APT Blanket System Loss-of-Flow Accident (LOFA) Analysis Based on Initial Conceptual Design - Case 1: with Beam Shutdown and Active RHR

by

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The internal technical review function is being performed at the APT project level and is coordinated through LANL.

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1 Introduction

This report is one of a series of reports that document normal operation and accident simulations for the Accelerator Production of Tritium (APT) blanket heat removal system, [1-7]. These simulations were performed for the Preliminary Safety Analysis Report. The results of simulations of a Loss-Of-Flow-Accident (LOFA) where power is lost to all of the pumps that circulate water in the blanket region are documented in this report. The accident simulations were performed, using TRAC to model transient behavior of the heat removal system, and FLOWTRAN-TF, a computer code developed at the Savannah River Technology Center, to model detailed transient behavior in a blanket module.

For the loss-of-flow accident analyses, parametric studies were performed varying the time for beam shutdown, the rate of primary pump coast-down, and the flowrate of coolant during post-incident residual heat removal. After the APT beam system shutdown, decay power drops rapidly. Figure 1-1 shows transient decay power after shutdown as a fraction of steady-state power for the 1700 MeV APT design with 13 tungsten ladders [8]. Results from a single TRAC system calculation were used to generate boundary conditions for the loss-of-flow accident analyses. The system calculation provided a transient for total coolant flow having approximately 5% of the pre-incident flow 60 seconds after initiation of the loss-of-flow-accident. As shown below, the results from that system calculation were then used to generate four additional sets of transient boundary conditions having exactly 1%, 2%, 5% and 10% of the pre-incident coolant flow 60 seconds into the transient. The flows, pressures and temperatures from these transients provided boundary conditions for a series of FLOWTRAN-TF calculations that produced the final results of the LOFA analyses.

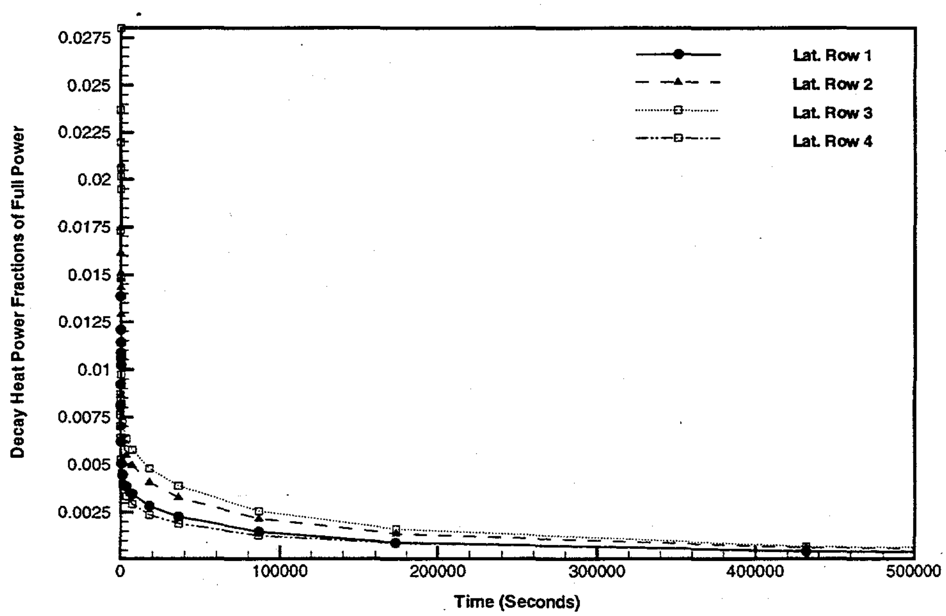

Figure 1-1 Decay heat power fractions of full power for various types of blanket modules.

2 TRAC 1-D System Model

Current blanket system consists of 16 unique blanket modules based on the existing cruciform-type design components (the necessary design specifications required to develop a plate-type set of modules is currently not available but will be used in future revisions to these calculations). Each module is separately connected to the two fixed coolant headers. A lumping strategy was developed based on module similarity, deposited power levels, and locations that resulted in a total of six separate lumped modules and reduced computational effort requirements. The six lumped modules are, respectively: the first-row lateral modules; the second-row lateral modules; the decoupler / Row 1 downstream module; the Row 1 / Row 2 downstream module; the Row 2 / Row 2 downstream module; and the remaining low-power modules, which consist of the upstream module, the four bottom modules, and the two top modules. Figure 2-1 shows cross-sectional face map for the 6 module blanket system. Table 2-1 summarizes module description, thermal deposited power, and connection pipe size of each of the 6 blanket modules as modeled in the one-dimensional lumped approach. Figure A-1 shows the locations of all the six modules and the internal piping connections as included in the one-dimensional TRAC system model. The TRAC components and piping connections for the heat removal (HR), pressurizer, residual heat removal (RHR) blanket coolant systems, and cavity vessel flood system are also shown in Figs. A-2 to A-6. Table A-1 lists all the blanket system components, number of cells for the components, and the component descriptions for the present one-dimensional lumped blanket system model. The present 6 lumped module TRAC blanket system model includes 170 components and 152 junctions with 10 trip control signals using for the transient loss-of flow accident (LOFA) simulation. Detailed TRAC system model descriptions are provided in Refs. [9, 10].

2.1 Scenario Description

Current blanket coolant system has one primary heat removal (HR), one secondary HR, two 100% primary residual heat removal (RHR), and two 100% secondary RHR. Both the HR and RHR loops are connected to the large fixed headers (20.5 inch diameter) internal to the target/blanket cavity vessel. Under steady-state normal operation condition the blanket module system is connected to a single main primary loop, with three 50% pumps in parallel. Two pumps are normally operating and the remaining pump is available for immediate startup in the event of failure of a running pump. The coolant loop has two 50% heat exchangers in parallel. The two RHR primary loops are both sized to accommodate 100% of the decay heat removal requirements. Currently, the RHR components are sized for approximately 4% of the full power flow, 1569 kg/sec, under any design basis accident conditions. Each of the RHR primary loops has one heat exchanger and one pump. The current baseline design has the RHR systems shutdown in standby mode during normal operation to enhance the system's response to some design basis accident scenarios such as loss-of-flow accident (LOFA) and loss-of-coolant accident (LOCA). Under the accident condition only one RHR system is activated to circulate the coolant water to the internal blanket modules. Normal operation conditions for the key blanket system parameters are shown in Appendix A.

As one of design basis accidents, the loss of pumping flow accident due to the loss of power in the primary and secondary HR pumps was simulated by restarting steady-state normal operation results performed by the one-dimensional 6 integrated module blanket system model in a transient mode. For the initiation of the LOFA simulation, two primary and secondary HR pumps are tripped off without time delay at the time 0 second. As soon as the accident occurs, the primary and secondary RHR pumps are initiated and are running continuously since the primary and secondary RHR pumps are supplied with on-site backup diesel power as well as a dc backup power supply. After the LOFA is initiated, system pressure is depressurized immediately and then the RHR pump reaches full speed in about 15 seconds after the accident starts. Detailed control signals for the key component operations are provided in Section 2.6.

2.2 Model Upgrades

Component action tables for the break component and check valves were updated to activate the action signals of the hardware components such as check valves, pumps, heat structures of the six blanket modules, and fill boundaries to simulate the LOFA scenario. Component action tables for the RHR pump and the HR/RHR check valves are based on the S-shaped forcing function values. Normal steady-state operation conditions can be obtained by using either transient mode or constrained steady-state with definition of the monitoring parameters of specific components. For the present accident analyses the constrained steady-state (CSS) capabilities are added to the TRAC normal operation system model. Signal variables and trip signals of the system model are also updated by using the control procedure for the LOFA scenario as described in Ref. [9].

2.3 Initial Conditions

Before simulating the accident condition, steady-state results under normal operation (NO) conditions are required to provide the restart input to the transient simulation model of the LOFA. The steady-state NO conditions of the APT blanket system were obtained by specifying maximum pump rotational speeds of the two HR pumps with desired total liquid flowrate using as a monitoring parameter under the constrained steady-state (CSS) controller option. Initial temperatures for the pressurizer and the RHR system components were 40 C. Steady-state values under normal operating conditions for the key system parameters of the APT blanket system are listed in Appendix A with additional details provided in Ref. [1].

2.4 Transient Boundary Conditions

The TRAC system model for the steady state NO calculations is documented in Refs. [9, 10]. The steady-state NO TRAC run was restarted in a transient mode to initiate the LOFA simulation. To establish an appropriate fly-wheel inertia for the primary heat removal pumps a parametric study was performed (i.e., varying the TRAC pump parameters) using the TRAC system model with the integrated six modules under the LOFA conditions. The inertia terms were set such that a 5% of pre-incident flowrate is achieved at 60 sec after pump deactivation occurs. System operation conditions of the secondary systems were simulated by using fill boundary condition with transient mass flowrate table at the inlet of the secondary sides of the two HR heat exchanger components.

2.5 Trips and Controls

Power to the two primary and secondary HR pumps was tripped off immediately to initiate the LOFA scenario, and the beam power was tripped off with 1.0 seconds time delay after the pressure difference between the suction side and the discharge side of each primary HR pump was reduced to 0.70788 MPa (102.7 psia) corresponding to 95% of the total pressure difference across the HR pump. The RHR pump was actuated without time delay after the pressure difference between the suction and discharge sides of each primary HR pump was reduced to 0.70788 MPa (102.7 psia). The beam trip was simulated by changing the steady-state NO power in the heat structure of each blanket module to the time dependent decay power curve. Figure 1-1 shows transient decay power curves for the blanket heat structures. The beam power trips actually occurred about 1.21 seconds after the initiation of the transient accident so that the time to reduce 5% of the pressure difference across the HR pump is about 0.21 second. The RHR pumping power signal was set to actuate without delay after 5% reduction of the pressure difference across the primary HR pump, and then the RHR pump speed was attained to the full speed (94.35 rad/sec) in 15 seconds after the accident initiation by using the component action table with S-shaped forcing function values [9]. Check valves on the discharge sides of the HR and RHR pumps were actuated to avoid flow reversal immediately after the initiation of the LOFA accident. If flow reversal occurs during the accident condition, the HR and RHR check valves were set to be closed immediately. Table 2.5-1 lists all the trip signals and component controls used for the LOFA simulation.

2.6 TRAC Version

This transient model was run using TRAC-PF1/MOD2 version 5.4.28a [18]. A modified version of TRAC to generate graphics files was employed [10].

Table 2-1 6 lumped blanket module system model used for the present PSAR analysis.

6 Lumped Modules	Prototypic 16 Full Blanket Modules	Thermal Deposited Power Downflow / Upflow / Total Power	Pipe Size (inch)
Module 1	Front 1st Lateral Dec. / Row 1 Module Back 1st Lateral Dec. / Row 1 Module	8.222 MW / 15.768 MW / 23.990 MW	7.500
Module 2	Front 2nd Lateral Row 2 /Row 3 Modules Back 2nd Lateral Row 2 / Row 3 Modules	3.060 MW / 7.660 MW / 10.720 MW	4.750
Module 3	1st Downstream Dec. / Row 1 Module	0.744 MW / 2.812 MW / 3.556 MW	3.750
Module 4	2nd Downstream Row 1 / Row 2 Module	3.924 MW / 5.412 MW / 9.336 MW	5.375
Module 5	3rd Downstream Row 2 / Row 2 Module	1.355 MW / 1.811 MW / 3.167 MW	6.000
Module 6	Low Power Modules Blanket Upstream Dec. / Row 2 Module Lower Front Dec. / Row 2 Module Lower Front Row 2 / Row 2 Module Lower Back Dec. / Row 2 Module Lower Back Row 2 / Row 2 Module Upper Front Row 2 / Row 2 Module Upper Back Row 2 / Row 2 Module	(Horizontal Flow) 0 MW / 5.712 MW / 5.712 MW	3.875
Total Deposited Power		17.305 MW / 39.175 MW / 56.480 MW	

Table 2.5-1 Trip signals used in the LOFA simulation.

Trip Signal ID	Control Component	Signal Variables ID Number (Control Variable)	Signal Values
101	Fill boundary for secondary heat exchanger side	1 (time)	1.0e-06 sec
102	Cavity flood system valve	10 (cavity vessel pressure)	valve closed
103	RHR check valve	1 (time) and action table (S-shaped forcing function)	1.0e-06 sec
104	Heat structure	4 (the pressure difference between the suction and discharge sides of the primary HR pump) and time delay	1.0 sec time delay after 5% reduction of the pressure difference across the primary HR pump
105	RHR pump	4 (the pressure difference between the suction and discharge sides of the primary HR pump), no time delay, and action table (S-shaped forcing function)	full speed in 15 sec. after 5% reduction of the pressure difference across the primary HR pump
106	Primary HR pump	no time delay	1.0e-06 sec
107	Primary HR check valve	1 (time) and action table (S-shaped forcing function)	1.0e-06 sec
108	Cavity vessel check valve	1 (time)	valve closed
109	Cavity vessel check valve on the HR side	1 (time)	valve closed
110	Cavity vessel vent valve	7 (pressurizer pressure)	valve closed

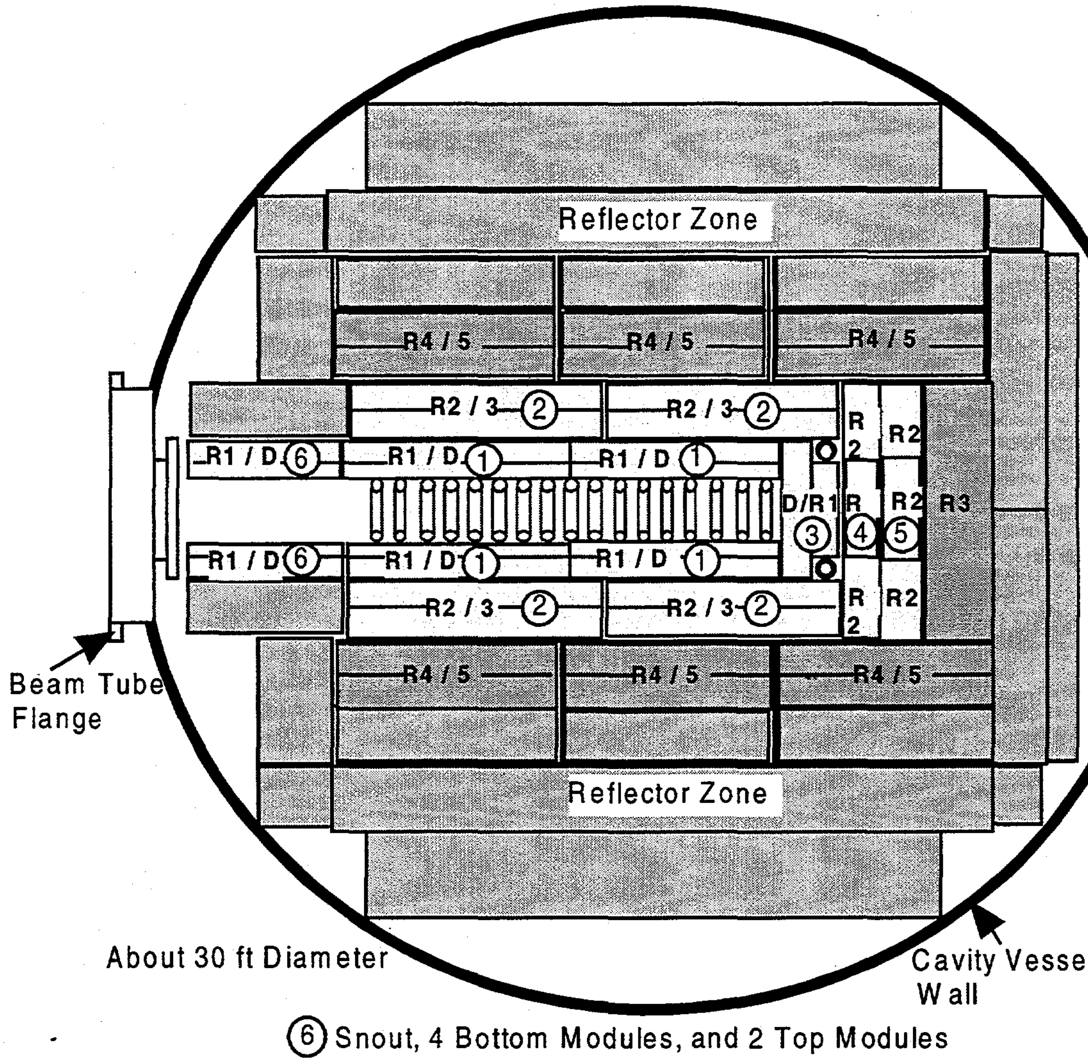

Figure 2-1 Top cross-sectional face map of 6 lumped blanket system modules

3 TRAC System Model Results

The LOFA model to simulate the loss of power for the primary and secondary HR pumps was run for 600 seconds after the initiation of the accident. The simulation results show that the pressurizer and a single RHR system can mitigate this design basis accident without any damage to the blanket module system and structure. During the accident the liquid in the pressurizer was not drained completely so that gas inside the pressurizer is not entrained into the heat removal system loops such as the HR and RHR ssystems. The temperature of the coolant water surrounding the blanket modules does not reach saturation temperature leading to the phase change inside the blanket system under any of the LOFA transient times. The next subsections provide descriptions of the transient phenomena for the key blanket component systems observed in the accident simulation in more detail.

3.1 Modules

Figure B1-1 shows the component layout of the internal blanket module system used in the TRAC system model. All the modules are connected to the fixed headers. Primary coolant water is supplied to the hot blanket modules through the inlet fixed header and returned to the outlet fixed header. These two fixed headers are located inside the cavity vessel. Figures B2-2a to B2-7d show the transient results for pressures, fluid temperatures, liquid subcoolings, and void fractions for the three plenums (inlet, middle, and exit plenums) of each blanket module. The results show that upflow region of each blanket module has near-stagnant liquid flow at about 60 seconds after the initiation of the LOFA at which primary HR flowrate was already reduced to below 5% of the full power flowrate (1569 kg/sec). None of the module channels have voidage within the liquid coolant through the transient accident period. The graphical results show that rapid transient behaviors for the flow channels of all the six blanket modules continue up to about 100 seconds after the initiation of the LOFA accident. RHR pump was actuated after the accident, and RHR coolant water with initial 40 C temperature came into the internal hot blanket module system. As a result, fluid temperatures of the six blanket modules dropped more quickly for about 20 seconds. Finally, the six blanket modules were established with small RHR liquid flowrates controlled by the gravitational hydraulic head.

Figs. B3-26 through B3-43 show detailed graphical results for the solid structures of the six blanket modules. Maximum lead temperature was 152 C during normal operation condition near the mid-plane of the first lateral module. Generally, solid temperatures were decreased quickly up to 50 seconds since the initiation of the loss of power, and then after rising up about 2 to 3 C for about 50 seconds the solid temperatures slowly approached steady-state equilibrium values following the trend of the decay heat curve shown in Fig. 1-1. Maximum aluminum cladding surface temperature was 93.5 C during normal operation condition at the mid-plane of the blanket module 1 and then it dropped to the minimum value (about 47 C) near the exit of the module 1 channel at the transient time of 50 seconds. After about 200 seconds, the aluminum surface temperatures started to approach stabilized cooling condition slowly.

3.2 HR Loop and Pressurizer

Figure B1-2 shows the HR system component layout used for the one-dimensional TRAC system model. Transient behaviors for key thermal-hydraulic parameters of the two internal fixed headers are graphically shown in Figs. B1-1a to B1-1d. As the primary HR liquid flowrate decreased quickly for the loss of pumping power, hot leg pressure increased radidly to 107 psia at about 60 seconds after the loss of power, and finally the hot-leg fixed header pressure is slightly higher than the cold-leg fixed header pressure by the elevation height difference. Cold-leg fixed header temperature was decreased by 2.5 C during first 35 seconds after the accident due to the incoming RHR cold water (40 C) and rapid decay of primary coolant water flowrate. Both of the fixed headers had zero voidage during the entire transient simulation period. Transient behaviors for important thermal-hydraulic parameters of most external balance of plant (BOP) components are shown in Figs. B2-8a to B2-25e. The results show that liquid flowrates for the two primary HR pumps have reduced to about 5% of the normal full flowrates through the primary HR loop at about 60 seconds after the loss of pumping power. Fluid temperature at the pump suction side was decreased rapidly and established as constant temperature of about 51.5 C at about 100 seconds as shown in Fig. B2-b8. At this time coolant liquid flowrate of the primary HR system was about zero. Figs. B2-9a to B2-10e show the transient behaviors of the two primary HR pumps during the LOFA simulation time. The two HR pumps show near-symmetric behaviors with no cavitation during the accident.

Figure B1-3 shows the component layout for the pressurizer system connected to the inlet fixed header external to the cavity vessel. Initial fluid temperature of the pressurizer was assumed to 40 C. Figs. B2-15a to B2-15e show transient behaviors of the key thermal-hydraulic parameters for the pressurizer and surge line during the loss of the pumping power accident. From the results, the liquid in the pressurizer was not drained completely during the accident so that gas inside the pressurizer is not entrained into the heat removal system loop. Void fraction in the surge line of the pressurizer was zero during the transient accident to satisfy the design requirement for the pressurizer component. No void was entrained into the primary HR loop through the surge line of the pressurizer during the entire transient time of the LOFA accident.

3.3 RHR Loop

Figure B1-4 shows layout for the RHR system. The initial temperature for the RHR system was 40 C. Maximum RHR flowrate was about 4% of total full power liquid flowrate. The RHR system has check valve on the RHR pump discharge side to prevent flow reversal during the LOFA scenario. The transient responses of the RHR system to the LOFA scenario are shown in Figs. B2-16a to B2-16e and B2-17a to B2-17e. Figure B2-16a shows pressures for the RHR pump suction and discharge sides. No void at the RHR pump suction and discharge sides was initiated during the accident as shown in Fig. B2-16e. During the initial phase of the accident RHR check valve was activated to avoid backflow in the RHR system, and then RHR flowrate was near zero for the RHR check valve closing. At about 60 seconds after the accident, liquid flowrate in the RHR system was established to the full capacity.

Figure B2-17b shows the RHR primary heat exchanger inlet and outlet temperatures. The current CDR has the two 100% RHR systems shutdown in standby mode during normal operation, but from the current baseline design only one RHR system is operated during the accident. Initial inlet temperature was the same as steady-state stagnant RHR temperature 40 C, and then RHR water temperature quickly increased as soon as the RHR pump circulates the water through the blanket modules internal to the cavity vessel.

3.4 Cavity Vessel and Flood System

Figure B1-5 shows the TRAC component layout that shows the heat transfer connections between the blanket module heat structures and the cavity vessel. Figure B1-6 shows the TRAC component layout for the cavity vessel and flood system. During the LOFA accident, the cavity flood system pool is stagnant with an ambient temperature of 40 C. The cavity vessel has no liquid phase with ambient temperature saturated at about 5 psia during the LOFA due to the loss of power.

4 FLOWTRAN-TF Detailed Bin Model

4.1 Model Description

The basic FLOWTRAN-TF model is described in Refs. [11, 12] and was used in this version for the LOFA analyses. The FLOWTRAN-TF model was developed to simulate the thermal-hydraulic conditions in a lateral row 1 blanket module using the reference 1 plate-type design [13]. The areal mesh of the bin model is shown in Figure 4-1 along with the location and indexing used for the 12 discrete flow channels.

4.2 Initial Conditions

Initial conditions for all of the flow transients are normal operating conditions as reported in Ref. [1]. The TRAC supplied initial conditions used in the FLOWTRAN-TF calculations are listed in Table 4.2-1.

In addition, based on information supplied by Los Alamos National Laboratory [14], we assume an initial pre-incident coolant flow of 1.488 kg/s to the 12 half flow channels that surround a single blanket plate-type module and a nominal pre-incident deposited power for a single plate of 61.5 kW.

4.3 Transient Boundary Conditions

Transient profiles of plate boundary condition variables generated by the TRAC system model and normalized to their respective pre-incident conditions are shown in Fig. 4.3-1. Conditions for the TRAC calculation were adjusted so that the coolant flow reached approximately 10% of the pre-incident flow 60 seconds into the accident. There was no void formation within the coolant loops for this accident scenario. From Fig. 4.3-1, we see that the flow decreases in an approximately exponential manner while the inlet temperature remains nearly constant. The inlet and exit pressures follow the flow transient and approach hydrostatic limits that depend on the system configuration. In fact, as shown in Fig. 4.3-2, the TRAC results can be closely approximated by the equations:

$$\frac{Q}{Q_0} = \frac{Q_\infty}{Q_0} + \left[1 - \frac{Q_\infty}{Q_0}\right] \exp\left(\frac{t}{\tau}\right) \qquad (4.3\text{-}1)$$

$$\frac{P_{in}}{P_{in}^0} = \frac{P_{in}^\infty - K_{in}\, Q^2}{P_{in}^\infty - K_{in}\, Q_0^2} \qquad (4.3\text{-}2)$$

$$\frac{P_{exit}}{P_{exit}^0} = \frac{P_{exit}^\infty - K_{exit}\, Q^2}{P_{exit}^\infty - K_{exit}\, Q_0^2} \qquad (4.3\text{-}3)$$

where:
- Q .... total mass flux to Row 1 blanket, kg/m^2-s
- τ .... time constant for flow decay, s
- t .... time into accident transient, s
- P_{in} .... pressure at inlet plenum, Pa
- P_{exit} .... pressure at outlet plenum, Pa
- K .... constant in pressure-flow equation
- 0 .... superscript/subscript indicating initial values
- ∞ .... superscript/subscript indicating steady state values

The parameters used in Eqs. (4.3-1) through (4.3-3) were obtained from the TRAC system calculations and from least squares fitting of the TRAC transients. Values of the fitted parameters are given in Table 4.3-1.

The K coefficients in Eqs. (4.3-2) and (4.3-3) were derived using mass flux at the inlet to the blanket modules in the correlations in place of volumetric flow rate. Neglecting density changes, the mass flux is directly proportional to volumetric flow and can be taken directly from the TRAC system calculations. Beyond 15 seconds, the fitted flow transient falls below the system calculation providing a conservative approximation to the flow. Prior to 15 seconds the two curves are very close to each other although the fitted curve is slightly non-conservative. There are slight offsets in the steady-state pressure transients that originate from the fact that the initial system pressure is not exactly reproduced. That is, at the inlet for example,

$$P_{in}^0 \neq P_{in}^\infty - K_{in}\, Q_0^2 \qquad (4.3\text{-}4)$$

The slight difference of about 1% in pressure between these values is indicated by the offset in the normalized pressure transients.

Using the parameters in Table 4.3-1, transients were created such that the coolant flow reached exactly 1%, 2%, 5% and 10% of the pre-incident value 60 seconds after initiation of the loss of flow accident. These transient pressure and flow profiles are shown in Figs. 4.3-3 through 4.3-6 for the 10%, 5%, 2% and 1% flow cases, respectively.

Table 4.2-1 Initial conditions for FLOWTRAN-TF LOFA analysis.

	Pressure (MPa)	Temperature (C)	Void
Channel Inlet	0.686	53.04	0
Channel Outlet	0.584		

Table 4.3-1 Transient Curve Fitting Parameters.

Equation Parameters From Data Fitting	Value
τ	14.025 sec
P_{in}^{∞}	819285 Pa
K_{in}	0.4204
P_{exit}^{∞}	791098 Pa
K_{exit}	0.7163

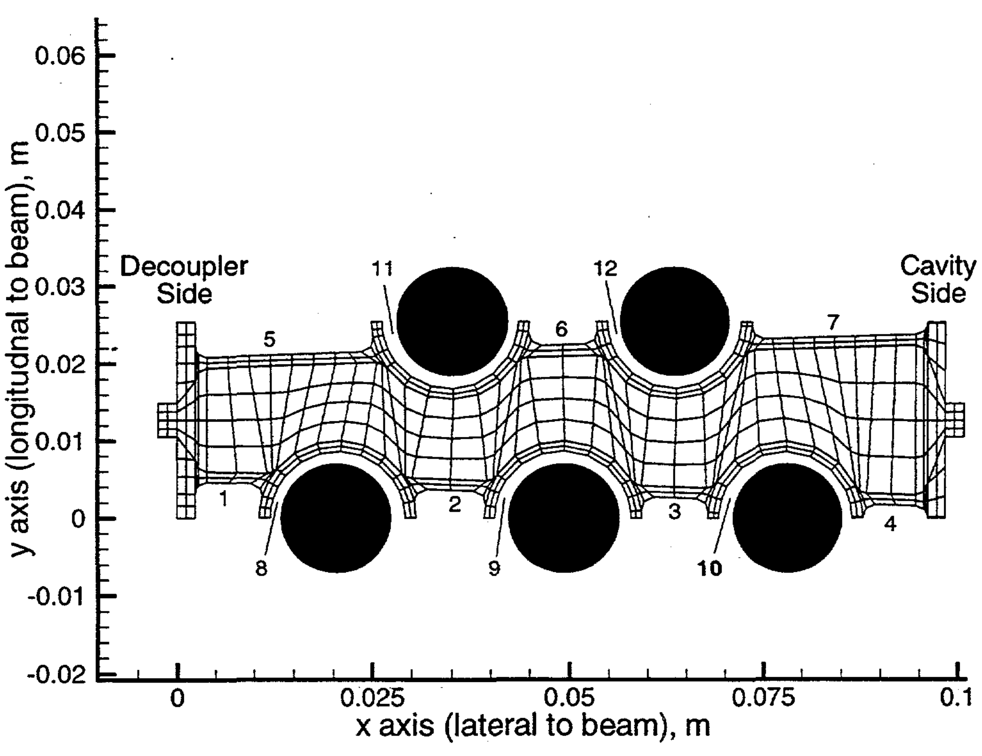

Figure 4-1 Finite element mesh of APT reference 1 blanket plate.

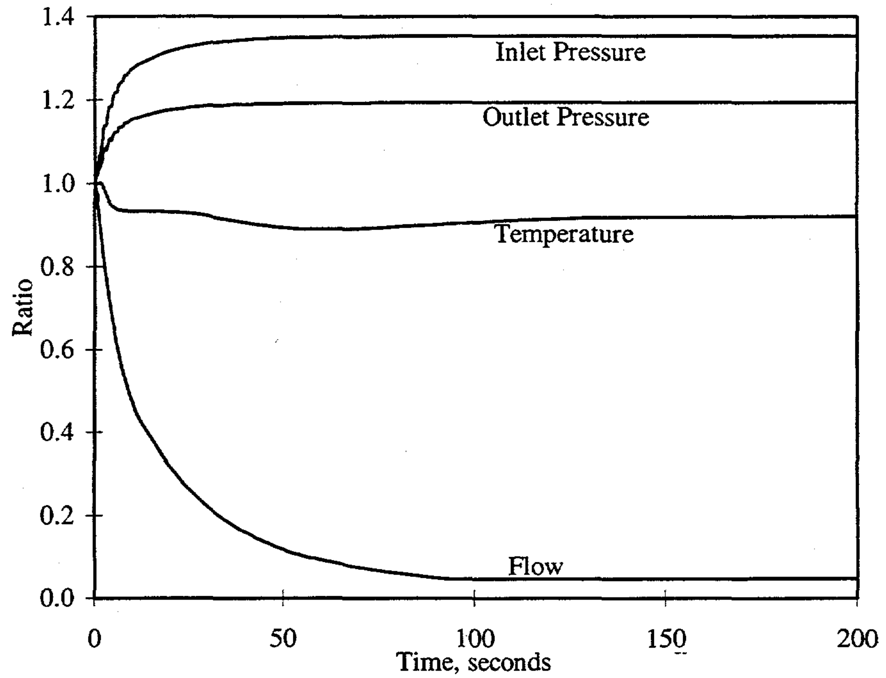

Figure 4.3-1 Pump coast down transients from TRAC system analysis.

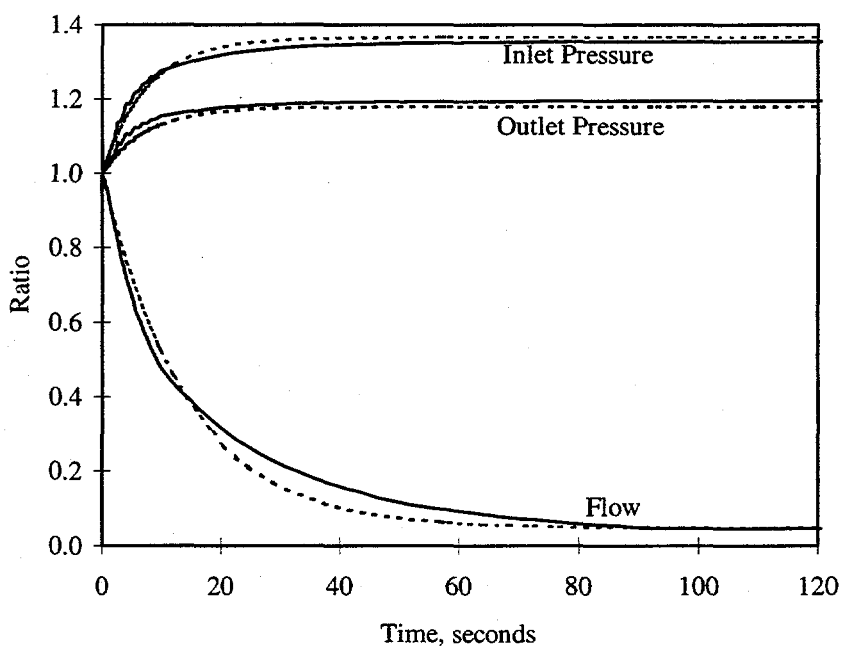

Figure 4.3-2 Curve fits (dashed lines) to TRAC transients (solid lines).

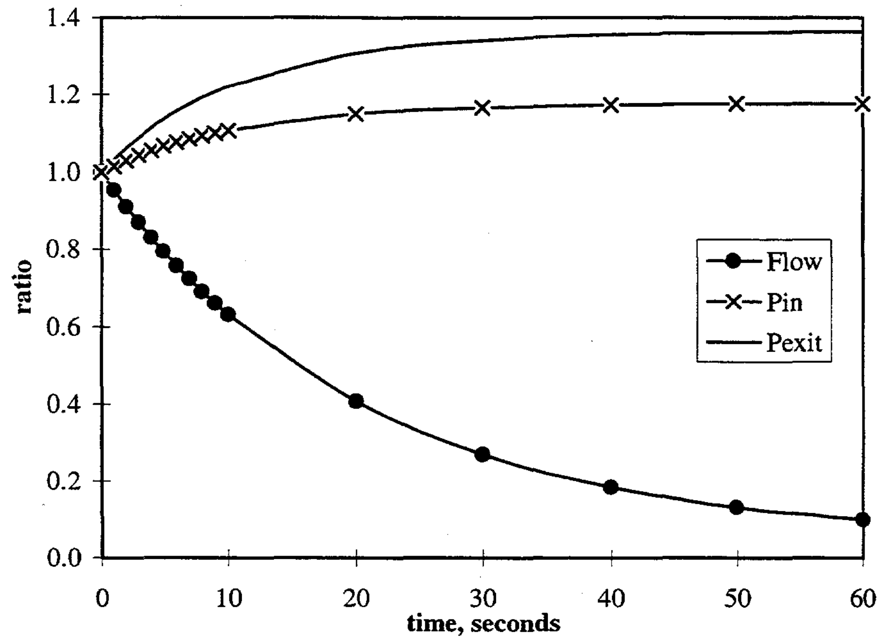

Figure 4.3-3 Pressure and flow transients with 10% pre-incident flow at 60 sec.

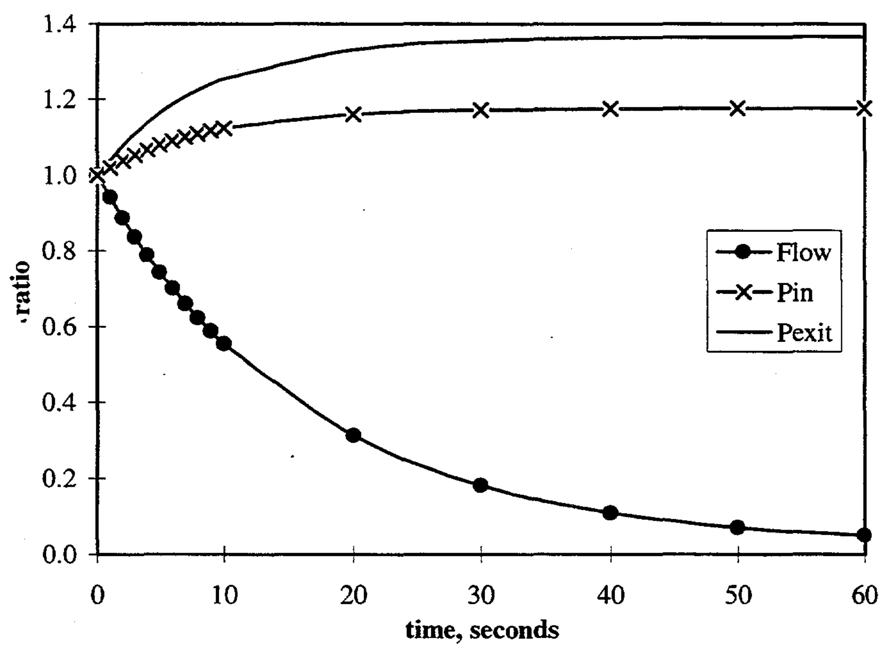

Figure 4.3-4 Pressure and flow transients with 5% pre-incident flow at 60 sec.

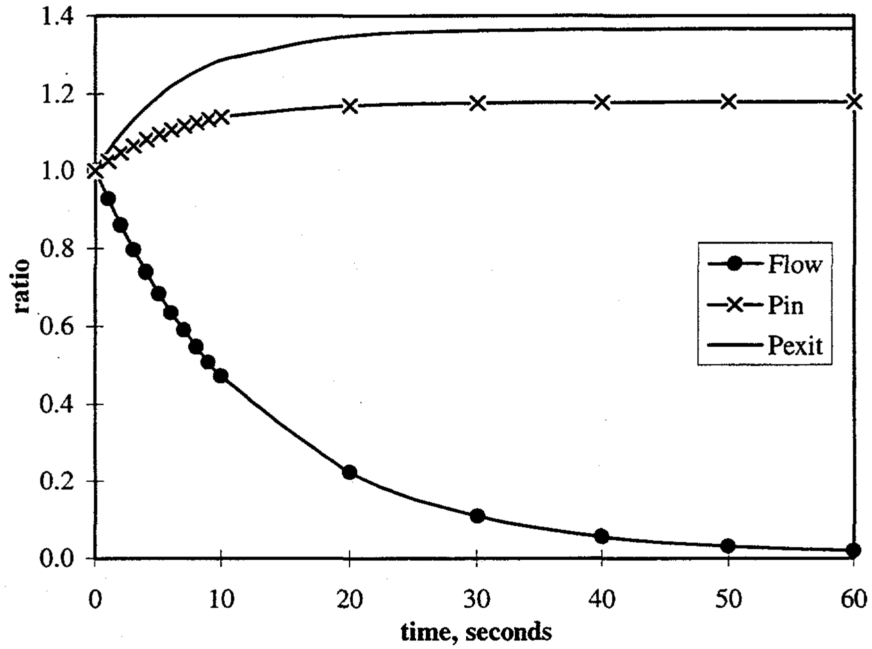

Figure 4.3-5 Pressure and flow transients with 2% pre-incident flow at 60 sec.

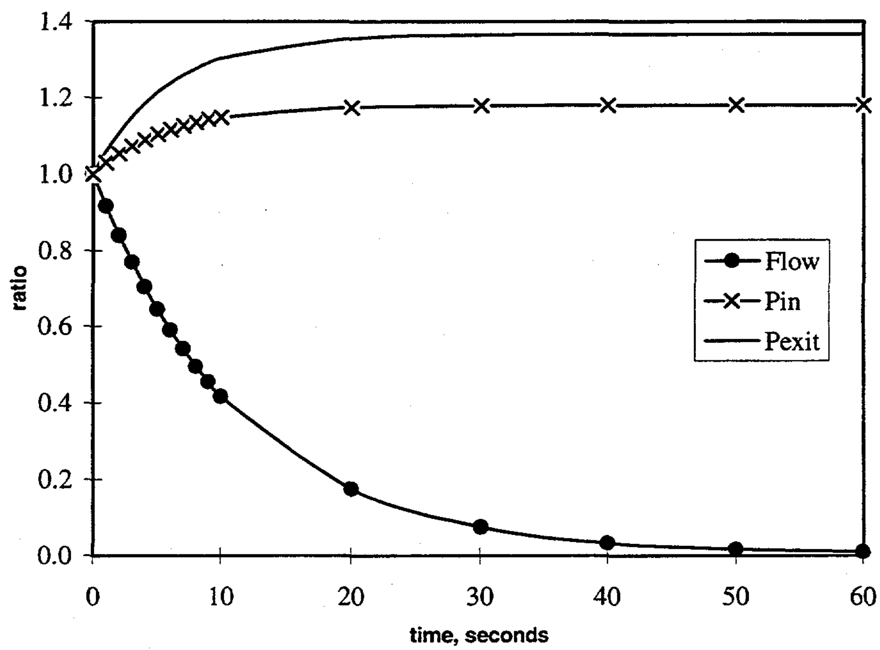

Figure 4.3-6 Pressure and flow transients with 1% pre-incident flow at 60 sec.

5 FLOWTRAN-TF Bin Model Results

The four sets of transient flow and pressure boundary conditions shown in Figs. 4.3-3 through 4.3-6 were run with the FLOWTRAN-TF model of a single reference 1 lateral row 1 blanket plate module to assess safety margins during a loss of flow accident. Since the inlet temperature does not change significantly during the first 60 seconds, the TRAC calculated inlet temperature transient shown in Fig. 4.3-1 was used for each of the calculations. The two safety criteria appropriate for LOFA accident scenarios are:

1. Keeping the aluminum metal temperature below the limit of 115 C imposed to maintain structural integrity. Material limits for the plate-type structures have been tentatively set to: (1) 115 C for steady-state normal operation or indefinite times of exposure; and (2) 150 C for exposures less than 10,000 hours.

2. Keeping the aluminum surface temperature below the local saturation temperature to prevent steam formation and possible flow blockage in the flow channels.

The analysis procedure was to run each of the above four transients while varying the time delay for beam trip. Nominally, a beam trip is expected to occur one second after the initiating event for the loss of flow accident. Determining the time delay that could be tolerated in these scenarios gives an indication of the safety margin inherent in the blanket module design. Table 5-1 summarizes results of these calculations. As a conservative measure, the delay time that keeps the aluminum temperature below the 115 C limit was found.

Table 5-1 Summary of LOFA Transient Results

Transient	Beam Trip Delay $T_{Al} = 115$ C	Beam Trip Delay $T_{wall} = T_{sat}$
10% Flow	22.5 sec	57 sec
5% Flow	18 sec	45 sec
2% Flow	15 sec	36 sec
1% Flow	13 sec	32 sec

Adding an additional 20% margin to the deposited power (i.e. using a pre-incident power of 73.8 kW), the 5% flow transient trims the $T_{wall} = T_{sat}$ criteria at 39 seconds. Maximum aluminum surface temperatures during the transients where the $T_{wall} = T_{sat}$ criteria are trimmed are plotted in Fig. 5-1. Maximum aluminum metal temperatures during the transients where the $T_{Al} = 115$ C criteria are trimmed are plotted in Fig. 5-2.

In Fig. 5-1 we see that, for all of the scenarios, the saturation temperature has reached a steady-state value of around 165 C by the time the surface temperature limits are reached. Local saturation temperature rises during the transients because the pressure is increasing. The conservative aluminum temperature limit of 115 C is exceeded at the surface for from 25 to 35 seconds during these transients. For all four cases, the wall temperature first exceeds saturation in flow channel number eight about mid way up the channel. After the beam power is tripped, at the time when the criterion is trimmed, the metal temperatures rapidly decrease.

From Fig. 5-2 we see that the maximum pre-incident aluminum temperature is about 100 C. Following the loss of coolant flow, the maximum aluminum temperature increases to the limit of 115 C in from 13 to 23 seconds depending on the flow transient. At this point, when the beam power is shut off, the metal temperatures rapidly decrease.

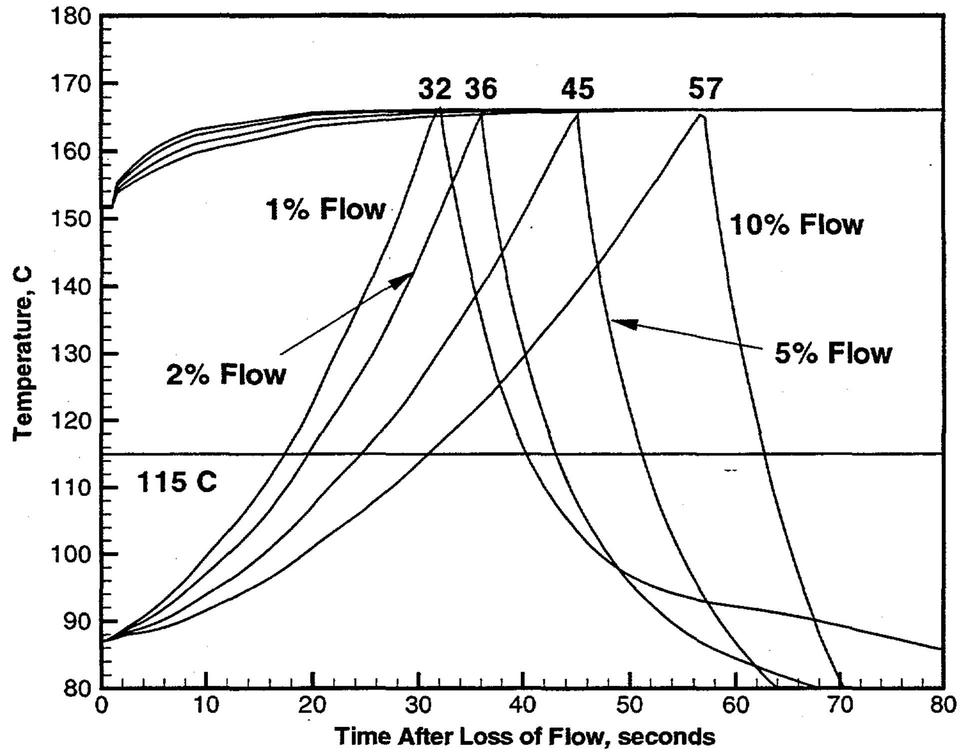

Figure 5-1 Aluminum surface temperature transients for $T_{wall} = T_{sat}$ criteria.

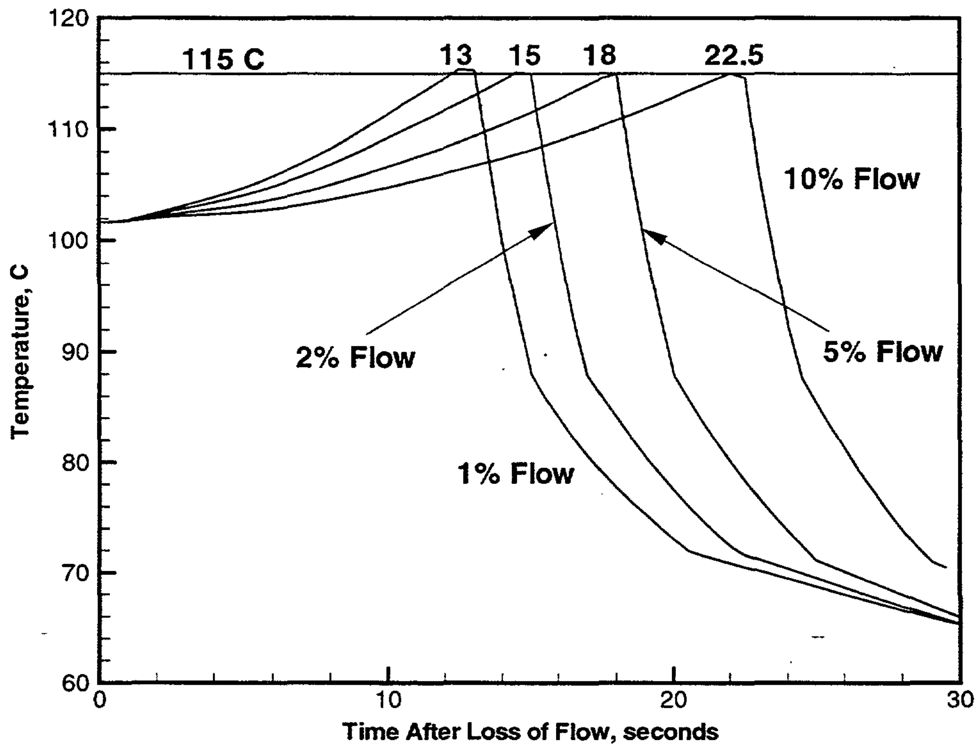

Figure 5-2 Maximum aluminum temperature transients for T_{Al} = 115 C criteria.

6 Conclusions

6.1 Comparison to Thermal/Hydraulic Design Criteria

Simulations performed using the TRAC system model and the FLOWTRAN-TF detailed bin model show that the APT blanket modules maintain a coolable geometry during the LOFA scenario. The thermal/hydraulic (T/H) design criteria, along with the basis for their development, is discussed in Refs. [15-16]. For LOFA the T/H onset criteria are based on meeting very strict phenomenological limits with a high degree of confidence, as follows:

- for local heated surfaces within the module components, the onset-of-significant-voids [OSV]) at a three sigma confidence level; and
- for the remaining unheated piping sections of the blanket system, the onset-of-bulk-boiling [OBB]) at a three sigma confidence level.

Additional (steady-state derived) material design criteria are imposed on the maximum lead and aluminum (Series 6061 - Type T6) metal temperatures acceptable for the module components. The limiting values for these parameters are 327.5 C and 115 C for lead and aluminum, respectively. These material design criteria ensure that a coolable geometry can be maintained throughout the expected lifetime of each module unit.

Confidence bounds are required to establish the acceptable level of probability of exceeding these criteria. The results presented in this report represent primarily best estimate values (however, some parameters were set to their estimated upper bounds, such as power density). Quantification of overall uncertainties and then their corresponding confidence levels (i.e., operating and modeling uncertainties) have not yet been performed. Future efforts to perform a response surface analysis are planned. At that time quantification of safety margins will be determined.

6.2 Design Issues

Adequate safety margin is provided by the reference 1 plate-type design to allow the APT blanket section to withstand the LOFA scenarios analyzed. In particular, the maximum aluminum temperature remained below 115 C with beam trips delayed by from 10 to 20 seconds. The maximum aluminum temperature exceeded 165 C if the beam trips were delayed by from 30 to 60 seconds. However, following beam trip, aluminum temperatures rapidly declined and the exposure limit was never approached. The design basis LOFA assumes beam trip within one second of the accident initiation. With the plate-type blanked design, this criteria provides a large safety margin.

The TRAC system model predicts a peak lead temperature in module #1 of 152 C and the detailed FLOWTRAN-TF bin model predicts a peak lead temperature of 112.8 C. The cruciform design was used in the TRAC system model, and the plate design was used in the FLOWTRAN-TF model. This points out the need for consistency between the two models. The TRAC model will be upgraded in order to provide this consistency.

6.3 Predicted Impact

Blanket conditions during LOFA fall within all specified thermal/hydraulic design criteria. No on-site or off-site impact to people or the environment would occur from conditions within the blanket region of the APT as a result of LOFA.

7 References

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2. L. L. Hamm, S. Y. Lee, M. A. Shadday, and F. G. Smith, III, "APT Blanket System Loss-of-Coolant Accident (LOCA) Analysis Based on Initial Conceptual Design - Case 1: External HR Break Near Inlet Header," Westinghouse Savannah River Company, WSRC-TR-98-0059 (July 1998).
3. L. L. Hamm, S. Y. Lee, M. A. Shadday, and F. G. Smith, III, "APT Blanket System Loss-of-Coolant Accident (LOCA) Analysis Based on Initial Conceptual Design - Case 2: External HR Break at Pump Outlet with Pump Trip," Westinghouse Savannah River Company, WSRC-TR-98-0060 (July 1998).

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14. R. Kapernick, "Preliminary Blanket Safety Calculations", e-mail memo from Los Alamos National Laboratory, December 11, 1997.

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Appendix A: TRAC Model Component Nomenclature

Table A-1 Blanket System Component Descriptions in TRAC Model.

System	Component Type	Comp #	No of Cells	Descriptions
HR	Fixed Header (FH)	380	1	coolant Supply FH
		340	1	coolant Return FH
	Pressurizer (Pzr)	760	1	Pzr surge line 1 connected to Supply FH 380
		761	2	Pzr surge line 2
		762	1	Pzr surge line 3
		763	1	Pzr surge line 4
		764	1	Pzr surge line 5
		765	13	Pzr surge line 6
		766	9	primary Pzr
	Hot Leg Loop	20	1	pipe connected to Return FH340
		21	1	plenum for potential break loc.
		22	7	pipe connection to external loop
		23	1	pipe connect. for potential break
		24	13	connection pipe
		25	1	connection pipe
		26	2	pipe connected to two pumps
		27	1	plenum for two pump connection
		28	2	pump#1 suction pipe
		29	7	pump#2 suction pipe
		30	2	pump located at cell face 2
		31	2	pump located at cell face 2
		32	3	check valve located at pump#1 discharge
		33	3	check valve located at pump#2 discharge
		34	1	pump outlet plenum
		36	1	connect. pipe between pump and pipe
		37	1	HX connect. pipe for potential break
		38	1	pipe connect. to two HX's inlet plenum
		40	1	plenum
	HX	48	3	HX #1 inlet pipe
		50	4	HX #1 1st pass
		52	3	HX #1 middle header
		54	4	HX #1 2nd pass
		49	3	HX #2 inlet pipe
		51	4	HX #2 1st pass
		53	3	HX #2 middle header
		55	4	HX #2 2nd pass
		710	1	HX #1 secondary side fill
		711	4	HX #1 2nd pass secondary side
		712	3	HX #1 middle header secondary side
		713	4	HX #1 1st pass secondary side
		714	1	HX #1 secondary side break BC
		730	1	HX #2 secondary side fill BC

Table A-1 Blanket System Component Descriptions in TRAC Model (continued).

System	Component Type	Comp #	No of Cells	Descriptions
		731	4	HX #2 2nd pass secondary side
		732	3	HX #2 middle header secondary side
		733	4	HX #2 1st pass secondary side
		734	1	HX #2 secondary side break BC
HR	Cold Leg Loop	56	3	HX #1 outlet pipe
		57	6	HX #2 outlet pipe
		60	3	HX outlet plenum merged after two HX's
		62	1	cold leg pipe
		63	1	cold leg pipe
		64	13	cold leg pipe located outside cavity wall
		65	1	pipe for cold leg pipe break
		66	1	horizontal cold leg pipe penetration
		67	1	plenum for internal break on HR loop
		854	2	HR isolation valve for internal break
		69	1	plenum for internal LOCA simulation
		68	5	pipe connect. to FH 340 inside cavity
Cavity Vessel	Cold Leg Loop	850	2	valve located bet. cavity vessel and HR
		852	2	valve located bet. cavity vessel and HR
			1	plenum for cavity vessel connection
		828	3	cavity vent valve
		802	1	break component for cavity vent pressure BC
		823	11	pipe for cavity lower section simulation
		824	1	plenum for cavity connection
		840	2	valve to connect cavity line to Module 1
		825	4	pipe for cavity middle section simulation
Cavity Pool	Cavity Flood Line	820	13	pipe for cavity pool connection to cavity vessel
		821	2	cavity flood line valve
		822	1	flood line pipe inside cavity vessel
	Cavity Flood Pool	801	1	break component for cavity pool BC
		810	10	pipe for top cavity pool section
		811	1	plenum for middle cavity pool section
		812	7	pipe for lower cavity pool section
		813	1	plenum for cavity pool bottom
RHR	RHR Loop	621	1	pipe located to return FH
		623	10	pipe located inside the cavity vessel
		624	1	pipe located outside the cavity vessel
		625	18	pipe bet. RHR pump and pipe comp. #624
		630	2	RHR pump located at face 2
		640	3	check valve located at pump discharge
		652	4	HX tubes
		660	16	pipe at the cold leg side
		661	1	pipe located before cavity vessel
		662	8	cold leg pipe inside cavity vessel

Table A-1 Blanket System Component Descriptions in TRAC Model (continued).

System	Component Type	Comp #	No of Cells	Descriptions
		663	1	cold leg pipe connected to supply FH
		672	1	fill for HX secondary side BC
		671	4	HX secondary shell side
		673	1	break comp. for HX secondary side BC
Module	Module 1 Flow	454	7	pipe connected to supply FH
		80	1	plenum for potential internal break simulation at Module 1
		375	5	pipe connection bet. Suuply FH and Module 1 upper plenum
		370	1	upper plenum for Module 1 downcomer
		360	5	Module 1 downflow region
		350	1	middle plenum bet. Module 1 downflow and upflow regions
		300	5	Module 1 upflow region
		330	1	upper plenum for module 1 upflow region
		335	5	connection pipe after Module 1 upper plenum
		429	4	pipe connected to return FH
	Module 2 Flow	173	7	pipe coonected to supply FH
		81	1	plenum for potential internal break simulation at Module 2
		82	3	pipe connection
		172	1	upper plenum for Module 2 downcomer
		158	6	Module 2 downflow region
		147	1	middle plenum bet. Module 2 downflow and upflow regions
		102	6	Module 2 upflow region
		133	1	upper plenum for module 2 upflow region
		136	7	pipe connected to return FH
	Module 3 Flow	415	7	pipe connected to supply FH
		85	1	plenum for potential internal break simulation at Module 3
		86	3	pipe connection
		479	1	upper plenum for Module 3 downcomer
		478	5	Module 3 downflow region
		418	1	middle plenum bet. Module 3 downflow and upflow regions
		409	5	Module 3 upflow region
		423	1	upper plenum for module 3 upflow region
		417	7	pipe connected to return FH
	Module 4 Flow	485	7	pipe connected to supply FH
		87	1	plenum for potential internal break simulation at Module 4
		88	3	pipe connection
		489	1	upper plenum for Module 4 downcomer

Table A-1 Blanket System Component Descriptions in TRAC Model (continued).

System	Component Type	Comp #	No of Cells	Descriptions
		480	6	Module 4 downflow region
		419	1	middle plenum bet. Module 4 downflow and upflow regions
		412	6	Module 4 upflow region
		483	1	upper plenum for module 4 upflow region
		484	7	pipe connected to return FH
Module	Module 5 Flow	513	7	pipe connected to supply FH
		89	1	plenum for potential internal break simulation at Module 5
		90	3	pipe connection
		510	1	upper plenum for Module 5 downcomer
		507	6	Module 5 downflow region
		503	1	middle plenum bet. Module 4 downflow and upflow regions
		500	6	Module 5 upflow region
		508	1	upper plenum for Module 5 upflow region
		511	7	pipe connected to return FH
	Module 6 Flow	541	7	pipe connected to supply FH
		83	1	plenum for potential internal break simulation at Module 6
		84	1	pipe connection
		538	1	upper plenum for Module 6 decoupler
		535	5	Module 6 downcomer region
		531	1	middle plenum bet. Module 6 decoupler and main heated regions
		528	5	Module 6 main heated region
		536	1	upper plenum for module 6 main heated region
		539	12	pipe connected to return FH
	Module 1 Heater Structure	901	5	Al tube structure in Row 1
		951	5	Lead zone with Al cladding in Row 1
		984	5	Al tube structure in decoupler
	Module 2 Heater Structure	905	6	Al tube structure in Row 2
		955	6	Lead zone with Al cladding in Row 2
		916	6	Al tube structure in Row 3
		966	6	Lead zone with Al cladding in Row 3
	Module 3 Heater Structure	911	5	Al tube structure in Row 1
		961	5	Lead zone with Al cladding in Row 1
		988	5	Al tube structure in decoupler
	Module 4 Heater Structure	912	6	Al tube structure in Row 1
		962	6	Lead zone with Al cladding in Row 1
		931	6	Al tube structure in Row 2

Table A-1 Blanket System Component Descriptions in TRAC Model (continued).

System	Component Type	Comp #	No of Cells	Descriptions
		978	6	Lead zone with Al cladding in Row 2
	Module 5 Heater Structure	913	6	Al tube structure in Row 2
		963	6	Lead zone with Al cladding in Row 2
		932	6	Al tube structure in Row 2
		979	6	Lead zone with Al cladding in Row 2
	Module 6 Heater Structure	915	5	Al tube structure in Row 2
		965	5	Lead zone with Al cladding in Row 2

Table A-2 Steady State Conditions.

Parameter	Units	Calculated Values
Total power deposited in blanket modules	MW	56.5
Total flow rate	kg/sec gpm	1569 25252
Pressure in cold-leg fixed header	MPa psia	0.7325 106.24
Pressure in hot-leg fixed header	MPa psia	0.4563 66.180
Pressurizer (cell #1) pressure	MPa psia	0.7311 106.03
Pump #1 suction pressure	MPa psia	0.2751 39.90
Pump #1 discharge pressure	MPa psia	1.0356 150.20
Pump #2 suction pressure	MPa psia	0.2958 42.91
Pump #2 discharge pressure	MPa psia	1.0409 150.97
Temperature in cold-leg fixed header	C F	49.43 121.0
Temperature in hot-leg fixed header	C F	58.03 136.5
Max. fluid temperature of the hottest module	C F	71.95 161.5

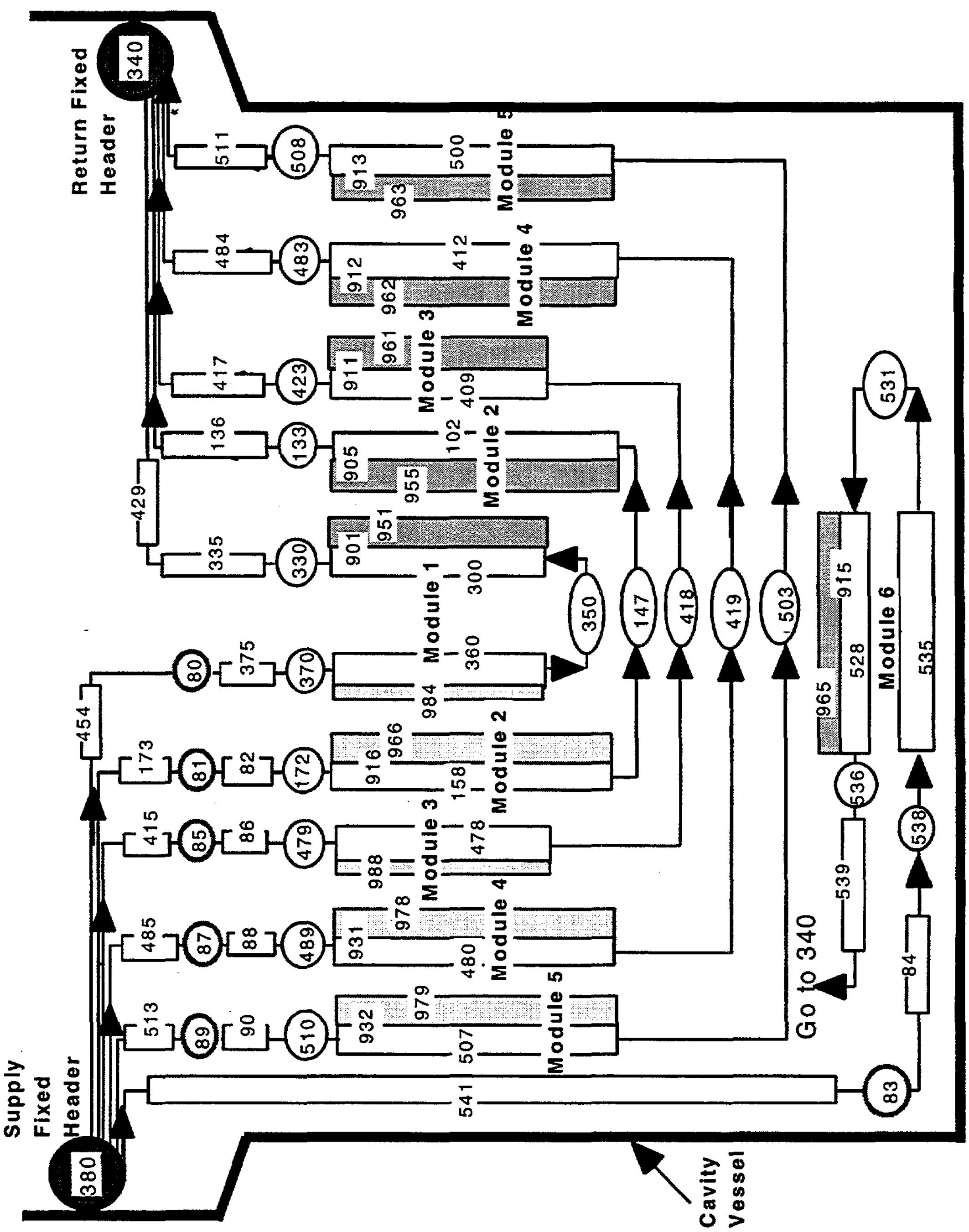

Figure A-1 6 blanket module layout for safety analysis.

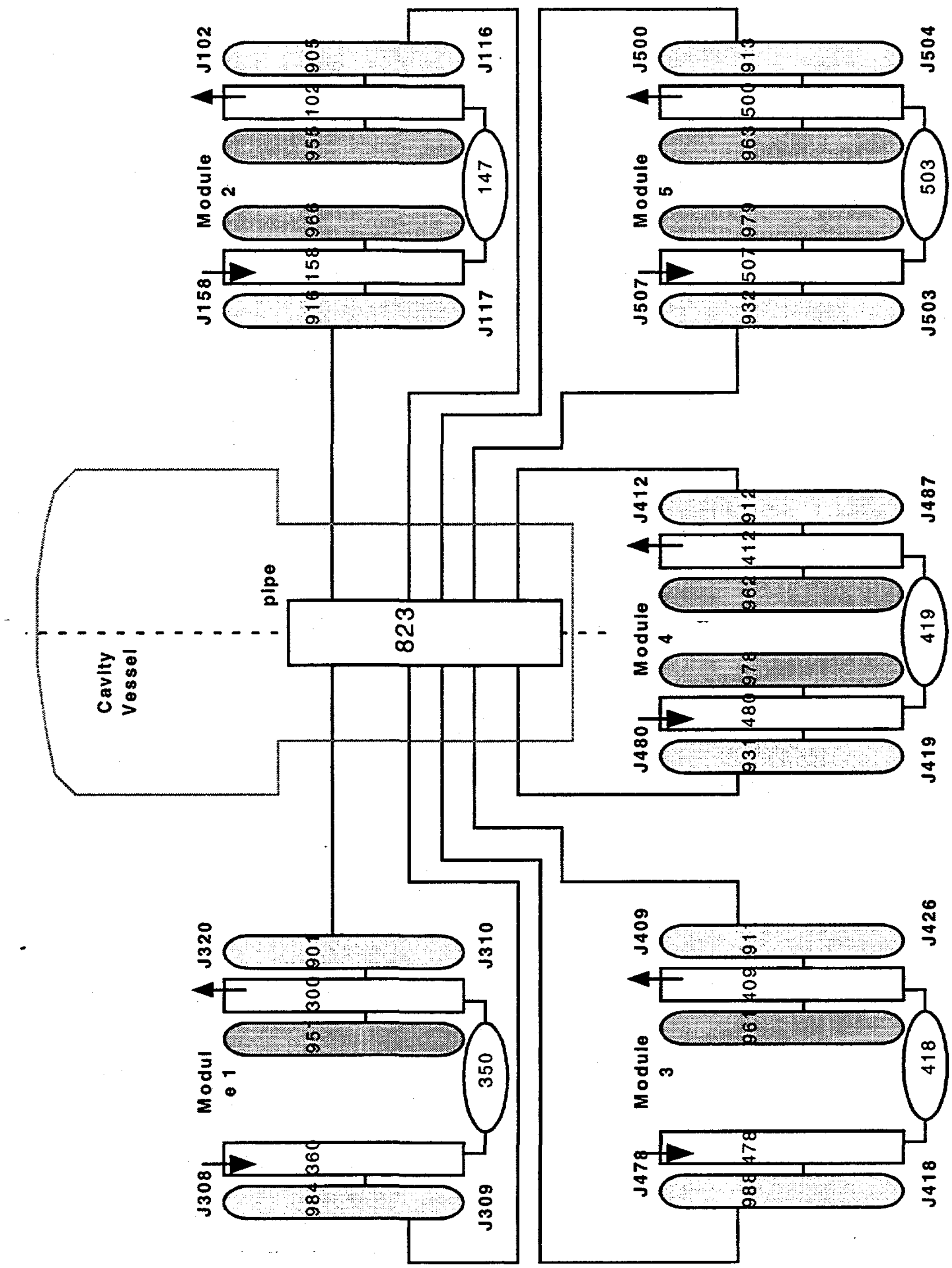

Figure A-2 TRAC component layout for the cavity vessel and blanket module heat structures.

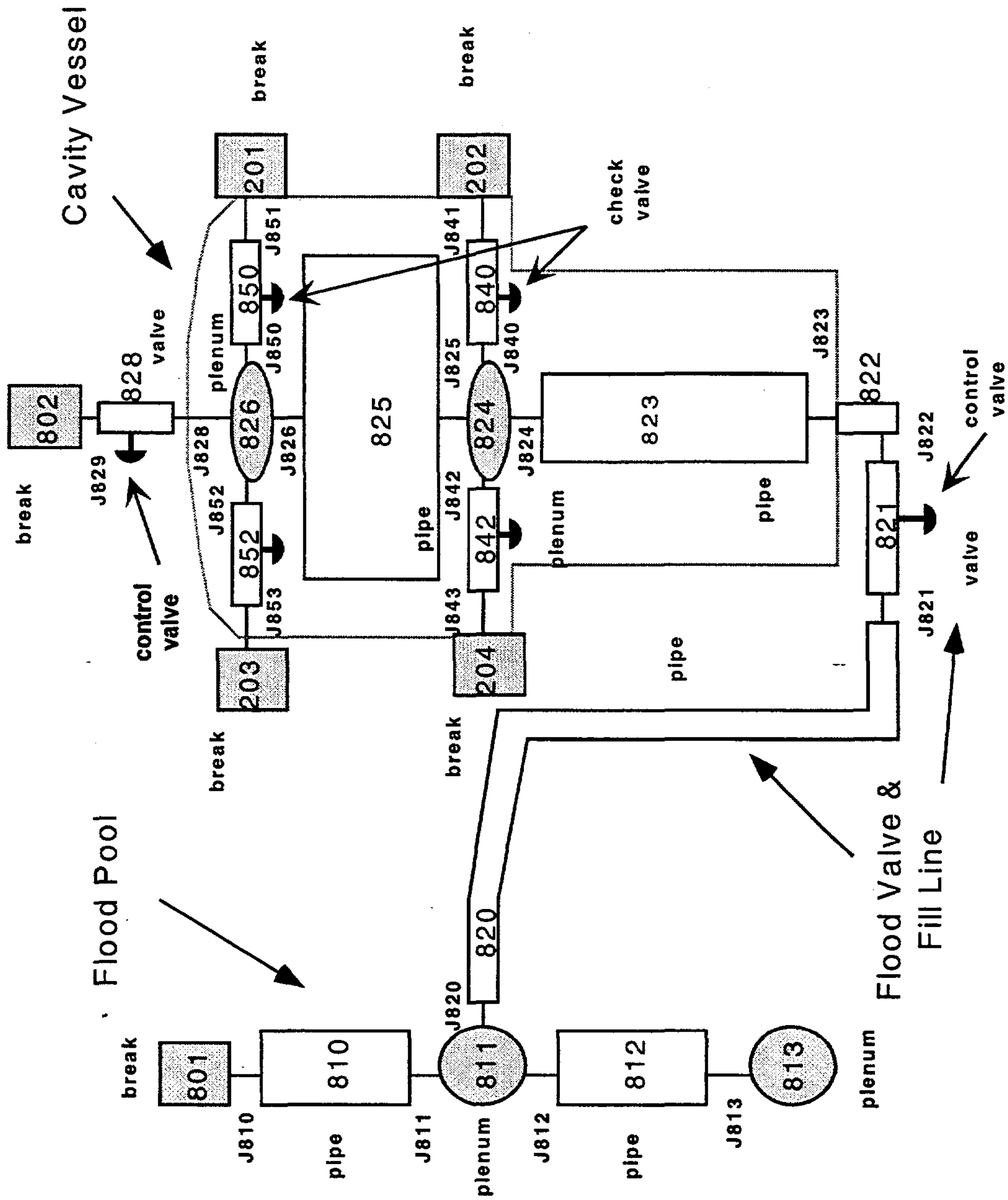

Figure A-3 TRAC component layout for the cavity vessel and cavity flood system.

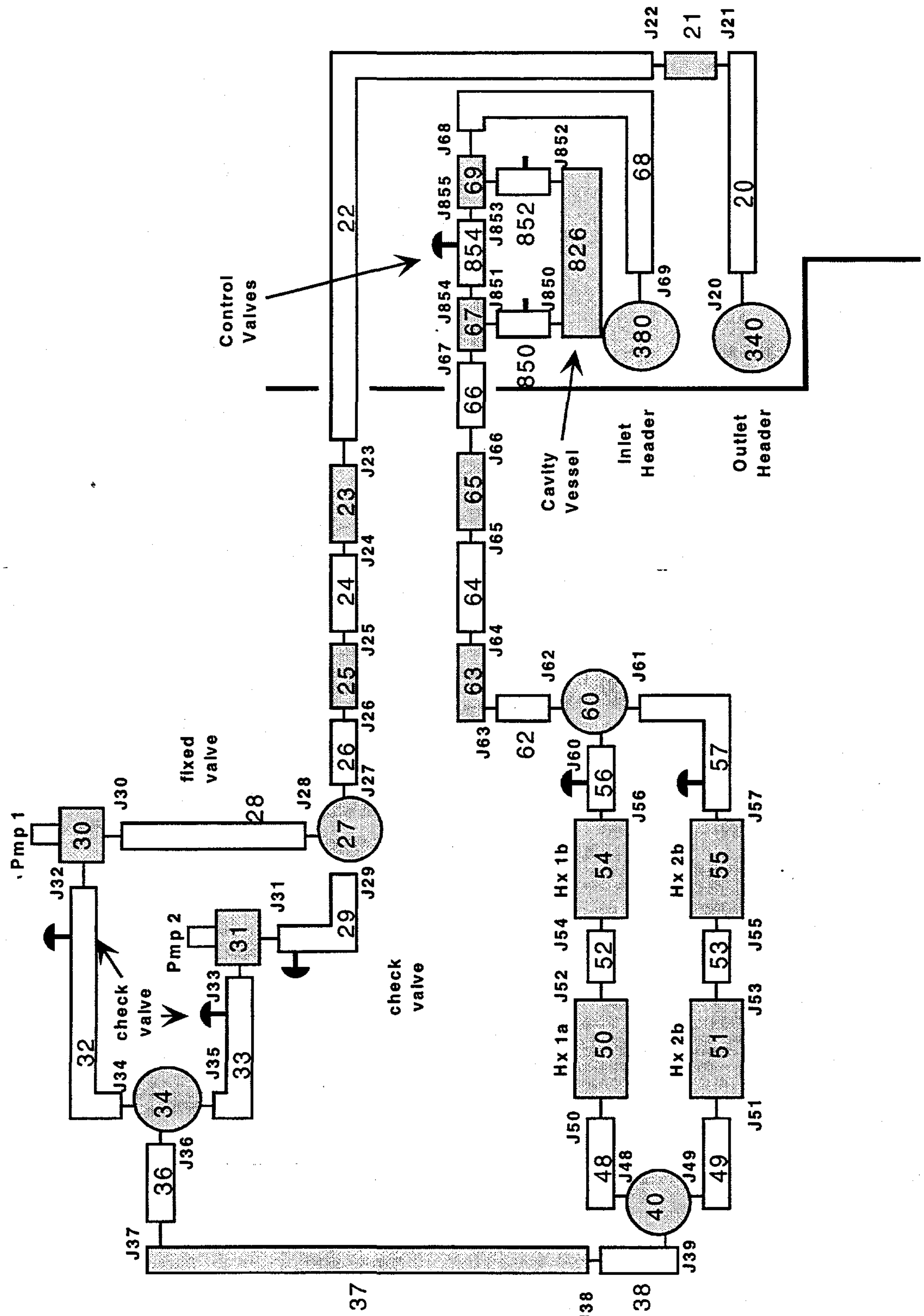

Figure A-4 TRAC component layout for blanket primary HR coolant loop.

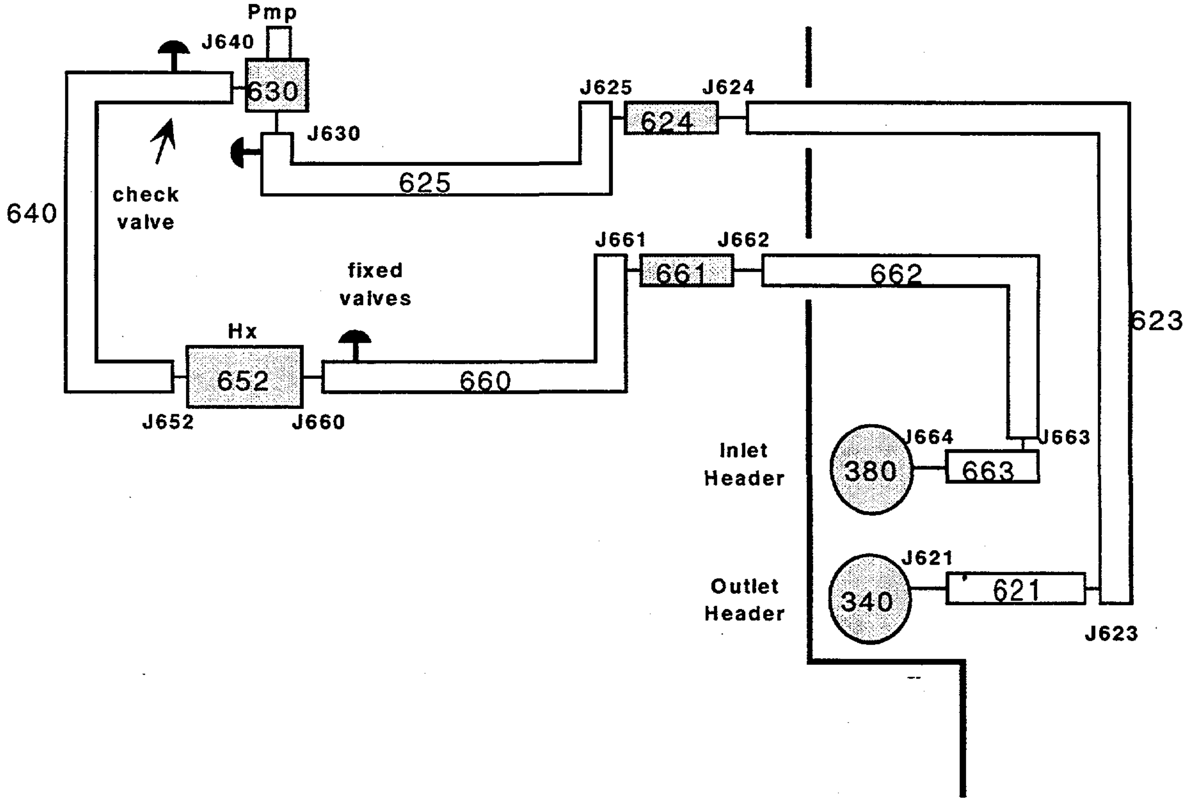

Figure A-5 TRAC component layout for blanket primary RHR coolant loop.

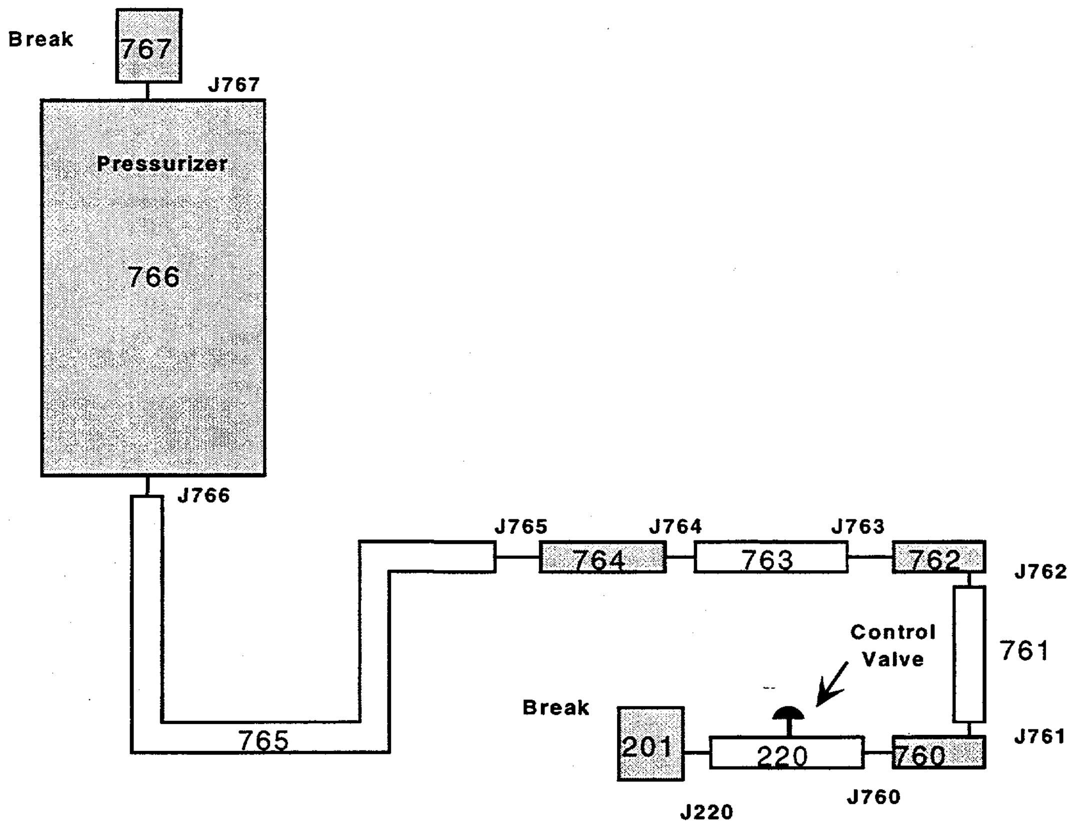

Figure A-6 TRAC component layout for blanket primary pressurizer and surge line.

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Appendix B: LOFA (Case 1) TRAC Results

Appendix B1 LOFA (Case 1) TRAC Plenum Component Figures

The following figures are from a TRAC simulation for Case 1 of a LOFA (with beam shutdown and active RHR):

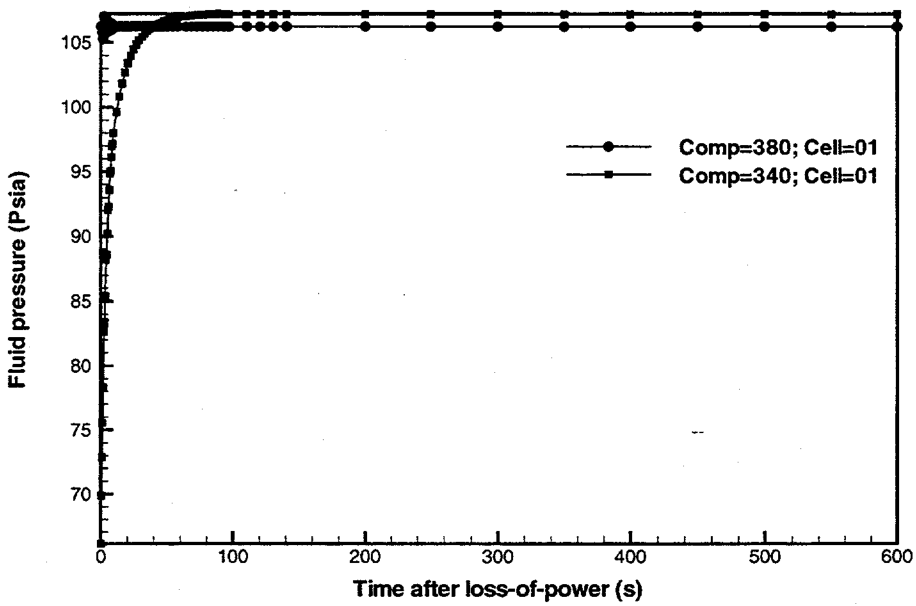

Figure B-1a Fixed header fluid pressures for a LOFA (Case 1: with beam shutdown and active RHR).

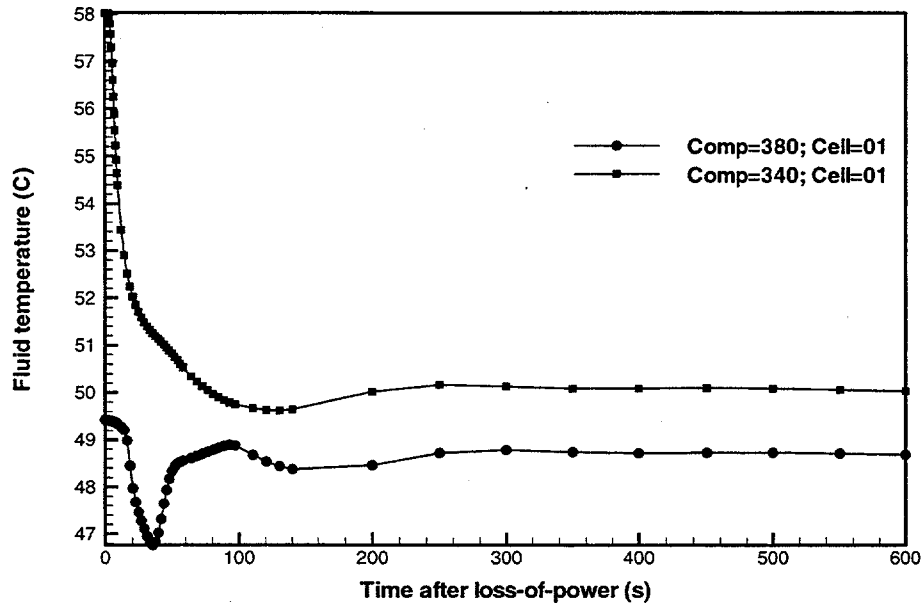

Figure B-1b Fixed header fluid temperatures for a LOFA (Case 1: with beam shutdown and active RHR).

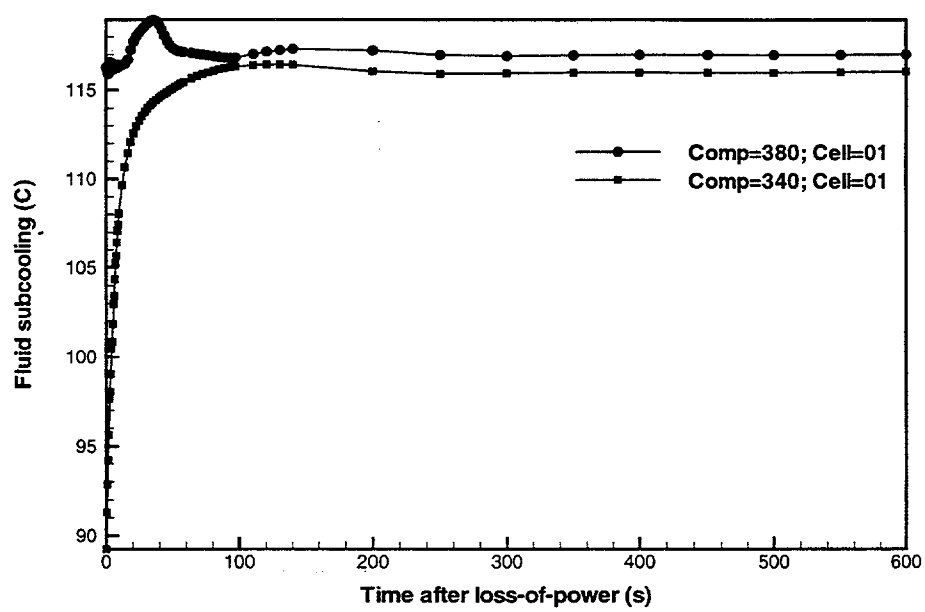

Figure B-1c Fixed header fluid subcoolings for a LOFA (Case 1: with beam shutdown and active RHR).

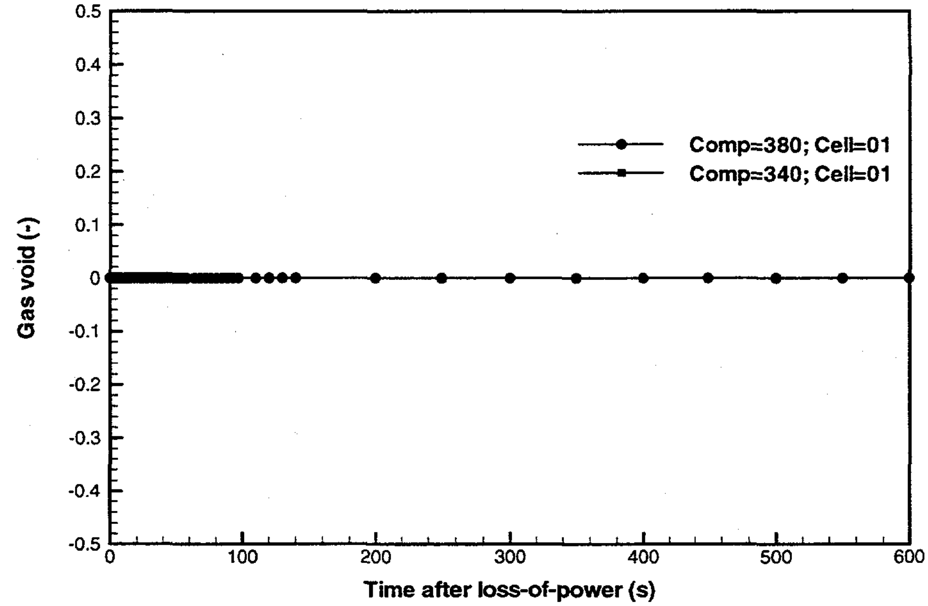

Figure B-1d Fixed header void fractions for a LOFA (Case 1: with beam shutdown and active RHR).

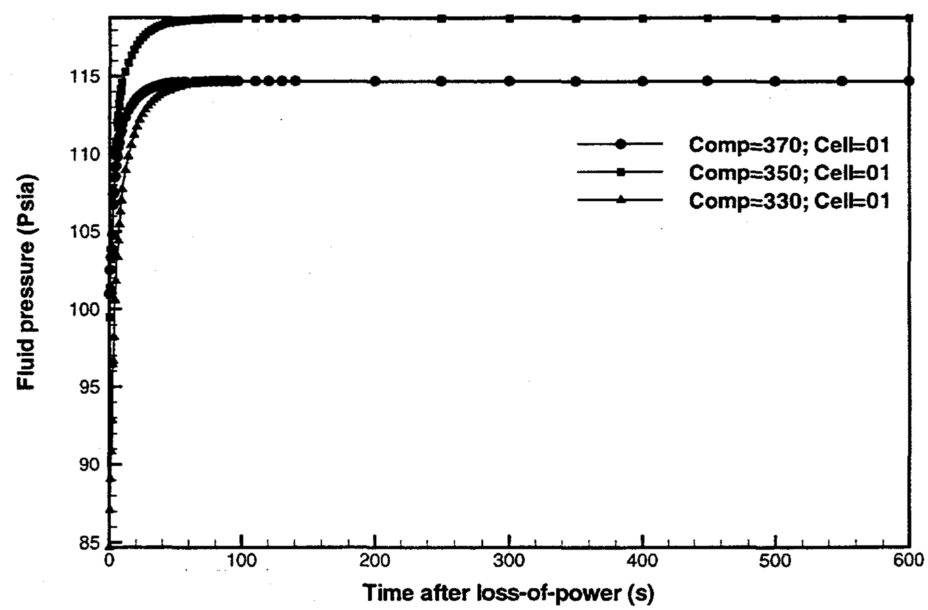

Figure B-2a Module 1 plenum fluid pressures for a LOFA (Case 1: with beam shutdown and active RHR).

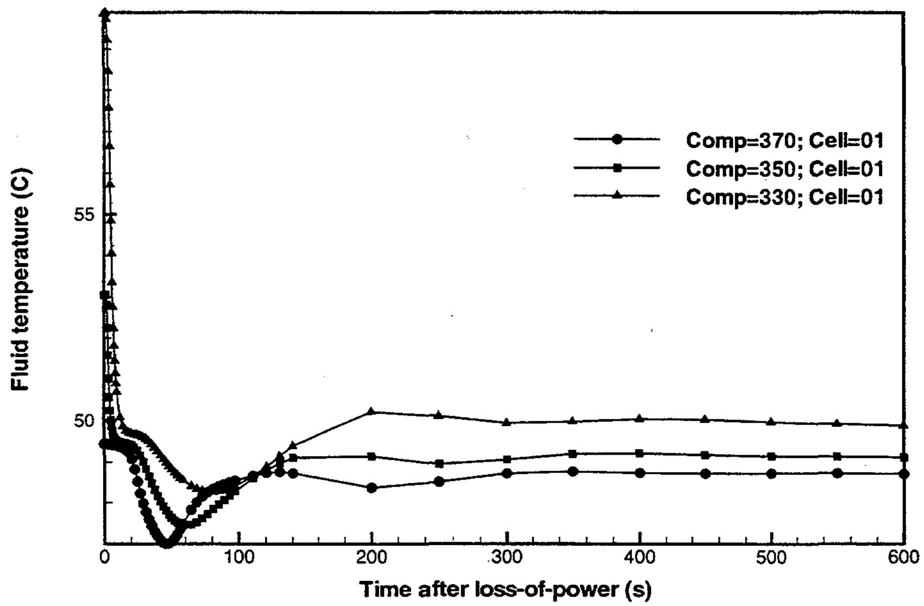

Figure B-2b Module 1 plenum fluid temperatures for a LOFA (Case 1: with beam shutdown and active RHR).

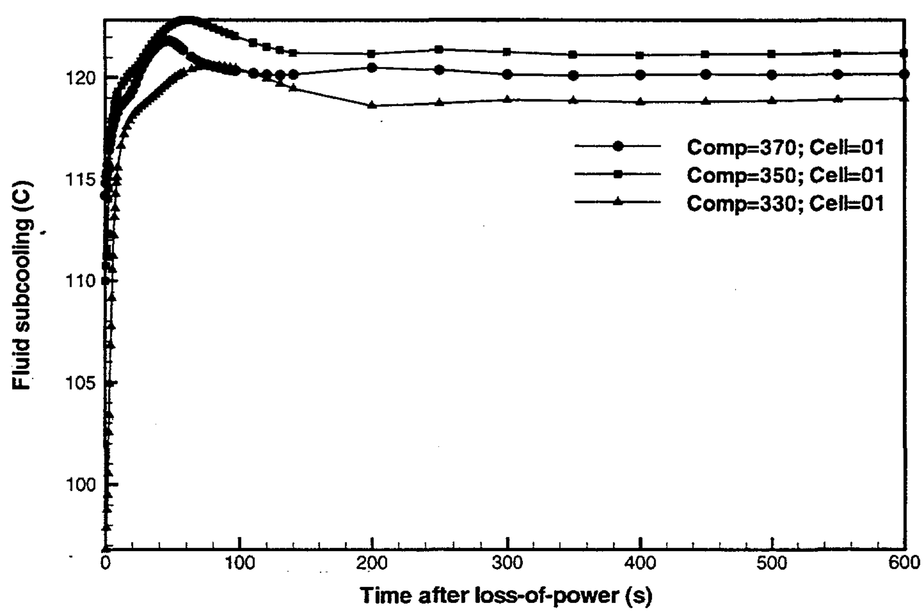

Figure B-2c Module 1 plenum fluid subcoolings for a LOFA (Case 1: with beam shutdown and active RHR).

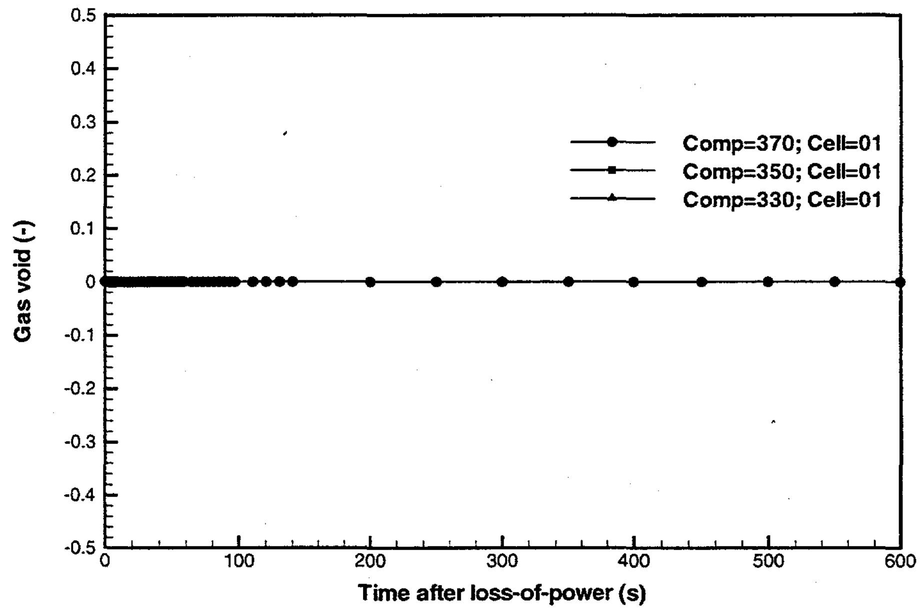

Figure B-2d Module 2 plenum void fractions for a LOFA (Case 1: with beam shutdown and active RHR).

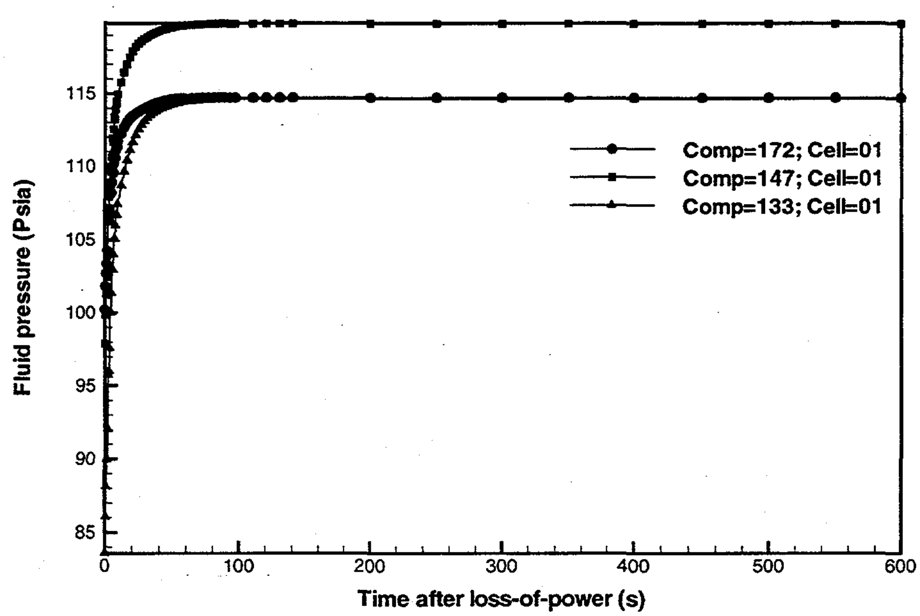

Figure B-3a Module 2 plenum fluid pressures for a LOFA (Case 1: with beam shutdown and active RHR).

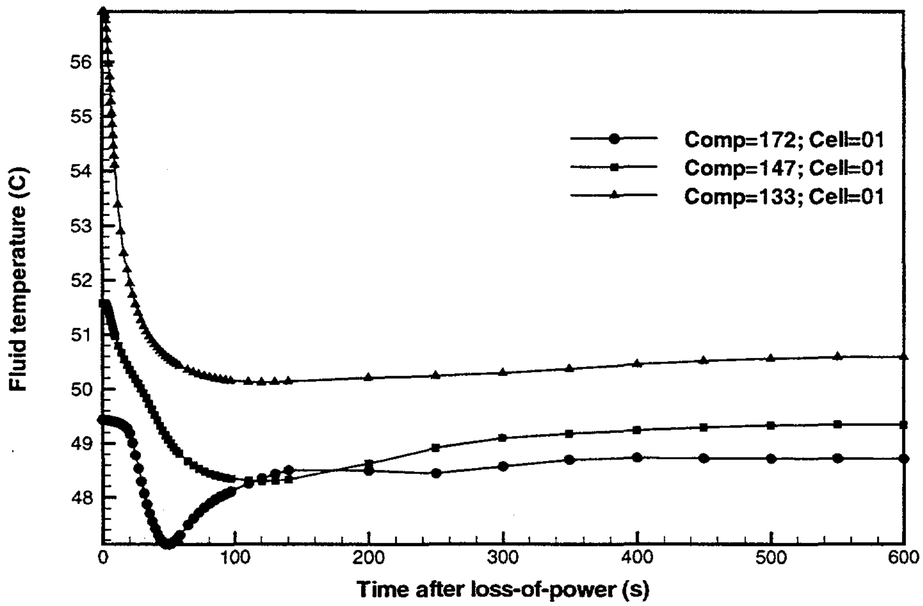

Figure B-3b Module 2 plenum fluid temperatures for a LOFA (Case 1: with beam shutdown and active RHR).

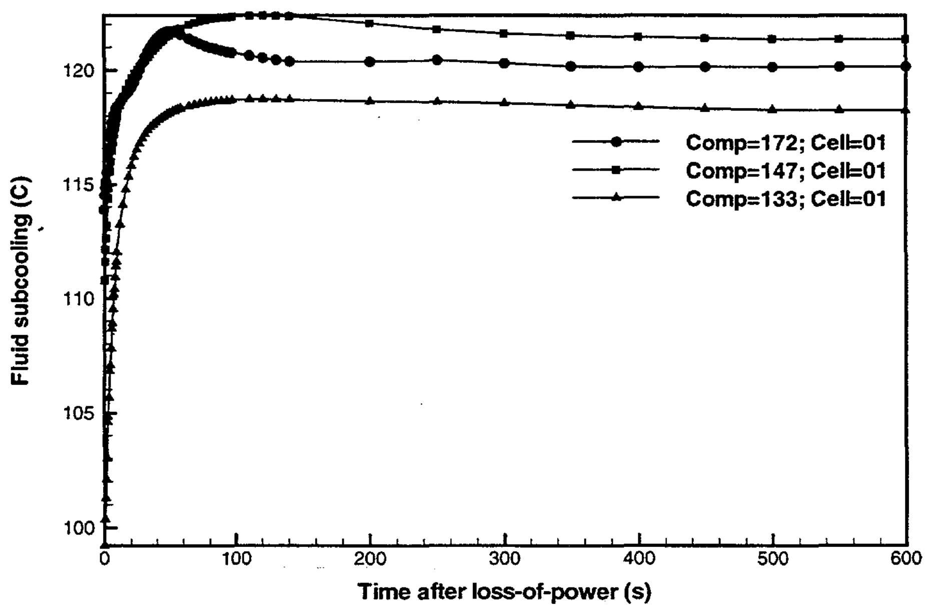

Figure B-3c Module 2 plenum fluid subcoolings for a LOFA (Case 1: with beam shutdown and active RHR).

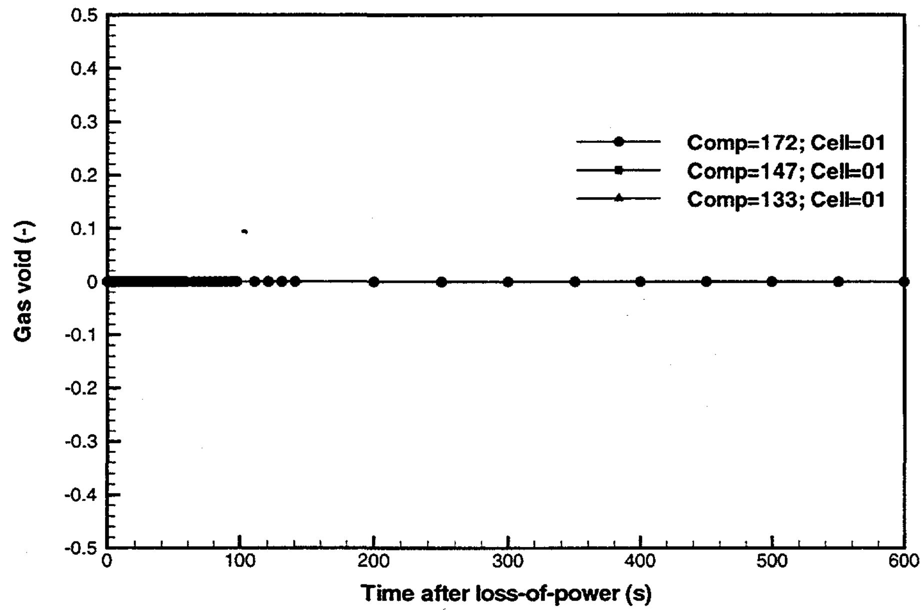

Figure B-3d Module 2 plenum void fractions for a LOFA (Case 1: with beam shutdown and active RHR).

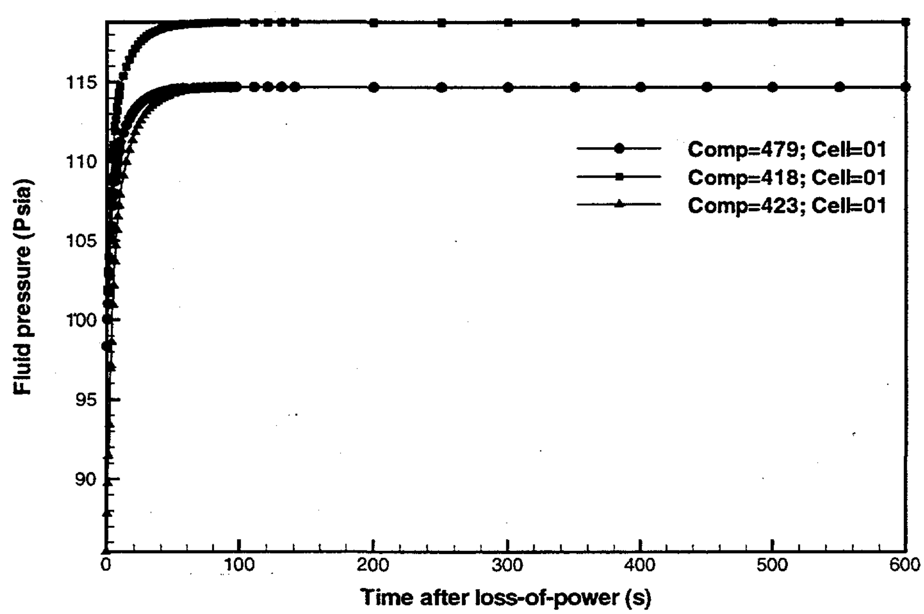

Figure B-4a Module 3 plenum fluid pressures for a LOFA (Case 1: with beam shutdown and active RHR).

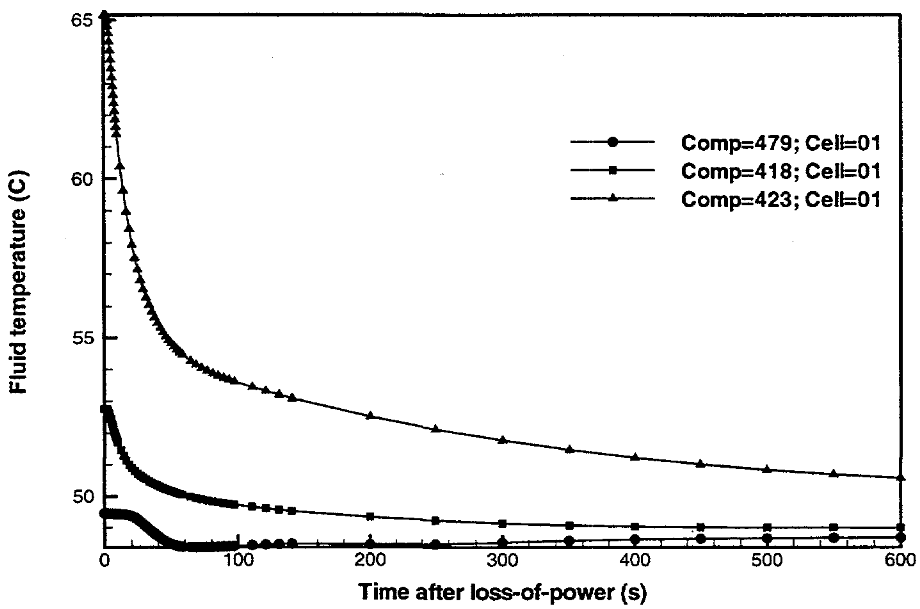

Figure B-4b Module 3 plenum fluid temperatures for a LOFA (Case 1: with beam shutdown and active RHR).

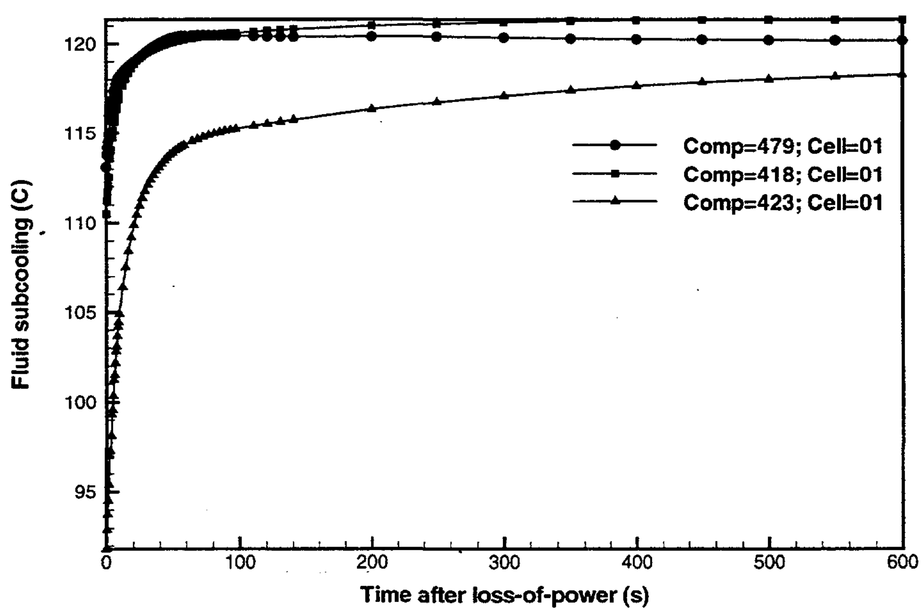

Figure B-4c Module 3 plenum fluid subcoolings for a LOFA (Case 1: with beam shutdown and active RHR).

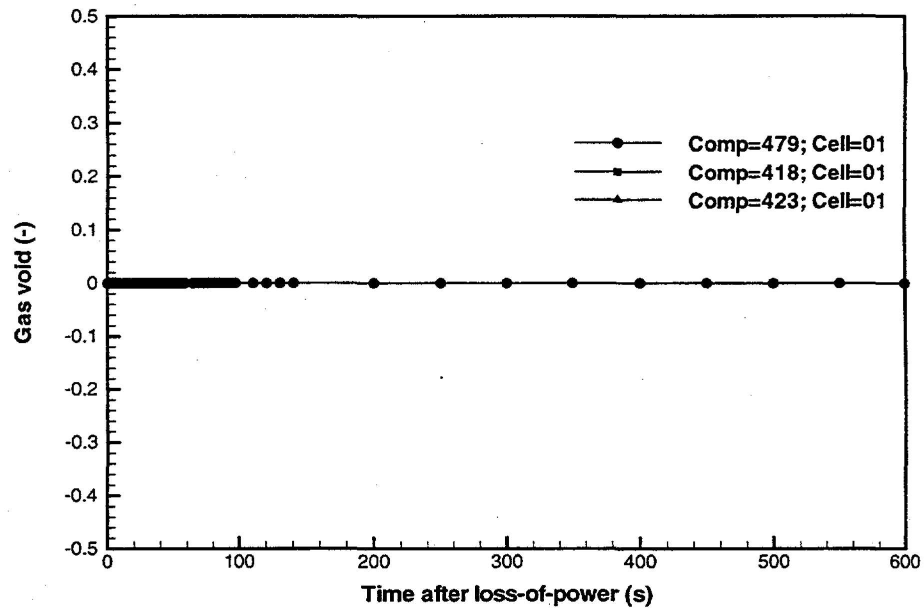

Figure B-4d Module 3 plenum void fractions for a LOFA (Case 1: with beam shutdown and active RHR).

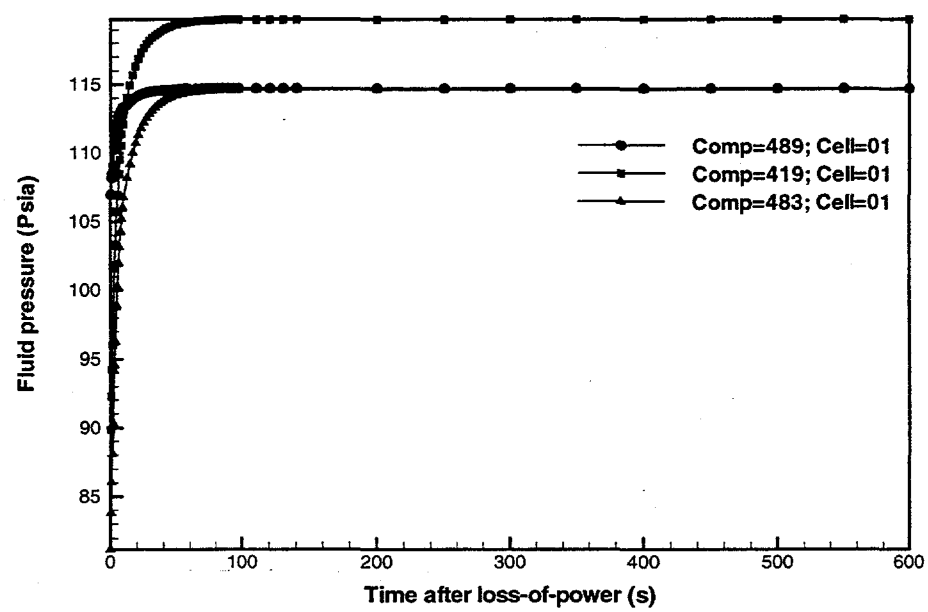

Figure B-5a Module 4 plenum fluid pressures for a LOFA (Case 1: with beam shutdown and active RHR).

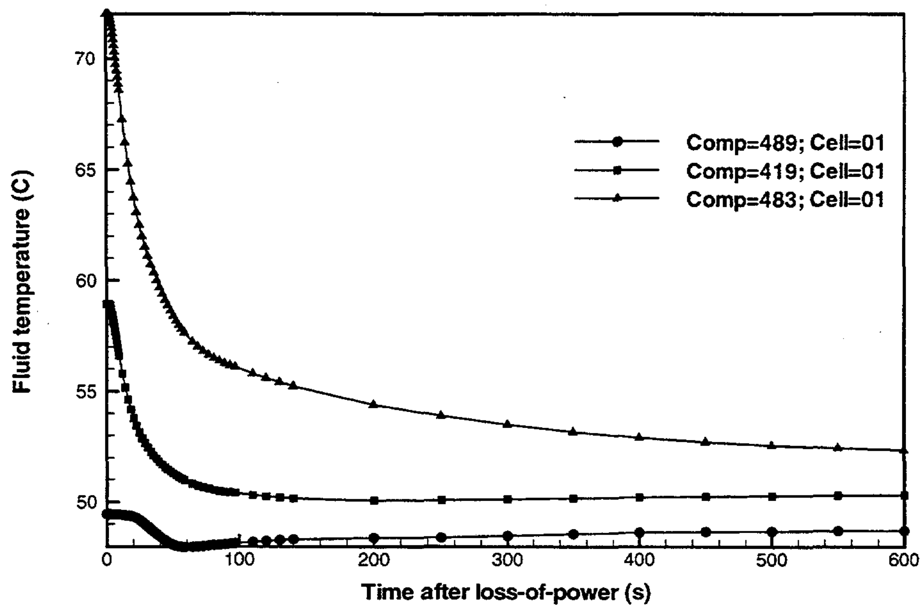

Figure B-5b Module 4 plenum fluid temperatures for a LOFA (Casē 1: with beam shutdown and active RHR).

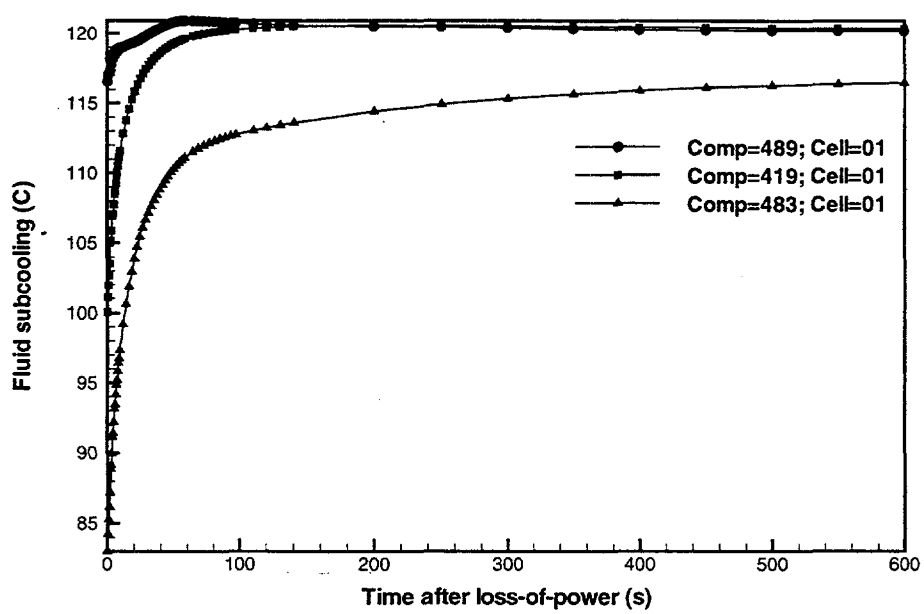

Figure B-5c Module 4 plenum fluid subcoolings for a LOFA (Case 1: with beam shutdown and active RHR).

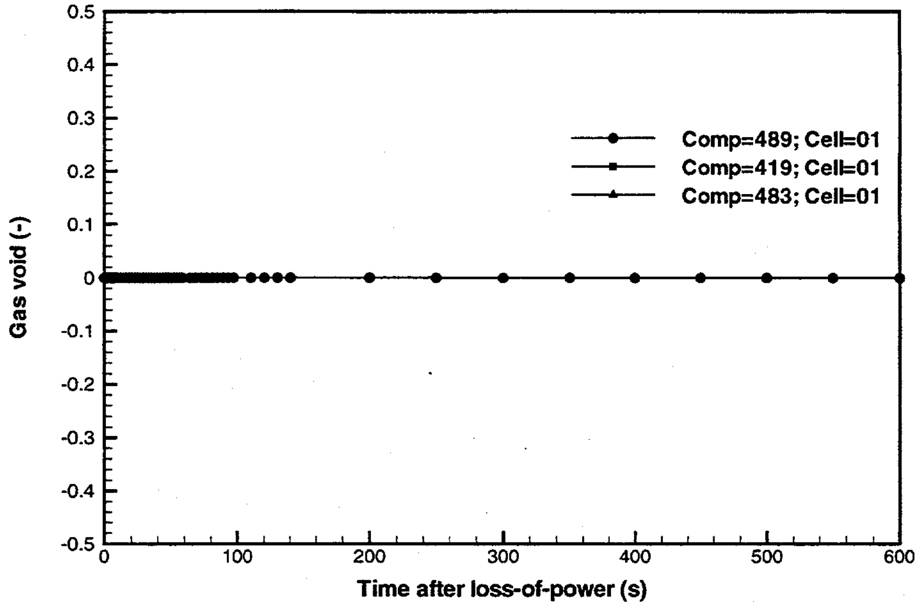

Figure B-5d Module 4 plenum void fractions for a LOFA (Case 1: with beam shutdown and active RHR).

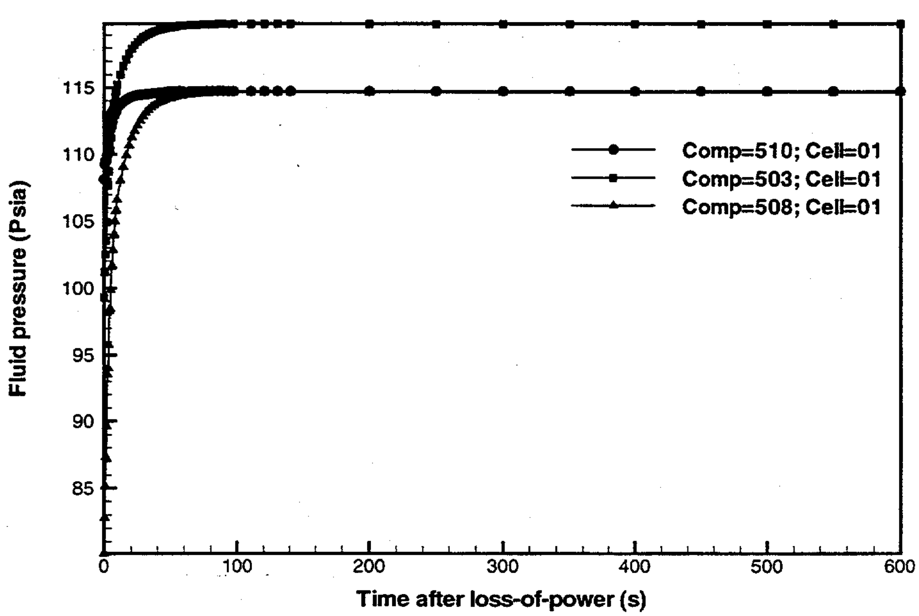

Figure B-6a Module 5 plenum fluid pressures for a LOFA (Case 1: with beam shutdown and active RHR).

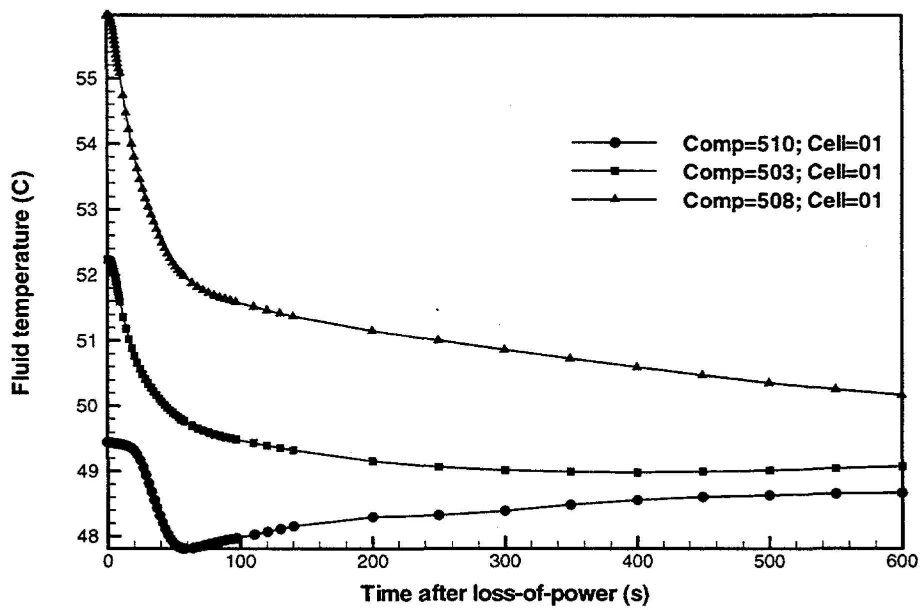

Figure B-6b Module 5 plenum fluid temperatures for a LOFA (Case 1: with beam shutdown and active RHR).

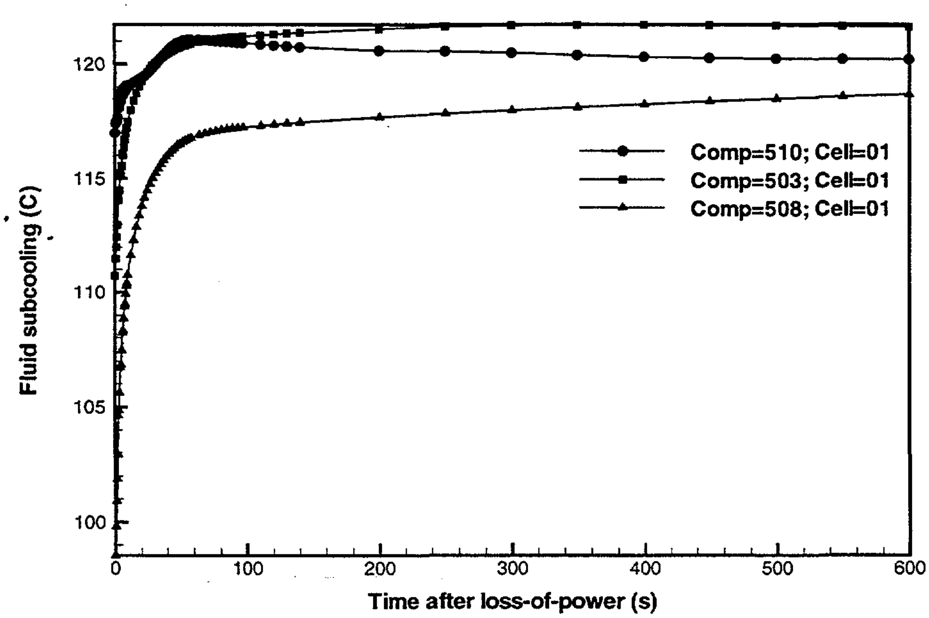

Figure B-6c Module 5 plenum fluid subcoolings for a LOFA (Case 1: with beam shutdown and active RHR).

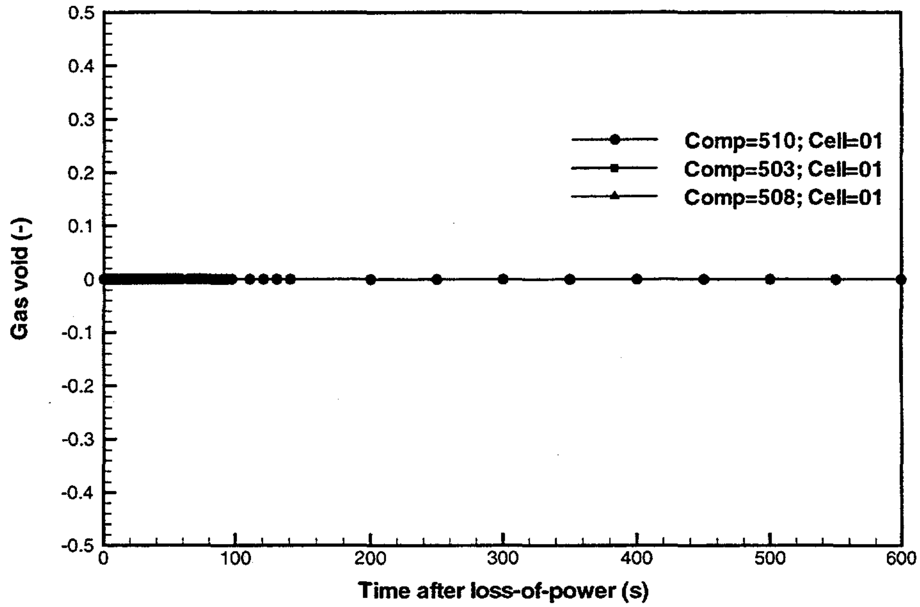

Figure B-6d Module 5 plenum void fractions for a LOFA (Case 1: with beam shutdown and active RHR).

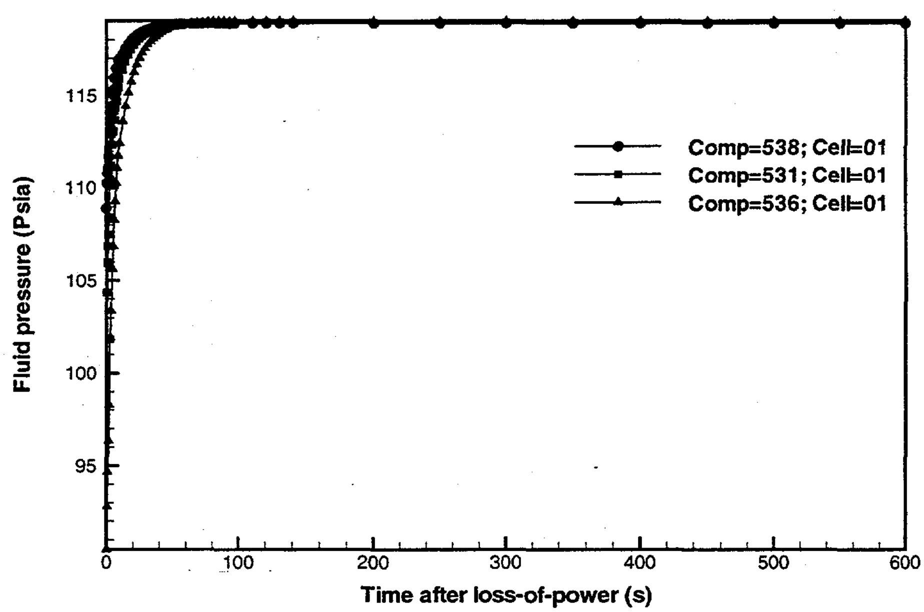

Figure B-7a Module 6 plenum fluid pressures for a LOFA (Case 1: with beam shutdown and active RHR).

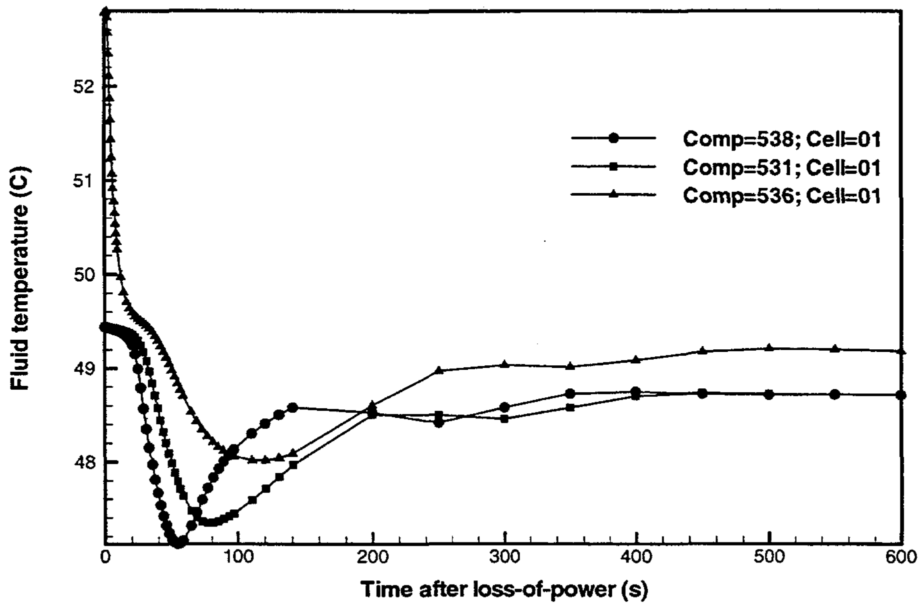

Figure B-7b Module 6 plenum fluid temperatures for a LOFA (Case 1: with beam shutdown and active RHR).

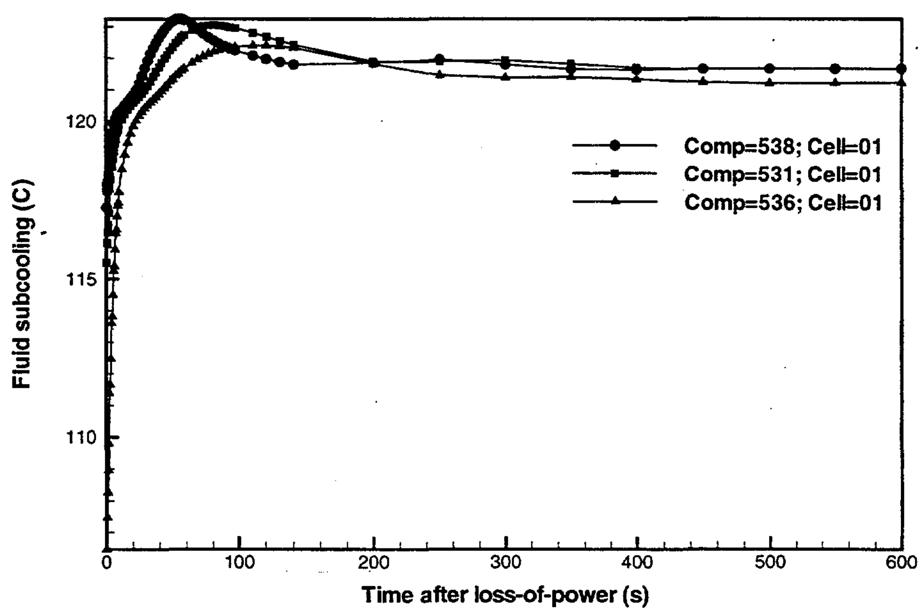

Figure B-7c Module 6 plenum fluid subcoolings for a LOFA (Case 1: with beam shutdown and active RHR).

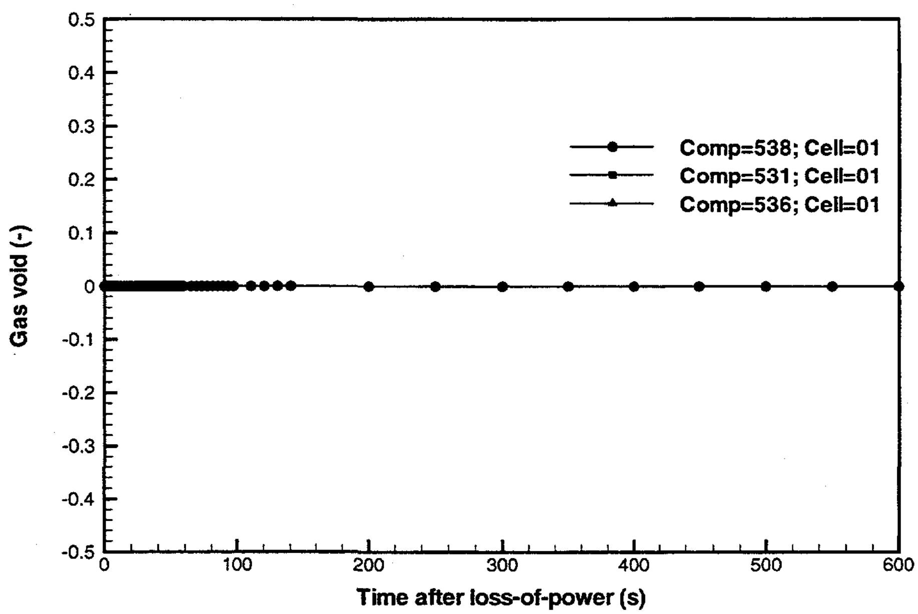

Figure B-7d Module 6 plenum void fractions for a LOFA (Case 1: with beam shutdown and active RHR).

Appendix B2 LOFA (Case 1) TRAC Pipe, Pump, and Valve Component Figures

The following figures are from a TRAC simulation for Case 1 of a LOFA (with beam shutdown and active RHR):

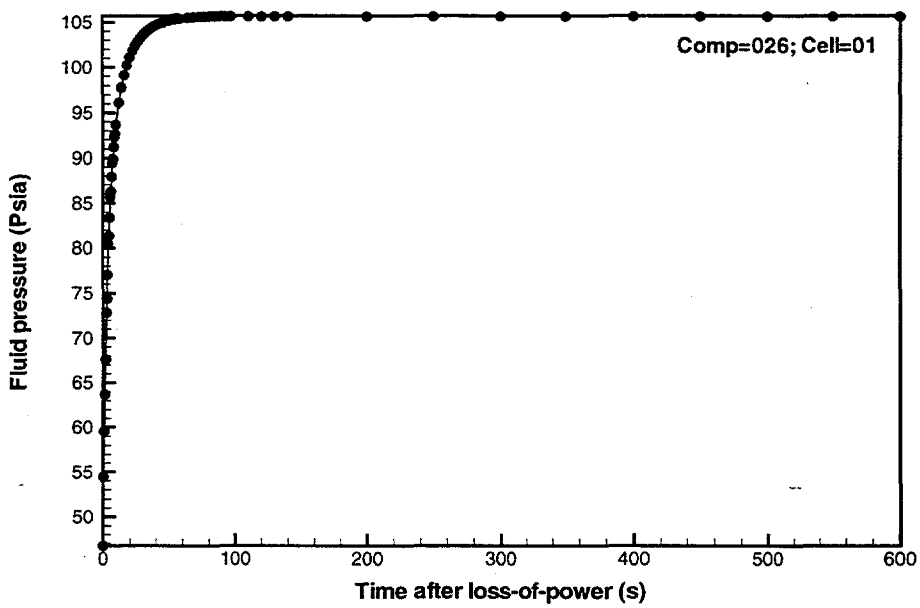

Figure B-8a Primary HR hot-leg piping fluid pressures for a LOFA (Case 1: with beam shutdown and active RHR).

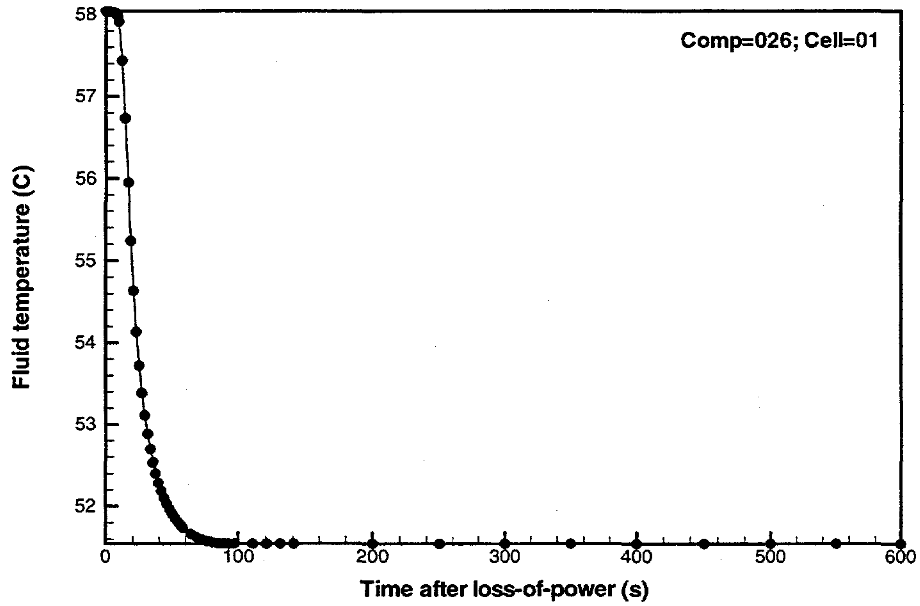

Figure B-8b Primary HR hot-leg piping fluid temperatures for a LOFA (Case 1: with beam shutdown and active RHR).

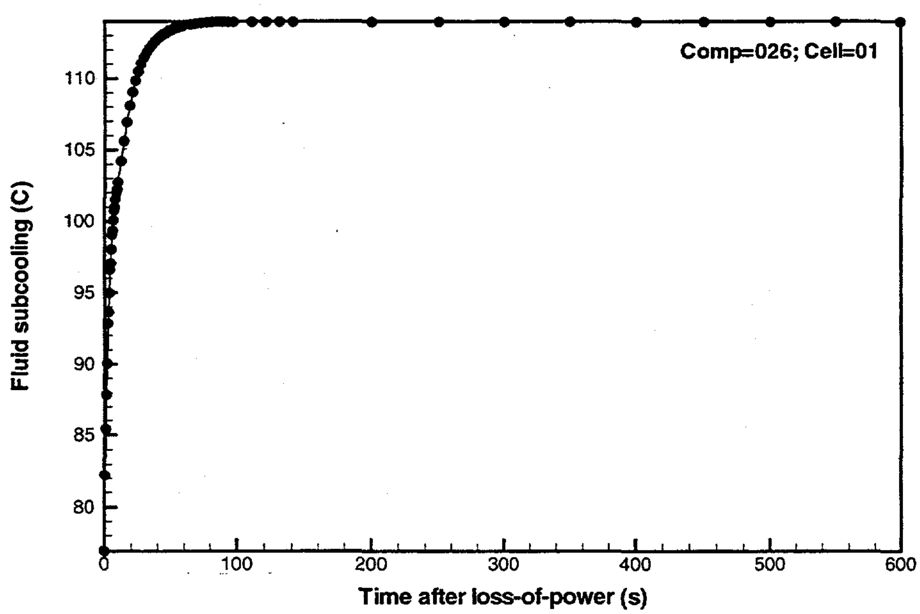

Figure B-8c Primary HR hot-leg piping fluid subcoolings for a LOFA (Case 1: with beam shutdown and active RHR).

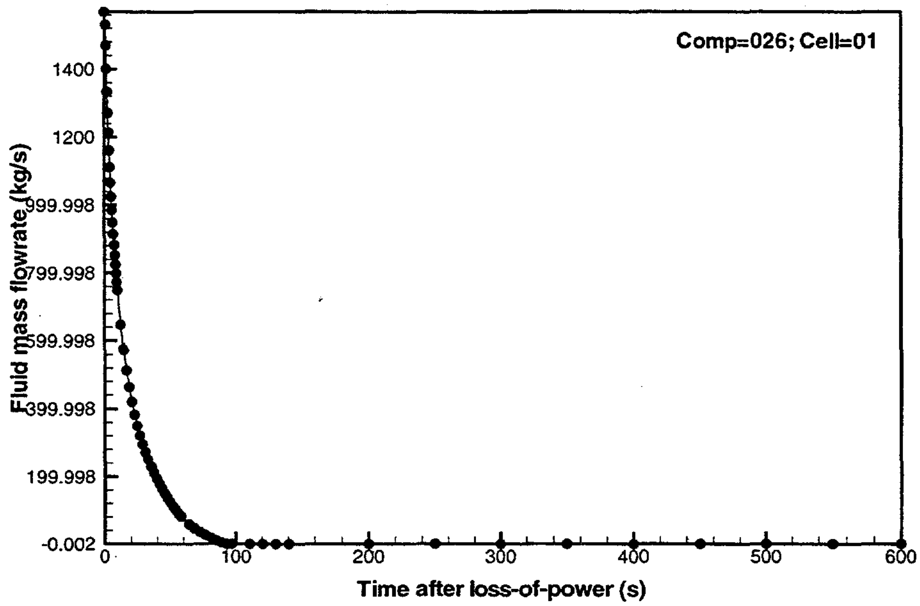

Figure B-8d Primary HR hot-leg piping liquid mass flowrates for a LOFA (Case 1: with beam shutdown and active RHR).

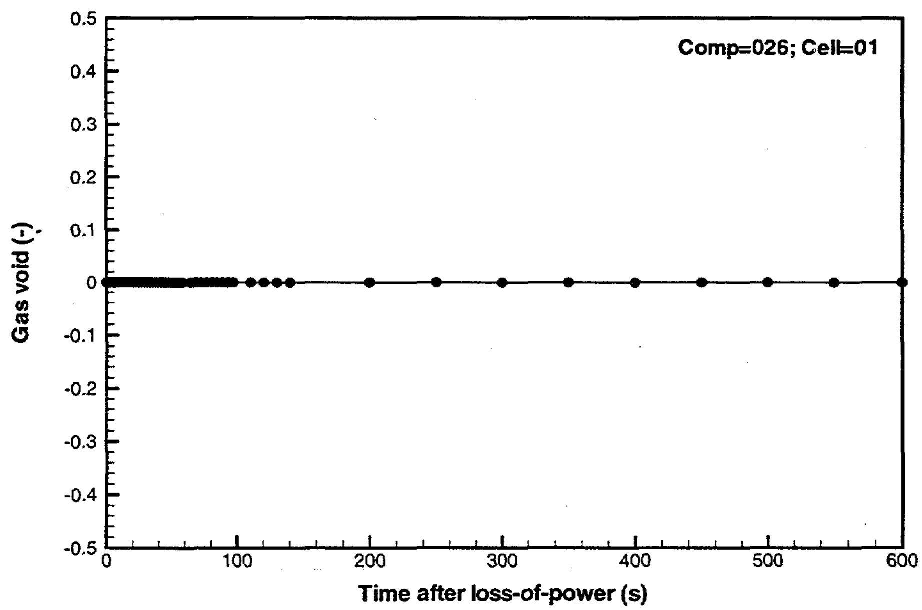

Figure B-8e Primary HR hot-leg piping void fractions for a LOFA (Case 1: with beam shutdown and active RHR).

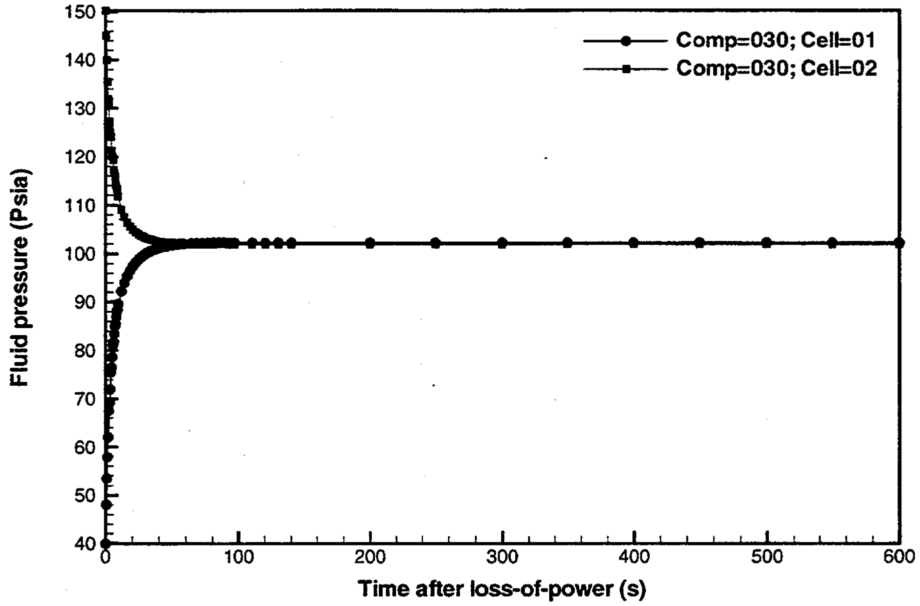

Figure B-9a Primary HR pump 1 fluid pressures for a LOFA (Case 1: with beam shutdown and active RHR).

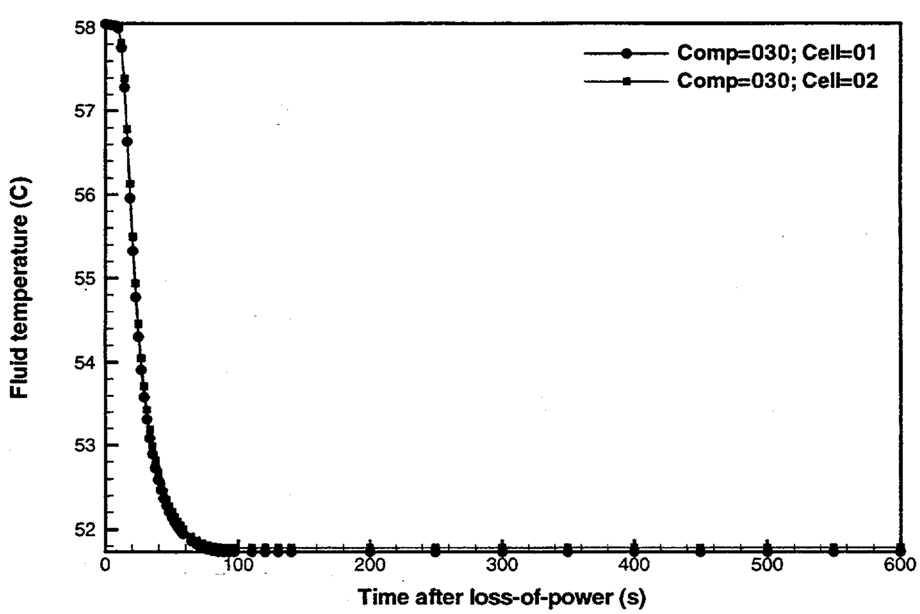

Figure B-9b Primary HR pump 1 fluid temperatures for a LOFA (Case 1: with beam shutdown and active RHR).

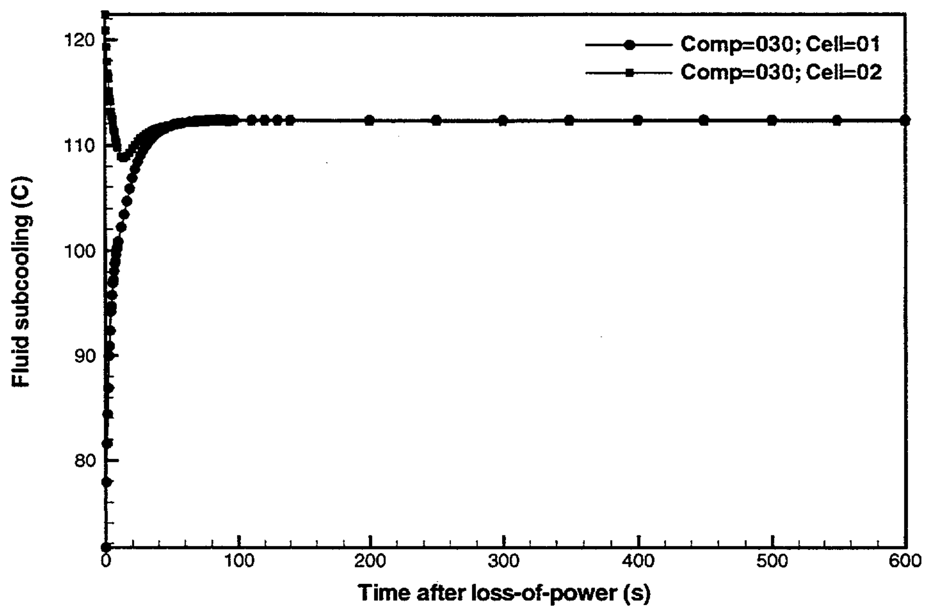

Figure B-9c Primary HR pump 1 fluid subcoolings for a LOFA (Case 1: with beam shutdown and active RHR).

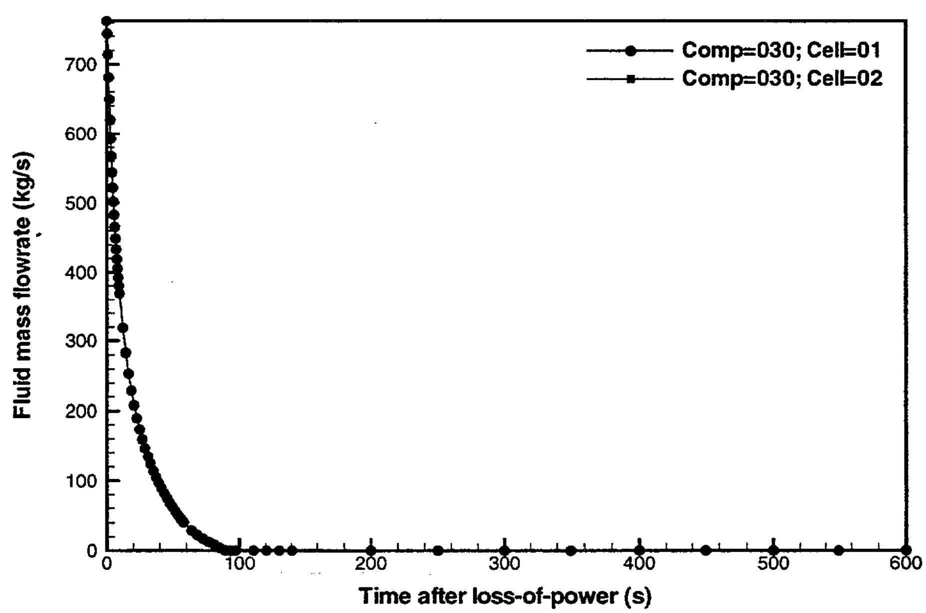

Figure B-9d Primary HR pump 1 liquid mass flowrates for a LOFA (Case 1: with beam shutdown and active RHR).

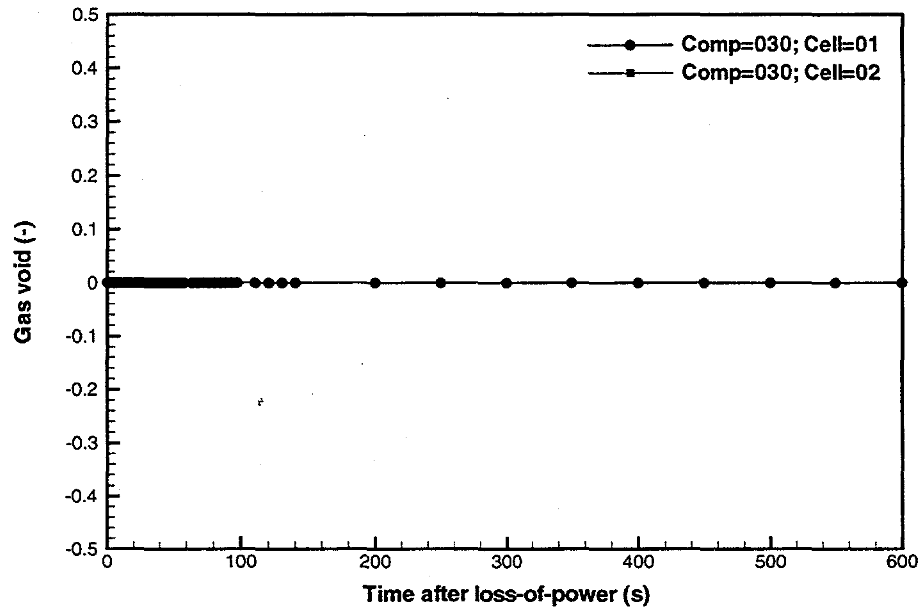

Figure B-9e Primary HR pump 1 void fractions for a LOFA (Case 1: with beam shutdown and active RHR).

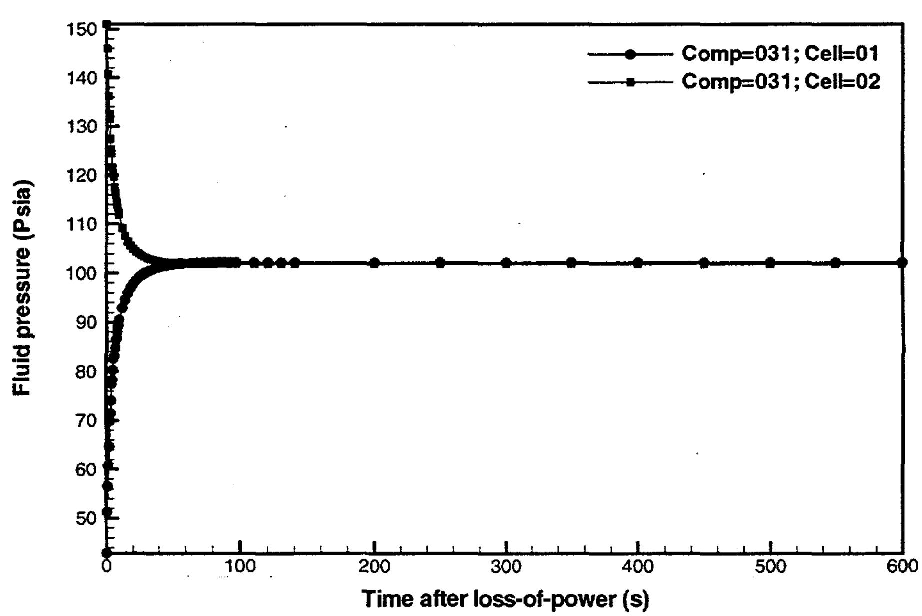

Figure B-10a Primary HR pump 2 fluid pressures for a LOFA (Case 1: with beam shutdown and active RHR).

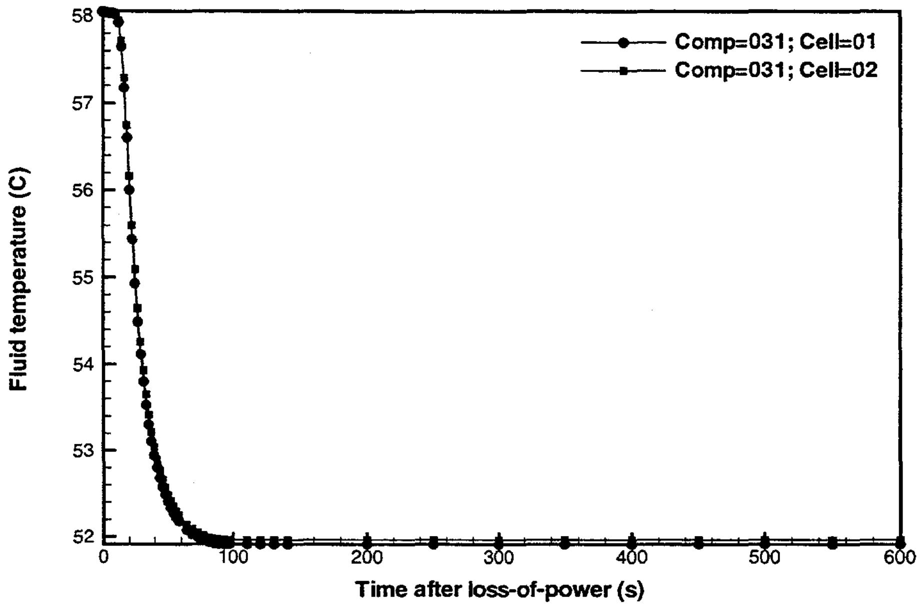

Figure B-10b Primary HR pump 2 fluid temperatures for a LOFA (Case 1: with beam shutdown and active RHR).

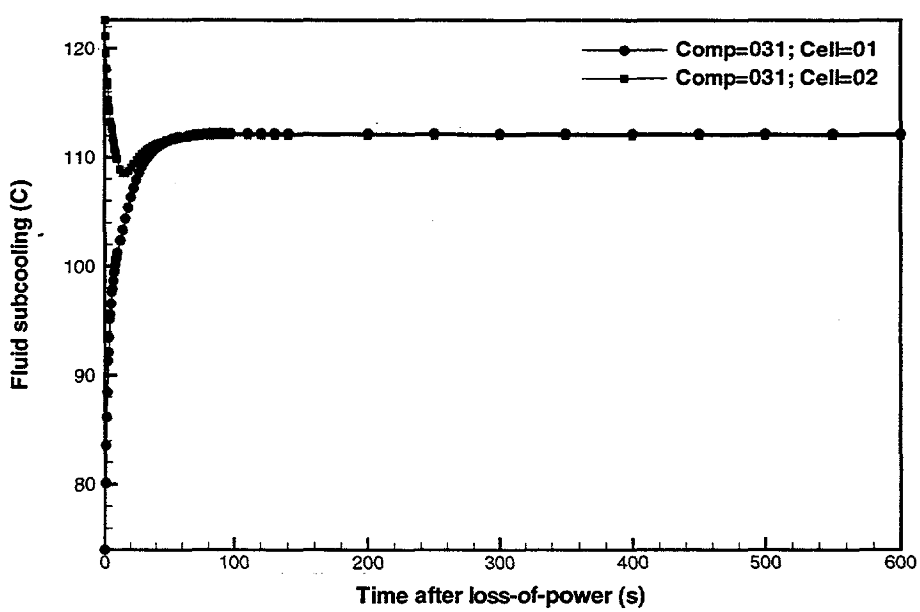

Figure B-10c Primary HR pump 2 fluid subcoolings for a LOFA (Case 1: with beam shutdown and active RHR).

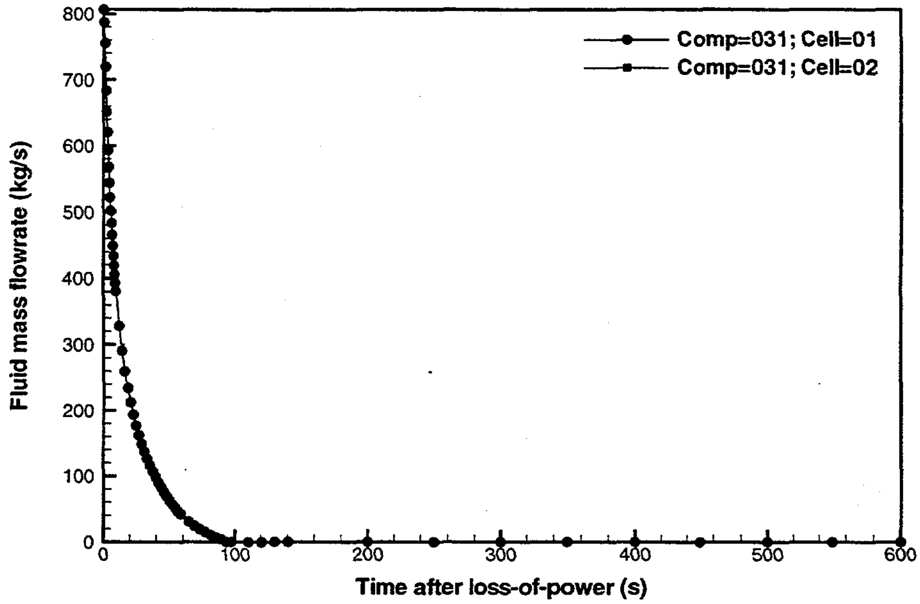

Figure B-10d Primary HR pump 2 liquid mass flowrates for a LOFA (Case 1: with beam shutdown and active RHR).

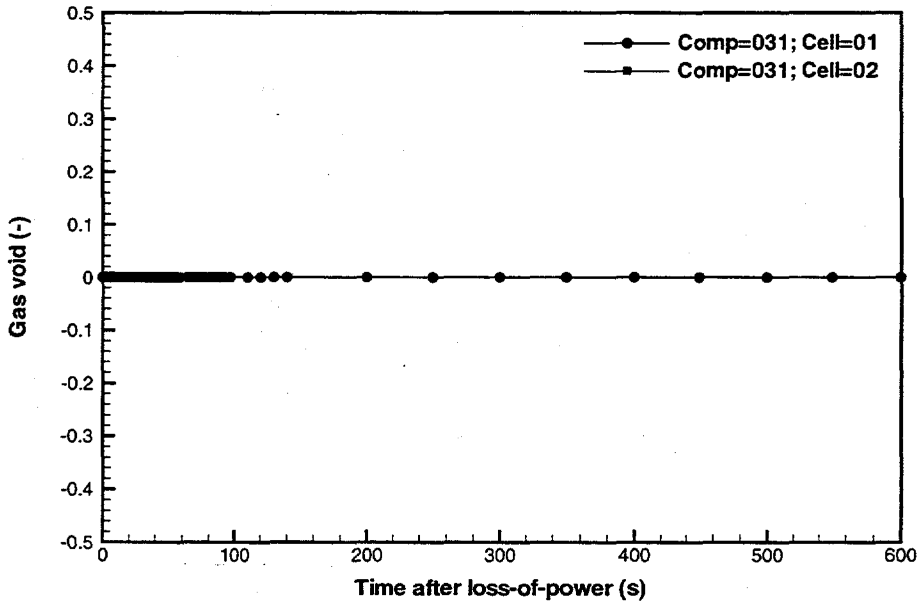

Figure B-10e Primary HR pump 2 void fractions for a LOFA (Case 1: with beam shutdown and active RHR).

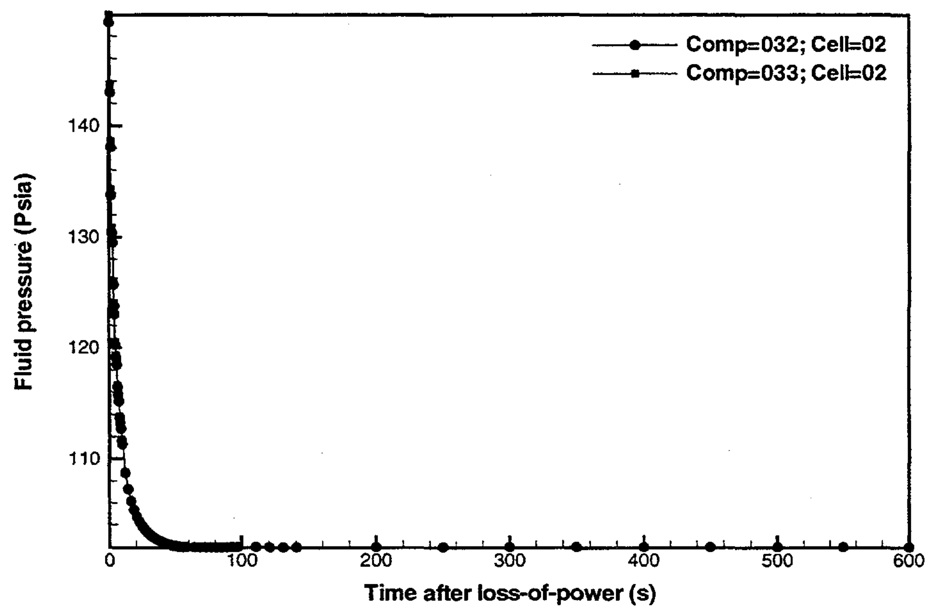

Figure B-11a Primary HR pump discharge piping fluid pressures for a LOFA (Case 1: with beam shutdown and active RHR).

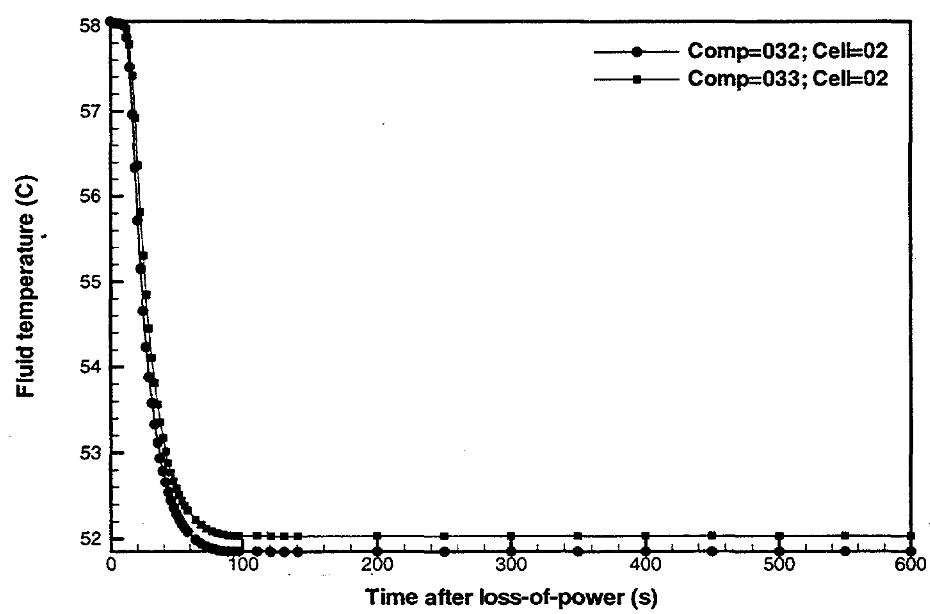

Figure B-11b Primary HR pump discharge piping fluid temperatures for a LOFA (Case 1: with beam shutdown and active RHR).

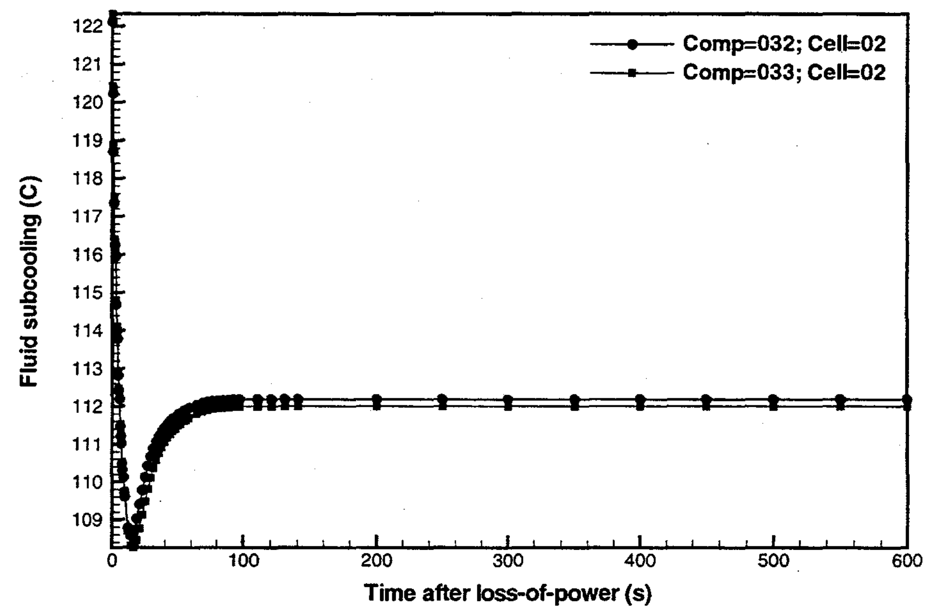

Figure B-11c Primary HR pump discharge piping fluid subcoolings for a LOFA (Case 1: with beam shutdown and active RHR).

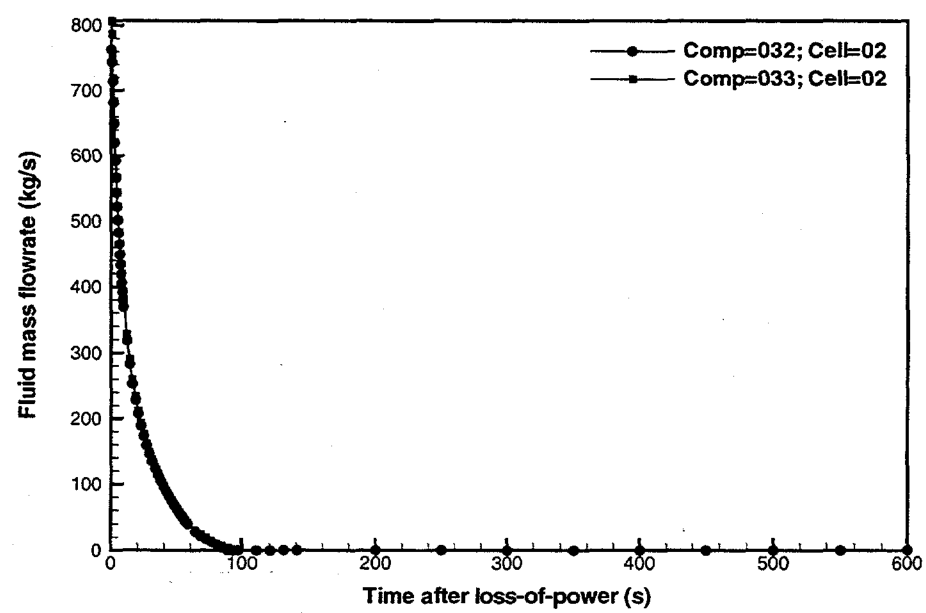

Figure B-11d Primary HR pump discharge piping liquid mass flowrates for a LOFA (Case 1: with beam shutdown and active RHR).

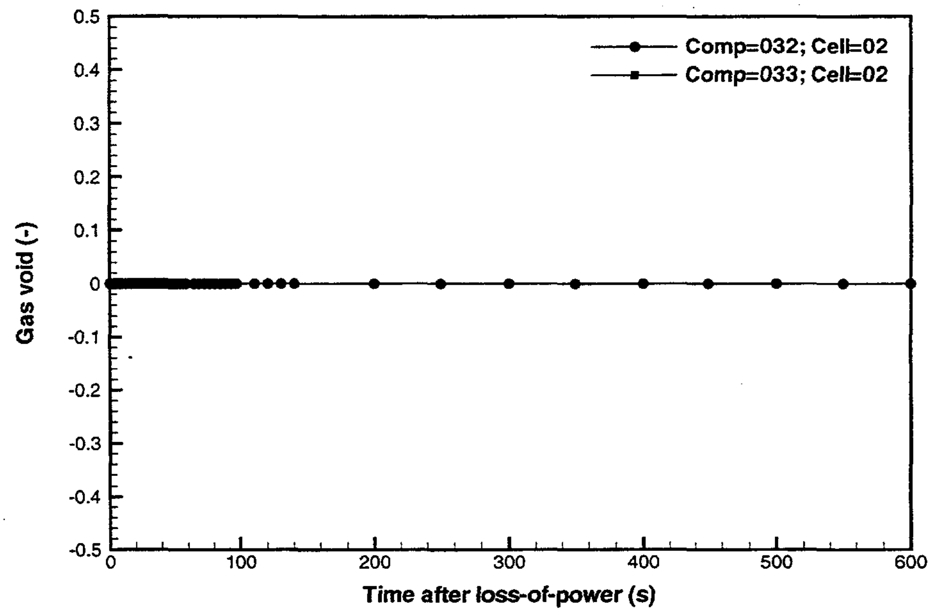

Figure B-11e Primary HR pump discharge piping void fractions for a LOFA (Case 1: with beam shutdown and active RHR).

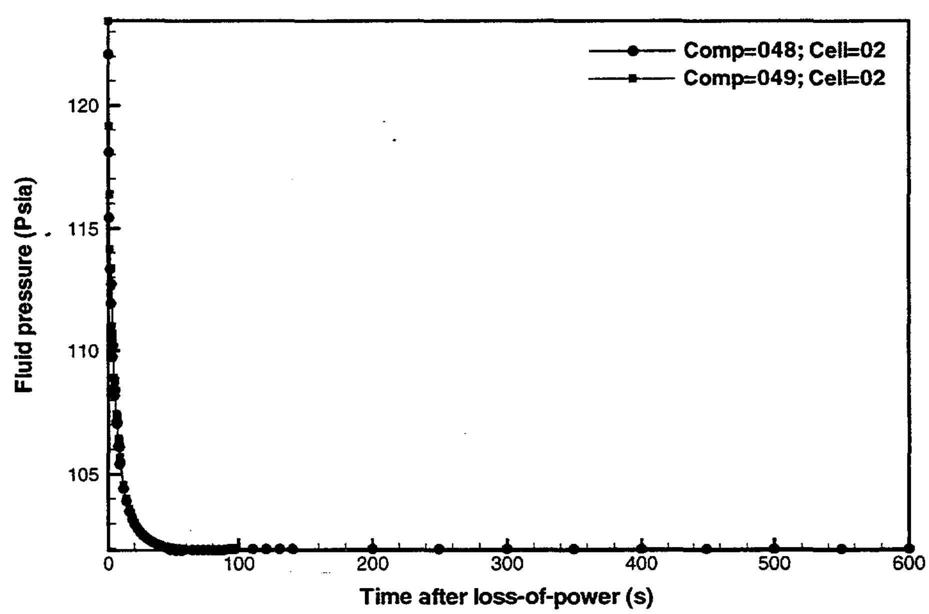

Figure B-12a Primary HR heat exchanger inlet piping fluid pressures for a LOFA (Case 1: with beam shutdown and active RHR).

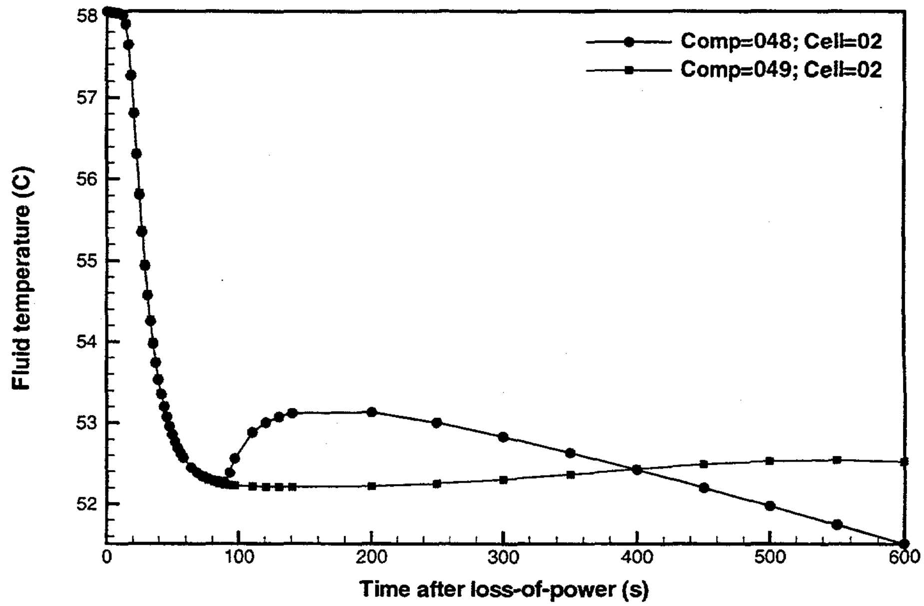

Figure B-12b Primary HR heat exchanger inlet piping fluid temperatures for a LOFA (Case 1: with beam shutdown and active RHR).

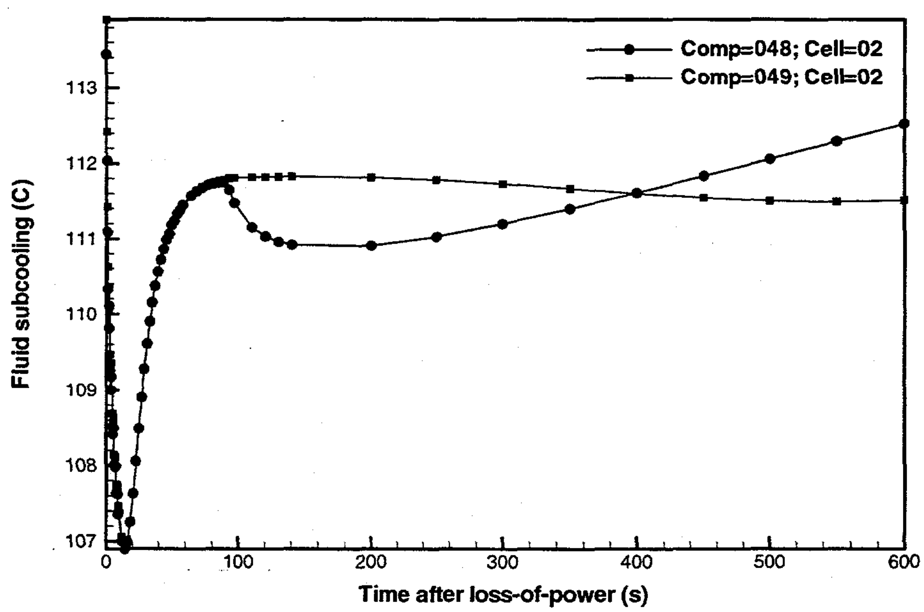

Figure B-12c Primary HR heat exchanger inlet piping fluid subcoolings for a LOFA (Case 1: with beam shutdown and active RHR).

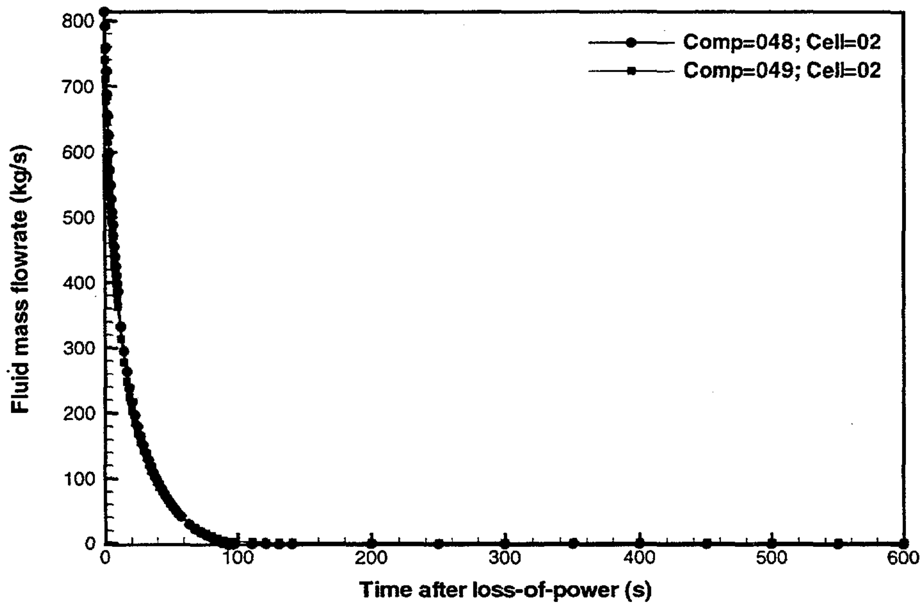

Figure B-12d Primary HR heat exchanger inlet piping liquid mass flowrates for a LOFA (Case 1: with beam shutdown and active RHR).

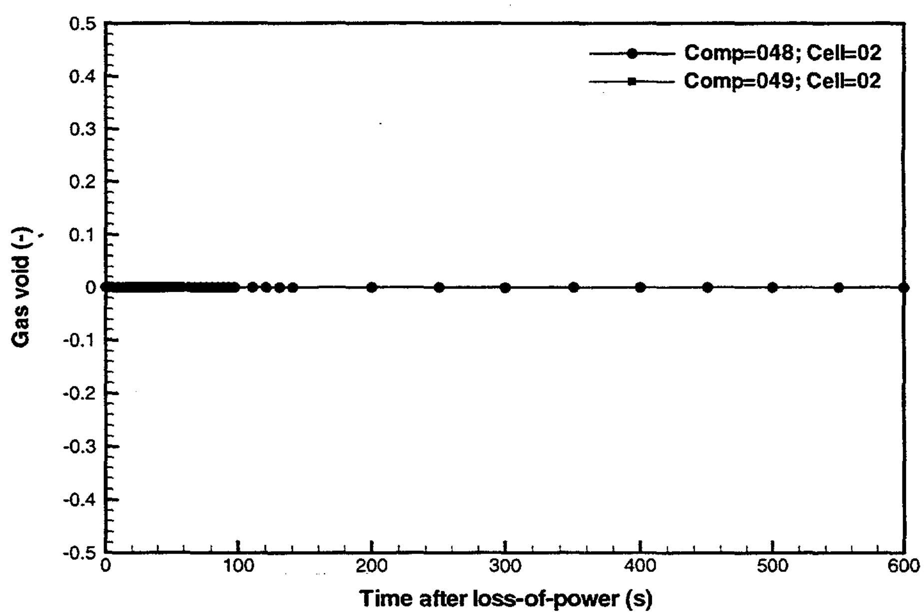

Figure B-12e Primary HR heat exchanger inlet piping void fractions for a LOFA (Case 1: with beam shutdown and active RHR).

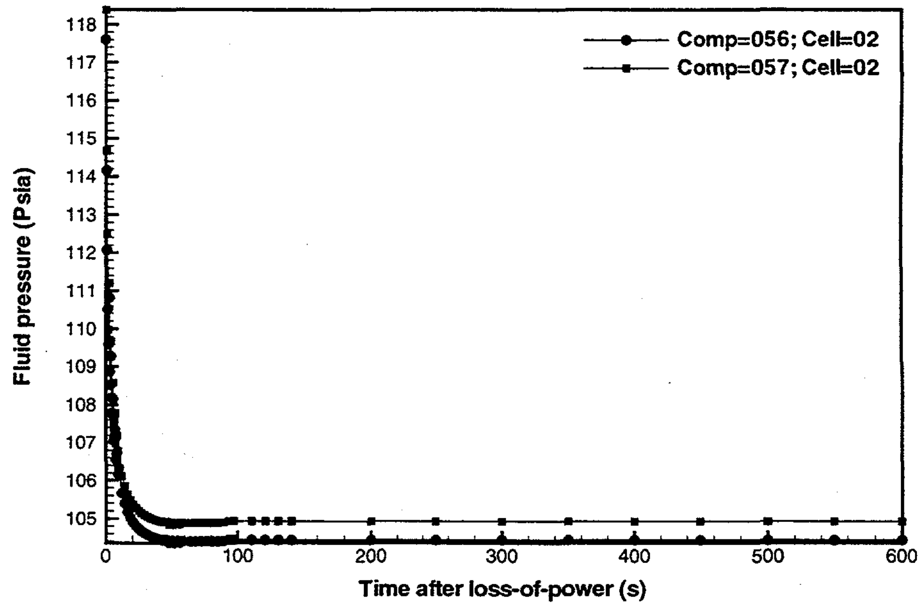

Figure B-13a Primary HR heat exchanger outlet piping fluid pressures for a LOFA (Case 1: with beam shutdown and active RHR).

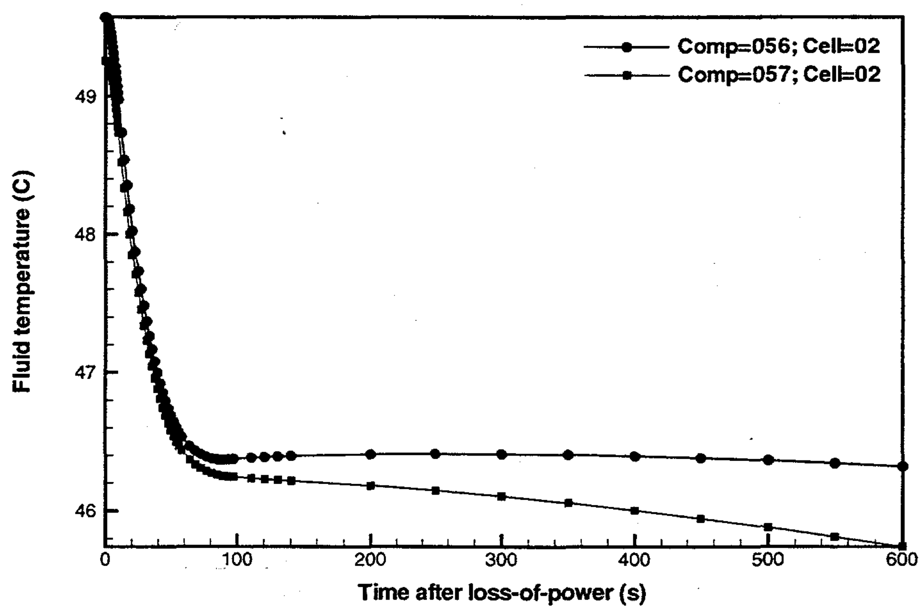

Figure B-13b Primary HR heat exchanger outlet piping fluid temperatures for a LOFA (Case 1: with beam shutdown and active RHR).

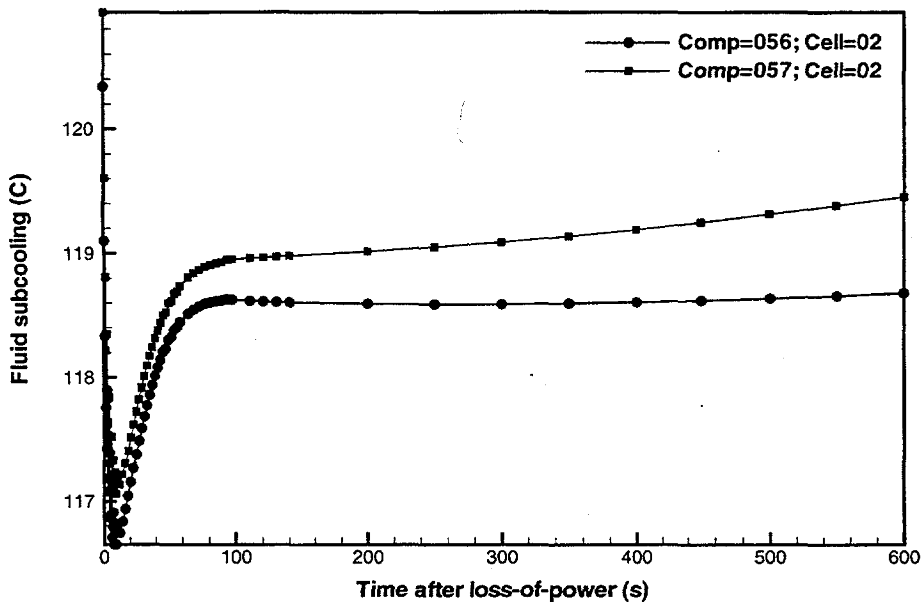

Figure B-13c Primary HR heat exchanger outlet piping fluid subcoolings for a LOFA (Case 1: with beam shutdown and active RHR).

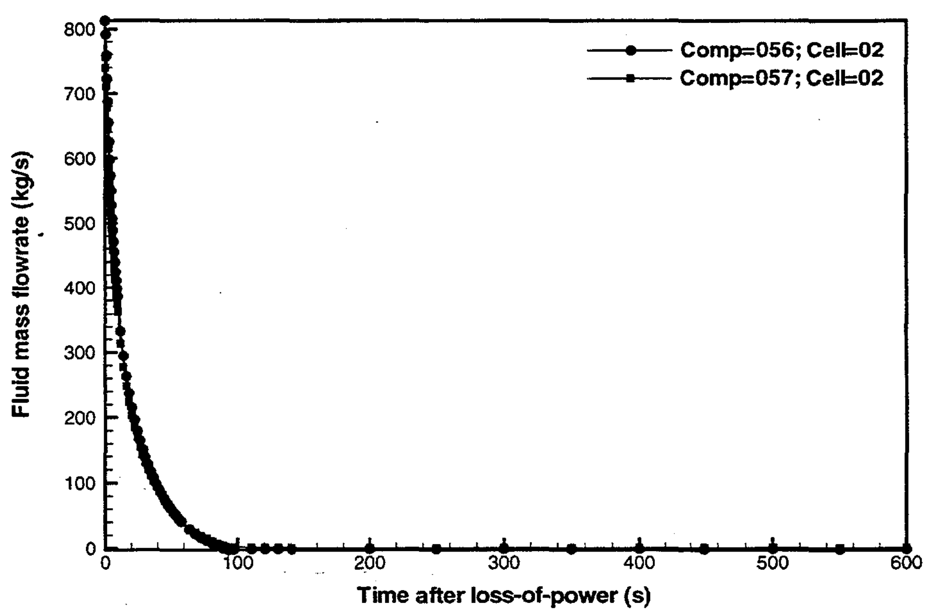

Figure B-13d Primary HR heat exchanger outlet piping liquid mass flowrates for a LOFA (Case 1: with beam shutdown and active RHR).

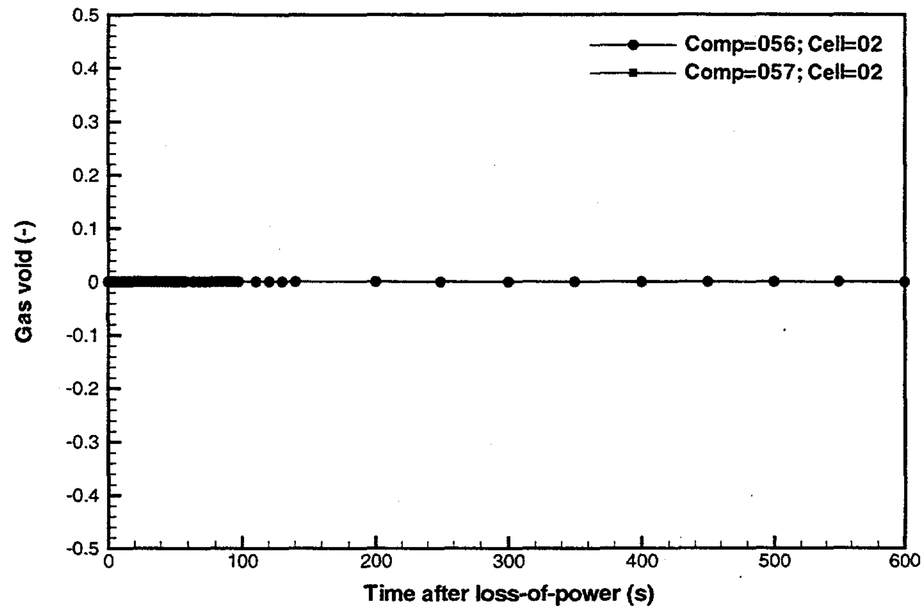

Figure B-13e Primary HR heat exchanger outlet piping void fractions for a LOFA (Case 1: with beam shutdown and active RHR).

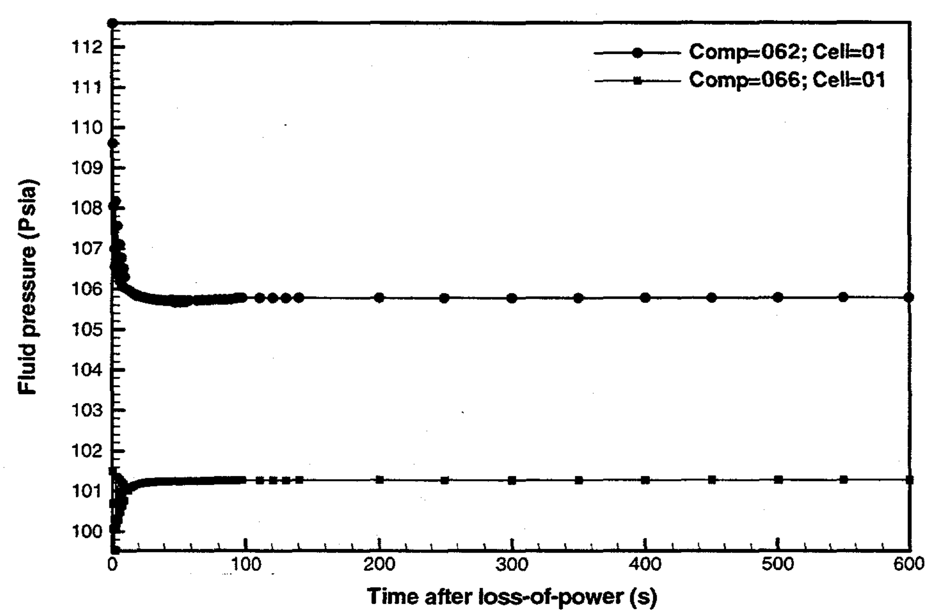

Figure B-14a Primary HR cold-leg piping fluid pressures for a LOFA (Case 1: with beam shutdown and active RHR).

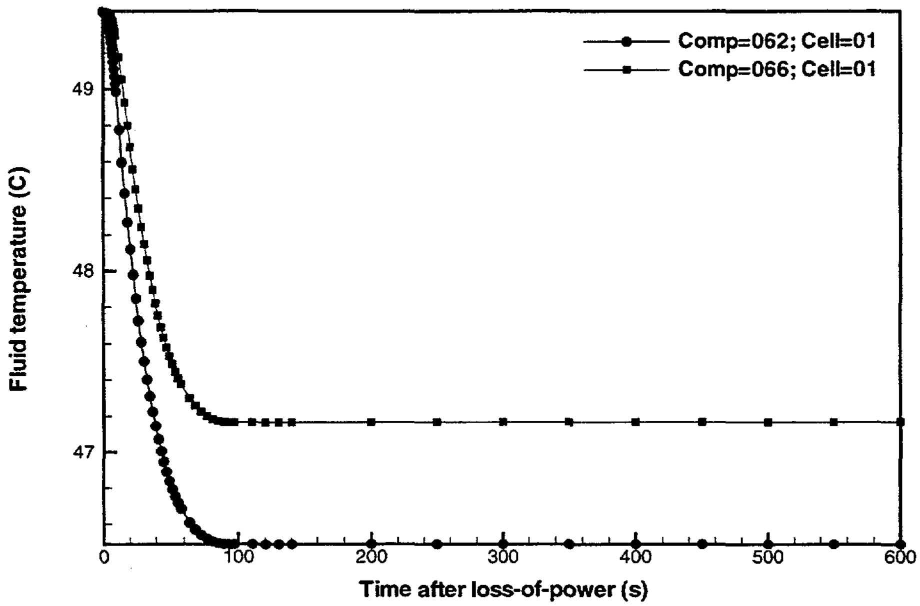

Figure B-14b Primary HR cold-leg piping fluid temperatures for a LOFA (Case 1: with beam shutdown and active RHR).

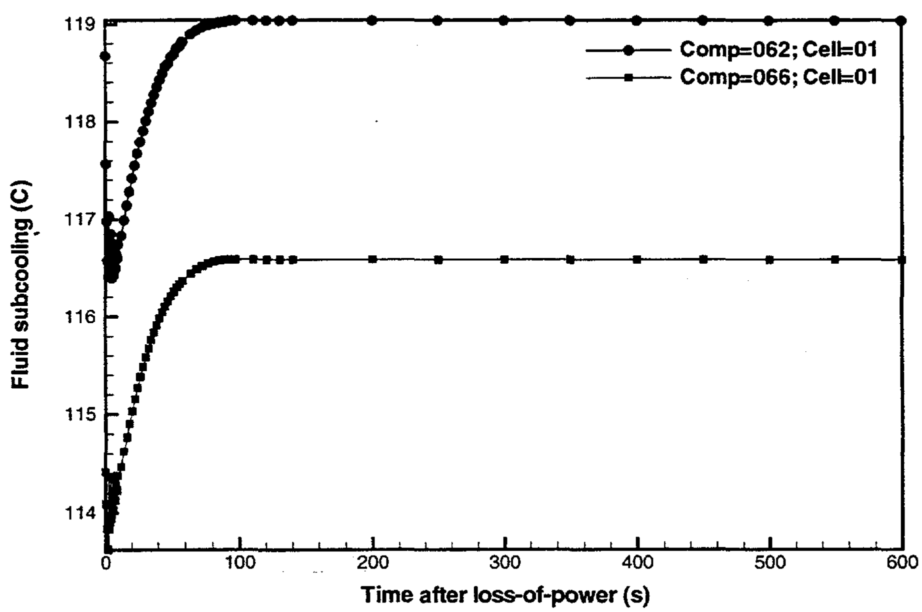

Figure B-14c Primary HR cold-leg piping fluid subcoolings for a LOFA (Case 1: with beam shutdown and active RHR).

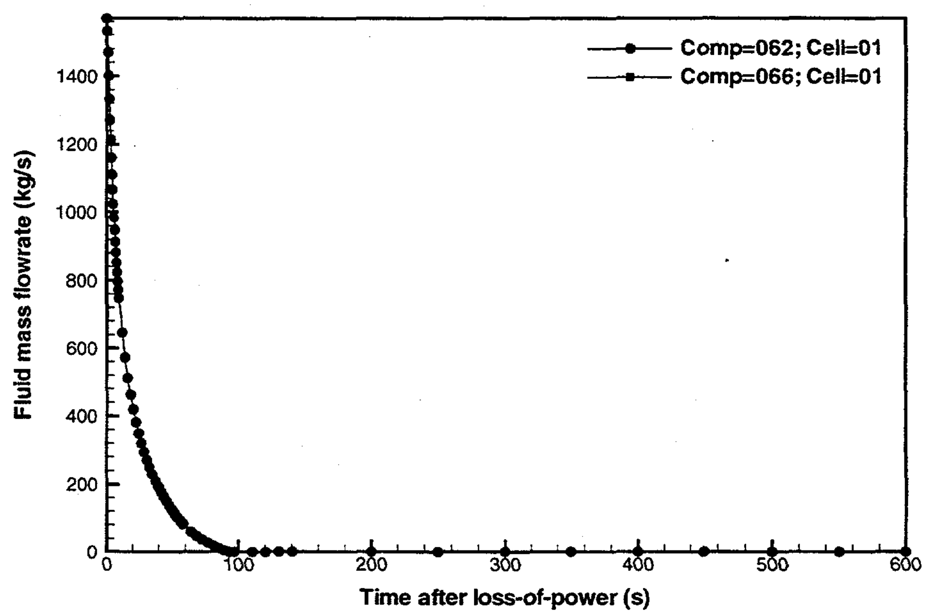

Figure B-14d Primary HR cold-leg piping liquid mass flowrates for a LOFA (Case 1: with beam shutdown and active RHR).

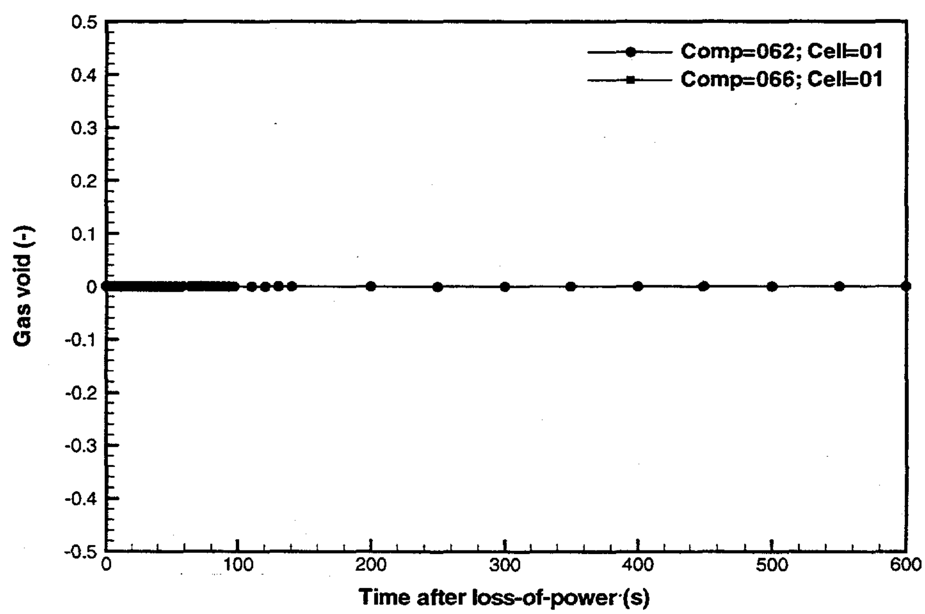

Figure B-14e Primary HR cold-leg piping void fractions for a LOFA (Case 1: with beam shutdown and active RHR).

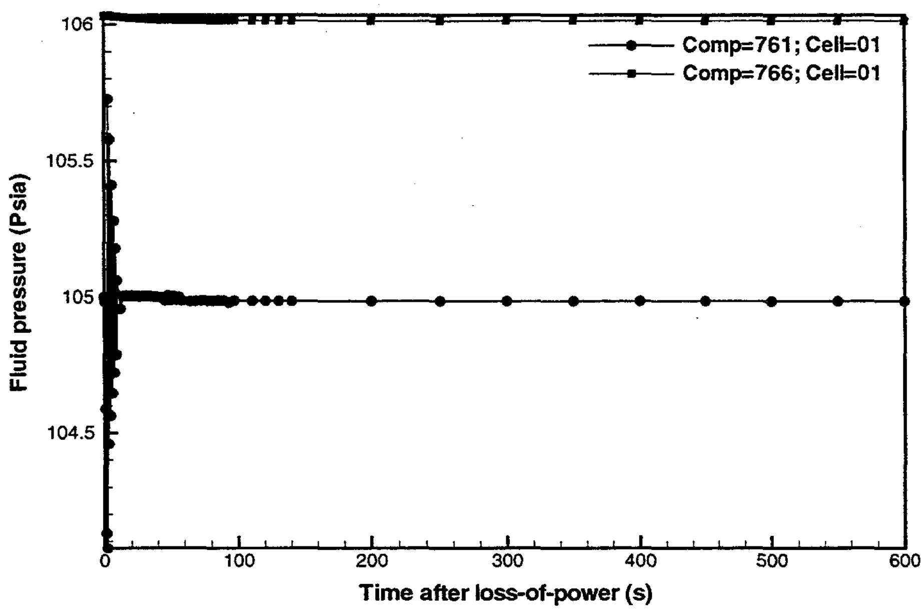

Figure B-15a Primary HR pressurizer and surge line fluid pressures for a LOFA (Case 1: with beam shutdown and active RHR).

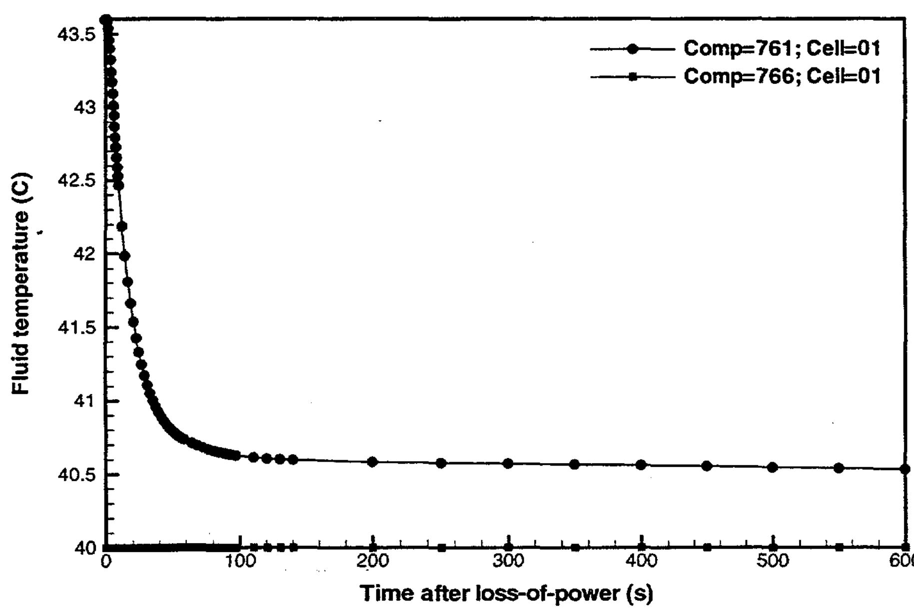

Figure B-15b Primary HR pressurizer and surge line fluid temperatures for a LOFA (Case 1: with beam shutdown and active RHR).

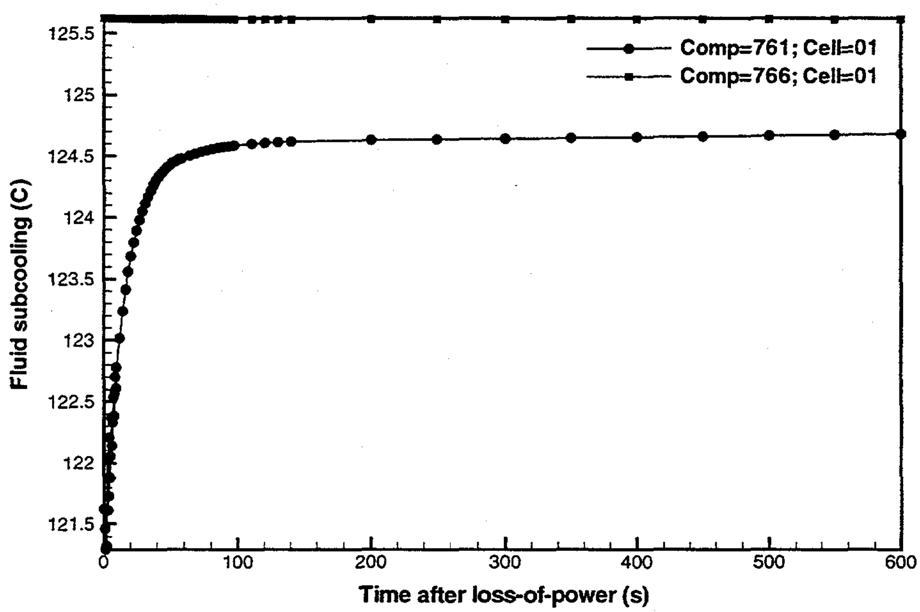

Figure B-15c Primary HR pressurizer and surge line fluid subcoolings for a LOFA (Case 1: with beam shutdown and active RHR).

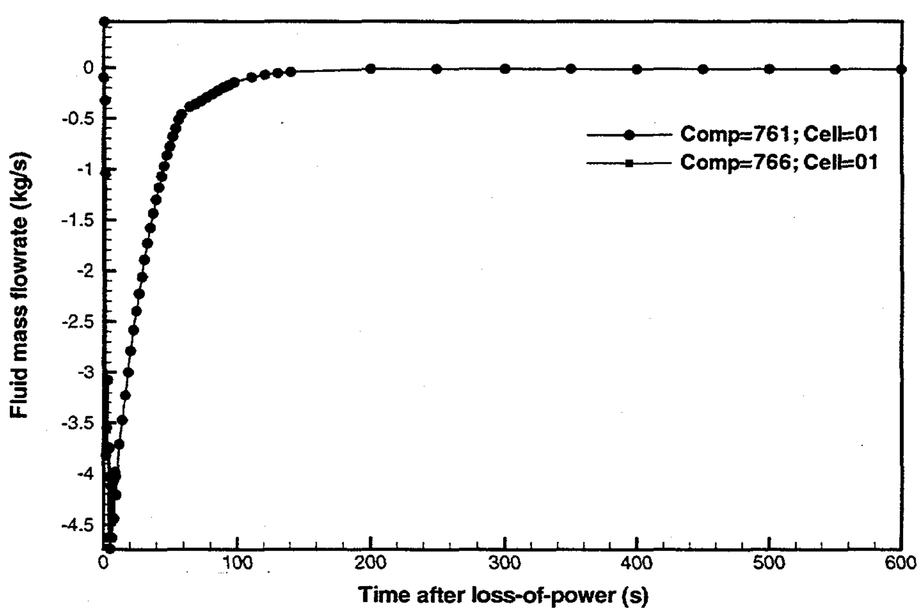

Figure B-15d Primary HR pressurizer and surge line liquid mass flowrates for a LOFA (Case 1: with beam shutdown and active RHR).

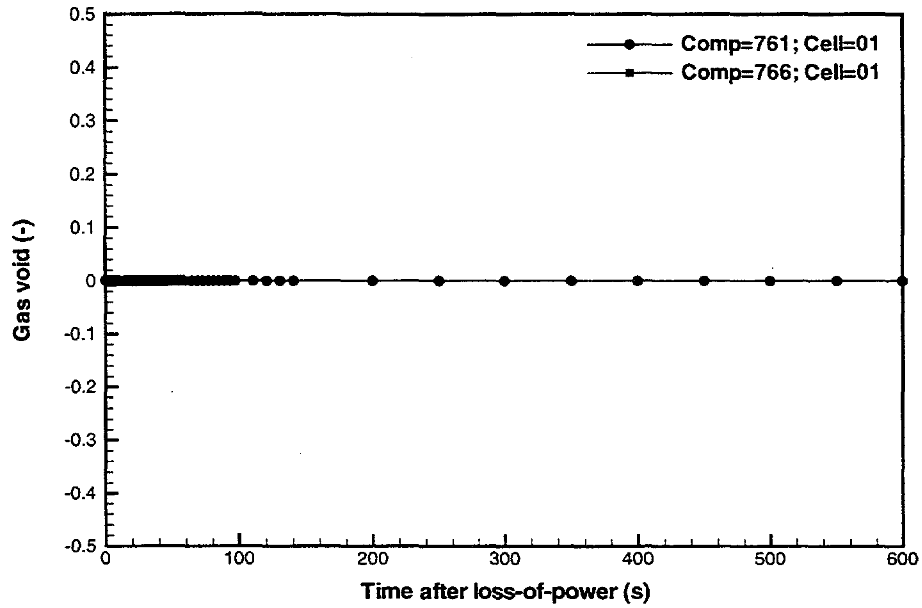

Figure B-15e Primary HR pressurizer and surge line void fractions for a LOFA (Case 1: with beam shutdown and active RHR).

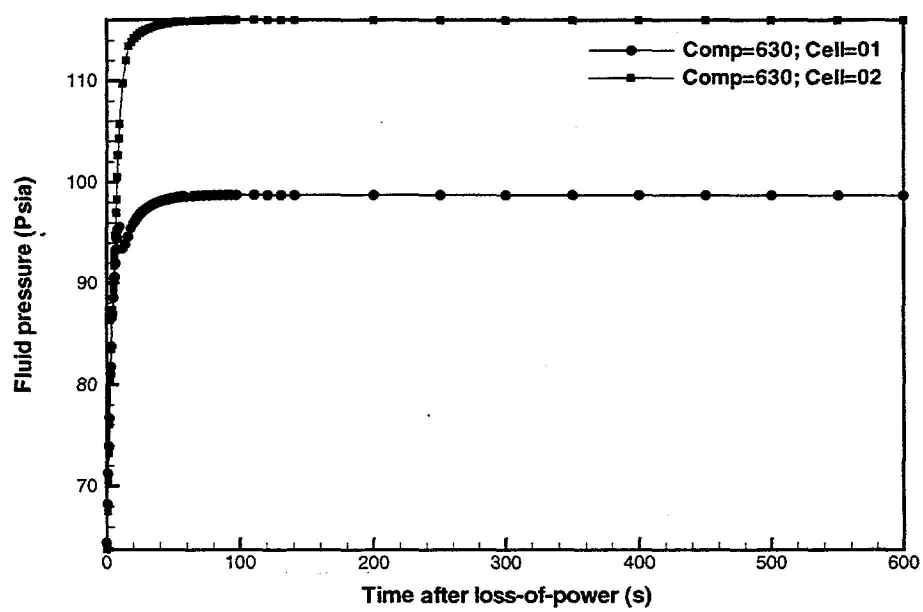

Figure B-16a Primary RHR pump fluid pressures for a LOFA (Case 1: with beam shutdown and active RHR).

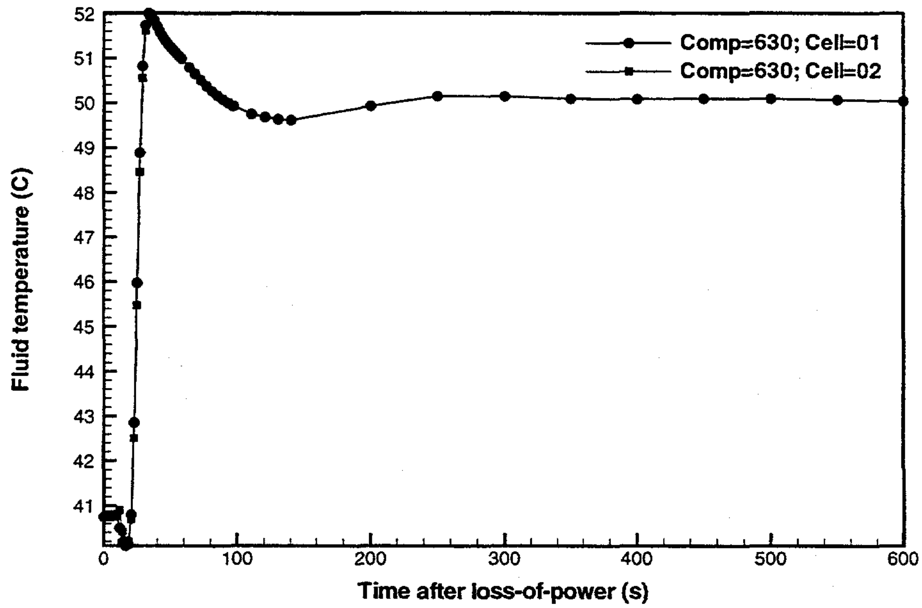

Figure B-16b Primary RHR pump fluid temperatures for a LOFA (Case 1: with beam shutdown and active RHR).

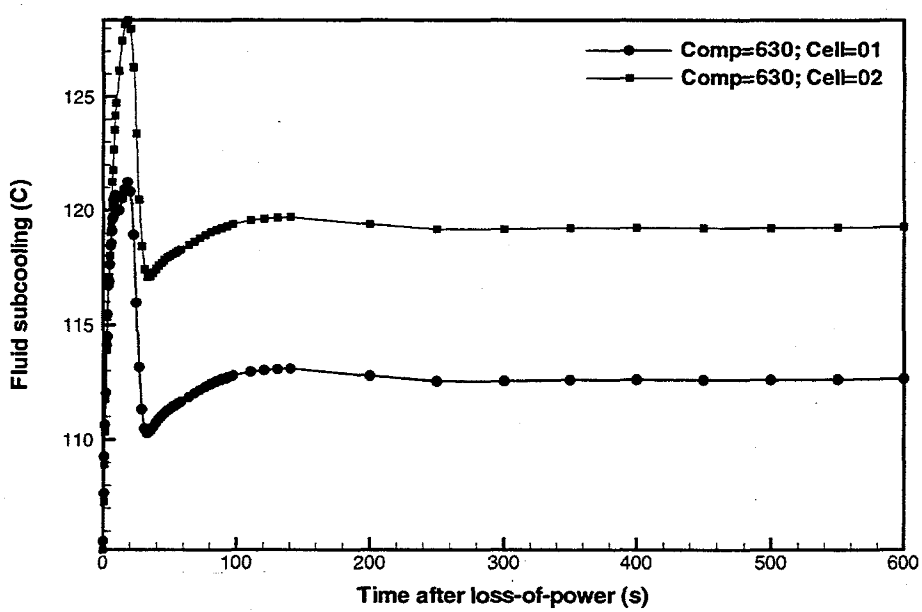

Figure B-16c Primary RHR pump fluid subcoolings for a LOFA (Case 1: with beam shutdown and active RHR).

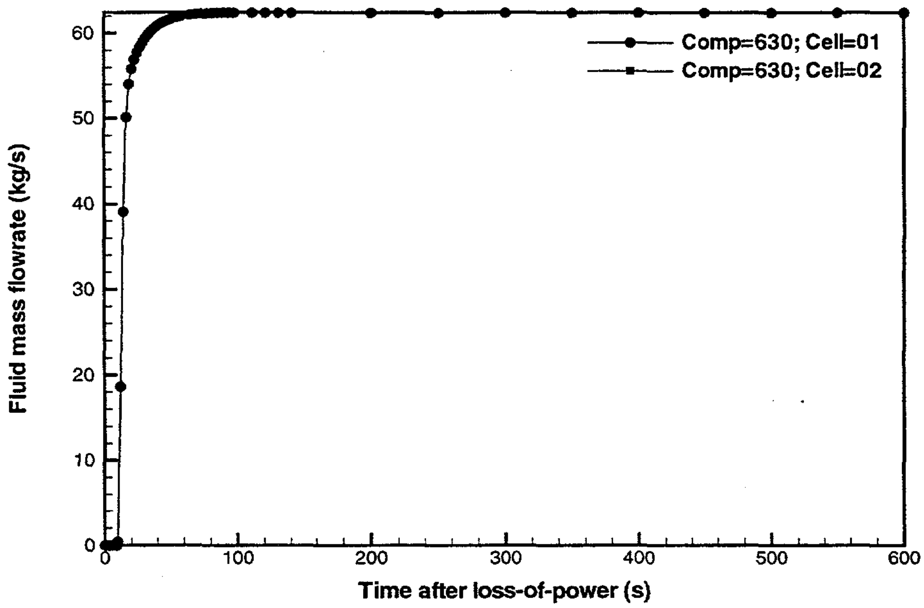

Figure B-16d Primary RHR pump liquid mass flowrates for a LOFA (Case 1: with beam shutdown and active RHR).

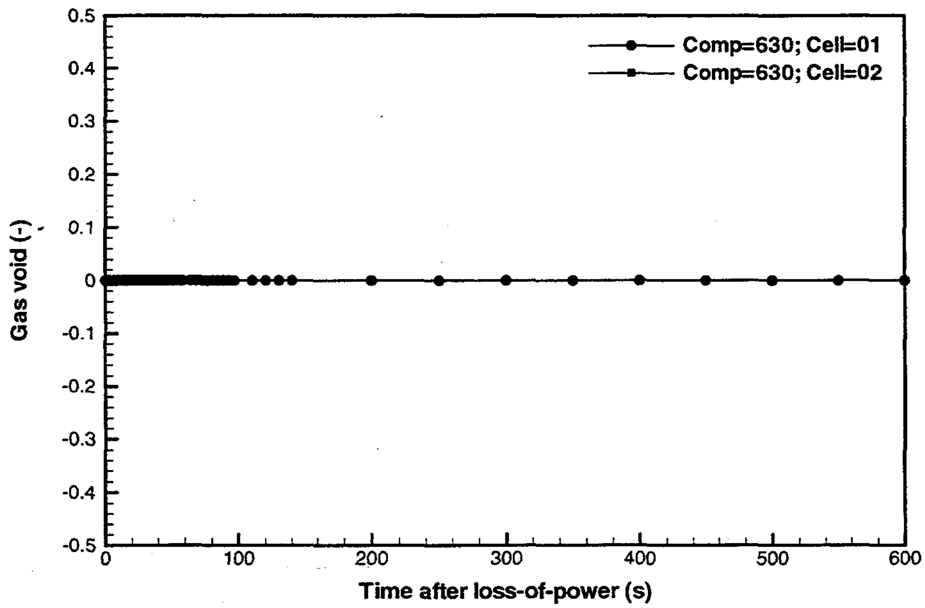

Figure B-16e Primary RHR pump void fractions for a LOFA (Case 1: with beam shutdown and active RHR).

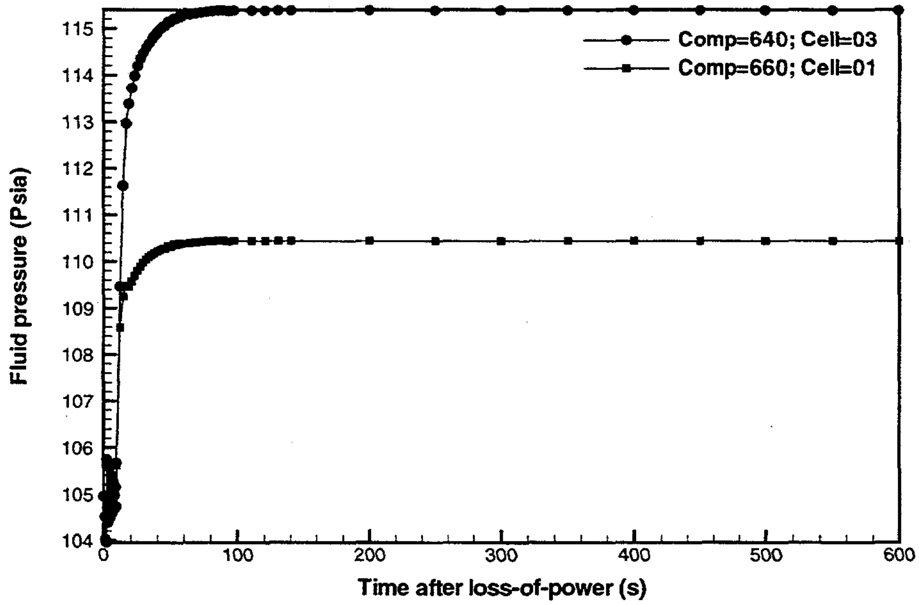

Figure B-17a Primary RHR heat exchanger fluid pressures for a LOFA (Case 1: with beam shutdown and active RHR).

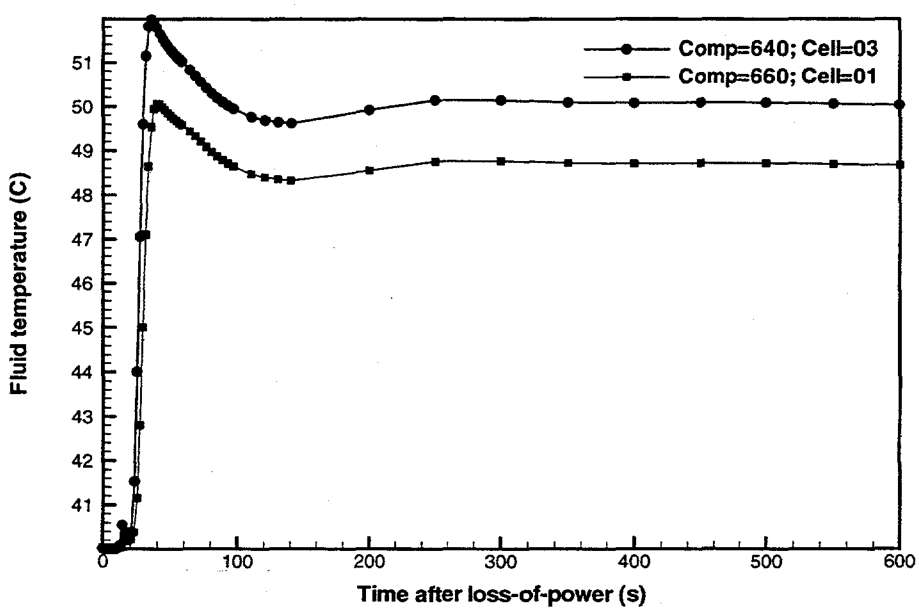

Figure B-17b Primary RHR heat exchanger fluid temperatures for a LOFA (Case 1: with beam shutdown and active RHR).

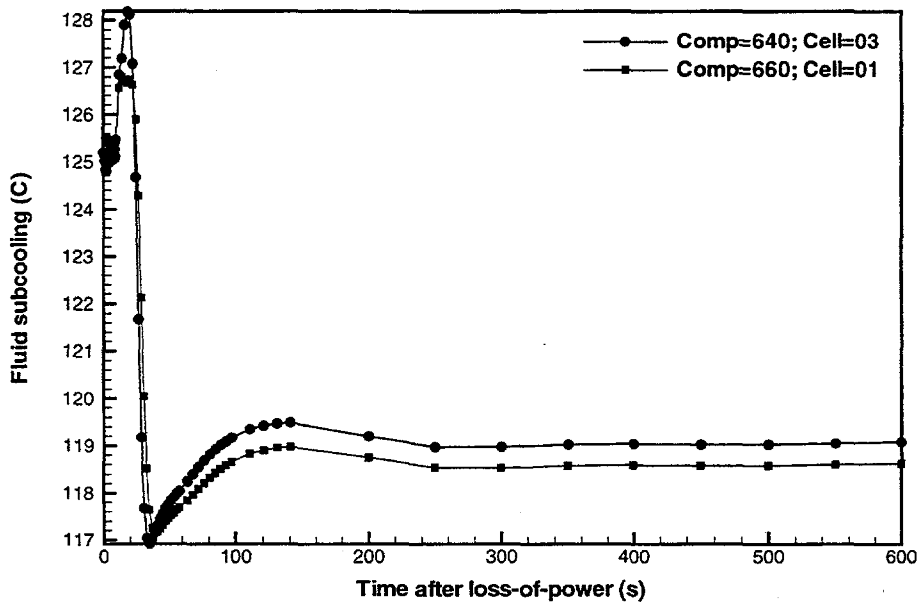

Figure B-17c Primary RHR heat exchanger fluid subcoolings for a LOFA (Case 1: with beam shutdown and active RHR).

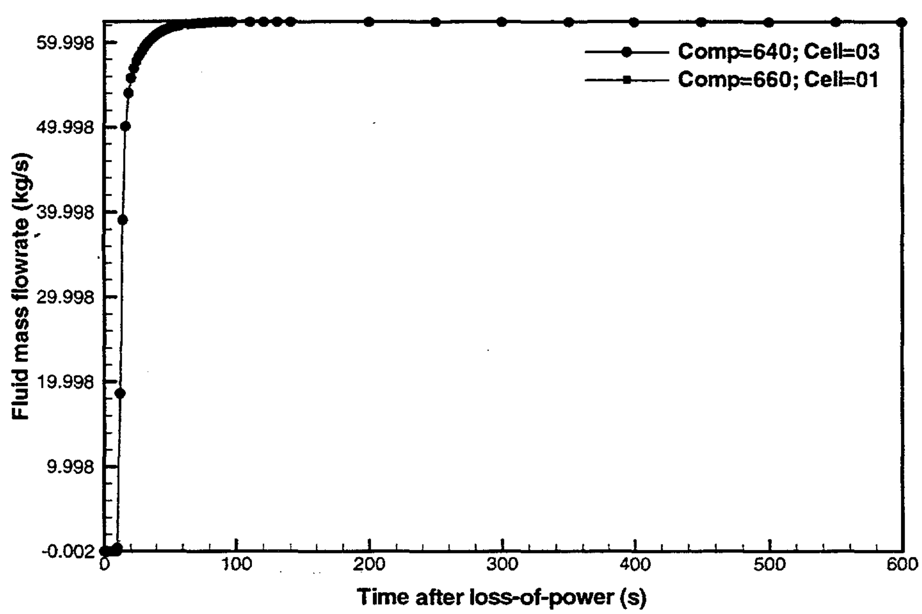

Figure B-17d Primary RHR heat exchanger liquid mass flowrates for a LOFA (Case 1: with beam shutdown and active RHR).

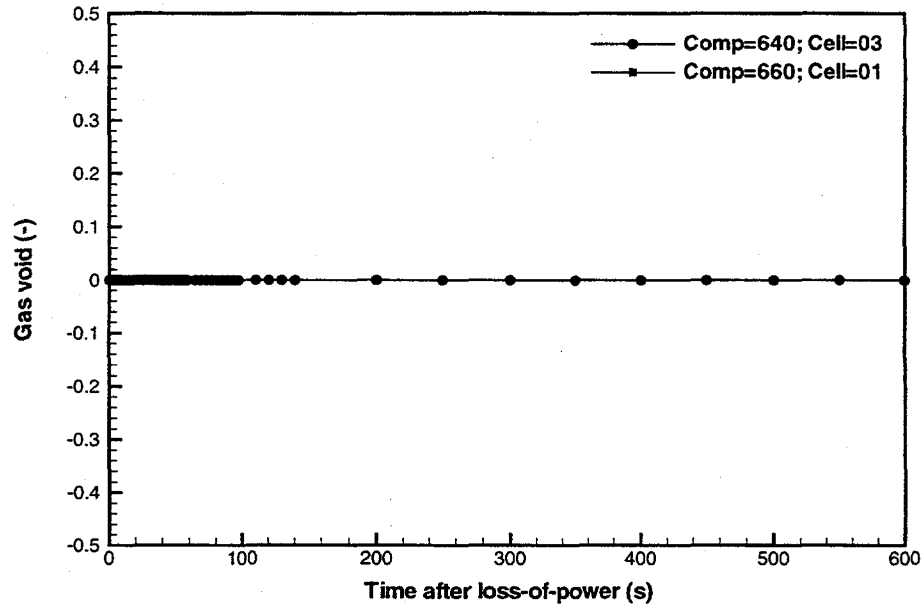

Figure B-17e Primary RHR heat exchanger void fractions for a LOFA (Case 1: with beam shutdown and active RHR).

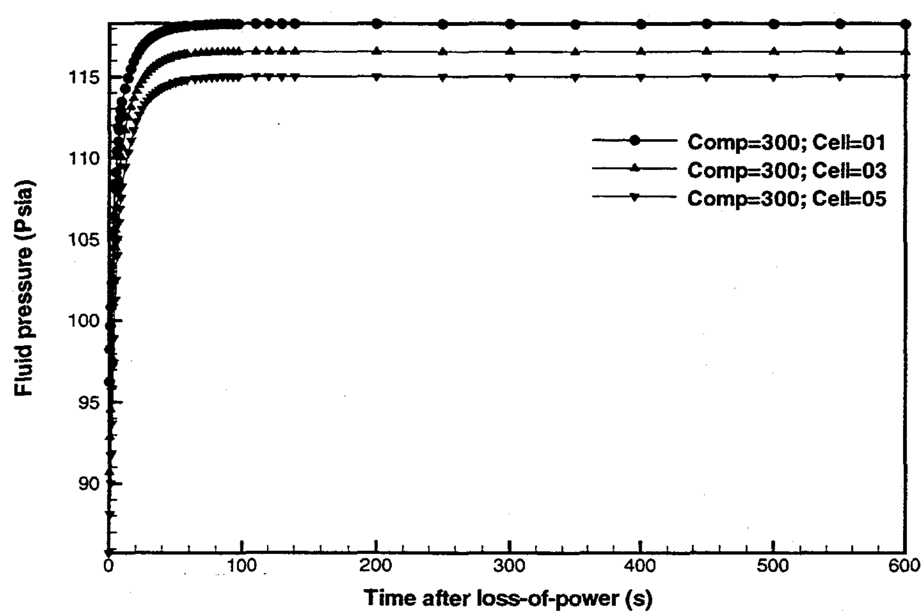

Figure B-18a Module 1 channel fluid pressures for a LOFA (Case 1: with beam shutdown and active RHR).

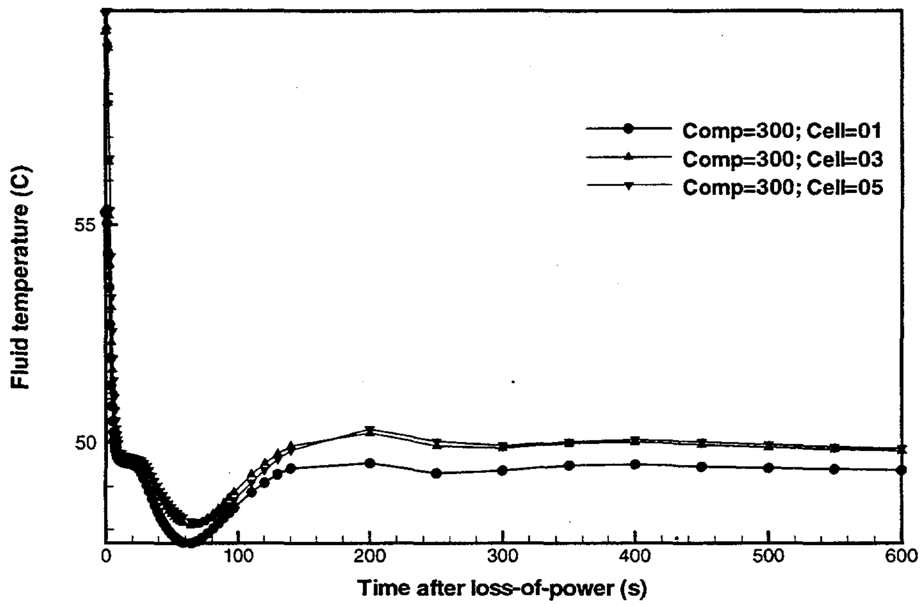

Figure B-18b Module 1 channel fluid temperatures for a LOFA (Case 1: with beam shutdown and active RHR).

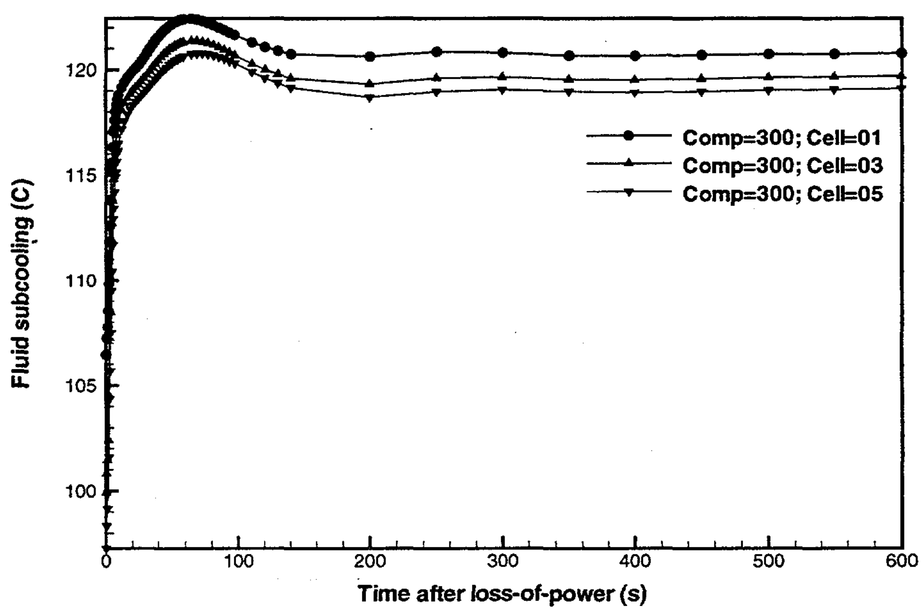

Figure B-18c Module 1 channel fluid subcoolings for a LOFA (Case 1: with beam shutdown and active RHR).

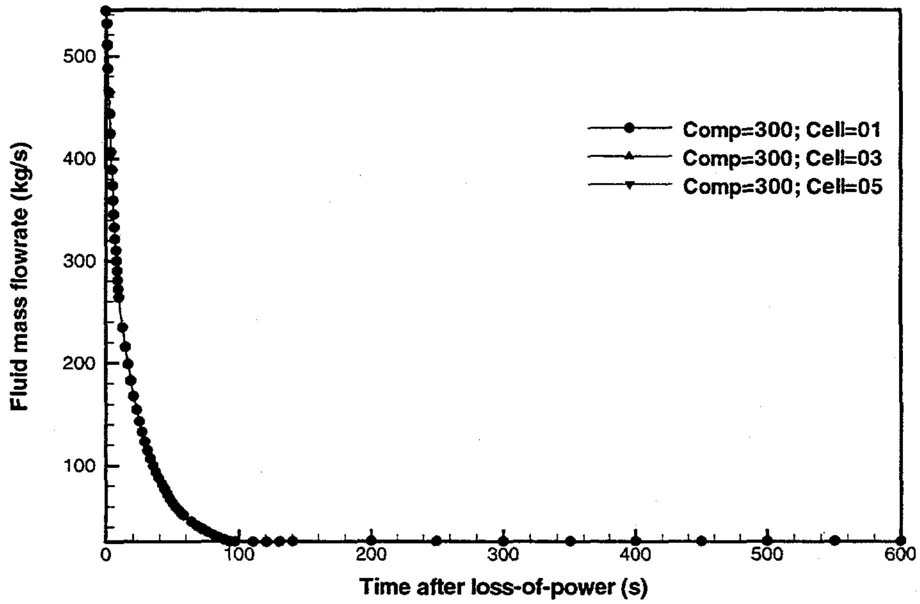

Figure B-18d Module 1 channel liquid mass flowrates for a LOFA (Case 1: with beam shutdown and active RHR).

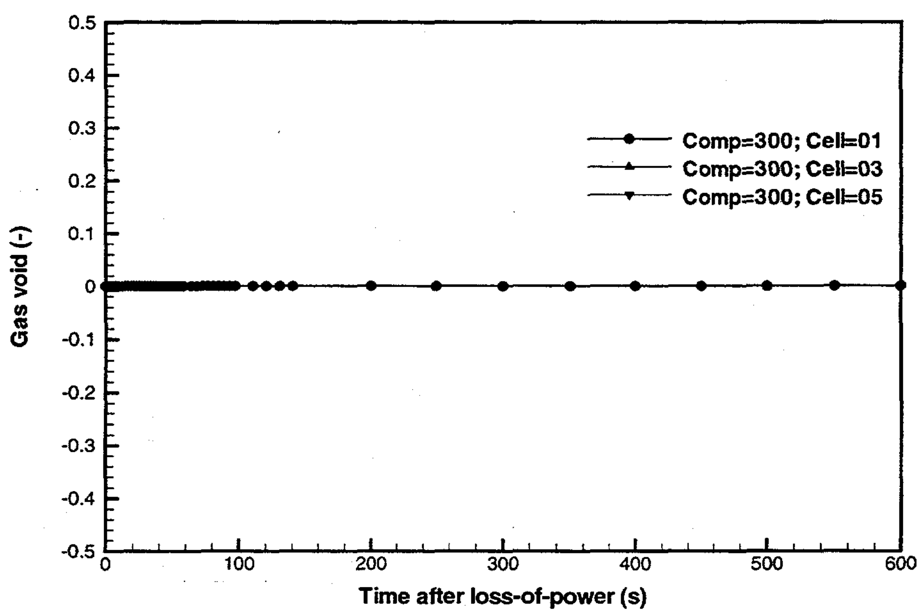

Figure B-8e Module 1 channel void fractions for a LOFA (Case 1: with beam shutdown and active RHR).

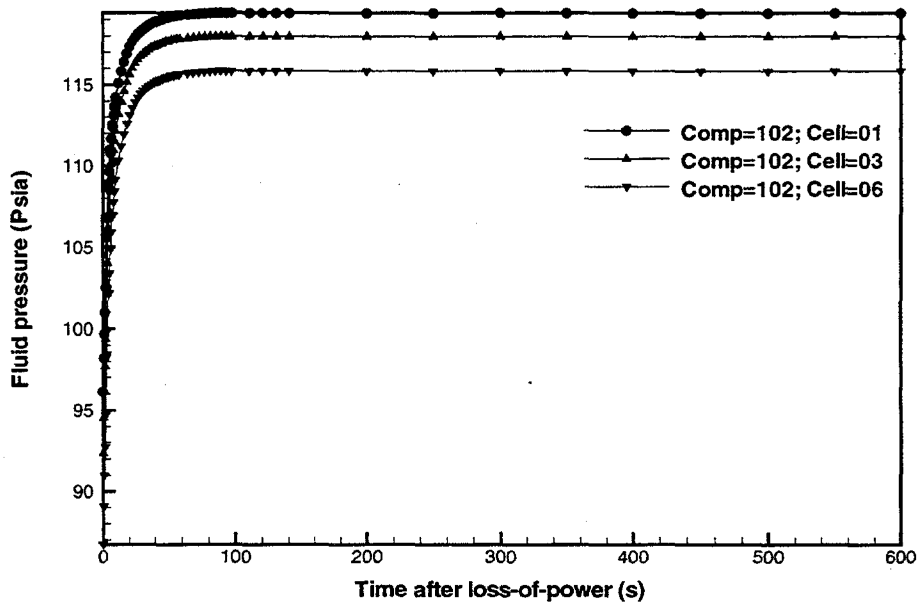

Figure B-19a Module 2 channel fluid pressures for a LOFA (Case 1: with beam shutdown and active RHR).

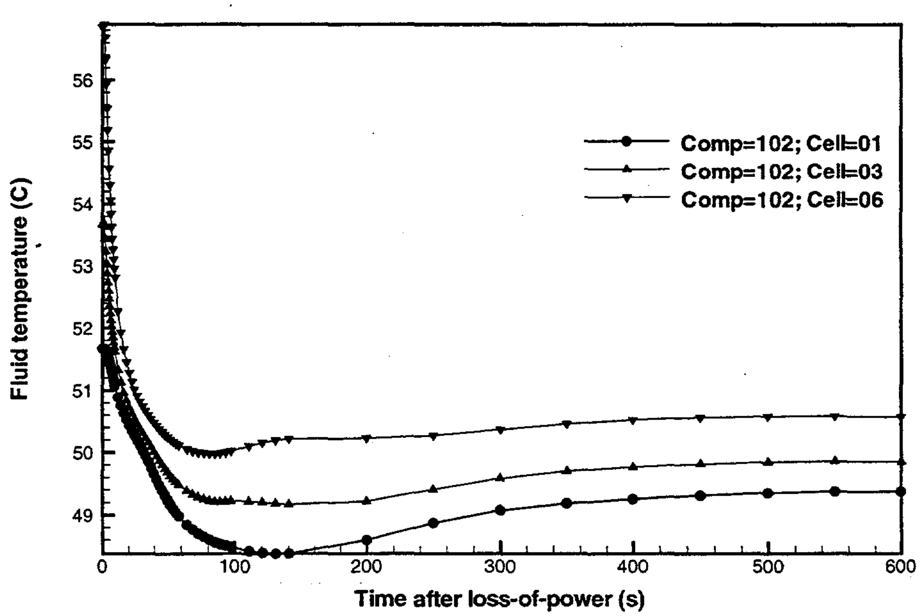

Figure B-19b Module 2 channel fluid temperatures for a LOFA (Case 1: with beam shutdown and active RHR).

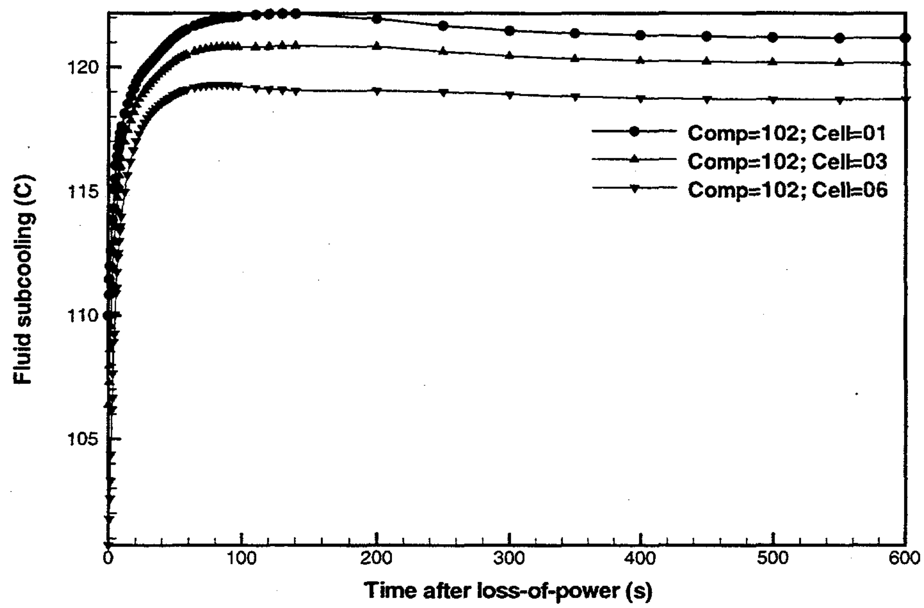

Figure B-19c Module 2 channel fluid subcoolings for a LOFA (Case 1: with beam shutdown and active RHR).

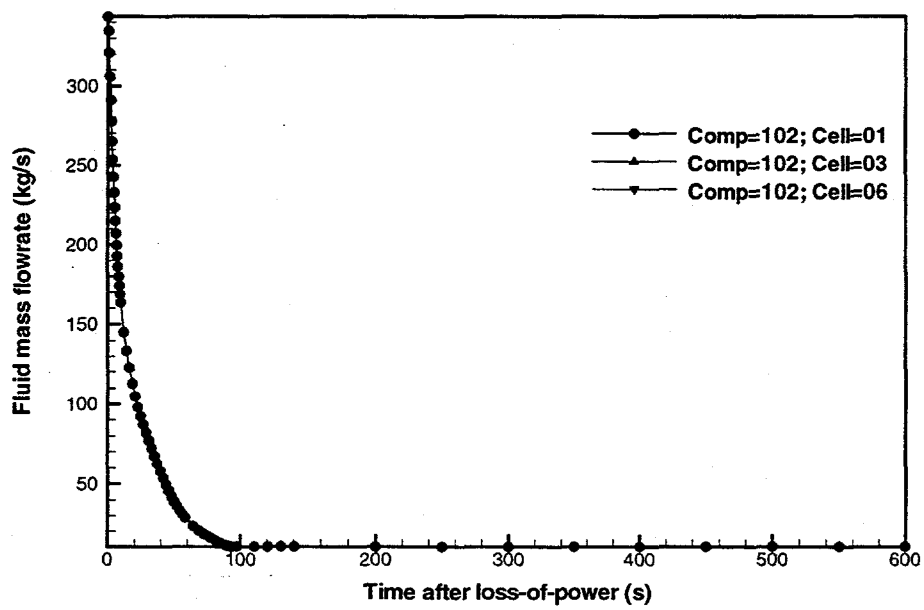

Figure B-19d Module 2 channel liquid mass flowrates for a LOFA (Case 1: with beam shutdown and active RHR).

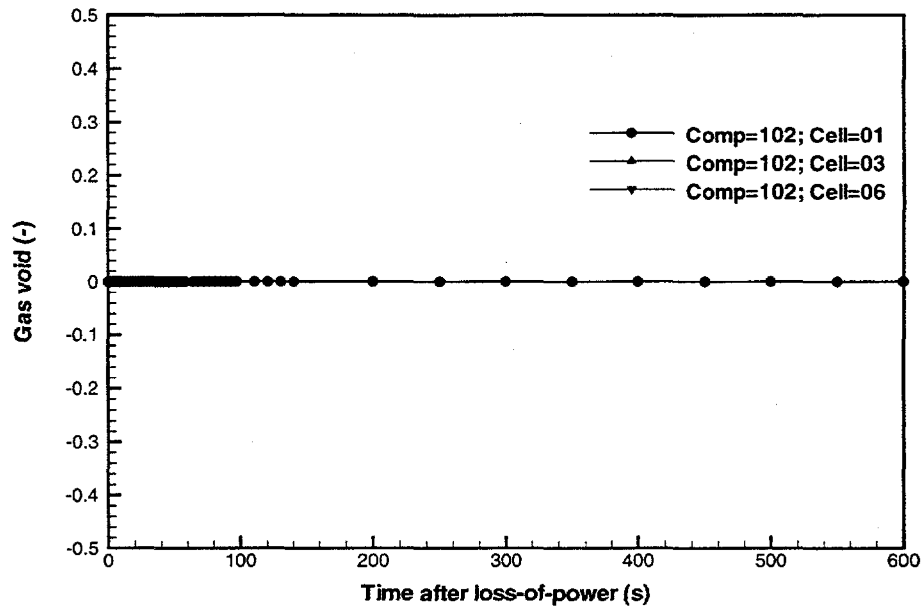

Figure B-19e Module 2 channel Module 2 channel void fractions for a LOFA (Case 1: with beam shutdown and active RHR).

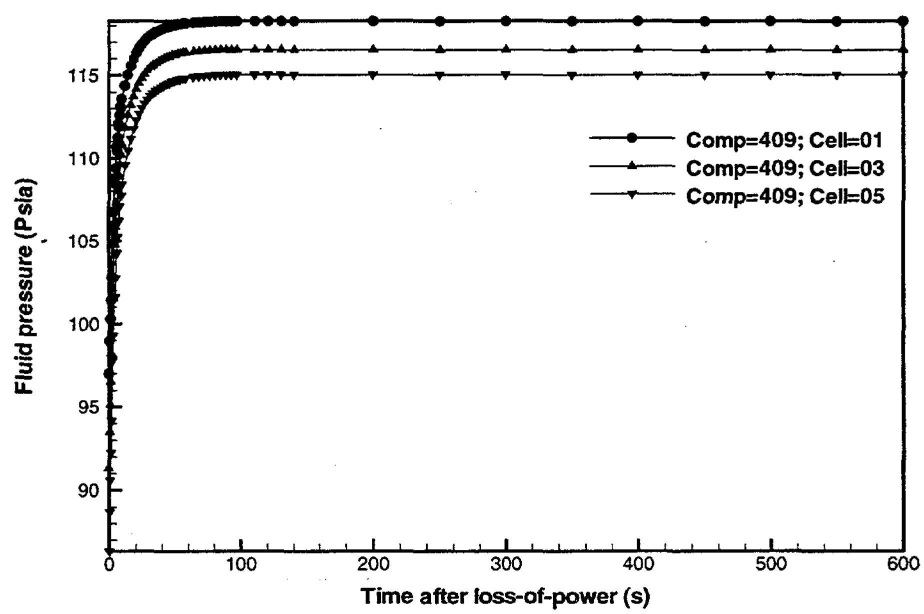

Figure B-20a Module 3 channel fluid pressures for a LOFA (Case 1: with beam shutdown and active RHR).

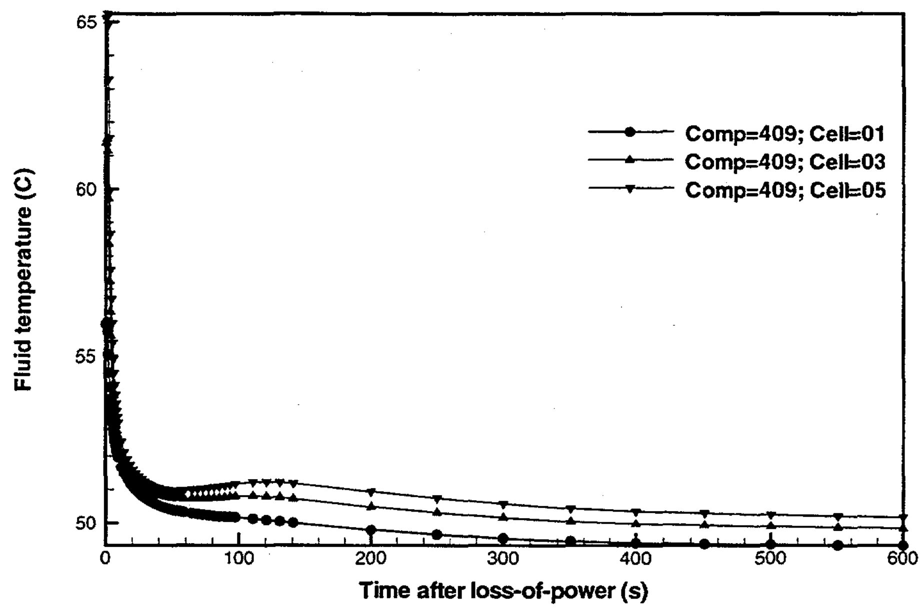

Figure B-20b Module 3 channel Module 3 channel fluid temperatures for a LOFA (Case 1: with beam shutdown and active RHR).

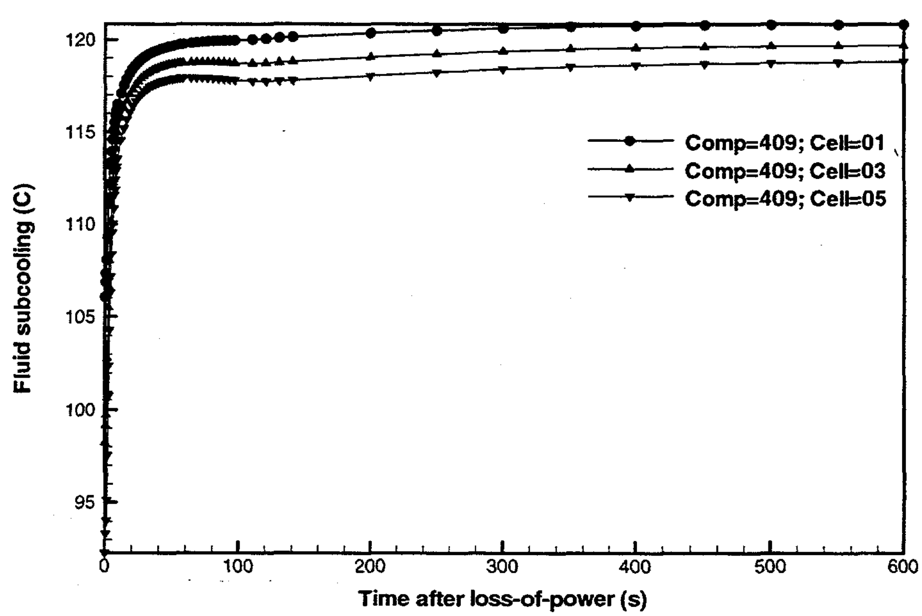

Figure B-20c Module 3 channel fluid subcoolings for a LOFA (Case 1: with beam shutdown and active RHR).

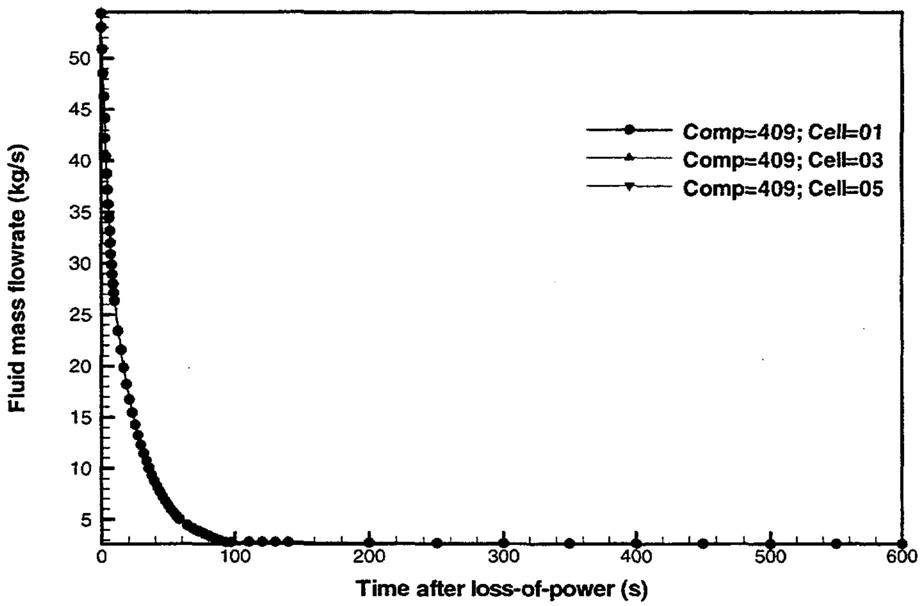

Figure B-20d Module 3 channel liquid mass flowrates for a LOFA (Case 1: with beam shutdown and active RHR).

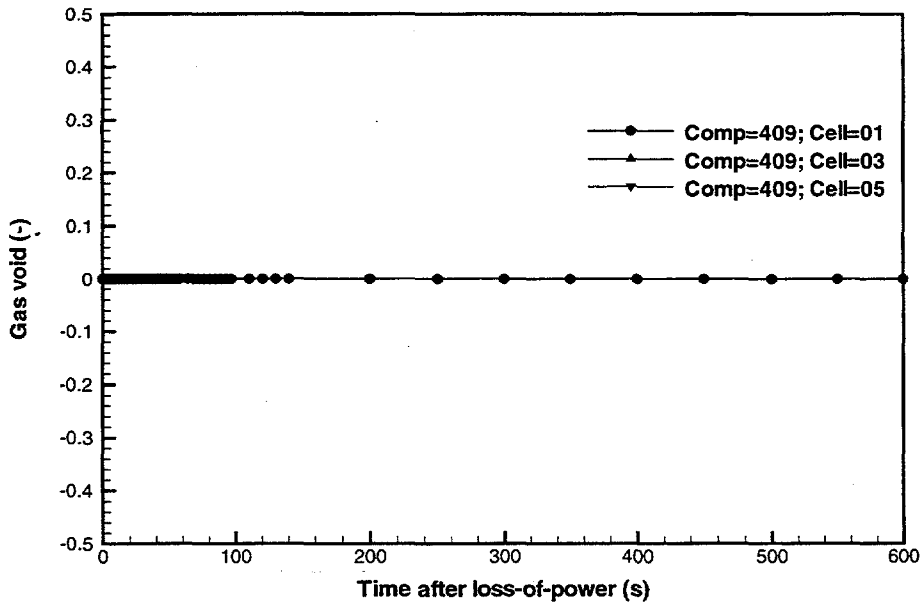

Figure B-20e Module 3 channel void fractions for a LOFA (Case 1: with beam shutdown and active RHR).

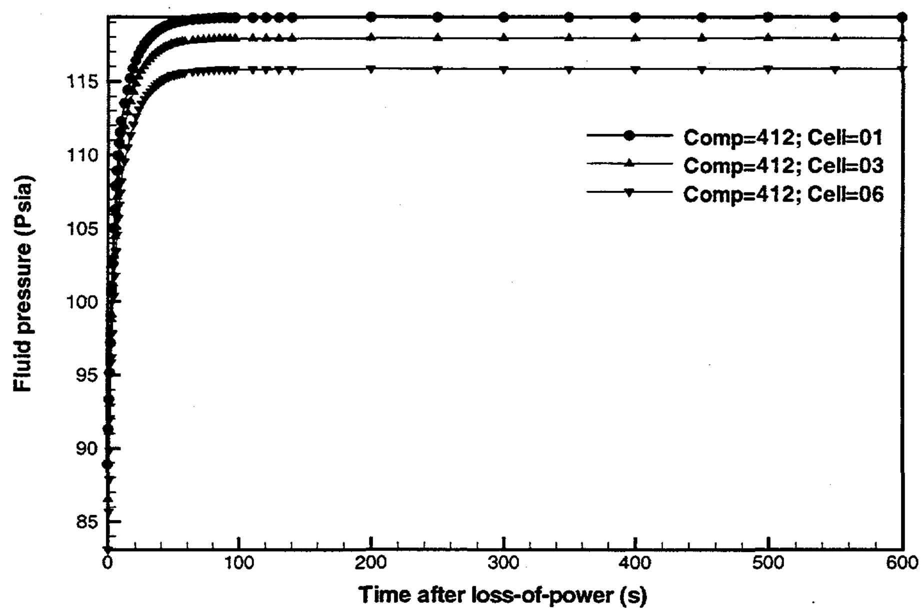

Figure B-21a Module 4 channel fluid pressures for a LOFA (Case 1: with beam shutdown and active RHR).

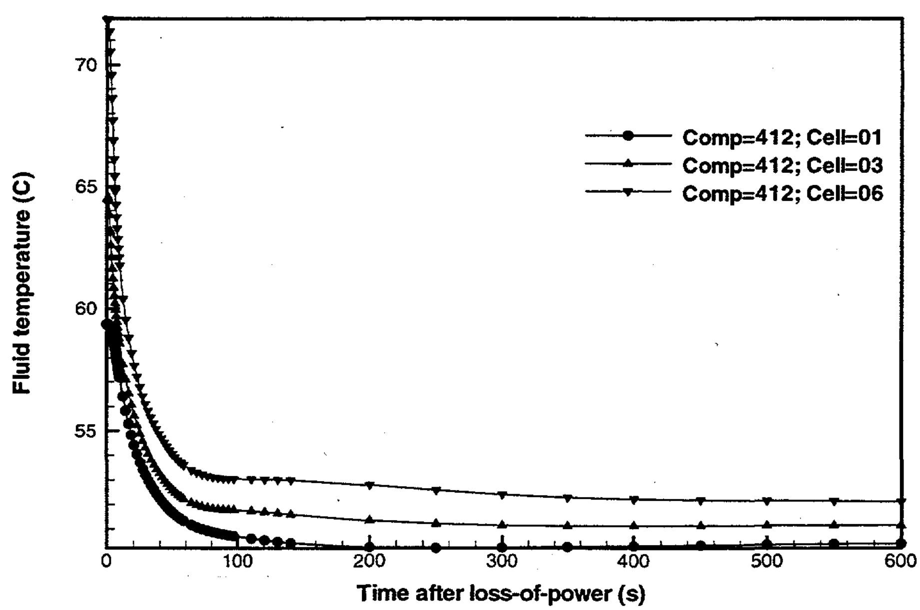

Figure B-21b Module 4 channel fluid temperatures for a LOFA (Case 1: with beam shutdown and active RHR).

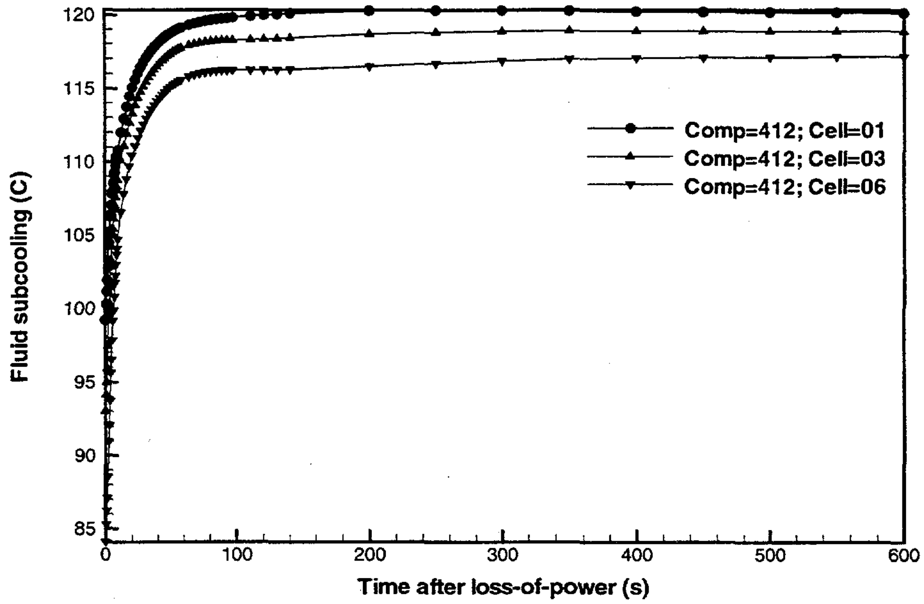

Figure B-21c Module 4 channel fluid subcoolings for a LOFA (Case 1: with beam shutdown and active RHR).

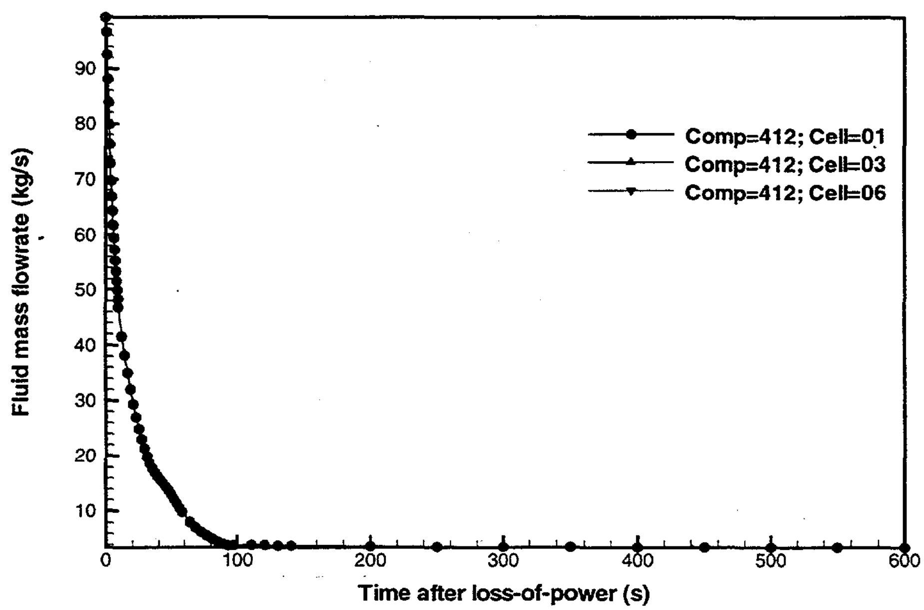

Figure B-21d Module 4 channel liquid mass flowrates for a LOFA (Case 1: with beam shutdown and active RHR).

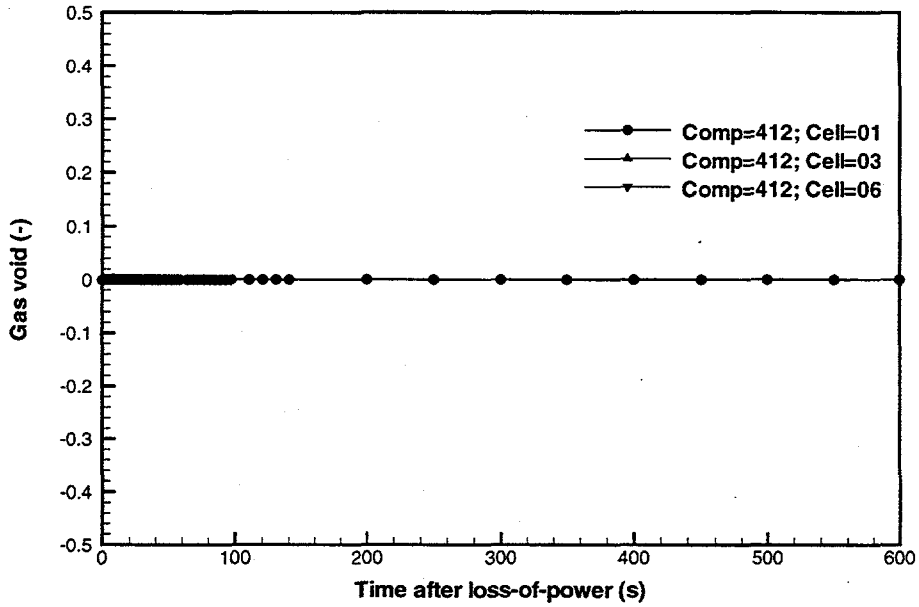

Figure B-21e Module 4 channel void fractions for a LOFA (Case 1: with beam shutdown and active RHR).

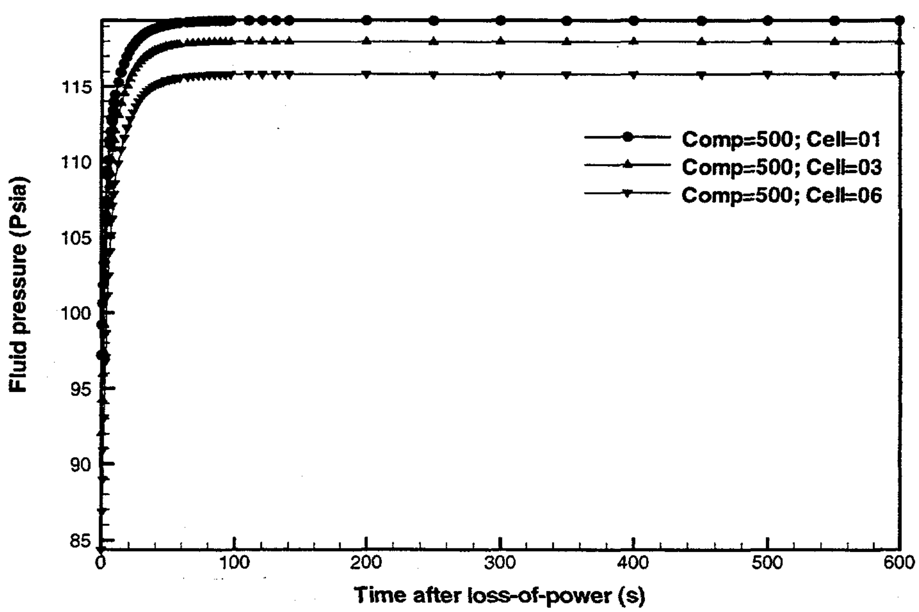

Figure B-22a Module 5 channel fluid pressures for a LOFA (Case 1: with beam shutdown and active RHR).

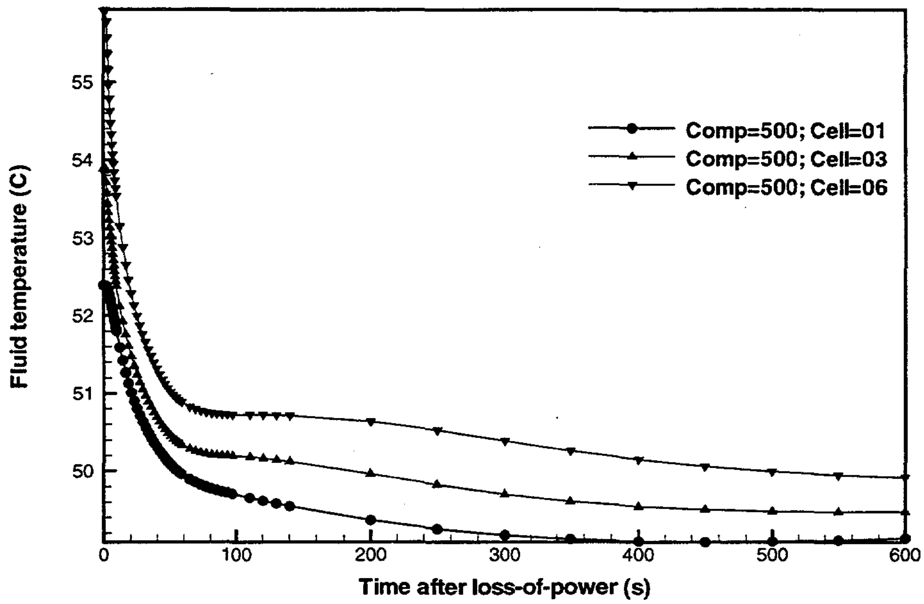

Figure B-22b Module 5 channel fluid temperatures for a LOFA (Case 1: with beam shutdown and active RHR).

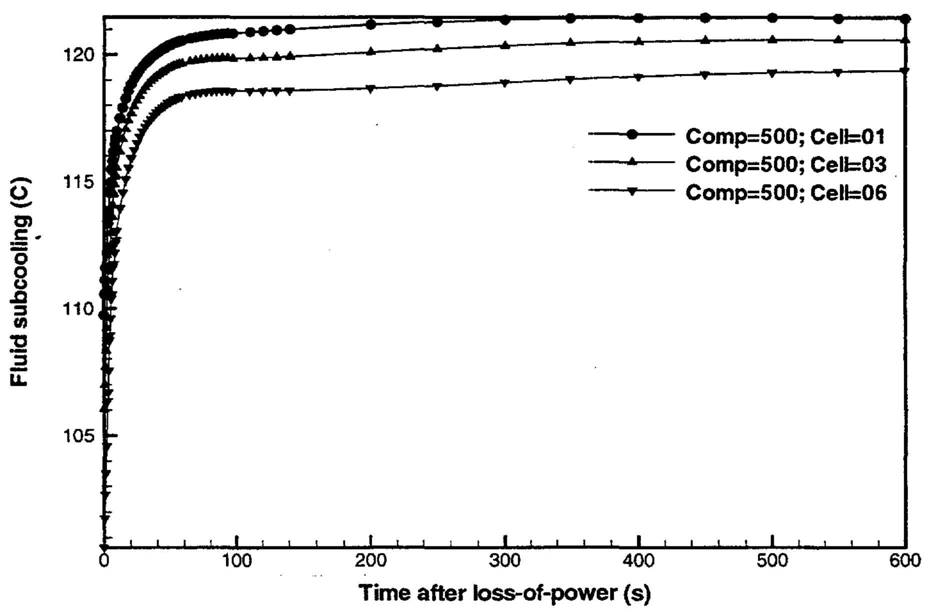

Figure B-22c Module 5 channel fluid subcoolings for a LOFA (Case 1: with beam shutdown and active RHR).

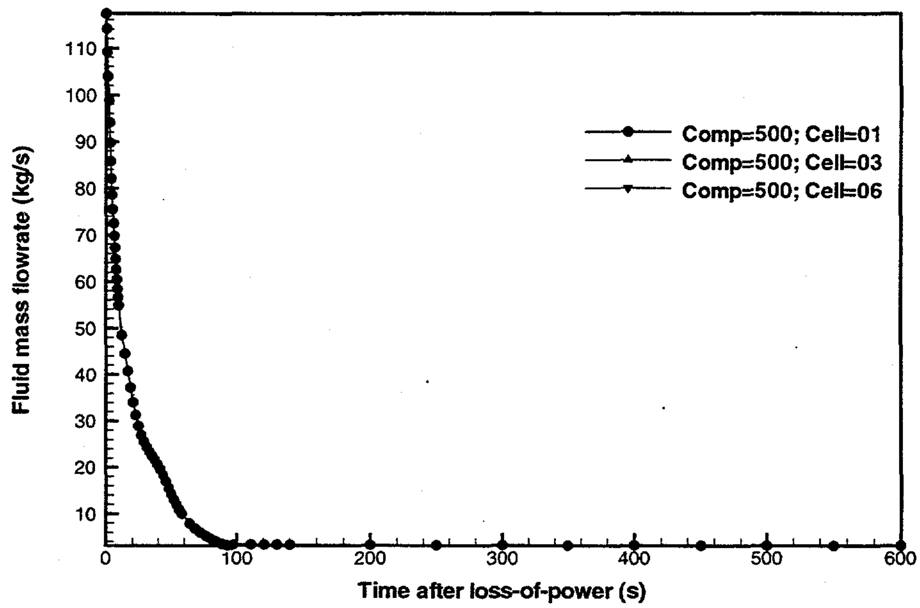

Figure B-22d Module 5 channel liquid mass flowrates for a LOFA (Case 1: with beam shutdown and active RHR).

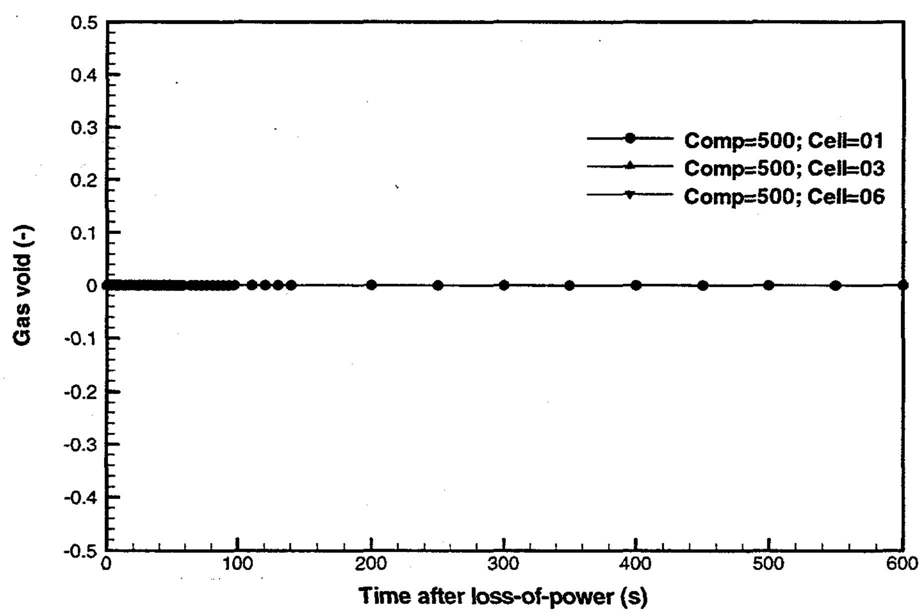

Figure B-22e Module 5 channel void fractions for a LOFA (Case 1: with beam shutdown and active RHR).

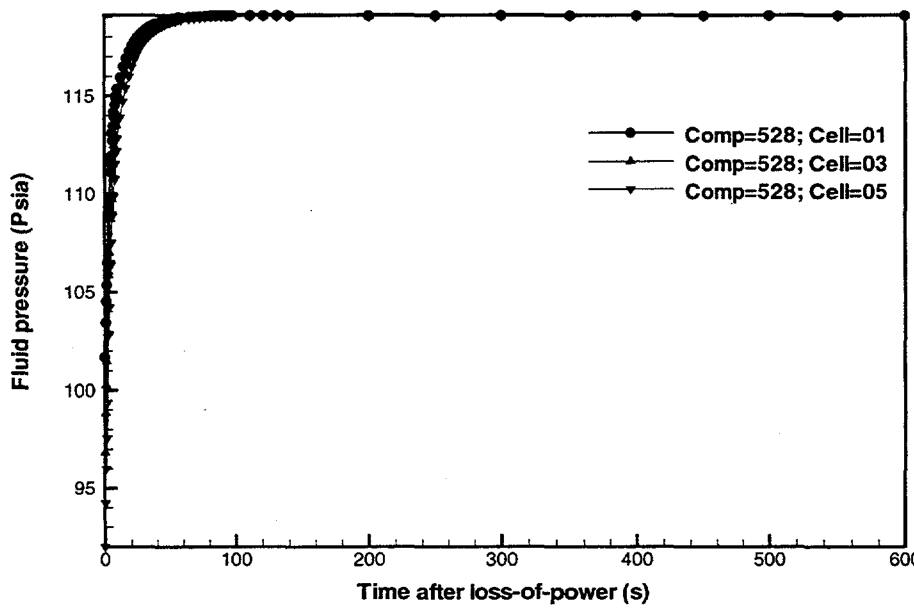

Figure B-23a Module 6 channel fluid pressures for a LOFA (Case 1: with beam shutdown and active RHR).

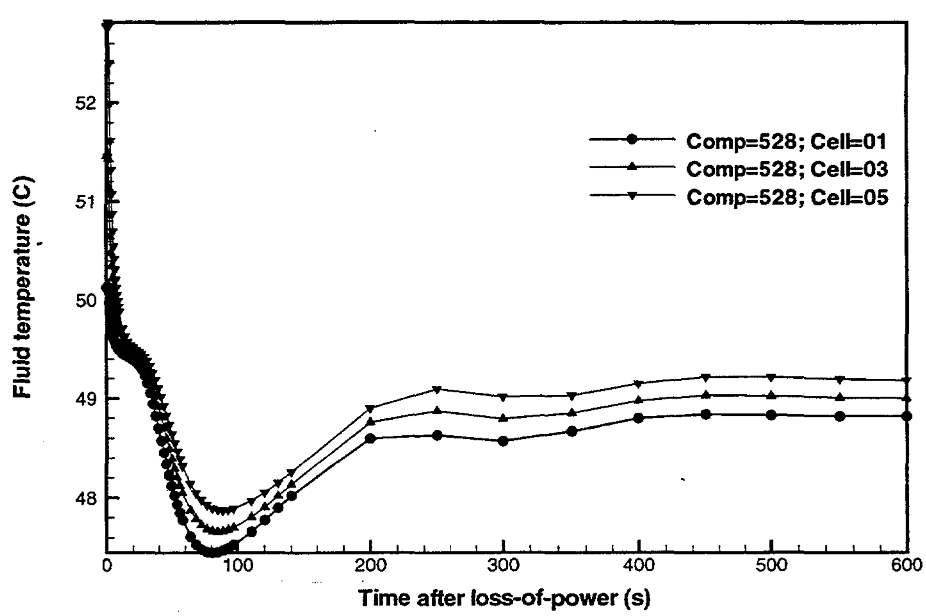

Figure B-23b Module 6 channel fluid temperatures for a LOFA (Case 1: with beam shutdown and active RHR).

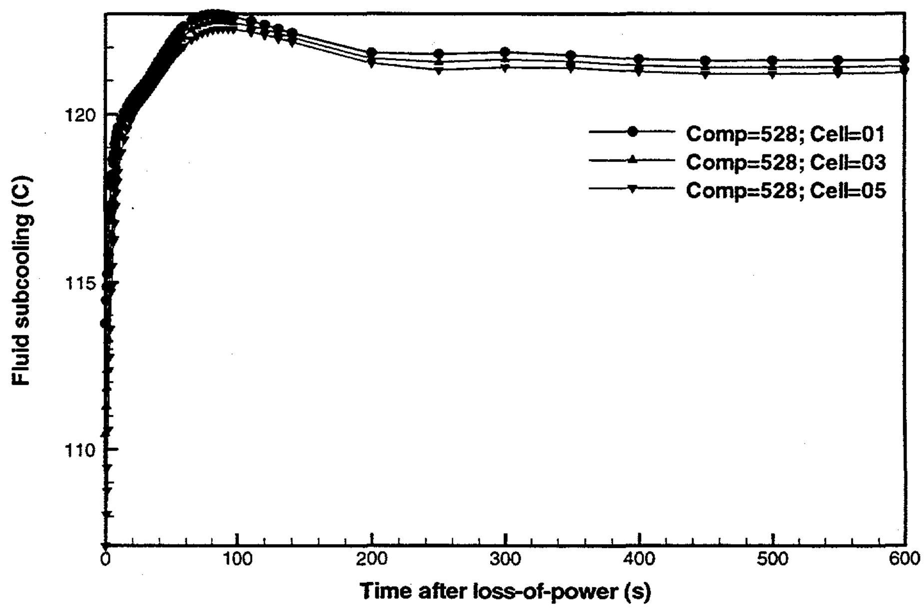

Figure B-23c Module 6 channel fluid subcoolings for a LOFA (Case 1: with beam shutdown and active RHR).

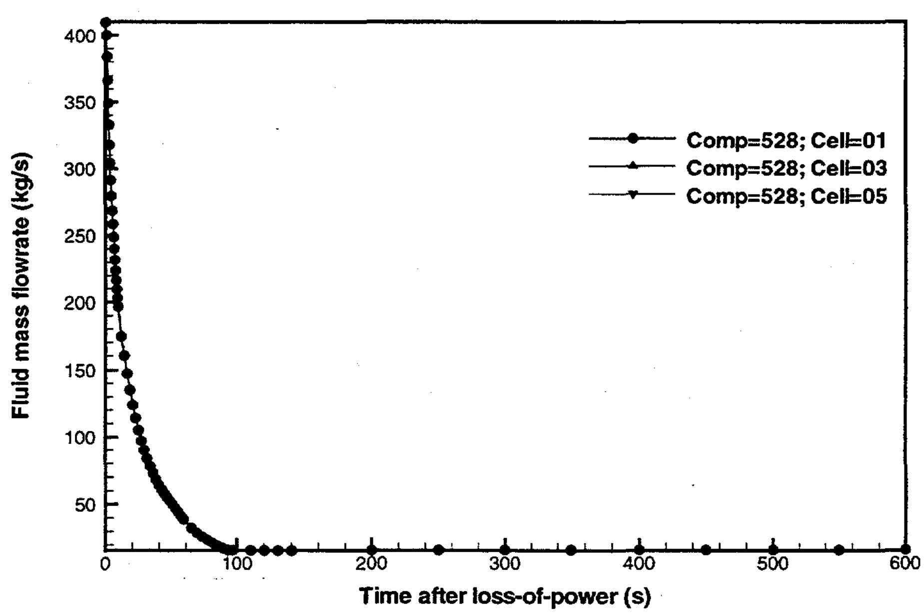

Figure B-23d Module 6 channel liquid mass flowrates for a LOFA (Case 1: with beam shutdown and active RHR).

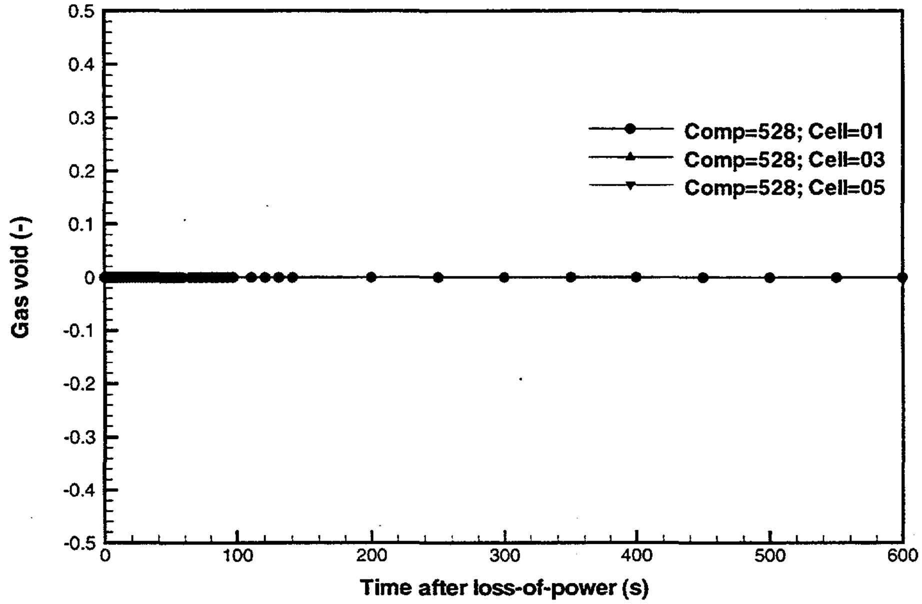

Figure B-23e Module 6 channel void fractions for a LOFA (Case 1: with beam shutdown and active RHR).

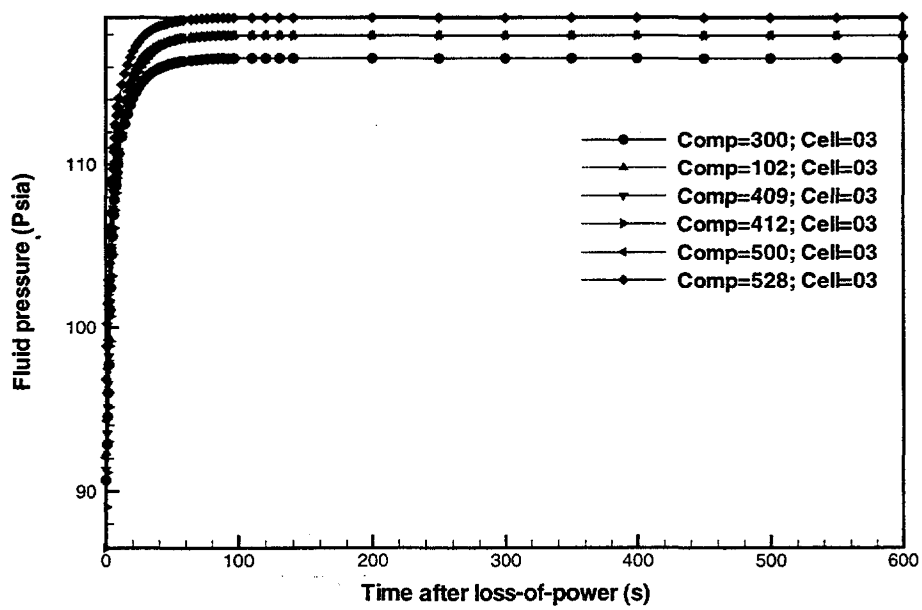

Figure B-24a Mid-plane module fluid pressures for a LOFA (Case 1: with beam shutdown and active RHR).

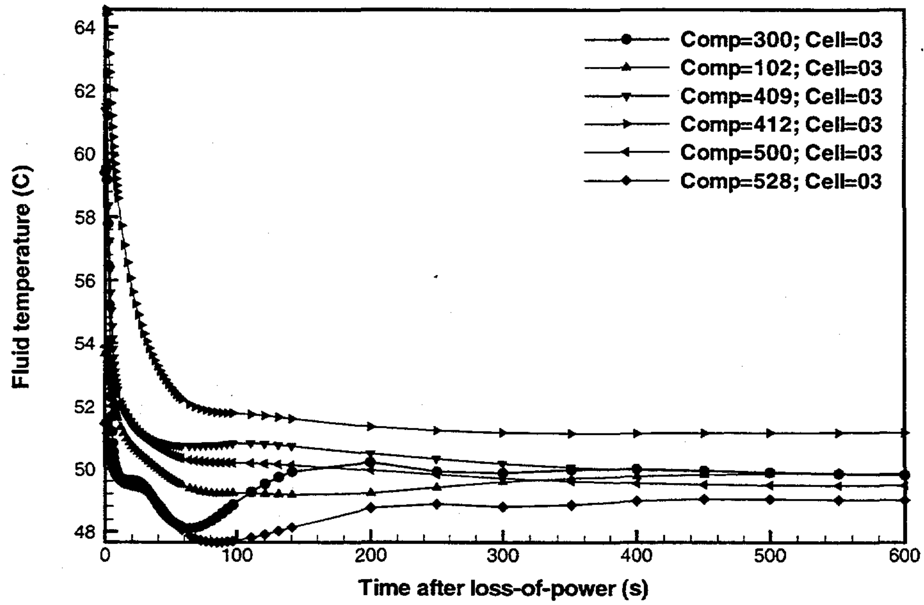

Figure B-24b Mid-plane module fluid temperatures for a LOFA (Case 1: with beam shutdown and active RHR).

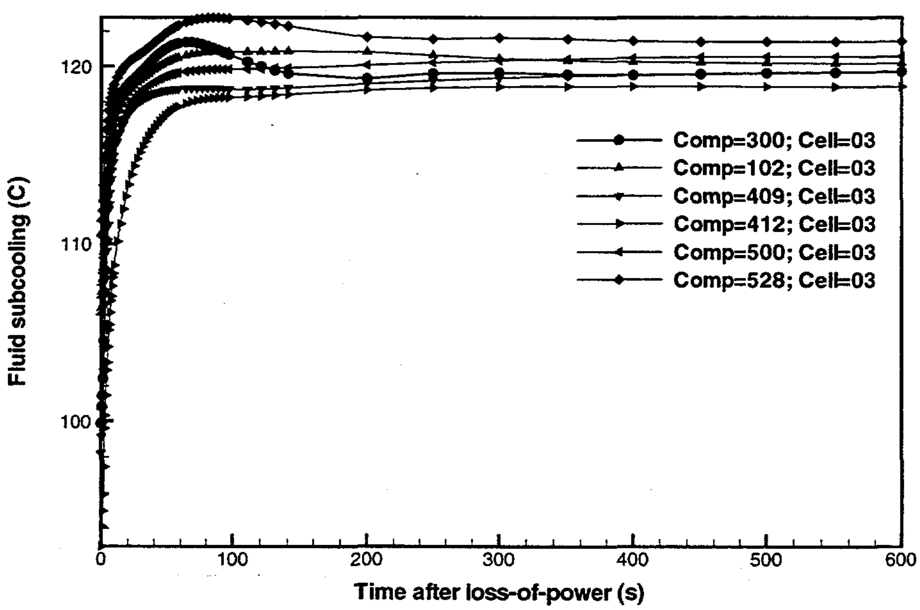

Figure B-24c Mid-plane module fluid subcoolings for a LOFA (Case 1: with beam shutdown and active RHR).

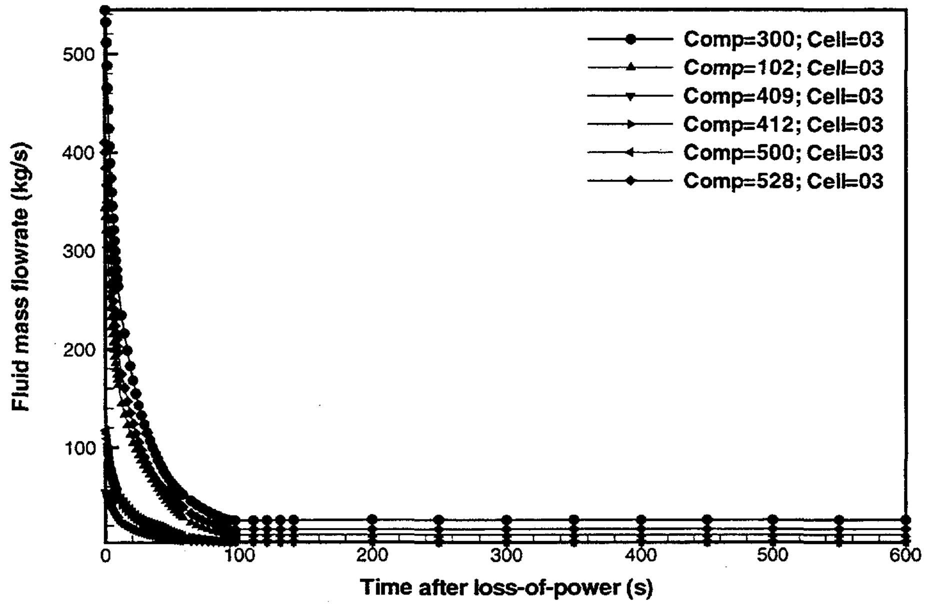

Figure B-24d Mid-plane module liquid mass flowrates for a LOFA (Case 1: with beam shutdown and active RHR).

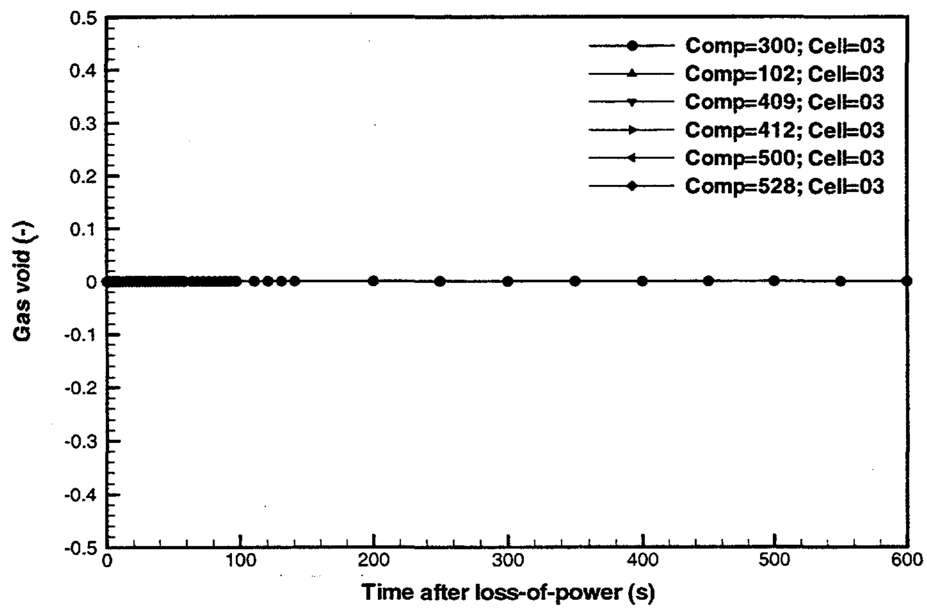

Figure B-24e Mid-plane module void fractions for a LOFA (Case 1: with beam shutdown and active RHR).

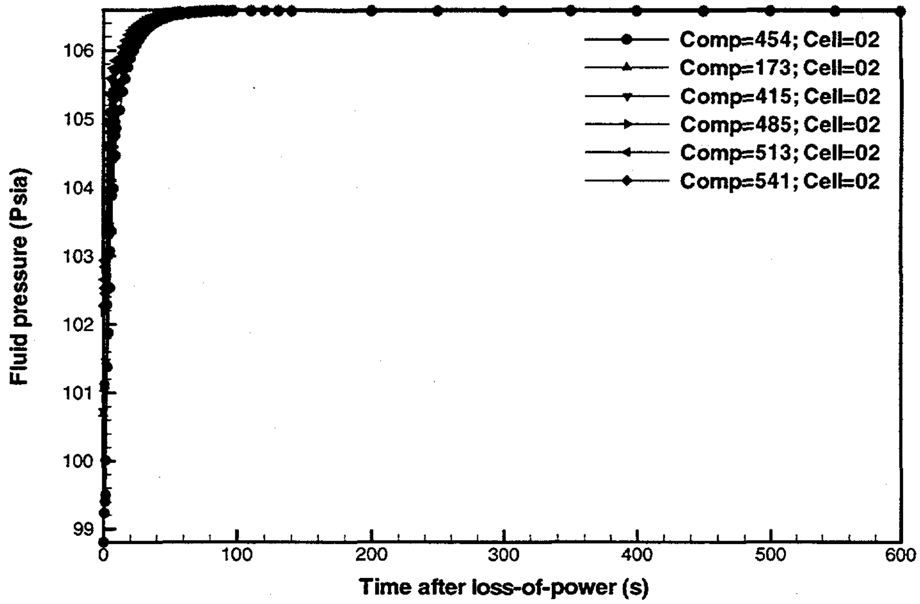

Figure B-25a Module inlet fluid pressures for a LOFA (Case 1: with beam shutdown and active RHR).

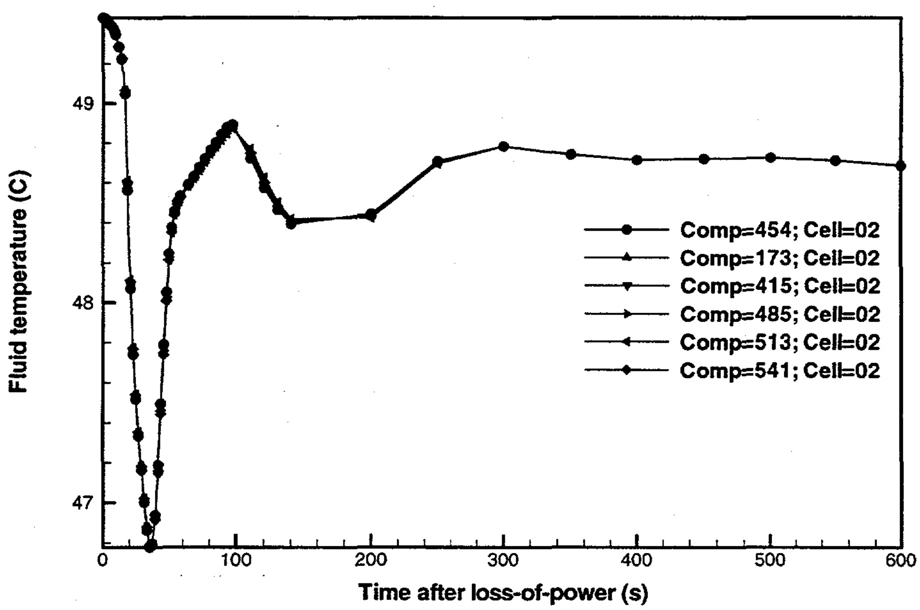

Figure B-25b Module inlet fluid temperatures for a LOFA (Case 1: with beam shutdown and active RHR).

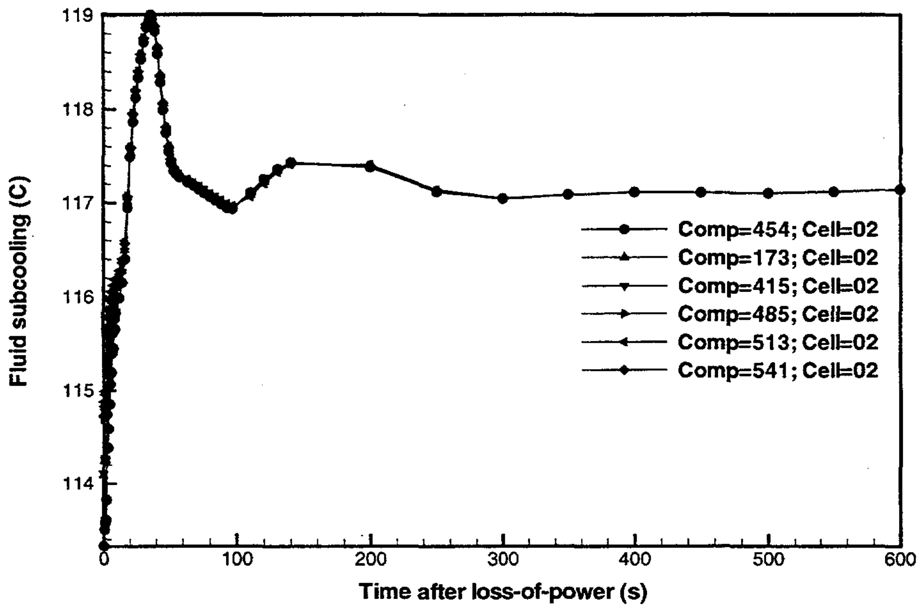

Figure B-25c Module inlet fluid subcoolings for a LOFA (Case 1: with beam shutdown and active RHR).

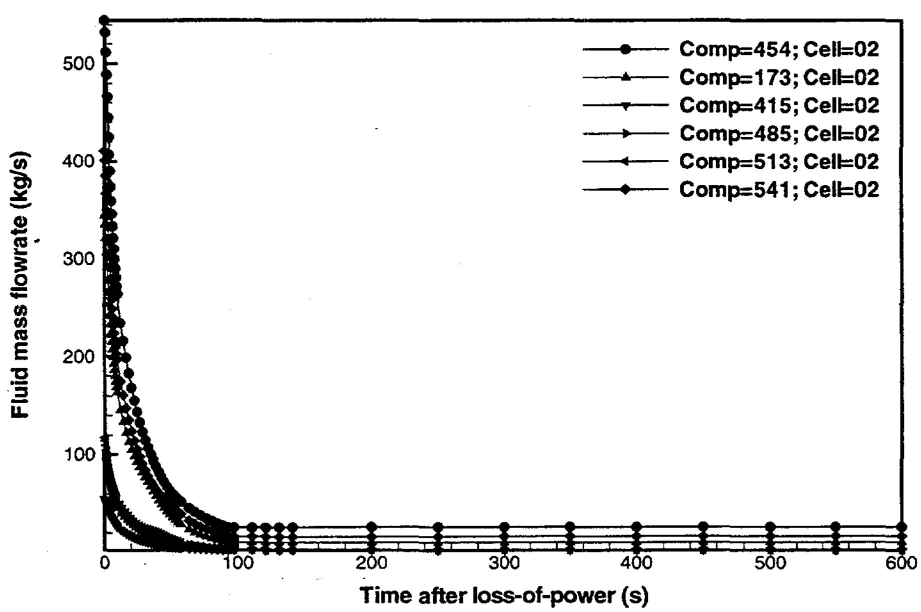

Figure B-25d Module inlet liquid mass flowrates for a LOFA (Case 1: with beam shutdown and active RHR).

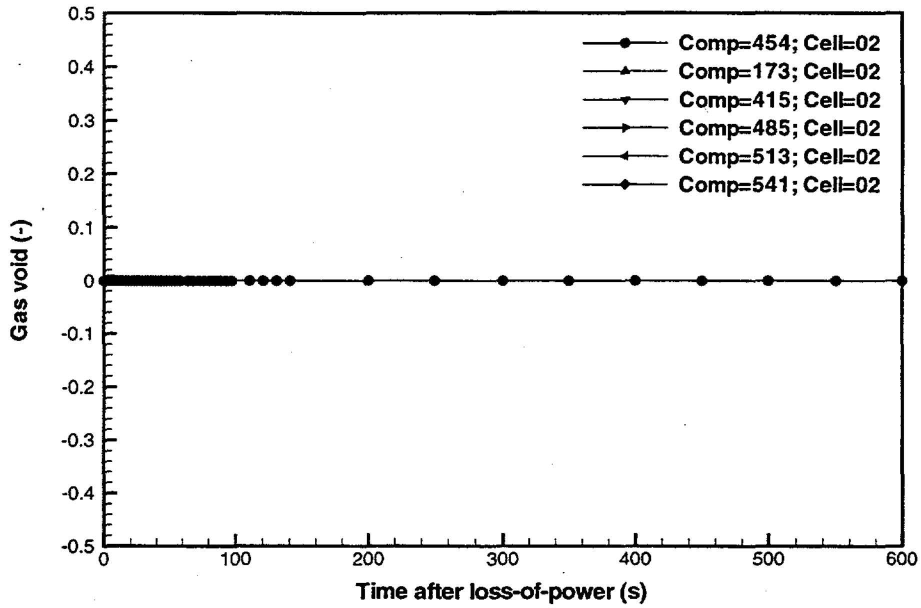

Figure B-25e Module inlet void fractions for a LOFA (Case 1: with beam shutdown and active RHR).

Appendix B3 LOFA (Case 1) TRAC Heat Structure Component Figures

The following figures are from a TRAC simulation for Case 1 of a LOFA (with beam shutdown and active RHR):

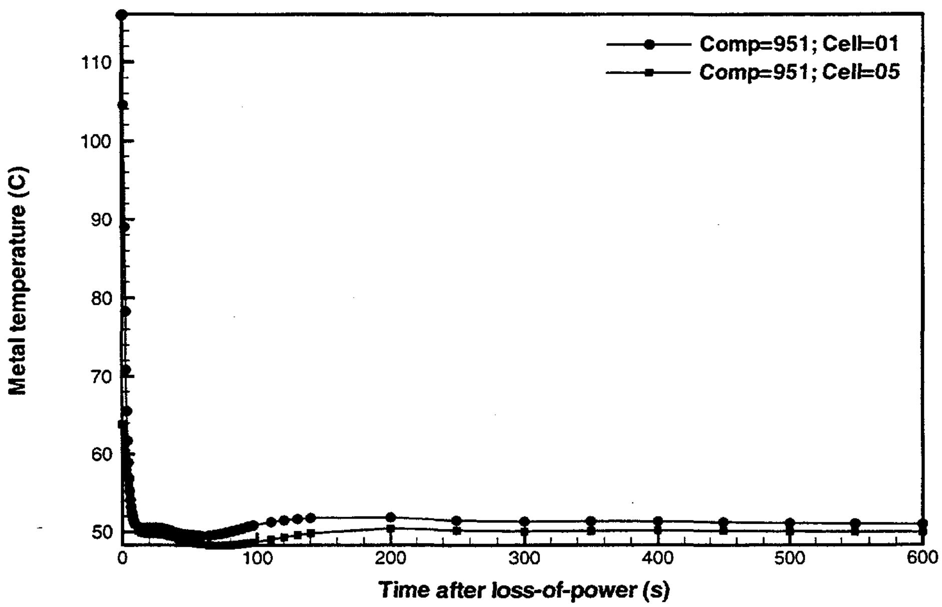

Figure B-26 Module 1 upflow section bottom and top maximum lead metal temperatures for a LOFA (Case 1: with beam shutdown and active RHR).

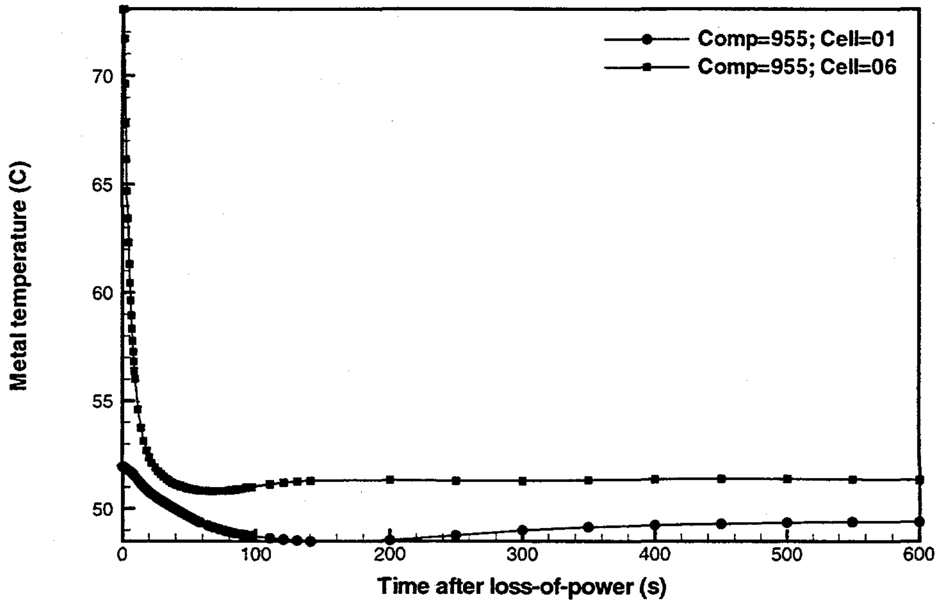

Figure B-27 Module 2 upflow section bottom and top maximum lead metal temperatures for a LOFA (Case 1: with beam shutdown and active RHR).

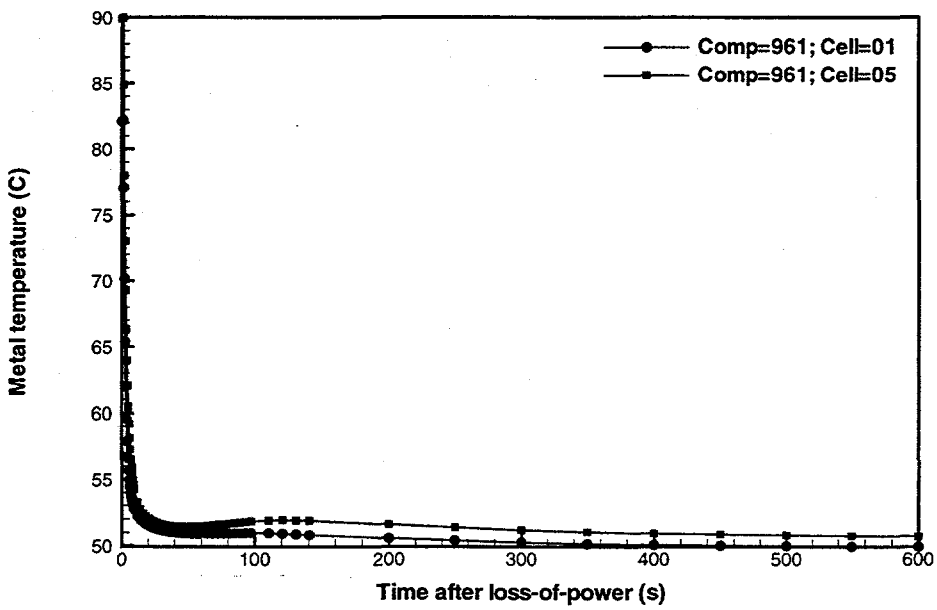

Figure B-28 Module 3 upflow section bottom and top maximum lead metal temperatures for a LOFA (Case 1: with beam shutdown and active RHR).

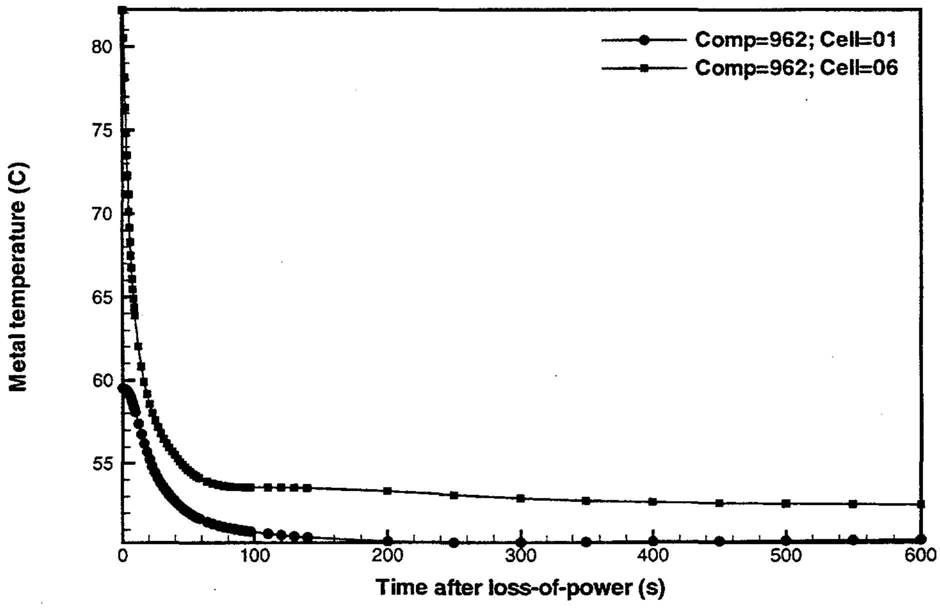

Figure B-29 Module 4 upflow section bottom and top maximum lead metal temperatures for a LOFA (Case 1: with beam shutdown and active RHR).

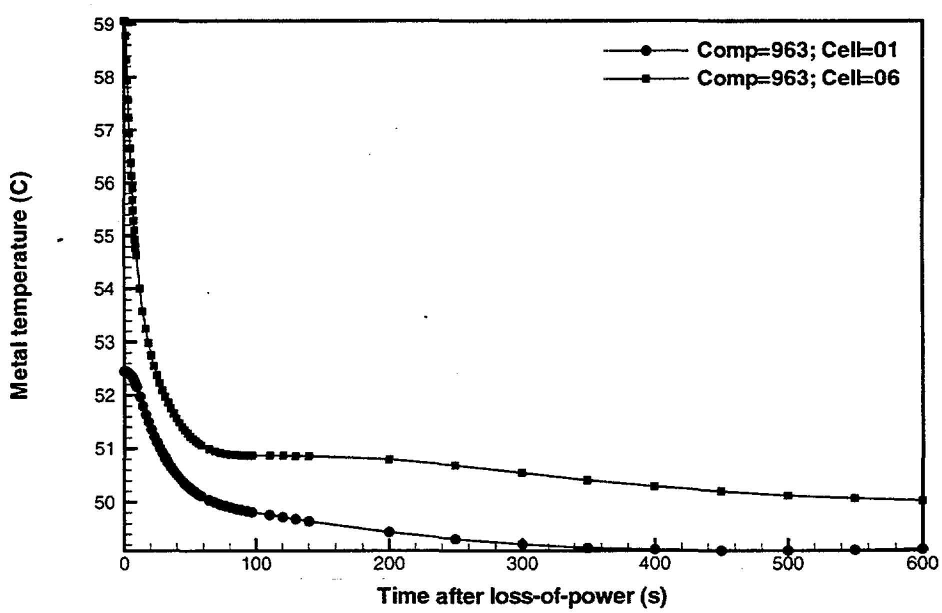

Figure B-30 Module 5 upflow section bottom and top maximum lead metal temperatures for a LOFA (Case 1: with beam shutdown and active RHR).

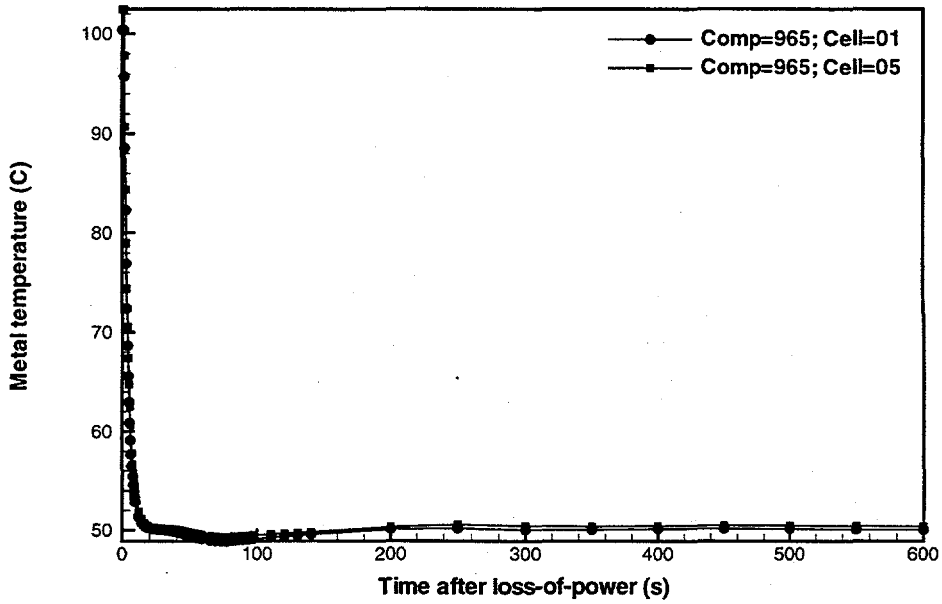

Figure B-31 Module 6 down-stream section bottom and top maximum lead metal temperatures for a LOFA (Case 1: with beam shutdown and active RHR).

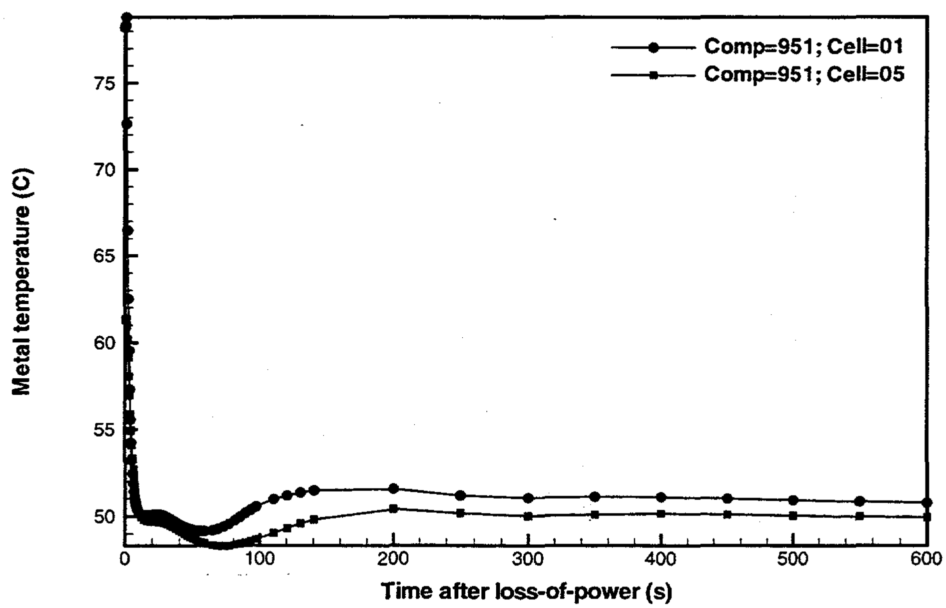

Figure B-32 Module 1 upflow section bottom and top maximum aluminum metal temperatures for a LOFA (Case 1: with beam shutdown and active RHR).

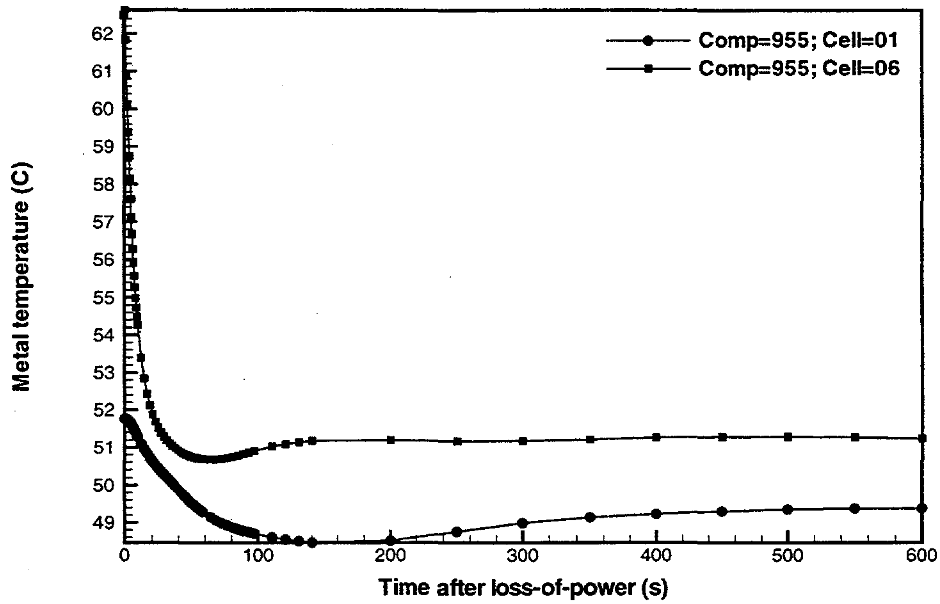

Figure B-33 Module 2 upflow section bottom and top maximum aluminum metal temperatures for a LOFA (Case 1: with beam shutdown and active RHR).

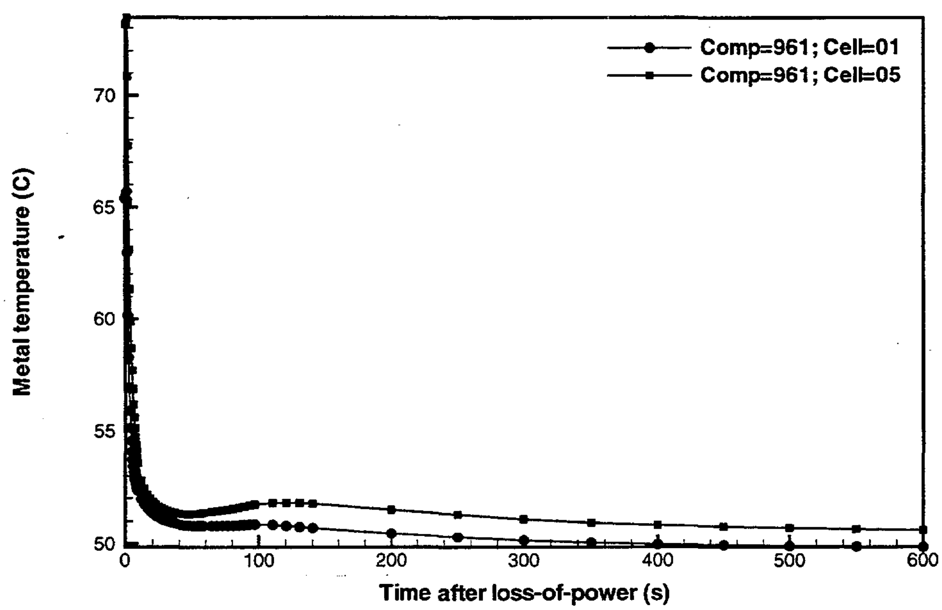

Figure B-34 Module 3 upflow section bottom and top maximum aluminum metal temperatures for a LOFA (Case 1: with beam shutdown and active RHR).

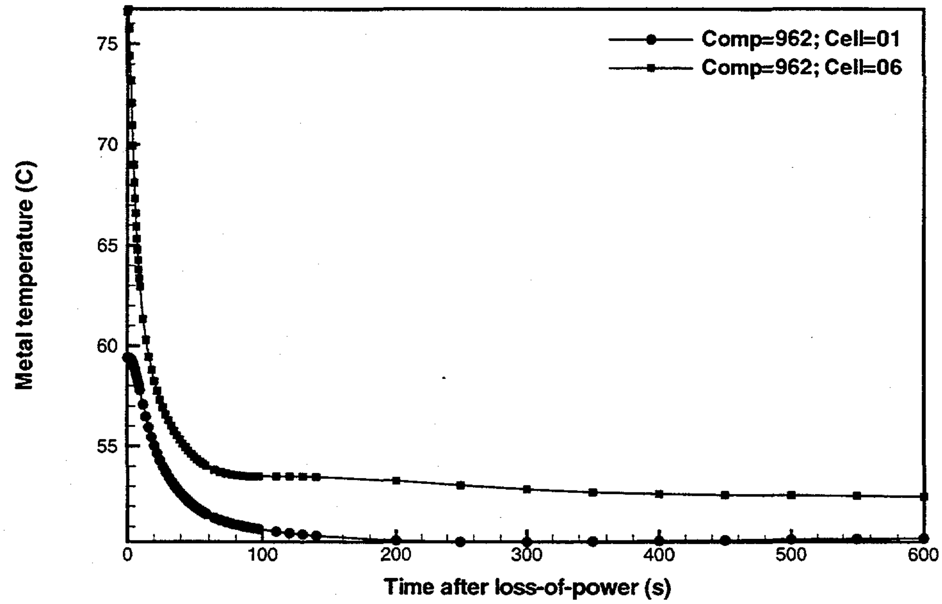

Figure B-35 Module 4 upflow section bottom and top maximum aluminum metal temperatures for a LOFA (Case 1: with beam shutdown and active RHR).

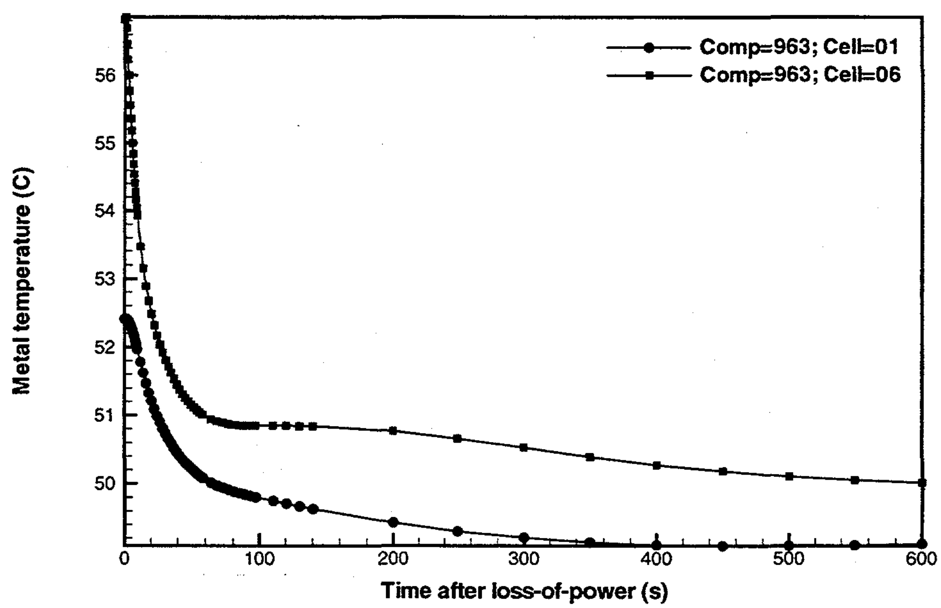

Figure B-36 Module 5 upflow section bottom and top maximum aluminum metal temperatures for a LOFA (Case 1: with beam shutdown and active RHR).

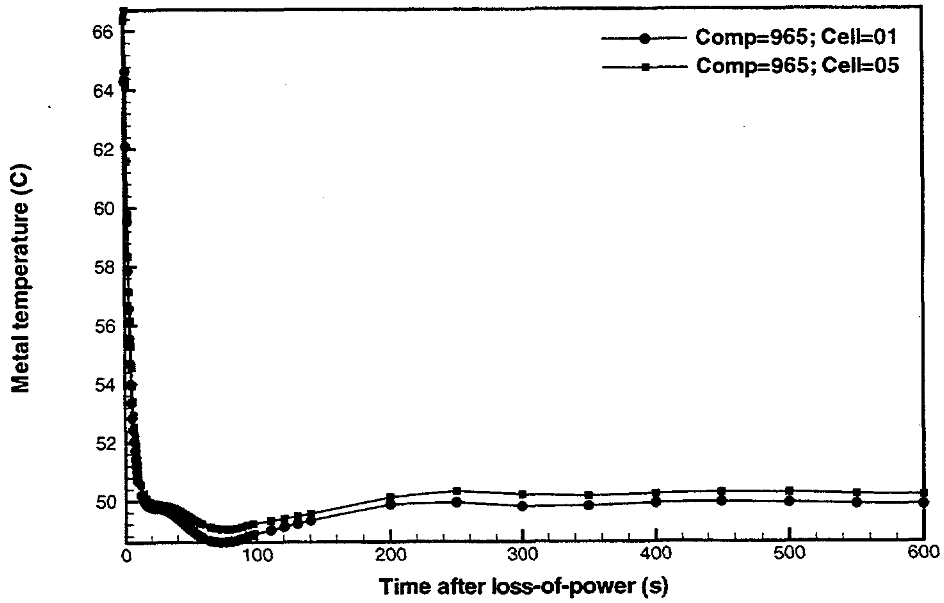

Figure B-37 Module 6 down-stream section bottom and top maximum aluminum metal temperatures for a LOFA (Case 1: with beam shutdown and active RHR).

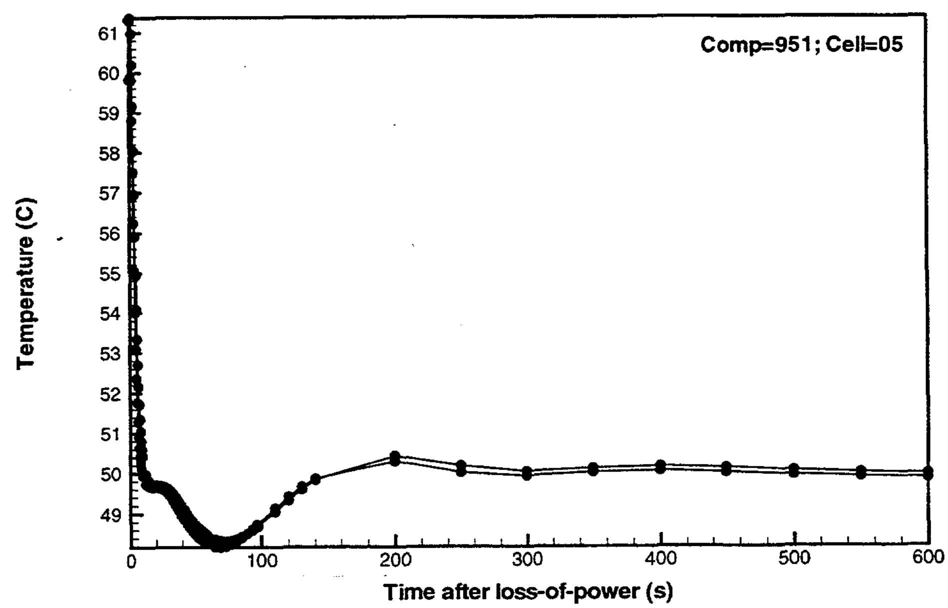

Figure B-38 Module 1 upflow section top-plane surface and fluid temperatures for a LOFA (Case 1: with beam shutdown and active RHR).

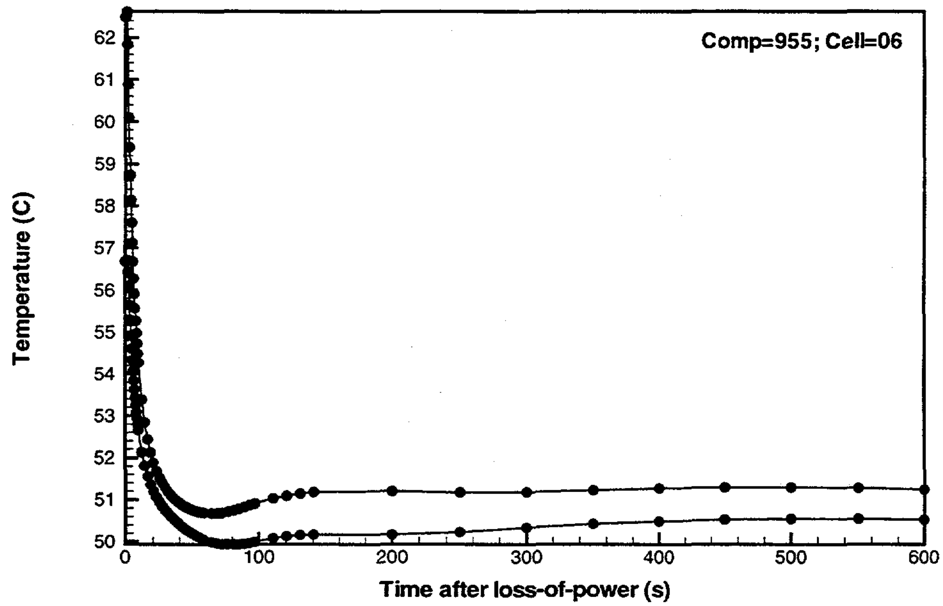

Figure B-39 Module 2 upflow section top-plane surface and fluid temperatures for a LOFA (Case 1: with beam shutdown and active RHR).

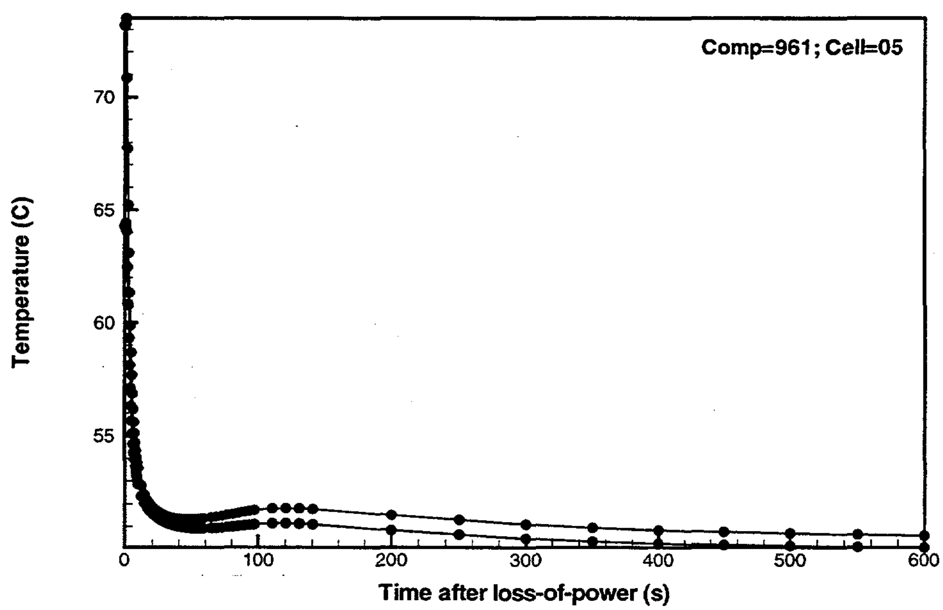

Figure B-40 Module 3 upflow section top-plane surface and fluid temperatures for a LOFA (Case 1: with beam shutdown and active RHR).

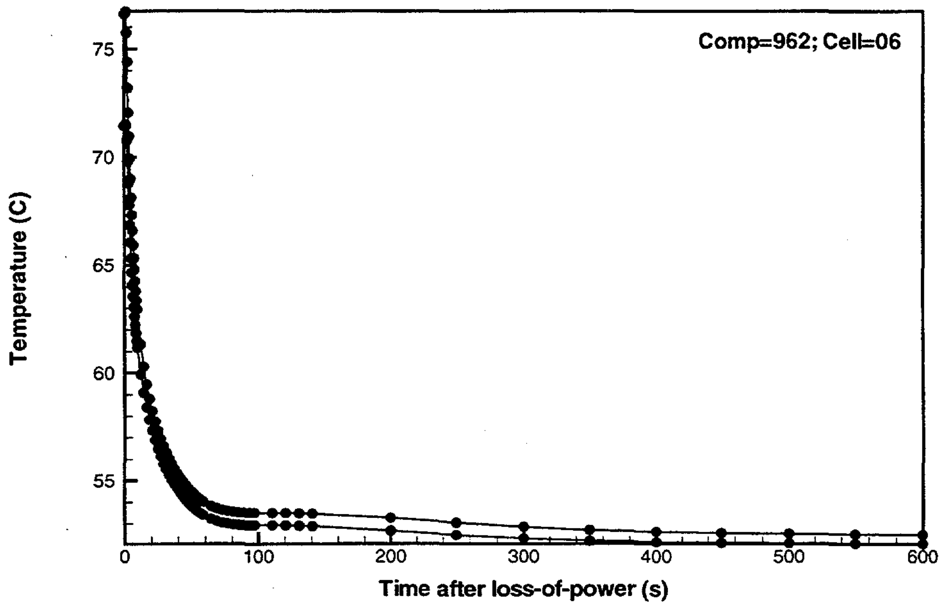

Figure B-41 Module 4 upflow section top-plane surface and fluid temperatures for a LOFA (Case 1: with beam shutdown and active RHR).

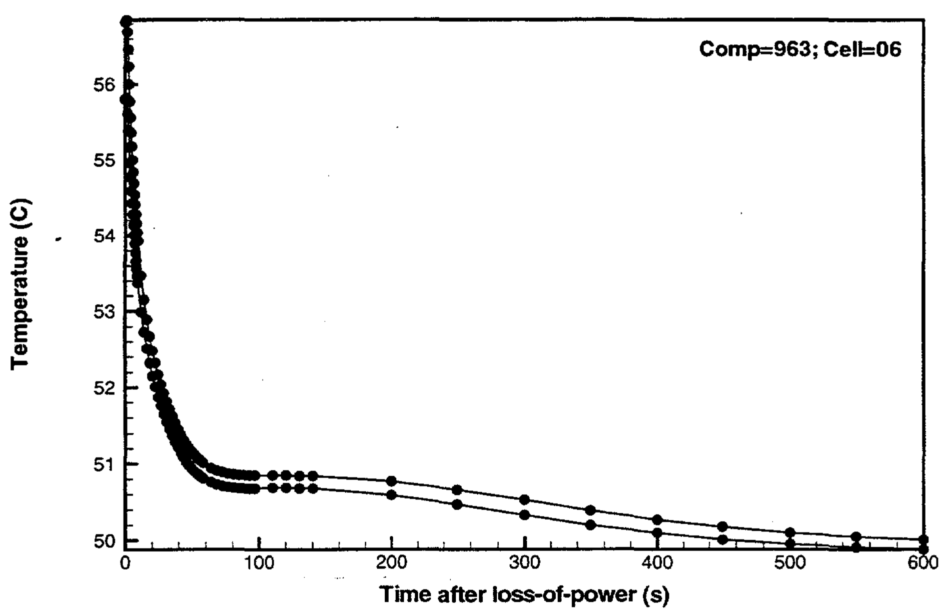

Figure B-42 Module 5 upflow section top-plane surface and fluid temperatures for a LOFA (Case 1: with beam shutdown and active RHR).

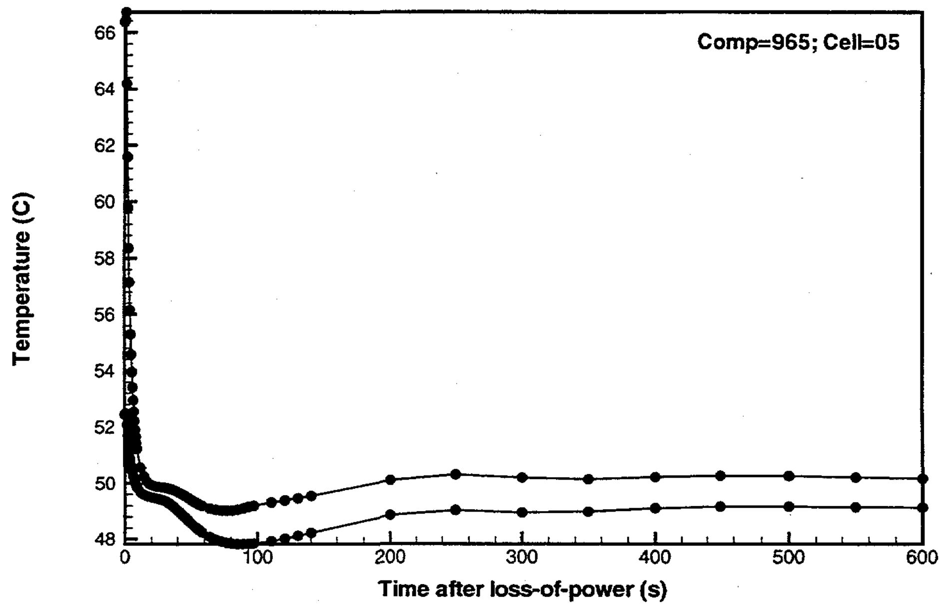

Figure B-43 Module 6 upflow section top-plane surface and fluid temperatures for a LOFA (Case 1: with beam shutdown and active RHR).

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Appendix C: TRAC Standard Input File for LOFA Case 1 (with Beam Shutdown and Active RHR)

The file listed below represents the TRAC code "tracin" file that corresponds to the LOFA Case 1 (with beam shutdown and active RHR) for the blanket system. This input deck assumes that a TRAC restart file ("trcrst") exists based on normal operation (NO).

Input file tracin:

```
*
free format
*************
* main data *
*************
*
*       numtcr          ieos          inopt          nmat          id2o
           37              0              1              2             0
* APT Lumped Blanket Model
  6 Module Lumped Model with Primary Coolant Loop and RHR Loop
  6 Modules - Lateral(R1/Dec) Module, R2/R3 Module,
              3 Backstop Modules, Low Power Module (12/18/1997)
  Hydraulic RHR Loop added as of 12/22/1997
  - This is based on check valve with flow reversal control logic.
  Number of material = 2 (Al and Pb)
  - This is single combined mod model without He comp (12/12/1997)
  - Aluminum, lead material table got from Ref. (3/5, 1997)
  - This is 1 module loop model without prmary coolant and RHR loops
  - adding two upper modules (L14B-back / L14F-front) as of 7/18/1997.
  - Row2/3 power updated (4/23/1997).
  - R2/R3 axial power distribution has been updated
    as of 4/25/1997.
  - Al and lead material properties updated already.
  - Unit cell cal. should be checked.
  - K-loss values for each comp and elevation levels need be checked.
  - Control signal variable was added (4/25/1997).
  - Module 5 6 7 8 connection to fixed header was updated (5/28/97).
  - Blanket primary loop pipe size (14 inch) was updated (5/28/1997).
  - Lower modules(module 15 16 17 18) were added/updated (5/29/1997).
  - Backstop 1st module was updated (5/29/1997).
  - Backstop 2nd and 3rd modules were updated (5/30/1997).
  - R2/R3 lateral modules were updated from 9 to 11 bins (6/3/1997).
  - Lateral module 1 to 4 decay powers were updated (6/23/1997).
  - Power for each module was updated from the 6/9/97 e-mail except
    for snout and top modules (6/26/97).
  - Decay power fraction for each module was updated from the 6/9/97
    e-mail except for snout and top modules (6/26/97).
  - Power for each module was updated from the 6/9/97 e-mail
    for snout module (7/8/97).
  - Decay power fraction for each module was updated from the 6/9/97
    e-mail for snout module (7/8/97).
  - Single loop to connect two front lateral modules was updated
    (7/16/97).
  - Single loop to connect two back lateral modules was updated
    (7/16/97).
*
*****************
* namelist data *
*****************
*
 &inopts nrslv=1, nhtstr=25, iconht=0, iadded=10, ielv=1, ipowr=-1,
```

```
    tpowr=10, igas=1, noair=0, nlt=12, ikfac=1, ithd=1, nsend=40000 &
*
*       dstep          timet
           -1      0.0000e+00
*      stdyst         transi          ncomp          njun          ipak
            0              1            140           120             1
*        epso           epss
   1.0000e-04     1.0000e-04
*      oitmax         sitmax         isolut         ncontr        nccfl
           50             50              0              2             0
*        ntsv           ntcb           ntcf           ntrp          ntcp
            7              0              0              7             1
*
************************
* component-number data *
************************
*
* iorder*
*
      760    s   * pipe          pressurizer surge line1
      761    s   * pipe          pressurizer surge line2
      762    s   * pipe          pressurizer surge line3
      763    s   * pipe          pressurizer surge line4
      764    s   * pipe          pressurizer surge line5
      765    s   * pipe          pressurizer surge line6
      766    s   * pipe          primary pressurizer
      767    s   * break         pressurizer boundary
*
* HR hot leg
       20    s   * pipe         HR pump suction pipe
       21    s   * plenum       HR pump suction pipe (bk)
       22    s   * pipe         HR pump suction pipe
       23    s   * pipe         HR pump suction pipe (bk)
       24    s   * pipe         HR pump suction pipe
       25    s   * pipe         HR pump suction pipe (bk)
       26    s   * pipe         HR pump suction pipe
* HR pumps
       27    s   * plenum       HR pump suction plenum
       28    s   * pipe         HR pump #1 inlet pipe
       30    s   * pump         HR pump #1
       32    s   * pipe         HR pump #1 outlet pipe
       29    s   * pipe         HR pump #2 inlet pipe
       31    s   * pump         HR pump #2
       33    s   * pipe         HR pump #2 outlet pipe
       34    s   * plenum       HR pump discharge plenum
* HR pump-to-hx piping
       36    s   * pipe         HR pump dicharge pipe
       37    s   * pipe         HR pump dicharge pipe (bk)
       38    s   * pipe         HR pump dicharge pipe
* HR hx's
       40    s   * plenum       HR hx inlet plenum
       48    s   * pipe         HR hx 1 inlet pipe
       50    s   * pipe         HR hx 1 tubes 1st pass
       52    s   * pipe         HR hx 1 mid-header
       54    s   * pipe         HR hx 1 tubes 2nd pass
       56    s   * pipe         HR hx 1 outlet pipe
       49    s   * pipe         HR hx 2 inlet pipe
       51    s   * pipe         HR hx 2 tubes 1st pass
       53    s   * pipe         HR hx 2 mid-header
       55    s   * pipe         HR hx 2 tubes 2nd pass
       57    s   * pipe         HR hx 2 outlet pipe
       60    s   * plenum       HR hx outlet plenum
```

```
* HR cold leg
       62    s   * pipe          HR hx discharge pipe
       63    s   * pipe          HR hx discharge pipe (bk)
       64    s   * pipe          HR hx discharge pipe
       65    s   * pipe          HR hx discharge pipe (bk)
       66    s   * pipe          HR hx discharge pipe
       67    s   * plenum        HR hx discharge pipe (bk)
       68    s   * pipe          HR hx discharge pipe
* HR hx Secondary Side
      710    s   * fill          HR hx Secondary Side-1
      711    s   * pipe          HR hx Secondary Side-1
      712    s   * pipe          HR hx Secondary Side-1
      713    s   * pipe          HR hx Secondary Side-1
      714    s   * break         HR hx Secondary Side-1
      730    s   * fill          HR hx Secondary Side-2
      731    s   * pipe          HR hx Secondary Side-2
      732    s   * pipe          HR hx Secondary Side-2
      733    s   * pipe          HR hx Secondary Side-2
      734    s   * break         HR hx Secondary Side-2
*
      621    s   * pipe          RHR hot leg sect 1 (bk)
      623    s   * pipe          RHR hot leg sect 2
      624    s   * pipe          RHR hot leg sect 3 (bk)
      625    s   * pipe          RHR hot leg sect 4
      630    s   * pump          RHR primary pump
      640    s   * valve         RHR pump discharge valve
      652    s   * pipe          RHR primary heat exchanger tubes
      660    s   * pipe          RHR cold leg sect 1
      661    s   * pipe          RHR cold leg sect 2 (bk)
      662    s   * pipe          RHR cold leg sect 3
      663    s   * pipe          RHR cold leg sect 4 (bk)
* RHR hx Secondary Side
      672    s   * fill          RHR hx Secondary Side
      671    s   * pipe          RHR hx Secondary Side
      673    s   * break         RHR hx Secondary Side
*
      300    s   * pipe            L1 Blanket Row1
      330    s   * plenum          L1 Blanket Row1 Plenum
      335    s   * pipe            L1 pipe conn. 330 - 340
      340    s   * plenum          L1 outlet header
      350    s   * plenum          L1 lower plenum
      360    s   * pipe            L1 decoupler
      370    s   * plenum          L1 decoupler upper plenum
      375    s   * pipe            L1 pipe conn. 370 - 380
      380    s   * plenum          L1 inlet header
      429    s   * pipe            L1 connect hot header-tee
      454    s   * pipe            L1 connect cold header-tee
*
      173    s   * pipe            L1 Blanket Row1
      172    s   * plenum          L1 Blanket Row1 Plenum
      158    s   * pipe            L1 pipe conn. 330 - 340
      147    s   * plenum          L1 outlet header
      102    s   * pipe            L1 lower plenum
      133    s   * plenum          L1 decoupler
      136    s   * pipe            L1 decoupler upper plenum
*
      541    s   * pipe            L1 Blanket Row1
      538    s   * plenum          L1 Blanket Row1 Plenum
      535    s   * pipe            L1 pipe conn. 330 - 340
      531    s   * plenum          L1 outlet header
      528    s   * pipe            L1 lower plenum
      536    s   * plenum          L1 decoupler
```

```
      539   s   * pipe          L1 decoupler upper plenum
*
      415   s   * pipe          L1 Blanket Row1
      479   s   * plenum        L1 Blanket Row1 Plenum
      478   s   * pipe          L1 pipe conn. 330 - 340
      418   s   * plenum        L1 outlet header
      409   s   * pipe          L1 lower plenum
      423   s   * plenum        L1 decoupler
      417   s   * pipe          L1 decoupler upper plenum
*
      485   s   * pipe          2nd DNS Blanket Row1
      489   s   * plenum        2nd DNS Blanket Row1 Plenum
      480   s   * pipe          2nd DNS pipe conn. 330 - 340
      419   s   * plenum        2nd DNS outlet header
      412   s   * pipe          2nd DNS lower plenum
      483   s   * plenum        2nd DNS decoupler
      484   s   * pipe          2nd DNS dec upper plenum
*
      513   s   * pipe          Third DNS Blanket Row1
      510   s   * plenum        Third DNS Row1 Plenum
      507   s   * pipe          Third DNS pipe conn. 330-340
      503   s   * plenum        Third DNS outlet header
      500   s   * pipe          Third DNS lower plenum
      508   s   * plenum        Third DNS decoupler
      511   s   * pipe          Third DNS dec upper plenum
*
      901   s   * rod          annular aluminum rod
      951   s   * rod           cylindrical lead rod
      984   s   * rod           cylindrical lead rod
*
      905   s   * rod          annular aluminum rod
      955   s   * rod           cylindrical lead rod
      916   s   * rod           cylindrical lead rod
      966   s   * rod           cylindrical lead rod
*
      915   s   * rod          annular aluminum rod
      965   s   * rod           cylindrical lead rod
*
      911   s   * rod          annular aluminum rod
      961   s   * rod           cylindrical lead rod
      988   s   * rod           cylindrical lead rod
*
      912   s   * rod          annular aluminum rod
      962   s   * rod           cylindrical lead rod
      931   s   * rod           cylindrical lead rod
      978   s   * rod           cylindrical lead rod
*
      913   s   * rod          annular aluminum rod
      963   s   * rod           cylindrical lead rod
      932   s   * rod           cylindrical lead rod
      979   s   * rod           cylindrical lead rod
*
      919   s   * rod          annular ss rod
      920   s   * rod           annular ss rod
      921   s   * rod           annular ss rod
      922   s   * rod           annular ss rod
      971   e   * rod           annular ss rod
*
****************************
* material-properties data *
****************************
*
```

```
* matb  *          51          52e
* ptbln *           2           6e
*
* lead material
*
*   prptb(1,i)    prptb(2,i)    prptb(3,i)    prptb(4,i)    prptb(5,i)
    2.7300e+02    1.1374e+04    1.2970e+02    3.4592e+01    2.8000e-01
    1.0000e+10    1.1374e+04    8.9538e+02    3.3382e+01    2.8000e-01
e
*
* aluminum material
*
*   prptb(1,i)    prptb(2,i)    prptb(3,i)    prptb(4,i)    prptb(5,i)
    2.7300e+02    2.6990e+03    8.6985e+02    2.1046e+02    5.0000e-02
    3.0000e+02    2.6990e+03    8.9000e+02    2.1046e+02    5.0000e-02
    3.7300e+02    2.6990e+03    9.4140e+02    2.1046e+02    5.0000e-02
    4.7300e+02    2.6990e+03    9.9538e+02    2.2175e+02    5.0000e-02
    6.7300e+02    2.6990e+03    1.0900e+03    2.2845e+02    5.0000e-02
    1.0000e+10    2.6990e+03    1.2000e+03    2.3000e+02    5.0000e-02
e
*
**************************
*
* CSS data
*
**************************
*
**************************
* control-parameter data *
**************************
*
**************************
* signal variables
**************************
*
* time
*         idsv          isvn          ilcn          icn1          icn2
             1             0             0             0             0
*
* pressure difference across RHR check valve
*         idsv          isvn          ilcn          icn1          icn2
             2           -21           640             1             2
*
* Elapse time since RHR pump activated
*         idsv          isvn          ilcn          icn1          icn2
             3             0             0             0             0
*
* Elapse time since HR pumps activated
*         idsv          isvn          ilcn          icn1          icn2
             4           -21            31             2             1
*
* pressure difference across HR check valve
*         idsv          isvn          ilcn          icn1          icn2
             5           -21            32             1             2
*
* pressure difference across HR check valve
*         idsv          isvn          ilcn          icn1          icn2
             6           -21            33             1             2
* pressure, cold leg at plenum, component 761
*         idsv          isvn          ilcn          icn1          icn2
             7            21            68             1             1
*
```

```
**************************
* control-block data *
**************************
*
**************************
* trips
**************************
* trips from off to on at time given by setp(2), fill BC
*          ntse          ntct          ntsf          ntdp          ntsd
              1             0             0             0             0
*          idtp          isrt          iset          itst          idsg
            101             2             0             1             1
*       setp(1)       setp(2)
     0.0000e+00    1.0000e-06
*       dtsp(1)       dtsp(2)
     0.0000e+00    0.0000e+00
*       ifsp(1)       ifsp(2)
              0             0
*
* trips from on to off at time given by setp(2)
*          idtp          isrt          iset          itst          idsg
            102             1             1             1             1
*       setp(1)       setp(2)
     0.0000e+00    1.0000e+04
*       dtsp(1)       dtsp(2)
     0.0000e+00    0.0000e+00
*       ifsp(1)       ifsp(2)
              0             0
*
* trips from off to on at time given by setp(2), trips RHR check valve
*          idtp          isrt          iset          itst          idsg
            103             2             0             1             1
*       setp(1)       setp(2)
     0.0000e+00    1.0000e-06
*       dtsp(1)       dtsp(2)
     0.0000e+00    0.0000e+00
*       ifsp(1)       ifsp(2)
              0             0
* trips from off to on when the cold leg 1 press. drops below setp(1)
*       trips power in bundles, heat structures
*          idtp          isrt          iset          itst          idsg
            104             1             0             1             4
*       setp(1)       setp(2)
     7.0788e+05    7.0788e+05
*       dtsp(1)       dtsp(2)
     1.0000e+00    1.0000e+00
*       ifsp(1)       ifsp(2)
              0             0
*
* trips from off to on at setp(2), starts RHR pump.
*          idtp          isrt          iset          itst          idsg
            105             1             0             1             4
*       setp(1)       setp(2)
     7.0788e+05    7.0788e+05
*       dtsp(1)       dtsp(2)
     0.0000e+00    0.0000e+00
*       ifsp(1)       ifsp(2)
              0             0
*
* trips from off to on at time given by setp(2), trips Primary HR pumps
*          idtp          isrt          iset          itst          idsg
            106             2             0             1             1
```

```
*       setp(1)       setp(2)
     0.0000e+00    1.0000e-06
*       dtsp(1)       dtsp(2)
     0.0000e+00    0.0000e+00
*       ifsp(1)       ifsp(2)
              0             0
*
* trips from off to on at time given by setp(2), trips HR check valves
*          idtp          isrt          iset          itst          idsg
            107             2             0             1             1
*       setp(1)       setp(2)
     0.0000e+00    1.0000e-06
*       dtsp(1)       dtsp(2)
     0.0000e+00    0.0000e+00
*       ifsp(1)       ifsp(2)
              0             0
*
******************
* component data *
******************
*
end
*
******************
* time-step data *
******************
*
*         dtmin         dtmax          tend         rtwfp
     1.0000e-07    1.0000e-03    2.0000e-02    1.0000e+01
*         edint         gfint        dmpint        sedint
     1.0000e-01    5.0000e+00    1.0000e+06    1.0000e+06
*
*         dtmin         dtmax          tend         rtwfp
     1.0000e-07    2.0000e-02    1.0000e+01    1.0000e+01
*         edint         gfint        dmpint        sedint
     5.0000e-01    5.0000e+00    1.0000e+06    1.0000e+06
*
*         dtmin         dtmax          tend         rtwfp
     1.0000e-07    3.0000e-01    6.0000e+01    1.0000e+01
*         edint         gfint        dmpint        sedint
     2.0000e+00    5.0000e+00    1.0000e+06    1.0000e+06
*
*         dtmin         dtmax          tend         rtwfp
     1.0000e-07    3.0000e-01    1.0000e+02    1.0000e+01
*         edint         gfint        dmpint        sedint
     4.0000e+00    5.0000e+00    1.0000e+06    1.0000e+06
*
*         dtmin         dtmax          tend         rtwfp
     1.0000e-07    5.0000e-01    1.5000e+02    1.0000e+01
*         edint         gfint        dmpint        sedint
     1.0000e+01    5.0000e+00    1.0000e+06    1.0000e+06
*
*         dtmin         dtmax          tend         rtwfp
     1.0000e-07    5.0000e-01    6.0000e+02    1.0000e+01
*         edint         gfint        dmpint        sedint
     5.0000e+01    5.0000e+00    1.0000e+06    1.0000e+06
*
*       endflag
    -1.0000e+00
```

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Appendix D: TRAC Graphics Input File for LOFA Case 1 (with Beam Shutdown and Active RHR)

The file listed below represents the TRAC code "graphin" file that corresponds to the LOFA case 1 (with beam shutdown and active RHR) for the blanket system. This input deck contains the various graphics points selected for output to the "tecsum.grf" file.

Input file tracin:

```
/ npoints /
    88
/ component        cell      ictype      itee/
    340              1          1           1     Fixed outlet header
    380              1          1           1     Fixed inlet header

    454              2          0           1     Module 1 pipe
    173              2          0           1     Module 2 pipe
    415              2          0           1     Module 3 pipe
    485              2          0           1     Module 4 pipe
    513              2          0           1     Module 5 pipe
    541              2          0           1     Module 6 pipe

    300              1          0           1     Module 1 Row1
    102              1          0           1     Module 2 Row2
    409              1          0           1     Module 3 Row1
    412              1          0           1     Module 4 Row1
    500              1          0           1     Module 5 Row2
    528              1          0           1     Module 6 Low Power

    300              3          0           1     Module 1 Row1
    102              3          0           1     Module 2 Row2
    409              3          0           1     Module 3 Row1
    412              3          0           1     Module 4 Row1
    500              3          0           1     Module 5 Row2
    528              3          0           1     Module 6 Low Power

    300              5          0           1     Module 1 Row1
    102              6          0           1     Module 2 Row2
    409              5          0           1     Module 3 Row1
    412              6          0           1     Module 4 Row1
    500              6          0           1     Module 5 Row2
    528              5          0           1     Module 6 Low Power

    370              1          1           1     Module 1 Inlet  Plenum
    350              1          1           1     Module 1 Middle Plenum
    330              1          1           1     Module 1 Outlet Plenum
    172              1          1           1     Module 2 Inlet  Plenum
    147              1          1           1     Module 2 middle Plenum
    133              1          1           1     Module 2 Outlet Plenum
    479              1          1           1     Module 3 Inlet  Plenum
    418              1          1           1     Module 3 Middle Plenum
    423              1          1           1     Module 3 Outlet Plenum
    489              1          1           1     Module 4 Inlet  Plenum
    419              1          1           1     Module 4 Middle Plenum
    483              1          1           1     Module 4 Outlet Plenum
    510              1          1           1     Module 5 Inlet  Plenum
    503              1          1           1     Module 5 Middle Plenum
    508              1          1           1     Module 5 Outlet Plenum
    538              1          1           1     Module 6 Inlet  Plenum
    531              1          1           1     Module 6 Middle Plenum
```

536	1	1	1	Module 6 Outlet Plenum
26	1	0	1	Hot leg pump suction line
30	1	0	1	PCL Pump 1 Suction
30	2	0	1	PCL Pump 1 Discharge
31	1	0	1	PCL Pump 2 Suction
31	2	0	1	PCL Pump 2 Discharge
32	2	0	1	PCL Pump 1 check valve
33	2	0	1	PCL Pump 2 check valve
37	1	0	1	PCL Pump to HX
48	2	0	1	PCL Hx 1 inlet
56	2	0	1	PCL Hx 1 outlet
49	2	0	1	PCL Hx 2 inlet
57	2	0	1	PCL Hx 2 outlet
62	1	0	1	Cold leg Hx discharge line
66	1	0	1	Cold leg Hx discharge line
630	1	0	1	RHR Pump Suction
630	2	0	1	RHR Pump Discharge
640	3	0	1	RHR Hx inlet
660	1	0	1	RHR Hx outlet
761	1	0	1	Pzr Pressure Signal
766	1	0	1	Pzr Bottom Pressure
951	1	3	1	Hot Module (1) upflow inside
951	5	3	1	Hot Module (1) upflow inside
951	1	3	2	Hot Module (1) upflow outside
951	5	3	2	Hot Module (1) upflow outside
955	1	3	1	Hot Module (2) upflow inside
955	6	3	1	Hot Module (2) upflow inside
955	1	3	2	Hot Module (2) upflow outside
955	6	3	2	Hot Module (2) upflow outside
961	1	3	1	Hot Module (3) upflow inside
961	5	3	1	Hot Module (3) upflow inside
961	1	3	2	Hot Module (3) upflow outside
961	5	3	2	Hot Module (3) upflow outside
962	1	3	1	Hot Module (4) upflow inside
962	6	3	1	Hot Module (4) upflow inside
962	1	3	2	Hot Module (4) upflow outside
962	6	3	2	Hot Module (4) upflow outside
963	1	3	1	Hot Module (5) upflow inside
963	6	3	1	Hot Module (5) upflow inside
963	1	3	2	Hot Module (5) upflow outside
963	6	3	2	Hot Module (5) upflow outside
965	1	3	1	Hot Module (6) upflow inside
965	5	3	1	Hot Module (6) upflow inside
965	1	3	2	Hot Module (6) upflow outside
965	5	3	2	Hot Module (6) upflow outside

INPUT NOTES:

npoints - number of locations (points) within TRAC model graphics requested
component - component id number containing specified graph point
cell - cell number with in component where graphics requested
ictype - type of component:
(0 for fill, pipe, pressurizer, pump, tee, turb, value)

```
            (1  for  plenum)
OUTPUT NOTES:

tsec      - Time into simulation (sec)
Psia      - Cell center pressure (psia)
Qf        - Liquid volumetric flowrate at cell face (gpm)
tl        - Liquid phase temperature (C)
tsub      - Liquid subcooling (C)
tsat      - Liquid saturation temperature (C)
rol       - Liquid phase density (kg/m^3)
vl        - Liquid phasic velocity at cell face (m/s)
Pa        - Cell center pressure (Pa)
qf        - Liquid volumetric flowrate at cell face (m^3/s)
void      - Gas void fraction (-)
Qg        - Gas volumetric flowrate at cell face (gpm)
qg        - Gas volumetric flowrate at cell face (m^3/s)
tv        - Gas phase temperature (C)
rov       - Gas phase density (kg/m^3)
vv        - Gas phasic velocity at cell face (m/s)
pair      - Partial pressure of non-condensable in gas phase (psia)
```

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Appendix E: FLOWTRAN-TF Input File for LOFA Case 1 (with Beam Shutdown and Active RHR)

Below is an abridged listing of the FLOWTRAN-TF input deck for LOFA Case 1. The finite element input of the solid geometric parameters used in the heat conduction calculations and the fluid geometry input are identical to the values given in Ref. [1] and have been edited from this listing to save space.

Input file apt.in:

```
/*** 12-channel APT input deck for flowtran-apt code ***/
!    Base Case: 10% pre-incident flow at 60 seconds into transient
!               100% nominal pre-incident power and flow
!
! Input Deck Description:
!
! General Comments:
!    *The solid input units are: [T] = C
!    *The fluid input units are determined by iunits as described below
!    *The working units in the fluid modules are: s, m, kg, K, Pa, J, W, ...
!    *The working units in the solid modules are: s, m, kg, C, Pa, J, W, ...
/RUN TIME, TIME STEP LIMITS, AND PRINT TIMES/
! total        minimum          maximum          minimum          maximum
!runtime  fluid time step  fluid time step  solid time step  solid time step
!-------------------------------------------------------------------------------
! runsec,      dtmin,           dtmax,           dtsmin,          dtsmax
  60.0         1.0e-3           0.10             0.1              0.5          !>
!
!            printing intervals in seconds
! fluid       solid       power       plot      criteria
! dtpfld,     dtpsld,     dtppwr,     dtpplt,    dtpcrt
  30.0        30.0        30.0        30.0       1.0                           !>
!-------------------------------------------------------------------------------
!
/BOUNDARY CONDITION, UNITS, RESTART, AND PRINT FLAGS/
! ibond: 1 = P         (fluid and gas momentum balances at plenum)
!        2 = Qf        (prescribed Qf replaces fluid mom. bal. at plenum)
!        3 = Qg        (prescribed Qg replaces gas mom. bal. at plenum)
!        4 = Qf,Qg     (prescribed Qf, Qg replace both mom. bal. at plenum)
!       -2 = Qf        (prescribed Qf replaces fluid mom. bal. at tank bottom)
!       -3 = Qg        (prescribed Qg replaces gas mom. bal. at tank bottom)
!       -4 = Qf,Qg     (prescribed Qf, Qg replace both mom. bal. at tank bottom)
! iunits applies to the fluid input only
! iunits: 1 = SI  (m , m^2 , m^3 , Pa   , m^3/s, C)
!         2 = SRS (in, in^2, in^3, psia, gpm  , C)
! istart: 0 = new
!         1 = restart (time = runsec)
!         2 = restart (time = zero)
!         3 = restart (time = tcrit0)
! isave:  0 = no restart file saved
!         1 = restart file saved and tsec set to runsec
!         2 = restart file saved and tsec set to zero
!         3 = restart file saved and tsec set to tcrit0
! iprint: 1 = short print
!         2 = long print
! icrit:  0 = no printing of criteria messages
!         1 = print criteria messages
! iscrn:  0 = no screen print
!         1 = long screen print
```

```
!          2 = short screen print
! istdy: -1 = grid generation only
!          0 = transient from tsec to runsec
!          1 = steady state from tsec
!          2 = steady state at tsec
!          3 = steady state at tsec followed by a transient to runsec
! igpsk:  0 = no node renumbering
!          1 = optimum node renumbering using Gibbs-Poole-Stockmeyer-King
!          2 = optimum node renumbering using Gibbs-Poole-Stockmeyer-Cuthill-Mckee
! inorm:  0 = use unnormalized axial power shapes
!          1 = normalize the axial power shape
!-------------------------------------------------------------------------------
! ibond,  iunits,  istart,  isave,  iprint
 -2       1        2        0       1                                       !>
! icrit,  iscrn,   istdy,   ippu,   ibpu
  0       2        0        0       0                                       !>
! igpsk   inorm
  1       0                                                                 !>
!
!-------------------------------------------------------------------------------
!
/REFERENCE PRESSURE, COMPRESSIBILITY FACTOR, .../
!    ilq: liquid identification, 1=H2O, 2=D2O
!   pref: reference pressure used in subroutine inner to compute
!         relative changes in the dp's
! factor: multiplier to drho,fluid/dP to increase fluid compressibility
!  vminz: minimum absolute velocity for full donoring in z direction
!    tol: accchk parameter
!  tolss: steady state tolerance on dhmix/dt, (J/m^3-s)
!  tolts: relative tolerance on solid temperature
!   ttol: relative tolerance on solid time step change
!  dtsup: wall superheat reduction, C
! htdamp: solid-fluid heat transfer damping factor
! cidamp: interfacial drag damping factor
!    xa0: source/sink air mass fraction
!    dtf: perturbation to liquid temperature for derivative estimation
!    dtg: perturbation to gas temperature for derivative estimation
!  nstdy: maximum iterations for steady-state (istdy > 0)
!   nmat: maximum number of solid materials
!  delox: surface oxide layer thickness (m)
!   tkox: oxide thermal conductivity (W/m-K)
!-------------------------------------------------------------------------------
! ilq,     pref,     factor,   vminz
  1        5.0e+5    1.0       0.05                                         !>
!
! tol,     tolss,    tolts,    ttol
  1.0      10.0      0.1       0.1                                          !>
!
! dtsup,   htdamp,   cidamp,   xa0
  0.0      1.0       0.1       0.0                                          !>
!
! dtf,     dtg,      nstdy,    nmat
  1.0      1.0       9000      9                                            !>
!
! delox,   tkox
  5.08e-5  2.16                                                              !>
!-------------------------------------------------------------------------------
!
/BOILING CURVE AND INTERPHASE TRANSPORT OPTIONS/
!  iboil:  0 = use specified heat transfer coefficient
!          1 = forced convection (SRL)
!          2 = forced convection (Dittus-Boelter)
```

```
!         3 = forced convection (Sieder-Tate)
!         4 = Mikic-Rohsenow interpolation
!         5 = Chen correlation
!   ichf: 1 = SRS correlation
!         2 = Biasi
! matgas: 1 = helium dissolved in water
!         2 =    air dissolved in water
! persat: percent of saturation (0-100)
!  igami: 0 = bulk interfacial mass transport off
!         1 = bulk interfacial mass transport on
!  igamw: 0 = wall interfacial mass transport off
!         1 = wall interfacial mass transport on
!-------------------------------------------------------------------------------
! iboil,    ichf,     matgas,    persat,   igami,    igamw
  2         2         2          0.0       0         0                      !>
!-------------------------------------------------------------------------------
!
/SOLID PARAMETERS/
! isolid: 0 = no solid calculations
!         1 = solid calculations with matrix decomposition every time step
!         2 = solid calculations with matrix decomposition first time step
! tsolid: initial solid temperature
!   beta: implicitness parameter in solid calculations
!  iheat: 0 = no wall heat transfer calculation
!         1 = wall heat transfer calculations
!  qsurf: specified surface heat flux         (used when iheat = 0)
!   hfix: specified heat transfer coefficient (used when iboil = 0)
! iaxcon: 0 = no axial conduction
!         1 = explicit axial conduction calculation
!-------------------------------------------------------------------------------
! isolid,   tsolid,  beta,  iheat,  qsurf,   hfix,    iaxcon
  2         53.04    1.0    1       0.0      1.0e4    1                     !>
!-------------------------------------------------------------------------------
!
/INNER ITERATION OPTIONS & NEWTON ITERATION PARAMETERS/
! irebal: 0 = no coarse mesh rebalance
!         1 = coarse mesh rebalance on first pass
!         2 = coarse mesh rebalance on each pass
!   ncmr: number of coarse mesh rebalances when irebal = 1 or 2
!  epsin: inner iteration convergence criterion for relative dp error
! initmx: max. number of inner iterations allowed
!   epsp: newton iteration convergence criterion for absolute p error in Pa
! epsalp: newton iteration convergence criterion for absolute alp error
!  epstg: newton iteration convergence criterion for absolute tg error in K
!  epstf: newton iteration convergence criterion for absolute tf error in K
!  epsxa: newton iteration convergence criterion for absolute xa error
! nitmax: |nitmax| = max. number of newton iterations allowed
!         If nitmax is positive and |nitmax| iterations are reached, then
!         then computations continue using the mth iterate values from the
!         |nitmax| iteration.
!         If nitmax is negative and |nitmax| iterations are reached, then
!         a new time step with a time step reduction is requested.
!-------------------------------------------------------------------------------
! irebal, ncmr, epsin,                                  initmx
  1       1     1.0e-5                                  200                 !>
!               epsy,    epsf,                          nitysi
                1.0e-5   0.01                           50                  !>
!               epsp,    epsalp,  epstg, epstf, epsxa,  nitmax
                50.0     0.0005   0.05   0.05   0.005  -100                 !>
!-------------------------------------------------------------------------------
!
/NUMBER OF SPLINE PROFILES AND DATA POINTS/
```

```
! ndata: number of data groups
! itime: number of time snapshots for axial power profiles
!-----------------------------------------------------------------------------
! ndata,  itime
  8       2                                                                 !>
!-----------------------------------------------------------------------------
! npdat: number of data points per data set
!  nset: number of data sets in data group
!-----------------------------------------------------------------------------
! npdat  nset
   3      1                                                                 !>
   4      1                                                                 !>
  29      1                                                                 !>
  13      1                                                                 !>
  15      1                                                                 !>
  15      1                                                                 !>
  15      1                                                                 !>
  15      1                                                                 !>
!-----------------------------------------------------------------------------
!
/GEOMETRIC DIMENSIONS:/
!  nchn: number of flow channels
!   nzt: number of top section axial cells (>=2)
!    nz: number of middle section axial cell layers (>=3)
!   nzb: number of bottom section axial cells (>=2)
!-----------------------------------------------------------------------------
! nchn,  nzt,  nz,   nzb
  12     2     20    2                                                      !>
!-----------------------------------------------------------------------------
!
/POWER ITERATION INPUT/
!  power: initial power in kW
!  maxpi: maximum number of power iterations
! tolpow: tolerance on power limit
!  ncrit: number of criteria used to check for power limit
!-----------------------------------------------------------------------------
! power,     maxpi,  tolpow,   ncrit
  61.5       1       0.005     8         ! nominal operating power           >
!-----------------------------------------------------------------------------
!
! SENSITIVITY VARIABLES INPUT SECTION
!
/SENSITIVITY PARAMETERS/
! cizfac: axial interfacial drag multiplying factor
!-----------------------------------------------------------------------------
! xcofh,   xreh,   xcofl,  xrel,    xkmet,    xcvmet
  1.0      1.0     1.0     1.0      1.0       1.0                           !>
!
! xhfi,    xhgi,   xkgi,   xphi
  1.0      1.0     1.0     1.0                                              !>
!
! cizfac   xfric,  plnht,  cipln,   formhs,  alphs
  1.0      1.0     8.75    1.0      5.382    0.05                           !>
!
! alb2,    als2,   ala2,   expbs,   expsa
  0.25     0.52    0.75    4.0      4.0                                     !>
!
!-----------------------------------------------------------------------------
! INPUT FOR SOLID FINITE ELEMENT CALCULATIONS
!
.
.
```

.

Solid mesh input for finite element regions, nodes and side boundary conditions is identical to that shown in reference [1]

```
.
.
.
!
!--------------------------------------------------------------------------------
! FLUID GEOMETRY AND MOMENTUM CLOSURE INPUT SECTION
!
.
.
.
```

Fluid geometry input is identical to that shown in reference [1]

```
.
.
.
!
!--------------------------------------------------------------------------------
/BOUNDARY CONDITION INPUT SECTION/
/OUTLET PLENUM (TOP)/
!   ppl0: multiplier to P transient profile
!   ippl: P transient identifier
! alppl0: multiplier to alpha transient profile
!  ialpl: alpha transient identifier
!  tfpl0: multiplier to Tf transient profile
!  itfpl: Tf transient identifier
!  tgpl0: multiplier to Tg transient profile
!  itgpl: Tg transient identifier
!  xapl0: multiplier to Xa transient profile
!  ixapl: Xa transient identifier
!--------------------------------------------------------------------------------
! ppl0,      ippl
  584133.9   8        !>
! alppl0,    ialpl
  1.0e-4     1        !>
! tf0l0,     itfpl
  53.04      1        !>
! tgpl0,     itgpl
  53.04      1        !>
! xapl0,     ixapl
  0.0        1        !>
!--------------------------------------------------------------------------------
!
/INLET PLENUM (BOTTOM)/
!   ptb0: multiplier to P transient profile
!   iptb: P transient identifier
! alptb0: multiplier to alpha transient profile
!  ialtb: alpha transient identifier
!  tftb0: multiplier to Tf transient profile
!  itftb: Tf transient identifier
!  tgtb0: multiplier to Tg transient profile
!  itgtb: Tg transient identifier
!  xatb0: multiplier to Xa transient profile
!  ixatb: Xa transient identifier
!--------------------------------------------------------------------------------
! ptb0,      iptb
  685997.1   7        !>
! alptb0,    ialtb
  1.0e-4     1        !>
! tftb0,     itftb
  53.04      6        !>
```

```
! tgtb0,     itgtb
  53.04      6        !>
! xatb0,     ixatb
  0.0        1        !>
!------------------------------------------------------------------------------
!
/INLET FLOW DATA/
! The following inlet flow data is always used to initialize
! axial velocities and will also be used to define the
! appropriate prescribed flowrate for t > 0 if ibond = 2, 3, or 4.
! qfin0: multiplier to Qf transient profile
! iqfin: Qf transient identifier
! qgin0: multiplier to Qg transient profile
! iqgin: Qg transient identifier
! qfin0 = Nominal APT total flow 12 half channels, transient
!------------------------------------------------------------------------------
! qfin0,     iqfin
  -1.508e-3  5         !>
! qgin0,     iqgin
   0.0       1         !>
!------------------------------------------------------------------------------
!
/INITIAL CONDITION INPUT SECTION/
! If iset0 > 0 then initial conditions are
! input for fluid parameters at each axial level
! iset0
   0
!------------------------------------------------------------------------------
!
/CRITERIA CHECKING FLAGS AND PEAKING FACTORS/
! checking flags for criteria  #1    #2    #3    #4    #5    #6    #7    #8
                                0     0     0     0     0     0     0     0   !>
!peaking factors for criteria  #1    #2    #3    #4    #5    #6    #7    #8
                              1.0   1.0   1.0   1.0   1.0   1.0   1.0   1.0   !>
/CRITERIA CHECKING TIME/
! time to begin criteria checking, sec
!------------------------------------------------------------------------------
! tcrit0
   0.0                 !>
!------------------------------------------------------------------------------
!
! POWER INPUT
!
/POWER PROFILE SPLINE POINTERS/
!  DECAY HEAT TRANSIENT
   4                   !>
!
/AXIAL SPLINE POINTERS AND TIMES/
   3   0.0        3  300.00
!
/TRANSIENT DATA SET INPUT SECTION/
/DATA SET NUMBER 1/
! enter data set label below
!------------------------------------------------------------------------------
data set 1 - UNIFORM
!------------------------------------------------------------------------------
! itype: 1 = linear spline
!        0 = cubic spline
!  x, y: data pairs
!------------------------------------------------------------------------------
!         itype
          1        !>
```

```
! x(ipt), y(ipt)   ipt=1,npts
    0.0  1.0       !>
    5.0  1.0       !>
  100.0  1.0       !>
!-------------------------------------------------------------------------------
!
/DATA SET NUMBER 2/
!-------------------------------------------------------------------------------
data set 2 - DECAY POWER SHAPE
!          itype
           1       !>
! x(ipt), y(ipt)   ipt=1,npts
    0.0  1.0       !>
    1.0  1.0       !>
   10.0  1.0       !>
 1000.0  1.0       !>
!-------------------------------------------------------------------------------
!
/DATA SET NUMBER 3/
!-------------------------------------------------------------------------------
data set 3 - NON-UNIFORM AXIAL POWER PROFILE
!          itype
           1       !>
! x(ipt), y(ipt)   ipt=1,npts
  0.00     0.032    !>
  0.10     0.043    !>
  0.20     0.049    !>
  0.30     0.074    !>
  0.40     0.093    !>
  0.50     0.124    !>
  0.60     0.165    !>
  0.70     0.217    !>
  0.80     0.317    !>
  0.90     0.508    !>
  1.00     0.943    !>
  1.10     1.446    !>
  1.20     1.658    !>
  1.30     1.754    !>
  1.40     1.783    !>
  1.50     1.827    !>
  1.60     1.870    !>
  1.70     1.881    !>
  1.80     1.915    !>
  1.90     1.915    !>
  2.00     1.887    !>
  2.10     1.864    !>
  2.20     1.790    !>
  2.30     1.660    !>
  2.40     1.423    !>
  2.50     0.932    !>
  2.60     0.506    !>
  2.70     0.313    !>
  2.80     0.229    !>
!-------------------------------------------------------------------------------
!
/DATA SET NUMBER 4/
!-------------------------------------------------------------------------------
data set 4 - DECAY POWER CURVE
!          itype
           1       !>
! x(ipt), y(ipt)   ipt=1,npts
      0.00   1.000000000E+00
```

```
      0.01   1.298500039E-02
      1.00   9.929999709E-03
      2.00   8.652999997E-03
      5.00   7.736000232E-03
     10.00   7.573999930E-03
     20.00   7.437000051E-03
     60.00   7.073000073E-03
    120.00   6.672000047E-03
    300.00   5.936999805E-03
    600.00   5.392999854E-03
   1200.00   4.968000110E-03
!
!-------------------------------------------------------------------------------
!
/DATA SET NUMBER 5/
!-------------------------------------------------------------------------------
data set 5 - FLOW TRANSIENT
!          itype
           1         !>
! x(ipt), y(ipt)   ipt=1,npts
     0.0  1.0000
     1.0  0.9545
     2.0  0.9112
     3.0  0.8699
     4.0  0.8307
     5.0  0.7933
     6.0  0.7577
     7.0  0.7238
     8.0  0.6915
     9.0  0.6608
    20.0  0.4060
    30.0  0.2679
    40.0  0.1834
    50.0  0.1317
    60.0  0.1000
!-------------------------------------------------------------------------------
!
/DATA SET NUMBER 6/
!-------------------------------------------------------------------------------
data set 6 - INLET TEMPERATURE TRANSIENT
!          itype
           1         !>
! x(ipt), y(ipt)   ipt=1,npts
     0.0  1.0000
     1.0  1.0000
     2.0  0.9957
     3.0  0.9725
     4.0  0.9531
     5.0  0.9429
     6.0  0.9378
     7.0  0.9353
     8.0  0.9340
     9.0  0.9335
    20.0  0.9310
    30.0  0.9193
    40.0  0.9057
    50.0  0.8944
    60.0  0.8903
!-------------------------------------------------------------------------------
!
/DATA SET NUMBER 7/
!-------------------------------------------------------------------------------
```

```
data set 7 - INLET PRESSURE TRANSIENT
!          itype
           1        !>
! x(ipt), y(ipt)   ipt=1,npts
     0.0  1.0000
     1.0  1.0159
     2.0  1.0304
     3.0  1.0436
     4.0  1.0556
     5.0  1.0665
     6.0  1.0764
     7.0  1.0854
     8.0  1.0936
     9.0  1.1010
    20.0  1.1497
    30.0  1.1664
    40.0  1.1733
    50.0  1.1762
    60.0  1.1775
!--------------------------------------------------------------------------------
!
/DATA SET NUMBER 8/
!--------------------------------------------------------------------------------
data set 8 - OUTLET PRESSURE TRANSIENT
!          itype
           1        !>
! x(ipt), y(ipt)   ipt=1,npts
     0.0  1.0000
     1.0  1.0326
     2.0  1.0622
     3.0  1.0892
     4.0  1.1136
     5.0  1.1359
     6.0  1.1561
     7.0  1.1746
     8.0  1.1913
     9.0  1.2065
    20.0  1.3062
    30.0  1.3403
    40.0  1.3543
    50.0  1.3603
    60.0  1.3630
!--------------------------------------------------------------------------------
/END OF INPUT FILE/
```

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