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Your ref: Docket No. 52-006
Our ref: DCP/NRC2127

April 28, 2008

Subject: Submittal of APP-PXS-GLR-001, Revision 0, "Impact on AP1000 Post-LOCA Long Term Cooling of Postulated Containment Sump Debris"

Westinghouse is submitting Revision 0 of APP-PXS-GLR-001, "Impact on AP1000 Post-LOCA Long Term Cooling of Postulated Containment Sump Debris." The purpose of this report is to demonstrate passive core cooling system performance during the IRWST injection/containment recirculation time frame following a LOCA. Sensitivity calculations of AP1000 long-term cooling performance are performed in which the resistances at the reactor lower core plate, the recirculation screen, and the IRWST screen are increased in a highly conservative manner. The sensitivity cases continue to exhibit no core uncovery. The results of these cases demonstrate the capability of the AP1000 passive systems to provide long term cooling for a limiting LOCA is maintained even when conservative blockage due to containment debris is postulated.

Westinghouse presented a description and the results of the long term cooling sensitivity study to the NRC in a technical review meeting on April 16, 2008 at the Westinghouse office in Rockville.

Submittal of this report along with the five submittals listed below completes ahead of schedule the Westinghouse commitment regarding recirculation and IRWST screens referenced in the February 15, 2008 NRC Review Schedule for the AP1000 Design Certification Amendment Application Revision 16.

1. APP-GW-GLN-147, Revision 1, "AP 1000 Containment Recirculation and IRWST Screen Design," Technical Report 147, submitted on March 3, 2008.
2. WCAP-16914-P, "Evaluation of Debris Loading Head Loss Tests for AP1000 Recirculation Screens and In-Containment Refueling Water Storage Tank Screens," submitted March 3, 2008.
3. APP-GW-GLR-079, Revision 3, Technical Report 26, "AP1000 Verification of Water Sources for Long-Term Recirculation Cooling Following a LOCA," submitted March 28, 2008.
4. APP-GW-GLE-002, "Impacts to AP1000 DCD to Address Generic Safety Issue (GSI)-191," submitted on March 28, 2008.
5. DCP/NRC2116, Regulatory Guide 1.82, Revision 3 Assessment, April 9, 2008.

This report is submitted in support of the AP1000 Design Certification Amendment Application (Docket No. 52-006). The information provided in this report is generic and is expected to apply to all Combined

D063
NRO

Operating License (COL) applicants referencing the AP1000 Design Certification and the AP1000 Design Certification Amendment Application.

Pursuant to 10 CFR 50.30(b), APP-PXS-GLR-001, "Impact on AP1000 Post-LOCA Long Term Cooling of Postulated Containment Sump Debris," is submitted as Enclosure 1 under the attached Oath of Affirmation.

Questions or requests for additional information related to content and preparation of this information should be directed to Westinghouse. Please send copies of such questions or requests to the prospective applicants for combined licenses referencing the AP1000 Design Certification. A representative for each applicant is included on the cc: list of letter.

Very truly yours,

Robert Sisk, Manager
Licensing and Customer Interface
Regulatory Affairs and Standardization

/Attachment

1. "Oath of Affirmation," dated April 28, 2008

/Enclosure

1. APP-PXS-GLR-001, "Impact on AP1000 Post-LOCA Long Term Cooling of Postulated Containment Sump Debris."

cc:	B. Gleaves	-	U.S. NRC	1E	1A
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	R. Grumbir	-	NuStart	1E	1A
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ATTACHMENT 1

"Oath of Affirmation"

ATTACHMENT 1

UNITED STATES OF AMERICA

NUCLEAR REGULATORY COMMISSION

In the Matter of:)

AP1000 Design Certification Amendment Application)

NRC Docket Number 52-006)

APPLICATION FOR REVIEW OF
"AP1000 GENERAL INFORMATION"
FOR DESIGN CERTIFICATION AMENDMENT APPLICATION REVIEW

W. E. Cummins, being duly sworn, states that he is Vice President, Regulatory Affairs & Standardization, for Westinghouse Electric Company; that he is authorized on the part of said company to sign and file with the Nuclear Regulatory Commission this document; that all statements made and matters set forth therein are true and correct to the best of his knowledge, information and belief.

W E Cummins

W. E. Cummins
Vice President
Regulatory Affairs & Standardization

Subscribed and sworn to
before me this 28th day
of April 2008.

COMMONWEALTH OF PENNSYLVANIA
Notarial Seal
Debra McCarthy, Notary Public
Monroeville Boro, Allegheny County
My Commission Expires Aug. 31, 2009
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ENCLOSURE 1

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ORIGINATING ORGANIZATION: Westinghouse Electric Company

TITLE: **Impact on AP1000 Post-LOCA Long-Term Cooling of Postulated Containment Sump Debris**

ATTACHMENTS:	DCP #/REV. INCORPORATED IN THIS DOCUMENT REVISION:
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**Plant Applicability: ☒ All AP1000 plants except: No exceptions

☐ Only the following plants:

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APP-PXS-GLR-001
Revision 0

April 2008

Impact on AP1000 Post-LOCA Long-Term Cooling of Postulated Containment Sump Debris

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1 INTRODUCTION

The AP1000 safety-related systems are designed to provide adequate cooling of the reactor indefinitely following a loss-of-coolant accident (LOCA). After the initial injection of water from the core makeup tanks and the accumulators, safety injection is provided by gravity drain from the in-containment refueling water storage tank (IRWST). After the IRWST level drops to a low setpoint, containment recirculation valves are opened to provide a supply of water for the reactor coolant system (RCS) that is adequate to support core cooling indefinitely.

Steam released from the automatic depressurization valves is condensed on the inner surface of the steel containment vessel. The containment vessel is cooled on the outside by the passive containment cooling system (PCS). The steam condensate is collected in a gutter located at the operating deck level and returned to the IRWST for injection into the RCS. Significant amounts of water are discharged from the automatic depressurization system (ADS) Stage 4 valves into the containment. This water is returned to the RCS through the passive core cooling system (PXS) containment recirculation screens and piping.

Long-term cooling analysis is provided in the AP1000 Design Control Document (DCD) Revision 16 to demonstrate that the passive systems provide adequate emergency core cooling system performance during the IRWST injection/containment recirculation time scale. The long-term cooling analysis is performed using the WCOBRA/TRAC computer code to verify that the passive injection system is providing sufficient flow to the reactor vessel to cool the core and to preclude boron precipitation.

The long-term cooling case analyzed in the DCD is a double-ended direct vessel injection (DEDVI) line break in one of the PXS valve rooms. This case was selected because it is the most limiting long-term cooling case since it has the highest decay power and the lowest available liquid driving head. The DEDVI break results in one of the IRWST injection lines spilling directly to the containment and as a result, the IRWST drains faster and containment recirculation is initiated earlier with higher core decay power. Because the break location is in one of the PXS rooms, the containment flood volume is greater and the containment water level during recirculation is lower.

Note that in DEDVI break cases, the containment water level exceeds the elevation of the break so water can flow from the containment into the reactor vessel through the broken direct vessel injection (DVI) line; this in-flow of water through the broken DVI line assists in the heat removal from the core. The WCOBRA/TRAC analysis presented in AP1000 DCD Revision 16 analyzes the DEDVI small-break LOCA event from a time (3000 seconds) at which IRWST injection is fully established to beyond the time of containment recirculation. During this time, the head of water to drive the flow into the vessel for IRWST injection decreases from the initial level to the containment recirculation actuation setpoint value at the containment recirculation switchover time.

In AP1000 DCD Revision 16, the long-term cooling phase begins after the simultaneous opening of the isolation valves in the IRWST DVI lines and the opening of ADS Stage 4 squib valves when flow injection from the IRWST has been fully established. A continuous analysis of the post-LOCA long-term cooling is provided in AP1000 DCD Revision 16 from the time of stable IRWST injection through the time of sump recirculation for the DEDVI break. Maximum design resistances are applied in WCOBRA/TRAC for both the ADS Stage 4 flow paths and the IRWST injection and containment recirculation flow paths.

The purpose of this report is to perform sensitivity studies of the AP1000 long-term cooling analysis to demonstrate that core cooling margins are maintained when large arbitrary, non-mechanistic, head losses are added to the containment recirculation and IRWST screens and to the core that bound the expected head losses. Note that the head losses with the AP1000 design, including debris amounts/types, flow rates, and screen size/type are expected to be insignificant (that is, a fraction of an inch of water). Testing of the AP1000 screens has confirmed this performance (Reference 1).

The DCD long-term cooling case was selected as the base for these sensitivity studies because of the following considerations:

- A cold leg break location results in a significant amount of debris bypassing the containment recirculation screens and being transported to the core. Hot leg breaks and elevated breaks would result in much less debris transport to the core.

- Note that a break location in the loop compartment maximizes the amount of debris that can be transported to the core. A DEDVI break in a PXS room would make available only a small portion of the debris that would be available for a loop break. The reason for this is that essentially all of the AP1000 debris is resident debris, which is distributed through out the containment on floors, walls, and equipment. Since the PXS room is small relative to the rest of the containment, it will contain only a small part of the containment debris. Also note that during recirculation, water from the IRWST continues to flow into the PXS room and maintains its level; the water flow from the IRWST passes through the IRWST screen, which would remove the debris that would be in the water.

- A DEDVI break results in the minimum break elevation on the cold leg side. A low break elevation makes the minimum elevation of water available to drive water through the core. The water level can not rise higher than the cold leg break elevation without spilling out the break and into the containment. A DEDVI break maximizes the impact of increased head loss across the core.

- A DEDVI break increases the line resistance in the faulted DVI line because of the added pipe exit and entrance factors.

- A DEDVI break in a PXS room results in higher decay heat levels and lower containment water levels. For example, a break of the main cold leg piping will not result in IRWST spill or flooding of a PXS room.

Sensitivity cases are performed to identify the potential impact of postulated sump debris on the AP1000 DCD Revision 16 subsection 15.6.5.4C analysis. The reactor vessel noding used in these AP1000 long-term cooling sensitivity analyses in core and hot leg regions is consistent with that used in the DCD long-term cooling simulations. The sensitivity cases model additional flow resistances to simulate the long-term cooling analysis impact of debris from containment collecting at specific locations. Note that the head losses assumed are much greater that those expected for the AP1000 (Reference 1).

2 DCD REVISION 16 DEDVI LINE BREAK WITH ADS STAGE 4 SINGLE FAILURE, PASSIVE CORE COOLING SYSTEM ONLY CASE; CONTINUOUS CASE

This section presents for reference the DEDVI line break analysis during IRWST injection phase continuing into sump recirculation from DCD subsection 15.6.5.4C. Initial conditions at the start of the case are prescribed based on the NOTRUMP DEDVI break results to allow a calculation to begin shortly after IRWST injection begins in the small break long-term cooling transient. The WCOBRA/TRAC calculation is then allowed to proceed until a quasi-steady-state is achieved. At this time, the predicted results are independent of the assumed initial conditions. This calculation uses boundary conditions taken from a WGOTHIC analysis of this event. During the calculation, which is carried out for 10,000 seconds until a quasi-steady-state sump recirculation condition has been established, the IRWST water level is decreased continuously until the sump recirculation setpoint is reached.

In the analysis, one of the two ADS Stage 4 valves in the passive residual heat removal (PRHR) loop is assumed to have failed. The initial reactor coolant system liquid inventory and temperatures are determined from the NOTRUMP calculation. The core makeup tanks do not contribute to the DVI injection during this phase of the transient. Steam generator secondary side conditions are taken from the NOTRUMP calculation (at the beginning of long-term cooling). The reactor coolant pumps are tripped and not rotating.

The levels and temperatures of the liquid in the containment sump and the containment pressure are based on WGOTHIC calculations of the conservative minimum pressure during this long-term cooling transient, including operation of the containment fan coolers. Small changes in the RCS compartment level do not have a major effect on the predicted core collapsed liquid level or on the predicted flow rate through the core. The minimum compartment floodup level for this break scenario is 107.8 feet or greater.

In this transient, the IRWST provides a hydraulic head sufficient to drive water into the downcomer through the intact DVI nozzle. Also, water flows into the downcomer from the broken DVI line once the liquid level in the compartment with the broken line is adequate to support flow. The water flows down the downcomer and up through the core, into the upper plenum. Steam produced in the core and liquid flow out of the RCS via the ADS Stage 4 valves. There is little flow out of ADS Stages 1, 2, and 3 even when the IRWST liquid level falls below the sparger elevation so they are not modeled in this calculation. The venting provided by the ADS Stage 4 paths enables the liquid flow through the core to maintain core cooling.

Approximately 500 seconds of WCOBRA/TRAC calculation are required to establish the quasi-steady-state condition associated with IRWST injection at the start of long-term cooling and so are ignored in the following discussion. The hot leg levels are such that during the IRWST injection phase the quality of the ADS Stage 4 mass flows varies as water is carried out of the hot legs. This periodically increases the pressure drop across the ADS Stage 4 valves and the upper plenum pressure. The higher pressure in the upper plenum reduces the injection flow. This cycle of pressure variations due to changing void fractions in the flow through ADS Stage 4 is consistent with test observations and is expected to recur often during long-term cooling.

The head of water in the IRWST causes a flow of subcooled water into the downcomer at an approximate rate of 170 lbm/s through the intact DVI nozzle at the start of long-term cooling. The downcomer level at the end of the code initiation (the start of long-term cooling) is about 18.0 feet (Figure 2-1). Note that the time scale of this and other figures in this section is offset by 2500 seconds; that is, a time of 500 seconds on the Figure 2-1 axis equals 3000 seconds transient time for the DEDVI break. All of the injection water flows down the downcomer and up through the core. The accumulators have been fully discharged before the start of the time window and do not contribute to the DVI flow.

Boiling in the core produces steam and a two-phase mixture, which flows into the upper plenum. The core is 14 feet high, and the core average collapsed liquid level (Figure 2-2) is shown from the start of long-term cooling. The boiling process causes a variable rate of steam production and resulting pressure changes, which in turn causes oscillations in the liquid flow rate at the bottom of the core and also variations in the core collapsed level and the flow rates of liquid and vapor out of the top of the core. In the WCOBRA/TRAC noding, the core is divided both axially and radially as described in Reference 2. The void fractions in the top two cells of the hot assembly are shown as Figures 2-3 and 2-4. The average void fraction of these upper core cells is about 0.8 during long-term cooling, during IRWST injection, and into the containment recirculation period. There is a continuous flow of two-phase fluid into the hot legs, and mainly vapor flow toward the ADS Stage 4 valve occurs at the top of the pipe. The collapsed liquid level in the hot leg varies between 0.8 feet to 1.6 feet (Figure 2-5). The hot legs on average are more than 50-percent full. Vapor and liquid flows at the top of the core are shown in Figures 2-6 and 2-7, the upper plenum collapsed liquid level in Figure 2-8. Figures 2-9 and 2-10 are ADS Stage 4 mass flow rates.

The pressure in the upper plenum is shown in Figure 2-11. The upper plenum pressure fluctuation that occurs is due to the ADS Stage 4 water discharge. The peak cladding temperature of the hot rod follows saturation temperature (Figure 2-12), which demonstrates that no uncovery and no cladding temperature excursion occurs. A small pressure drop is calculated across the reactor vessel, and injection rates through the DVI lines into the vessel are presented in Figures 2-13 and 2-14. The recirculation core liquid throughput is more than adequate to preclude any boron buildup on the fuel.

3 SENSITIVITY TO BLOCKAGE WITH CONTAINMENT DEBRIS

There are three areas of concern with debris causing pressure drop that might adversely affect long-term core cooling following a LOCA; these areas include the core, containment recirculation screens, and IRWST screens. The approach taken is to consider two different magnitudes of added pressure drop at the core inlet and at both screens. Both cases outlined below far exceed any blockage impact indicated by the analyses and testing performed for the AP1000 screen design. Case 1 considers a more moderate increase in the core and screen pressure drops due to debris blockage. Case 2 increases these pressure drops by a greater amount. Each case includes added pressure drop across the core, recirculation screens, and IRWST screens. Only the containment recirculation portion of the analysis is addressed in this report because the debris would not collect at the core entrance/screens before that time.

Sensitivity Case 1 – The DCD DEDVI case assumes the break is in the PXS room, which results in a lower final floodup level. The flow resistance of the lower support plate at the core inlet is increased to model a pressure drop of 3 feet of water at the DCD analysis flow rate of 152 lbm/s. The resistance of the flow through the PXS recirculation/IRWST injection lines is also increased. The DEDVI line break

model considers injection through two separate flow paths: one from the containment, through the intact recirculation line to the associated DVI nozzle, the other from the IRWST into the IRWST injection line to the break where the flow leaves the pipe and goes into the room, then re-enters the broken pipe and flows to the associated DVI nozzle. In this case, the containment recirculation screen pressure drop is increased by about 7 inches of water at 77 lbm/s flow rate, and the IRWST screen pressure drop is increased by 7 inches of water at a 75 lbm/s flow rate.

Sensitivity Case 2 – This case is the same as Case 1 except that higher differential pressures are assumed. The core inlet pressure drop is assumed to be 6 feet of water at 152 lbm/s. The recirculation screen pressure drop is assumed to be 14 inches of water at 77 lbm/s, and the IRWST screen pressure drop is assumed to be 14 inches of water at 75 lbm/s.

The testing performed on the AP1000 screens showed that there should be negligible pressure drop across the screens even with more than the expected amounts of containment debris. As a result, these cases are considered bounding sensitivity cases.

For both sensitivity cases, the head losses across the core and the containment recirculation and IRWST screens were evaluated assuming they increased when the PXS recirculation valves opened. For the containment recirculation screens, this assumption is conservative because these screens see no flow until the recirculation valves open; in addition, it takes several hours of recirculation to process the containment water volume once, which would be a minimum time to accumulate the resident debris on these screens.

For the core and IRWST screens, some debris could be transferred to them prior to opening of the recirculation valves, which could result in their head loss increasing earlier. As in the case of the containment recirculation screens, it is expected to take several hours to transfer all of the debris that they would eventually see. In order to bound this effect, the impact of increasing the core and IRWST screen resistance at the start of IRWST injection was assessed. The outcome is the same as that described for the containment recirculation windows; namely, that there was an increase in the downcomer liquid level and a small decrease in flows into the RCS without a measurable impact on core cooling margin.

3.1 Sensitivity Case 1 Results

Figures 3.1-1 through 3.1-14 present the sensitivity of long-term cooling performance to the Case 1 postulated resistance increases at the containment screens and core inlet. The DEDVI break from Section 2 is reanalyzed beginning at the switchover to containment recirculation (6500 seconds) to assess in a window mode calculation the effect of this reduced flow capability at the most limiting time in the DEDVI transient, the switchover to containment recirculation. Under the window mode methodology of WCAP-14776 (Reference 3), the figures in this section begin at the restart point of 6500 seconds.

Focusing on Case 1 during this post-switchover time interval, the containment liquid continues to provide hydraulic head sufficient to drive water into the downcomer through the DVI nozzles. The water introduced into the downcomer flows down the downcomer and up through the core, into the upper plenum. Steam produced in the core entrains liquid and flows out of the reactor coolant system via the ADS Stage 4 valves. The DVI flow and the venting provided by the ADS paths provide a liquid flow

through the core that enables the core to remain cool, and liquid carryover is adequate to preclude concentration of boric acid.

Figure 3.1-1 shows that in the Sensitivity Case 1 window, the downcomer liquid is established at a higher level than in the DCD analysis due to the greater added resistance at the core entrance. Boiling in the core produces steam and a two-phase mixture, which flows out of the core into the upper plenum. The core is 14 feet high, and the core collapsed liquid level (Figure 3.1-2) is maintained at a mean level close to the top of the core even with the added core entrance resistance and added resistance at the PXS screens. Boiling causes pressure variations, which in turn, cause variations in the core collapsed level and the flow rates of liquid and vapor out of the top of the core. In the WCOBRA/TRAC analysis of Sensitivity Case 1, the void fraction in the top cell is shown in Figure 3.1-3 for the core hot assembly, and Figure 3.1-4 shows the void fraction that exists one cell further down in the hot assembly. The peak cladding temperature does not rise appreciably above the saturation temperature (Figure 3.1-12). The flow through the core and out of the reactor coolant system is more than sufficient to provide adequate flushing to preclude concentration of the boric acid solution. Liquid collects above the upper core plate in the upper plenum, where the average collapsed liquid level remains well above the active fuel length (Figure 3.1-8). There is no significant flow through the cold legs into either the broken or the intact loops, and there is no significant quantity of liquid residing in any of the cold legs.

The pressure in the upper plenum is shown in Figure 3.1-11. The upper plenum pressure of 22 psia is essentially unchanged from the DCD case. Injection rates through the DVI lines into the vessel are presented in Figures 3.1-13 and 3.1-14. They are only slightly diminished from the DCD case values. Flow through the intact DVI line is reduced to 73.6 lbm/s in Sensitivity Case 1, versus 77.2 lbm/s in the DCD analysis. Flow into the vessel through the broken DVI line is reduced from 75 lbm/s in the DCD analysis to 72 lbm/s in Sensitivity Case 1. The quality of the flow discharged through ADS Stage 4 is about the same as in the DCD case, approximately 0.25. The other figures for Sensitivity Case 1 demonstrate comparable long-term cooling performance to the DCD analysis. Therefore, the most notable effect of increasing flow resistance at the core entrance and the containment screen locations is an increase in downcomer liquid level; the core flow exhibits very little reduction.

3.2 Sensitivity Case 2 Results

Figures 3.2-1 through 3.2-14 present the sensitivity of long-term cooling performance to the Case 2 postulated resistance increases at the containment screens and core inlet. The DEDVI break from Section 2 is reanalyzed beginning at the switchover to containment recirculation (6500 seconds) to assess in a window mode calculation the effect of this reduced flow capability at the most limiting time in the DEDVI transient, the switchover to containment recirculation. Under the window mode methodology of WCAP-14776 (Reference 3), the figures in this section begin at the restart point of 6500 seconds.

Focusing on Case 2 during this post-switchover time interval, the containment liquid continues to provide hydraulic head sufficient to drive water into the downcomer through the DVI nozzles. The water introduced into the downcomer flows down the downcomer and up through the core, into the upper plenum. Steam produced in the core entrains liquid and flows out of the reactor coolant system via the ADS Stage 4 valves. The DVI flow and the venting provided by the ADS paths provide a liquid flow through the core that enables the core to remain cool, and liquid carryover is adequate to preclude concentration of boric acid.

Figure 3.2-1 shows that in the Sensitivity Case 2 window, the downcomer liquid is established at a higher level than Sensitivity Case 1 due to the greater added resistance at the core entrance. Boiling in the core produces steam and a two-phase mixture, which flows out of the core into the upper plenum. The core is 14 feet high, and the core collapsed liquid level (Figure 3.2-2) is maintained at a mean level close to the top of the core even with the added core entrance resistance and added resistance at the PXS screens. Boiling causes pressure variations, which in turn, cause variations in the core collapsed level and the flow rates of liquid and vapor out of the top of the core. In the WCOBRA/TRAC analysis of Sensitivity Case 2, the void fraction in the top cell is shown in Figure 3.2-3 for the core hot assembly, and Figure 3.2-4 shows the void fraction that exists one cell further down in the hot assembly. The peak cladding temperature does not rise appreciably above the saturation temperature (Figure 3.2-12). The flow through the core and out of the reactor coolant system is more than sufficient to provide adequate flushing to preclude concentration of the boric acid solution. Liquid collects above the upper core plate in the upper plenum, where the average collapsed liquid level remains well above the active fuel length (Figure 3.2-8). There is no significant flow through the cold legs into either the broken or the intact loops, and there is no significant quantity of liquid residing in any of the cold legs.

The pressure in the upper plenum is shown in Figure 3.2-11. The upper plenum pressure of 22 psia is essentially unchanged from the DCD case. Injection rates through the DVI lines into the vessel are presented in Figures 3.2-13 and 3.2-14. They are only slightly diminished from the DCD case values. Flow through the intact DVI line is reduced to 69 lbm/s in Sensitivity Case 2, versus 77.2 lbm/s in the DCD analysis. Flow into the vessel through the broken DVI line is reduced from 75 lbm/s in the DCD analysis to 67.5 lbm/s in Sensitivity Case 2. The quality of the flow discharged through ADS Stage 4 is about the same as in the DCD case, approximately 0.25. The other figures for Sensitivity Case 2 demonstrate comparable long-term cooling performance to the DCD analysis. Therefore, the most notable effect of increasing flow resistance at the core entrance and the containment screen locations is an increase in downcomer liquid level; the core flow exhibits very little reduction.

4 CONCLUSIONS

Sensitivity calculations of AP1000 long-term cooling performance have been performed using the WCOBRA/TRAC model developed for AP1000. The DEDVI case from the DCD is chosen because it reaches sump recirculation at the earliest time (and highest decay heat). Window mode cases are performed in which the resistances at the reactor lower core plate, the sump screen, and the IRWST screen are increased. The sensitivity cases continue to exhibit no core uncovery. Adequate reactor coolant system mass inventory continues to exist during the long-term cooling containment recirculation phase. The liquid level in the downcomer rises due to the postulated blockage at the core inlet, and an adequate flow through the core is provided to maintain a low cladding temperature and to prevent any buildup of boric acid on the fuel rods in the sensitivity cases. The results of these cases demonstrate the capability of the AP1000 passive systems to provide long-term cooling for a limiting LOCA event is maintained even when massively conservative blockage due to containment debris is postulated.

5 REFERENCES

1. "Evaluation of Debris Loading Head Loss Tests for AP1000 Recirculation Screens and In-Containment Refueling Water Storage Tank Screens," WCAP-16914-P (Proprietary) and WCAP-16914-NP (Nonproprietary), Revision 0, March 2008.

2. "AP1000 Code Applicability Report," WCAP-15644-P (Proprietary) and WCAP-15644-NP (Nonproprietary), Revision 2, March 2004.

3. "WCOBRA/TRAC OSU Long-Term Cooling Final Validation Report," WCAP-14776, Revision 4, March 1998.

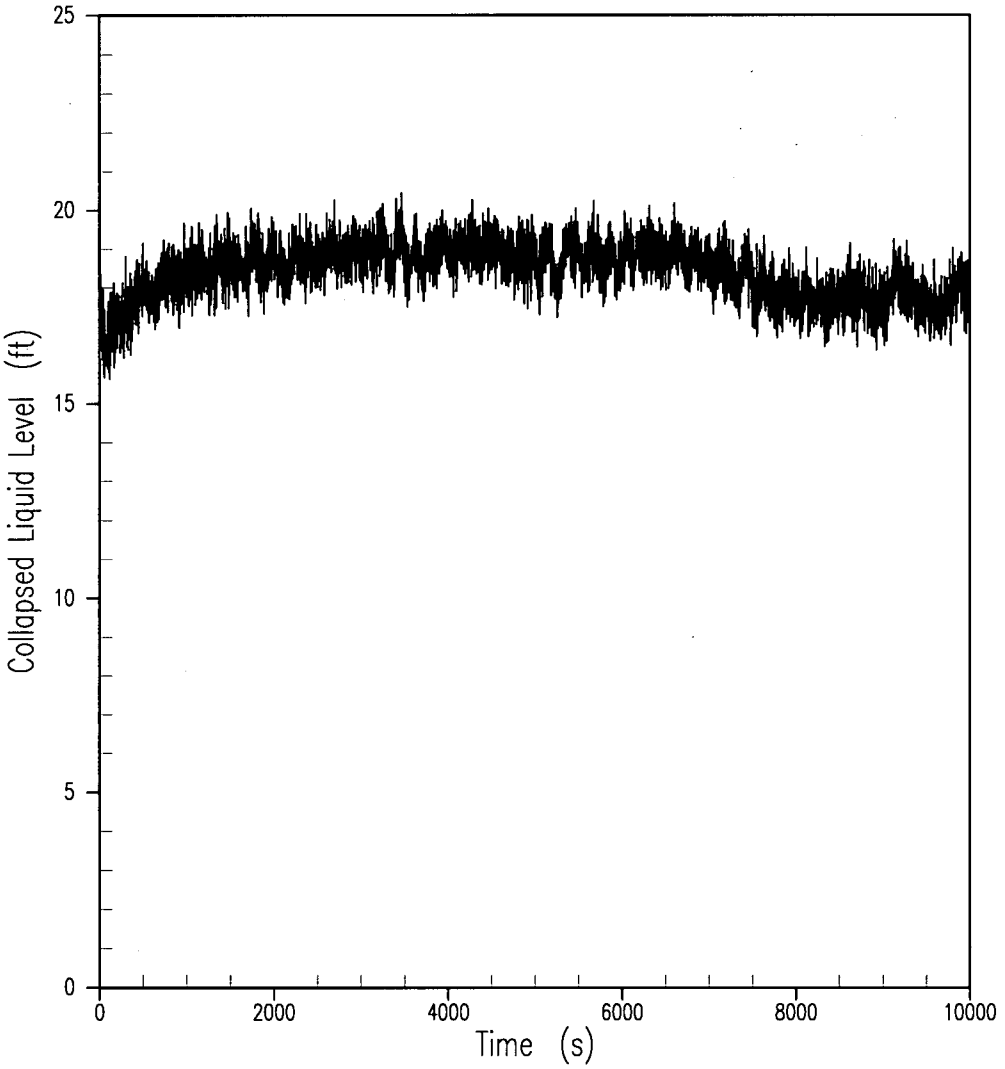

Figure 2-1
Collapsed Level of Liquid in Downcomer
(DCD DEDVI Case)

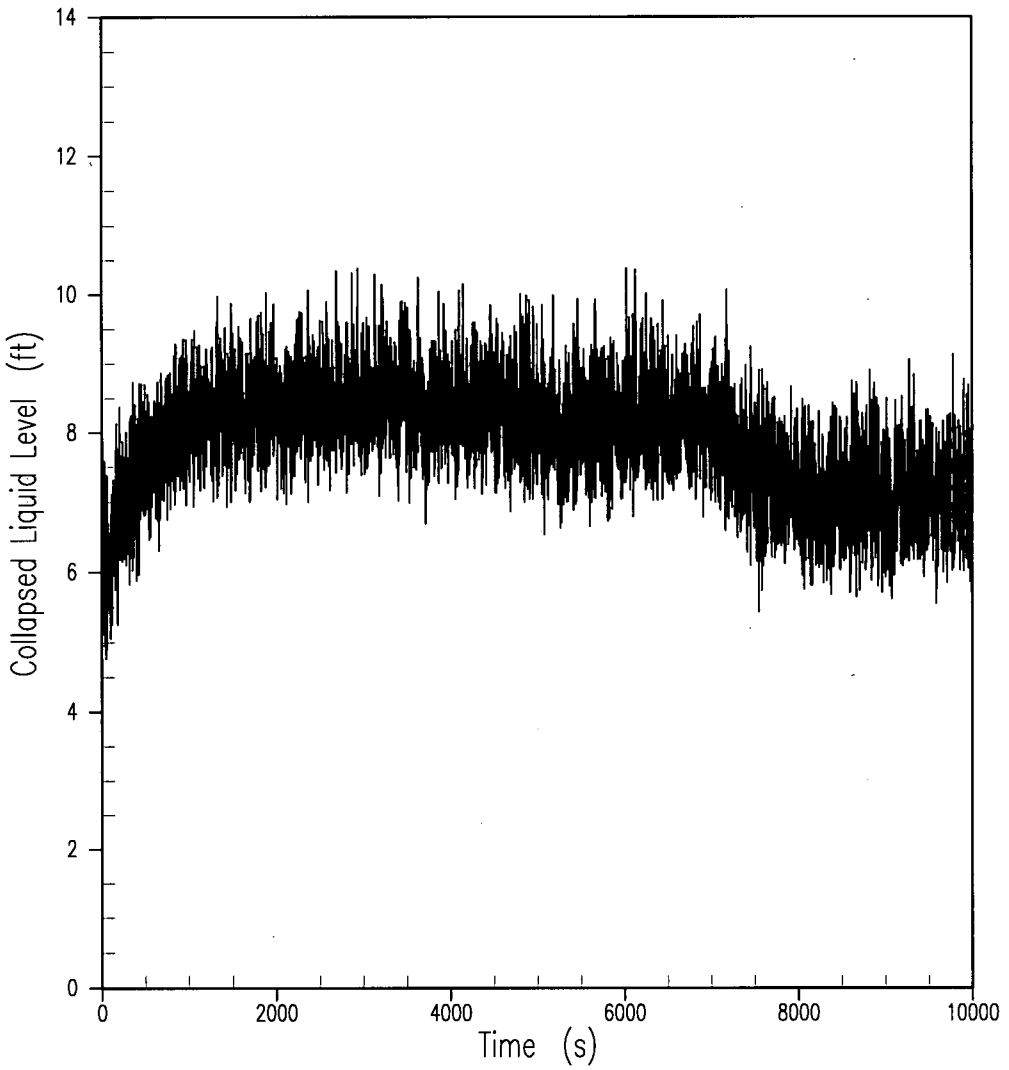

Figure 2-2
Collapsed Level of Liquid Over Heated Length of Fuel
(DCD DEDVI Case)

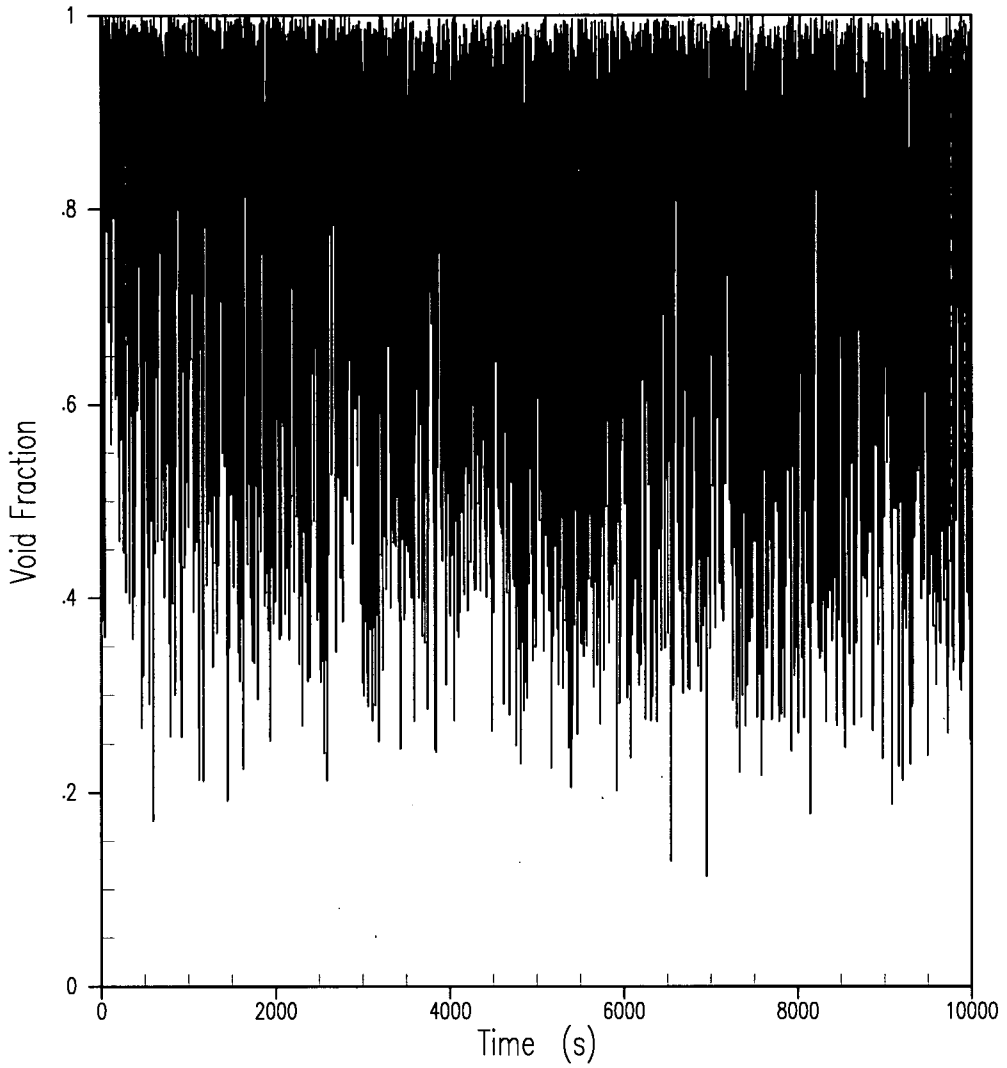

Figure 2-3
Void Fraction in Core Hot Assembly Top Cell
(DCD DEDVI Case)

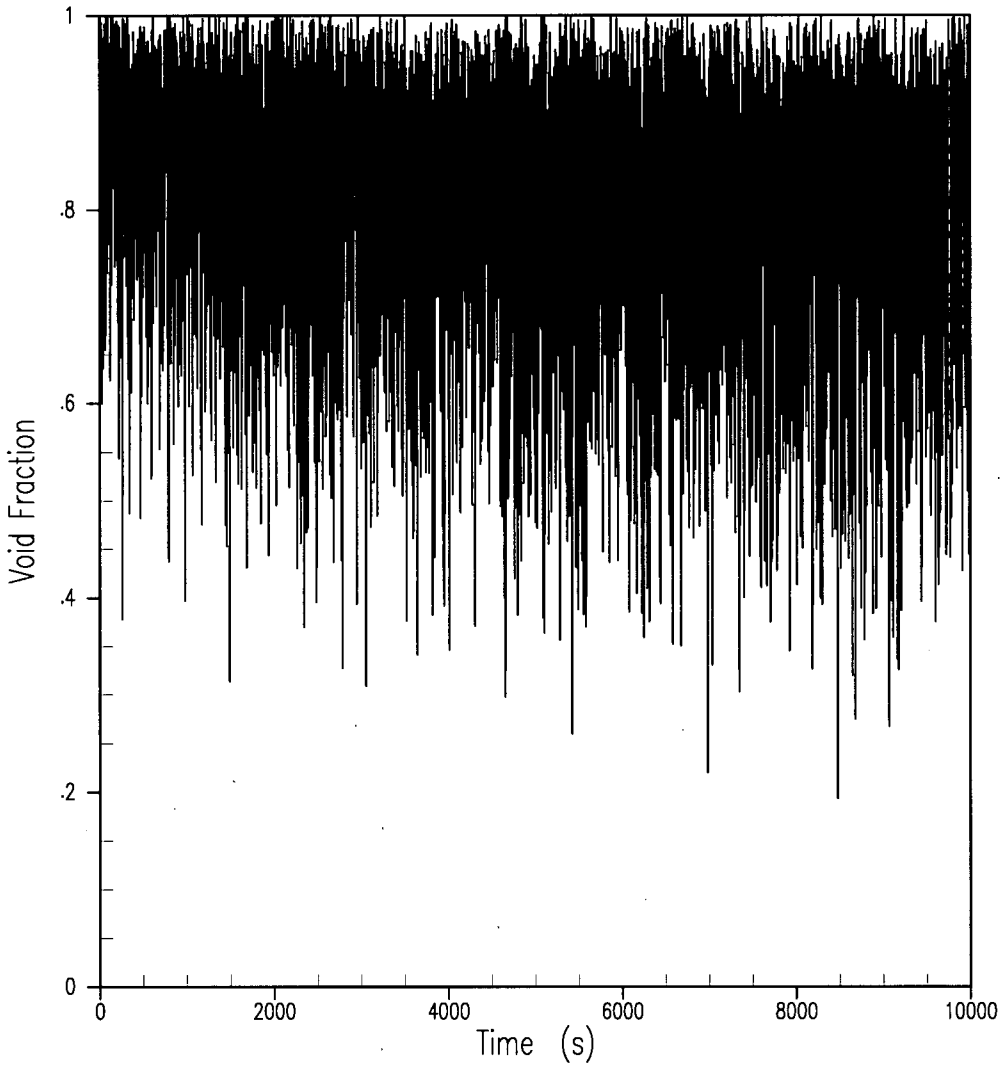

Figure 2-4
Void Fraction in Core Hot Assembly Second from Top Cell
(DCD DEDVI Case)

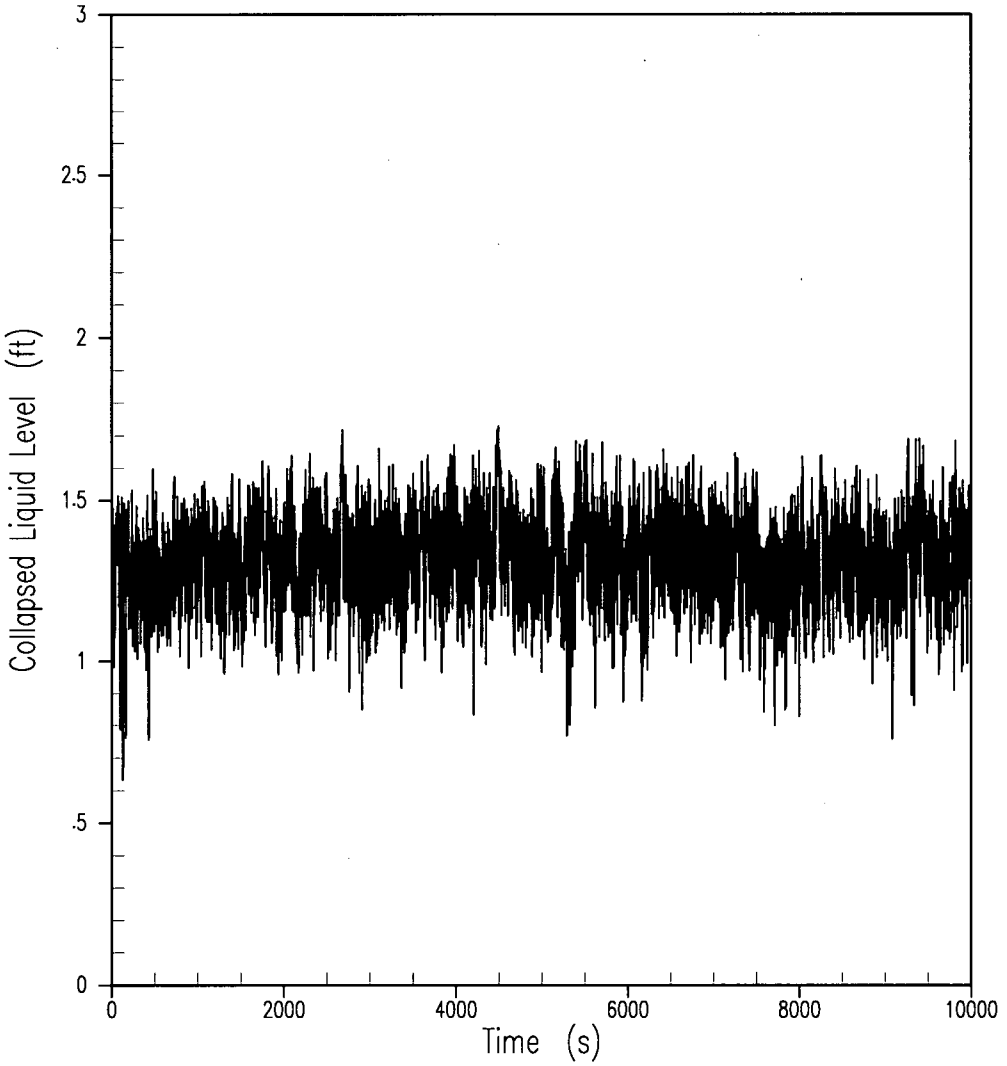

Figure 2-5
Collapsed Liquid Level in Hot Leg of Pressurizer Loop (DCD DEDVI Case)

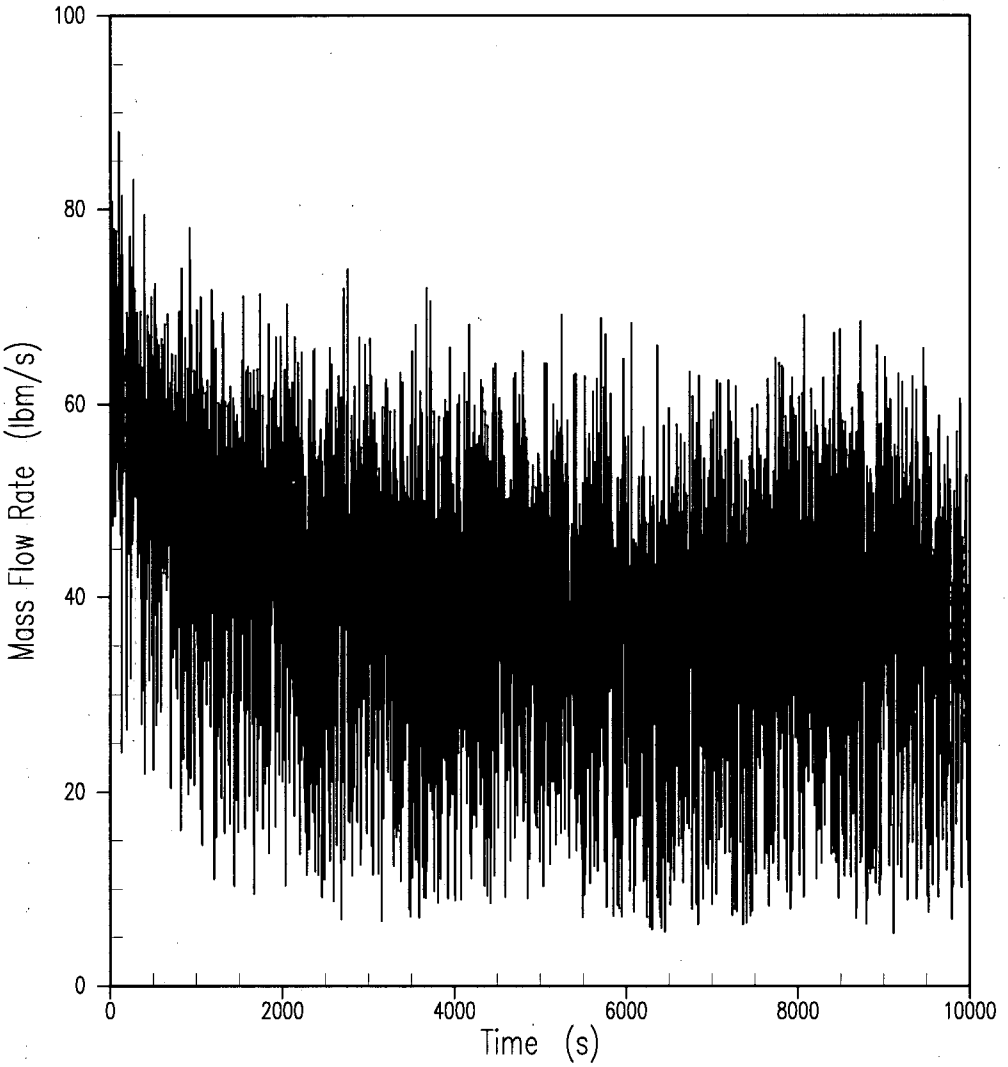

Figure 2-6
Vapor Rate Out of Core
(DCD DEDVI Case)

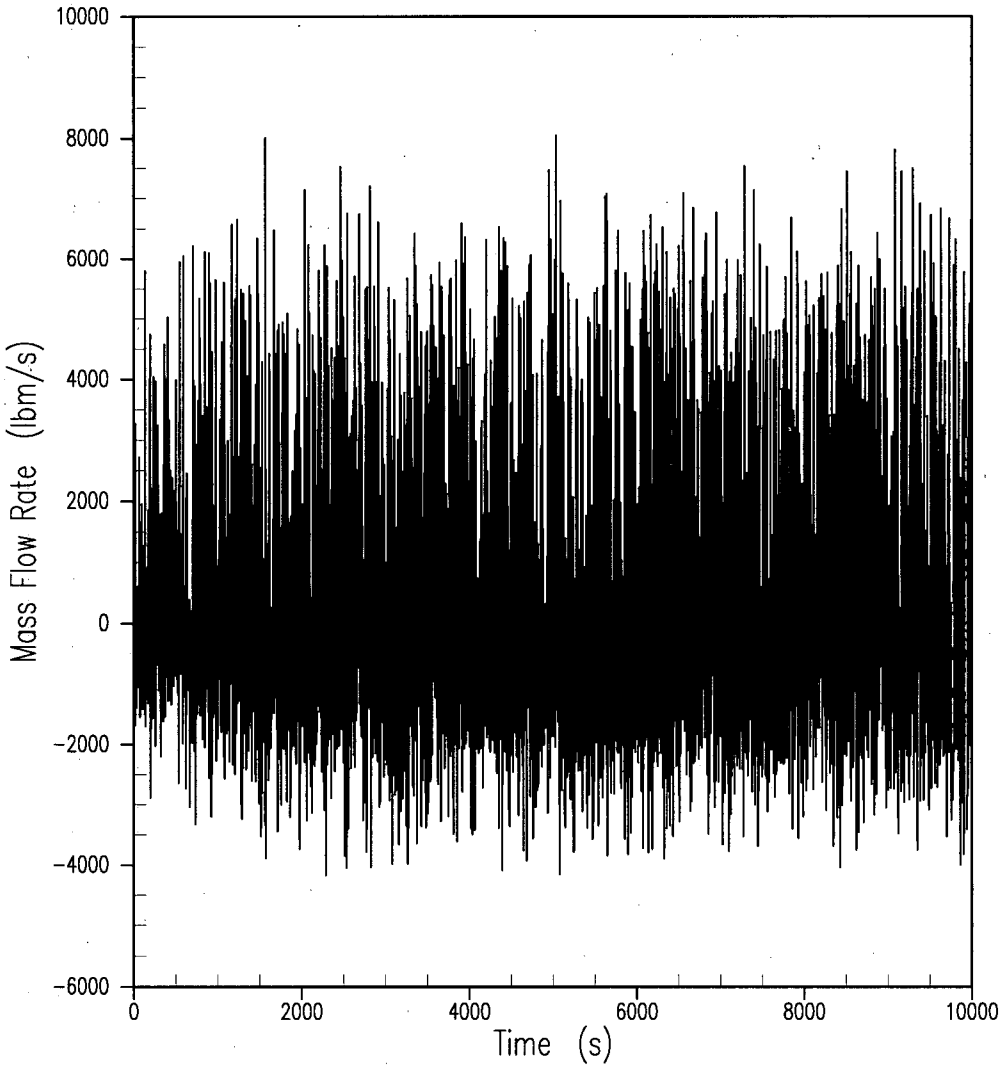

Figure 2-7
Liquid Flow Rate Out of Core
(DCD DEDVI Case)

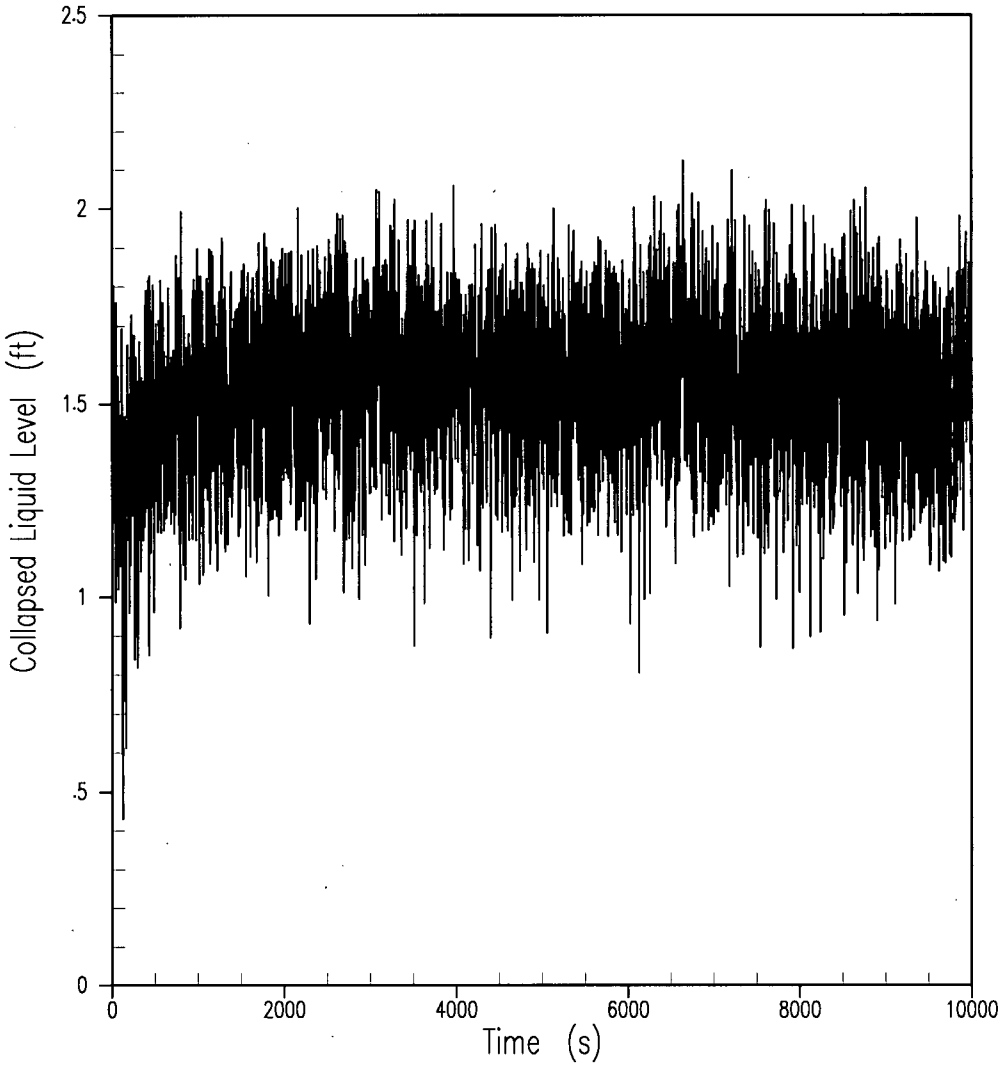

Figure 2-8
Collapsed Liquid Level in Upper Plenum
(DCD DEDVI Case)

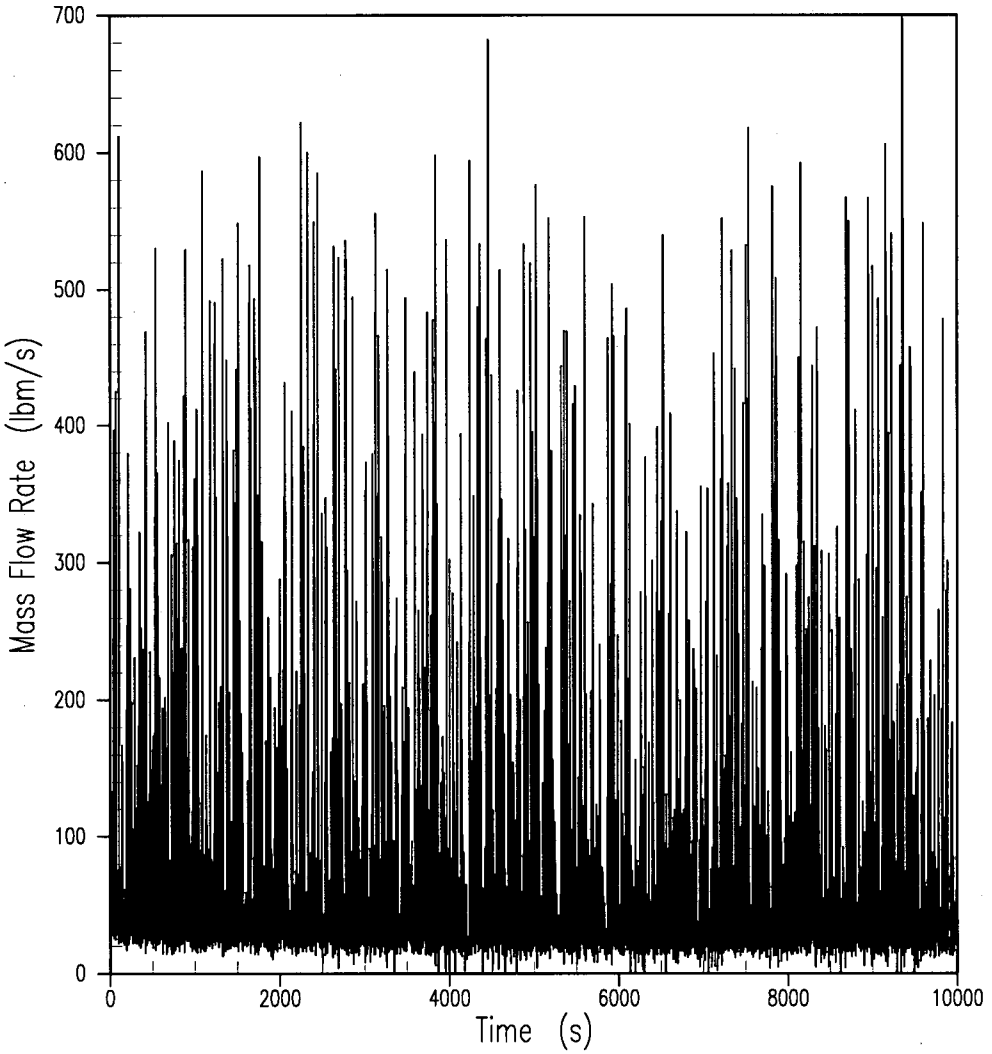

Figure 2-9
Mixture Flow Rate Through ADS Stage 4A Valves
(DCD DEDVI Case)

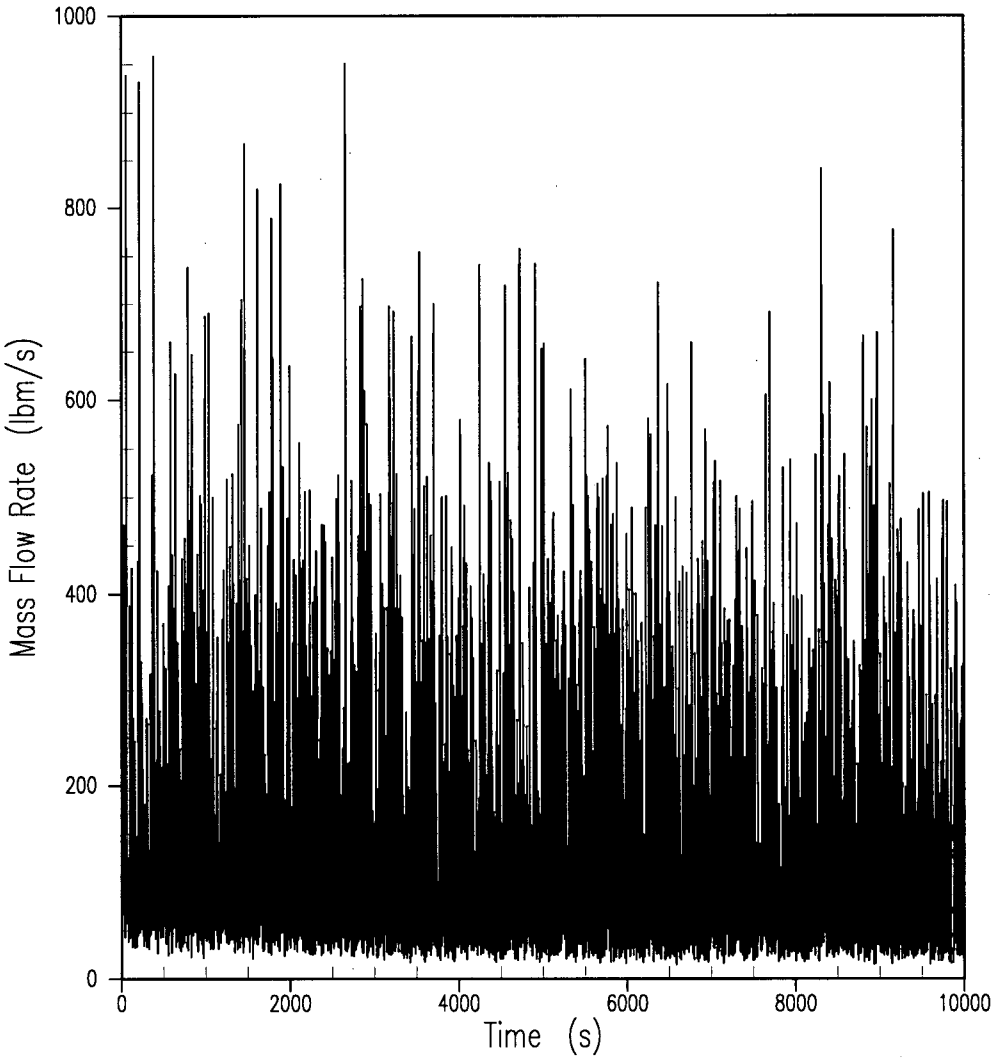

Figure 2-10
Mixture Flow Rate Through ADS Stage 4B Valves
(DCD DEDVI Case)

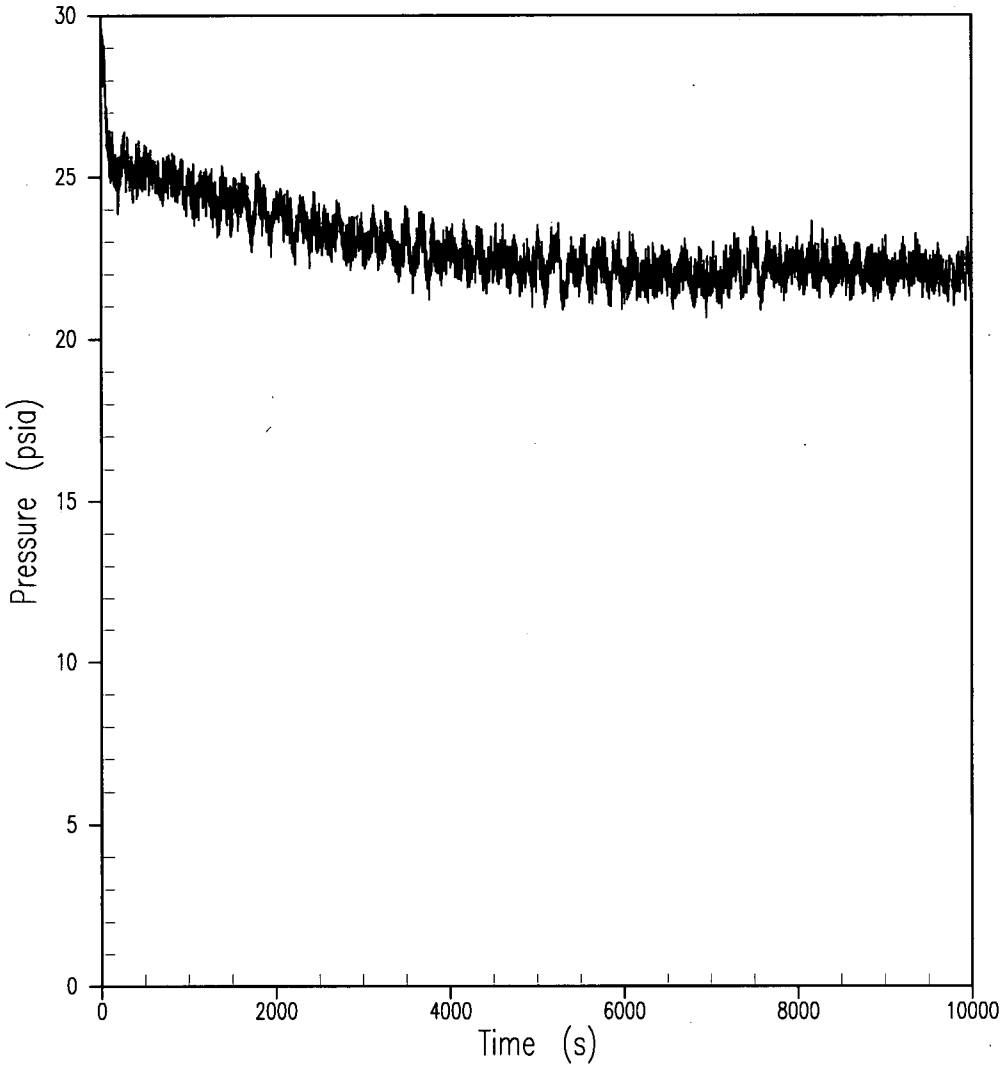

Figure 2-11
Upper Plenum Pressure
(DCD DEDVI Case)

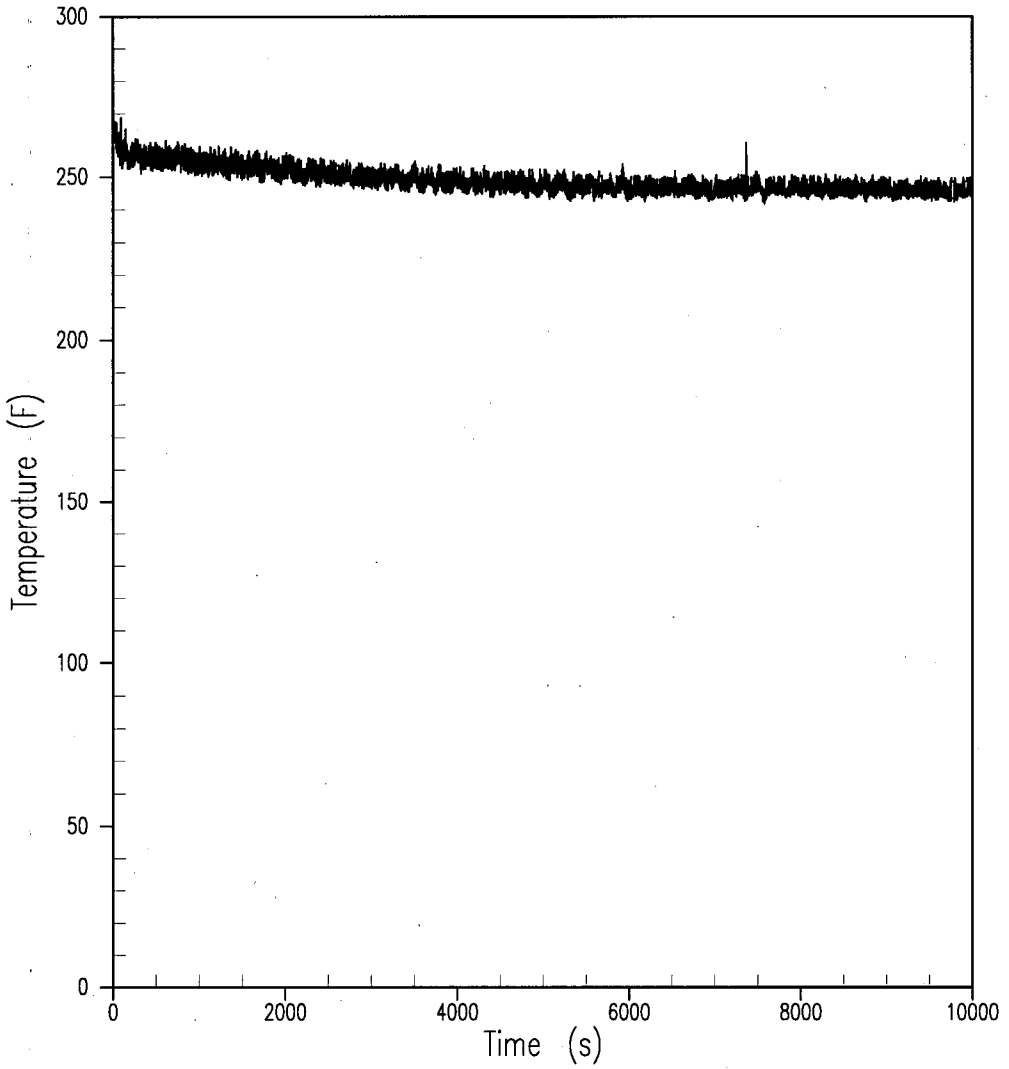

Figure 2-12
Peak Cladding Temperature
(DCD DEDVI Case)

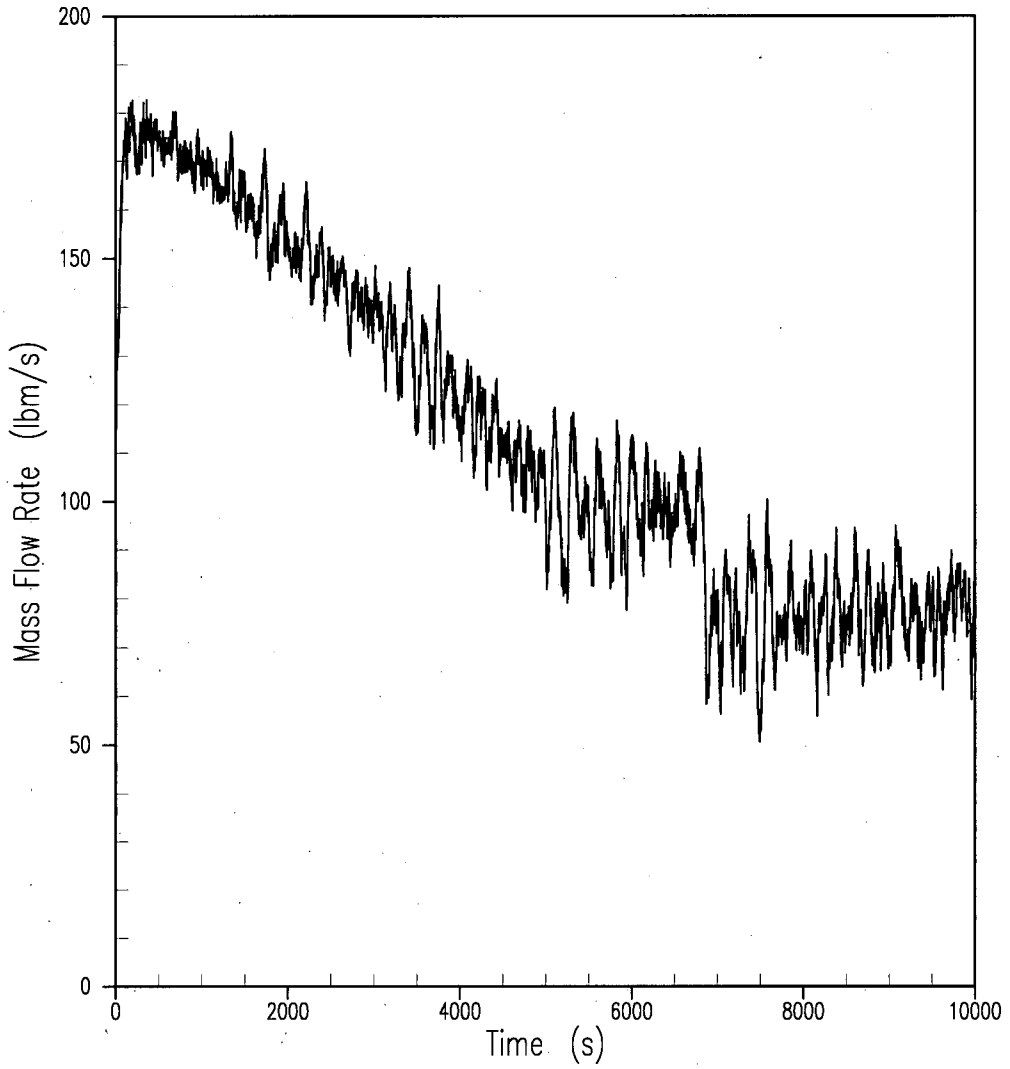

Figure 2-13
DVI–A Mixture Flow Rate
(DCD DEDVI Case)

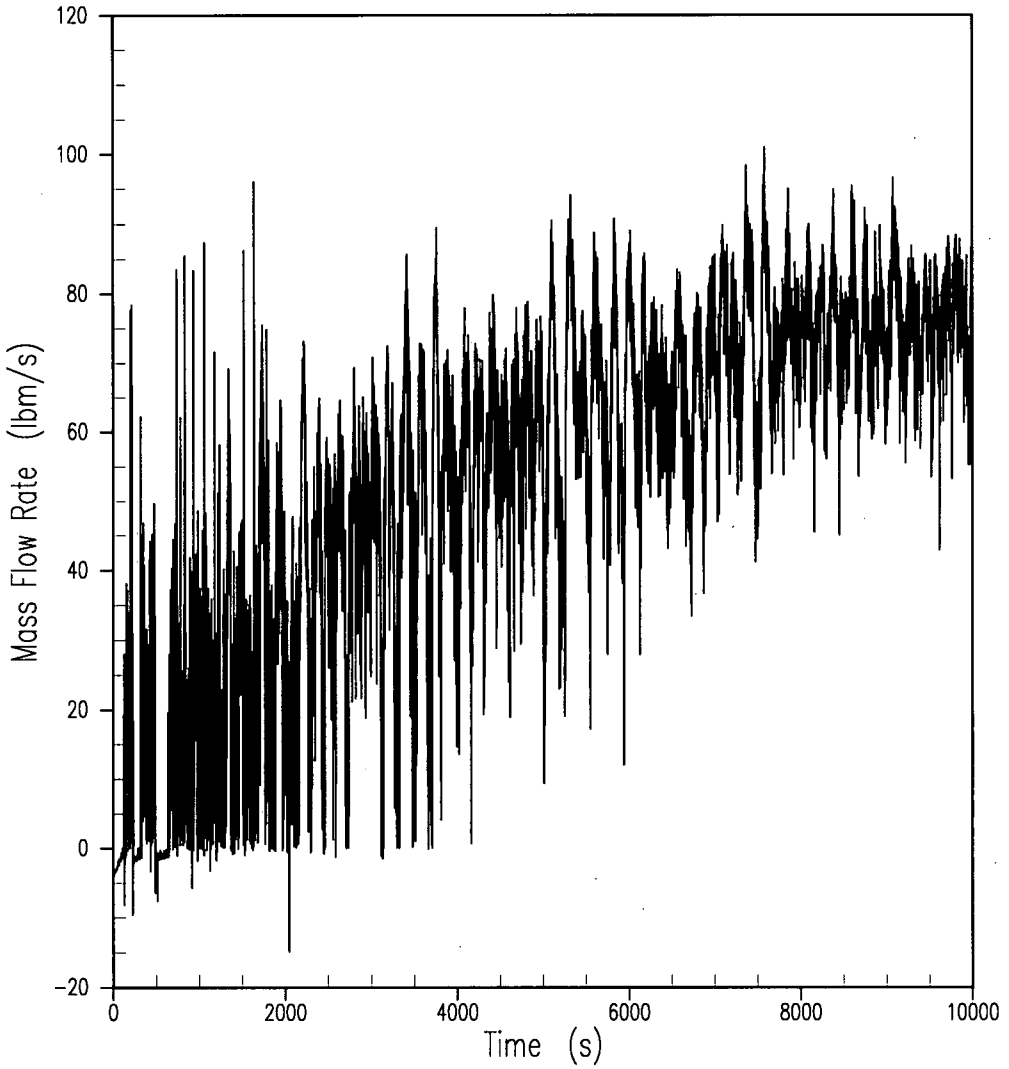

Figure 2-14
DVI–B Mixture Flow Rate
(DCD DEDVI Case)

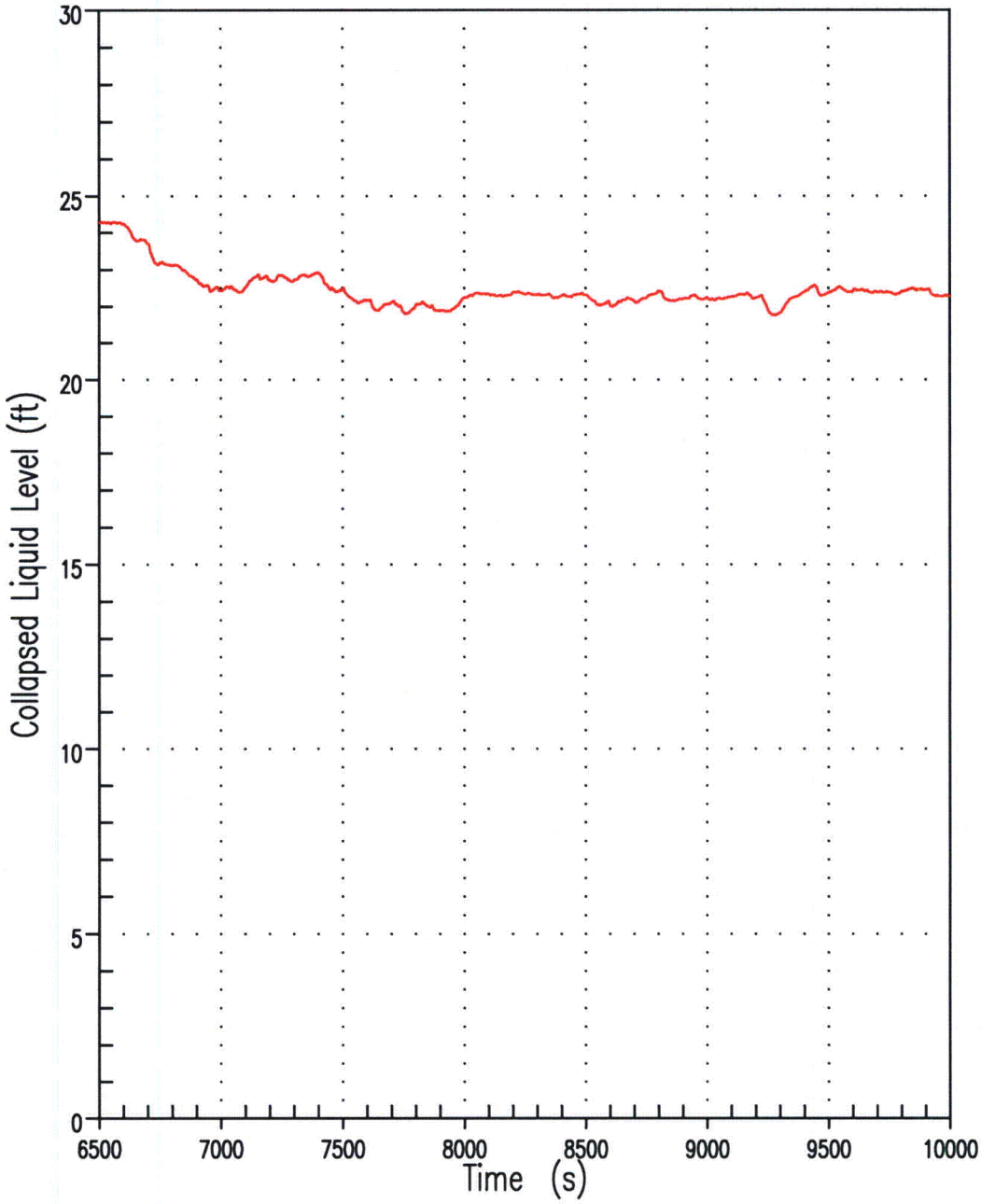

Figure 3.1-1
Collapsed Level of Liquid in Downcomer
(Sensitivity Case 1)

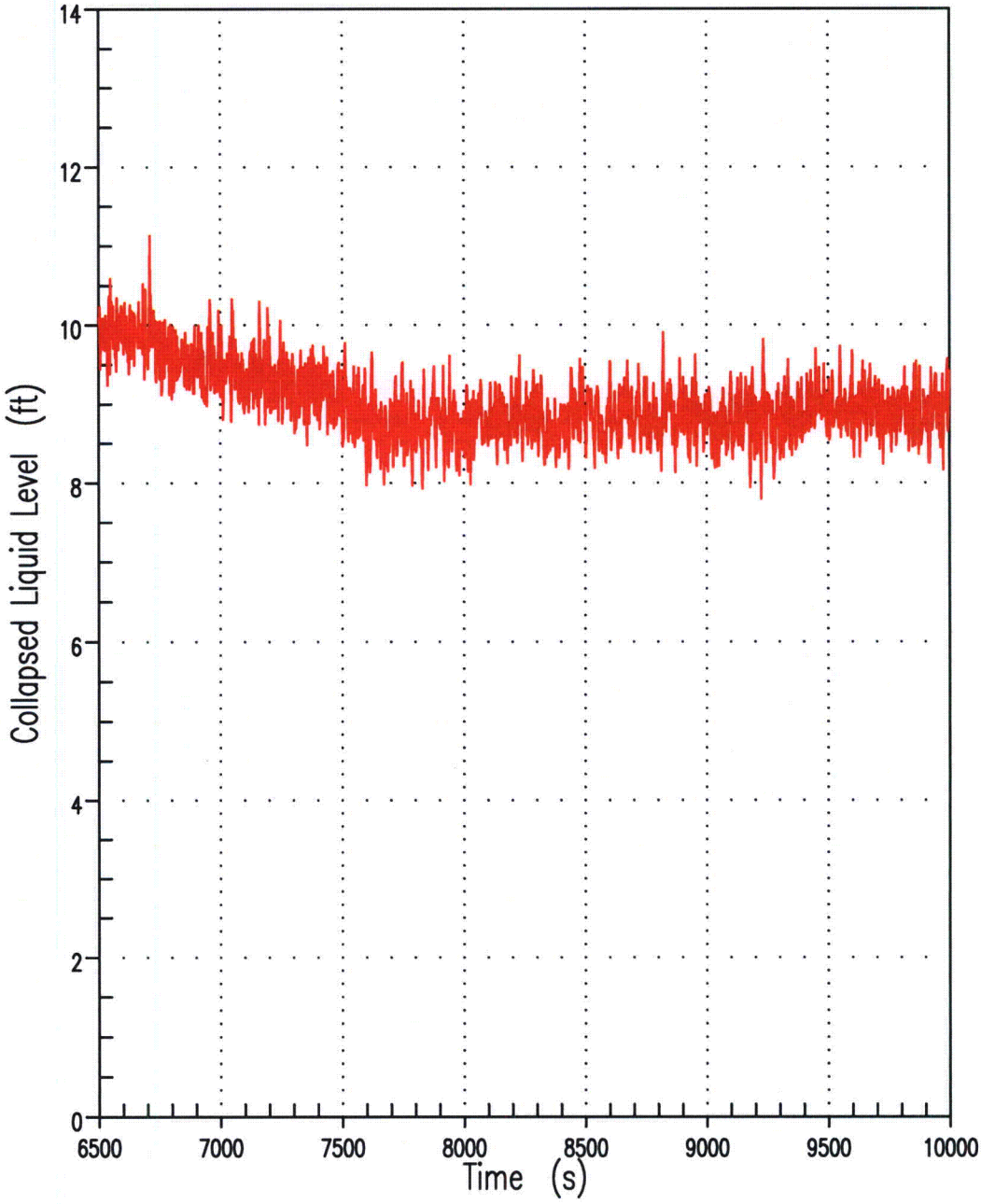

Figure 3.1-2
Collapsed Level of Liquid Over Heated Length of Fuel
(Sensitivity Case 1)

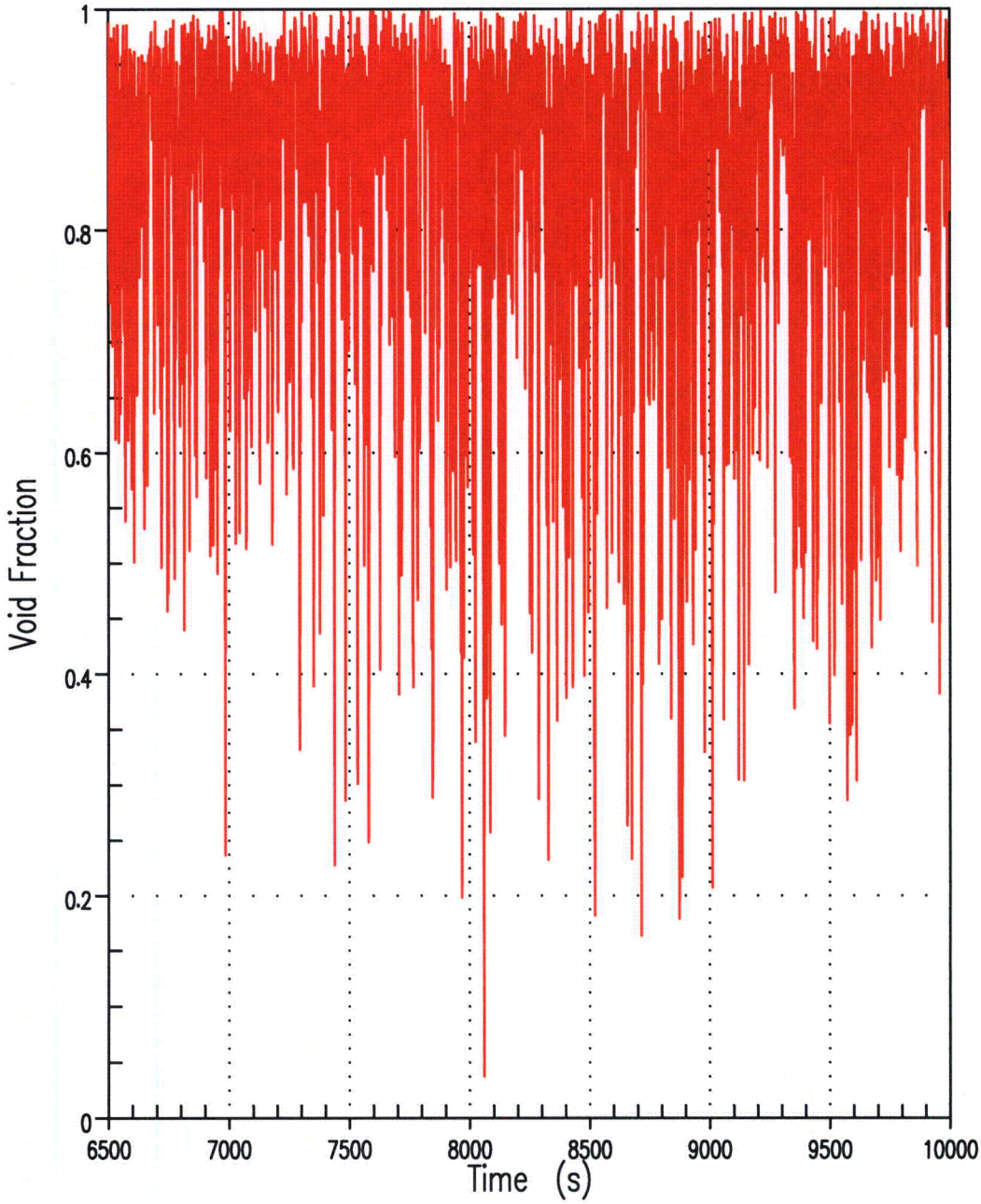

Figure 3.1-3
Void Fraction in Core Hot Assembly Top Cell
(Sensitivity Case 1)

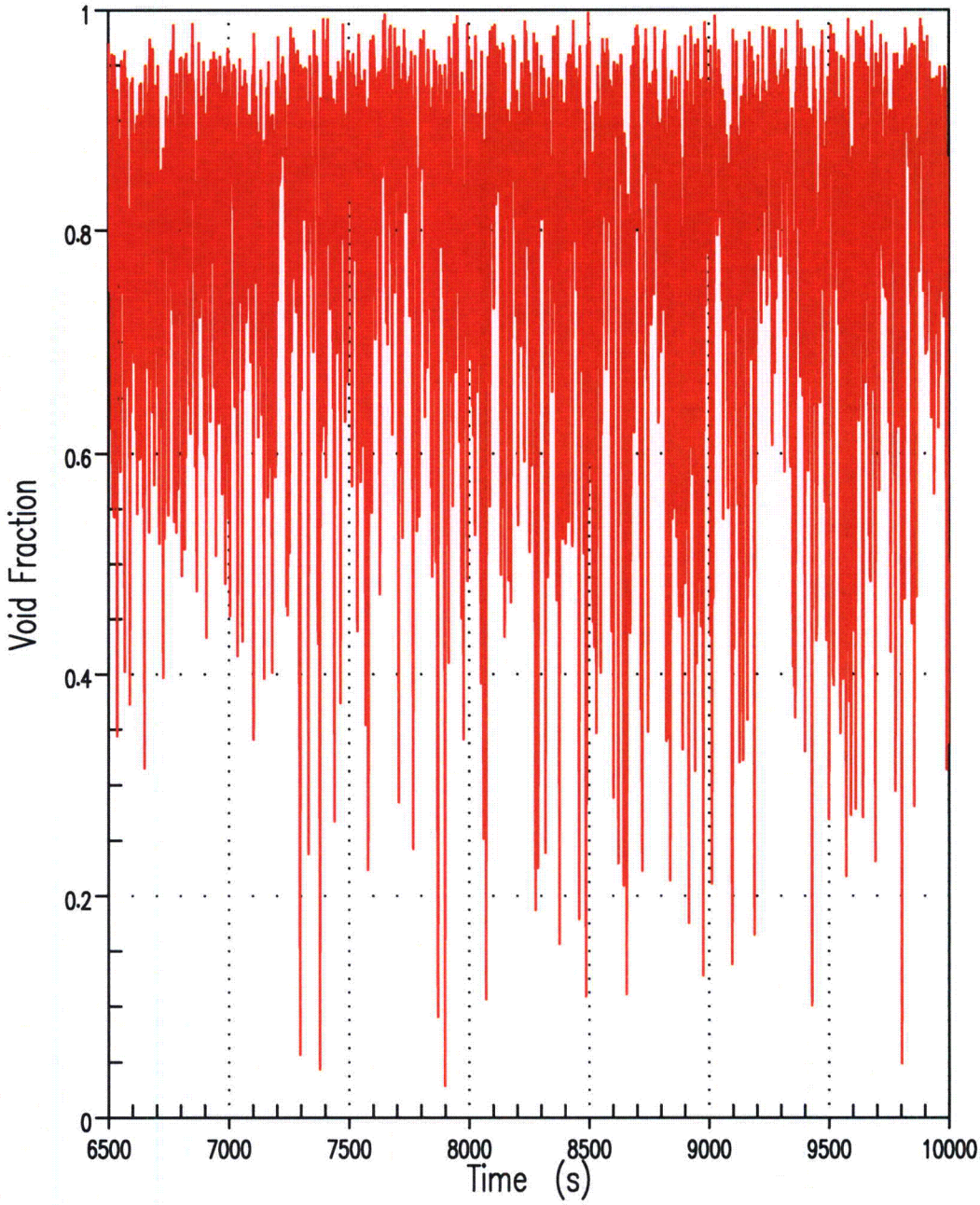

Figure 3.1-4
Void Fraction in Core Hot Assembly Second from Top Cell
(Sensitivity Case 1)

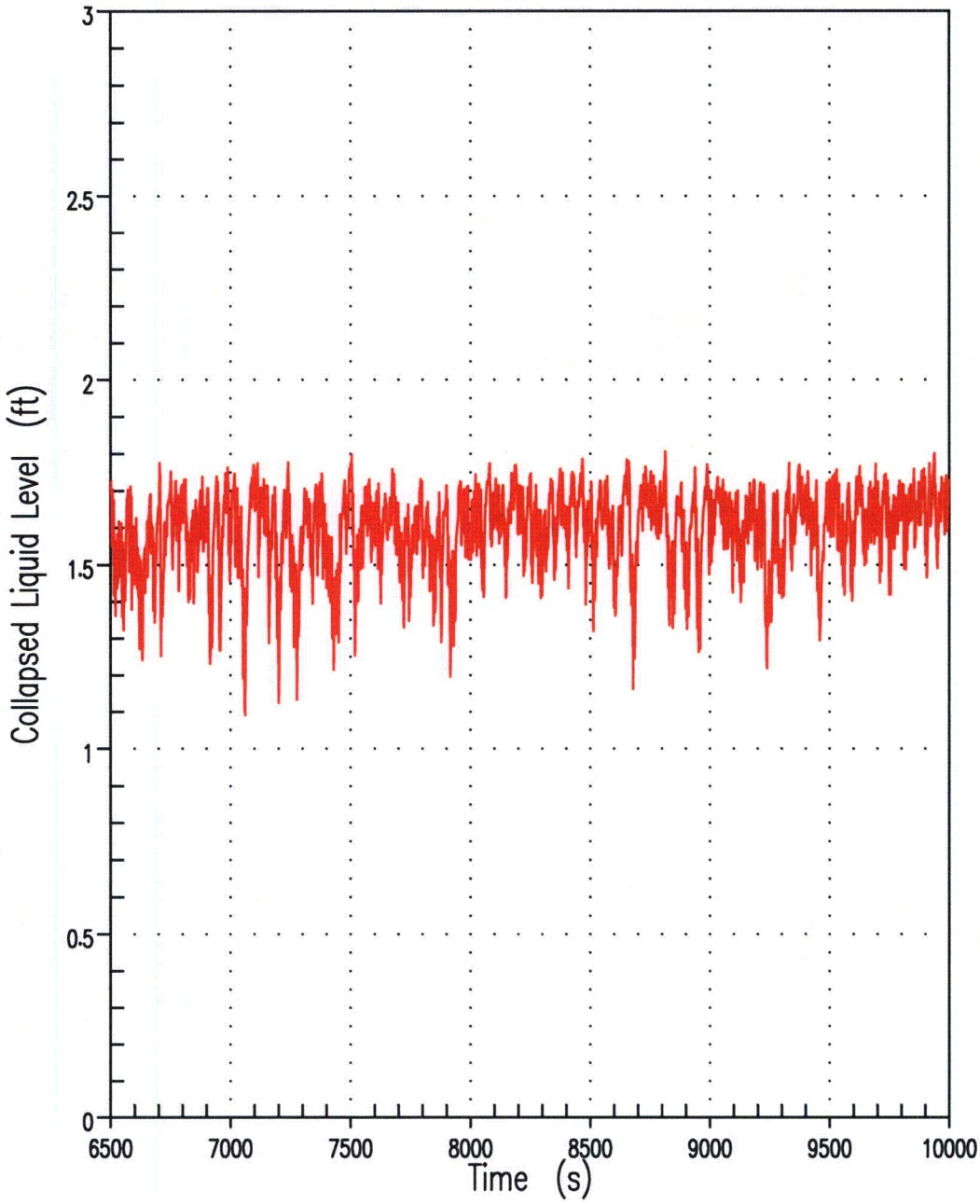

Figure 3.1-5
Collapsed Liquid Level in Hot Leg of Pressurizer Loop (Sensitivity Case 1)

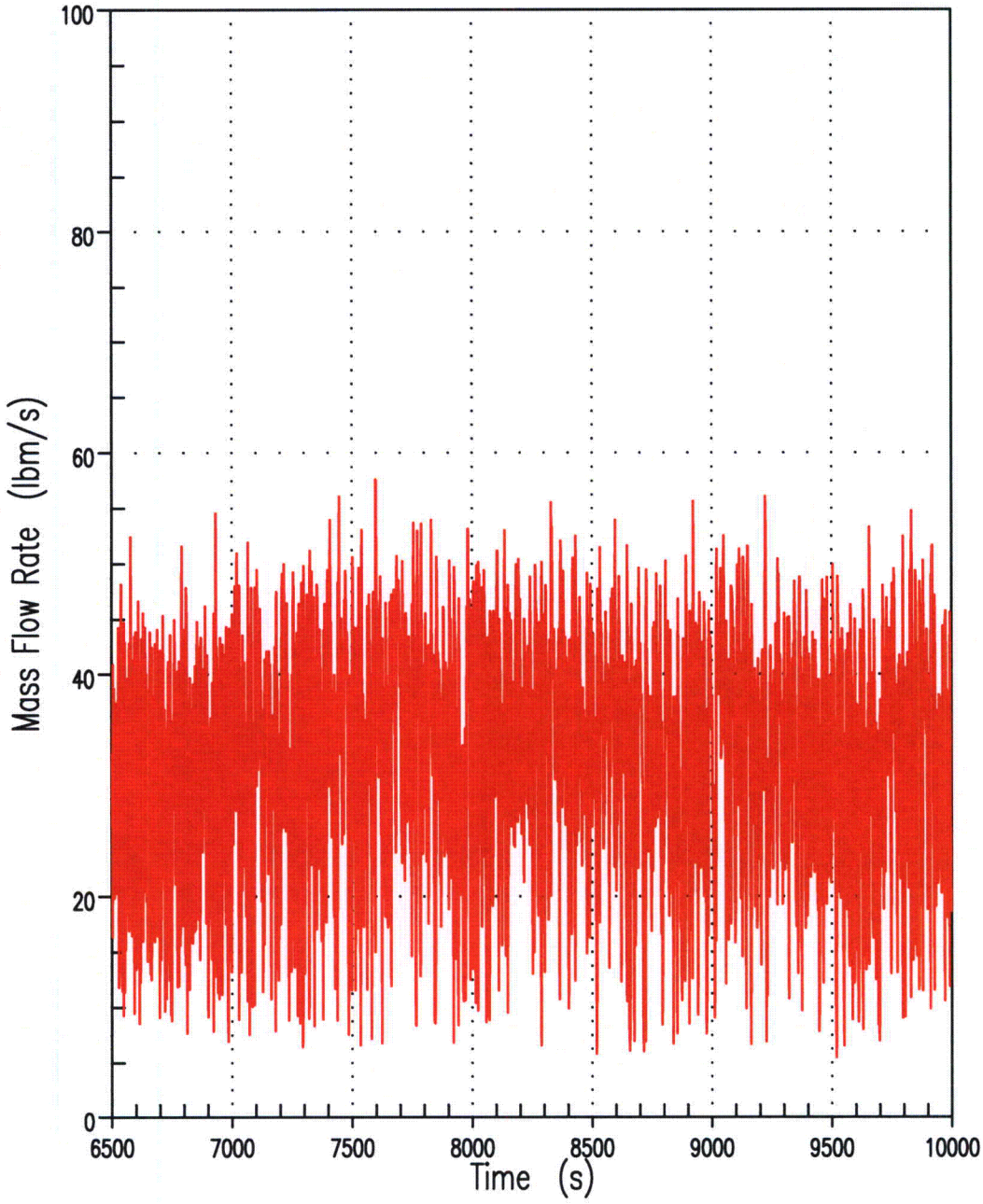

Figure 3.1-6
Vapor Rate Out of Core
(Sensitivity Case 1)

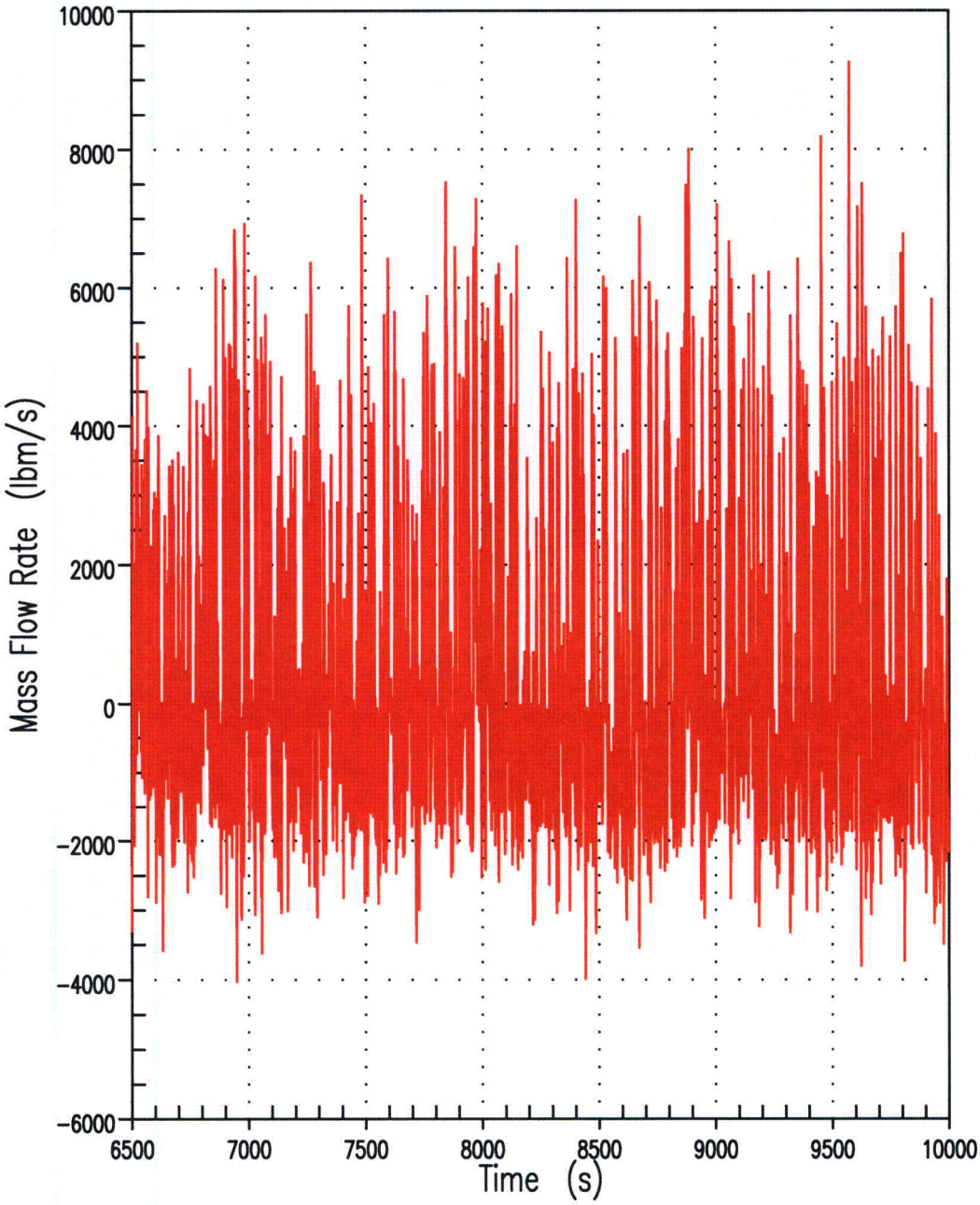

Figure 3.1-7
Liquid Flow Rate Out of Core
(Sensitivity Case 1)

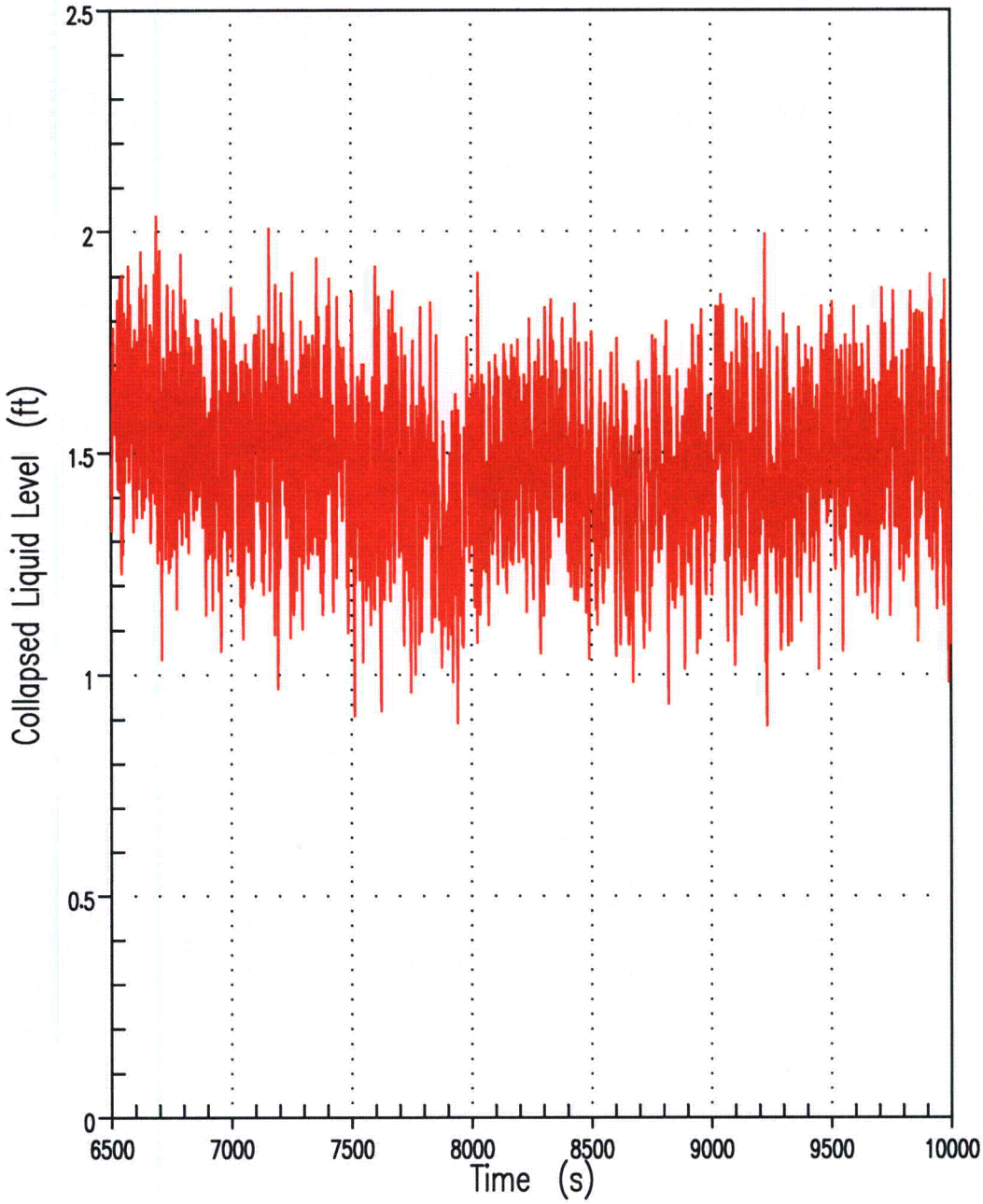

Figure 3.1-8
Collapsed Liquid Level in Upper Plenum
(Sensitivity Case 1)

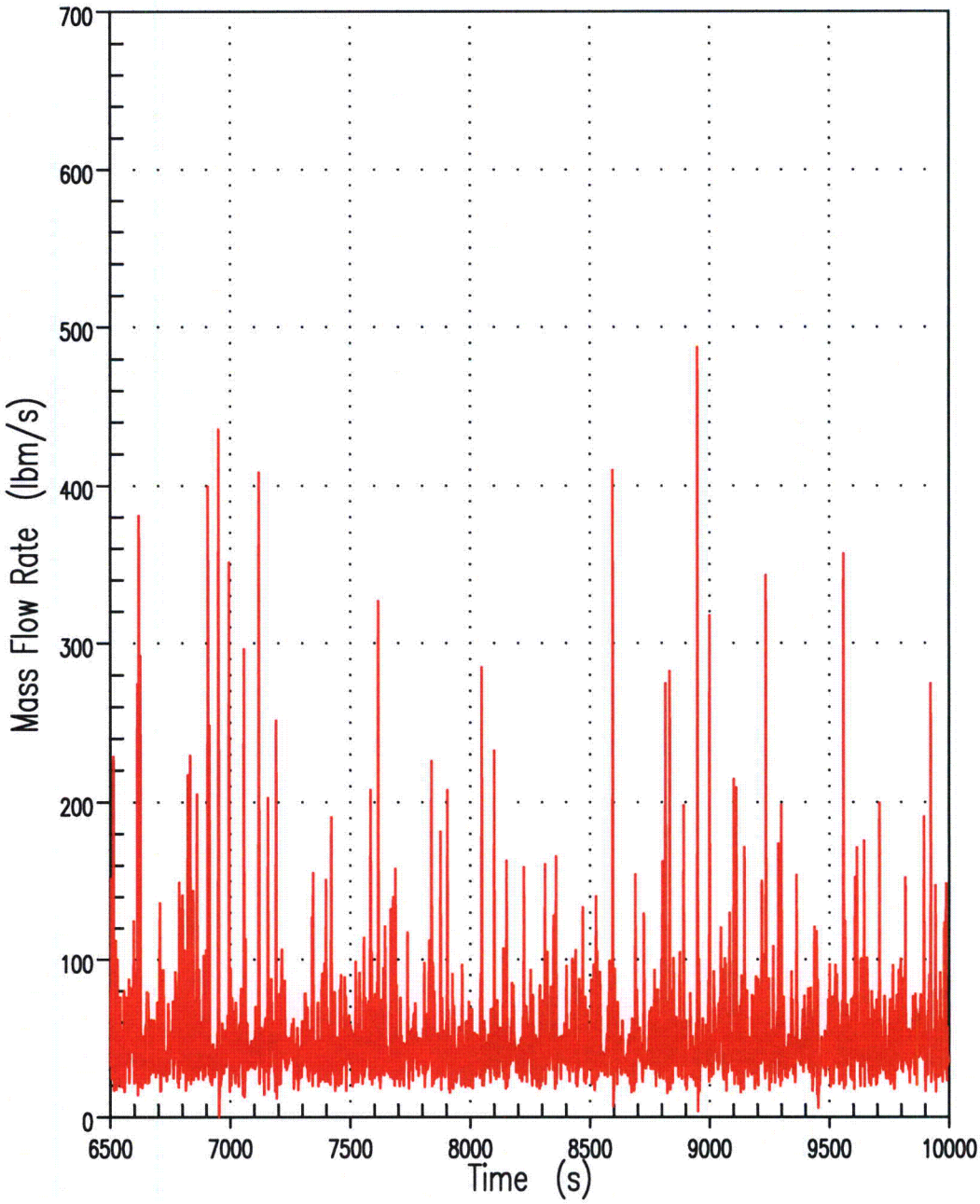

Figure 3.1-9
Mixture Flow Rate Through ADS Stage 4A Valves
(Sensitivity Case 1)

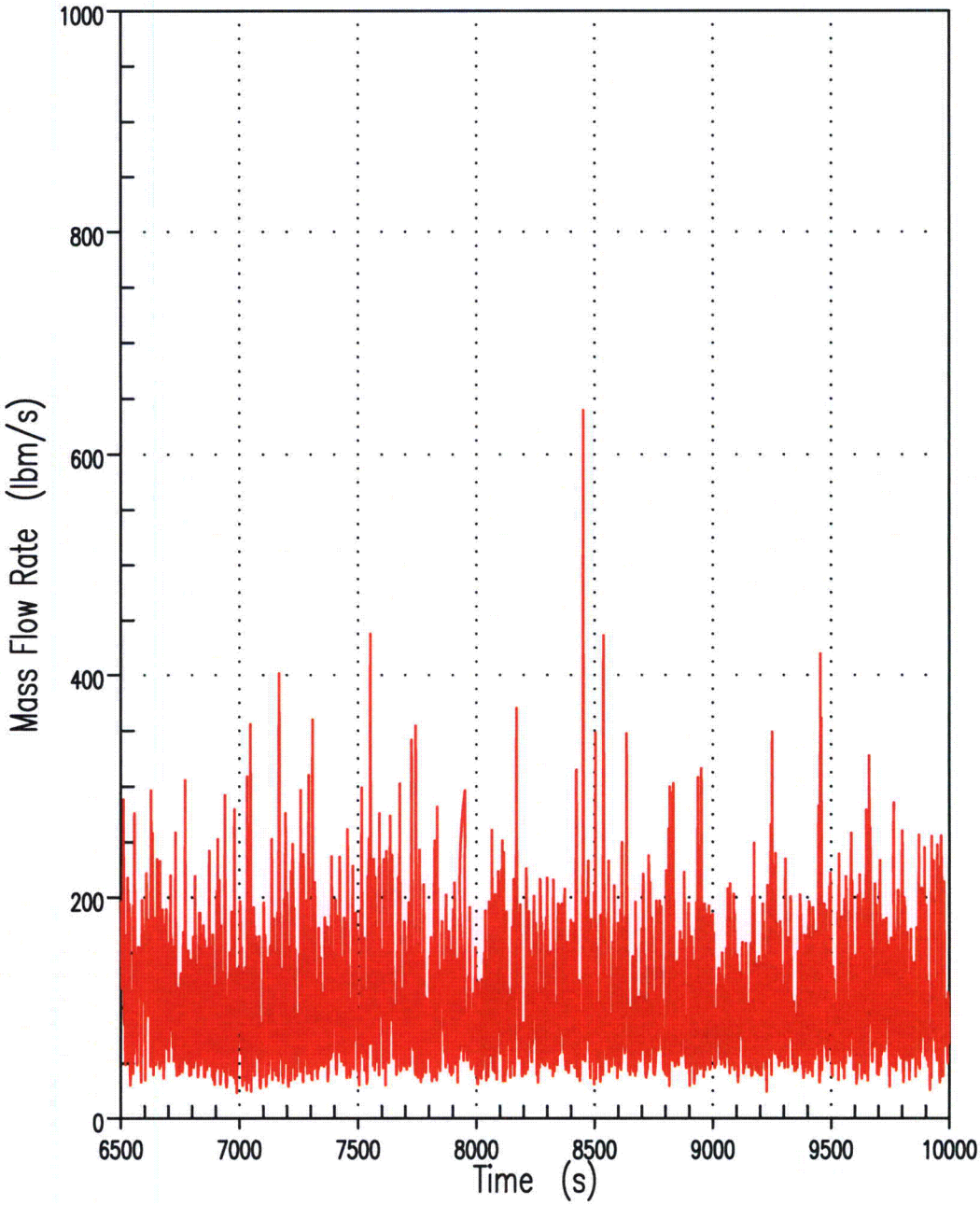

Figure 3.1-10
Mixture Flow Rate Through ADS Stage 4B Valves
(Sensitivity Case 1)

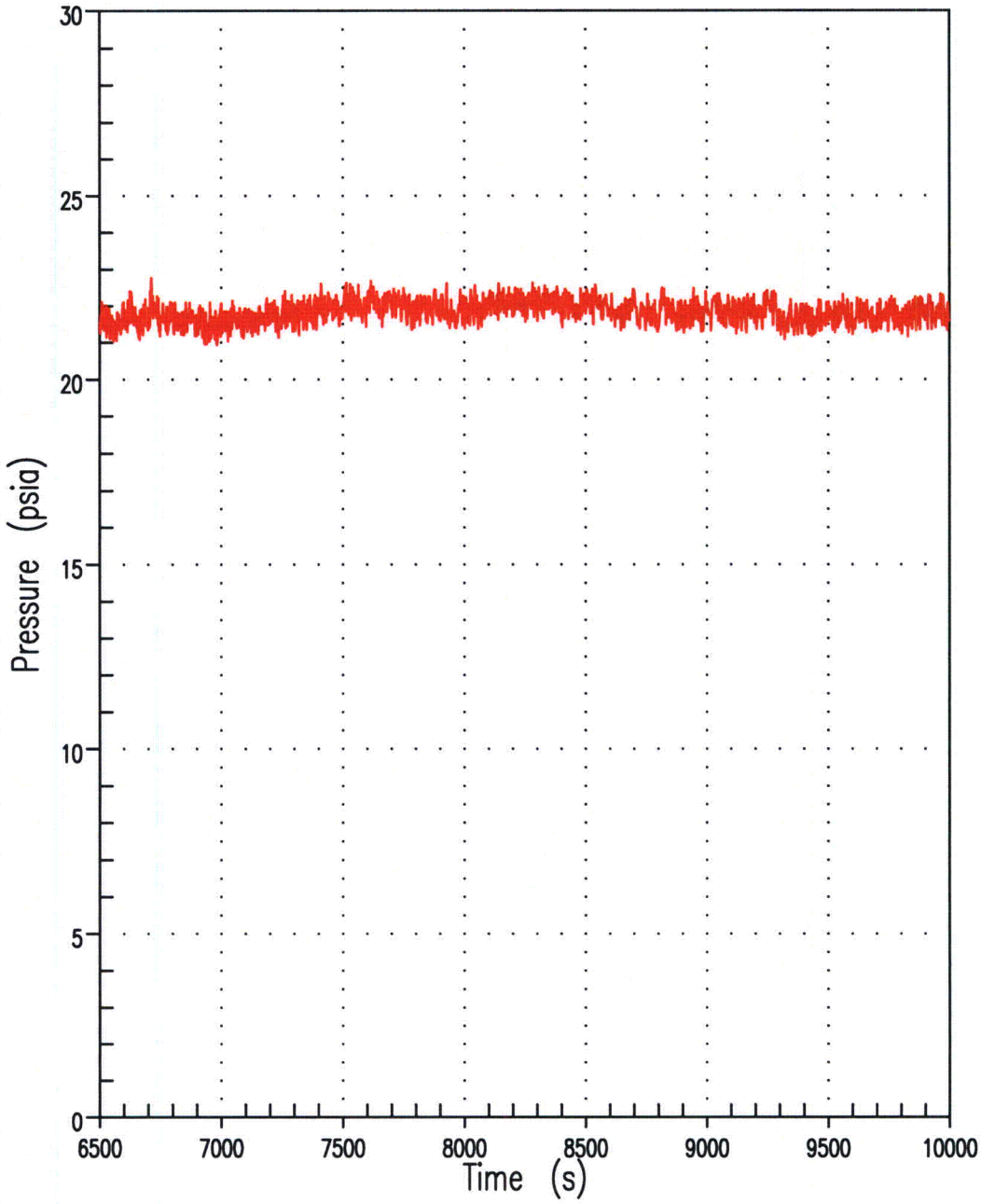

Figure 3.1-11
Upper Plenum Pressure
(Sensitivity Case 1)

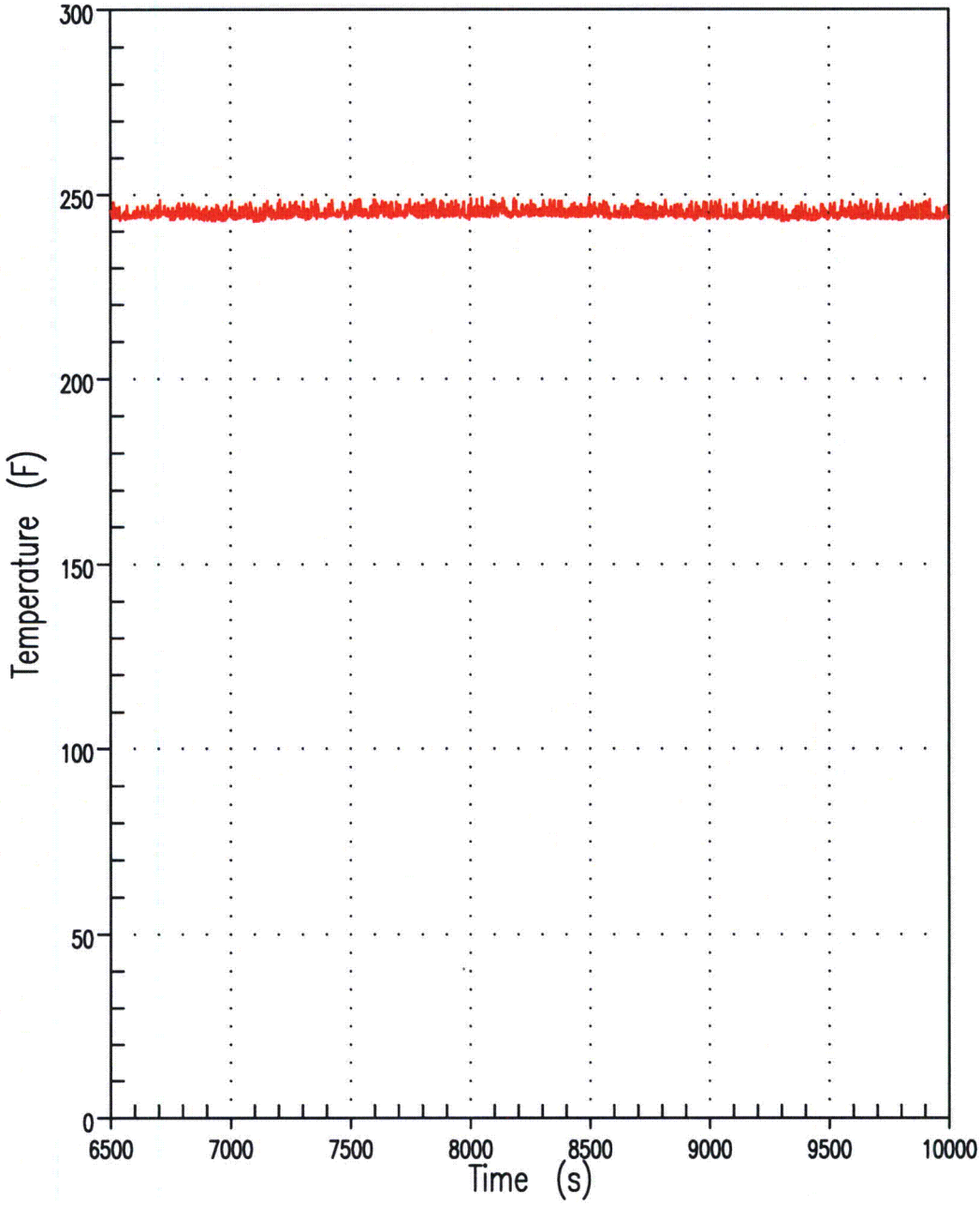

Figure 3.1-12
Peak Cladding Temperature
(Sensitivity Case 1)

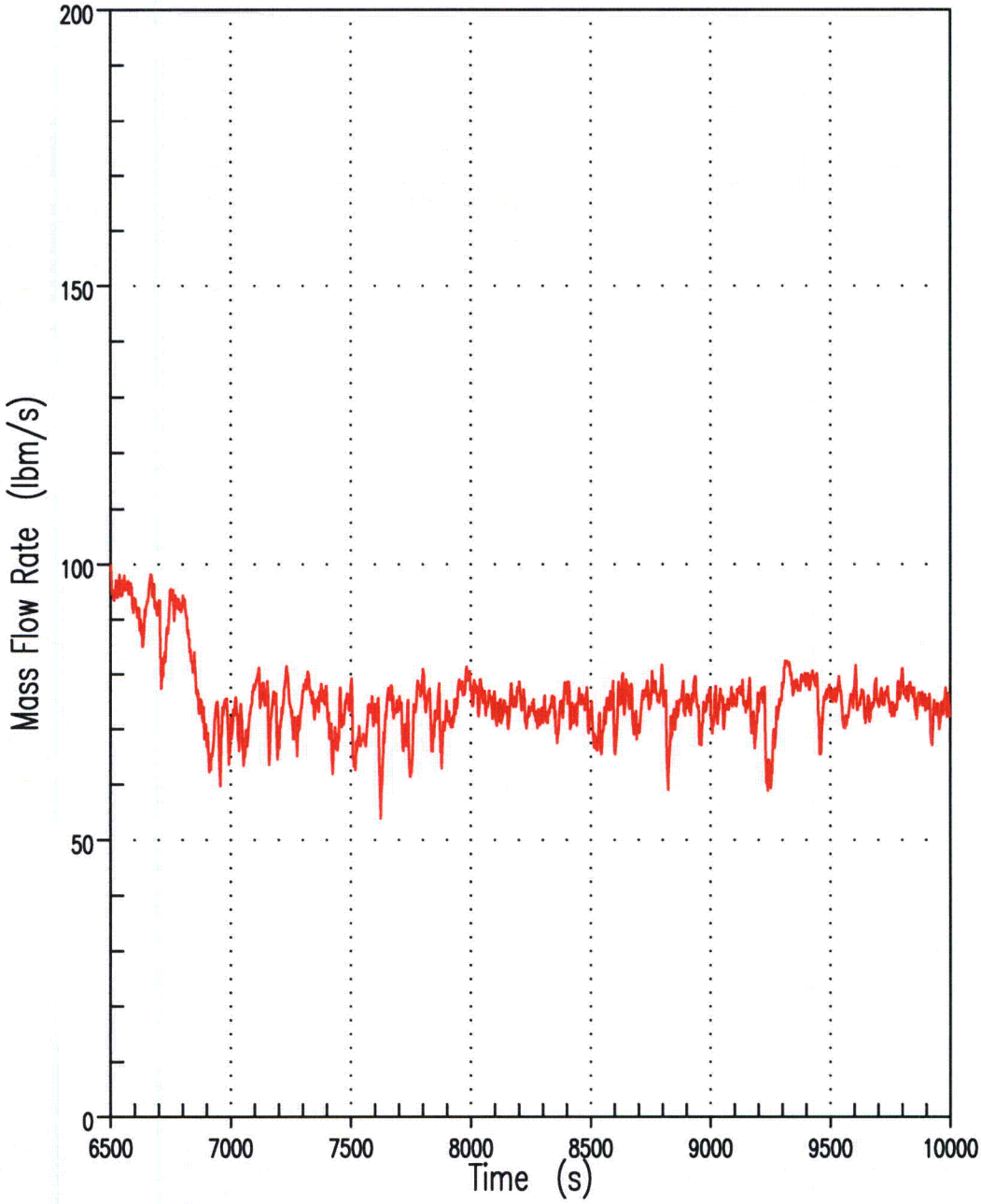

Figure 3.1-13
DVI–A Mixture Flow Rate
(Sensitivity Case 1)

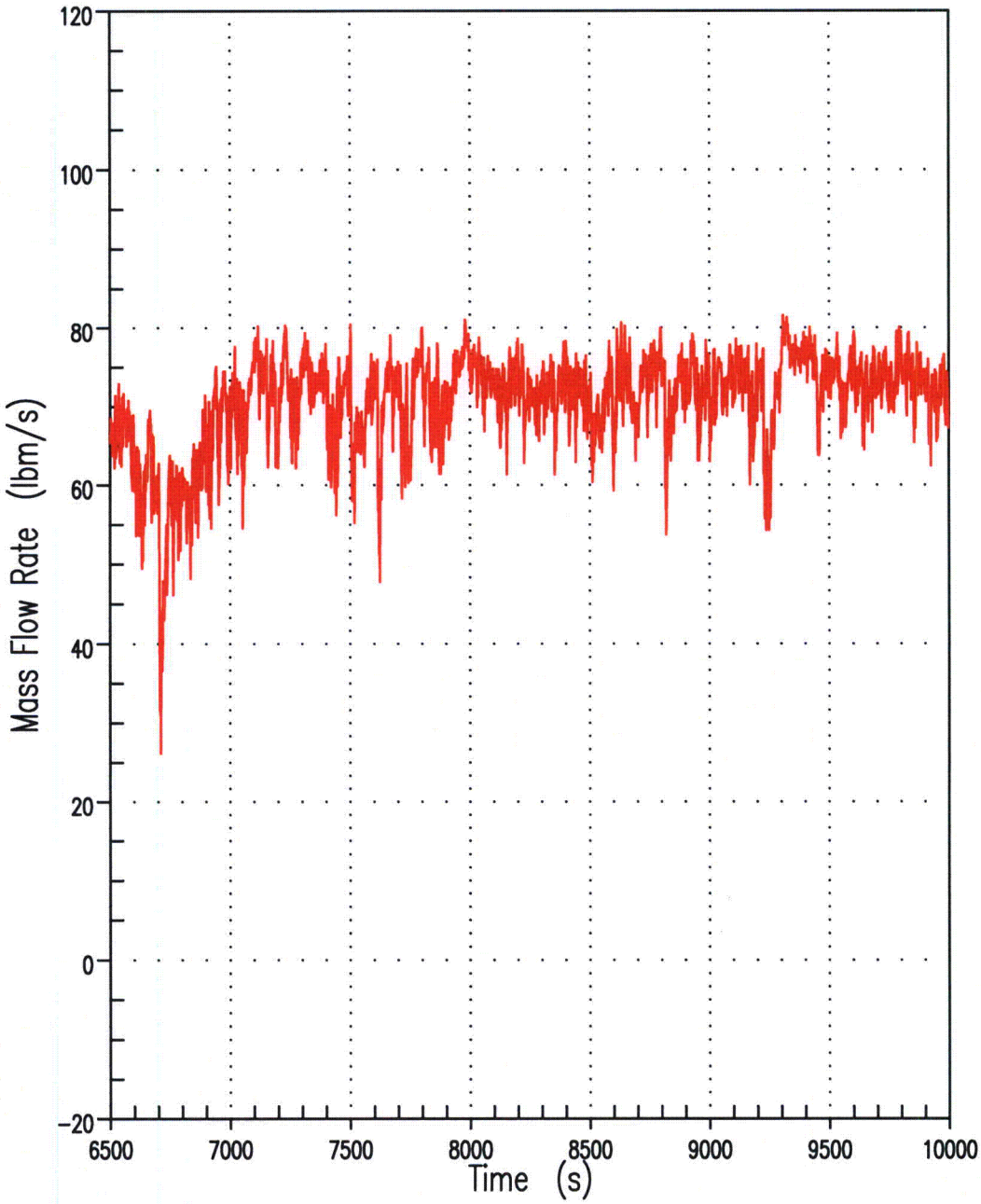

Figure 3.1-14
DVI–B Mixture Flow Rate
(Sensitivity Case 1)

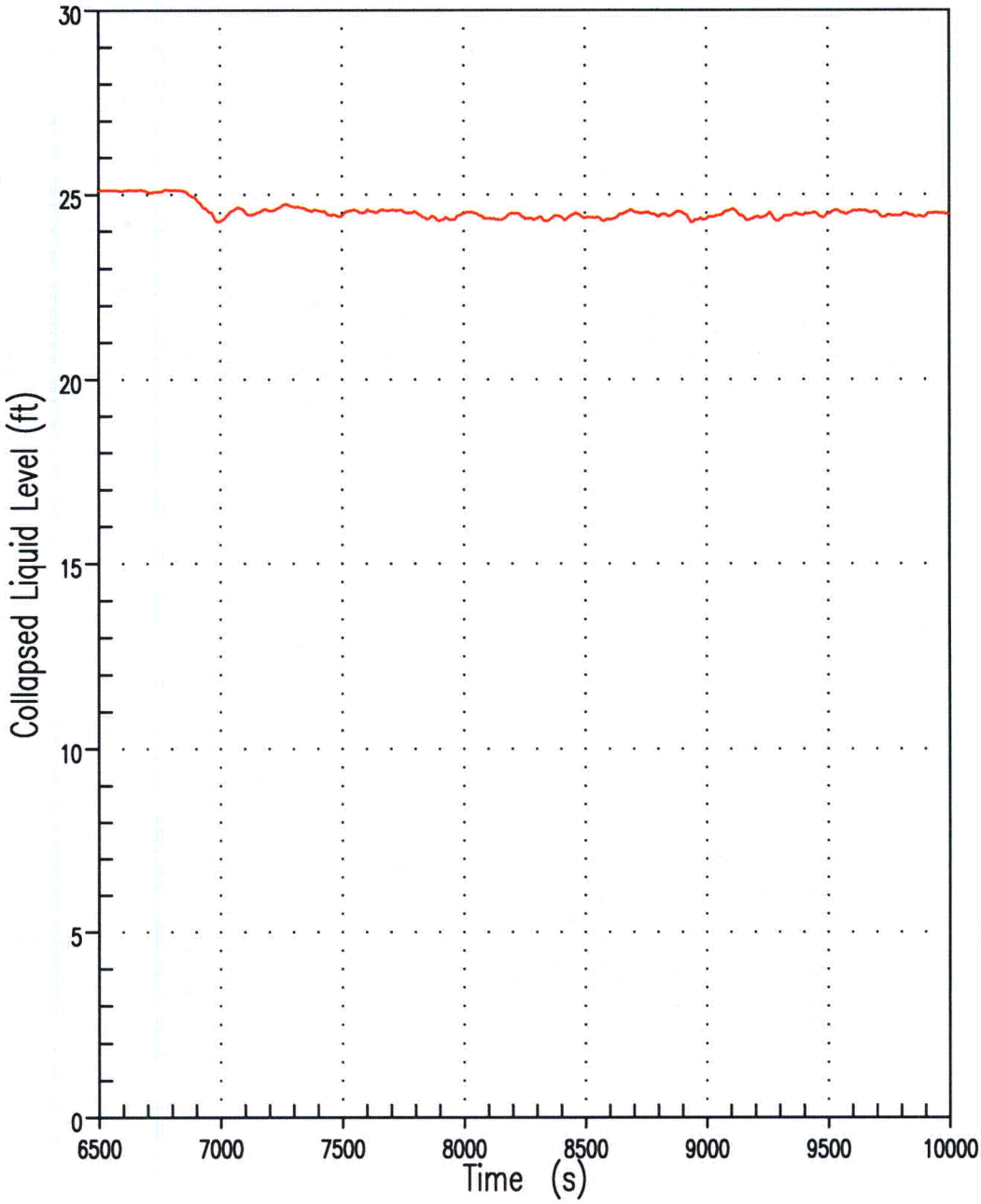

Figure 3.2-1
Collapsed Level of Liquid in Downcomer
(Sensitivity Case 2)

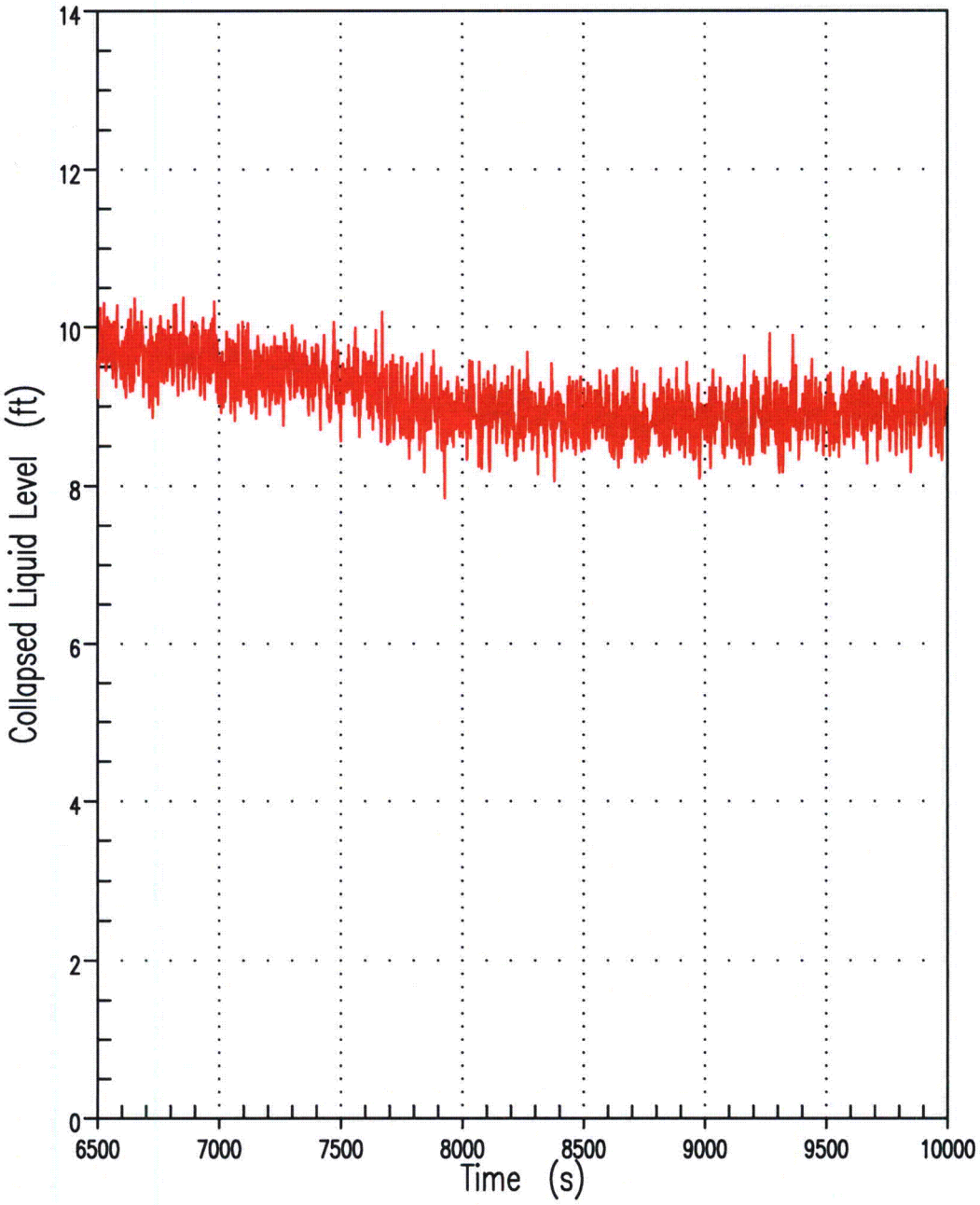

Figure 3.2-2
Collapsed Level of Liquid Over Heated Length of Fuel
(Sensitivity Case 2)

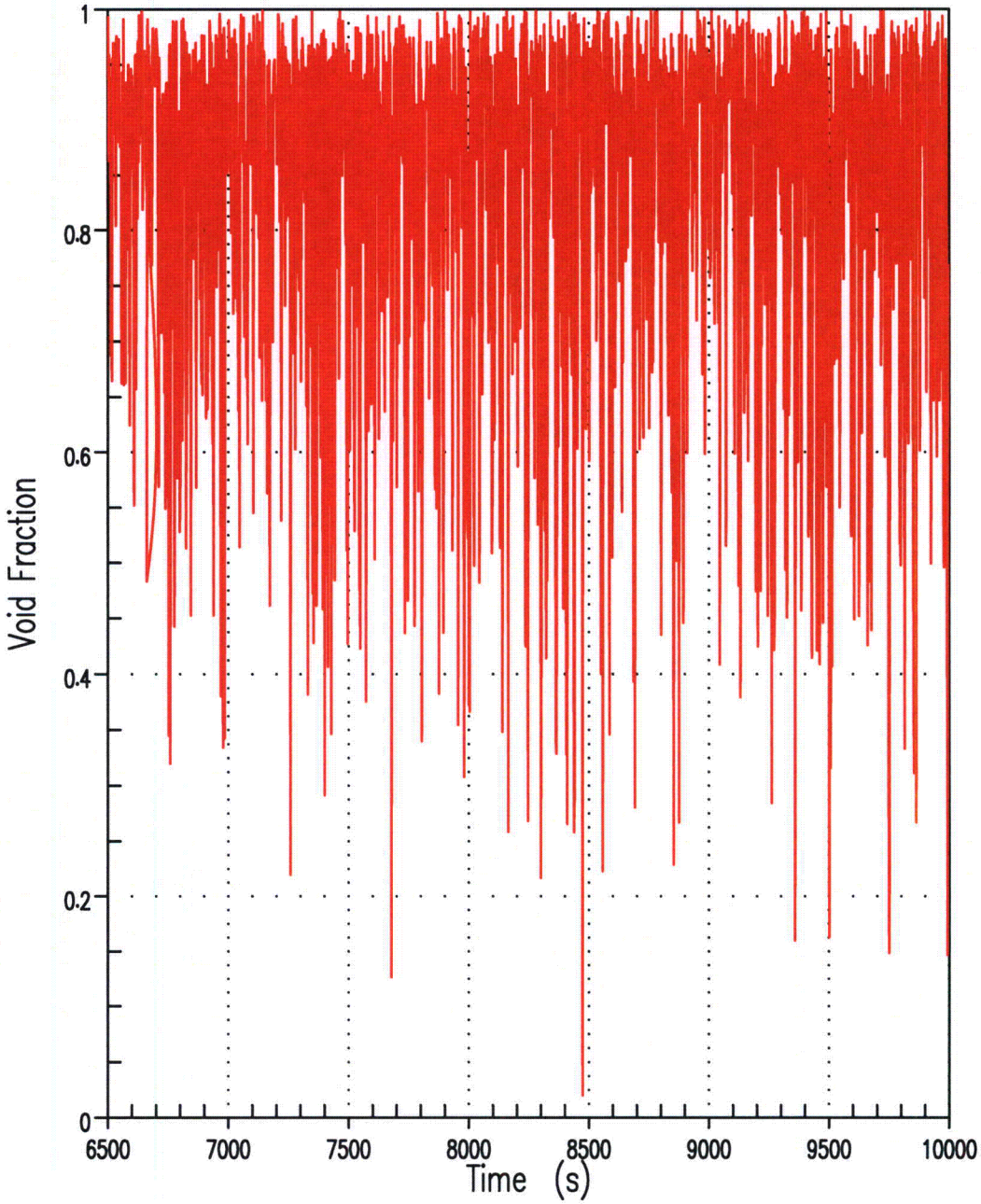

Figure 3.2-3
Void Fraction in Core Hot Assembly Top Cell
(Sensitivity Case 2)

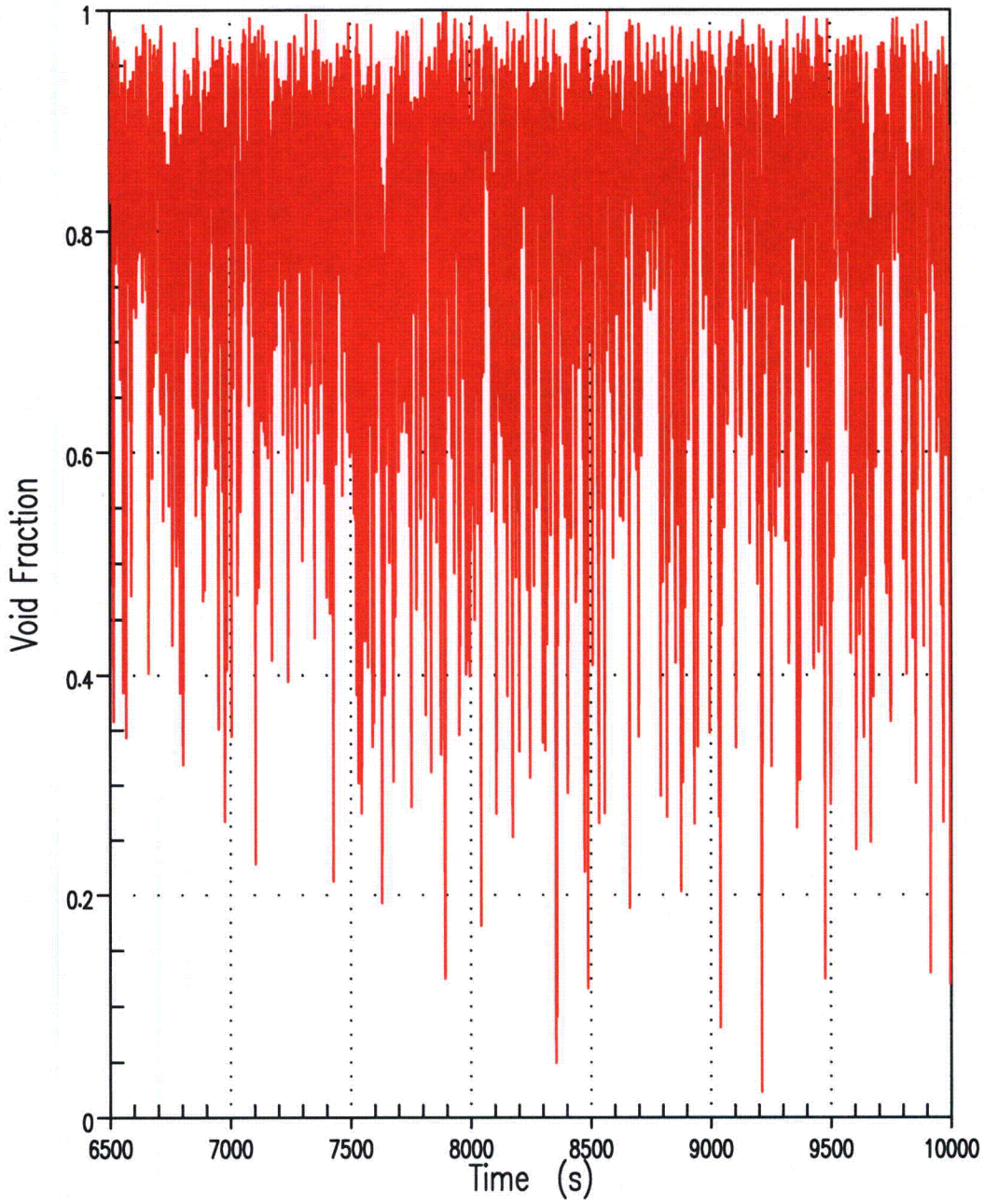

Figure 3.2-4
Void Fraction in Core Hot Assembly Second from Top Cell
(Sensitivity Case 2)

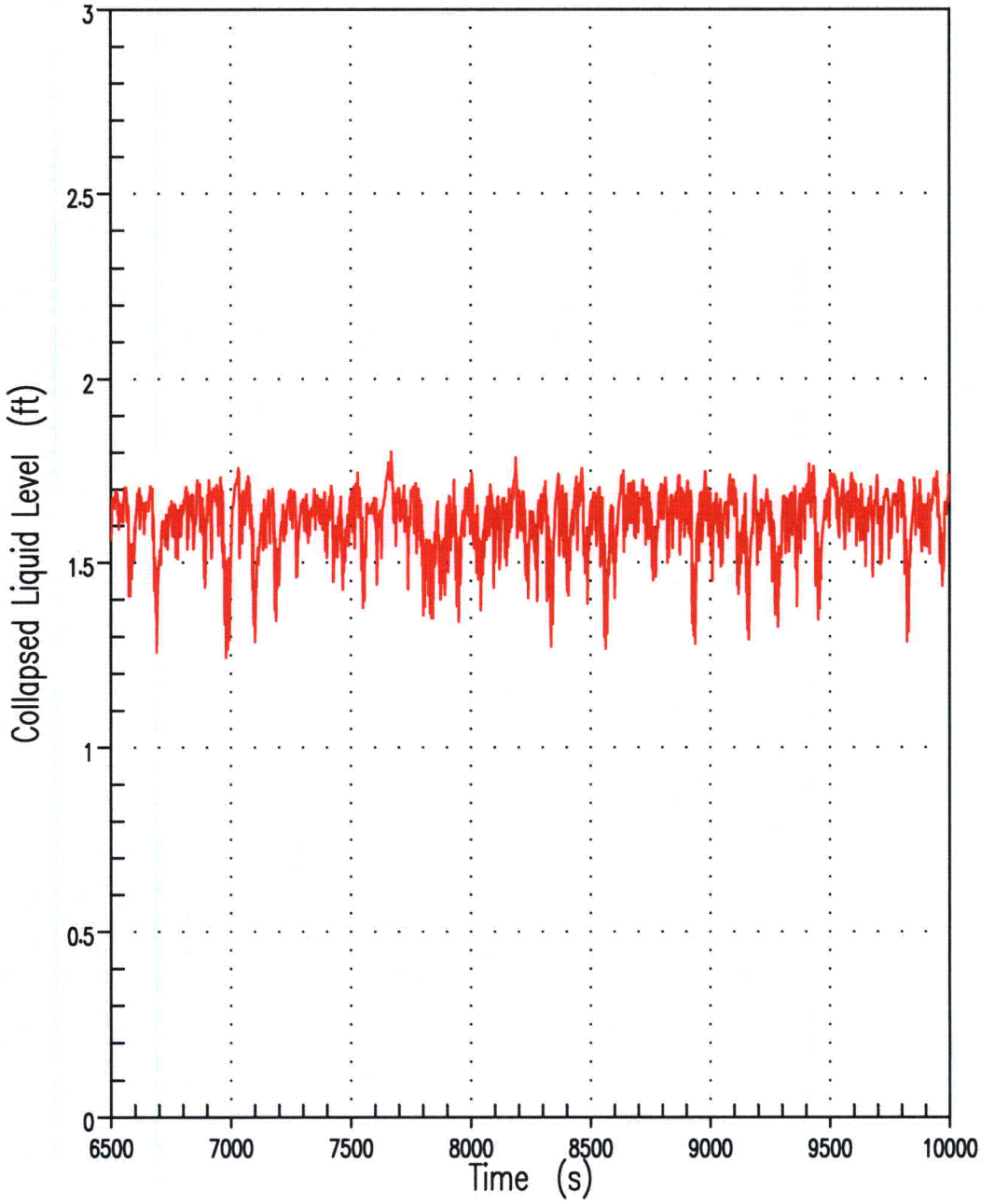

Figure 3.2-5
Collapsed Liquid Level in Hot Leg
of Pressurizer Loop (Sensitivity Case 2)

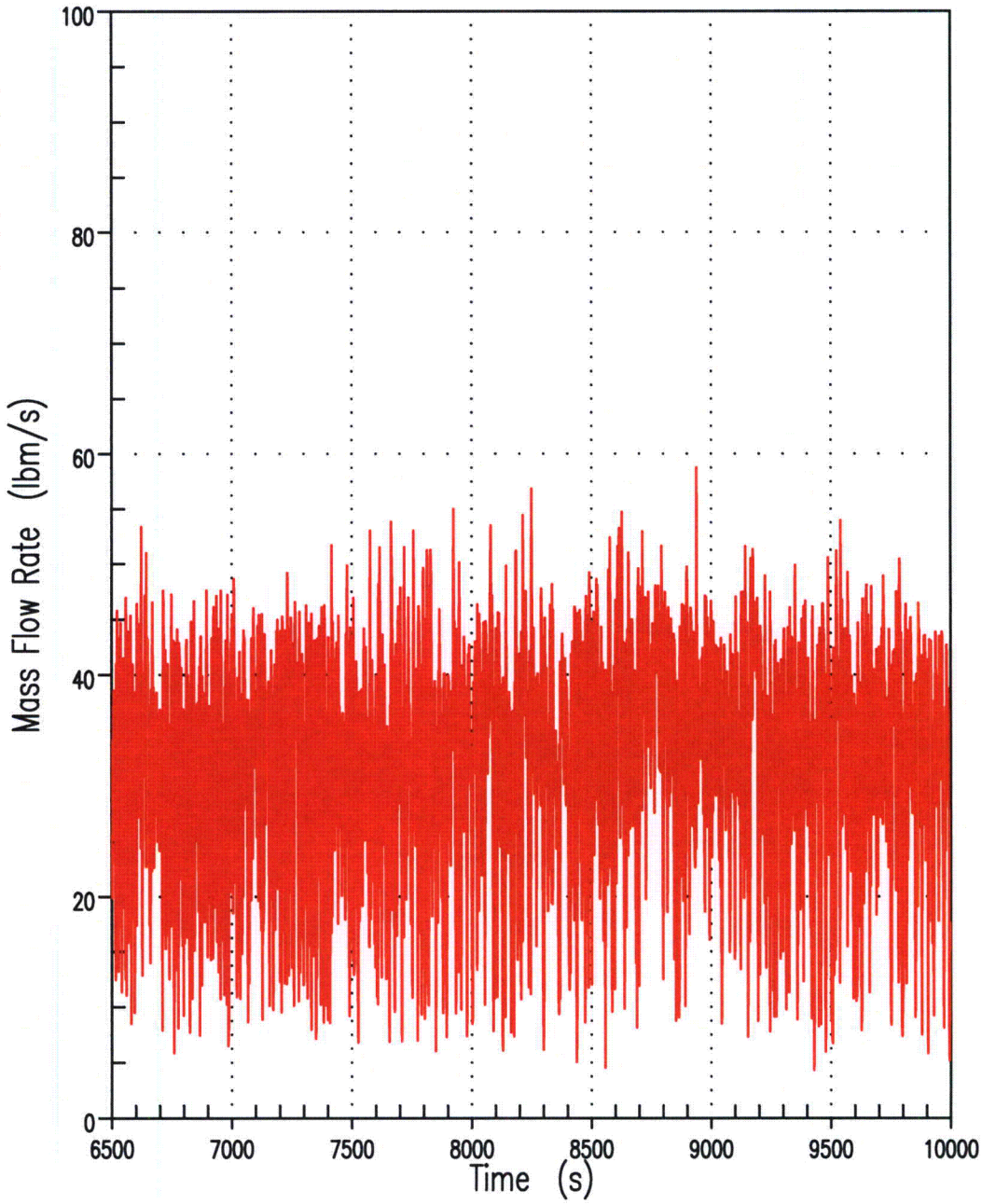

Figure 3.2-6
Vapor Rate Out of Core
(Sensitivity Case 2)

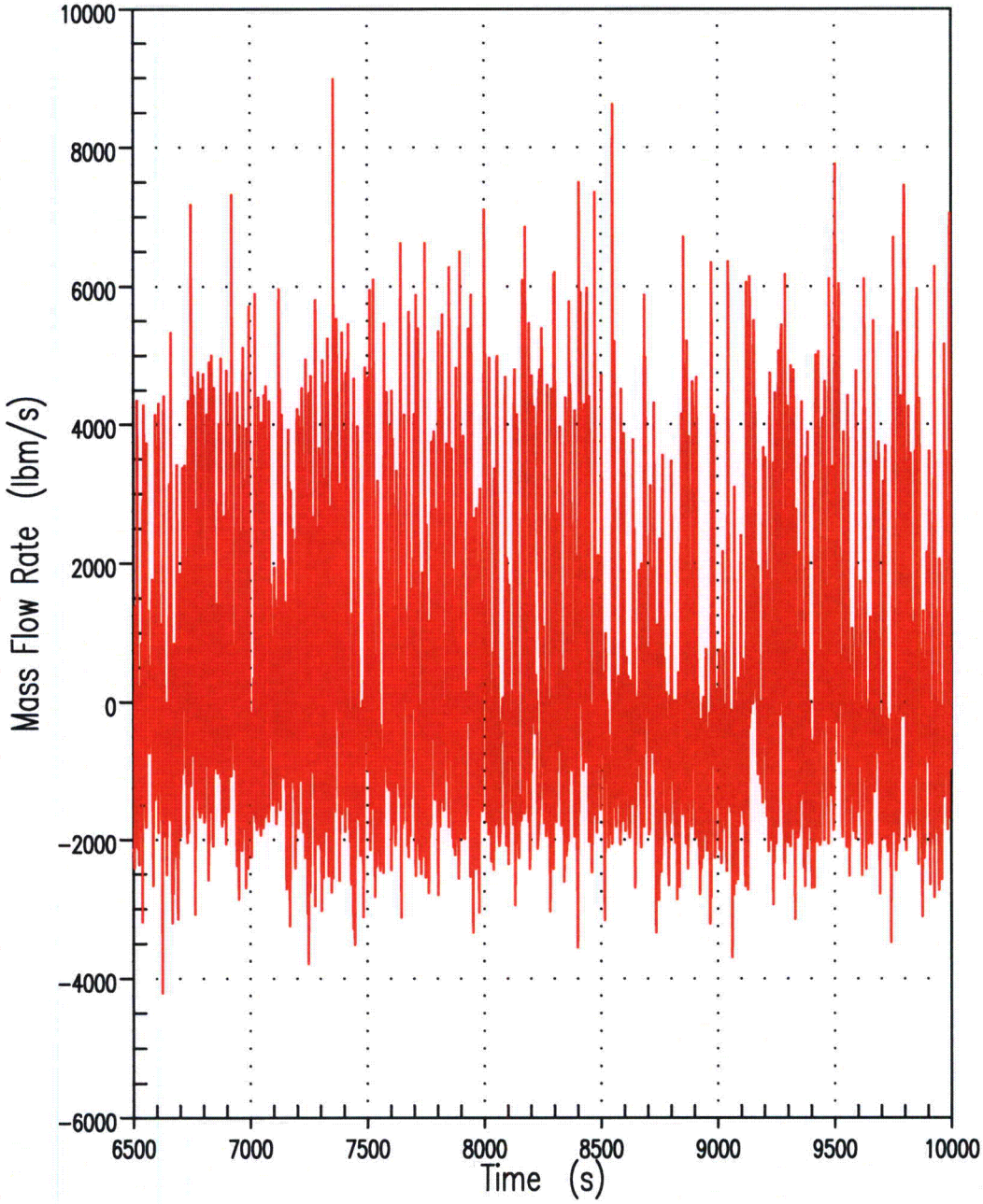

Figure 3.2-7
Liquid Flow Rate Out of Core
(Sensitivity Case 2)

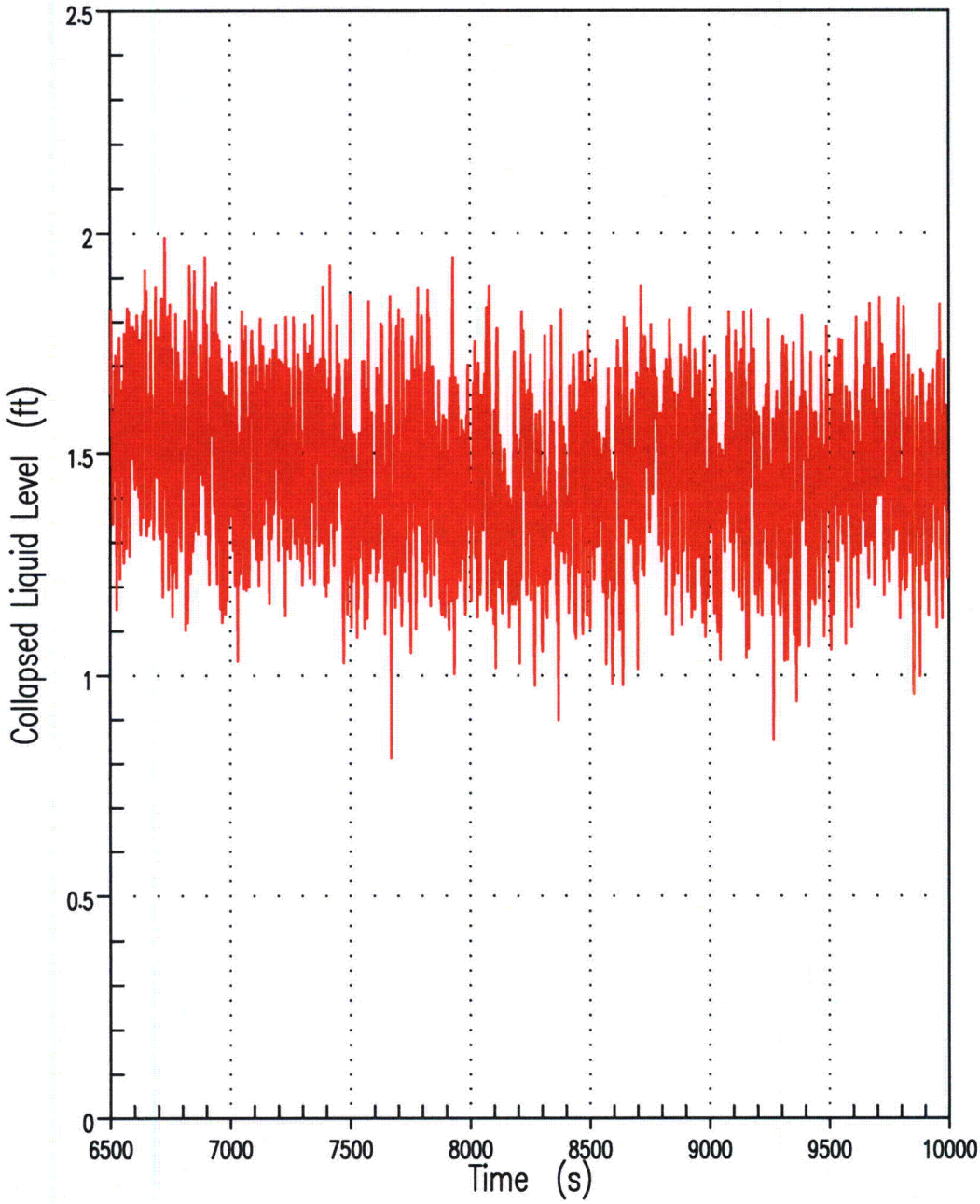

Figure 3.2-8
Collapsed Liquid Level in Upper Plenum
(Sensitivity Case 2)

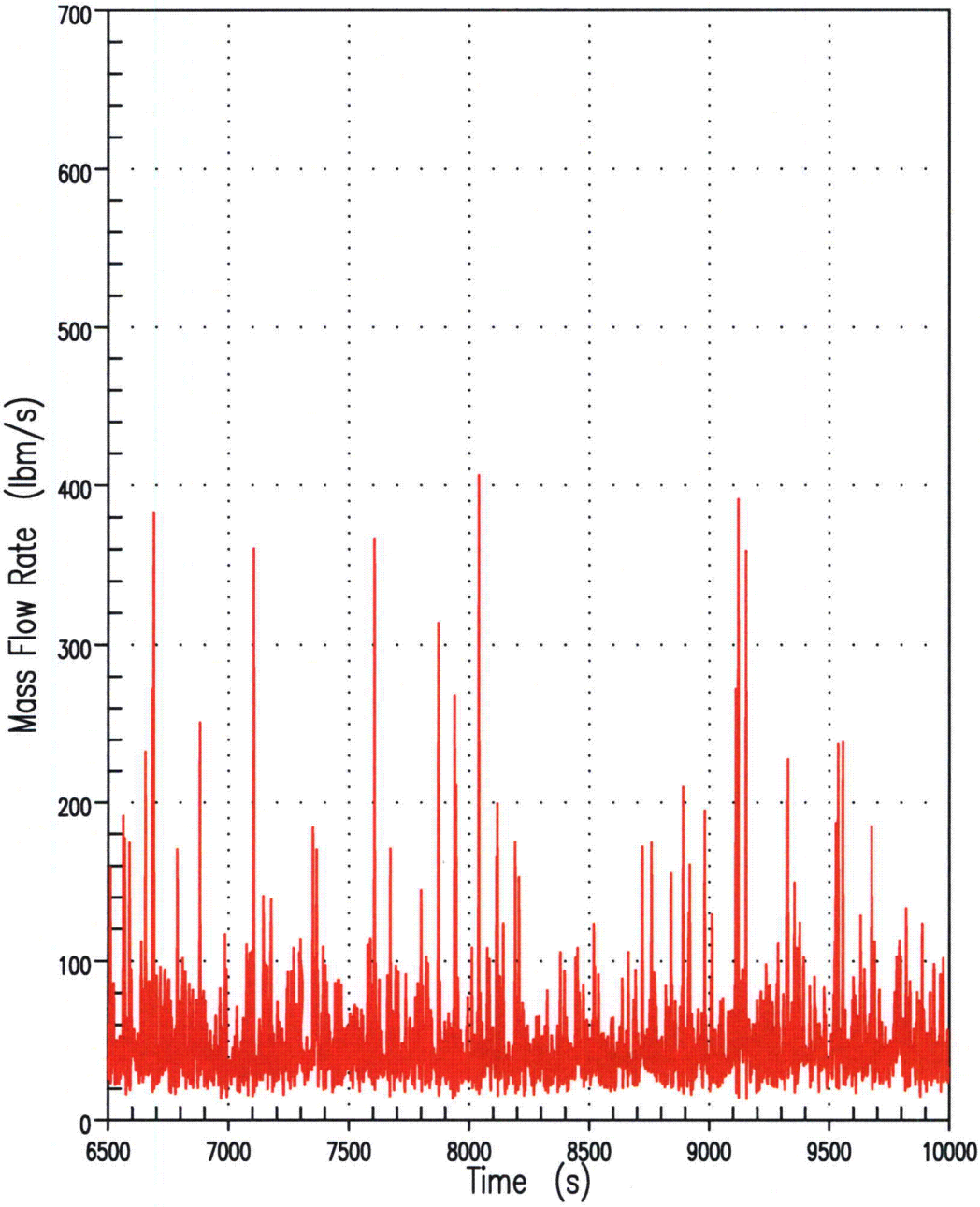

Figure 3.2-9
Mixture Flow Rate Through ADS Stage 4A Valves
(Sensitivity Case 2)

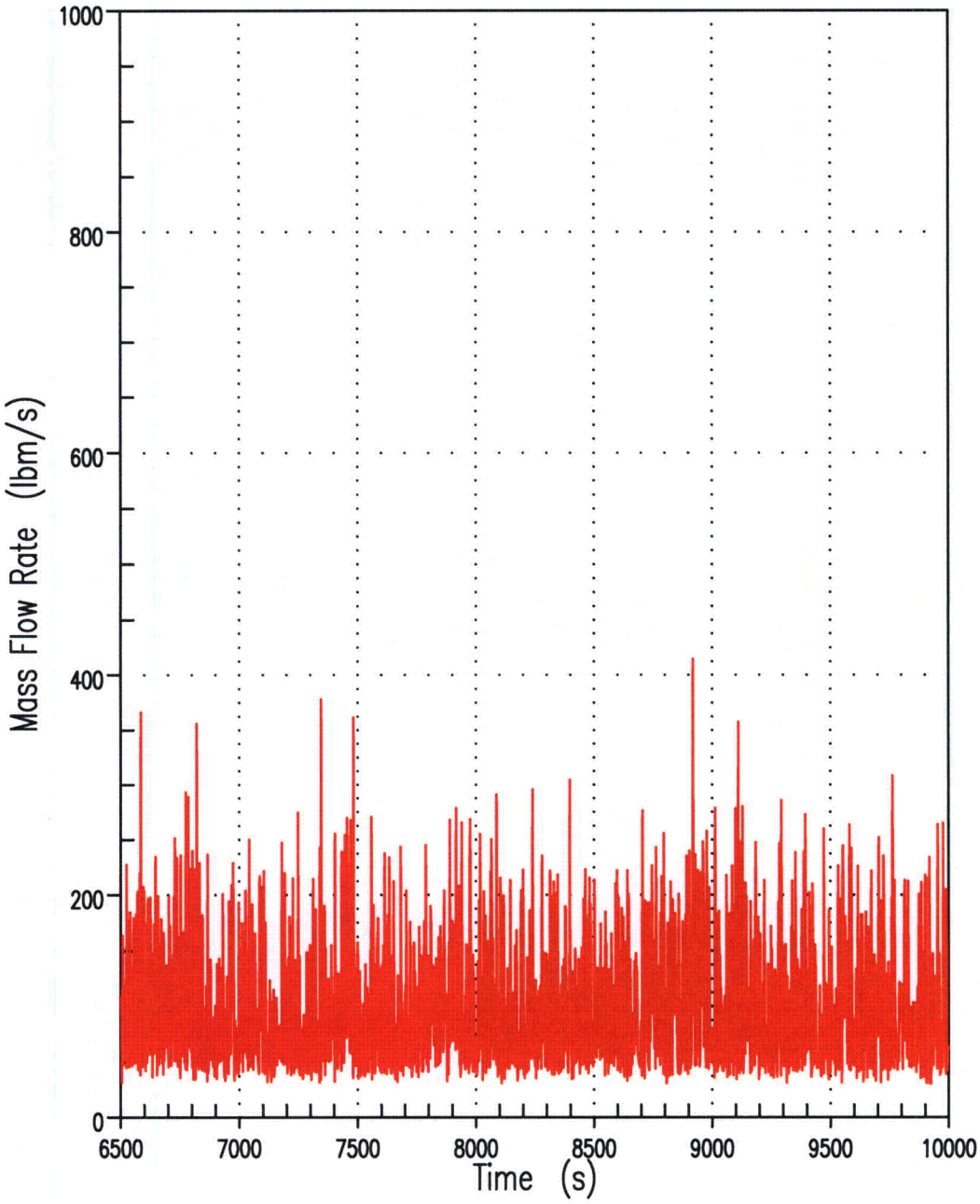

Figure 3.2-10
Mixture Flow Rate Through ADS Stage 4B Valves
(Sensitivity Case 2)

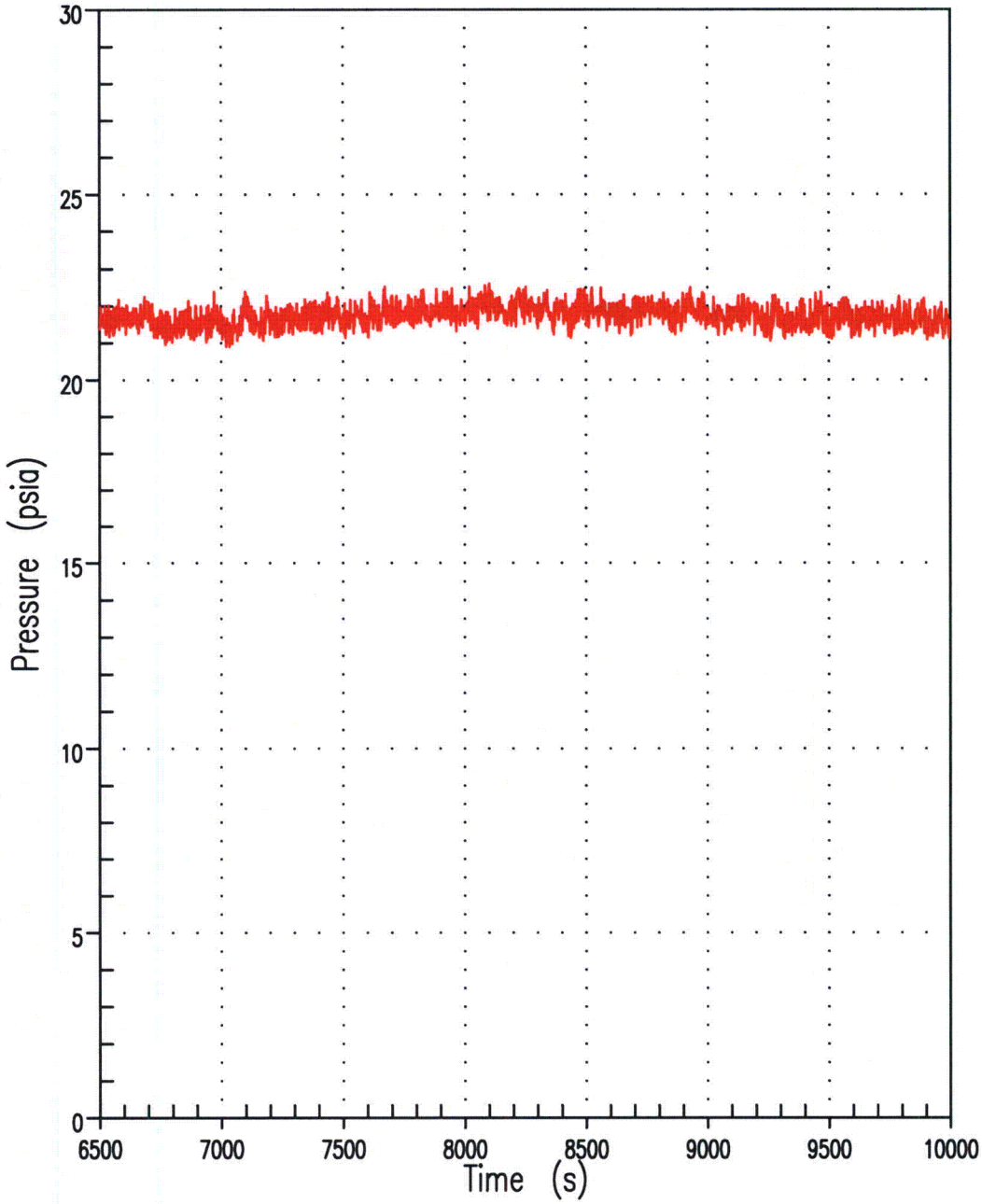

Figure 3.2-11
Upper Plenum Pressure
(Sensitivity Case 2)

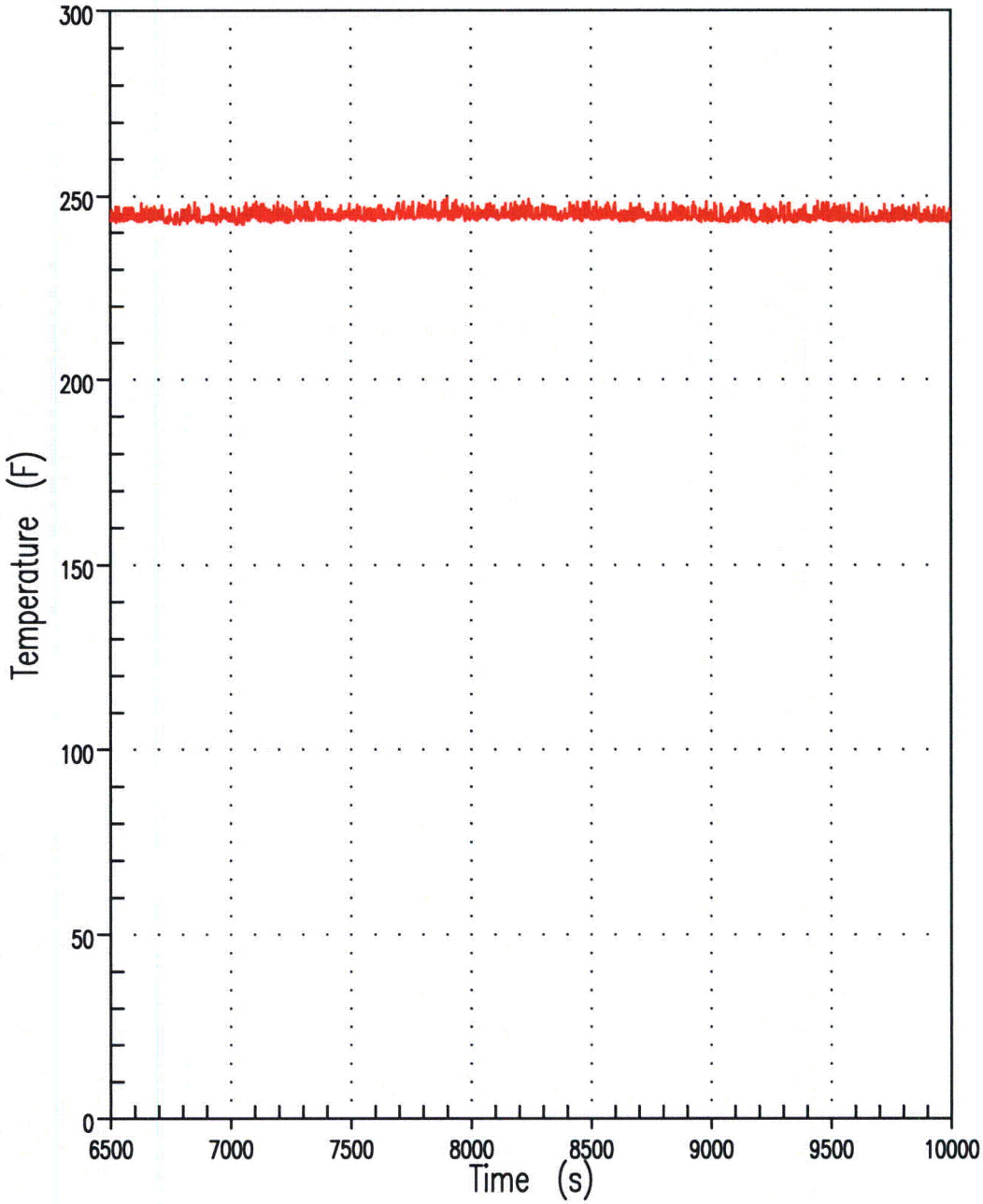

Figure 3.2-12
Peak Cladding Temperature
(Sensitivity Case 2)

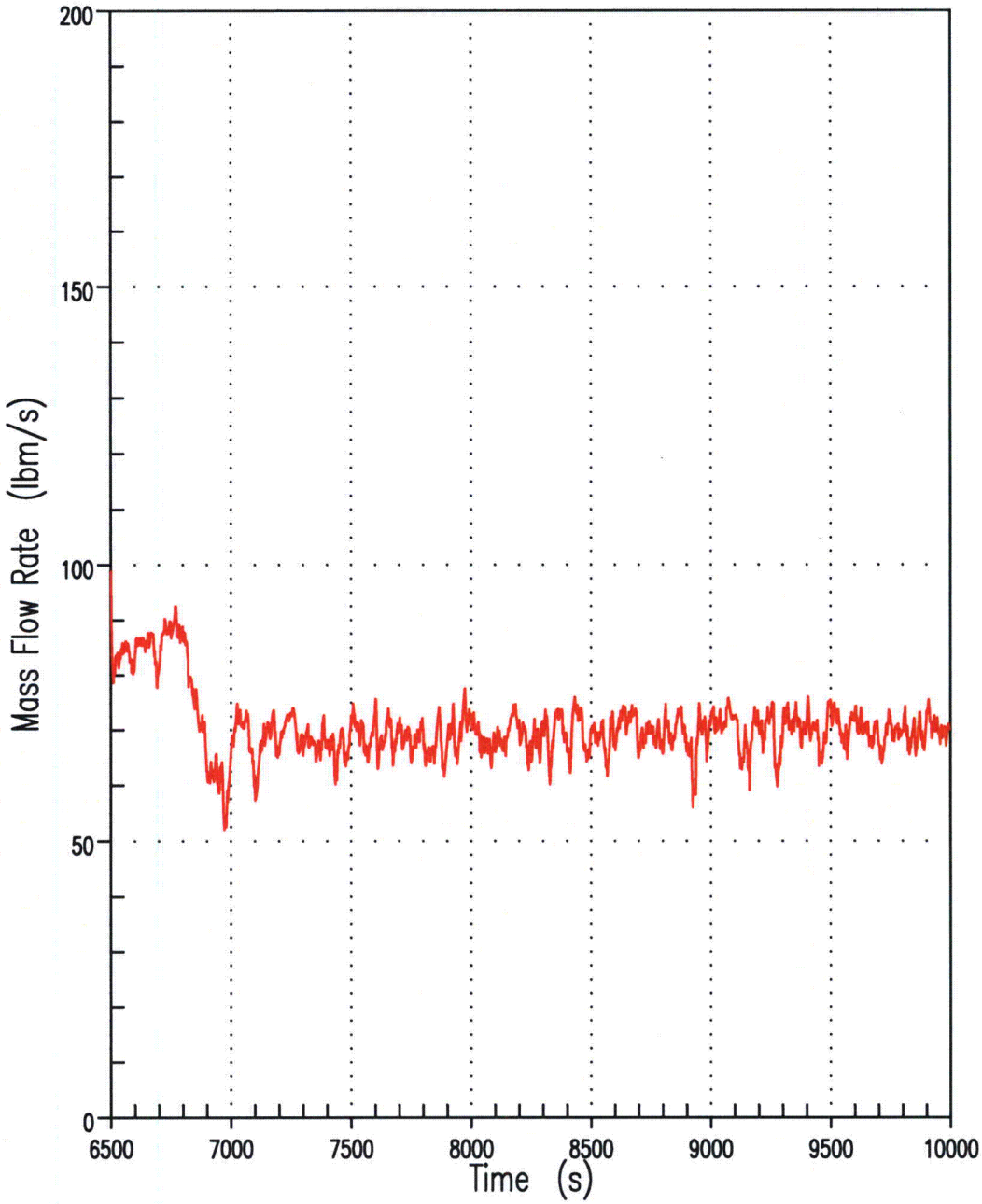

Figure 3.2-13
DVI–A Mixture Flow Rate
(Sensitivity Case 2)

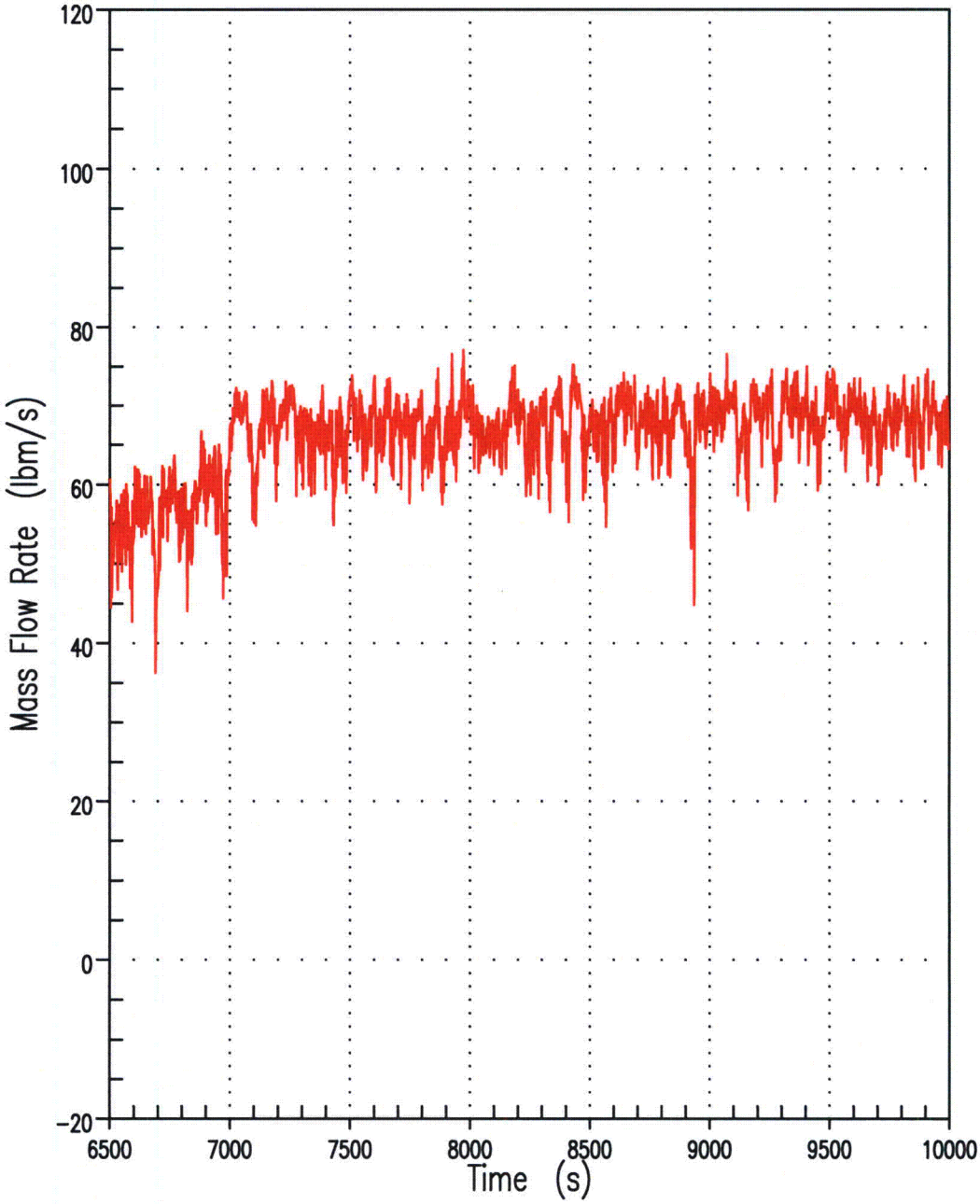

Figure 3.2-14
DVI–B Mixture Flow Rate
(Sensitivity Case 2)