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Trip Coverage Analysis of the Loss of Secondary Circuit Pressure Control Accident for Wolsong1 NPP Loaded with the CANFLEX-NU Fuel

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ABSTRACT

A safety analysis of the loss of 2nday circuit pressure control for Wolsong 1 Nuclear Power Plant (NPP) loaded with the CANFLEX-NU fuel that could lead to either steam generator depressurization or pressurization is done for an assessment of reactor trip coverage. Events that require shutdown system action are identified and the relief capacity of the overpressure protection system (i.e., MSSVs) is demonstrated. The analysis was performed using the PHT circuit model in conjunction with the CATHENA computer code. In the case of loss of secondary control which leads to steam generator depressurization such as an inadvertent opening of all CSDVs during the alternate mode of operation, the system reaches a quasi-steady state with the steam generator pressure control restoring steam generator pressure to a value near the operating level. For events such as an inadvertent opening of all MSSVs during the alternate mode of operation, the pressurizer low level trip is effective both shutdown systems. High HT pressure and steam generator low level trips are effective for SDS1 and SDS2 as a second shutdown system respectively. For the loss secondary control pressurization scenario (a loss of condenser vacuum), the overpressure protection system always limits the pressure rise by opening all MSSVs. If only 12 out of 16 MSSVs are credited, the system reaches a quasi-steady state with the steam generator pressure stable around 5.1 MPa with reactor regulating system (RRS) operating. Once the secondary circuit inventory is depleted due to discharge from the MSSVs, reactor trip would occur on low boiler level or high heat transport system pressure. The high neutron power trip and the delayed high HT pressure trip are effective for both shutdown systems when RRS is not operating. At lower power levels, automatic trips are not required since 12 out of 16 MSSVs suffice to limit the pressurization. Process system action (a reactor setback), if credited, is effective as well to safely terminate this event. Therefore, adequate trip coverage is demonstrated, where required, for a loss of secondary pressure control transient.

1. Introduction

The loss of secondary circuit pressure control analysis, is one portion of the trip coverage assessment required for both shutdown systems. This analysis discusses the loss of secondary circuit pressure control system failures that could lead to either steam generator (SG) pressurization or depressurization and identifies events that require either safety system or operator intervention to mitigate the consequences of the failure. It also assesses the effectiveness of the shutdown systems where they are required.

Pressurization of the heat transport secondary side can be the result of an excessive amount of heat from the reactor or from an inadequate rejection of steam via the regulating valves. The fuel is not at risk unless the reactor power is excessive. A fast increase in pressure corresponds to a loss of condenser vacuum, which would trip the turbine and cause the condenser steam discharge valves to close. This prevents turbine bypass flow, which would control pressurization. Thus, this event tests the relief capacity of the atmospheric steam discharge valves (ASDVs) and the main steam safety valves (MSSVs). Steam generator depressurization can be caused by the heat removal rate via steam discharge exceeding the heat generation rate. This can be caused by the inadvertent opening of either the ASDVs, the CSDVs or the MSSVs.

The analysis was performed with the CATHENA thermalhydraulic computer code. Feedline low pressure trip, SG low level trip, high heat transport system pressure trip, high neutron power trip, low pressurizer level trip, and low heat transport system pressure trip were considered for both shutdown systems in this analysis. A more detailed assessment of fuel and sheath temperatures was also performed for a few cases using the CATHENA single channel model.

2. Event Description

2.1 Steam generator Depressurization

Steam generator depressurization is caused by the heat removal rate via the discharge of steam exceeding the heat generation rate. Events that could lead to depressurization are:

a) inadvertent opening of either the atmospheric steam discharge valves (ASDVs), condenser steam discharge valves (CSDVs) or main steam safety valves (MSSVs), or
b) failure of the turbine governor valves to unload (close) following a reduction in reactor power.

2.2 Steam Generator Pressurization

Steam generator pressurization is caused by a steam generation rate greater than the steam discharge rate. For such an event to occur, control system failures must occur which result in a sustained imbalance between the reactor power and the total steam loads.

The cause of the overpressurization is selected as a loss of condenser vacuum, since it gives a fast rate of pressurization. The CSDVs are closed on a high condenser vacuum signal. This prevents turbine bypass flow which would otherwise control the pressurization, since the CSDVs can pass 100 percent nominal steam flow. Thus, the choice of this initiating event as a cause of the secondary heat transport system pressurization tests the relief capabilities of the ASDVs and MSSVs.

3. Analysis Models and Methodology

The trip coverage analysis was performed using the CATHENA circuit model [3 and 4]. More detailed fuel and sheath temperature calculations were performed with a CATHENA single channel [5] model.

3.1 CATHENA Model

CATHENA was used for the thermalhydraulic trip coverage analysis for loss of secondary circuit pressure control as stated in this analysis. CATHENA was used to predict the reactor trip times, the reactor power transient as well as pressure and flow transients. The nodalization for the channel inlet feeder and end fitting, fuel string, channel outlet endfitting and channel outlet feeder is used for the Wolsong 1 CATHENA Model. The feed and bleed system, which is modelled with pipe components connected to each reactor loop, the pressurizer and degasser-condenser system, and steam and feedwater system are included. The pressurizer, which is connected to each reactor loop at the riser downstream of headers 3 and 7, is modelled by a CATHENA Generalized Tank Model. The two loops of the Primary Heat Transport System (PHTS) are modelled. For the trip coverage analysis, CATHENA two loops model will be used always.

3.2 Shutdown System No.1

Table 1 shows the SDS1 trip parameters. SDS1 reactivity is calculated under the assumption that the two most effective rods are unavailable. When fully inserted, SDS1 static reactivity worth is 57 mk [9].

3.3 Shutdown System No.2

Table 2 shows the SDS2 trip parameters. The SDS2 reactivity is calculated under the assumption that the most effective liquid injection system nozzle is out of service. In trip coverage assessment, the SDS1 reactivity curve may be conservatively used.

3.4 CATHENA Simulation

A CATHENA high powered channel model (O6_mod) for the CANFLEX-NU was simulated to assess the fuel performance in more detail [5 to 7] for a few limiting cases. As described in Reference 5, channel O6 was identified as a high powered channel and as having the minimum critical channel power ratio (CPR) with respect to dryout. The fuel and sheath temperatures were calculated for this channel, using the boundary conditions generated by the CATHENA simulation of the PHT circuit.

The channel power for this high powered channel (O6) for the CANFLEX-NU is 7.3MW which is the maximum allowable operating channel power. This licensing limit flux profile has the two central bundles at the maximum allowable operating bundle power limit of 935kW at the maximum allowable operating channel power of 7.3MW. The CATHENA high powered channel model (O6) is described in detail in Reference 5.

4. Analysis Results

Analyses were performed for the scenarios described in the last section. The analysis was performed for full power (103 percent). After the reactor is shut down, the steam generators are required to provide a heat sink to the HT system for a period of time sufficient for the operator to establish an alternative long term heat sink. The period of time for which heat sink capability is assured is related to the water inventory in the steam generators at the time of the reactor trip.

4.1 Steam Generator Depressurization

Transient analyses are presented for three scenarios: an opening of all CSDVs, an opening of all MSSVs, and the failure of turbine governor valve unloading following a reactor trip. The CSDVs have a combined capacity of 100% at steam generator operating pressure, used to bypass the turbine and discharge live steam to the condenser. The combined capacity of the MSSVs is such that 3 out of 4 MSSVs provide a capacity of 115% of steam flow from each steam generator [11].

4.1.1 Results for An Inadvertent Opening of the CSDVs

Inadvertent opening of the CSDVs causes the steam flow from the steam generators to accelerate. The steam generator pressure begins to fall. This depressurization event was analyzed for an initial power of 103 percent FP assuming the reactor is operating in alternate mode. The nominal operation conditions at various percent Power Levels are given in Table 3. The event transient results are given in Figures 1 to 2.

The steam generator pressure transient, steam flow to turbine and flow through the CSDVs are given in Figure 1. When all twelve CSDVs open at full power, boiler pressure decreases to around 4 MPa, but then recovers back to normal pressure by 100 seconds, as turbine governor valve closes. It closes in response to decrease in boiler pressure as part of the Boiler Pressure control logic with plant operating in alternate mode. The flow to the turbine then stops as the valve closes, and the flow through the open CSDVs becomes steady near 950 kg/s.

Figure 2 shows the reactor power, outlet header pressure and pressurizer level transient. There is a brief decrease in outlet header pressure in response to the sudden increase in secondary side flows and decrease in pressure resulting from the CSDVs opening. Outlet header pressure also recovers and stabilizes near the setpoint of 9.99 MPa. The pressurizer level follows a similar trend as the outlet header pressure. That is, the level decreases at the beginning to accommodate shrinkage of the primary heat transport coolant as the boilers remove more heat at first. Eventually, the level stabilizes to slightly under 10 metres. This is lower than the initial level of 12 metres because the inlet header temperature is much lower (only 261 degrees C) than what it was at the beginning when the event started (267 C).

No process trip are predicted here, and none are required, since adequate cooling is maintained following the events, and the system soon achieves a quasi-steady state condition which can continue until operator intervention.

4.1.2 Results for An Inadvertent Opening of the MSSVs

Figure 3 shows the subsequence of the reactor power, steam generator pressure and steam generator level. Boiler pressure falls quickly to near 4 MPa after MSSVs open, but then pressure recovers slightly after turbine governor valve is closed due to sudden increase in boiler level which trips the turbine. Boiler pressure gradually falls during the transient to 400 seconds as the flow leaving the boilers is slightly higher than nominal steam flow at full power. Over-cooling of the HTS occurs during this time, until feedwater stops at 400 seconds. This causes the PHTS to depressurize and get cooler and the pressurizer level to fall as the primary system coolant shrinks.

Between 400 and 450 seconds, the inventory remaining in the boiler still maintains some heat removal from the primary side. Boiler pressure rises during this time as the secondary side inventory heats up and boils off in the absence of feedwater inflow (with the saturation temperature and pressure increasing together).

HTS pressure gradually decreases during first 200 seconds, then holds nearly steady at around 9 MPa in the outlet headers (See Figure 4). After 400 seconds, ROH pressure increases once the heat transfer to secondary side is reduced as feedwater flow stops. The pressure rises enough to open the LRVs around 440 seconds. ROH pressure falls after reactor trip.

Feedwater flow is maintained around 250 kg/s until 400 seconds when feedwater supply from deaerator storage tank is exhausted. Secondary circuit inventory is lost through the MSSVs; therefore, there is no recovery of feedwater supply from the condensers.

Reactor trips at 466 seconds. Pressurizer low level trip at 273.3 seconds on both SDS1 and SDS2. SDS1 high HTS pressure at 451.9 seconds. SDS2 low boiler level trip at 466.6

seconds.

4.1.3 Results for A Failure to Unload the Turbine After a Reactor Trip

Following a reactor trip, the steam generator pressure control operates in alternate mode and signals the turbine governor valve to begin closing in response to the power reduction directly and to subsequent drop in steam generator pressure as the heat load decreases. The generator was assumed not to respond at all in this case and was assumed to remained “frozen” at the operating position.

The governor valve stays open at the steady state position in this analysis (Figure 5). Turbine chest pressure falls as reactor power decreases, but it is unknown how fast it falls, so for this analysis, it is assumed to suddenly fall to 1.0 MPa. Figure 6 shows the steam generator pressure, outlet header pressure and pressurizer level transient. Depressurization of the secondary side however, is much faster than that for a normal reactor trip since the governor valve would normally close to keep the pressure up. The PHTS pressure falls rapidly - partly the result of the reactor trip, and partly because of the secondary side depressurization.

Feedwater flows and boiler levels are predicted to become unstable at decay power levels because this CATHENA model is not able to simulate steady state steam generator conditions (except pressure) at low power. However, this does not affect the conclusions of this analysis in the context of trip coverage. Good cooling of the core is maintained indefinitely for this transient, and there is no loss of secondary side feedwater inventory for this scenario.

4.1.4 Trip Coverage Summary for Steam Generator Depressurization Events

A loss of secondary circuit pressure control which leads to depressurization causes excessive cooling of the primary circuit. For event such as CSDVs opening at full power during the alternate mode of operation, no automatic trips are required. The steam generator pressure control restores steam generator pressure to a value near the operating level. The reactor is operating in a quasi-steady state condition.

For event such as MSSVs opening at full power, SDS1/SDS2 pressurizer low level trip and SDS1 high HTS pressure trip and SDS2 low boiler level trip are effective.

For event such as failure to unload the turbine following a reactor trip, there is no impairment of fuel cooling and a heat sink is continuously available.

4.2 Steam Generator Pressurization

Steam generator pressurization is caused by a steam generation rate greater than the steam discharge rate. The transient analysis is presented for the scenario of a loss of condenser vacuum. This initiating event gives a fast rate of pressurization.

4.2.1 Results for A Loss of Condenser Vacuum with Reactor Regulating System Operating

This pressurization event was analyzed for an initial power of 103 percent FP crediting the reactor regulating system action. For conservatism, the ASDVs were not credited. The analysis was first performed to test the relief capacity of the MSSVs. The capacity of all MSSVs provide a capacity of 115% of steam flow from each steam generator [4]. Primary and secondary circuit integrity is maintained throughout the pressurization event.

Figure 7 shows the pressurization transient results on the steam generator pressure, steam generator level and MSSVs flow. Steam Generator pressure increases initially to 5.15 MPa due to closing of the governor valve and CSDV remain closed causing the MSSV's to open to relieve pressure. The SG pressure increases to 5.5 MPa and then decreases back to 5.15 MPa, and remains steady thereafter as the open MSSV's try to cope with the steam load.

The SG level continues to fall, eventually reaching the trip setpoints for both SDS, because the feedwater flow is reduced somewhat due to the higher secondary side pressure. The feedwater valves are fully open; however the flow is still limited by the capacity of the feedwater pumps. The primary and secondary system flows, pressures and temperatures reach a quazi steady state, which is maintained until the feedwater inventory is nearly exhausted, and the feedwater pumps trip.

Figure 8 shows the PHTS inlet temperature, LRV flow and heat to boiler. The boiler itself still is able to remove some of the heat from the core until its inventory is exhausted. However, the PHTS inlet header temperature and pressure rise steadily after the feed water flow to the boiler stops. The LRVs open again, but the pressure continues to rise, eventually reaching the respective trip setpoint for each SDS. The reactor is assumed to trip at the time of the SDS2 HP trip which is the 2nd trip of the later SDS.

After reactor trip, heat removal from the core is provided by the remaining boiler secondary side inventory, and then the operator would then establish an alternative heat sink by initiating Emergency Water Supply (EWS) or Shutdown Cooling.

4.2.2 Results for A Loss of Condenser Vacuum with Reactor Regulating System Frozen

The above pressurization event crediting only 12 out of 16 MSSVs was repeated for an initial power of 103 percent FP with the reactor regulating system (RRS) frozen. In this case, it is assumed that the Reactor Regulating system (RRS) devices are frozen, and are thus unable to respond to changes in core conditions affecting reactor power. The transient results are given in Figures 9 and 10.

Figure 9 presents the Reactor Power, ROH Pressure and SG Pressure. As in the RRS working case, the steam generator pressure increases initially to 5.15 MPa due to closing of the governor valve and CSDV remain closed causing the MSSV's to open to relieve pressure. The pressure continues to increase thereafter as the reactor power rises. This indicates that 3 of 4 MSSVs opening is not quite enough to allow sufficient steam flow to remove the heat generated in the core at full power.

The increase in SG pressure (and saturation temperature) causes the primary heat transport system pressure to rise enough to open the LRVs (Figure 10). The opening of the LRVs allows coolant to escape the PHTS and results in increased void in the core. This, in turn, causes the reactor power to increase, which in turn, causes the PHTS and steam generator pressure to increase even more. The delayed HP trip for both SDS occurred at 11.8 seconds, however reactor trip is not simulated until the second parameter. The pressure continues to rise until the ROH pressure increases beyond the trip setpoints for SDS1 and SDS2. The SG pressure peaks at 5.3 MPa, when reactor trip occurs. The power increases till the ROP trip setpoints for both SDS around 23 seconds. This is the second trip parameter.

4.2.3 Trip Coverage Summary for Steam Generator Pressurization Events

Analysis of the secondary circuit response to a pressurization event indicates that the pressure rise may be terminated by overpressure relief if RRS can maintain constant reactor power. The overpressure protection system limits the pressure rise by opening 3 out of 4 MSSVs provide a capacity of 115% of steam flow from each steam generator and therefore terminate any pressurise rise. In the case where RRS is frozen and cannot arrest the increase in reactor power, 3 of 4 MSSVs does not quite provide enough relief capacity and thus the boiler pressure will continue to rise..

If 12 out of 16 MSSVs are credited, the SDS1 and SDS2 steam generator low level trips as well as SDS1 and SDS2 high HTS pressure trips are effective. For the case where RRS is frozen, the SDS1 and SDS2 high neutron power trips as well as the SDS1 and SDS2 delayed high HTS pressure trips are effective. Primary and secondary circuit integrity is maintained throughout the pressurization event.

4.3 CATHENA Slave Channel Results

The fuel and sheath temperatures were calculated for a few limiting cases using a CATHENA high powered channel model (O6_mod). These cases include both the depressurization and pressurization events. The results show that the fuel and sheath temperatures remain low throughout these transients (Figures 11 and 12). Fuel and fuel channel integrity is maintained.

6. Conclusions

Trip coverage for a loss of secondary pressure control which leads to steam generator depressurization has been assessed. For an inadvertent opening of all CSDVs during the alternate mode of operation, the system reaches a quasi-steady state with the steam generator pressure control restoring steam generator pressure to a value near the operating level. Since pressure remains low and the fuel remains well cooled, automatic trips are not required for this event. For an inadvertent opening of all MSSVs, there are two effective trip parameters on both SDS1 and SDS2. For failure to unload the turbine following a reactor trip, there is no impairment of fuel cooling and a heat sink is continuously available.

For the loss of secondary pressure control pressurization transient (a loss of condenser vacuum), the overpressure protection system always limits the pressure rise by opening MSSVs.

If only 12 out of 16 MSSVs are credited, the SDS1 and SDS2 steam generator low level trips as well as SDS1 and SDS2 high HTS pressure trips are effective. The PHT pressure remains within ASME limits. Fuel and sheath temperatures remain low and hence, fuel and fuel channel integrity is maintained. When the RRS is frozen, the high power trip is effective, as well asthe delayed high HTS pressure trip for both shutdown systems. Fuel cooling capability is not impaired by control failures leading to pressurization of the steam generators and primary and secondary circuit integrity is maintained.

After the reactor is shut down, the steam generators are required to provide a heat sink to the HT system for a period of time sufficient for the operator to establish an alternative long term heat sink. The period of time for which heat sink capability is assured is related to the water inventory in the steam generators at the time of the reactor trip. In cases where the MSSVs remain closed, there is no feedwater loss for a loss of secondary pressure control. However, if the MSSVs open, the supply of feedwater may be terminated. However, the water remaining in the steam generators would provide an adequate heat sink for the PHT circuit heat generation. Long term transient to show that the steam generators can remove the PHT heat is therefore bounded by the feedwater system failures analysis [1].

Adequate trip coverage is demonstrated, where a trip is required, for a loss of secondary pressure control. Therefore, R-8 requirements [2] for this event are satisfied.

The fuel type (CANFLEX) appears to have no significant effect on the trip coverage results.

6. References

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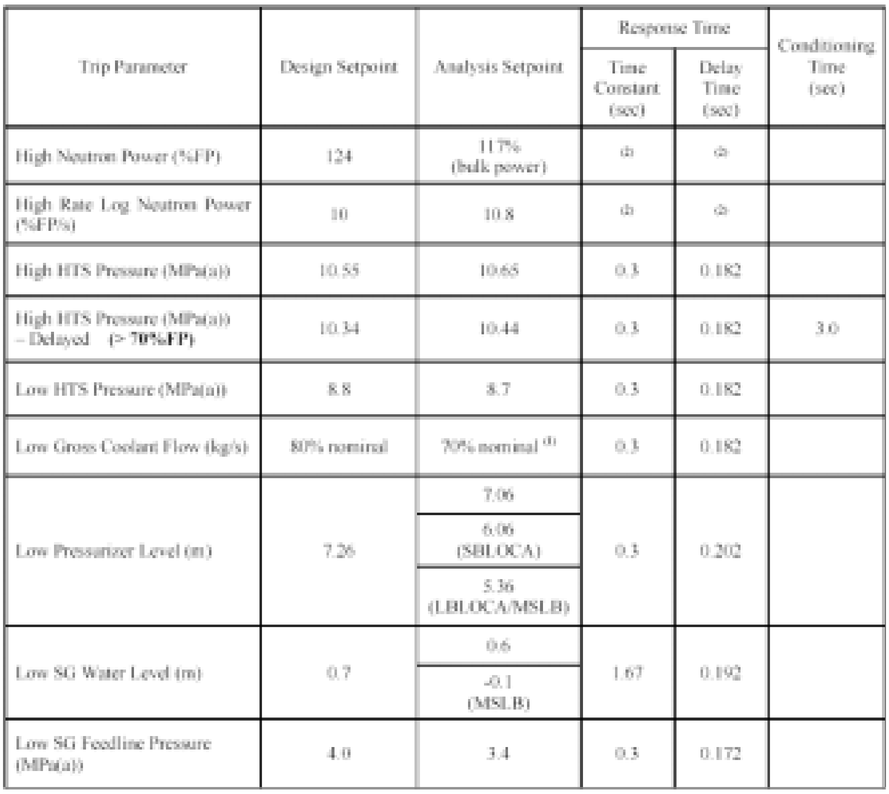
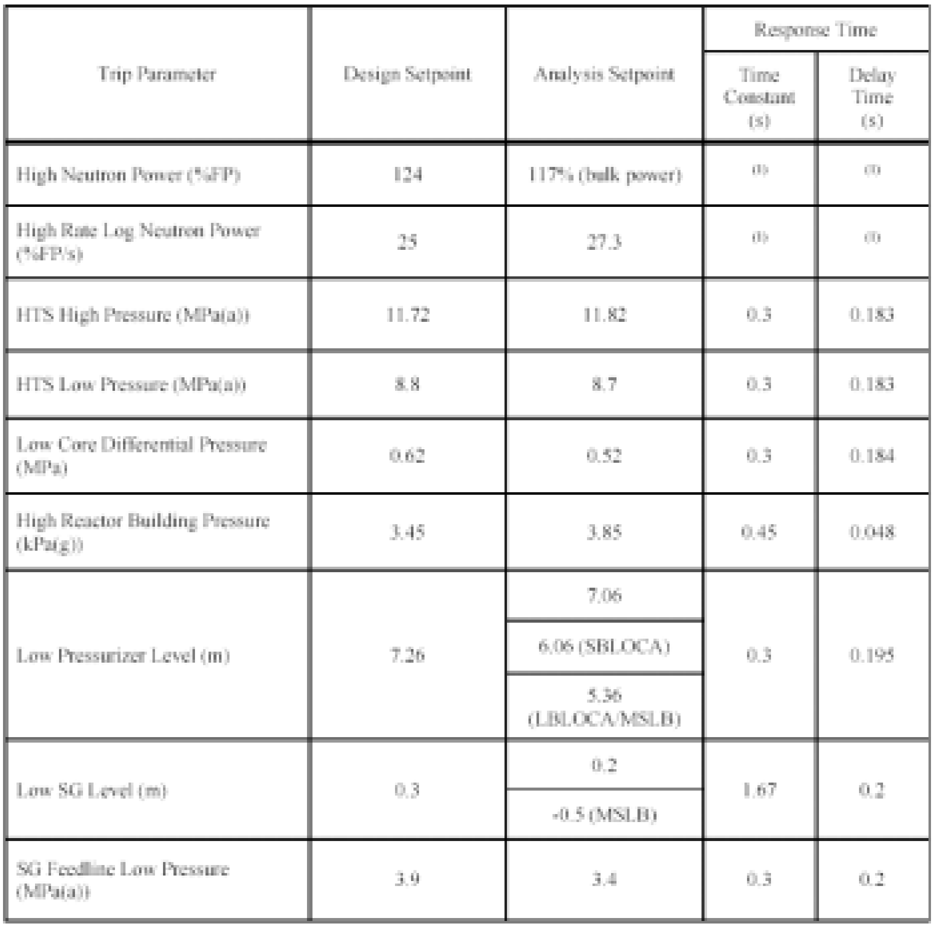
Table 1
SDS1 Trip Setpoints for Loss of Secondary Circuit Pressure and Inventory Control Analysis



Trip Parameter	Design Setpoint	Analysis Setpoint	Response Time		Conditioning Time (sec)
			Time Constant (sec)	Delay Time (sec)	
High Neutron Power (%FP)	124	117% (bulk power)	(1)	(2)	
High Rate Log Neutron Power (%FP/s)	10	10.8	(1)	(2)	
High HTS Pressure (MPa(a))	10.55	10.65	0.3	0.182	
High HTS Pressure (MPa(a)) – Delayed (> **70%FP**)	10.34	10.44	0.3	0.182	3.0
Low HTS Pressure (MPa(a))	8.8	8.7	0.3	0.182	
Low Gross Coolant Flow (kg/s)	80% nominal	70% nominal (3)	0.3	0.182	
Low Pressurizer Level (m)	7.26	7.06 6.06 (SBLOCA) 5.36 (LBLOCA/MSLB)	0.3	0.202	
Low SG Water Level (m)	0.7	0.6 -0.1 (MSLB)	1.67	0.192	
Low SG Feedline Pressure (MPa(a))	4.0	3.4	0.3	0.172	

Table 2
SDS2 Trip Setpoints for Loss of Secondary Circuit Pressure and Inventory Control Analysis



Trip Parameter	Design Setpoint	Analysis Setpoint	Response Time	
			Time Constant (s)	Delay Time (s)
High Neutron Power (%FP)	124	117% (bulk power)	(1)	(1)
High Rate Log Neutron Power (%FP/s)	25	27.3	(1)	(1)
HTS High Pressure (MPa(a))	11.72	11.82	0.3	0.183
HTS Low Pressure (MPa(a))	8.8	8.7	0.3	0.183
Low Core Differential Pressure (MPa)	0.62	0.52	0.3	0.184
High Reactor Building Pressure (kPa(g))	3.45	3.85	0.45	0.048
Low Pressurizer Level (m)	7.26	7.06	0.3	0.195
		6.06 (SBLOCA)		
		5.36 (LBLOCA/MSLB)		
Low SG Level (m)	0.3	0.2	1.67	0.2
		-0.5 (MSLB)		
SG Feedline Low Pressure (MPa(a))	3.9	3.4	0.3	0.2

Table 3
Nominal Operating Conditions at Various Power Levels

Initial Power	**(%FP)**	**103**	**75**	**50**
Fuel Type		**Equilibrium**	**Equilibrium**	**Equilibrium**
Total Thermal Power-to-Coolant	(MW)	2112	1536	1024
Average Channel Power	(MW)	5.55	4.04	2.69
RIH Pressure	(MPa(a))	11.35	11.32	11.32
ROH Pressure	(MPa(a))	10.03	10.0	10.0
RIH Temperature	(°C)	268	265	263
ROH Temperature	(°C)	311	303	290
ROH Quality	(%)	4.5	0.0	0.0
Mass Flow Rate per Pass	(kg/s)	1917	1972	1984
Steam Generator Condition		fouled	fouled	Fouled
Steam Flow to Turbine	(kg/s)	1077	774	508
Steam Generator Power	(MW)	2124	1552	1040
Steam Generator Pressure	(MPa(a))	4.69	4.69	4.69

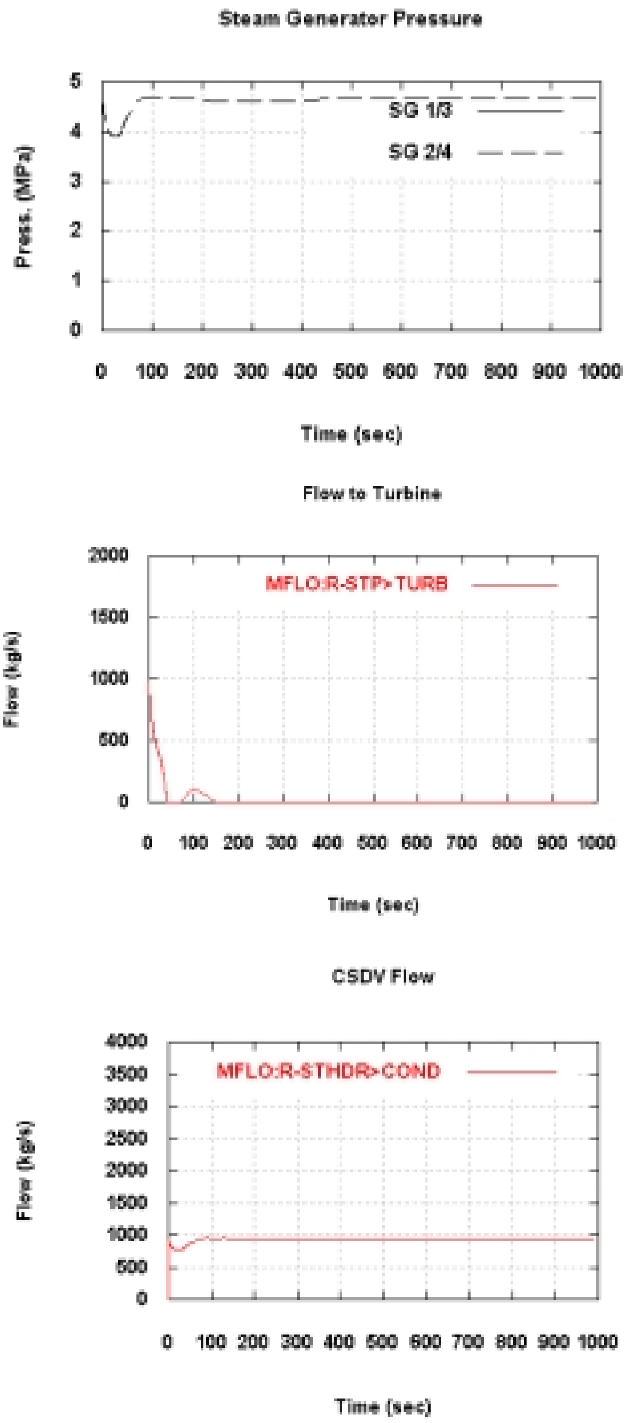


Figure 1 Depressurization Transient I (CSDVs Failed Open) from 103%FP, Alternate Mode of Operation - SG Pressure, Flow to Turbine and CSDV Flow

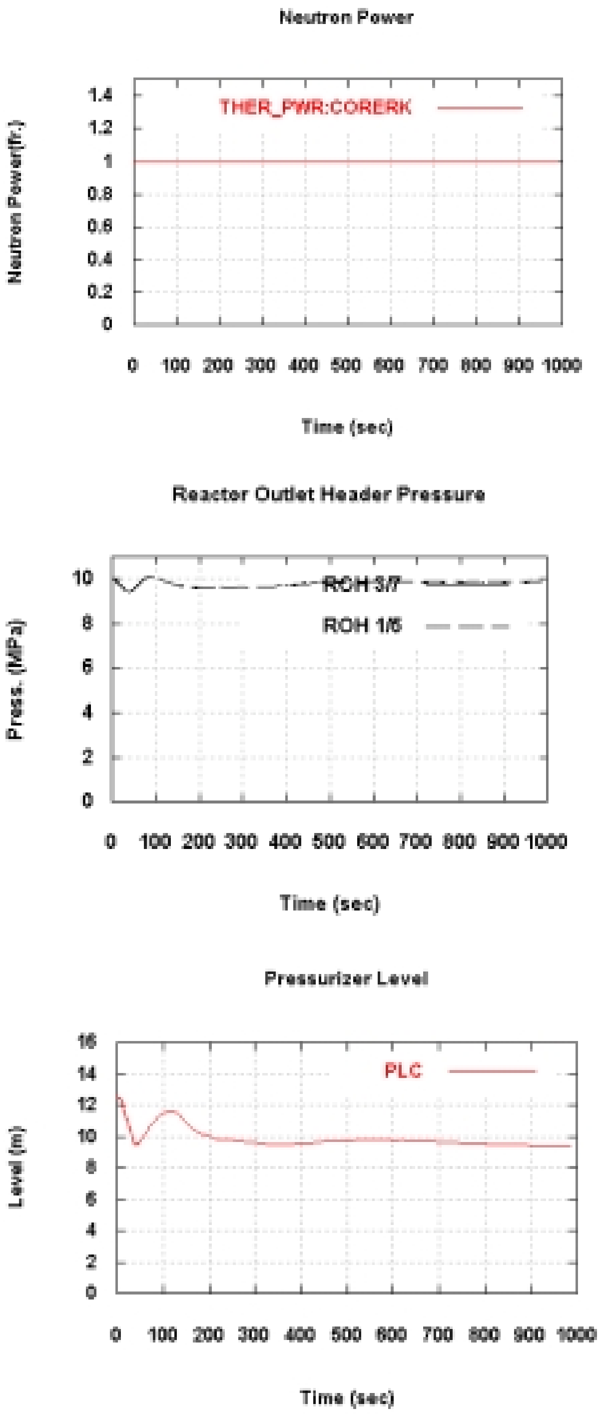


Figure 2 Depressurization Transient II (CSDVs Failed Open) from 103%FP, Alternate Mode of Operation – Reactor Power, ROH Pressure and Pressurizer Level

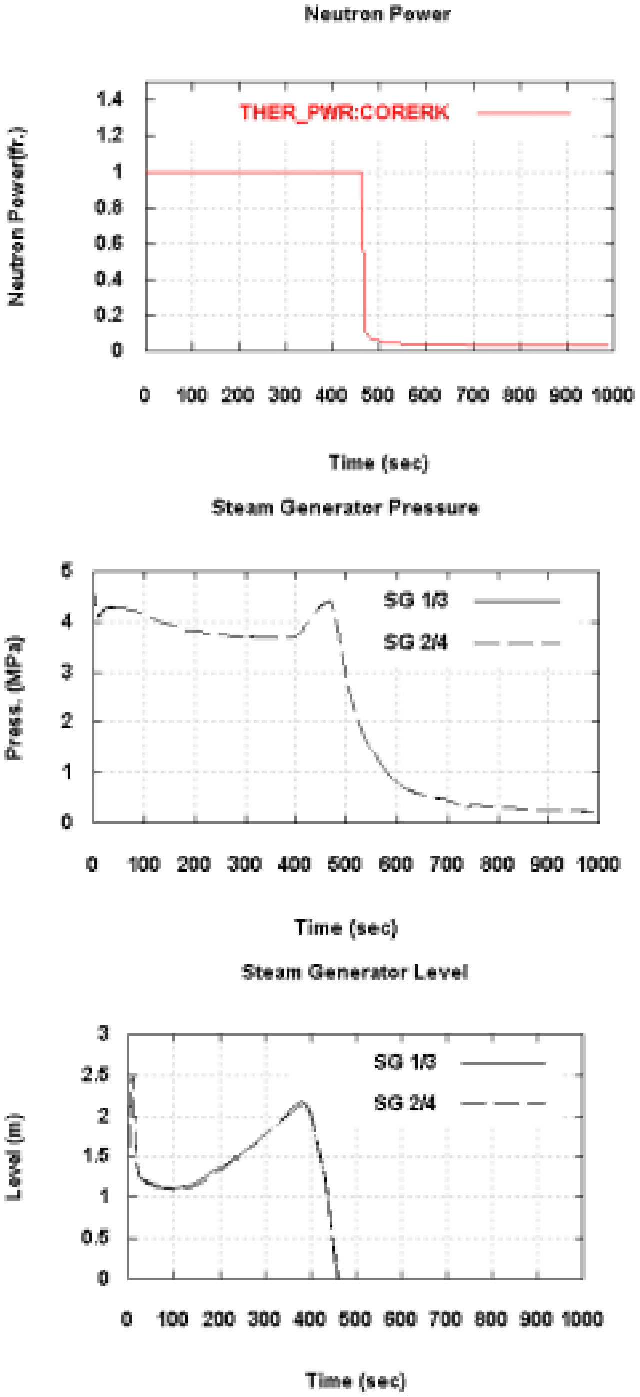


Figure 3 Depressurization Transient I (MSSVs Failed Open) from 103%FP (SDS 1&2 Pressurizer Low Level Trip) - Reactor Power, SG Pressure and Level

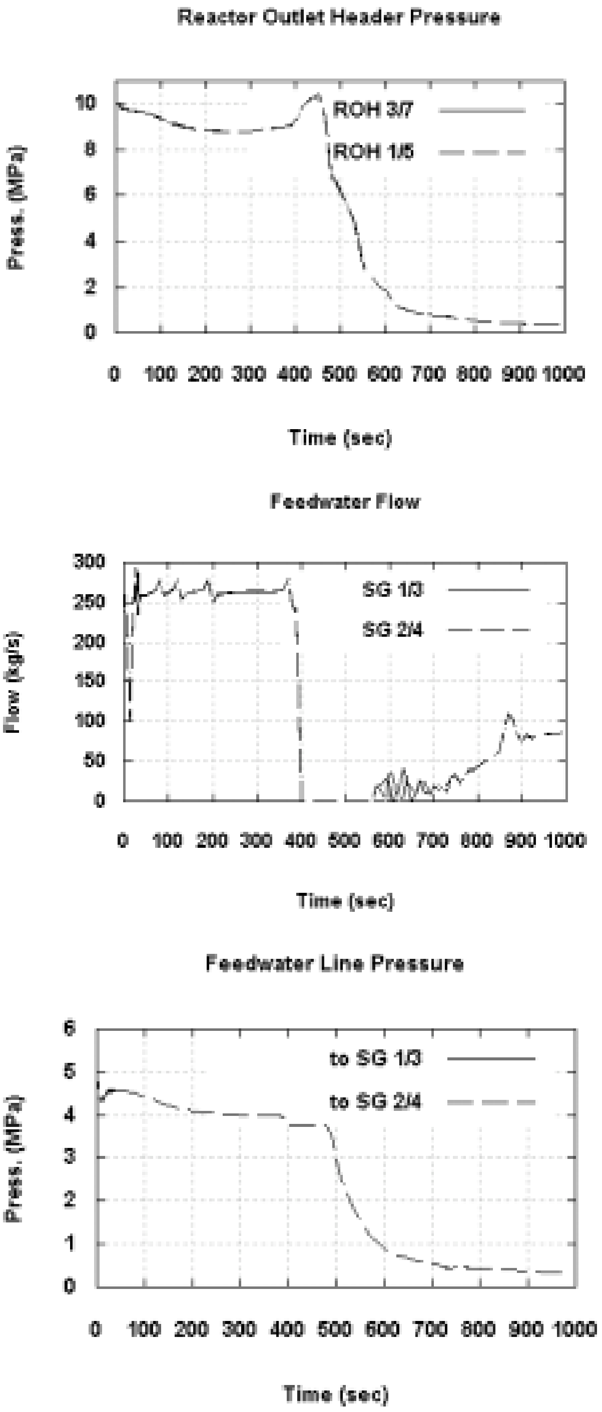


Figure 4 Depressurization Transient II (MSSVs Failed Open) from 103%FP (SDS 1&2 Pressurizer Low Level Trip) - ROH Pressure, Feedwater Flow and Line Pressure

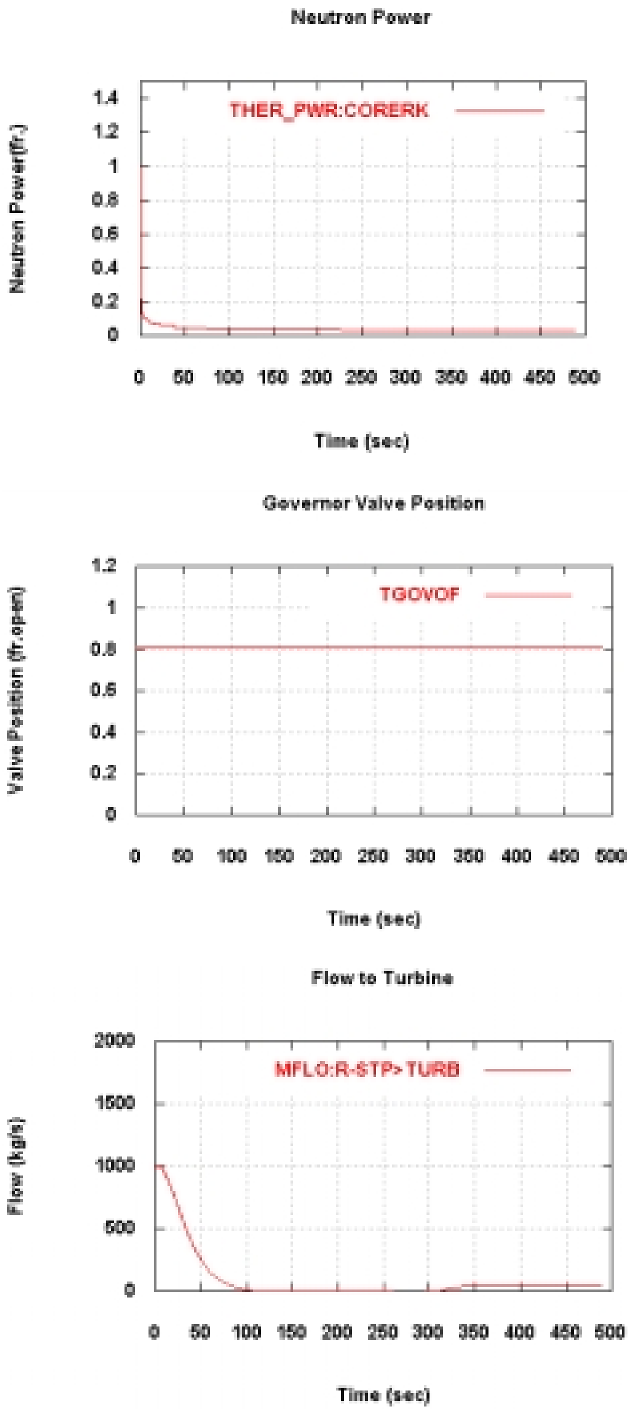


Figure 5 Depressurization Transient I (Fail to Unload Turbine after Reactor Trip) from 103%FP - Reactor Power, Governor Valve Position and Flow to Turbine

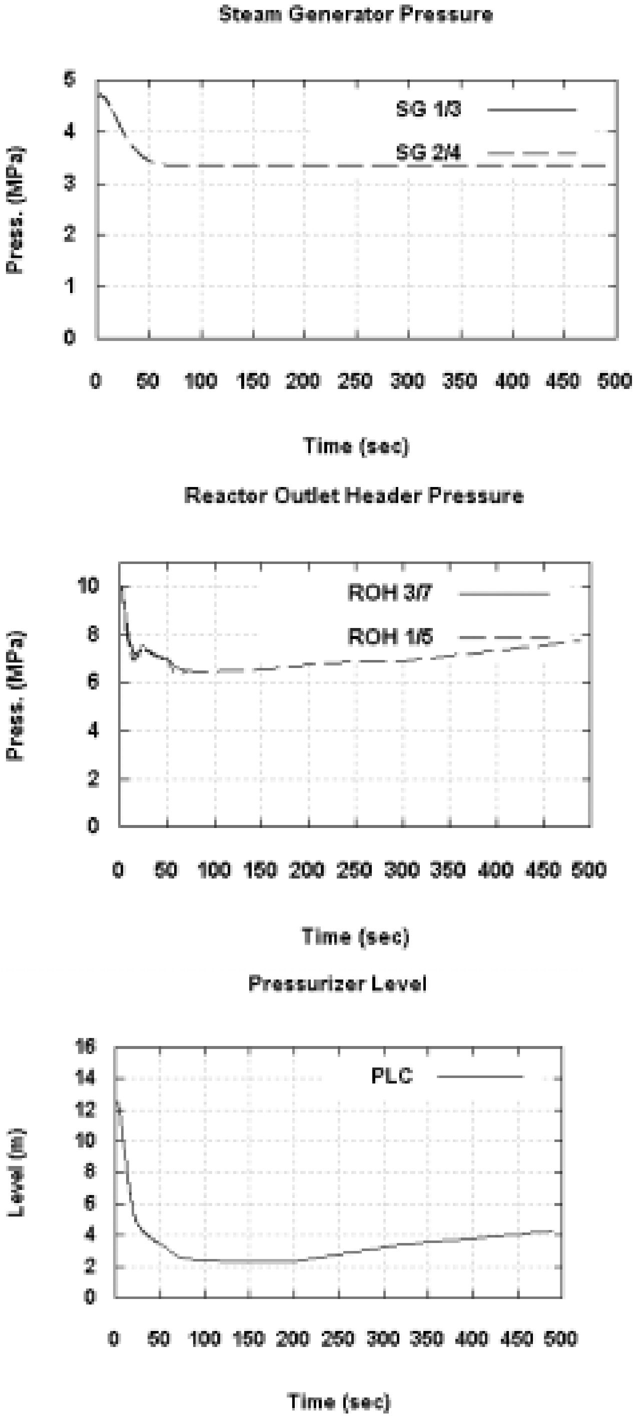


Figure 6 Depressurization Transient II (Fail to Unload Turbine after Reactor Trip) from 103%FP - SG Pressure, ROH Pressure, Pressurizer Level

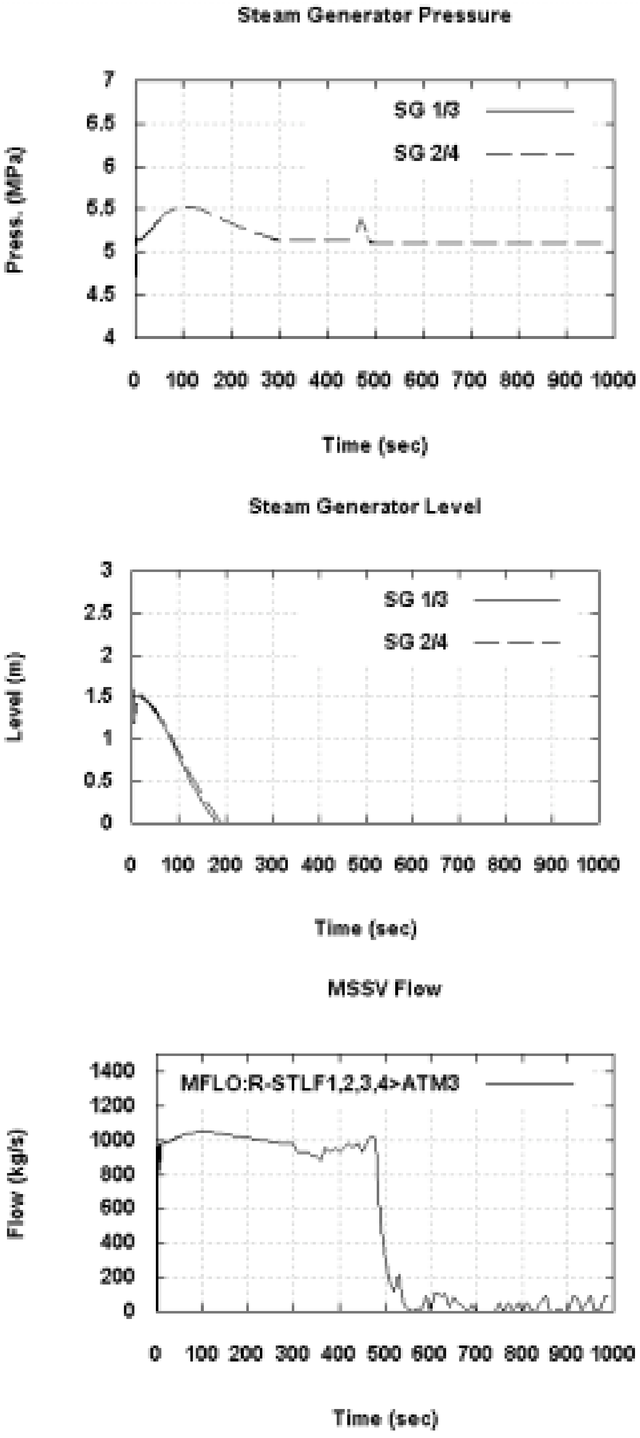


Figure 7 Pressurization Transient I (A Loss of Condenser Vacuum) from 103%FP
(12 out of 16 MSSVs Credited and RRS Operating) – SG Pressure, Level and MSSV Flow

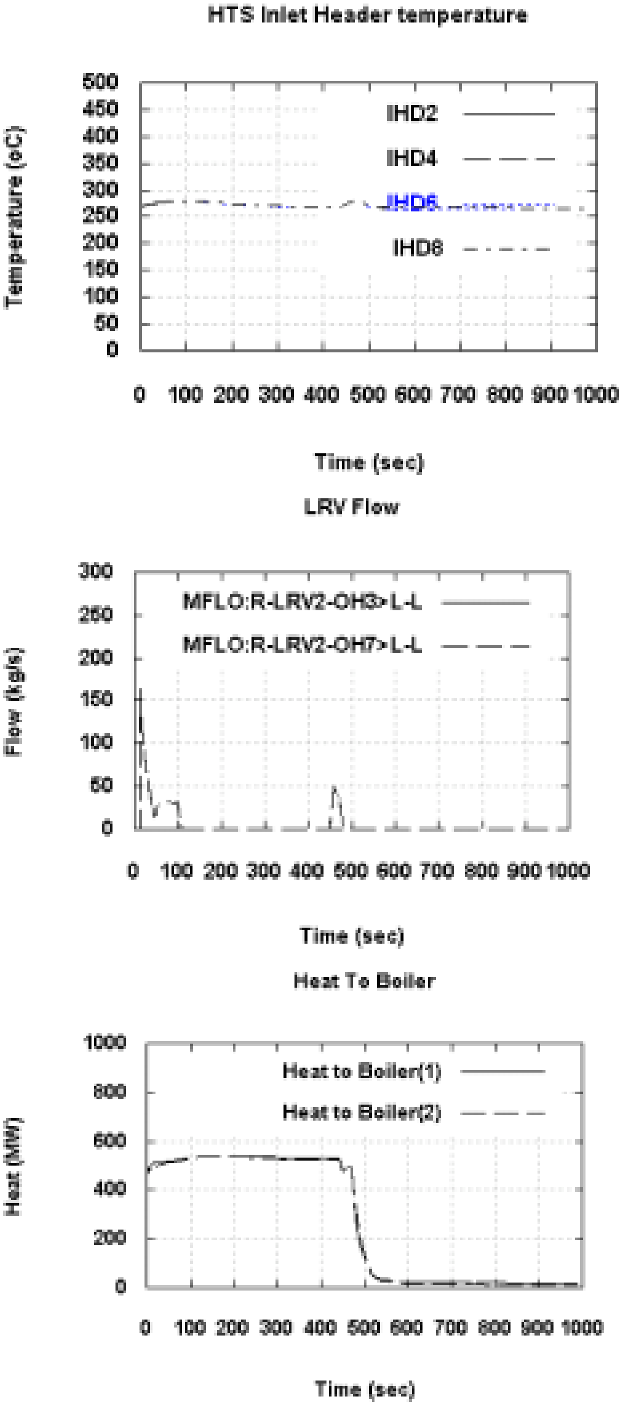


Figure 8 Pressurization Transient II (A Loss of Condenser Vacuum) from 103%FP (12 out of 16 MSSVs Credited and RRS Operating) – PHTS Inlet Temperature, LRV Flow and Heat to

Boiler

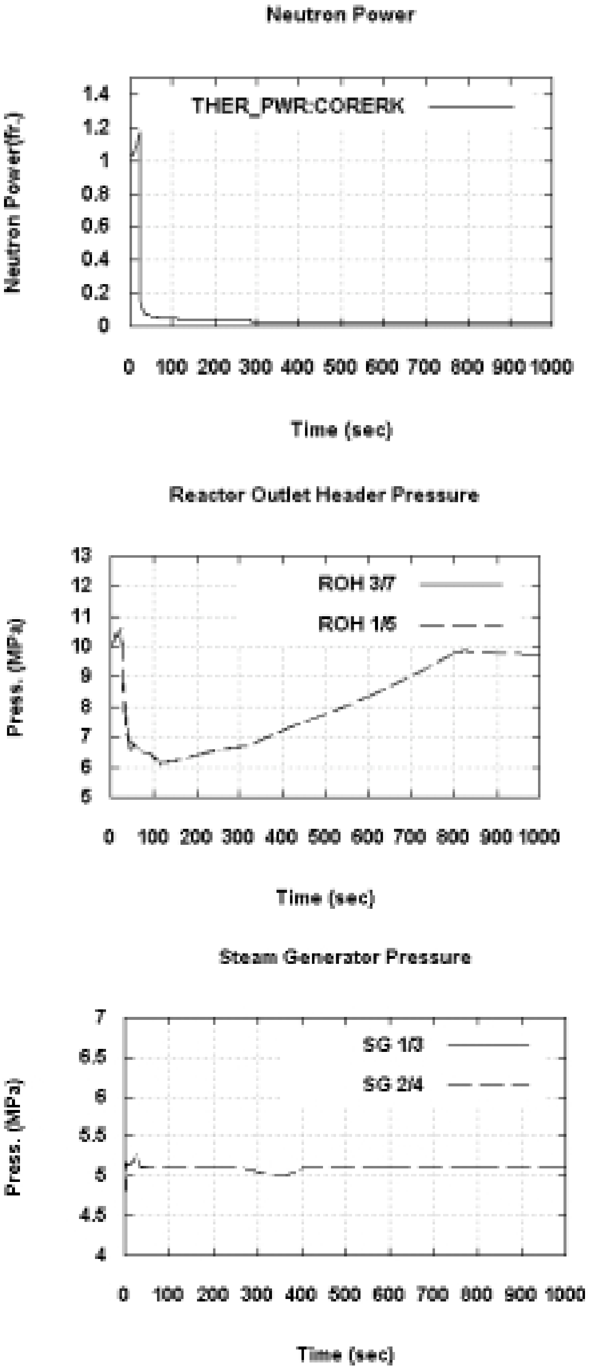


Figure 9 Pressurization Transient III (A Loss of Condenser Vacuum) from 103%FP (12 out of 16 MSSVs Credited , SDS2 High Neutron Power Trip, RRS Frozen) – Reactor Power, ROH Pressure and SG Pressure

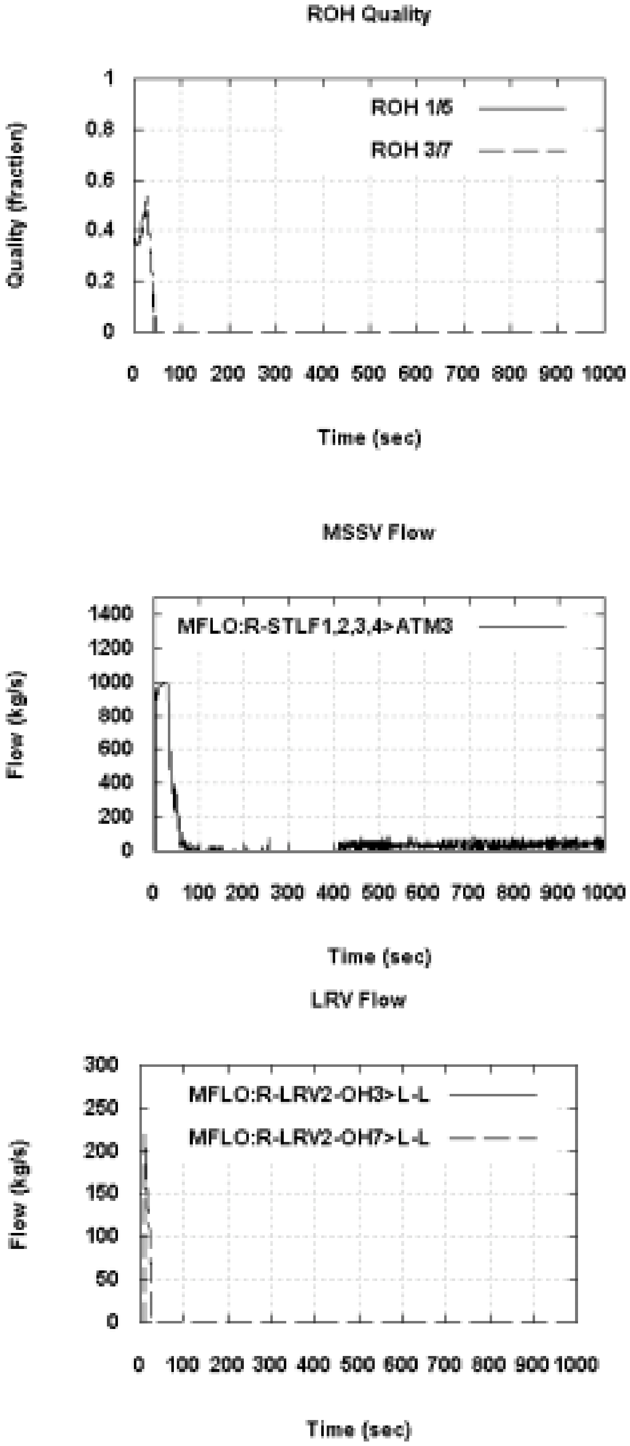


Figure 10 Pressurization Transient IV (A Loss of Condenser Vacuum) from 103%FP (12 out of 16 MSSVs Credited, SDS2 High Neutron Power Trip, RRS Frozen) –ROH Quality, MSSV Flow and LRV Flow

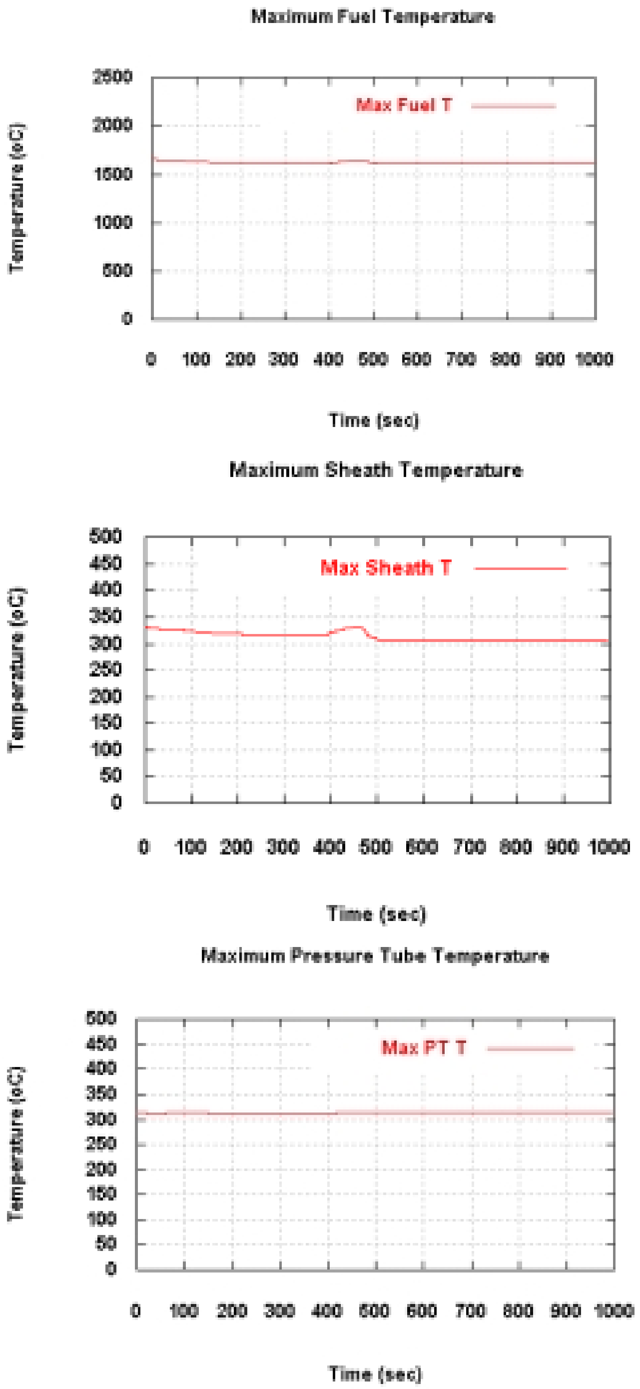


Figure 11 CATHENA Slave Channel Results for Depressurization Transient (MSSVs Failed to Open) from 103%, SDS 1&2 Pressurizer Low Level Trip

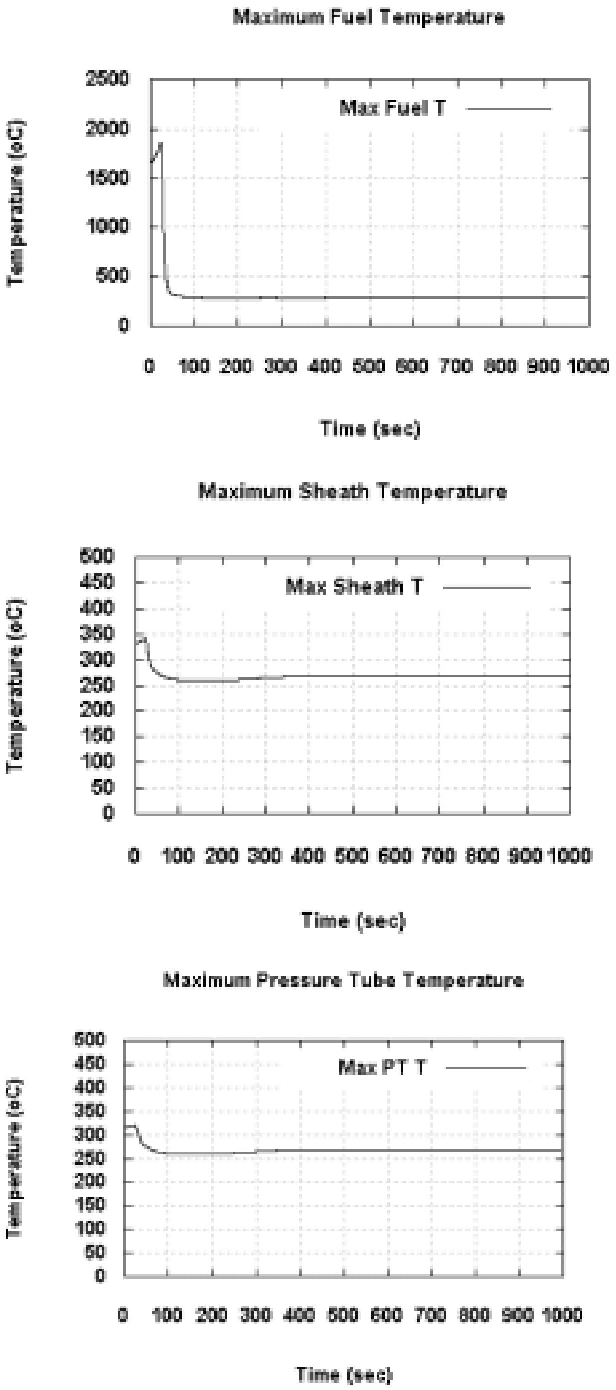


Figure 12 CATHENA Slave Channel Results for Pressurization Transient (Loss of Condenser Vacuum) from 103% RRS Frozen, SDS 1&2 high Neutron Power Trip