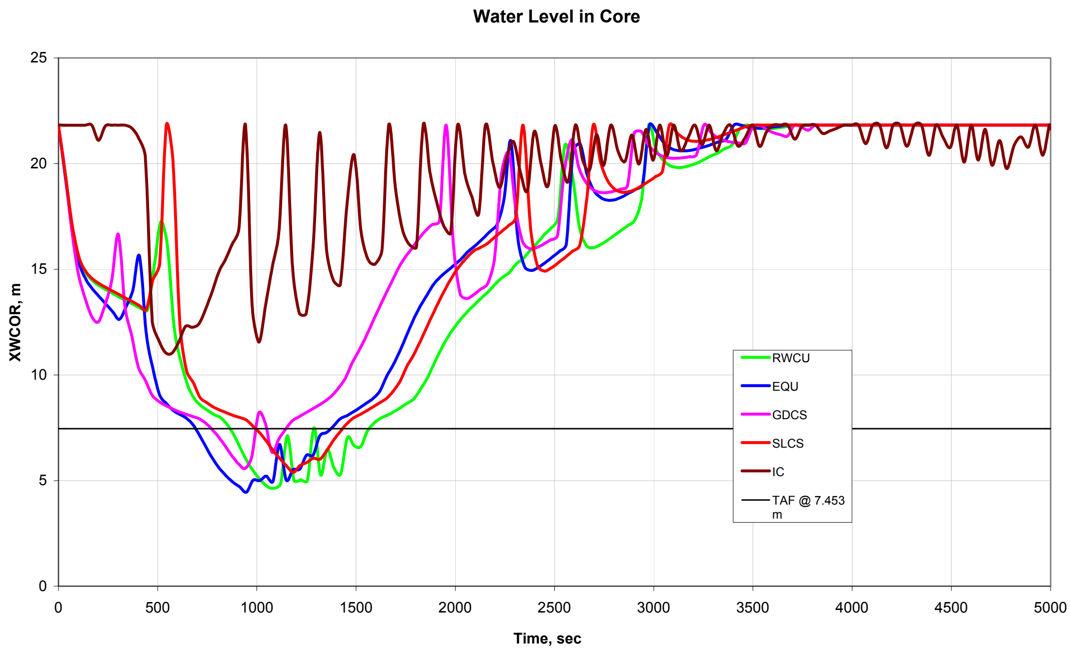

Figure 11A-13. LOCA Sensitivity – Level Profile of XWCOR for MLOCA

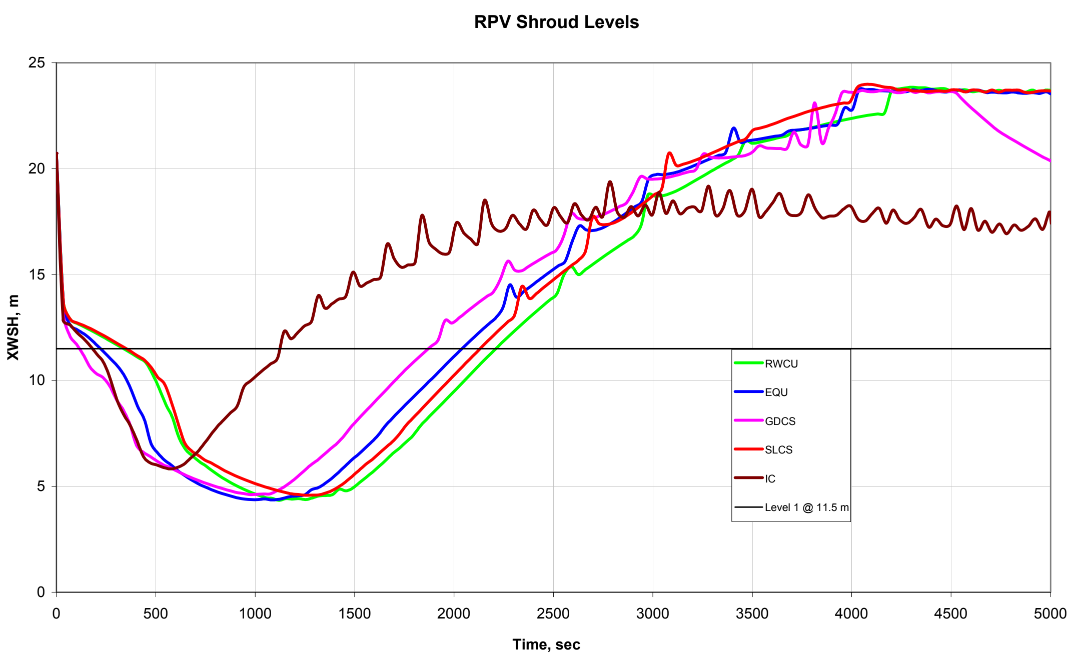

Figure 11A-14. LOCA Sensitivity – Level Profile of XWSH for MLOCA

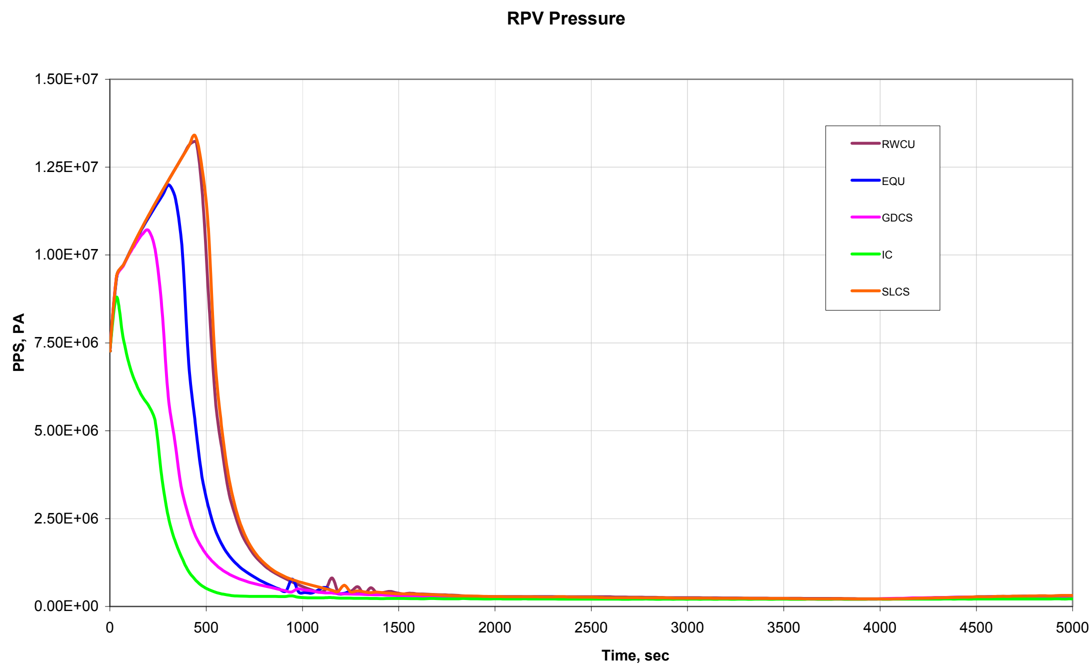

Figure 11A-15. LOCA Sensitivity – Pressure Profile of PPS for MLOCA

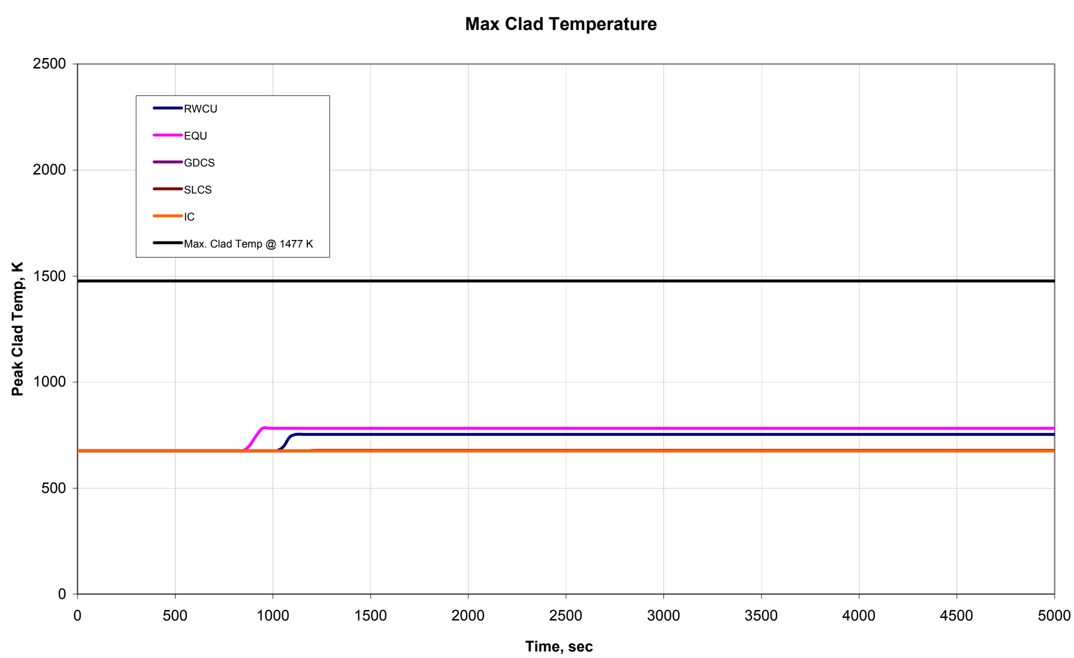

Figure 11A-16. LOCA Sensitivity – Temperature Profile of Max Clad Temp for MLOCA

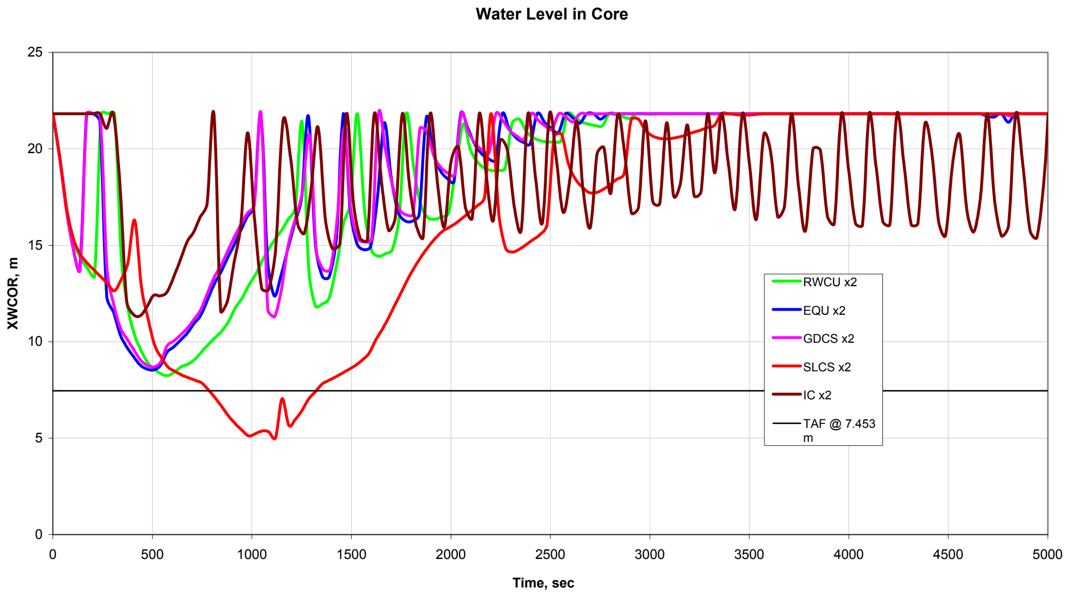

Figure 11A-17. LOCA Sensitivity – Level Profile of XWCOR for MLOCA x2

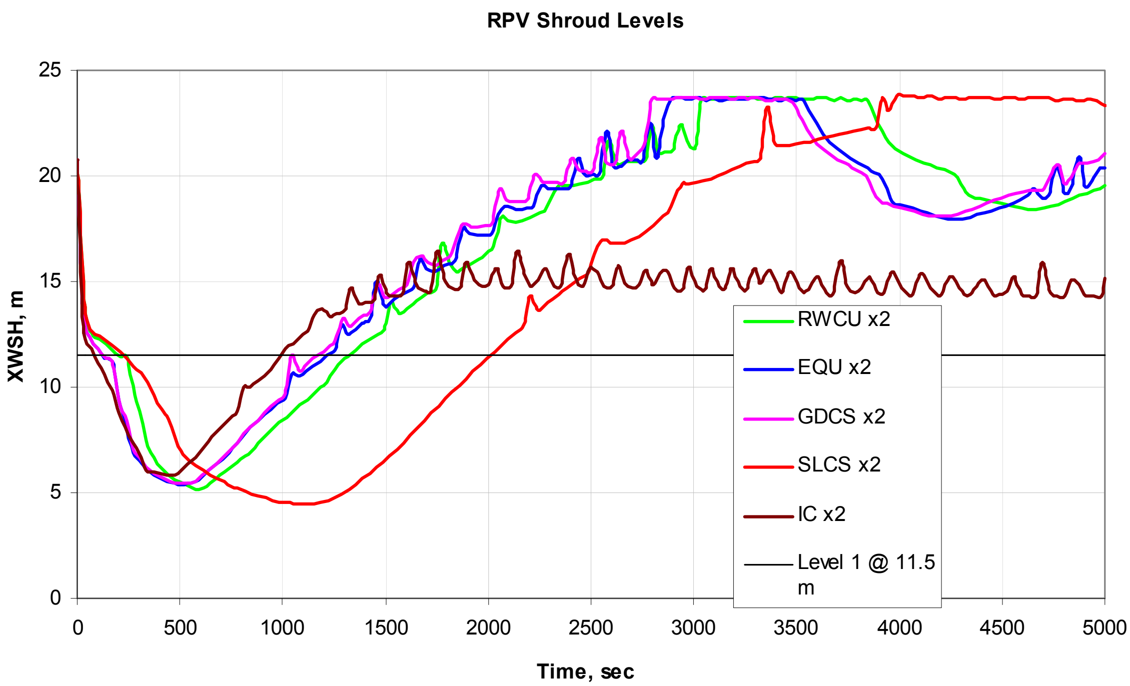

Figure 11A-18. LOCA Sensitivity – Level Profile of XWSH for MLOCA x2

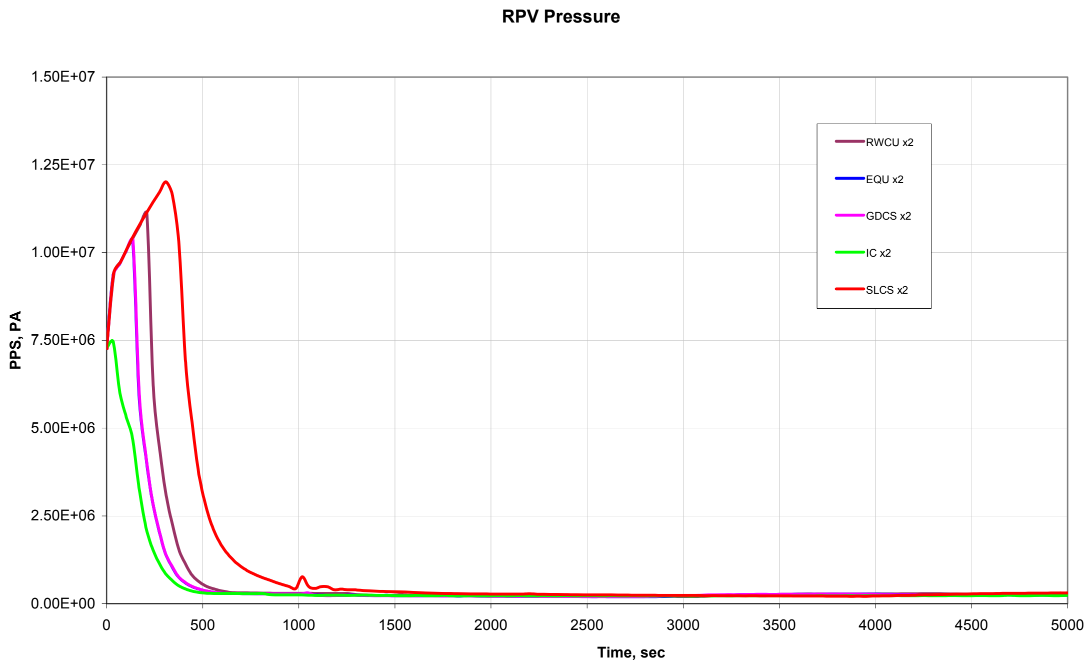

Figure 11A-19. LOCA Sensitivity – Pressure Profile of PPS for MLOCA x2

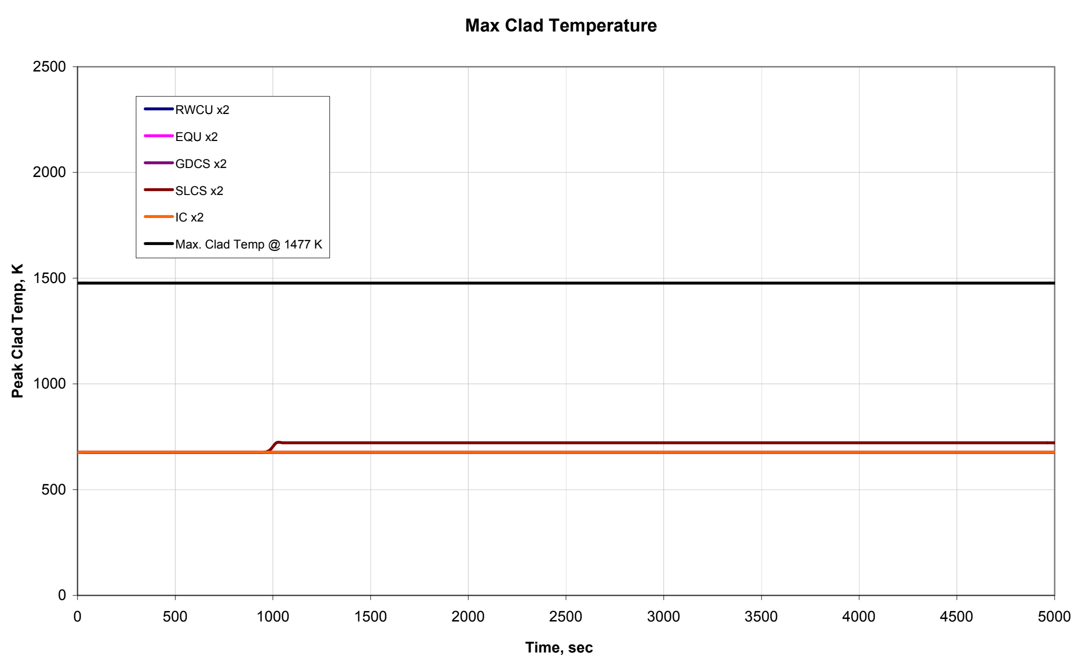

Figure 11A-20. LOCA Sensitivity – Temperature Profile of Max Clad Temp for MLOCA x2

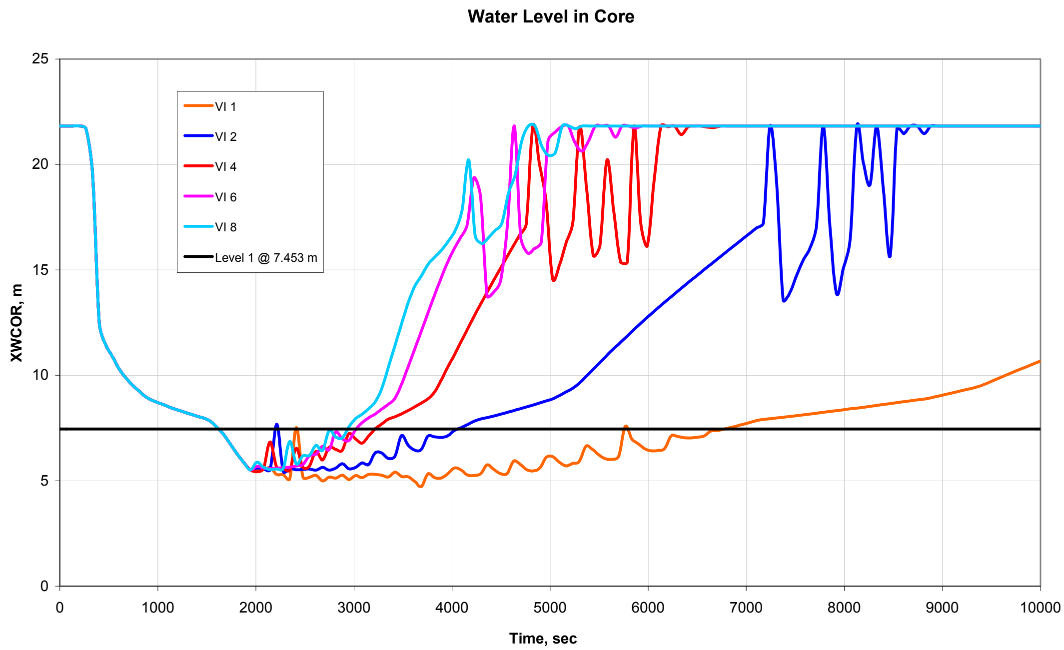

Figure 11A-21. GDCS Injection – Level Profile of XWCOR for LLOCA

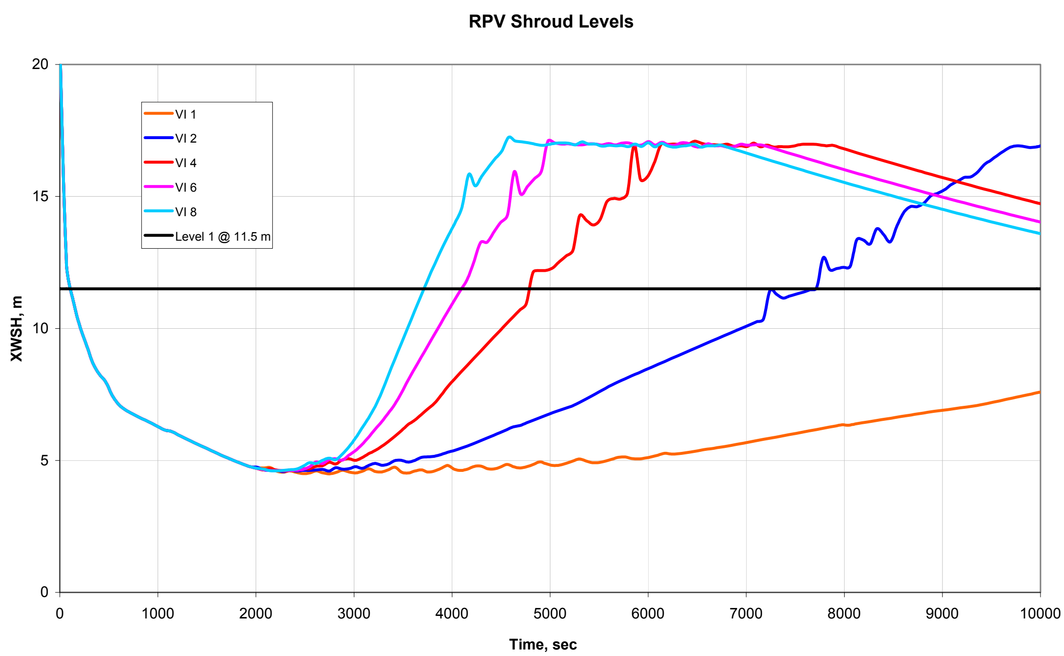

Figure 11A-22. GDCS Injection – Level Profile of XWSH for LLOCA

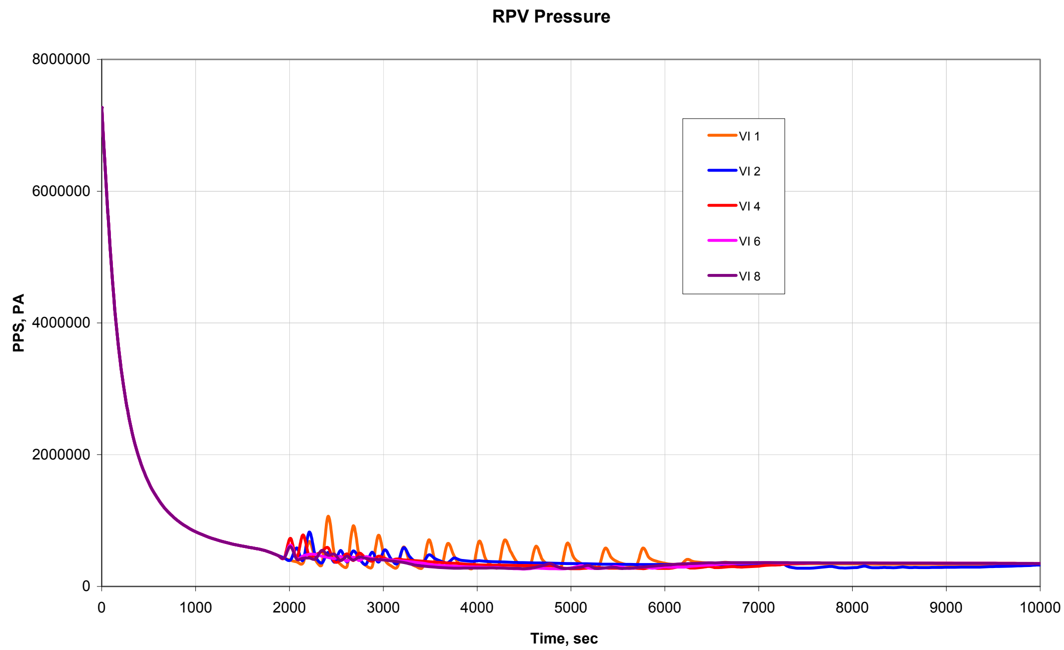

Figure 11A-23. GDCS Injection – Pressure Profile of PPS for LLOCA

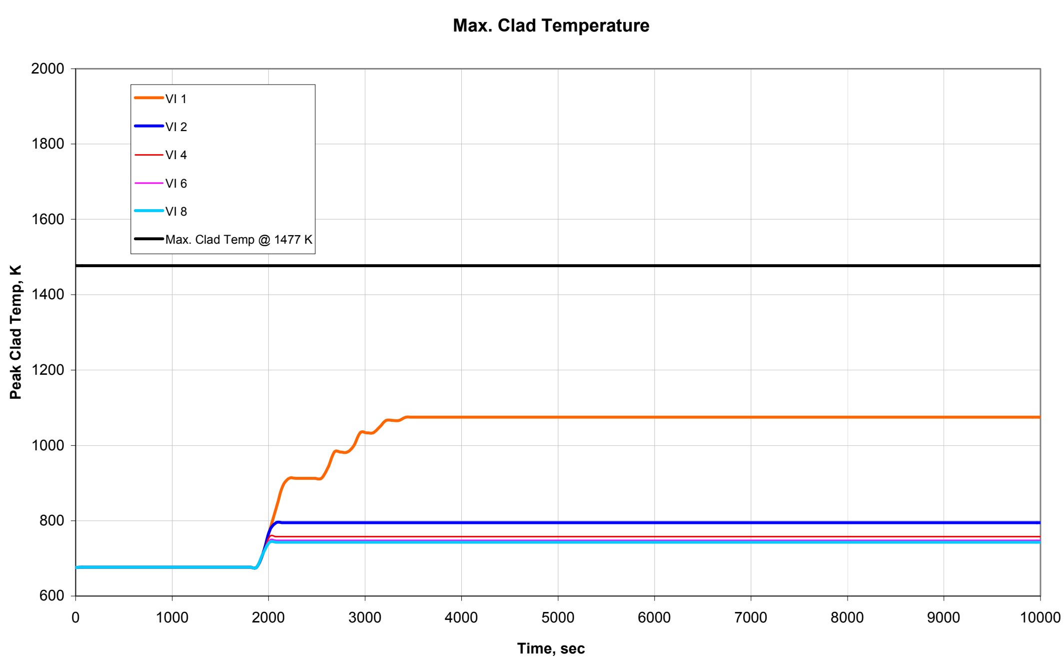

Figure 11A-24. GDCS Injection – Temperature Profile of Max Clad Temp for LLOCA

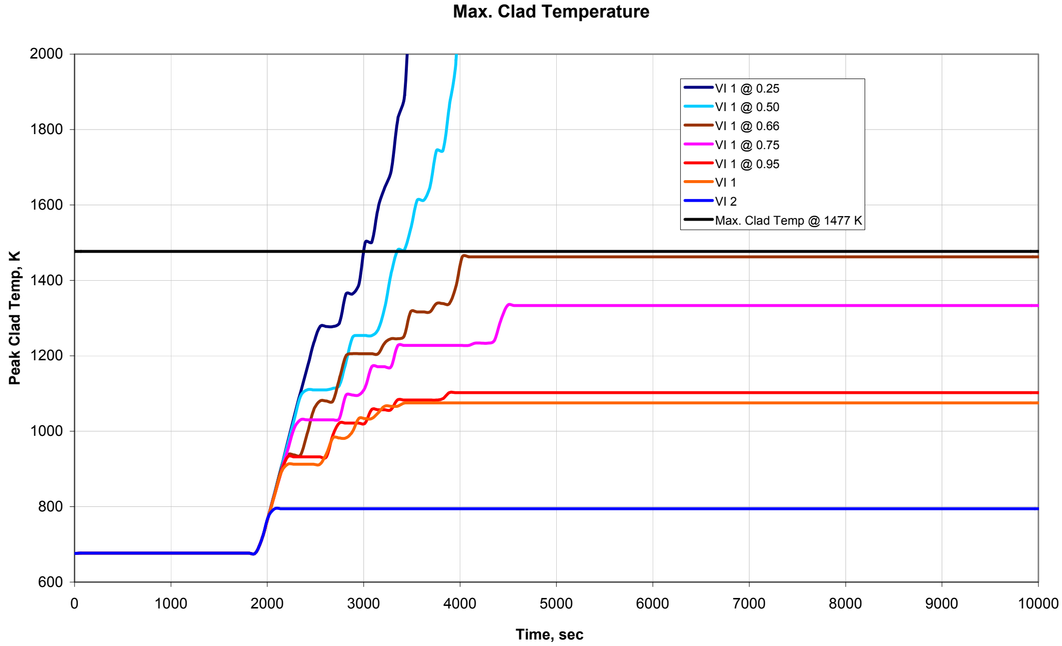

Figure 11A-25. GDCS Injection – Temperature Profile of Max Clad Temp for LLOCA – 1 GDCS Valve

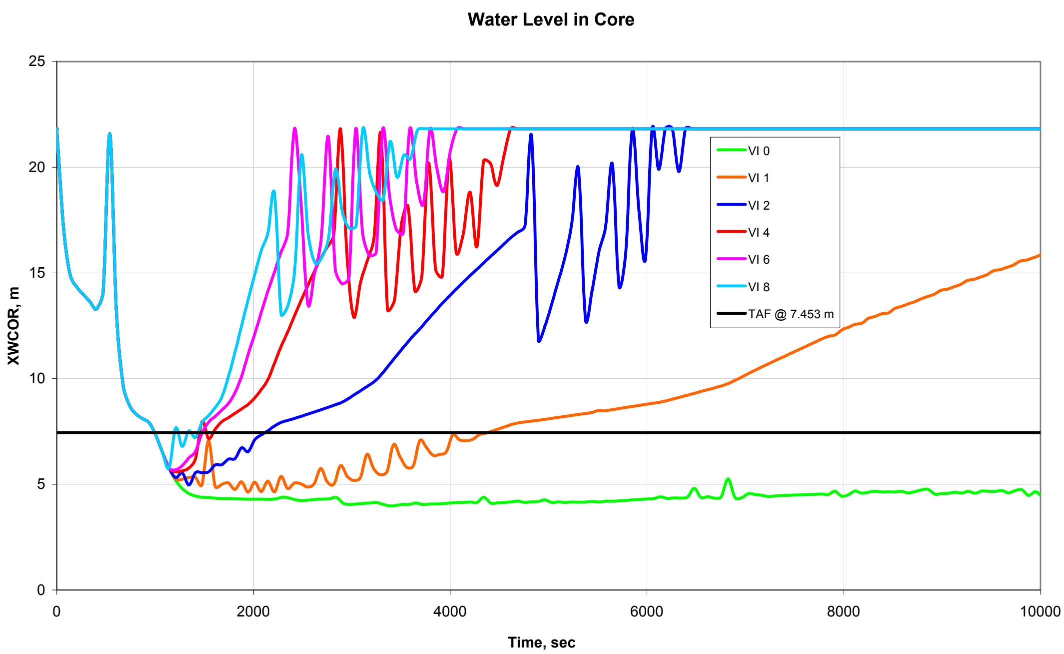

Figure 11A-26. GDCS Injection – Level Profile of XWCOR for MLOCA

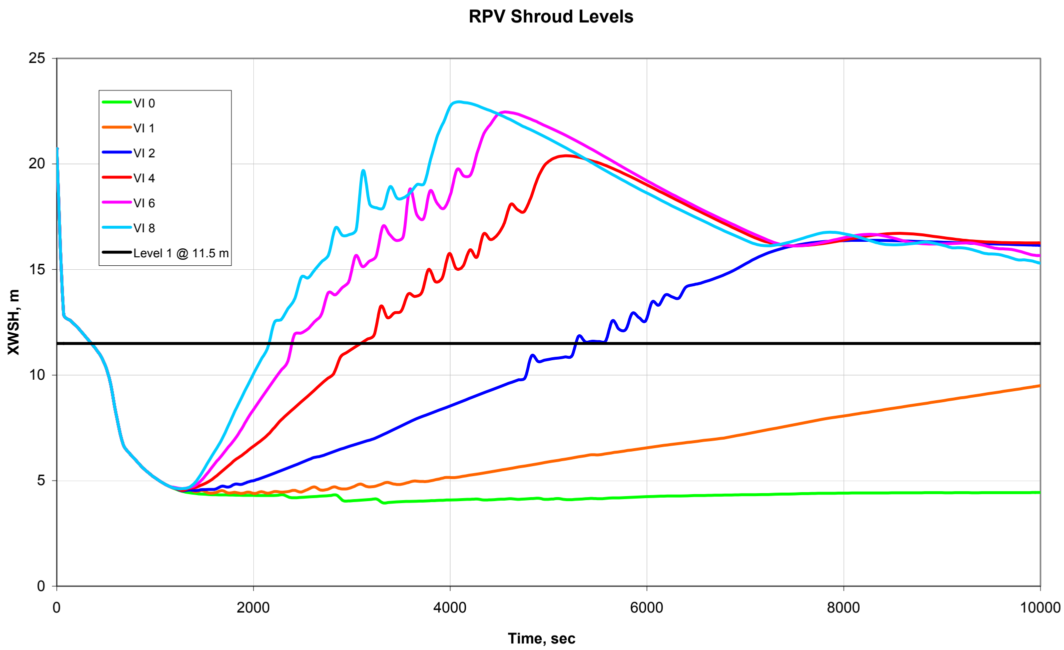

Figure 11A-27. GDCS Injection – Level Profile of XWSH for MLOCA

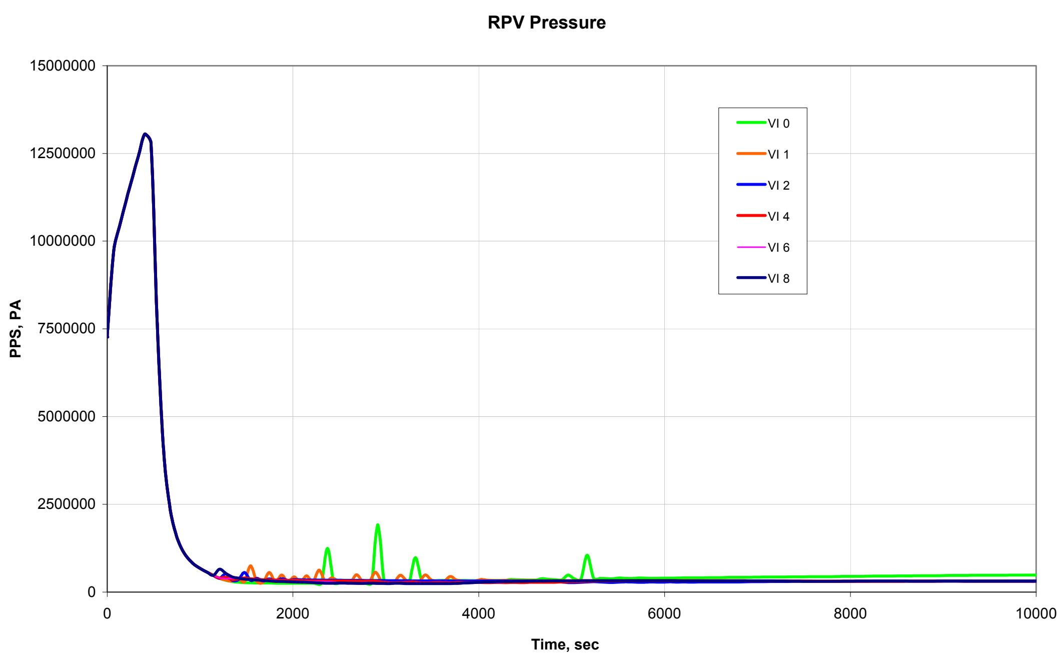

Figure 11A-28. GDCS Injection – Pressure Profile of PPS for MLOCA

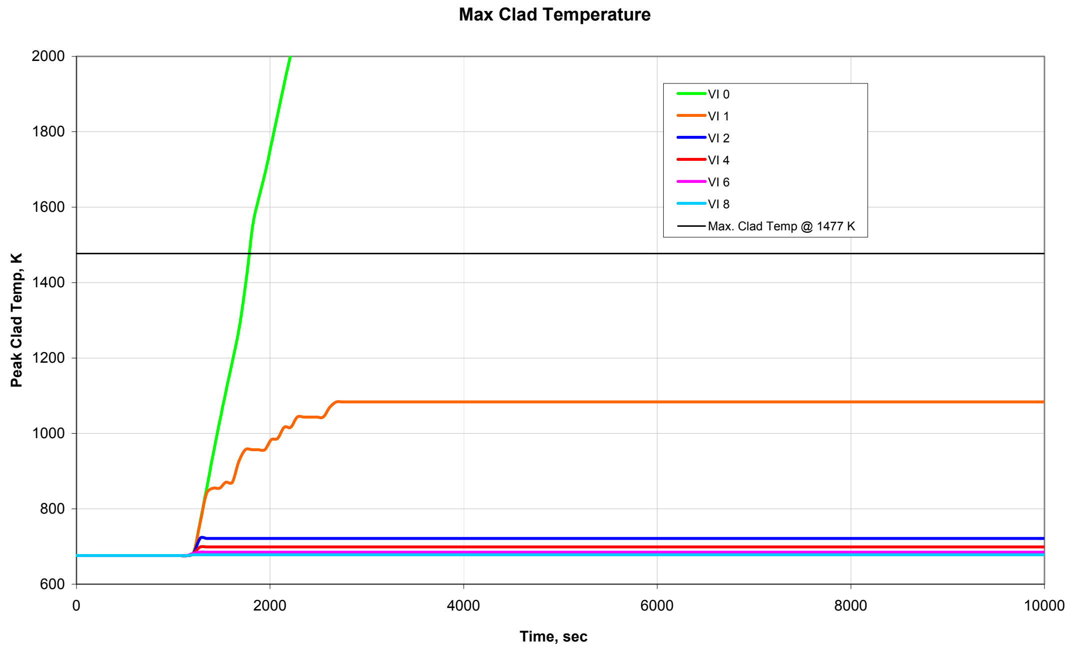

Figure 11A-29. GDCS Injection – Temperature Profile of Max Clad Temp for MLOCA

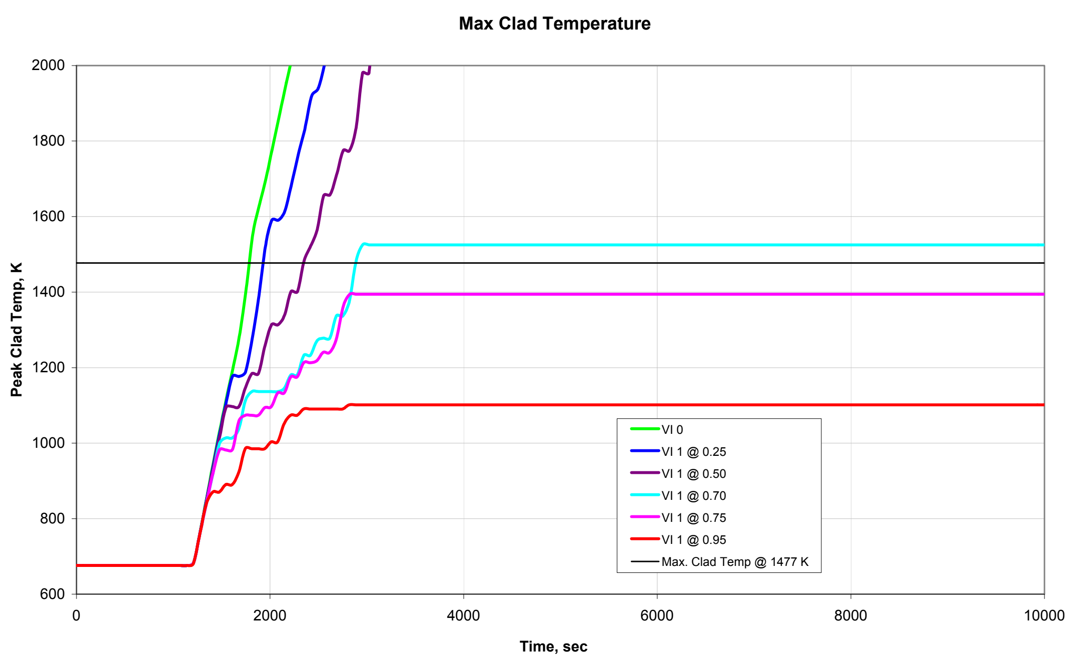

Figure 11A-30. GDCS Injection – Temperature Profile of Max Clad Temp for MLOCA -1 GDCS Valve

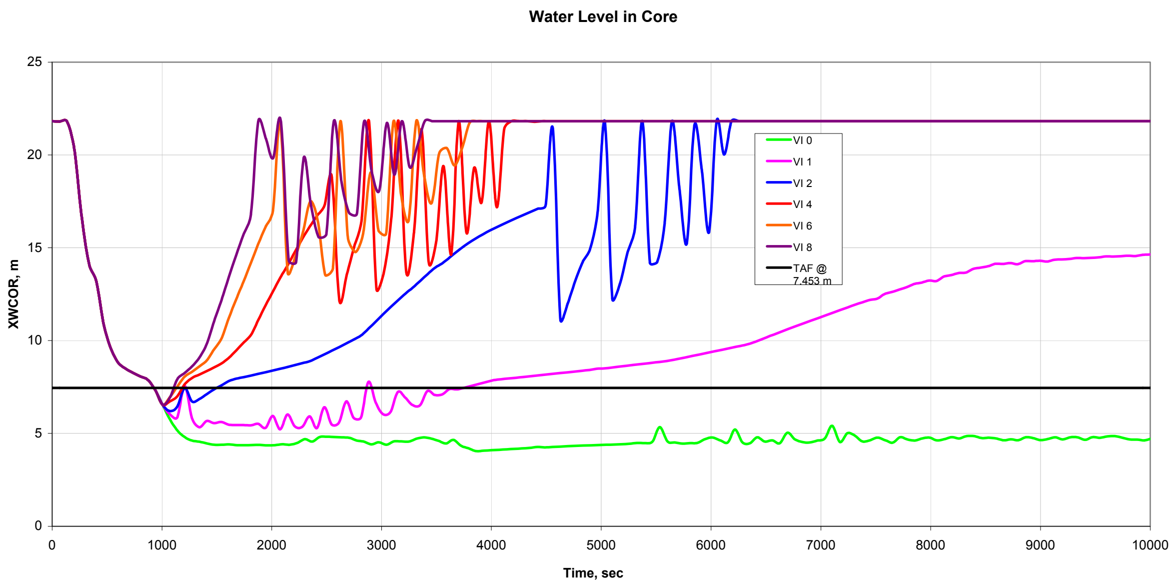

Figure 11A-31. GDCS Injection – Level Profile of XWCOR for IORV

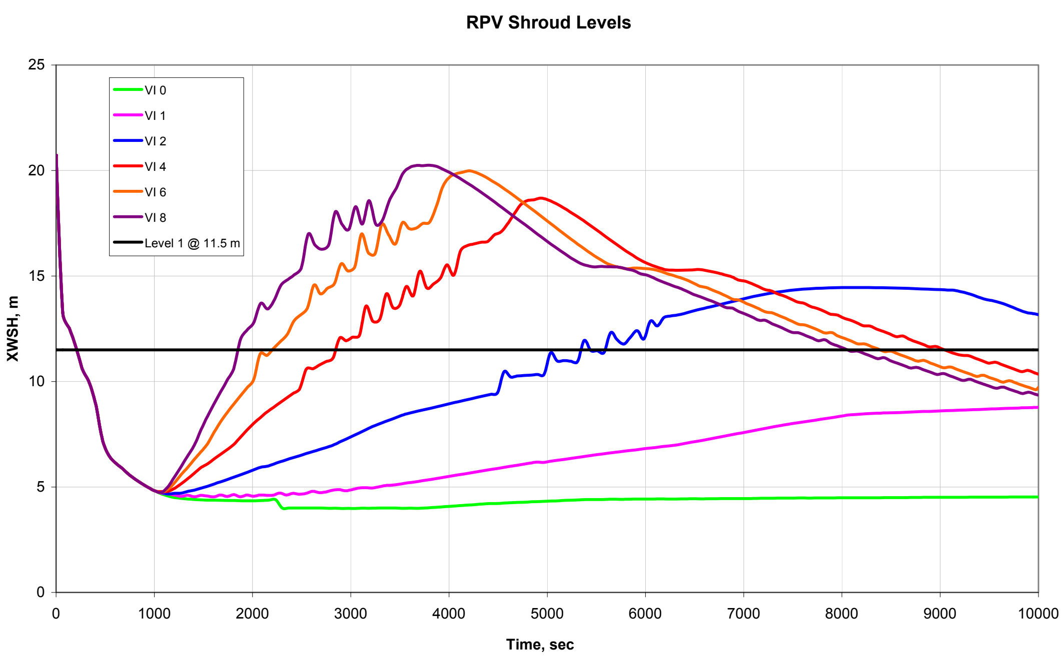

Figure 11A-32. GDCS Injection – Level Profile of XWSH for IORV

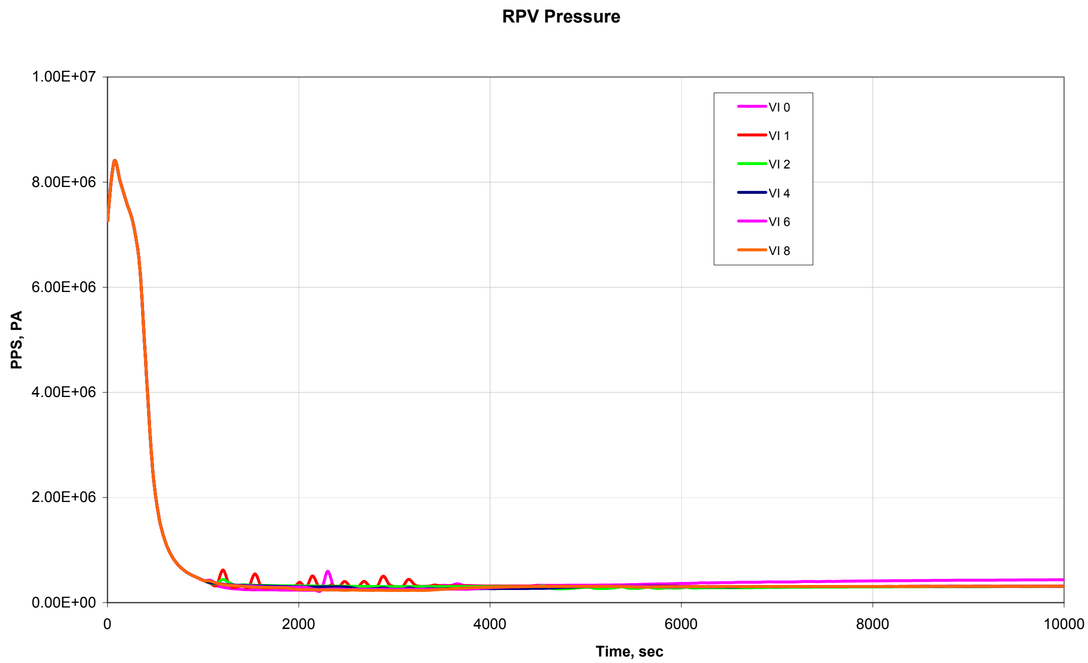

Figure 11A-33. GDCS Injection – Pressure Profile of PPS for IORV

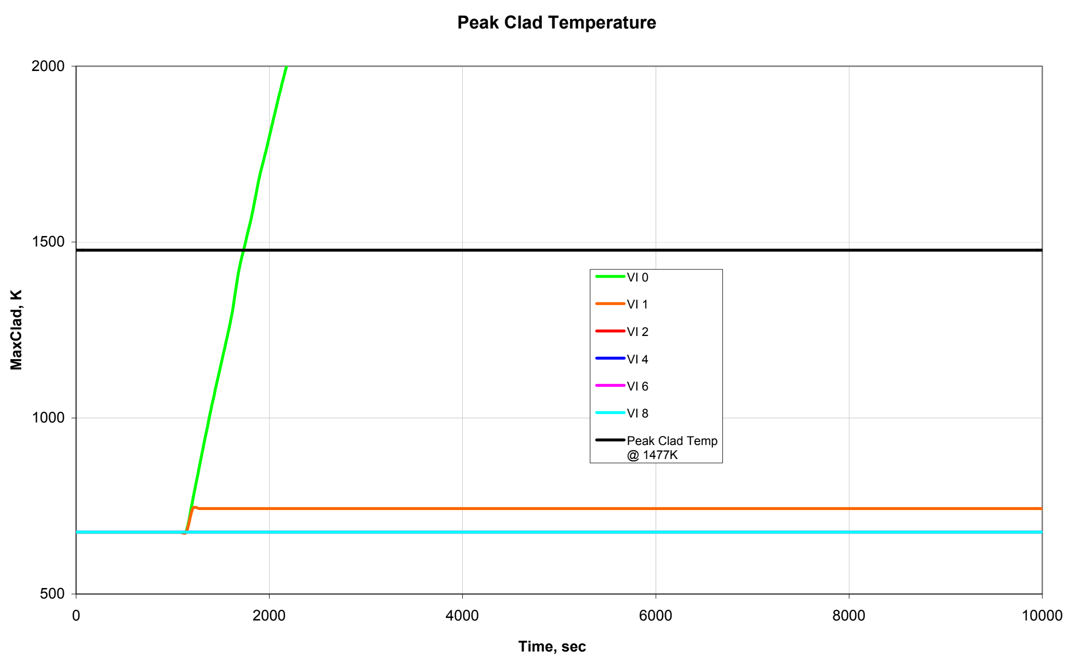

Figure 11A-34. GDCS Injection – Temperature Profile of Max Clad Temp for IORV

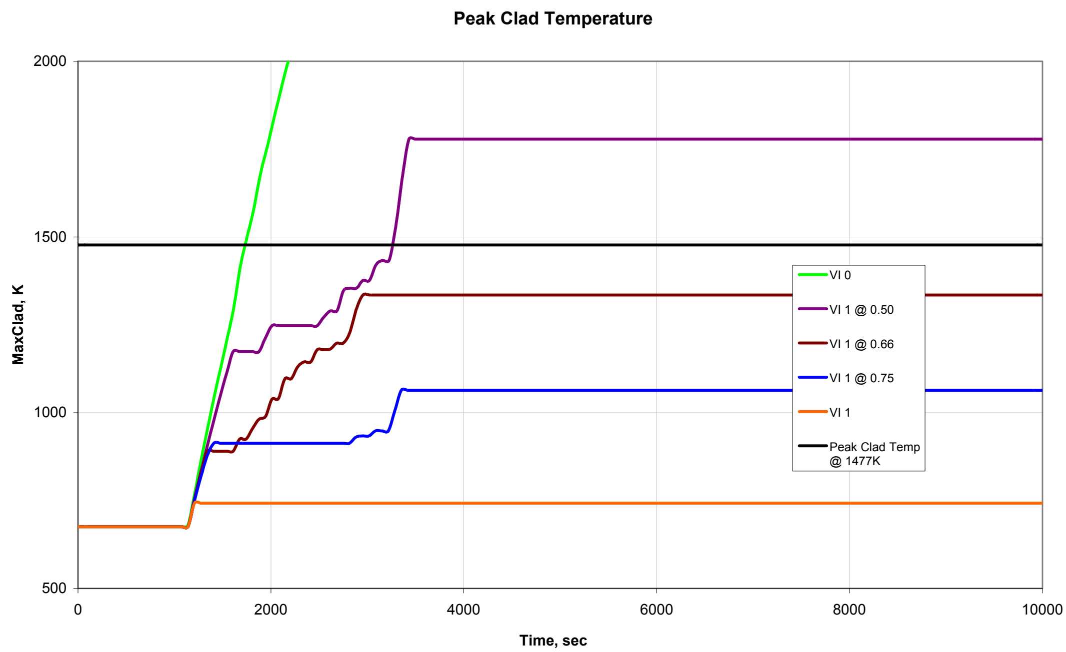

Figure 11A-35. GDCS Injection – Temperature Profile of Max Clad Temp for IORV -1 GDCS Valve

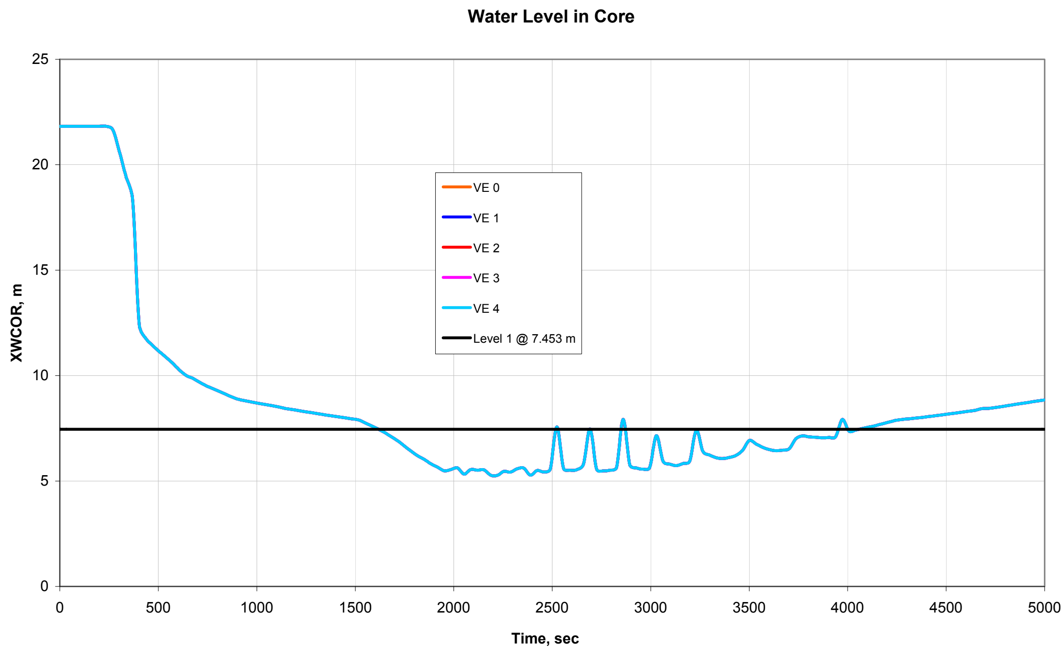

Figure 11A-36. GDCS Equalization – Level Profile of XWCOR for LLOCA

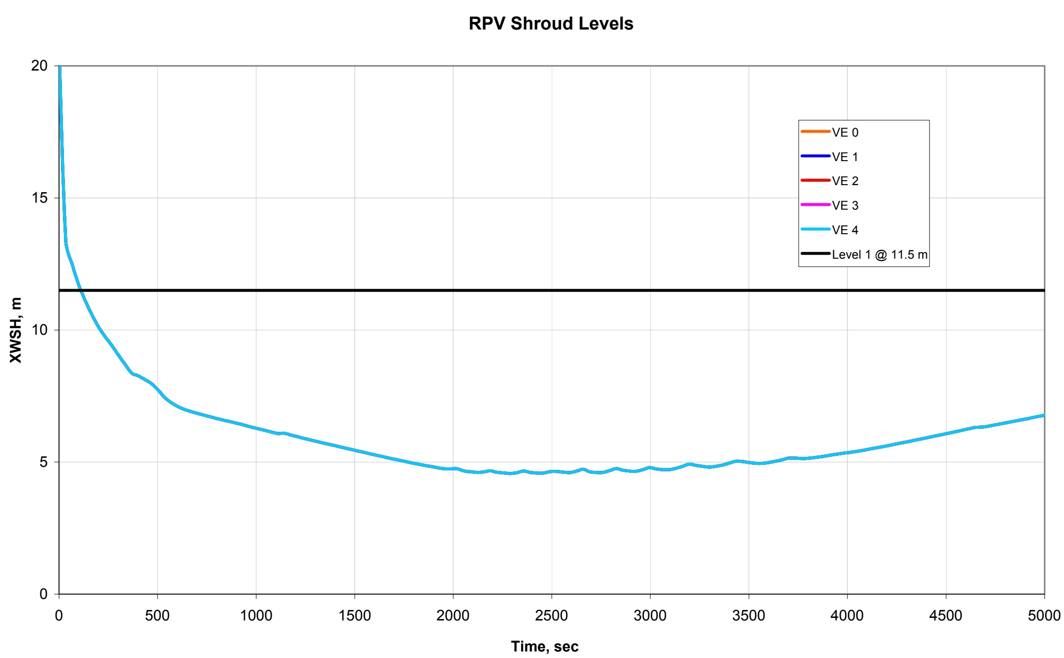

Figure 11A-37. GDCS Equalization – Level Profile of XWSH for LLOCA

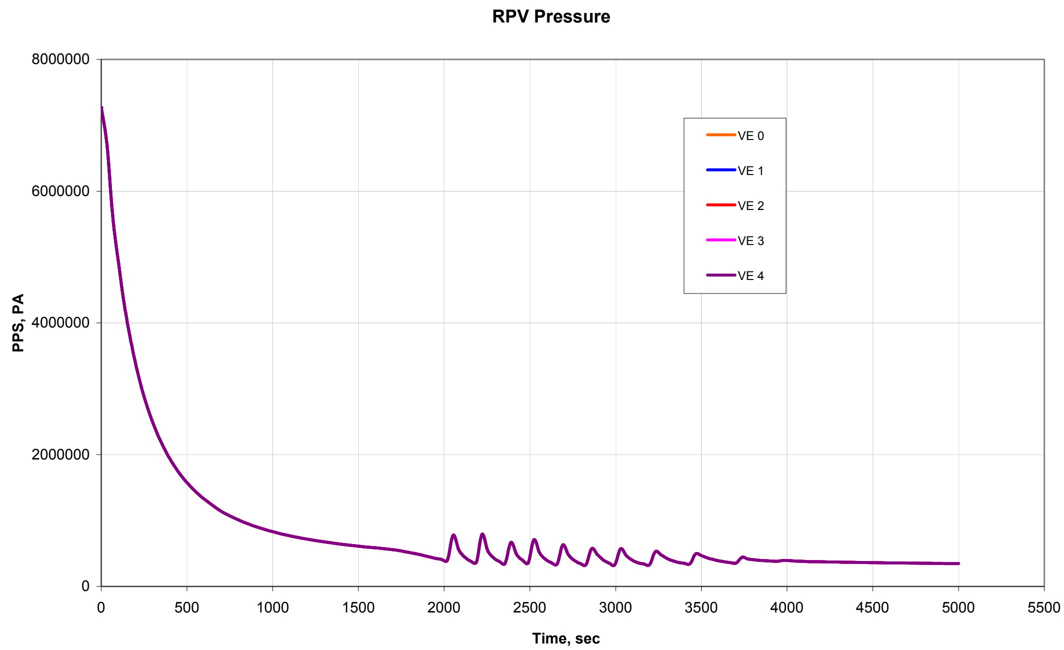

Figure 11A-38. GDCS Equalization – Pressure Profile of PPS for LLOCA

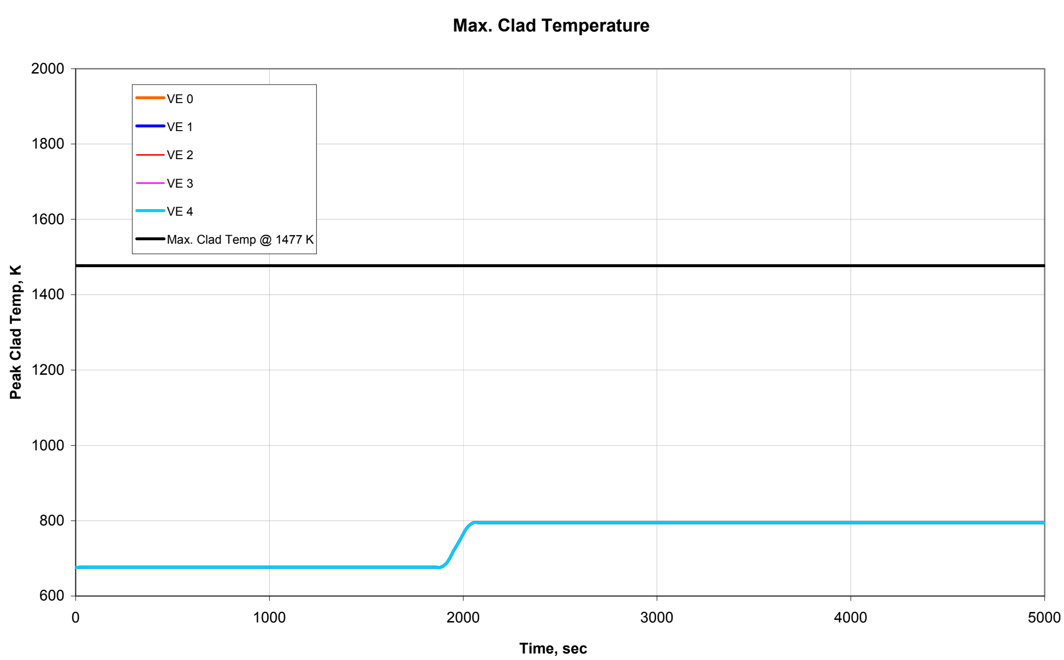

Figure 11A-39. GDCS Equalization – Temperature Profile of Max Clad Temp for LLOCA

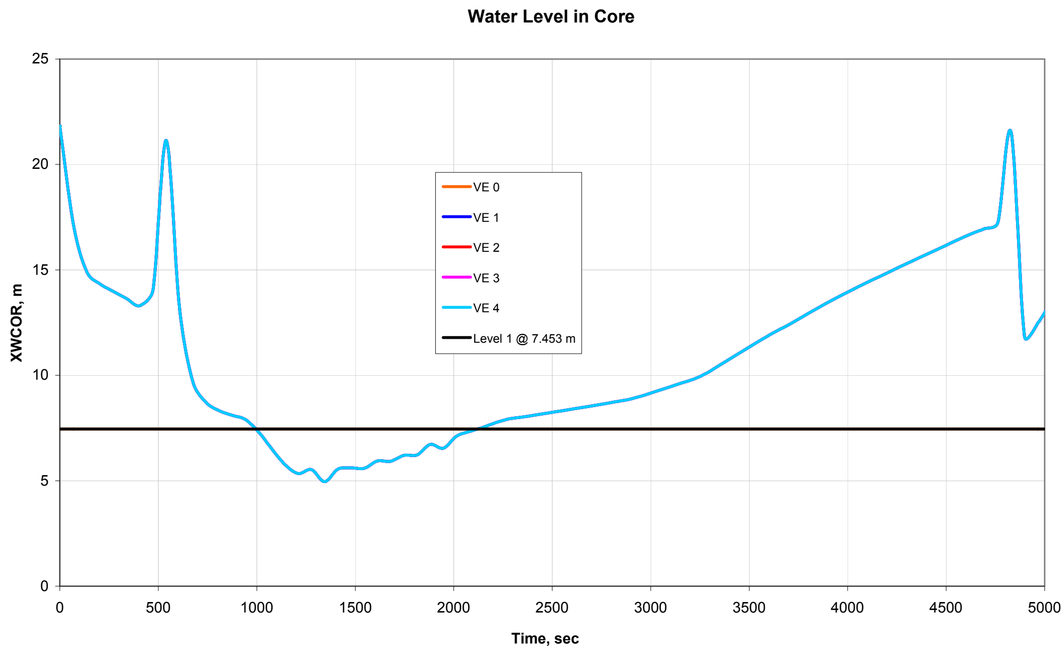

Figure 11A-40. GDCS Equalization – Level Profile of XWCOR for MLOCA

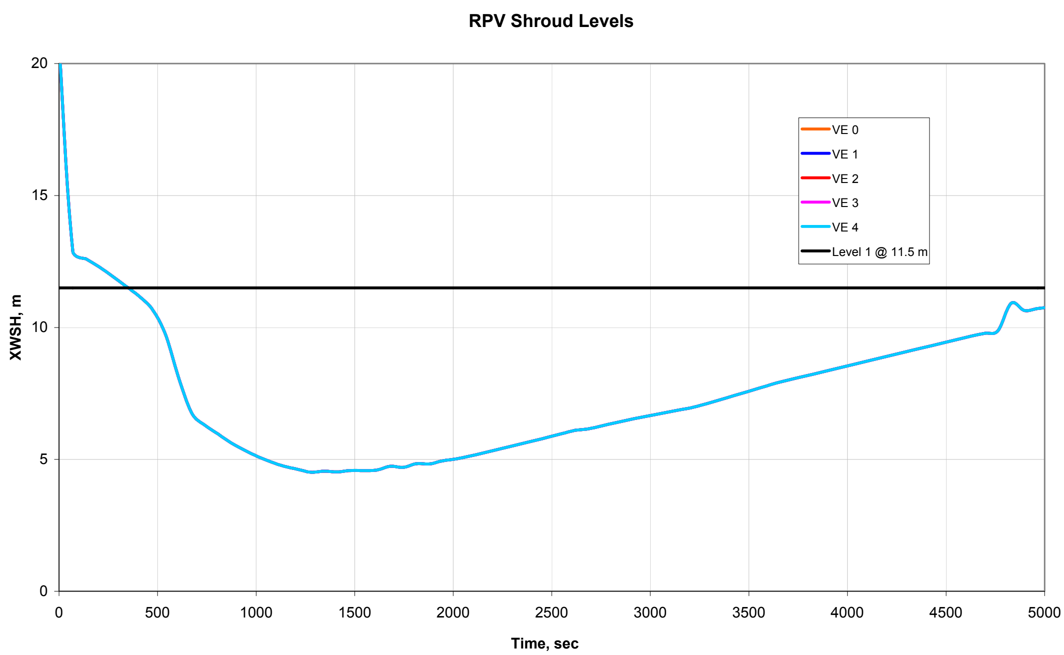

Figure 11A-41. GDCS Equalization – Level Profile of XWSH for MLOCA

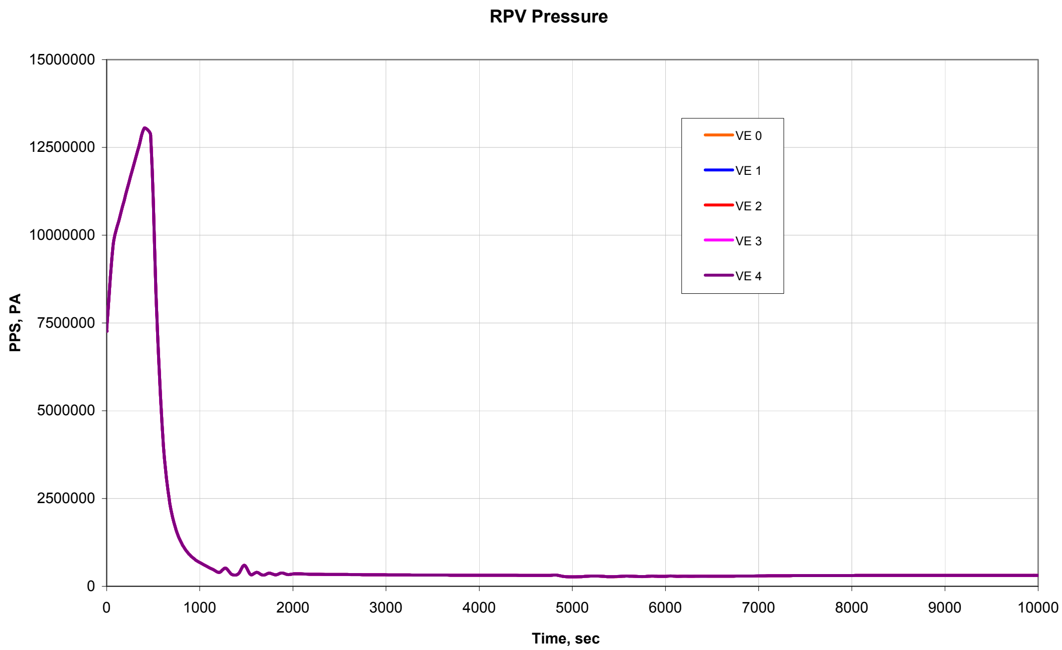

Figure 11A-42. GDCS Equalization – Pressure Profile of PPS for MLOCA

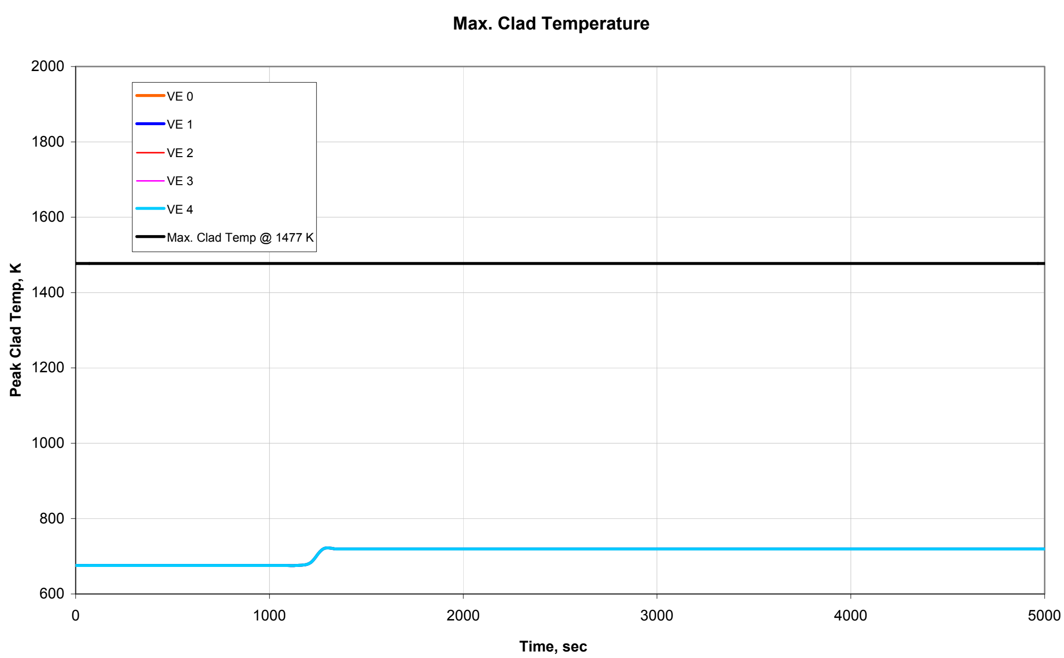

Figure 11A-43. GDCS Equalization – Temperature Profile of Max Clad Temp for MLOCA

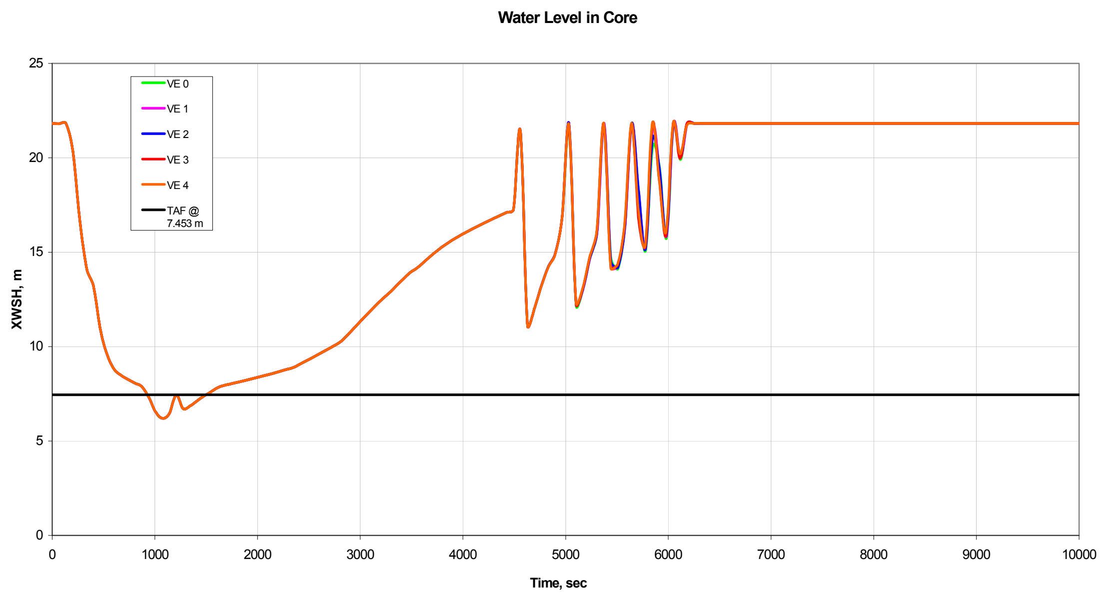

Figure 11A-44. GDCS Equalization – Level Profile of XWCOR for IORV

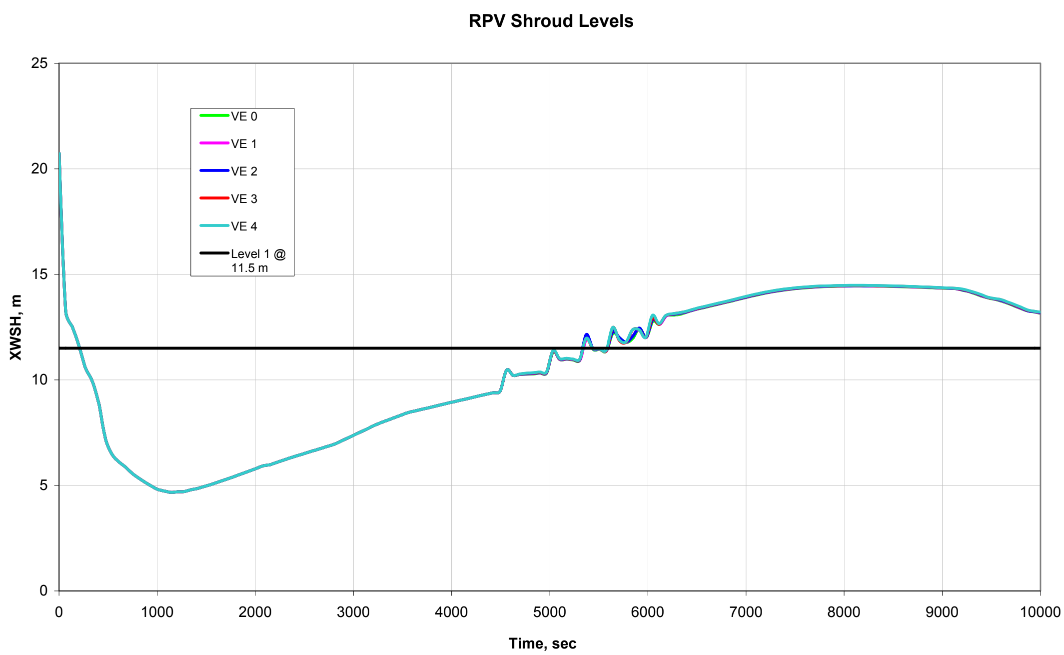

Figure 11A-45. GDCS Equalization – Level Profile of XWSH for IORV

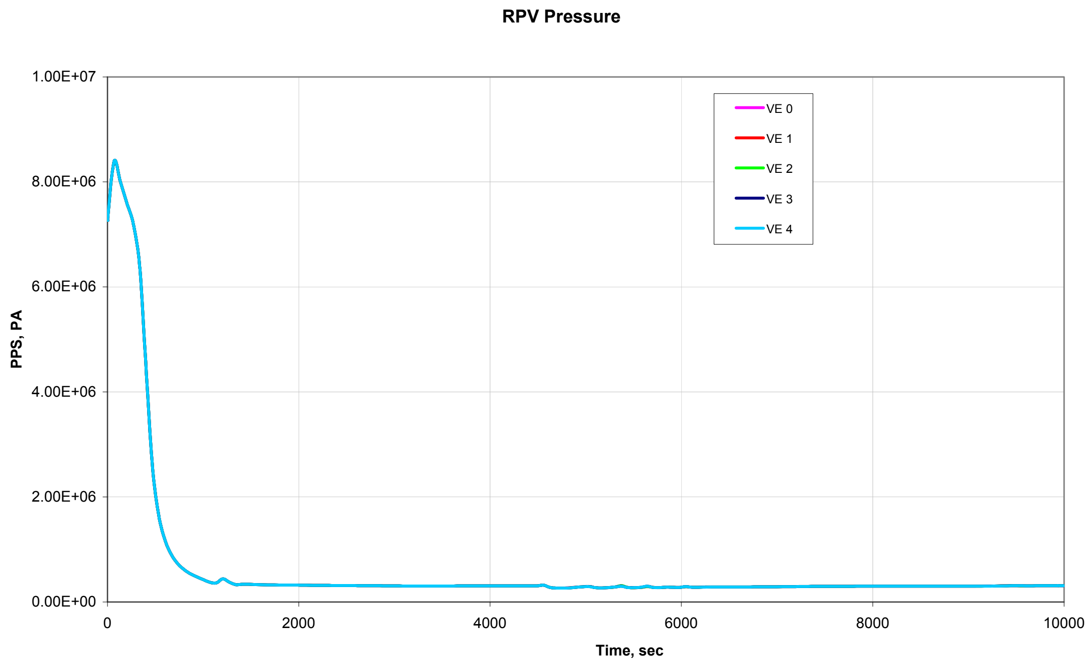

Figure 11A-46. GDCS Equalization – Pressure Profile of PPS for IORV

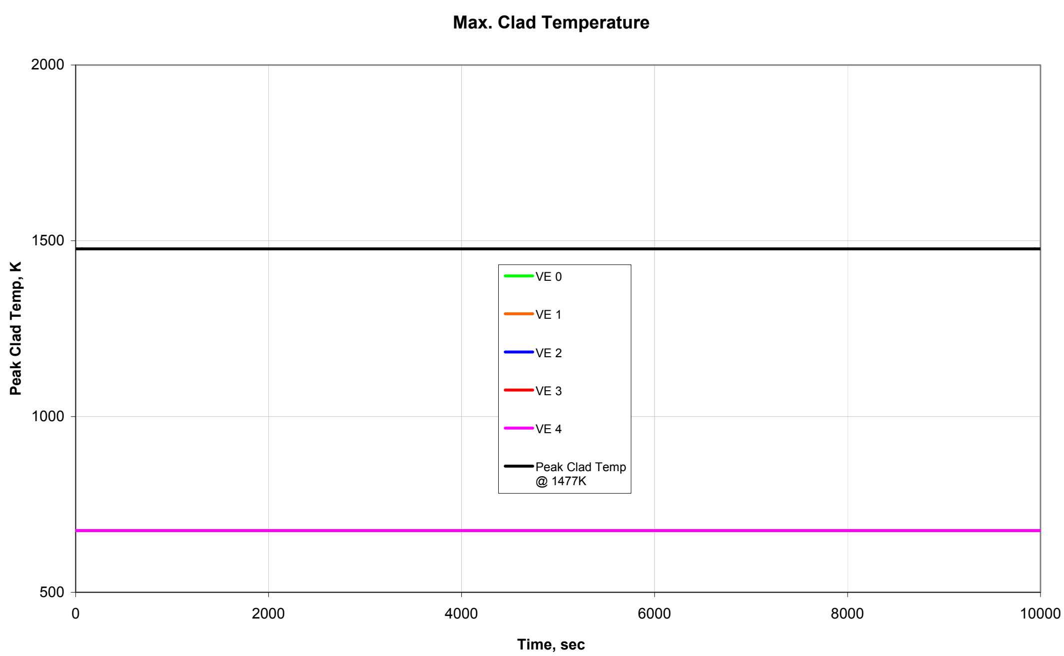

Figure 11A-47. GDCS Equalization – Temperature Profile of Max Clad Temp for IORV

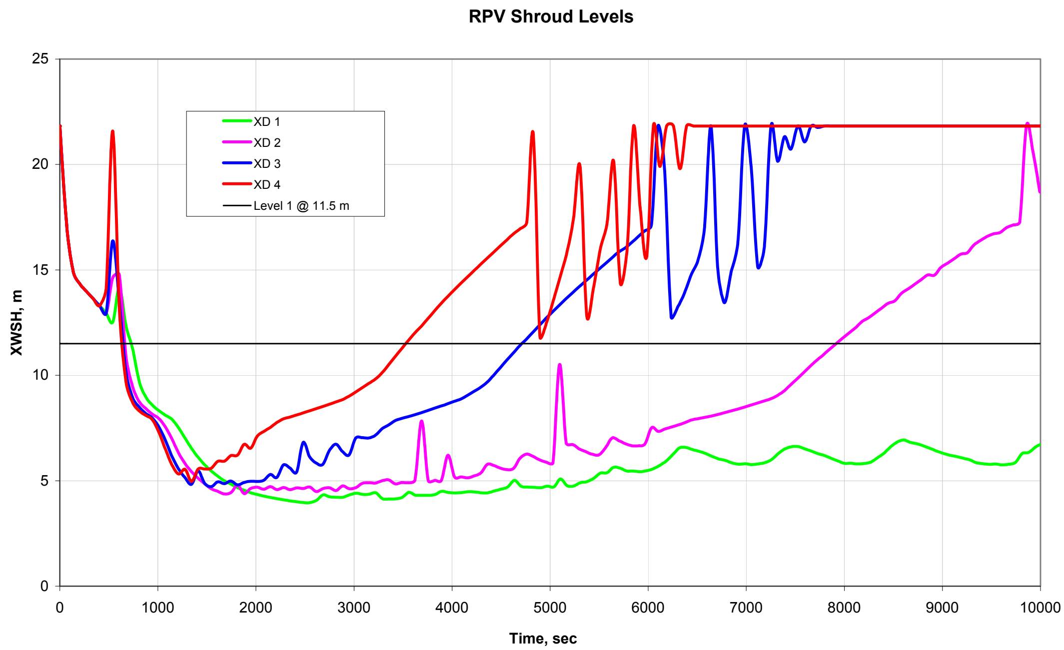

Figure 11A-48. ADS – Level Profile of XWCOR for MLOCA

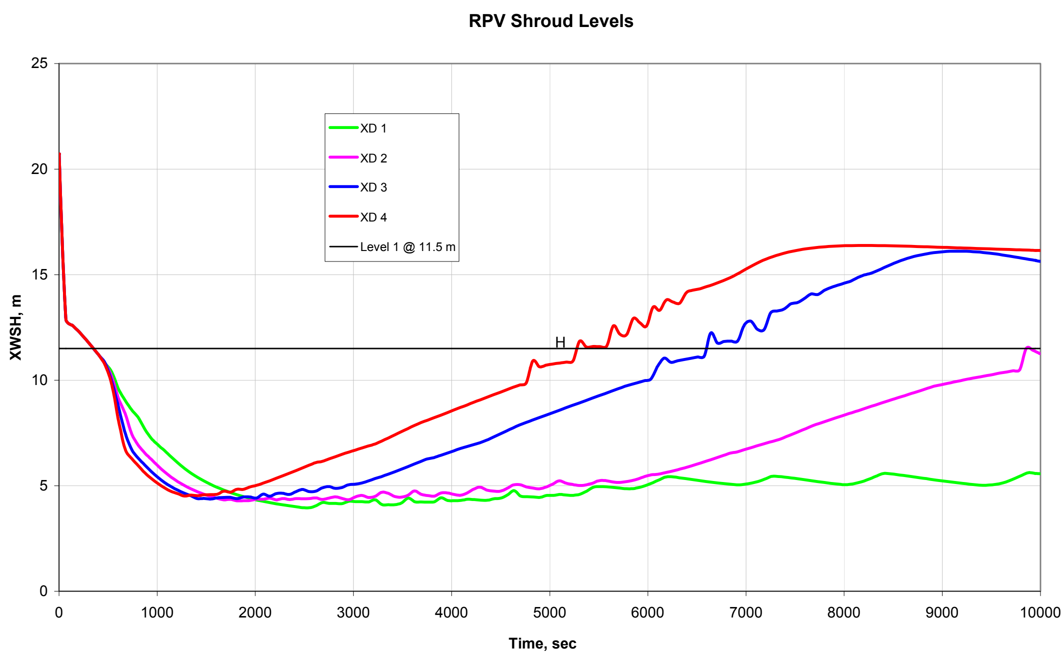

Figure 11A-49. ADS – Level Profile of XWSH for MLOCA

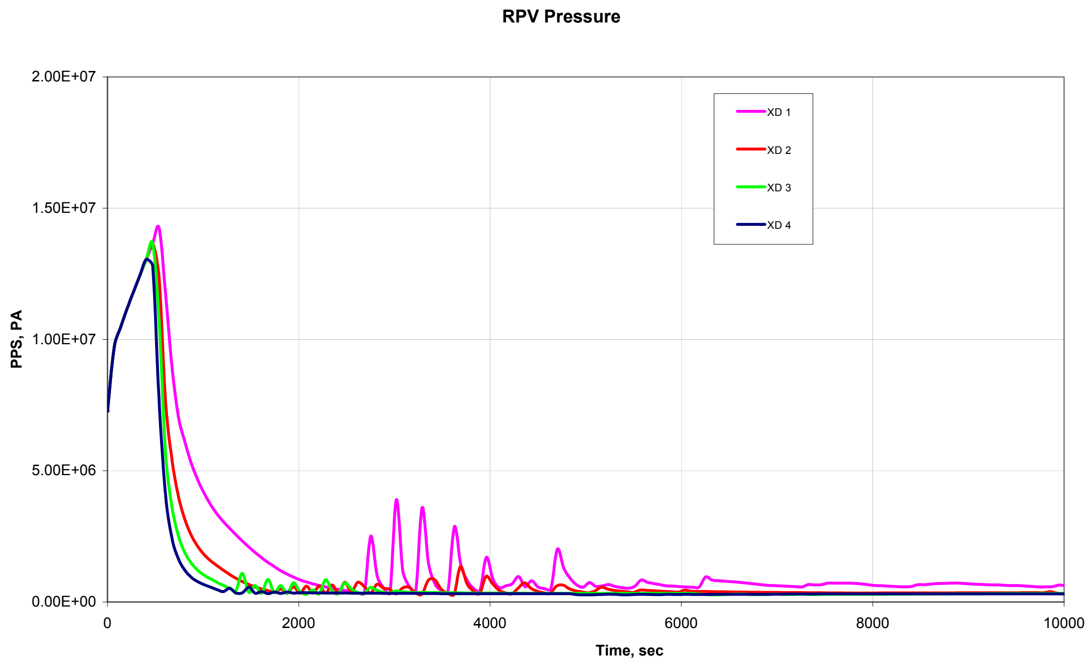

Figure 11A-50. ADS – Pressure Profile of PPS for MLOCA

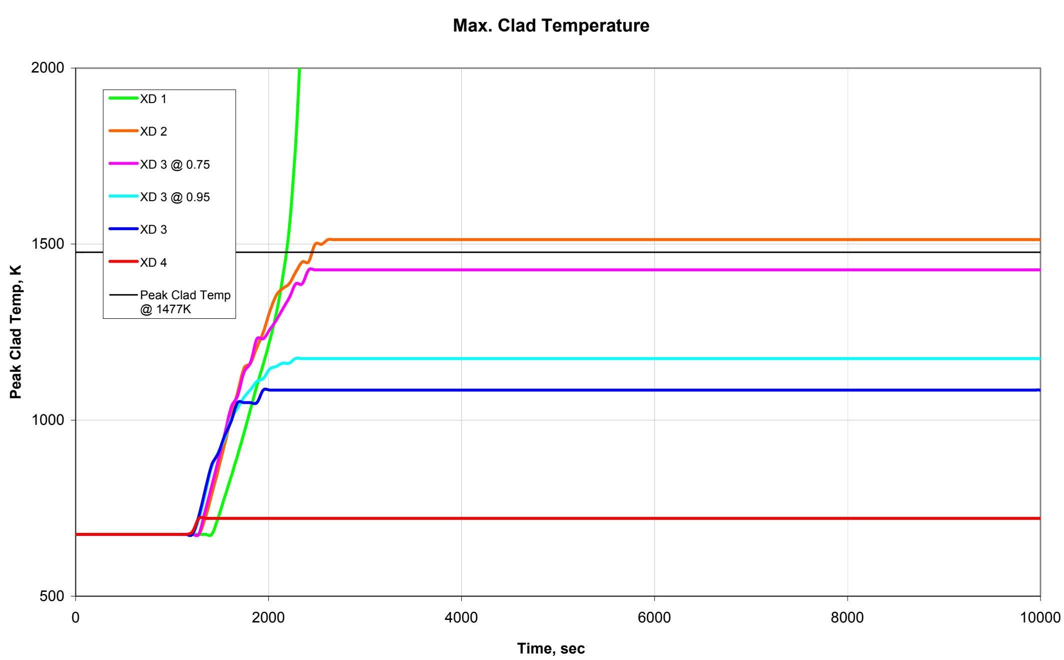

Figure 11A-51. ADS – Temperature Profile of Max Clad Temp for MLOCA

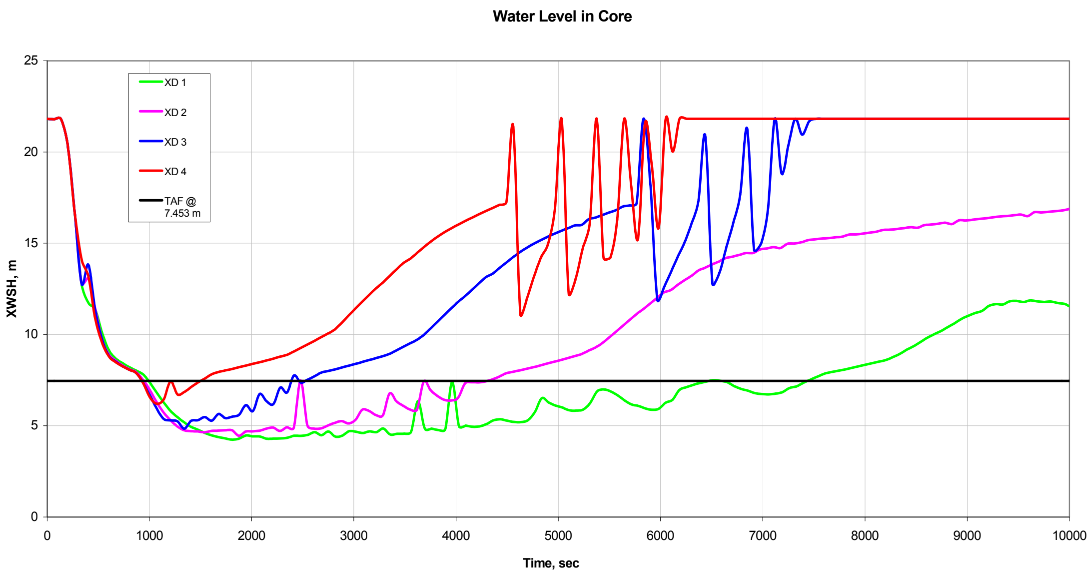

Figure 11A-52. ADS – Level Profile of XWCOR for IORV

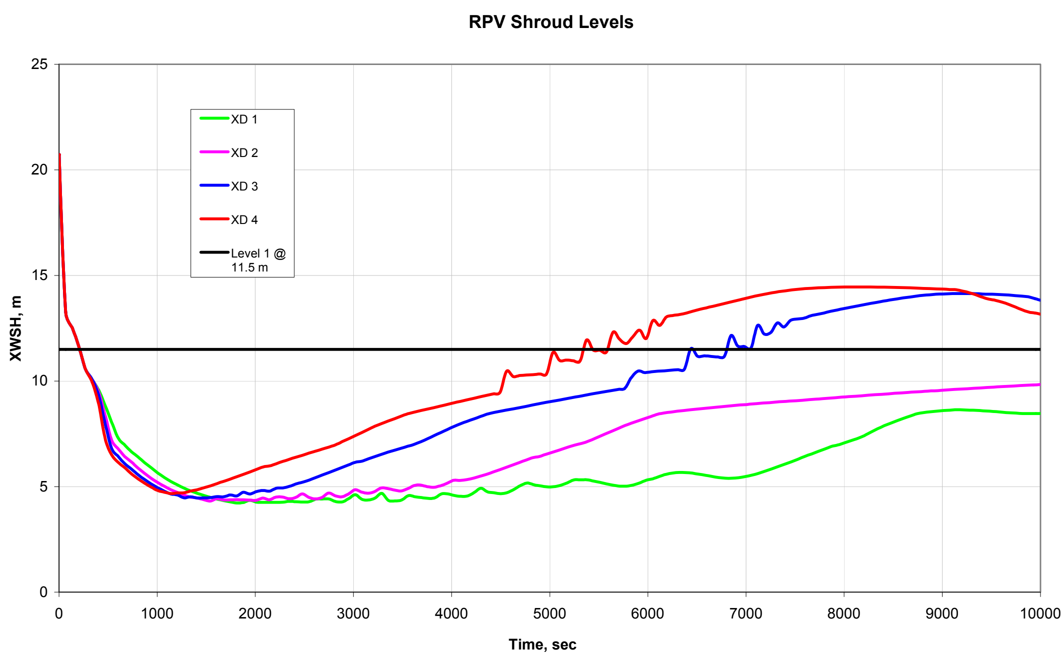

Figure 11A-53. ADS – Level Profile of XWSH for IORV

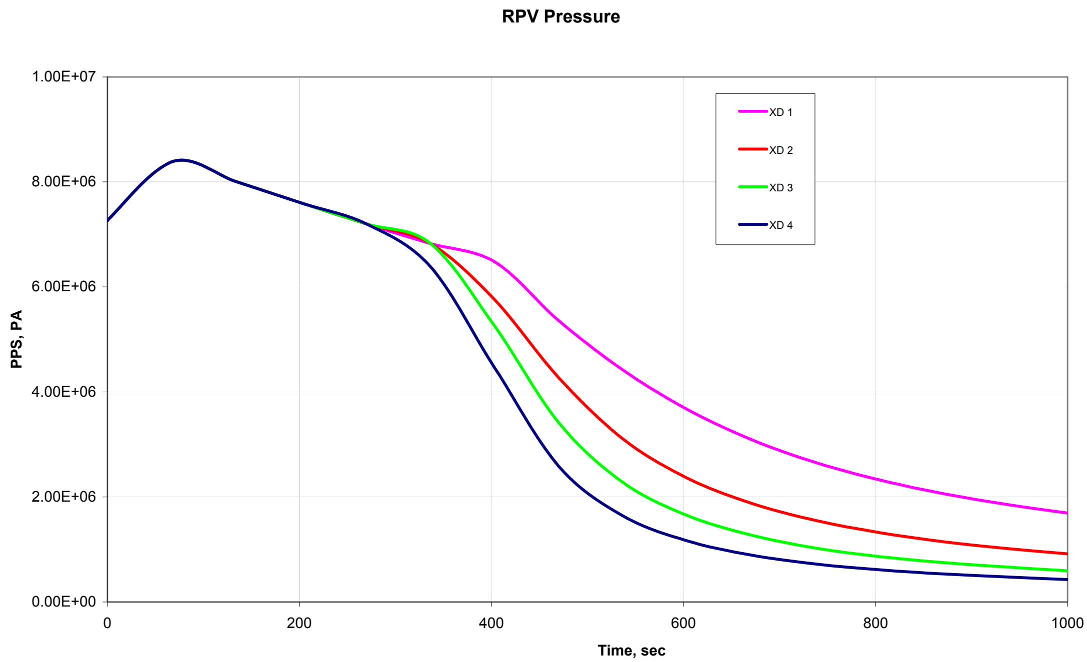

Figure 11A-54. ADS – Pressure Profile of PPS for IORV

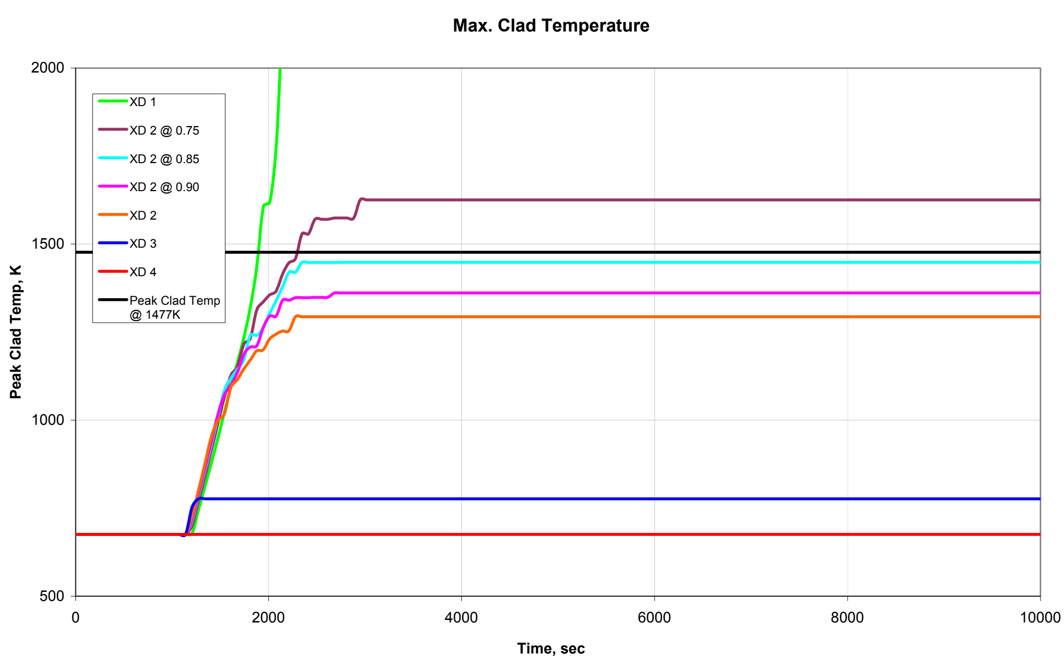

Figure 11A-55. ADS– Temperature Profile of Max Clad Temp for IORV

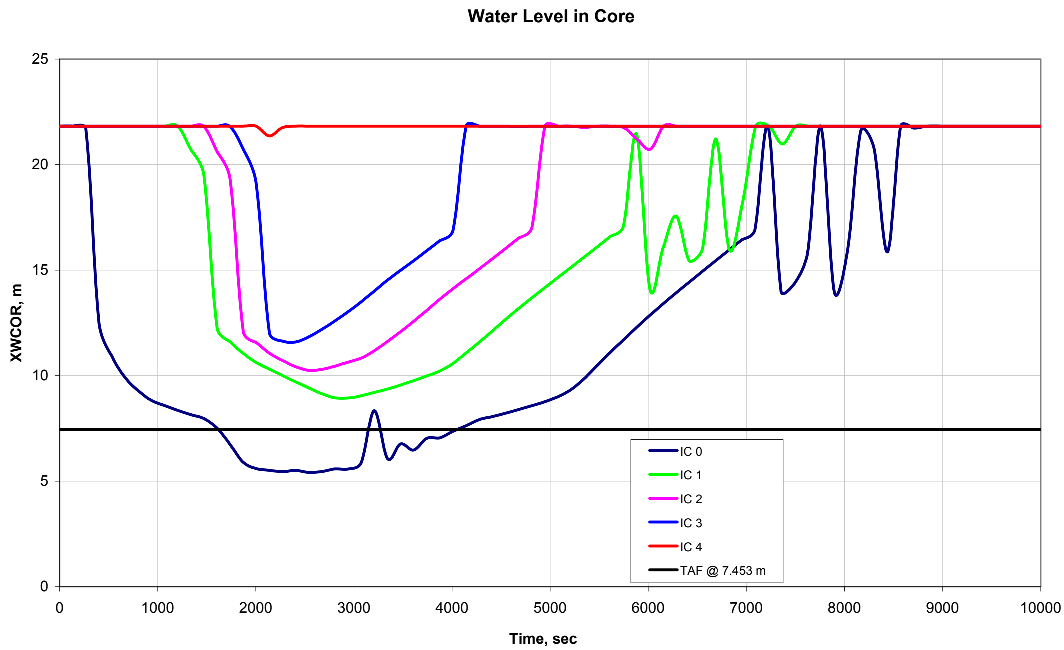

Figure 11A-56. ICS – Level Profile of XWCOR for LLOCA

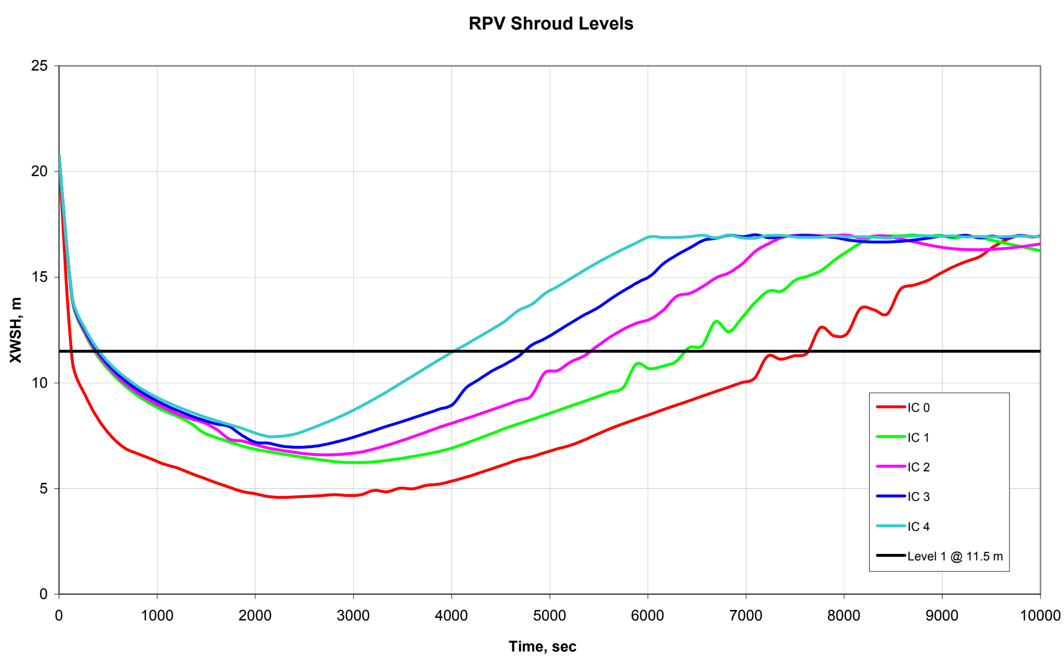

Figure 11A-57. ICS – Level Profile of XWSH for LLOCA

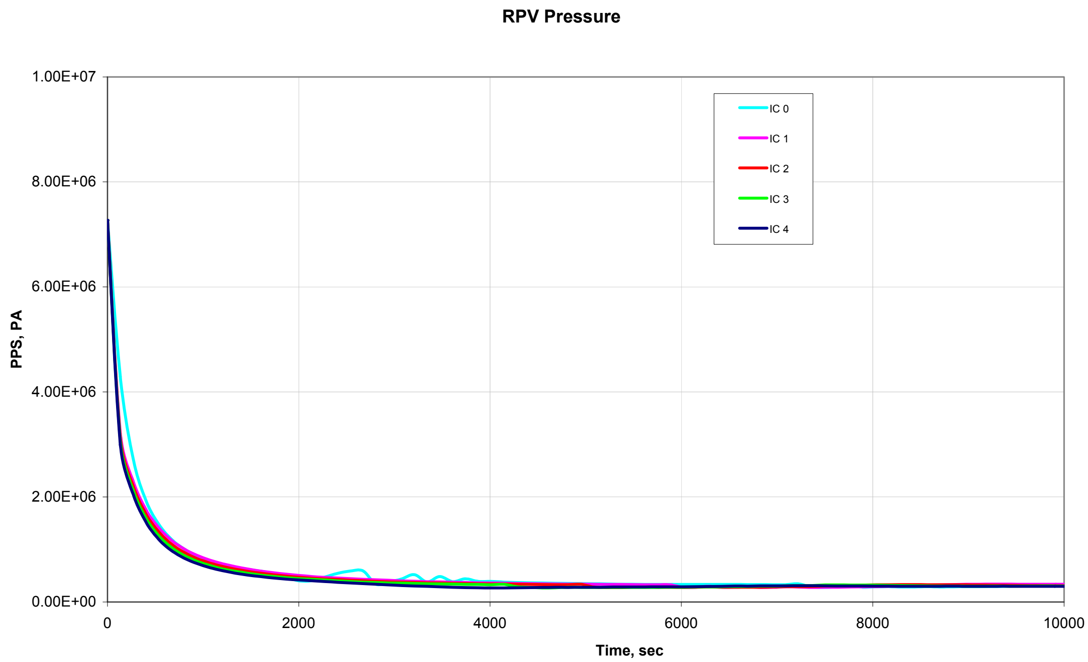

Figure 11A-58. ICS – Pressure Profile of PPS for LLOCA

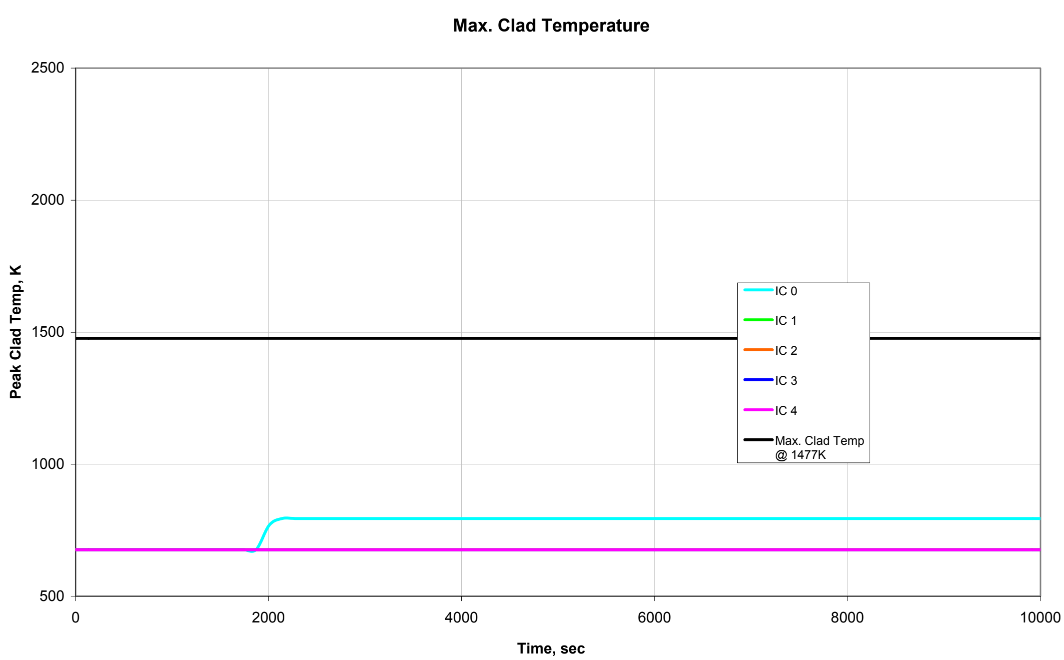

Figure 11A-59. ICS – Temperature Profile of Max Clad Temp for LLOCA

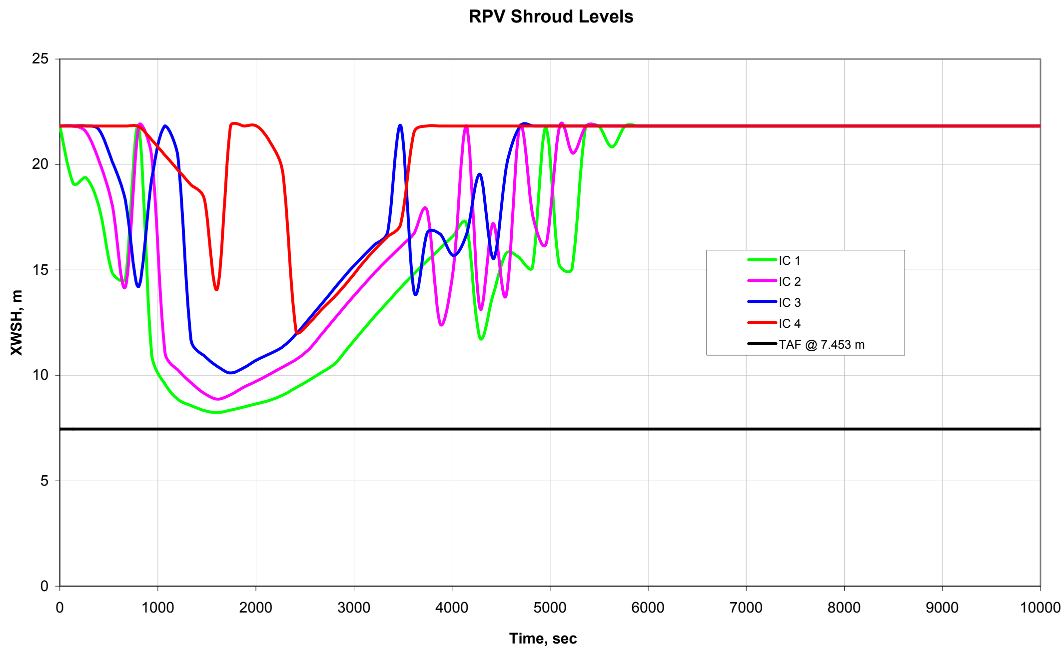

Figure 11A-60. ICS – Level Profile of XWCOR for MLOCA

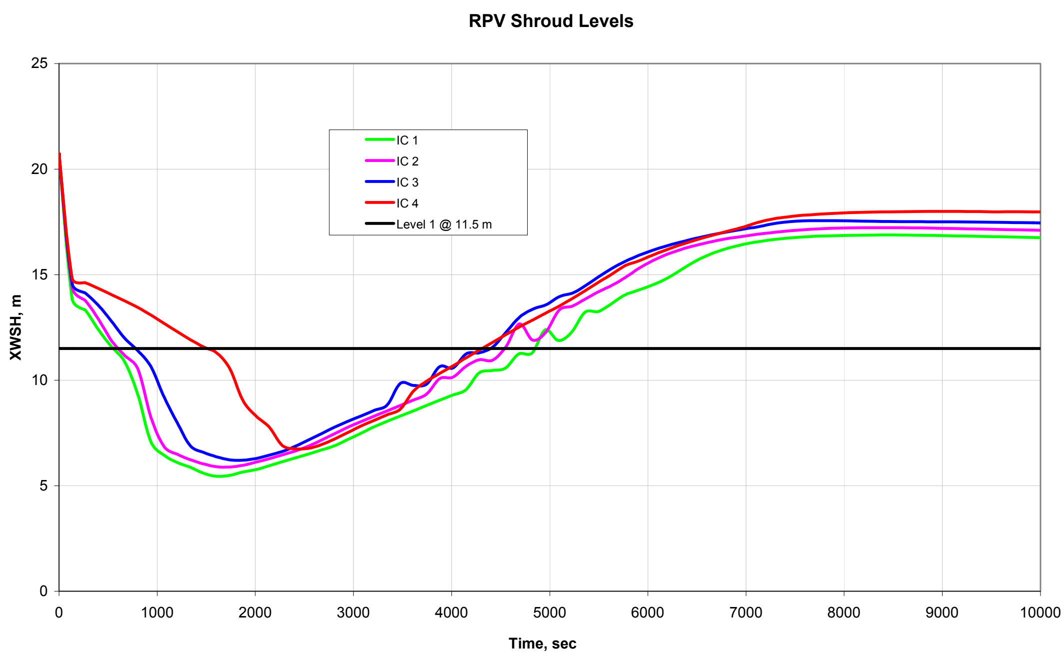

Figure 11A-61. ICS – Level Profile of XWSH for MLOCA

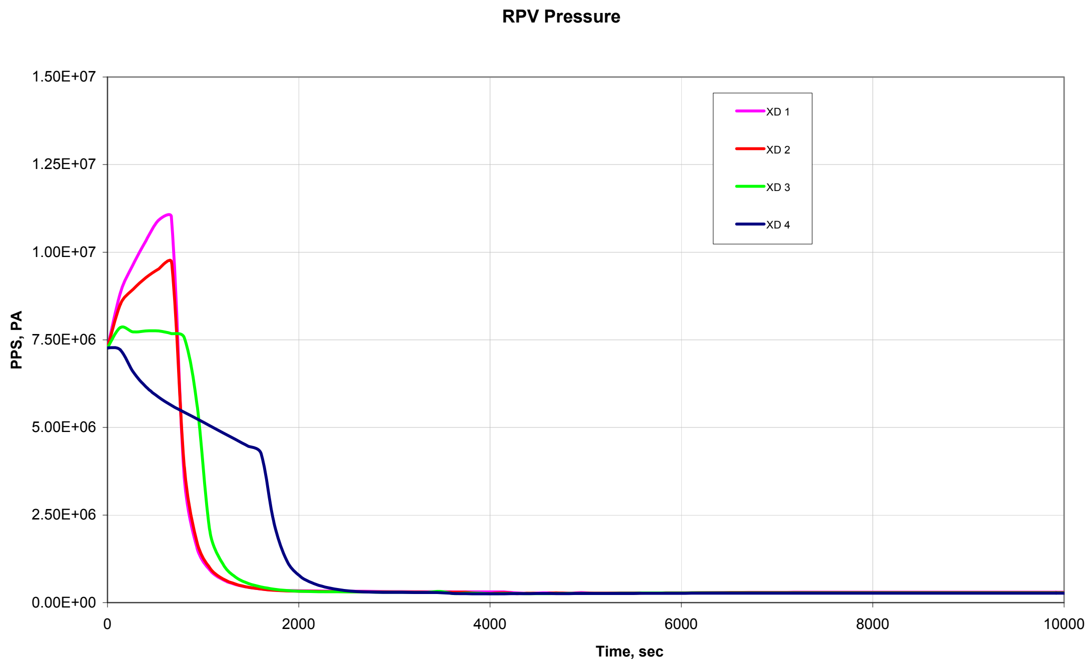

Figure 11A-62. ICS – Pressure Profile of PPS for MLOCA

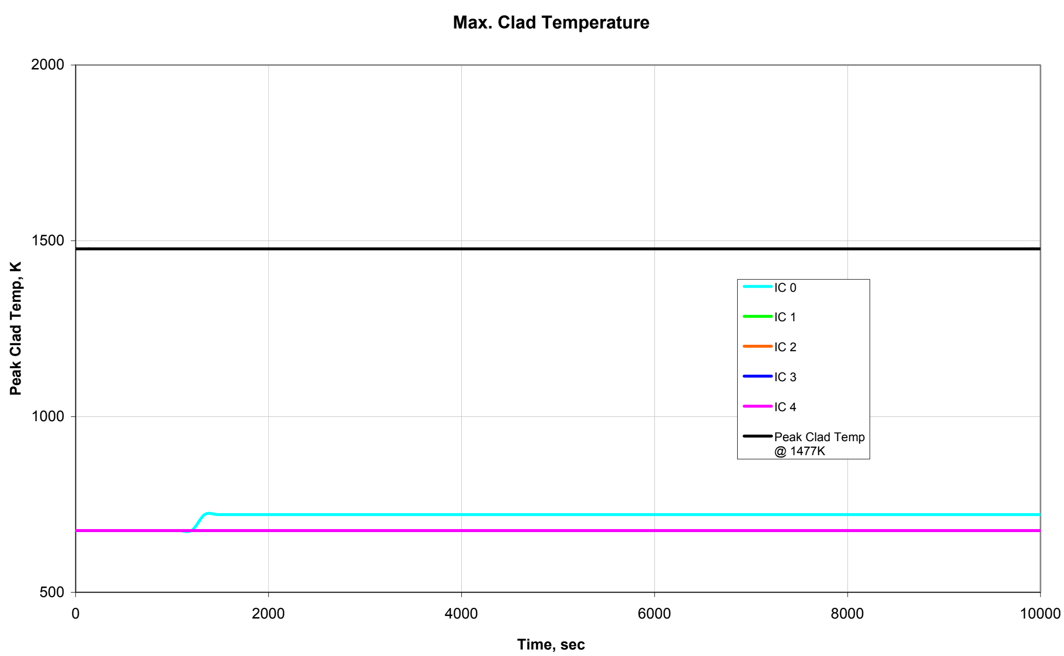

Figure 11A-63. ICS– Temperature Profile of Max Clad Temp for MLOCA

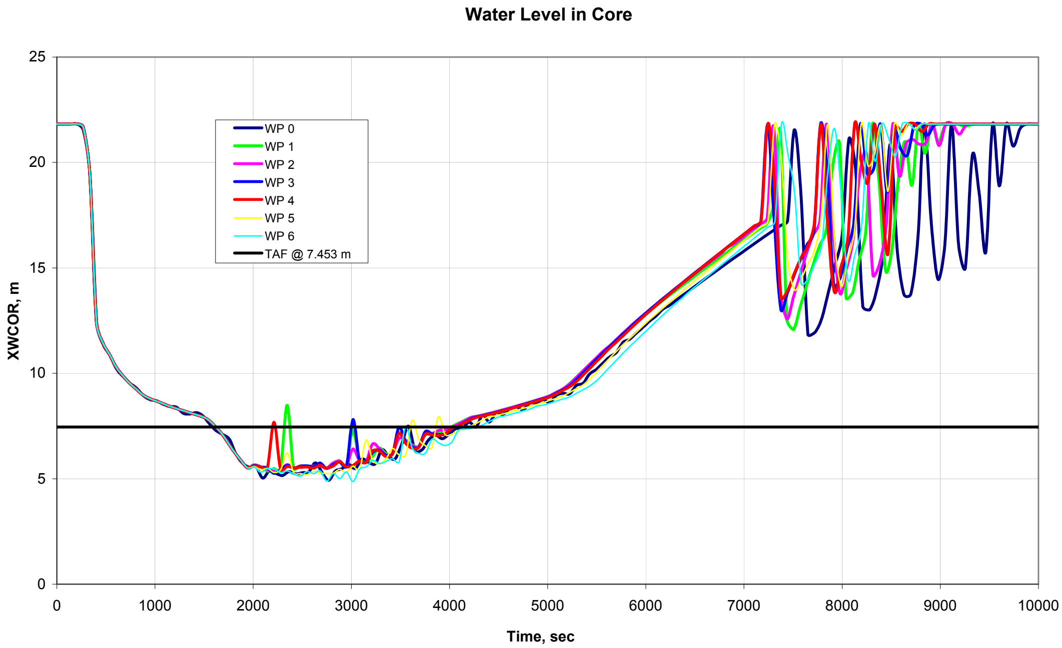

Figure 11A-64. PCCS – Level Profile of XWCOR for LLOCA

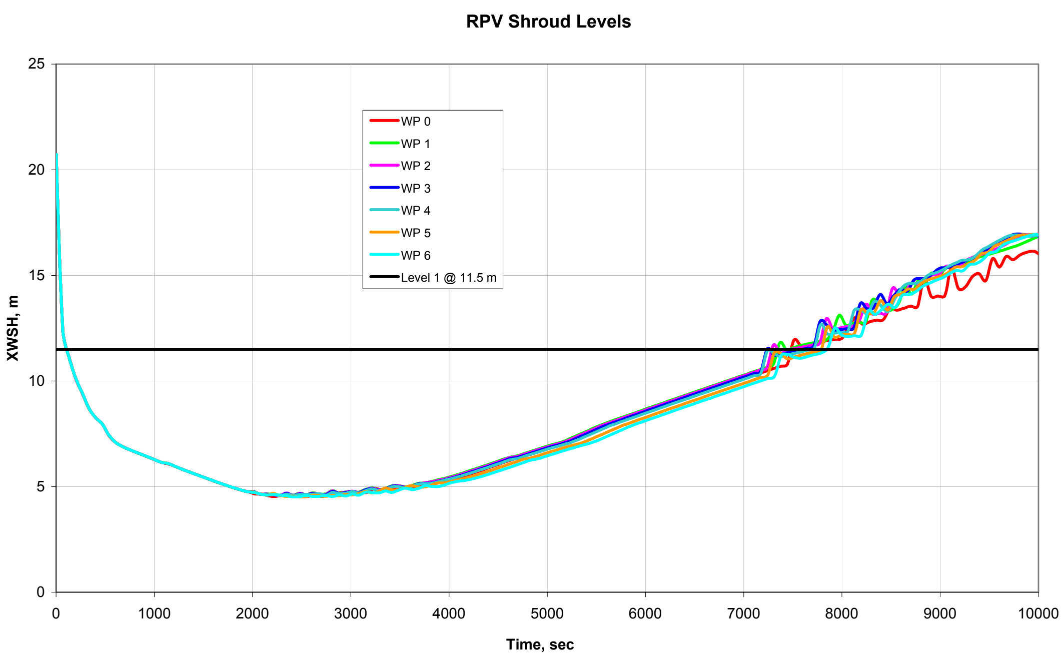

Figure 11A-65. PCCS – Level Profile of XWSH for LLOCA

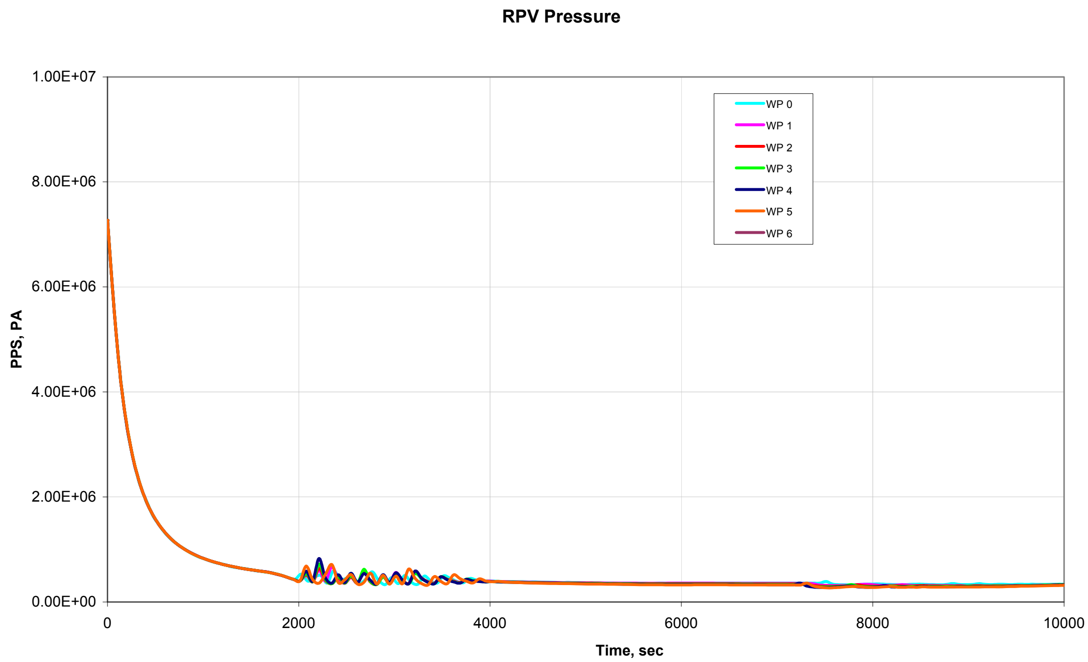

Figure 11A-66. PCCS – Pressure Profile of PPS for LLOCA

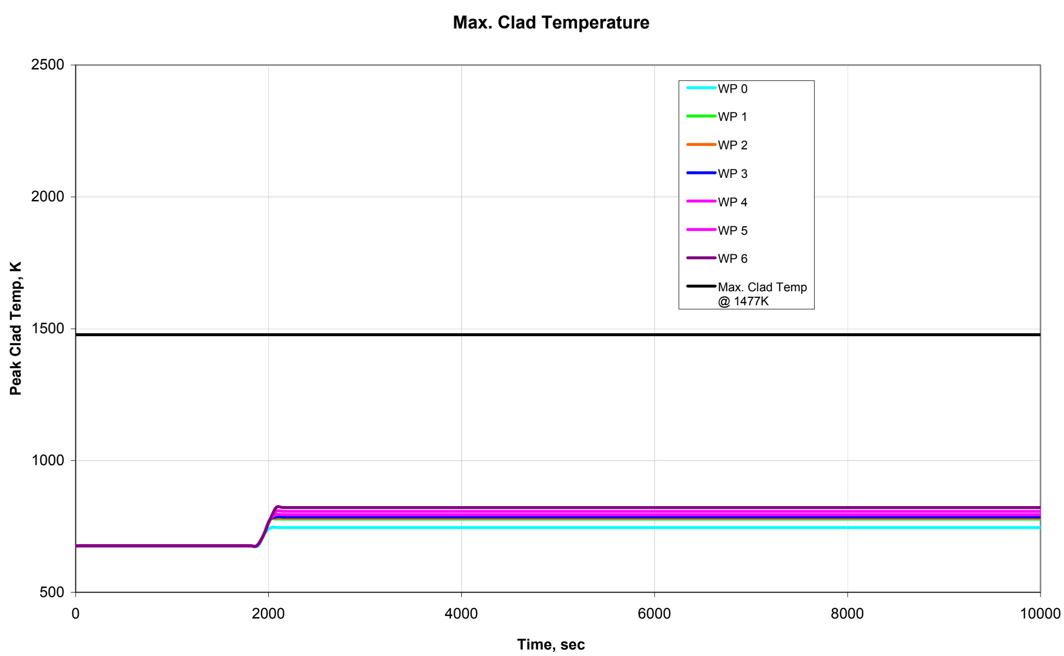

Figure 11A-67. PCCS – Temperature Profile of Max Clad Temp for LLOCA

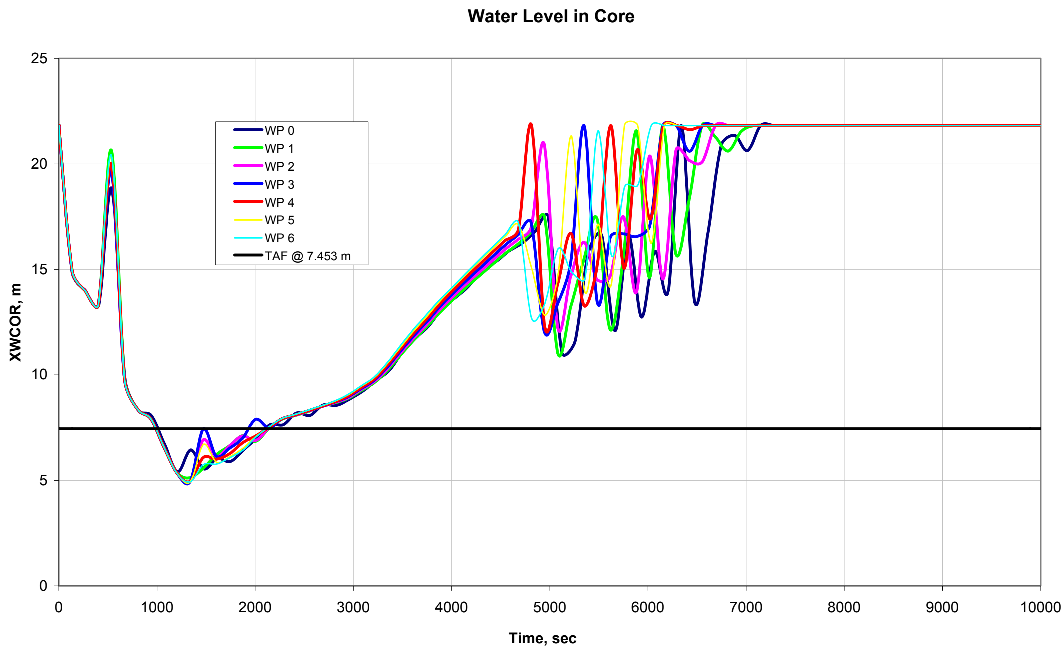

Figure 11A-68. PCCS – Level Profile of XWCOR for MLOCA

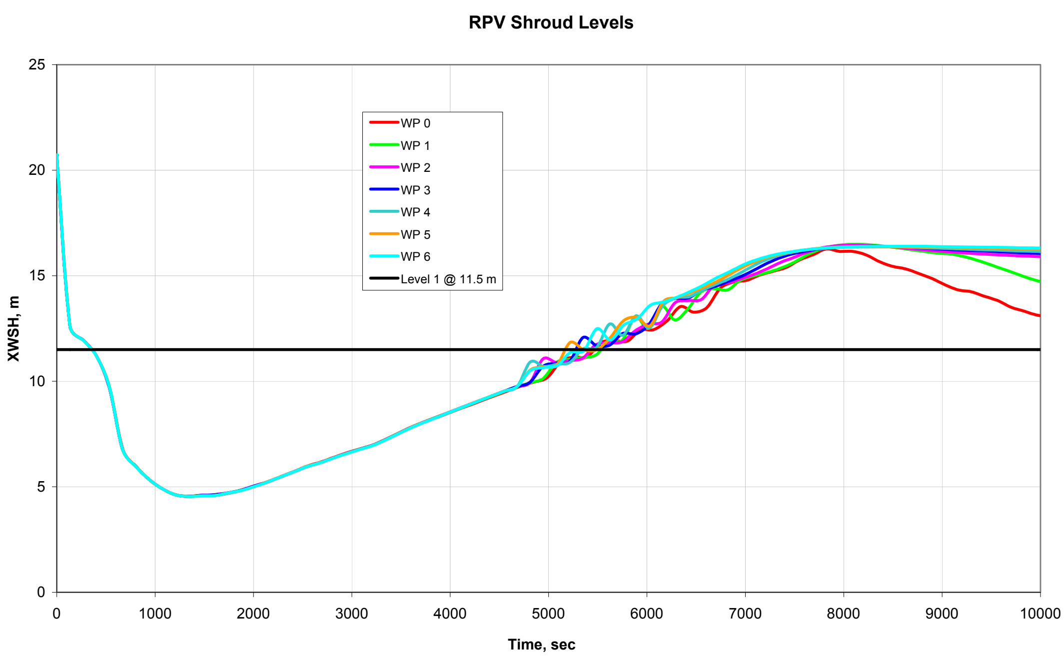

Figure 11A-69. PCCS – Level Profile of XWSH for MLOCA

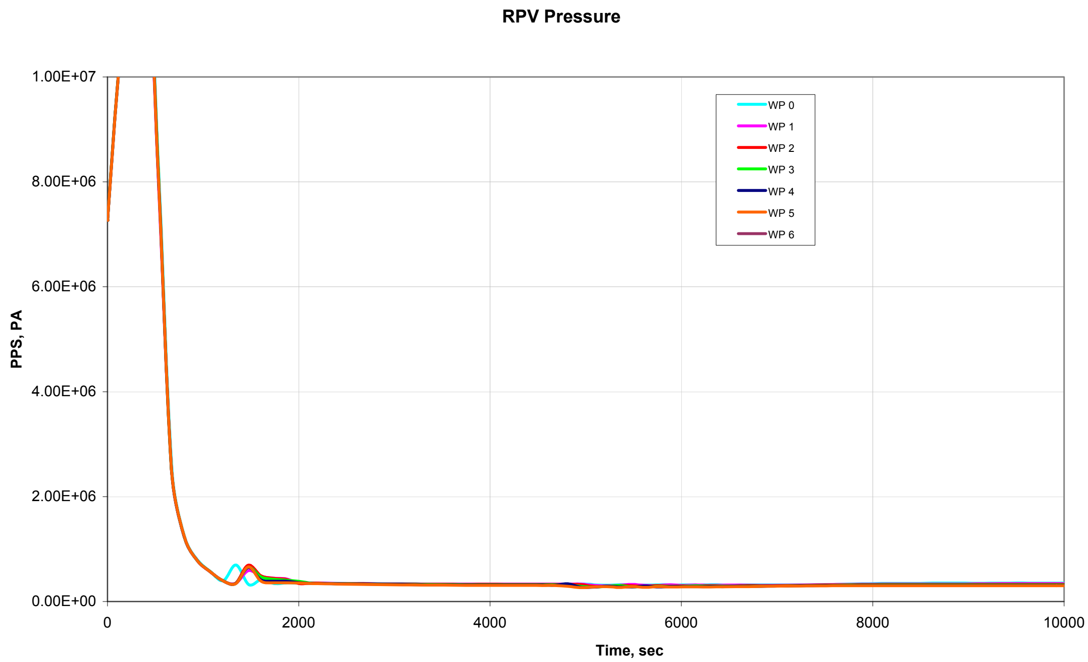

Figure 11A-70. PCCS – Pressure Profile of PPS for MLOCA

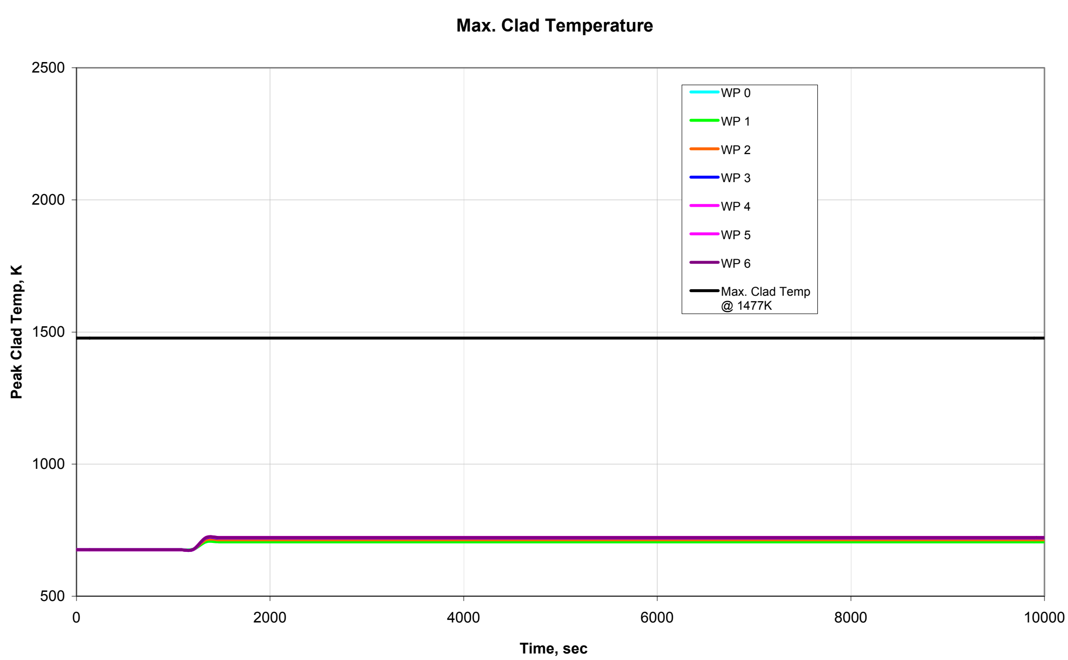

Figure 11A-71. PCCS– Temperature Profile of Max Clad Temp for MLOCA

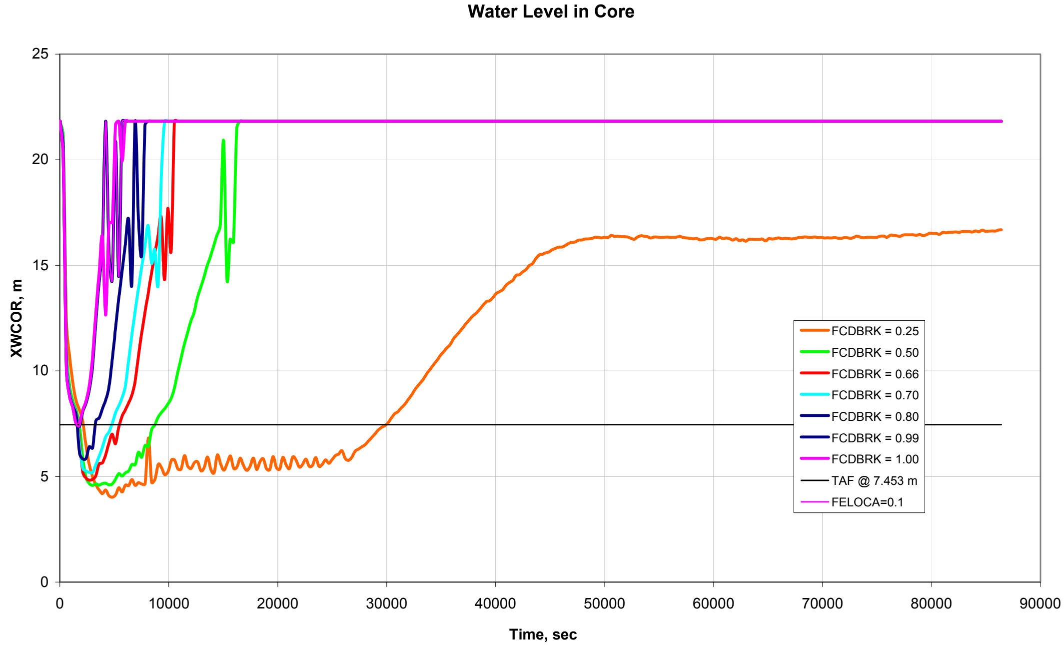

Figure 11A-72. Break Flow – Level Profile of XWCOR for LLOCA

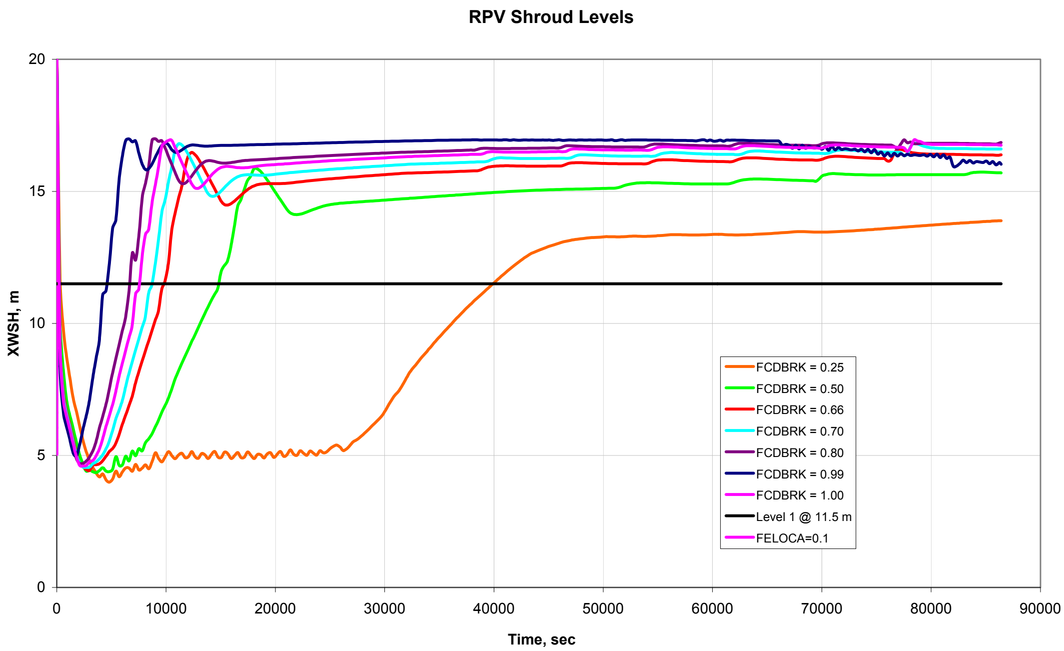

Figure 11A-73. Break Flow – Level Profile of XWSH for LLOCA

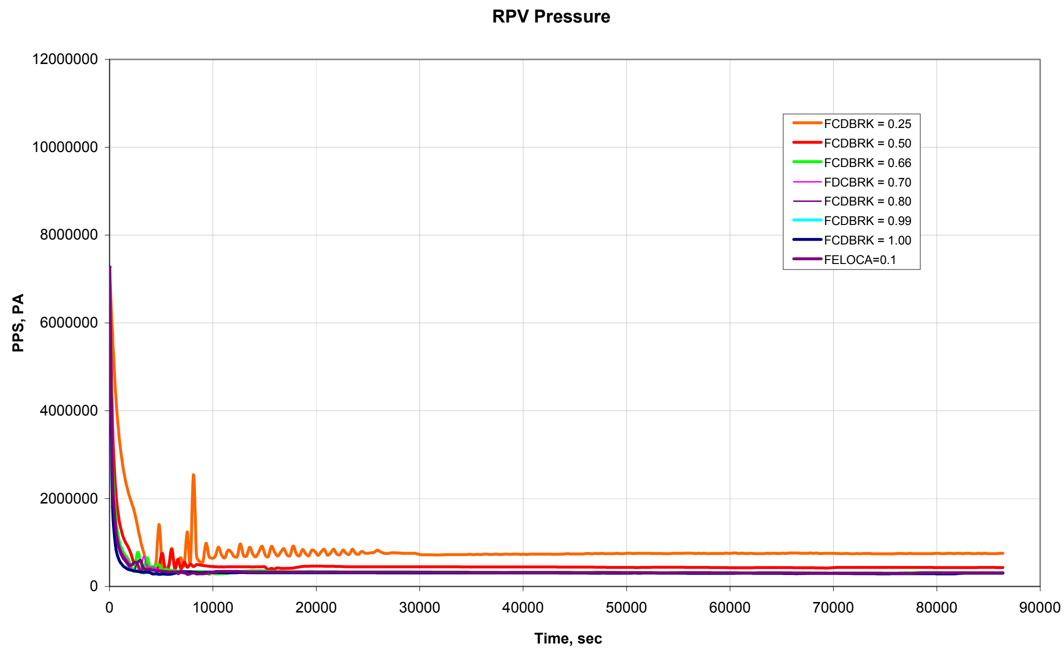

Figure 11A-74. Break Flow – Pressure Profile of PPS for LLOCA

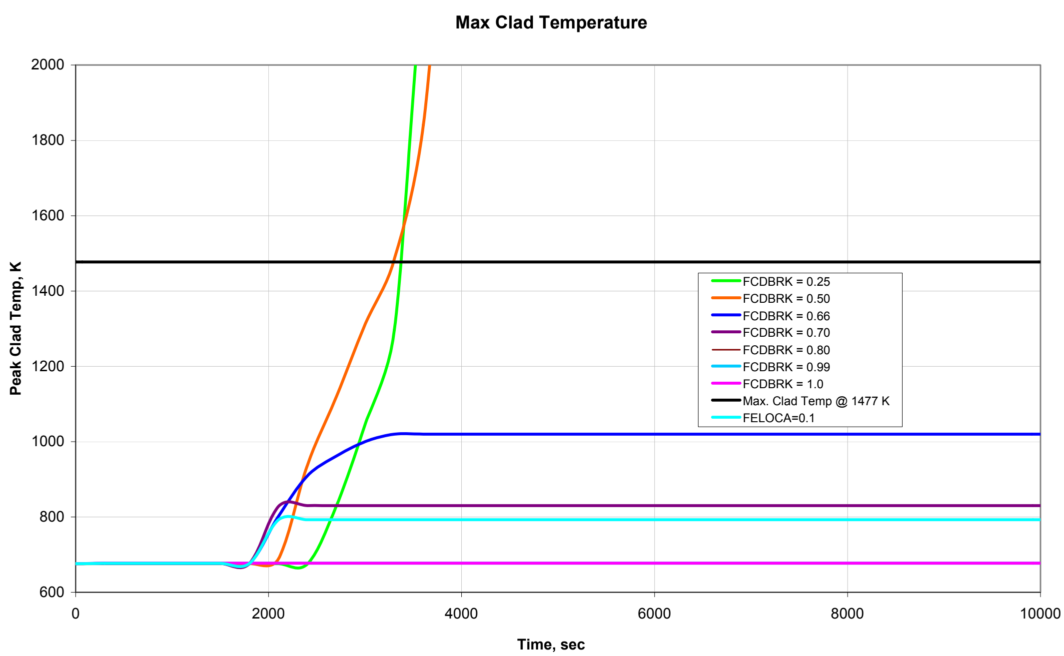

Figure 11A-75. Break Flow– Temperature Profile of Max Clad Temp for LLOCA

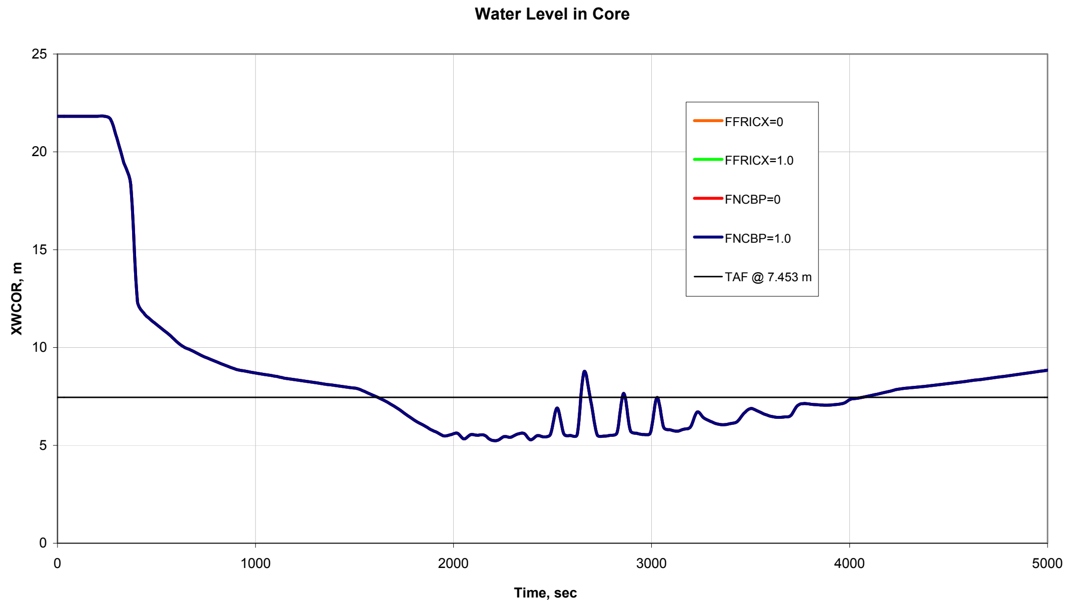

Figure 11A-76. Natural Circulation – Level Profile of XWCOR for LLOCA

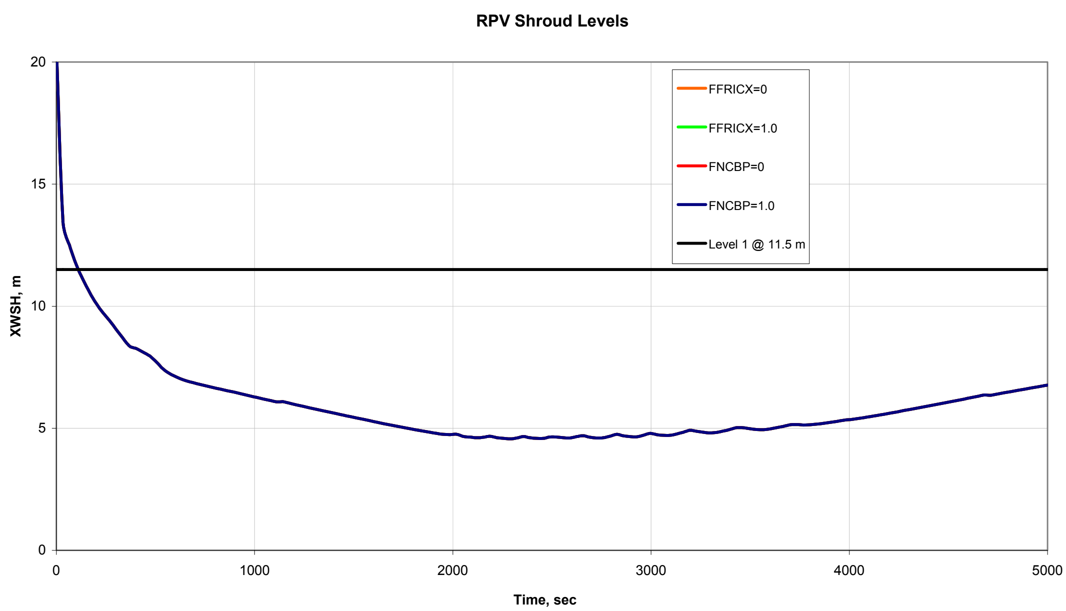

Figure 11A-77. Natural Circulation – Level Profile of XWSH for LLOCA

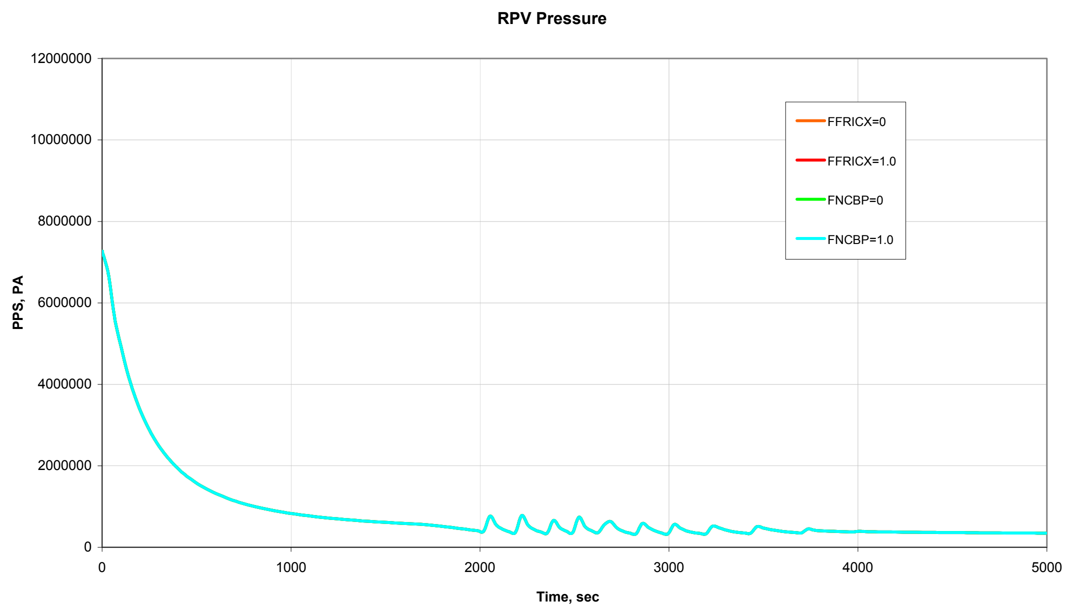

Figure 11A-78. Natural Circulation – Pressure Profile of PPS for LLOCA

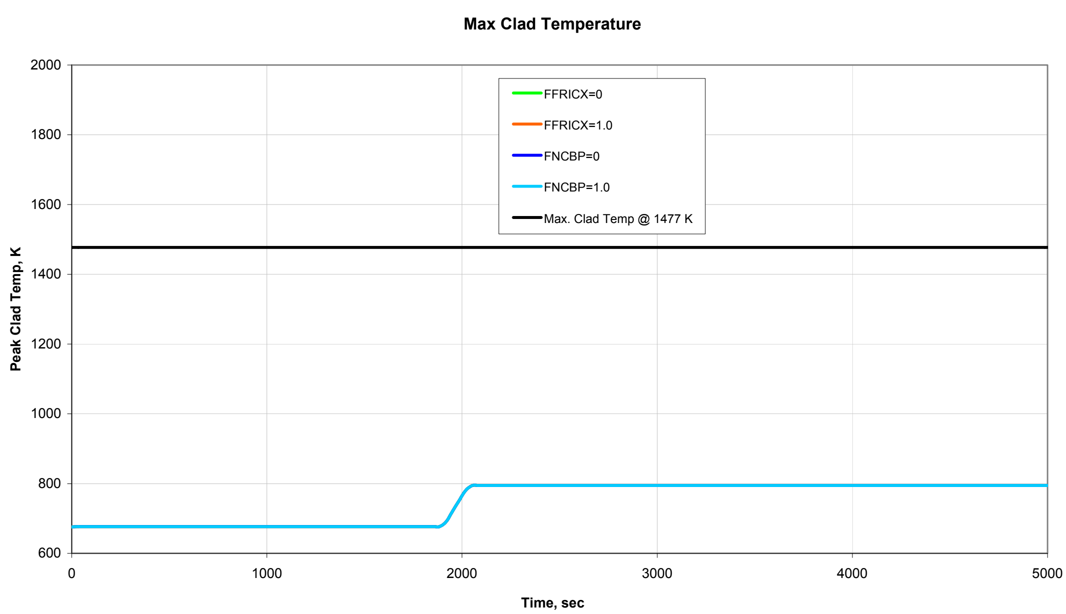

Figure 11A-79. Natural Circulation – Temperature Profile of Max Clad Temp for LLOCA