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APT Blanket System Loss-of-Helium-Gas Accident Based on Initial Conceptual Design - Helium Supply Rupture into Blanket Module

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APT BLANKET SYSTEM LOSS-OF-HELIUM-GAS ACCIDENT (LOHGA) BASED ON INITIAL CONCEPTUAL DESIGN -

Helium Supply Rupture into Blanket Module

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1 Introduction

The APT blanket system has about 57 MW of thermal energy deposited within the blanket region under normal operating conditions from the release of neutrons and the interaction of the high energy particles with the blanket materials. This corresponds to about 48% of total thermal energy deposited in the APT target/blanket system [1]. The deposited thermal energy under normal operation (NO) conditions is an important input parameter used in thermal-hydraulic design and accident analyses. The thermal deposited power of the blanket system corresponds to the steady-state power of the 1700 Mev APT design with 13 tungsten ladders.

The hazard analysis (HA) performed for the blanket primary heat removal (HR) systems identified the loss-of-helium gas accident (LOHGA), due to a compromise in the integrity of the helium gas supply system inside the Target/Blanket building, as a design basis accident. There are two types of Target/Blanket building LOHGAs:

1. Those internal to a blanket module (i.e., internal break (IB) LOHGA) where helium gas enters the blanket system's primary HR system coolant; and
2. Those external to a module (i.e., external break (EB) LOHGA) where helium gas does not enter the blanket system's primary HR system coolant.

LOHGAs vary from slow pin-hole leaks (Small Break LOHGA) to a catastrophic failure of a helium tube resulting in the sudden release of a large volume of gas (Large Break LOHGA). In addition, two scenarios can be considered:

1. LOHGAs with the pressurizer relief valve remaining closed during the event; and
2. LOHGAs with the pressurizer relief valve opening and remaining open during the event.

When the relief valve remains closed, the helium/tritium gas mixture is contained within the blanket HR system. This gas can subsequently be recovered without release to the environment. If the relief valve opens, helium/tritium gas released into the blanket HR system could be vented to the environment. Therefore, this accident scenario would have onsite and possibly off-site consequences. In this report, two Large Break LOHGA accidents internal to the blanket module with the pressurizer relief valve remaining closed are analyzed. Future analyses addressing the varous other scenario options will be performed.

The helium gas supply system, manifolding, and blanket gas tubes have been designed to operate up to about 200 psia and down to a partial vacuum, which is required to evacuate the He^3 gas. Two configurations for the operation of the Tritium Extraction Facility are being considered: (1) a continuous extraction of carrier gas and (2) an online batching process. Under this situation, the potential for wear during operation may cause a helium-3 gas leak from the high pressure gas system into the lower blanket coolant. Helium supply plenum break accidents were simulated to investigate the transient thermal-hydraulic response of the blanket system to helium gas release into the blanket primary coolant system. The helium gas leak accident from the pressurized gas system into the blanket coolant is simulated to occur under NO conditions. Based on LANL information [2], initial conditions for the helium reservoir are assumed to be 1 m^3 helium gas volume, 200 psia, and 40 C initial temperature. Break locations are simulated near the inlet and outlet plenums of the decoupler in a lateral Row-1 blanket module. In this report, Case 1, as the first of two cases of LOHGA presented, simulated a plenum break of the helium gas supply system near the inlet of the lateral module 1 decoupler using the one-dimensional TRAC system model with 6 lumped modules [3]. The break location for Case 1 is shown in Fig.1-1. In Case 2 the break in the helium gas supply was placed at the decoupler outlet of module 1. The break location for Case 2 is shown in Fig.1-2. The blanket system is completely enveloped within the enclosed system boundary to ensure that any hydrogen or tritium gas egress is contained and recovered even after the leak accident into the coolant.

The model results are used to determine if beam power shutdown is necessary (or not) as a result of the LOHGA accident to maintain the blanket system well below any of the thermal-hydraulic constraints imposed on the design. The results also provide boundary conditions to the detailed bin model to study the detailed temperature response of the hot blanket module structure. The results for these two cases are documented in this report.

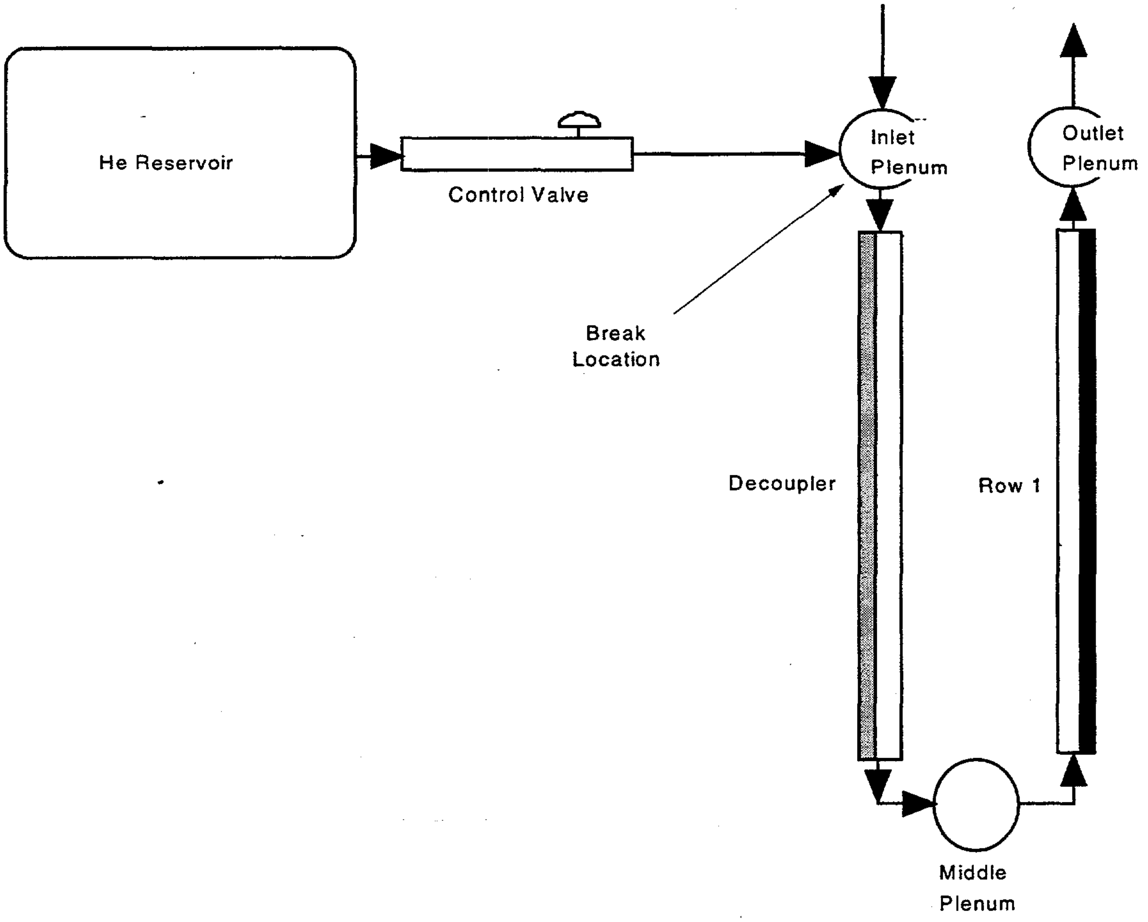


Figure 1-1 Break location for the helium tube rupture accident (Case 1: Break at lateral blanket Decoupler inlet plenum).

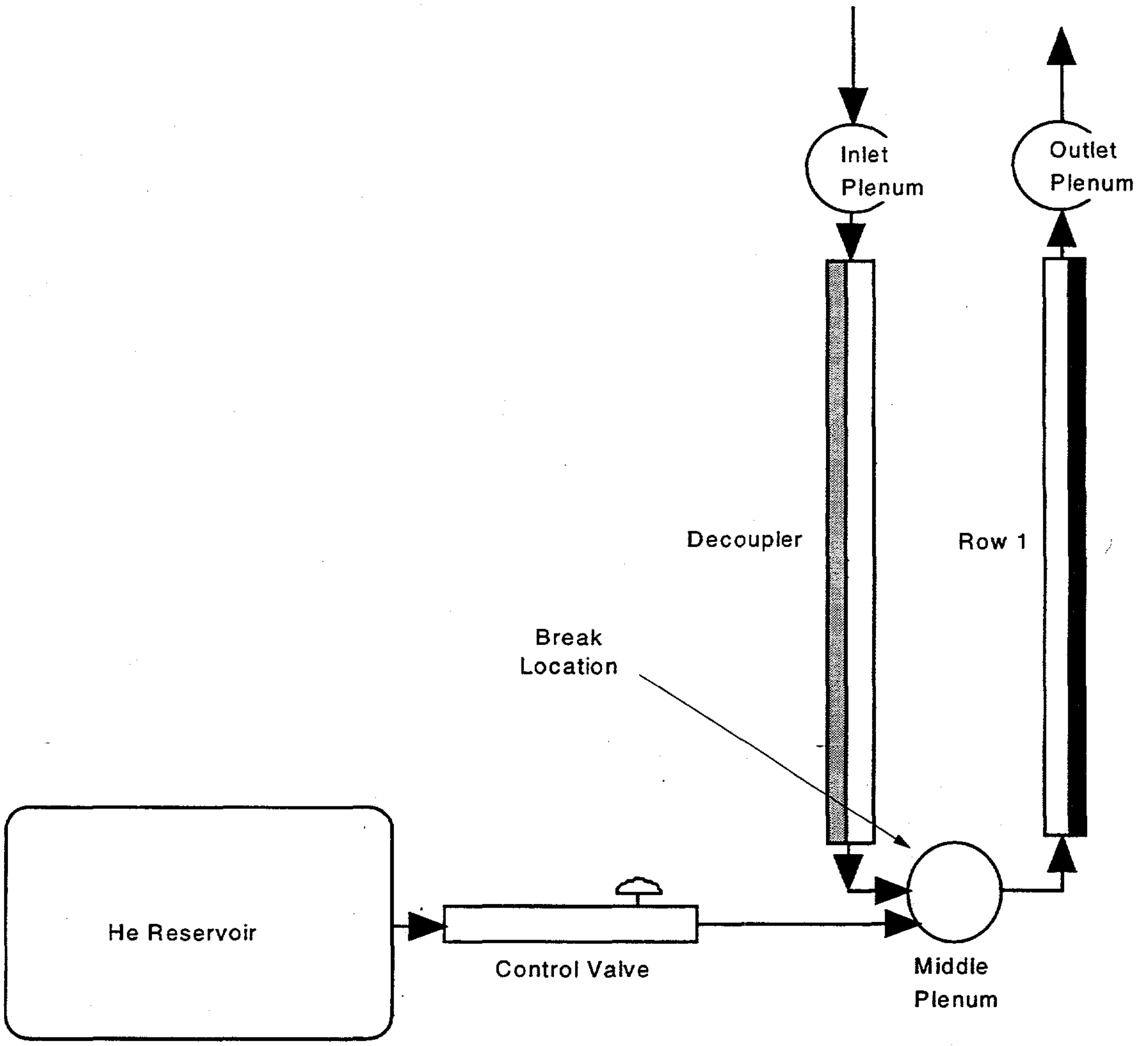


Figure 1-2 Break location for the helium tube rupture accident (Case 2: Break at lateral blanket Decoupler/ Row-1 middle plenum).

2 TRAC 1-D System Model

The 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 are currently not available). 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 significantly reduced computational effort requirements. The six lumped modules are:

1. First-row lateral modules;
2. Second-row lateral modules;
3. Decoupler / Row 1 downstream modules;
4. Row 1 / Row 2 downstream modules;

5. Row 2 / Row 2 downstream modules; and
6. Remaining low-power modules, which consist of the upstream module, the four bottom modules, and the two top modules.

Figure 2-1 shows a cross-sectional facemap for the six module blanket system. Table 2-1 summarizes module description, thermal deposited power, and connection pipe size of each of the six blanket modules as modeled in the one-dimensional lumped approach. Figure A-1 shows the locations of all six modules and the internal piping connections as included in the 1-D TRAC system model [3]. The TRAC components and piping connections for the HR, pressurizer, 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 six lumped module blanket system model includes 170 components and 152 junctions with 10 trip control signals for analyzing the transient LOHGA accident simulations.

2.1 Scenario Description

As design basis accidents, helium gas supply line breaks at the Decoupler inlet and outlet of the lateral module 1 shown in Fig. 2-1 were simulated by restarting steady-state normal operating results for the one-dimensional six module blanket system model in a transient mode. Normal operation conditions for the key blanket system parameters are shown in Table A-2. A detailed description of the lumped six module TRAC system model is provided in Ref. [3].

A Loss-of-Helium-Gas Accident (LOHGA) for Case 1 and Case 2 was simulated as a helium gas pipe break near the inlet and outlet of the Decoupler in the module 1, respectively. The break location for accident simulation of Case 1 is component number 370 shown in Fig. A-1. When helium gas is leaked into the blanket coolant system through the PLENUM component 370 (under NO conditions for the Case 1 simulation), the system rapidly pressurizes and the blanket coolant temperature increases shortly after the accident. Case 2 was simulated at PLENUM component 350, middle plenum of the lateral module 1 under the same accident conditions as those of Case 1. Normal system operation conditions are still maintained without any trip of beam power or heat removal pumps during the entire accident simulation of the LOHGA. Detailed control signals for the key component operations are provided later.

2.2 Model Upgrades

PLENUM and VALVE components were added to the original TRAC system model [3] for the LOHGA accident simulations. The plenum component was used for the simulation of the helium gas reservoir, and the valve component was used for transient simulation of the helium gas leakage. Since the details associated with the helium supply system is still under development, a simple plenum reservoir was deemed to be adequate for the present set of analyses. The control valve for the helium gas release into the blanket coolant system via the inlet/outlet Decoupler of the blanket module 1 was opened completely within 0.1 seconds. The valve is actuated within 10^{-4} seconds after the accident. The system is maintained under the normal operating conditions shown in Fig. A-2 during the accident simulation. Constrained steady-state (CSS) TRAC options were used to establish the NO prior to the transient runs.

2.3 Initial Conditions

Before simulating the accident condition, steady-state results under NO conditions are required to provide initial input to the transient simulation model of the LOHGA (see Ref. [4]). Based on personal communication with Jack N. Edwards at LANL [2], the initial volume and pressure of the helium reservoir system were specified to be 1 m^3 and 200 psia, respecitvely. The initial temperature for the helium reservoir components is assumed to be 40 C, which is the initial condition of the pressurizer, RHR system, and HR heat exchangers. 40 C corresponds to the maximum expected building air temperature during operating conditions. Table A-2 shows the initial steady-state values for the key system parameters of the blanket system.

2.4 Transient Boundary Conditions

The TRAC system model is documented in the report for the steady state NO calculations [3,4]. The NO TRAC run was restarted in transient mode to initiate the LOHGA simulations of Case 1 and Case 2. The helium gas reservoir component was a PLENUM component (component 430) connected to the inlet and outlet plenums of the module 1 Decoupler using the VALVE component (component 440). The helium gas line break location was selected to be close to the cold-leg downflow region where the primary coolant is distributed into the parallel multi-channel region of the blanket module system. For the LOHGA initiation, the VALVE component 440 was actuated within 10^{-4} seconds using the control signal logic to simulate a helium gas release into the primary coolant system. The VALVE component was set to change from closed to complete open within 0.1 seconds after initiation of the accident. The valve size was assumed to be 3 inch in diameter. The other blanket system conditions during the entire period of the accident simulation (600 seconds after the accident) remained the same as the NO conditions.

2.5 Trips and Controls

Normal operating power and system conditions were maintained during the entire transient simulation period beyond the initiation of the LOHGA accident. Normal operation trips to the beam power and HR pumps were assumed to occur. The helium release valve on the discharge side of the helium reservoir was actuated in 0.1 seconds after the initiation of the LOHGA accident. We note that pressurizer relief valve settings have not been determined and that this analysis needs to be performed. The analysis presented here assumes that the relief valve remain closed throughout the entire simulation period.

2.6 TRAC Version

This transient model was run using TRAC-PF1/MOD2 version 5.4.28a [10]. A modified version of TRAC to generate graphics files was employed [9].

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

Six Lumped Modules	Prototypic 16 Full Blanket Modules	Thermal Deposited Power Downflow / Upflow / Total Power	Pipe Size (inch)
Module 1	Front 1st Lateral Decoupler / Row 1 Module Back 1st Lateral Decoupler / 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 Decoupler / Row 2 Module Lower Front Decoupler / Row 2 Module Lower Front Row 2 / Row 2 Module Lower Back Decoupler / 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	

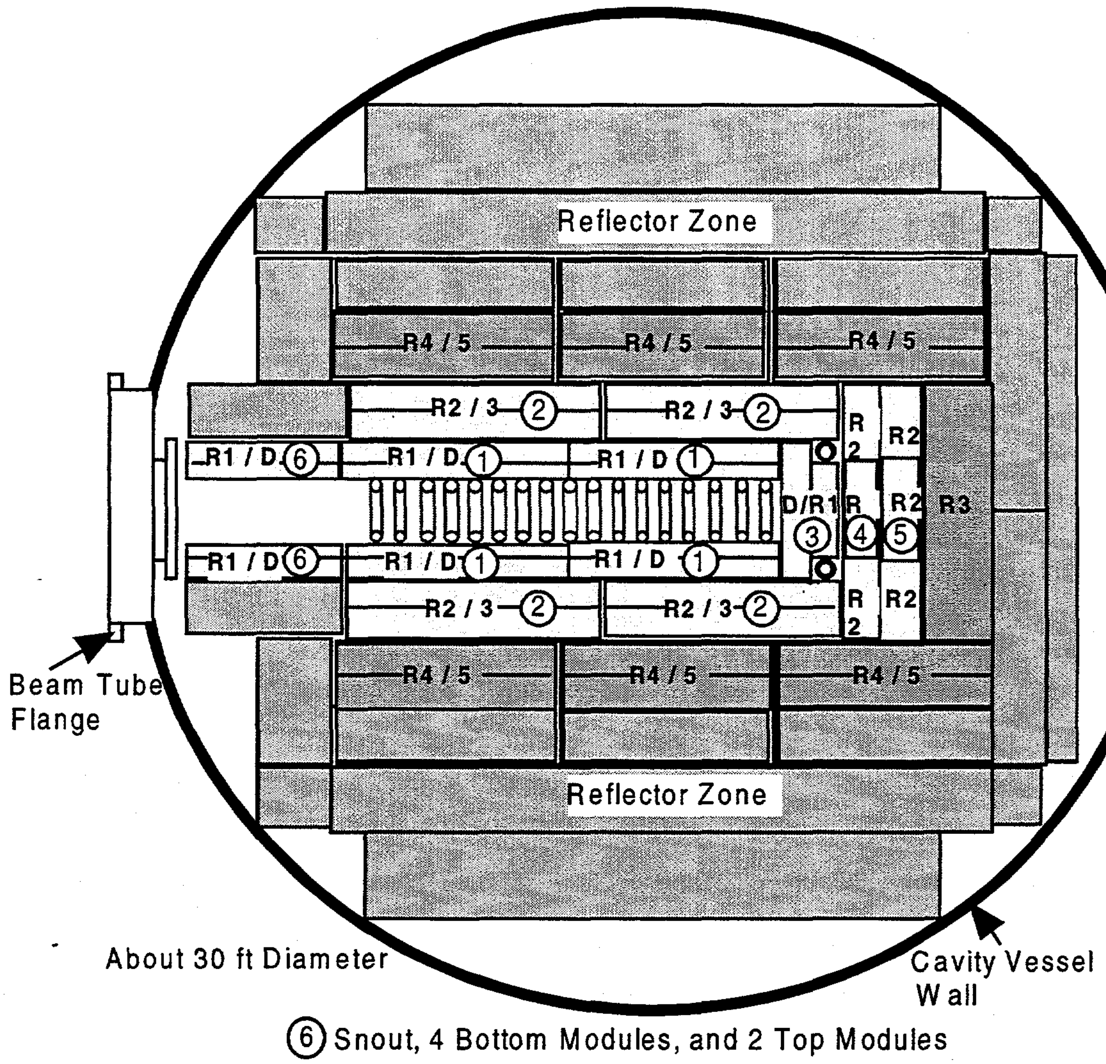


Figure 2-1 Top cross-sectional facemap of 6 lumped blanket system modules.

3 TRAC System Model Results

The TRAC simulation model for the rupture of a helium tube was run for 600 seconds after initiation of the accident. Simulation results show that the APT system can withstand the release of 1.0 m^3 of helium into the blanket module without any damage to the blanket module system and structure. No safety systems need to be activated to mitigate this event. The following subsections provide (in more detail) descriptions of the transient phenomena for the key blanket component systems observed in the accident simulation. Since none of the safety systems are activated during this transient, the RHR loop, cavity vessel and flood system remain in their normal operating states throughout the accident and will not be discussed.

Results are presented in graphical form in Appendix B from the TRAC system model calculations for a helium tube rupture in PLENUM component 370 (decoupler inlet). Section B1 of Appendix B shows output for the TRAC plenum components and Section B2 of Appendix B contains the output for pipe, pump and valve components. Similar results from the TRAC system model calculations for a helium tube rupture in PLENUM component 350 (decoupler outlet) are presented in graphical form in Appendix C. A listing of the TRAC input file used for the calculations of the system response to the helium rupture is provided in Appendix D and a listing of the graphics input file used to create the graphical output is given in Appendix E.

Results from the two helium tube rupture cases are very similar. The primary difference with respect to the impact on the blanket module is that channel voiding occurs immediately with a tube rupture at the decoupler outlet while there is about a two second delay in channel voiding when the gas is released into the decoupler inlet. Reduction in coolant flow, increase in void fraction, and increase in system pressure are similar for the two cases. The following sections of this report give a brief discussion of the TRAC results for the case of a helium tube rupture at PLENUM component 350 (decoupler outlet).

3.1 Helium Supply

The helium supply is assumed to be a 1 m^3 tank at 200 psia. Figure C-1a shows the transient pressure in the helium gas supply system. The valve between the helium supply and the break location is opened within 0.1 second. Since the blanket system pressure is 100 psia, the helium in the supply system quickly expands to a volume of 2 m^3 as the pressures equilibrate at slightly above 100 psia releasing 1 m^3 into the blanket module. As shown in Fig. C-1d, following this initial release, there is a slow replacement of the helium in the supply system from water in-leakage and another 0.5 m^3 of helium is released into the blanket module over the next 500 seconds.

3.2 Modules

Figure A-1 shows the component layout of the internal blanket module system used in the TRAC system model. Transient results for coolant hydraulic parameters through the six blanket upward flow regions from the simulation of a helium tube rupture in TRAC component 350 are graphically shown in Figs. C-3a through C-11d. The results show a rapid transient behavior in the flow channels of all six blanket modules continuing out to about 60 seconds after initiation of the accident. The most significant part of the transient behavior is confined to the first few seconds of the accident when there is a rapid pressurization of the HR system as the helium tube ruptures. However, as shown in Fig C-3a for module 1, the pressure recovers to nearly the initial operating value after about 10 seconds followed by some small oscillations about that point. Pressure responses in the other modules are similar to that seen in module 1.

Figure C-3b shows that the fluid temperature at the inlet to the blanket modules increases by only 1.0 C at the start of the transient. Figure C-3d shows channel void fractions at the top, middle and bottom plenums in module 1. Since the helium tube rupture occurs at PLENUM component 350, the void fraction at this location almost immediately increases to 16% and returns to nearly zero after a few seconds. Void fractions in the other modules not directly connected to the gas release are very small. As shown in Fig. C-21d, fluid flow in module 1 is momentarily decreased for a few seconds at the start of the transient to about 80% of its normal operating value and quickly recovers. Fluid temperature, void fraction, and coolant flow responses in the other modules are significantly smaller than that observed in module 1.

As seen in Figs. C-23a through C-24e, similar patterns are observed in all of the modules for the operating temperature and pressure transients. The release of the pressurized helium into the blanket modules produces an almost instantaneous increase in pressure. Only module 1, where the helium is released, experiences a significant increase in void fraction and corresponding decrease in coolant flow. The initial transient response is short lived with recovery of all system parameters to near normal operating values within a few seconds of the gas release. After the first 10 seconds, during which the significant transient response occurs, there is a period of about 50 seconds where the operating values oscillate about their steady-state conditions. Beyond 60 seconds, all of the module parameters have essentially returned to the normal operating values.

3.3 Primary HR Loop

Figure A-4 shows the HR system component layout used for the one-dimensional TRAC system model. With the initiation of a helium tube rupture, the system pressure in the HR loop increases rapidly. Figure C-2a shows fixed header fluid pressures for the simulation of a helium tube rupture near the decoupler outlet. Pressures in the hot and cold legs increase steeply following initiation of the accident. The results show that the most significant transient response in the fixed header pressures occurs within about 20 seconds. Pressures of both fixed headers are stabilized at the normal operating values about 60 seconds after the accident occurs as shown in Fig. C-2a. As shown in Fig. C-2d, the void fraction in the fixed header downstream of the gas release reaches a maximum value of just over 6% within a few seconds of the tube rupture and is less than 1% beyond about 30 seconds.

Similar responses are shown throughout the primary HR piping (Figs. C-13a through C-13e and C-16a through C-19e) and in the coolant pumps (Figs. C-14a through C-15e). All of the systems experience a sudden pressure increase, relatively small temperature increases and void fractions of 12% or less. One exception is the primary HR heat exchanger outlet piping void fractions shown in Fig. C-18e. This is the highest elevation in the system and is the point where the released helium gas accumulates. The void fraction at this location increases from zero to about 12% at 20 seconds when the released gas reaches that component. Thereafter, the void increases steadily to over 25% at 500 seconds as helium is slowly displaced from the source volume by water. As shown in Fig. C-20d, a brief flow transient is induced in the pressurizer and surge line by the pressure fluctuations occurring when the helium tube ruptures.

4 FLOWTRAN-TF Detailed Bin Model

The basic FLOWTRAN-TF model of a single APT blanket plate is described in Refs. [6,7] and was used in this version for the helium tube rupture 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 [5]. The cross-sectional mesh of the plate model is shown in Figure 4-1 along with the location and indexing used for the 12 discrete flow channels.

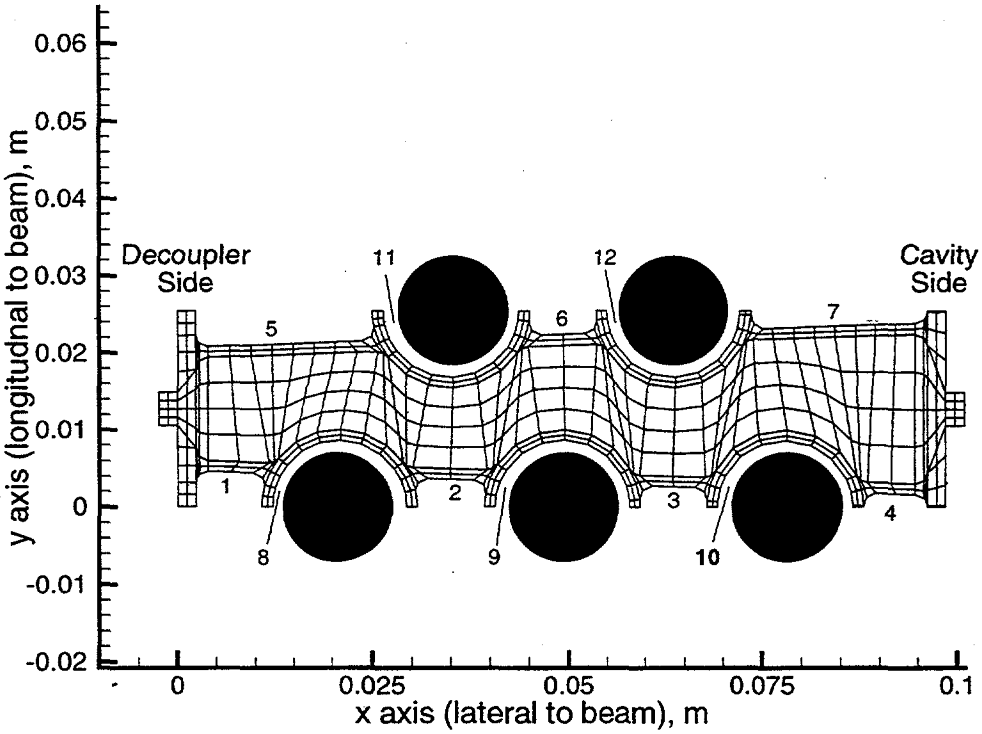


Figure 4-1 Finite element mesh of APT reference 1 lateral row 1 blanket plate.

4.1 Model Upgrades

No modifications to the original plate model were required for the helium tube rupture analyses.

4.2 Initial Conditions

Initial conditions for all of the flow transients are the normal operating conditions reported in Ref. [4]. The TRAC supplied initial conditions used in the FLOWTRAN-TF calculations are listed in Table 4.2-1.

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

	Pressure (MPa)	Temperature (C)	Void
Channel Inlet	0.686	53.03	0
Channel Outlet	0.584	-	-

4.3 Transient Boundary Conditions

Results from the TRAC LOHGA transient were used to supply boundary conditions to the FLOWTRAN-TF code for detailed calculations of the thermal-hydraulic behavior of a single Row 1 blanket plate. The TRAC transient results used in these calculations were:

1. Total coolant flow to the lateral Row 1 blanket module taken from TRAC PIPE component 454.
2. Inlet cooling water temperature, pressure and void fraction taken from TRAC PLENUM component 350. The calculations used inlet flow as an applied boundary condition and inlet pressure was used only for physical property evaluations.
3. Outlet pressure taken from TRAC PLENUM component 330.

Inlet conditions derived from the TRAC system analysis are shown in Figs. 4.3-1 and 4.3-2 for a helium tube rupture in TRAC PLENUM component 350 and in Figs. 4.3-3 and 4.3-4 for a helium tube rupture in TRAC PLENUM component 370. The boundary conditions are plotted as transient values relative to the pre-incident conditions. The pre-incident flow to a single blanket plate is taken to be 1.488 kg/s. Since void fraction naturally falls between zero and one, absolute values of void fraction are plotted in the figure.

The FLOWTRAN-TF transient calculations were run for 300 seconds using the boundary conditions shown in Figs. 4.3-1 and 4.3-3. For the helium tube rupture cases, a significant amount of void fraction appears at the inlet to the coolant flow channels within the first 10 seconds of the transient. The pressure and coolant flow respond to the introduction of pressurized gas during the early period of the transient and then return to close to pre-incident operating conditions. To better show the significant boundary conditions that were used in the detailed bin calculations, the first 60 seconds of the two accident scenarios are plotted in Figs. 4.3-2 and 4.3-4.

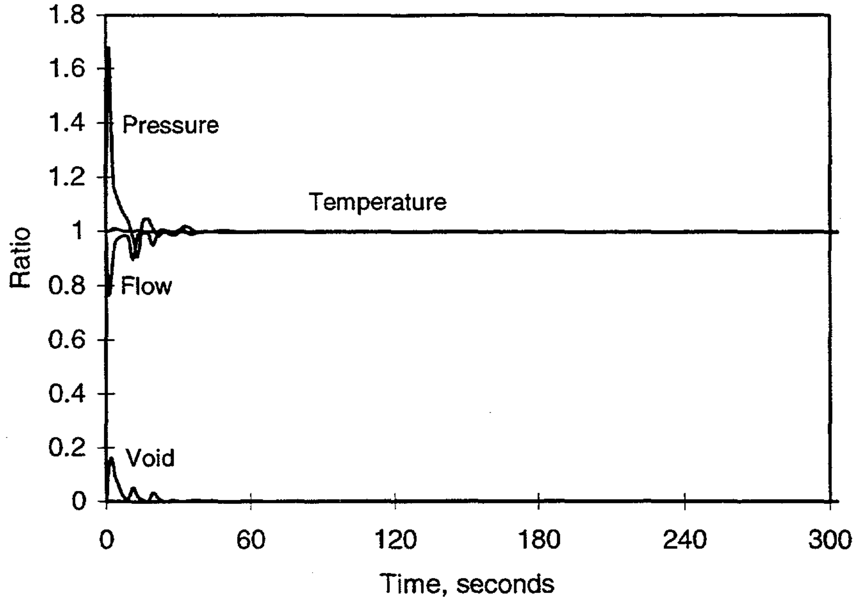


Figure 4.3-1 Inlet boundary conditions for helium tube rupture at TRAC component 350 out to 300 seconds.

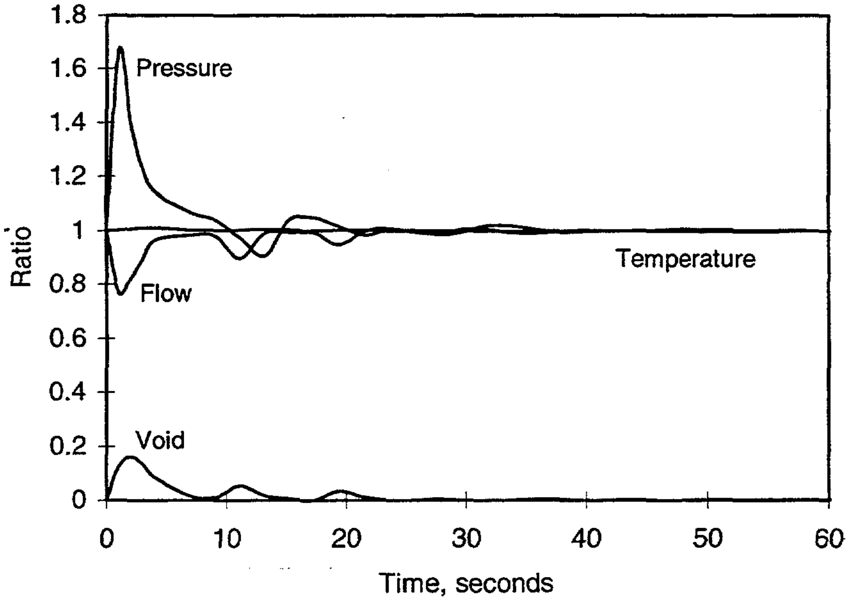


Figure 4.3-2 Inlet boundary conditions for helium tube rupture at TRAC component 350 out to 60 seconds.

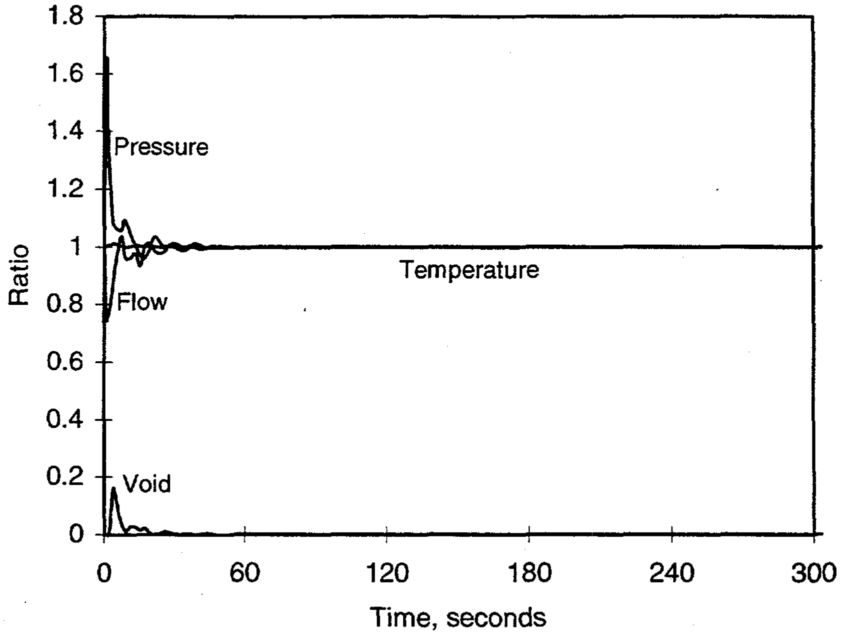


Figure 4.3-3 Inlet boundary conditions for helium tube rupture at TRAC component 370 out to 300 seconds.

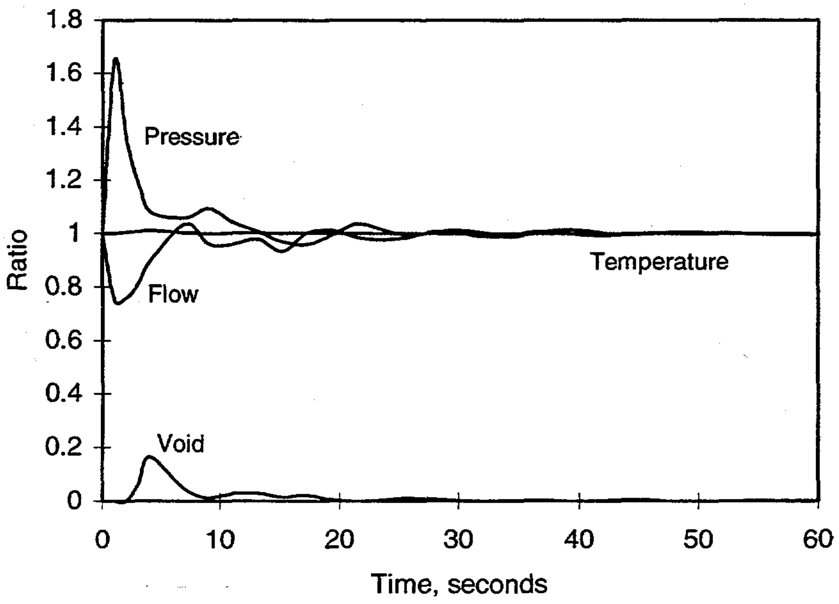


Figure 4.3-4 Inlet boundary conditions for helium tube rupture at TRAC component 370 out to 60 seconds.

5 FLOWTRAN-TF Detailed Bin Model Results

Results from the two sets of FLOWTRAN-TF calculations at the different break locations are presented in the following sections of this report. In both of these sets of calculations, it is assumed that the accelerator beam is not tripped during the accident and that the total deposited power in the plate remains constant at the nominal pre-incident value of 61.5 kW. At steady-state pre-incident conditions, the initial maximum aluminum temperature is about 100.0 C while the initial maximum lead temperature is about 113 C. Maximum metal temperatures occur in the region of the plate nearest the decoupler side and closest to the point of beam impact. The highest metal temperatures were found at axial level 12 in the model. A partial listing of the input deck used for the FLOWTRAN-TF calculations of the plate response to a helium tube rupture at TRAC component 350 is given in Appendix F.

5.1 FLOWTRAN-TF Results for Component 350 Rupture

Maximum metal temperatures from the FLOWTRAN-TF calculations for a rupture in the helium tube at TRAC component 350 are shown in Fig. 5.1-1. The maximum aluminum temperature found anywhere in the plate cladding and the maximum lead temperature anywhere in the plate are plotted as functions of time into the accident transient. The two figures are plotted on the same scale for easier comparison. The decrease in coolant flow in the early part of the transient leads to a temperature increase in the metal of only about 2.5 C. As expected, the metal temperature returns to its initial value as the flow disturbance passes. It is clear from the plotted metal temperatures that surface temperatures in the flow channels following beam trip are not close to local boiling conditions. At typical module pressures, the saturation temperature is around 165 C. At no point in the transient does the flow channel become completely voided.

To further illustrate safety margins in the plate type design, operating surface heat fluxes (q_{ohf}) were compared to the heat fluxes predicted for onset of nucleate boiling (q_{onb}), onset of significant void formation (q_{osv}) and the critical heat flux (q_{chf}). Since each of the 12 flow channels has 20 axial cells and at each axial level the surface is composed of from 8 to 17 surface nodes there are many (2760) surface heat fluxes at any time in the calculation. To reduce the number of data points, we have taken the approach of reporting the maximum heat flux at each axial position that is within the channel irrespective of the particular surface node where the maximum occurs. Further we can restrict the examination to the location of the peak axial heat fluxes. The highest operating surface heat fluxes were observed to occur in axial cells 10 through 15 of the 20 cells that were used to discretize the axial dimension for the safety calculations.

To show some representative results, the operating surface heat flux and the calculated limits for the helium tube rupture in component 350 are shown in Figs. 5.1-2 through 5.1-4 for all of the flow channels at axial level 10. Channels 1 and 5 are the rectangular flow channels nearest the decoupler side of the plate while channel 8 is the first annular flow channel on that side (see Fig. 4.1). The decoupler side of the plate absorbs the largest fraction of the deposited power and has a larger fraction of the coolant flow. Channels 4 and 7 are the rectangular flow channels nearest the cavity side of the plate where the deposited power and coolant flow are lowest.

Results from other axial locations on the plate surface where there is significant deposited power are similar demonstrating a substantial margin between the surface heat flux and the potentially limiting values. The closest approach of the operating heat flux to the limiting values typically occurs in flow channels 1 or 8. Near the top of the plate, the surface heat flux can reverse as energy flows from the heated water back into the cooler metal. This condition was observed in the flow channels in regions of the plate where the deposited power was low.

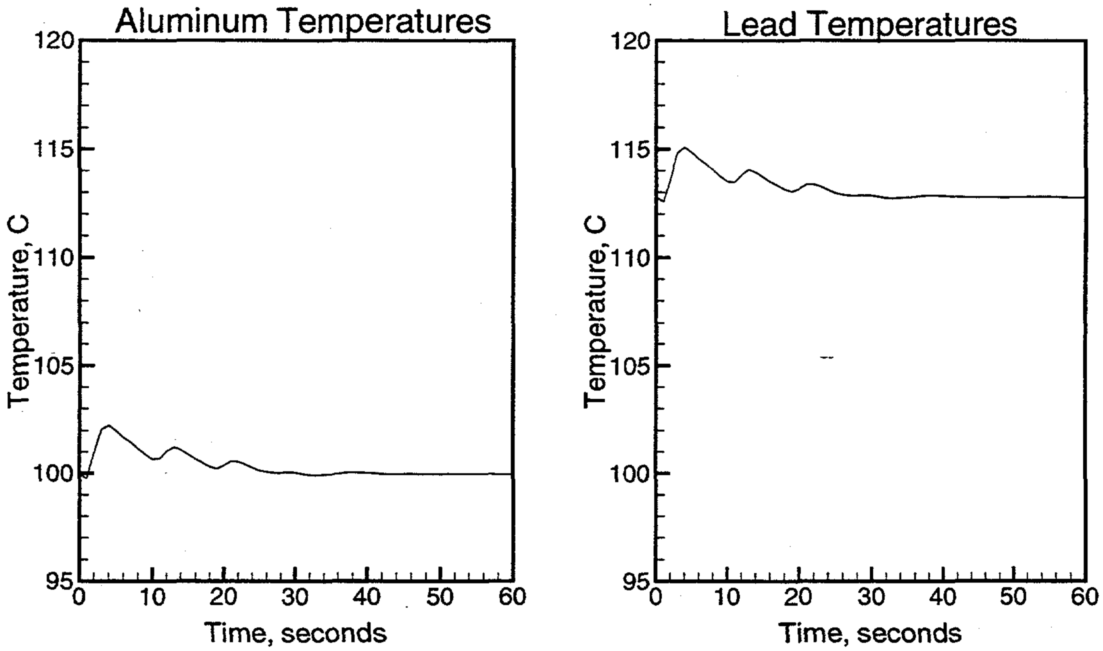


Figure 5.1-1 Maximum metal temperatures for helium tube rupture at TRAC component 350 out to 60 seconds.

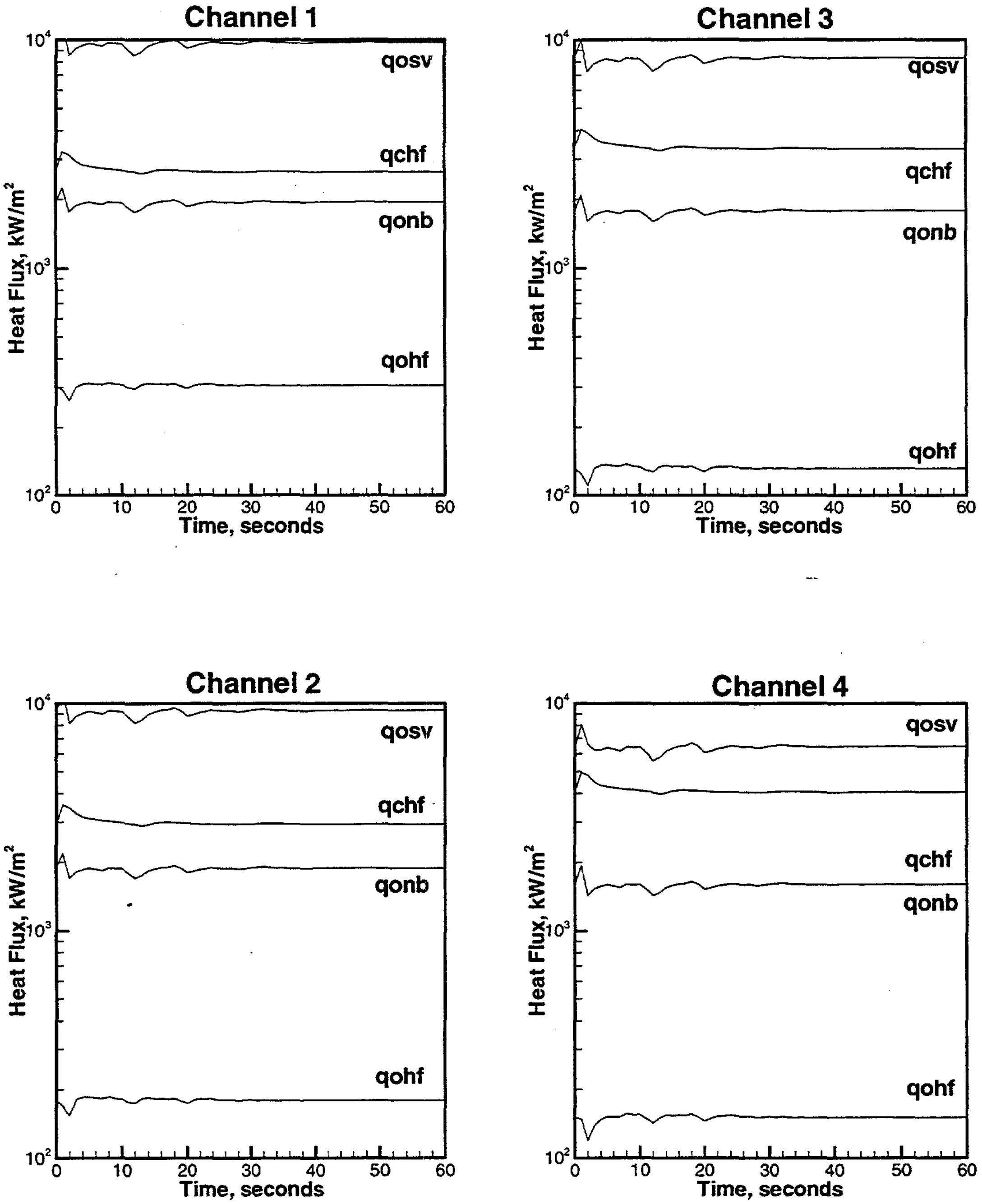
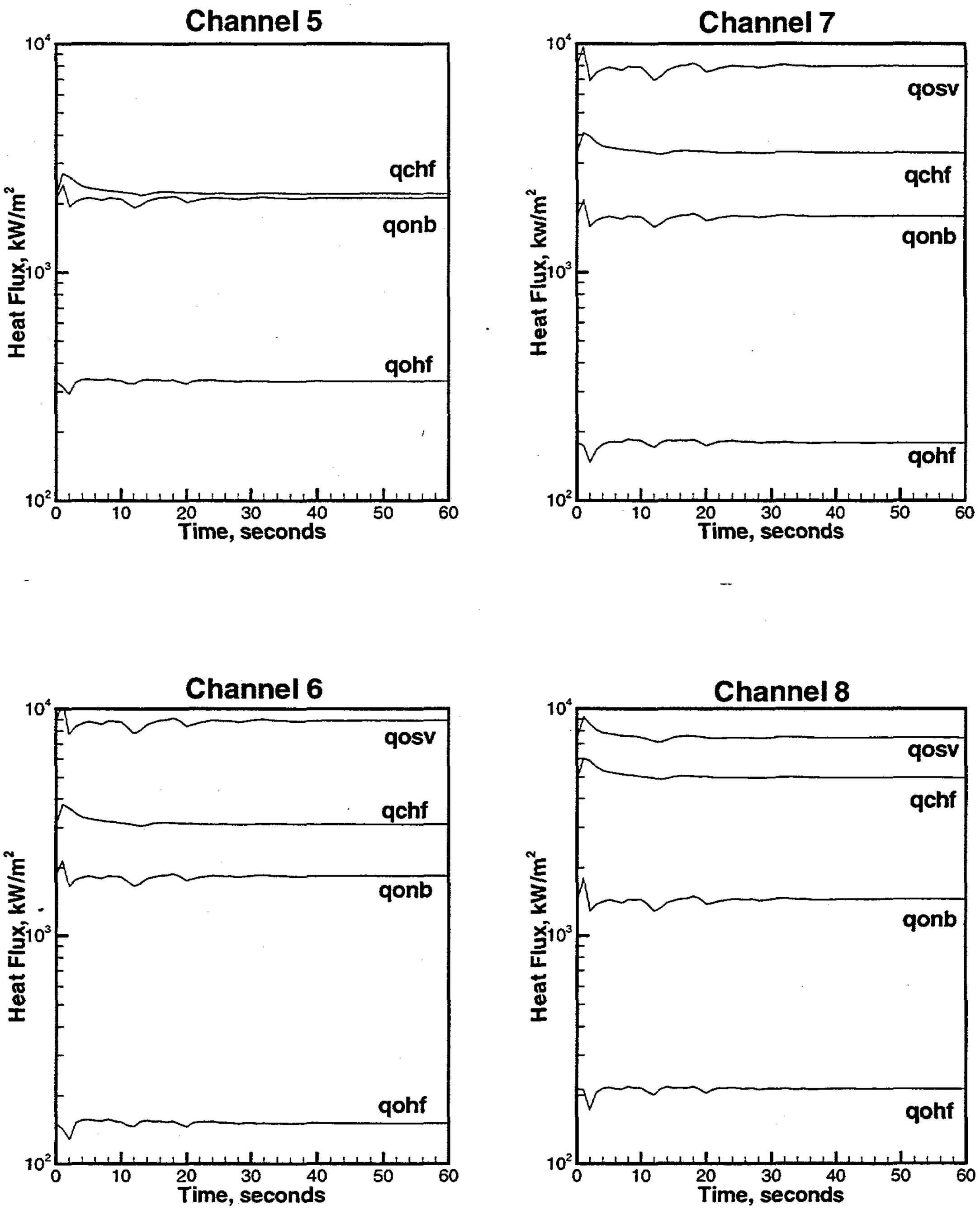


Figure 5.1-2 Surface heat fluxes for helium tube rupture at TRAC component 350 out to 60 seconds, axial level 10, channels 1-4.



Channel 5

Channel 7

Channel 6

Channel 8

Figure 5.1-3 Surface heat fluxes for helium tube rupture at TRAC component 350 out to 60 seconds, axial level 10, channels 5-8.

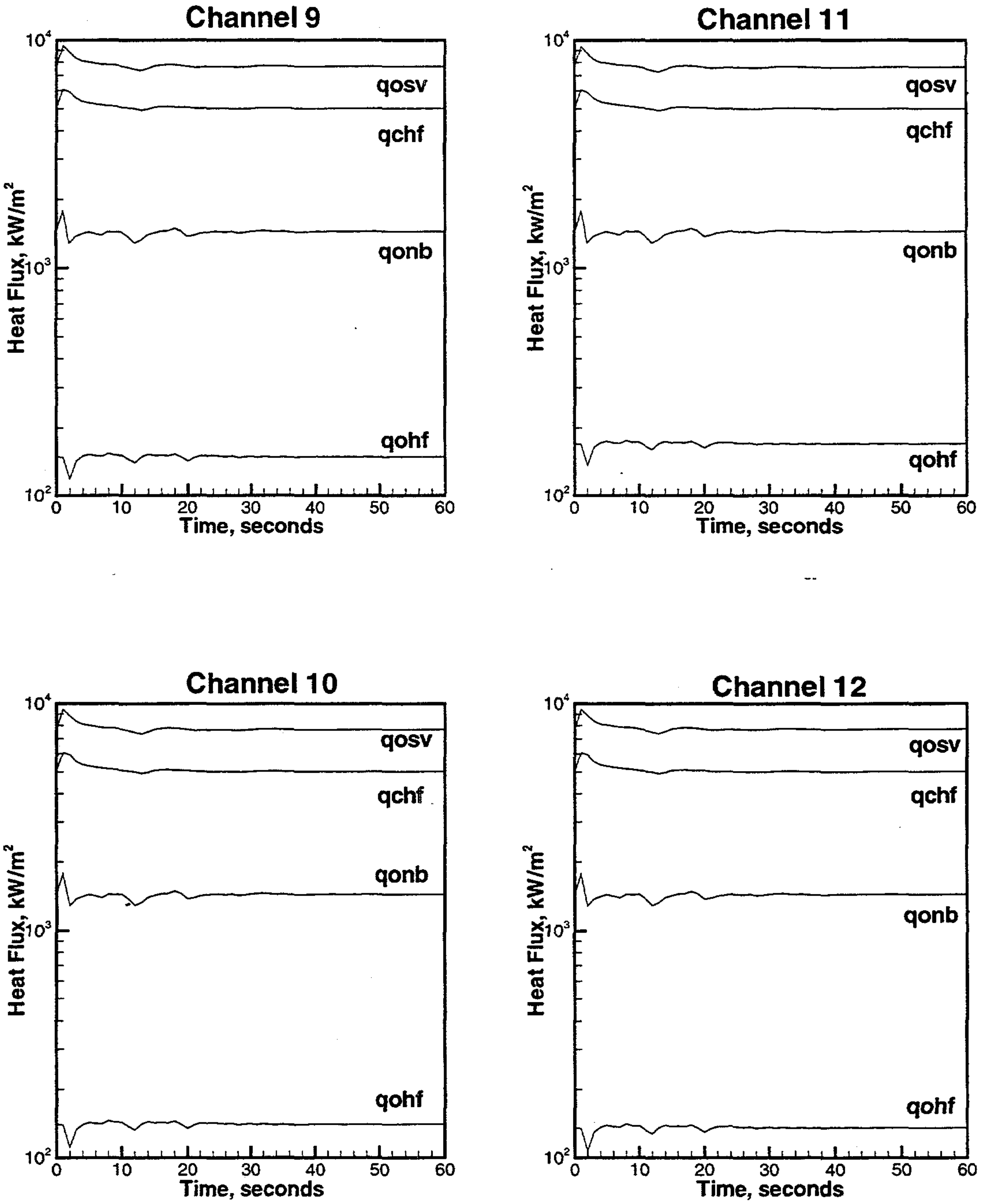


Figure 5.1-4 Surface heat fluxes for helium tube rupture at TRAC component 350 out to 60 seconds, axial level 10, channels 9-12.

5.2 FLOWTRAN-TF Results for Component 370 Rupture

Maximum metal temperatures from the FLOWTRAN-TF calculations for a rupture in the helium tube at TRAC component 370 are shown in Fig. 5.2-1. The maximum aluminum temperature found anywhere in the plate cladding and the maximum lead temperature anywhere in the plate are plotted as functions of time into the accident transient. As with the other helium tube rupture accident, the decrease in coolant flow in the early part of the transient leads to a temperature increase in the metal of only about 2.5 C. As in the previous case, the metal temperature returns to its initial value within 60 seconds of the start of the accident as the flow disturbance passes. It is clear from the metal temperatures that surface temperatures in the flow channels following beam trip are not close to local boiling conditions.

Representative results for the operating surface heat flux and the calculated heat flux limits for the helium tube rupture in component 370 are shown in Figs. 5.2-2 through 5.2-4 for all of the flow channels at axial level 10. Channels 1 and 5 are the rectangular flow channels nearest the decoupler side of the plate while channel 8 is the first annular flow channel on that side. Channels 4 and 7 are the rectangular flow channels nearest the cavity side of the plate where deposited power and coolant flow are lowest.

Results from other axial locations on the plate surface are again similar demonstrating a substantial margin between the surface heat flux and the potentially limiting values. As before, the closest approach of the operating heat flux to the limiting values typically occurs in flow channels 1 or 8. Near the top of the plate, the surface heat flux can reverse as energy flows from the heated water back into the cooler metal. This condition was observed in the flow channels in regions of the plate where the deposited power was lowest.

The plate response to a helium tube rupture at component 370 is very similar to the response for a rupture at component 350. The most significant disturbance to the coolant flow passes through the channels within the first 10 seconds of the transient and has no major impact on the plate performance.

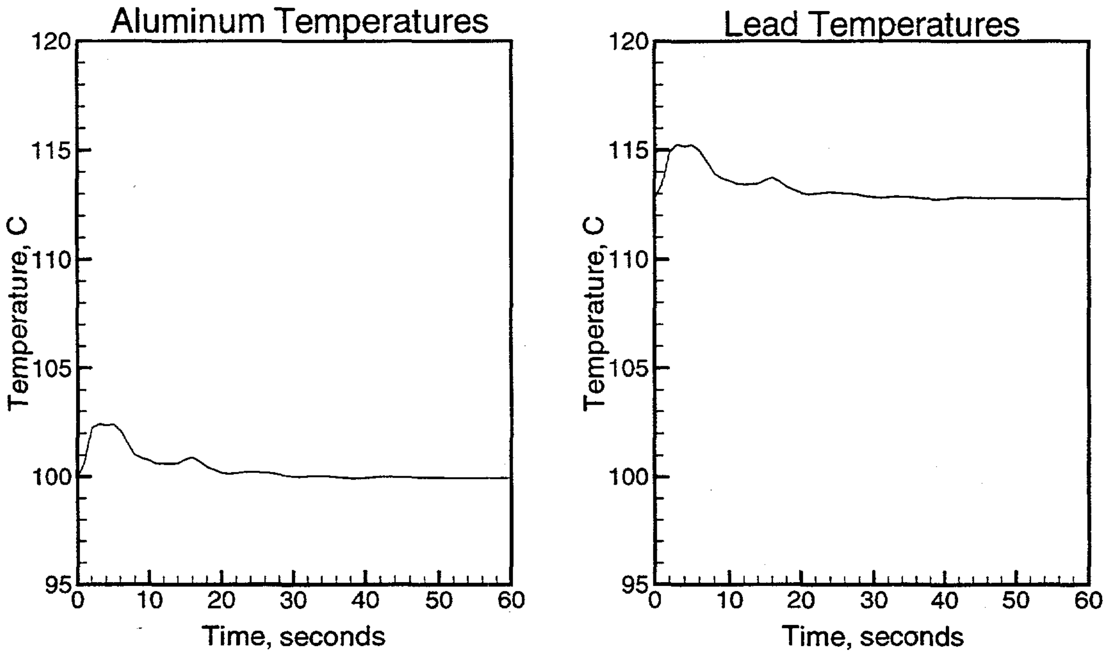


Figure 5.2-1 Maximum metal temperatures for helium tube rupture at TRAC component 370 out to 60 seconds.

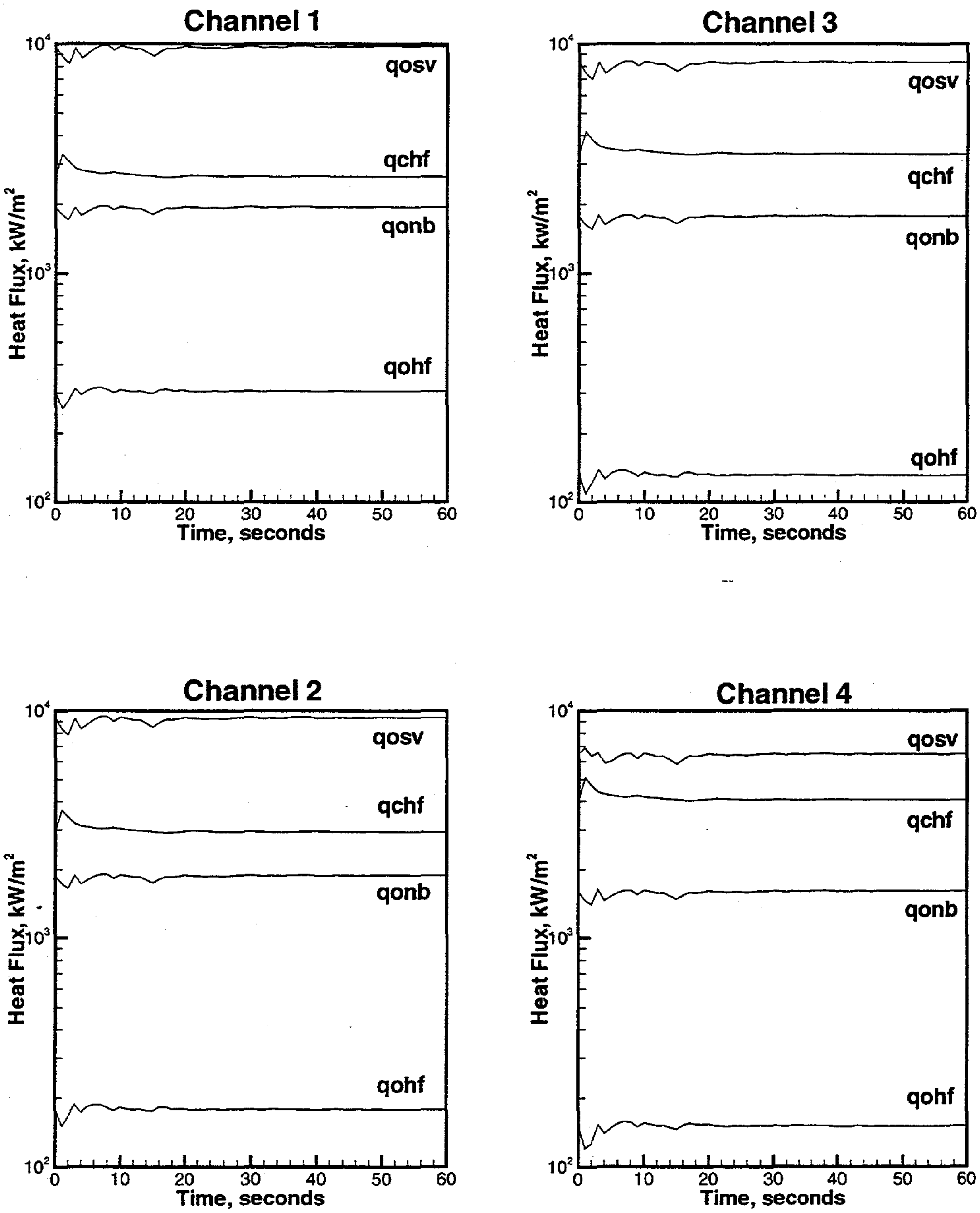


Figure 5.2-2 Surface heat fluxes for helium tube rupture at TRAC component 370 out to 60 seconds, axial level 10, channels 1-4.

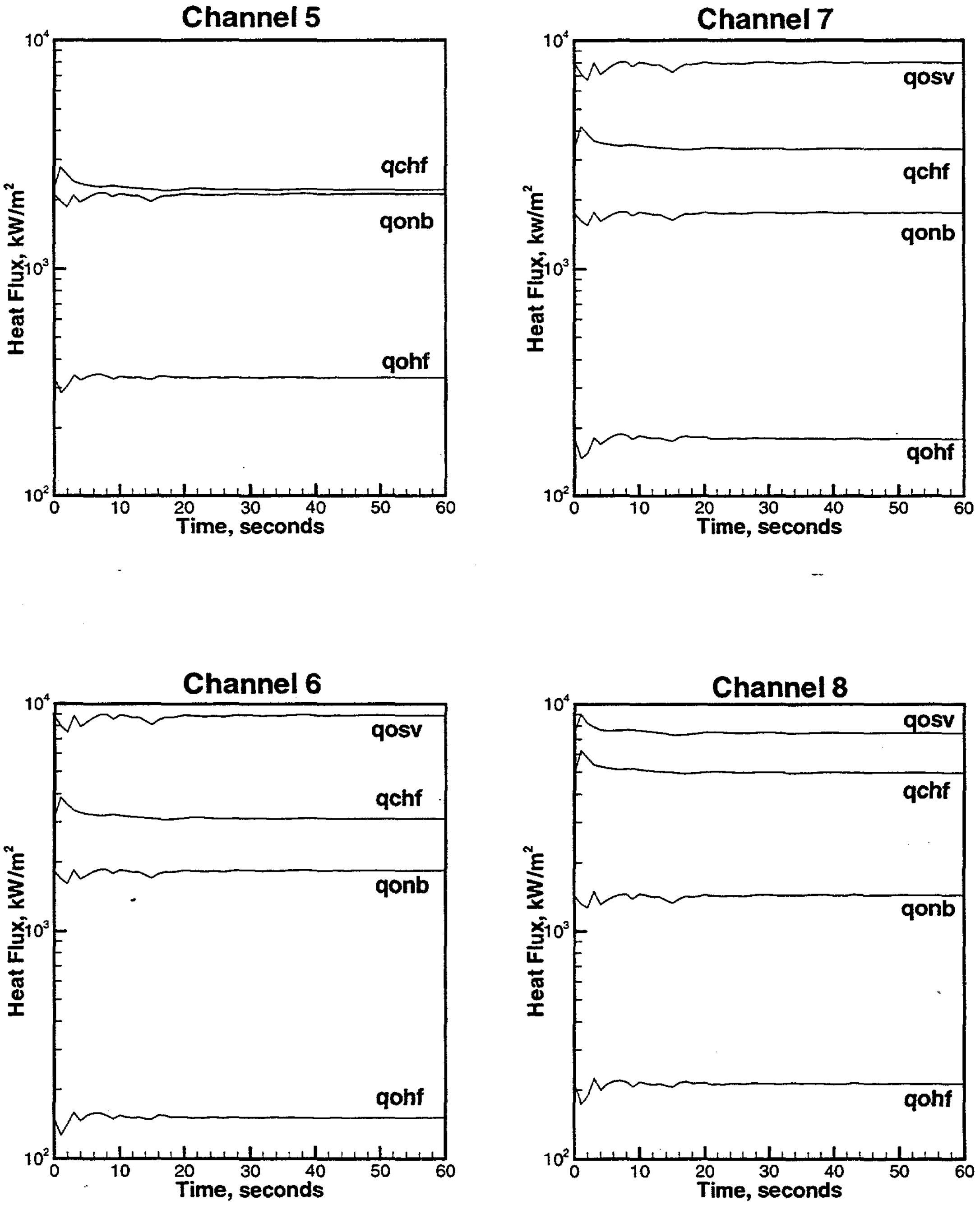


Figure 5.2-3 *Surface heat fluxes for helium tube rupture at TRAC component 370 out to 60 seconds, axial level 10, channels 5-8.*

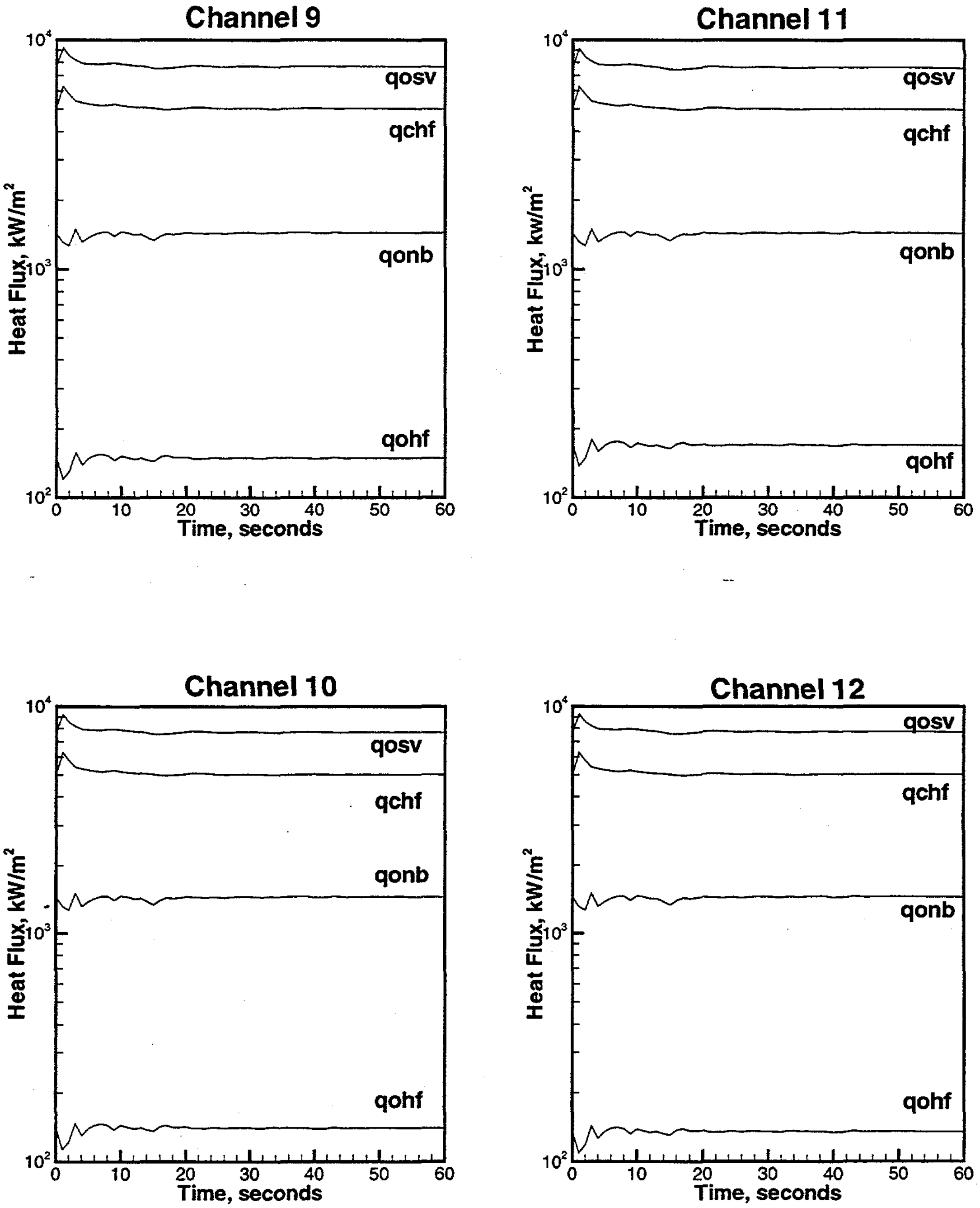


Figure 5.2-4 Surface heat fluxes for helium tube rupture at TRAC component 370 out to 60 seconds, axial level 10, channels 9-12.

6 Conclusions

6.1 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 helium tube rupture scenarios. This conclusion is based on the analysis of two Large Break LOHGA accidents internal to the blanket module where the pressurizer relief valve remains closed. The thermal/hydraulic (T/H) design criteria, along with the basis for their development, is discussed in Refs. [1,8]. For LOHGA 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.

On a module-by-module basis, the above steady-state material and thermal onset criteria for LOHGA are compared to the FLOWTRAN-TF detailed bin model results. The bin model results for the reference 1 plate-type module are tabulated in Table 6.1-1 (note that only module 1 results are currently available since the design specifications for modules 2 through 6 do not presently exist). However, module 1 should be close to the most limiting module. Additional thermal onset criteria, which are typically considered, are also provided in Table 6.1-1. Note that these are generally more stringent than the imposed design criteria chosen.

The definitions of the criteria ratios in Table 6.1-1 are listed below, as follows:

$$R_{SUB} = \max\left(\frac{T_f - T_{in}}{T_{sat} - T_{in}}\right)$$, liquid subcooling

$$R_{SUP} = \max\left(\frac{T_w - T_{in}}{T_{sat} - T_{in}}\right)$$, wall superheating

$$R_{ONB} = \max\left(\frac{q''_{OHF}}{q''_{ONB}}\right)$$, ONB heat flux

$$R_{OSV} = \max\left(\frac{q''_{OHF}}{q''_{OSV}}\right), \text{ OSV heat flux}$$

$$R_{CHF} = \max\left(\frac{q''_{OHF}}{q''_{CHF}}\right), \text{ CHF heat flux}$$

where:

q''_{OHF}	operating heat flux
q''_{ONB}	heat flux at onset of subcooled nucleate boiling
q''_{OSV}	heat flux at onset of significant void formation
q''_{CHF}	critical heat flux
T_f	fluid temperature
T_{in}	fluid temperature at inlet to flow channels, (53.05 C)
T_{sat}	local fluid saturation temperature
T_w	wall temperature

To evaluate these criteria, the maximum value corresponds to its limit spatially, as well as over the time period of the event sequence. The ratio of OHF-to-CHF is sometimes referred to as the departure from nucleate boiling ratio (DNBR). Predicted thermal onset ratios should not exceed unity.

Confidence bounds are required to establish the acceptable level of probability of exceeding these criteria. The results presented in Table 6.1-1 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.

The peak blanket metal temperature that occurs in module #1 during this accident scenario is 115.1 C, as predicted by the FLOWTRAN-TF model. This occurs in the lead plate, and is well below the lead melting point, 327.5 C. The peak aluminum temperature that occurs in module #1 is 102.2 C, which is well below the long-term temperature limit of 115 C. Maximum temperatures are reached about 10 seconds after the start of the accident as the released gas voids the flow channels and decreases coolant flow. However, the transient gas flow passes through the system very quickly and operating parameters return to what are essentially normal operating conditions approximately 60 seconds after the initiation of the accident event. The thermal inertia of the solid is such that the blanket system response to this short transient is very small with little impact on the operating conditions.

Table 6.1-1 FLOWTRAN-TF model results under helium tube rupture conditions.

Module Number	Max Pb Temp (C)	Max Al Temp (C)	Max Subcooling Ratio	Max Superheat Ratio	Max ONB Ratio	Max OSV Ratio	Max CHR Ratio
1	115.1	102.2	0.165	0.326	0.178	0.036	0.157
2	TBD	TBD	TBD	TBD	TBD	TBD	TBD
3	TBD	TBD	TBD	TBD	TBD	TBD	TBD
4	TBD	TBD	TBD	TBD	TBD	TBD	TBD
5	TBD	TBD	TBD	TBD	TBD	TBD	TBD
6	TBD	TBD	TBD	TBD	TBD	TBD	TBD

6.2 Design Issues

This analysis indicates that a rupture of a helium tube releasing gas into the blanket cooling system results in no impact on the plant operations. None of the safety systems need to be activated to mitigate the consequences of this accident. The current system design can sustain the sudden release of 1 m^3 of helium with no adverse impacts.

6.3 Predicted Impact

Blanket conditions during large break helium tube rupture accidents internal to the blanket system fall within all specified thermal/hydraulic design criteria. No off-site impact to people or the environment would occur as a result of a rupture in the helium tubes that suddenly releases 1 m^3 of gas into the blanket cooling system assuming that the pressurizer relief valve remains closed. The only on-site consequence would result from the contamination of the cooling water with tritium.

7 References

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2. Personal communication with Jack N. Edwards at LANL, April 22, 1998.
3. L. L. Hamm, S. Y. Lee, M. A. Shadday, and F. G. Smith, III, "APT Blanket System Model Based on Initial Conceptual Design - Integrated 1-D TRAC System Model," Westinghouse Savannah River Company, WSRC-TR-98-0053 (July 1998).
4. L. L. Hamm, S. Y. Lee, M. A. Shadday, and F. G. Smith, III, "Normal operation (NO) of APT Blanket System and Its Components Based on Initial Conceptual Design", Westinghouse Savannah River Company, WSRC-TR-98-0057 (July 1998).
5. R. Kapernick, "Blanket Reference 1 Plate-Type Design for Lateral Row 1 Module", e-mail memo from Los Alamos National Laboratory, Oct. 11, 1997.
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7. L. L. Hamm, S. Y. Lee, M. A. Shadday, and F. G. Smith, III, "FLOWTRAN-TF Code Modifications made for APT Blanket Safety Analyses", Westinghouse Savannah River Company, WSRC-TR-98-0056 (July 1998).
8. L. L. Hamm, S. Y. Lee, M. A. Shadday, and F. G. Smith, III, "APT Blanket System Safety Analysis Methodology," Westinghouse Savannah River Company, Westinghouse Savannah River Company, WSRC-TR-98-0052 (May 1998).
9. L. L. Hamm, S. Y. Lee, M. A. Shadday, and F. G. Smith, III, "TRAC Code Modifications made for APT Blanket Safety Analysis," Westinghouse Savannah River Company, WSRC-TR-98-0054 (July 1998).
10. Safety Code Development Group, "TRAC-PF1/MOD2: An Advanced Best Estimate Computer Program for Pressurized Water Reactor Thermal-Hydraulic Analysis," Los Alamos National Laboratory report LA-12031-M, Vol. 1 (NUREG/CR-5673), (July 21, 1993).
11. L. L. Hamm, S. Y. Lee, M. A. Shadday, and F. G. Smith, III, "APT Blanket System Loss-of-Flow Accident (LOFA) Analyses Based on Initial Conceptual Design - Case 1: with Beam Shutdown and Active RHR," Westinghouse Savannah River Company, WSRC-TR-98-0058 (July 1998).

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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 2^{nd} pass secondary side
		732	3	HX #2 middle header secondary side
		733	4	HX #2 1^{st} 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

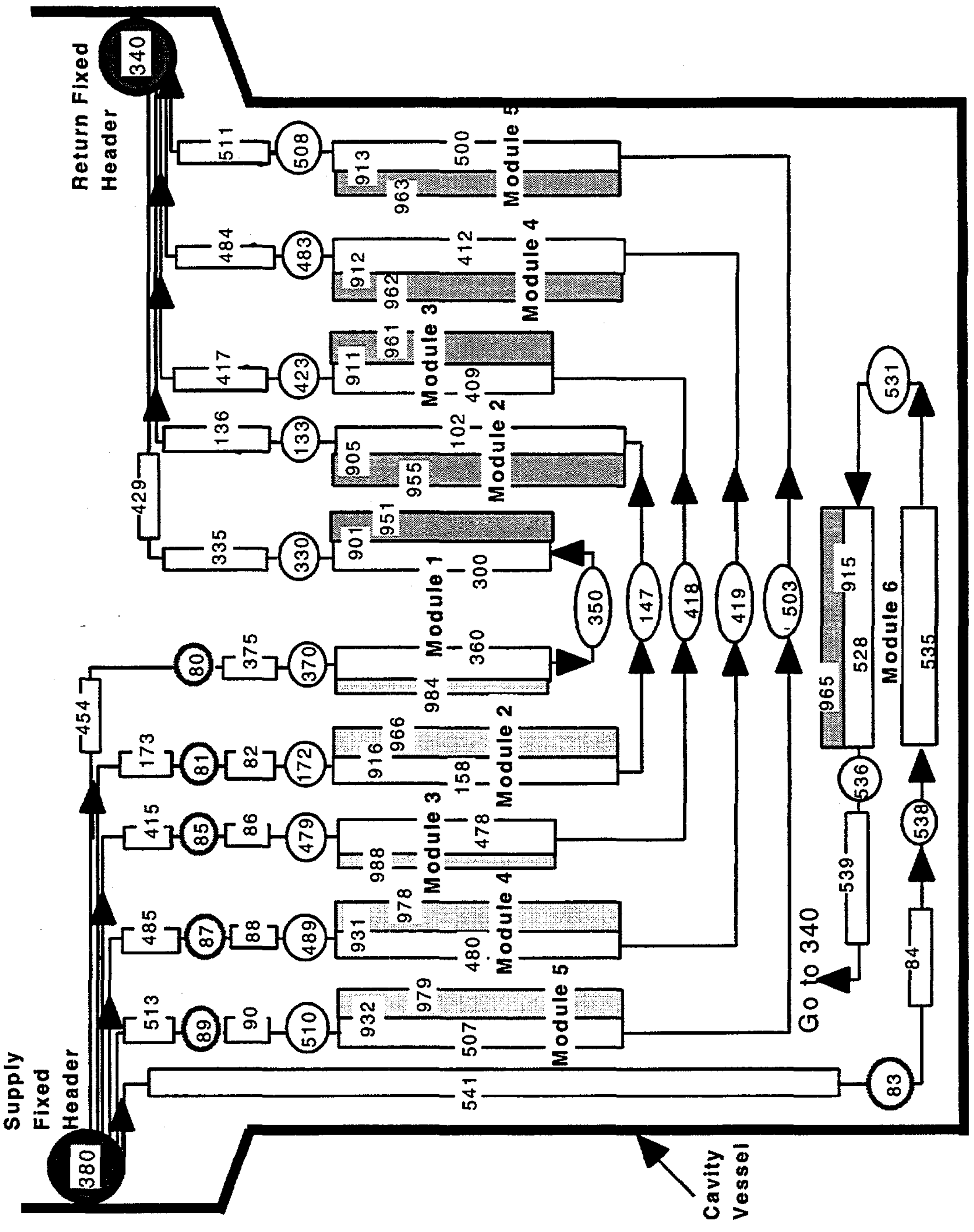

Figure A-1 6 blanket module layout for safety analysis.

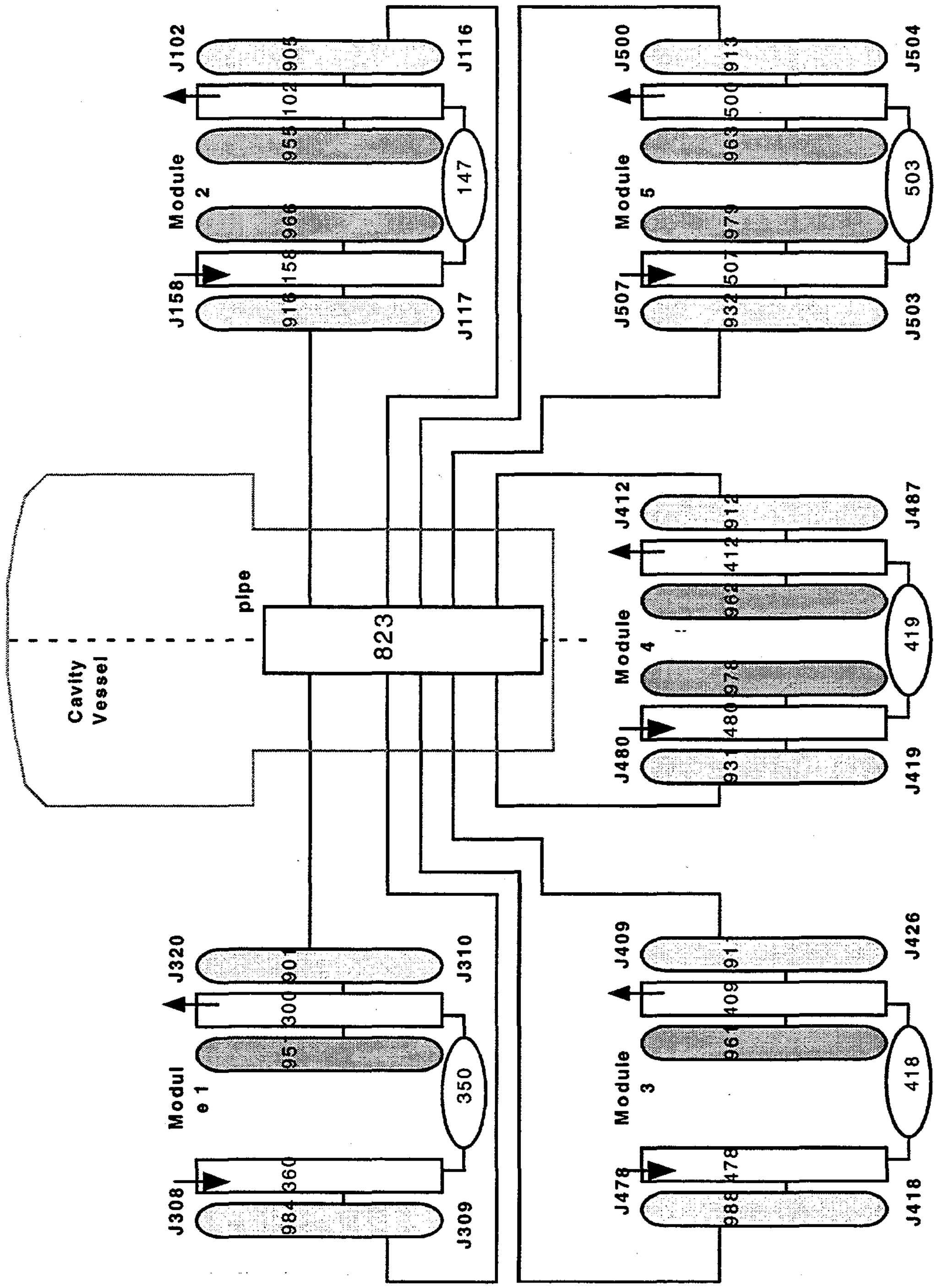

Figure A-2 TRAC component layout for the cavity vessel and blanket module heat structures.

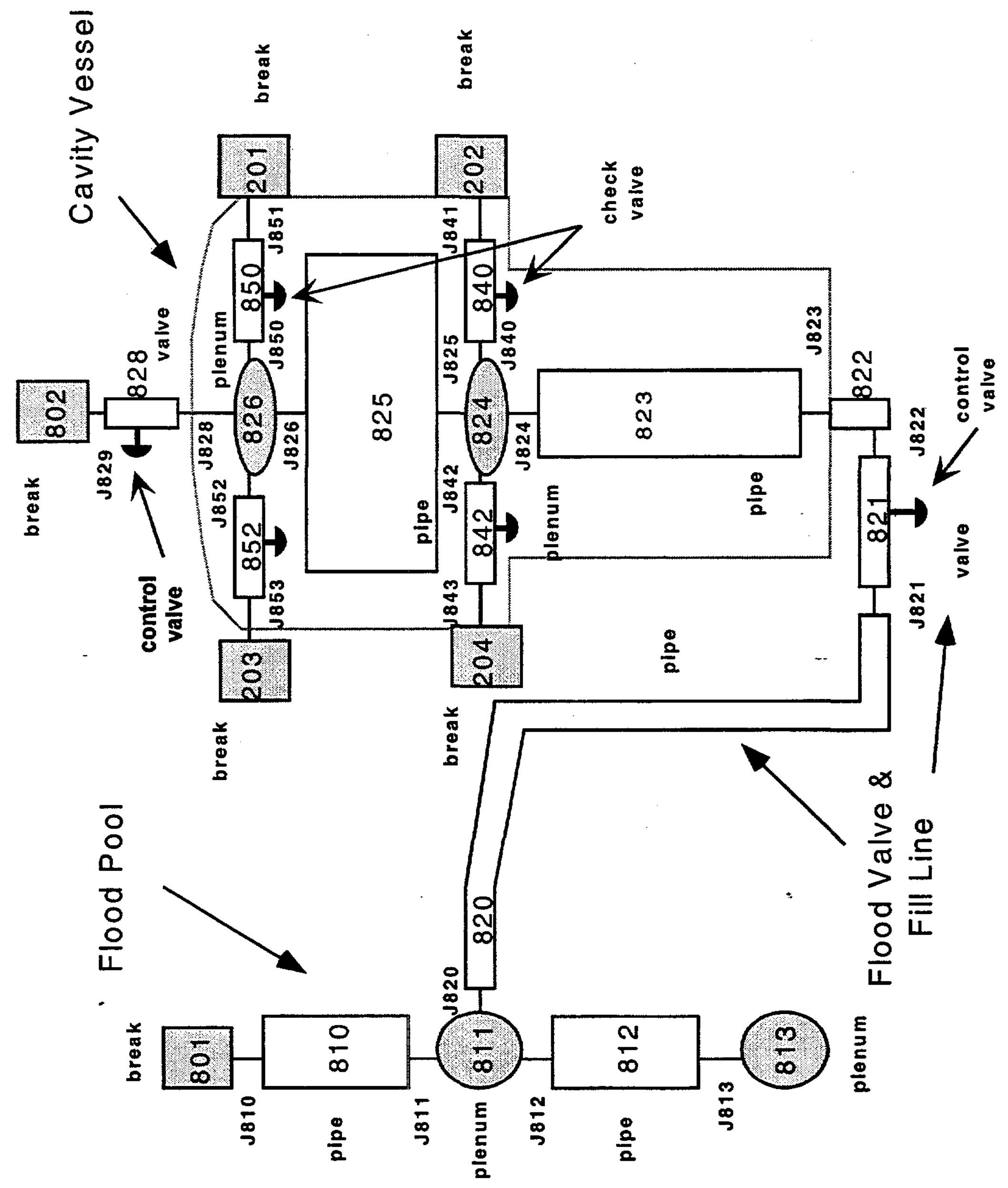

Figure A-3 TRAC component layout for the cavity vessel and cavity flood system.

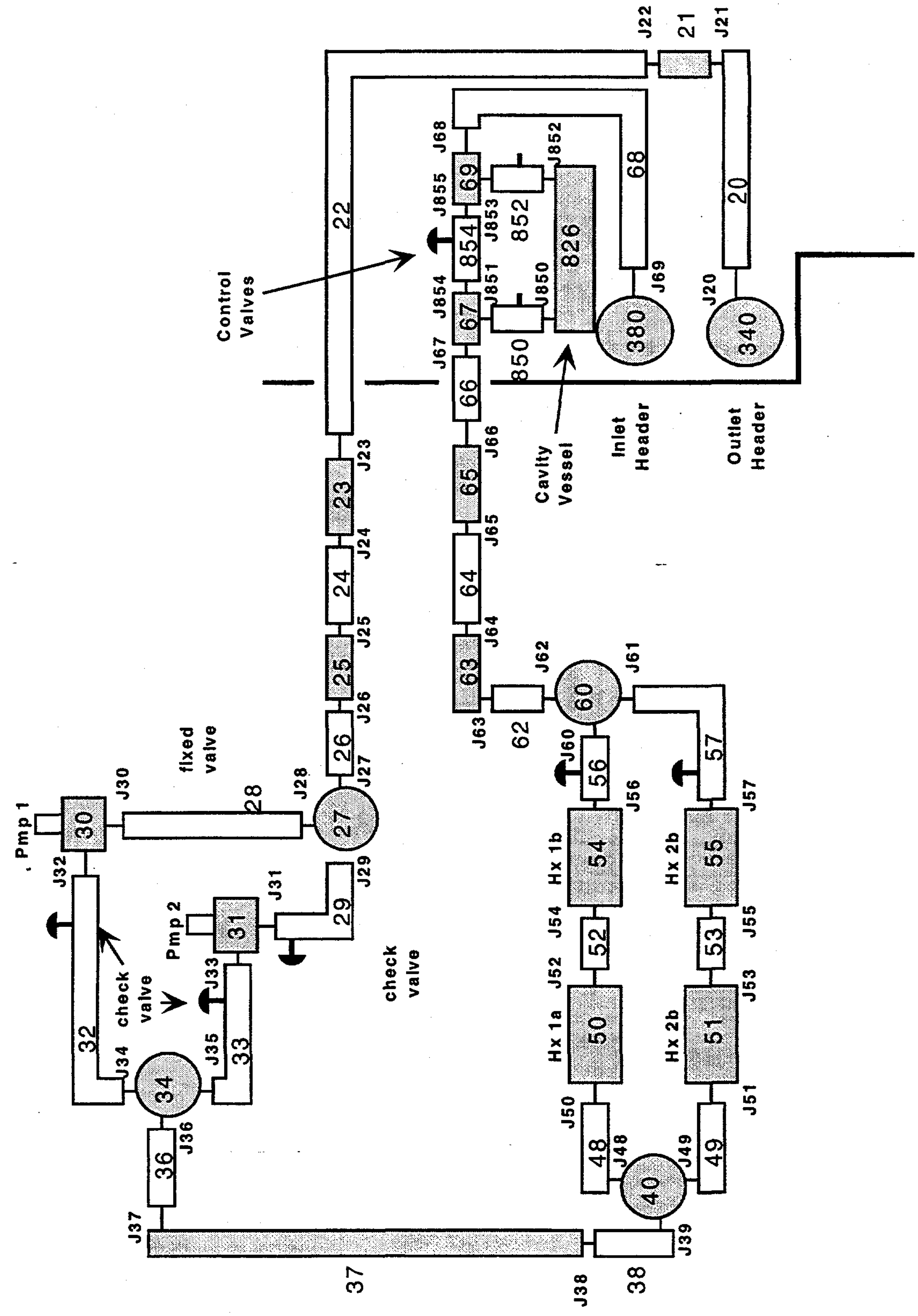

Figure A-4 TRAC component layout for blanket primary HR coolant loop.

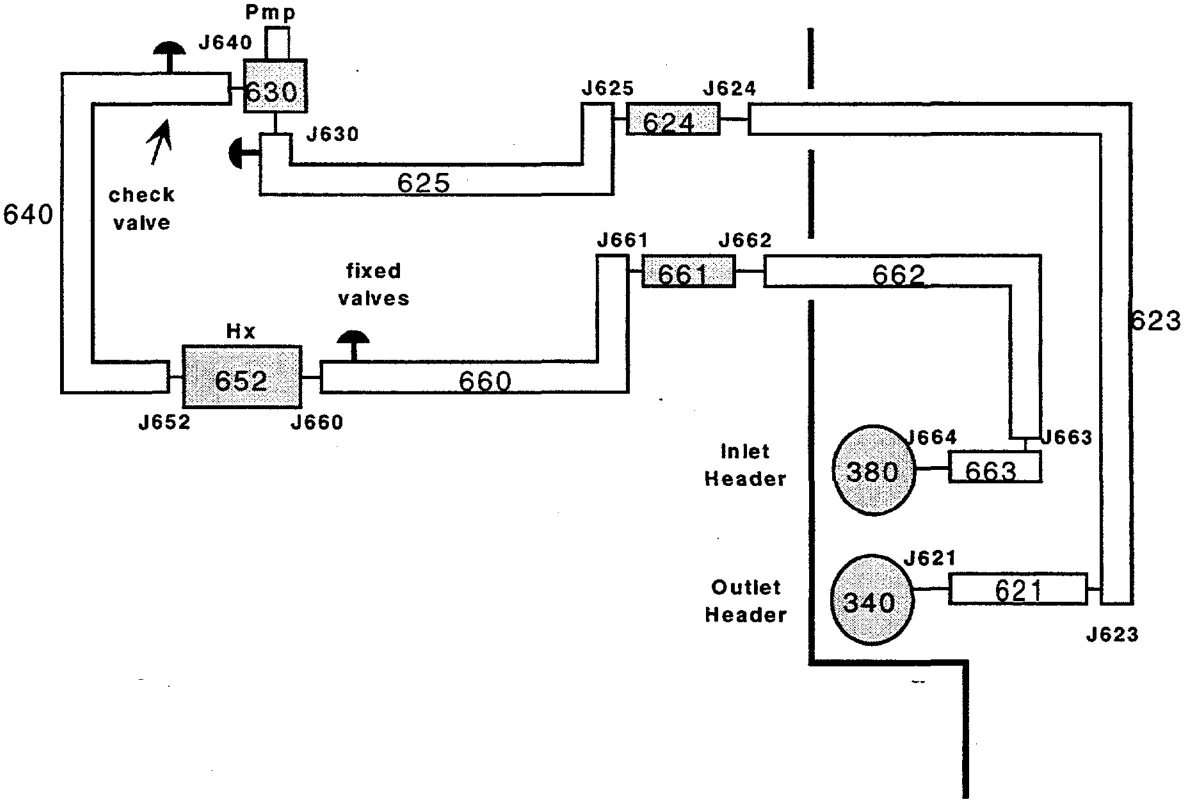

Figure A-5 TRAC component layout for blanket primary RHR coolant loop.

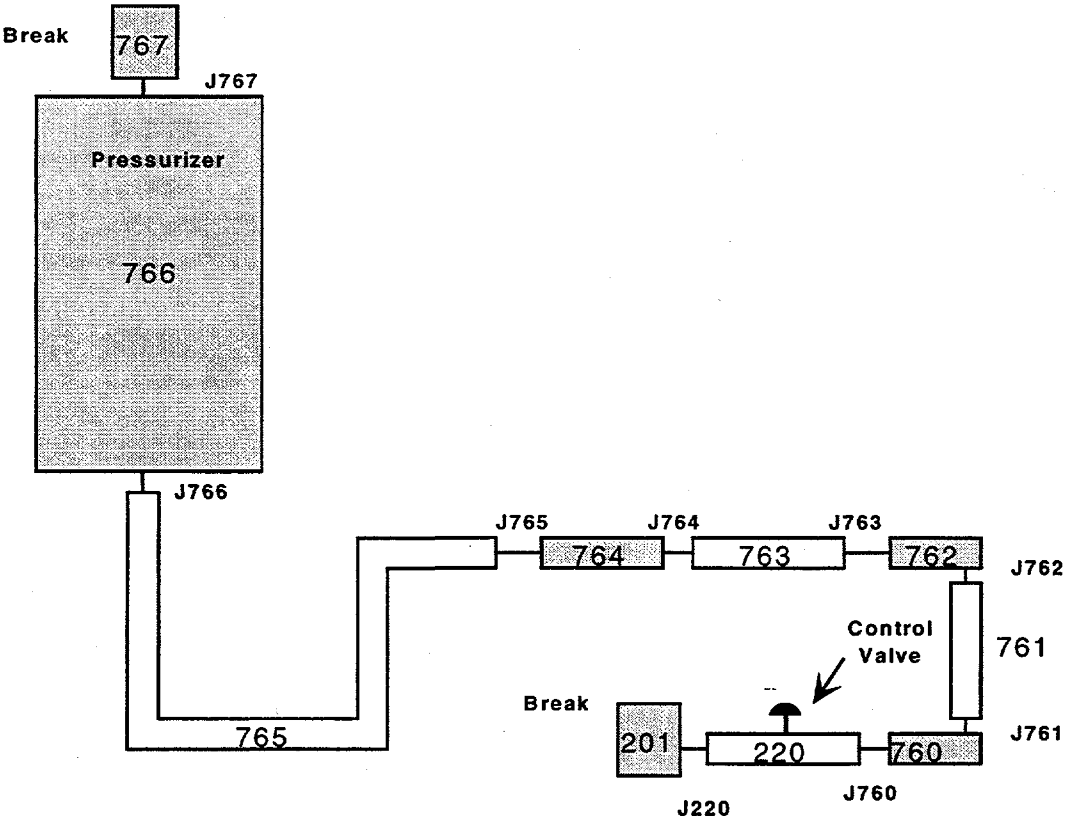

Figure A-6 TRAC component layout for blanket primary pressurizer and surge line.

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Appendix B: LOHGA (Case 1) TRAC Results

Appendix B1 LOHGA (Case 1) TRAC Plenum Component Figures

The following figures are from a TRAC simulation for Case 1 of a LOHGA (Helium supply plenum break near decoupler inlet):

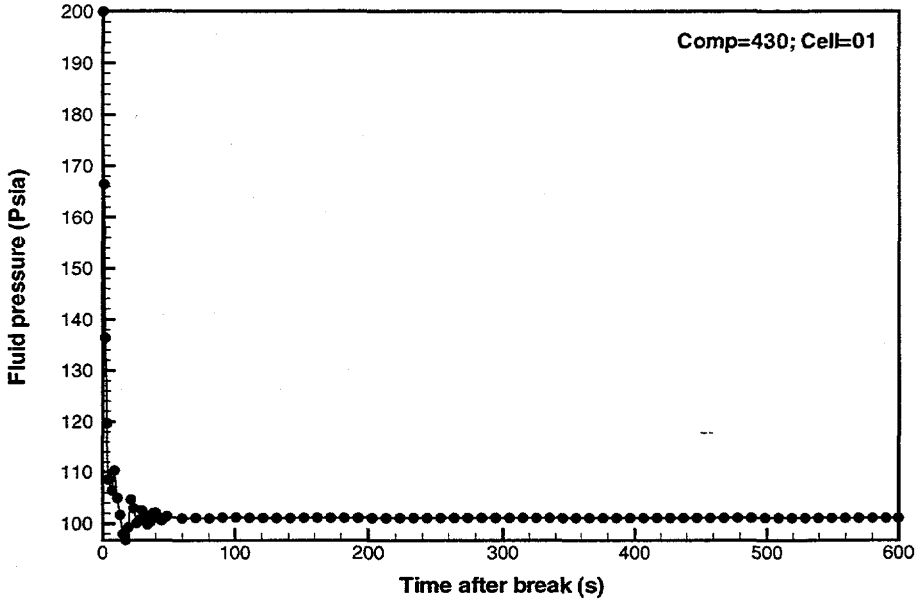

Figure B-1a Helium gas supply fluid pressures for a LOHGA (Case 1: helium supply plenum break near decoupler inlet).

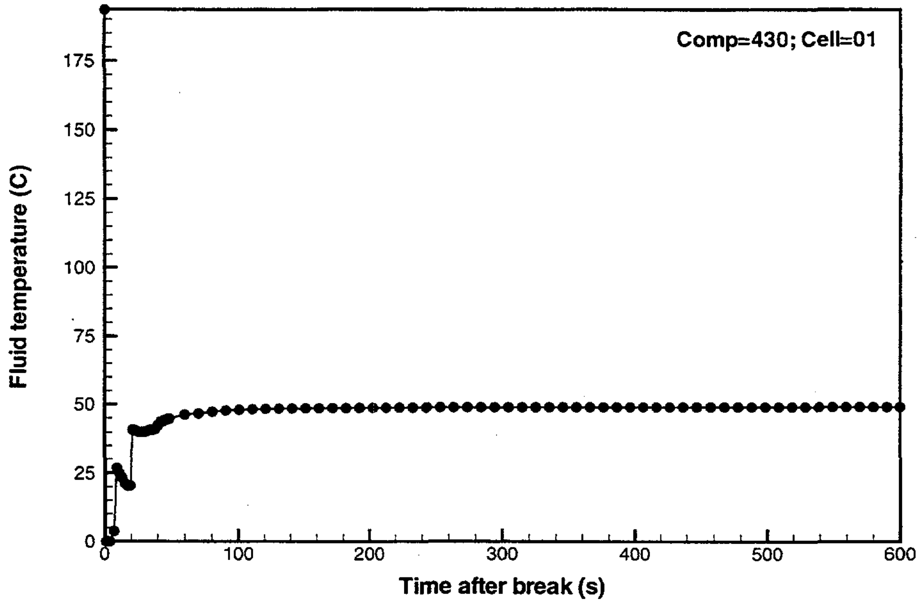

Figure B-1b Helium gas supply fluid temperatures for a LOHGA (Case 1: helium supply plenum break near decoupler inlet).

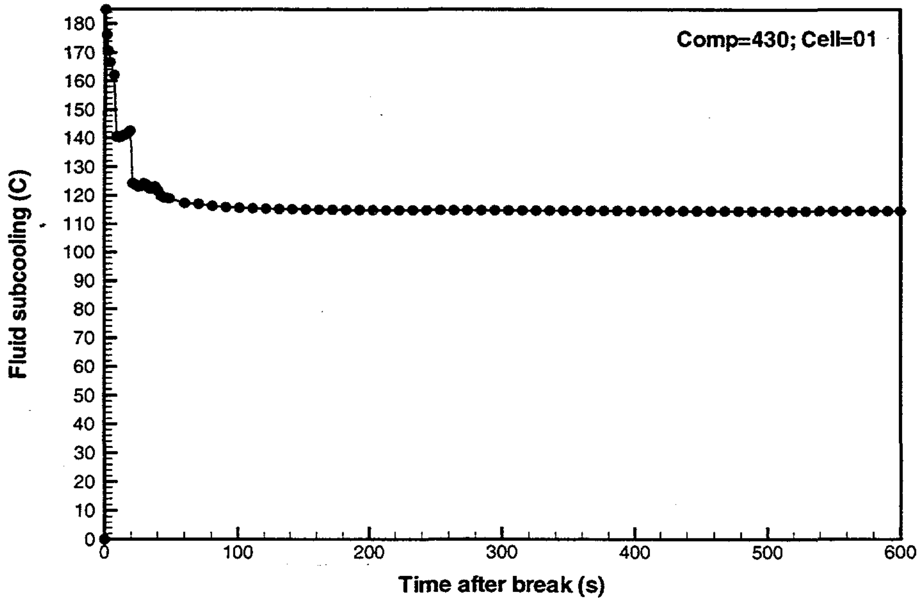

Figure B-1c Helium gas supply fluid subcoolings for a LOHGA (Case 1: helium supply plenum break near decoupler inlet).

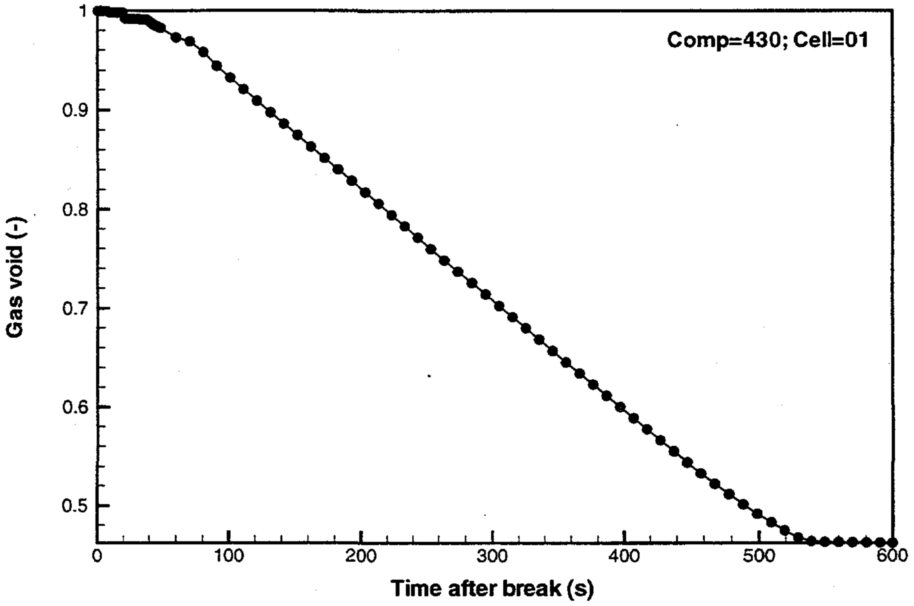

Figure B-1d Helium gas supply void fractions for a LOHGA (Case 1: helium supply plenum break near decoupler inlet).

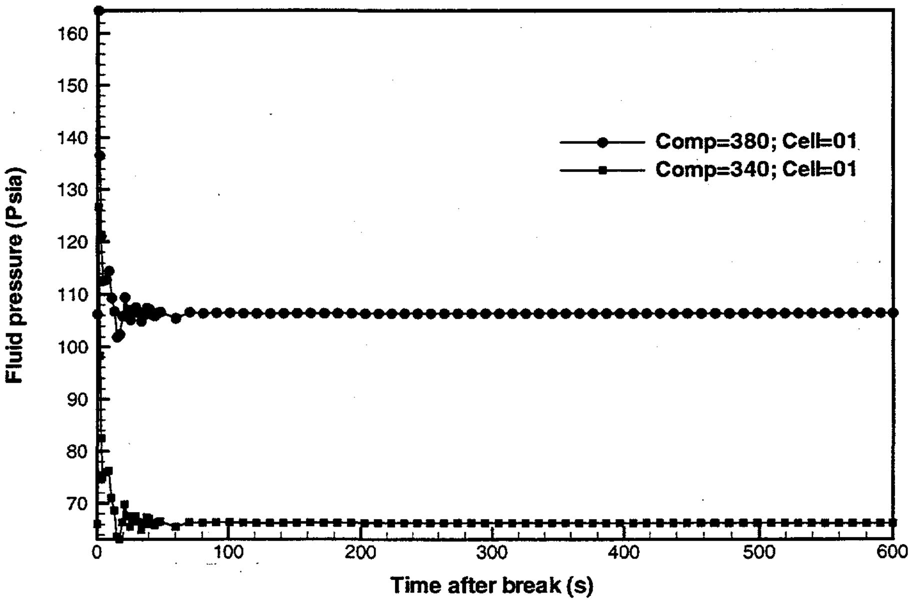

Figure B-2a Fixed header fluid pressures for a LOHGA (Case 1: helium supply plenum break near decoupler inlet).

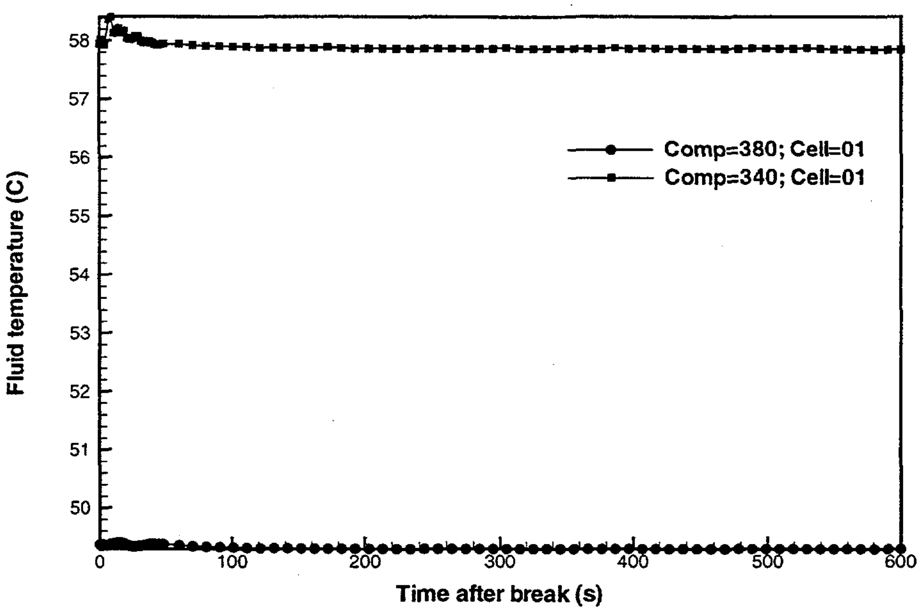

Figure B-2b Fixed header fluid temperatures for a LOHGA (Case 1: helium supply plenum break near decoupler inlet).

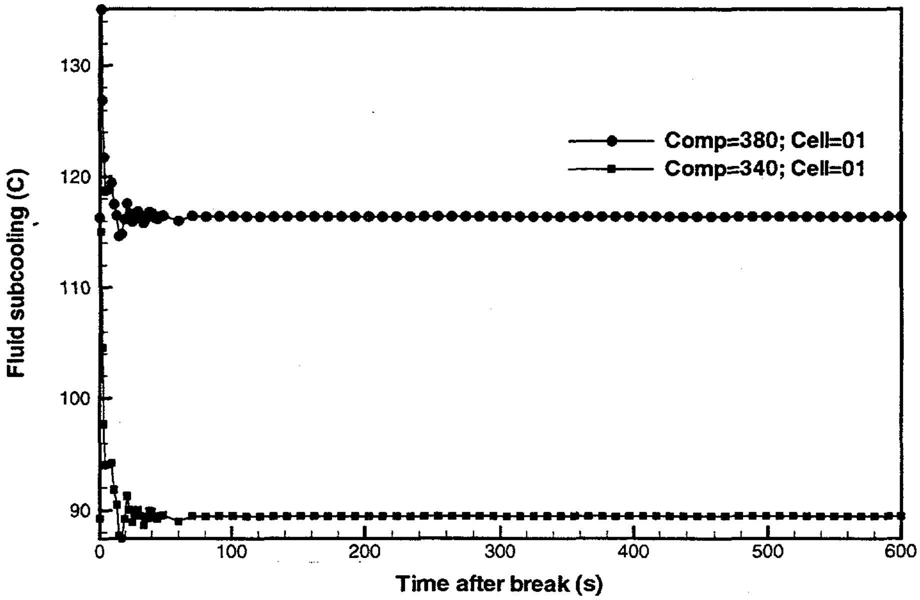

Figure B-2c Fixed header fluid subcoolings for a LOHGA (Case 1: helium supply plenum break near decoupler inlet).

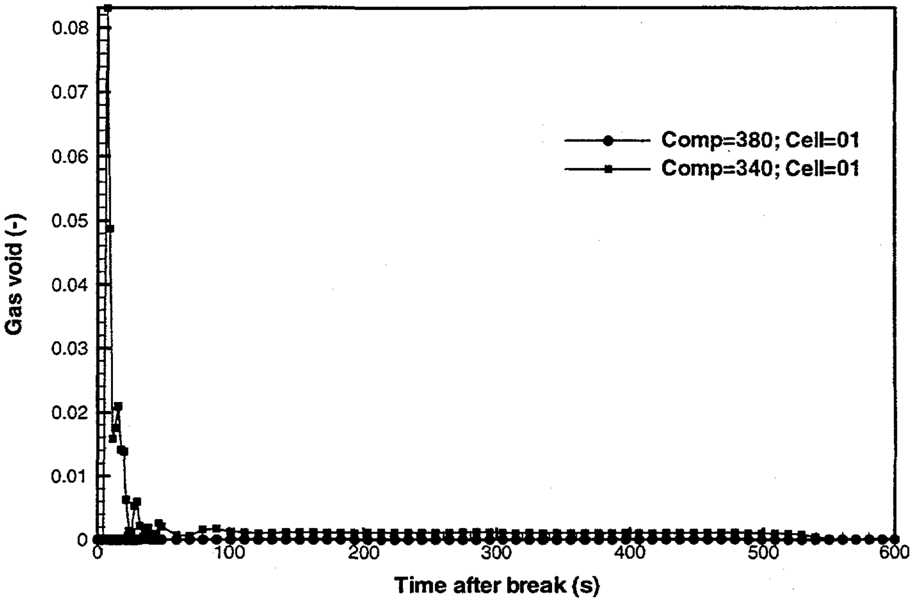

Figure B-2d Fixed header void fractions for a LOHGA (Case 1: helium supply plenum break near decoupler inlet).

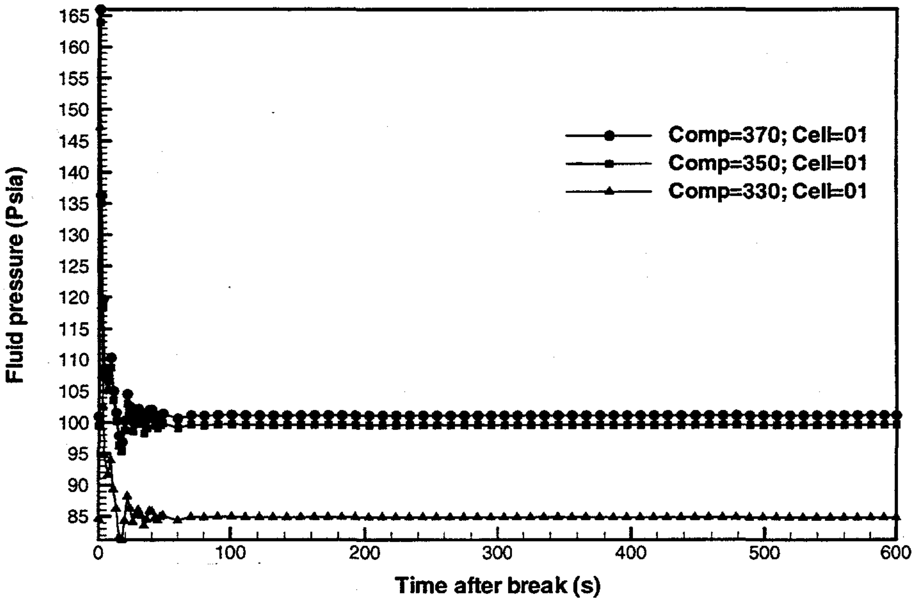

Figure B-3a Module 1 plenum fluid pressures for a LOHGA (Case 1: helium supply plenum break near decoupler inlet).

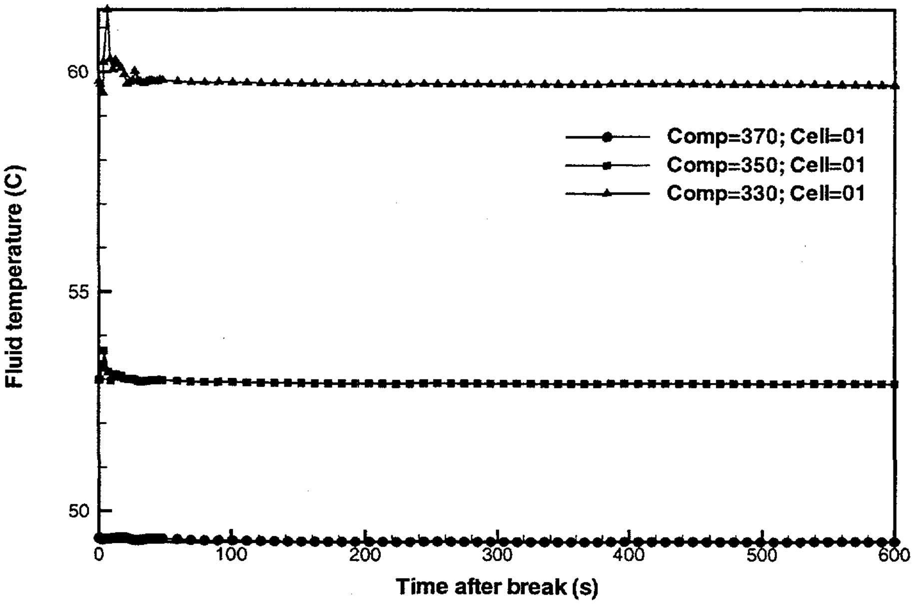

Figure B-3b Module 1 plenum fluid temperatures for a LOHGA (Case 1: helium supply plenum break near decoupler inlet).

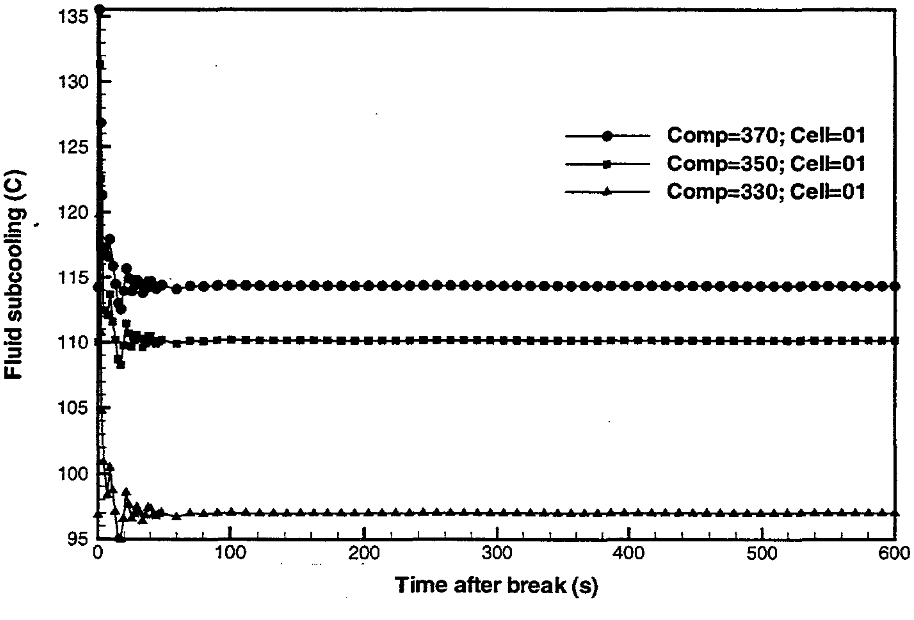

Figure B-3c Module 1 plenum fluid subcoolings for a LOHGA (Case 1: helium supply plenum break near decoupler inlet).

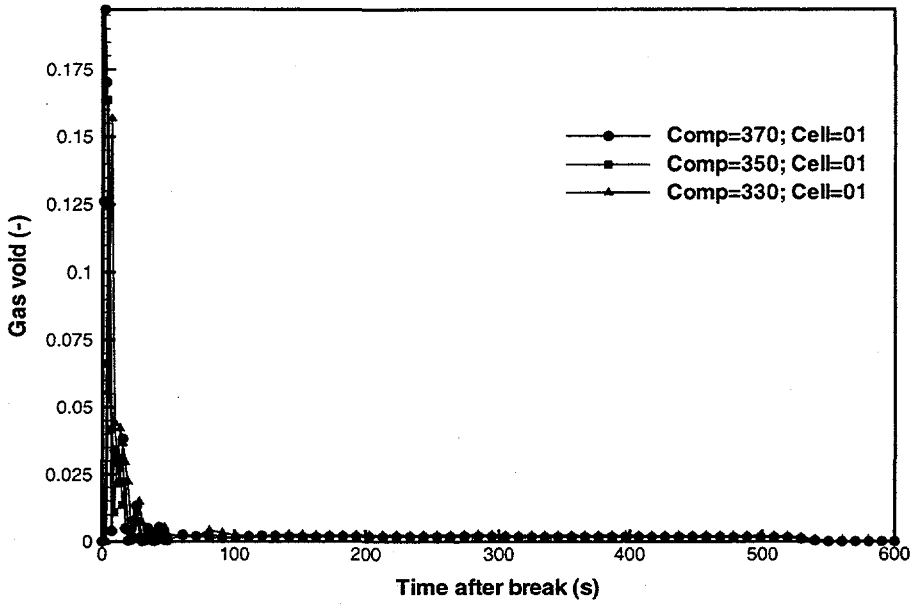

Figure B-3d Module 1 plenum void fractions for a LOHGA (Case 1: helium supply plenum break near decoupler inlet).

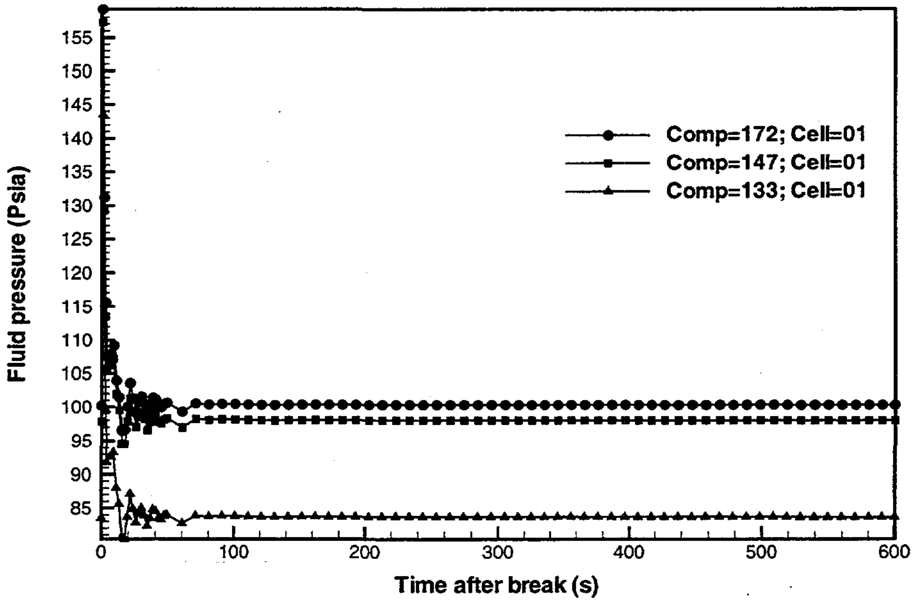

Figure B-4a Module 2 plenum fluid pressures for a LOHGA (Case 1: helium supply plenum break near decoupler inlet).

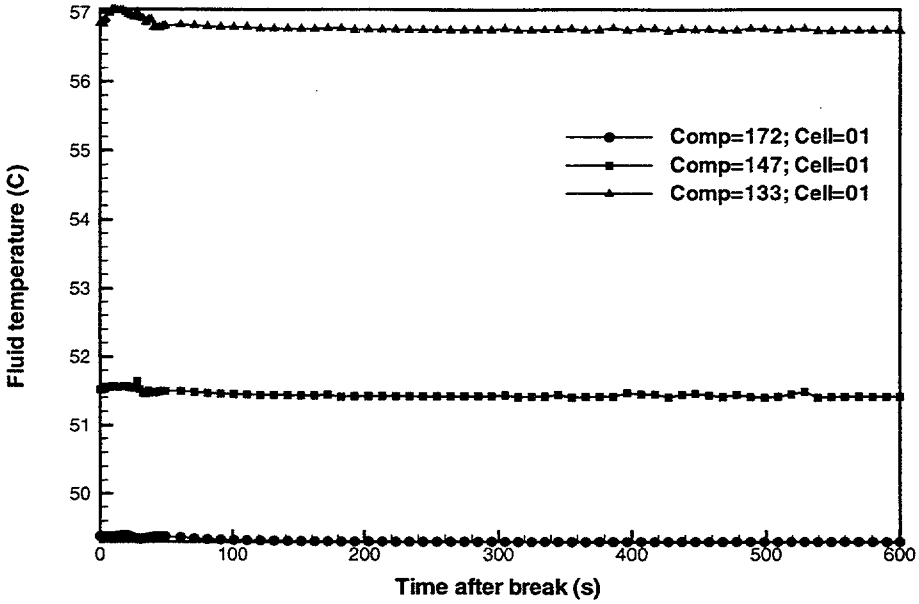

Figure B-4b Module 2 plenum fluid temperatures for a LOHGA (Case 1: helium supply plenum break near decoupler inlet).

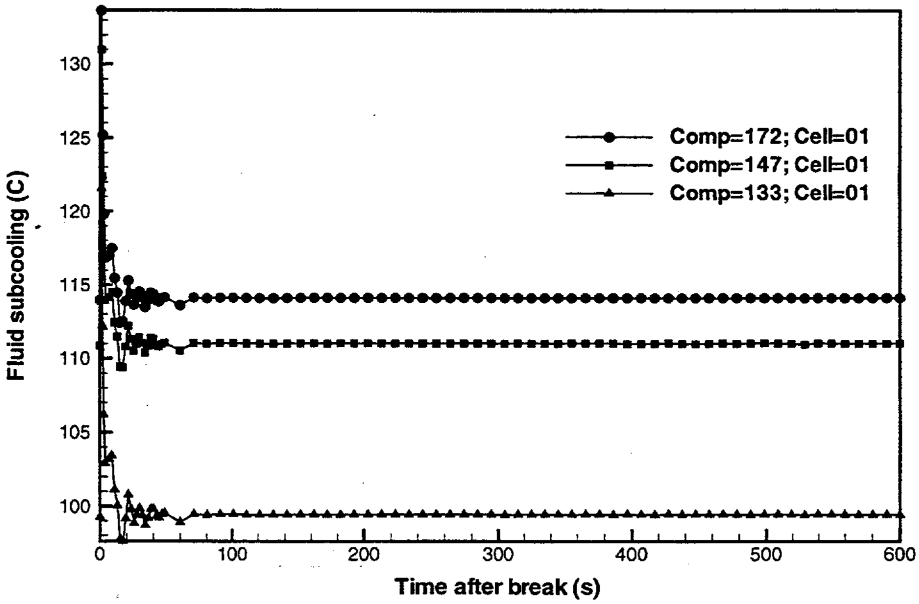

Figure B-4c Module 2 plenum fluid subcoolings for a LOHGA (Case 1: helium supply plenum break near decoupler inlet).

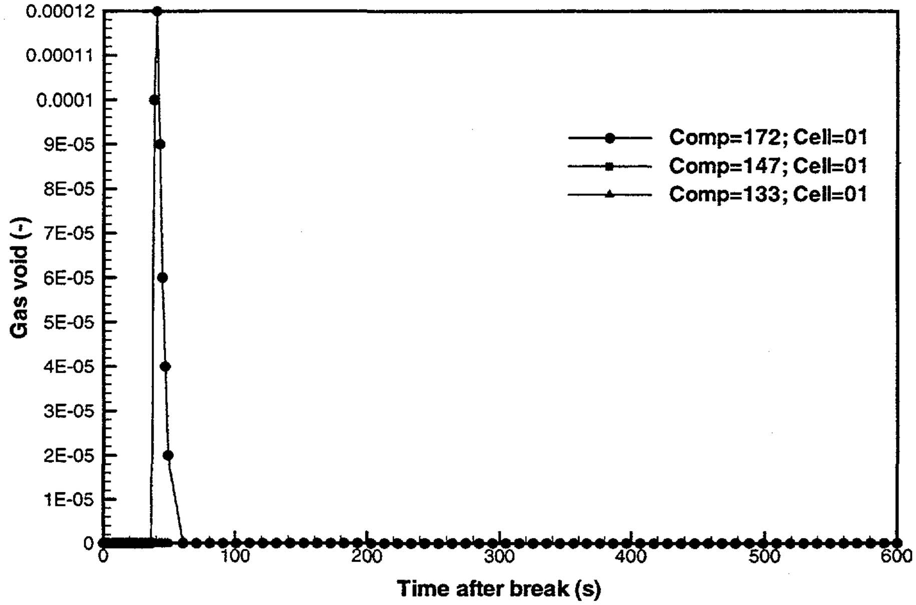

Figure B-4d Module 2 plenum void fractions for a LOHGA (Case 1: helium supply plenum break near decoupler inlet).

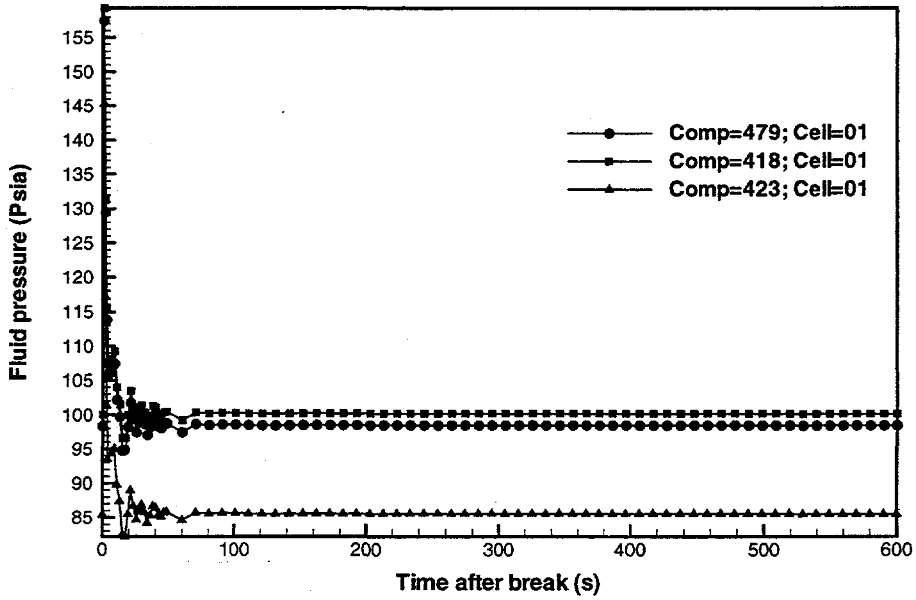

Figure B-5a Module 3 plenum fluid pressures for a LOHGA (Case 1: helium supply plenum break near decoupler inlet).

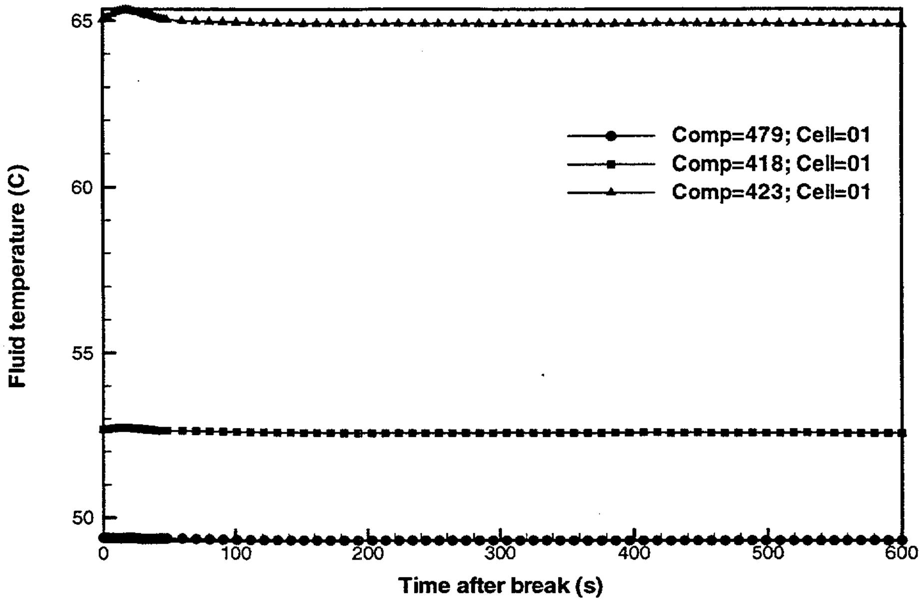

Figure B-5b Module 3 plenum fluid temperatures for a LOHGA (Case 1: helium supply plenum break near decoupler inlet).

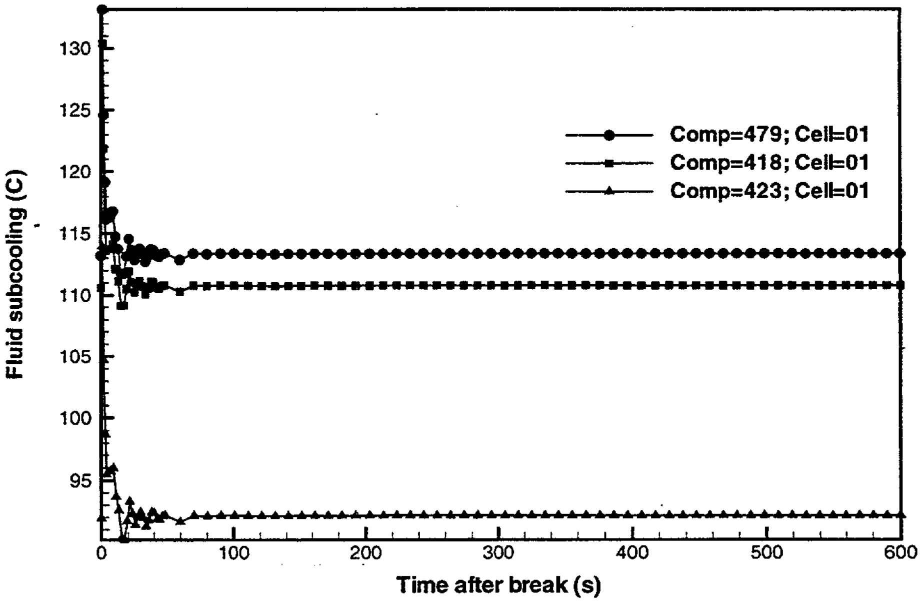

Figure B-5c Module 3 plenum fluid subcoolings for a LOHGA (Case 1: helium supply plenum break near decoupler inlet).

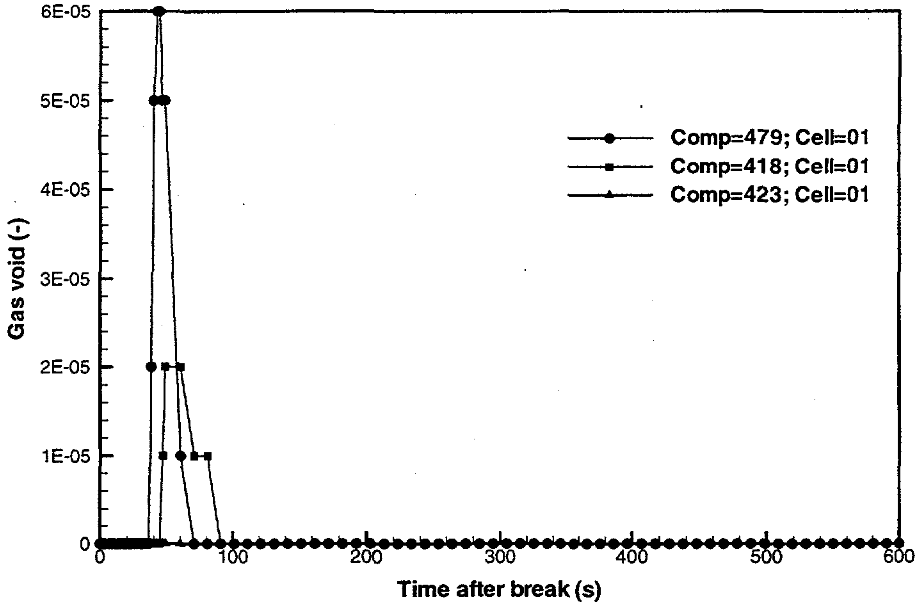

Figure B-5d Module 3 plenum void fractions for a LOHGA (Case 1: helium supply plenum break near decoupler inlet).

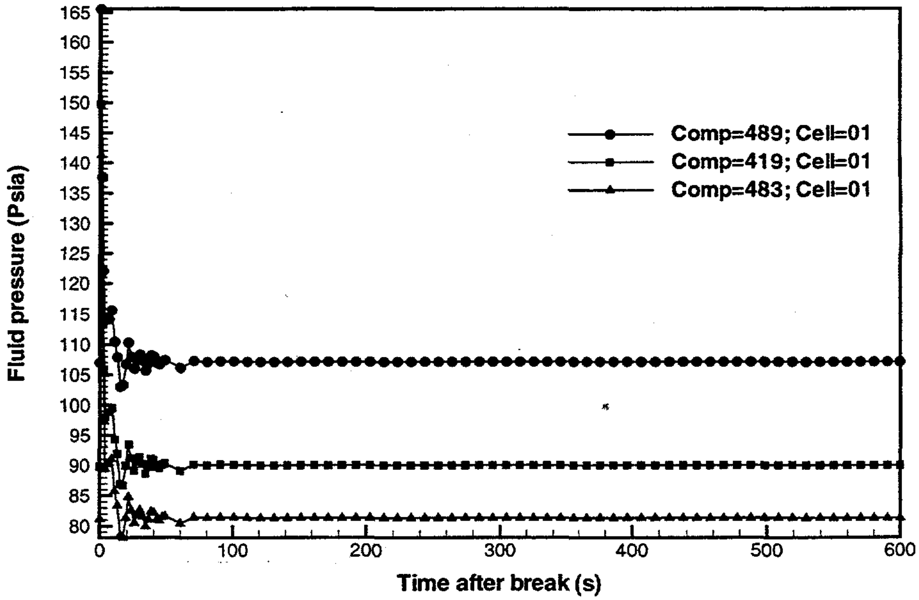

Figure B-6a Module 4 plenum fluid pressures for a LOHGA (Case 1: helium supply plenum break near decoupler inlet).

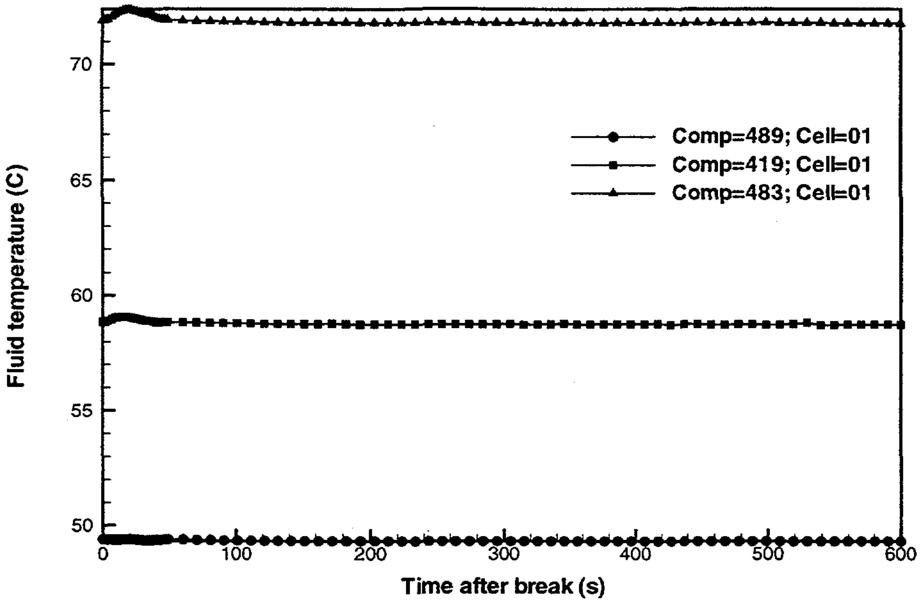

Figure B-6b Module 4 plenum fluid temperatures for a LOHGA (Case 1: helium supply plenum break near decoupler inlet).

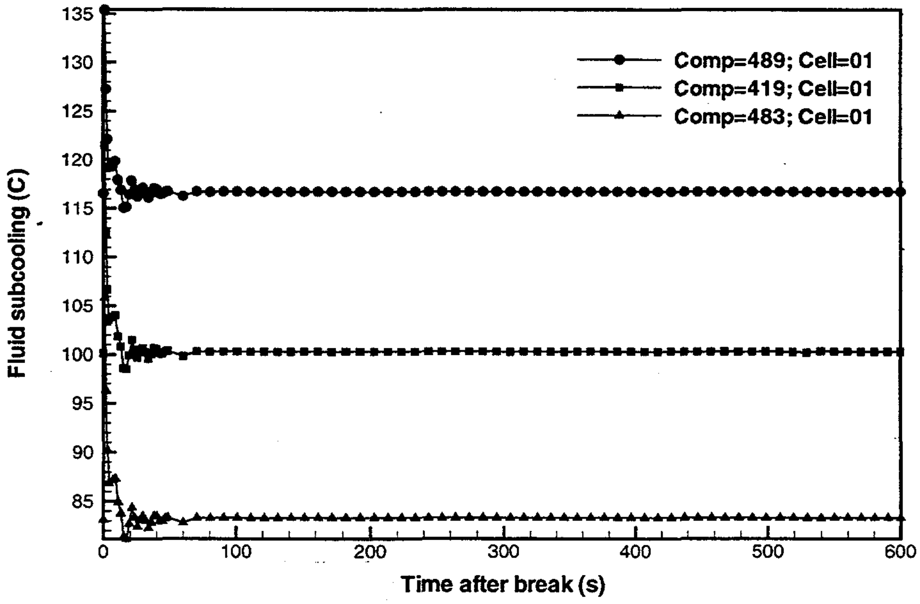

Figure B-6c Module 4 plenum fluid subcoolings for a LOHGA (Case 1: helium supply plenum break near decoupler inlet).

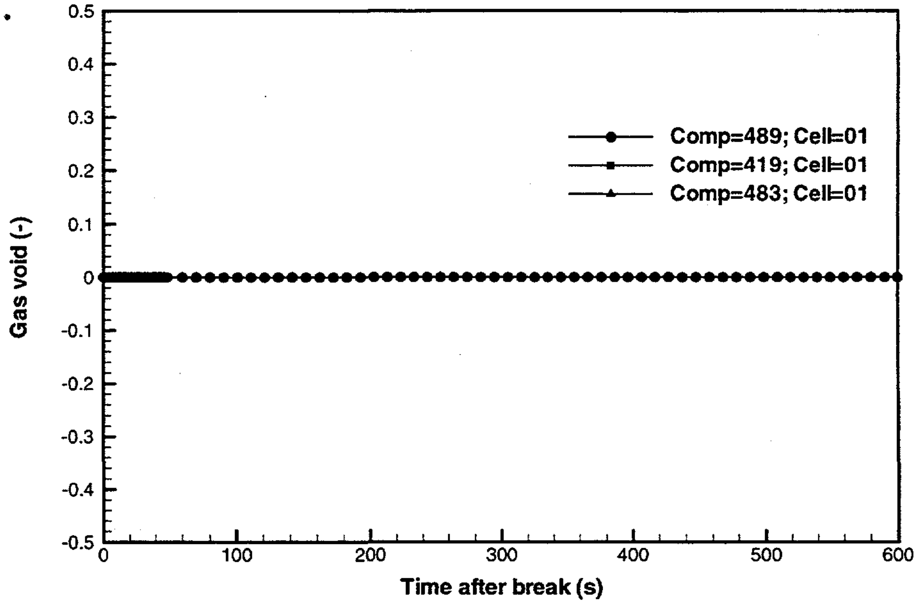

Figure B-6d Module 4 plenum void fractions for a LOHGA (Case 1: helium supply plenum break near decoupler inlet).

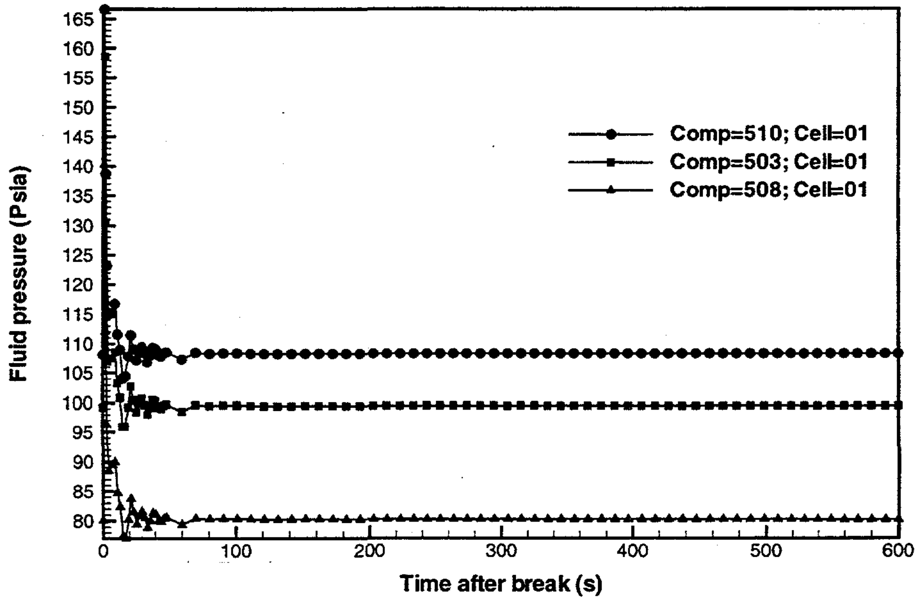

Figure B-7a Module 5 plenum fluid pressures for a LOHGA (Case 1: helium supply plenum break near decoupler inlet).

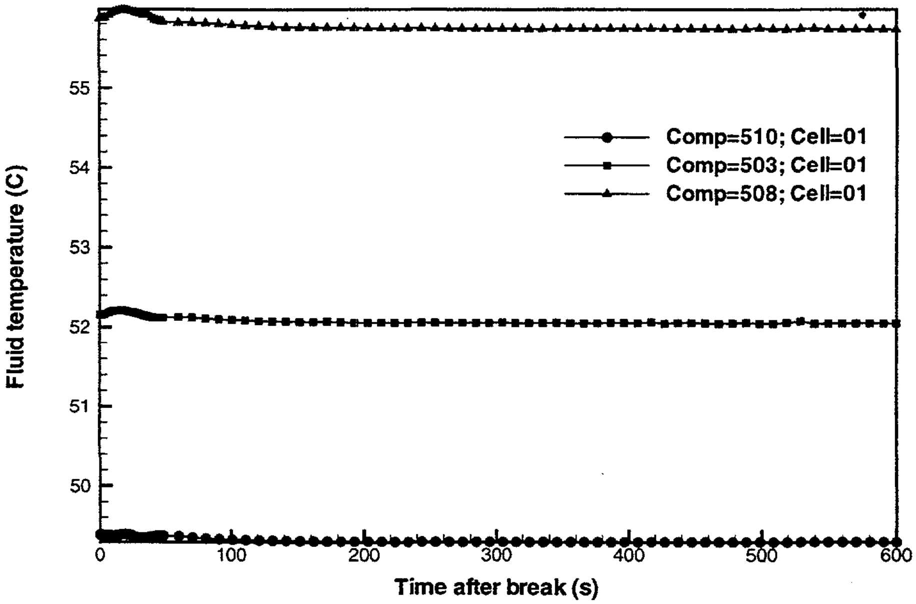

Figure B-7b Module 5 plenum fluid temperatures for a LOHGA (Case 1: helium supply plenum break near decoupler inlet).

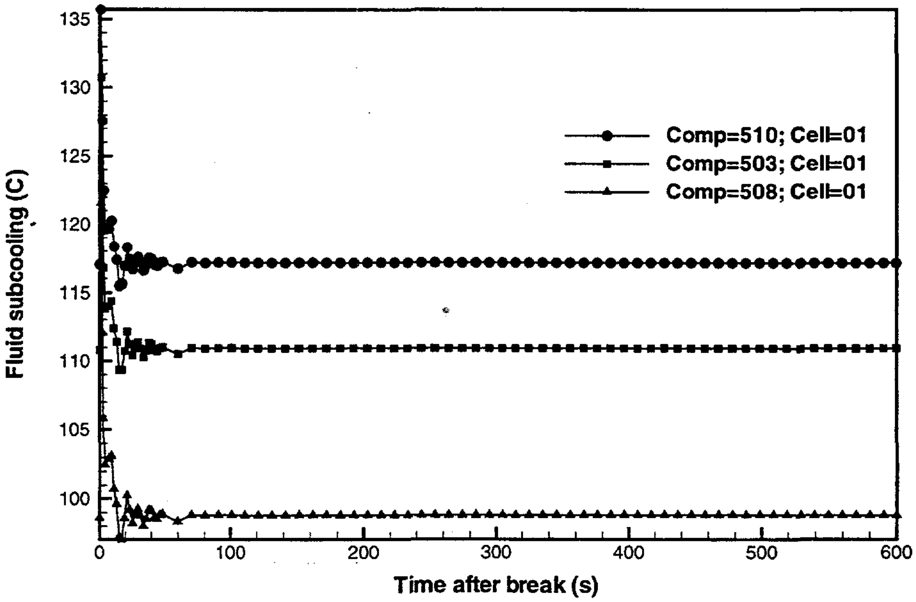

Figure B-7c Module 5 plenum fluid subcoolings for a LOHGA (Case 1: helium supply plenum break near decoupler inlet).

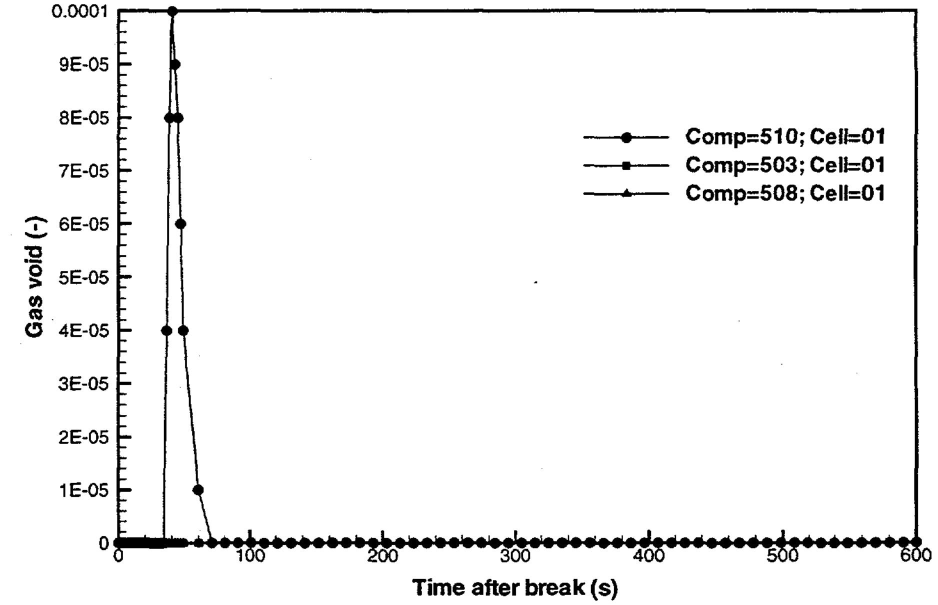

Figure B-7d Module 5 plenum void fractions for a LOHGA (Case 1: helium supply plenum break near decoupler inlet).

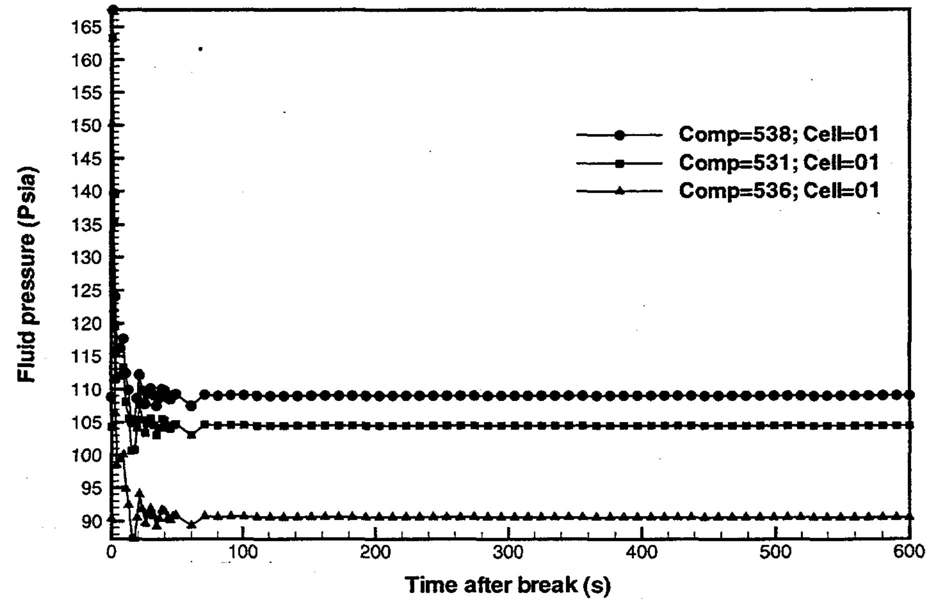

Figure B-8a Module 6 plenum fluid pressures for a LOHGA (Case 1: helium supply plenum break near decoupler inlet).

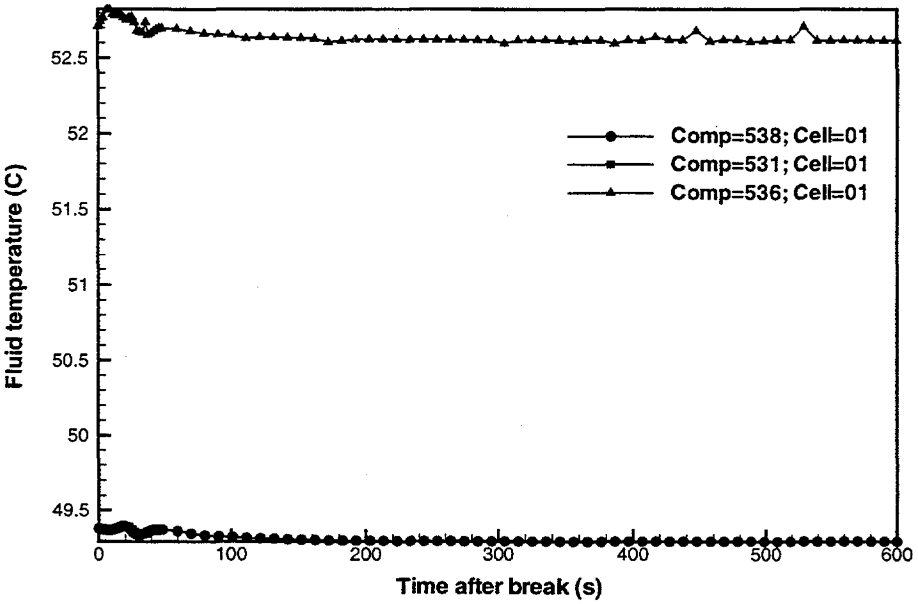

Figure B-8b Module 6 plenum fluid temperatures for a LOHGA (Case 1: helium supply plenum break near decoupler inlet).

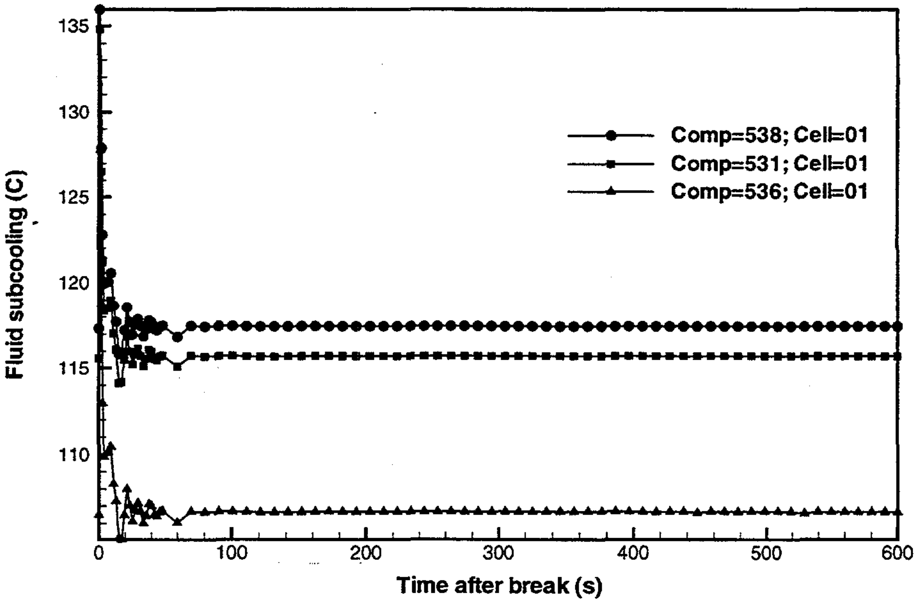

Figure B-8c Module 6 plenum fluid subcoolings for a LOHGA (Case 1: helium supply plenum break near decoupler inlet).

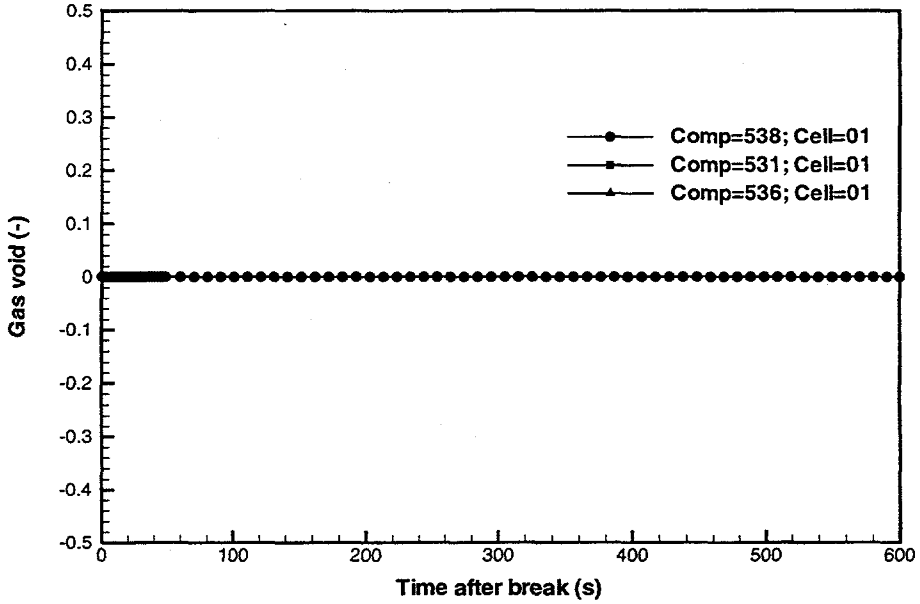

Figure B-8d Module 6 plenum void fractions for a LOHGA (Case 1: helium supply plenum break near decoupler inlet).

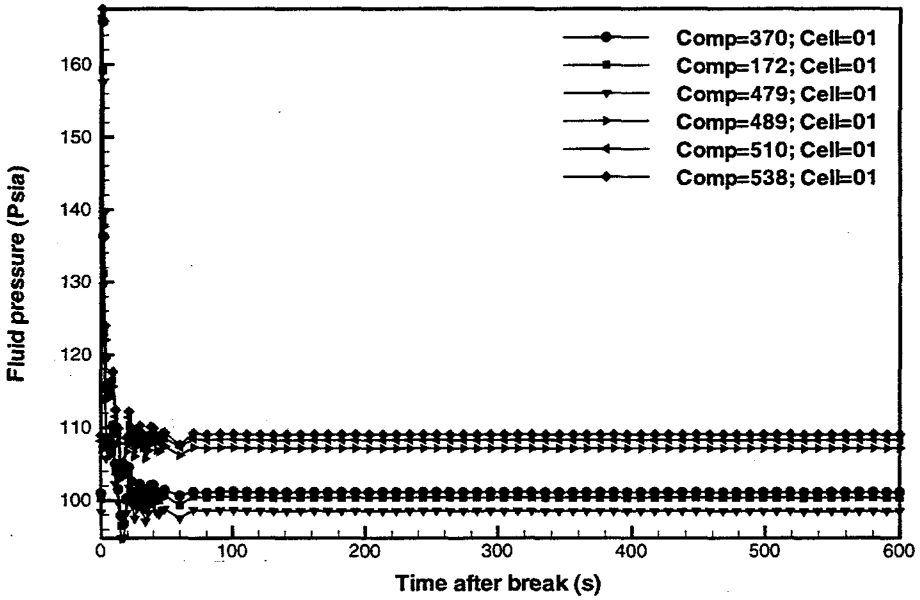

Figure B-9a Module inlet plenum fluid pressures for a LOHGA (Case 1: helium supply plenum break near decoupler inlet).

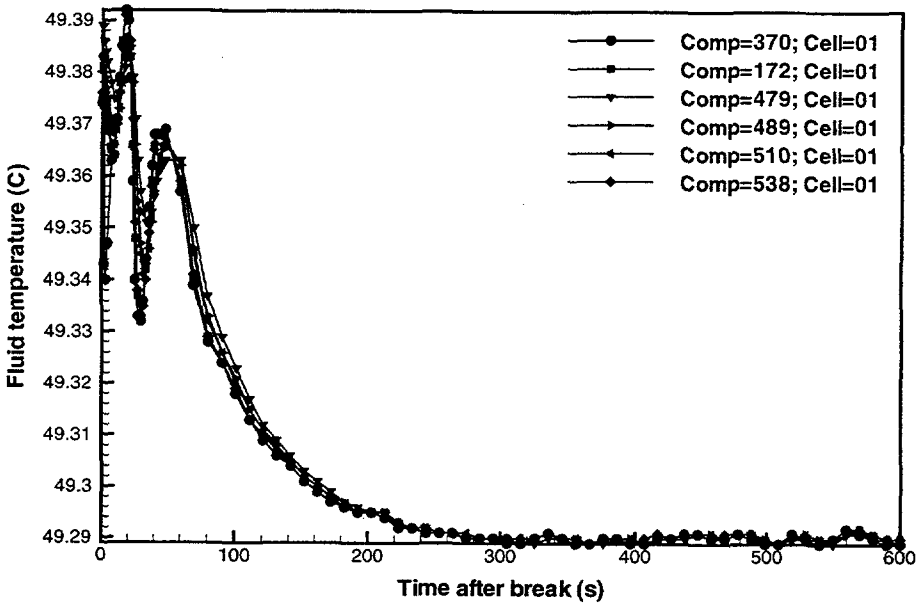

Figure B-9b Module inlet plenum fluid temperatures for a LOHGA (Case 1: helium supply plenum break near decoupler inlet).

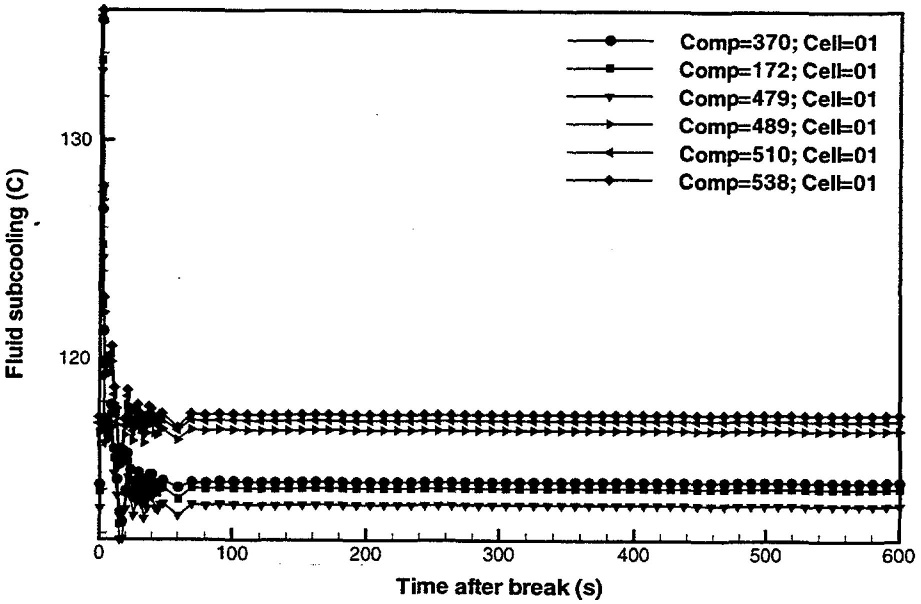

Figure B-9c Module inlet plenum fluid subcoolings for a LOHGA (Case 1: helium supply plenum break near decoupler inlet).

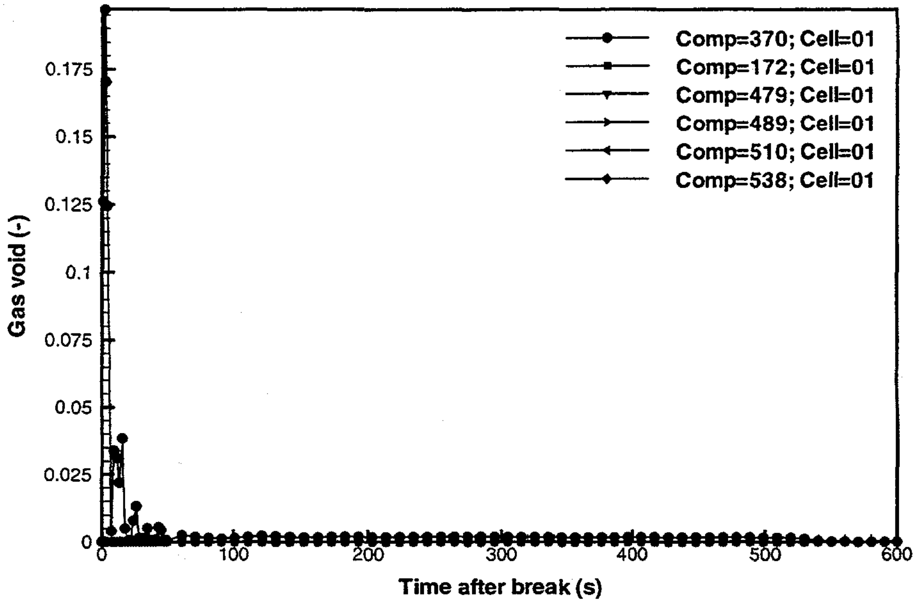

Figure B-9d Module inlet plenum void fractions for a LOHGA (Case 1: helium supply plenum break near decoupler inlet).

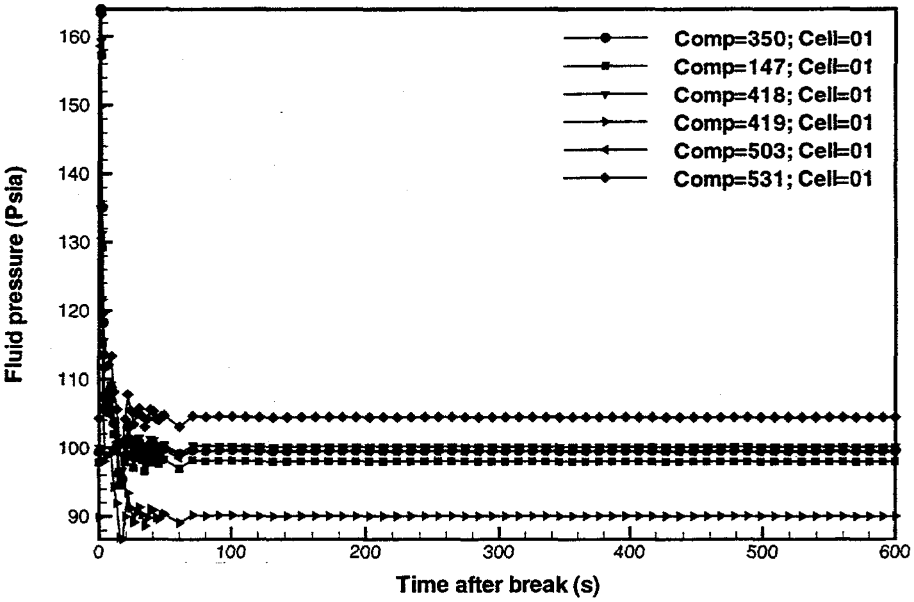

Figure B-10a Module middle plenum fluid pressures for a LOHGA (Case 1: helium supply plenum break near decoupler inlet).

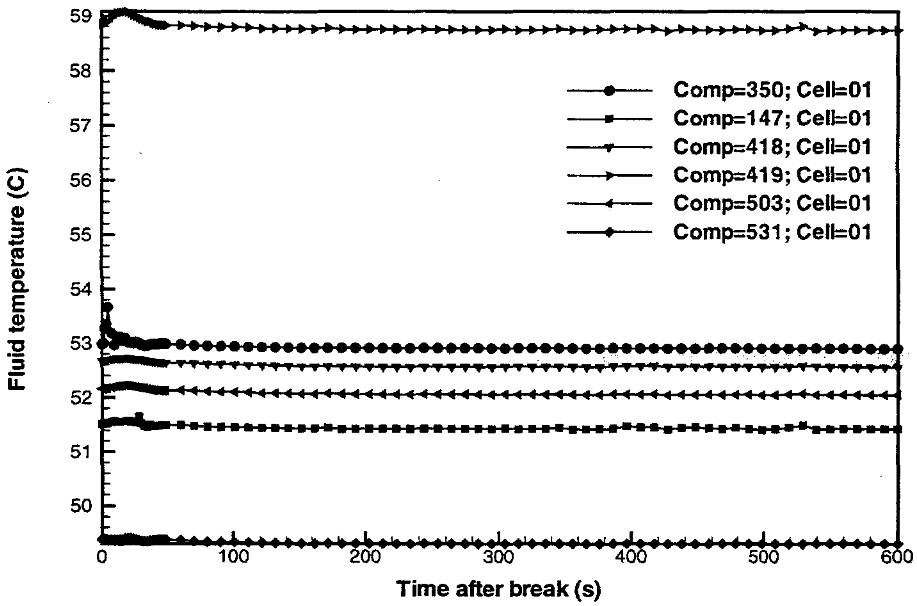

Figure B-10b Module middle plenum fluid temperatures for a LOHGA (Case 1: helium supply plenum break near decoupler inlet).

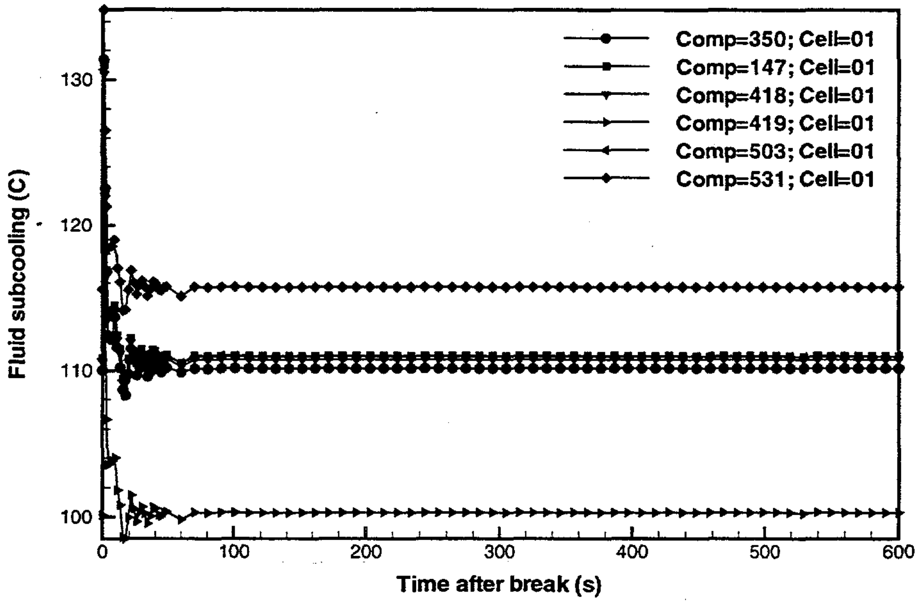

Figure B-10c Module middle plenum fluid subcoolings for a LOHGA (Case 1: helium supply plenum break near decoupler inlet).

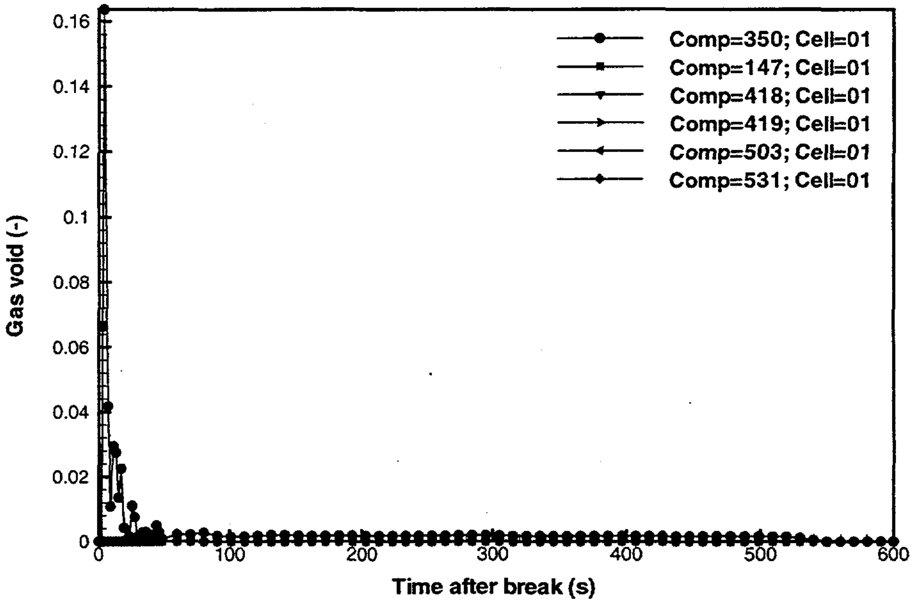

Figure B-10d Module middle plenum void fractions for a LOHGA (Case 1: helium supply plenum break near decoupler inlet).

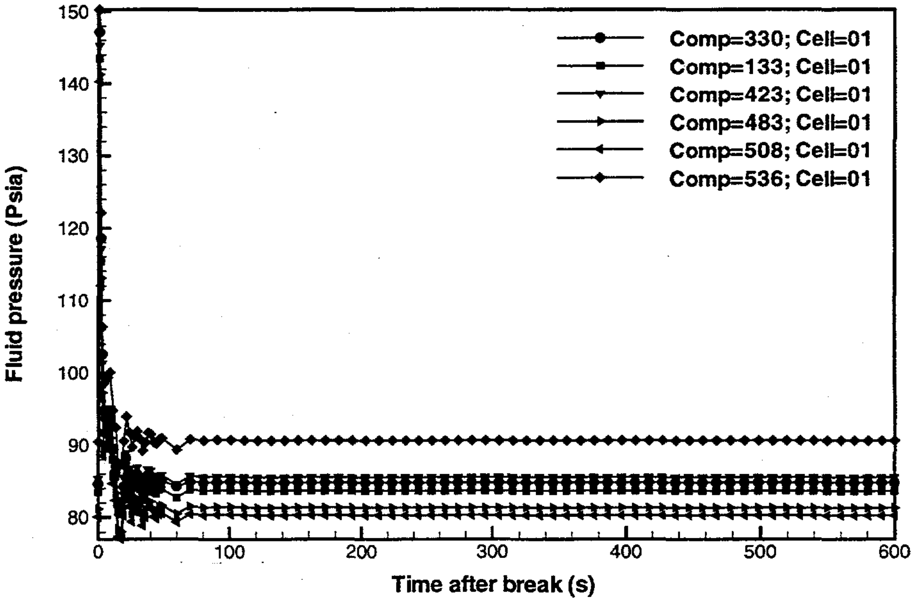

Figure B-11a Module outlet plenum fluid pressures for a LOHGA (Case 1: helium supply plenum break near decoupler inlet).

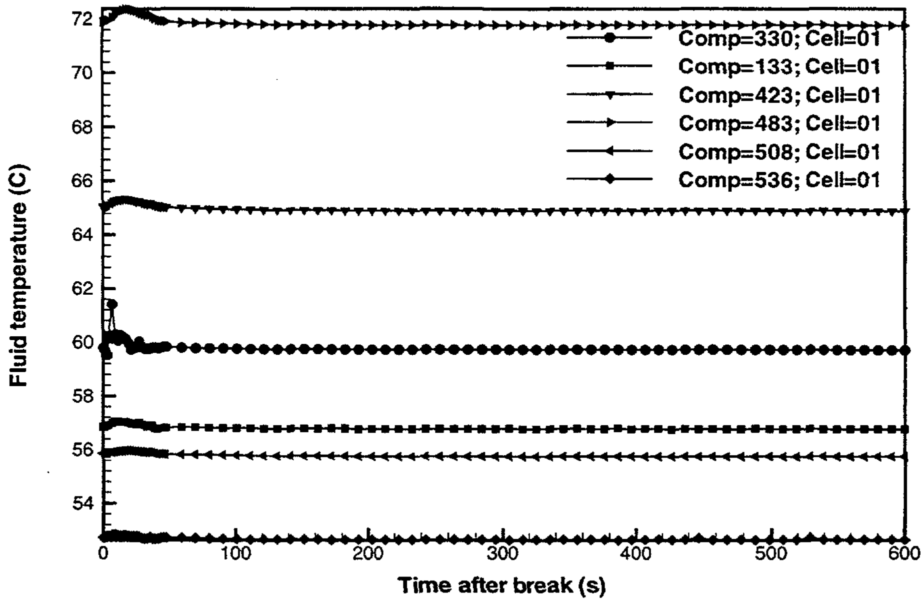

Figure B-11b Module outlet plenum fluid temperatures for a LOHGA (Case 1: helium supply plenum break near decoupler inlet).

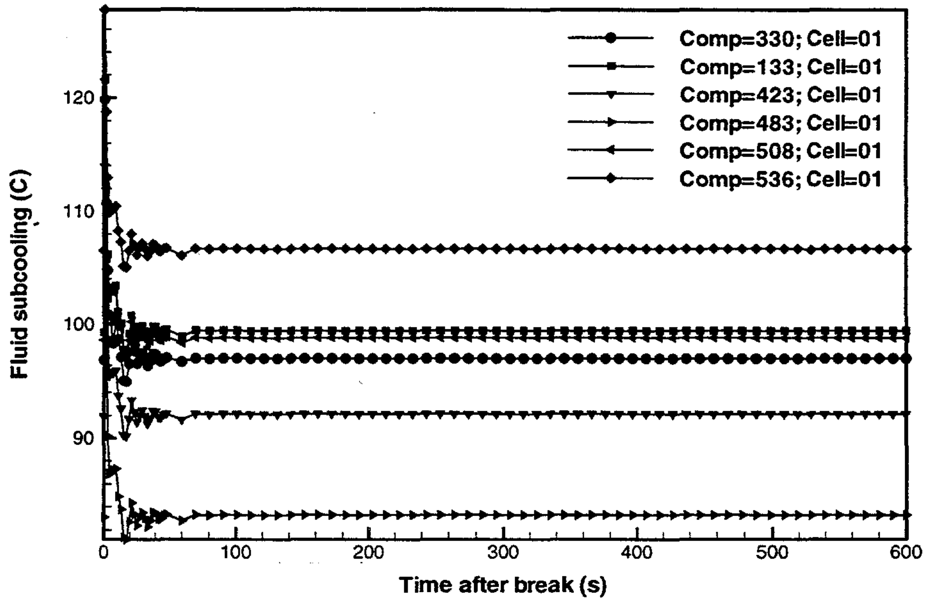

Figure B-11c Module outlet plenum fluid subcoolings for a LOHGA (Case 1: helium supply plenum break near decoupler inlet).

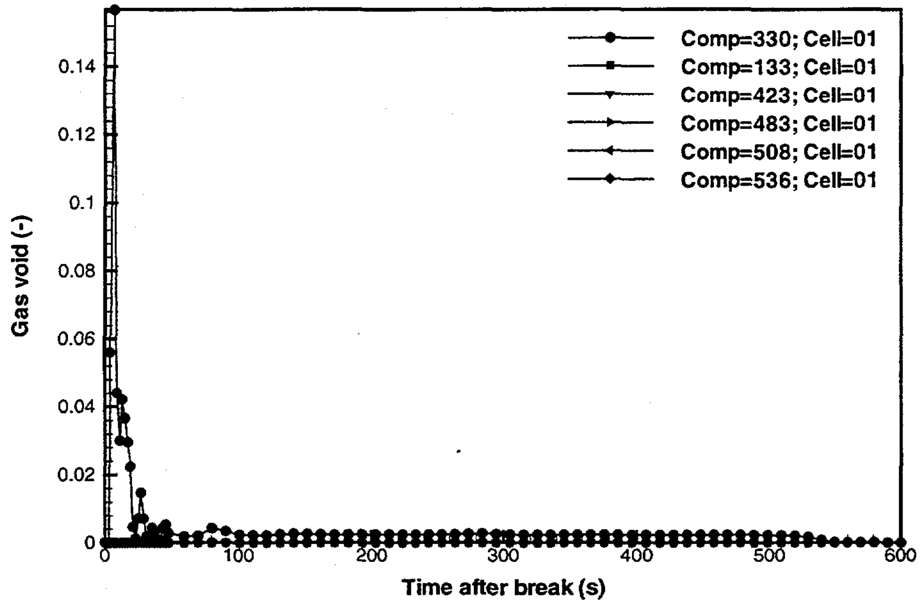

Figure B-11d Module outlet plenum void fractions for a LOHGA (Case 1: helium supply plenum break near decoupler inlet).

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

The following figures are from a TRAC simulation for Case 1 of a LOHGA (Helium supply plenum break near decoupler inlet):

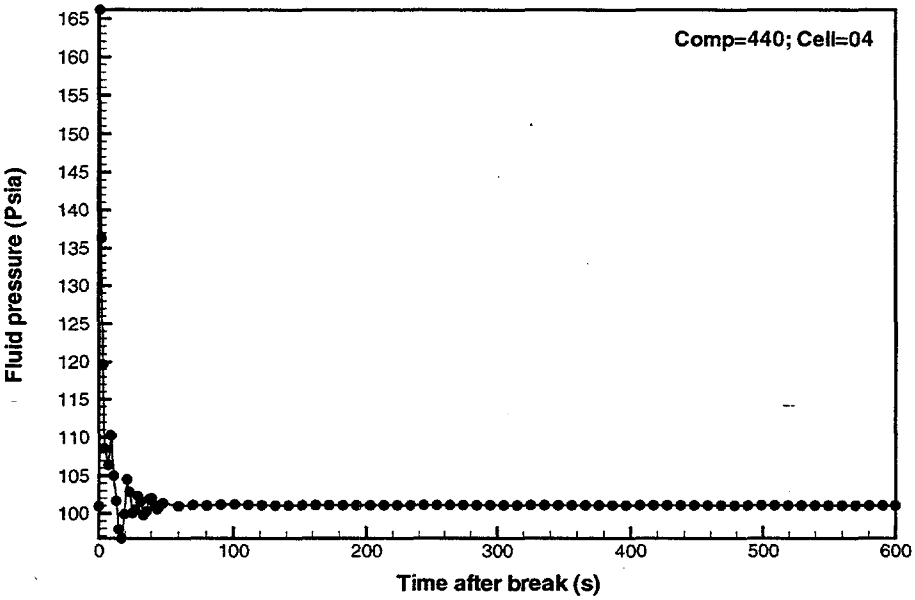

Figure B-12a Helium gas line fluid pressures for a LOHGA (Case 1: helium supply plenum break near decoupler inlet).

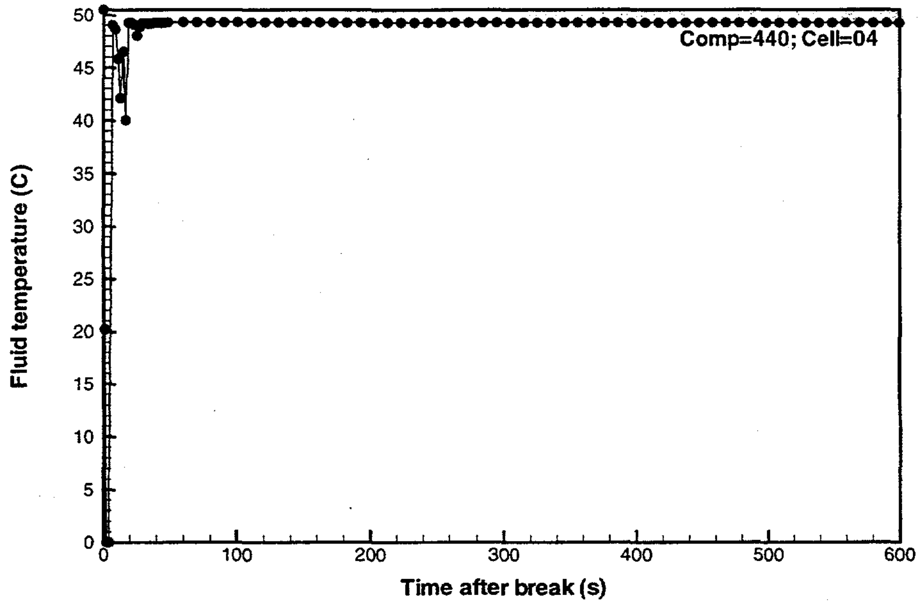

Figure B-12b Helium gas line fluid temperatures for a LOHGA (Case 1: helium supply plenum break near decoupler inlet).

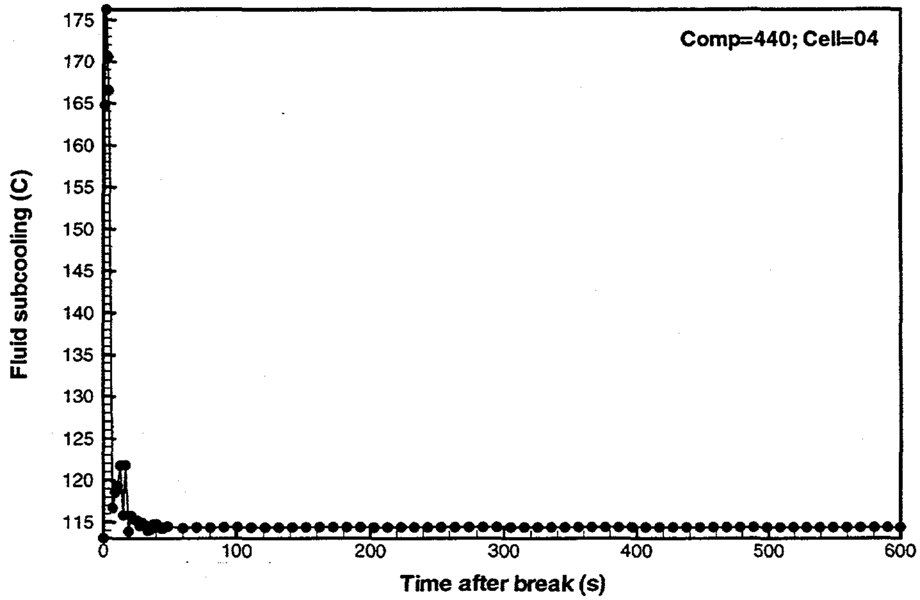

Figure B-12c Helium gas line fluid subcoolings for a LOHGA (Case 1: helium supply plenum break near decoupler inlet).

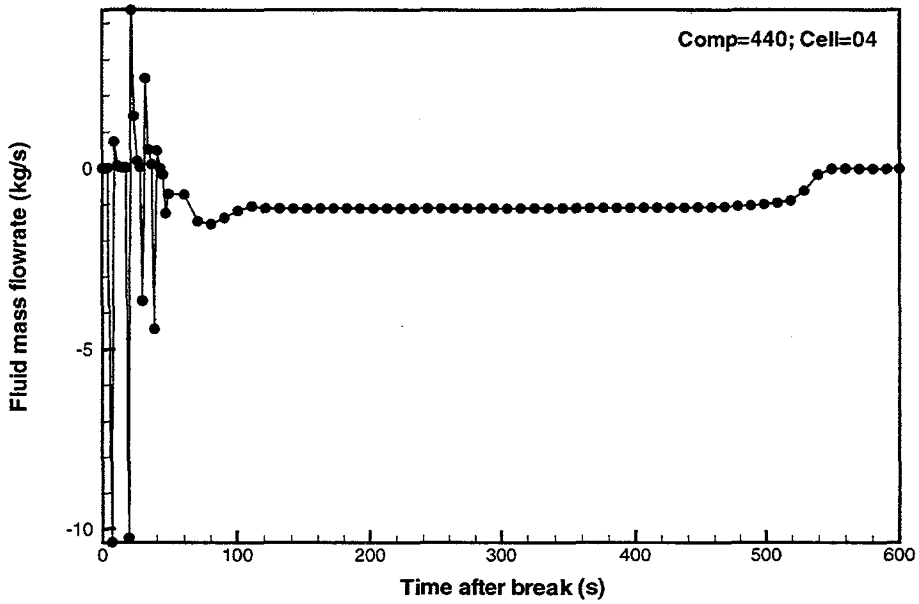

Figure B-12d Helium gas line liquid mass flowrates for a LOHGA (Case 1: helium supply plenum break near decoupler inlet).

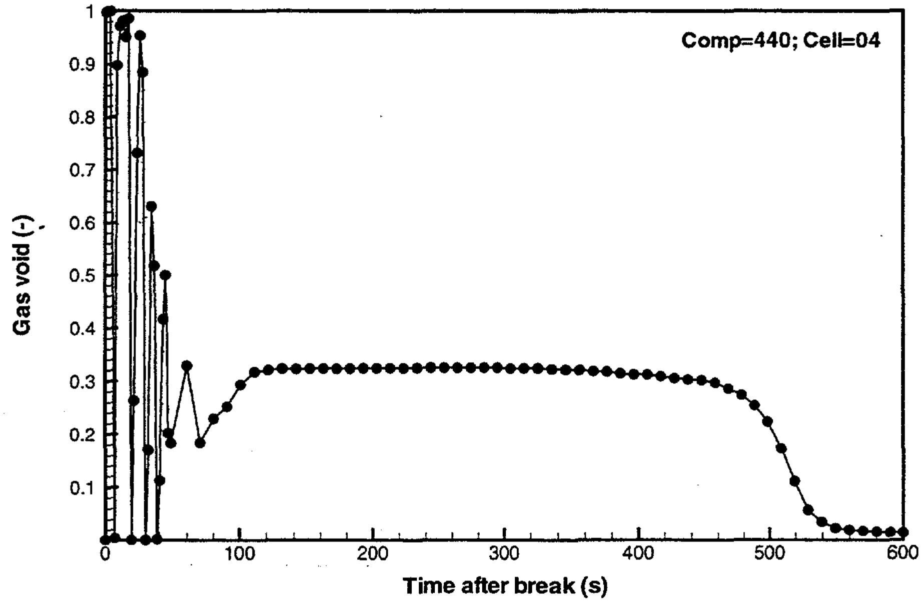

Figure B-12e Helium gas line void fractions for a LOHGA (Case 1: helium supply plenum break near decoupler inlet).

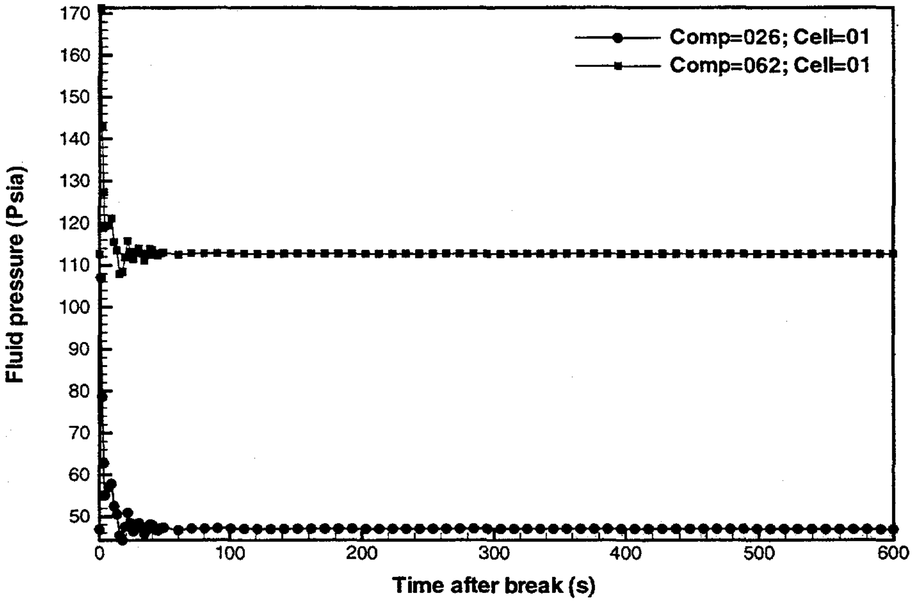

Figure B-13a Primary HR hot and cold leg piping fluid pressures for a LOHGA (Case 1: helium supply plenum break near decoupler inlet).

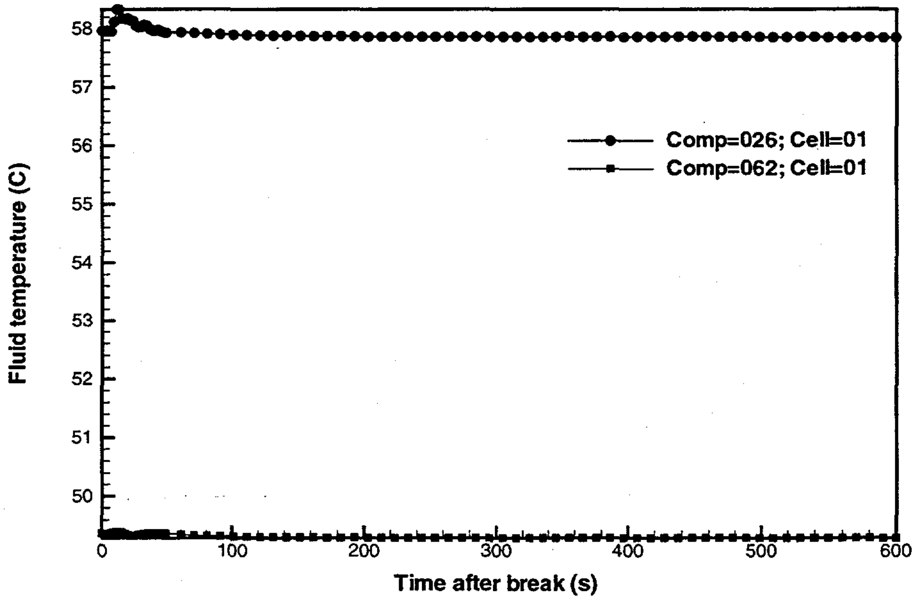

Figure B-13b Primary HR hot and cold leg piping fluid temperatures for a LOHGA (Case 1: helium supply plenum break near decoupler inlet).

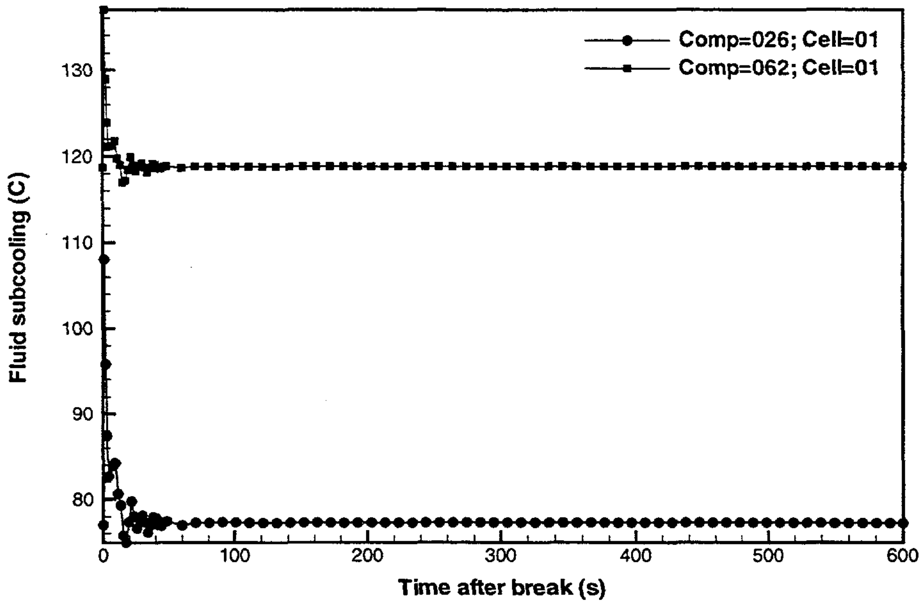

Figure B-13c Primary HR hot and cold leg piping fluid subcoolings for a LOHGA (Case 1: helium supply plenum break near decoupler inlet).

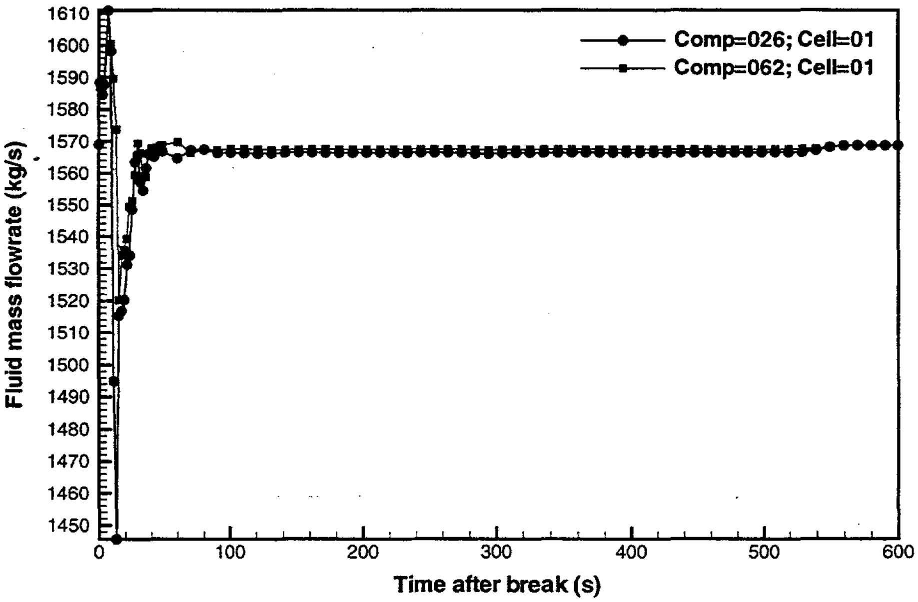

Figure B-13d Primary HR hot and cold leg piping liquid mass flowrates for a LOHGA (Case 1: helium supply plenum break near decoupler inlet).

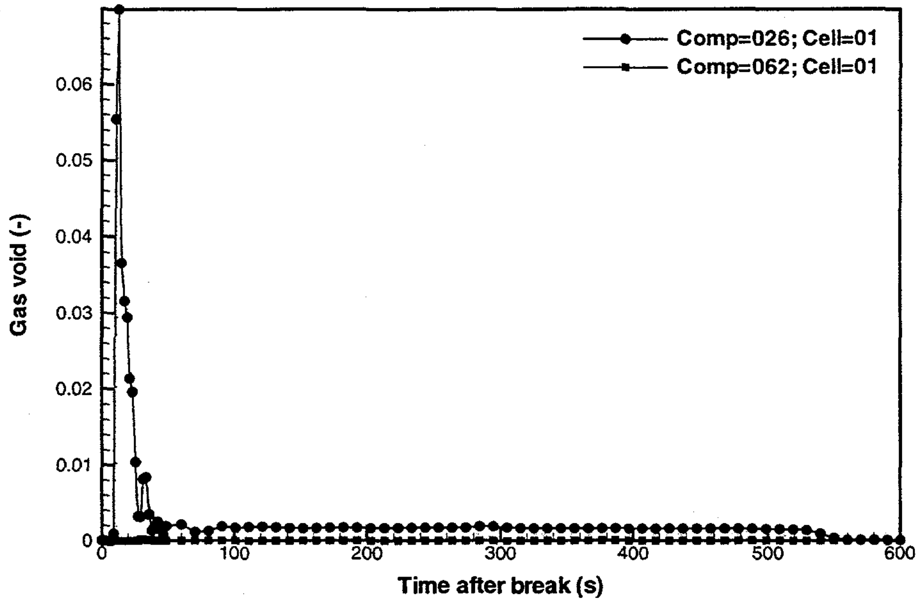

Figure B-13e Primary HR hot and cold leg piping void fractions for a LOHGA (Case 1: helium supply plenum break near decoupler inlet).

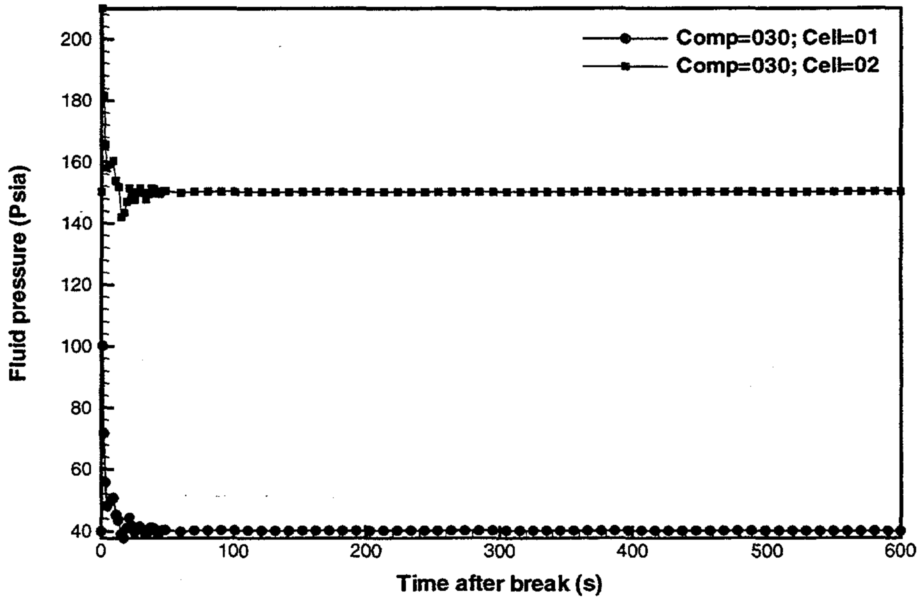

Figure B-14a Primary HR pump 1 fluid pressures for a LOHGA (Case 1: helium supply plenum break near decoupler inlet).

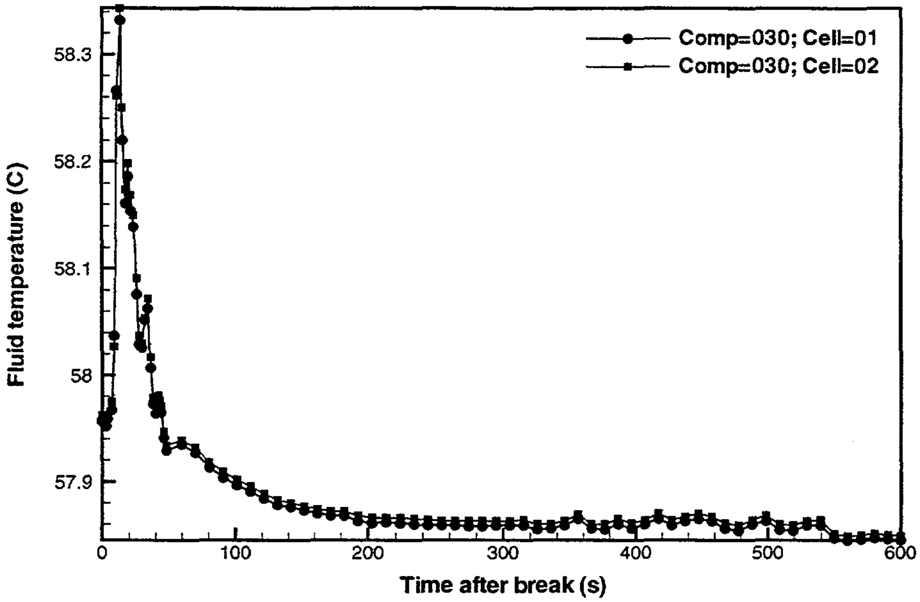

Figure B-14b Primary HR pump 1 fluid temperatures for a LOHGA (Case 1: helium supply plenum break near decoupler inlet).

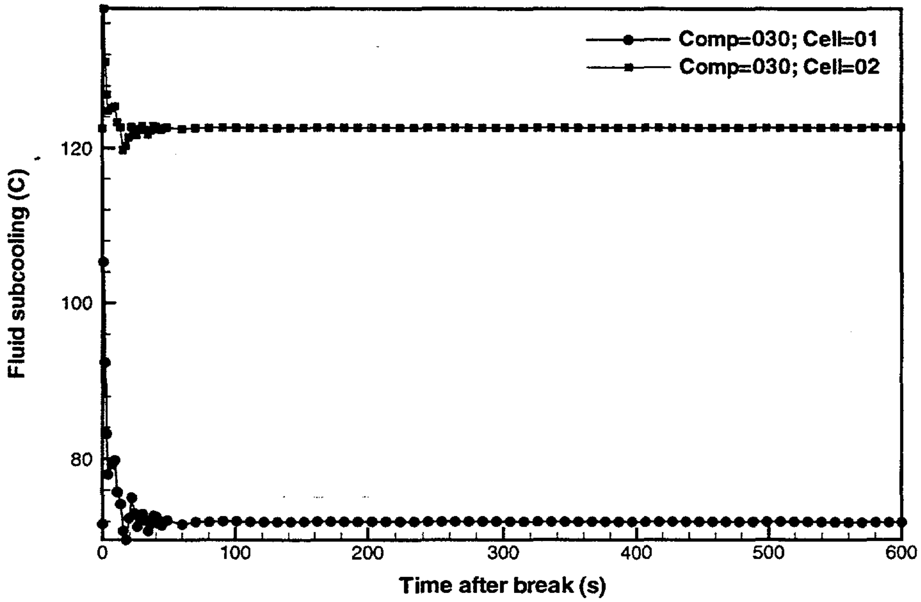

Figure B-14c Primary HR pump 1 fluid subcoolings for a LOHGA (Case 1: helium supply plenum break near decoupler inlet).

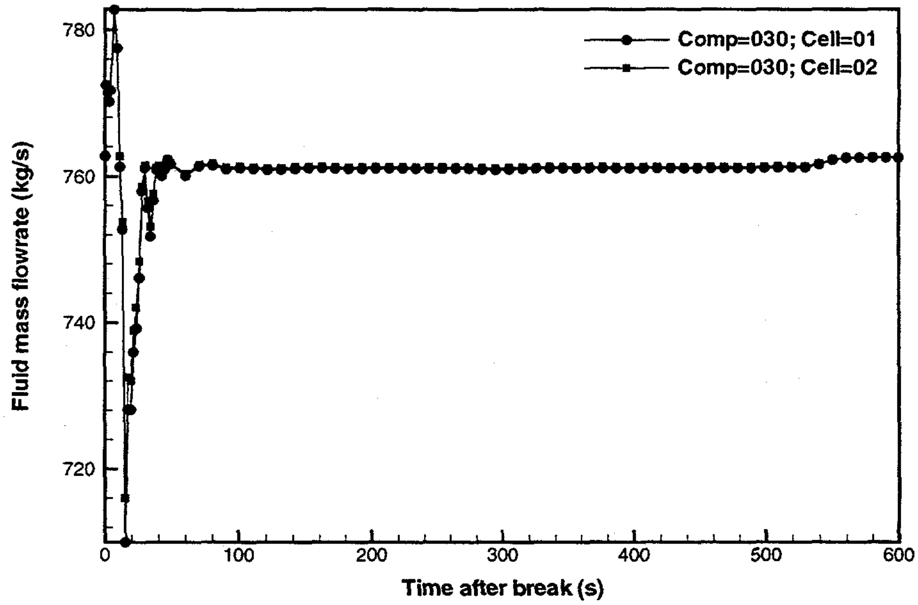

Figure B-14d Primary HR pump 1 liquid mass flowrates for a LOHGA (Case 1: helium supply plenum break near decoupler inlet).

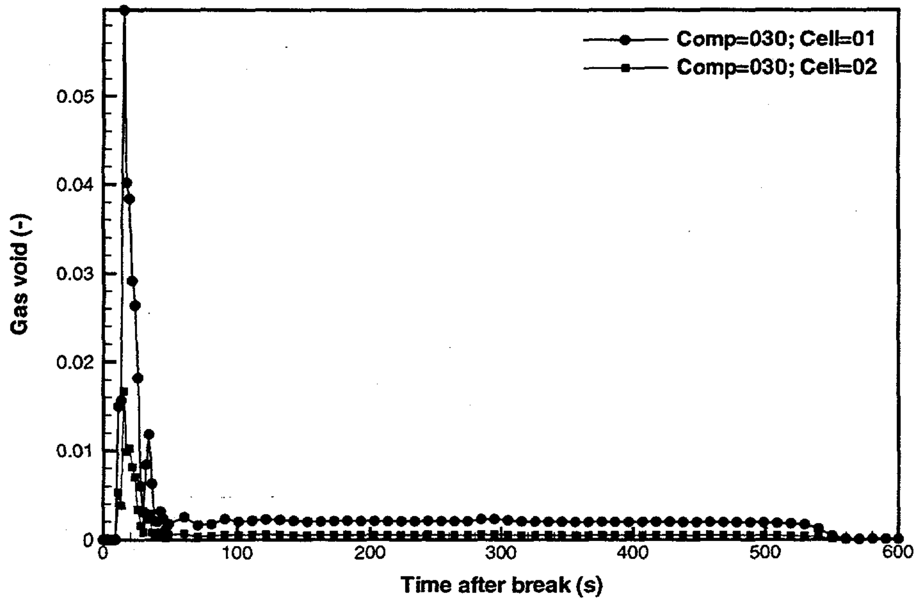

Figure B-14e Primary HR pump 1 void fractions for a LOHGA (Case 1: helium supply plenum break near decoupler inlet).

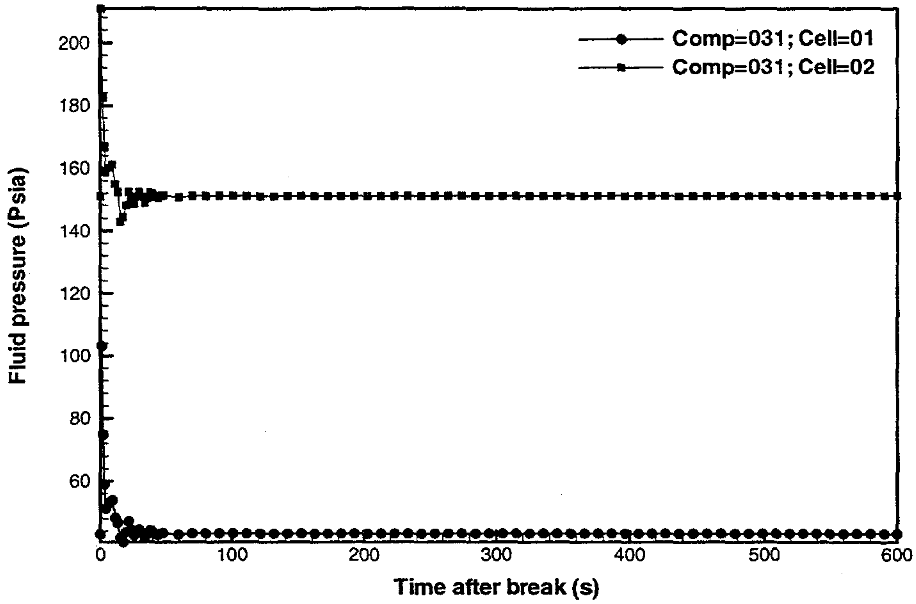

Figure B-15a Primary HR pump 2 fluid pressures for a LOHGA (Case 1: helium supply plenum break near decoupler inlet).

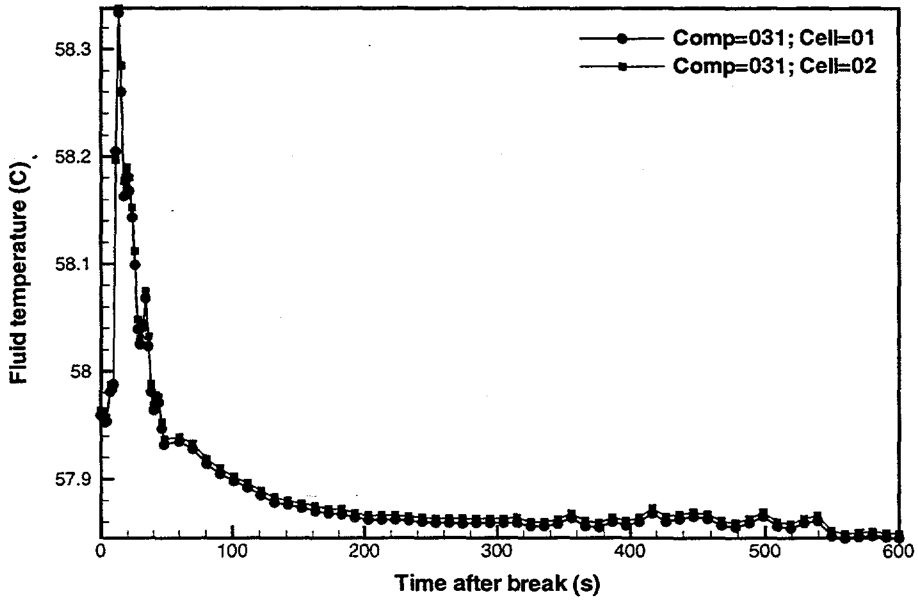

Figure B-15b Primary HR pump 2 fluid temperatures for a LOHGA (Case 1: helium supply plenum break near decoupler inlet).

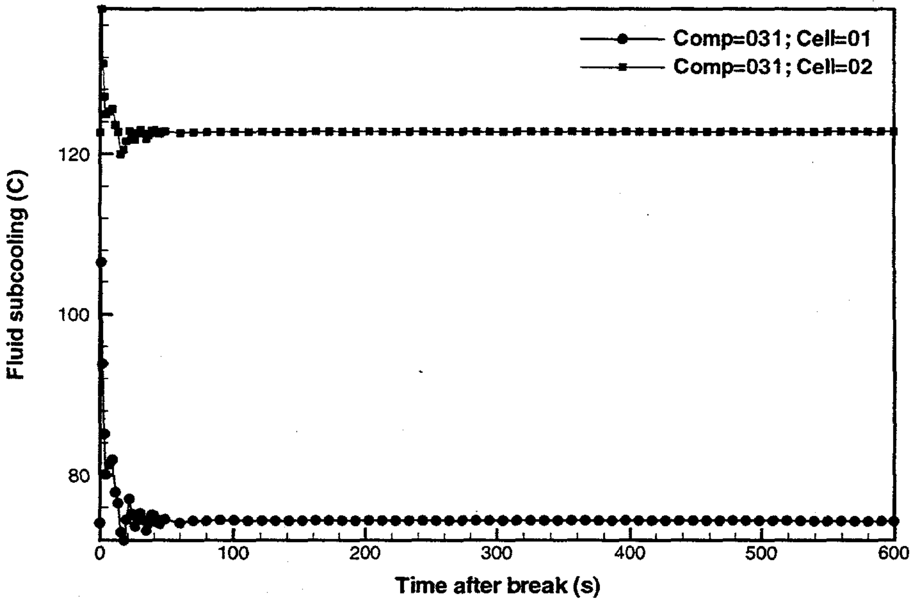

Figure B-15c Primary HR pump 2 fluid subcoolings for a LOHGA (Case 1: helium supply plenum break near decoupler inlet).

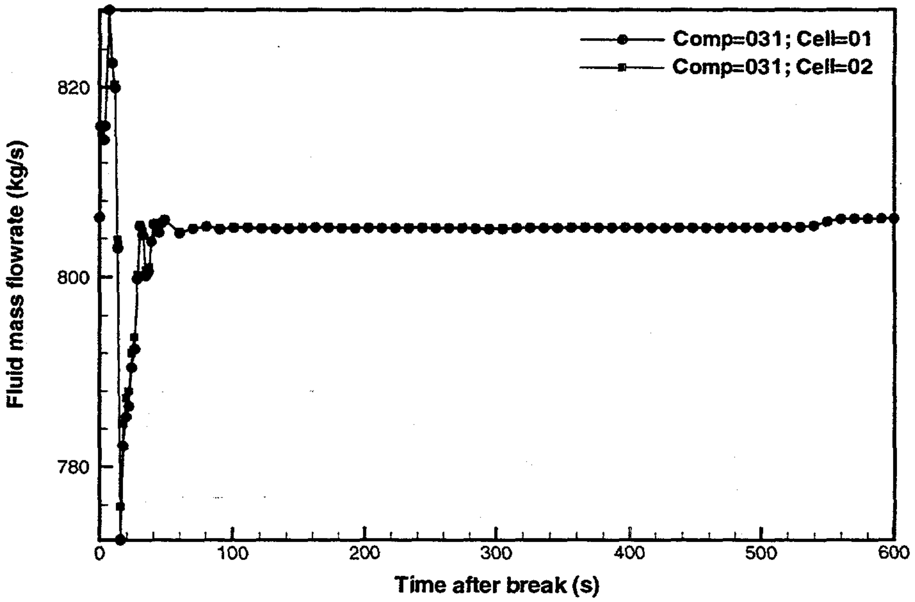

Figure B-15d Primary HR pump 2 liquid mass flowrates for a LOHGA (Case 1: helium supply plenum break near decoupler inlet).

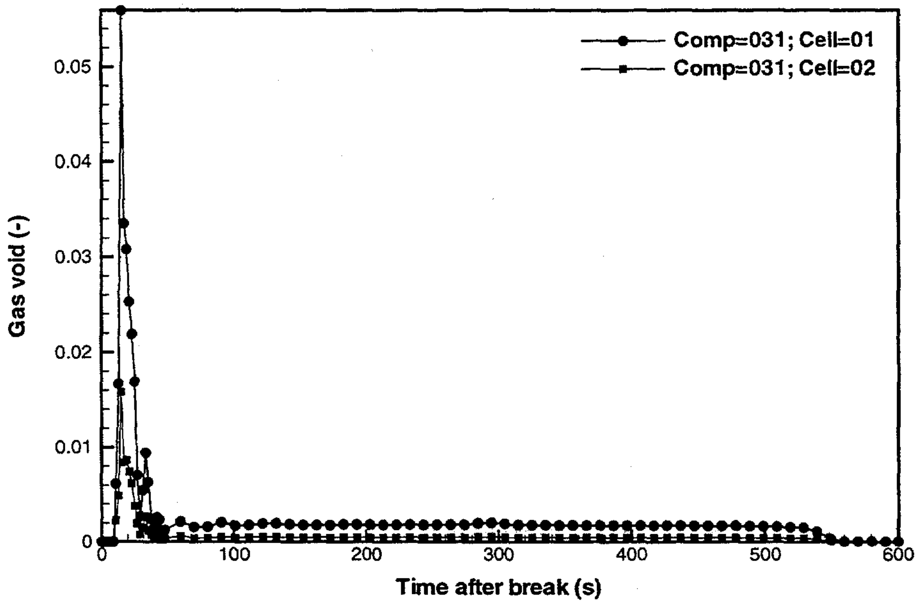

Figure B-15e Primary HR pump 2 void fractions for a LOHGA (Case 1: helium supply plenum break near decoupler inlet).

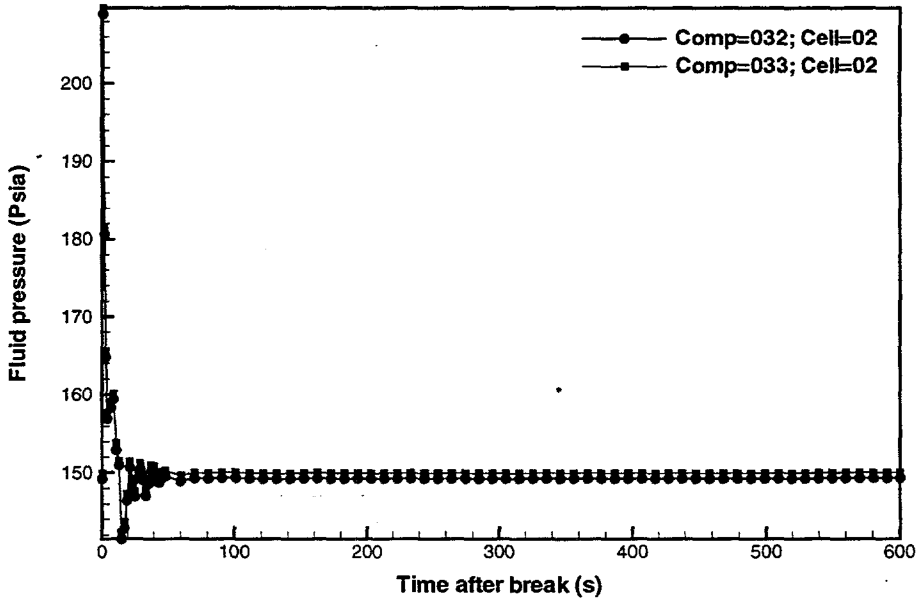

Figure B-16a Primary HR pump discharge piping fluid pressures for a LOHGA (Case 1: helium supply plenum break near decoupler inlet).

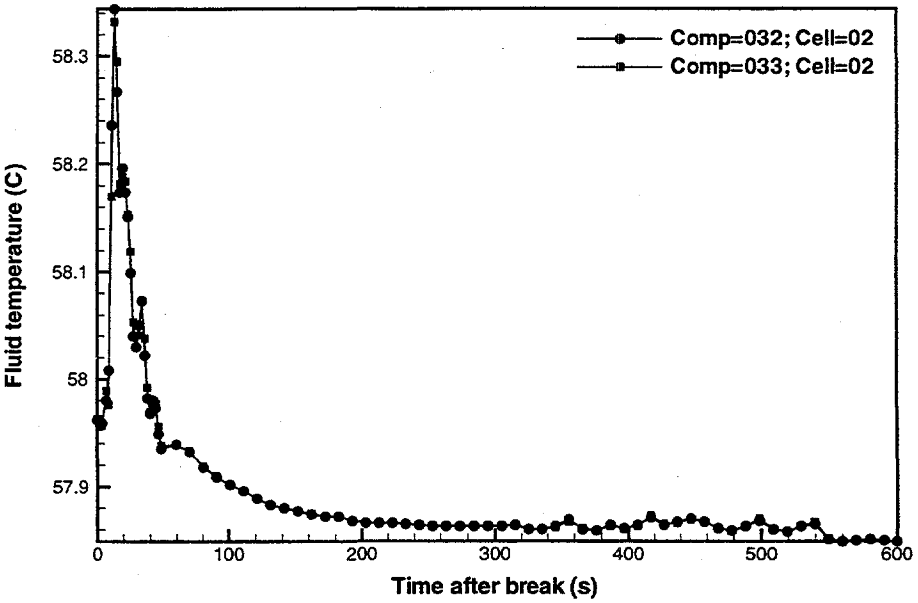

Figure B-16b Primary HR pump discharge piping fluid temperatures for a LOHGA (Case 1: helium supply plenum break near decoupler inlet).

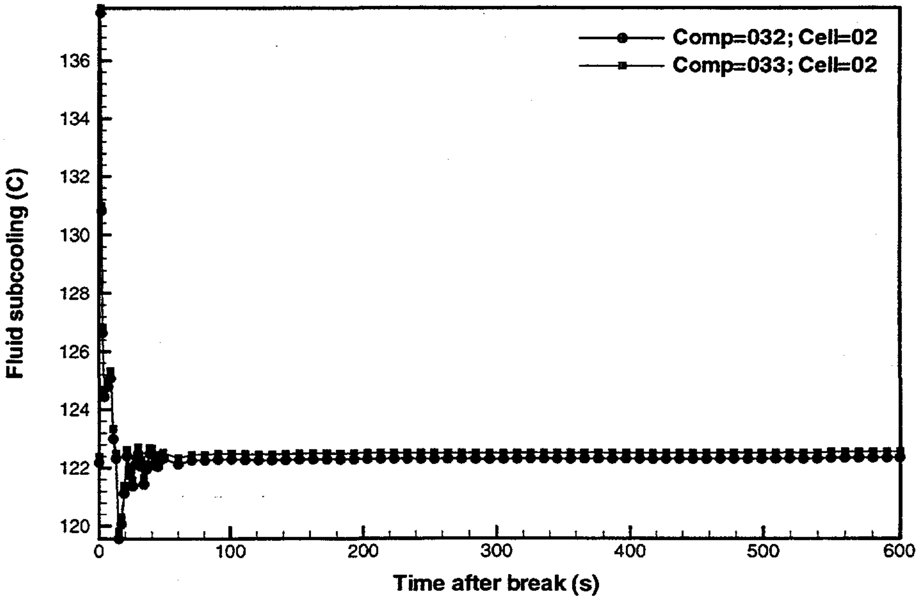

Figure B-16c Primary HR pump discharge piping fluid subcoolings for a LOHGA (Case 1: helium supply plenum break near decoupler inlet).

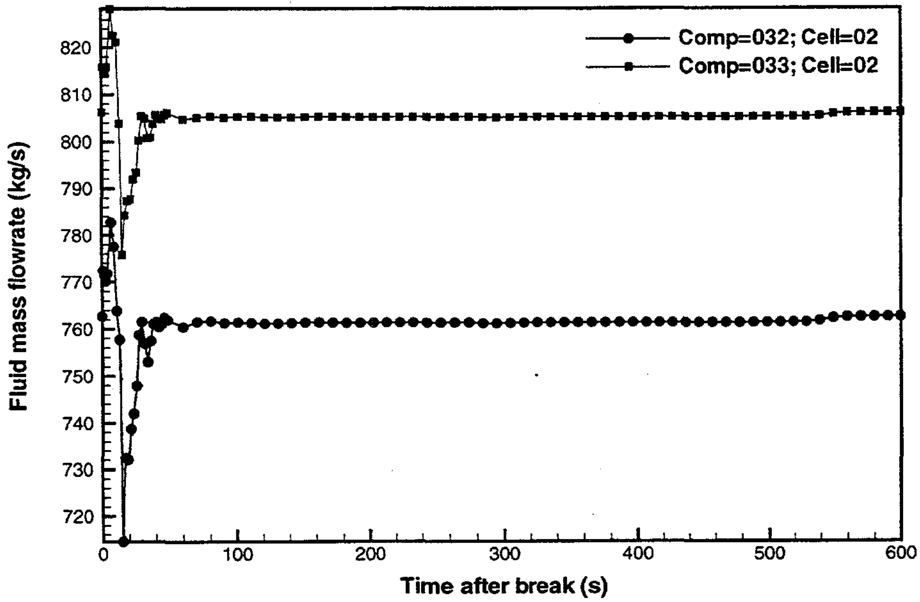

Figure B-16d Primary HR pump discharge piping liquid mass flowrates for a LOHGA (Case 1: helium supply plenum break near decoupler inlet).

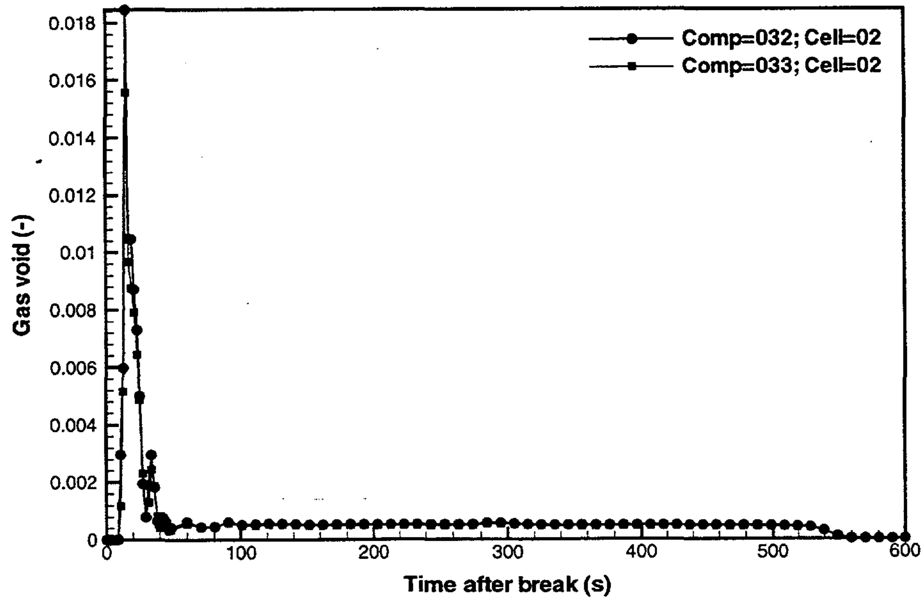

Figure B-16e Primary HR pump discharge piping void fractions for a LOHGA (Case 1: helium supply plenum break near decoupler inlet).

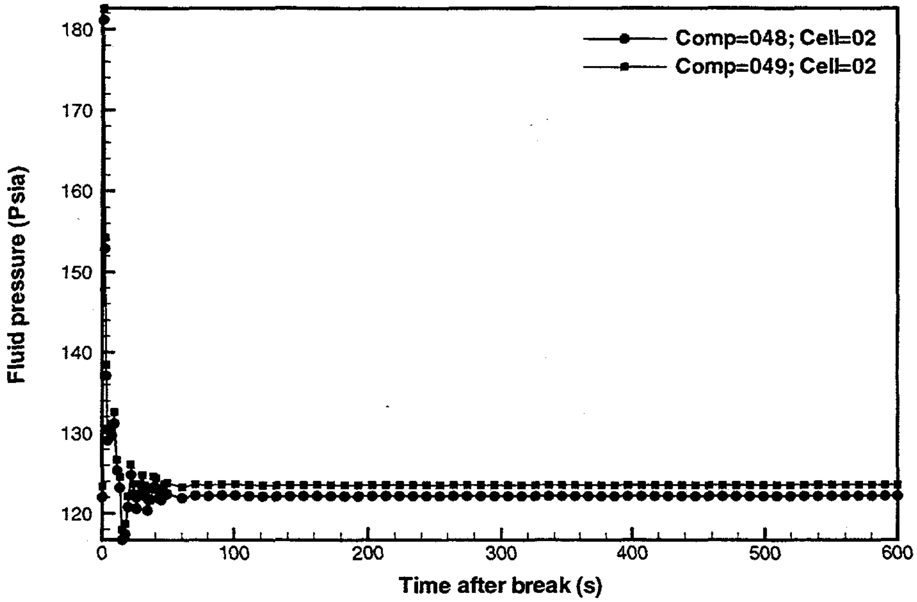

Figure B-17a Primary HR heat exchanger inlet piping fluid pressures for a LOHGA (Case 1: helium supply plenum break near decoupler inlet).

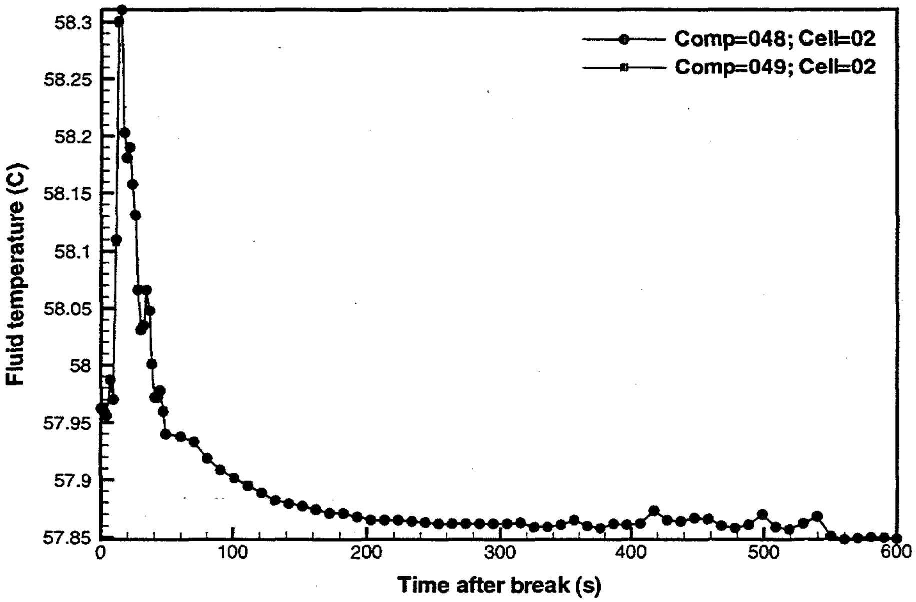

Figure B-17b Primary HR heat exchanger inlet piping fluid temperatures for a LOHGA (Case 1: helium supply plenum break near decoupler inlet).

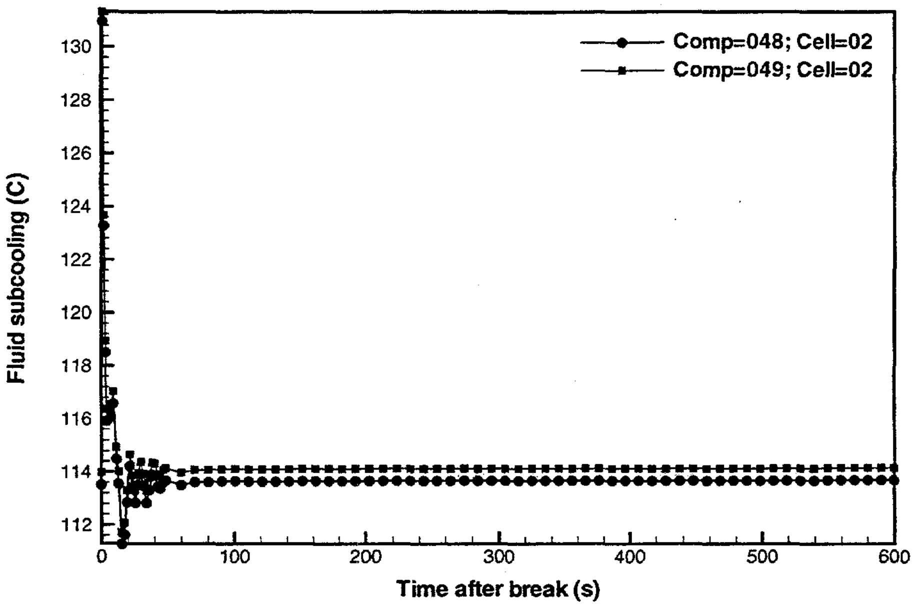

Figure B-17c Primary HR heat exchanger inlet piping fluid subcoolings for a LOHGA (Case 1: helium supply plenum break near decoupler inlet).

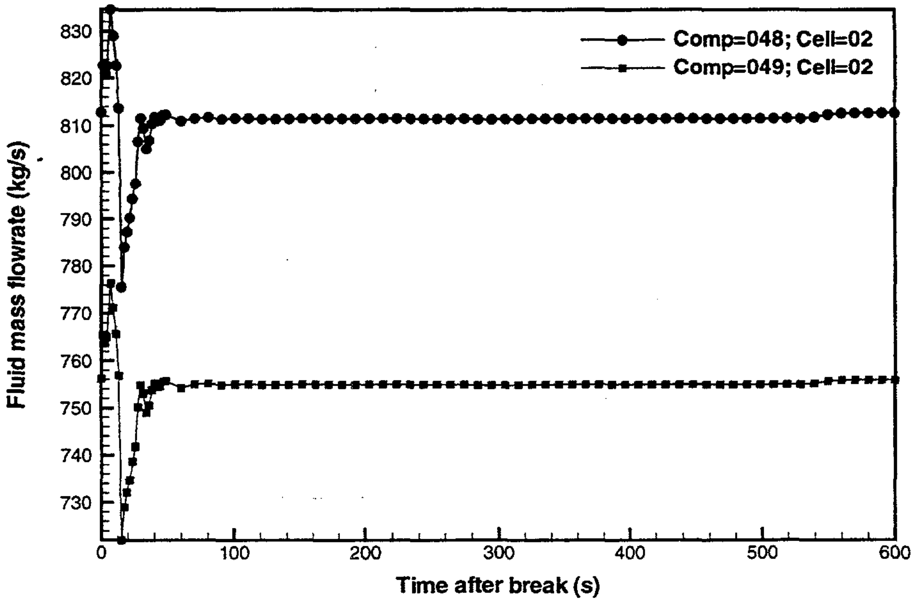

Figure B-17d Primary HR heat exchanger inlet piping liquid mass flowrates for a LOHGA (Case 1: helium supply plenum break near decoupler inlet).

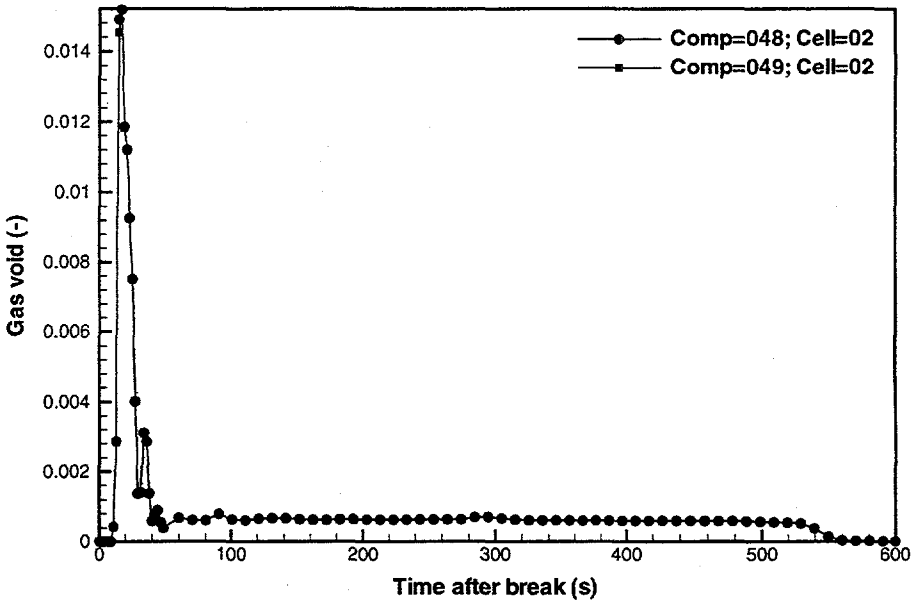

Figure B-17e Primary HR heat exchanger inlet piping void fractions for a LOHGA (Case 1: helium supply plenum break near decoupler inlet).

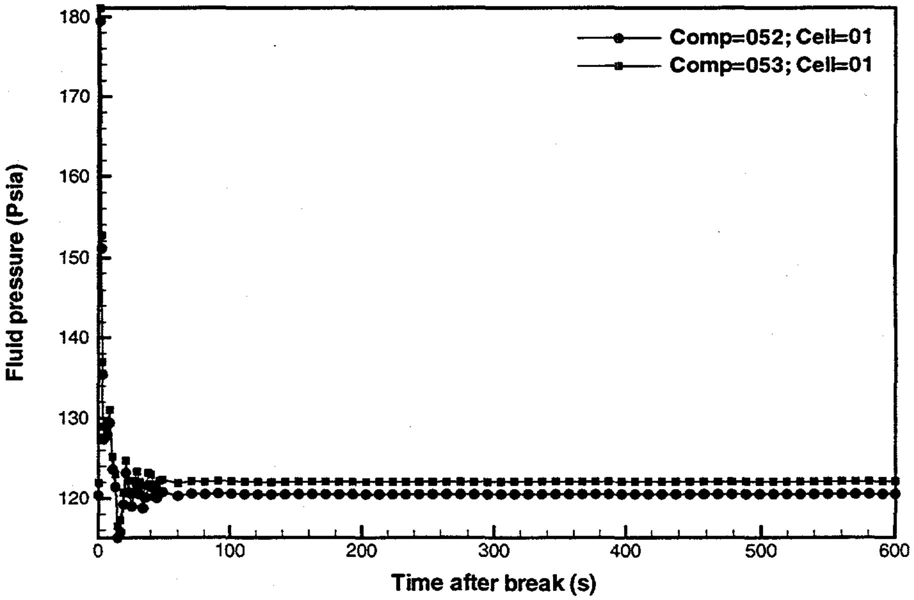

Figure B-18a Primary HR heat exchanger first pass outlet piping fluid pressures for a LOHGA (Case 1: helium supply plenum break near decoupler inlet).

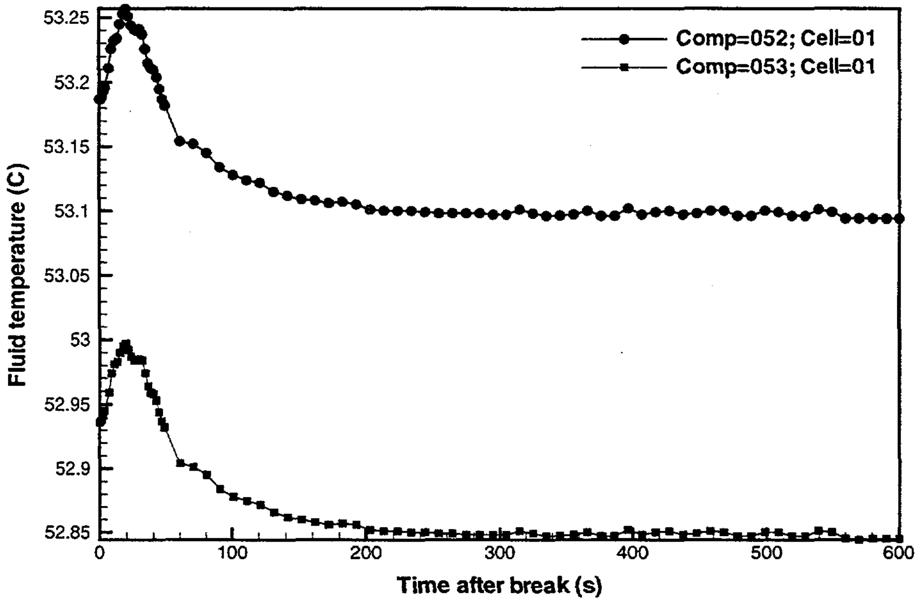

Figure B-18b Primary HR heat exchanger first pass outlet piping fluid temperatures for a LOHGA (Case 1: helium supply plenum break near decoupler inlet).

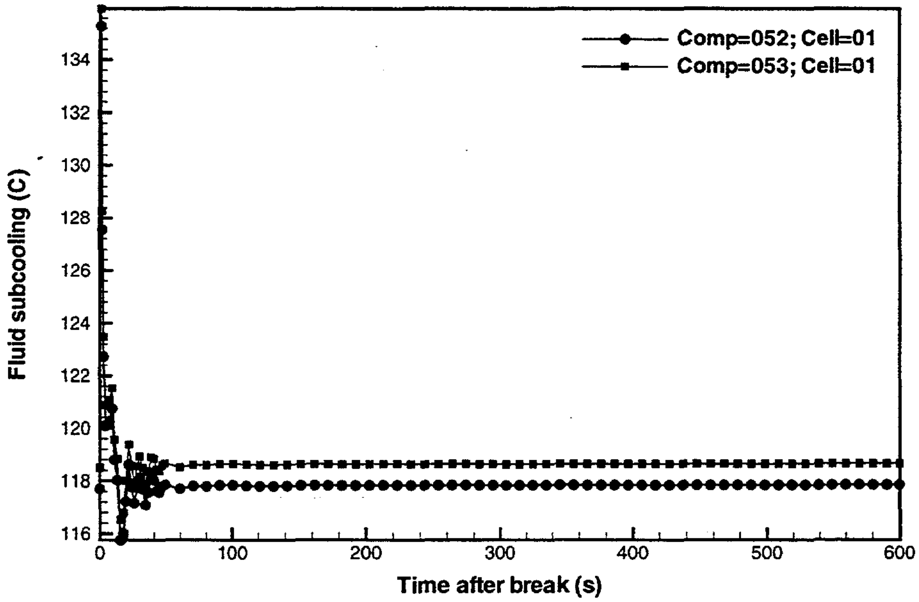

Figure B-18c Primary HR heat exchanger first pass outlet piping fluid subcoolings for a LOHGA (Case 1: helium supply plenum break near decoupler inlet).

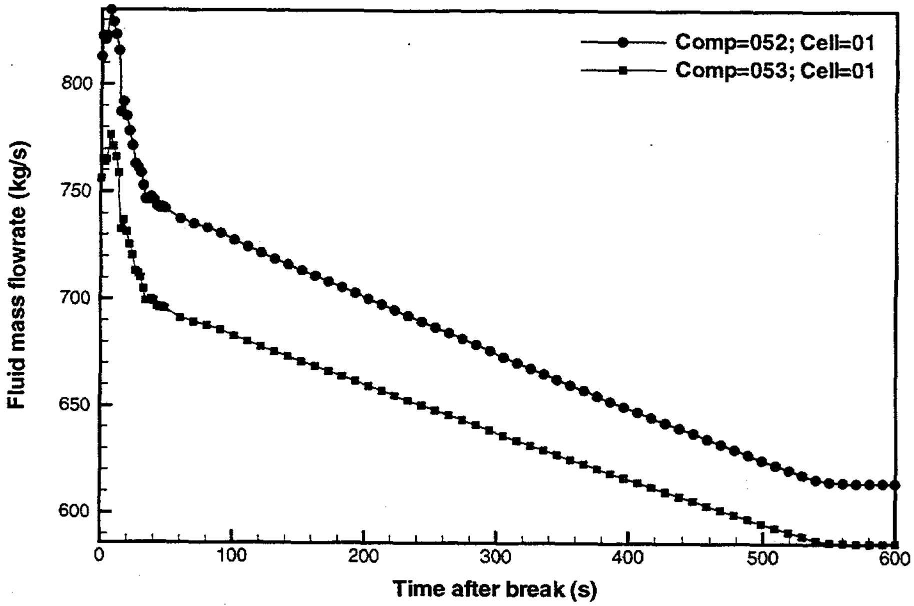

Figure B-18d Primary HR heat exchanger first pass outlet piping liquid mass flowrates for a LOHGA (Case 1: helium supply plenum break near decoupler inlet).

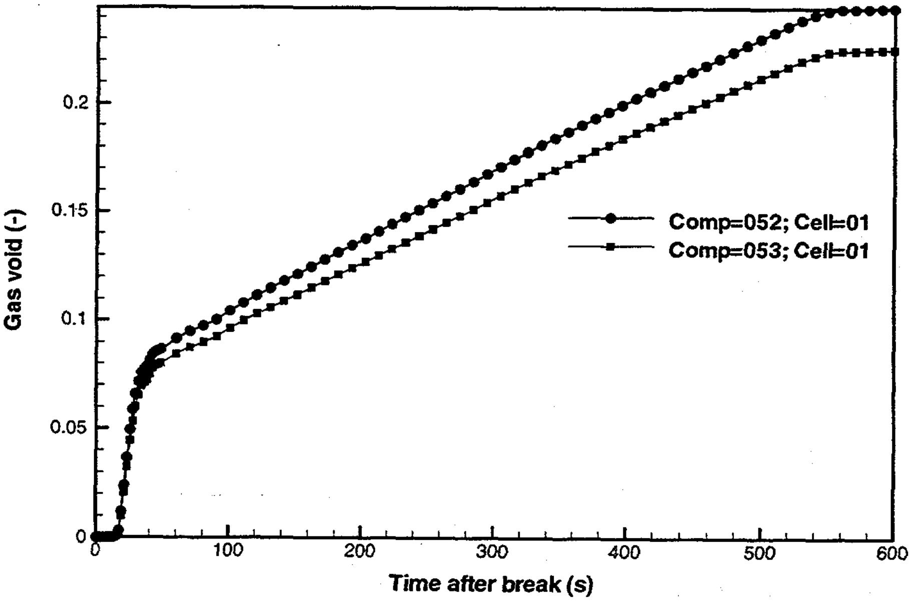

Figure B-18e Primary HR heat exchanger first pass outlet piping void fractions for a LOHGA (Case 1: helium supply plenum break near decoupler inlet).

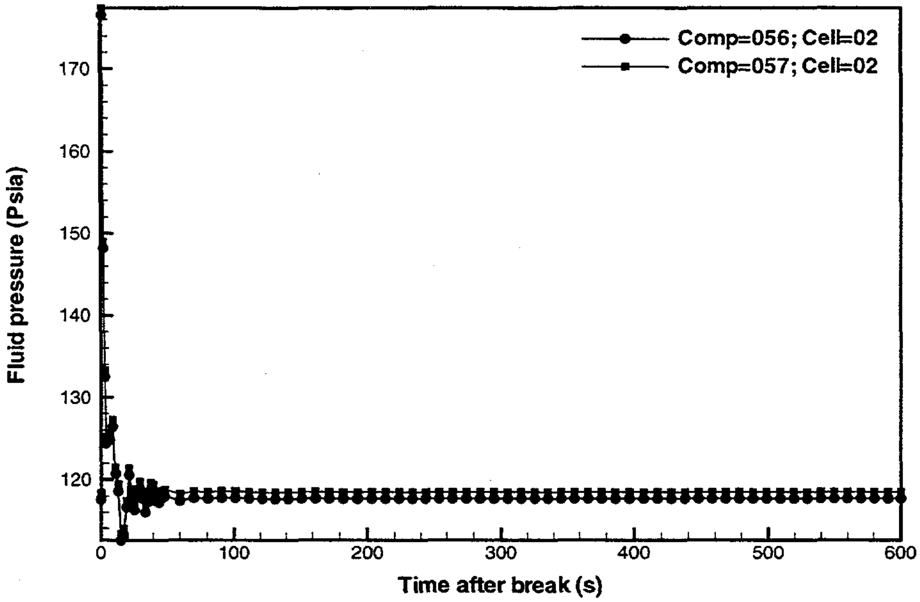

Figure B-19a Primary HR heat exchanger outlet piping fluid pressures for a LOHGA (Case 1: helium supply plenum break near decoupler inlet).

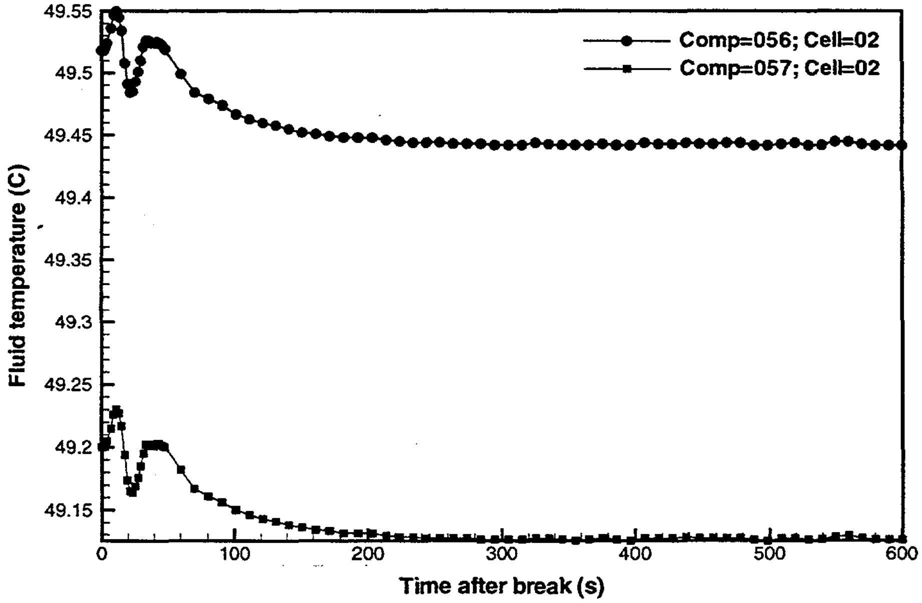

Figure B-19b Primary HR heat exchanger outlet piping fluid temperatures for a LOHGA (Case 1: helium supply plenum break near decoupler inlet).

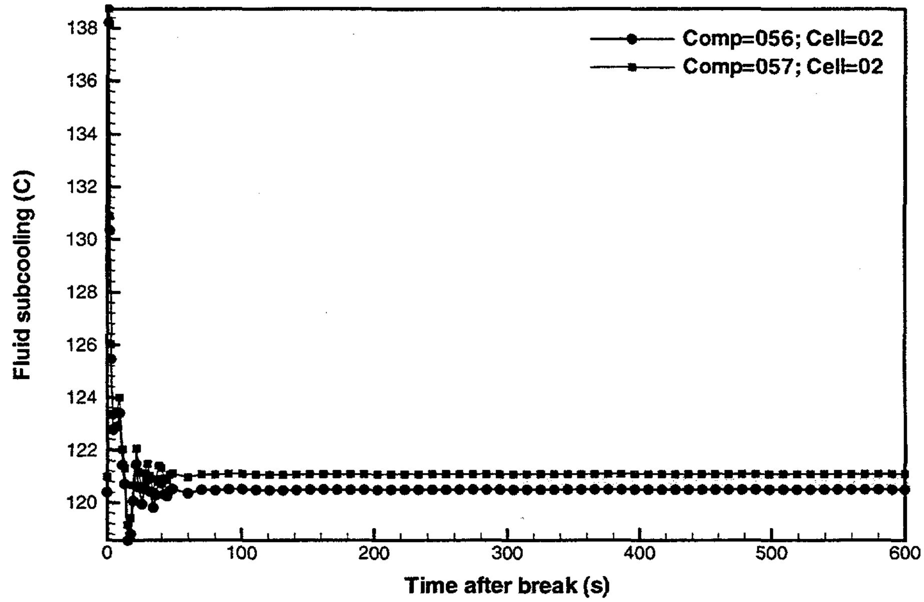

Figure B-19c Primary HR heat exchanger outlet piping fluid subcoolings for a LOHGA (Case 1: helium supply plenum break near decoupler inlet).

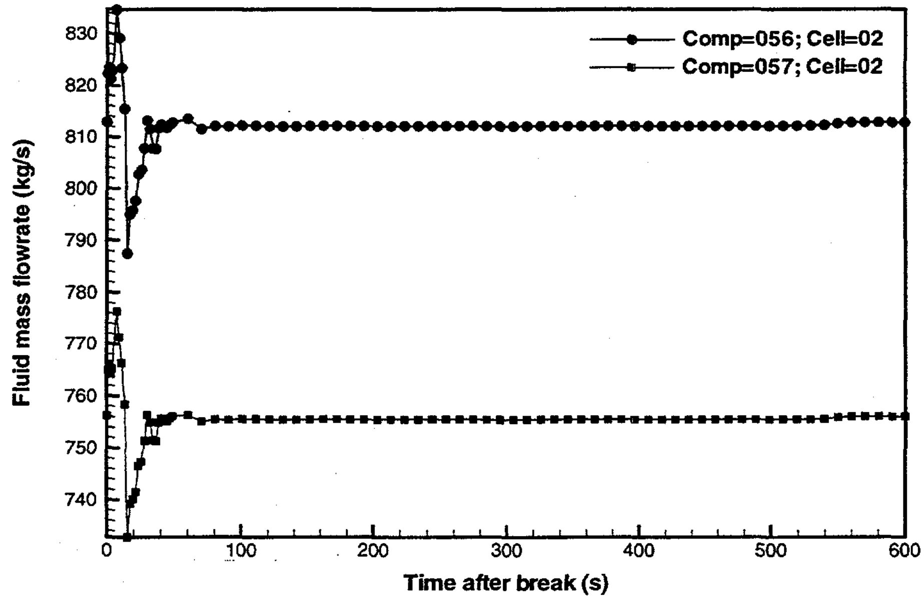

Figure B-19d Primary HR heat exchanger outlet piping liquid mass flowrates for a LOHGA (Case 1: helium supply plenum break near decoupler inlet).

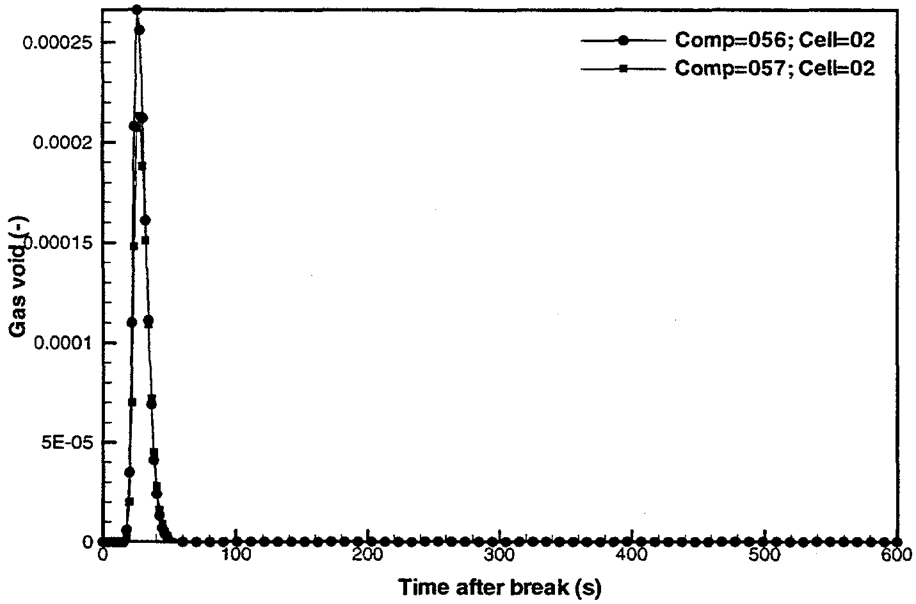

Figure B-19e Primary HR heat exchanger outlet piping void fractions for a LOHGA (Case 1: helium supply plenum break near decoupler inlet).

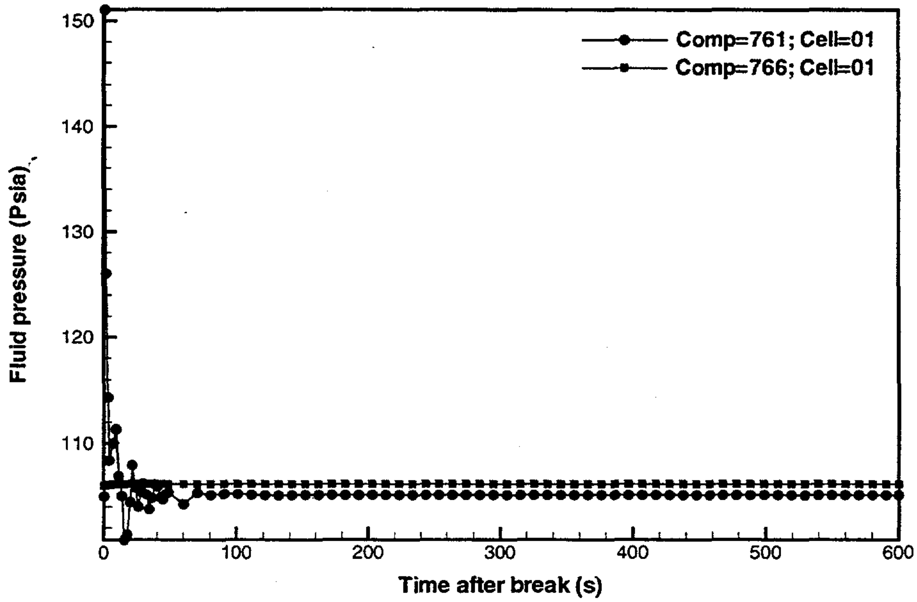

Figure B-20a Primary HR pressurizer and surge line fluid pressures for a LOHGA (Case 1: helium supply plenum break near decoupler inlet).

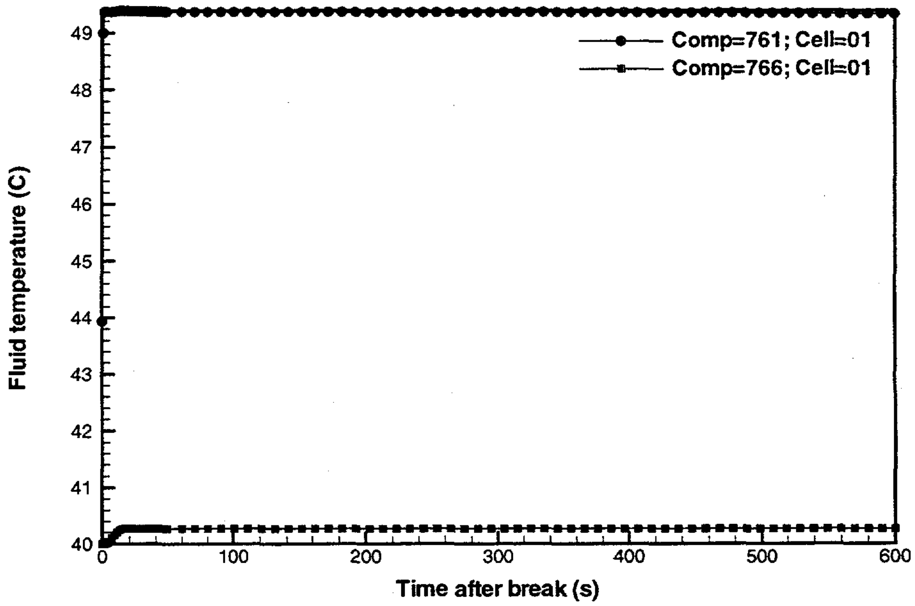

Figure B-20b Primary HR pressurizer and surge line fluid temperatures for a LOHGA (Case 1: helium supply plenum break near decoupler inlet).

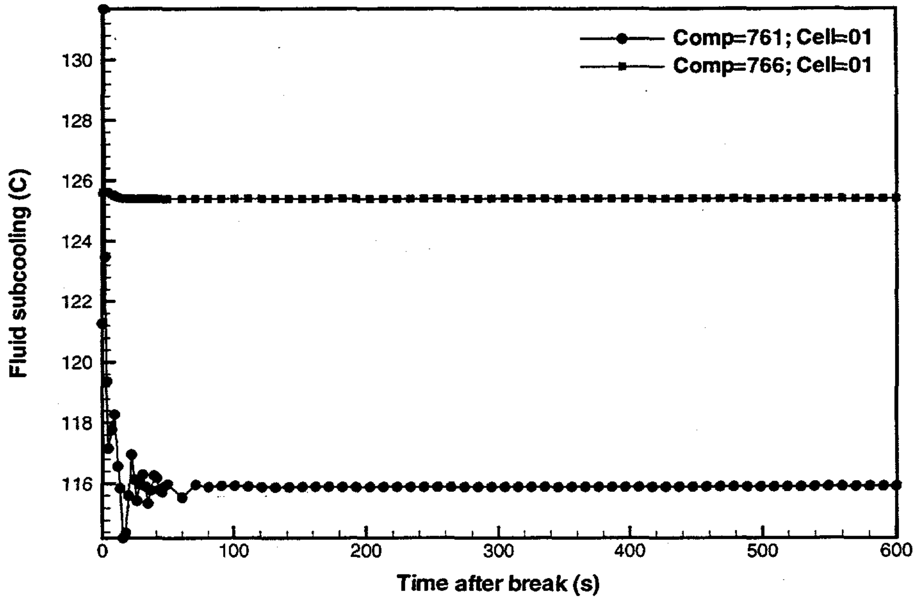

Figure B-20c Primary HR pressurizer and surge line fluid subcoolings for a LOHGA (Case 1: helium supply plenum break near decoupler inlet).

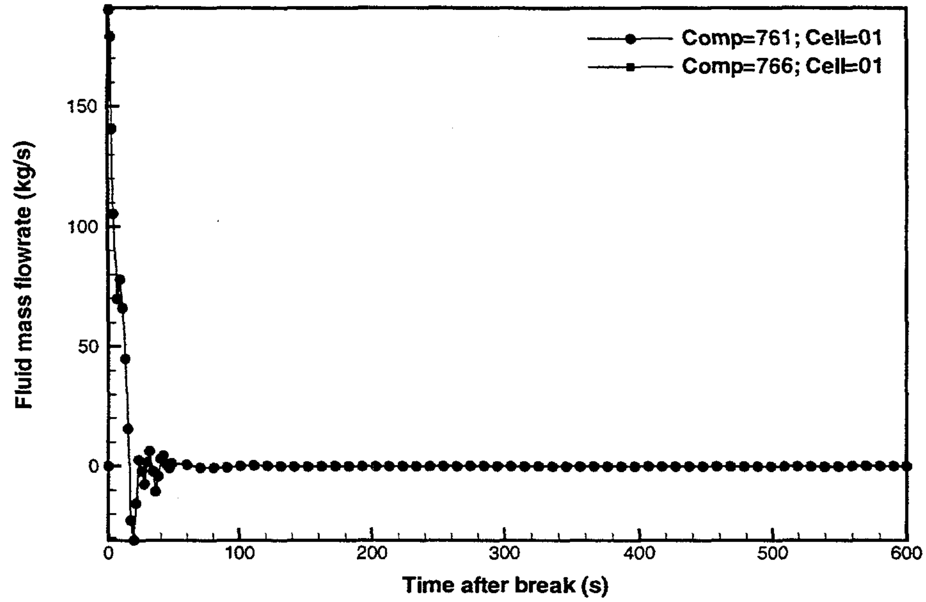

Figure B-20d Primary HR pressurizer and surge line liquid mass flowrates for a LOHGA (Case 1: helium supply plenum break near decoupler inlet).

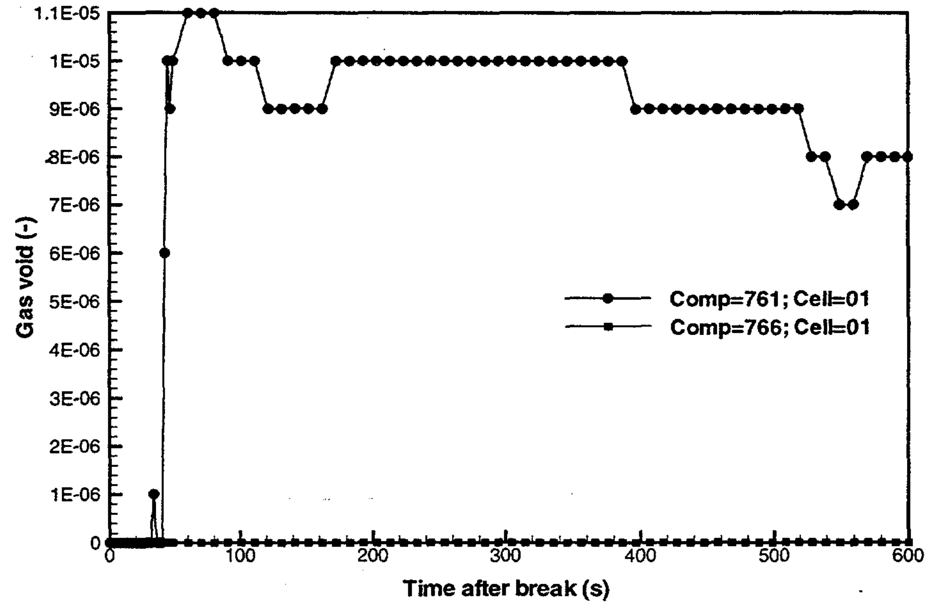

Figure B-20e Primary HR pressurizer and surge line void fractions for a LOHGA (Case 1: helium supply plenum break near decoupler inlet).

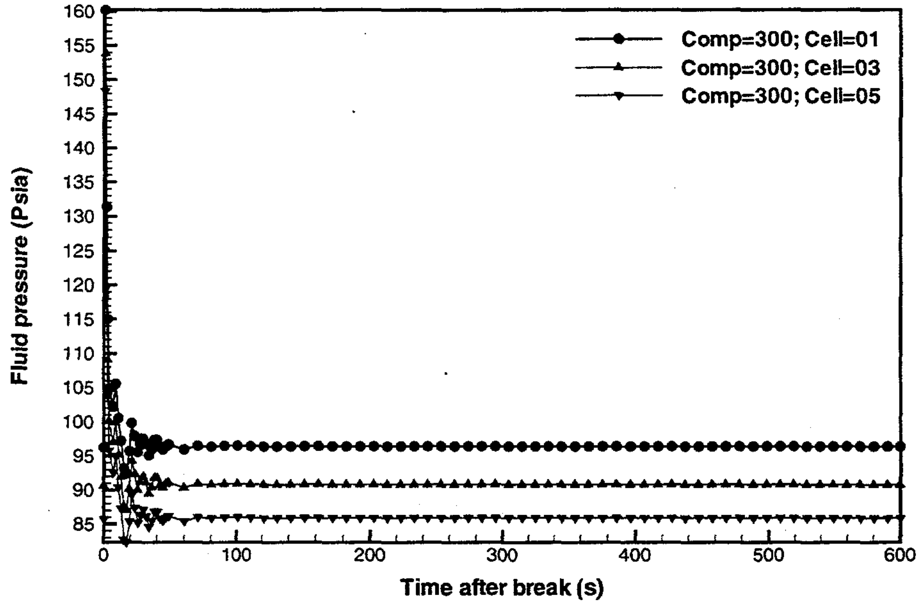

Figure B-21a Module 1 row 1 channel fluid pressures for a LOHGA (Case 1: helium supply plenum break near decoupler inlet).

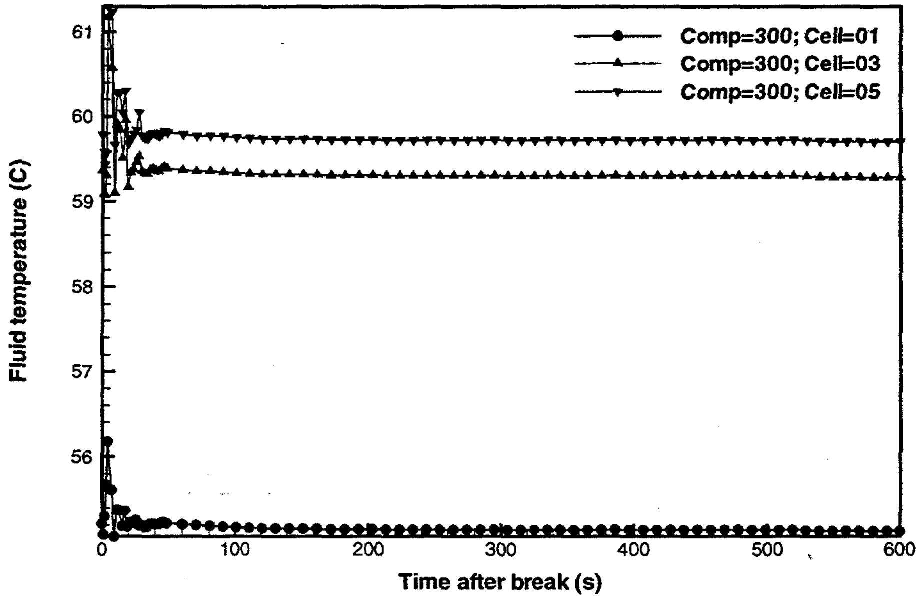

Figure B-21b Module 1 row 1 channel fluid temperatures for a LOHGA (Case 1: helium supply plenum break near decoupler inlet).

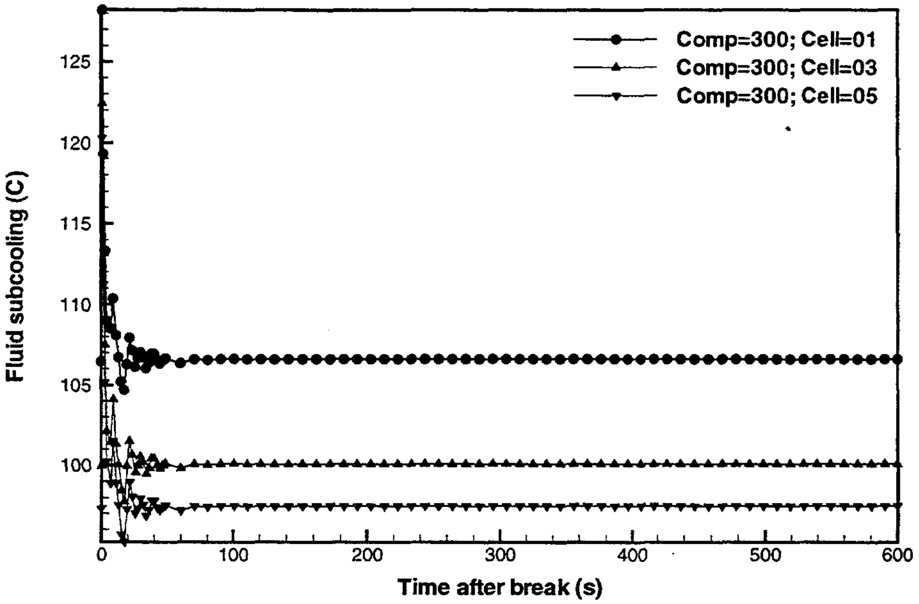

Figure B-21c Module 1 row 1 channel fluid subcoolings for a LOHGA (Case 1: helium supply plenum break near decoupler inlet).

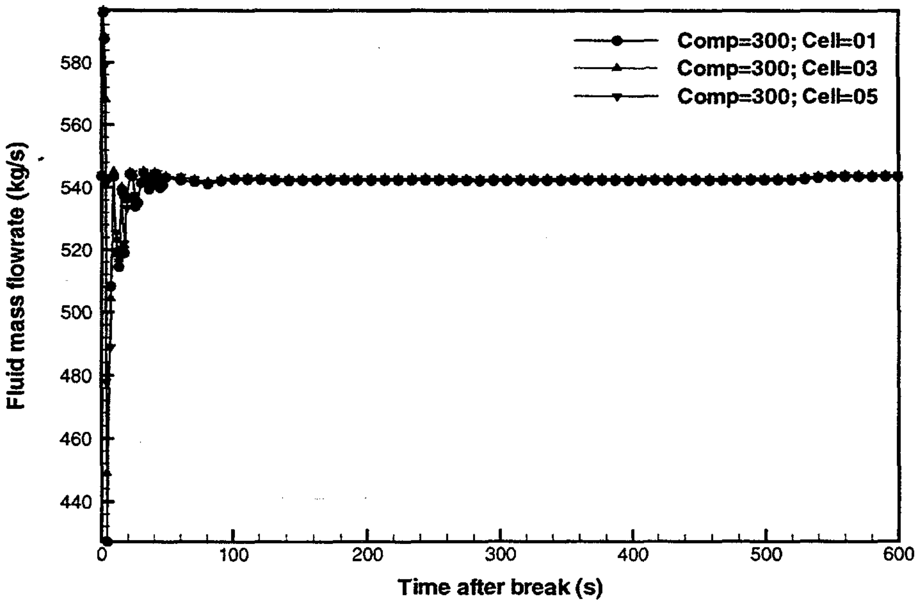

Figure B-21d Module 1 row 1 channel liquid mass flowrates for a LOHGA (Case 1: helium supply plenum break near decoupler inlet).

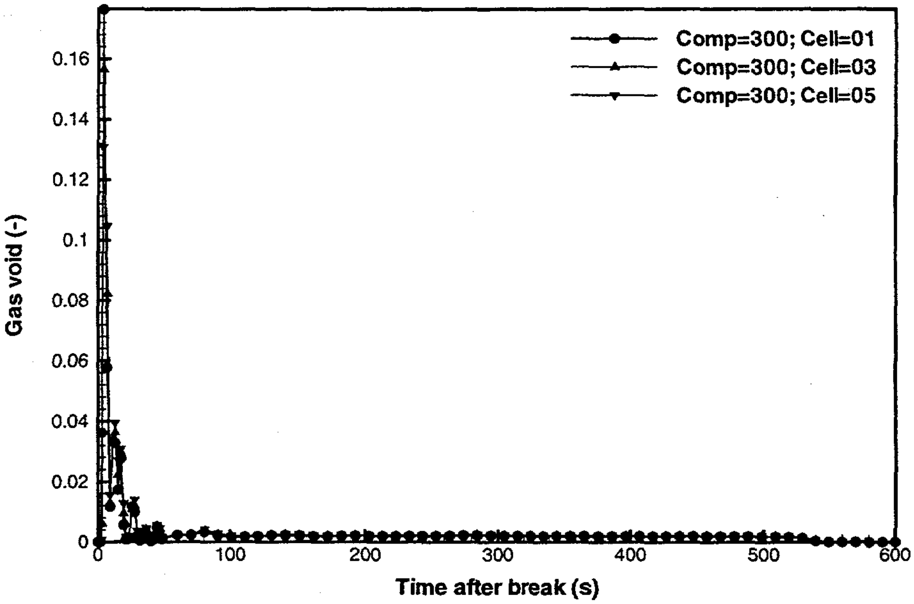

Figure B-21e Module 1 row 1 channel void fractions for a LOHGA (Case 1: helium supply plenum break near decoupler inlet).

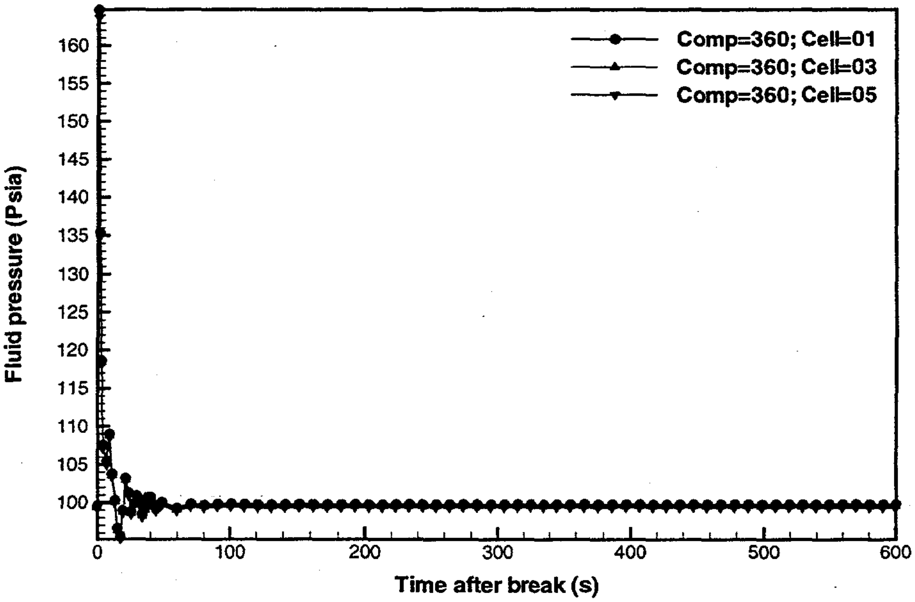

Figure B-22a Module 1 decoupler channel fluid pressures for a LOHGA (Case 1: helium supply plenum break near decoupler inlet).

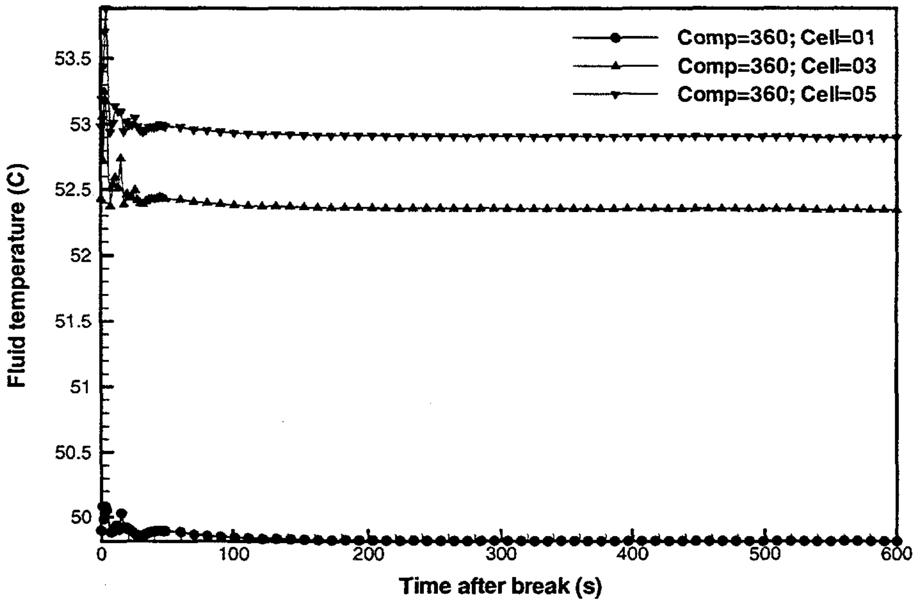

Figure B-22b Module 1 decoupler channel fluid temperatures for a LOHGA (Case 1: helium supply plenum break near decoupler inlet).

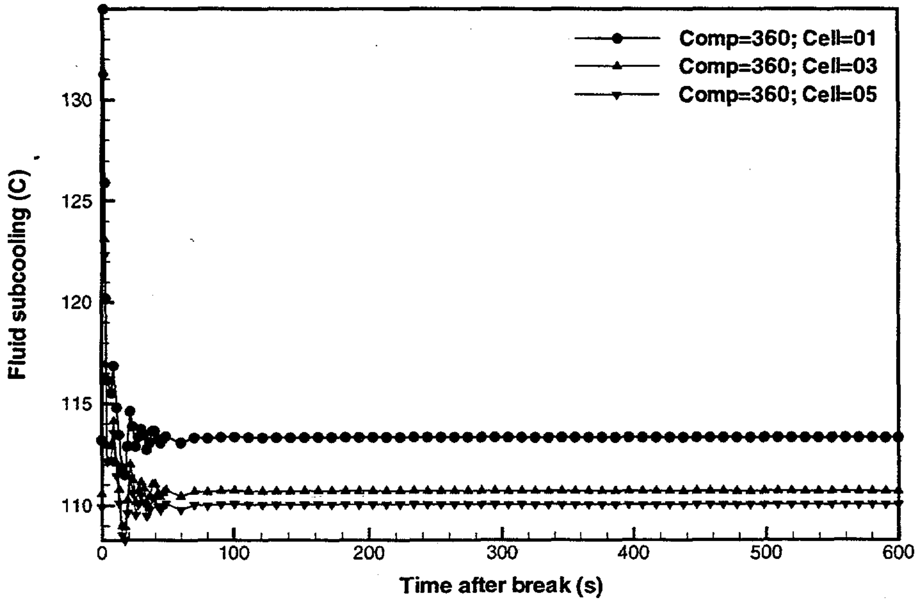

Figure B-22c Module 1 decoupler channel fluid subcoolings for a LOHGA (Case 1: helium supply plenum break near decoupler inlet).

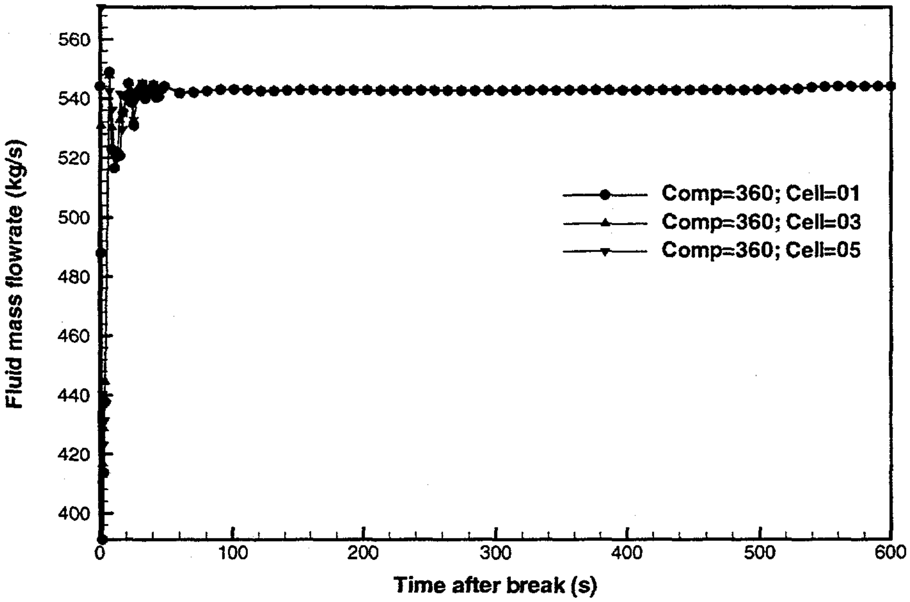

Figure B-22d Module 1 decoupler channel liquid mass flowrates for a LOHGA (Case 1: helium supply plenum break near decoupler inlet).

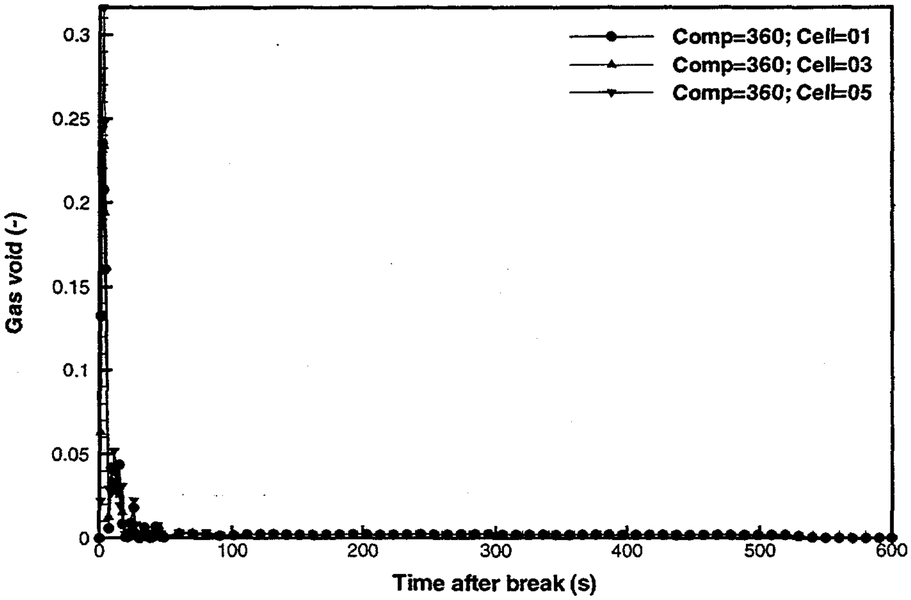

Figure B-22e Module 1 decoupler channel Module 2 channel void fractions for a LOHGA (Case 1: helium supply plenum break near decoupler inlet).

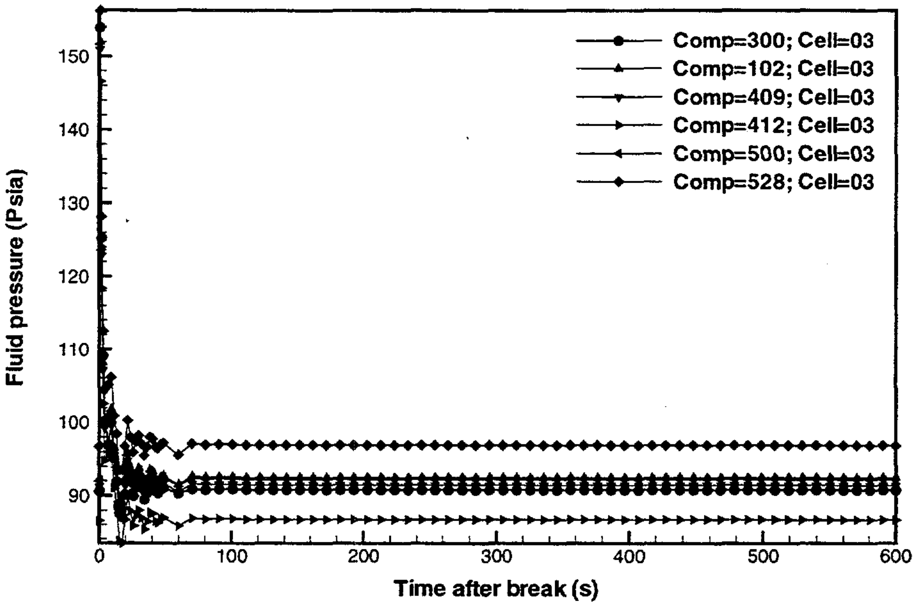

Figure B-23a Mid-plane module fluid pressures for a LOHGA (Case 1: helium supply plenum break near decoupler inlet).

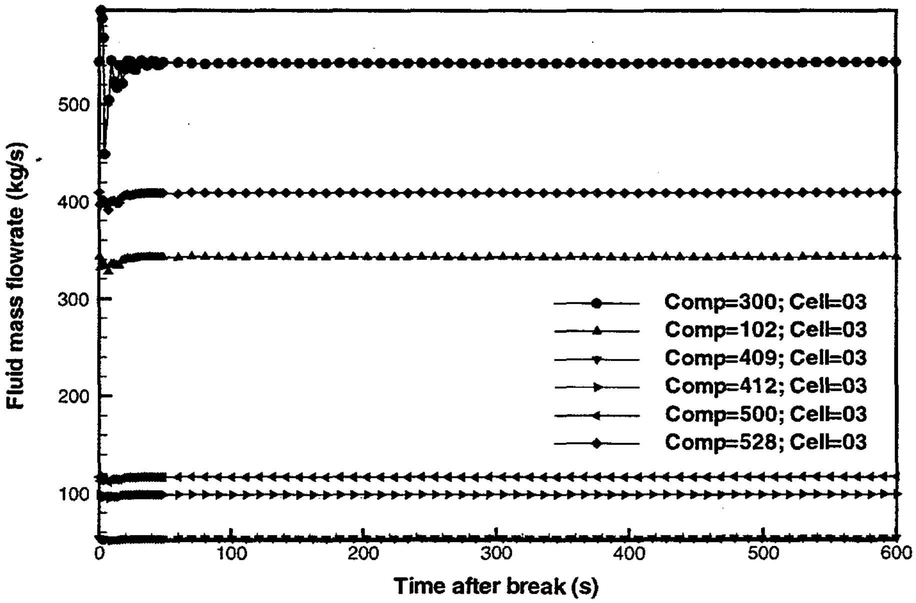

Figure B-23b Mid-plane module fluid temperatures for a LOHGA (Case 1: helium supply plenum break near decoupler inlet).

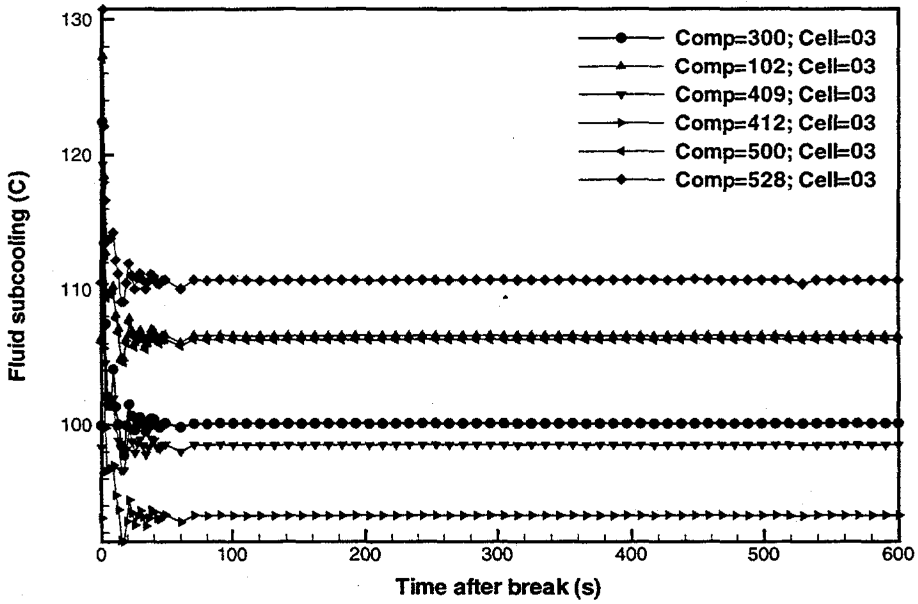

Figure B-23c Mid-plane module fluid subcoolings for a LOHGA (Case 1: helium supply plenum break near decoupler inlet).

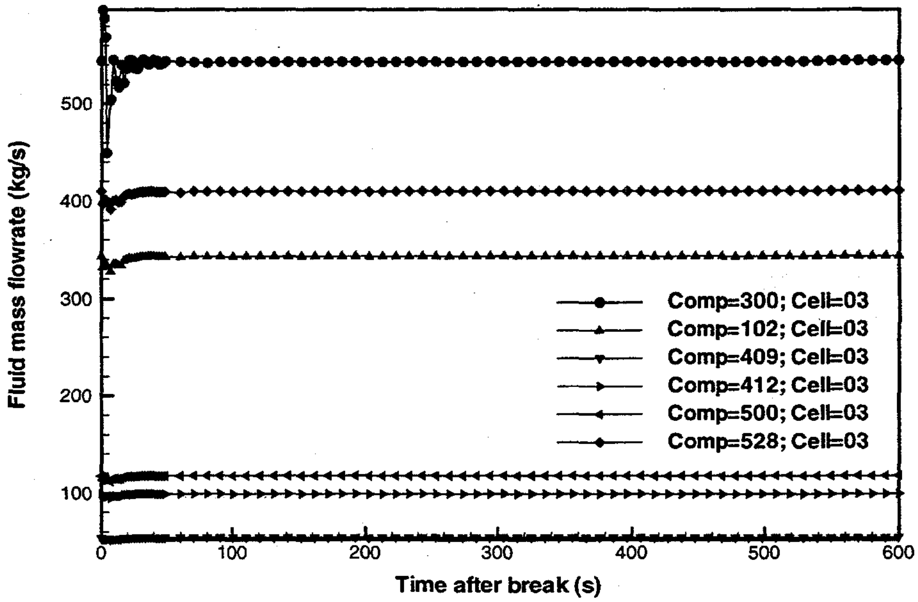

Figure B-23d Mid-plane module liquid mass flowrates for a LOHGA (Case 1: helium supply plenum break near decoupler inlet).

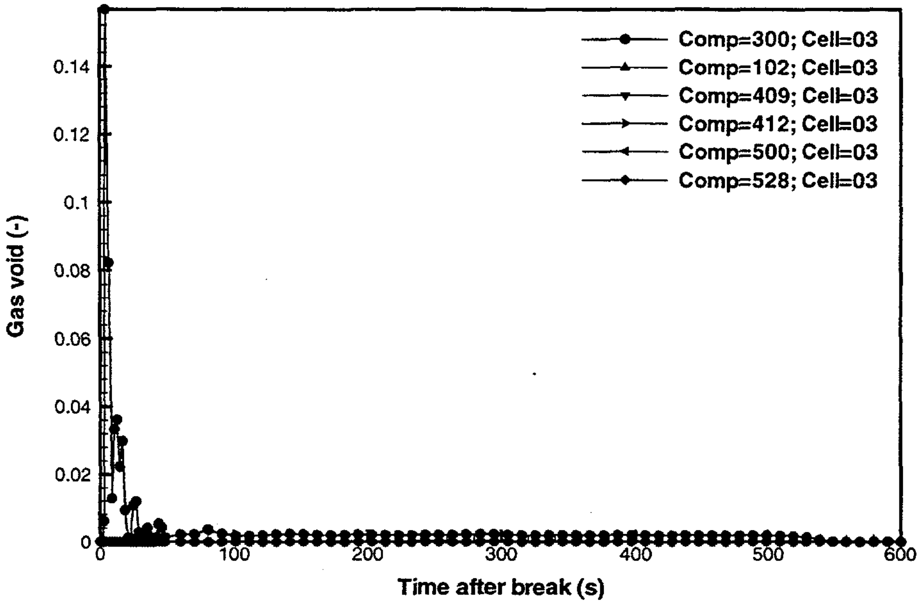

Figure B-23e Mid-plane module void fractions for a LOHGA (Case 1: helium supply plenum break near decoupler inlet).

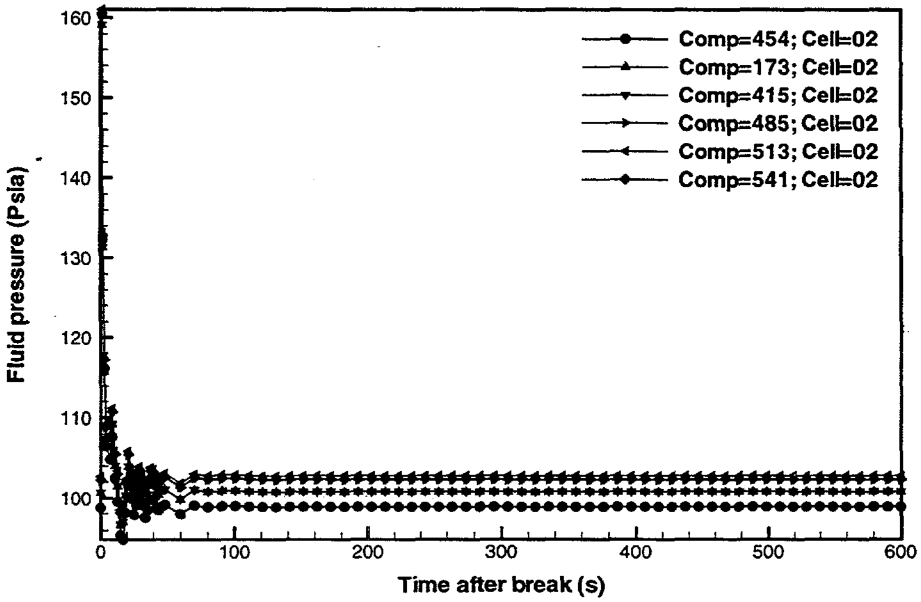

Figure B-24a Module inlet fluid pressures for a LOHGA (Case 1: helium supply plenum break near decoupler inlet).

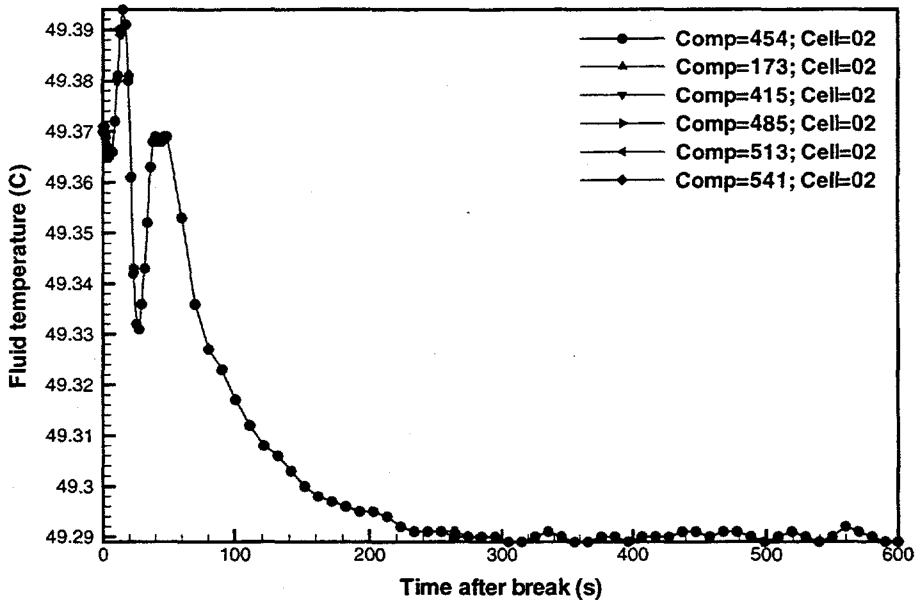

Figure B-24b Module inlet fluid temperatures for a LOHGA (Case 1: helium supply plenum break near decoupler inlet).

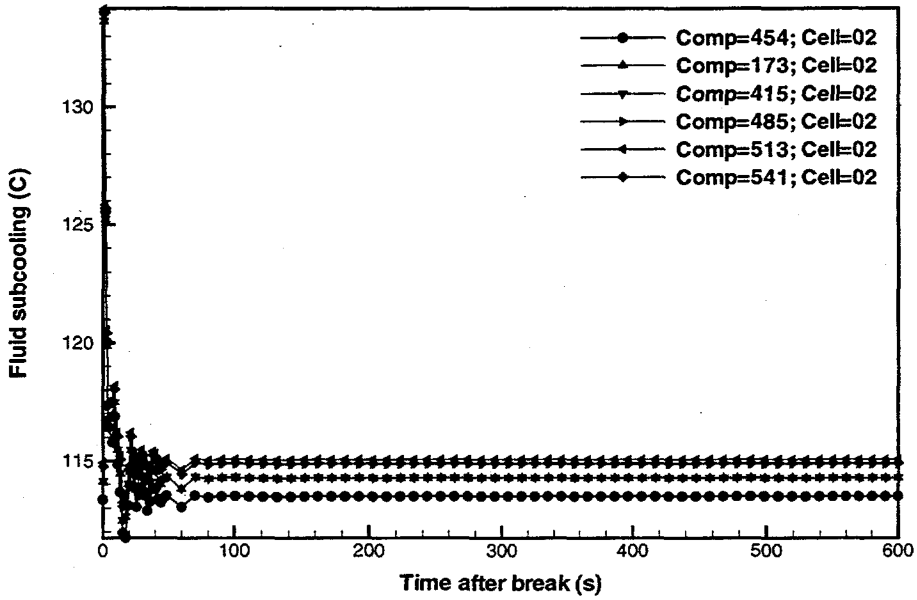

Figure B-24c Module inlet fluid subcoolings for a LOHGA (Case 1: helium supply plenum break near decoupler inlet).

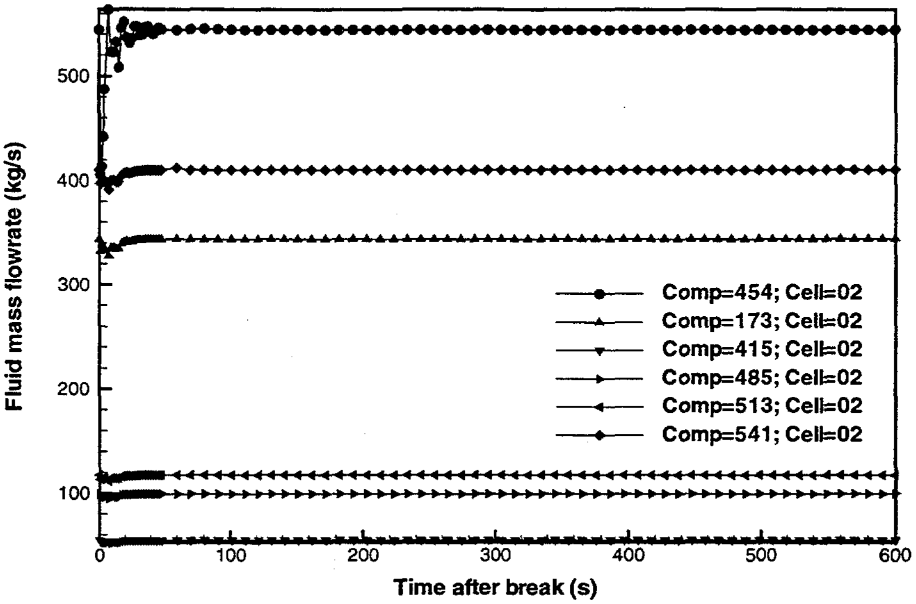

Figure B-24d Module inlet liquid mass flowrates for a LOHGA (Case 1: helium supply plenum break near decoupler inlet).

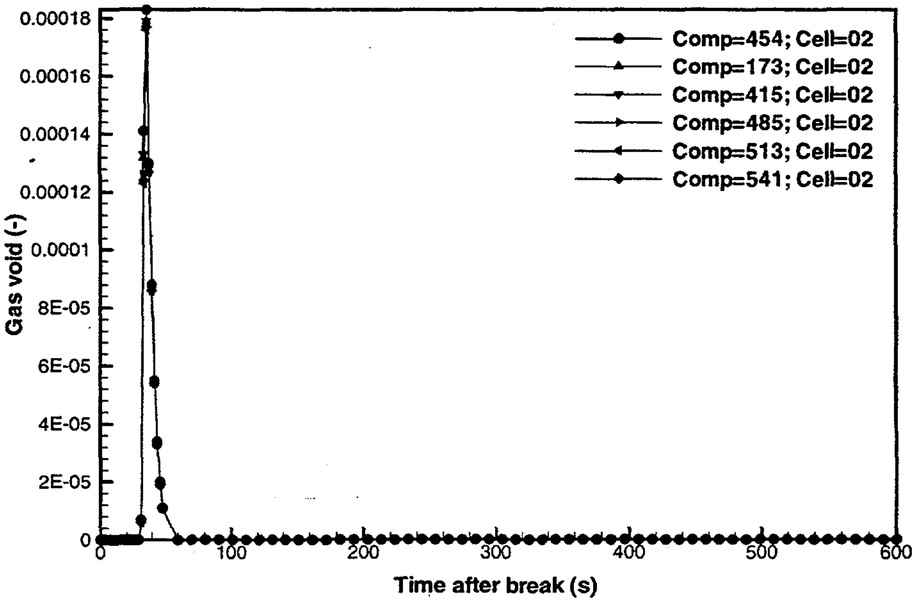

Figure B-24e Module inlet void fractions for a LOHGA (Case 1: helium supply plenum break near decoupler inlet).

Appendix C: LOHGA (Case 2) TRAC Results

Appendix C1 LOHGA (Case 2) TRAC Plenum Component Figures

The following figures are from a TRAC simulation for Case 2 of a LOHGA (Helium supply plenum break near decoupler outlet):

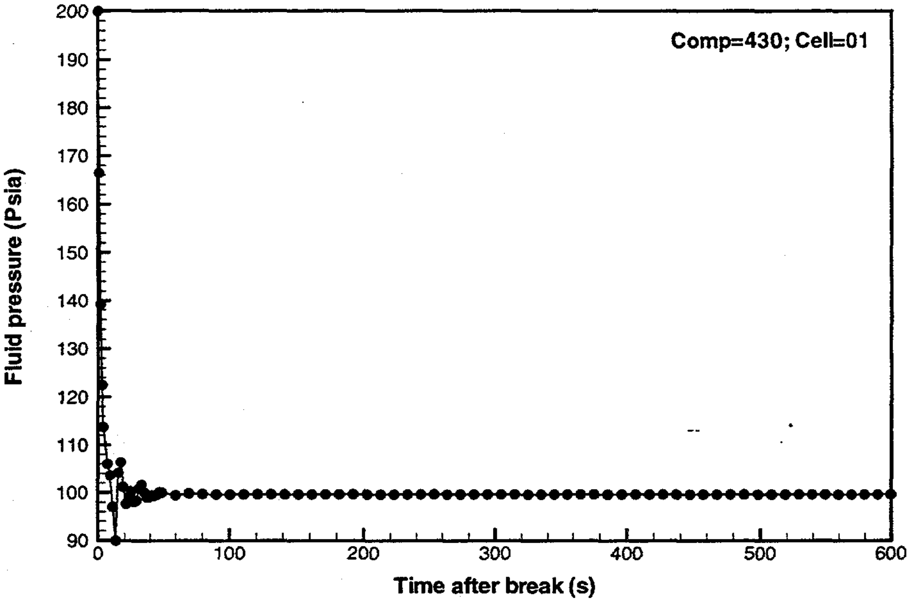

Figure C-1a Helium gas supply fluid pressures for a LOHGA (Case 2: helium supply plenum break near decoupler outlet).

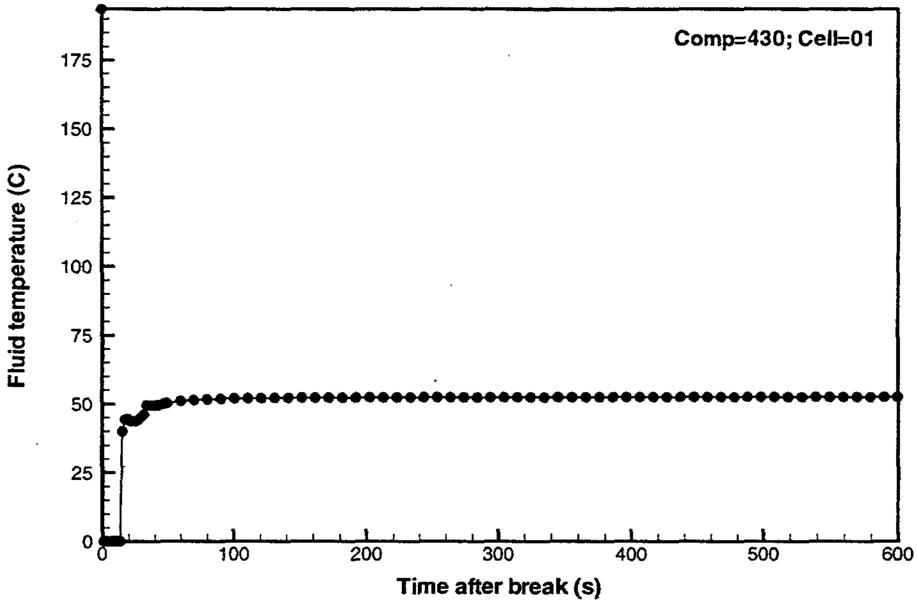

Figure C-1b Helium gas supply fluid temperatures for a LOHGA (Case 2: helium supply plenum break near decoupler outlet).

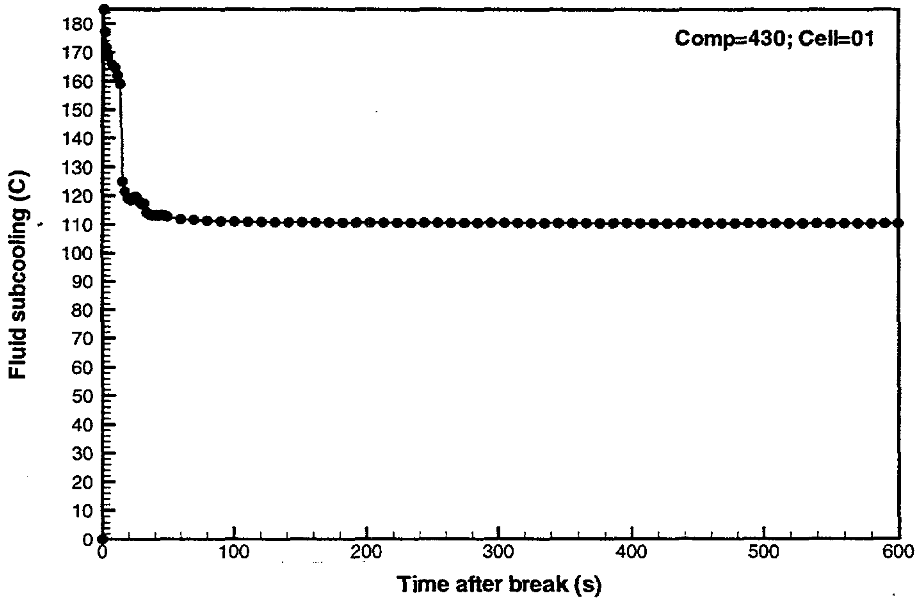

Figure C-1c Helium gas supply fluid subcoolings for a LOHGA (Case 2: helium supply plenum break near decoupler outlet).

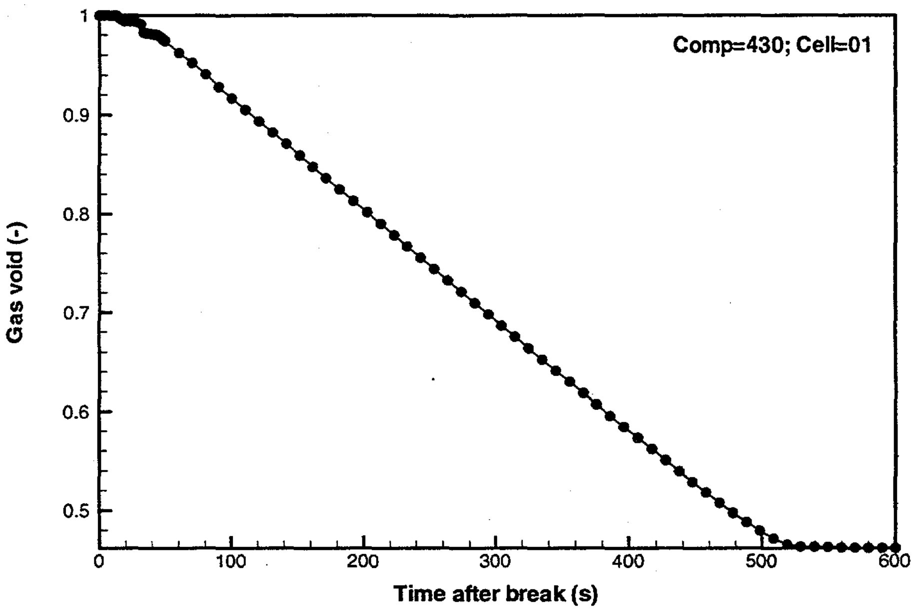

Figure C-1d Helium gas supply void fractions for a LOHGA (Case 2: helium supply plenum break near decoupler outlet).

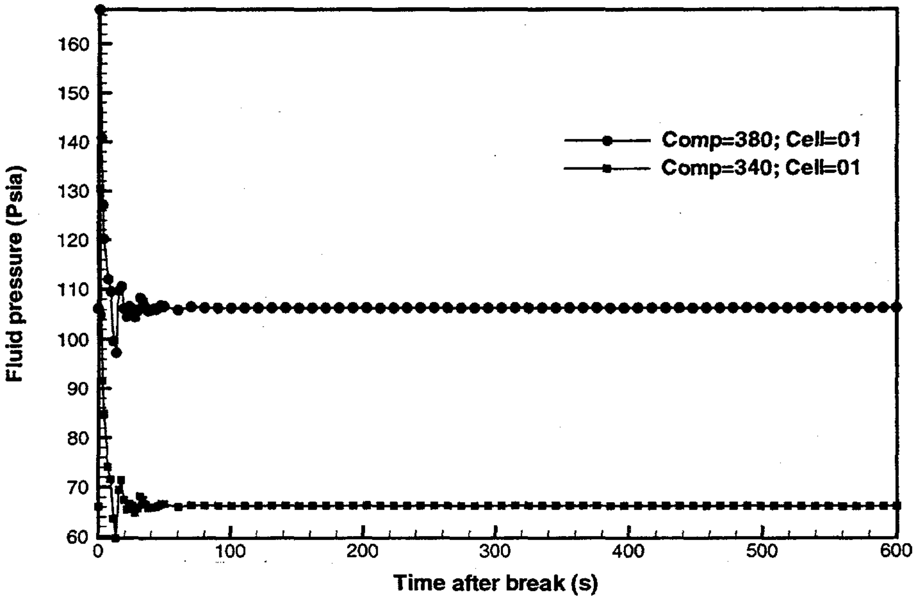

Figure C-2a Fixed header fluid pressures for a LOHGA (Case 2: helium supply plenum break near decoupler outlet).

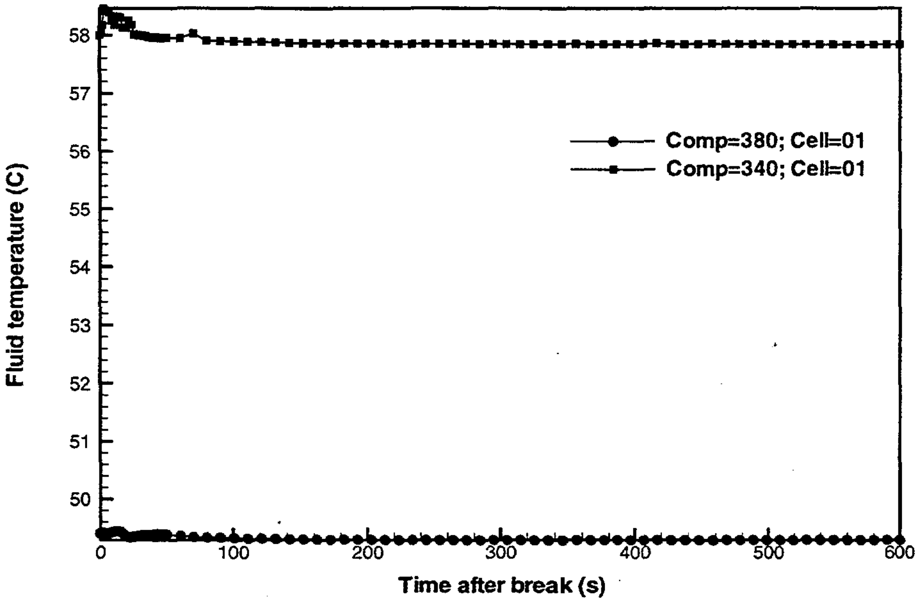

Figure C-2b Fixed header fluid temperatures for a LOHGA (Case 2: helium supply plenum break near decoupler outlet).

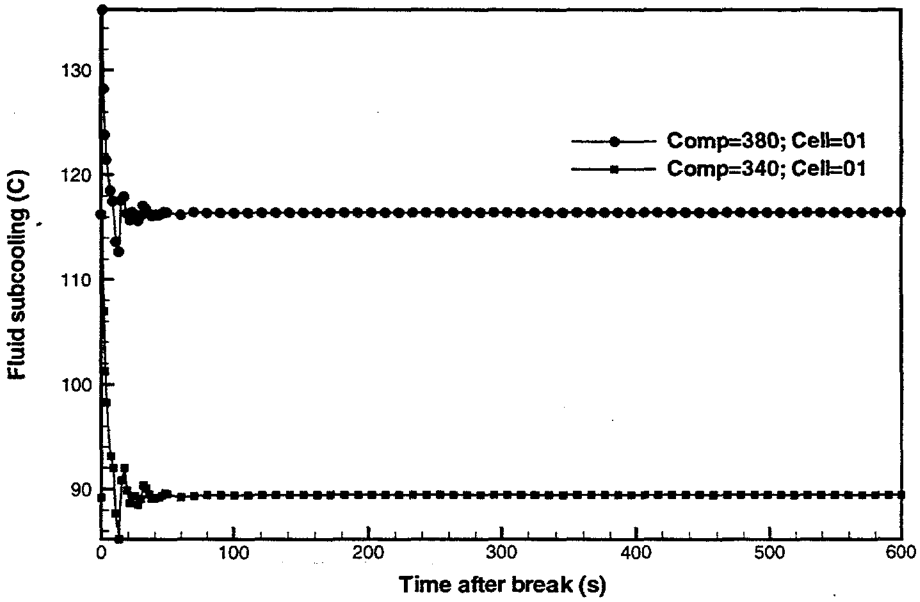

Figure C-2c Fixed header fluid subcoolings for a LOHGA (Case 2: helium supply plenum break near decoupler outlet).

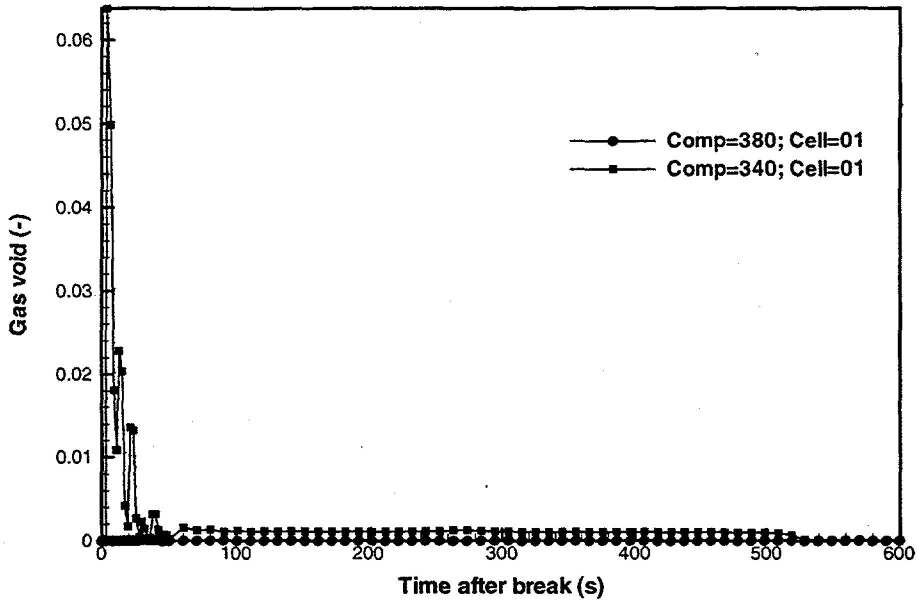

Figure C-2d Fixed header void fractions for a LOHGA (Case 2: helium supply plenum break near decoupler outlet).

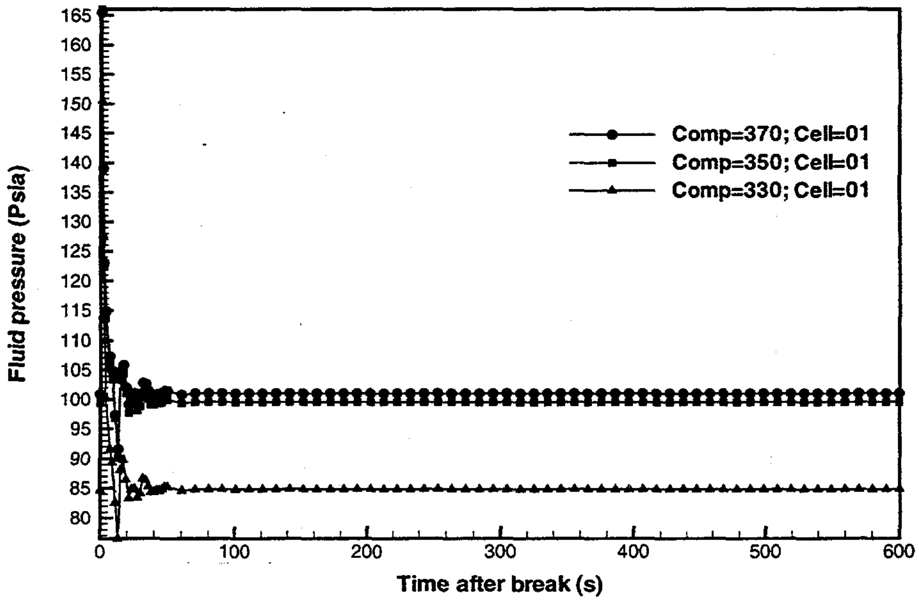

Figure C-3a Module 1 plenum fluid pressures for a LOHGA (Case 2: helium supply plenum break near decoupler outlet).

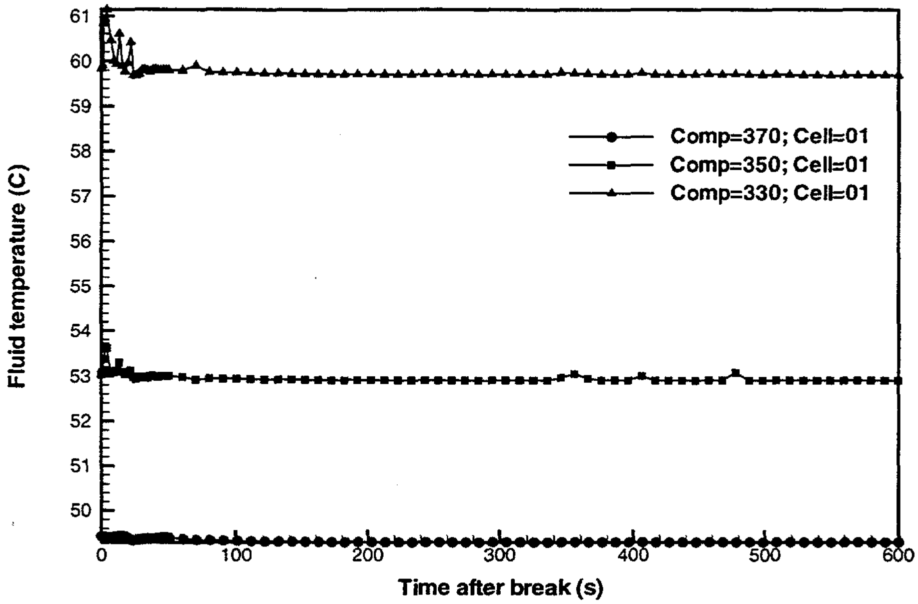

Figure C-3b Module 1 plenum fluid temperatures for a LOHGA (Case 2: helium supply plenum break near decoupler outlet).

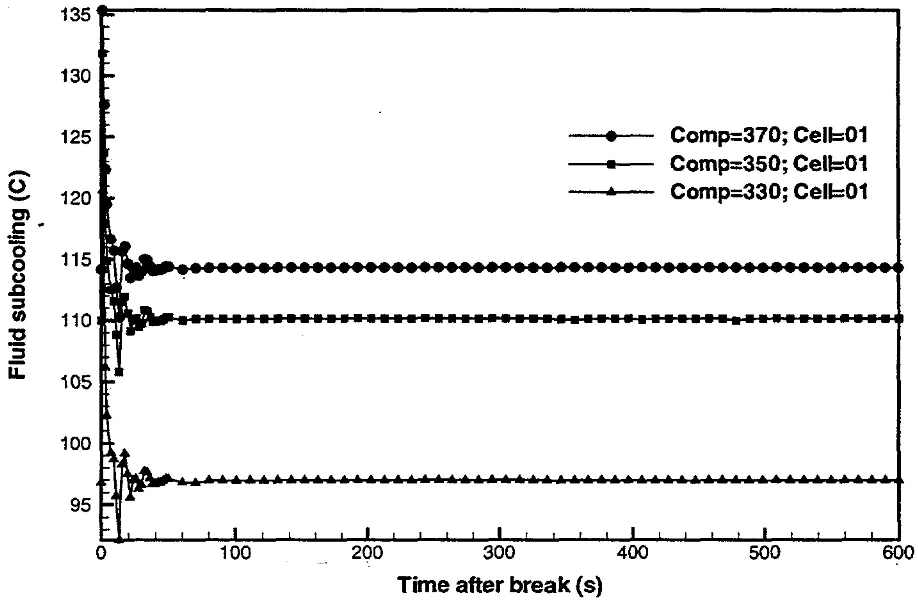

Figure C-3c Module 1 plenum fluid subcoolings for a LOHGA (Case 2: helium supply plenum break near decoupler outlet).

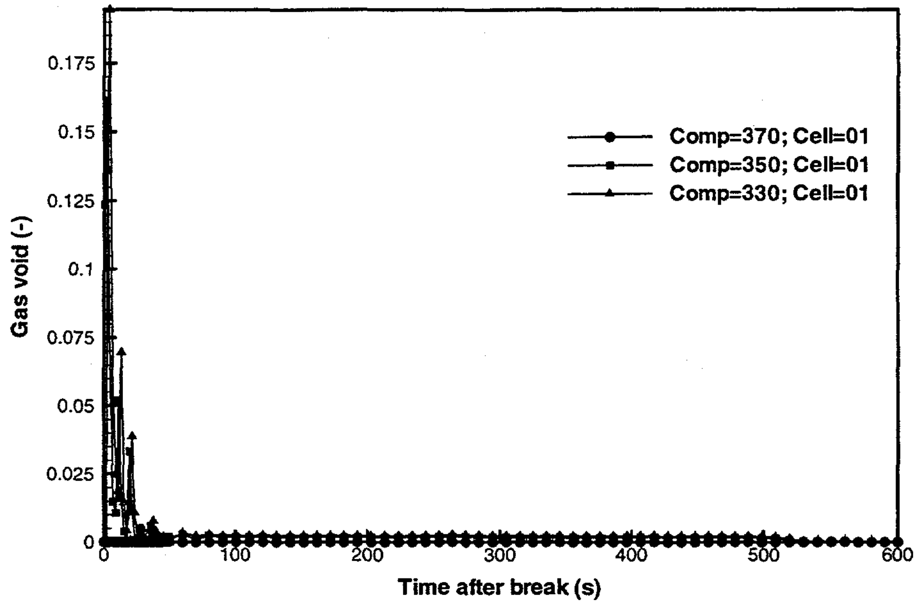

Figure C-3d Module 1 plenum void fractions for a LOHGA (Case 2: helium supply plenum break near decoupler outlet).

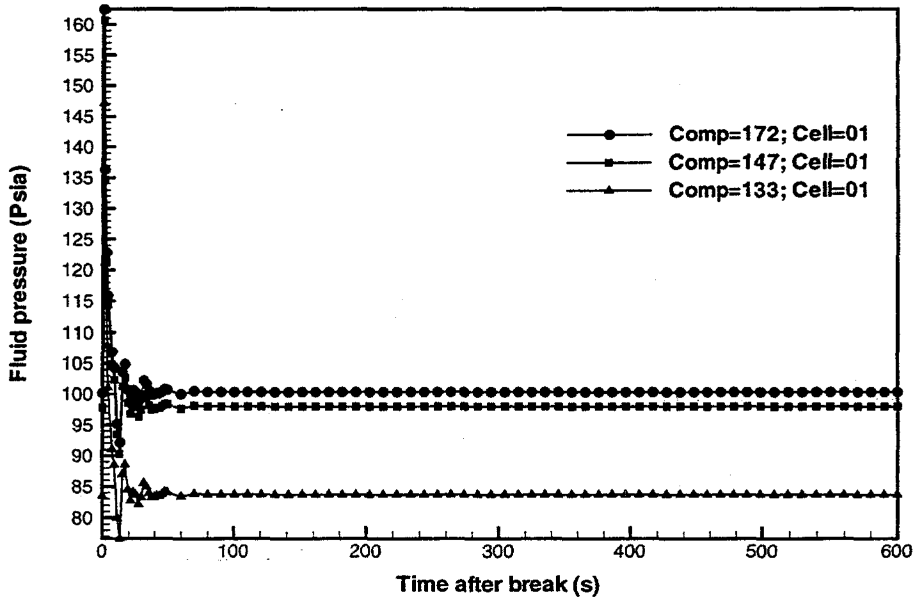

Figure C-4a Module 2 plenum fluid pressures for a LOHGA (Case 2: helium supply plenum break near decoupler outlet).

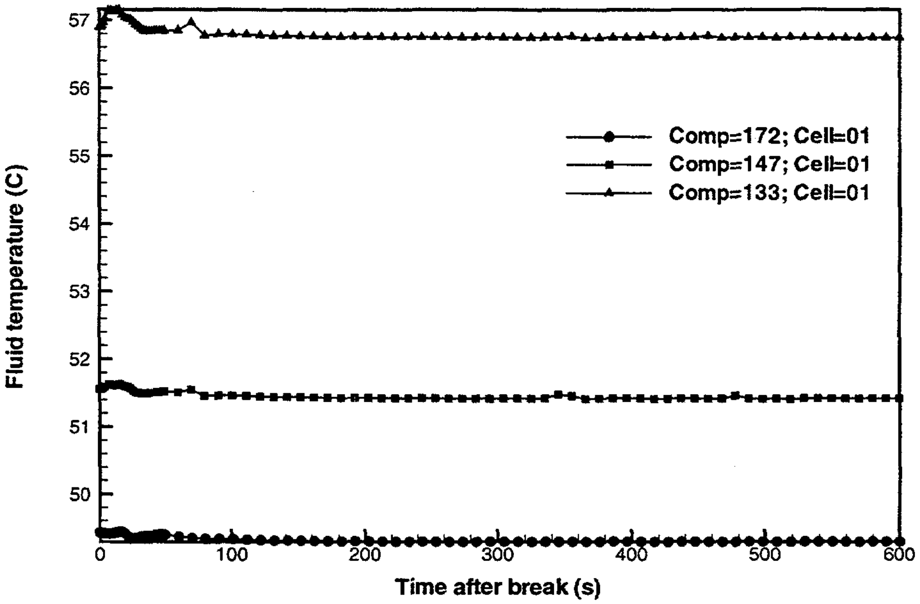

Figure C-4b Module 2 plenum fluid temperatures for a LOHGA (Case 2: helium supply plenum break near decoupler outlet).

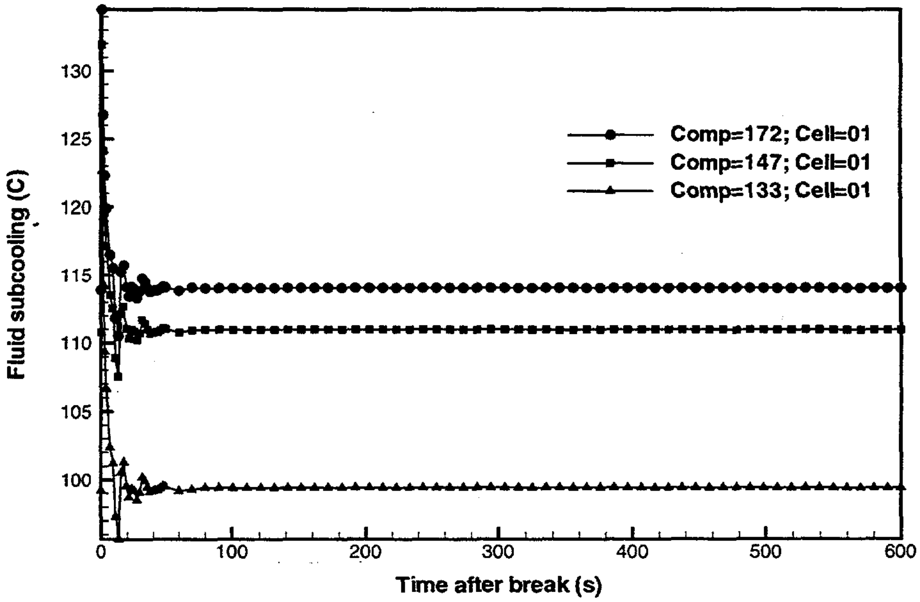

Figure C-4c Module 2 plenum fluid subcoolings for a LOHGA (Case 2: helium supply plenum break near decoupler outlet).

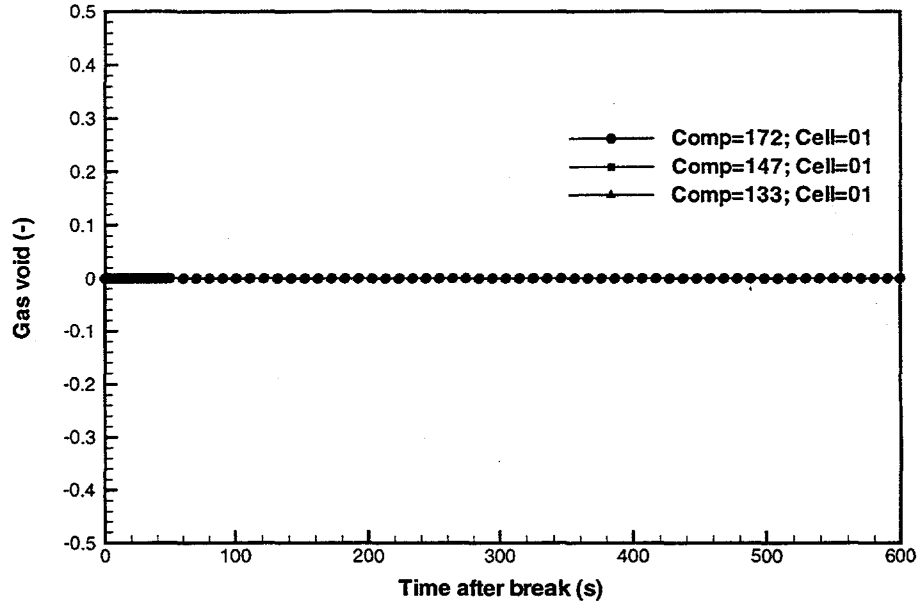

Figure C-4d Module 2 plenum void fractions for a LOHGA (Case 2: helium supply plenum break near decoupler outlet).

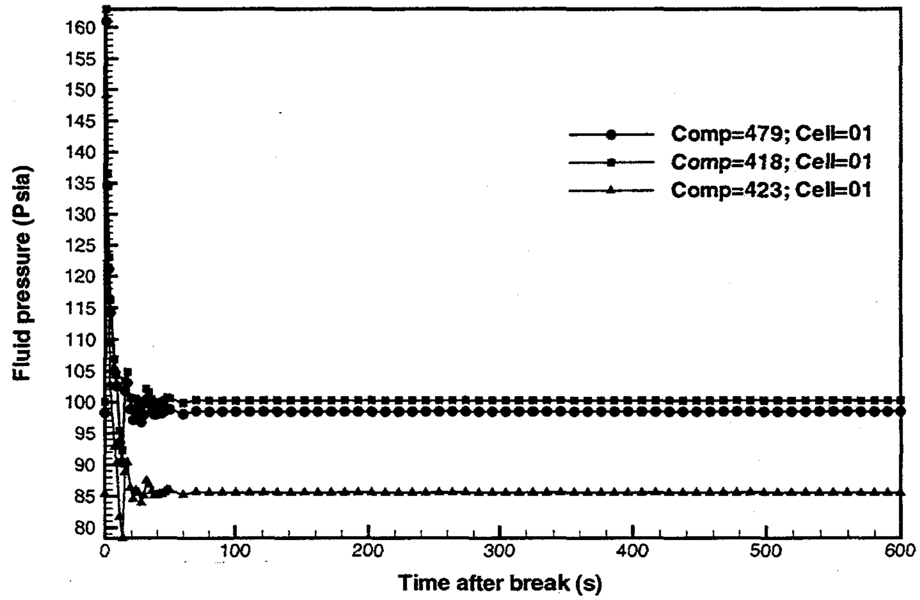

Figure C-5a Module 3 plenum fluid pressures for a LOHGA (Case 2: helium supply plenum break near decoupler outlet).

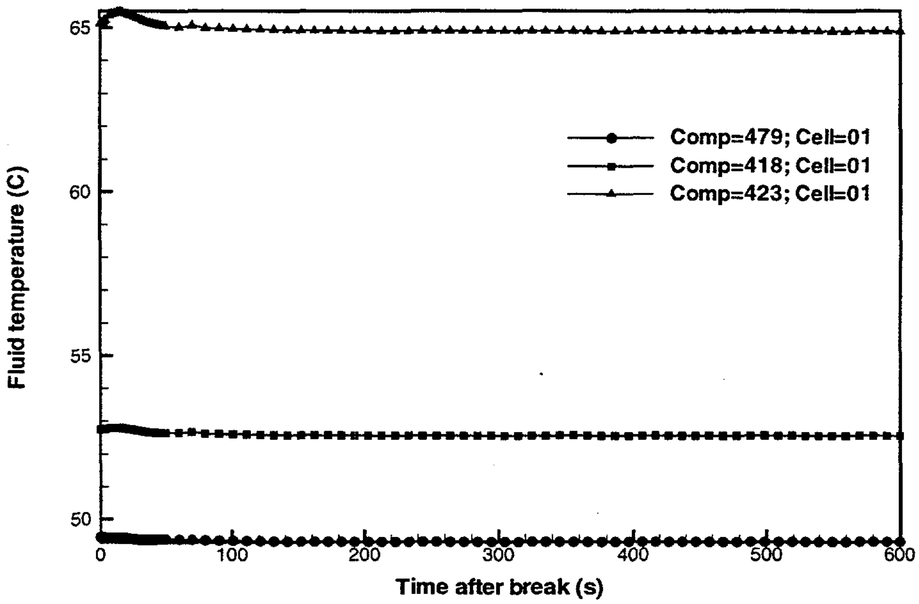

Figure C-5b Module 3 plenum fluid temperatures for a LOHGA (Case 2: helium supply plenum break near decoupler outlet).

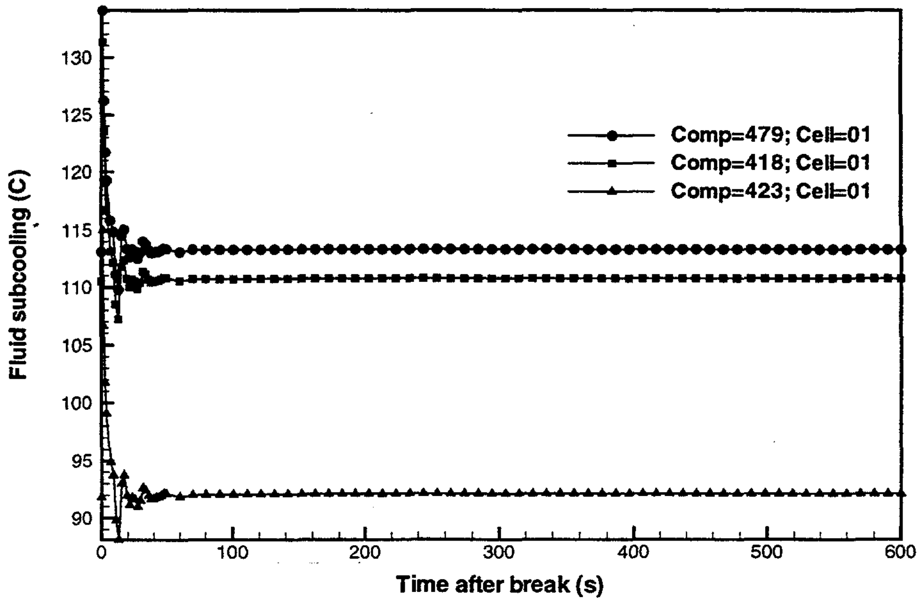

Figure C-5c Module 3 plenum fluid subcoolings for a LOHGA (Case 2: helium supply plenum break near decoupler outlet).

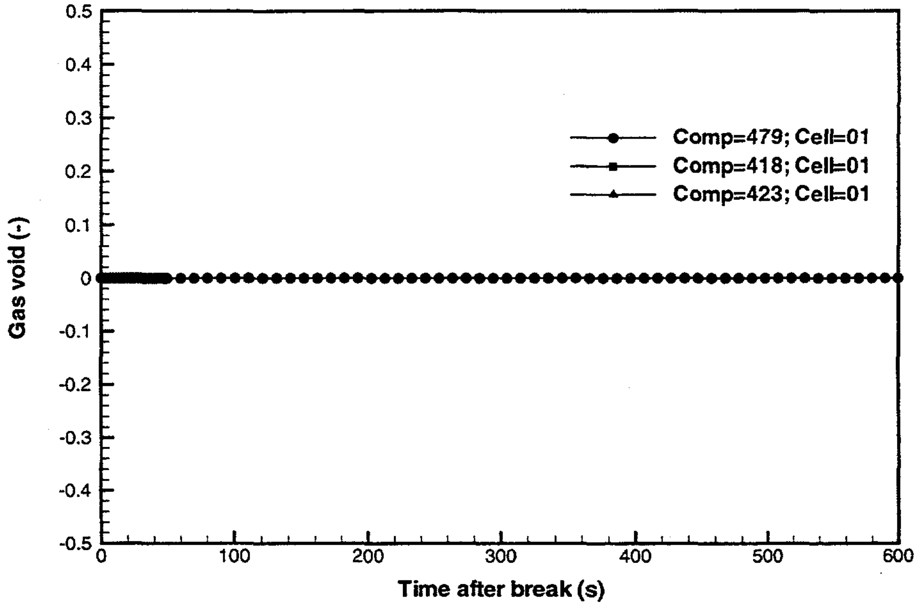

Figure C-5d Module 3 plenum void fractions for a LOHGA (Case 2: helium supply plenum break near decoupler outlet).

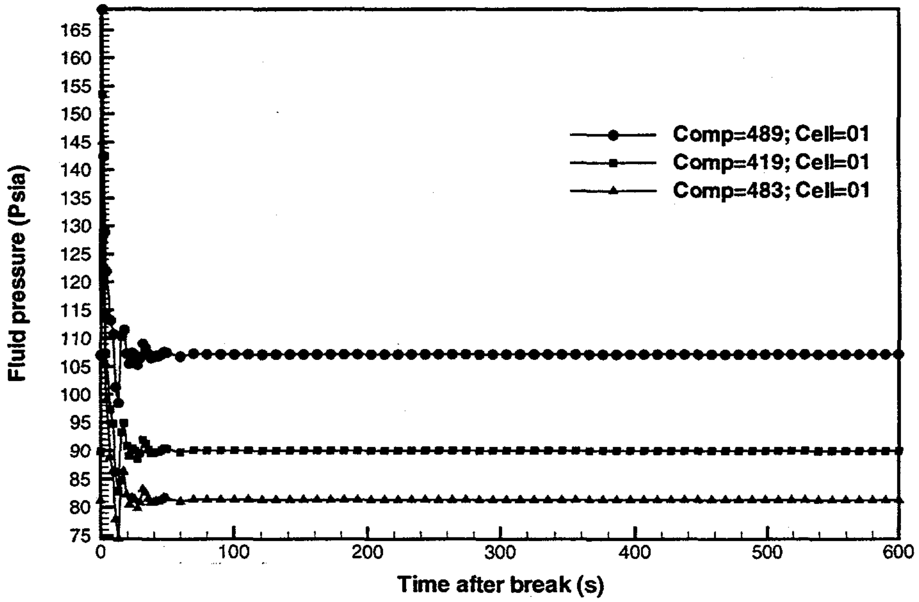

Figure C-6a Module 4 plenum fluid pressures for a LOHGA (Case 2: helium supply plenum break near decoupler outlet).

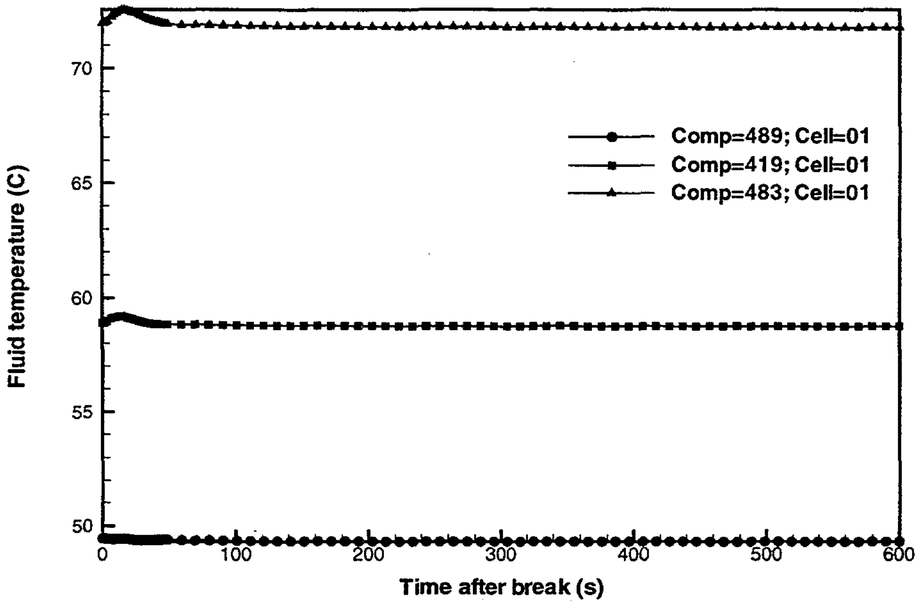

Figure C-6b Module 4 plenum fluid temperatures for a LOHGA (Case 2: helium supply plenum break near decoupler outlet).

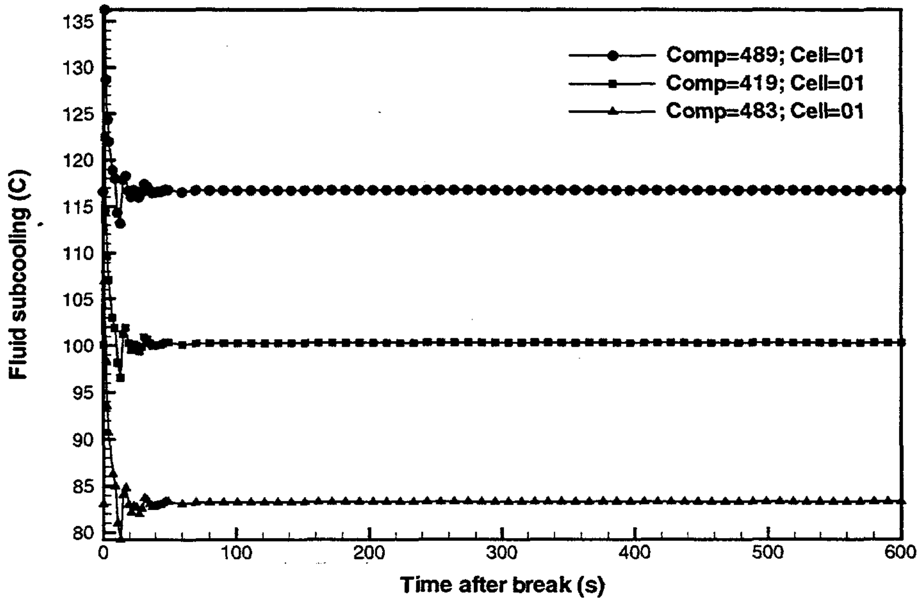

Figure C-6c Module 4 plenum fluid subcoolings for a LOHGA (Case 2: helium supply plenum break near decoupler outlet).

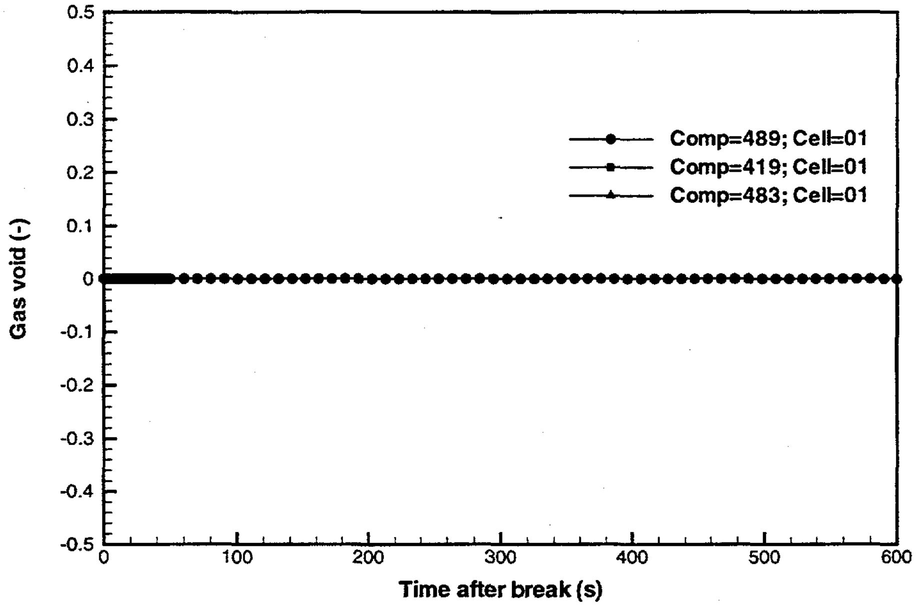

Figure C-6d Module 4 plenum void fractions for a LOHGA (Case 2: helium supply plenum break near decoupler outlet).

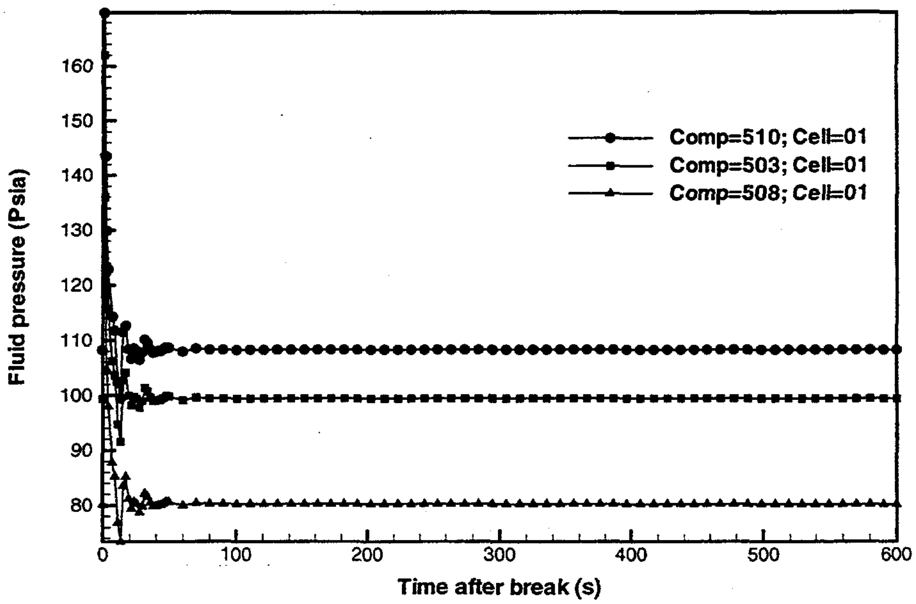

Figure C-7a Module 5 plenum fluid pressures for a LOHGA (Case 2: helium supply plenum break near decoupler outlet).

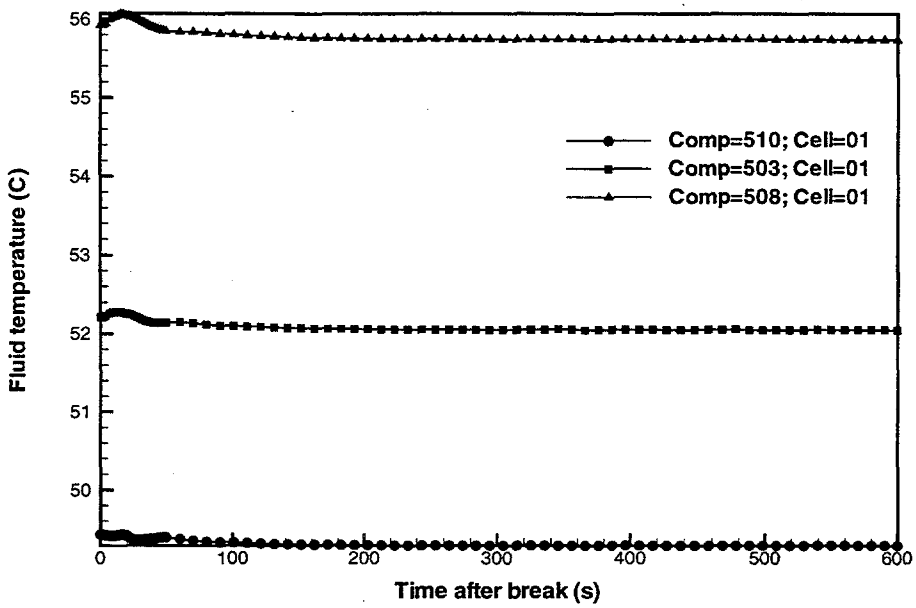

Figure C-7b Module 5 plenum fluid temperatures for a LOHGA (Case 2: helium supply plenum break near decoupler outlet).

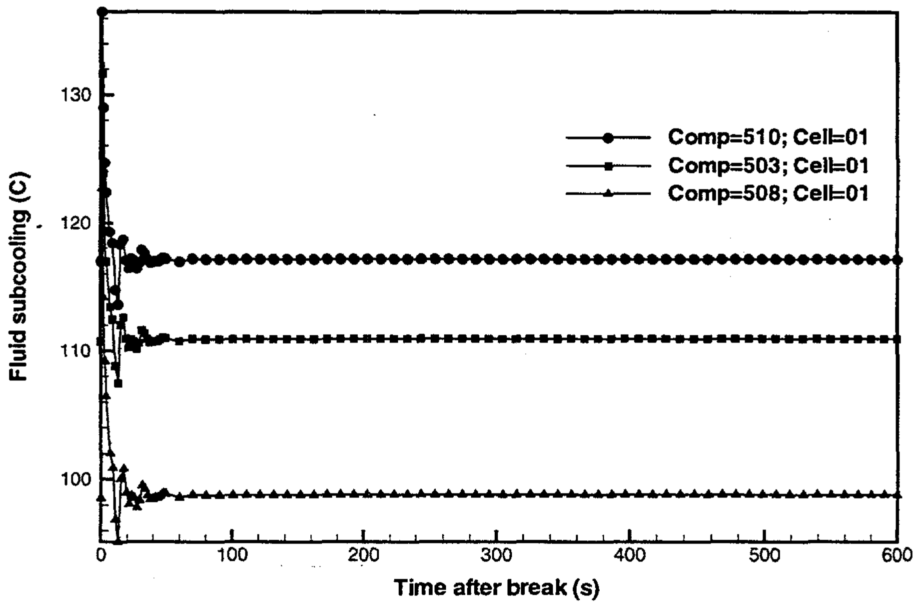

Figure C-7c Module 5 plenum fluid subcoolings for a LOHGA (Case 2: helium supply plenum break near decoupler outlet).

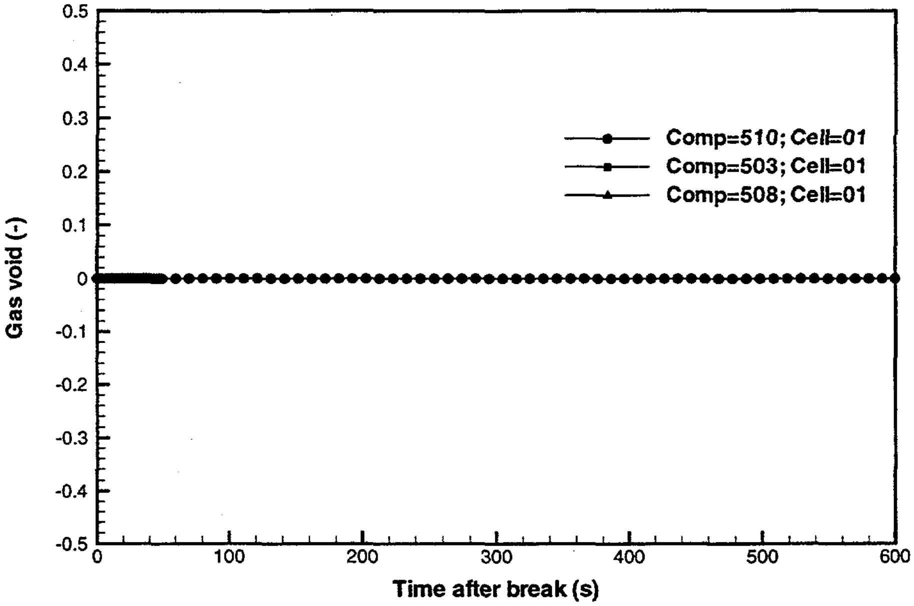

Figure C-7d Module 5 plenum void fractions for a LOHGA (Case 2: helium supply plenum break near decoupler outlet).

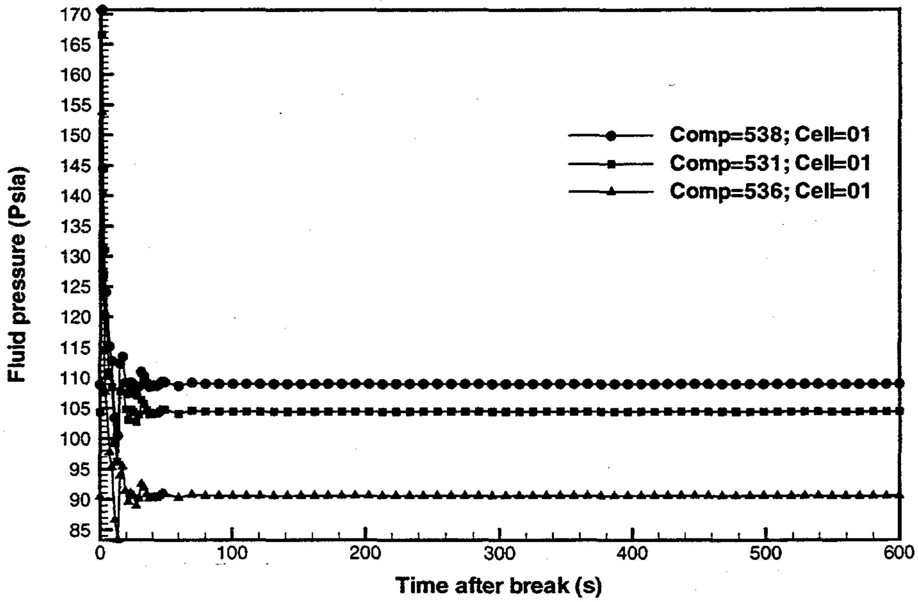

Figure C-8a Module 6 plenum fluid pressures for a LOHGA (Case 2: helium supply plenum break near decoupler outlet).

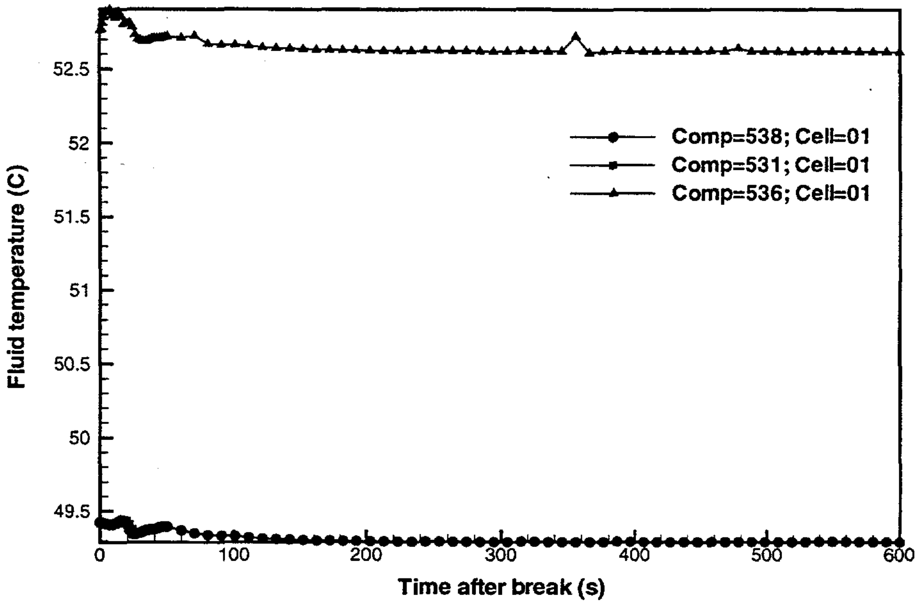

Figure C-8b Module 6 plenum fluid temperatures for a LOHGA (Case 2: helium supply plenum break near decoupler outlet).

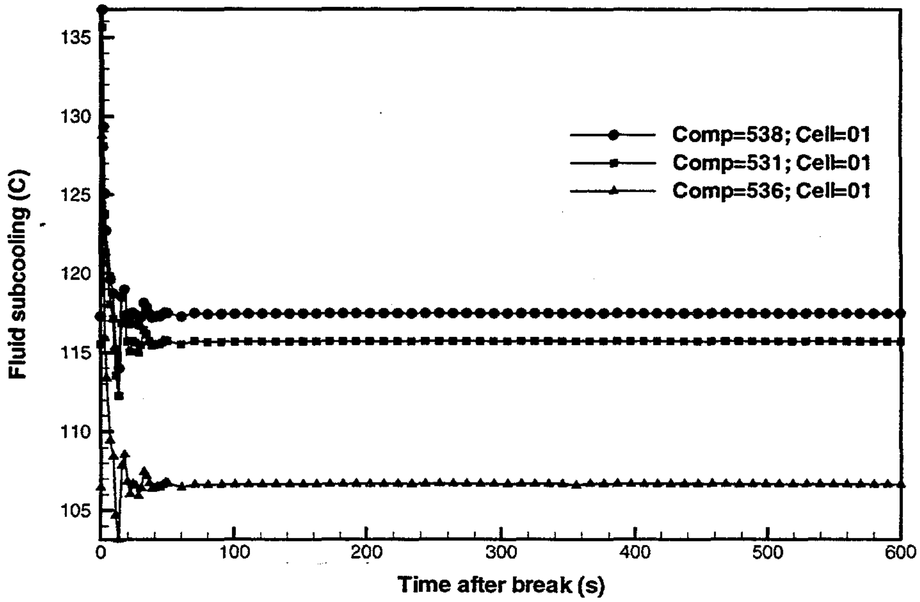

Figure C-8c Module 6 plenum fluid subcoolings for a LOHGA (Case 2: helium supply plenum break near decoupler outlet).

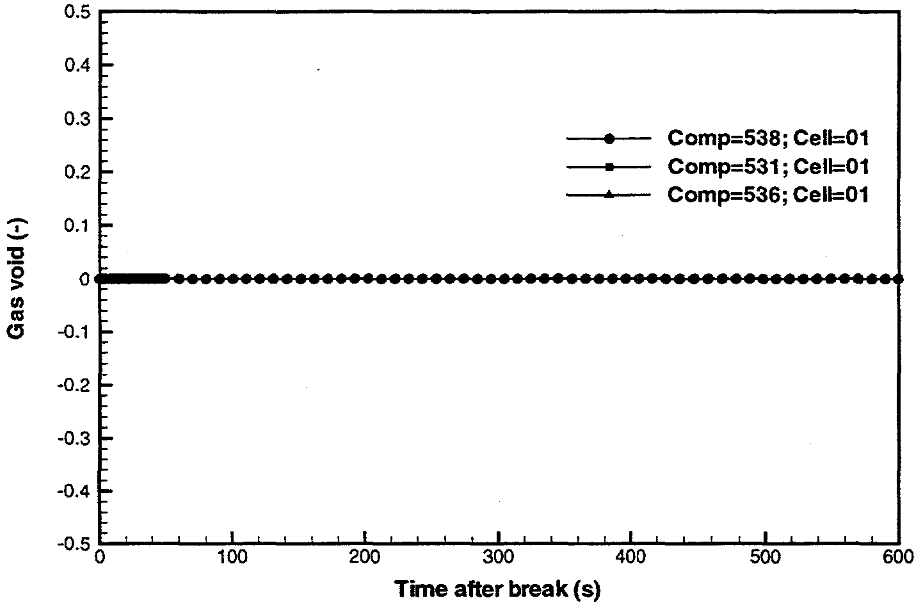

Figure C-8d Module 6 plenum void fractions for a LOHGA (Case 2: helium supply plenum break near decoupler outlet).

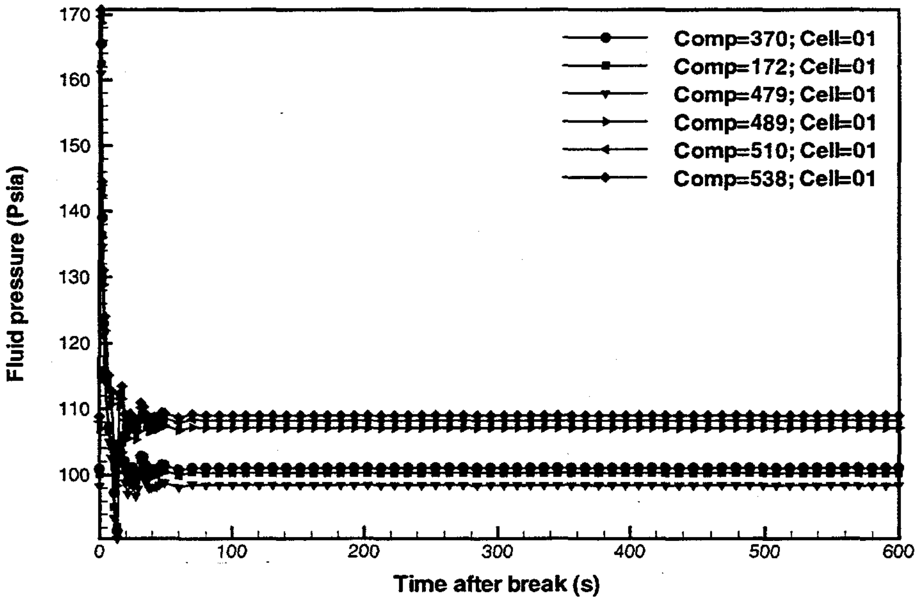

Figure C-9a Module outlet plenum fluid pressures for a LOHGA (Case 2: helium supply plenum break near decoupler outlet).

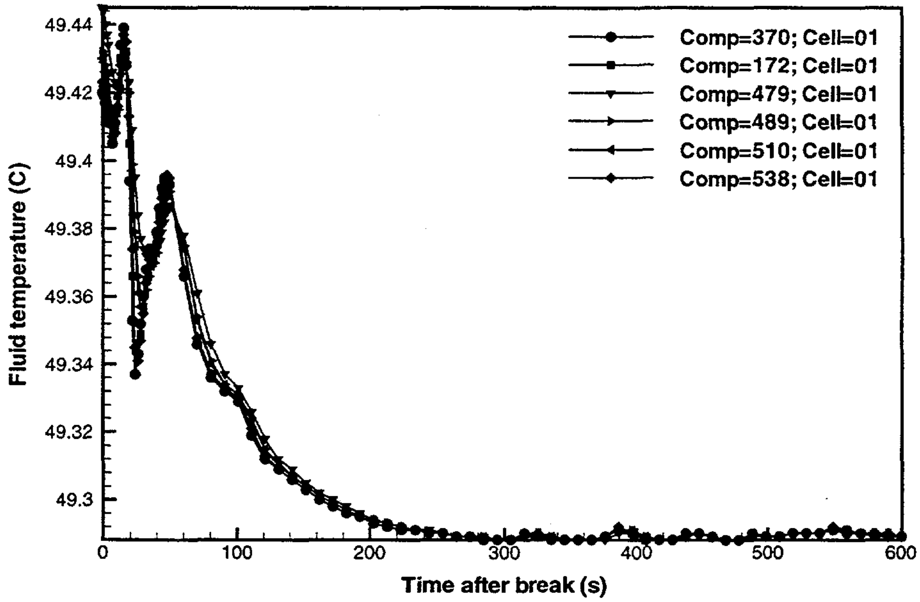

Figure C-9b Module outlet plenum fluid temperatures for a LOHGA (Case 2: helium supply plenum break near decoupler outlet).

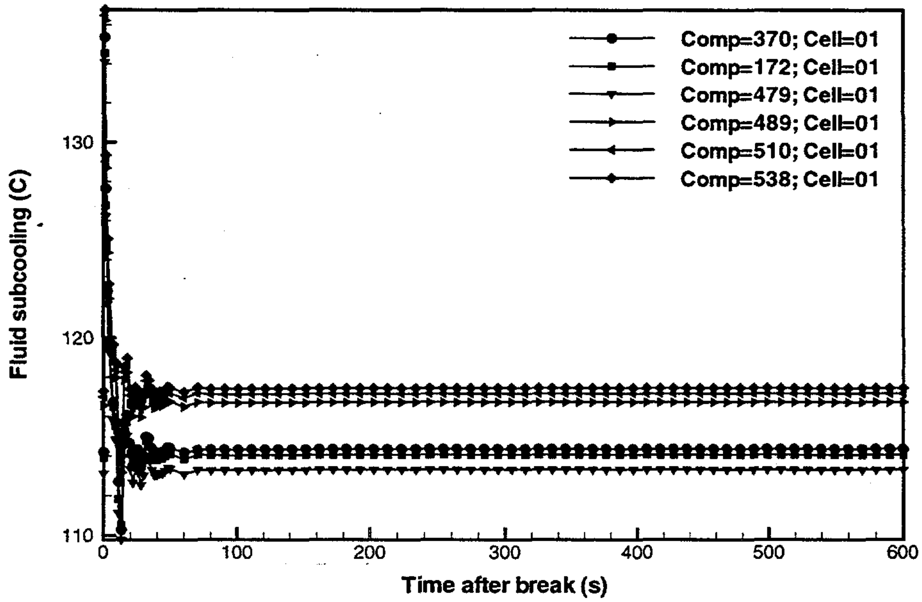

Figure C-9c Module outlet plenum fluid subcoolings for a LOHGA (Case 2: helium supply plenum break near decoupler outlet).

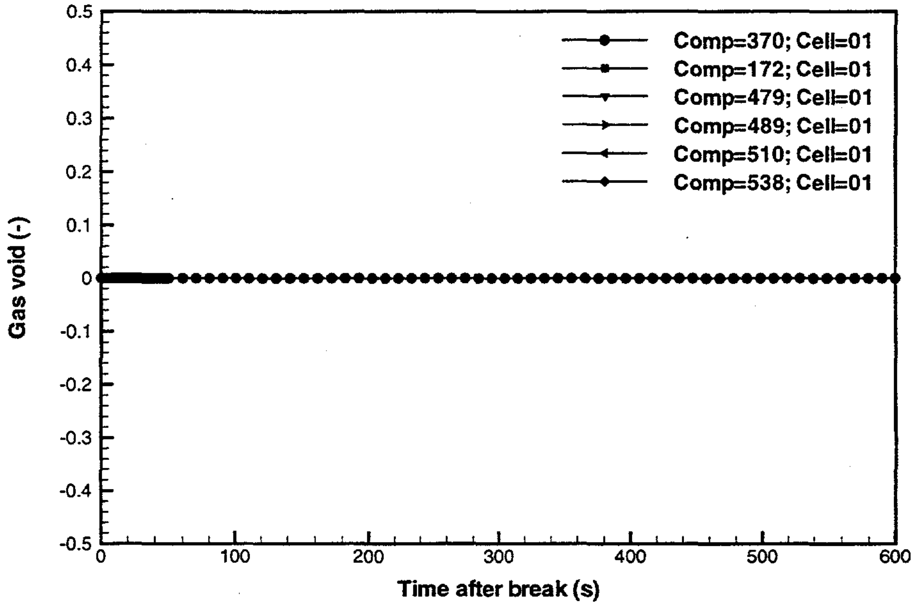

Figure C-9d Module outlet plenum void fractions for a LOHGA (Case 2: helium supply plenum break near decoupler outlet).

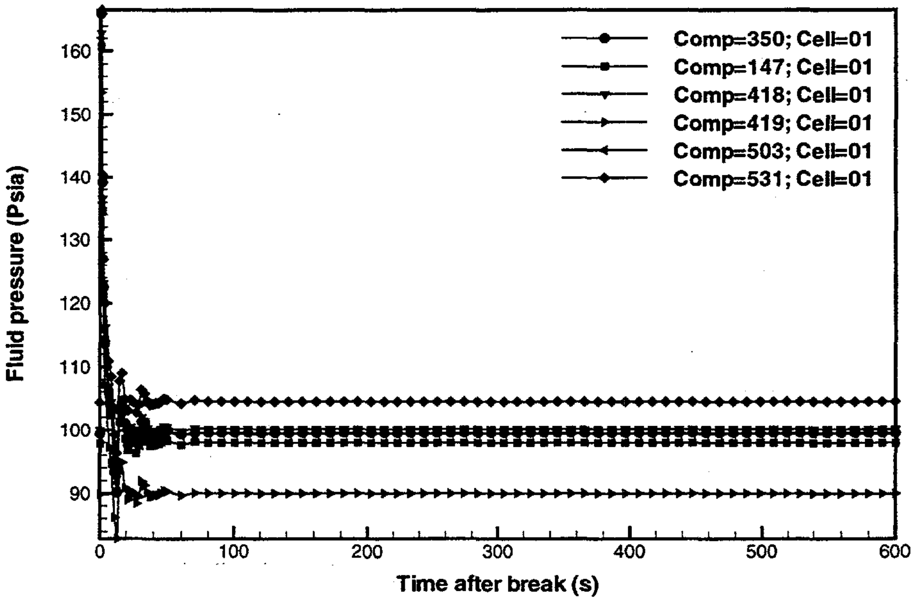

Figure C-10a Module middle plenum fluid pressures for a LOHGA (Case 2: helium supply plenum break near decoupler outlet).

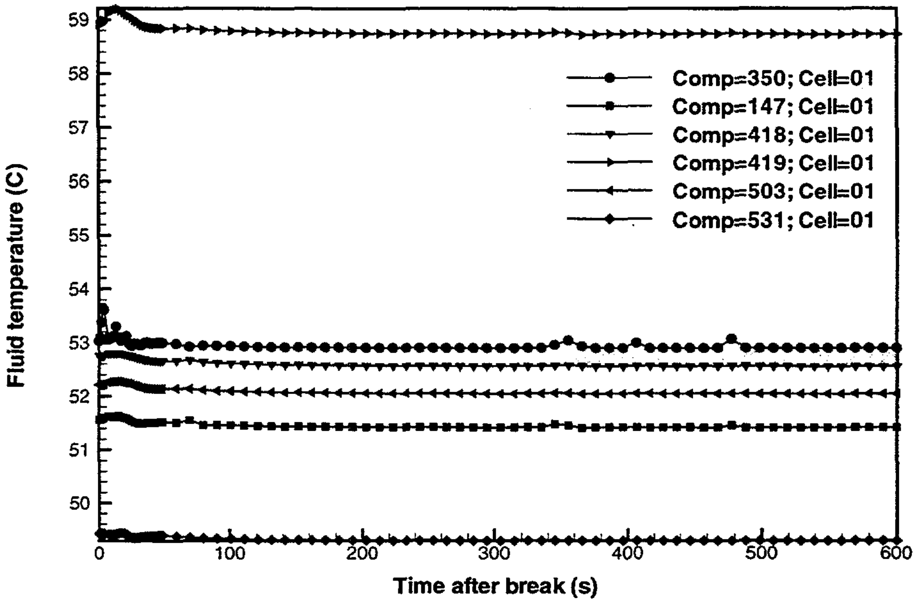

Figure C-10b Module middle plenum fluid temperatures for a LOHGA (Case 2: helium supply plenum break near decoupler outlet).

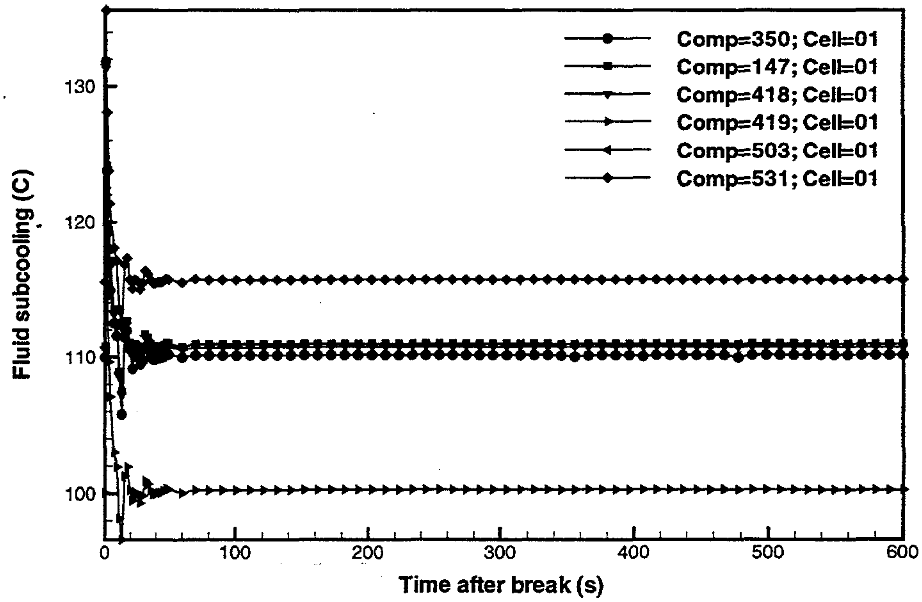

Figure C-10c Module middle plenum fluid subcoolings for a LOHGA (Case 2: helium supply plenum break near decoupler outlet).

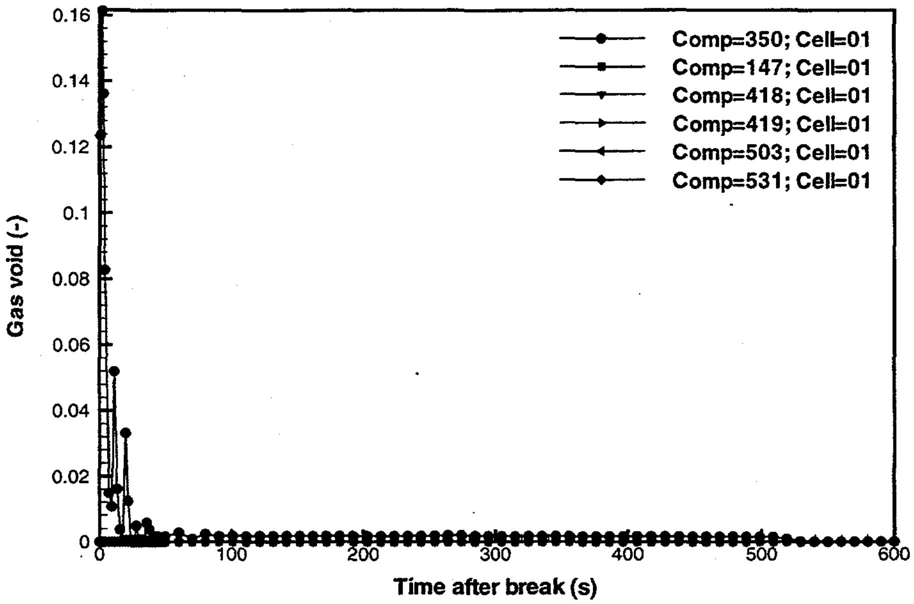

Figure C-10d Module middle plenum void fractions for a LOHGA (Case 2: helium supply plenum break near decoupler outlet).

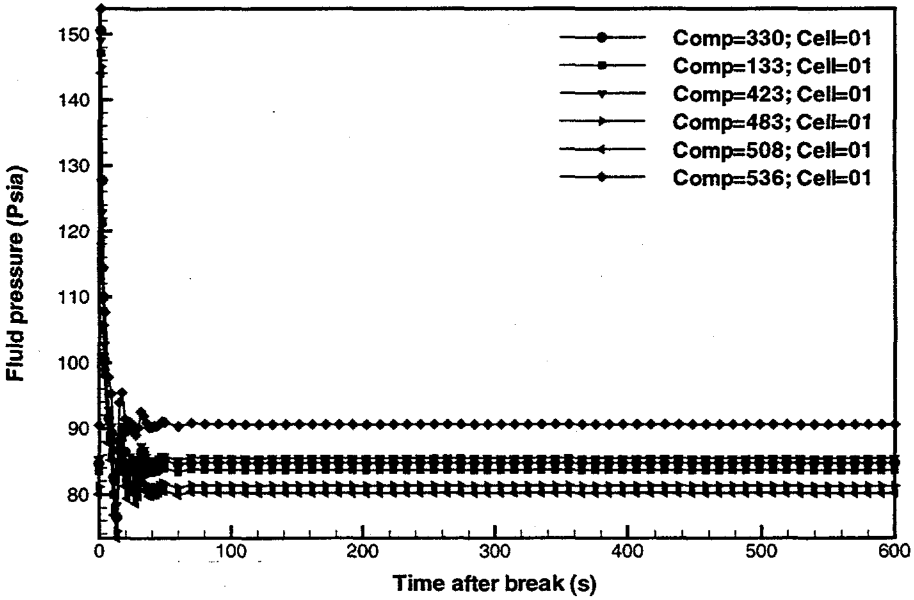

Figure C-11a Module outlet plenum fluid pressures for a LOHGA (Case 2: helium supply plenum break near decoupler outlet).

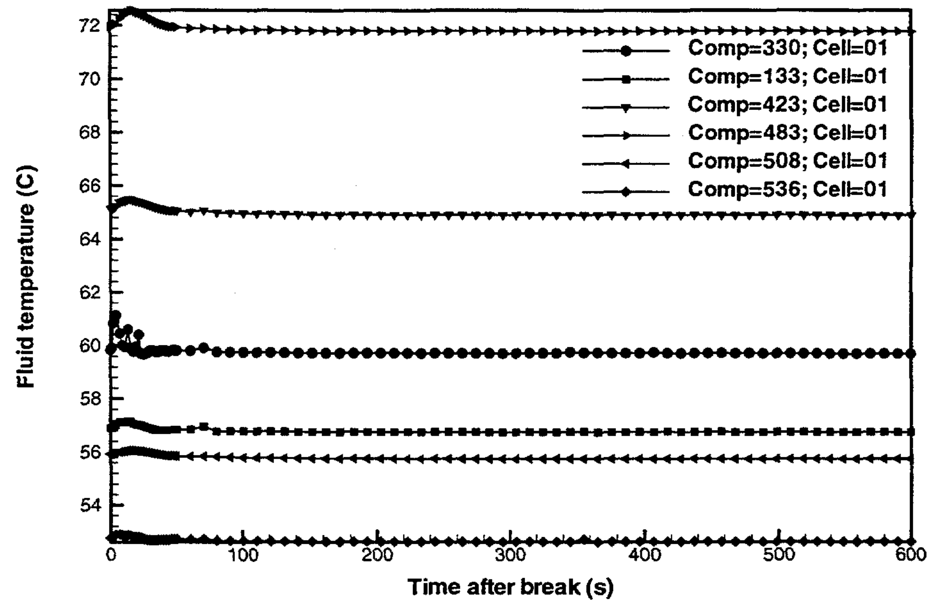

Figure C-11b Module outlet plenum fluid temperatures for a LOHGA (Case 2: helium supply plenum break near decoupler outlet).

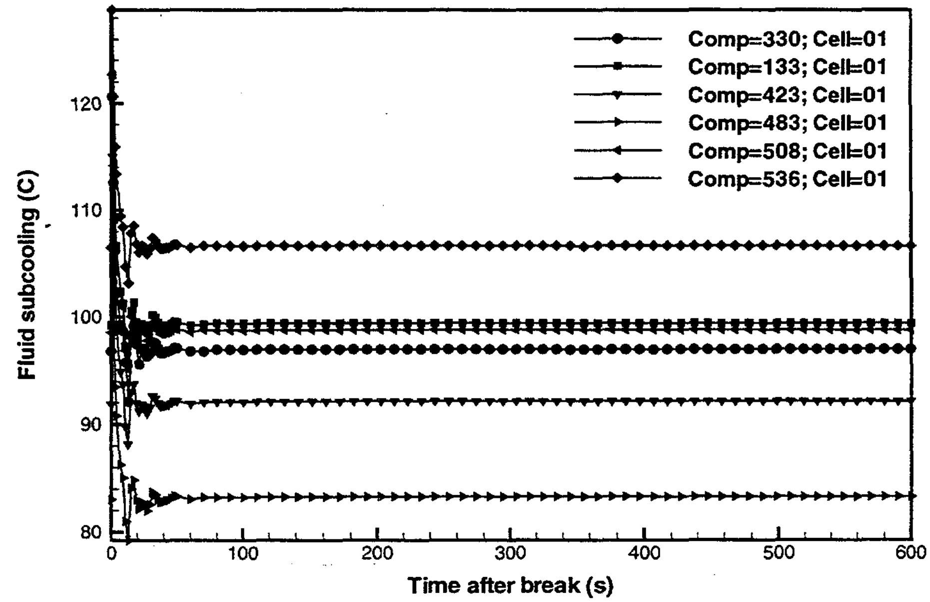

Figure C-11c Module outlet plenum fluid subcoolings for a LOHGA (Case 2: helium supply plenum break near decoupler outlet).

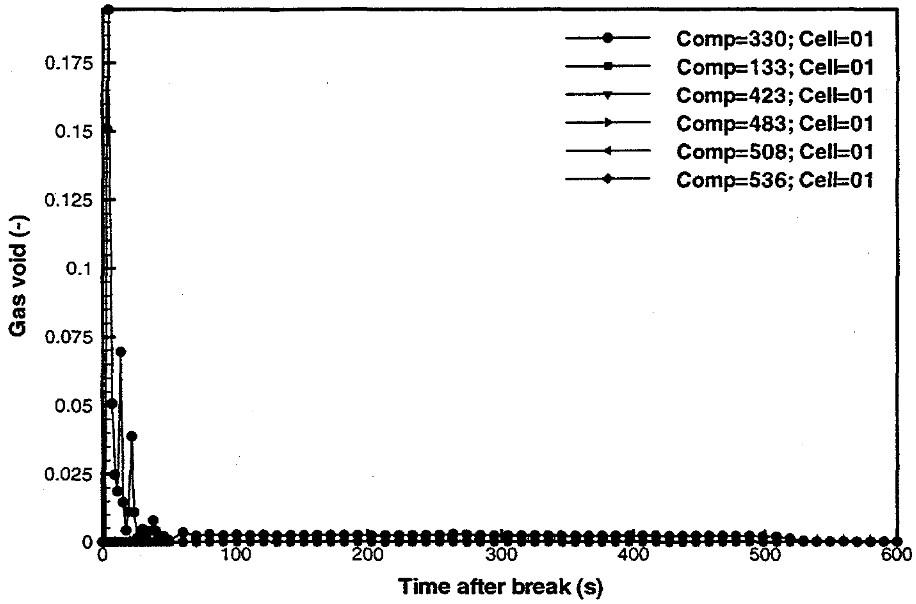

Figure C-11d Module outlet plenum void fractions for a LOHGA (Case 2: helium supply plenum break near decoupler outlet).

Appendix C2 LOHGA (Case 2) TRAC Pipe, Pump, and Valve Component Figures

The following figures are from a TRAC simulation for Case 2 of a LOHGA (Helium supply plenum break near decoupler outlet):

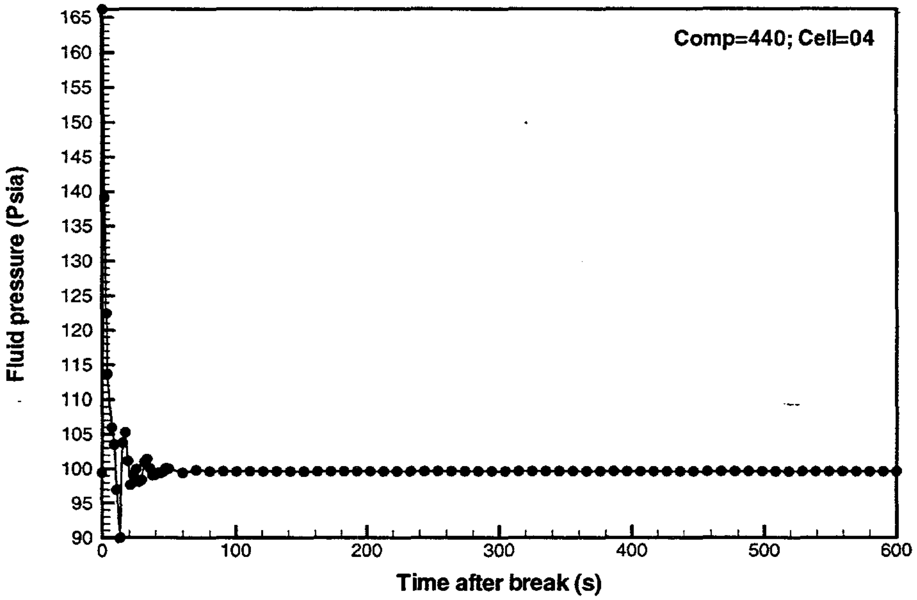

Figure C-12a Helium gas line fluid pressures for a LOHGA (Case 2: helium supply plenum break near decoupler outlet).

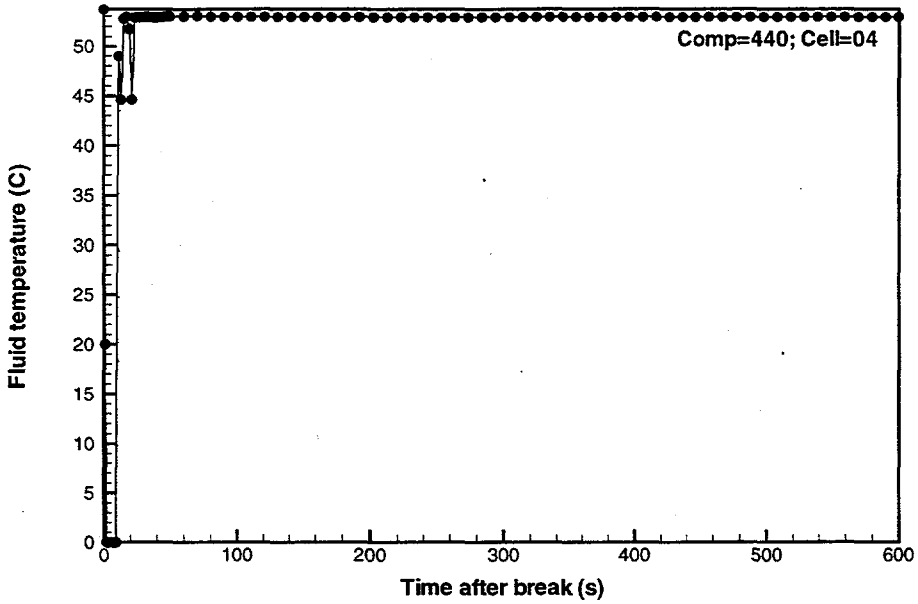

Figure C-12b Helium gas line fluid temperatures for a LOHGA (Case 2: helium supply plenum break near decoupler outlet).

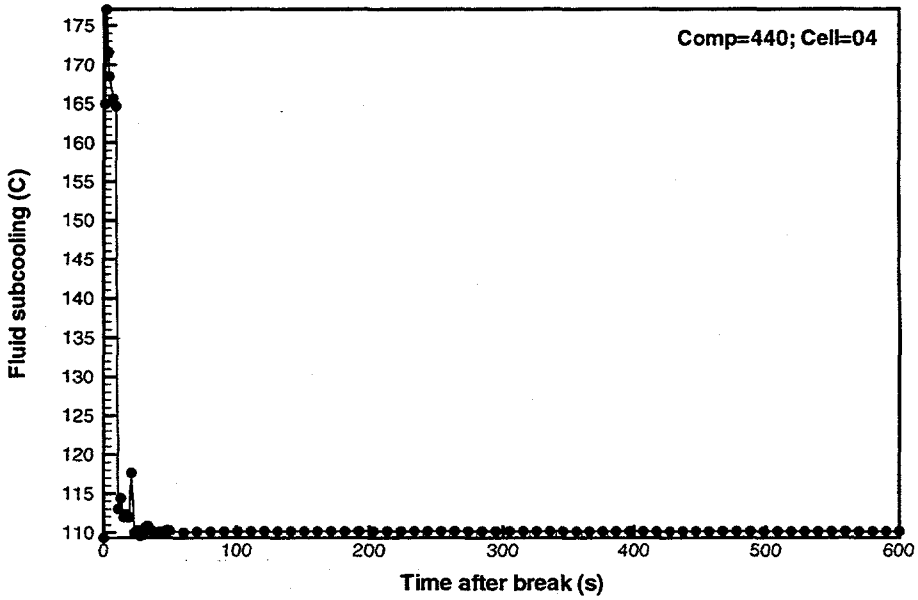

Figure C-12c Helium gas line fluid subcoolings for a LOHGA (Case 2: helium supply plenum break near decoupler outlet).

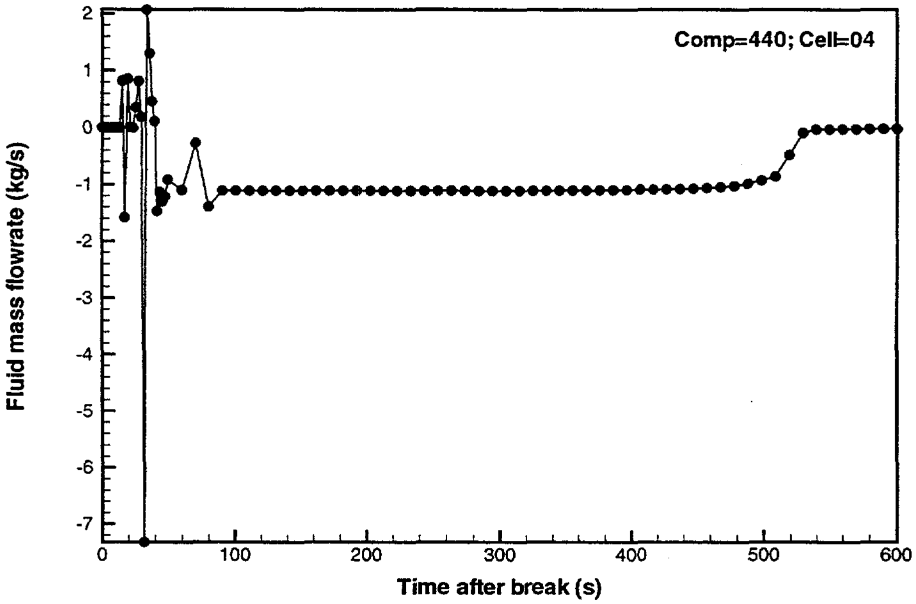

Figure C-12d Helium gas line liquid mass flowrates for a LOHGA (Case 2: helium supply plenum break near decoupler outlet).

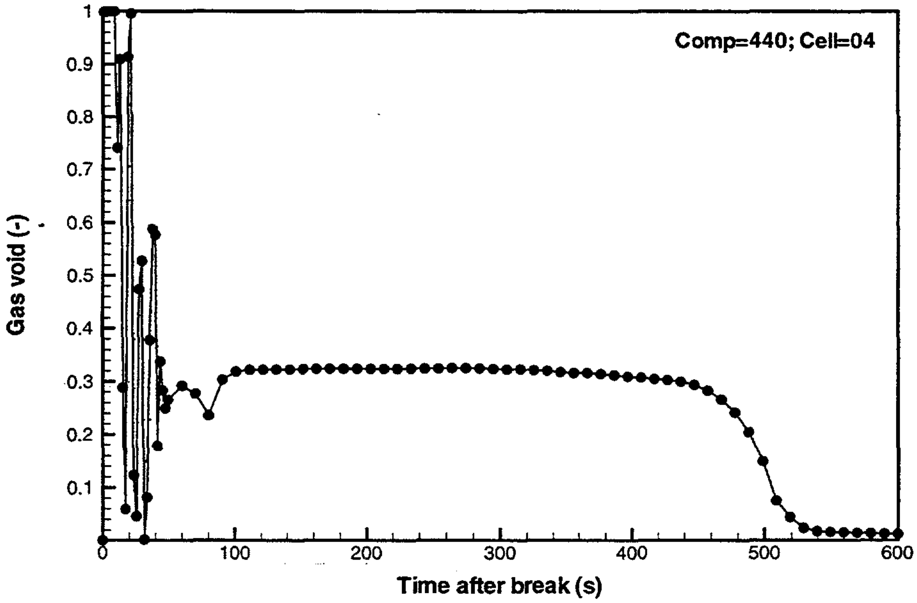

Figure C-12e Helium gas line void fractions for a LOHGA (Case 2: helium supply plenum break near decoupler outlet).

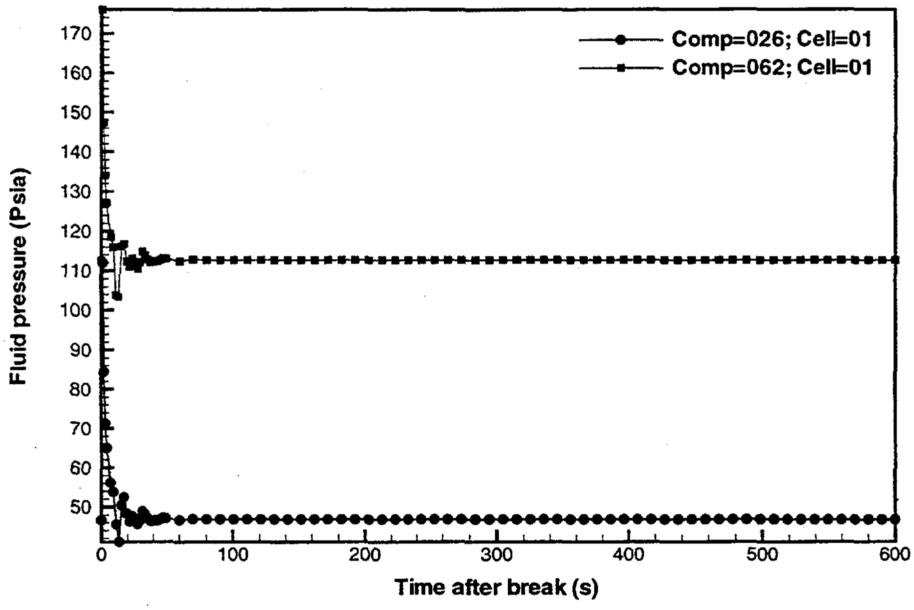

Figure C-13a Primary HR hot and cold leg piping fluid pressures for a LOHGA (Case 2: helium supply plenum break near decoupler outlet).

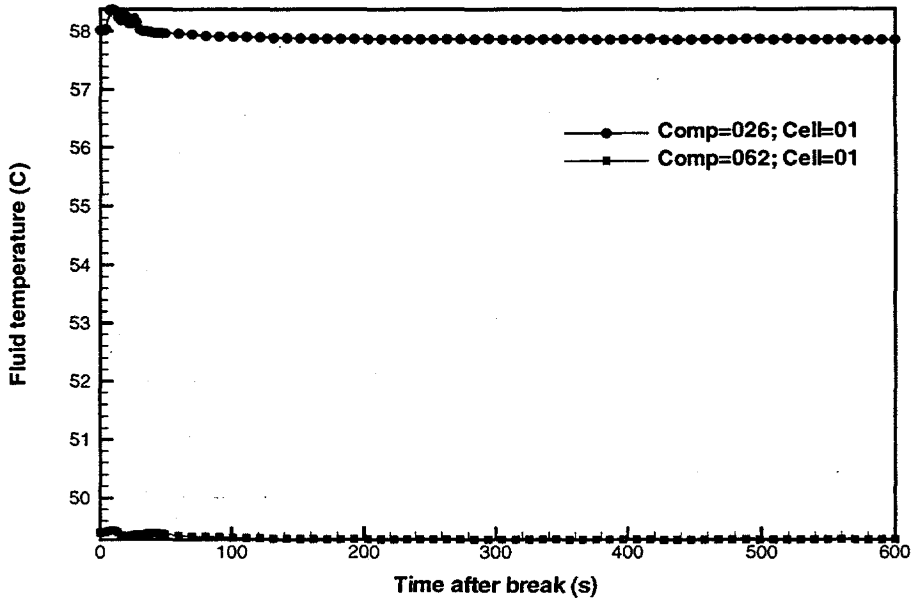

Figure C-13b Primary HR hot and cold leg piping fluid temperatures for a LOHGA (Case 2: helium supply plenum break near decoupler outlet).

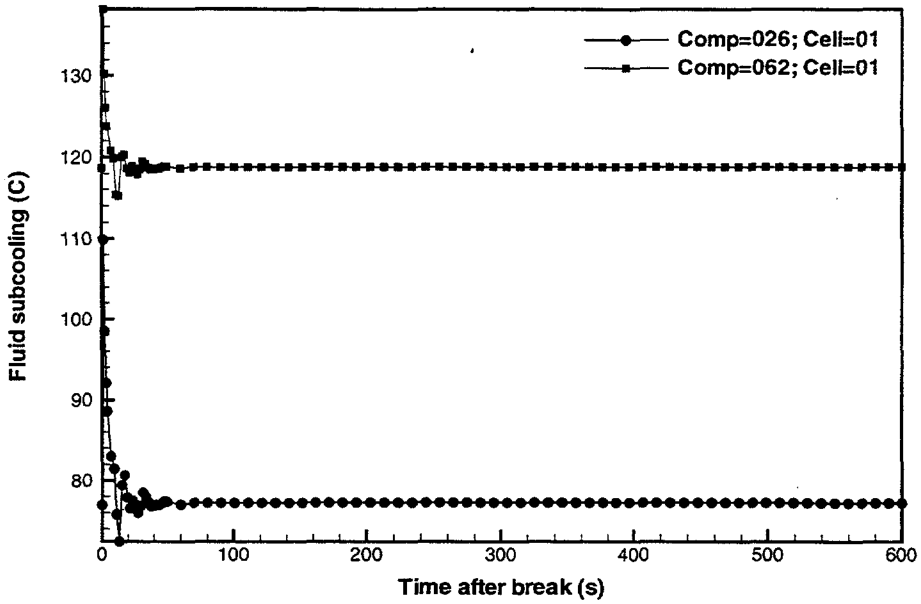

Figure C-13c Primary HR hot and cold leg piping fluid subcoolings for a LOHGA (Case 2: helium supply plenum break near decoupler outlet).

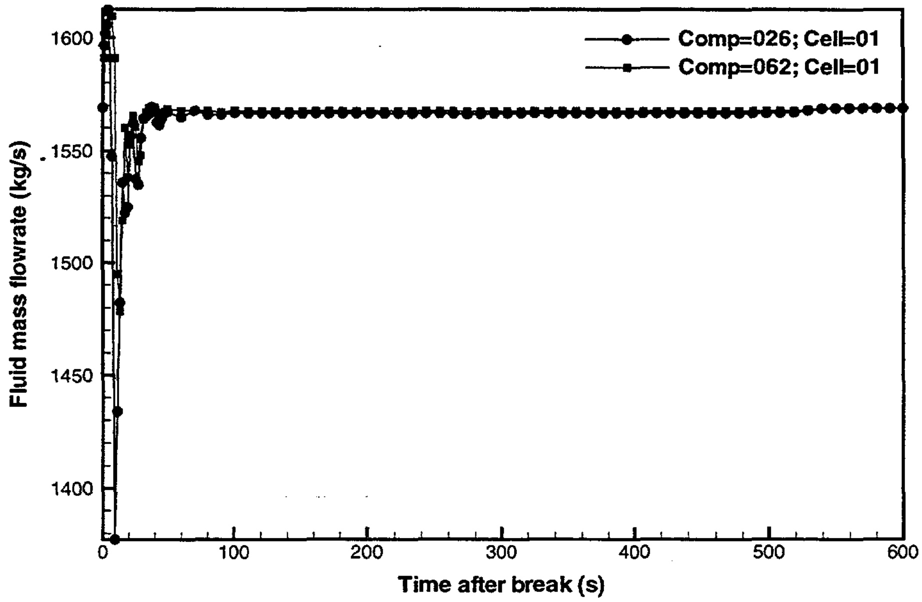

Figure C-13d Primary HR hot and cold leg piping liquid mass flowrates for a LOHGA (Case 2: helium supply plenum break near decoupler outlet).

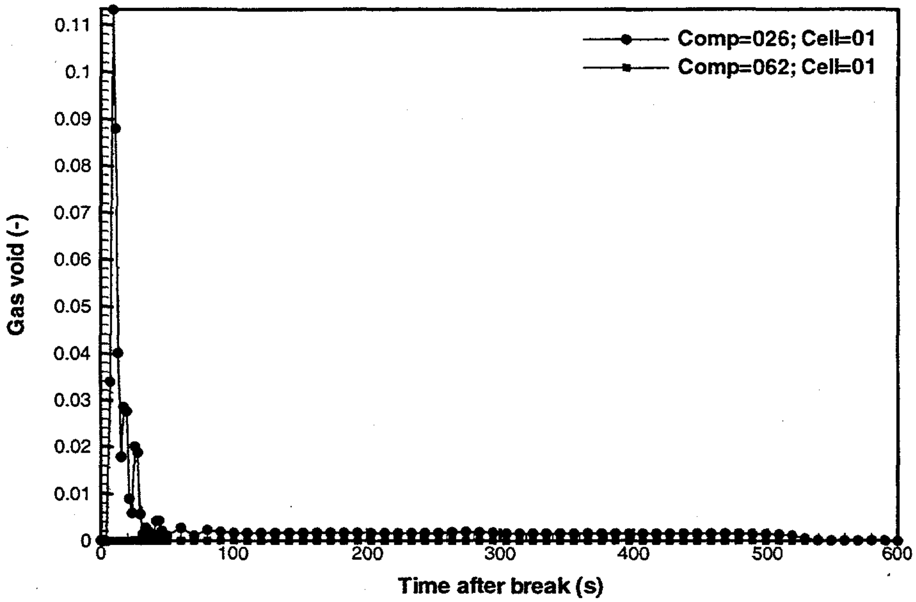

Figure C-13e Primary HR hot and cold leg piping void fractions for a LOHGA (Case 2: helium supply plenum break near decoupler outlet).

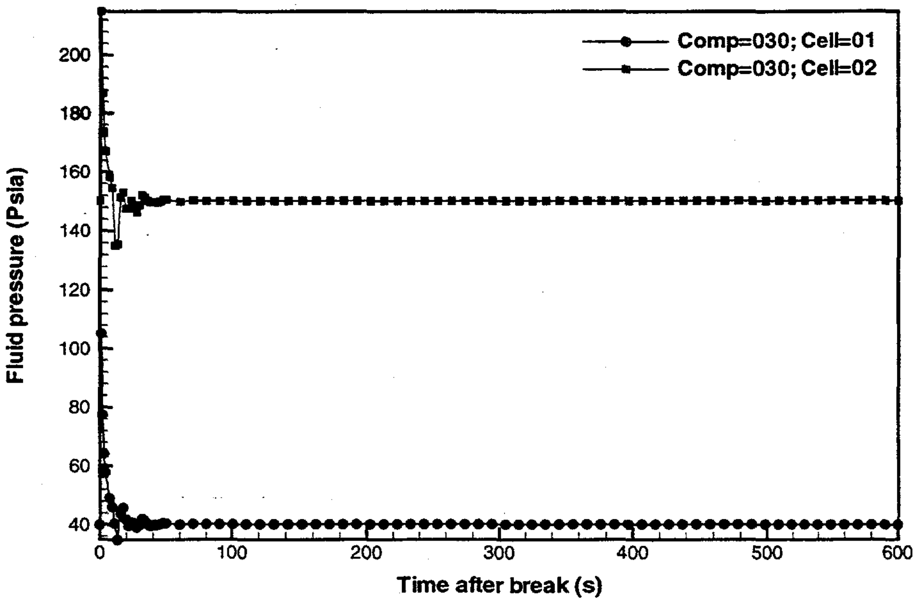

Figure C-14a Primary HR pump 1 fluid pressures for a LOHGA (Case 2: helium supply plenum break near decoupler outlet).

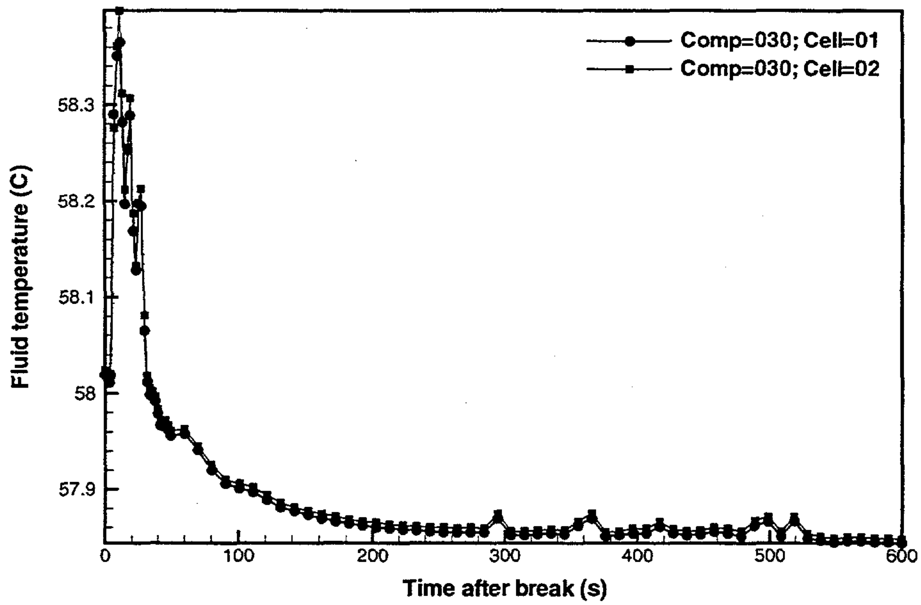

Figure C-14b Primary HR pump 1 fluid temperatures for a LOHGA (Case 2: helium supply plenum break near decoupler outlet).

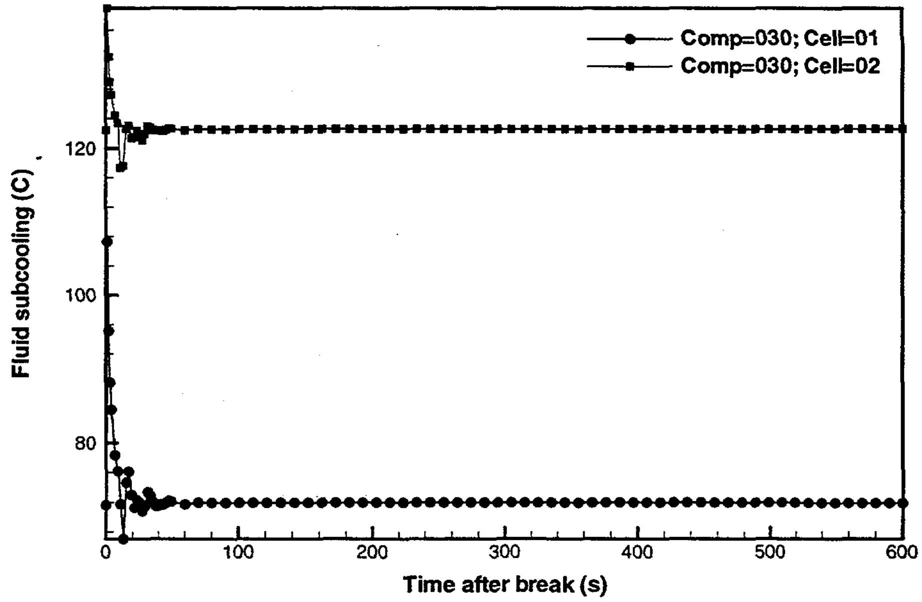

Figure C-14c Primary HR pump 1 fluid subcoolings for a LOHGA (Case 2: helium supply plenum break near decoupler outlet).

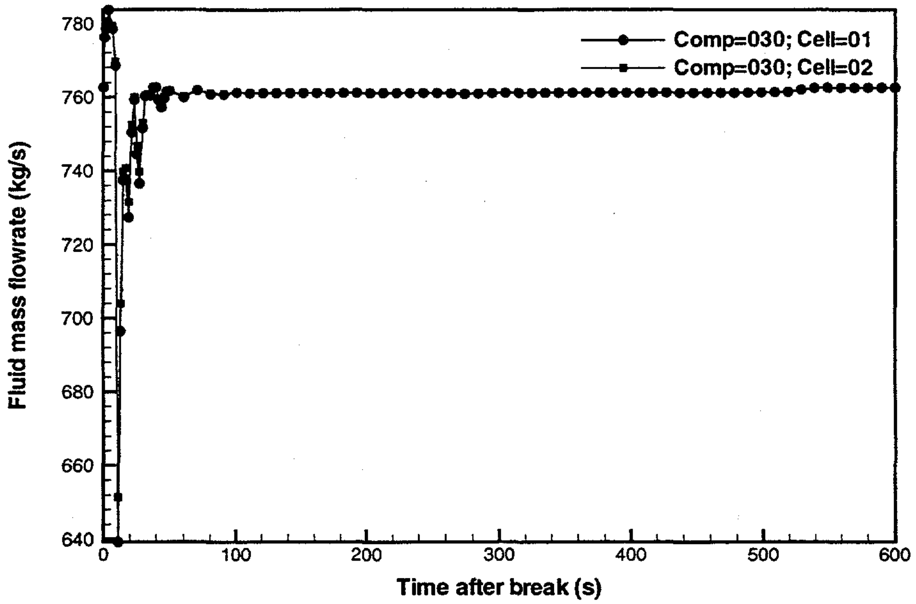

Figure C-14d Primary HR pump 1 liquid mass flowrates for a LOHGA (Case 2: helium supply plenum break near decoupler outlet).

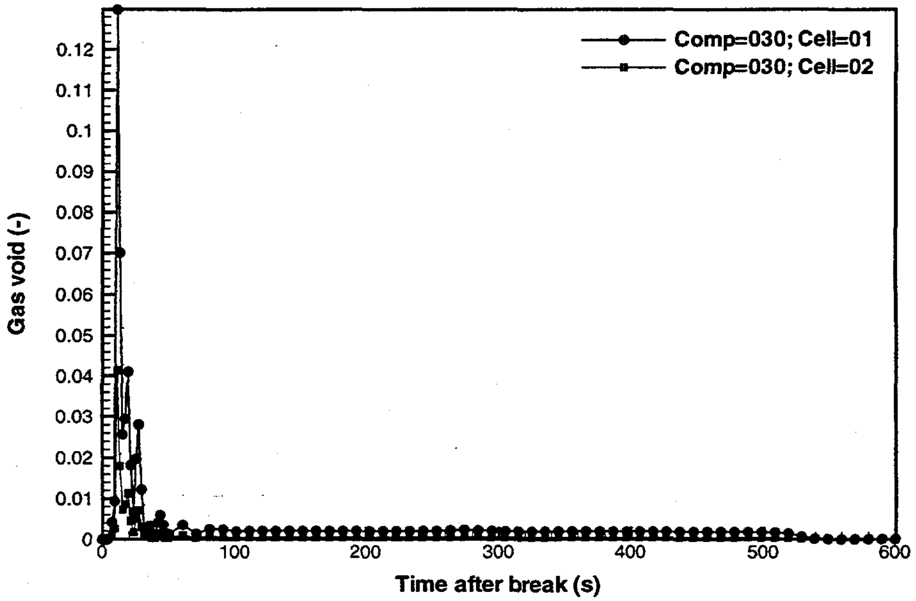

Figure C-14e Primary HR pump 1 void fractions for a LOHGA (Case 2: helium supply plenum break near decoupler outlet).

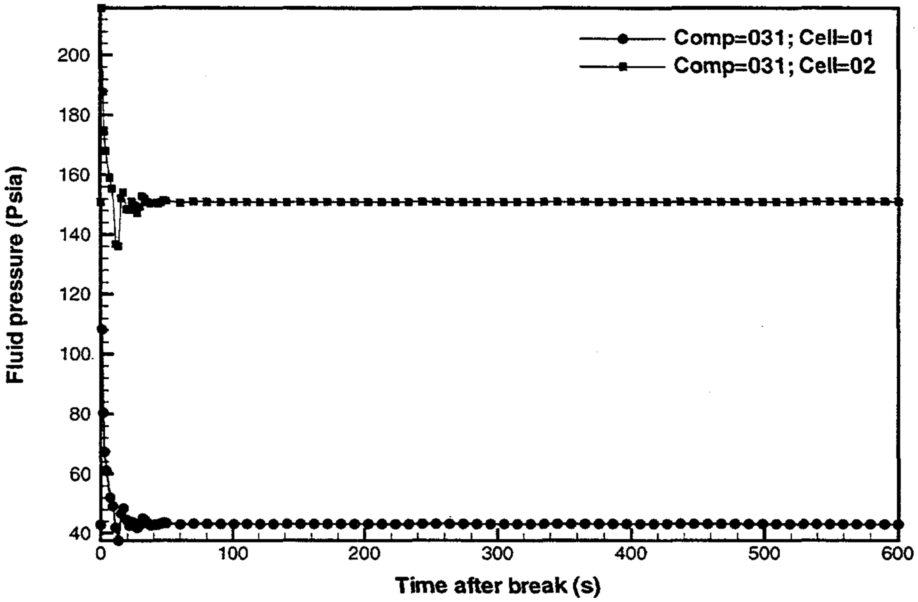

Figure C-15a Primary HR pump 2 fluid pressures for a LOHGA (Case 2: helium supply plenum break near decoupler outlet).

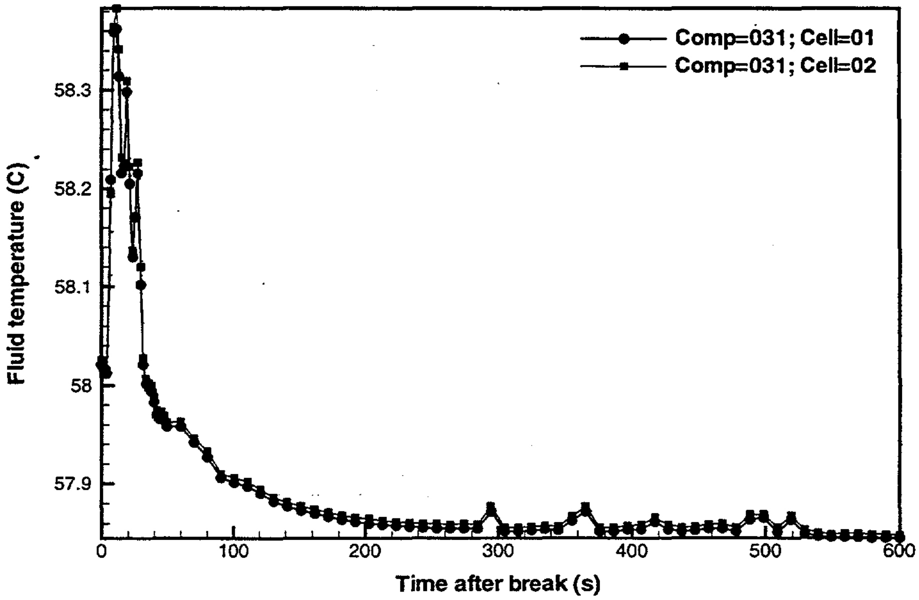

Figure C-15b Primary HR pump 2 fluid temperatures for a LOHGA (Case 2: helium supply plenum break near decoupler outlet).

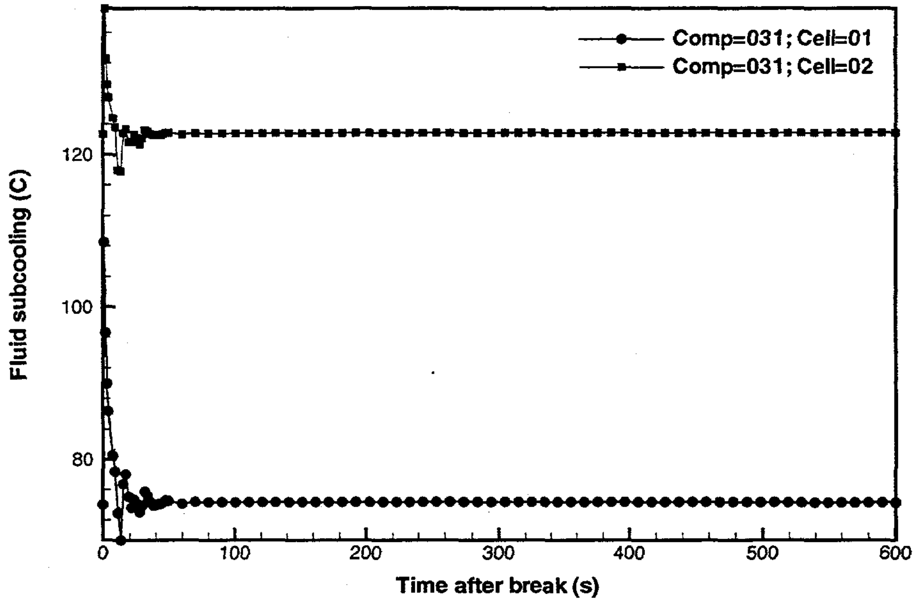

Figure C-15c Primary HR pump 2 fluid subcoolings for a LOHGA (Case 2: helium supply plenum break near decoupler outlet).

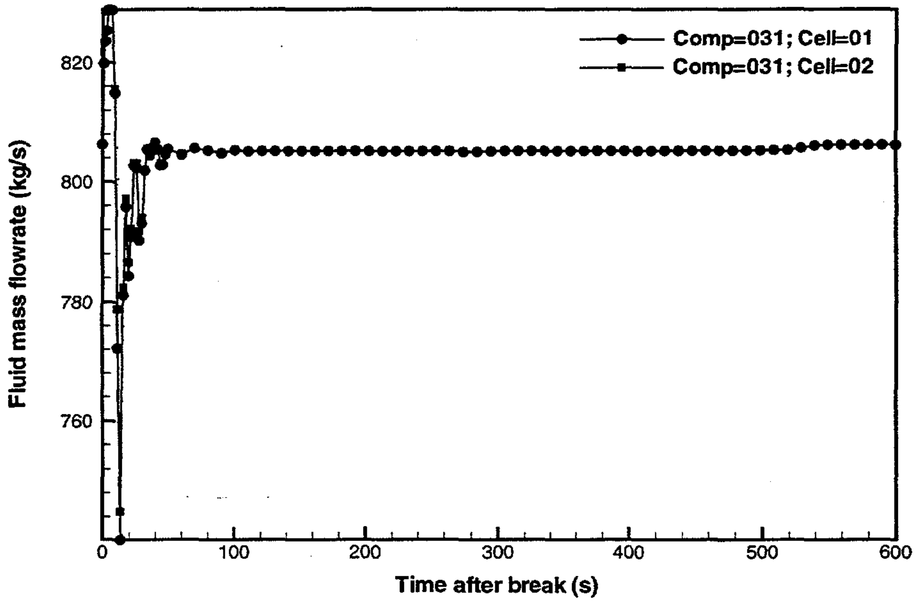

Figure C-15d Primary HR pump 2 liquid mass flowrates for a LOHGA (Case 2: helium supply plenum break near decoupler outlet).

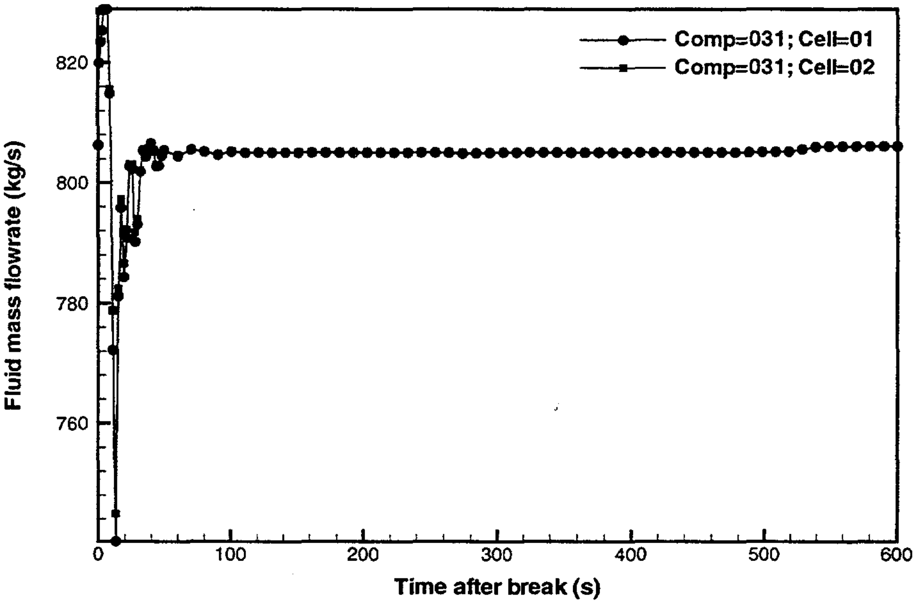

Figure C-15e Primary HR pump 2 void fractions for a LOHGA (Case 2: helium supply plenum break near decoupler outlet).

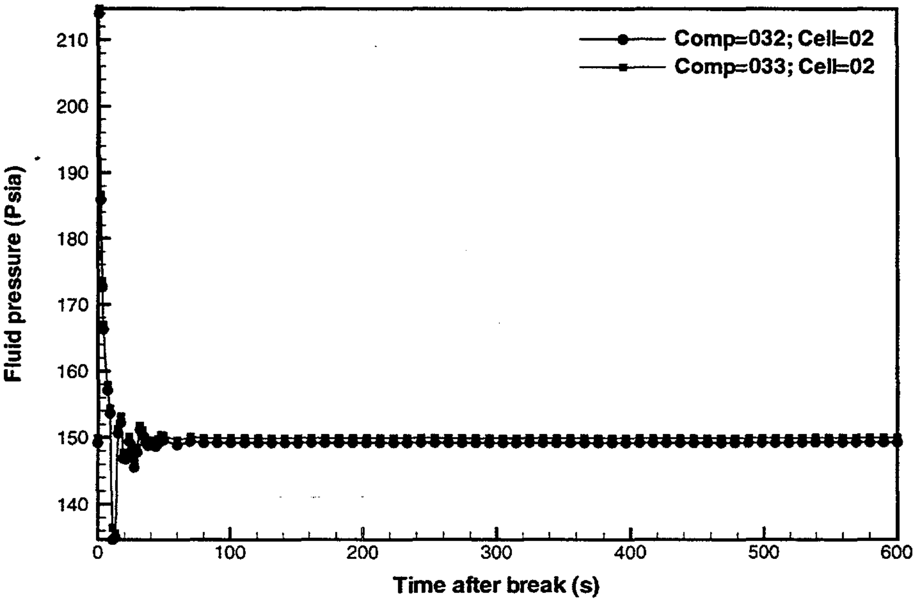

Figure C-16a Primary HR pump discharge piping fluid pressures for a LOHGA (Case 2: helium supply plenum break near decoupler outlet).

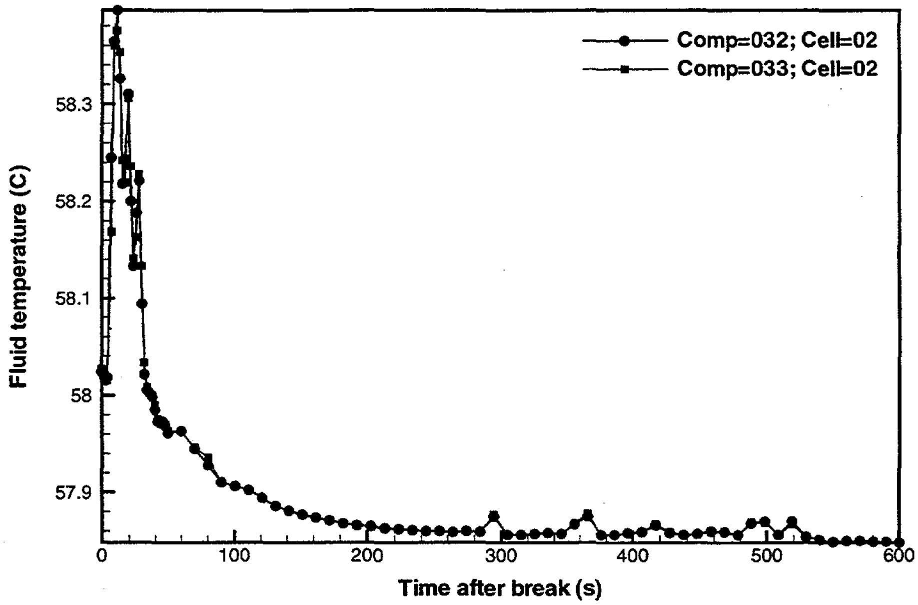

Figure C-16b Primary HR pump discharge piping fluid temperatures for a LOHGA (Case 2: helium supply plenum break near decoupler outlet).

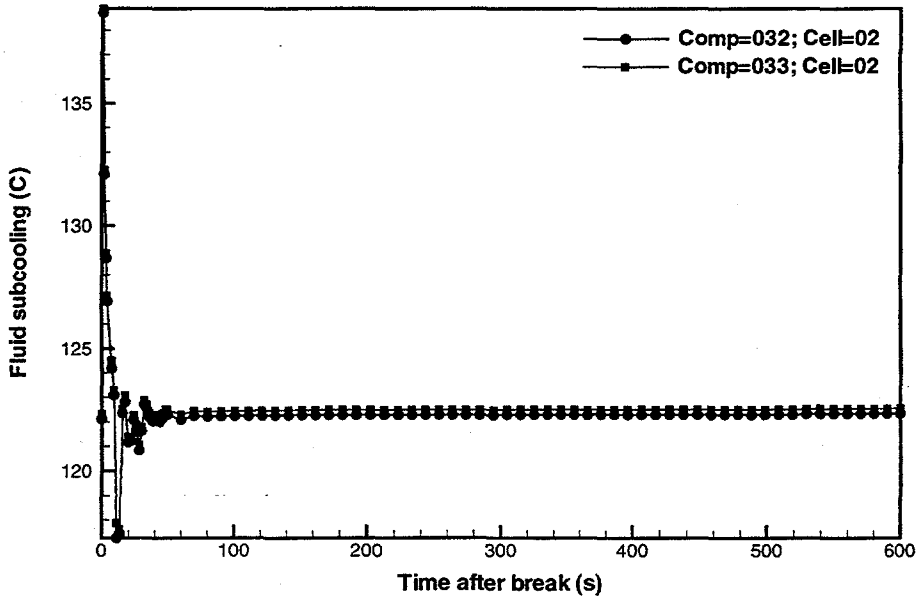

Figure C-16c Primary HR pump discharge piping fluid subcoolings for a LOHGA (Case 2: helium supply plenum break near decoupler outlet).

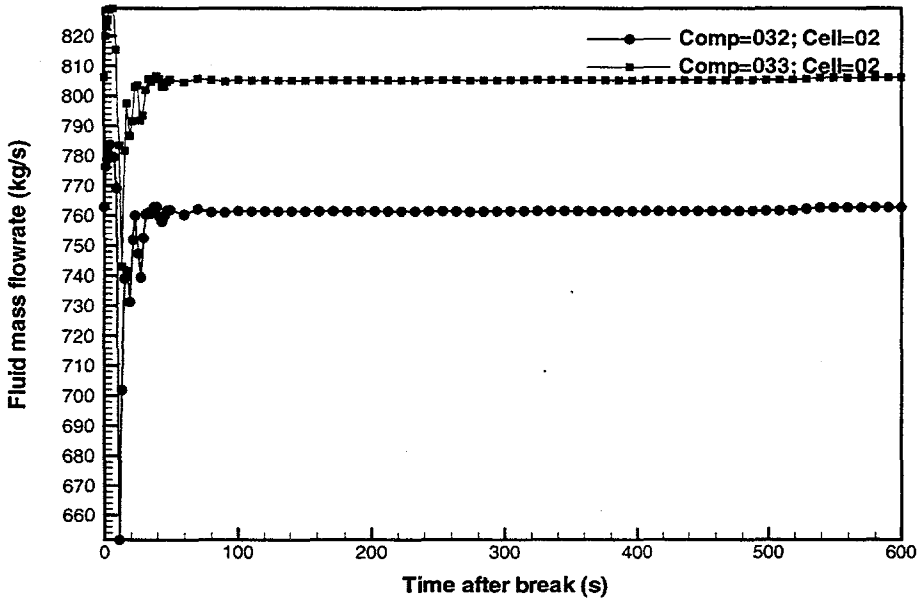

Figure C-16d Primary HR pump discharge piping liquid mass flowrates for a LOHGA (Case 2: helium supply plenum break near decoupler outlet).

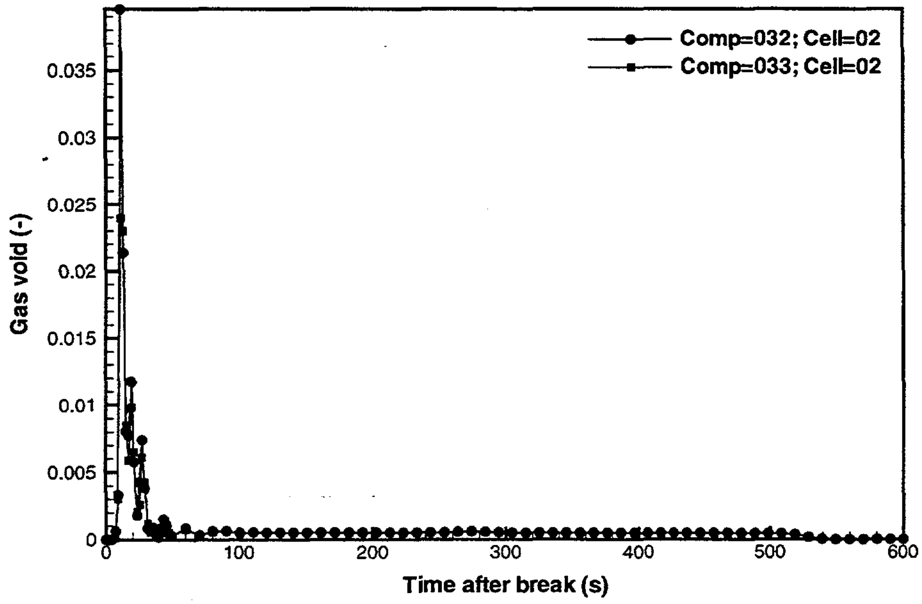

Figure C-16e Primary HR pump discharge piping void fractions for a LOHGA (Case 2: helium supply plenum break near decoupler outlet).

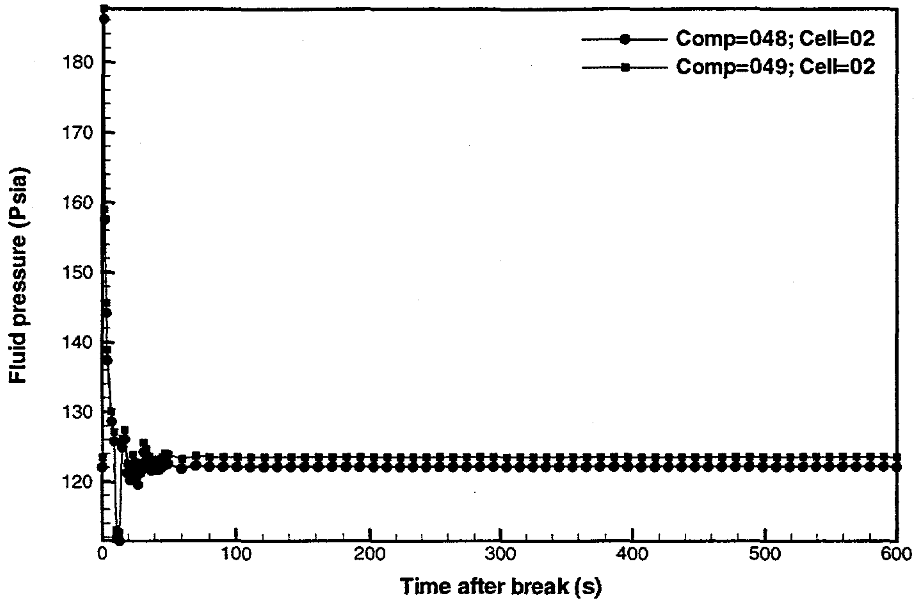

Figure C-17a Primary HR heat exchanger outlet piping fluid pressures for a LOHGA (Case 2: helium supply plenum break near decoupler outlet).

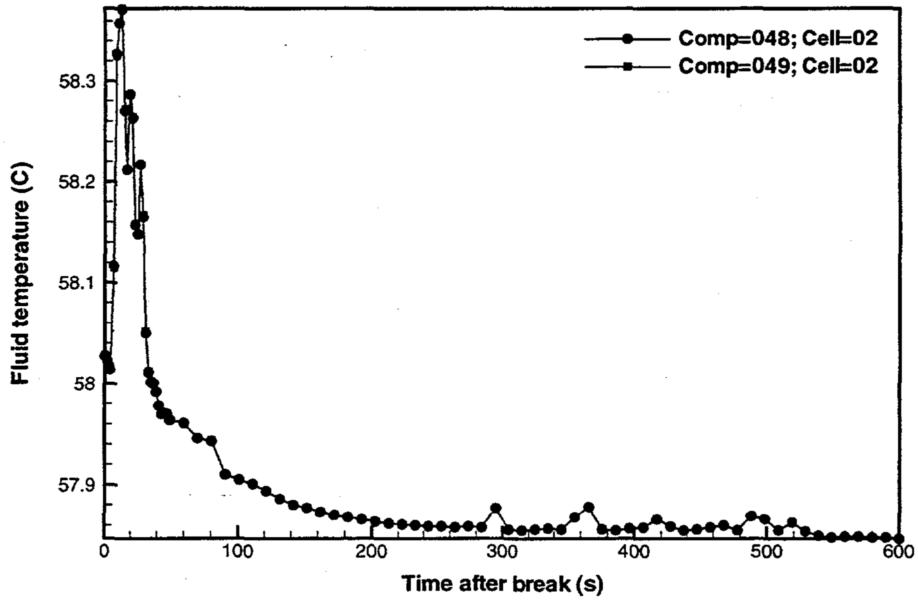

Figure C-17b Primary HR heat exchanger outlet piping fluid temperatures for a LOHGA (Case 2: helium supply plenum break near decoupler outlet).

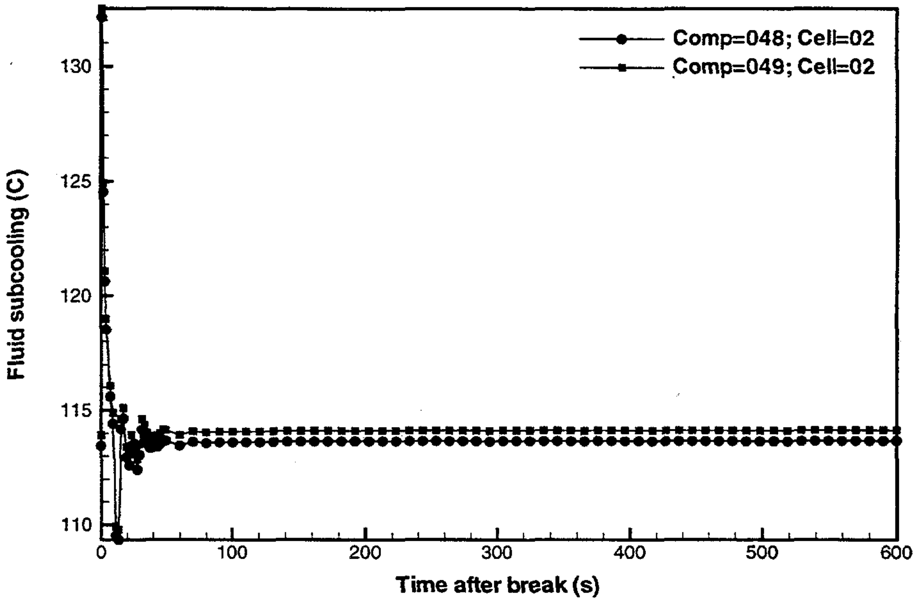

Figure C-17c Primary HR heat exchanger outlet piping fluid subcoolings for a LOHGA (Case 2: helium supply plenum break near decoupler outlet).

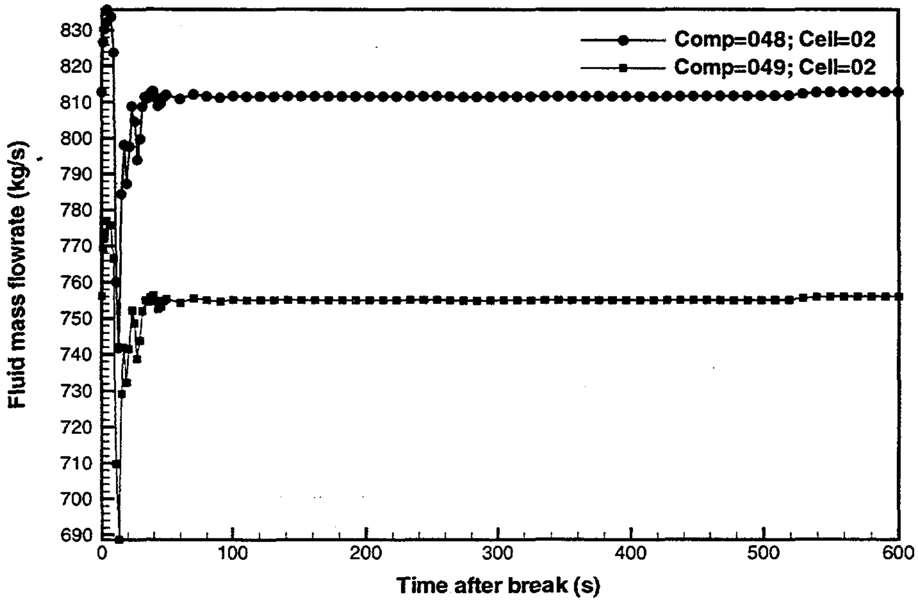

Figure C-17d Primary HR heat exchanger outlet piping liquid mass flowrates for a LOHGA (Case 2: helium supply plenum break near decoupler outlet).

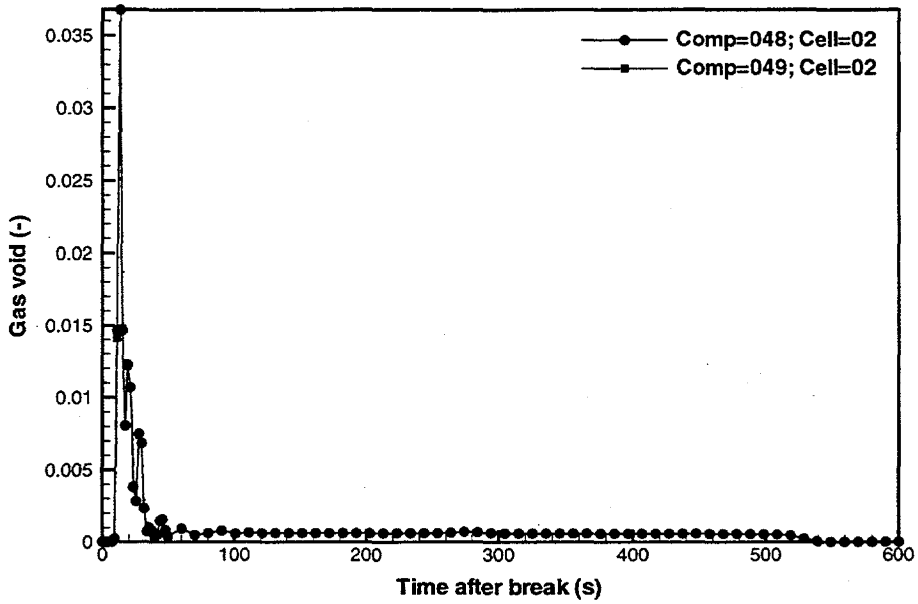

Figure C-17e Primary HR heat exchanger outlet piping void fractions for a LOHGA (Case 2: helium supply plenum break near decoupler outlet).

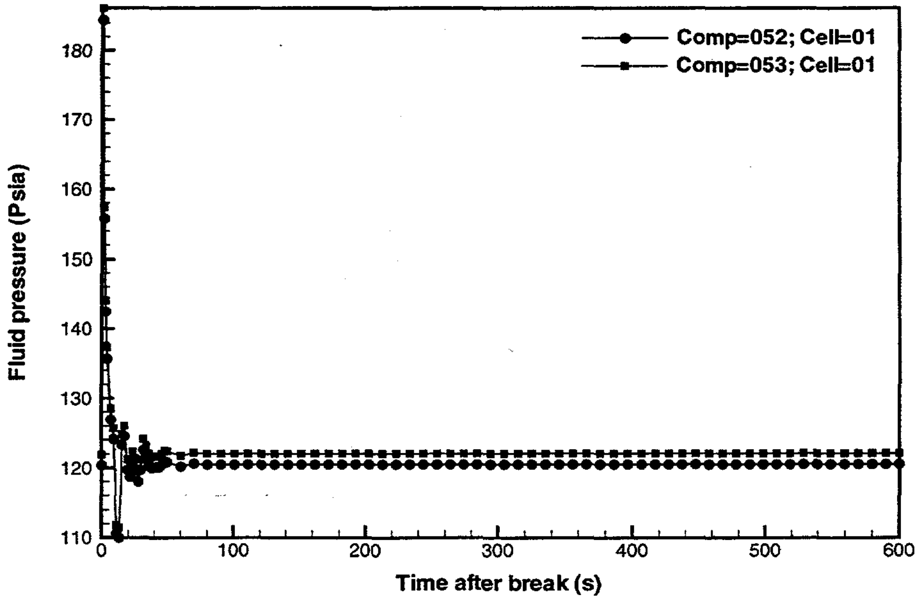

Figure C-18a Primary HR heat exchanger first pass outlet piping fluid pressures for a LOHGA (Case 2: helium supply plenum break near decoupler outlet).

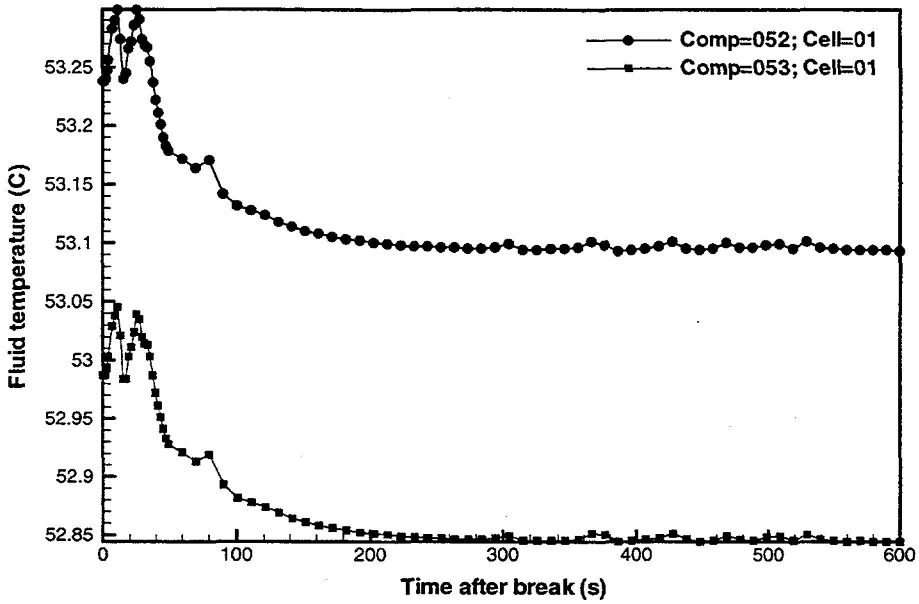

Figure C-18b Primary HR heat exchanger first pass outlet piping fluid temperatures for a LOHGA (Case 2: helium supply plenum break near decoupler outlet).

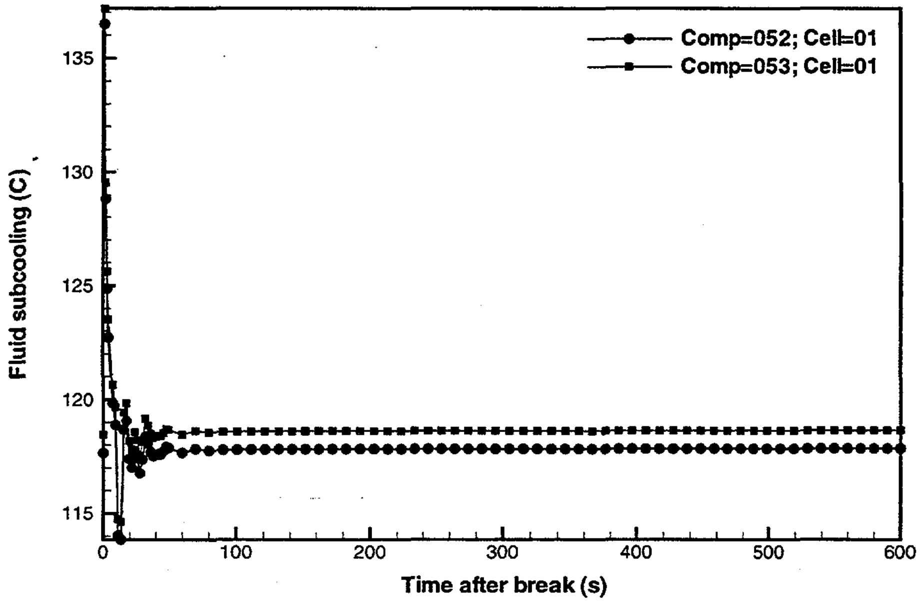

Figure C-18c Primary HR heat exchanger first pass outlet piping fluid subcoolings for a LOHGA (Case 2: helium supply plenum break near decoupler outlet).

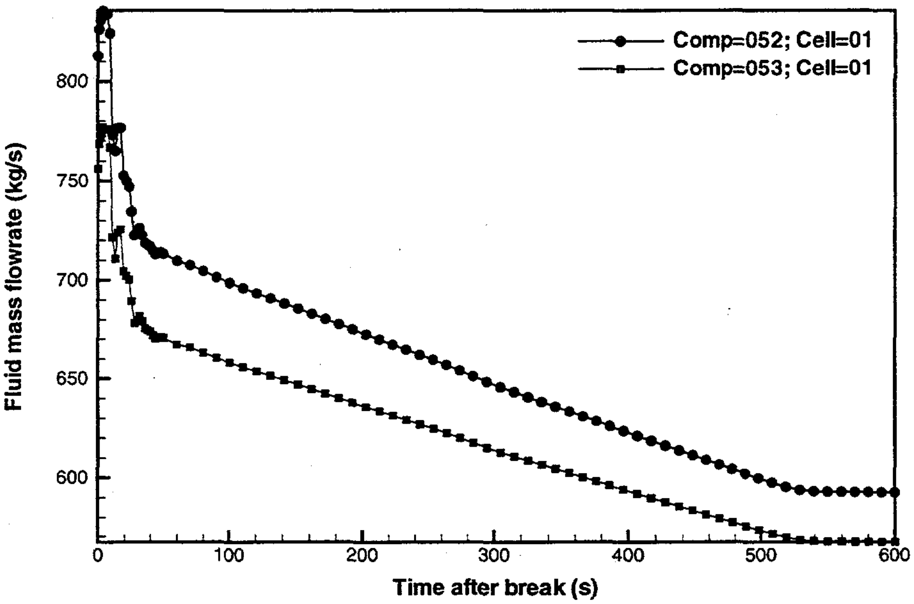

Figure C-18d Primary HR heat exchanger first pass outlet piping liquid mass flowrates for a LOHGA (Case 2: helium supply plenum break near decoupler outlet).

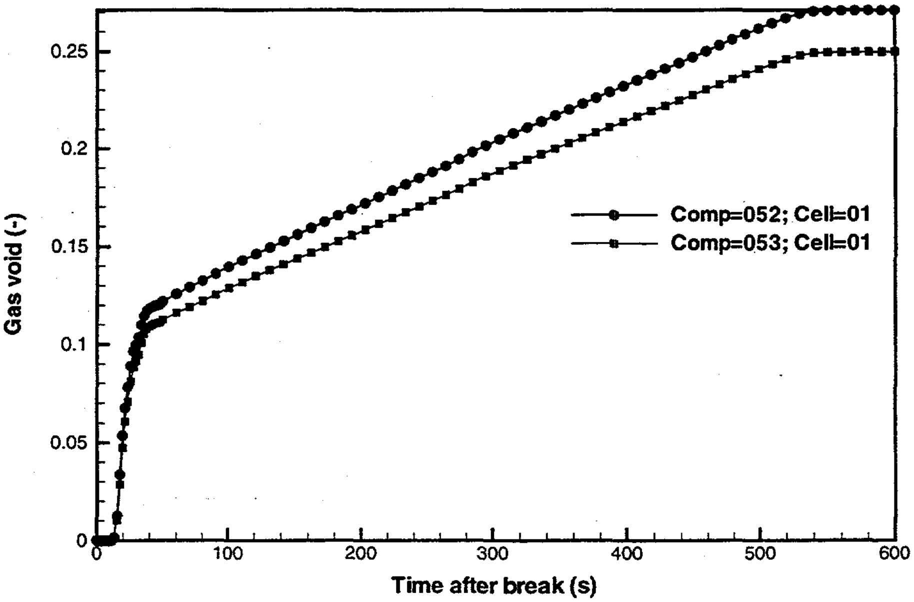

Figure C-18e Primary HR heat exchanger first pass outlet piping void fractions for a LOHGA (Case 2: helium supply plenum break near decoupler outlet).

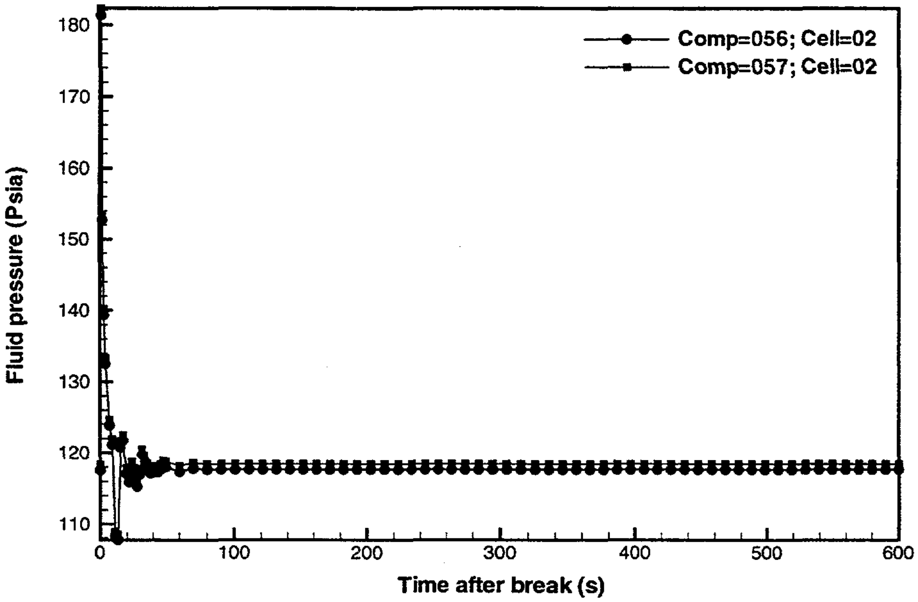

Figure C-19a Primary HR heat exchanger outlet piping fluid pressures for a LOHGA (Case 2: helium supply plenum break near decoupler outlet).

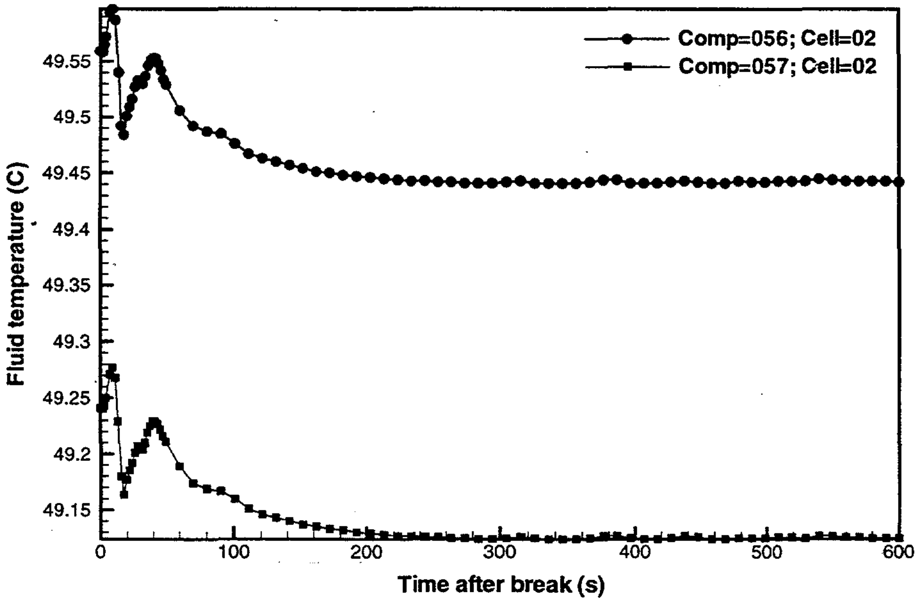

Figure C-19b Primary HR heat exchanger outlet piping fluid temperatures for a LOHGA (Case 2: helium supply plenum break near decoupler outlet).

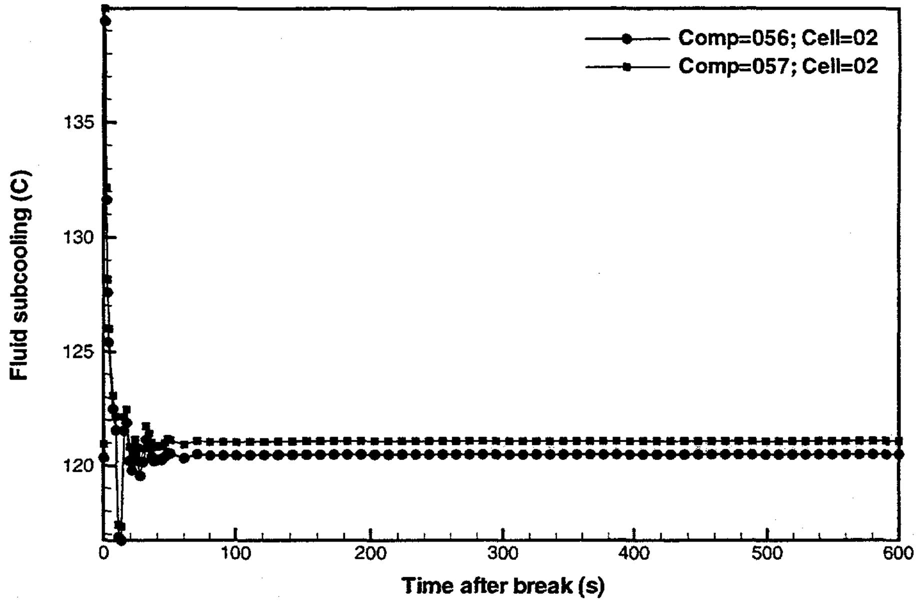

Figure C-19c Primary HR heat exchanger outlet piping fluid subcoolings for a LOHGA (Case 2: helium supply plenum break near decoupler outlet).

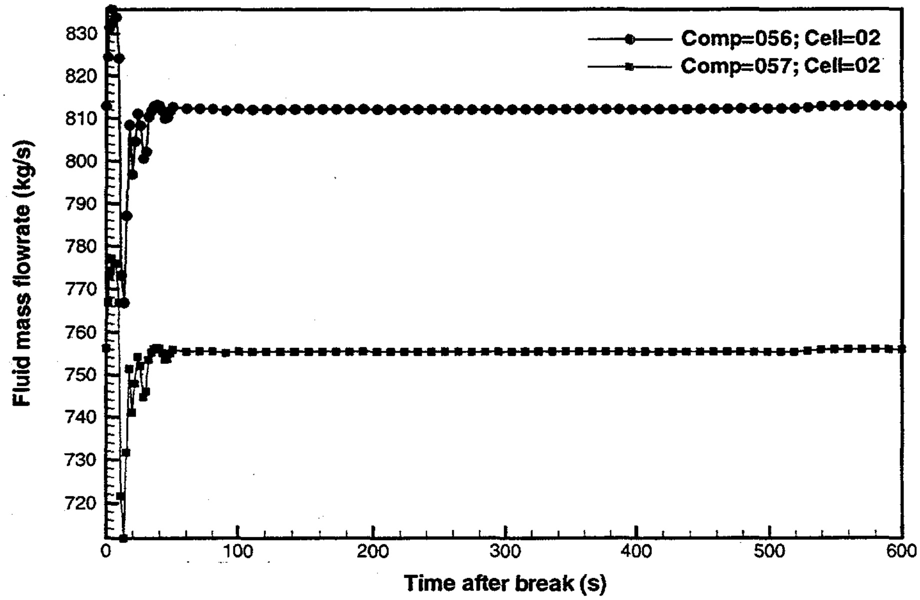

Figure C-19d Primary HR heat exchanger outlet piping liquid mass flowrates for a LOHGA (Case 2: helium supply plenum break near decoupler outlet).

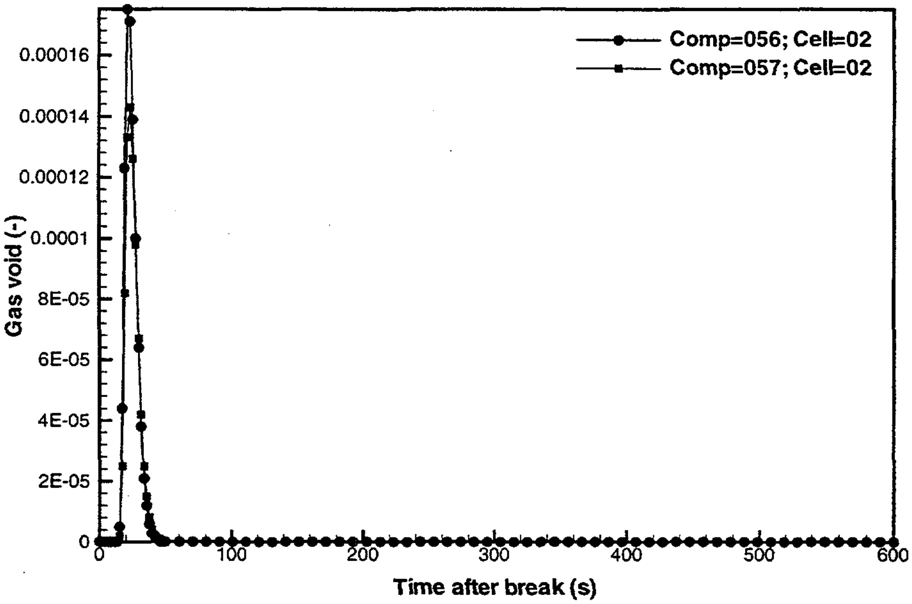

Figure C-19e Primary HR heat exchanger outlet piping void fractions for a LOHGA (Case 2: helium supply plenum break near decoupler outlet).

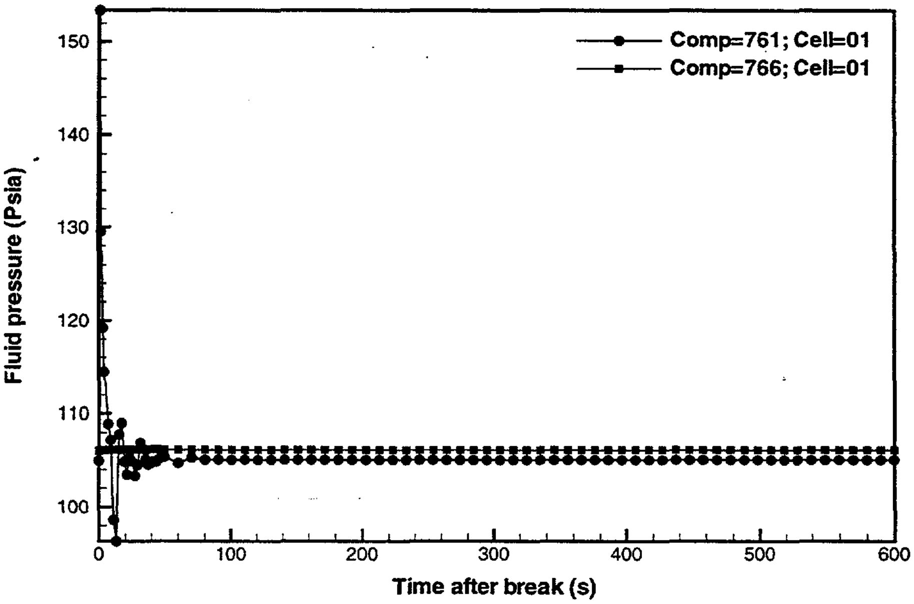

Figure C-20a Primary HR pressurizer and surge line fluid pressures for a LOHGA (Case 2: helium supply plenum break near decoupler outlet).

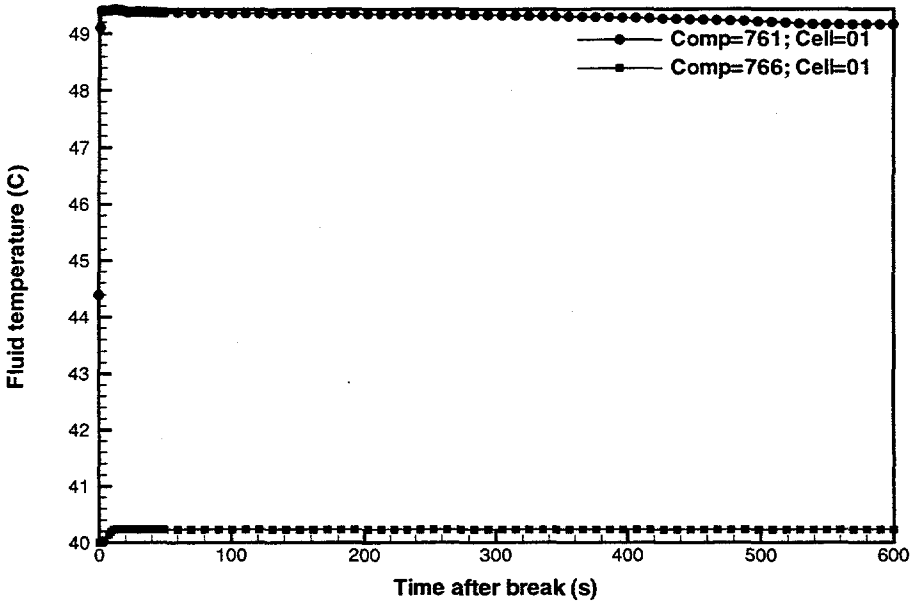

Figure C-20b Primary HR pressurizer and surge line fluid temperatures for a LOHGA (Case 2: helium supply plenum break near decoupler outlet).

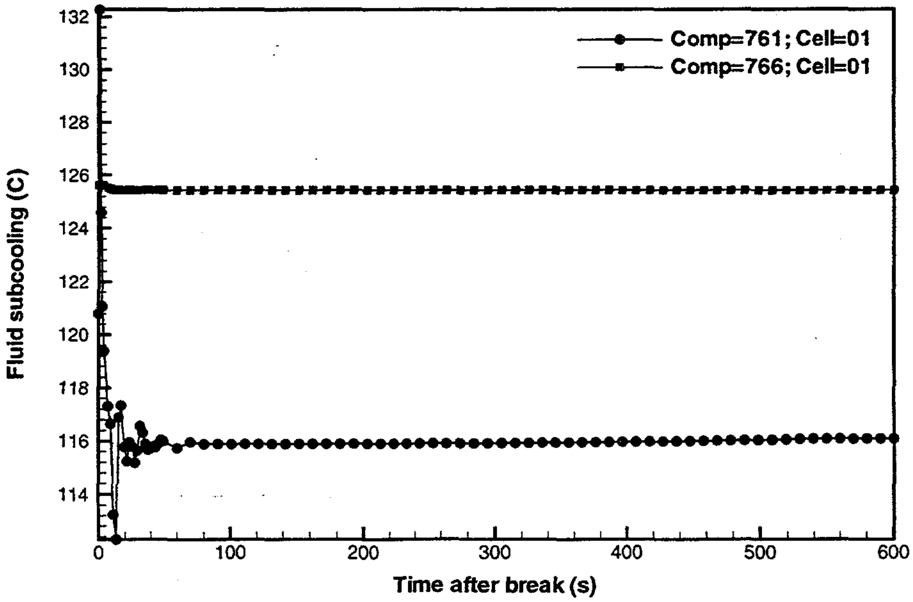

Figure C-20c Primary HR pressurizer and surge line fluid subcoolings for a LOHGA (Case 2: helium supply plenum break near decoupler outlet).

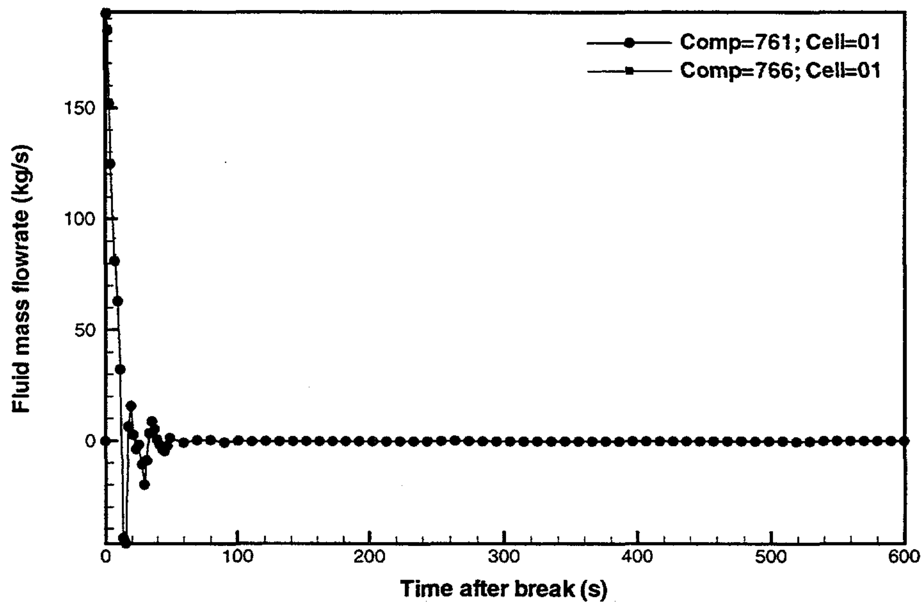

Figure C-20d Primary HR pressurizer and surge line liquid mass flowrates for a LOHGA (Case 2: helium supply plenum break near decoupler outlet).

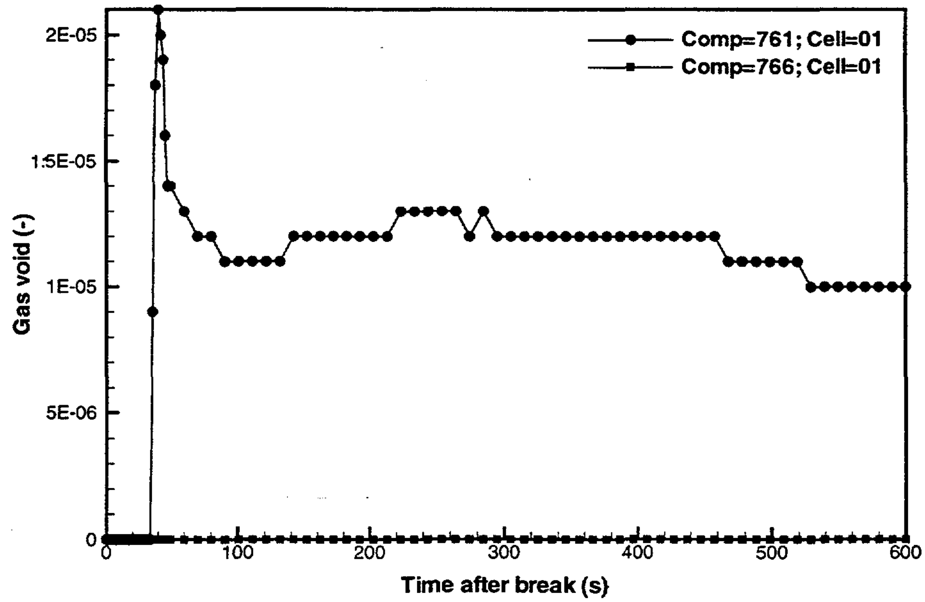

Figure C-20e Primary HR pressurizer and surge line void fractions for a LOHGA (Case 2: helium supply plenum break near decoupler outlet).

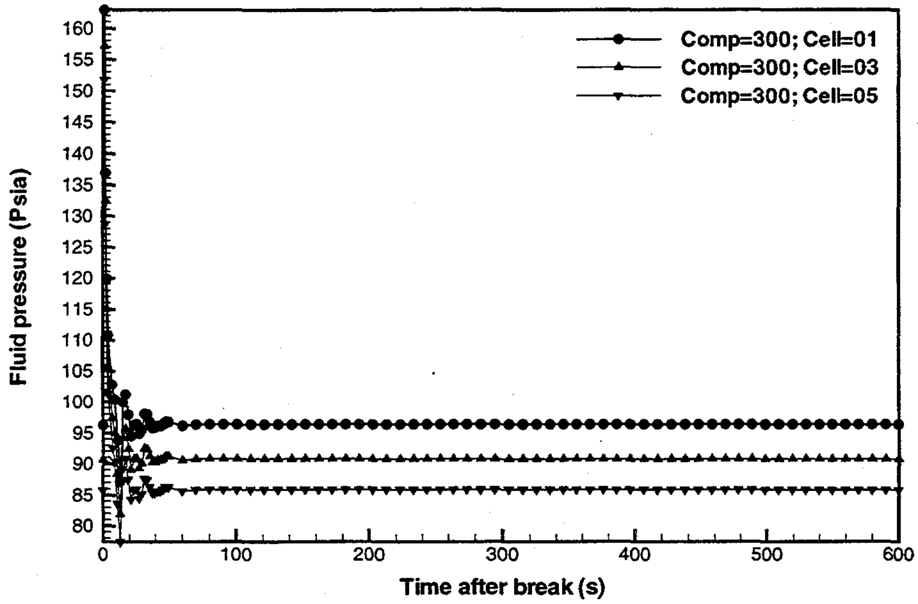

Figure C-21a Module 1 row 1 channel fluid pressures for a LOHGA (Case 2: helium supply plenum break near decoupler outlet).

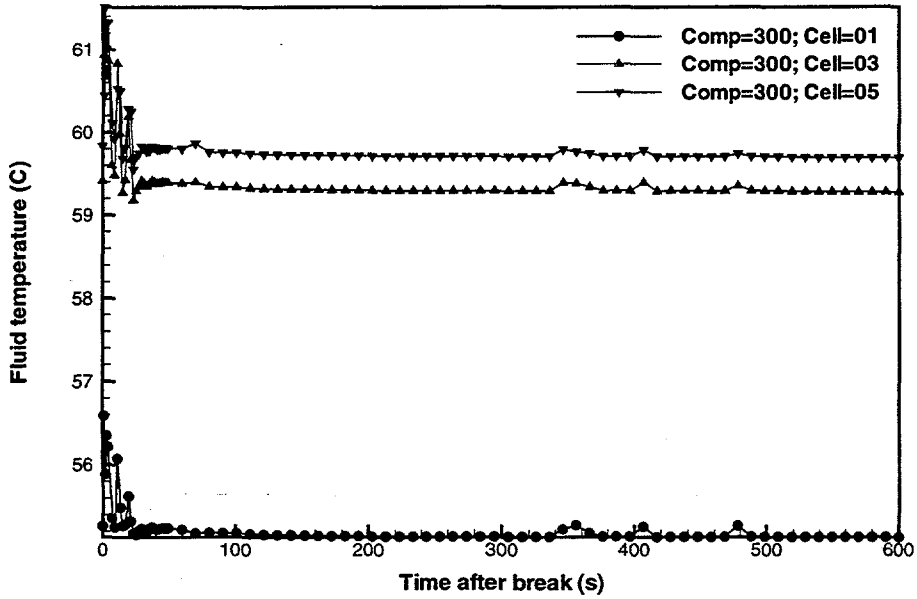

Figure C-21b Module 1 row 1 channel fluid temperatures for a LOHGA (Case 2: helium supply plenum break near decoupler outlet).

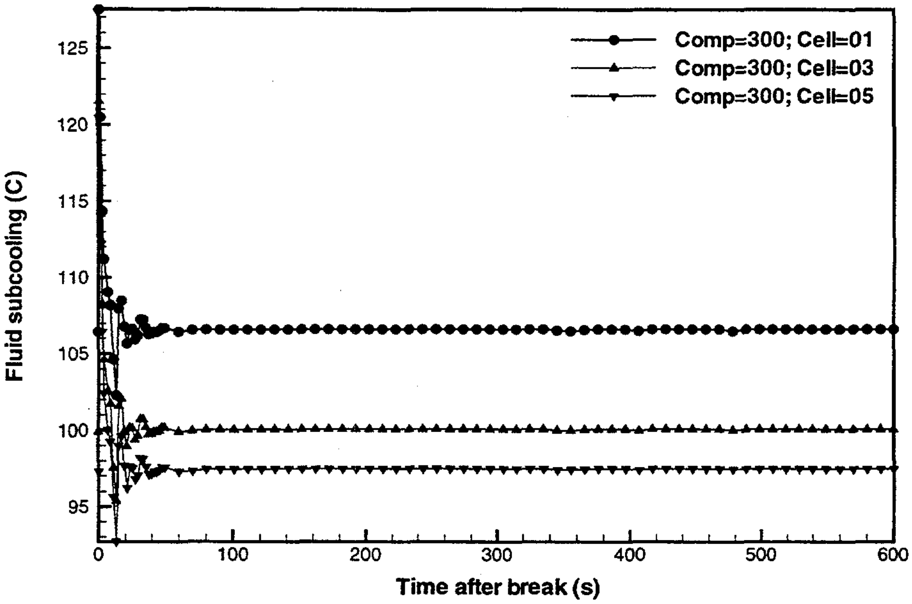

Figure C-21c Module 1 row 1 channel fluid subcoolings for a LOHGA (Case 2: helium supply plenum break near decoupler outlet).

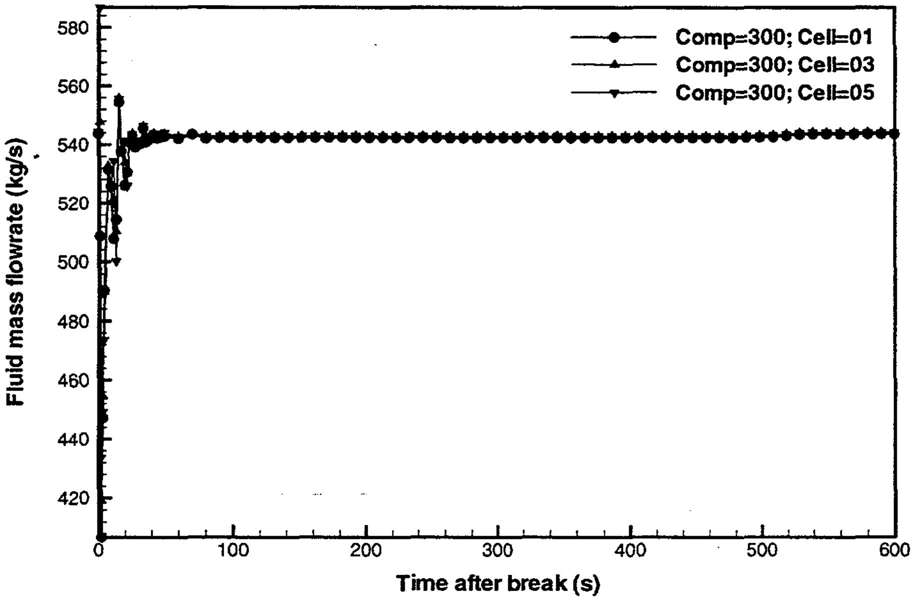

Figure C-21d Module 1 row 1 channel liquid mass flowrates for a LOHGA (Case 2: helium supply plenum break near decoupler outlet).

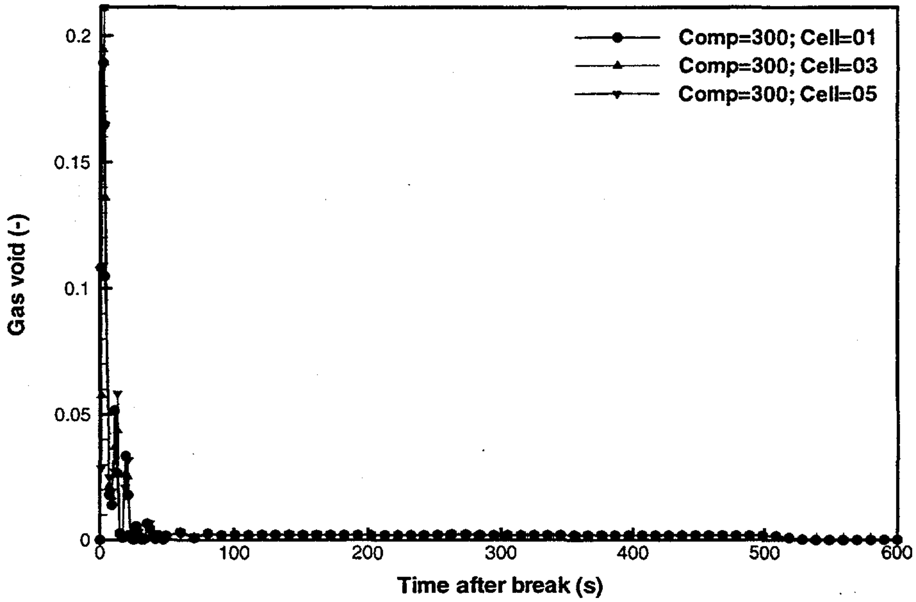

Figure C-21e Module 1 row 1 channel void fractions for a LOHGA (Case 2: helium supply plenum break near decoupler outlet).

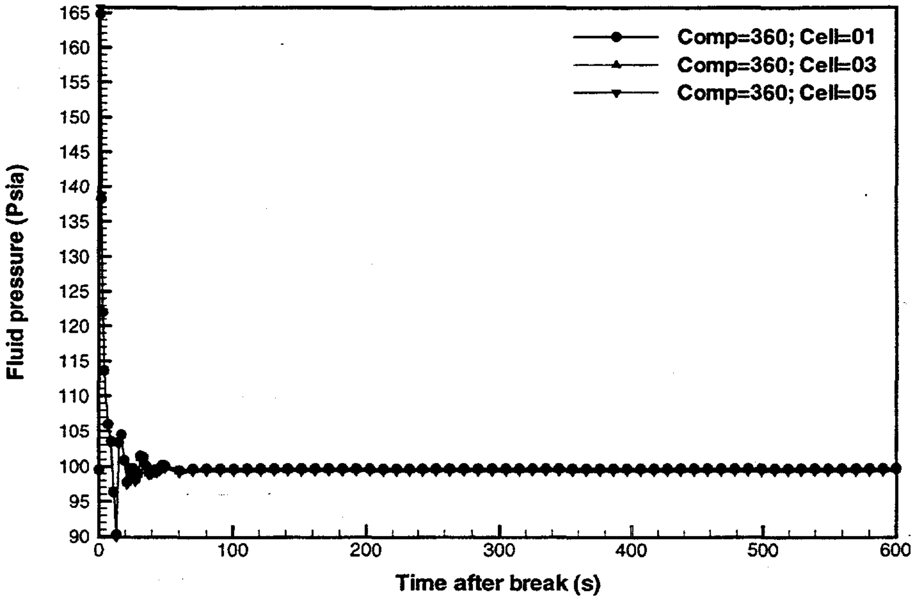

Figure C-22a Module 1 decoupler channel fluid pressures for a LOHGA (Case 2: helium supply plenum break near decoupler outlet).

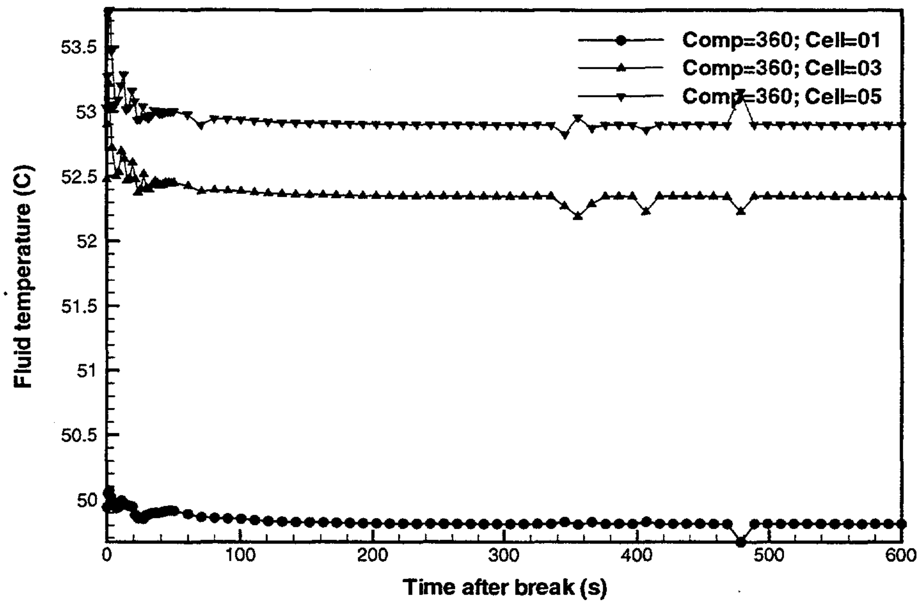

Figure C-22b Module 1 decoupler channel fluid temperatures for a LOHGA (Case 2: helium supply plenum break near decoupler outlet).

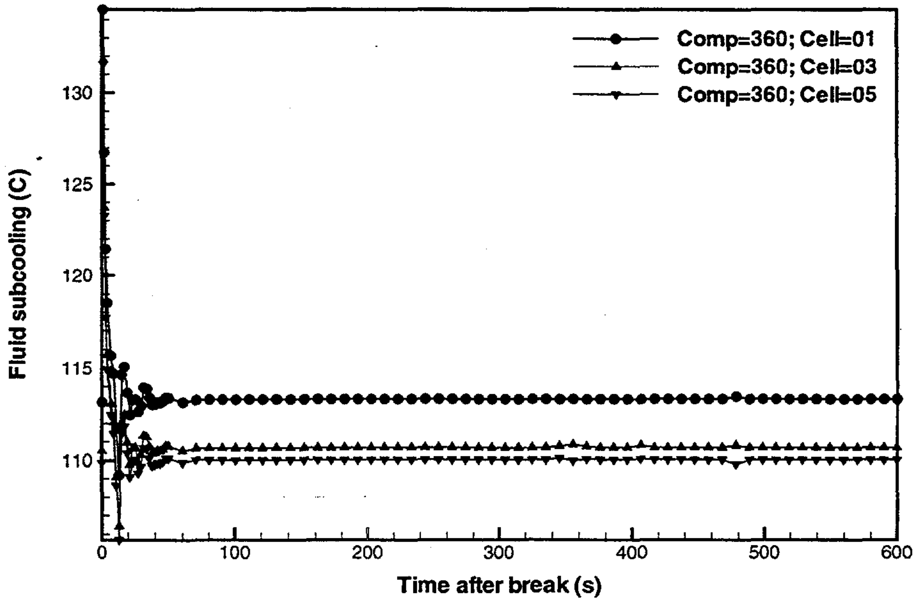

Figure C-22c Module 1 decoupler channel fluid subcoolings for a LOHGA (Case 2: helium supply plenum break near decoupler outlet).

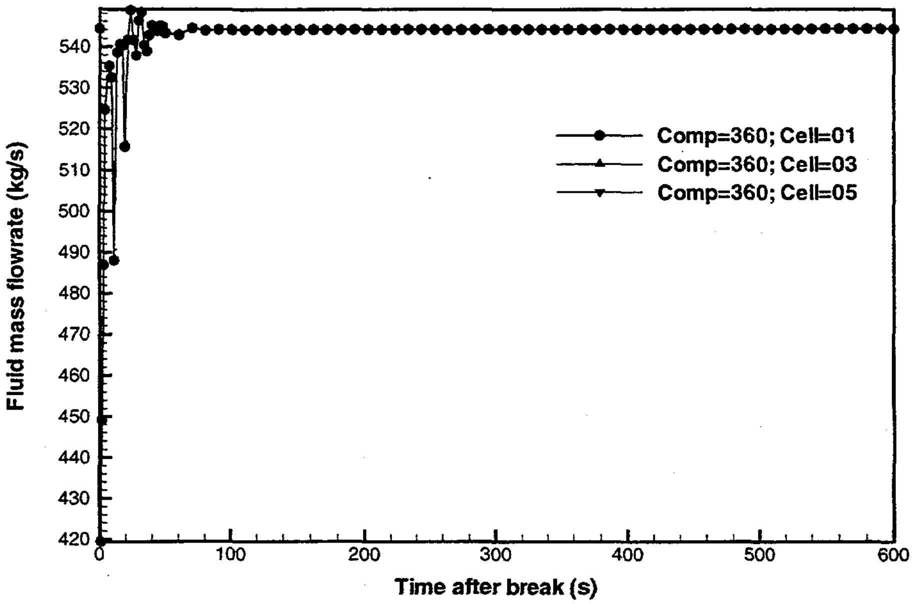

Figure C-22d Module 1 decoupler channel liquid mass flowrates for a LOHGA (Case 2: helium supply plenum break near decoupler outlet).

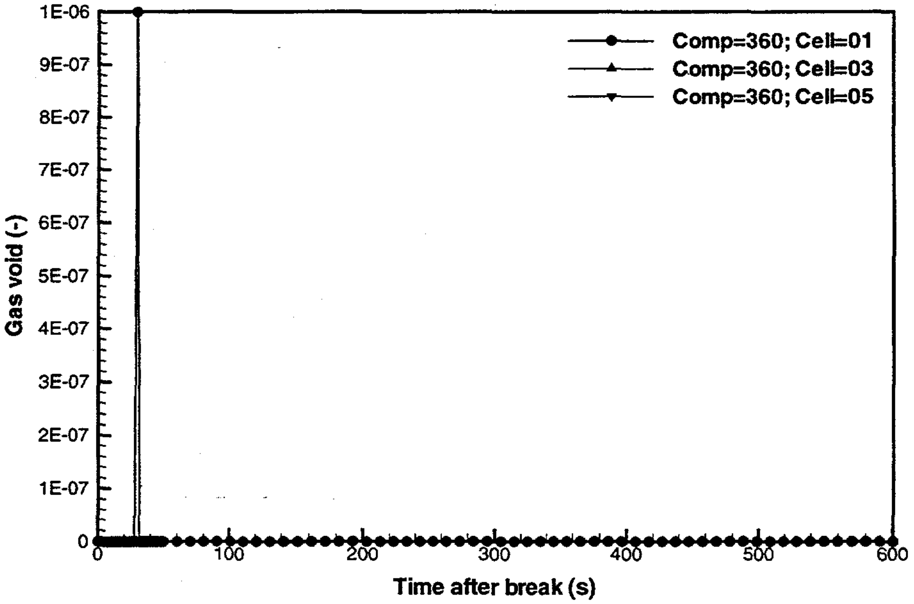

Figure C-22e Module 1 decoupler channel Module 2 channel void fractions for a LOHGA (Case 2: helium supply plenum break near decoupler outlet).

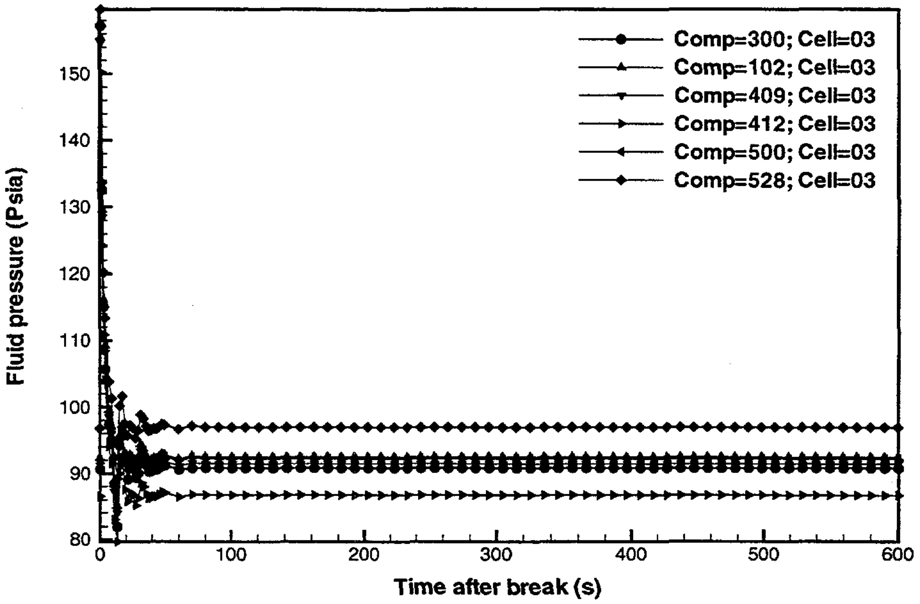

Figure C-23a Mid-plane module fluid pressures for a LOHGA (Case 2: helium supply plenum break near decoupler outlet).

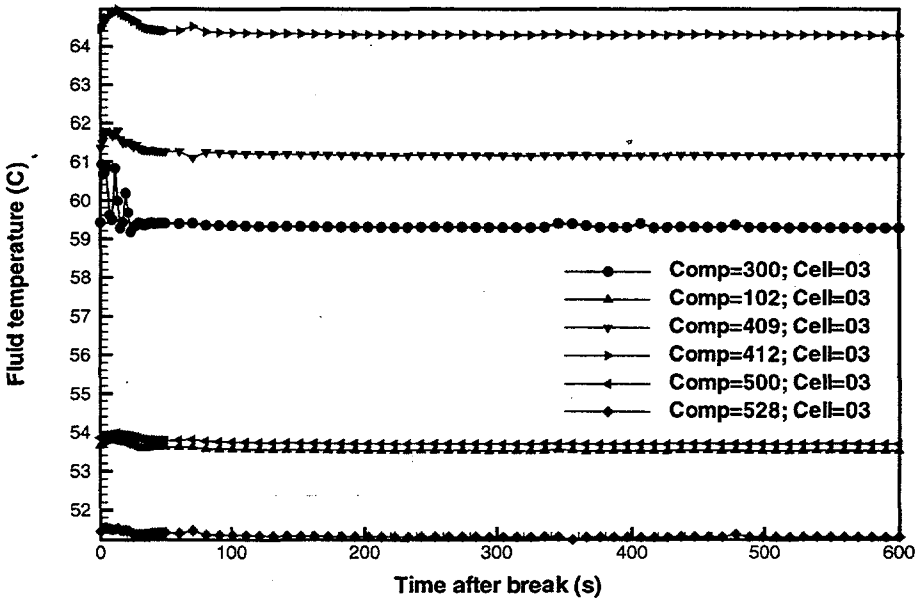

Figure C-23b Mid-plane module fluid temperatures for a LOHGA (Case 2: helium supply plenum break near decoupler outlet).

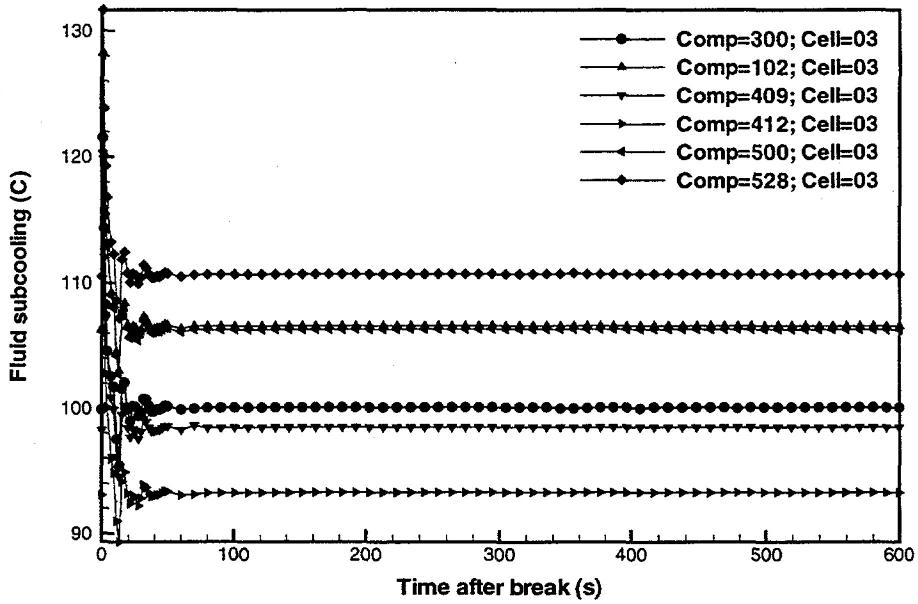

Figure C-23c Mid-plane module fluid subcoolings for a LOHGA (Case 2: helium supply plenum break near decoupler outlet).

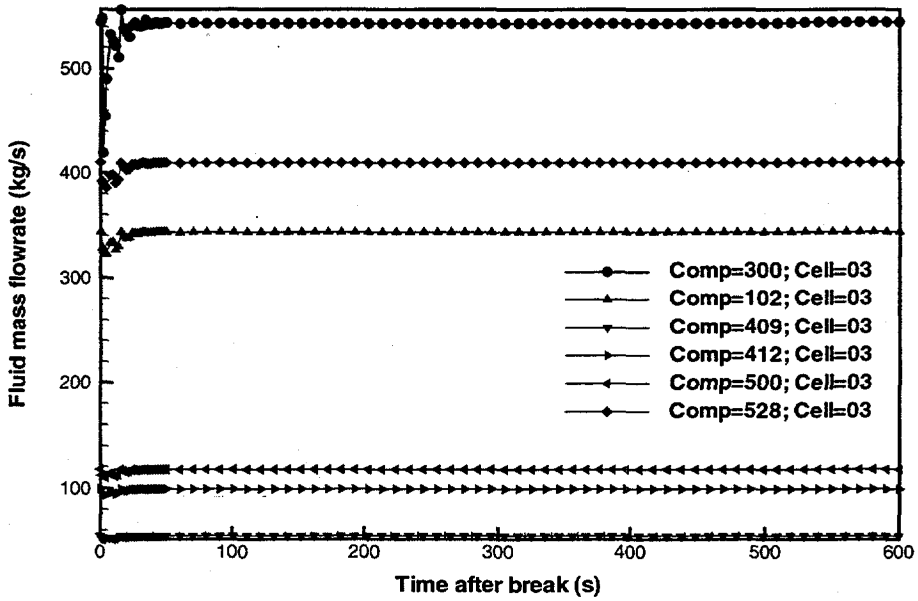

Figure C-23d Mid-plane module liquid mass flowrates for a LOHGA (Case 2: helium supply plenum break near decoupler outlet).

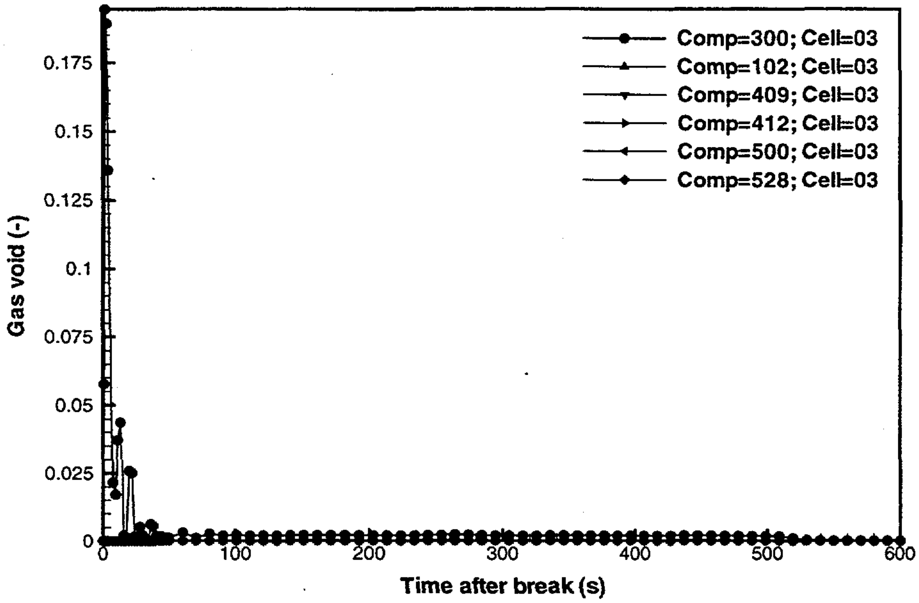

Figure C-23e Mid-plane module void fractions for a LOHGA (Case 2: helium supply plenum break near decoupler outlet).

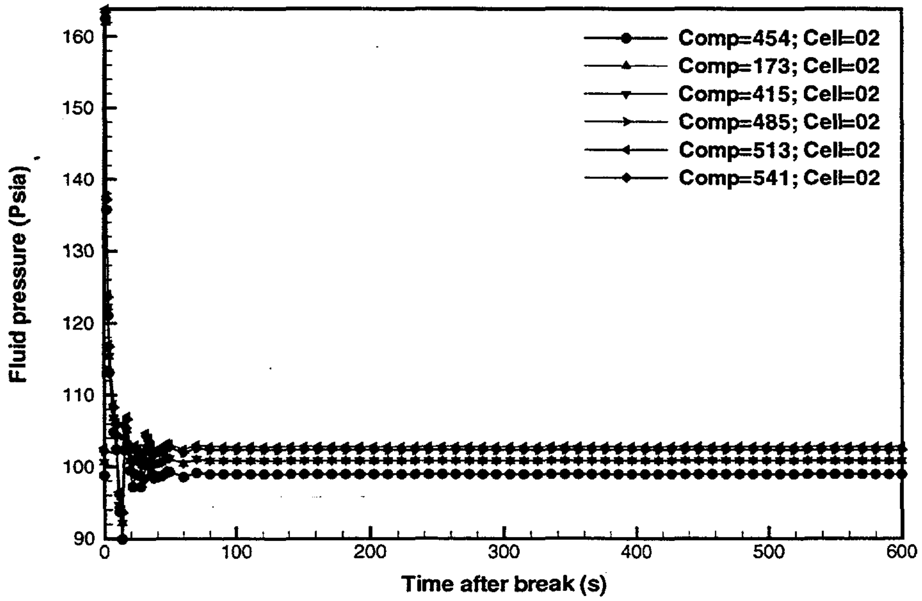

Figure C-24a Module inlet fluid pressures for a LOHGA (Case 2: helium supply plenum break near decoupler outlet).

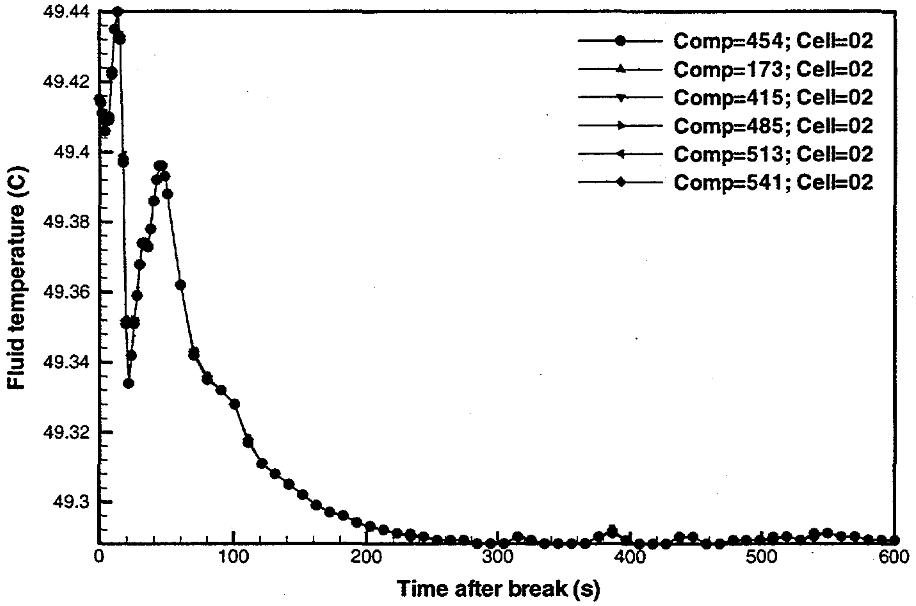

Figure C-24b Module inlet fluid temperatures for a LOHGA (Case 2: helium supply plenum break near decoupler outlet).

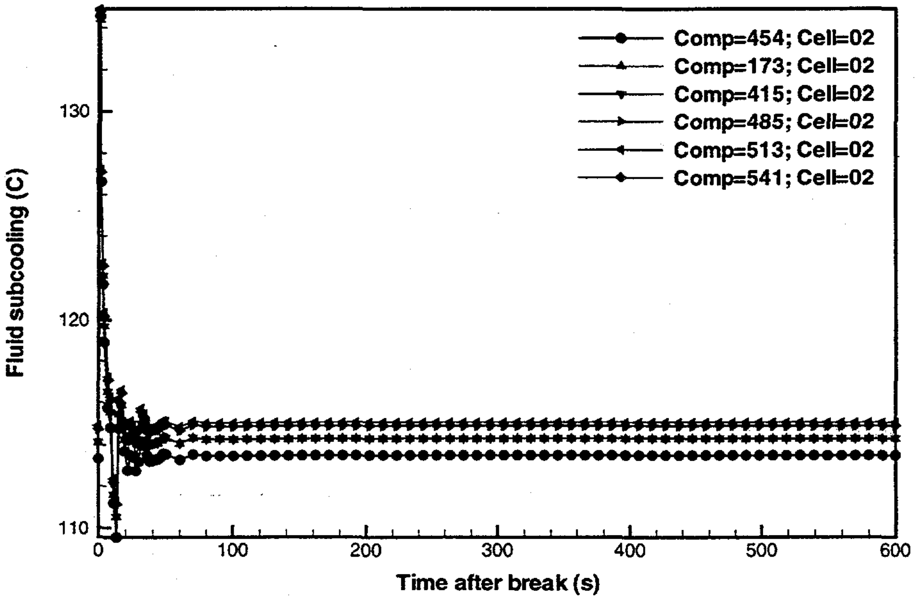

Figure C-24c Module inlet fluid subcoolings for a LOHGA (Case 2: helium supply plenum break near decoupler outlet).

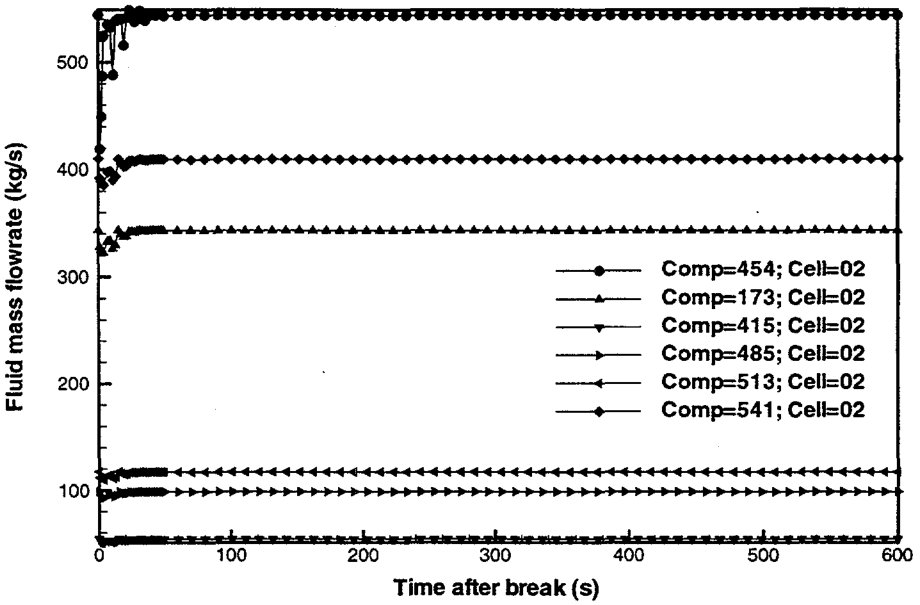

Figure C-24d Module inlet liquid mass flowrates for a LOHGA (Case 2: helium supply plenum break near decoupler outlet).

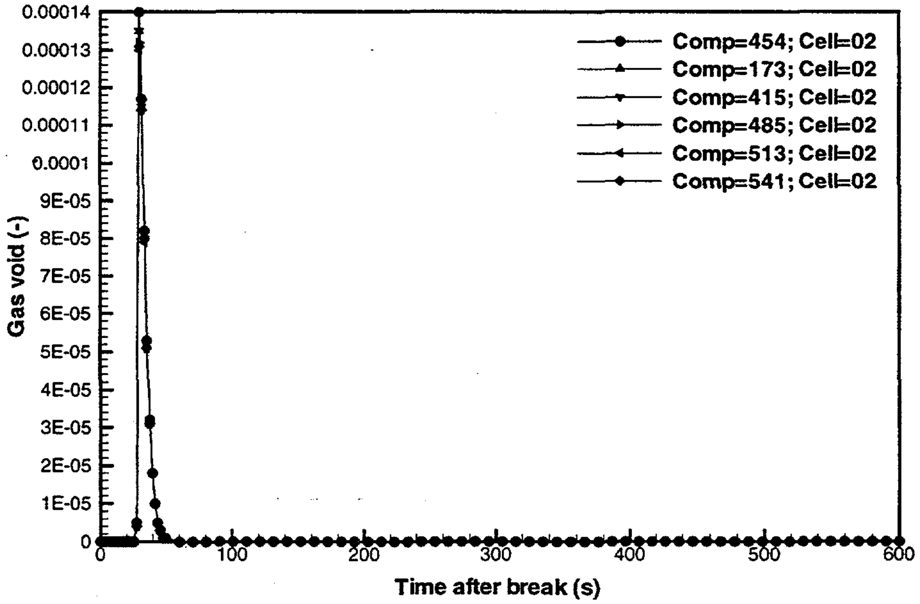

Figure C-24e Module inlet void fractions for a LOHGA (Case 2: helium supply plenum break near decoupler outlet).

Appendix D: TRAC Standard Input File for LOHGA

The file listed below represents the TRAC code "tracin" file that corresponds to the LOHGA 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
           41              0             1              2             0
* APT Lumped Blanket Model **** Helium Tube Rupture Accident *****
  He-reservoir was added -(4/22/1998)
  SRS Pressurizer was updated - elev. level down (1/22/1998)
  SRS Primary Coolant Loop and RHR Loop were added (12/28/1997)
  SRS Pump homologous Curve for Primary/RHR were added (12/28/1997)
  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=3, noair=0, nlt=12, ikfac=1, ithd=1, nsend=40000 &
*
*        dstep         timet
            -1         0.0000e+00
*       stdyst        transi        ncomp         njun          ipak
             0             1          142          122             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             8             1
*
*************************
* component-number data *
*************************
*
* iorder*
*
       430   s  * plenum        He reservoir
       440   s  * valve         He connection pipe
*
       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  * valve         HR pump #1 outlet pipe
        29   s  * pipe          HR pump #2 inlet pipe
        31   s  * pump          HR pump #2
        33   s  * valve         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             0           640             0             0
*
* 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             0             0             0             0
```

```
*
* pressure difference across HR check valve
*         idsv          isvn          ilcn          icn1          icn2
             5             0            32             0             0
*
* pressure difference across HR check valve
*         idsv          isvn          ilcn          icn1          icn2
             6             0            33             0             0
* pressure, cold leg at plenum, component 761
*         idsv          isvn          ilcn          icn1          icn2
             7             0            68             0             0
*
**************************
* control-block data *
**************************
*
**************************
* trips
**************************
*
* trips from off to on at time given by setp(2), trips pumps, sec., br.
*         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 valves
*         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             2             0             1             1
*      setp(1)       setp(2)
    0.0000e+00    1.0000e+06
*      dtsp(1)       dtsp(2)
    2.0000e-01    2.0000e-01
*      ifsp(1)       ifsp(2)
             0             0
*
```

```
* trips from off to on at setp(2), starts RHR pump.
*          idtp          isrt          iset          itst          idsg
            105             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 Primary HR pumps
*          idtp          isrt          iset          itst          idsg
            106             2             0             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 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
*
* trips from off to on at time given by setp(2), He control valves
*          idtp          isrt          iset          itst          idsg
            108             2             0             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
*
******************
* component data *
******************
*
end
*
******************
* time-step data *
******************
*
*         dtmin         dtmax          tend         rtwfp
     1.0000e-07    1.0000e-03    2.0000e-03    1.0000e+01
*         edint         gfint        dmpint        sedint
     1.0000e-02    5.0000e+00    1.0000e+06    1.0000e+06
*
*         dtmin         dtmax          tend         rtwfp
     1.0000e-06    1.0000e-02    5.0000e+00    1.0000e+01
*         edint         gfint        dmpint        sedint
     1.0000e+00    5.0000e+00    1.0000e+06    1.0000e+06
*
*         dtmin         dtmax          tend         rtwfp
     1.0000e-06    1.0000e-01    5.0000e+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-06    3.0000e-01     6.0000e+02     1.0000e+01
*         edint         gfint         dmpint         sedint
     1.0000e+01    5.0000e+00     1.0000e+06     1.0000e+06
*
*       endflag
-1.0000e+00
```

Appendix E: TRAC Graphics Input File for LOHGA

The file listed below represents the TRAC code "graphin" file that corresponds to the LOHGA for the blanket system. This input deck contains the various graphics points selected for output to the "tecsum.grf" file.

Input file graphin:

```
/ npoints /
   97
/ 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

    360             1          0          1     Module 1 Dec

    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

    360             3          0          1     Module 1 Dec

    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

    360             5          0          1     Module 1 Dec

    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

    430             1          1          1     Helium Reserv Plenum

    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
440	4	0	1	He Pipe Inlet valve
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
50	4	0	1	PCL Hx 1 inlet
52	1	0	1	PCL Hx 1 inlet
51	4	0	1	PCL Hx 1 inlet
53	1	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 F: FLOWTRAN-TF Input File for LOHGA

Below is an abridged listing of the FLOWTRAN-TF input deck for LOHGA. 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. [6] 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: decay to rhr 4% pre-incident flow
!
! Input Deck Description:
!
!    Input deck to test coupled flowtran-tf + heatel code
!
! 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
  300.0        1.0e-6           0.020            0.1              0.5          !>
!
!             printing intervals in seconds
! fluid       solid       power       plot      criteria
! dtpfld,     dtpsld,     dtppwr,     dtpplt,   dtpcrt
  300.0       300.0       300.0       300.0     10.0                         !>
!---------------------------------------------------------------------------
!
/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        2       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         1                         !>
!------------------------------------------------------------------------------
!
/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         54.9     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
  10      2                                                                  !>
!-------------------------------------------------------------------------------
! npdat: number of data points per data set
!  nset: number of data sets in data group
!-------------------------------------------------------------------------------
! npdat  nset
   3      1                                                                  !>
  29      1                                                                  !>
  13      1                                                                  !>
  81      1                                                                  !>
  81      1                                                                  !>
  81      1                                                                  !>
  81      1                                                                  !>
  81      1                                                                  !>
  81      1                                                                  !>
  81      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                                         !>
!-------------------------------------------------------------------------------
!
! 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 [6]

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

Fluid geometry input is identical to that shown in reference [6]

```
.
.
.
!
!------------------------------------------------------------------------------
/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
  583798.1   8       !>
! alppl0,    ialpl
  1.0        10      !>
! tf010,     itfpl
  59.84      9       !>
! tgpl0,     itgpl
  59.84      9       !>
! xapl0,     ixapl
  0.01       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
  685663.1   5       !>
! alptb0,    ialtb
  1.0        7       !>
```

```
! tftb0,     itftb
  53.03      6          !>
! tgtb0,     itgtb
  53.03      6          !>
! xatb0,     ixatb
  0.99       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  4          !  1   >
! 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
   1                   !>
!
/AXIAL SPLINE POINTERS AND TIMES/
   2   0.0        2  600.00
!
/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       !>
   60.0   1.0       !>
  600.0   1.0       !>
!------------------------------------------------------------------------------
!
/DATA SET NUMBER 2/
!------------------------------------------------------------------------------
data set 2 - 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 3/
!------------------------------------------------------------------------------
data set 3 - DECAY POWER CURVE (+1 second time delay)
!         itype
          1         !>
! x(ipt), y(ipt)    ipt=1,npts
     0.00   1.000000000E+00
     1.00   1.000000000E+00
     1.01   1.298500039E-02
     2.00   9.929999709E-03
     3.00   8.652999997E-03
     6.00   7.736000232E-03
    11.00   7.573999930E-03
    21.00   7.437000051E-03
    61.00   7.073000073E-03
   121.00   6.672000047E-03
```

```
   301.00   5.936999805E-03
   601.00   5.392999854E-03
  1201.00   4.968000110E-03
!-----------------------------------------------------------------------------
!
/DATA SET NUMBER  4/
!-----------------------------------------------------------------------------
data set  4 - COOLANT FLOW TRANSIENT
!         itype
            1
!     x(ipt),       y(ipt)   ipt=1,npts
        0.00      1.00000E+00
        1.01      7.70408E-01
        2.01      8.24990E-01
        3.01      8.94548E-01
        4.02      9.64089E-01
        7.08      9.83655E-01
        9.08      9.78418E-01
       11.11      8.96791E-01
       13.21      9.89722E-01
       15.23      9.93217E-01
       17.27      9.92801E-01
       19.35      9.47602E-01
       21.44      9.95208E-01
       23.47      1.00834E+00
       25.54      9.95067E-01
       27.59      9.88241E-01
       29.59      1.00349E+00
       31.63      1.00732E+00
       33.65      9.92899E-01
       35.66      9.90142E-01
       37.66      9.97259E-01
       39.66      1.00133E+00
       41.66      1.00026E+00
       43.66      9.99043E-01
       45.66      1.00113E+00
       47.66      1.00091E+00
       49.66      9.98134E-01
       60.11      9.98925E-01
       70.16      1.00018E+00
       80.33      9.99198E-01
       90.53      9.99566E-01
      100.73      9.99585E-01
      110.93      9.99590E-01
      121.13      9.99574E-01
      131.33      9.99591E-01
      141.53      9.99590E-01
      151.73      9.99584E-01
      161.93      9.99592E-01
      172.13      9.99588E-01
      182.33      9.99587E-01
      192.53      9.99592E-01
      202.73      9.99588E-01
      212.93      9.99587E-01
      223.13      9.99588E-01
      233.33      9.99583E-01
      243.53      9.99584E-01
      253.73      9.99512E-01
      263.93      9.99359E-01
      274.13      9.99408E-01
      284.33      9.99512E-01
      294.53      9.99590E-01
```

```
       304.73      9.99622E-01
       314.93      9.99637E-01
       325.13      9.99631E-01
       335.33      9.99634E-01
       345.53      9.99616E-01
       355.73      9.99629E-01
       365.93      9.99632E-01
       376.13      9.99626E-01
       386.33      9.99631E-01
       396.53      9.99621E-01
       406.73      9.99632E-01
       416.93      9.99630E-01
       427.13      9.99626E-01
       437.33      9.99626E-01
       447.53      9.99624E-01
       457.73      9.99607E-01
       467.93      9.99632E-01
       478.13      9.99630E-01
       488.33      9.99629E-01
       498.53      9.99644E-01
       508.73      9.99656E-01
       518.93      9.99694E-01
       529.13      9.99658E-01
       539.33      9.99801E-01
       549.53      9.99842E-01
       559.73      9.99842E-01
       569.93      9.99845E-01
       580.13      9.99847E-01
       590.33      9.99849E-01
       600.23      9.99851E-01
!--------------------------------------------------------------------------------
!
/DATA SET NUMBER  5/
!--------------------------------------------------------------------------------
data set  5 - INLET PRESSURE TRANSIENT
!         itype
            1
!      x(ipt),      y(ipt)   ipt=1,npts
         0.00      1.00000E+00
         1.01      1.66935E+00
         2.01      1.39938E+00
         3.01      1.23134E+00
         4.02      1.14308E+00
         7.08      1.06565E+00
         9.08      1.04077E+00
        11.11      9.74030E-01
        13.21      9.06417E-01
        15.23      1.03867E+00
        17.27      1.04970E+00
        19.35      1.01627E+00
        21.44      9.81855E-01
        23.47      1.00021E+00
        25.54      1.00226E+00
        27.59      9.86236E-01
        29.59      9.93214E-01
        31.63      1.01792E+00
        33.65      1.01765E+00
        35.66      1.00561E+00
        37.66      9.95866E-01
        39.66      9.96217E-01
        41.66      9.98957E-01
        43.66      9.98662E-01
```

```
      45.66      1.00110E+00
      47.66      1.00556E+00
      49.66      1.00536E+00
      60.11      9.98976E-01
      70.16      1.00096E+00
      80.33      1.00152E+00
      90.53      1.00137E+00
     100.73      1.00115E+00
     110.93      1.00139E+00
     121.13      1.00120E+00
     131.33      1.00131E+00
     141.53      1.00123E+00
     151.73      1.00128E+00
     161.93      1.00125E+00
     172.13      1.00126E+00
     182.33      1.00125E+00
     192.53      1.00125E+00
     202.73      1.00125E+00
     212.93      1.00124E+00
     223.13      1.00124E+00
     233.33      1.00124E+00
     243.53      1.00124E+00
     253.73      1.00136E+00
     263.93      1.00129E+00
     274.13      1.00127E+00
     284.33      1.00121E+00
     294.53      1.00123E+00
     304.73      1.00119E+00
     314.93      1.00121E+00
     325.13      1.00119E+00
     335.33      1.00120E+00
     345.53      1.00119E+00
     355.73      1.00122E+00
     365.93      1.00117E+00
     376.13      1.00119E+00
     386.33      1.00118E+00
     396.53      1.00118E+00
     406.73      1.00119E+00
     416.93      1.00114E+00
     427.13      1.00118E+00
     437.33      1.00116E+00
     447.53      1.00116E+00
     457.73      1.00111E+00
     467.93      1.00117E+00
     478.13      1.00116E+00
     488.33      1.00116E+00
     498.53      1.00116E+00
     508.73      1.00113E+00
     518.93      1.00110E+00
     529.13      1.00119E+00
     539.33      1.00113E+00
     549.53      1.00106E+00
     559.73      1.00106E+00
     569.93      1.00106E+00
     580.13      1.00106E+00
     590.33      1.00106E+00
     600.23      1.00106E+00
!------------------------------------------------------------------------------
!
/DATA SET NUMBER  6/
!------------------------------------------------------------------------------
data set  6 - INLET TEMPERATURE TRANSIENT
```

```
!        itype
          1
!     x(ipt),       y(ipt)   ipt=1,npts
       0.00      1.00000E+00
       1.01      1.00113E+00
       2.01      1.00660E+00
       3.01      1.01169E+00
       4.02      1.01094E+00
       7.08      1.00113E+00
       9.08      1.00094E+00
      11.11      1.00170E+00
      13.21      1.00509E+00
      15.23      1.00132E+00
      17.27      1.00019E+00
      19.35      1.00132E+00
      21.44      1.00170E+00
      23.47      9.99246E-01
      25.54      9.98303E-01
      27.59      9.99057E-01
      29.59      9.99057E-01
      31.63      9.98680E-01
      33.65      9.98680E-01
      35.66      9.99434E-01
      37.66      9.99623E-01
      39.66      9.99246E-01
      41.66      9.99246E-01
      43.66      9.99246E-01
      45.66      9.99434E-01
      47.66      9.99434E-01
      49.66      9.99434E-01
      60.11      9.99057E-01
      70.16      9.97926E-01
      80.33      9.98491E-01
      90.53      9.98303E-01
     100.73      9.98303E-01
     110.93      9.98114E-01
     121.13      9.97926E-01
     131.33      9.97926E-01
     141.53      9.97926E-01
     151.73      9.97737E-01
     161.93      9.97737E-01
     172.13      9.97737E-01
     182.33      9.97737E-01
     192.53      9.97549E-01
     202.73      9.97549E-01
     212.93      9.97549E-01
     223.13      9.97549E-01
     233.33      9.97549E-01
     243.53      9.97549E-01
     253.73      9.97549E-01
     263.93      9.97549E-01
     274.13      9.97549E-01
     284.33      9.97549E-01
     294.53      9.97549E-01
     304.73      9.97549E-01
     314.93      9.97549E-01
     325.13      9.97549E-01
     335.33      9.97549E-01
     345.53      9.98680E-01
     355.73      1.00019E+00
     365.93      9.98114E-01
     376.13      9.97549E-01
```

```
     386.33      9.97549E-01
     396.53      9.97549E-01
     406.73      9.99434E-01
     416.93      9.97360E-01
     427.13      9.97549E-01
     437.33      9.97549E-01
     447.53      9.97549E-01
     457.73      9.97360E-01
     467.93      9.97549E-01
     478.13      1.00094E+00
     488.33      9.97549E-01
     498.53      9.97549E-01
     508.73      9.97549E-01
     518.93      9.97549E-01
     529.13      9.97549E-01
     539.33      9.97549E-01
     549.53      9.97549E-01
     559.73      9.97549E-01
     569.93      9.97549E-01
     580.13      9.97549E-01
     590.33      9.97549E-01
     600.23      9.97549E-01
!---------------------------------------------------------------------------
!
/DATA SET NUMBER  7/
!---------------------------------------------------------------------------
data set  7 - INLET VOID TRANSIENT
!        itype
          1
!     x(ipt),      y(ipt)   ipt=1,npts
       0.00      0.00000E+00
       1.01      1.23600E-01
       2.01      1.61500E-01
       3.01      1.36100E-01
       4.02      8.27000E-02
       7.08      1.48000E-02
       9.08      1.07000E-02
      11.11      5.19000E-02
      13.21      1.61000E-02
      15.23      3.70000E-03
      17.27      6.00000E-04
      19.35      3.31000E-02
      21.44      1.24000E-02
      23.47      7.00000E-04
      25.54      1.00000E-04
      27.59      5.00000E-03
      29.59      9.00000E-04
      31.63      1.00000E-04
      33.65      8.00000E-04
      35.66      5.80000E-03
      37.66      3.80000E-03
      39.66      9.00000E-04
      41.66      5.00000E-04
      43.66      1.80000E-03
      45.66      7.00000E-04
      47.66      1.00000E-04
      49.66      1.70000E-03
      60.11      2.90000E-03
      70.16      9.00000E-04
      80.33      2.40000E-03
      90.53      1.70000E-03
     100.73      1.90000E-03
```

```
     110.93      1.70000E-03
     121.13      1.80000E-03
     131.33      1.80000E-03
     141.53      1.80000E-03
     151.73      1.80000E-03
     161.93      1.80000E-03
     172.13      1.80000E-03
     182.33      1.80000E-03
     192.53      1.80000E-03
     202.73      1.80000E-03
     212.93      1.80000E-03
     223.13      1.80000E-03
     233.33      1.80000E-03
     243.53      1.80000E-03
     253.73      1.80000E-03
     263.93      2.00000E-03
     274.13      2.00000E-03
     284.33      1.80000E-03
     294.53      1.70000E-03
     304.73      1.70000E-03
     314.93      1.70000E-03
     325.13      1.70000E-03
     335.33      1.70000E-03
     345.53      1.70000E-03
     355.73      1.70000E-03
     365.93      1.70000E-03
     376.13      1.70000E-03
     386.33      1.70000E-03
     396.53      1.70000E-03
     406.73      1.70000E-03
     416.93      1.70000E-03
     427.13      1.70000E-03
     437.33      1.70000E-03
     447.53      1.70000E-03
     457.73      1.70000E-03
     467.93      1.60000E-03
     478.13      1.70000E-03
     488.33      1.60000E-03
     498.53      1.50000E-03
     508.73      1.50000E-03
     518.93      8.00000E-04
     529.13      2.00000E-04
     539.33      1.00000E-04
     549.53      1.00000E-04
     559.73      0.00000E+00
     569.93      0.00000E+00
     580.13      0.00000E+00
     590.33      0.00000E+00
     600.23      0.00000E+00
!------------------------------------------------------------------------------
!
/DATA SET NUMBER  8/
!------------------------------------------------------------------------------
data set  8 - OUTLET PRESSURE TRANSIENT
!         itype
            1
!      x(ipt),       y(ipt)   ipt=1,npts
        0.00      1.00000E+00
        1.01      1.77830E+00
        2.01      1.50819E+00
        3.01      1.29845E+00
        4.02      1.18550E+00
```

7.08	1.08128E+00
9.08	1.05487E+00
11.11	9.75299E-01
13.21	9.03303E-01
15.23	1.04034E+00
17.27	1.06088E+00
19.35	1.02095E+00
21.44	9.84029E-01
23.47	1.00170E+00
25.54	1.00282E+00
27.59	9.84981E-01
29.59	9.93816E-01
31.63	1.02251E+00
33.65	1.01975E+00
35.66	1.00694E+00
37.66	9.95908E-01
39.66	9.96000E-01
41.66	9.98926E-01
43.66	9.98906E-01
45.66	1.00189E+00
47.66	1.00682E+00
49.66	1.00640E+00
60.11	9.99211E-01
70.16	1.00145E+00
80.33	1.00222E+00
90.53	1.00203E+00
100.73	1.00177E+00
110.93	1.00204E+00
121.13	1.00181E+00
131.33	1.00194E+00
141.53	1.00185E+00
151.73	1.00191E+00
161.93	1.00187E+00
172.13	1.00188E+00
182.33	1.00187E+00
192.53	1.00187E+00
202.73	1.00186E+00
212.93	1.00186E+00
223.13	1.00186E+00
233.33	1.00186E+00
243.53	1.00186E+00
253.73	1.00200E+00
263.93	1.00194E+00
274.13	1.00193E+00
284.33	1.00184E+00
294.53	1.00185E+00
304.73	1.00180E+00
314.93	1.00181E+00
325.13	1.00180E+00
335.33	1.00180E+00
345.53	1.00182E+00
355.73	1.00185E+00
365.93	1.00178E+00
376.13	1.00179E+00
386.33	1.00178E+00
396.53	1.00178E+00
406.73	1.00182E+00
416.93	1.00173E+00
427.13	1.00178E+00
437.33	1.00175E+00
447.53	1.00175E+00
457.73	1.00170E+00

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          467.93      1.00176E+00
          478.13      1.00175E+00
          488.33      1.00172E+00
          498.53      1.00171E+00
          508.73      1.00166E+00
          518.93      1.00151E+00
          529.13      1.00145E+00
          539.33      1.00134E+00
          549.53      1.00125E+00
          559.73      1.00124E+00
          569.93      1.00124E+00
          580.13      1.00124E+00
          590.33      1.00124E+00
          600.23      1.00124E+00
!-------------------------------------------------------------------------------
!
/DATA SET NUMBER  9/
!-------------------------------------------------------------------------------
data set  9 - OUTLET TEMPERATURE TRANSIENT
!        itype
          1
!     x(ipt),       y(ipt)   ipt=1,npts
            0.00      1.00000E+00
            1.01      1.00117E+00
            2.01      1.01671E+00
            3.01      1.01822E+00
            4.02      1.02172E+00
            7.08      1.01019E+00
            9.08      1.00284E+00
           11.11      1.00184E+00
           13.21      1.01270E+00
           15.23      1.00100E+00
           17.27      9.98997E-01
           19.35      1.00217E+00
           21.44      1.00953E+00
           23.47      9.97828E-01
           25.54      9.97326E-01
           27.59      9.97995E-01
           29.59      9.99332E-01
           31.63      9.99666E-01
           33.65      9.99164E-01
           35.66      9.98830E-01
           37.66      9.99499E-01
           39.66      9.99666E-01
           41.66      9.99499E-01
           43.66      9.99332E-01
           45.66      9.99499E-01
           47.66      9.99499E-01
           49.66      9.99499E-01
           60.11      9.99332E-01
           70.16      1.00117E+00
           80.33      9.98663E-01
           90.53      9.98663E-01
          100.73      9.98663E-01
          110.93      9.98496E-01
          121.13      9.98329E-01
          131.33      9.98162E-01
          141.53      9.98162E-01
          151.73      9.98162E-01
          161.93      9.97995E-01
          172.13      9.97995E-01
          182.33      9.97995E-01
```

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     192.53      9.97995E-01
     202.73      9.97995E-01
     212.93      9.97995E-01
     223.13      9.97828E-01
     233.33      9.97828E-01
     243.53      9.97828E-01
     253.73      9.97828E-01
     263.93      9.97828E-01
     274.13      9.97828E-01
     284.33      9.97828E-01
     294.53      9.97828E-01
     304.73      9.97828E-01
     314.93      9.97828E-01
     325.13      9.97828E-01
     335.33      9.97828E-01
     345.53      9.98663E-01
     355.73      9.98162E-01
     365.93      9.98162E-01
     376.13      9.97828E-01
     386.33      9.97828E-01
     396.53      9.97828E-01
     406.73      9.98496E-01
     416.93      9.97995E-01
     427.13      9.97828E-01
     437.33      9.97828E-01
     447.53      9.97828E-01
     457.73      9.97995E-01
     467.93      9.97828E-01
     478.13      9.97995E-01
     488.33      9.97828E-01
     498.53      9.97828E-01
     508.73      9.97828E-01
     518.93      9.97660E-01
     529.13      9.97660E-01
     539.33      9.97660E-01
     549.53      9.97660E-01
     559.73      9.97660E-01
     569.93      9.97660E-01
     580.13      9.97660E-01
     590.33      9.97660E-01
     600.23      9.97660E-01
!------------------------------------------------------------------------------
!
/DATA SET NUMBER 10/
!------------------------------------------------------------------------------
data set 10 - OUTLET VOID TRANSIENT
!        itype
          1
!     x(ipt),      y(ipt)   ipt=1,npts
       0.00      0.00000E+00
       1.01      0.00000E+00
       2.01      0.00000E+00
       3.01      1.51000E-01
       4.02      1.94500E-01
       7.08      5.08000E-02
       9.08      2.48000E-02
      11.11      1.87000E-02
      13.21      6.96000E-02
      15.23      1.46000E-02
      17.27      4.20000E-03
      19.35      1.11000E-02
      21.44      3.88000E-02
```

23.47	1.09000E-02
25.54	1.40000E-03
27.59	2.60000E-03
29.59	4.70000E-03
31.63	1.20000E-03
33.65	2.00000E-04
35.66	4.00000E-03
37.66	7.80000E-03
39.66	4.00000E-03
41.66	1.20000E-03
43.66	1.30000E-03
45.66	1.90000E-03
47.66	7.00000E-04
49.66	5.00000E-04
60.11	3.50000E-03
70.16	2.30000E-03
80.33	2.80000E-03
90.53	2.30000E-03
100.73	2.60000E-03
110.93	2.30000E-03
121.13	2.40000E-03
131.33	2.40000E-03
141.53	2.40000E-03
151.73	2.40000E-03
161.93	2.40000E-03
172.13	2.40000E-03
182.33	2.40000E-03
192.53	2.40000E-03
202.73	2.40000E-03
212.93	2.40000E-03
223.13	2.40000E-03
233.33	2.40000E-03
243.53	2.40000E-03
253.73	2.40000E-03
263.93	2.70000E-03
274.13	2.60000E-03
284.33	2.40000E-03
294.53	2.30000E-03
304.73	2.30000E-03
314.93	2.20000E-03
325.13	2.30000E-03
335.33	2.20000E-03
345.53	2.20000E-03
355.73	2.20000E-03
365.93	2.20000E-03
376.13	2.20000E-03
386.33	2.20000E-03
396.53	2.20000E-03
406.73	2.20000E-03
416.93	2.20000E-03
427.13	2.20000E-03
437.33	2.20000E-03
447.53	2.20000E-03
457.73	2.20000E-03
467.93	2.20000E-03
478.13	2.10000E-03
488.33	2.10000E-03
498.53	2.00000E-03
508.73	1.90000E-03
518.93	1.20000E-03
529.13	4.00000E-04
539.33	1.00000E-04

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     549.53      1.00000E-04
     559.73      1.00000E-04
     569.93      1.00000E-04
     580.13      0.00000E+00
     590.33      0.00000E+00
     600.23      0.00000E+00
!---------------------------------------------------------------------------
/END OF INPUT FILE/
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