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IJESTINGHOUSE CLASS 3

Loss of Feedwater Induced Loss of Coolant Accident Analysis Report

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ABSTRACT

The results of a complete loss of all feedwater accident subject to LOCA constraints is presented for Westinghouse design plants. Plants with minimum capacity PORV's can prevent core uncovery by holding all the PORV's open 5 minutes after SG dryout if the plant has safety grade charging SI or 4 minutes before SG dryout if the plant does not have safety grade charging SI. Manual initiation of a best estimate maximum safety grade charging SI thirteen minutes after steam generator dryout resulted in a covered core but a decreasing primary inventory 2.5 hours after the loss of feedwater.

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1.0 INTRODUCTION TO LOFW-LOCA ANALYSIS

In the event that main feedwater is lost and auxilary feedwater is unavailable, a small loss of coolant accident (LOCA) will result when the power operated relief valves (PORV's) open to relieve the increasing primary system pressure which builds up as the secondary heat removal capability degrades. If no action is taken to mitigate the loss of heat sink events, the PORV's will flutter thereby removing decay heat and primary mass inventory until the core is uncovered.

In WCAP-9600 (Report on Small Break Accidents for Westinghous NSSS Systems)[1], the results of a complete loss of feedwater induced small LOCA study were published. That analysis was performed for a two loop plant which has the smallest primary-volume to core-power ratio. That plant configuration would pressurize to the PORV pressure setpoint the fastest once the secondary heat sink has been lost and would exhibit the earliest core uncovery if no actions are taken to mitigate the events. That analysis was expected to provide information regarding the minimum time available to an operator before some action must be taken. The WCAP-9600 analysis established that the operator had to initiate either auxilary feedwater prior to core uncovery at 4000 seconds, or open all the PORV's by 2500 seconds, roughly 10 minutes after steam generator secondary dry out, in order to depressurize below the safety injection setpoint to get significant safety injection flow which would continue the depressurization.

The WCAP-9600 analysis is conservative from the viewpoint of establishing the minimum time avalable for an operator to establish some form of effective feedwater. The PORV-flow to core-power ratio provides an indication of the ability of a plant to depressurize by creating a small LOCA and depressurizing through the PORV's. Although the case examined in WCAP-9600 had the smallest PORV-flow to core-power ratio observed for two loop plants, that PORV-flow to core-power ratio is relatively large when compared to some high power four loop plants. For plants with smaller PORV-flow to core-power ratios, the ability to depressurize as rapidly is diminished and there is some concern that a higher power plant with a relatively small PORV flow capacity may not have as much operator action time as the WCAP-9600 case of 2500 seconds. Specifically, the case analyzed in WCAP-9600 had a PORV-flow to core-power ratio of 190.8 (lbm/hr)/MWt, while some high power four loop plants have PORV capacities of only 104.95 (lbm/hr)/MWt.

In addition, for plants which have safety grade charging flow, it is important to determine if allowing the PORV's to flutter with safety injection manually initiated and no operator action to hold open the PORV's is a desirable alternative.

2.0 PURPOSE

The purpose of this analysis is to complete the bounding calculational limits on the minimum operator action time for all Westinghouse design plants subject to loss of secondary heat sink accidents. To reiterate, the bounding calculation for establishing auxilary feedwater flow was performed in WCAP-9600. This analysis, on the other hand, establishes limiting constraints on the opening of the PORV's to recover from a LOFW-LOCA sequence for plants with or without safety grade charging flow.

Table 1 correlates some typical Westinghouse design plants with some of the key parameters which influence the ability of a plant to recover from a LOFW-LOCA by depressurizing through all the PORV's. Clearly the WCAP-9600 analysis bounds the two loop plants and bounds all Westinghouse design plants for establishing auxilary feedwater. However, it does not bound all Westinghouse design plants when depressurizing through the PORV's is the action chosen, and may be especially non-conservative for those plants which do not have safety grade charging flow. A bounding analysis for a high power small PORV capacity plant is needed in each case.

The small PORV-BLOWDOWN case represents the analytic parameters used in the analysis of a high power small PORV capacity plant. This case has the minimum PORV capacity observed on any Westinghouse design plant. The primary-volume to core-power ratio is virtually the smallest (less than 1% larger than the Watts Bar units). The small PORV blowdown analysis case bounds the ability of Westinghouse plants with safety grade charging flow to recover from LOFW-LOCA events by depressurizing through the PORV's.

The small PORV blowdown analysis includes the effect of safety grade charging flow which provides liquid inventory and sensible cooling once the safety injection signal setpoint and delay have been achieved. Plants which do not have safety grade charging pumps will experience additional difficulty in depressurizing through the PORV's since the injection of subcooled liquid may be delayed. There is somewhat of an offsetting benefit because plants which do not have safety grade charging flow all have a PORV capacity larger than the minimum flow capac..y used in the small PORV blowdown analysis. So, to bound those plants without safety grade charging flow, a Low Shutoff Head HPSI PORV blowdown analysis will be performed using input parameters from a plant with a low shutoff head safety injection pump, the minimum PORV capacity observed for low shutoff head HPSI plants, and small volume to power ratio.

Both the small PORV LOFW-LOCA blowdown analysis and the Low Shutoff Head HPSI LOFW-LOCA analysis rely on the rapid depressurization of the plant to a pressure below the safety injection shutoff head in order to remove primary energy through the PORV's and replace the lost inventory with safety injection liquid. Some members of the NRC staff and the ACRS have expressed concern over this method of LOFW-LOCA recovery, and believe that the recovery may be accomplished by manually initiating charging flow while allowing the PORV's to flutter normally in those plants which have safety grade charging flow. This mechanism of Feed and Bleed cooling in the LOFW-LOCA scenario is examined by utilizing the small PORV blowdown case, but instead of opening all the PORV's, the best safety grade charging flow expected on any Westinghouse plant is manually initiated while the PORV's are fluttering.

These three types of analysis are examined under the topical heading LOFW-LOCA analysis and in conjunction with the WCAP-9600 results should provide limiting bounds on the ability of Westinghouse plants to recover from the loss of secondary heat sink by;

1. Establishing effective feedwater,

2. Opening the PORV's, and

3. Initiating safety injection manually.

Four cases are presented in this report covering the three types of analyses.

Case A - This case presents the results of the small PORV blowdown LOFW-LOCA analysis (described previously) in which all the PORV's are held open at 2700 seconds after the loss of all feedwater. This case did not keep the core covered and is used to present the general transient discussion in section 4.0.

Case B - This case presents the results of a small PORV blowdown LOFW-LOCA analysis in which all the PORV's are held open at 2500 seconds after the loss of all feedwater. This case did not exhibit any core uncovery. It is described in section 5.1.

Case C - This case presents the results of the Feed and Bleed analysis where the same plant examined in cases A and B is analyzed, but instead of opening the PORV's they were allowed to flutter normally. Furthermore, this case manually initiated the best safety grade charging flow 3000 seconds after the loss of all feedwater instead of using minimum safeguards automatically initiated.

Case D - This case presents the results of a low shutoff head SI plant subject to blowdown recovery from a LOFW-LOCA using the PORV's. In this case the PORV's had to be all held open at 1500 seconds after the loss of all feedwater. No core uncovery resulted.

Case	Power (MWt)	Volume Power (ft^3/MWt)	PORV CAP. (lb/hr)/MWt	SI S.O. Head PSIA	SI Initiation
A	3411	3.70	105	2600	Automatic
B	3411	3.70	105	2600	Automatic
C	3411	3.70	105	2600	Manual
D	3025	3.98	139	1500	Automatic

3.0 ANALYSIS PROCEDURE

A modified configuration control version of the WFLASH IV computer code was employed to evaluate the expected plant response to the loss of feedwater induced LOCA. This version of WFLASH is identical to the evaluation version except that it includes the following modifications;

1. An extended plot package similar to the one used in WCAP-9600 was incorporated to provide additional visual understanding of the transients,

2. An extended multiple restart capability was incorporated, similar in effect to the restart package used in WCAP-9600 except that this package was more flexible and would reduce costs since more restart points could be written in any given run, and

3. Extended flowpath areas as functions of time or pressure were permitted. These are similar to the variable flowpath areas used in WCAP-9600 except that they are more versatile.

Incorporation of these code modifications will not alter the evaluation model results.

The following model assumptions which are not included in a typical Appendix K analysis were used;

1. The PORV's and Pressurizer safety valves are modeled as a variable break flow area versus pressure flowpath from the top of the Pressurizer to the containment. This form of modeling provides a number of advantages over the modeling used in WCAP-9600. In WCAP-9600 the PORV's were modeled as a simple pipe type of flowpath whose area varied with pressure. The flowpath opened over a 10 psi span to permit the code to run, and small time steps were required. If a smaller opening span or larger time steps were used, then the code became unstable. The break flow area permits a 1 psi opening span

and large time steps to reduce running time and expense. It also permits a more realistic modeling of the PORV and safety valve operation. Whereas, the WCAP-9600 analysis tended to sit at some valve opening area less than full open, the current model only fully opens and closes the valve. In reality the valve commonly opens fully at 2335 psia and reseats at 2315 psia. In effect, the WCAP-9600 used a junction type of flowpath which is normally used for connecting control volumes to connect a control volume and the containment. So, some artificiality was built in. In this report a leak type of flowpath from a control volume to the containment was used. The leak type of flowpath typically is used to represent flow from a control volume to the containment.

2. Drift flux is incorporated into the Pressurizer surge line flowpath. This permits the realistic draining of the Pressurizer when it is calculated to occur.

3. The Pressurizer surge line connection was elevated above the hot leg center line. This permits a preferential steam flow to the Pressurizer as the vessel mixture level drops. Westinghouse believes this to be more realistic and this feature is consistent with the WCAP-9600 analysis.

4. The reactor, turbine, and feedwater trip setpoints are immediately activated upon code initialization. The appropriate trip actions are modeled to occur as they should by using an appropriate time delay in the code.

The analysis also makes the following assumptions regarding the plant conditions and system responses;

1. Core power is assumed to be operating at 102% of steady state full power prior to reactor trip. This is consistent with Appendix K assumptions and accounts for power level uncertainty.

2. 1971 ANS 5.1 standard decay heat for infinite reactor operation plus 20% is used a reactor trip This is consistent with standard design ana and maintains continuity with the WCAP-9600 analysis.

3. Feedwater is assumed to coastdown to zero flow starting from transient initiation in 0.1 seconds. This coastdown duration is consistent with more typical loss of feedwater accident analysis.

4. The Reactor Trip Signal is set by coincident steam flow - feed flow mismatch and steam generator secondary lo-level. This assum on is consistent with the standard loss of feedwater accident analysis for some types of steam generators, and notably for the steam generators used in this analysis and the WCAP-9600 analysis.

5. The control rods are assumed to shut down the reactor core 4.4 seconds after the calculated reactor trip signal, which is also consistent with typical Appendix K analysis.

6. Steam generator steam flow is assumed to ramp down to zero flow 0.5 seconds after the calculated reactor trip signal, which is consistent with typical Appendix K analysis.

7. With the exception of the Feed and Bleed analysis, the safety injection for these analyses consists of minimum safeguards with no spill and is initiated when the Pressurizer pressure falls below the lo-pressure setpoint with a 25 second delay. This is consistent with Appendix K analysis. The Feed and Bleed analysis assumes a maximum composite undegraded safety injection flow for plants with safety grade charging pumps and this represents the greatest amount of safety injection flow that any Westinghouse design plant may expect at the elevated PORV setpoint pressures.

A number of conservatisms for this type of analysis may be immediately identified;

1. 102% steady state full power.

2. 20% additional decay heat.

3. Steam generator secondary dry-out calculation performed conservatively in accordance with Reactor Protection Analysis assumptions.

4. Reactor coolant pumps are assumed to run until steam generator secondary dry-out to provide a more uniform temperature distribution. A more uniform heatup will result in less subcooling flow through the core once the PORV's are opened. This assumption is also consistent with the typical loss of feedwater analysis for conservative S.G. dryout calculation.

5. Minimum safeguards ECCS considerations provides a lower bound on the safety injection flow consistent with the Appendix K single failure criteria.

4.0 POSSIBLE LOFW-LOCA TRANSIENT BEHAVIOR

To provide a foundation for understanding the results contained in this report and the WCAP-9600 results, a general loss of feedwater induced LOCA will be examined. The transient behavior presents the results of a small PORV blowdown analysis which did not open the PORV's early enough to prevent core uncovery. This presents some of the transient phenomena which a plant might encounter during a LOFW-LOCA.

This analysis (Case A) examined a small PORV blowdown LOFW-LOCA simulation in which the PORV's were opened too late to prevent core uncovery. The small PORV blowdown LOFW-LOCA analysis examines a typical four loop Westinghouse plant design which has a steady state 100 percent power level of 3411 MWt, top hat design upper support plate, thermal shield, downflow barrel baffle, 93A 6000 HP reactor coolant pump, series 51 steam generator, and 17 x 17 generic fuel design. A minimum PORV capacity of 104.95 is incorporated corresponding to a total PORV flow of 358000 lbm/hr of saturated steam at 2335 psia for two PORV's. The safety injection flow employed for this case was minimum safeguards for a 412 standard plant without a spilling line. This design includes safety grade charging pumps which for analysis purposes have a shutoff head of 2450 psia.

Generally, the LOFW-LOCA transient may exhibit 13 distinct phases; 1) powered pressurization, 2) trip depressurization, 3) quasi-steady state, 4) primary heatup, 5) pressurization to the PORV setpoint, 6) PORV fluttering, 7) subcooled blowdown, 8) subcooled break flow repressurization, 9) two phase break flow repressurization, 10) intermittent two phase fluid-steam break flow repressurization, 11) steam break flow repressurization, 12) pressure stabilization, and 13) core uncovery depressurization. The purpose of this LOFW-LOCA transient description is to present some of these features which may be exhibited by most LOFW-LOCA transients so that the results of the analysis in which the operator took action early enough to prevent core uncovery may simply be compared to this discussion.

The loss of feedwater induced LOCA transient begins with a very rapid coast down of the main feedwater to zero flow. The steam generator secondary mixture level (figure A-8) begins rapidly decreasing since steam is still flowing to the turbine without being replaced. On the other hand, the secondary pressure (figure A-2) and secondary fluid temperature (figure A-19) climb rapidly since the cooling effect of raising the subcooled feedwater to saturation has been lost. The degrading primary to secondary heat transfer coefficient (figure A-30) which is caused by the reduction in primary to secondary temperature drop forces the primary pressure (figure A-1) and temperature (figures A-16 and A-17) to increase. The primary fluid is forced to absorb some of the full core power since the degrading secondary conditions cannot remove all of the core power. The resultant temperature increases swell the primary fluid causing a surge (figure A-12) into the pressurizer raising its mixture level (figure A-6). These initial pressurization and heatup events are terminated when the reactor and turbine throttle valve trip on the coincident signals from steam flow - feed flow mismatch and steam generator secondary lo-level. This early, short-lived phase is characterized as a power pressurization since the reactor core remains at full power for about 16 seconds after main feedwater is lost.

After the trip, the primary pressure and hot leg temperature immediately drop. The surge line mass flow rate reverses and mass flows out of the pressurizer reducing the mixture level as the primary fluid "cools and shrinks". Although not as rapidly as before trip, the secondary mixture level continues to fall as the secondary mixture level shrinks. The secondary mixture level is also dropping because the secondary pressure has risen to the safety valve setpoint and the valves are intermittently opening and closing relieving pressure and removing secondary mass and energy. This phase of the transient represents the trip depressurization.

The initial primary depressurization after reactor trip gives way to a quasi-steady state period characterized by decay heat energy removal through the steam generator secondary as it slowly dries out as secondary mass is depleted through the steam generator safety valves. The primary pressure and temperatures are relatively constant during this period. The steam generator secondary mixture level is decreasing slowly and is beginning to uncover the tubes. There is still sufficient decay heat removal capability at this time even with a portion of the tubes uncovered to maintain stable primary temperatures and pressure.

When approximately 70% of the height of the steam generator tubes is uncovered, the primary to secondary heat transfer has been degraded enough so that the primary begins a gradual heatup. The heatup rate is slowly increasing as the secondary mixture level approaches dry out. The primary temperatures are increasing uniformly which swells the primary fluid. The fluid swell is reflected in the increasing pressurizer surge line mass flow rate. The pressure in the primary would be expected to be increasing as a reflection of the fluid swell and increasing temperatures, however the code predicts a slight decrease in the pressure. This decrease is due to the code calculation of the pressure for the equilibrium pressurizer model.

During each time step the code computes the mass flow into or out of the pressurizer. When the equilibrium pressurizer model is incorporated, the steam and liquid masses are determined by homogenizing the mass and internal energy. The equilibrium pressurizer model takes the subcooled fluid flowing into the pressurizer and calculates the appropriate mass and internal energy smeared over the node. Then saturation conditions are determined. The subcooled fluid surging into the pressurizer will tend to decrease the pressurizer temperature and pressure since the mass averaged internal energy is reduced. This behavior may be directly observed from the pressurizer fluid temperature (figure A-18). The pressurizer fluid temperature is decreasing as the subcooled surge line mass flow reduces the saturation temperature while the hot leg fluid temperature and cold leg fluid temperatures are increasing. Thus the equilibrium pressurizer tends to see a reduction in pressure as the primary heats up and subcooled mass surges in from swell. The remaining portions of the system are heating up, but because the pressurizer pressure feeds back throughout the primary, the RCS pressure is predicted to decrease.

Realistically, the pressure would be expected to increase as a reflection of primary heatup. Simple calculations can be performed to reflect this belief. In reality, the pressurizer is a highly non-equilibrium fluid volume, and when subcooled fluid flows into the pressurizer some of the steam is condensed and supplies heat necessary to raise the mixed fluid to near saturation. Calculations indicated that the volume of fluid surged into the pressurizer is greater than the volume of condensed steam. Therefore the pressure should be increasing.

The unrealistic decrease in primary pressure during the heatup phase does not pose significant non-conservative analytical problems. As will be indicated later, one of the key parameters in determining when to open the PORV's is the primary fluid temperature. The core fluid temperatures are computed correctly. Had an appropriate non-equilibrium pressurizer model been available, it may have projected a slightly earlier opening of the PORV's. So a more accurate calculation would only mean that a slightly smaller mass inventory would remain for the same primary temperature.

Once the steam generators dry out, the secondary is no longer capable of removing decay heat which now virtually all goes into raising the primary fluid temperature through sensible heat absorption. The primary pressure reverses its gradual decrease as the pressurizer nears filling from mass which has surged in due to primary fluid swell. The pressure rises very rapidly to the PORV setpoint as the pressurizer becomes water solid. Pressurization to the PORV setpoint would realistically activate the PORV's slightly before the pressurizer goes water solid due to the piston compression action of the fluid on the non-condensible gas and steam mixture.

The reactor coolant pumps are assumed to run until the steam generator secondaries dry out. This assumption leads to a much more uniform heatup of the primary fluid and hence higher fluid temperatures when the PORV's finally lift. Following reactor coolant pump trip, the hot leg mass flow rate falls from the forced circulation flow rate of about 9088 lbm/sec down to a natural circulation flow rate of about 450 lbm/sec. The natural circulation flowrate exists to some degree because of the pump coastdown but also because some decay heat is still removed from the primary as the secondary steam is superheated.

After the system has pressurized to the PORV setpoint, some of the decay heat is removed through the PORV's as they flutter open and closed. Some of the remaining decay heat superheats the secondary, but the majority of the decay heat forces the temperature higher through sensible heat absorption. The mass flow rate leaving the primary through the PORV's is governed by the primary fluid swell which is related to the temperature rise. As the fluid temperature increases, the specific volume increases which results in higher pressures since the confining system is inelastic. The higher pressure activates the PORV's and mass is removed from the system reducing the pressure. Thus the PORV fluttering period is characterized by a constant system pressure hanging at the PORV setpoint with the primary and secondary fluid temperatures increasing.

Even the minimum capacity PORV's are calculated to be large enough to compensate for the increasing specific volume of the primary fluid while it is still subcooled. The pressure is not calculated to rise to the safety valve setpoint since the intermittent PORV discharge, corresponding to times when the PORV's are open, exceeds the fluid swell. If no action is taken, the system would continue in this mode until saturation temperatures are reached in the core. Then the decay heat could no longer be removed as sensible heat, and is instead removed from the fuel rods as latent heat through steam void production. If the PORV's are not large enough to compensate for the greater specific volume increases once boiling begins, the primary pressure would rise above the PORV setpoint and move toward the safety setpoint. If this happens the PORV's are effectively all held open continuously.

If the PORV's are held open when the core fluid temperature is still subcooled, a characteristic subcooled blowdown results. The pressure drops rapidly toward saturation. The open PORV's result in a massive subcooled surge line mass flow rate. During the PORV fluttering period the subcooled fluid which is forced into the pressurizer by specific volume increases is small but tends to drive the voids from the pressurizer. In this case the subcooled fluid reduces the pressurizer void fraction to zero, and subcooled break flow results. The subcooled PORV discharge volume removed from the system exceeds the specific volume increases until the core fluid temperature approaches saturation. The core fluid temperature at the time the PORV's are opened governs the degree of depressurization. The longer the delay in opening the valves, the hotter the core fluid will be and the saturation pressure will be correspondingly higher. The rate of depressurization is governed by the size of the break, and even in this minimum PORV capacity case the PORV's are sufficient to result in rapid depressurization to the saturation pressure in the core at the time the PORV's are opened.

As the pressure reaches saturation, voids begin to form in the core. The pressurizer is still expelling subcooled fluid through the PORV's. Decay heat is being absorbed by the fluid latently in the saturated core region and, the specific volume increases due to void formation outweigh the volume removal through the PORV's. So, the pressure begins climbing from a minimum and the saturation temperature begins rising. The pressure rise is the most rapid during the subcooled break flow repressurization period since the energy and volume removal from the system is a minimum.

At this point the PORV capacity exhibits its importance, since the PORV break size, as determined from the PORV capacity, governs the specific volume of fluid which can be removed. If the PORV capacity is large enough, then the volume of fluid which can be removed from the system will exceed the specific volume increases due to void formation and depressurization will continue. This is the reason why the two loop case, presented in WCAP-9600, did not exhibit a large and extended repressurization phase, and this is also the reason why it is not the limiting case displaying the ability of Westinghouse plants to depressurize through the PORV's. A secondary influencing effect due to the fact that the PORV is now modeled as a variable break flow area flowpath versus pressure instead of a variable pipe flow path area versus pressure, may result in a reduced ability to remove volume.

The voids formed in the core once saturation has been reached result in an increasing surge line quality. This begins to increase the void fraction in the pressurizer and that forms the transition to the two phase PORV discharge repressurization period. The two phase PORV discharge repressurization is not as rapid as the subcooled PORV discharge repressurization since the volume and energy removal through the PORV's is greater than before, but still does not equal the decay heat produced specific volume increases.

The voids collect and there is a phase separation in the reactor vessel. The vessel mixture level decreases as the steam formed from decay heat collects at the top. The vessel mixture level will continue to drop since the surge line removes only a minimal amount of the steam voids because the vessel mixture level has not reached that elevation yet.

The two phase PORV discharge repressurization period ends shortly after the vessel mixture level reaches the surge line elevation. At this time an intermittent period of two phase and steam surge line flow results as the vessel mixture level "hangs" at the surge line. An intermittent two phase - steam PORV discharge repressurization phase results since the PORV break is still unable to remove all of the volume production from decay heat. However, unlike the subcooled and two phase PORV discharge periods when the excess void production and phase separation resulted in a depressed vessel mixture level, the intermittent period permits the level to remain relatively constant oscillating about the surge line elevation.

The oscillating vessel mixture level intermittently results a slug of steam flowing to the pressurizer as the decay heat produced steam builds up and the mixture level falls below the surge line elevation. The volumetric steam relief is sufficient to allow the vessel mixture level to recover the surge line. Then two phase fluid flows to the pressurizer. An oscillating mixture level also results at the PORV elevation in the pressurizer. The steam PORV discharge is incapable of volumetrically equaling a slug of surge line steam flow and the pressurizer mixture level recovers the PORV elevation. This further reduces the volumetric removal through the PORV which feed back reducing the surge line flow. This results in the vessel mixture level dropping as steam collects in the core. The reduced two phase surge line flow permits the PORV flow to "catch-up" and eventually the PORV's uncover allowing larger volumes of steam to be vented. This feeds back as the vessel mixture level rises and the cycle repeats.

Complicating the understanding of the oscillatory process is the fact that some of the surging steam is "absorbed" in the pressurizer fluid mixture by increasing the pressurizer void fraction, while there is a smaller reduction of steam voids from the bubble rise phase separation. More steam can be produced through decay heat absorbtion than could be directly removed by the PORV's. The difference between the amount of steam that could be vented and the amount of steam that is produced is the amount of steam which gets "stored" through increasing the pressurizer void fraction. The void fraction increases as an amount of bubbles rise out of the mixture while a larger amount surges in. That is why more steam can be removed from the core than can be vented, and why the vessel mixture level hangs at the surge line elevation.

The duration of time that the vessel mixture level "hangs" at the pressurizer surge line elevation is governed by a relationship between the pressurizer void fraction, the bubble rise velocity and the PORV discharge rates. The pressurizer bubble rise velocity governs the rate at which the pressurizer steam voids attempt phase separation. At low void fractions for a given bubble rise velocity, less steam is released from the mixture than is being put into the pressurizer through the surge line. So there is little phase separation.

The pressurizer fluid was driven subcooled during the early blowdown phase. Then as two phase fluid flowed into the surge line the pressurizer void fraction was governed by, but lagged behind, the core void fraction. The pressurizer void fraction remains small until the vessel mixture level reaches the surge line elevation. Once this happens, steam which is produced by decay heat boiling has a much more direct "communication" with the PORV's whenever the surge line flow quality switches to all steam. Before the mixture level reaches the surge line, the decay heat produced steam can only remotely communicate with the PORV's through steam void migration in the two phase fluid.

The decay heat produced steam is now able to pass through the surge line and accumulate in the pressurizer, increasing the pressurizer void fraction instead of collecting in the vessel. The accumulation process will continue until a maximum pressurizer void fraction is reached based upon the bubble rise velocity. The mass flow rate of bubbles phase separating from the presurizer fluid mixture is a product of the bubble rise velocity, pressurizer cross sectional area, fluid void fraction, and steam density. When the void fraction is small, as it is just after the end of the subcooled break flow period, then the mass of bubbles leaving the mixture is smaller than the mass of steam surging in, and the pressurizer mixture level swells as liquid and steam are discharged out the break. As the void fraction increases, the bubble separation rate increases and approaches the surge line steam flow rate. Once the maximum void fraction is reached, as determined by bubble separation rate equalling surge line steam flow rate for a given bubble rise velocity, the mixture no longer swells as the fluid sits just below the PORV elevation. If the void fraction were to increase any further, then the phase separation rate would exceed the steam PORV discharge rate which would result in a significant steam space growing at the top of the pressurizer and the the pressurizer mixture level would decrease. The liquid would tend to flow back into the RCS in a counter current type of flow. However, the steam flow is too large for this to happen so, instead, the steam bubble in the vessel grows.

Since the time the core reached saturation, low quality two phase fluid has flowed into the hot legs. This results in a slowly rising void fraction in the steam generator uphill tube region. This continues until there is a phase separation and the downhill tube region begins to drain at about midway into the period when the vessel mixture level is hanging at the surge line. Hot and cold leg mass flow rates which were relatively constant at about 450 lbm/second begin to decrease as "natural circulation" would be predicted to die out.

Once the vessel mixtur level begins to decrease below the surge line elevation, steam flows through the surge line, and in integrated effect, equals the steam PORV discharge. The PORV discharge, however, remains intermittent a little longer. This occurs because of the time necessary for bubbles to rise and separate. The void fraction has reached the maximum value permitted by bubble rise considerations, so that any steam entering the pressurizer must be matched by PORV discharge and phase separation considerations. The oscillatory pressurizer mixture level phenomena continues until sufficient two phase fluid has been vented so that the mixture level at maximum void fraction just sits below the PORV elevation. The amount of steam PORV discharge then equals surge line flow so that phase separation matches steam surge line flow. Furthermore, the surge line flow is still sufficient to preclude counter current drain back of the pressurizer two phase fluid.

A steam PORV discharge repressurization period results when the pressurizer two phase fluid is finally drained to just below the PORV elevation. The system continues to pressurize for the same reasons as before, the specific volume increases due to decay heat produced steam exceed the amount of steam which can be vented out the PORV's. Even though the decay heat removal mechanism can "communicate" directly with the decay heat production mechanism, the system will continue to pressurize.

The vessel mixture level continues to drain down until the hot leg elevation is reached. The level then hangs up at this elevation for many of the same reasons that tended to retain the mixture level at the surge line elevation. Intermittent two phase fluid and steam flows into the loops. The uphill tube region void fraction begins increasing more rapidly, and the downhill steam generator tube region continues to drain. During this period, the upper head begins to drain. So the mixture level "hang" is similar to the surge line phenomena.

As the pressure increases, the steam PORV discharge rate increases to about 95 lbm/second. The decay heat rate has slowly, but continually decreased to about 1.6 percent of full power by 4500 seconds after the start of the transient. The decay heat at this level serves to heat the draining subcooled fluid entering the core to saturation and then to latently create steam. The volume production of steam now only slightly exceeds the volume of steam which can be removed through the PORV's and so the pressure rise reverses and levels off. The pressure would tend to remain fairly constant at that value since the decay heat is only slowly decreasing at this time provided that there is sufficient mass drainage into the core to make up for the boil-off.

During this draining pressure stabilizat period, the upper head continues to drain into the upper downcomer. The upper head void fraction increases until the guide tubes uncover. The downhill steam generator tube region drains fairly early during this period, and the loop seal begins to drain.

Once the upper head has drained, steam can pass through the guide tubes to the upper head and then from the upper head to the upper downcomer through the head cooling spray nozzles. So steam can now flow from the core to the cold portions of the loop without fully draining the loop seal. With steam flowing to the upper downcomer, the driving head pushing fluid into the core is reduced as the void fraction in the upper downcomer begins to increase. The boil-off begins to exceed the flow into the core and the mixture level begins dropping.

The final LOFW-LOCA transient phase begins as the vessel mixture level falls below the top of the core. As the core uncovers, the pressure begins to fall. The pressure decreases because steam production is inhibited. Only a fraction of the amount of steam which could be generated by the decay heat is actually produced. Some of the remaining decay heat superheats the boil-off steam while the remainder heats up the fuel cladding. The mixture level continues to fall and shows a couple of spikes which occur due to loop seal uncovery.

Eventually the pressure decreases below the safety injection pressure setpoint and safety injection would begin. However, by the time the safety injection starts to inject fluid, the vessel mixture level has completely uncovered the core.

If the initial subcooled blowdown had depressurized to a point below the safety injection setpoint, it may have been possible to keep the core covered.

If the safety injection mass flow rate is large enough, it may be possible to forestall an extended repressurization period. The PORV discharge would still tend to drain the system and it would be necessary to drain down to the surge line to pass steam to the break before further depressurization could occur. But now mass would be injected replacing some of the lost mass, and an additional heat sink would be provided through sensible heat with the subcooled safety injection. So, the specific volume increases would not be as large and the PORV's may be able to accommodate the reduced specific volume increases.

Even if safety injection is initiated though, it may be possible to enter an extended repressurization phase if the subcooled safety injection does not provide a large enough sensible heat sink. Alternately, the extended repressurization may occur even with safety injection initiated, if the PORV capacity is incapable of accommodating the specific volume increases, and this situation may snowball. As the pressure begins to rise, the safety injection will be choked off reducing the injected mass and sensible heat sink which tends to promote the specific volume increases driving the pressure even higher.

The major factor governing the extended repressurization or the culmination of the transient itself, is the amount of mass that is calculated to be removed through the PORV's. The analysis used a break flow area to represent the PORV's. The break area was determined by applying Moody critical flow considerations to the rated capacity of two valves at the setpoint pressure. Specifically, the break area was determined for a Moody critical flow of 358000 lbm/hr at 2335 psia, with a discharge coefficient of 1.0. This area was used in the code for all periods of PORV discharge, subcooled, two phase, and steam. The code calculates the PORV discharge for steam and two phase fluid by using a Moody critical flow correlation, while the subcooled PORV discharge uses a modified Zaloudek correlation. Since the steam PORV discharge was matched to rated flow, large errors during the steam PORV discharge period are not anticipated. The two phase flow may be slightly underpredicted, and the subcooled PORV discharge may be overpredicted.

Another factor influencing the PORV discharge, and transient behavior in general, is the value used for the pressurizer bubble rise velocity. As noted earlier, this value controls the intermittent surge flow duration, and the pressurizer mixture level. If the bubble rise velocity is greater than the value used in the code, then the PORV discharge would switch to steam earlier and the vessel mixture level would be depressed earlier. If that is the case, the extended repressurization would be less severe. This analysis used a bubble rise velocity consistent with typical Appendix K analyses.

Finally, the reactor coolant pumps can have an impact on the PORV discharge considerations and thus the degree of repressurization. If the pumps are kept running during the transient, the mixture level would tend to be elevated and perhaps kept artificially high. This extends the two phase surge line flow much longer. The associated PORV discharge remains two phase much longer and the repressurization is more severe. The pumps would not be tripped while following the Westinghouse reactor coolant pump trip criteria. The system pressure does not reach the low pressures required for trip (100 psia over steam generator safety valve setpoint) and there is no automatic safety injection if the PORV's are left fluttering.

5292A

5.0 RESULTS - PLANTS WITH SAFETY GRADE CHARGING FLOW

A bounding calculation was performed for the loss of all feedwater induced LOCA from two viewpoints of single operator action. In the first viewpoint the only manual action the operator is assumed to perform is to hold open all the PORV's. A calculation was performed to determine a limiting time by which the valves must be opened when only minimum safeguards is available. The second viewpoint approaches the problem from the opposite end. This viewpoint assumes that the only action that the operator takes is to manually initiate a maximum composite undearaded safety injection flow. These calculations are very closely tied to the previous discussion (Case A).

A. Small PORV Blowdown

As noted before, the small PORV blowdown analysis examines a typical four loop Westinghouse plant design which has a steady state 100 percent power level of 3411 MWt, top hat design upper support plate, thermal shield, downflow barrel baffle, 93A 6000HP reactor coolant pump, series 51 steam generator, and 17 x 17 generic fuel design. A minimum PORV capacity of 104.95 (lbm/hr)/MWt is incorporated corresponding to a total PORV flow of 358000 lbm/hr of saturated steam at 2335 psia for two PORV's. Minimum safeguards safety injection for a 412 standard plant without a spilling line was employed for the safety injection flow in the analysis. This design includes safety grade charging pumps which for analysis assumption purposes, have a shutoff head of 2450 psia.

In this small PORV blowdown LOFW-LOCA case (Case B) the PORV's are opened earlier than in the previous LOFW-LOCA case (Case A) since a deep core uncovery was observed in that case. An earlier opening of the valves is warranted since the case presented earlier (Case A) did not depressurize low enough to activate the safety injection signal, since the degree of depressurization is governed by the core temperature at the time the PORV's are opened. That temperature defines the saturation pressure and the point at which specific volume increases from void formation force a repressurization. So an earlier opening of the valves will permit a greater degree of depressurization.

The limiting analysis results are obtained using the same initial portion of the transient documented in Case A, except that in this case all the PORV's were held opened slightly after the time the PORV setpoint is reached, some 200 seconds earlier than in the previous case. In this small PORV blowdown analysis case, the subcooled blowdown depressurizes the plant to a point below the safety injection signal setpoint and safety injection begins after a 25 second delay which accounts for getting the diesels and pumps up to speed. The safety injection starts to deliver about 38 lbm/sec before the subcooled blowdown period has ended.

All the PORV's are held open at 2500 seconds after the main feedwater has been lost. The resultant subcooled blowdown period lasts until about 2600 seconds when the pressure has decreased to saturation at 1668 psia. The safety injection comes on during the subcooled blowdown period, at about 2580 seconds and begins delivering about 38 lbm/sec. When the pressure has reached saturation, voids begin forming in the core and begin flowing to the pressurizer. This causes the PORV discharge to switch from subcooled to two phase at about 2650 seconds. The vessel mixture level begins to drop and reaches the surge line elevation at about 2800 seconds. The intermittent steam flow in the surge line results in the PORV discharge switching to intermittent two phase fluid and steam at about 2835 seconds.

During the intermittent PORV discharge period, two phase fluid still flows in the hot legs. The voids begin to collect and phase separation starts to drain the downhill steam generator tube region at about 2962 seconds. Meanwhile, the intermittent two phase and steam flow in the surge line raises the pressurizer mixture quality to about 4.76 percent. The mixture level in the vessel begins to drop below the surge line at about 31"0 seconds. The upper head also begins to drain at about this time. The falling mixture level results in 100 percent steam flow to the pressurizer which results in the PORV discharge switching to all steam at about 3200 seconds.

During the steam PORV discharge period the vessel mixture level reaches the hot leg elevation at about 3450 seconds and intermittent two phase fluid and steam flows into the loops. At about 3460 seconds natural circulation type flow is lost. The upper head fully drains at about 4750 seconds permitting steam to flow into the upper downcomer. At about 4785 seconds the primary pressure begins to decrease because the decay heat has decreased enough so that the safety injection mass and the associated subcooling is sufficient to make up for the specific volume increases.

In this case, the pressurizer surge line steam flow is insufficient to prevent counter-current draining once the primary pressure begins to decrease and the pressurizer mixture level begins to fall at about 5100 seconds. The decreasing primary pressure reduces the saturation temperature and by 6170 seconds the secondary steam, which had been superheated, begins to decrease as heat flows into the primary from the secondary.

By 7265 seconds the steam generator tubes have completely drained and the loop seal begins to drain at 7365 seconds. The continuing pressure decrease allows greater and greater amounts of HPSI to deliver which effectively stops the draining process and begins refilling the system at about 7550 seconds. At 8270 seconds the uphill steam generator tube region reaches its maximum mixture quality of about 67 percent. The loop seal refills by 8673 seconds which is followed by the downhill steam generator tube region beginning to refill at 8860 seconds. Some small pressure oscillations are observed starting at about 9200 seconds as the system refills.

This case, Case B of the small PORV blowdown transient, exhibits many of the features of the previous LOFW-LOCA transient, but there are a few notable differences, basically due to the fact that safety injection was sufficient to permit recovery of the plant.

The initial depressurization rate in this case is the same as the previous case, except that Case B deperssurizes to a much lower saturation pressure. This limiting case depressurizes to a pressure of about 1668 psia which corresponds to a core fluid temperature of about 609°F while Case A depressurizes to about 1900 psia for a core temperature of 629°F.

Once saturation is reached in both cases, the systems repressurize since the subcooled break flow is unable to compensate for the specific volume increases caused by void formation. The degree of repressurization is greater in Case A because there was a longer period of subcooled surge line flow due to fluttering of the PORV's.

The degree and rate of two phase repressurization is slightly less severe in Case A and this may be attributed to the difference in core void formation and the differences in core bubble rise velocity due to the different pressures. The limiting case is at a lower pressure so there is a higher bubble rise velocity which permits a faster phase separation. This results in the vessel mixture level dropping to the surge line earlier when compared to the time the PORV's were opened. So, intermittent two phase and steam begins flowing to the pressurizer earlier once the PORV's are opened in Case B. The intermittent two phase fluid and steam flow period flows more steam in Case B than in Case A, and so the pressurizer void fraction is forced to its maximum earlier. The length of time that the vessel mixture level hangs at the surge line elevation is only about 210 seconds in Case B while it is about 275 seconds in Case A. The maximum void fractions are about the same in each case, but are slightly different due to the differing pressures.

The steam PORV discharge repressurization is much less severe in case B because of the safety injection. The sensible heat sink provided by the subcooling reduces the rate of void formation. Furthermore, there is a higher latent heat of vaporization. Since the specific volume increases are lower, the repressurization rate is lower. Once the upper head has drained and the decay heat has decreased sufficiently, the repressurization ends and the pressure decreases. In Case A the pressure only decreases once the core has uncovered. However, Case B shows no core uncovery, and the vessel mixture level remains at the hot legs.

So, the PORV's may be used to recover from a LOFW-LOCA transient by opening them at 2500 seconds, which turns out to be the time that the PORV's had to be opened in WCAP-9600. Opening the valves at this time results in no core uncovery. Whereas in WCAP-9600 the valves were opened about 10 minutes after the steam generator secondaries dried out and a minor core uncovery resulted. In this case the PORV's need to be opened about 5 minutes after the steam generator secondaries dry out.

B. Feed & Bleed Operation

The second single operator action considered to mitigate the loss of feedwater induced LOCA was the manual initiation of safety injection flow forcing a feed and bleed mode of recovery. That is, the operator manually initiates safety injection thereby feeding the plant with safety grade charging flow, while the PORV's sit and flutter as they may normally be expected to do which bleeds mass from the system.

In this case (Case C), the same plant was examined that was analyzed in Cases A and B of the small PORV LOFW-LOCA blowdown analysis, except that the safety injection was changed to be manually initiated at 3000 seconds. The safety injection was assumed to consist of a maximum composite undegraded safety grade charging flow which had all trains delivery, i.e. all three charging pumps operating. The flow rate assumed was the maximum safety grade charging flow rate expected for any Westinghouse design plant. So, this case must be considered an upper bound on the ability of plants with safety grade charging HPSI to recover from a LOFW-LOCA by manually activating the safety injection.

The first portion of the Case A transient was again the starting point, but instead of manually holding open the PORV's, they were allowed to flutter. At 3000 seconds after the main feedwater was lost, the best safety grade charging flow is manually initiated. The subcooled fluid which surged into the pressurizer and caused the PORV's to begin to flutter continues the insurge. The PORV discharge continues to be subcooled as the valves open and close relieving the pressure. The specific volume increases caused by heating of the subcooled primary fluid and the injected fluid may be compensated for by an intermittent opening and closing of the valves. This intermittent subcooled PORV discharge period continues until about 3950 when the core fluid temperature has risen to saturation at 2335 psia, and voids begin to form in the core.

The fluttering PORV discharge switches from subcooled fluid to two phase fluid at about 4000 seconds. The voids formed in the core begin separate phases and the vessel mixture level begins to drop. The downhill steam generator tube region mixture level begins to drop at about 4010 seconds while natural circulation type flow is predicted to cease at about 4020 seconds. In this case, the pressurizer is subjected to a slow prolonged surge of two phase fluid as the vessel mixture level drops. Although the two phase PORV discharge results in a pressurization above the PORV setpoint, the increasing surge line flow quality is carrying in larger amounts of steam and the void fraction is increasing. At 4230 seconds the vessel mixture level drops to the surge line elevation, but only hangs there momentarily since the pressurizer void fraction has accumulated during the extended fluttering and is very near the maximum. At 4310 the vessel mixture level has dropped below the surge line elevation.

The PORV discharge enters into an intermittent two phase fluid and steam flow period. The steam PORV discharge at this time is about 100 lbm/sec. Meanwhile, the vessel mixture level has dropped to the hot leg elevation at 4405 seconds. The loop seal exhibits a brief mixture level reduction spike at 4481 seconds. The pressurizer in this case is predicted to begin to drain starting at about 4530 seconds and the upper head begins to drain at about 4886 seconds.

The PORV discharge shifts to all steam at about 5800 seconds. The upper head has completely drained by 6330 seconds which permits steam to flow to the upper downcomer. The pressurizer which began to drain at 4530 seconds completely drains by about 8430 seconds. Again, in this case, the reduced steam surge line flow is insufficient to prevent countercurrent drain back. In this case, however, the lower surge line flow rate is due to the fact that the PORV's are only intermittently open, whereas Case B of the small PORV blowdown had reduced surge line flow because the pressure was lower. The safety injection continues to deliver about 40 lbm/sec to the system, while the break is removing about 75 lbm/sec whenever the PORV's are open. The integrated effect of the PORV openings and closings is a PROV mass discharge rate of about 45 lbm/sec of continuous flow.

This case was run out to 10,000 seconds. Even at that time, the integrated effect of PORV discharge had not equaled the best safety injection mass flow. The downhill steam generator tube region was still draining, while the decay heat is down to about 1 percent of the full power level and is decreasing only very slowly. So, it is likely that the system drain will continue. The vessel mixture level is still at or above the hot leg elevation, but the fact that the system is still draining can only lead to the conclusion that the best safety injection will result in only a marginal system ability to keep the core covered to 10,000 seconds. The safety injection could have been manually initiated early, but that would only serve to extend the transient. The same system mass inventory would be reached but at a later time.

Since this case (Case C) yielded a marginal ability to keep the core covered and since the uncertainties in the calculation such as PORV capacity, are large compared to the margin in ability to keep the core covered, Westinghouse does not recommend this mode of operating the plant following the loss of steam generator heat sink. This method could be used to forestall holding open the PORV's if there is positive assurance that auxiliary feedwater would be available.

6.0 RESULTS - PLANT WITHOUT SAFETY GRADE CHARGING FLOW

The small PORV blowdown analysis has given an indication that depressurizing below the safety injection setpoint in order to activate the safety injection flow is very important to mitigating the LOFW-LOCA effects. A bounding calculation was perfomred for the single operator action of opening the PORV's in plants without safety grade charging flows. This is presented as Case D.

Plants which have low shutoff head HPSI are lower in power than the previous cases and the PORV capacities are larger. So, the low shutoff head HPSI PORV blowdown analysis will examine a plant which has a steady-state 100 percent core power level of 3025 MWt, top hat design upper support plate, thermal shield, downflow barrel baffle, Model 93 reactor coolant pump, Series 44 steam generator, and 15 x 15 generic fuel. A PORV capacity of 139 (lbm/hr)/MWt corresponding to a total flowrate of 420,000 lbm/sec of saturated steam at 2335 psia was incorporated. This is the minimum PORV capacity observed for low shutoff head HPSI plants. Again, minimum safeguards safety injection without a spilling line was incorporated in the analysis, except now the effective shutoff head in the analysis was 1470 psia.

In the low shutoff head HPSI PORV blowdown analysis, the PORV's had to be held open at 1500 seconds after the loss of main feedwater in order to keep the core adequately covered. The core fluid temperature at the time the PORV's were opened in this case was only 566°F. The subcooled blowdown period extended from 1500 to 1622 seconds. The safety injection signal and delay result in the delivery of about 53 lbm/sec starting at 1566 seconds.

The PORV discharge is effectively subcooled from 1500 to 1760 seconds. The primary saturation pressure of 1197 psia is reached at about 1620 seconds, while the downhill steam generator tube region begins to drain at about 1630 seconds which also corresponds to a momentary two phase mixture spike in the loop seal. The initial maximum safety injection delivery rate of 58 lbm/sec is reached at 1735 seconds, but the PORV discharge rate is much larger at about 180 lbm/second.

A two phase fluid PROV discharge begins at 1760 seconds and lasts until 1870 seconds. At 1811 seconds the upper head begins to drain. The upper regions appear to drain earlier in this case than in the previous cases because the PORV's are larger. The vessel mixture level drops rapidly past the surge line and an intermittent but mostly steam surge line flow results driving the pressurizer void fraction to its maximum very rapidly. The mixture level is at the surge line at about 1950 seconds, and effectively reaches the hot leg elevation at about 3640 seconds. During this time the upper head drains at about 3075 seconds. This case did not exhibit any core uncovery.

The low shutoff head HPSI PORV case does not exhibit an extensive repressurization because of the low pressures and large amount of sub-cooling safety injection flow. So even though there is a two phase break flow period the sensible heat subcooling and larger PORV capacity can accommodate the specific volume increases. The system enters the steam PORV discharge period at 4850 seconds and the PORV discharge is exceeded by the safety injection at about 5000 seconds.

7.0 TMI-2 INCIDENT

The Three Mile Island Unit 2 incident is not suitable for use as a verification of the Westinghouse LOFW-LOCA model because of a number of complicating issues. However, some of the trends indicated in the early portion of the incident are similar to the results predicted in this LOFW-LOCA analysis report. The purpose of this section is to relate some of the TMI-2 incident trends to the behavior of Westinghouse plants predicted in this report.

The simplistic model (single operator action, multiple failure, etc.) developed in this report for application to LOFW-LOCA transients is incapable in its present form of handling the number of operator and non-operator actions which took place during the TMI-2 incident. Furthermore, the TMI-2 once through steam generators accentuate the loss of feedwater events tending to speed the transient events and perhaps washout some of the observable results presented in this report. However, this section will attempt to make some comparisons between the LOFW-LOCA predicted events, and the observed TMI-2 behavior.

The TMI-2 incident began with a problem in the condensate polishing tank which led to the loss of main feedwater when the main feedwater pumps tripped. The auxiliary feedwater was inadvertently valved out. The plant was effectively subjected to a complete loss of feedwater transient as put forth in this report. The loss of secondary heat sink leads to a much more rapid series of events in the TMI-2 plant since the steam generators contain a comparatively small secondary mass. The first 8 minutes of the transient, prior to activation of auxiliary feedwater, will provide an indication of some of the LOFW-LOCA trends. Once the auxiliary feedwater is initiated, the comparability ends because the LOFW-LOCA model did not assume two operator actions, i.e., holding the PORV's open and starting auxiliary feedwater.

The early sequence of events differs from the projected Westinghouse response due to the rapid feedback effects of the TMI-2 once through steam generators (OTSG). The turbine trips almost immediately upon the loss of main feedwater, but the core remains at full power for 8 seconds forcing the primary pressure to increase lifting the PORV's. Once the PORV fails to reseat after the core trips, the transient resembles the subcooled blowdown portion of the LOFW-LOCA analysis, except that the blowdown is not as rapid since only one PORV remains open. The pressure continues a slow subcooled blowdown until the pressure reaches saturation at 1350 psia at about 6 minutes (Figure E-1). The pressure then begins to climb until the auxiliary feedwater is started at 8 minutes.

The pressurizer mixture level (Figure E-2) exhibits a rapid rise as fluid surges in during the powered pressurization. The mixture level then drops as the mixture shrinks after the reactor trips. This behavior is exhibited even though one PORV is stuck open. As the temperatures begin to climb, the pressurizer mixture level begins to rise. Subcooled fluid begins to surge into the pressurizer as a combination of swell and break flow. This continues until the pressurizer becomes water solid.

The temperatures (Figure E-3) begin to rise during the powered pressurization period, and then they drop to a quasi-equilibrium state as decay heat is being removed through the PORV and the degrading steam generators. The temperatures begin a slow rise as the steam generators dry out at about 1 minute. The temperature rise continues until the safety injection is started at about 3 minutes. Once the safety injection begins, the temperatures stabilize as the injected mass absorbs some decay heat sensibly. When the safety injection is terminated at about 4.5 minutes, the temperatures begin a dramatic rise. Finally, the temperatures begin to decrease at 8 minutes when the auxiliary feedwater is initiated.

The most interesting observed behavior during the first 8 minutes of the TMI-2 transient is the subcooled blowdown depressurization giving way to a repressurization once the pressure has reached saturation. This exact phenomena is predicted by the LOFW-LOCA analysis report. Clearly, a single stuck open PORV is incapable of compensating for the specific volume increases once saturation conditions have been reached. One of the most important predictions of the LOFW-LOCA analysis report is observed in the TMI-2 incident.

The TMI-2 temperature profiles behave virtually as expected. They rise during the powered pressurization, drop rapidly after trip, remain fairly constant during the safety injection period, and rising rapidly once safety injection is terminated. The LOFW-LOCA analysis report replicates the powered pressurization, and trip depressurization effects on the temperatures. The temperature rise once saturation is reached is predicted and matches the period when safety injection has been terminated. None of these are surprising in themselves. An interesting feature though, is the temperature stabilization during the safety injection period. The safety injection is able to absorb enough decay heat through sensible heat that the temperature does not rise. This is an additional and important feature to the plant recovery. It is important to not only put mass into the system, but to add the sensible heat sink.

The pressurizer mixture level rises in the TMI-2 incident, but the reasons are slightly different from the LOFW-LOCA report. The LOFW-LOCA analysis report predicts a surge into the pressurizer as the system heats up and swells. The insurge continues and holds the mixture level near the top once the PORV's begin to flutter or are held open. In the TMI-2 case, the level rises. The level is maintained near the top for the same reasons as the LOFW-LOCA case.

8.0 OVERALL CONCLUSIONS

The bounding calculations for operator action time in the loss of feedwater induced LOCA scenario have been performed for a single operator action. The analyses presented in this LOFW-LOCA analysis report in conjunction with the analysis performed in WCAP-9600 should bound all Westinghouse design plants for single operator action in the event of the complete loss of feedwater.

These analyses used best engineering judgment to set up the models.

Three single operator actions were considered and the minimum operator action times which would preclude significant core damage were determined for each case:

1. Establish Effective Feedwater (WCAP-9600)

   In this case the operator had until just before core uncovery to establish effective auxiliary feedwater to depressurize and prevent core uncovery. That specific analysis presented a minimum time of 4000 seconds.

2. Opening PORV's to Blowdown (LOFW-LOCA Report)

   If the operator decides to depressurize by blowing down through the PORV's, he must open all the PORV's 5 minutes after S.G. dryout or before in plants with safety grade charging flow. Specifically, the analysis indicates that opening all the PORV's by 2500 seconds should yield acceptable results. Delaying opening the PORV's until 2700 seconds will result in a deep and prolonged core uncovery. If charging flow is not assumed, the PORV's must be opened before steam generator dryout when there is still significant level in order to calculate acceptable results. The PORV heat sink must be established prior to losing the steam generator heat sink. Specifically, the analysis indicates that the PORV's must be opened at 1500 seconds. Delaying opening the PORV's until 1750 seconds results in a deep and prolonged core uncovery. All the PORV's must be opened if that course of action is taken. Opening only one PORV will yield a deep and prolonged core uncovery.

To reiterate, plants may recover from a LOFW-LOCA transient if the operators take action to hold the PORV's open 5 minutes after S.G. dryout in plants with safety grade charging pumps, and 4 minutes before S.G. dryout in plants without safety grade charging flow.

3. Manual Initiation of Safety Grade Charging Flow (LOFW-LOCA Report)

If the operator is assumed to manually initiate charging flow as late as 3000 seconds after the loss of all feedwater flow, the maximum safety grade charging flow specified for any Westinghouse four loop NSSS provides only marginal capability for keeping the core covered up to 10,000 seconds.

If the operator chooses to open the PORV's to depressurize, it should be emphasized that the safety injection should be started, or verified as available before the PORV's are opened. Opening the PORV's without the availability of safety injection will result in a deep and prolonged core uncovery.

Also if main feedwater is lost and there is little chance of auxiliary feedwater being available, the operator must open the PORV's before there are any indications of inadequate core cooling from the core exit thermocouples or vessel level. When opening the PORV's prevented core damage, the core damage, the core exit thermocouples indicated temperatures of less than 650°F (subcooled).

It should be noted that the scenarios considered in this report go beyond design basis conditions and that the analyses were performed with evaluation type models. These analyses were performed under a number of conservative assumptions, such as a steady state power level of 102% of core power, 120% of decay heat after trip, early steam generator dryout time, and minimum safeguards in most cases. As such, these analyses represent bounding calculation for the minimum operator action time.

APPENDIX I

DESCRIPTION OF FIGURES

Description of Figures

The analysis plot figures for each case analyzed and miscellaneous tables and figures are described in this appendix.

The following analysis plot figures are common to all four analysis cases considered;

1. RCS Pressure
2. Steam Generator Secondary Pressure
3. Core Mixture Level
4. Upper Head Mixture Level
5. Downcomer Mixture Level
6. Pressurizer Mixture Level
7. Steam Generator Downhill Tube Section Mixture Level
8. Steam Generator Secondary Mixture Level
9. Loop Seal Mixture Level
10. Hot Leg Mass Flow Rate
11. Cold Leg Mass Flow Rate
12. Pressurizer Surge Line Mass Flow Rate
13. Safety Injection Mass Flow Rate
14. Break Mass Flow Rate
15. Steam Generator Safety Valve Mass Flow Rate
16. Hot Leg Fluid Temperature
17. Cold Leg Fluid Temperature
18. Pressurizer Fluid Temperature
19. Steam Generator Secondary Fluid Temperature
20. Hot Leg Flow Quality
21. Cold Leg Flow Quality
22. Pressurizer Surge Line Quality
23. Break Flow Quality
24. Core Mixture Quality
25. Pressurizer Mixture Quality
26. Steam Generator Uphill Tube Section Mixture Quality
27. Steam Generator Secondary Mixture Quality
28. Integral of Break Mass Flow Rate

29. Integral of Break Energy Mass Flow Rate
30. Steam Generator Uphill Tube Section Heat Transfer Coefficient

Case A - This case presents the results of the small PORV blowdown analysis where the PORV's are manually held open at 2700 seconds into the transient and is used for the general description of the LOFW-LOCA phenomena.

Case B - This case presents the results of the small PORV blowdown analysis where the PORV's are manually held open at 2500 seconds. This case represents the bounding case for PORV action for plants with safety grade charging pumps.

Case C - This case presents the results of the small PORV Feed and Bleed analysis where the PORV's are allowed to flutter normally and the best safety grade charging flow is manually initiated at 3000 seconds after the loss of main feedwater.

Case D - This case represents the results of the Low Shutoff Head HPSI PORV blowdown analysis and represents the bounding case for PORV action to mitigate LOFW-LOCA events for plants without safety grade charging flow.

So, Figure C-9 would represent the loop seal mixture level for the Feed and Bleed analysis.

The following additional plots and tables are contained in this report;

1. Table 1 - Presents a compilation of some Westinghouse design plants and key LOFW-LOCA parameters

2. Figure E-1 - Presents the first 8 minutes of the pressure transient of TMI-2 LOFW-LOCA.

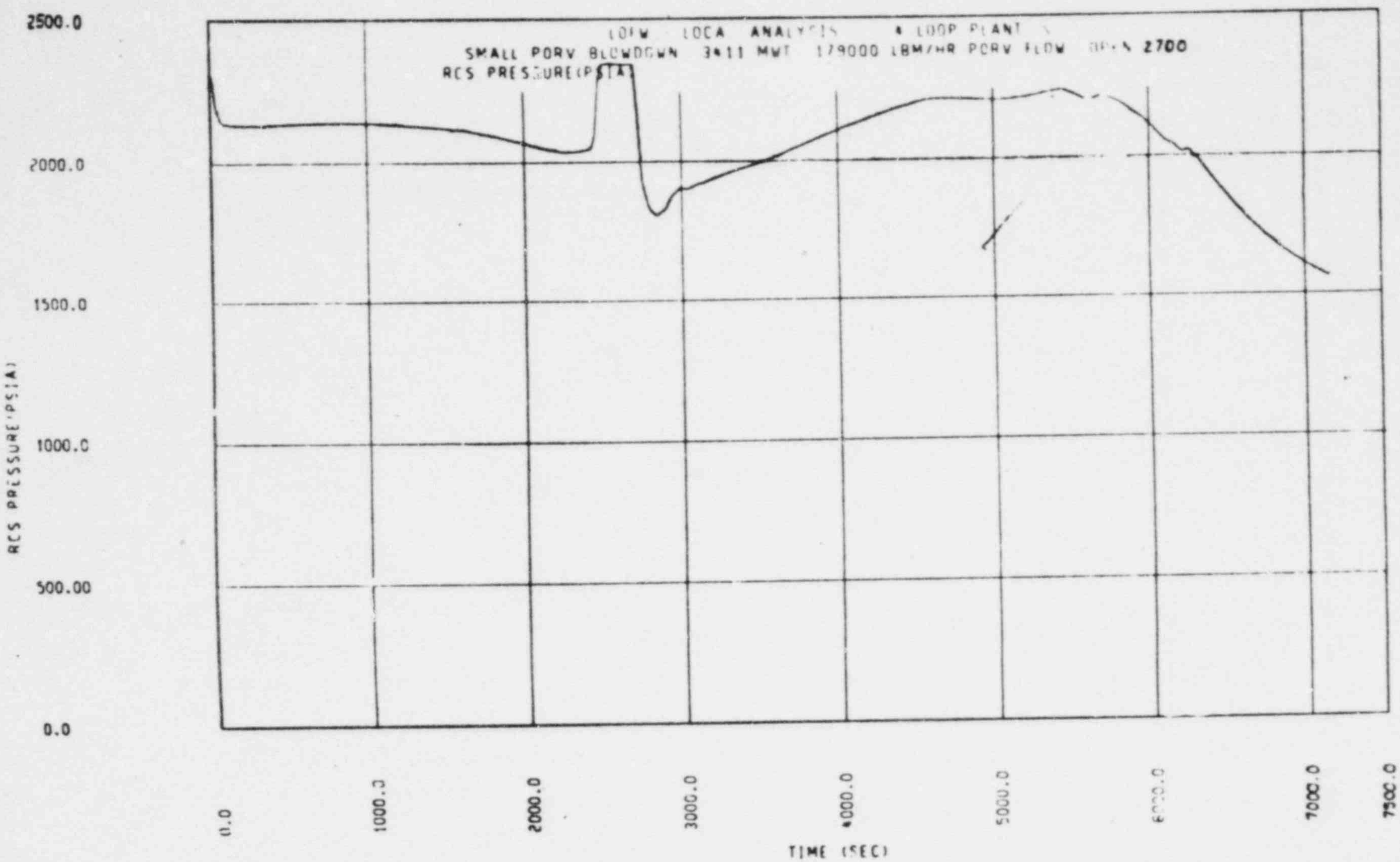
3. Figure E-2 - Presents the pressurizer mixture level during the first 8 minutes of the TMI-2 LOFW-LOCA.

4. Figure E-3 - Presents the Loop B hot & cold leg temperature profiles for this first 8 minutes of the TMI-2 LOFW-LOCA.

TABLE 1

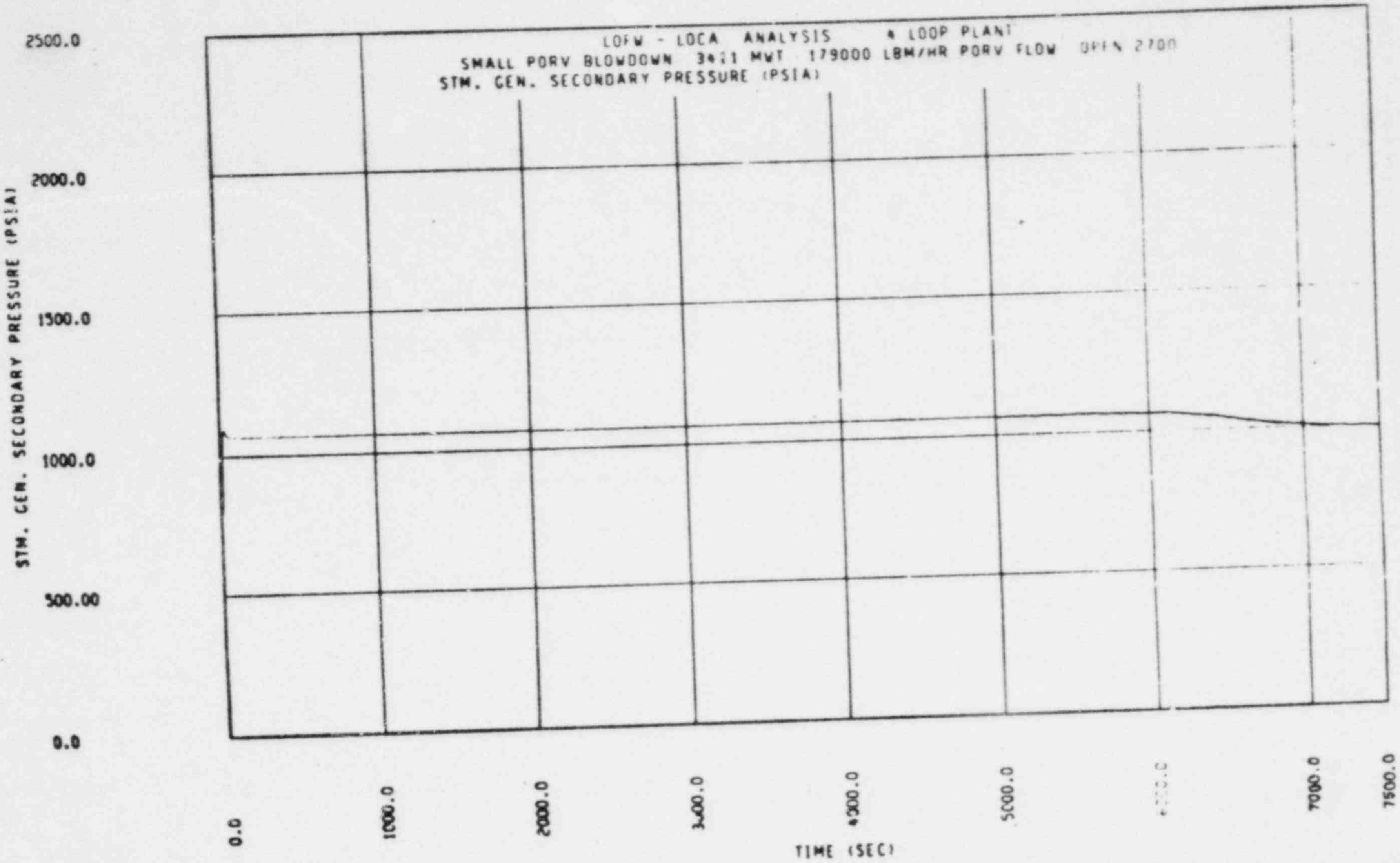
PORV BLOWDOWN COMPARISON

PLANT	# LOOPS	POWER (MWt)	VOLUME RATIO (FT /MWt)	PORV CAPACITY (LB/HR)/MWt	SG/DRYOUT (SEC)	SI SHUTOFF HEAD (PSIA)
WCAP-9600	2	1876	3.44	190.83	D3/1900	2200 +
SCE	3	1347	5.15	160.36	27/1180	1200
PORV-BLOWDOWN	4	3411	3.70	104.95	51/2182	2600
INT	4	3025	3.98	138.84	44/1752	1517
IPP	4	2758	4.43	152.28	44/1890	1517
COM/CWE	4	3250	3.69	129.23	51/2748	2600
WAT/WBT	4	3411	3.67	104.95	D3/NA	2600
[illegible]	3	2200	4.25	190.90	44/1920	1430
FPL/FLA	3	2208	4.23	190.22	44/1878	1517
RGE	2	1520	4.11	235.53	44/1740	1485
KOR	2	1724	3.46	204.18	51/NA	1517
NSP	2	1650	3.91	254.5	51/1482	2168
WPS	2	1650	3.75	254.5	51/2652	2167
WEP/WIS	2	1518.5	4.25	213.33	44/2400	1539



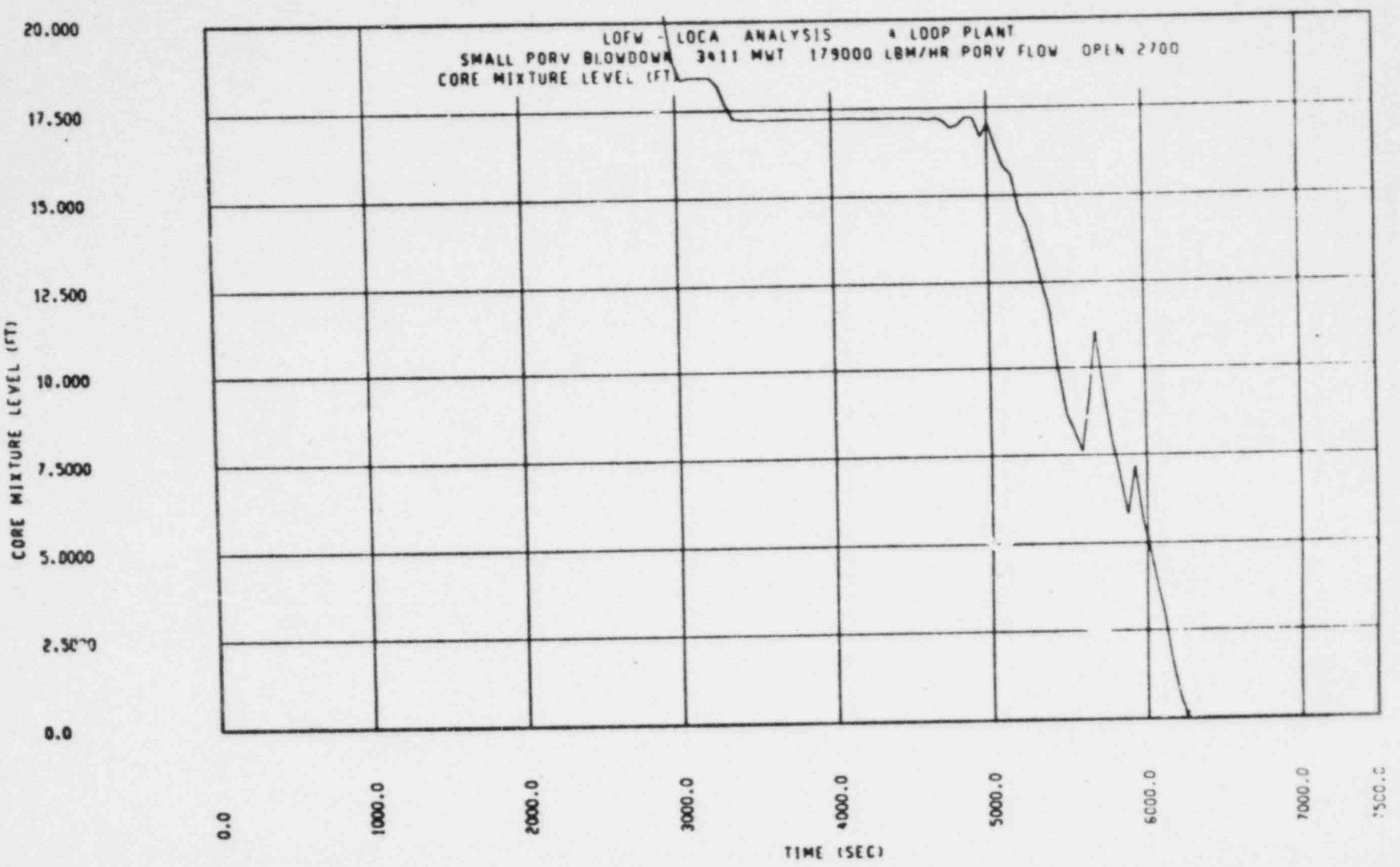
LOFW LOCA ANALYSIS 4 LOOP PLANT
SMALL PORV BLOWDOWN 3411 MWT 179000 LBM/HR PORV FLOW OPEN 2700
RCS PRESSURE(PSIA)
2500.0
2000.0
1500.0
1000.0
500.00
0.0
RCS PRESSURE(PSIA)
0.0
1000.0
2000.0
3000.0
4000.0
5000.0
6000.0
7000.0
7500.0
TIME (SEC)

FIGURE A - 1



LOFW - LOCA ANALYSIS 4 LOOP PLANT
SMALL PORV BLOWDOWN 3411 MWT 179000 LBM/HR PORV FLOW OPEN 2700
STM. GEN. SECONDARY PRESSURE (PSIA)
STM. GEN. SECONDARY PRESSURE (PSIA)
2500.0
2000.0
1500.0
1000.0
500.00
0.0
0.0
1000.0
2000.0
3000.0
4000.0
5000.0
7000.0
7500.0
TIME (SEC)

FIGURE A - 2

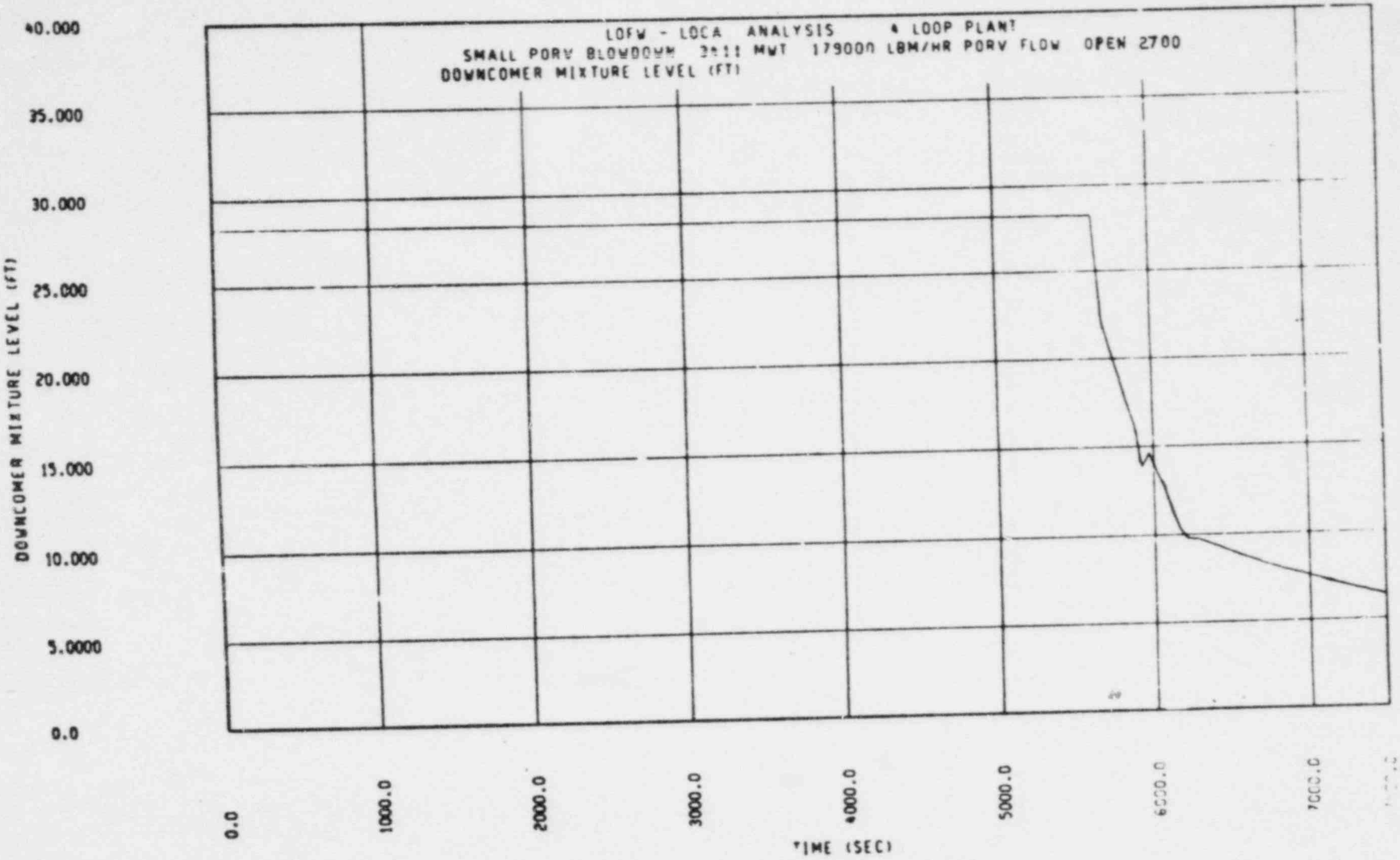


LOFW - LOCA ANALYSIS 4 LOOP PLANT
SMALL PORV BLOWDOWN 3411 MWT 179000 LBM/HR PORV FLOW OPEN 2700
CORE MIXTURE LEVEL (FT)
20.000
17.500
15.000
12.500
10.000
7.5000
5.0000
2.5000
0.0
CORE MIXTURE LEVEL (FT)
0.0
1000.0
2000.0
3000.0
4000.0
5000.0
6000.0
7000.0
7500.0
TIME (SEC)

FIGURE A - 3

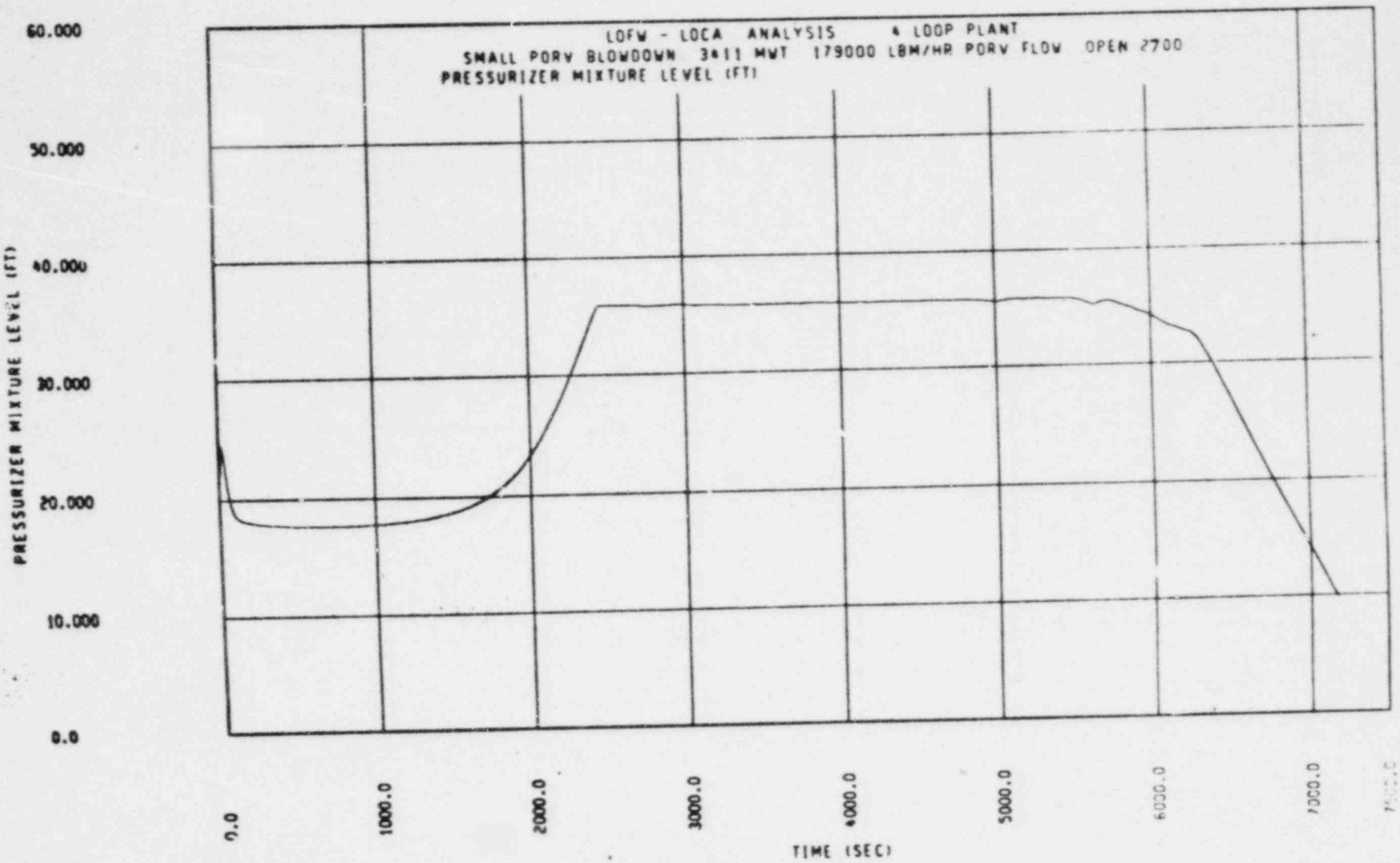

LOFW - LOCA ANALYSIS 4 LOOP PLANT
SMALL PORV BLOWDOWN 3411 MWT 179000 LBM/HR PORV FLOW OPEN 2700
UPPER HEAD MIXTURE LEVEL (FT)
10.000
8.0000
6.0000
4.0000
2.0000
0.0
UPPER HEAD MIXTURE LEVEL (FT)
0.0
1000.0
2000.0
3000.0
4000.0
5000.0
6000.0
7000.0
7500.0
TIME (SEC)

FIGURE A - 4



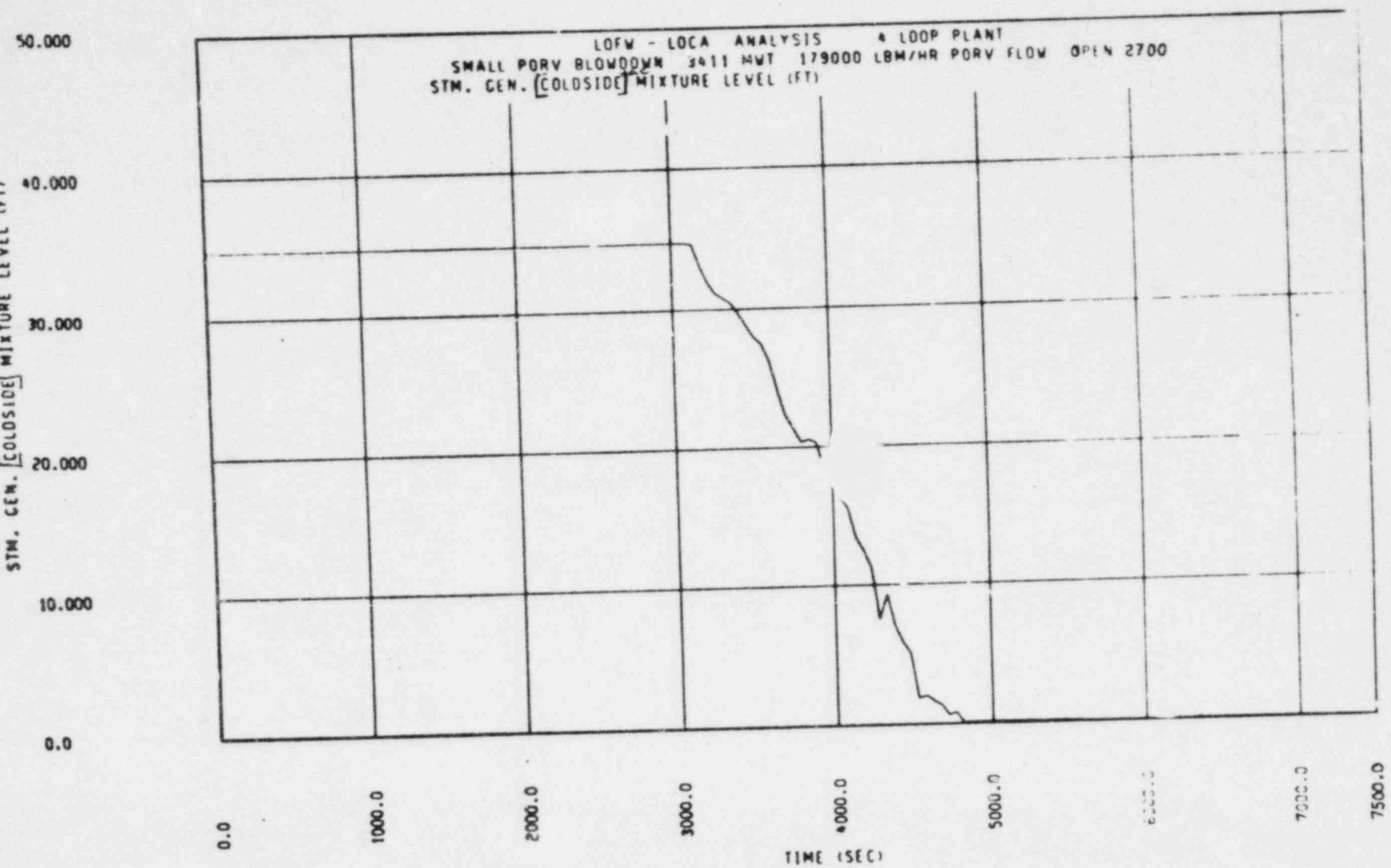
LOFW - LOCA ANALYSIS 4 LOOP PLANT
SMALL PORV BLOWDOWN 3411 MWT 179000 LBM/HR PORV FLOW OPEN 2700
DOWNCOMER MIXTURE LEVEL (FT)
40.000
35.000
30.000
25.000
20.000
15.000
10.000
5.0000
0.0
DOWNCOMER MIXTURE LEVEL (FT)
0.0
1000.0
2000.0
3000.0
4000.0
5000.0
6000.0
7000.0
TIME (SEC)

FIGURE A - 5



LOFW - LOCA ANALYSIS 4 LOOP PLANT
SMALL PORV BLOWDOWN 3411 MWT 179000 LBM/HR PORV FLOW OPEN 2700
PRESSURIZER MIXTURE LEVEL (FT)
60.000
50.000
40.000
30.000
20.000
10.000
0.0
PRESSURIZER MIXTURE LEVEL (FT)
0.0
1000.0
2000.0
3000.0
4000.0
5000.0
6000.0
7000.0
TIME (SEC)

FIGURE A - 6



LOFW - LOCA ANALYSIS 4 LOOP PLANT
SMALL PORV BLOWDOWN 3411 MWT 179000 LBM/HR PORV FLOW OPEN 2700
STM. GEN. [COLDSIDE] MIXTURE LEVEL (FT)
STM. GEN. [COLDSIDE]a,c MIXTURE LEVEL (FT)
50.000
40.000
30.000
20.000
10.000
0.0
1000.0
2000.0
3000.0
4000.0
5000.0
7000.0
7500.0
TIME (SEC)

FIGURE A - 7


LOFW - LOCA ANALYSIS 4 LOOP PLANT
SMALL PORV BLOWDOWN 3411 MWT 179000 LBM/HR PORV FLOW OPEN 2700
STM. GEN. SECONDARY MIXTURE LEVEL (FT)
120.00
100.00
80.000
60.000
40.000
20.000
0.0
STM. GEN. SECONDARY MIXTURE LEVEL (FT)
0.0
1000.0
2000.0
3000.0
4000.0
5000.0
6000.0
7000.0
TIME (SEC)

FIGURE A - 8

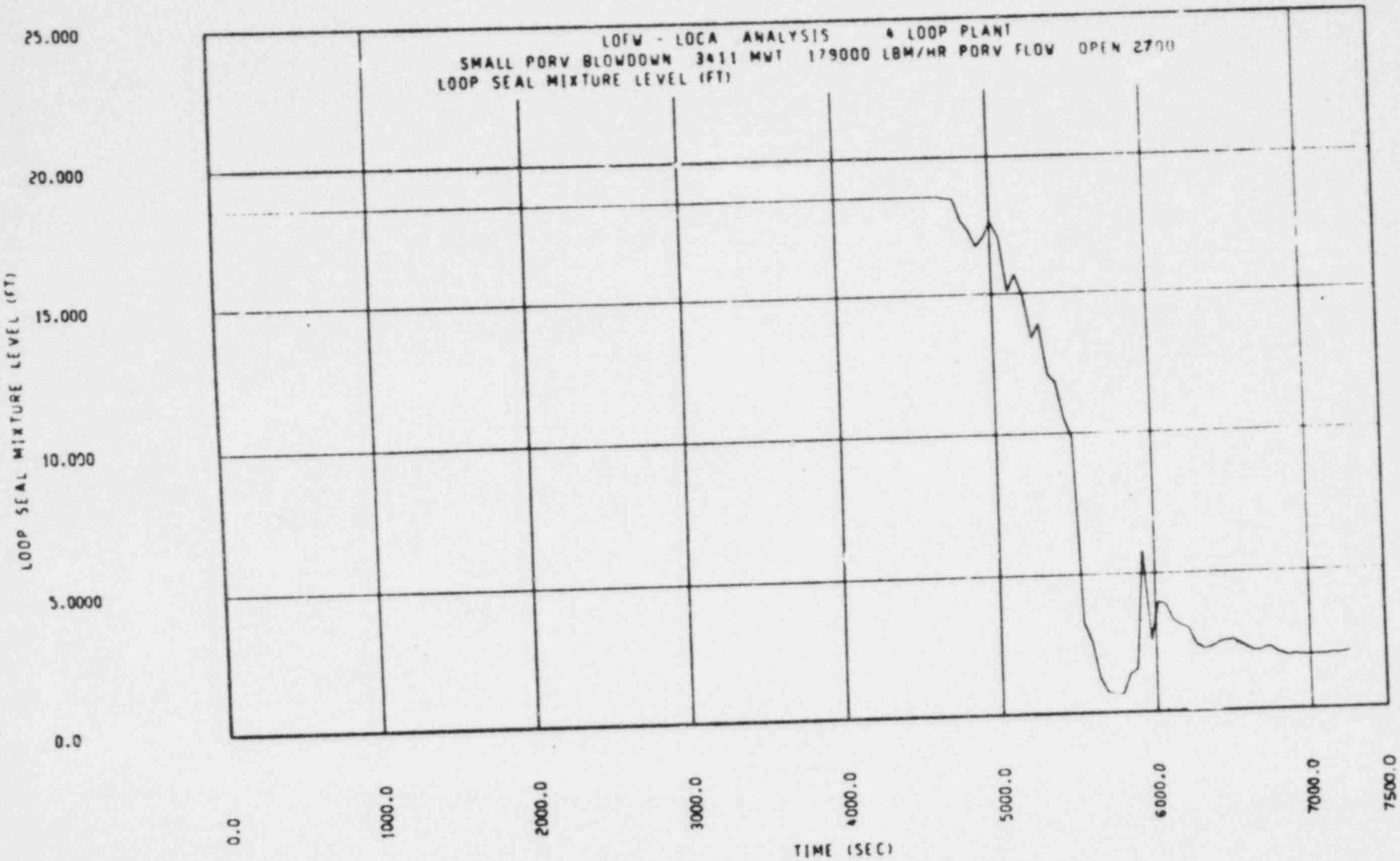
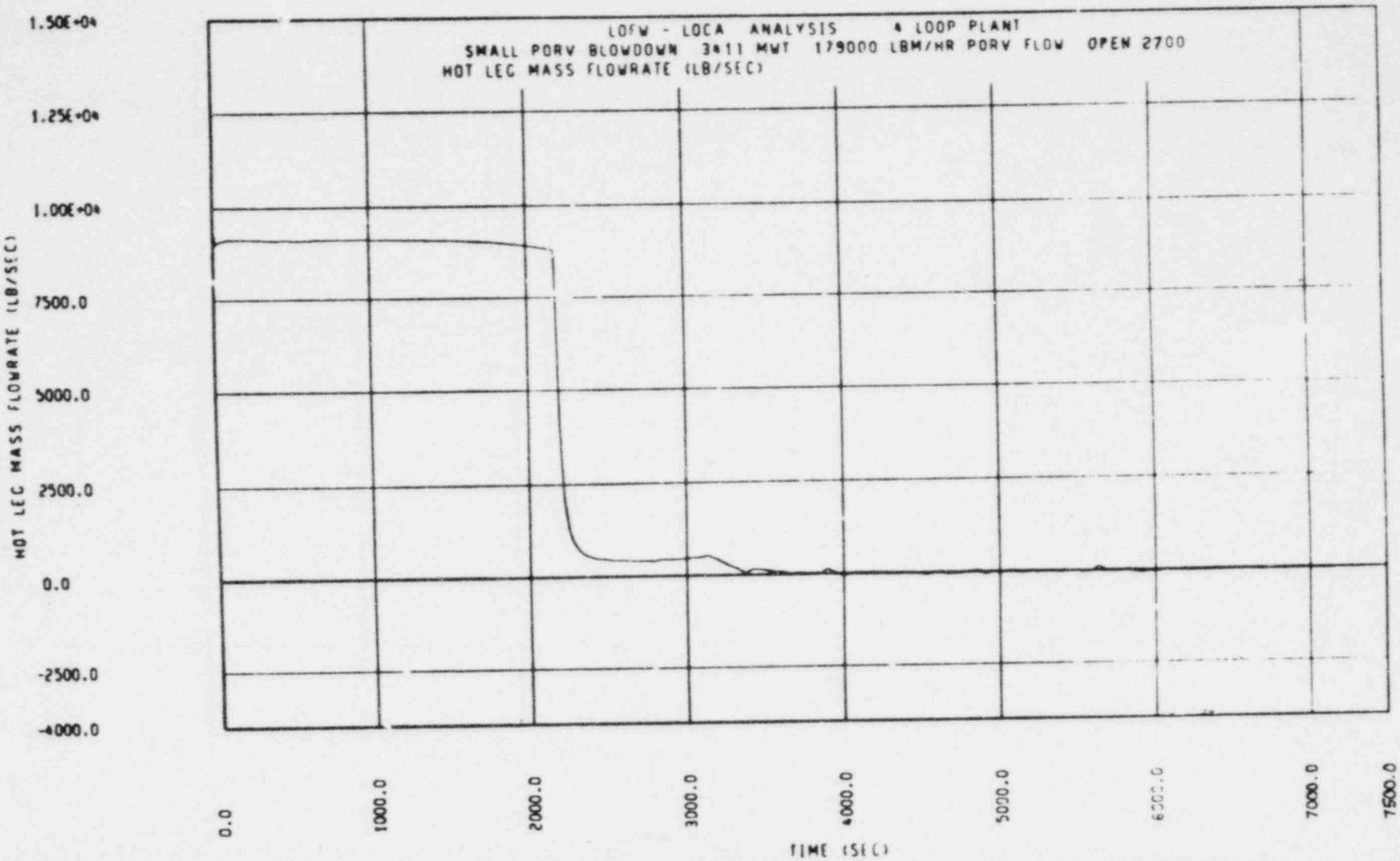

LOFW - LOCA ANALYSIS 4 LOOP PLANT
SMALL PORV BLOWDOWN 3411 MWT 179000 LBM/HR PORV FLOW OPEN 2700
LOOP SEAL MIXTURE LEVEL (FT)
LOOP SEAL MIXTURE LEVEL (FT)
25.000
20.000
15.000
10.000
5.0000
0.0
0.0
1000.0
2000.0
3000.0
4000.0
5000.0
6000.0
7000.0
7500.0
TIME (SEC)

FIGURE A - 9



LOFW - LOCA ANALYSIS 4 LOOP PLANT
SMALL PORV BLOWDOWN 3411 MWT 179000 LBM/HR PORV FLOW OPEN 2700
HOT LEG MASS FLOWRATE (LB/SEC)
1.50E+04
1.25E+04
1.00E+04
7500.0
5000.0
2500.0
0.0
-2500.0
-4000.0
HOT LEG MASS FLOWRATE (LB/SEC)
0.0
1000.0
2000.0
3000.0
4000.0
5000.0
6000.0
7000.0
7500.0
TIME (SEC)

FIGURE A - 10

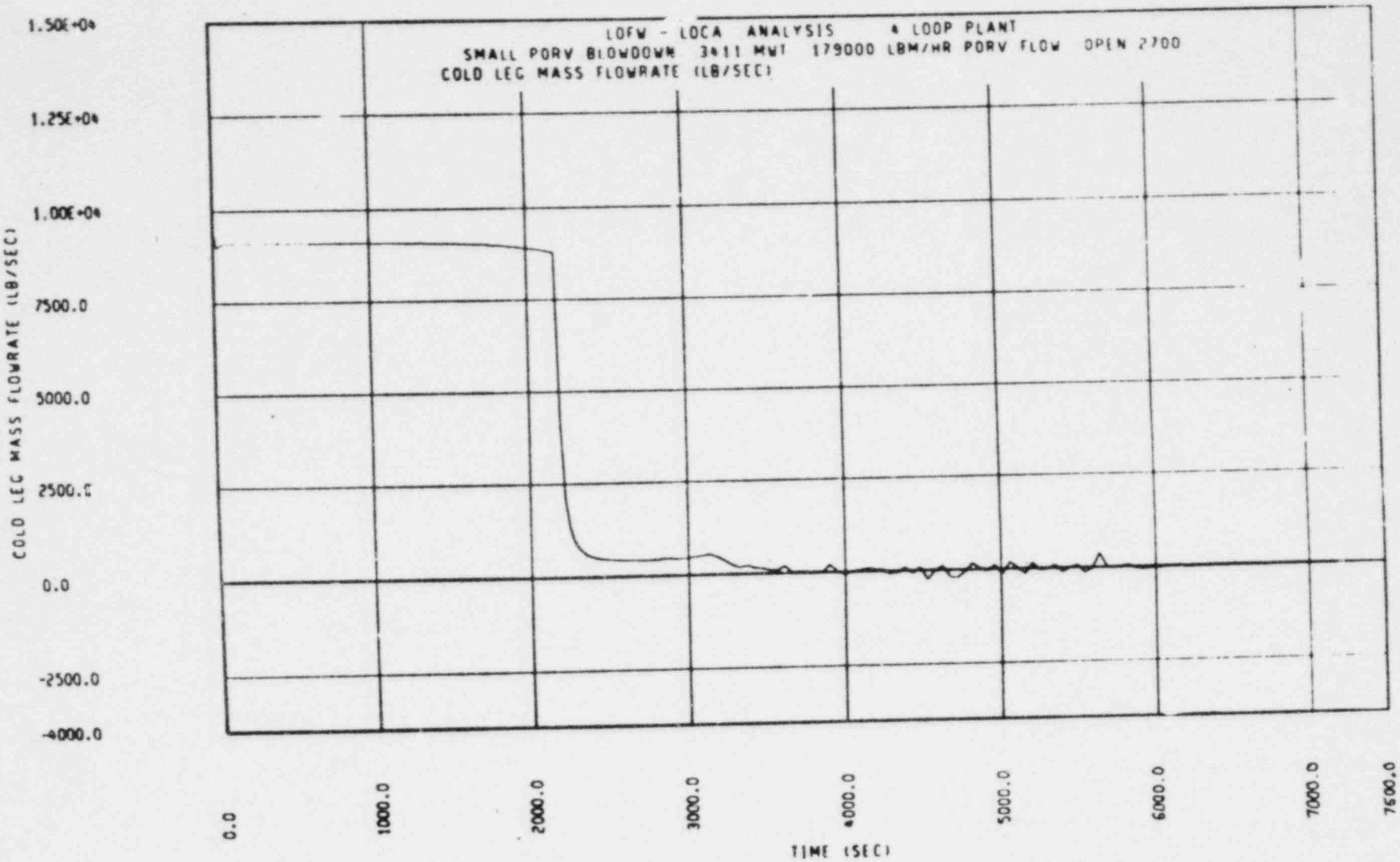

LOFW - LOCA ANALYSIS 4 LOOP PLANT
SMALL PORV BLOWDOWN 3411 MWT 179000 LBM/HR PORV FLOW OPEN 2700
COLD LEG MASS FLOWRATE (LB/SEC)
1.50E+04
1.25E+04
1.00E+04
7500.0
5000.0
2500.0
0.0
-2500.0
-4000.0
COLD LEG MASS FLOWRATE (LB/SEC)
0.0
1000.0
2000.0
3000.0
4000.0
5000.0
6000.0
7000.0
7500.0
TIME (SEC)

FIGURE A - 11

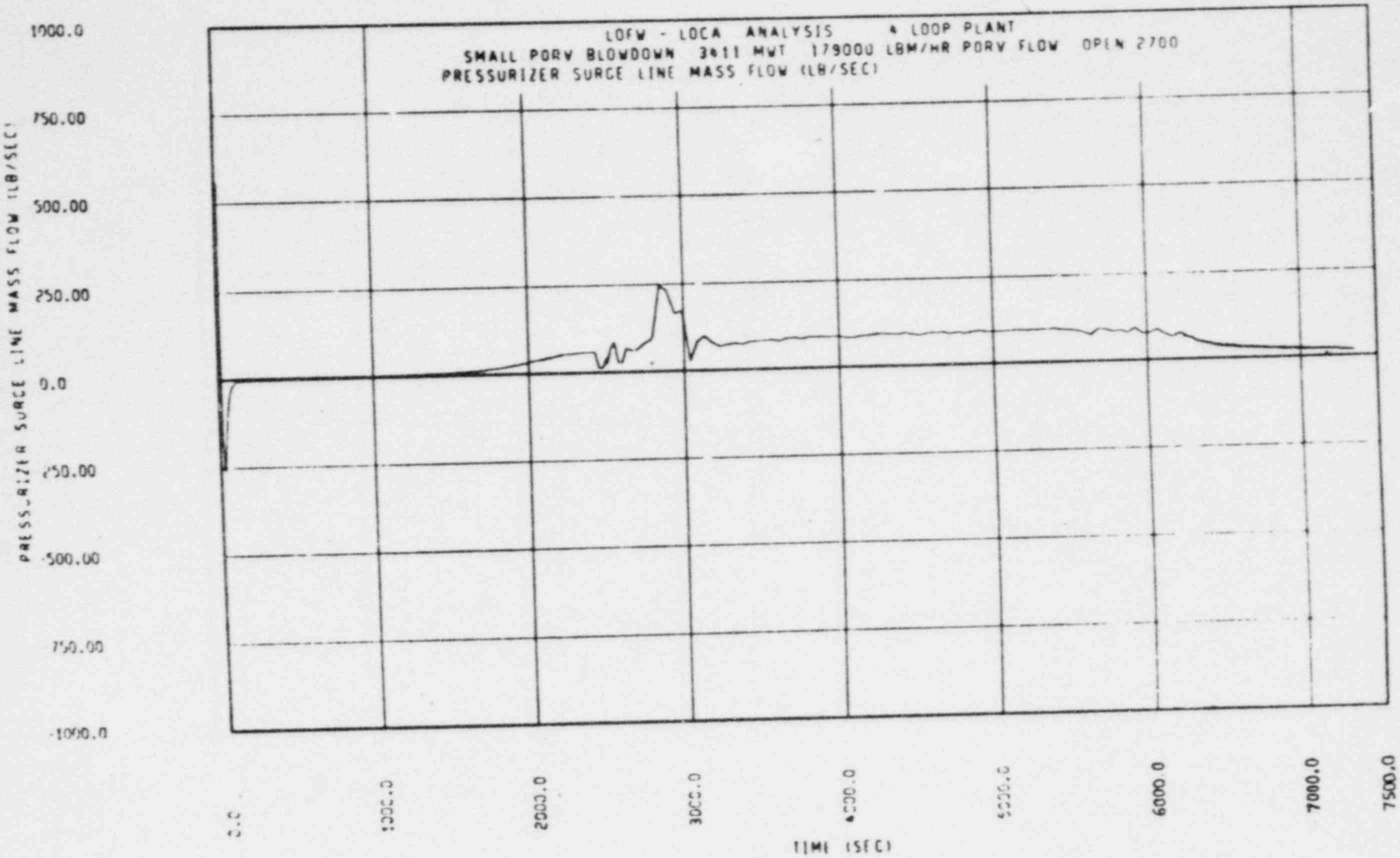
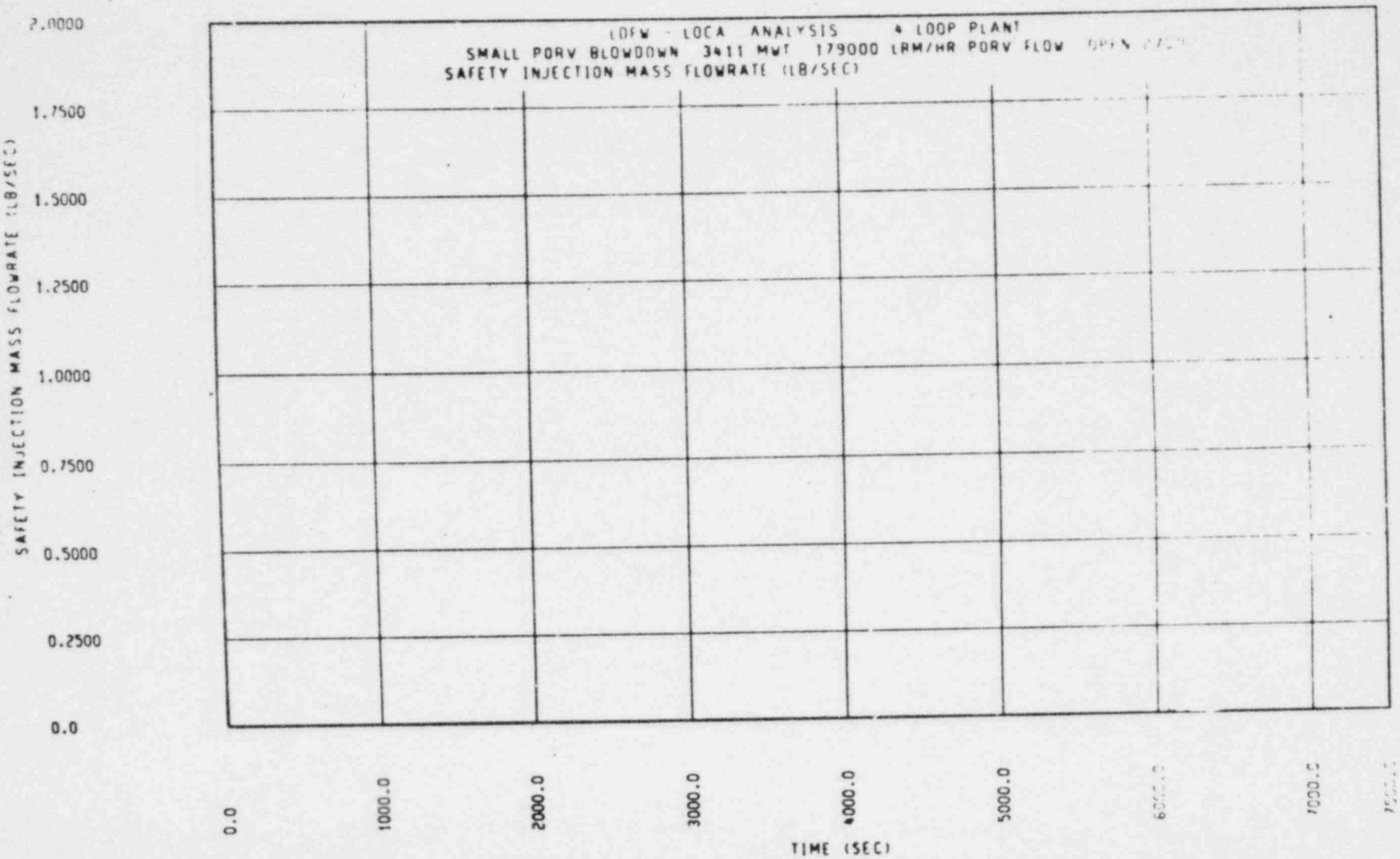
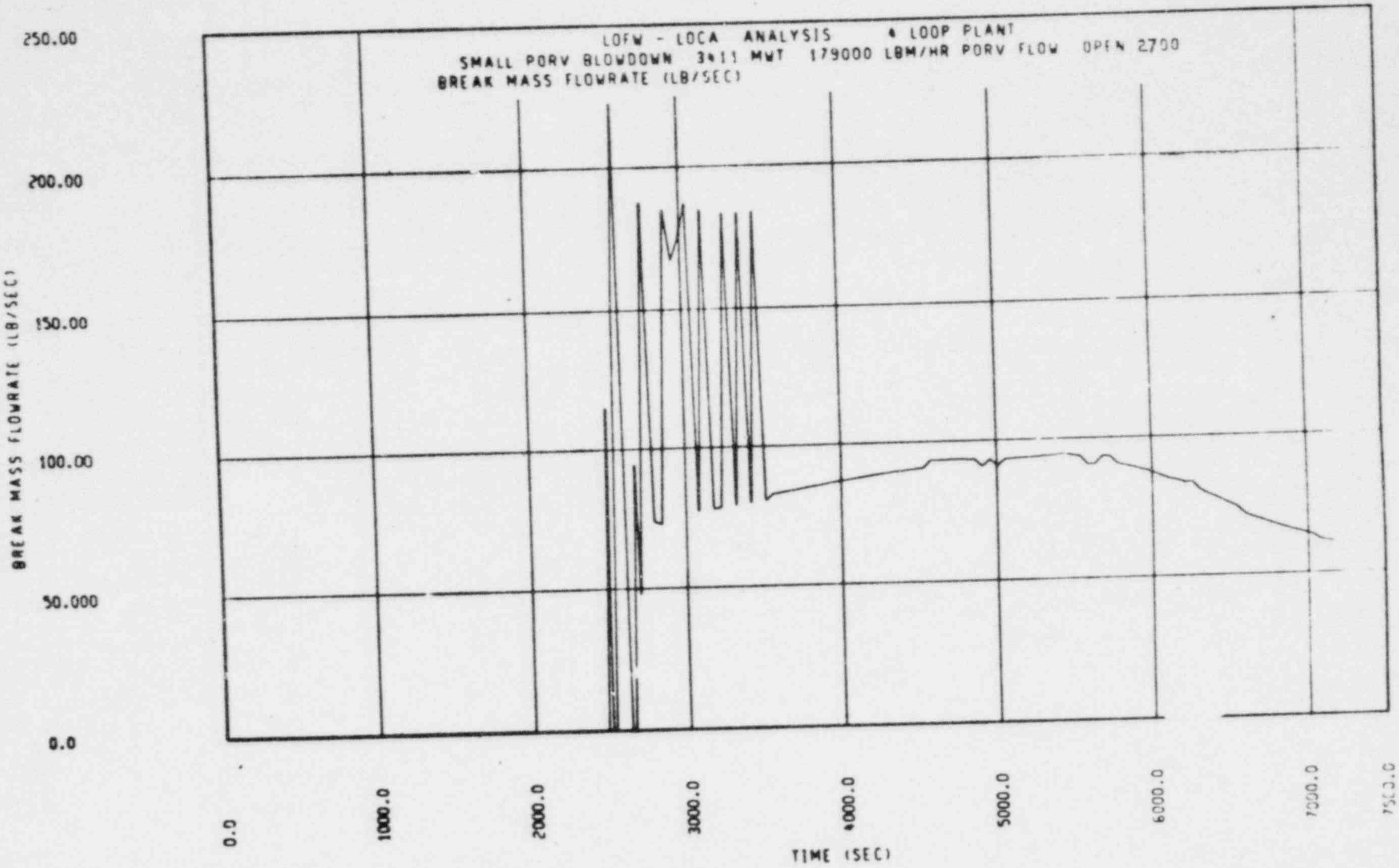

LOFW - LOCA ANALYSIS 4 LOOP PLANT
SMALL PORV BLOWDOWN 3411 MWT 179000 LBM/HR PORV FLOW OPEN 2700
PRESSURIZER SURGE LINE MASS FLOW (LB/SEC)
1000.0
750.00
500.00
250.00
0.0
-250.00
-500.00
-750.00
-1000.0
PRESSURIZER SURGE LINE MASS FLOW (LB/SEC)
0.0
1000.0
2000.0
3000.0
4000.0
5000.0
6000.0
7000.0
7500.0
TIME (SEC)

FIGURE A - 12



LOFW - LOCA ANALYSIS 4 LOOP PLANT
SMALL PORV BLOWDOWN 3411 MWT 179000 LBM/HR PORV FLOW
SAFETY INJECTION MASS FLOWRATE (LB/SEC)
2.0000
1.7500
1.5000
1.2500
1.0000
0.7500
0.5000
0.2500
0.0
SAFETY INJECTION MASS FLOWRATE (LB/SEC)
0.0
1000.0
2000.0
3000.0
4000.0
5000.0
7000.0
TIME (SEC)

FIGURE A - 13



LOFW - LOCA ANALYSIS 4 LOOP PLANT
SMALL PORV BLOWDOWN 3411 MWT 179000 LBM/HR PORV FLOW OPEN 2700
BREAK MASS FLOWRATE (LB/SEC)
BREAK MASS FLOWRATE (LB/SEC)
250.00
200.00
150.00
100.00
50.000
0.0
0.0
1000.0
2000.0
3000.0
4000.0
5000.0
6000.0
7000.0
7500.0
TIME (SEC)

FIGURE A - 14

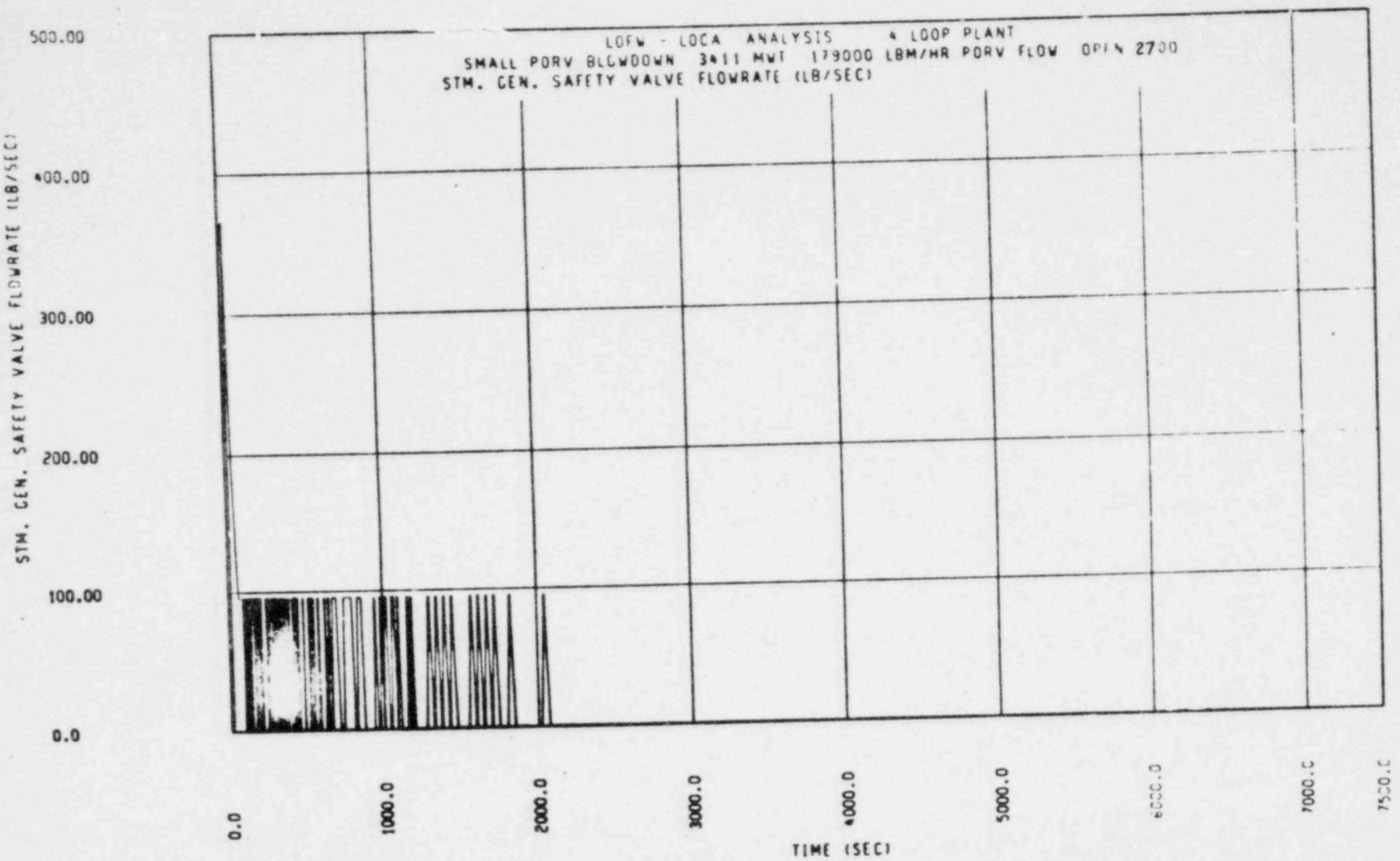

LOFW - LOCA ANALYSIS 4 LOOP PLANT
SMALL PORV BLOWDOWN 3411 MWT 179000 LBM/HR PORV FLOW OPEN 2700
STM. GEN. SAFETY VALVE FLOWRATE (LB/SEC)
STM. GEN. SAFETY VALVE FLOWRATE (LB/SEC)
500.00
400.00
300.00
200.00
100.00
0.0
0.0
1000.0
2000.0
3000.0
4000.0
5000.0
6000.0
7000.0
7500.0
TIME (SEC)

FIGURE A - 15

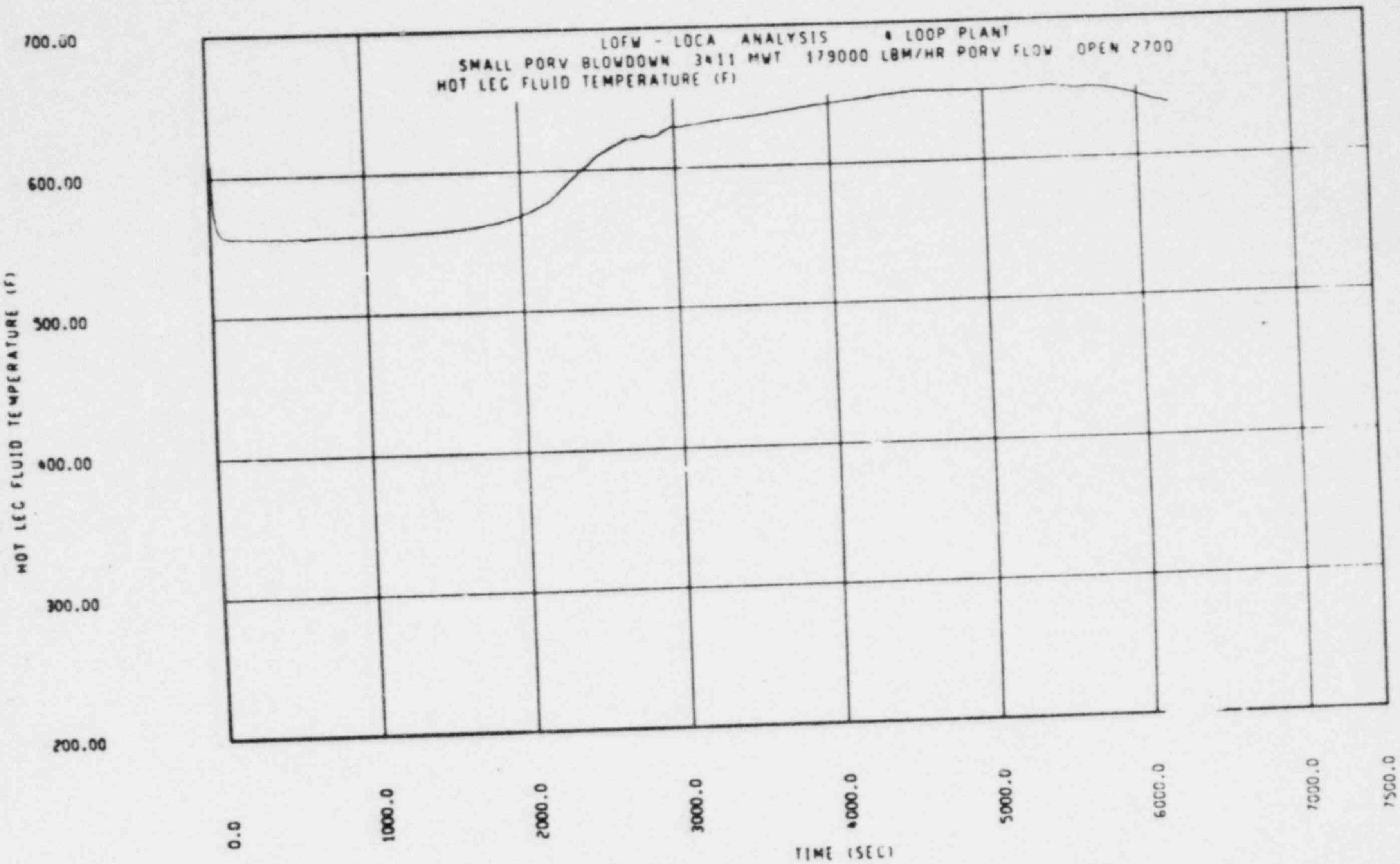

LOFW - LOCA ANALYSIS 4 LOOP PLANT
SMALL PORV BLOWDOWN 3411 MWT 179000 LBM/HR PORV FLOW OPEN 2700
HOT LEG FLUID TEMPERATURE (F)
700.00
600.00
500.00
400.00
300.00
200.00
HOT LEG FLUID TEMPERATURE (F)
0.0
1000.0
2000.0
3000.0
4000.0
5000.0
6000.0
7000.0
7500.0
TIME (SEC)

FIGURE A - 16

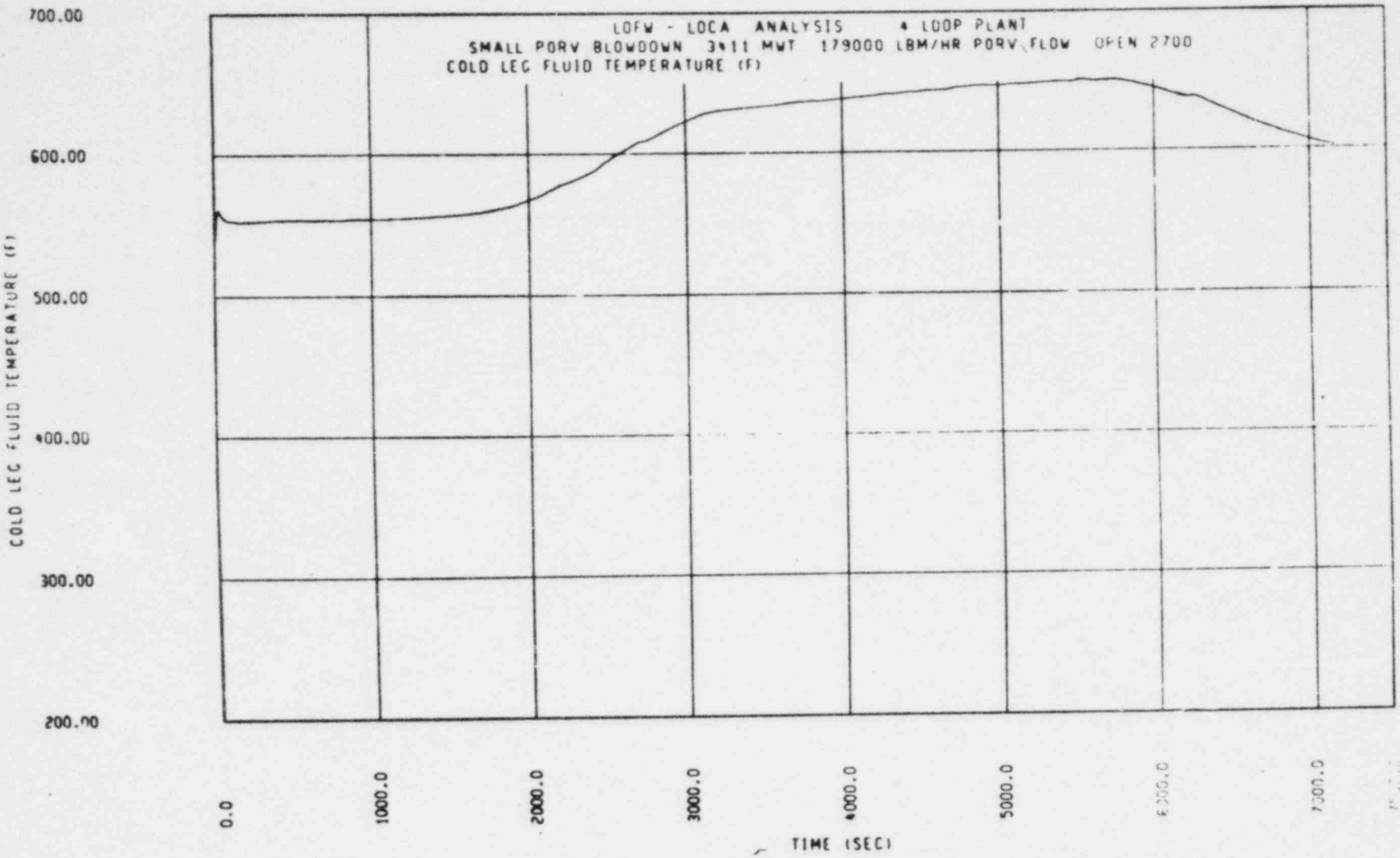

LOFW - LOCA ANALYSIS 4 LOOP PLANT
SMALL PORV BLOWDOWN 3411 MWT 179000 LBM/HR PORV FLOW OPEN 2700
COLD LEG FLUID TEMPERATURE (F)
700.00
600.00
500.00
400.00
300.00
200.00
COLD LEG FLUID TEMPERATURE (F)
0.0
1000.0
2000.0
3000.0
4000.0
5000.0
6000.0
7000.0
TIME (SEC)

FIGURE A - 17

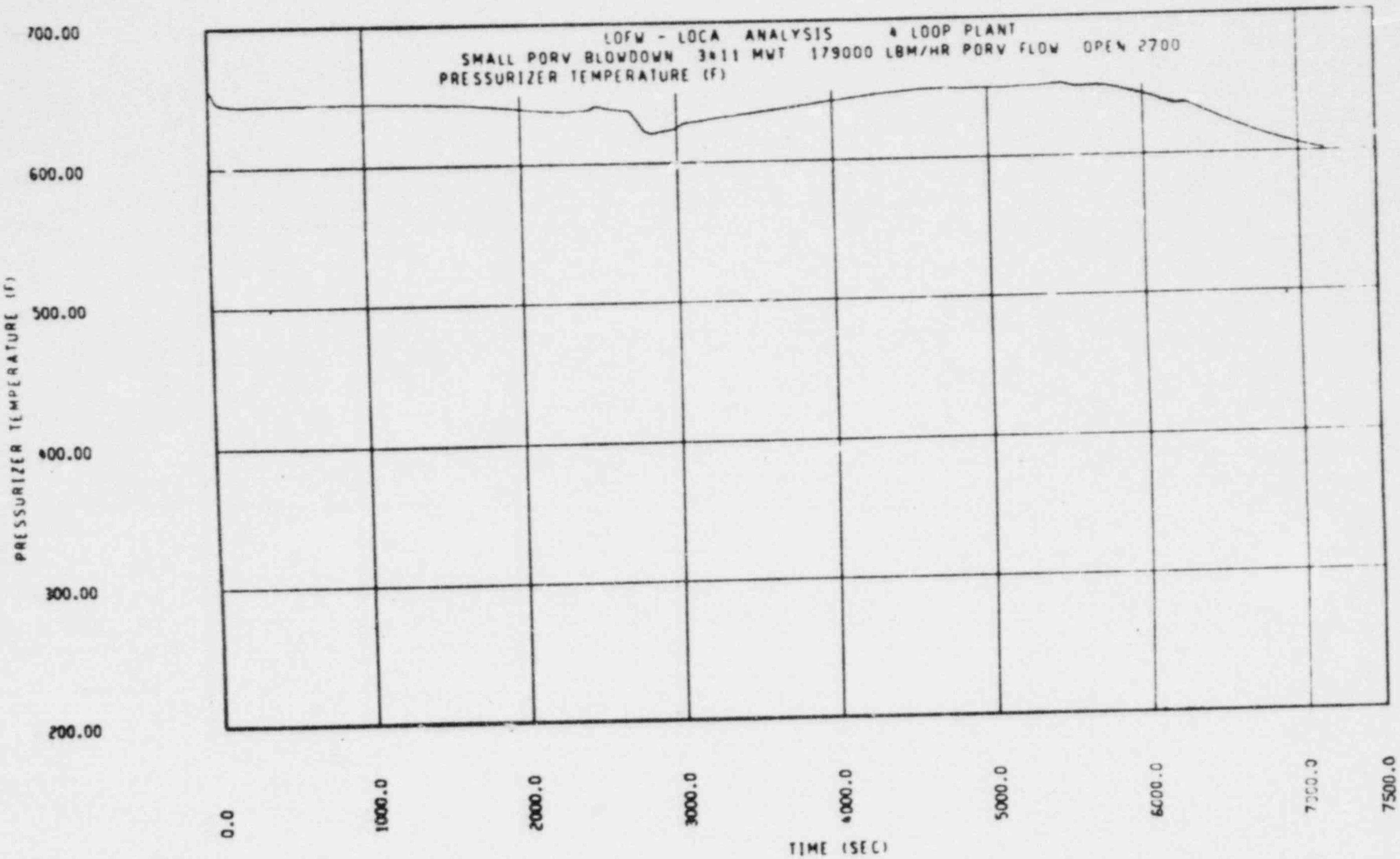

LOFW - LOCA ANALYSIS 4 LOOP PLANT
SMALL PORV BLOWDOWN 3411 MWT 179000 LBM/HR PORV FLOW OPEN 2700
PRESSURIZER TEMPERATURE (F)
700.00
600.00
500.00
400.00
300.00
200.00
PRESSURIZER TEMPERATURE (F)
0.0
1000.0
2000.0
3000.0
4000.0
5000.0
6000.0
7000.0
7500.0
TIME (SEC)

FIGURE A - 18

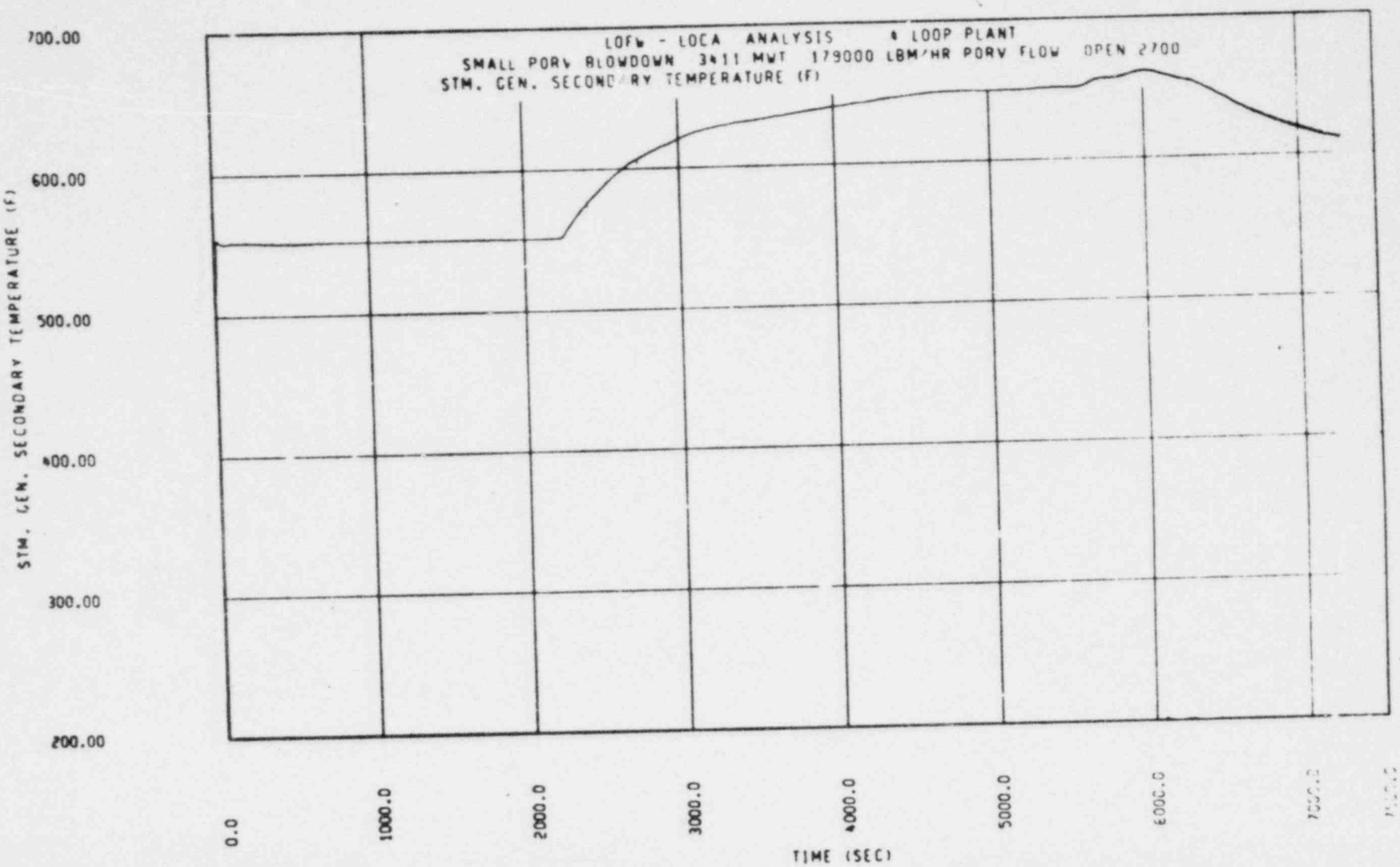

LOFW - LOCA ANALYSIS 4 LOOP PLANT
SMALL PORV BLOWDOWN 3411 MWT 179000 LBM/HR PORV FLOW OPEN 2700
STM. GEN. SECONDARY TEMPERATURE (F)
700.00
600.00
500.00
400.00
300.00
200.00
STM. GEN. SECONDARY TEMPERATURE (F)
0.0
1000.0
2000.0
3000.0
4000.0
5000.0
6000.0
TIME (SEC)

FIGURE A - 19

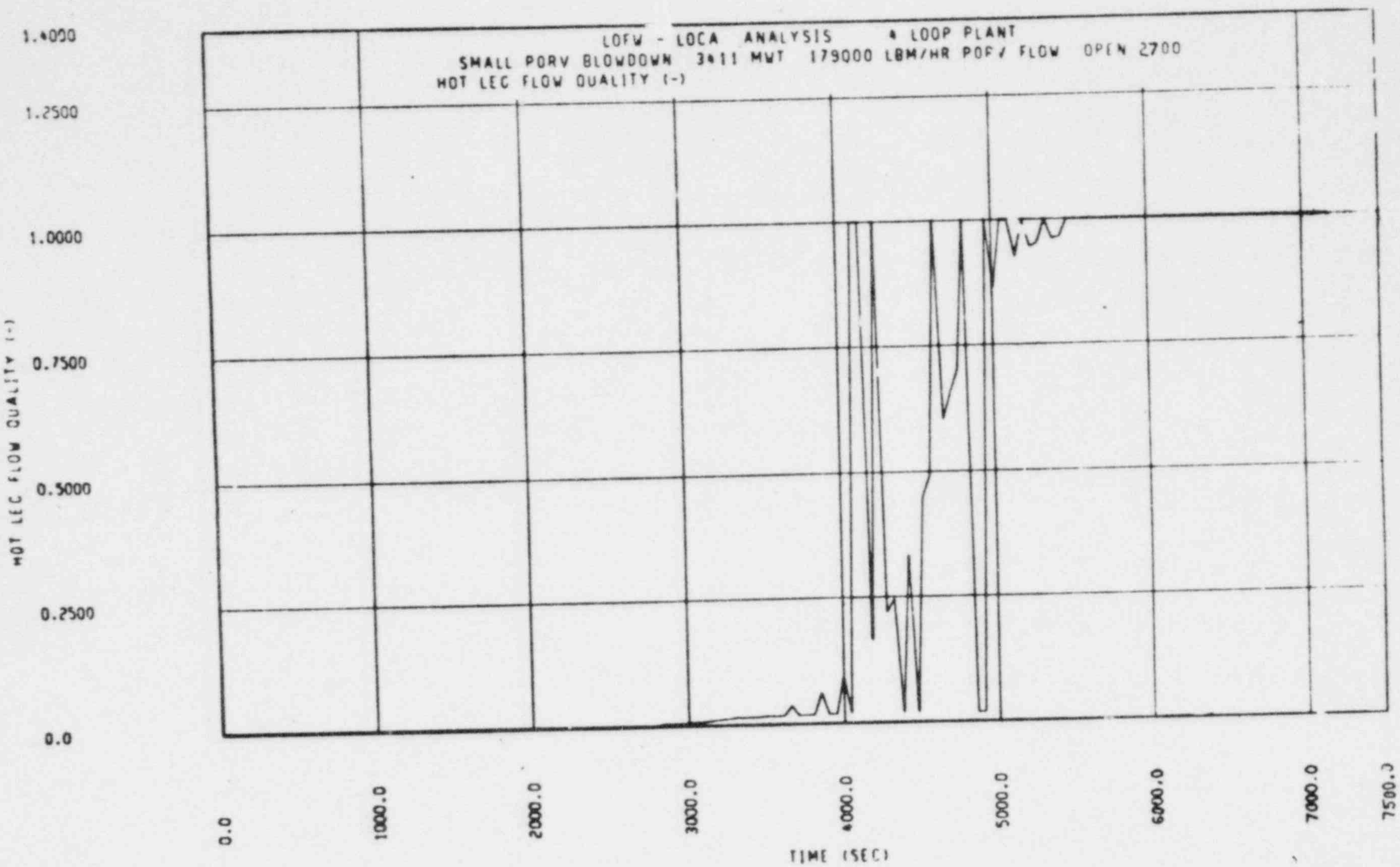

LOFW - LOCA ANALYSIS 4 LOOP PLANT
SMALL PORV BLOWDOWN 3411 MWT 179000 LBM/HR PORV FLOW OPEN 2700
HOT LEG FLOW QUALITY (-)
1.4000
1.2500
1.0000
0.7500
0.5000
0.2500
0.0
HOT LEG FLOW QUALITY (-)
0.0
1000.0
2000.0
3000.0
4000.0
5000.0
6000.0
7000.0
7500.0
TIME (SEC)

FIGURE A - 20

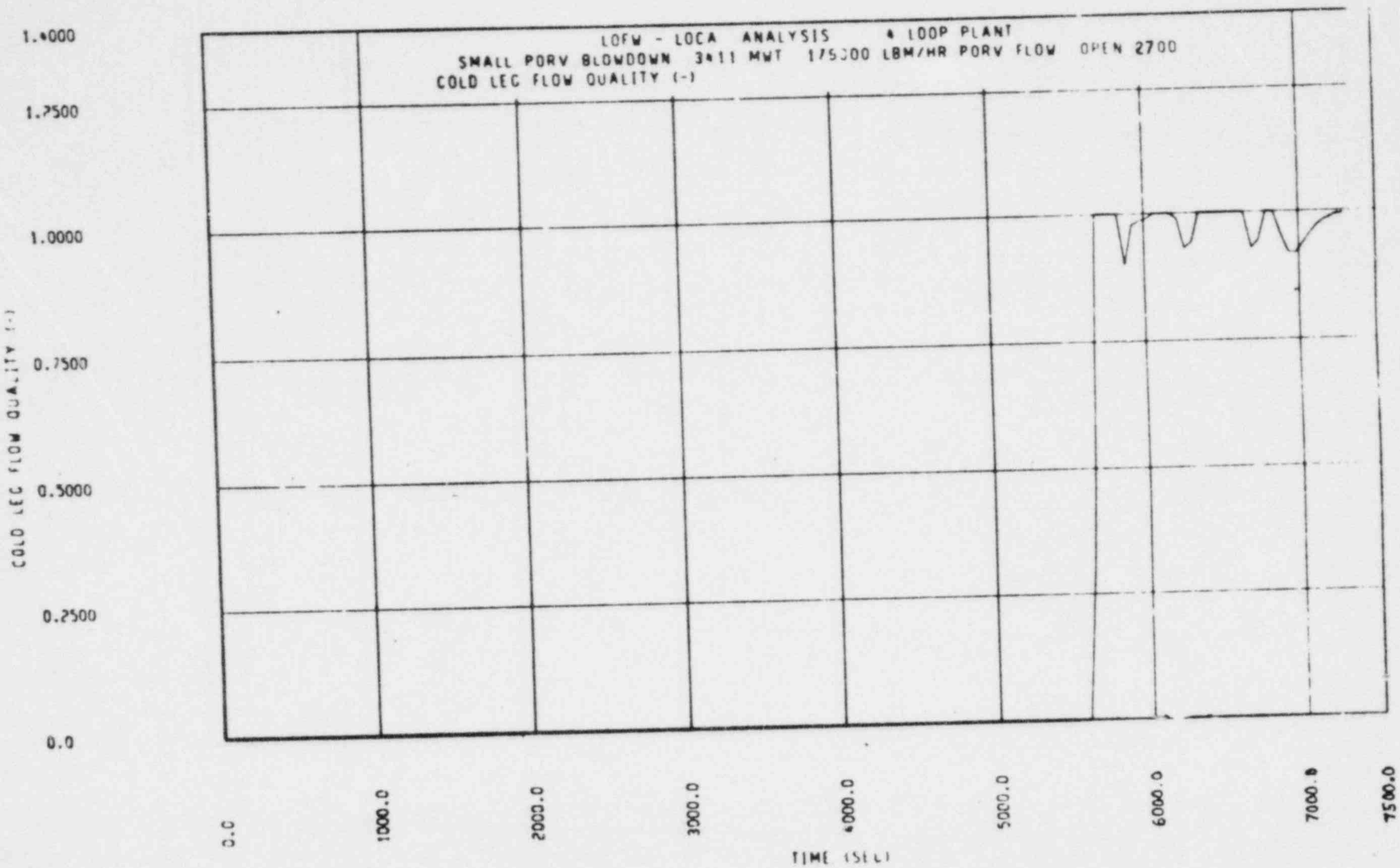
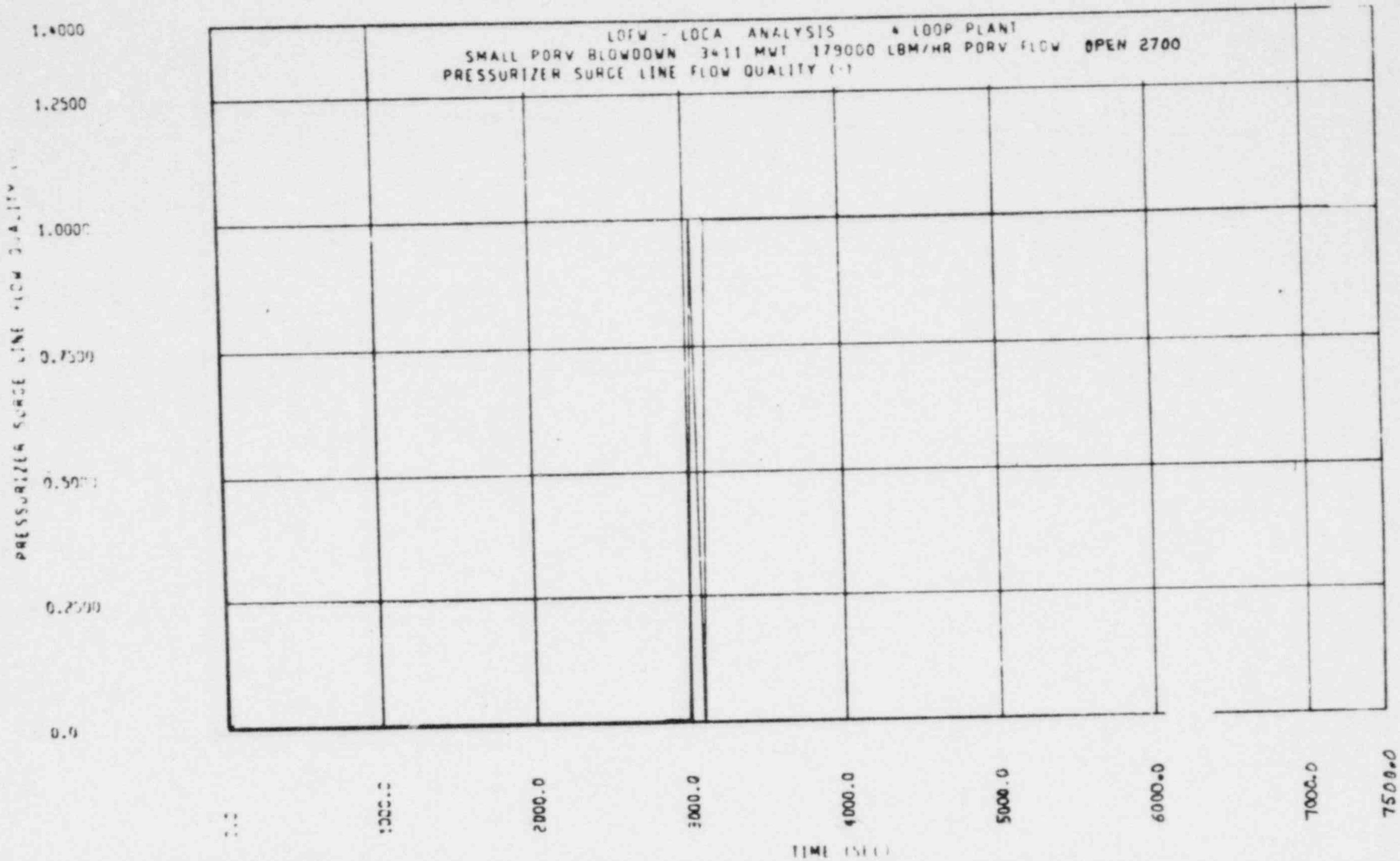

LOFW - LOCA ANALYSIS 4 LOOP PLANT
SMALL PORV BLOWDOWN 3411 MWT 175000 LBM/HR PORV FLOW OPEN 2700
COLD LEG FLOW QUALITY (-)
1.4000
1.2500
1.0000
0.7500
0.5000
0.2500
0.0
COLD LEG FLOW QUALITY (-)
0.0
1000.0
2000.0
3000.0
4000.0
5000.0
6000.0
7000.0
7500.0
TIME (SEC)

FIGURE A - 21



LOFW - LOCA ANALYSIS 4 LOOP PLANT
SMALL PORV BLOWDOWN 3411 MWT 179000 LBM/HR PORV FLOW OPEN 2700
PRESSURIZER SURGE LINE FLOW QUALITY (-)
1.4000
1.2500
1.0000
0.7500
0.5000
0.2500
0.0
2000.0
3000.0
4000.0
5000.0
6000.0
7000.0
7500.0
TIME (SEC)

FIGURE A - 22

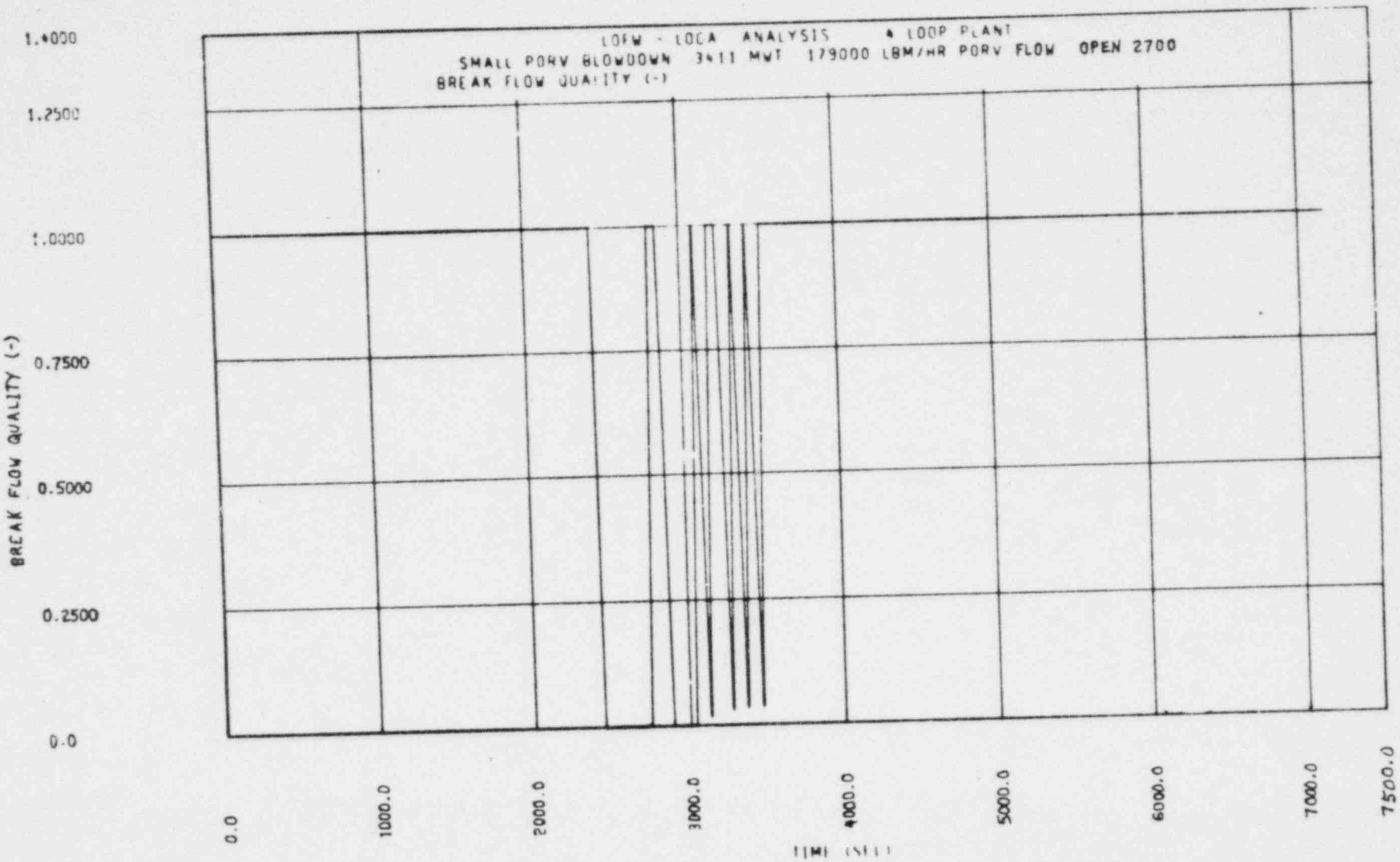
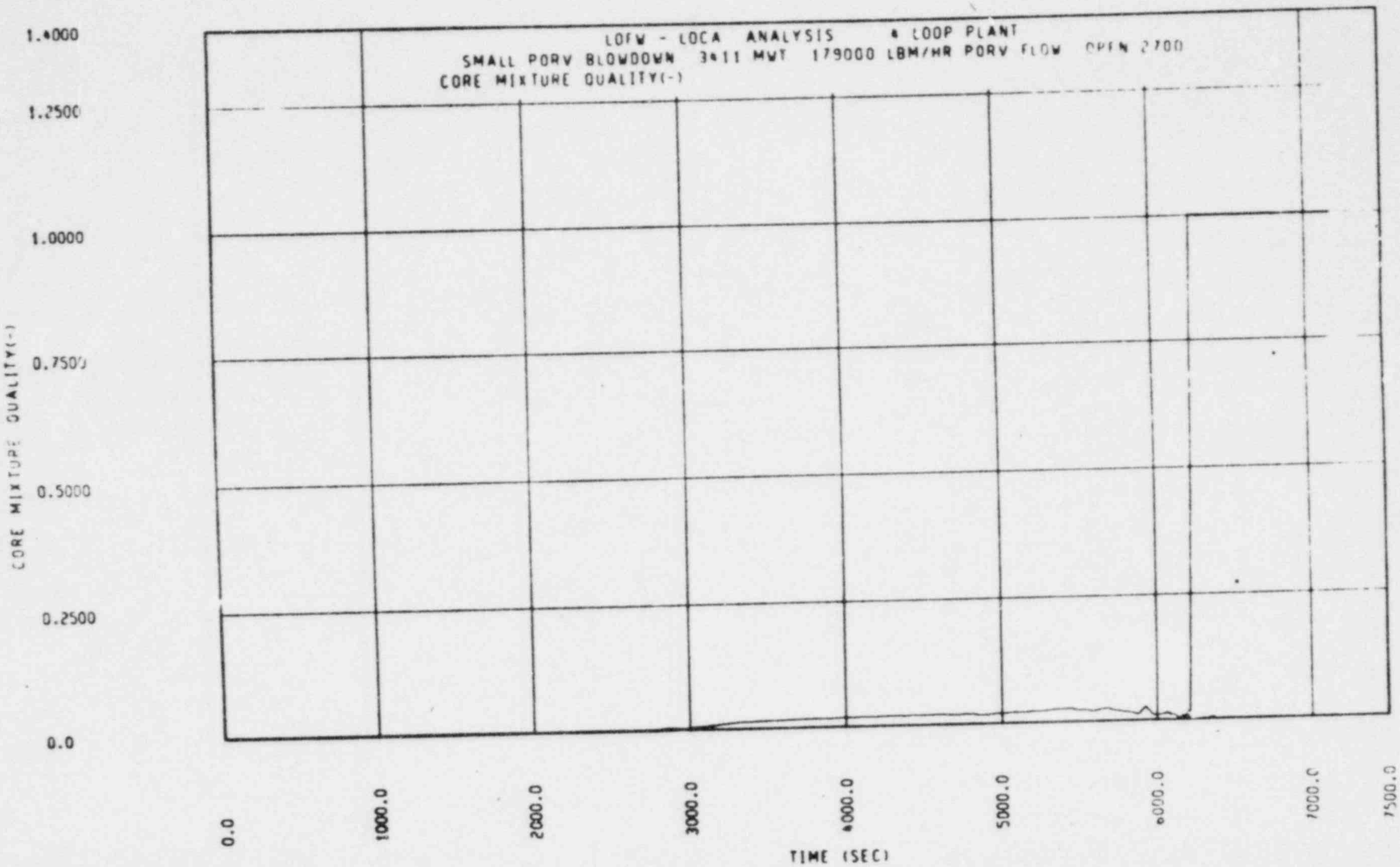

LOFW - LOCA ANALYSIS 4 LOOP PLANT
SMALL PORV BLOWDOWN 3411 MWT 179000 LBM/HR PORV FLOW OPEN 2700
BREAK FLOW QUALITY (-)
1.4000
1.2500
1.0000
0.7500
0.5000
0.2500
0.0
BREAK FLOW QUALITY (-)
0.0
1000.0
2000.0
3000.0
4000.0
5000.0
6000.0
7000.0
7500.0
TIME (SEC)

FIGURE A - 23



LOFW - LOCA ANALYSIS 4 LOOP PLANT
SMALL PORV BLOWDOWN 3411 MWT 179000 LBM/HR PORV FLOW OPEN 2700
CORE MIXTURE QUALITY(-)
1.4000
1.2500
1.0000
0.7500
0.5000
0.2500
0.0
CORE MIXTURE QUALITY(-)
0.0
1000.0
2000.0
3000.0
4000.0
5000.0
6000.0
7000.0
7500.0
TIME (SEC)

FIGURE A - 24

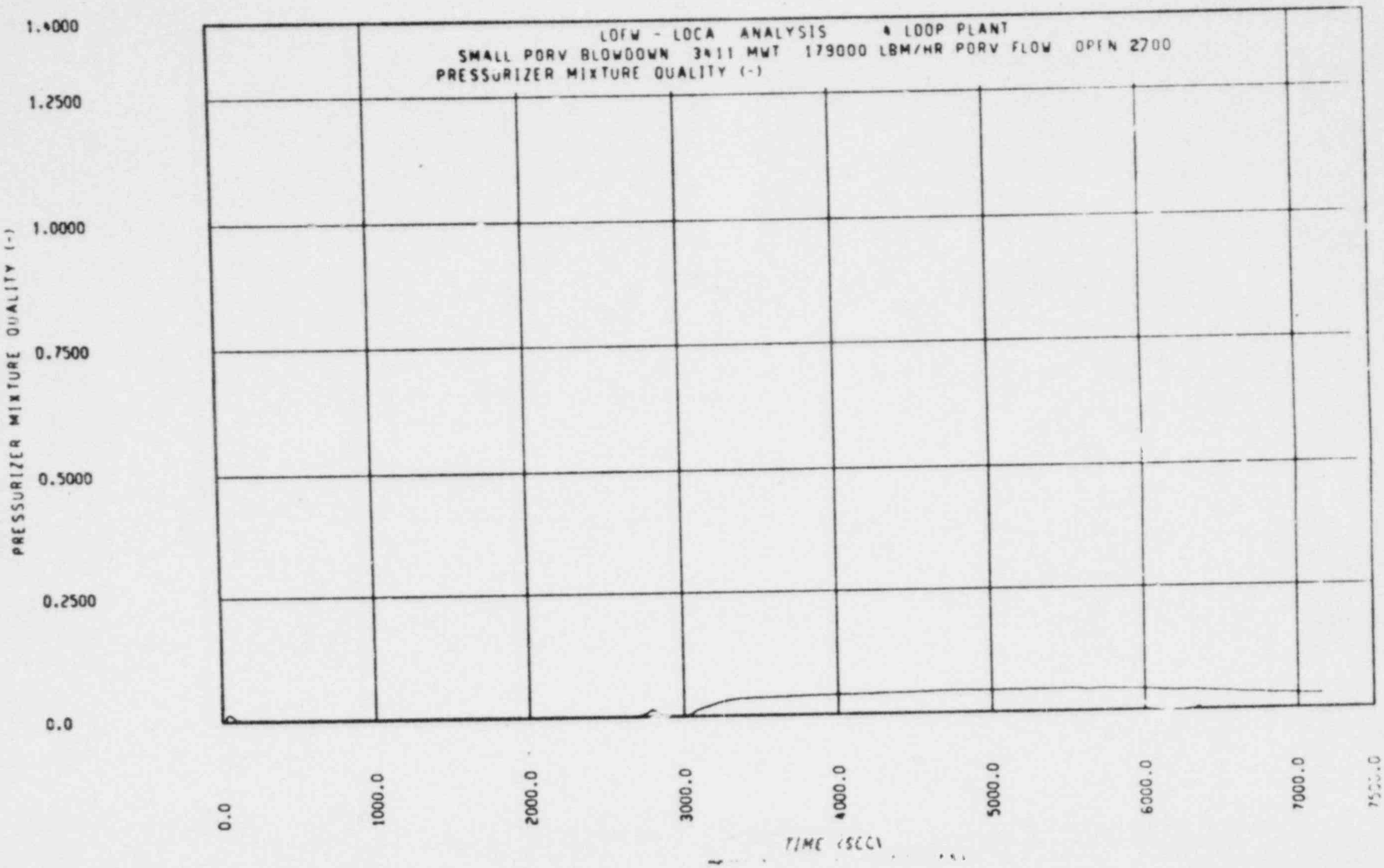

LOFW - LOCA ANALYSIS 4 LOOP PLANT
SMALL PORV BLOWDOWN 3411 MWT 179000 LBM/HR PORV FLOW OPEN 2700
PRESSURIZER MIXTURE QUALITY (-)
1.4000
1.2500
1.0000
0.7500
0.5000
0.2500
0.0
PRESSURIZER MIXTURE QUALITY (-)
0.0
1000.0
2000.0
3000.0
4000.0
5000.0
6000.0
7000.0
TIME (SEC)

FIGURE A - 25

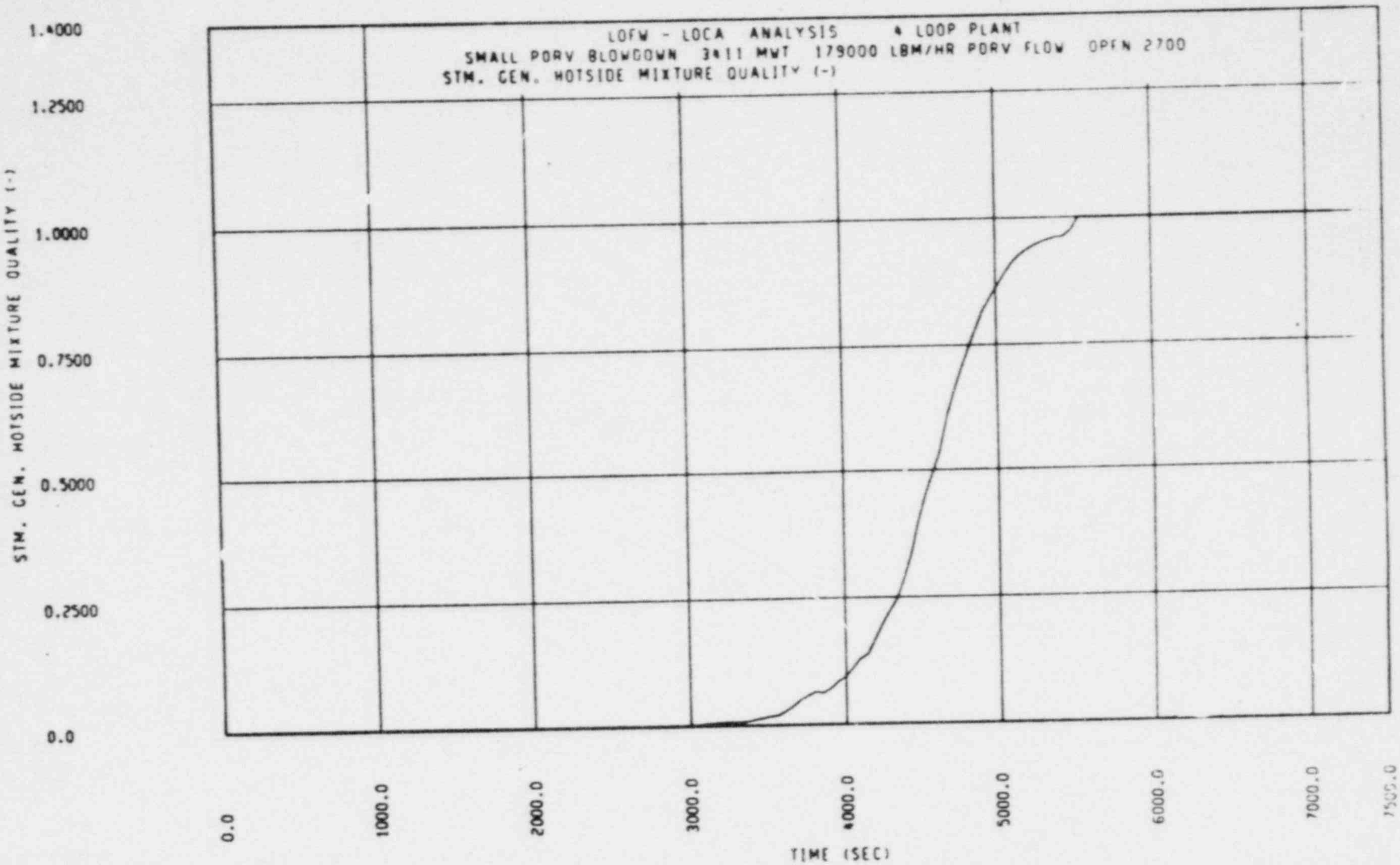

LOFW - LOCA ANALYSIS 4 LOOP PLANT
SMALL PORV BLOWDOWN 3411 MWT 179000 LBM/HR PORV FLOW OPEN 2700
STM. GEN. HOTSIDE MIXTURE QUALITY (-)
STM. GEN. HOTSIDE MIXTURE QUALITY (-)
1.4000
1.2500
1.0000
0.7500
0.5000
0.2500
0.0
0.0
1000.0
2000.0
3000.0
4000.0
5000.0
6000.0
7000.0
7500.0
TIME (SEC)

FIGURE A - 26

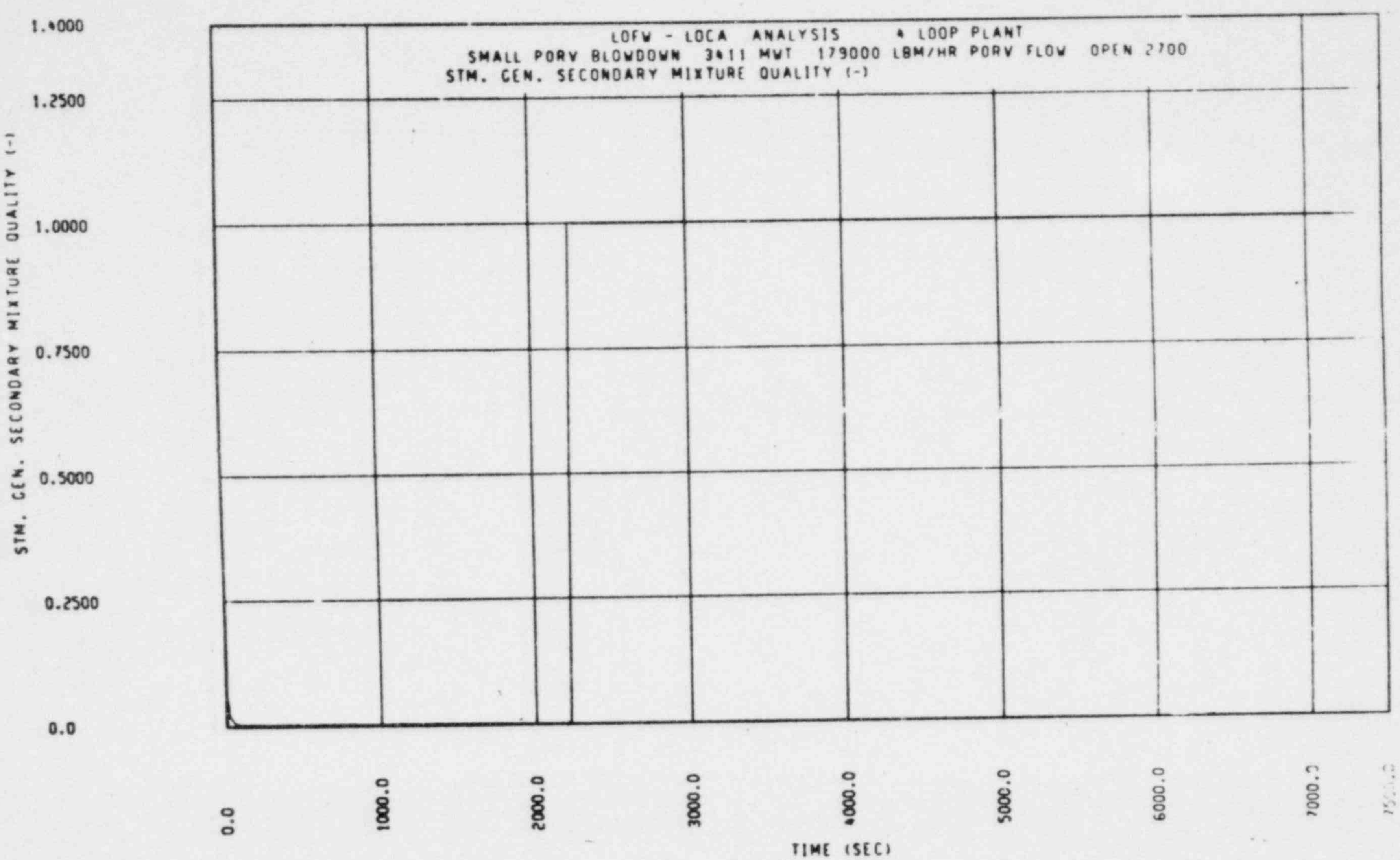
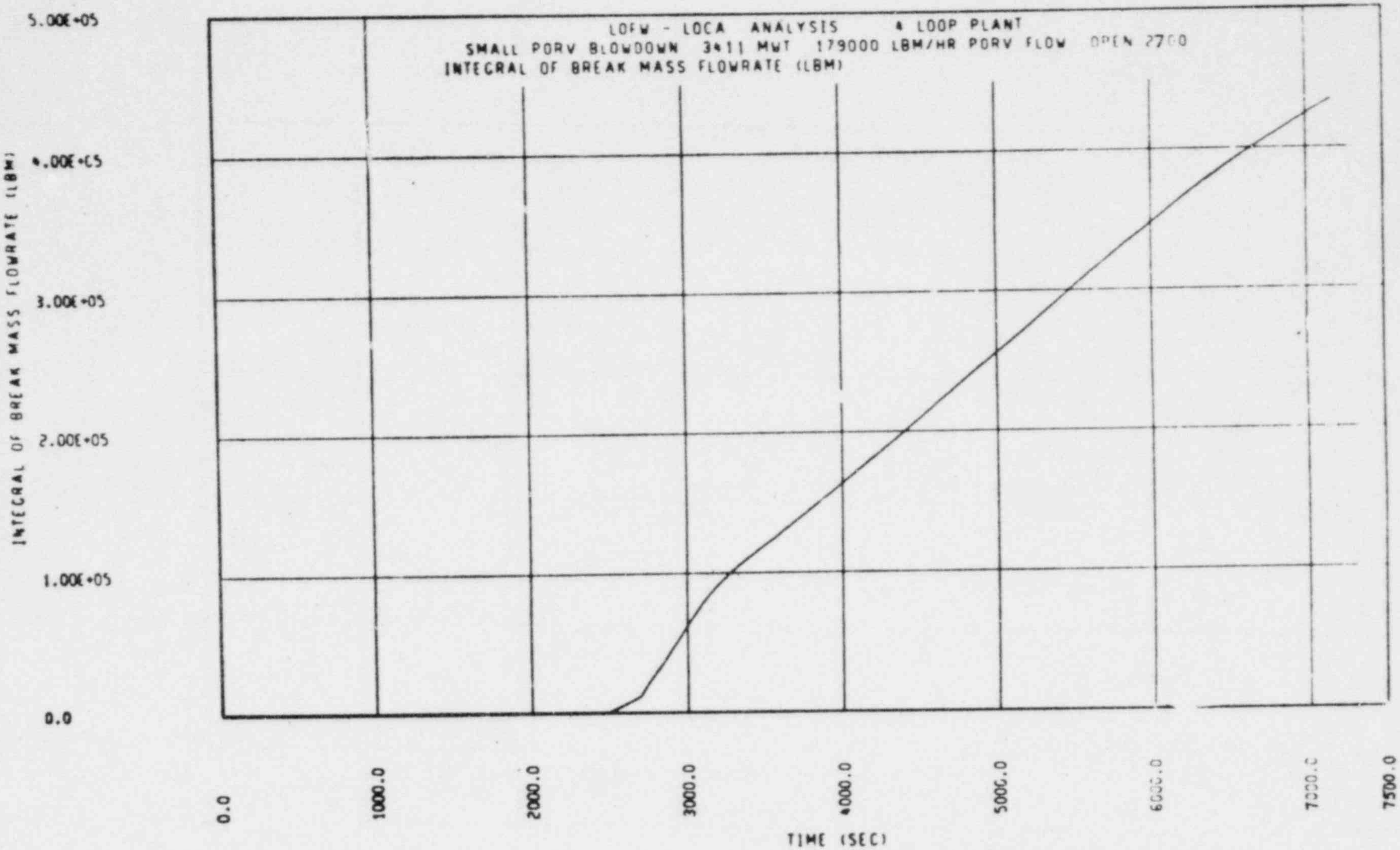

LOFW - LOCA ANALYSIS 4 LOOP PLANT
SMALL PORV BLOWDOWN 3411 MWT 179000 LBM/HR PORV FLOW OPEN 2700
STM. GEN. SECONDARY MIXTURE QUALITY (-)
STM. GEN. SECONDARY MIXTURE QUALITY (-)
1.4000
1.2500
1.0000
0.7500
0.5000
0.2500
0.0
0.0
1000.0
2000.0
3000.0
4000.0
5000.0
6000.0
7000.0
TIME (SEC)

FIGURE A - 27



LOFW - LOCA ANALYSIS 4 LOOP PLANT
SMALL PORV BLOWDOWN 3411 MWT 179000 LBM/HR PORV FLOW OPEN 2700
INTEGRAL OF BREAK MASS FLOWRATE (LBM)
INTEGRAL OF BREAK MASS FLOWRATE (LBM)
5.00E+05
4.00E+05
3.00E+05
2.00E+05
1.00E+05
0.0
0.0
1000.0
2000.0
3000.0
4000.0
5000.0
6000.0
7000.0
7500.0
TIME (SEC)

FIGURE A - 28

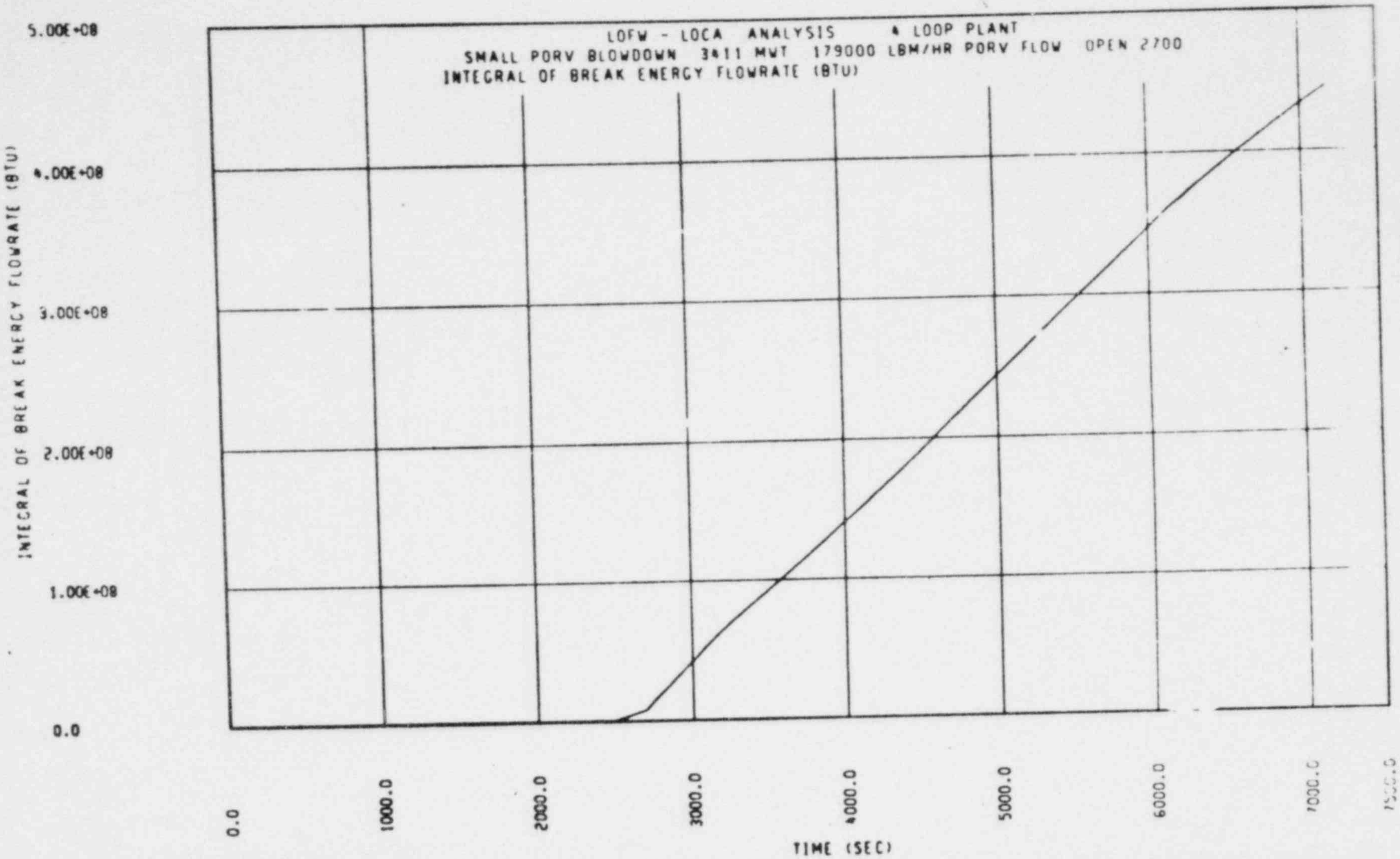

LOFW - LOCA ANALYSIS 4 LOOP PLANT
SMALL PORV BLOWDOWN 3411 MWT 179000 LBM/HR PORV FLOW OPEN 2700
INTEGRAL OF BREAK ENERGY FLOWRATE (BTU)
INTEGRAL OF BREAK ENERGY FLOWRATE (BTU)
5.00E+08
4.00E+08
3.00E+08
2.00E+08
1.00E+08
0.0
0.0
1000.0
2000.0
3000.0
4000.0
5000.0
6000.0
7000.0
TIME (SEC)

FIGURE A - 29

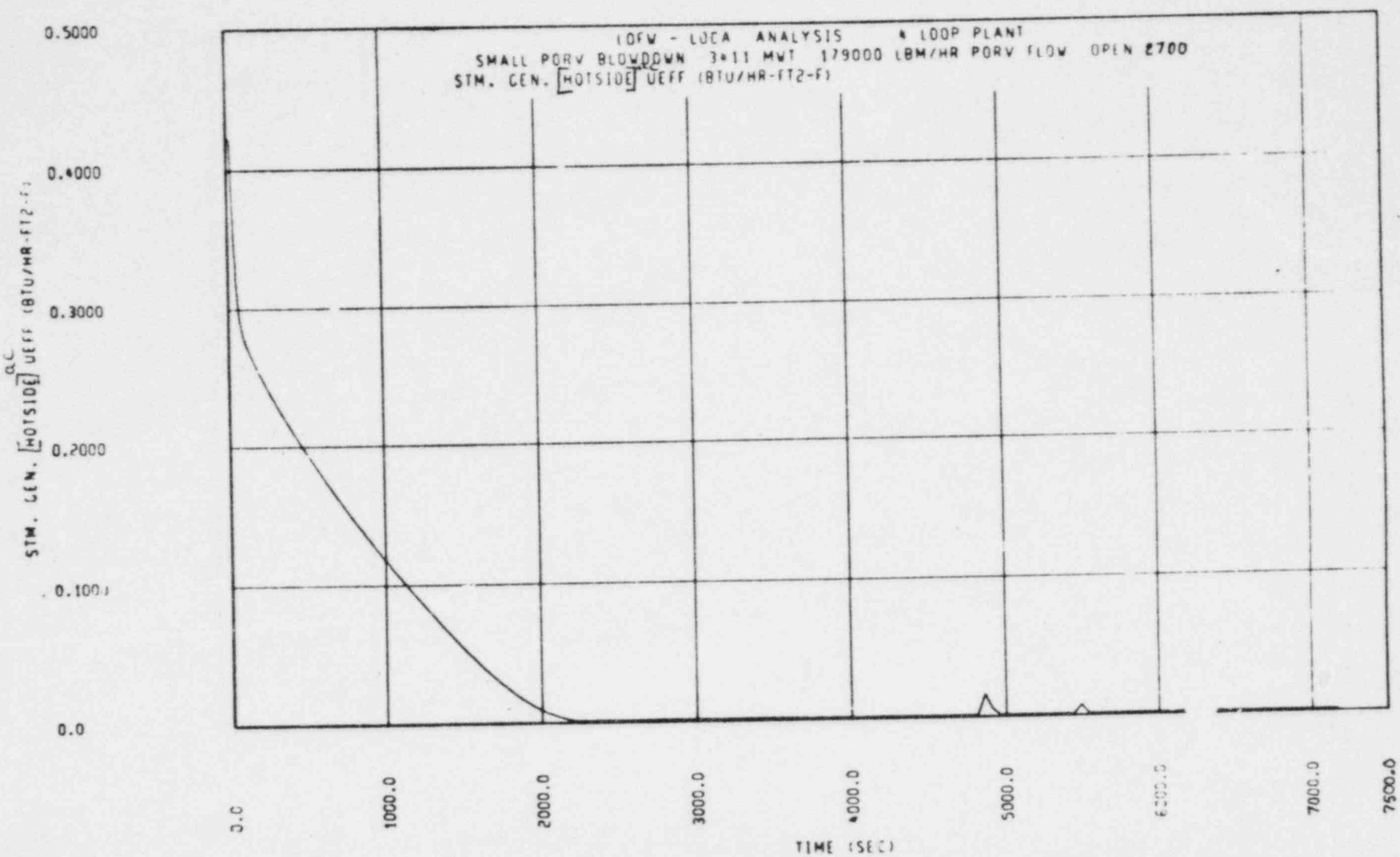

LOFW - LOCA ANALYSIS 4 LOOP PLANT
SMALL PORV BLOWDOWN 3411 MWT 179000 LBM/HR PORV FLOW OPEN 2700
STM. GEN. [HOTSIDE] UEFF (BTU/HR-FT2-F)
a,c
STM. GEN. [HOTSIDE] UEFF (BTU/HR-FT2-F)
0.5000
0.4000
0.3000
0.2000
0.1000
0.0
0.0
1000.0
2000.0
3000.0
4000.0
5000.0
6000.0
7000.0
7500.0
TIME (SEC)

FIGURE A - 30

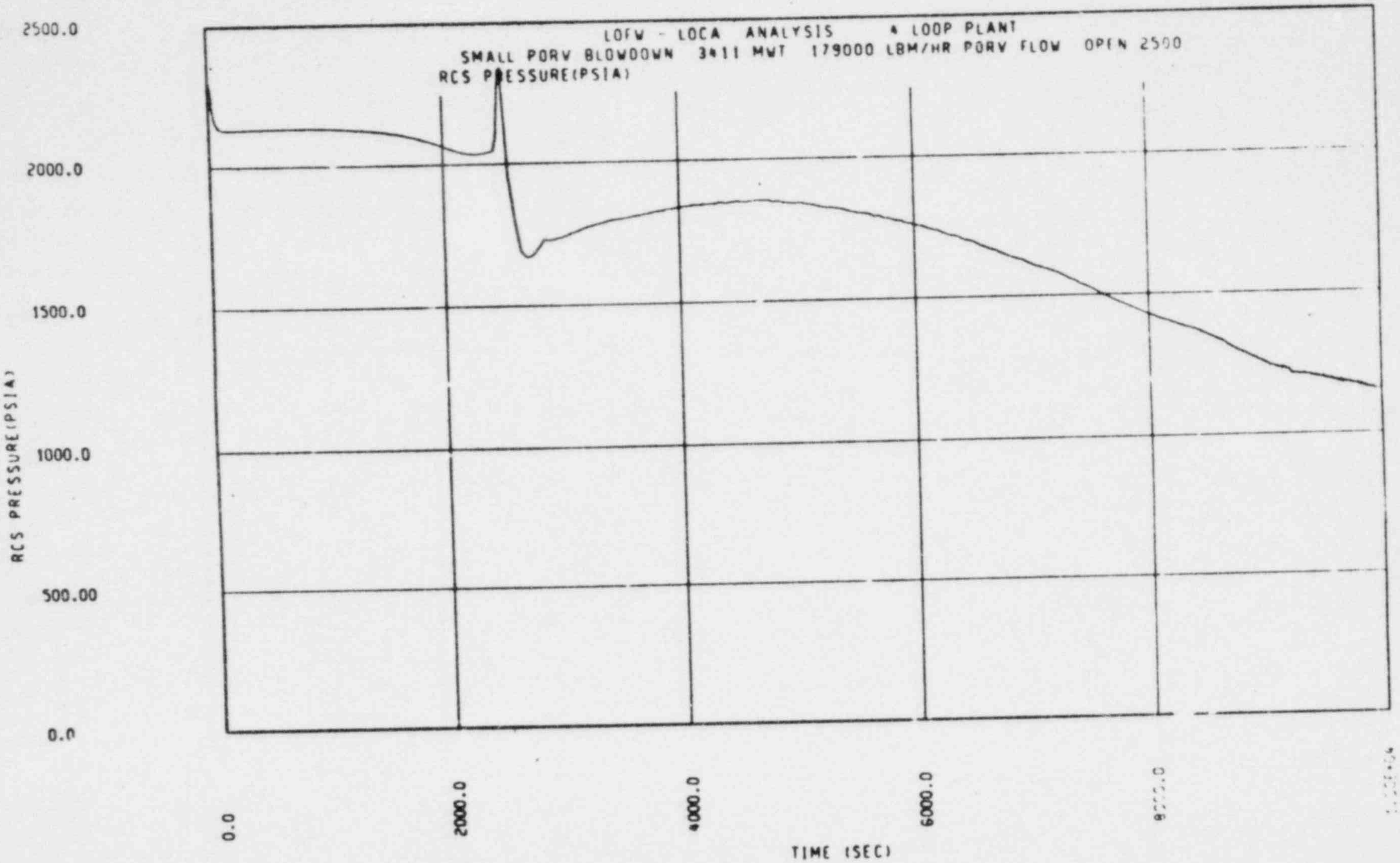

LOFW - LOCA ANALYSIS 4 LOOP PLANT
SMALL PORV BLOWDOWN 3411 MWT 179000 LBM/HR PORV FLOW OPEN 2500
RCS PRESSURE(PSIA)
2500.0
2000.0
1500.0
1000.0
500.00
0.0
RCS PRESSURE(PSIA)
0.0
2000.0
4000.0
6000.0
TIME (SEC)

FIGURE B - 1

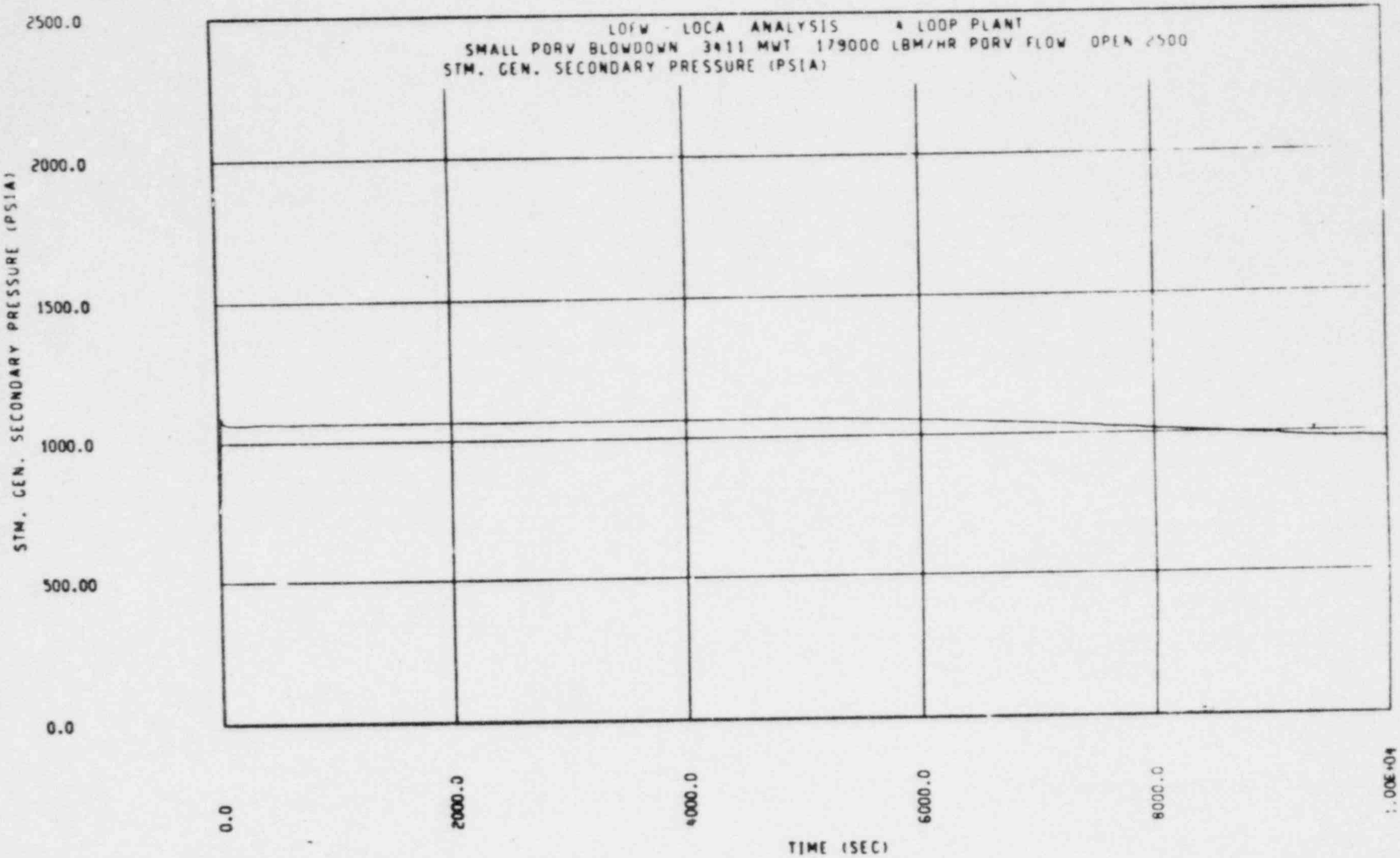

LOFW - LOCA ANALYSIS 4 LOOP PLANT
SMALL PORV BLOWDOWN 3411 MWT 179000 LBM/HR PORV FLOW OPEN 2500
STM. GEN. SECONDARY PRESSURE (PSIA)
STM. GEN. SECONDARY PRESSURE (PSIA)
2500.0
2000.0
1500.0
1000.0
500.00
0.0
0.0
2000.0
4000.0
6000.0
8000.0
TIME (SEC)

FIGURE B - 2

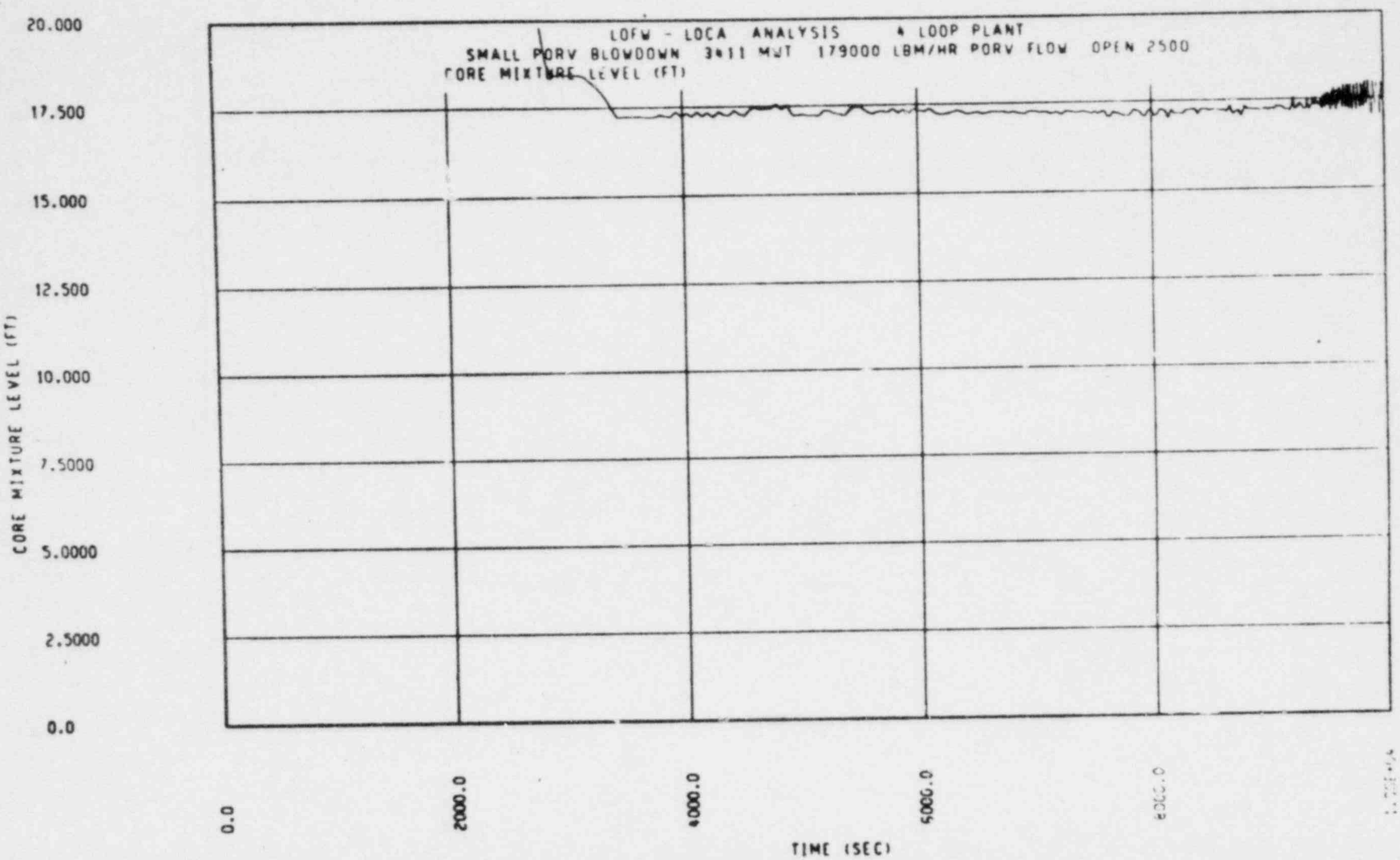

LOFW - LOCA ANALYSIS 4 LOOP PLANT
SMALL PORV BLOWDOWN 3411 MWT 179000 LBM/HR PORV FLOW OPEN 2500
CORE MIXTURE LEVEL (FT)
20.000
17.500
15.000
12.500
10.000
7.5000
5.0000
2.5000
0.0
CORE MIXTURE LEVEL (FT)
0.0
2000.0
4000.0
6000.0
8000.0
TIME (SEC)

FIGURE B - 3

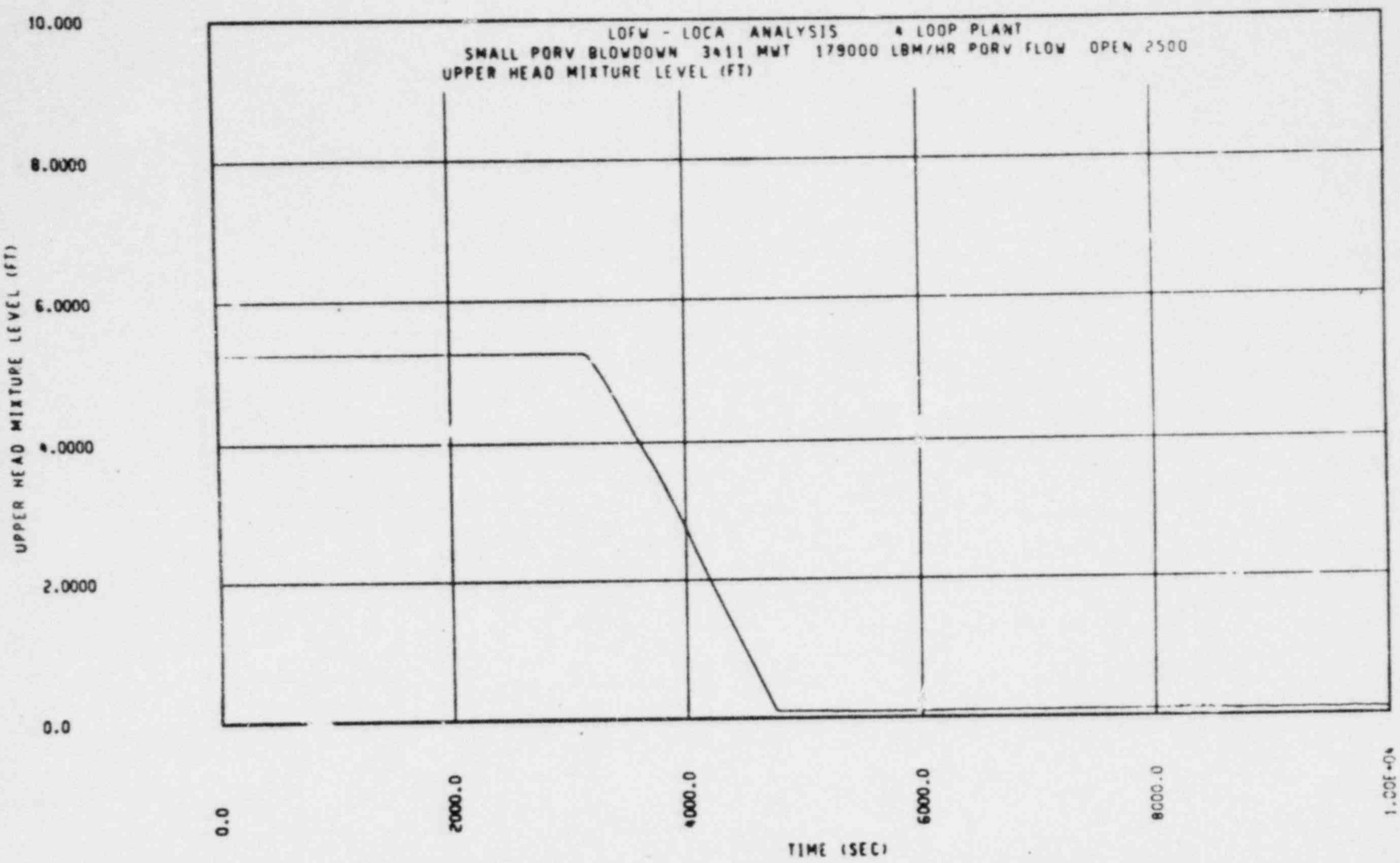
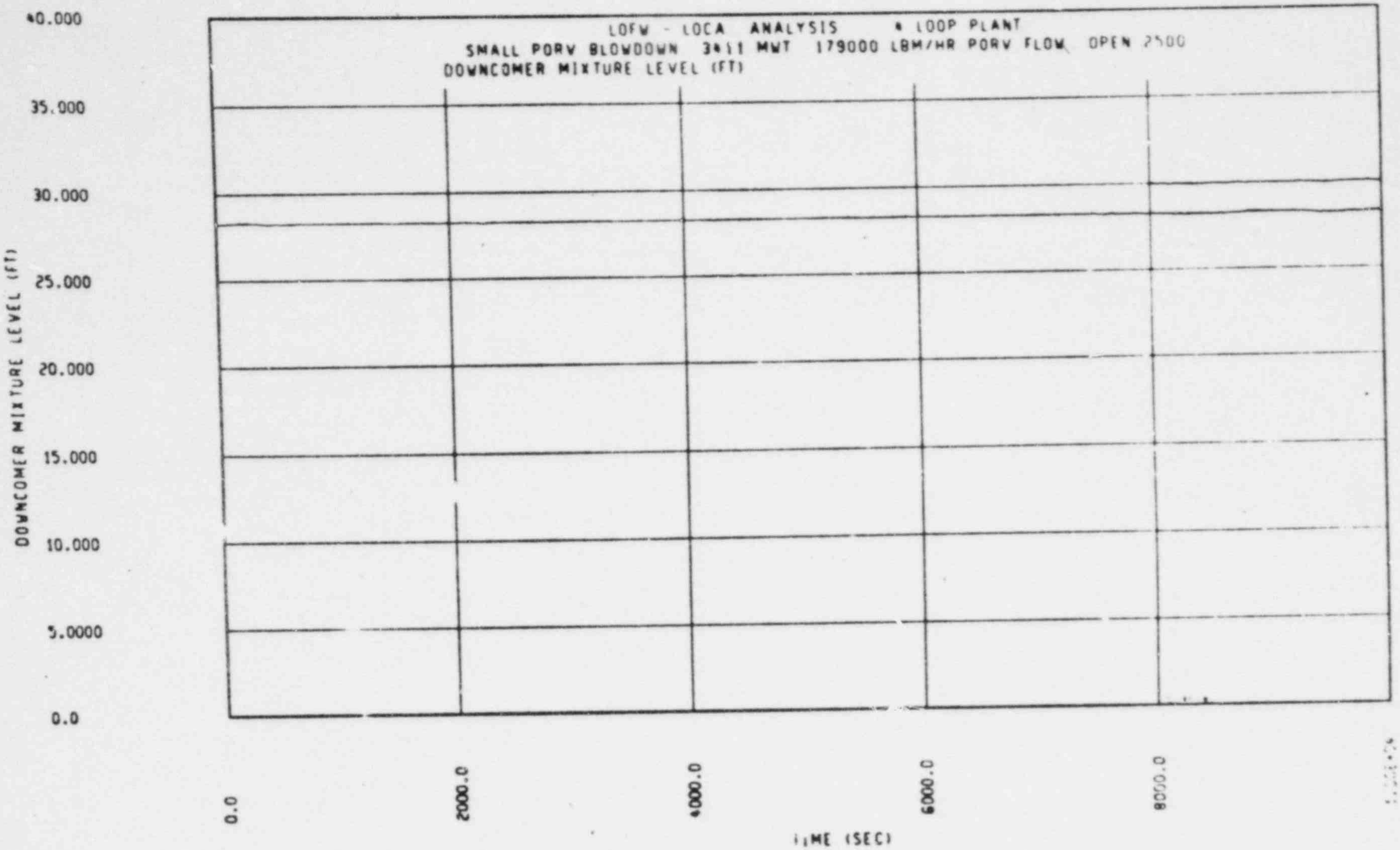

LOFW - LOCA ANALYSIS 4 LOOP PLANT
SMALL PORV BLOWDOWN 3411 MWT 179000 LBM/HR PORV FLOW OPEN 2500
UPPER HEAD MIXTURE LEVEL (FT)
10.000
8.0000
6.0000
4.0000
2.0000
0.0
UPPER HEAD MIXTURE LEVEL (FT)
0.0
2000.0
4000.0
6000.0
8000.0
1.00E+04
TIME (SEC)

FIGURE B - 4



LOFW - LOCA ANALYSIS 4 LOOP PLANT
SMALL PORV BLOWDOWN 3411 MWT 179000 LBM/HR PORV FLOW OPEN 2500
DOWNCOMER MIXTURE LEVEL (FT)
40.000
35.000
30.000
25.000
20.000
15.000
10.000
5.0000
0.0
DOWNCOMER MIXTURE LEVEL (FT)
0.0
2000.0
4000.0
6000.0
8000.0
TIME (SEC)

FIGURE B - 5

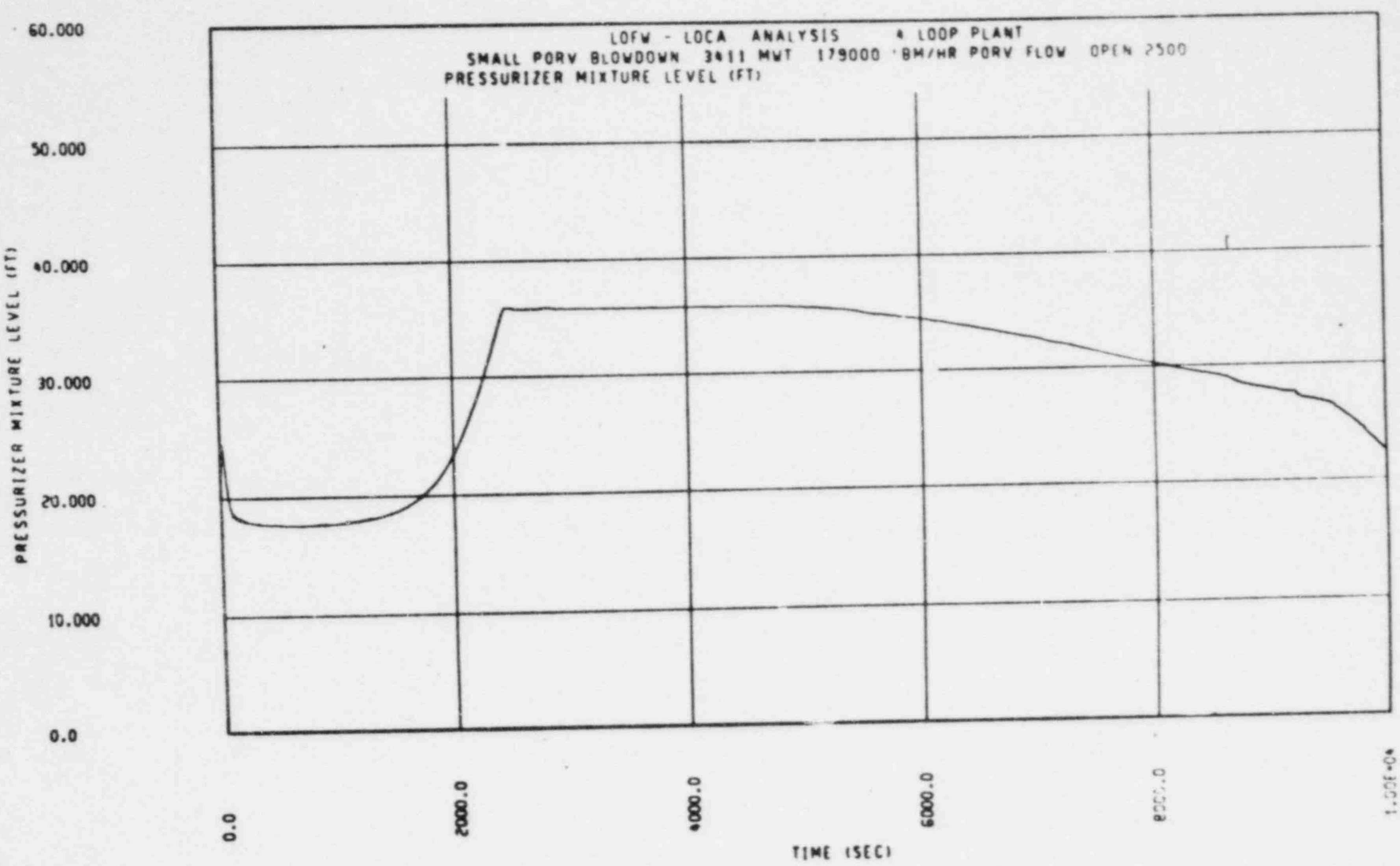

LOFW - LOCA ANALYSIS 4 LOOP PLANT
SMALL PORV BLOWDOWN 3411 MWT 179000 LBM/HR PORV FLOW OPEN 2500
PRESSURIZER MIXTURE LEVEL (FT)
60.000
50.000
40.000
30.000
20.000
10.000
0.0
PRESSURIZER MIXTURE LEVEL (FT)
0.0
2000.0
4000.0
6000.0
8000.0
1.00E+04
TIME (SEC)

FIGURE B - 6

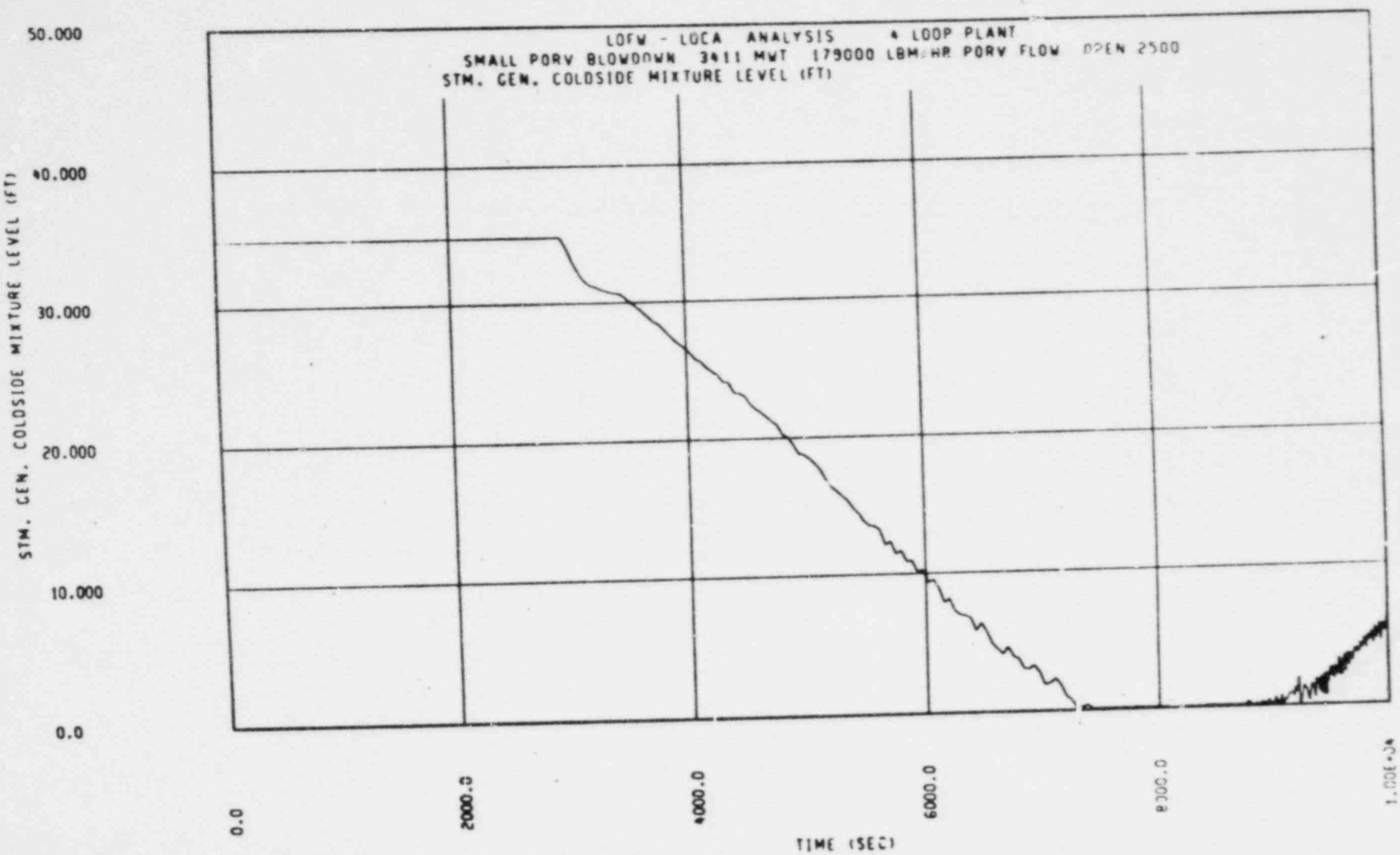
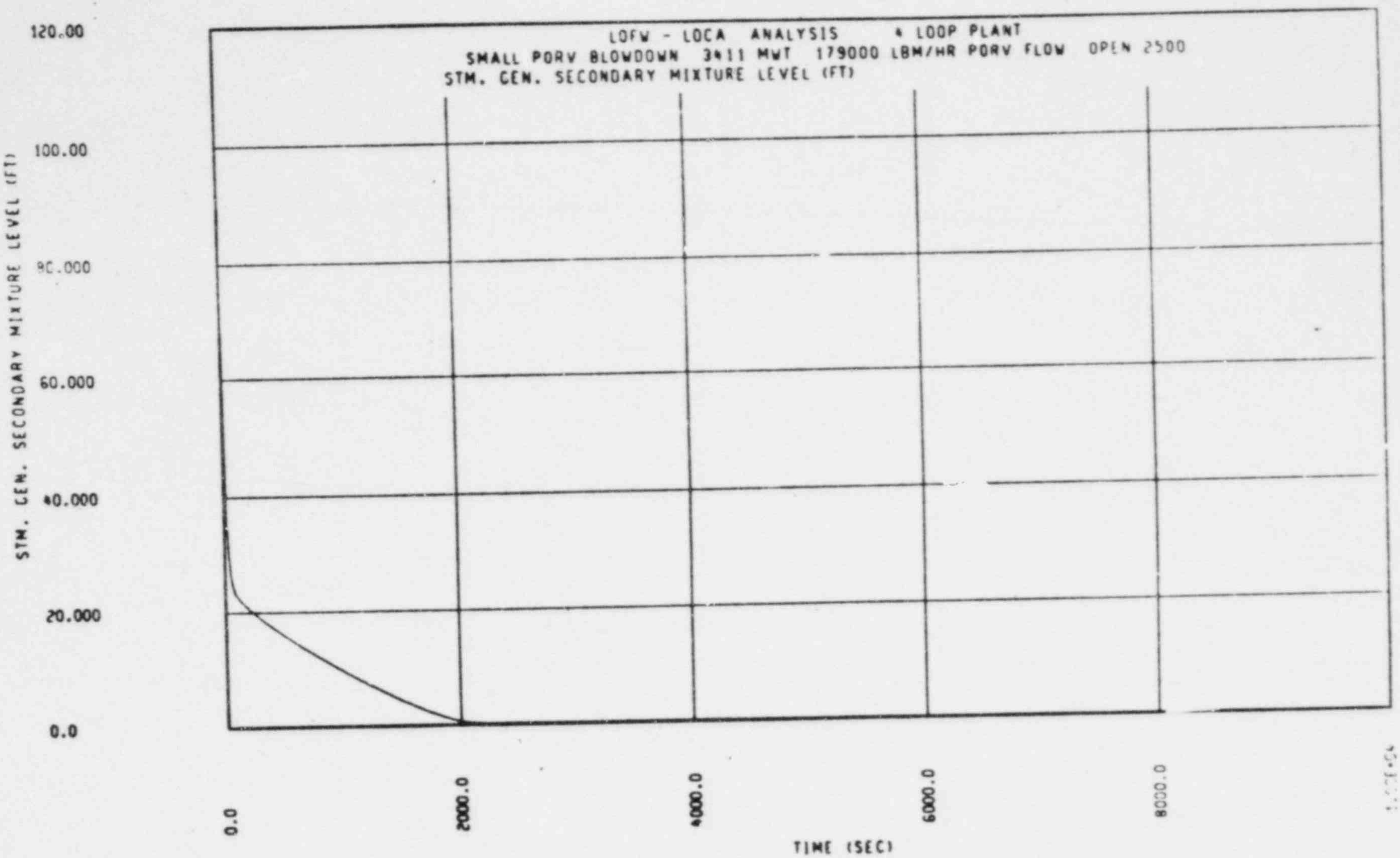
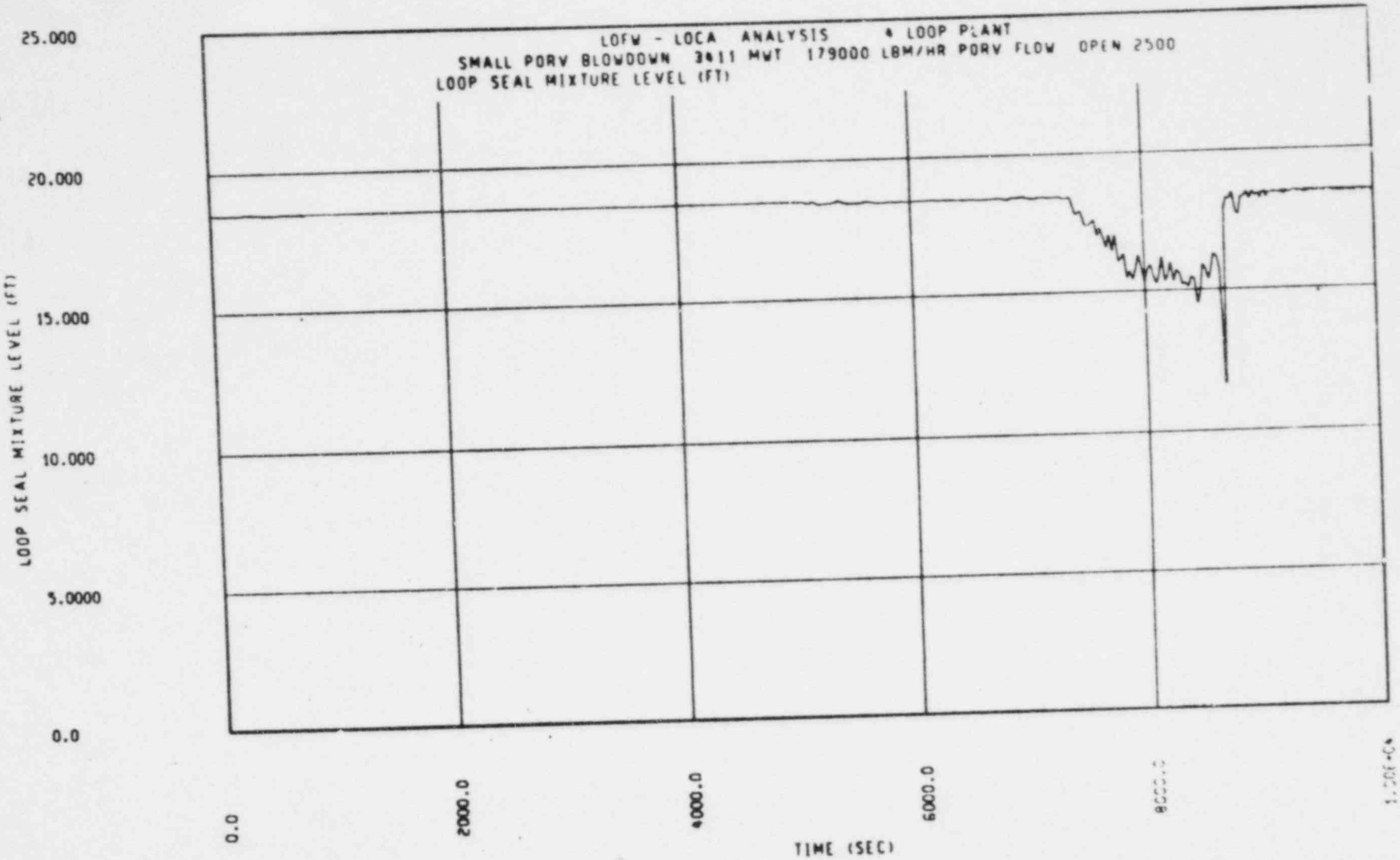

LOFW - LOCA ANALYSIS 4 LOOP PLANT
SMALL PORV BLOWDOWN 3411 MWT 179000 LBM/HR PORV FLOW OPEN 2500
STM. GEN. COLDSIDE MIXTURE LEVEL (FT)
50.000
40.000
30.000
20.000
10.000
0.0
STM. GEN. COLDSIDE MIXTURE LEVEL (FT)
0.0
2000.0
4000.0
6000.0
8000.0
1.00E+04
TIME (SEC)

FIGURE B - 7



LOFW - LOCA ANALYSIS 4 LOOP PLANT
SMALL PORV BLOWDOWN 3411 MWT 179000 LBM/HR PORV FLOW OPEN 2500
STM. GEN. SECONDARY MIXTURE LEVEL (FT)
120.00
100.00
80.000
60.000
40.000
20.000
0.0
STM. GEN. SECONDARY MIXTURE LEVEL (FT)
0.0
2000.0
4000.0
6000.0
8000.0
TIME (SEC)

FIGURE B - 8



LOFW - LOCA ANALYSIS 4 LOOP PLANT
SMALL PORV BLOWDOWN 3411 MWT 179000 LBM/HR PORV FLOW OPEN 2500
LOOP SEAL MIXTURE LEVEL (FT)
25.000
20.000
15.000
10.000
5.0000
0.0
LOOP SEAL MIXTURE LEVEL (FT)
0.0
2000.0
4000.0
6000.0
8000.0
TIME (SEC)

FIGURE B - 9

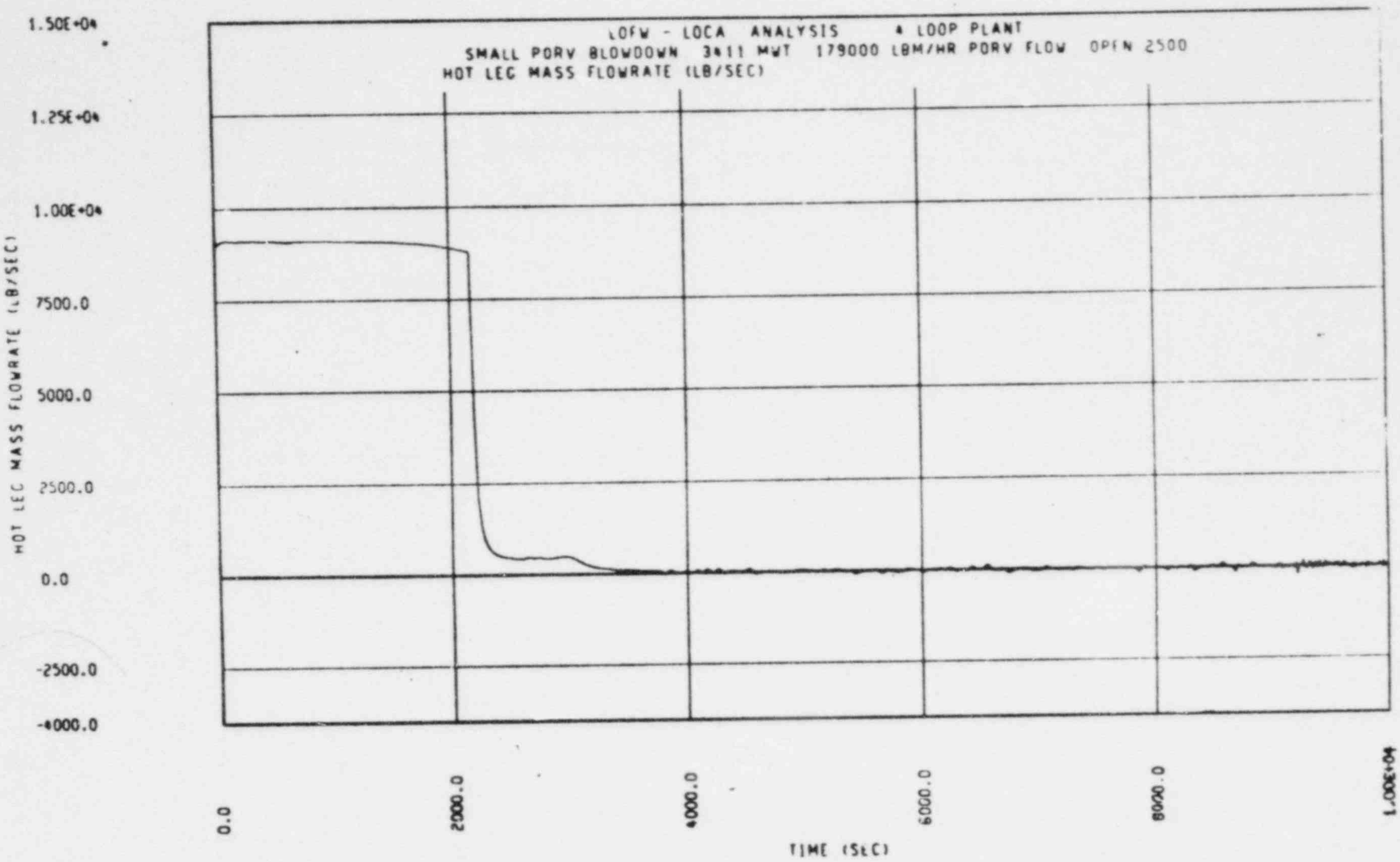

LOFW - LOCA ANALYSIS 4 LOOP PLANT
SMALL PORV BLOWDOWN 3411 MWT 179000 LBM/HR PORV FLOW OPEN 2500
HOT LEG MASS FLOWRATE (LB/SEC)
1.50E+04
1.25E+04
1.00E+04
7500.0
5000.0
2500.0
0.0
-2500.0
-4000.0
HOT LEG MASS FLOWRATE (LB/SEC)
0.0
2000.0
4000.0
6000.0
8000.0
1.00E+04
TIME (SEC)

FIGURE B - 10

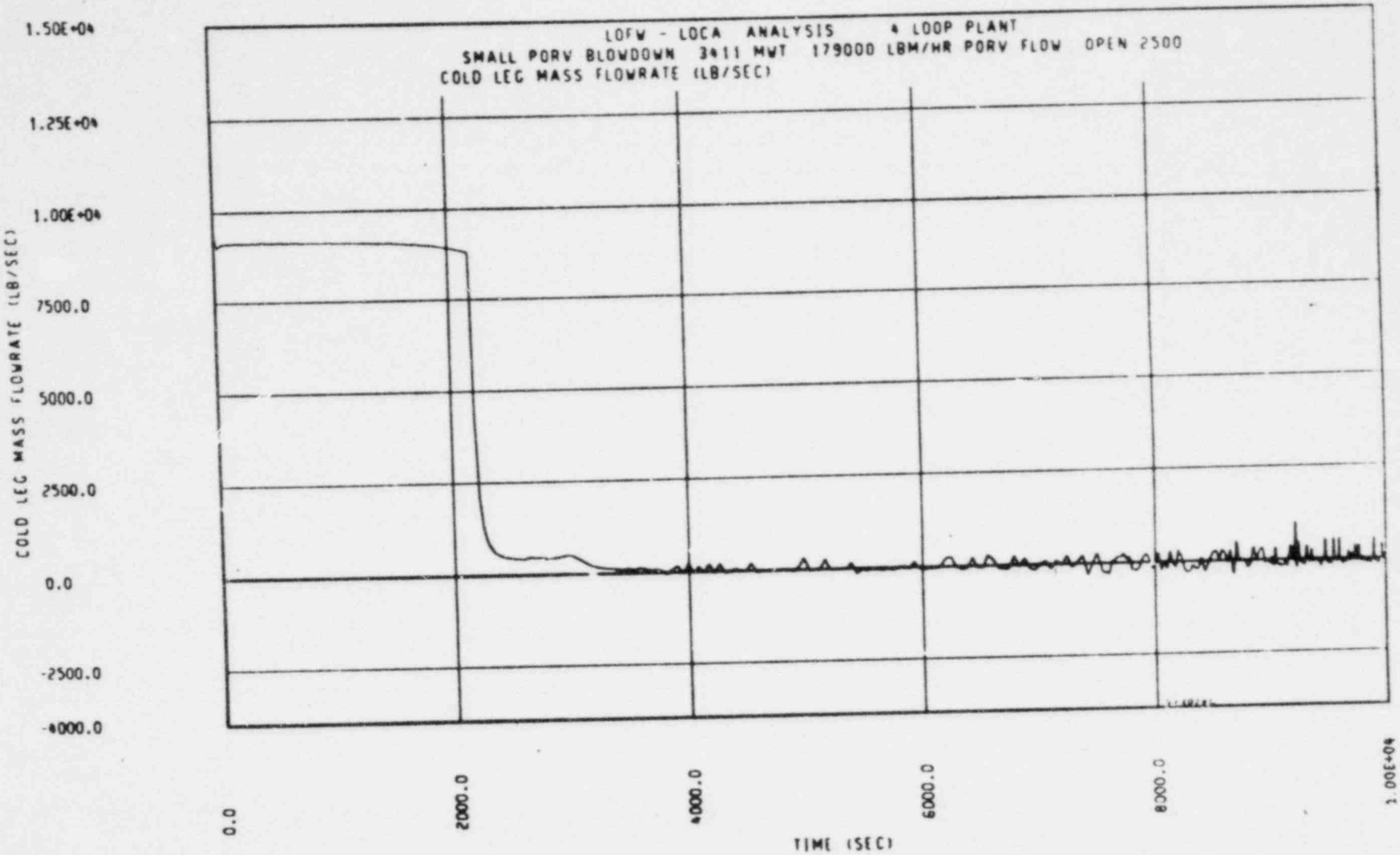
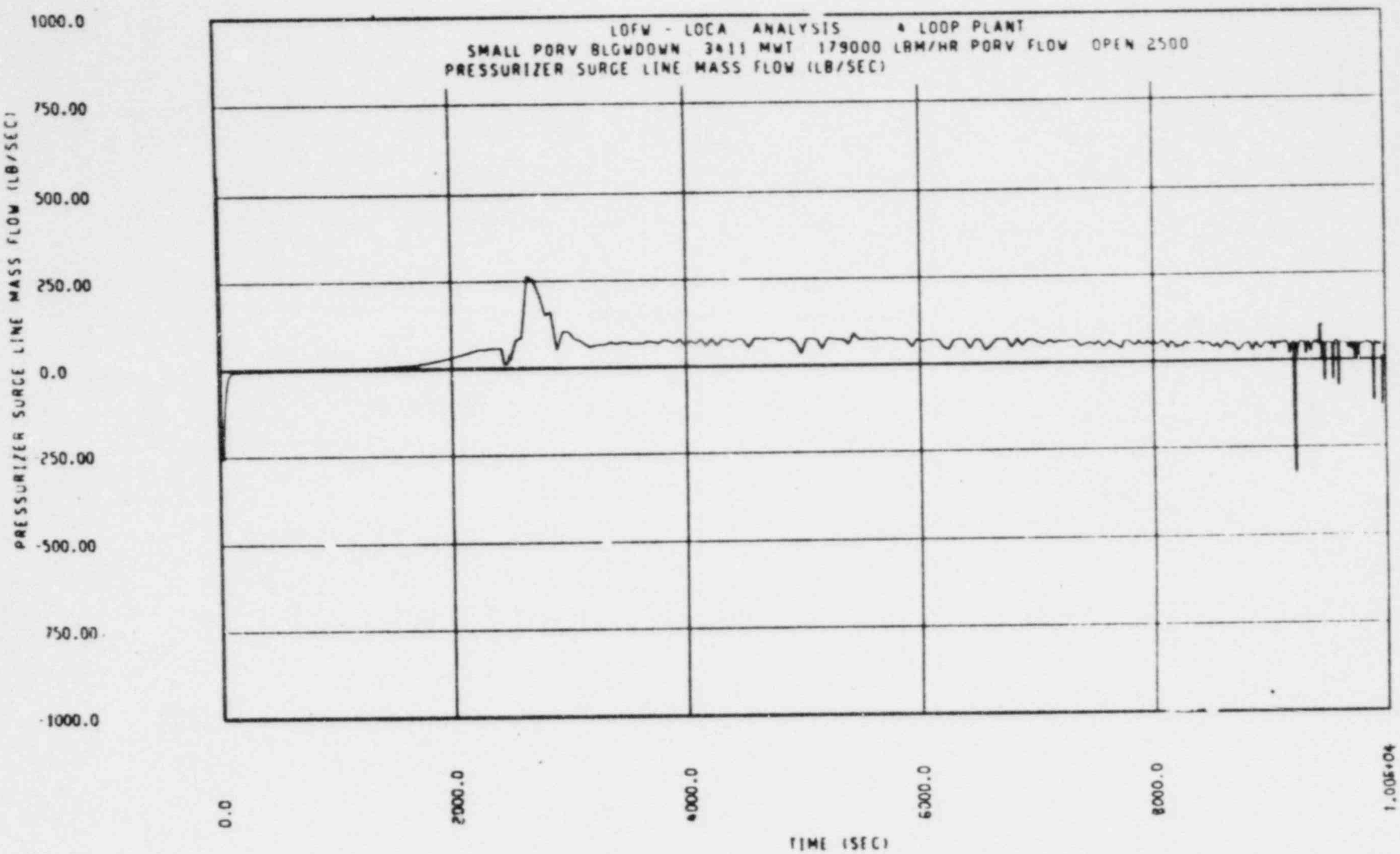

LOFW - LOCA ANALYSIS 4 LOOP PLANT
SMALL PORV BLOWDOWN 3411 MWT 179000 LBM/HR PORV FLOW OPEN 2500
COLD LEG MASS FLOWRATE (LB/SEC)
1.50E+04
1.25E+04
1.00E+04
7500.0
5000.0
2500.0
0.0
-2500.0
-4000.0
COLD LEG MASS FLOWRATE (LB/SEC)
0.0
2000.0
4000.0
6000.0
8000.0
1.00E+04
TIME (SEC)

FIGURE B - 11

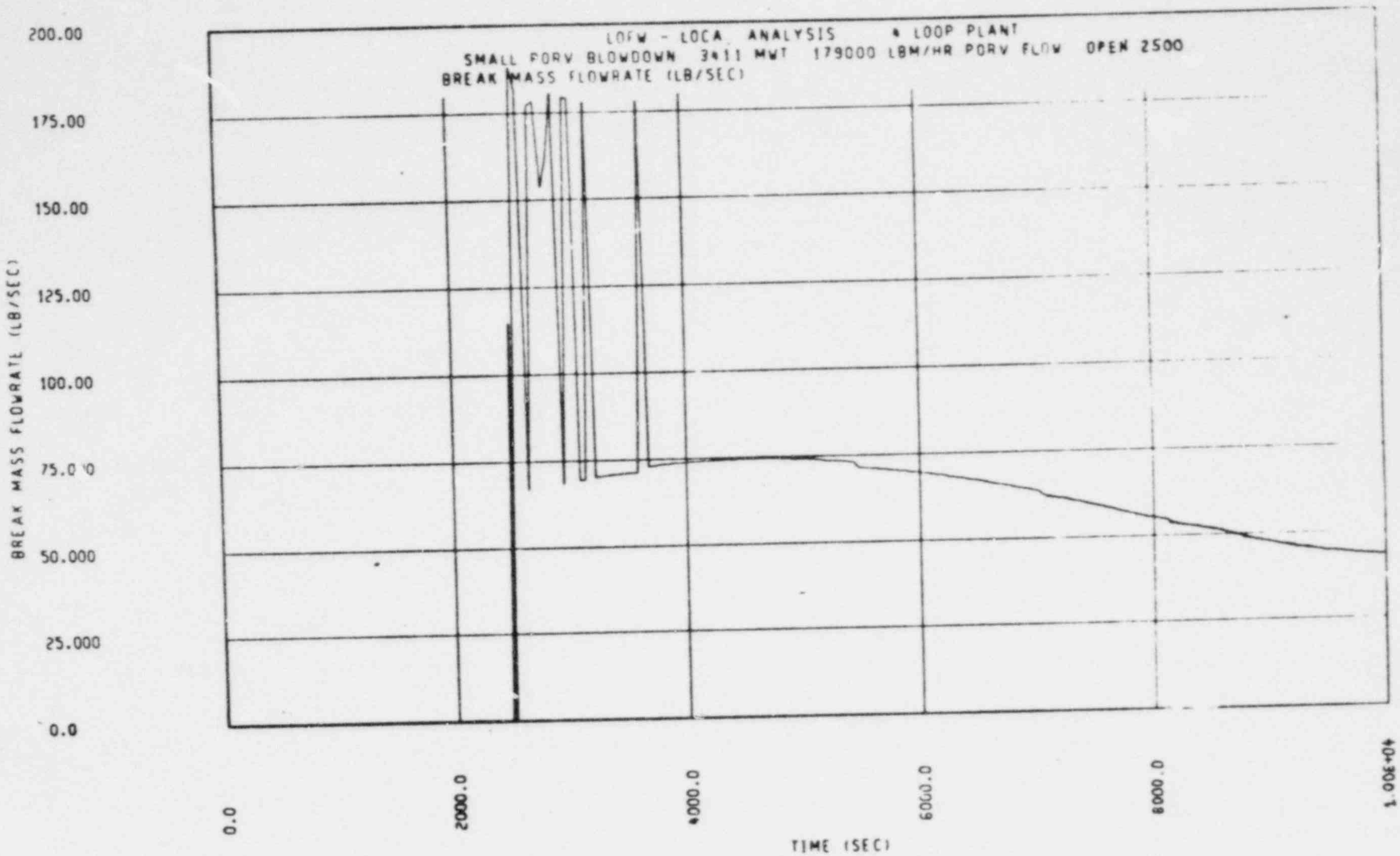


LOFW - LOCA ANALYSIS 4 LOOP PLANT
SMALL PORV BLOWDOWN 3411 MWT 179000 LBM/HR PORV FLOW OPEN 2500
PRESSURIZER SURGE LINE MASS FLOW (LB/SEC)
1000.0
750.00
500.00
250.00
0.0
-250.00
-500.00
-750.00
-1000.0
PRESSURIZER SURGE LINE MASS FLOW (LB/SEC)
0.0
2000.0
4000.0
6000.0
8000.0
1.00E+04
TIME (SEC)

FIGURE B - 12


LOFW - LOCA ANALYSIS 4 LOOP PLANT
SMALL PORV BLOWDOWN 3411 MWT 179000 LBM/HR PORV FLOW OPEN 2500
SAFETY INJECTION MASS FLOWRATE (LB/SEC)
100.00
80.000
60.000
40.000
20.000
0.0
SAFETY INJECTION MASS FLOWRATE (LB/SEC)
0.0
2000.0
4000.0
6000.0
8000.0
1.00E+04
TIME (SEC)

FIGURE B - 13



LOFW - LOCA ANALYSIS 4 LOOP PLANT
SMALL PORV BLOWDOWN 3411 MWT 179000 LBM/HR PORV FLOW OPEN 2500
BREAK MASS FLOWRATE (LB/SEC)
200.00
175.00
150.00
125.00
100.00
75.000
50.000
25.000
0.0
BREAK MASS FLOWRATE (LB/SEC)
0.0
2000.0
4000.0
6000.0
8000.0
1.00E+04
TIME (SEC)

FIGURE B - 14

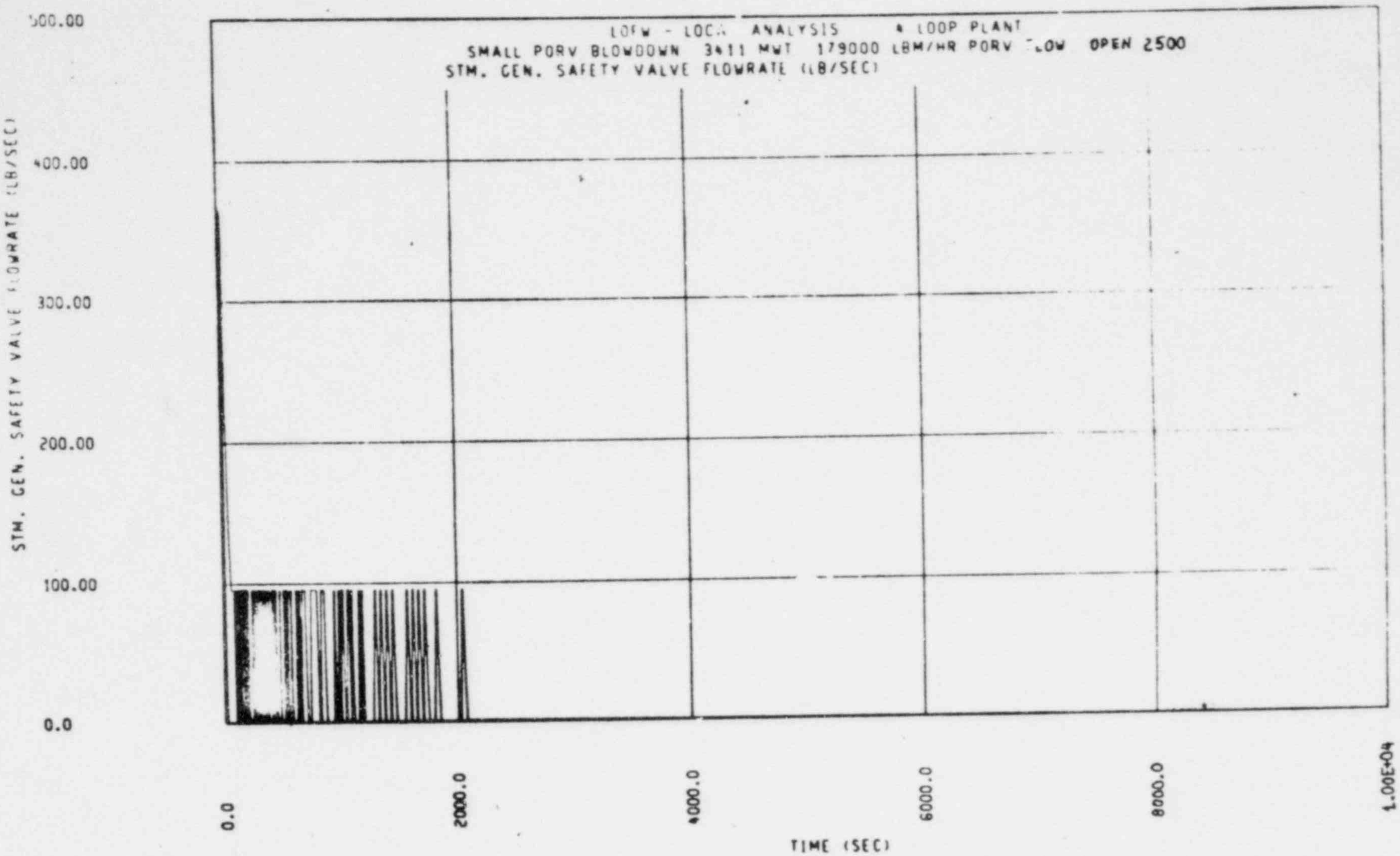

LOFW - LOCA ANALYSIS 4 LOOP PLANT
SMALL PORV BLOWDOWN 3411 MWT 179000 LBM/HR PORV FLOW OPEN 2500
STM. GEN. SAFETY VALVE FLOWRATE (LB/SEC)
500.00
400.00
300.00
200.00
100.00
0.0
STM. GEN. SAFETY VALVE FLOWRATE (LB/SEC)
0.0
2000.0
4000.0
6000.0
8000.0
1.00E+04
TIME (SEC)

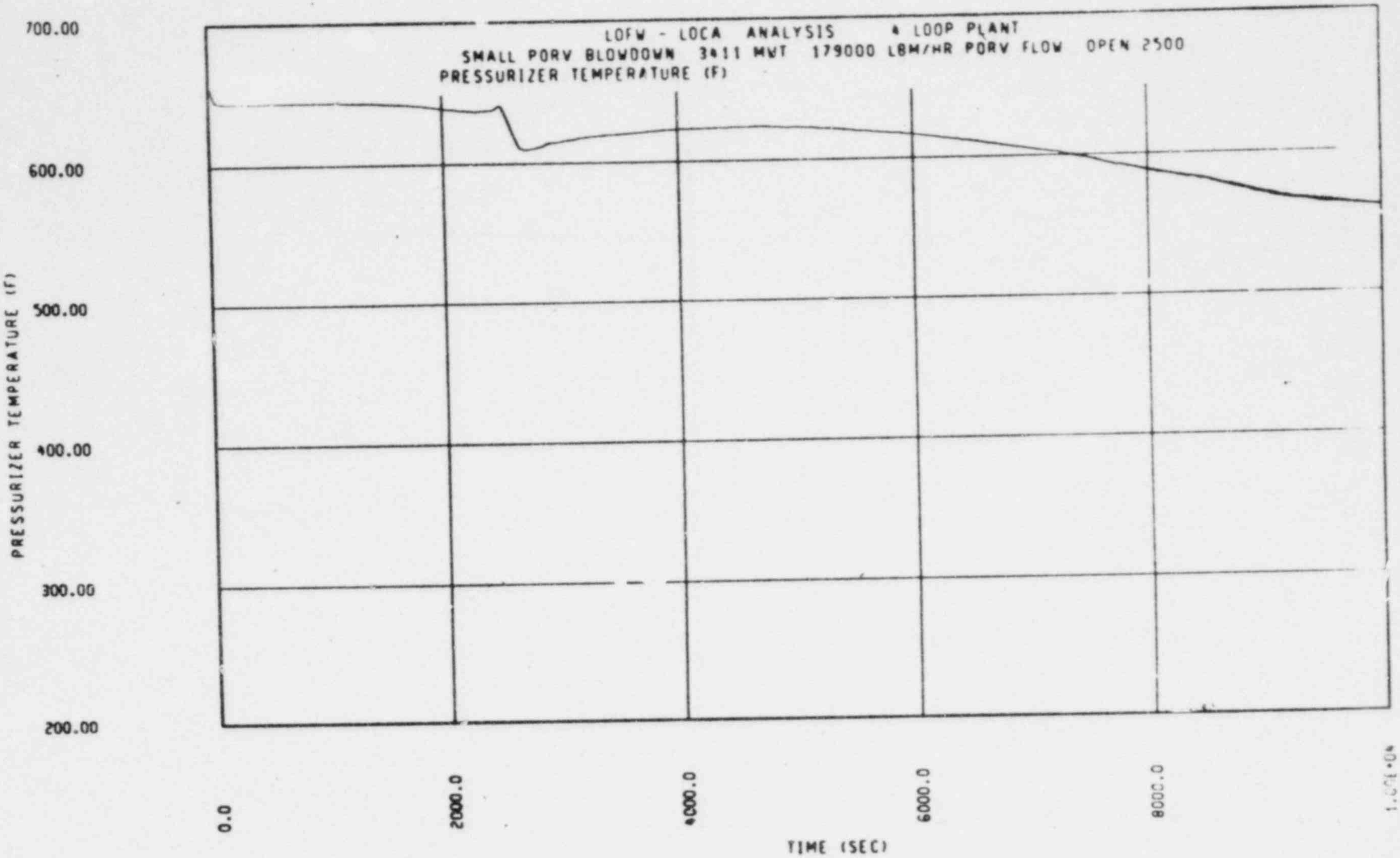
FIGURE B - 15


LOFW - LOCA ANALYSIS 4 LOOP PLANT
SMALL PORV BLOWDOWN 3411 MWT 179000 LBM/HR PORV FLOW OPEN 2500
HOT LEG FLUID TEMPERATURE (F)
700.00
600.00
500.00
400.00
300.00
200.00
HOT LEG FLUID TEMPERATURE (F)
0.0
2000.0
4000.0
6000.0
8000.0
TIME (SEC)

FIGURE B - 16

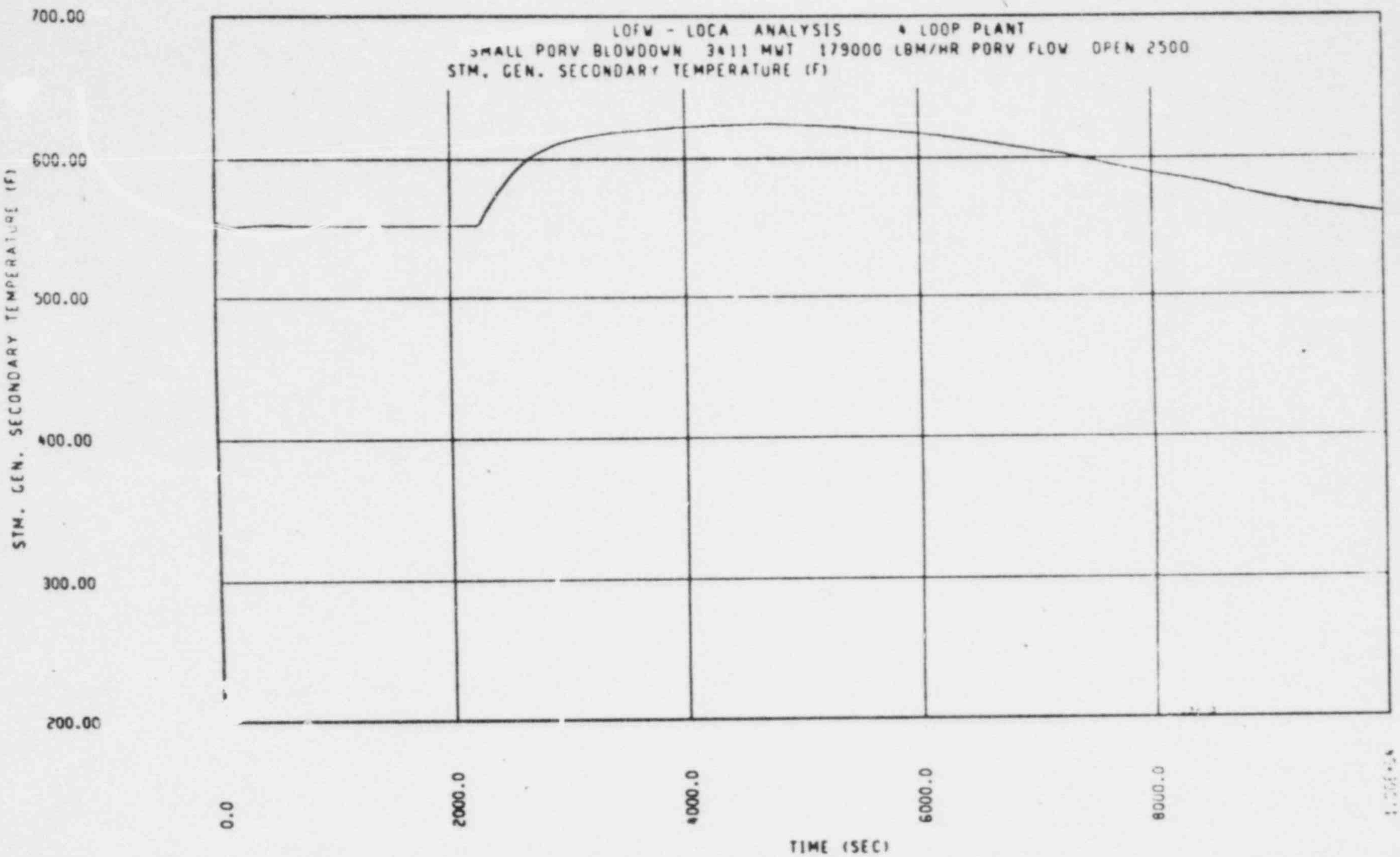
LOFW - LOCA ANALYSIS 4 LOOP PLANT
SMALL PORV BLOWDOWN 3411 MWT 179000 LBM/HR PORV FLOW OPEN 2500
COLD LEG FLUID TEMPERATURE (F)
700.00
600.00
500.00
400.00
300.00
200.00
COLD LEG FLUID TEMPERATURE (F)
0.0
2000.0
4000.0
6000.0
8000.0
1.00E+04
TIME (SEC)

FIGURE B - 17



LOFW - LOCA ANALYSIS 4 LOOP PLANT
SMALL PORV BLOWDOWN 3411 MWT 179000 LBM/HR PORV FLOW OPEN 2500
PRESSURIZER TEMPERATURE (F)
700.00
600.00
500.00
400.00
300.00
200.00
PRESSURIZER TEMPERATURE (F)
0.0
2000.0
4000.0
6000.0
8000.0
TIME (SEC)

FIGURE B - 18



LOFW - LOCA ANALYSIS 4 LOOP PLANT
SMALL PORV BLOWDOWN 3411 MWT 179000 LBM/HR PORV FLOW OPEN 2500
STM. GEN. SECONDARY TEMPERATURE (F)
700.00
600.00
500.00
400.00
300.00
200.00
STM. GEN. SECONDARY TEMPERATURE (F)
0.0
2000.0
4000.0
6000.0
8000.0
TIME (SEC)

FIGURE B - 19

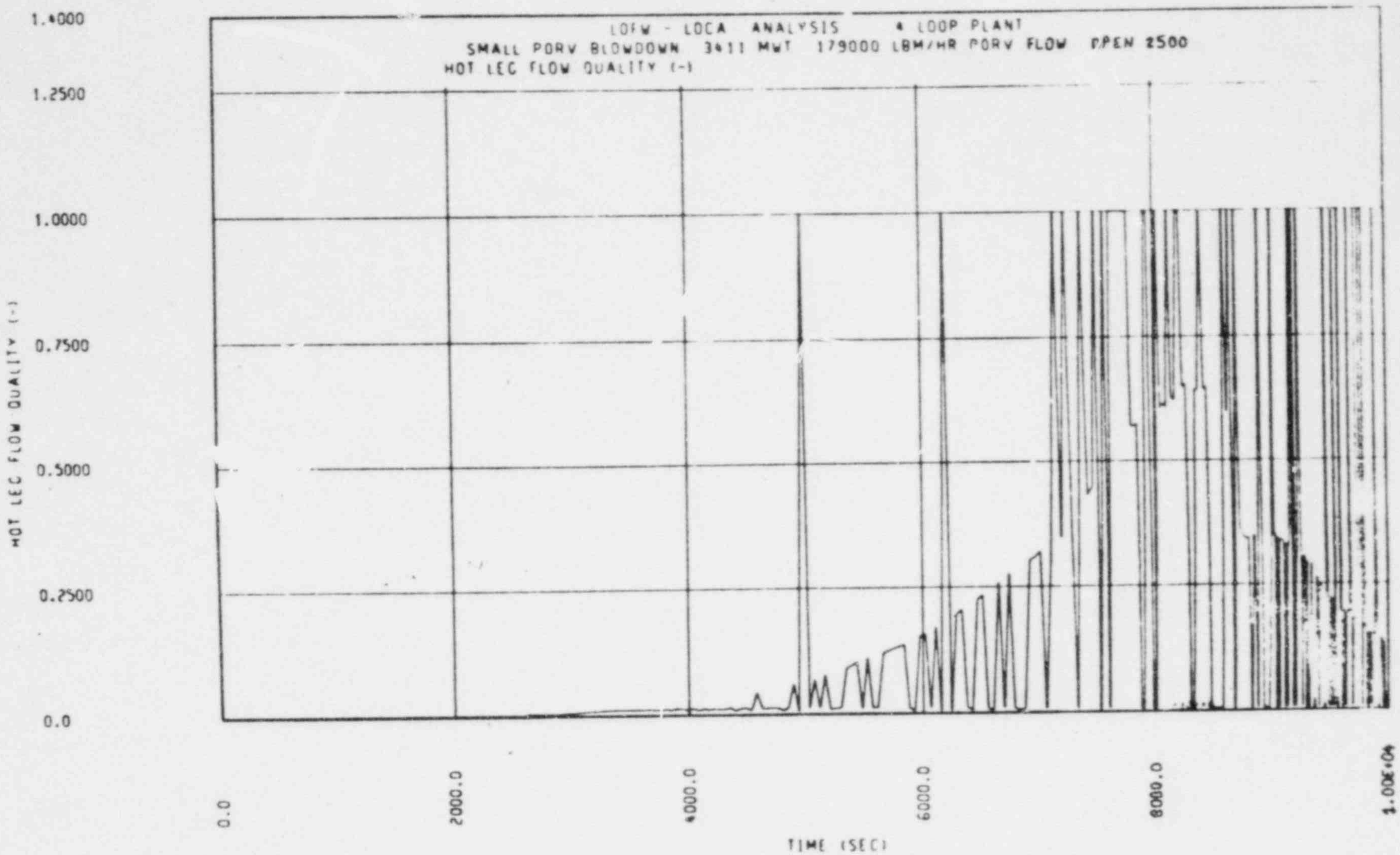
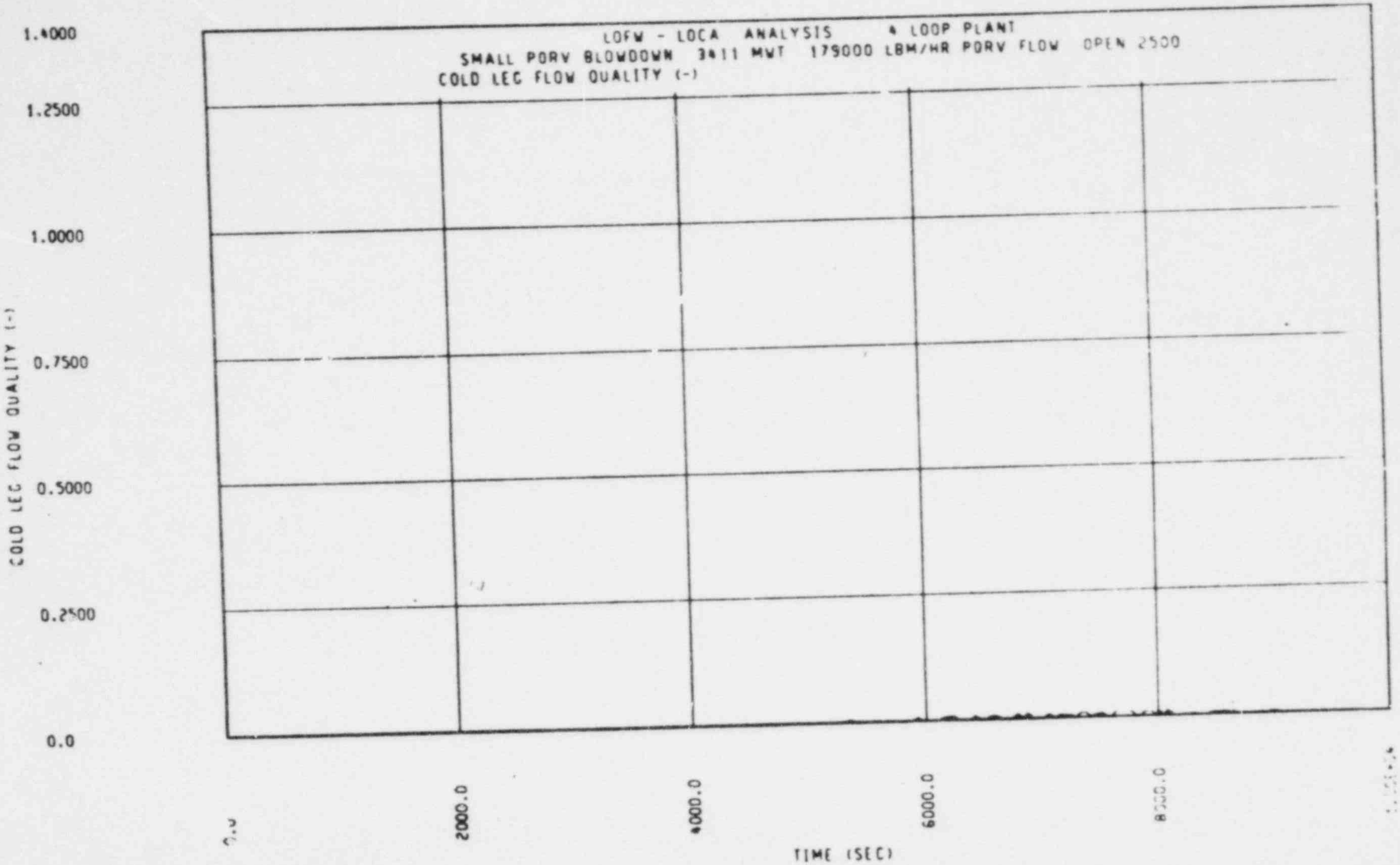
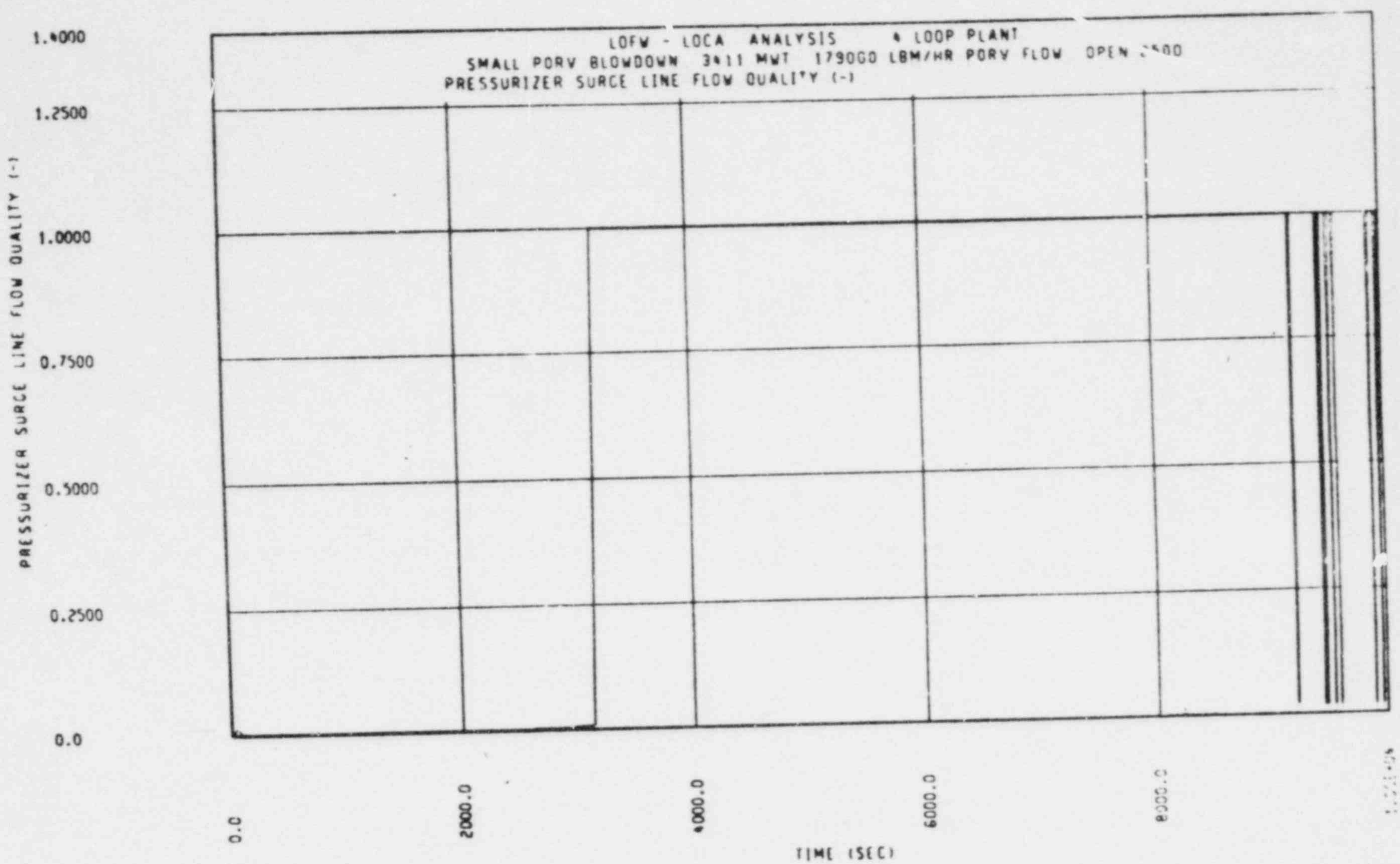

LOFW - LOCA ANALYSIS 4 LOOP PLANT
SMALL PORV BLOWDOWN 3411 MWT 179000 LBM/HR PORV FLOW OPEN 2500
HOT LEG FLOW QUALITY (-)
1.4000
1.2500
1.0000
0.7500
0.5000
0.2500
0.0
HOT LEG FLOW QUALITY (-)
0.0
2000.0
4000.0
6000.0
8000.0
1.00E+04
TIME (SEC)

FIGURE B - 20



LOFW - LOCA ANALYSIS 4 LOOP PLANT
SMALL PORV BLOWDOWN 3411 MWT 179000 LBM/HR PORV FLOW OPEN 2500
COLD LEG FLOW QUALITY (-)
1.4000
1.2500
1.0000
0.7500
0.5000
0.2500
0.0
COLD LEG FLOW QUALITY (-)
2000.0
4000.0
6000.0
8000.0
TIME (SEC)

FIGURE B - 21



LOFW - LOCA ANALYSIS 4 LOOP PLANT
SMALL PORV BLOWDOWN 3411 MWT 179000 LBM/HR PORV FLOW OPEN
PRESSURIZER SURGE LINE FLOW QUALITY (-)
1.4000
1.2500
1.0000
0.7500
0.5000
0.2500
0.0
PRESSURIZER SURGE LINE FLOW QUALITY (-)
0.0
2000.0
4000.0
6000.0
8000.0
TIME (SEC)

FIGURE B - 22

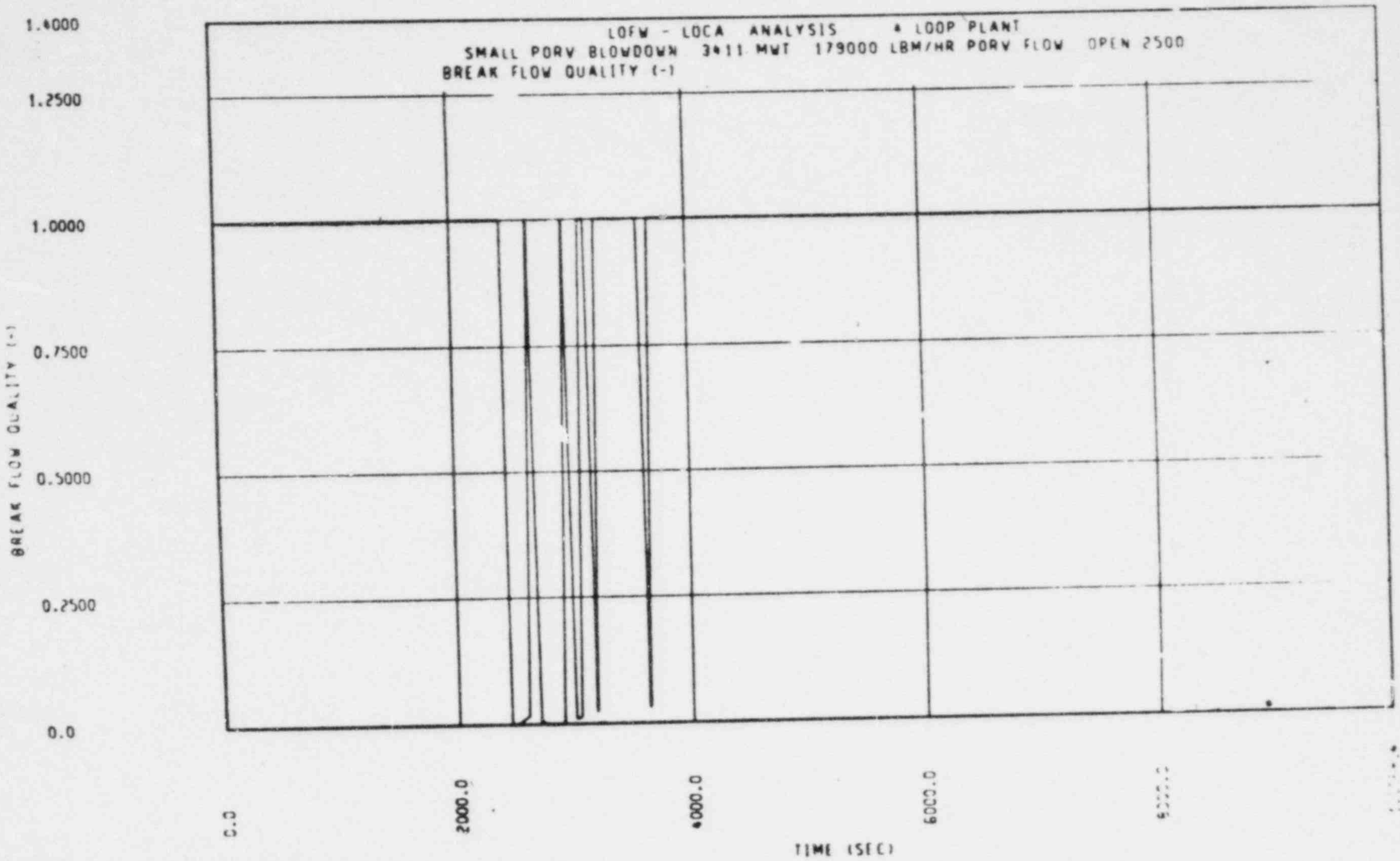
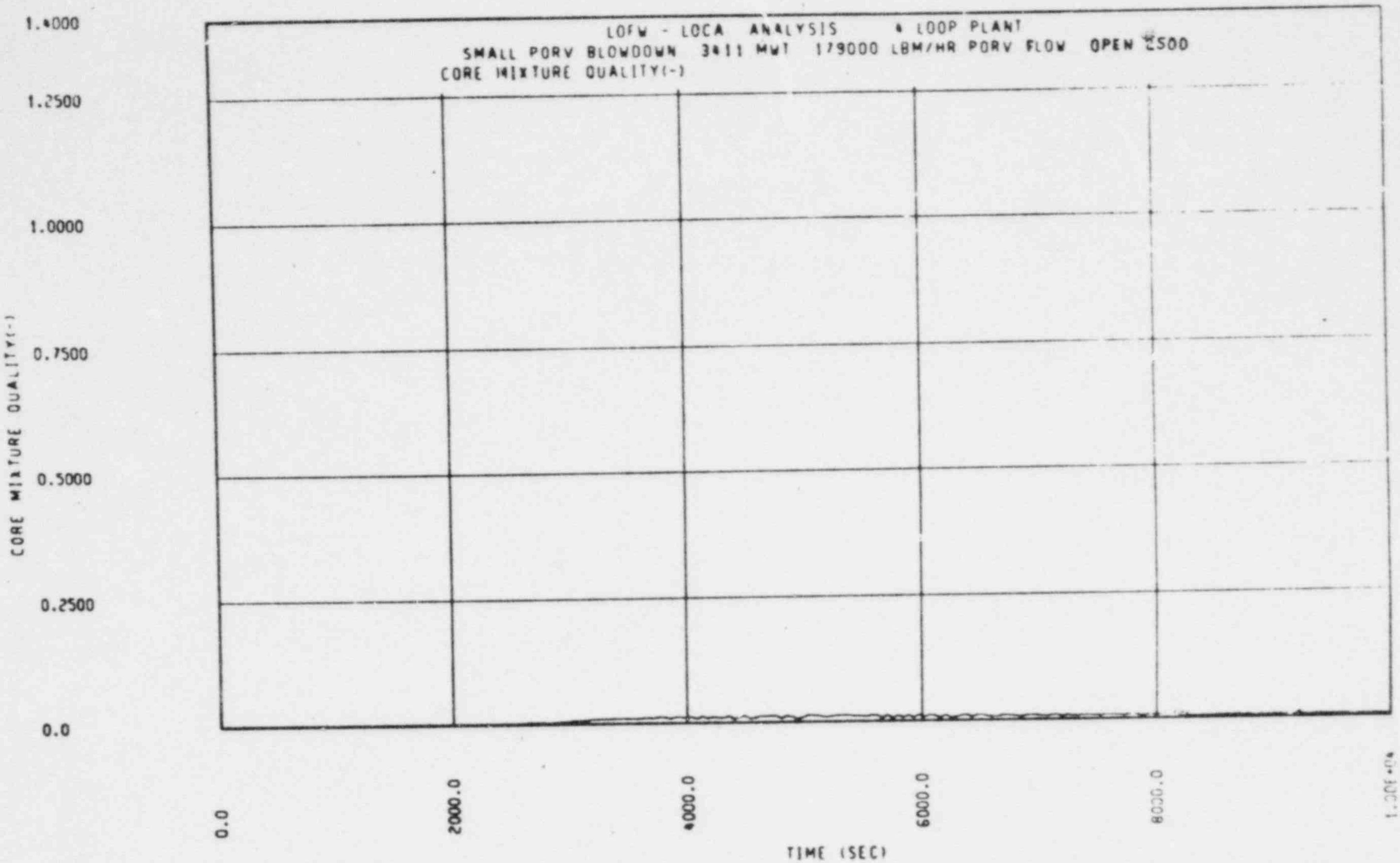
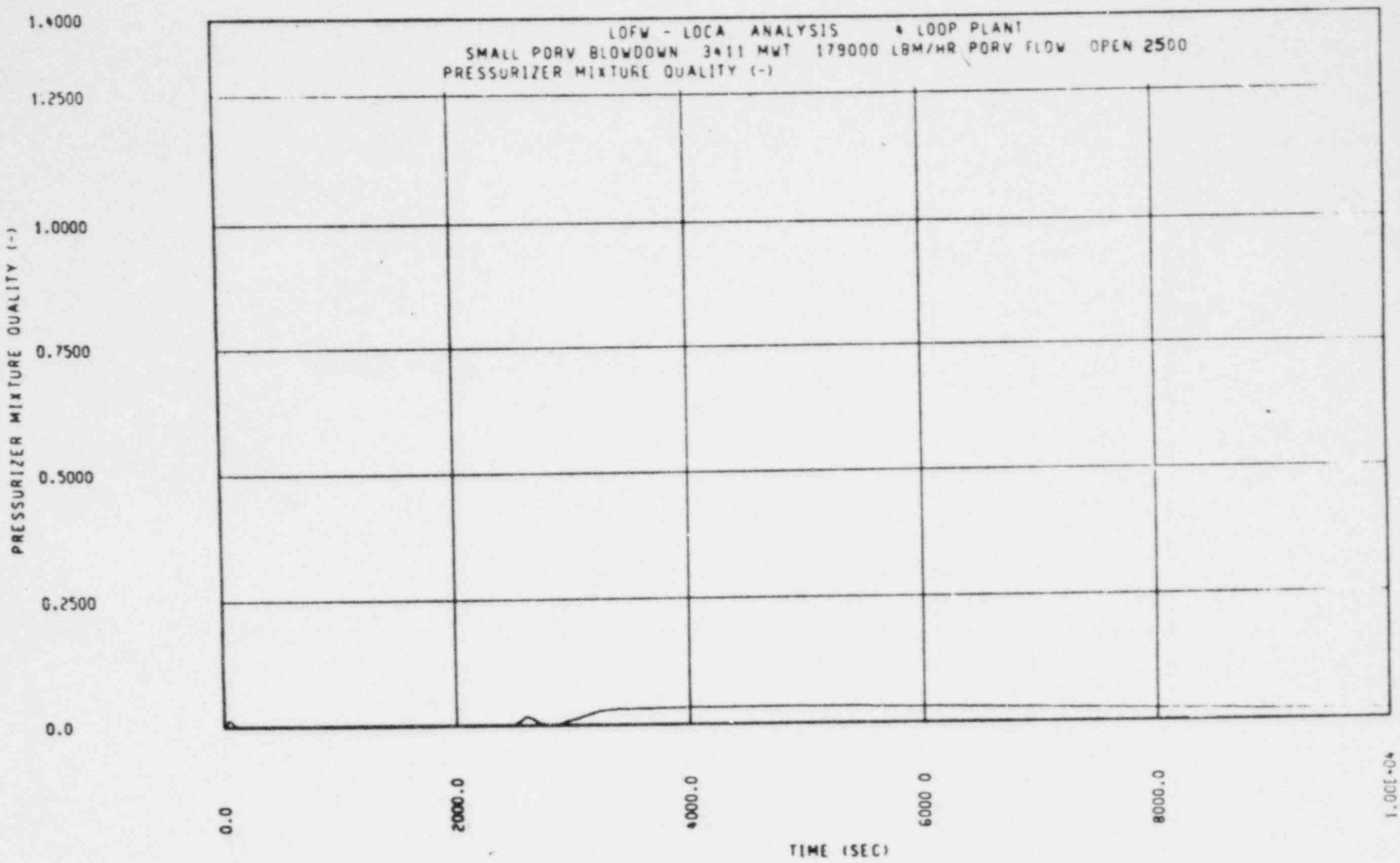

LOFW - LOCA ANALYSIS 4 LOOP PLANT
SMALL PORV BLOWDOWN 3411 MWT 179000 LBM/HR PORV FLOW OPEN 2500
BREAK FLOW QUALITY (-)
1.4000
1.2500
1.0000
0.7500
0.5000
0.2500
0.0
BREAK FLOW QUALITY (-)
0.0
2000.0
4000.0
6000.0
TIME (SEC)

FIGURE B - 23



LOFW - LOCA ANALYSIS 4 LOOP PLANT
SMALL PORV BLOWDOWN 3411 MWT 179000 LBM/HR PORV FLOW OPEN 2500
CORE MIXTURE QUALITY(-)
1.4000
1.2500
1.0000
0.7500
0.5000
0.2500
0.0
CORE MIXTURE QUALITY(-)
0.0
2000.0
4000.0
6000.0
8000.0
1.00E+04
TIME (SEC)

FIGURE B - 24

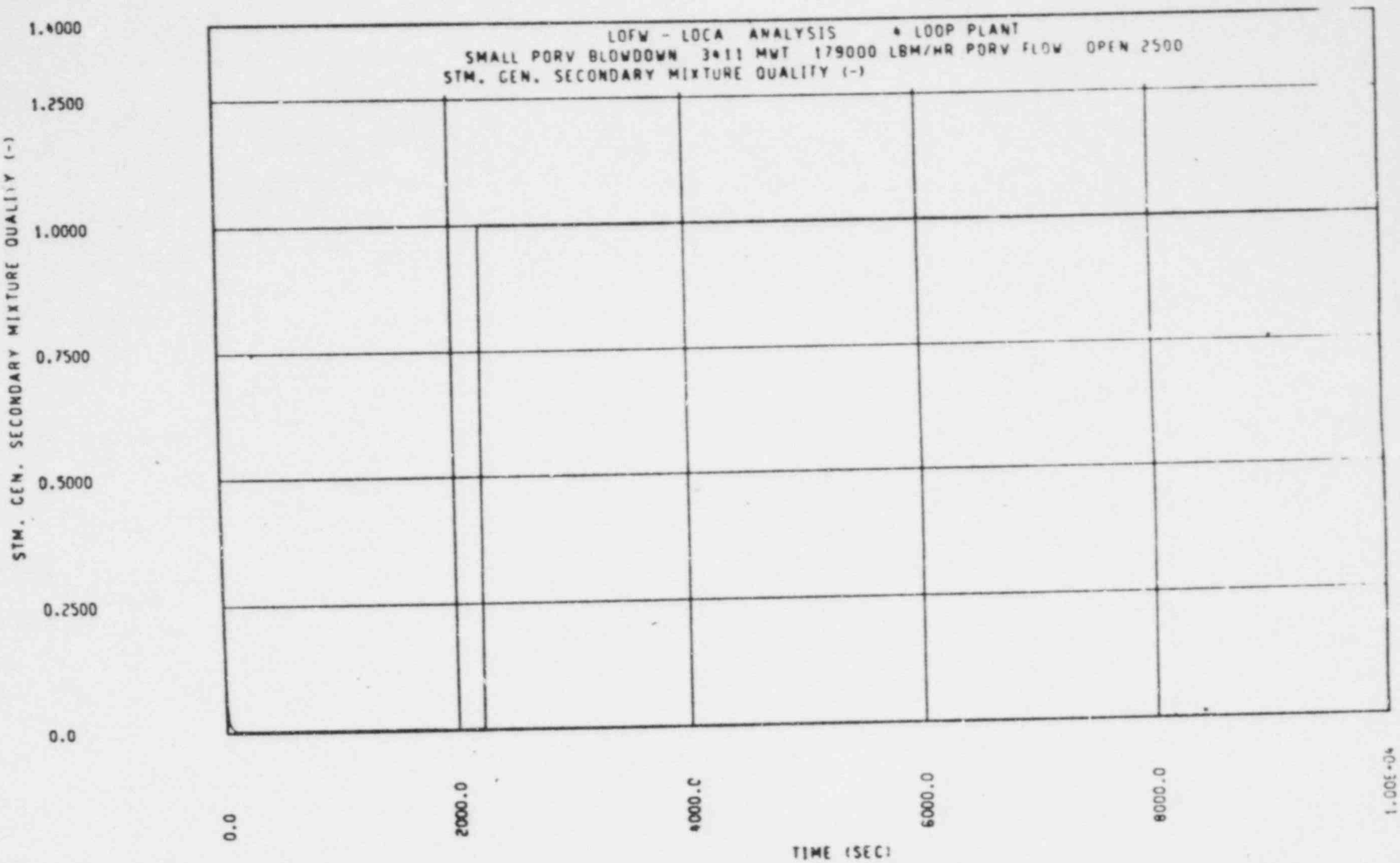


LOFW - LOCA ANALYSIS 4 LOOP PLANT
SMALL PORV BLOWDOWN 3411 MWT 179000 LBM/HR PORV FLOW OPEN 2500
PRESSURIZER MIXTURE QUALITY (-)
1.4000
1.2500
1.0000
0.7500
0.5000
0.2500
0.0
PRESSURIZER MIXTURE QUALITY (-)
0.0
2000.0
4000.0
6000.0
8000.0
1.00E+04
TIME (SEC)

FIGURE B - 25

LOFW - LOCA ANALYSIS 4 LOOP PLANT
SMALL PORV BLOWDOWN 3411 MWT 179000 LBM/HR PORV FLOW OPEN 2500
STM. GEN. HOTSIDE MIXTURE QUALITY (-)
STM. GEN. HOTSIDE MIXTURE QUALITY (-)
1.4000
1.2500
1.0000
0.7500
0.5000
0.2500
0.0
0.0
2000.0
4000.0
6000.0
8000.0
TIME (SEC)

FIGURE B - 26



LOFW - LOCA ANALYSIS 4 LOOP PLANT
SMALL PORV BLOWDOWN 3411 MWT 179000 LBM/HR PORV FLOW OPEN 2500
STM. GEN. SECONDARY MIXTURE QUALITY (-)
1.4000
1.2500
1.0000
0.7500
0.5000
0.2500
0.0
STM. GEN. SECONDARY MIXTURE QUALITY (-)
0.0
2000.0
4000.0
6000.0
8000.0
1.00E+04
TIME (SEC)

FIGURE B - 27

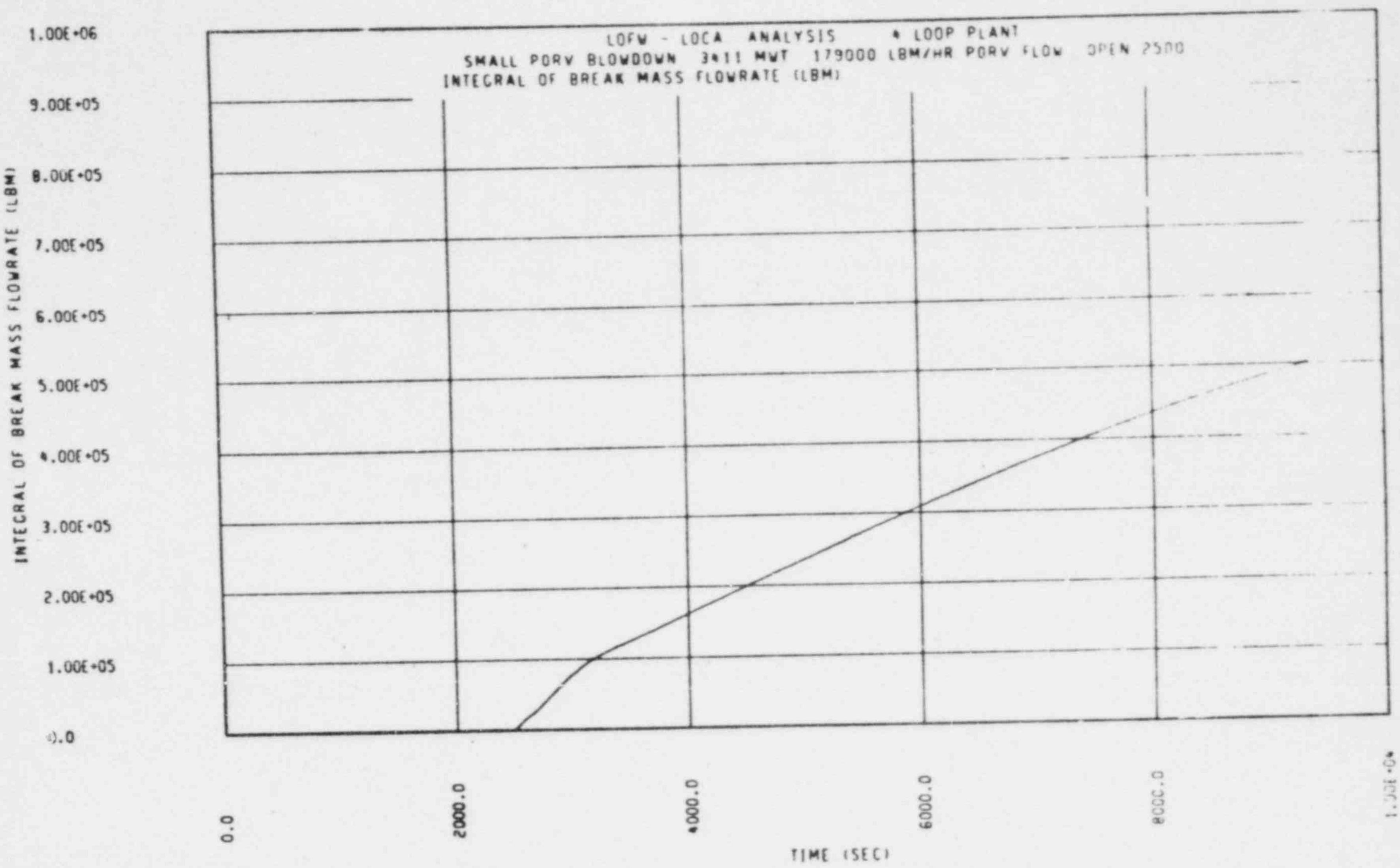
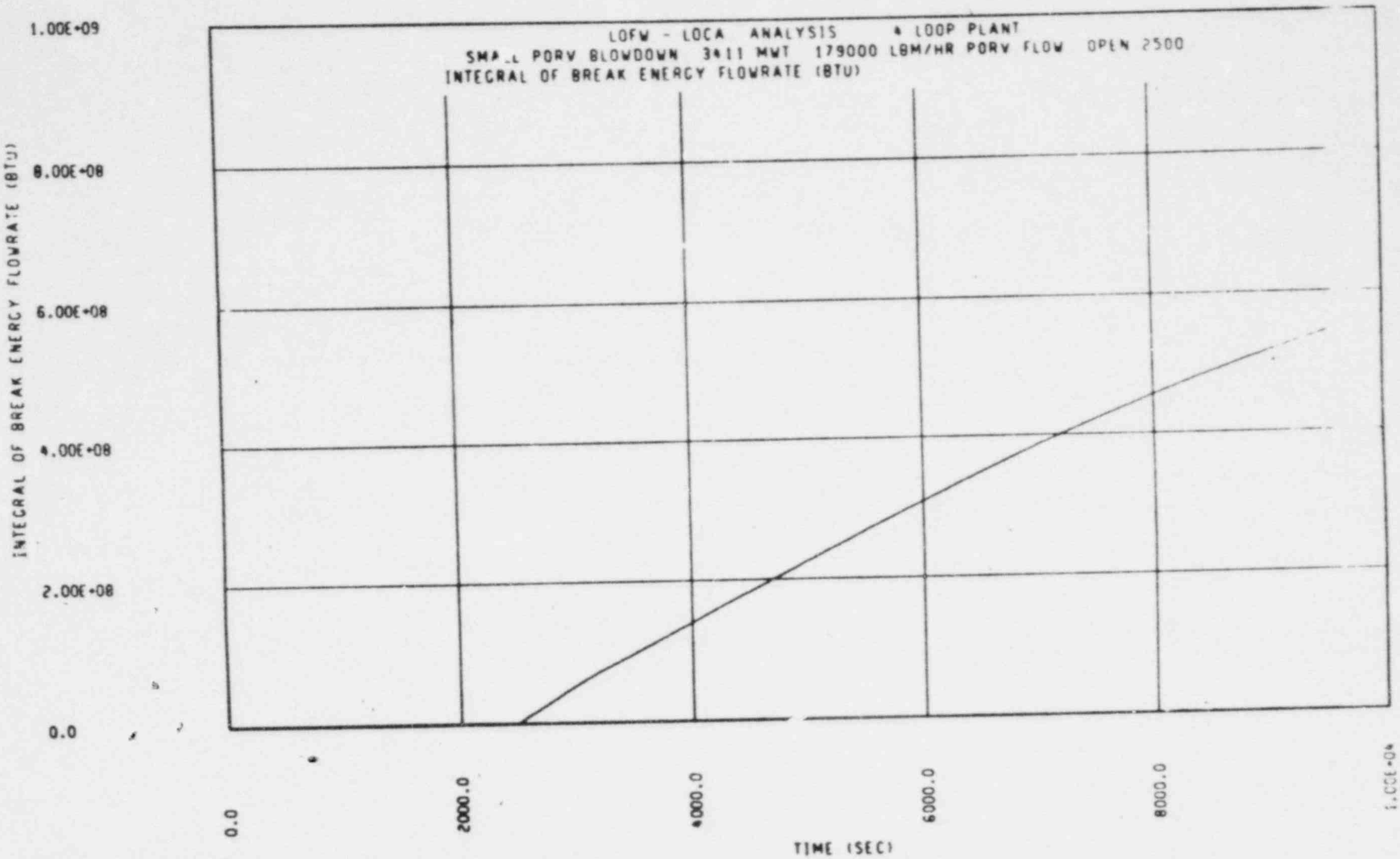
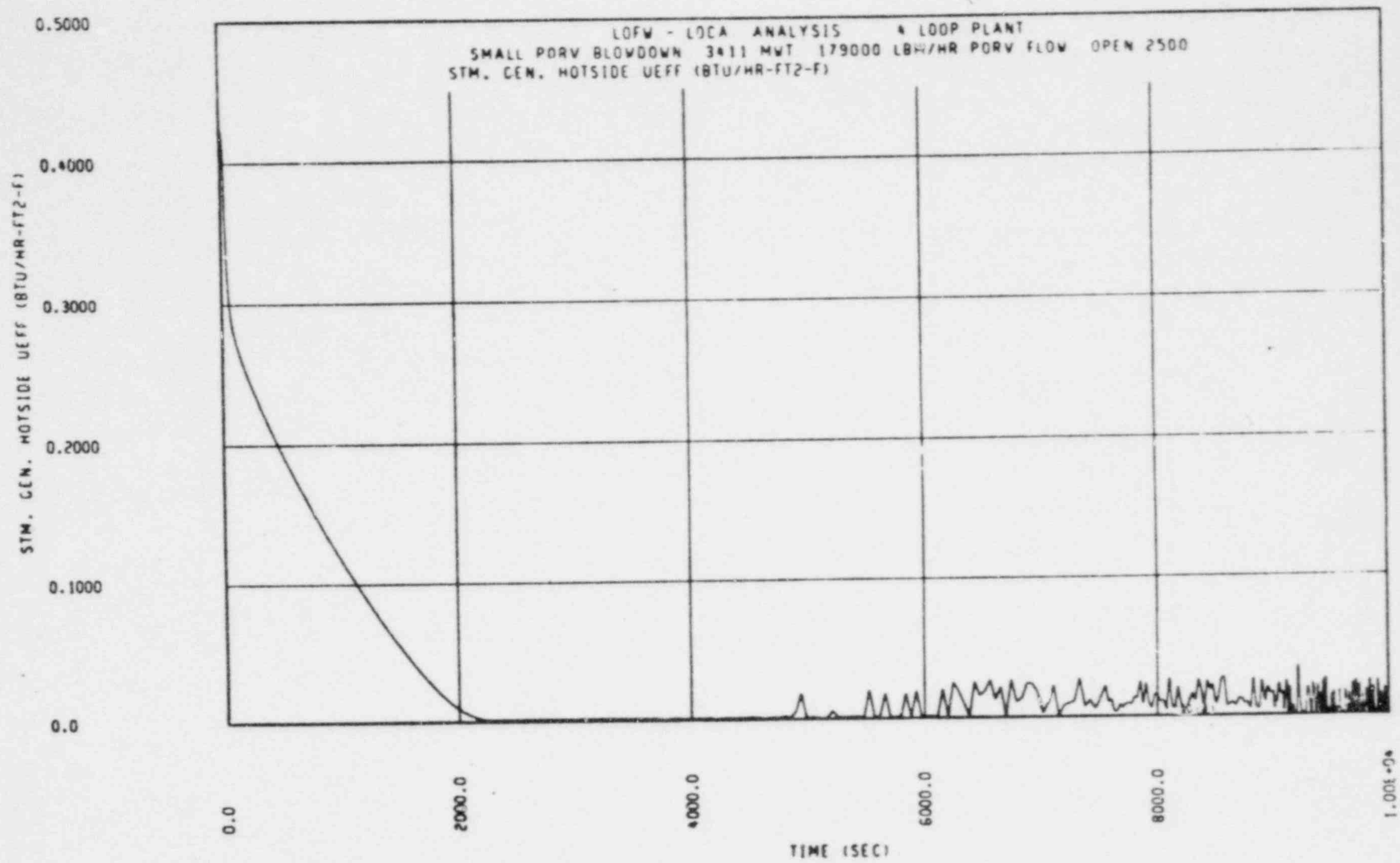

LOFW - LOCA ANALYSIS 4 LOOP PLANT
SMALL PORV BLOWDOWN 3411 MWT 179000 LBM/HR PORV FLOW OPEN 2500
INTEGRAL OF BREAK MASS FLOWRATE (LBM)
INTEGRAL OF BREAK MASS FLOWRATE (LBM)
1.00E+06
9.00E+05
8.00E+05
7.00E+05
6.00E+05
5.00E+05
4.00E+05
3.00E+05
2.00E+05
1.00E+05
0.0
0.0
2000.0
4000.0
6000.0
8000.0
TIME (SEC)

FIGURE B - 28



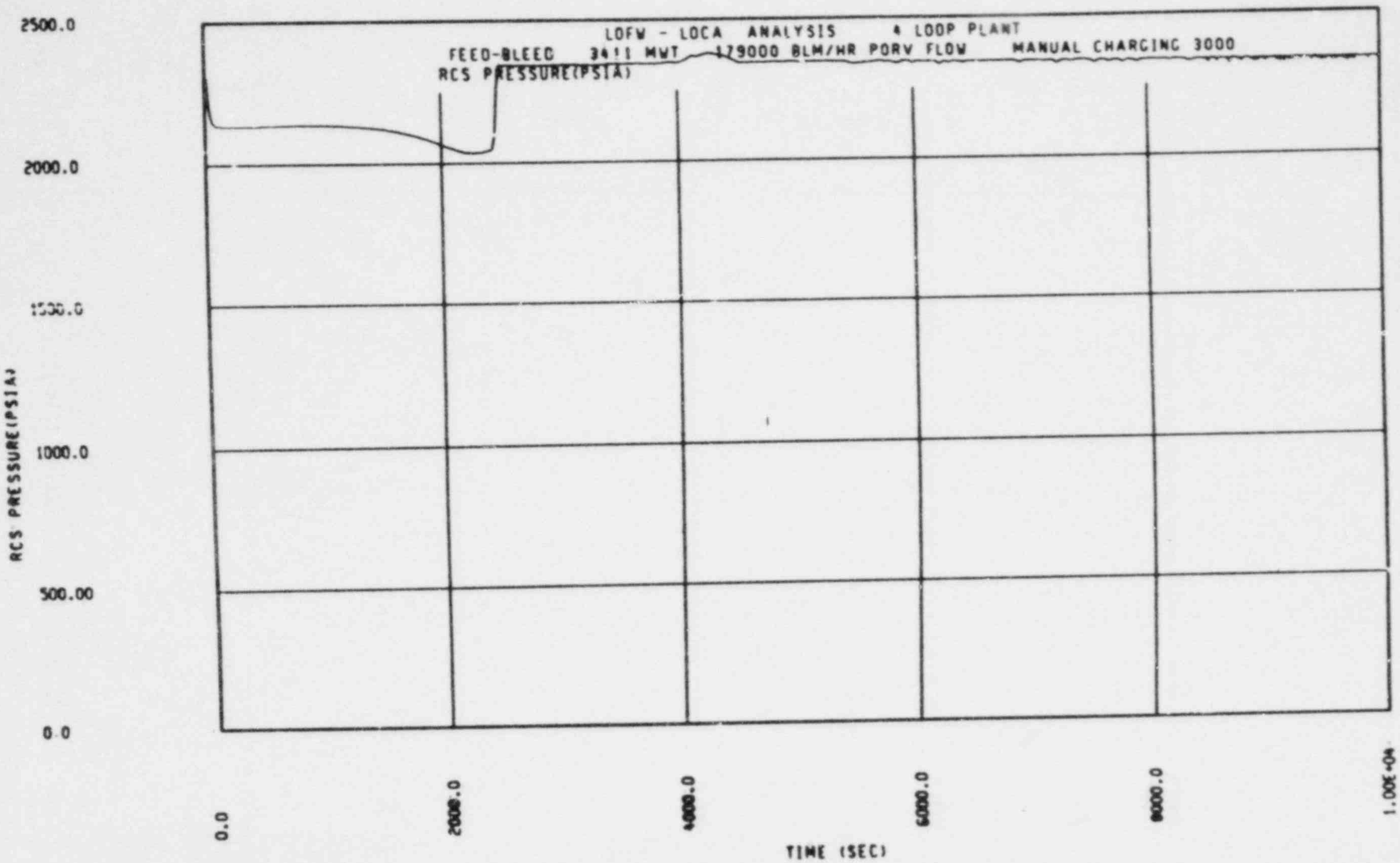
LOFW - LOCA ANALYSIS 4 LOOP PLANT
SMALL PORV BLOWDOWN 3411 MWT 179000 LBM/HR PORV FLOW OPEN 2500
INTEGRAL OF BREAK ENERGY FLOWRATE (BTU)
INTEGRAL OF BREAK ENERGY FLOWRATE (BTU)
1.00E+09
8.00E+08
6.00E+08
4.00E+08
2.00E+08
0.0
0.0
2000.0
4000.0
6000.0
8000.0
1.00E+04
TIME (SEC)

FIGURE B - 29



LOFW - LOCA ANALYSIS 4 LOOP PLANT
SMALL PORV BLOWDOWN 3411 MWT 179000 LBM/HR PORV FLOW OPEN 2500
STM. GEN. HOTSIDE UEFF (BTU/HR-FT2-F)
0.5000
0.4000
0.3000
0.2000
0.1000
0.0
STM. GEN. HOTSIDE UEFF (BTU/HR-FT2-F)
0.0
2000.0
4000.0
6000.0
8000.0
1.00E+04
TIME (SEC)

FIGURE B - 30



LOFW - LOCA ANALYSIS 4 LOOP PLANT
FEED-BLEED 3411 MWT 179000 BLM/HR PORV FLOW MANUAL CHARGING 3000
RCS PRESSURE(PSIA)
2500.0
2000.0
1500.0
1000.0
500.00
0.0
RCS PRESSURE(PSIA)
0.0
2000.0
4000.0
6000.0
8000.0
1.00E+04
TIME (SEC)

FIGURE C - 1

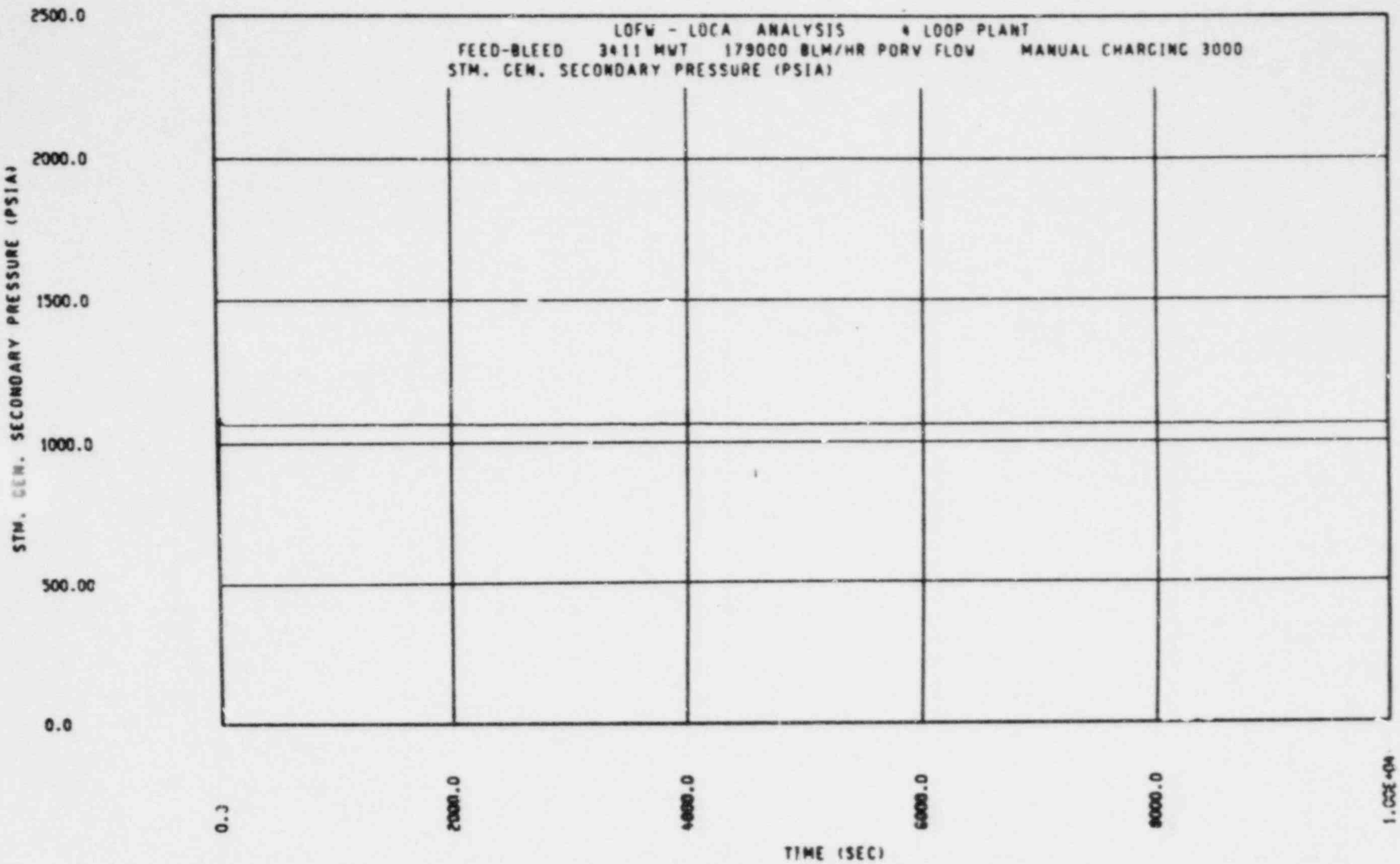
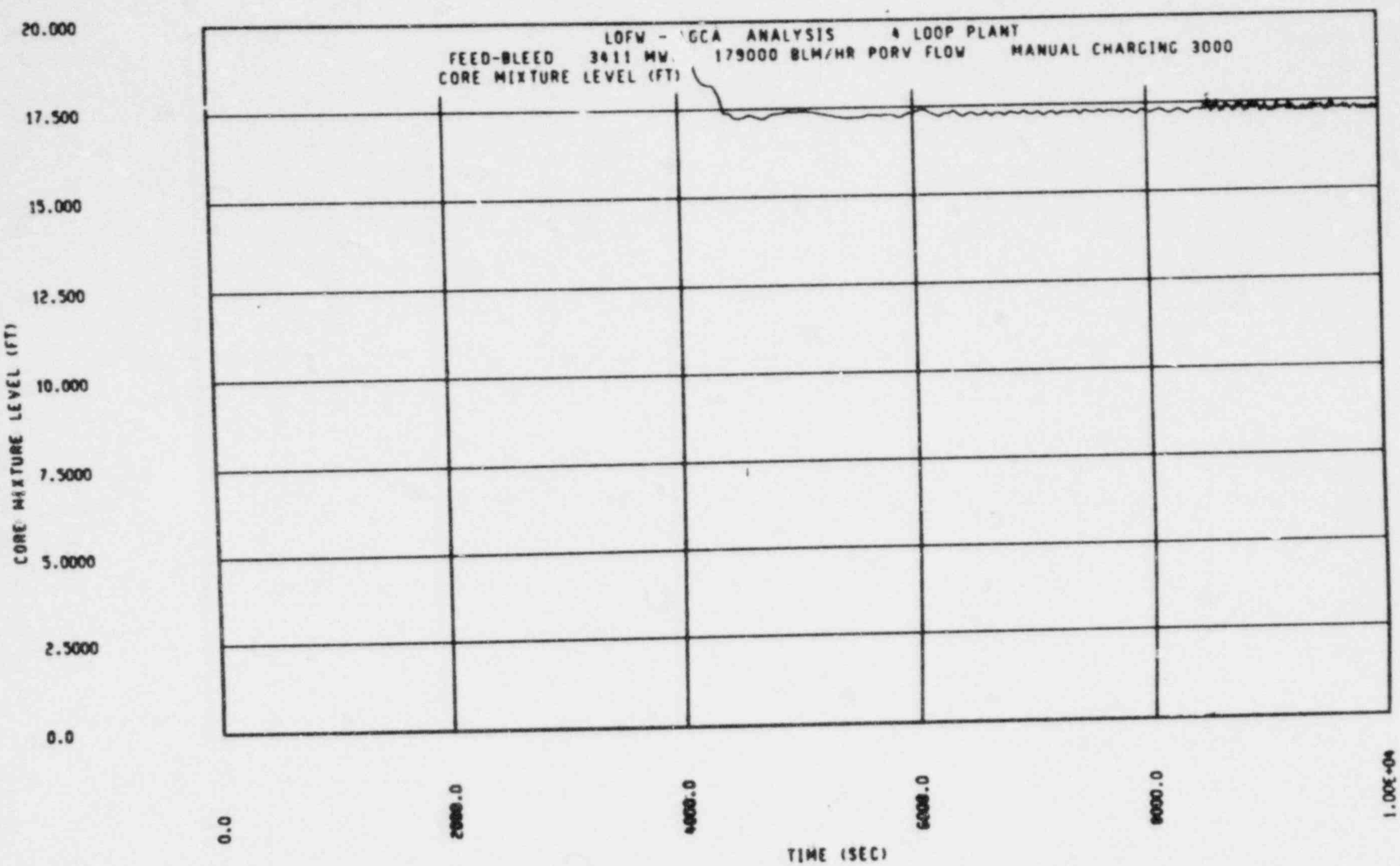

LOFW - LOCA ANALYSIS 4 LOOP PLANT
FEED-BLEED 3411 MWT 179000 BLM/HR PORV FLOW MANUAL CHARGING 3000
STM. GEN. SECONDARY PRESSURE (PSIA)
2500.0
2000.0
1500.0
1000.0
500.00
0.0
STM. GEN. SECONDARY PRESSURE (PSIA)
0.0
2000.0
4000.0
6000.0
8000.0
1.00E+04
TIME (SEC)

FIGURE C - 2



LOFW - LOCA ANALYSIS 4 LOOP PLANT
FEED-BLEED 3411 MW. 179000 BLM/HR PORV FLOW MANUAL CHARGING 3000
CORE MIXTURE LEVEL (FT)
20.000
17.500
15.000
12.500
10.000
7.5000
5.0000
2.5000
0.0
CORE MIXTURE LEVEL (FT)
0.0
2000.0
4000.0
6000.0
8000.0
1.00E+04
TIME (SEC)

FIGURE C - 3

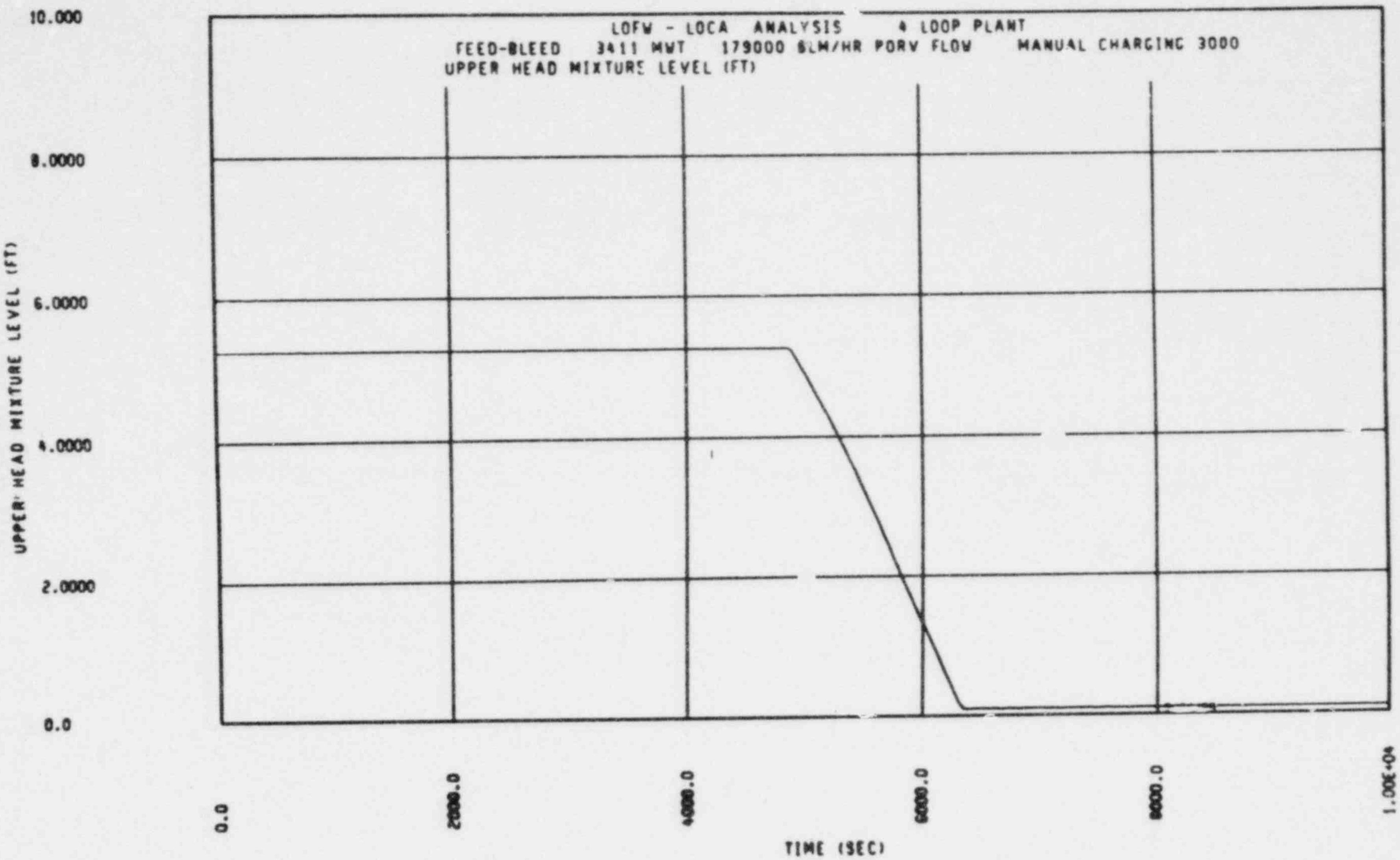

LOFW - LOCA ANALYSIS 4 LOOP PLANT
FEED-BLEED 3411 MWT 179000 LBM/HR PORV FLOW MANUAL CHARGING 3000
UPPER HEAD MIXTURE LEVEL (FT)
10.000
8.0000
6.0000
4.0000
2.0000
0.0
UPPER HEAD MIXTURE LEVEL (FT)
0.0
2000.0
4000.0
6000.0
8000.0
1.00E+04
TIME (SEC)

FIGURE C - 4

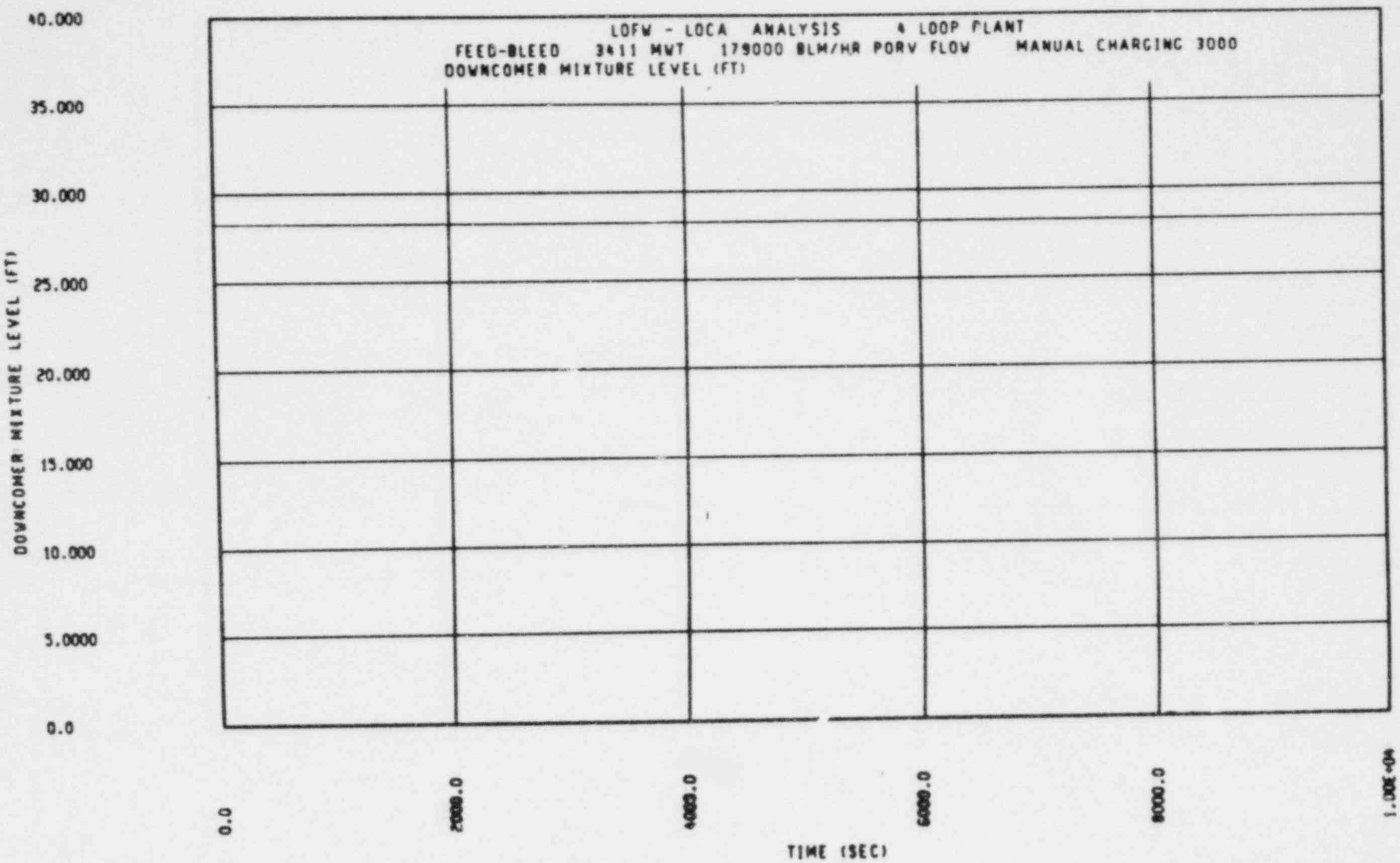
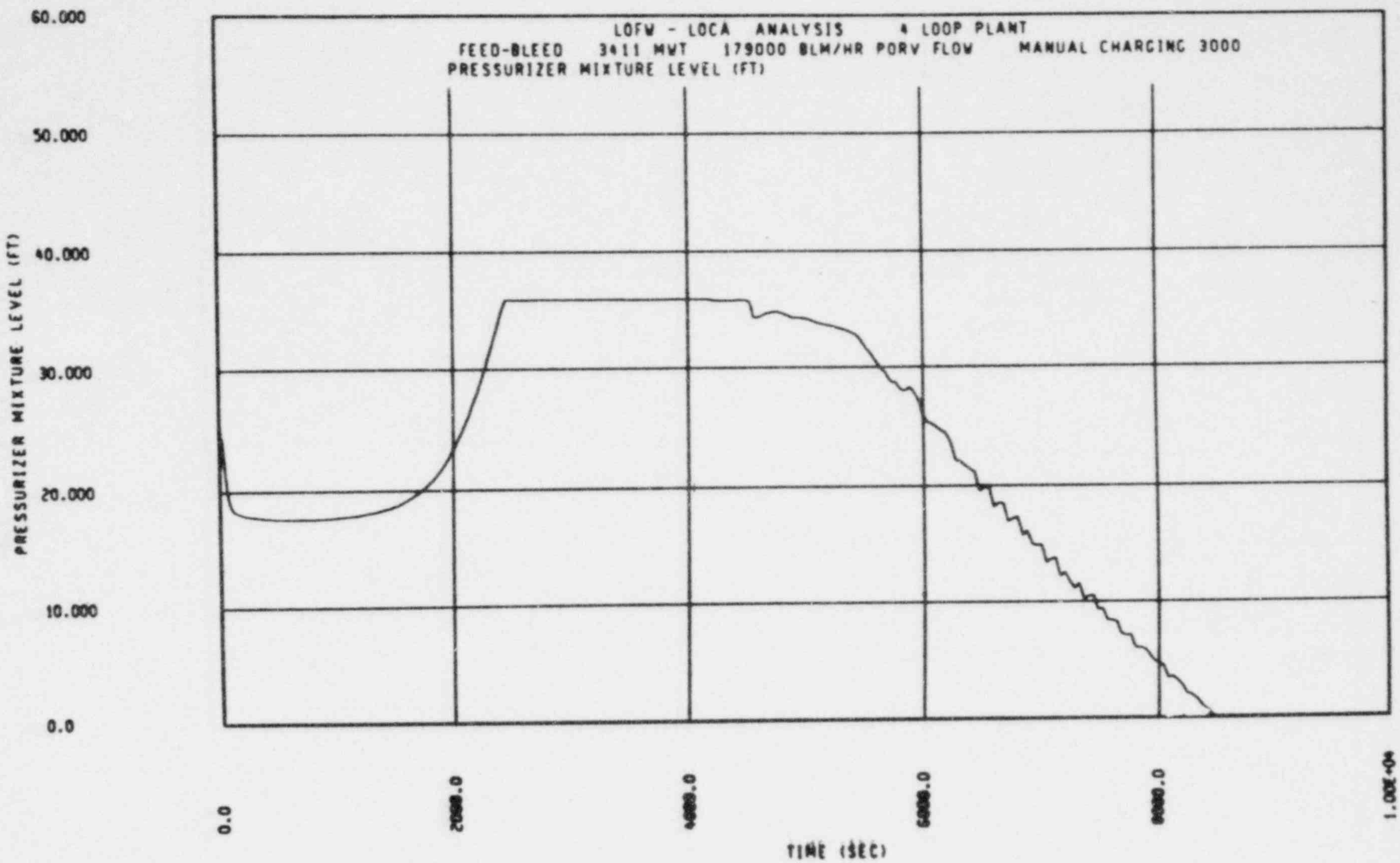

LOFW - LOCA ANALYSIS 4 LOOP PLANT
FEED-BLEED 3411 MWT 179000 BLM/HR PORV FLOW MANUAL CHARGING 3000
DOWNCOMER MIXTURE LEVEL (FT)
DOWNCOMER MIXTURE LEVEL (FT)
40.000
35.000
30.000
25.000
20.000
15.000
10.000
5.0000
0.0
0.0
2000.0
4000.0
6000.0
8000.0
1.00E+04
TIME (SEC)

FIGURE C - 5



LOFW - LOCA ANALYSIS 4 LOOP PLANT
FEED-BLEED 3411 MWT 179000 BLM/HR PORV FLOW MANUAL CHARGING 3000
PRESSURIZER MIXTURE LEVEL (FT)
60.000
50.000
40.000
30.000
20.000
10.000
0.0
PRESSURIZER MIXTURE LEVEL (FT)
0.0
2000.0
4000.0
6000.0
8000.0
1.00E+04
TIME (SEC)

FIGURE C - 6

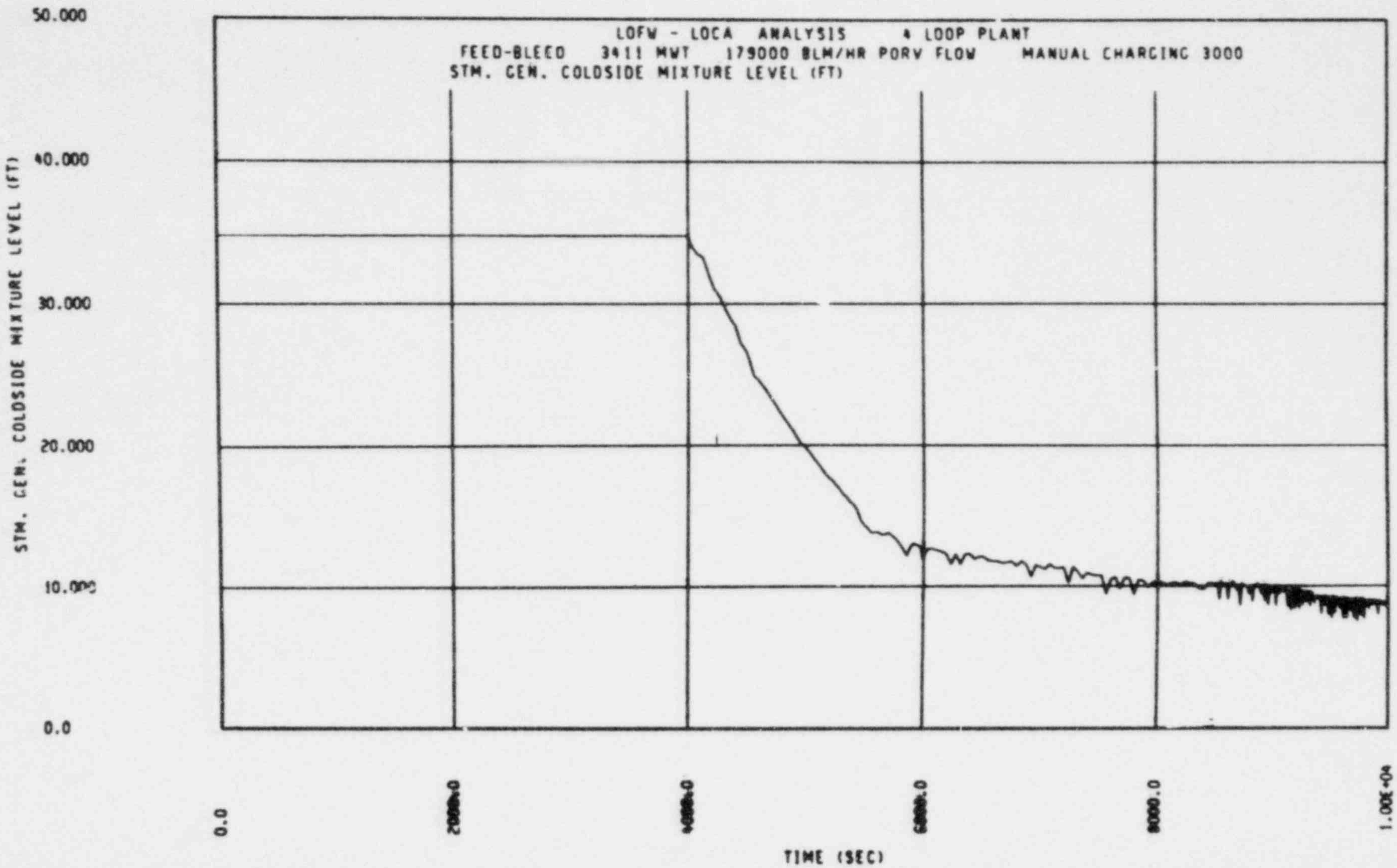

LOFW - LOCA ANALYSIS 4 LOOP PLANT
FEED-BLEED 3411 MWT 179000 BLM/HR PORV FLOW MANUAL CHARGING 3000
STM. GEN. COLDSIDE MIXTURE LEVEL (FT)
50.000
40.000
30.000
20.000
0.0
STM. GEN. COLDSIDE MIXTURE LEVEL (FT)
0.0
6000.0
8000.0
1.00E+04
TIME (SEC)

FIGURE C - 7

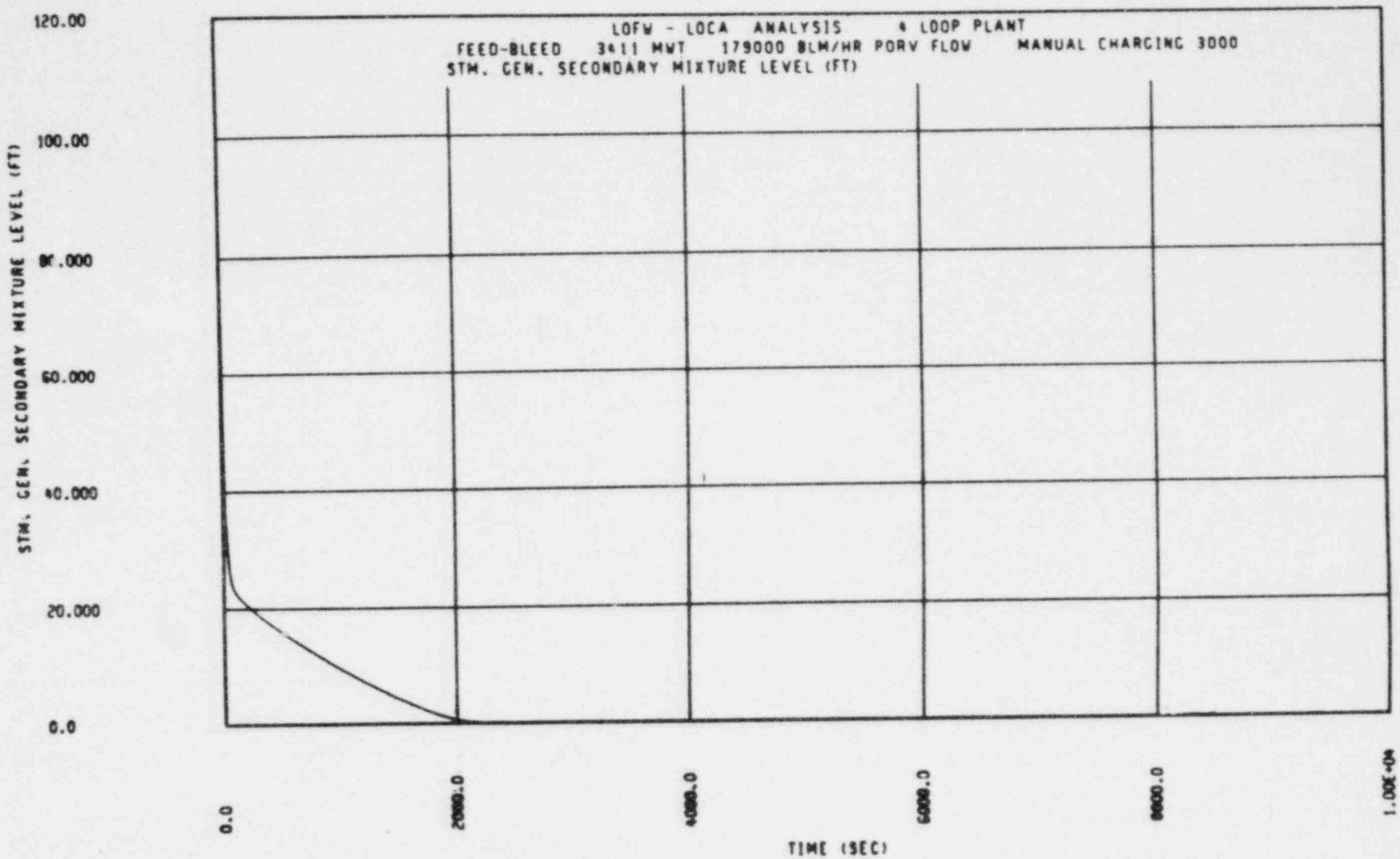
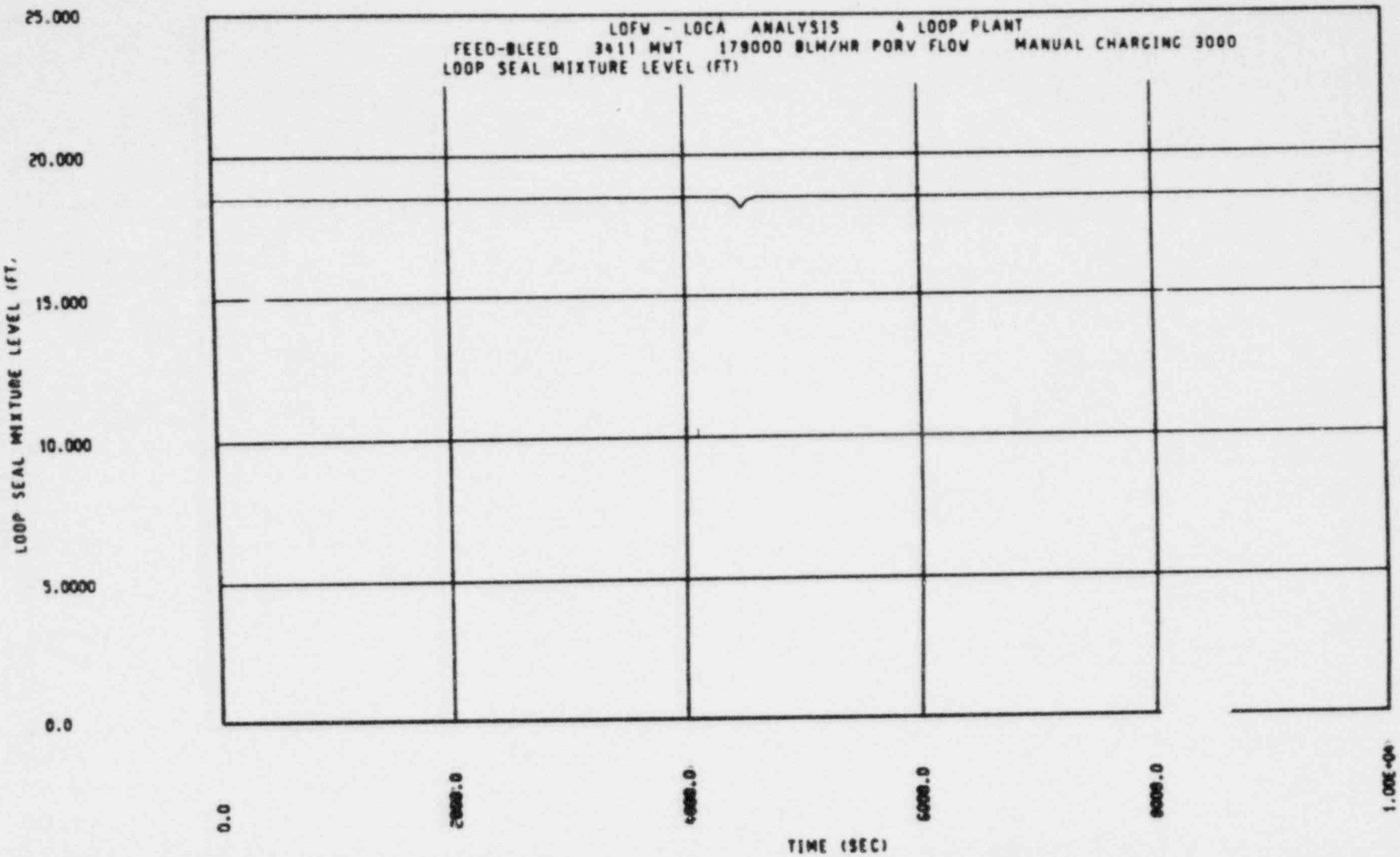

LOFW - LOCA ANALYSIS 4 LOOP PLANT
FEED-BLEED 3411 MWT 179000 BLM/HR PORV FLOW MANUAL CHARGING 3000
STM. GEN. SECONDARY MIXTURE LEVEL (FT)
120.00
100.00
80.000
60.000
40.000
20.000
0.0
STM. GEN. SECONDARY MIXTURE LEVEL (FT)
0.0
2000.0
4000.0
6000.0
8000.0
1.00E+04
TIME (SEC)

FIGURE C - 8



LOFW - LOCA ANALYSIS 4 LOOP PLANT
FEED-BLEED 3411 MWT 179000 BLM/HR PORV FLOW MANUAL CHARGING 3000
LOOP SEAL MIXTURE LEVEL (FT)
25.000
20.000
15.000
10.000
5.0000
0.0
LOOP SEAL MIXTURE LEVEL (FT.
0.0
2000.0
4000.0
6000.0
8000.0
1.00E+04
TIME (SEC)

FIGURE C - 9

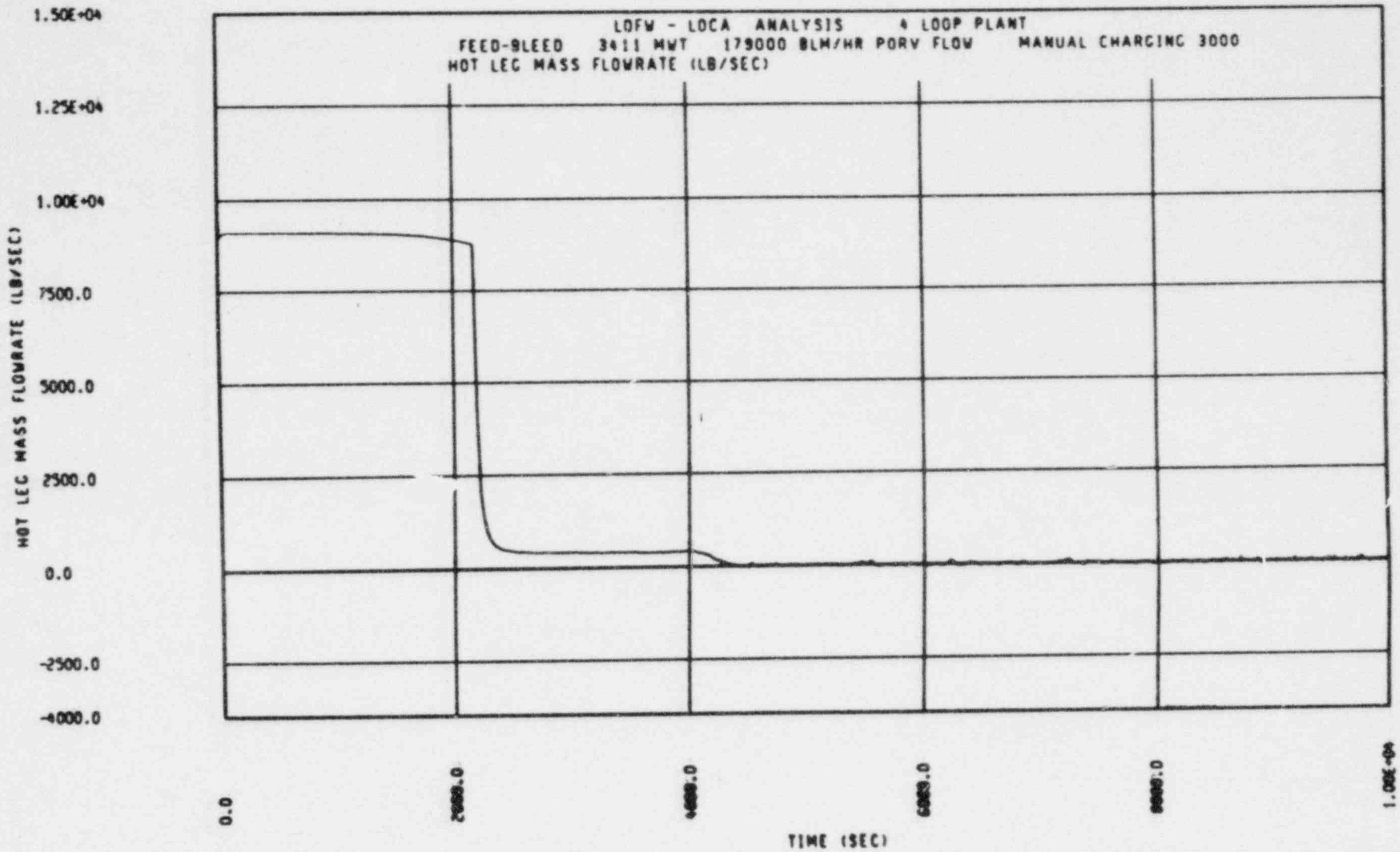

LOFW - LOCA ANALYSIS 4 LOOP PLANT
FEED-BLEED 3411 MWT 179000 BLM/HR PORV FLOW MANUAL CHARGING 3000
HOT LEG MASS FLOWRATE (LB/SEC)
1.50E+04
1.25E+04
1.00E+04
7500.0
5000.0
2500.0
0.0
-2500.0
-4000.0
HOT LEG MASS FLOWRATE (LB/SEC)
0.0
2000.0
4000.0
6000.0
8000.0
1.00E+04
TIME (SEC)

FIGURE C - 10

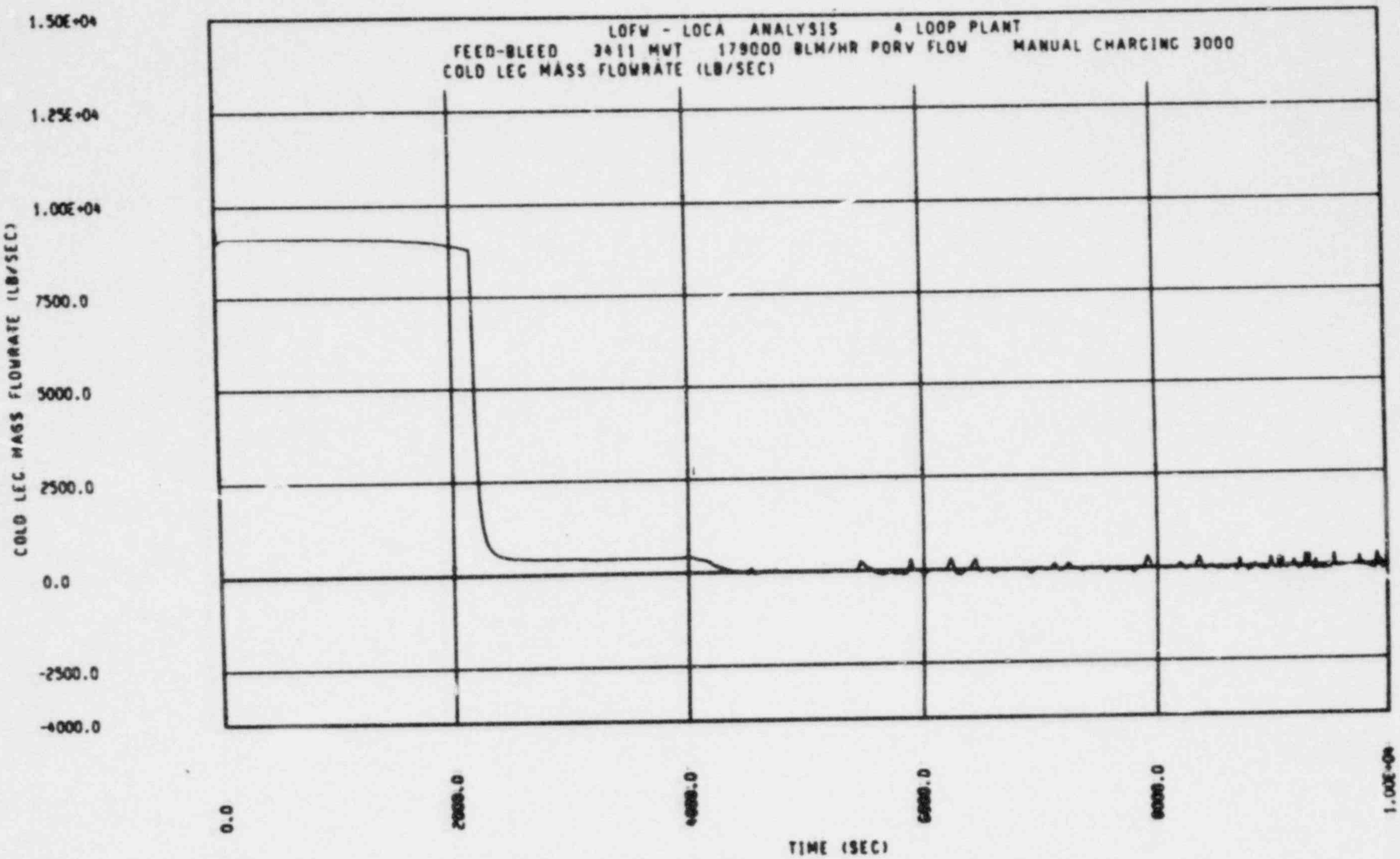
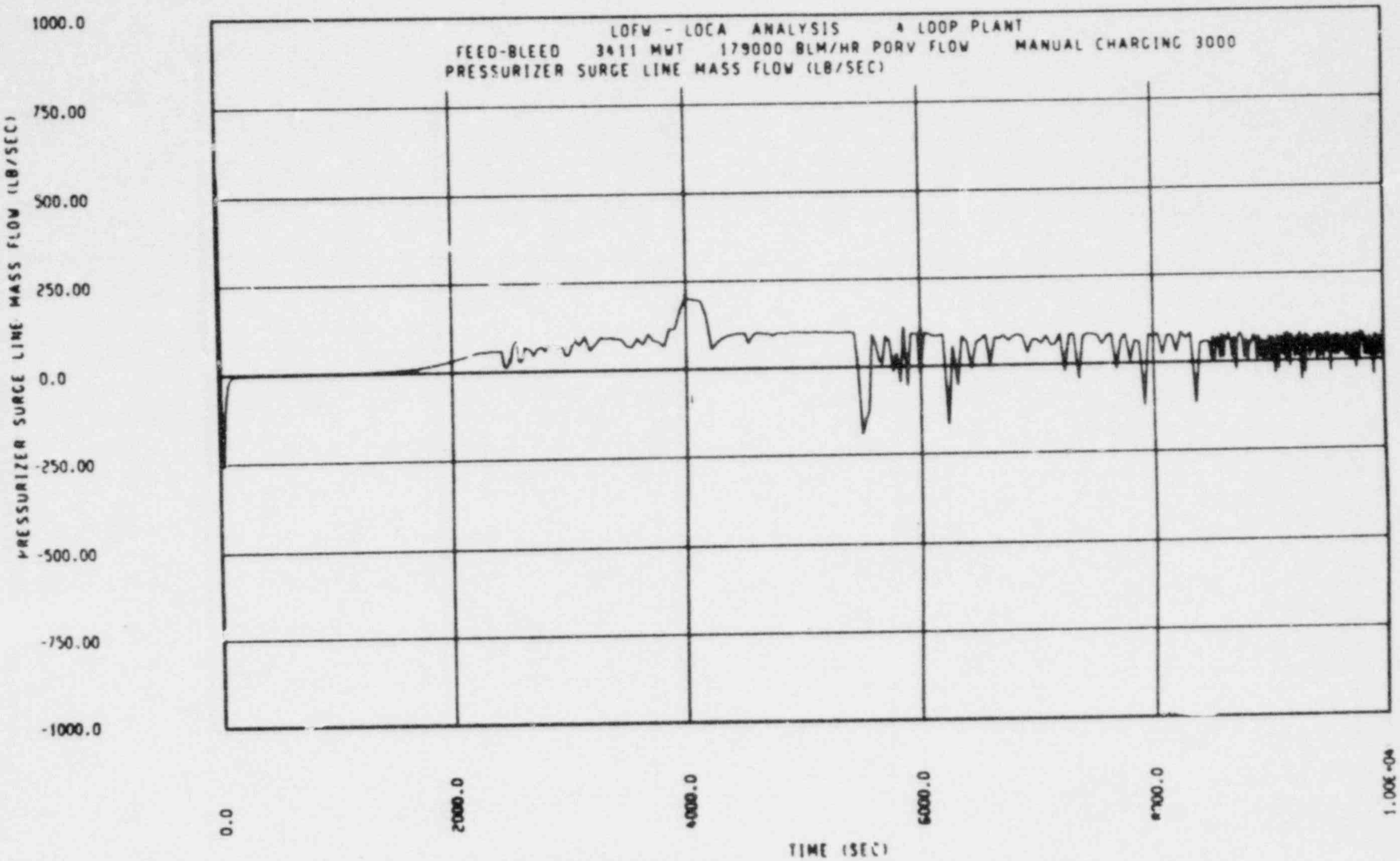

LOFW - LOCA ANALYSIS 4 LOOP PLANT
FEED-BLEED 3411 MWT 179000 BLM/HR PORV FLOW MANUAL CHARGING 3000
COLD LEG MASS FLOWRATE (LB/SEC)
1.50E+04
1.25E+04
1.00E+04
7500.0
5000.0
2500.0
0.0
-2500.0
-4000.0
COLD LEG MASS FLOWRATE (LB/SEC)
0.0
2000.0
4000.0
6000.0
8000.0
1.00E+04
TIME (SEC)

FIGURE C - 11 *



LOFW - LOCA ANALYSIS 4 LOOP PLANT
FEED-BLEED 3411 MWT 179000 BLM/HR PORV FLOW MANUAL CHARGING 3000
PRESSURIZER SURGE LINE MASS FLOW (LB/SEC)
1000.0
750.00
500.00
250.00
0.0
-250.00
-500.00
-750.00
-1000.0
PRESSURIZER SURGE LINE MASS FLOW (LB/SEC)
0.0
2000.0
4000.0
6000.0
1.00E+04
TIME (SEC)

FIGURE C - 12

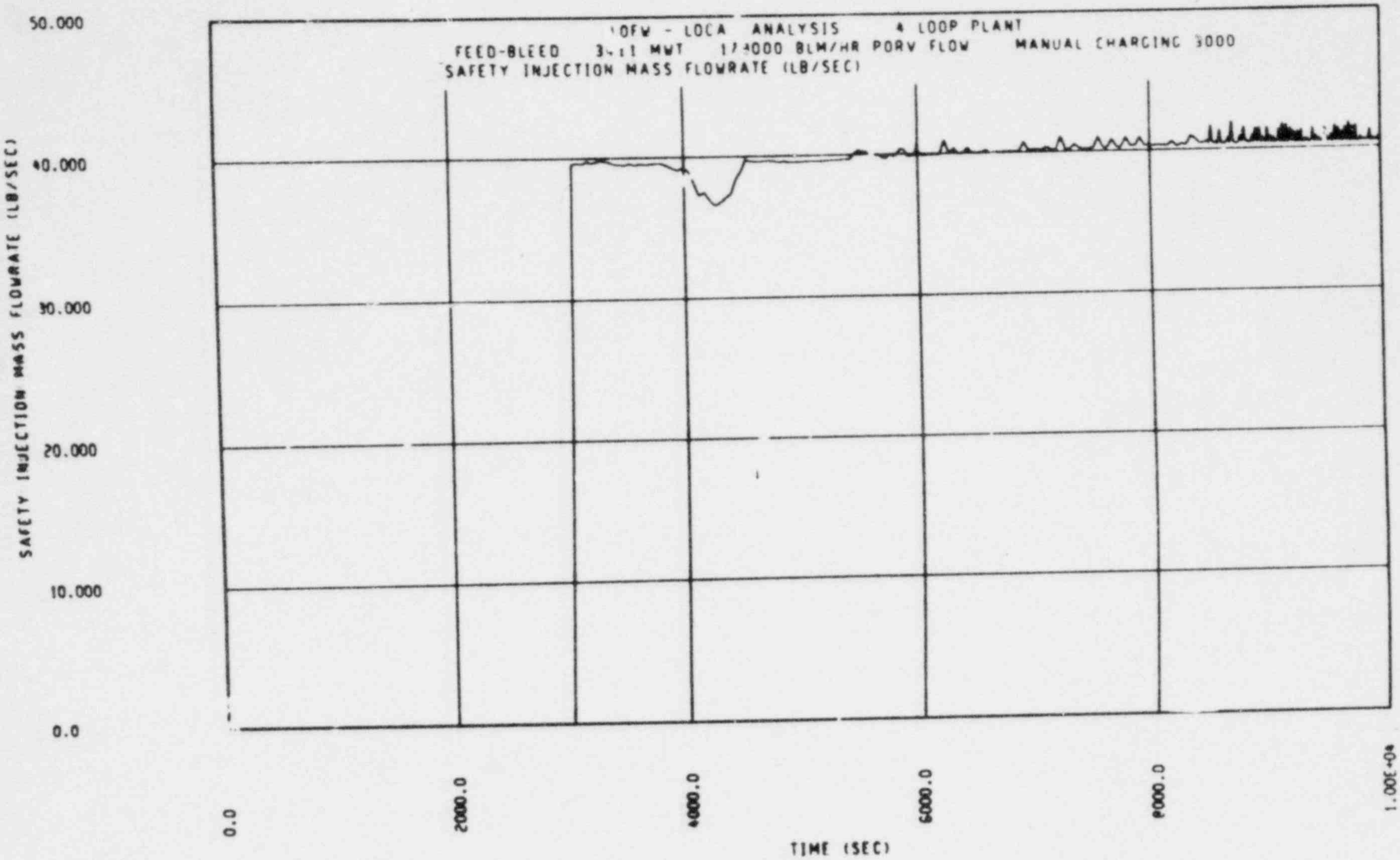

LOFW - LOCA ANALYSIS 4 LOOP PLANT
FEED-BLEED 3411 MWT 174000 BLM/HR PORV FLOW MANUAL CHARGING 3000
SAFETY INJECTION MASS FLOWRATE (LB/SEC)
50.000
40.000
30.000
20.000
10.000
0.0
SAFETY INJECTION MASS FLOWRATE (LB/SEC)
0.0
2000.0
4000.0
6000.0
8000.0
1.00E+04
TIME (SEC)

FIGURE C - 13

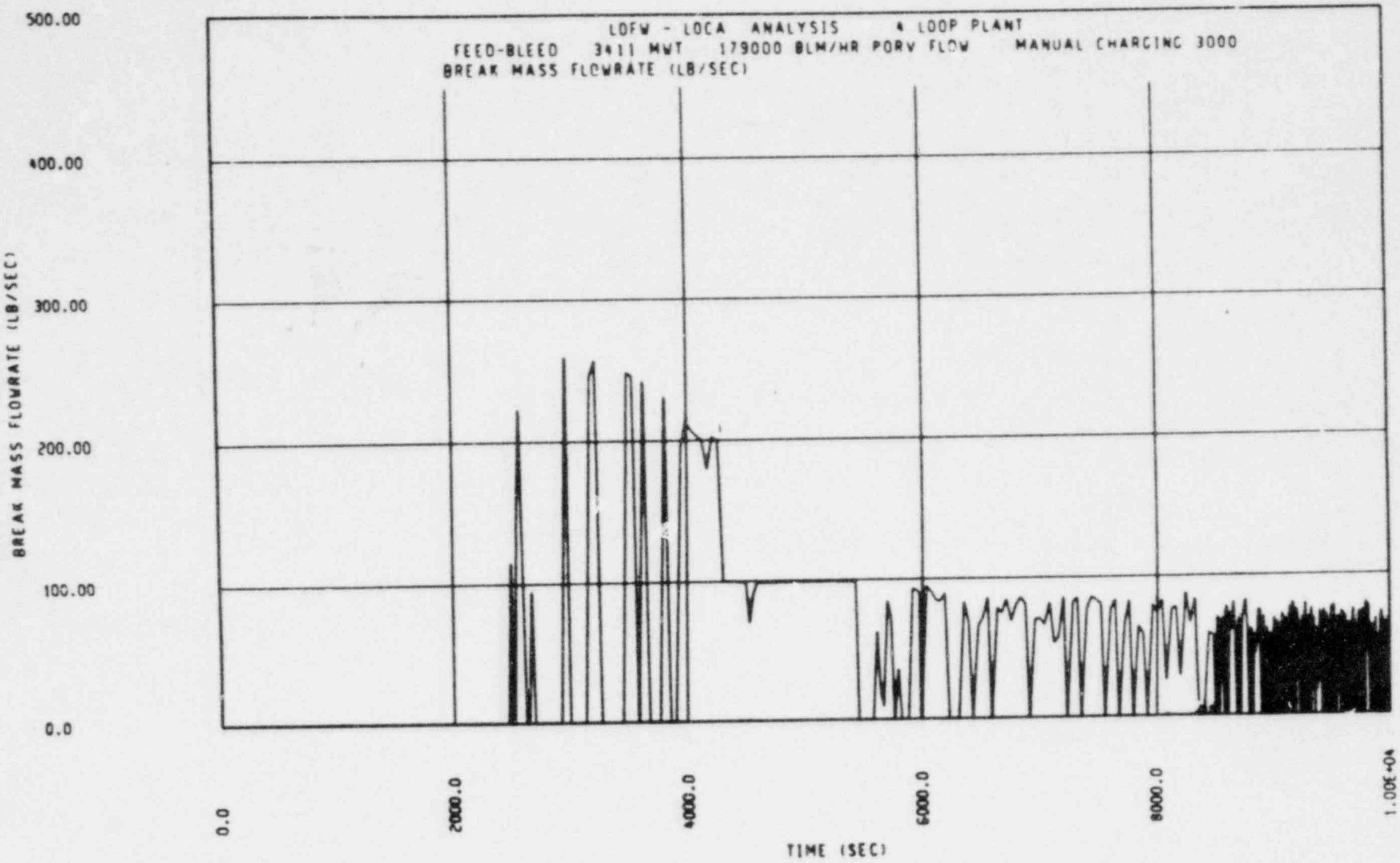
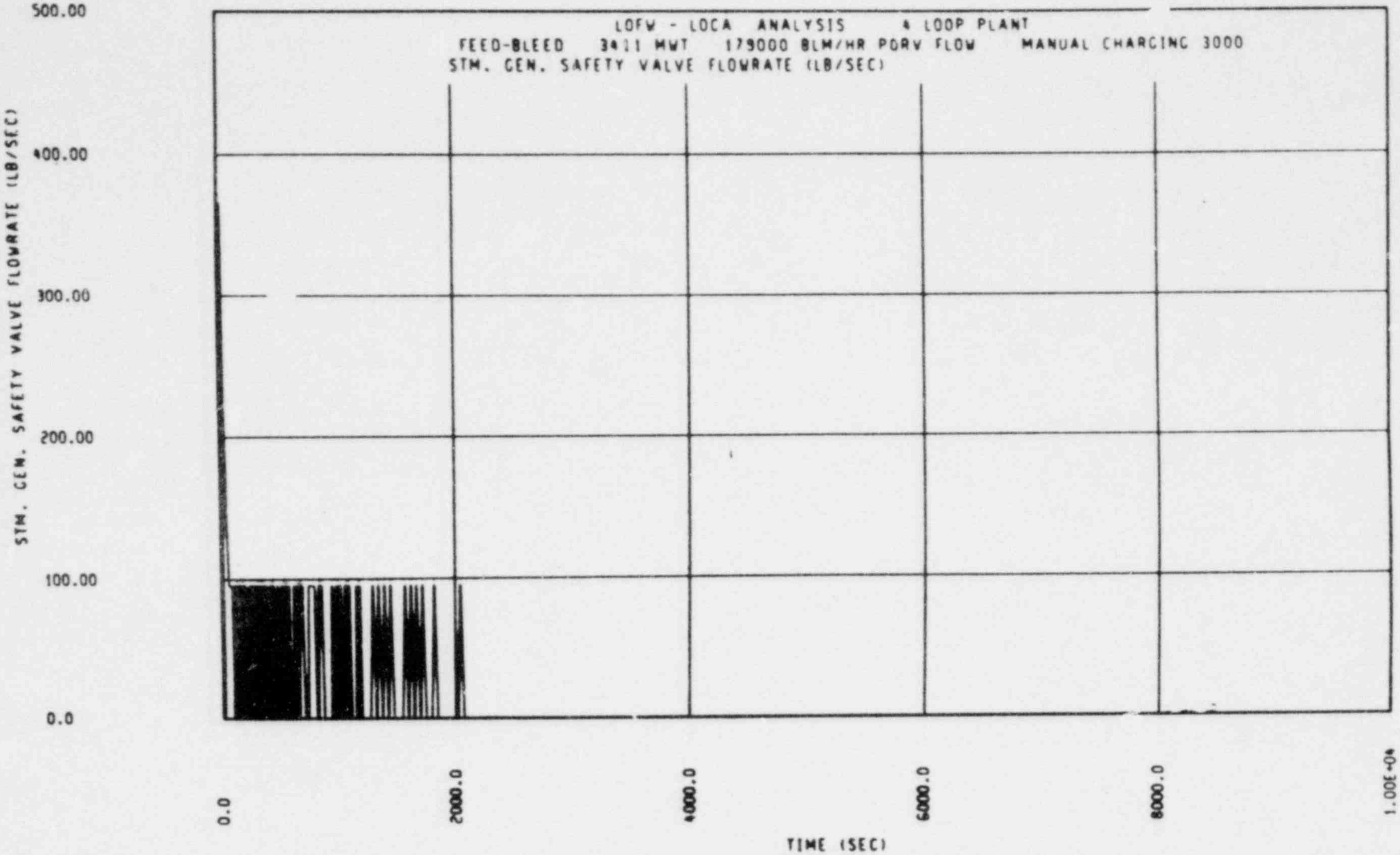

LOFW - LOCA ANALYSIS 4 LOOP PLANT
FEED-BLEED 3411 MWT 179000 BLM/HR PORV FLOW MANUAL CHARGING 3000
BREAK MASS FLOWRATE (LB/SEC)
500.00
400.00
300.00
200.00
100.00
0.0
BREAK MASS FLOWRATE (LB/SEC)
0.0
2000.0
4000.0
6000.0
8000.0
1.00E+04
TIME (SEC)

FIGURE C - 14



LOFW - LOCA ANALYSIS 4 LOOP PLANT
FEED-BLEED 3411 MWT 179000 BLM/HR PORV FLOW MANUAL CHARGING 3000
STM. GEN. SAFETY VALVE FLOWRATE (LB/SEC)
500.00
400.00
300.00
200.00
100.00
0.0
STM. GEN. SAFETY VALVE FLOWRATE (LB/SEC)
0.0
2000.0
4000.0
6000.0
8000.0
1.00E+04
TIME (SEC)

FIGURE C - 15

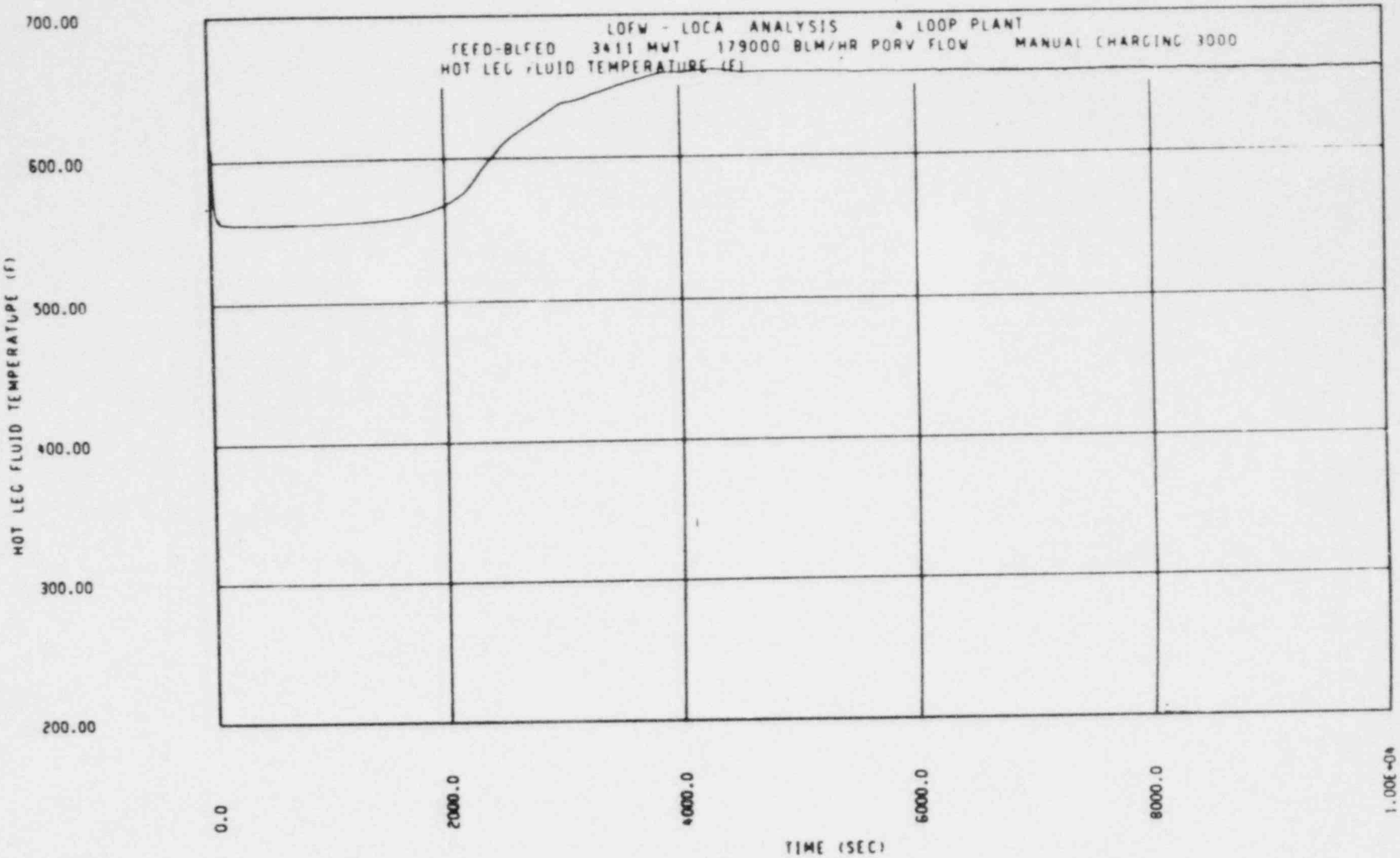
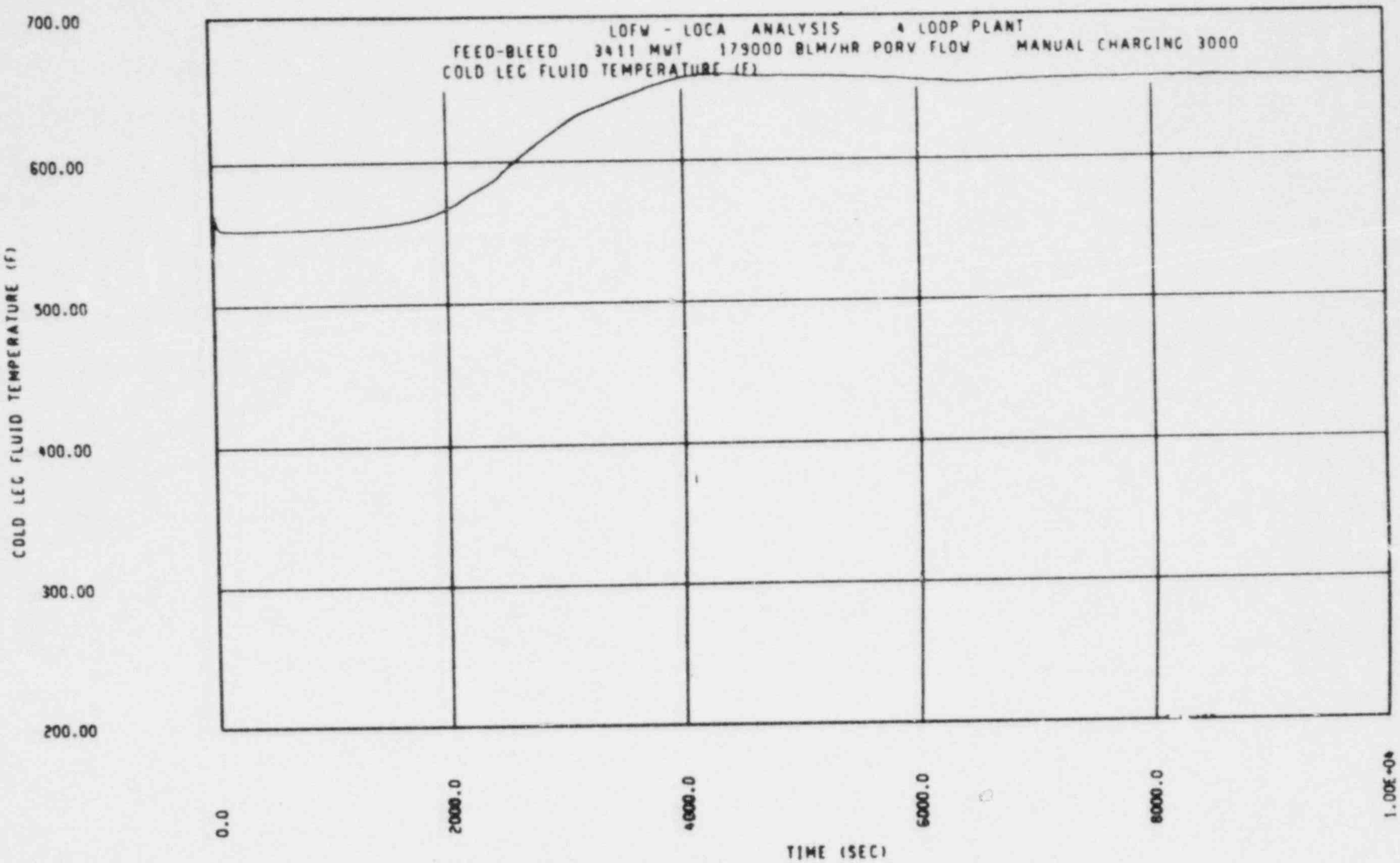

LOFW - LOCA ANALYSIS 4 LOOP PLANT
FEED-BLEED 3411 MWT 179000 BLM/HR PORV FLOW MANUAL CHARGING 3000
HOT LEG FLUID TEMPERATURE (F)
700.00
600.00
500.00
400.00
300.00
200.00
HOT LEG FLUID TEMPERATURE (F)
0.0
2000.0
4000.0
6000.0
8000.0
1.00E+04
TIME (SEC)

FIGURE C - 16



LOFW - LOCA ANALYSIS 4 LOOP PLANT
FEED-BLEED 3411 MWT 179000 BLM/HR PORV FLOW MANUAL CHARGING 3000
COLD LEG FLUID TEMPERATURE (F)
700.00
600.00
500.00
400.00
300.00
200.00
COLD LEG FLUID TEMPERATURE (F)
0.0
2000.0
4000.0
6000.0
8000.0
1.00E+04
TIME (SEC)

FIGURE C - 17

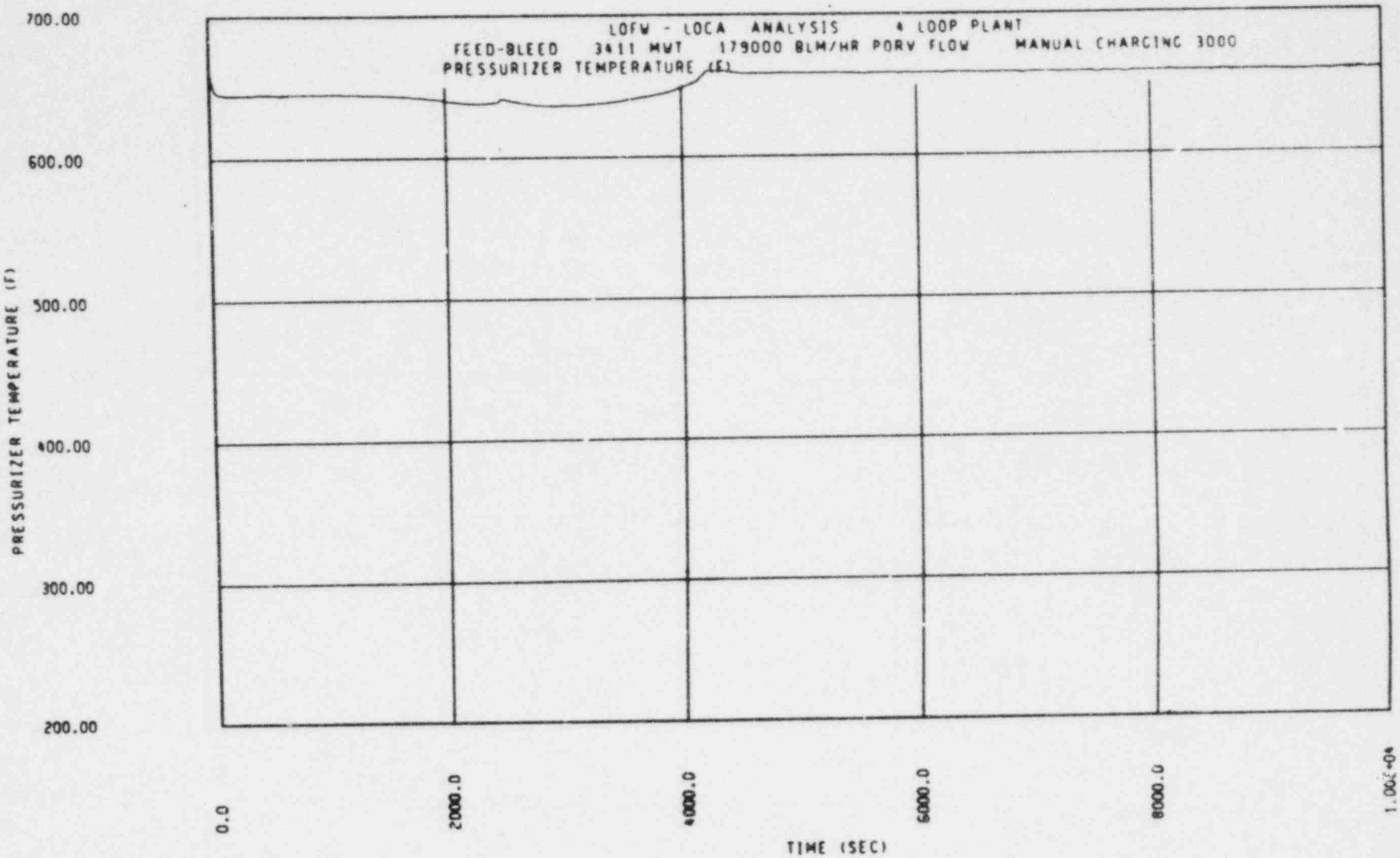
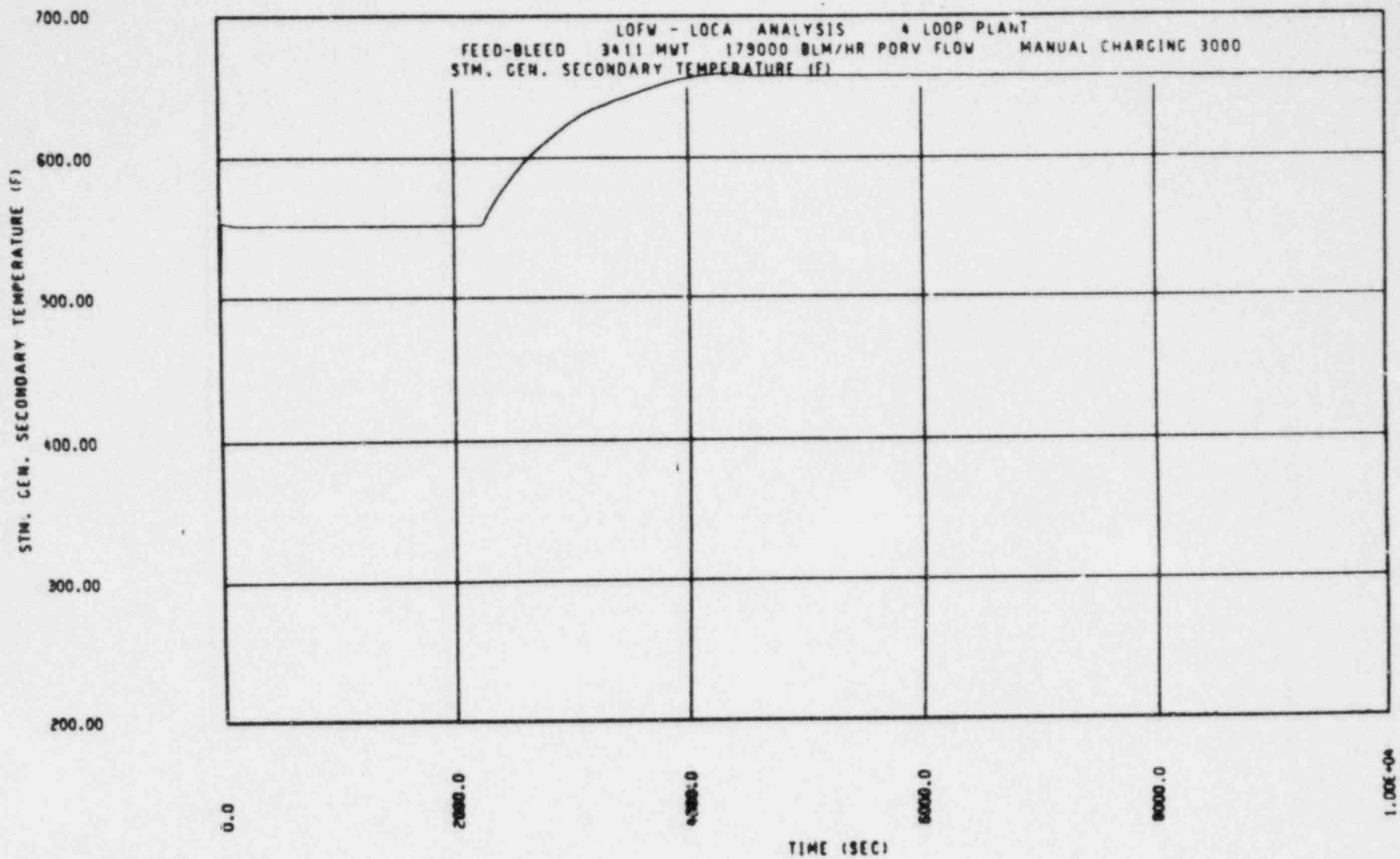

LOFW - LOCA ANALYSIS 4 LOOP PLANT
FEED-BLEED 3411 MWT 179000 BLM/HR PORV FLOW MANUAL CHARGING 3000
PRESSURIZER TEMPERATURE (F)
700.00
600.00
500.00
400.00
300.00
200.00
PRESSURIZER TEMPERATURE (F)
0.0
2000.0
4000.0
6000.0
8000.0
1.00E+04
TIME (SEC)

FIGURE C - 18



LOFW - LOCA ANALYSIS 4 LOOP PLANT
FEED-BLEED 3411 MWT 179000 BLM/HR PORV FLOW MANUAL CHARGING 3000
STM. GEN. SECONDARY TEMPERATURE (F)
700.00
600.00
500.00
400.00
300.00
200.00
STM. GEN. SECONDARY TEMPERATURE (F)
0.0
2000.0
4000.0
6000.0
8000.0
1.00E+04
TIME (SEC)

FIGURE C - 19

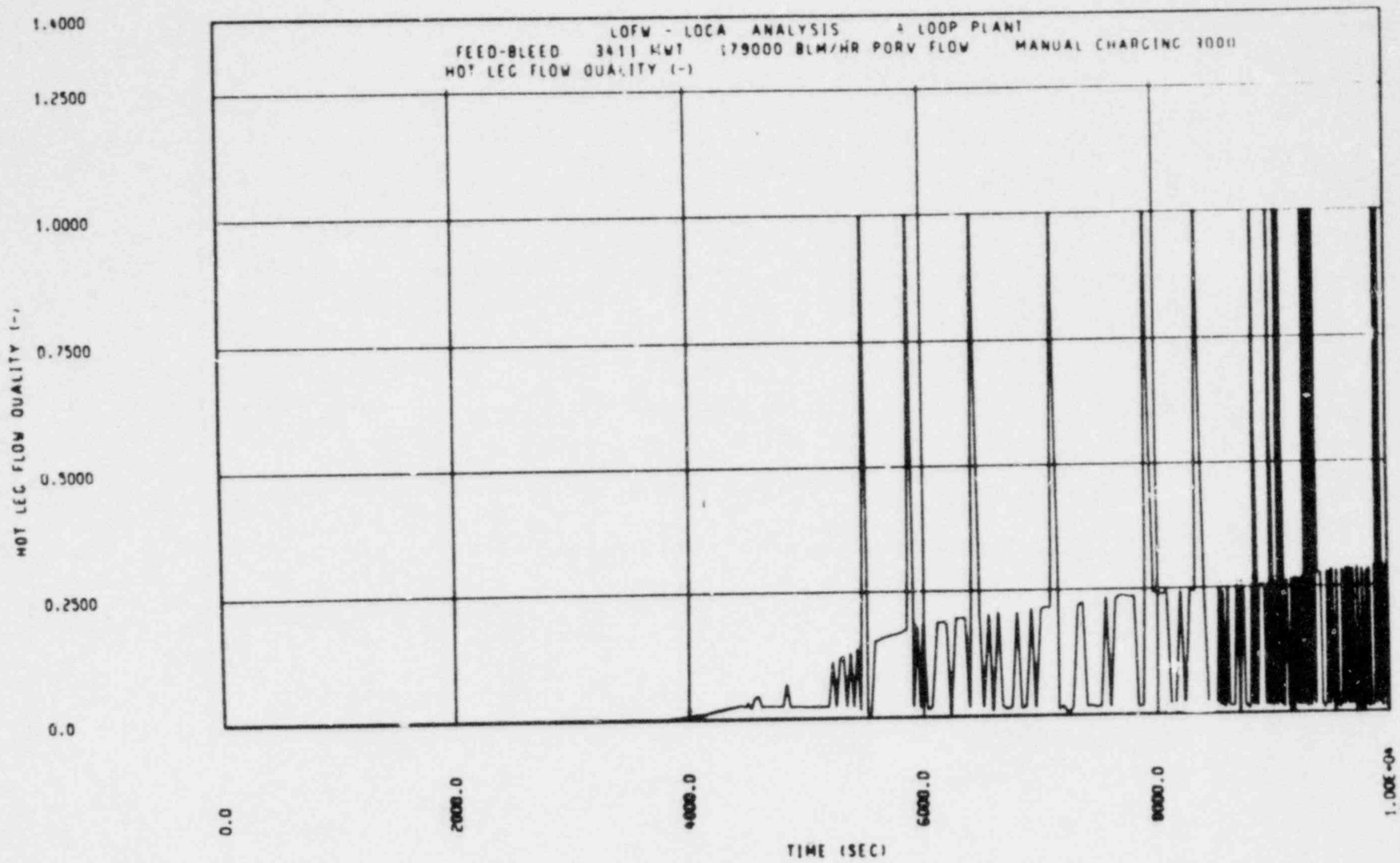
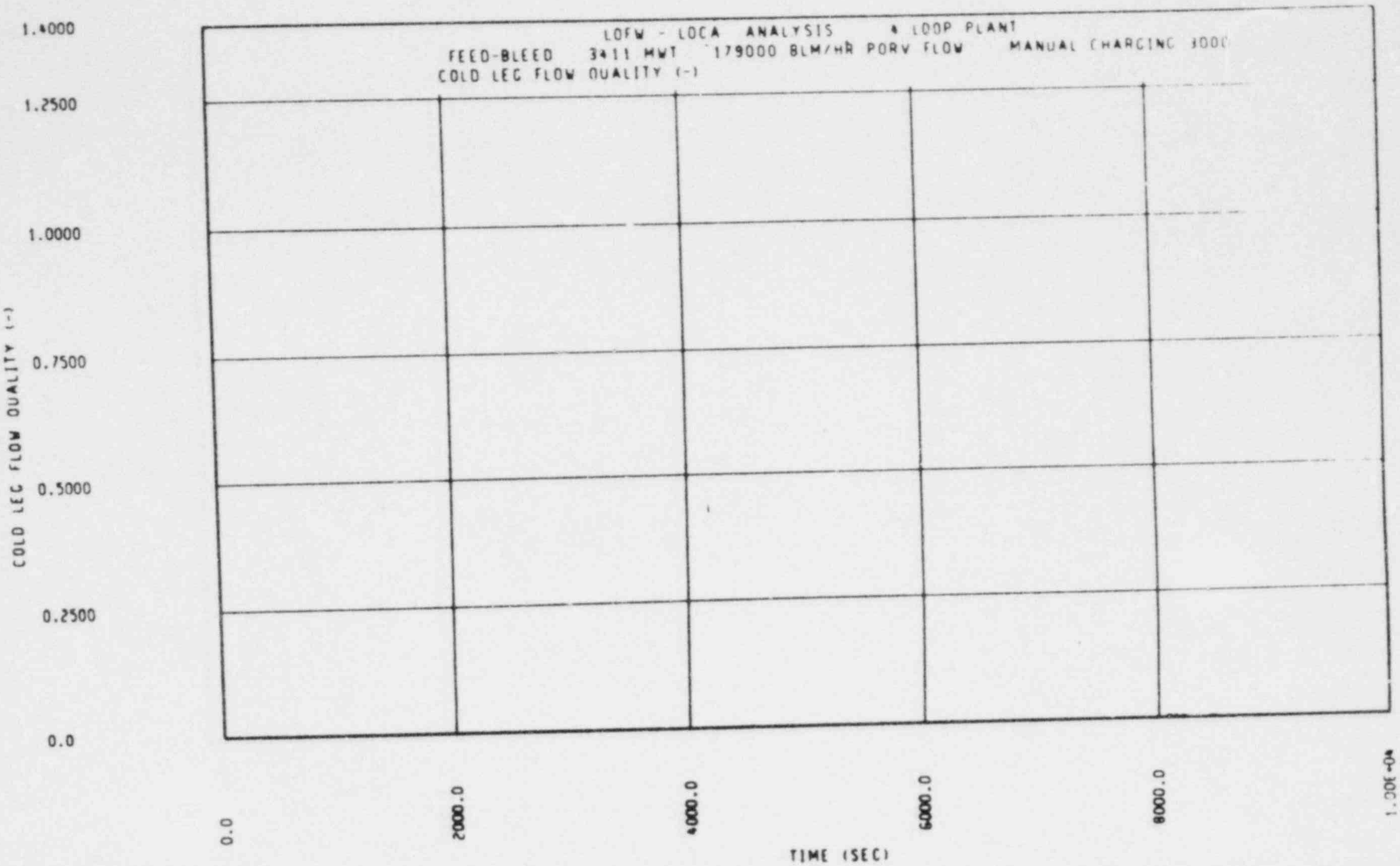

LOFW - LOCA ANALYSIS 4 LOOP PLANT
FEED-BLEED 3411 MWT 179000 BLM/HR PORV FLOW MANUAL CHARGING 3000
HOT LEG FLOW QUALITY (-)
1.4000
1.2500
1.0000
0.7500
0.5000
0.2500
0.0
HOT LEG FLOW QUALITY (-)
0.0
2000.0
4000.0
6000.0
8000.0
1.00E+04
TIME (SEC)

FIGURE C - 20



LOFW - LOCA ANALYSIS 4 LOOP PLANT
FEED-BLEED 3411 MWT 179000 BLM/HR PORV FLOW MANUAL CHARGING 300
COLD LEG FLOW QUALITY (-)
1.4000
1.2500
1.0000
0.7500
0.5000
0.2500
0.0
COLD LEG FLOW QUALITY (-)
0.0
2000.0
4000.0
6000.0
8000.0
1.00E+04
TIME (SEC)

FIGURE C - 21

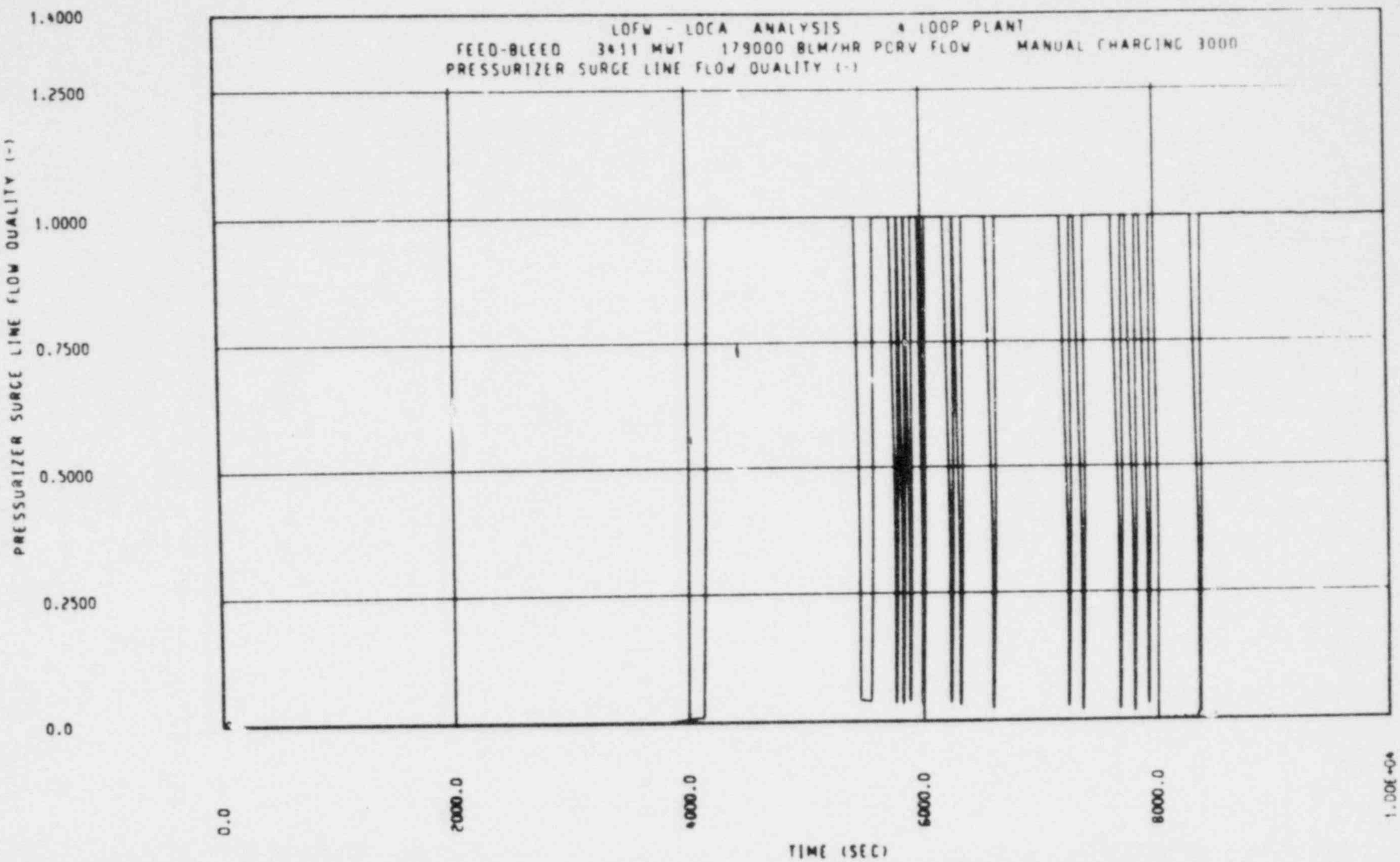
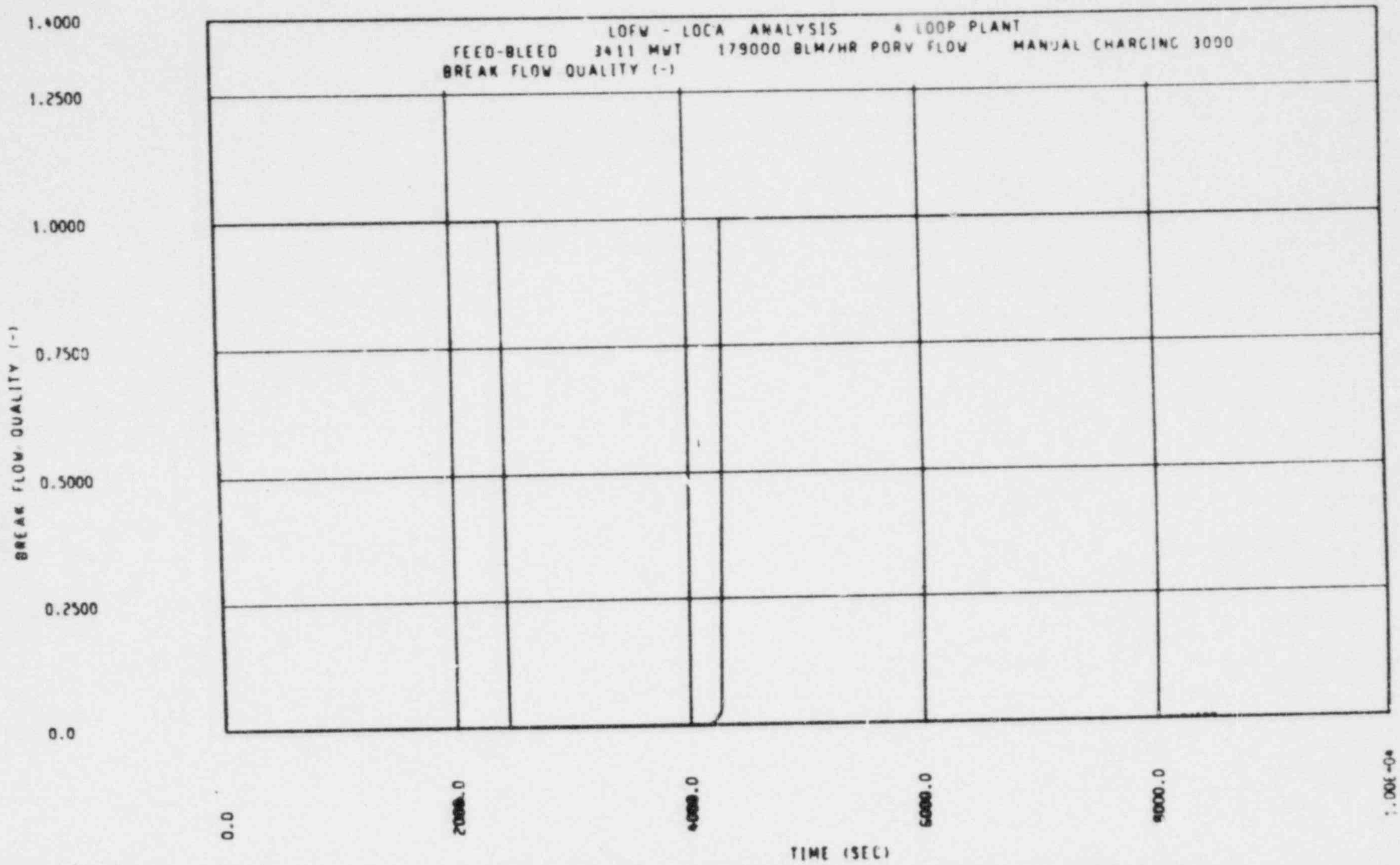

LOFW - LOCA ANALYSIS 4 LOOP PLANT
FEED-BLEED 3411 MWT 179000 BLM/HR PCRV FLOW MANUAL CHARCINC 3000
PRESSURIZER SURGE LINE FLOW QUALITY (-)
1.4000
1.2500
1.0000
0.7500
0.5000
0.2500
0.0
PRESSURIZER SURGE LINE FLOW QUALITY (-)
0.0
2000.0
4000.0
6000.0
8000.0
1.00E+04
TIME (SEC)

FIGURE C - 22



LOFW - LOCA ANALYSIS 4 LOOP PLANT
FEED-BLEED 3411 MWT 179000 BLM/HR PORV FLOW MANUAL CHARGING 3000
BREAK FLOW QUALITY (-)
1.4000
1.2500
1.0000
0.7500
0.5000
0.2500
0.0
BREAK FLOW QUALITY (-)
0.0
2000.0
4000.0
6000.0
8000.0
1.00E+04
TIME (SEC)

FIGURE C - 23

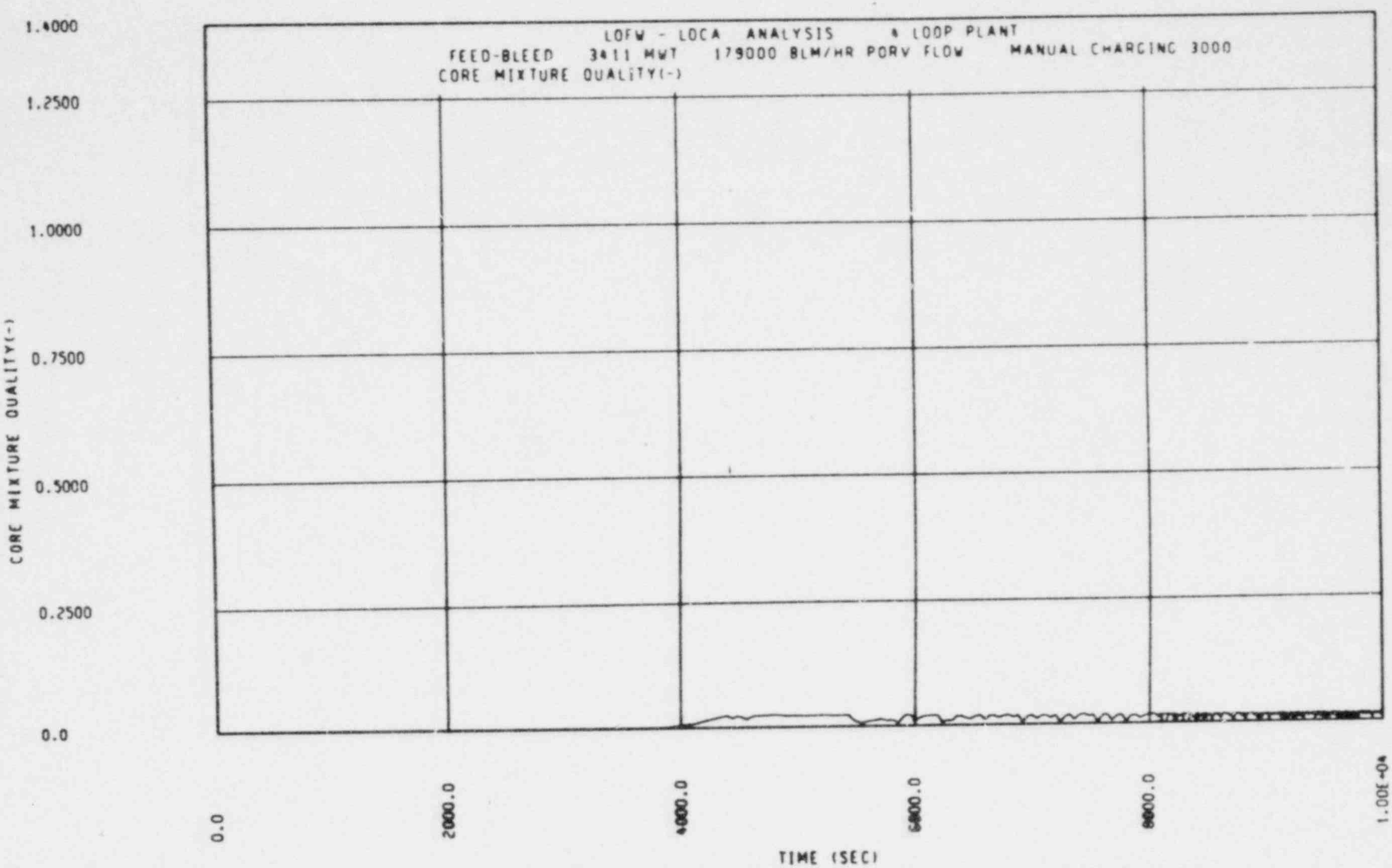
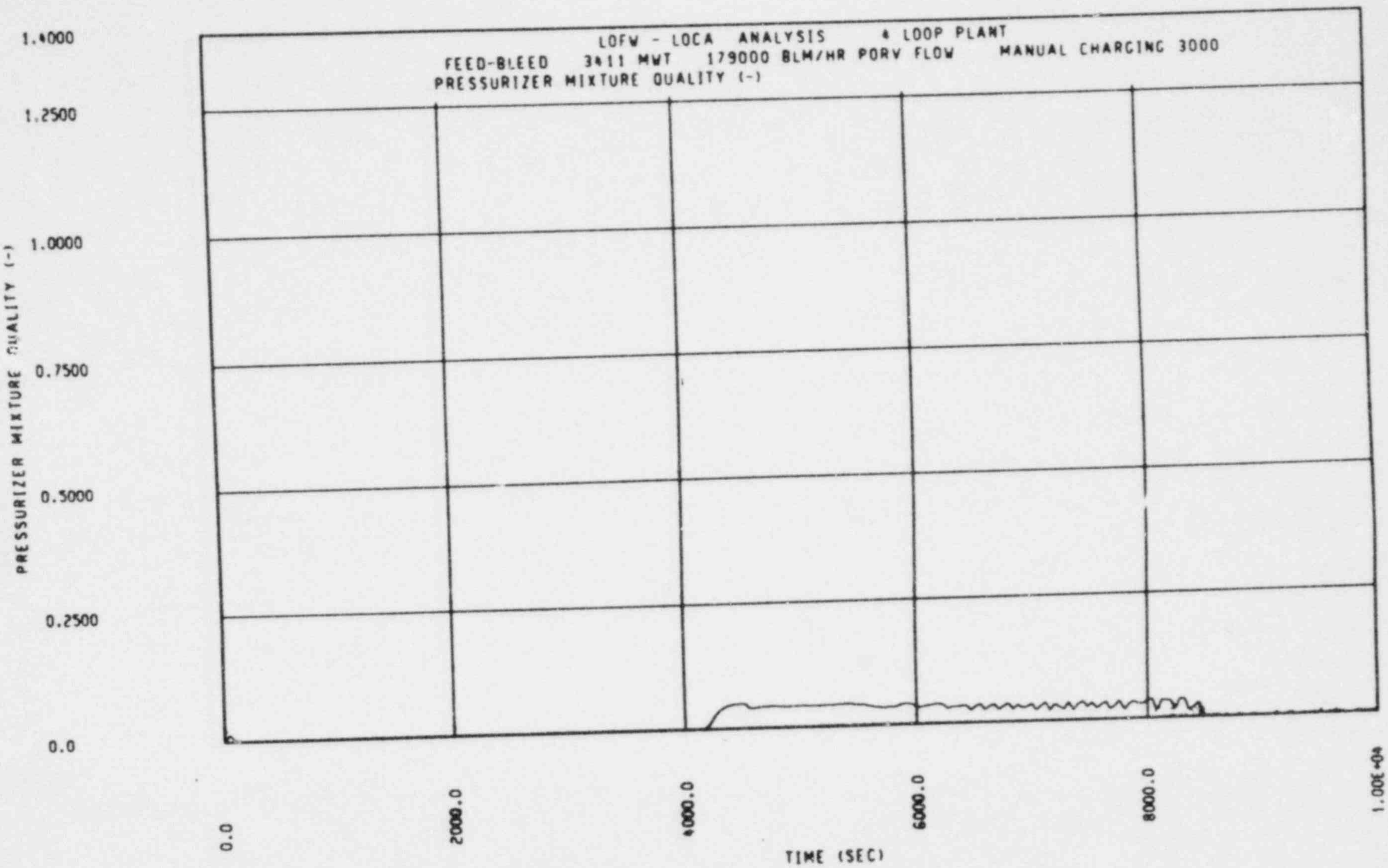

LOFW - LOCA ANALYSIS 4 LOOP PLANT
FEED-BLEED 3411 MWT 179000 BLM/HR PORV FLOW MANUAL CHARGING 3000
CORE MIXTURE QUALITY(-)
1.4000
1.2500
1.0000
0.7500
0.5000
0.2500
0.0
CORE MIXTURE QUALITY(-)
0.0
2000.0
4000.0
6000.0
8000.0
1.00E+04
TIME (SEC)

FIGURE C - 24



LOFW - LOCA ANALYSIS 4 LOOP PLANT
FEED-BLEED 3411 MWT 179000 BLM/HR PORV FLOW MANUAL CHARGING 3000
PRESSURIZER MIXTURE QUALITY (-)
1.4000
1.2500
1.0000
0.7500
0.5000
0.2500
0.0
PRESSURIZER MIXTURE QUALITY (-)
0.0
2000.0
4000.0
6000.0
8000.0
1.00E+04
TIME (SEC)

FIGURE C - 25


LOFW - LOCA ANALYSIS 4 LOOP PLANT
FEED-BLEED 3411 MWT 179000 BLM/HR PORV FLOW MANUAL CHARGINC 3000
STM. GEN. HOTSIDE MIXTURE QUALITY (-)
1.4000
1.2500
1.0000
0.7500
0.5000
0.2500
0.0
STM. GEN. HOTSIDE MIXTURE QUALITY (-)
0.0
2000.0
4000.0
6000.0
8000.0
1.00E+04
TIME (SEC)

FIGURE C - 26

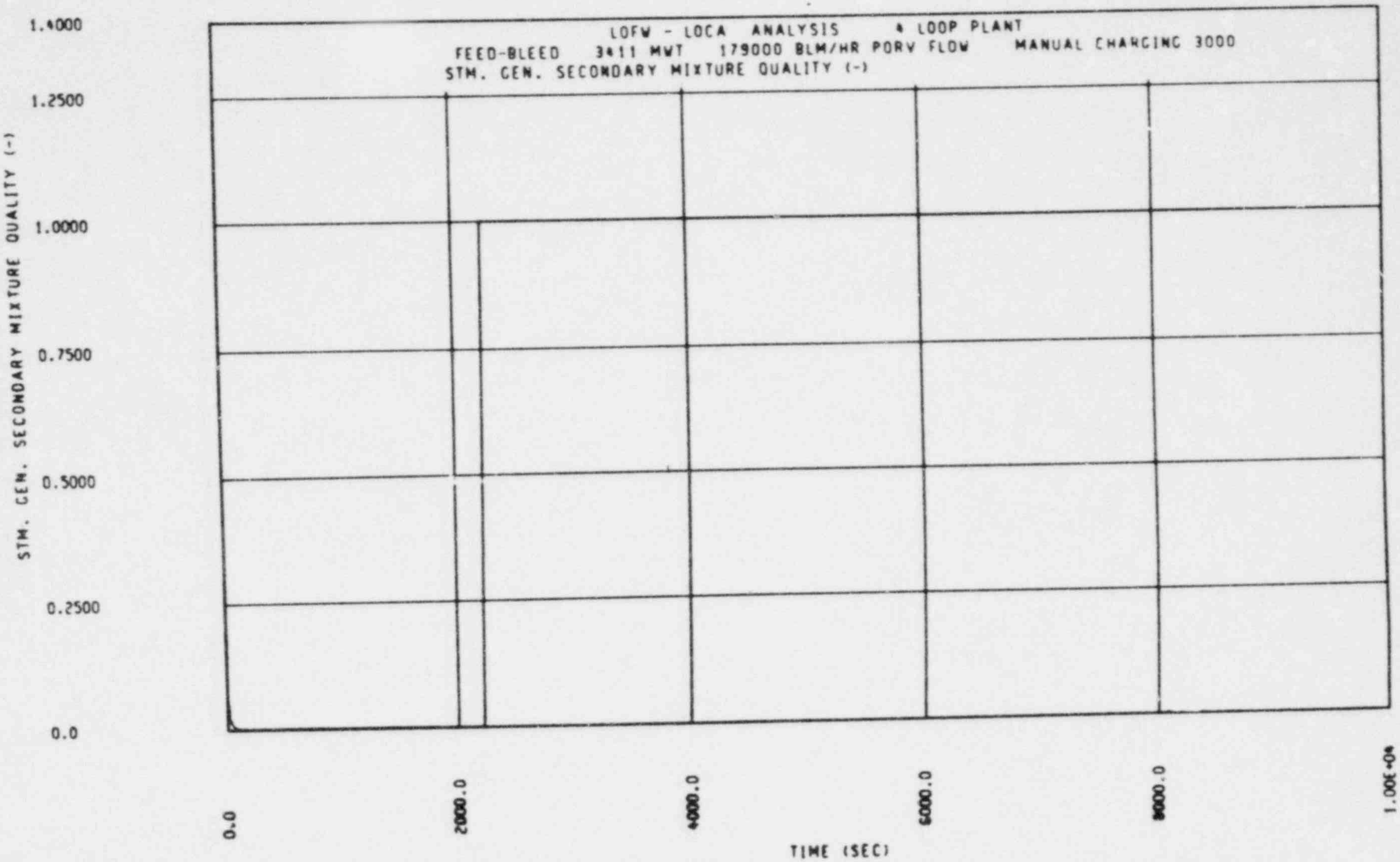

LOFW - LOCA ANALYSIS 4 LOOP PLANT
FEED-BLEED 3411 MWT 179000 BLM/HR PORV FLOW MANUAL CHARGINC 3000
STM. GEN. SECONDARY MIXTURE QUALITY (-)
STM. GEN. SECONDARY MIXTURE QUALITY (-)
1.4000
1.2500
1.0000
0.7500
0.5000
0.2500
0.0
0.0
2000.0
4000.0
6000.0
8000.0
1.00E+04
TIME (SEC)

FIGURE C - 27

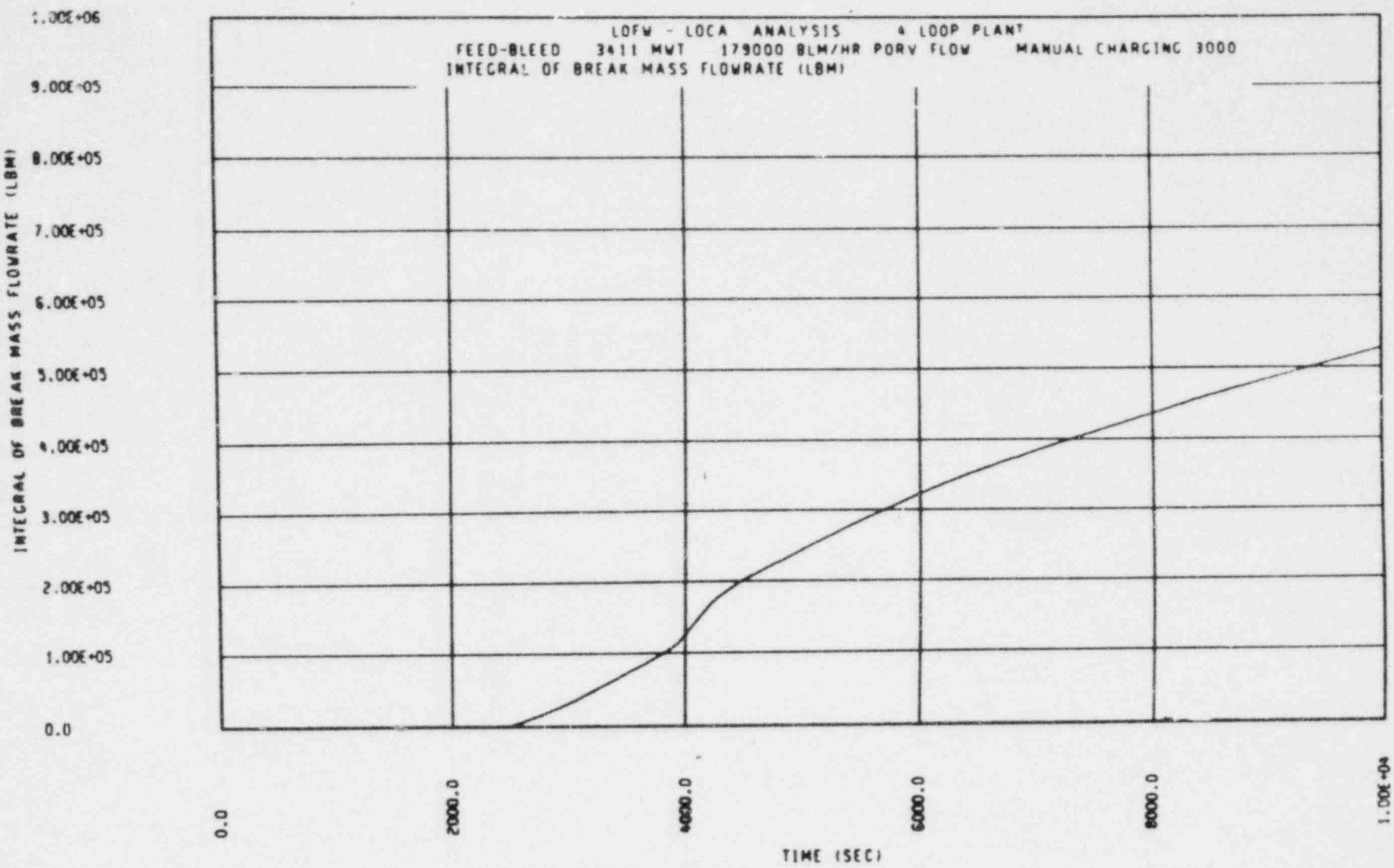

LOFW - LOCA ANALYSIS 4 LOOP PLANT
FEED-BLEED 3411 MWT 179000 BLM/HR PORV FLOW MANUAL CHARGING 3000
INTEGRAL OF BREAK MASS FLOWRATE (LBM)
1.00E+06
9.00E+05
8.00E+05
7.00E+05
6.00E+05
5.00E+05
4.00E+05
3.00E+05
2.00E+05
1.00E+05
0.0
INTEGRAL OF BREAK MASS FLOWRATE (LBM)
0.0
2000.0
4000.0
6000.0
8000.0
1.00E+04
TIME (SEC)

FIGURE C - 28

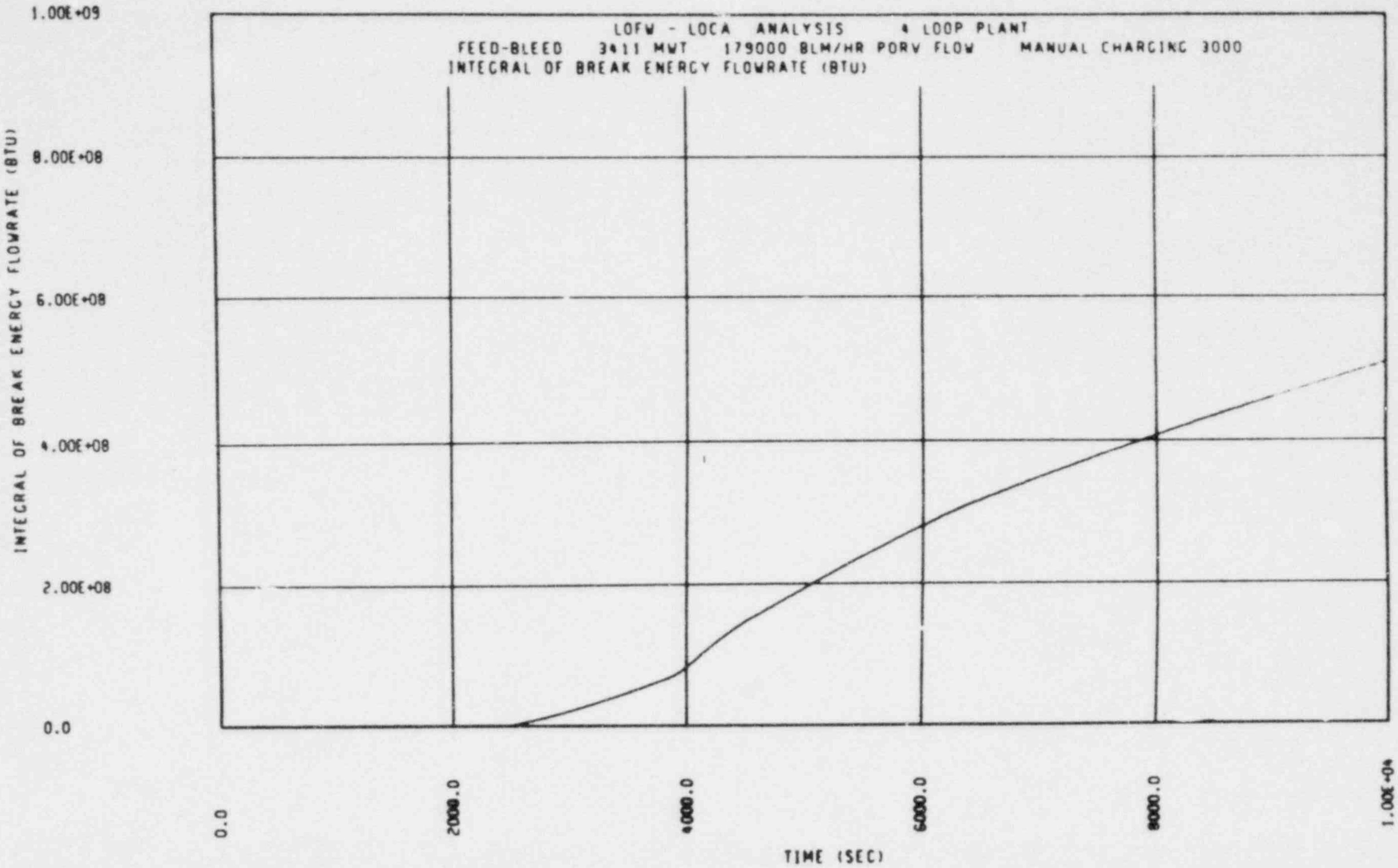

LOFW - LOCA ANALYSIS 4 LOOP PLANT
FEED-BLEED 3411 MWT 179000 BLM/HR PORV FLOW MANUAL CHARGING 3000
INTEGRAL OF BREAK ENERGY FLOWRATE (BTU)
1.00E+09
8.00E+08
6.00E+08
4.00E+08
2.00E+08
0.0
INTEGRAL OF BREAK ENERGY FLOWRATE (BTU)
0.0
2000.0
4000.0
6000.0
8000.0
1.00E+04
TIME (SEC)

FIGURE C - 29

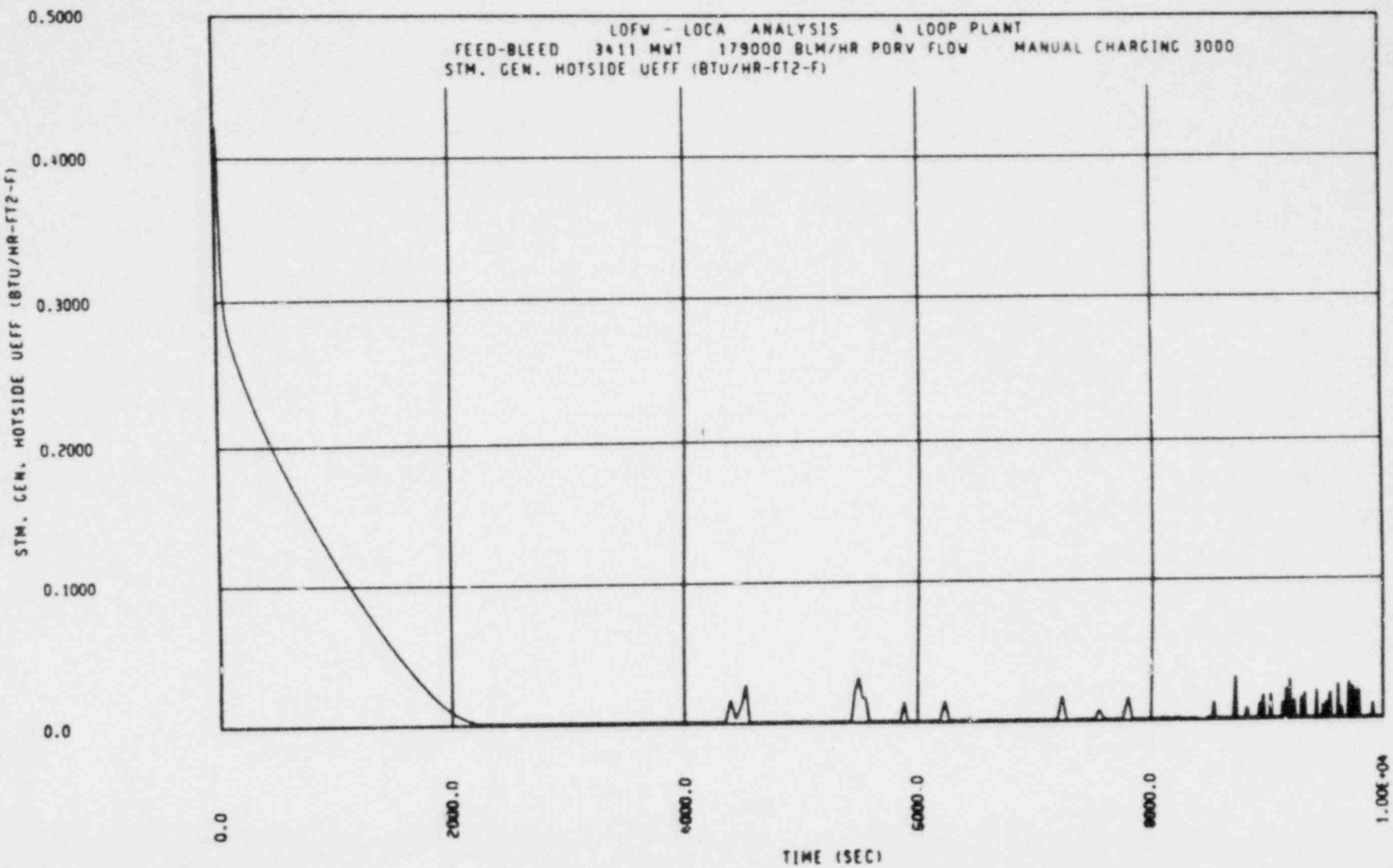

LOFW - LOCA ANALYSIS 4 LOOP PLANT
FEED-BLEED 3411 MWT 179000 BLM/HR PORV FLOW MANUAL CHARGING 3000
STM. GEN. HOTSIDE UEFF (BTU/HR-FT2-F)
0.5000
0.4000
0.3000
0.2000
0.1000
0.0
STM. GEN. HOTSIDE UEFF (BTU/HR-FT2-F)
0.0
2000.0
4000.0
6000.0
8000.0
1.00E+04
TIME (SEC)

FIGURE C - 30

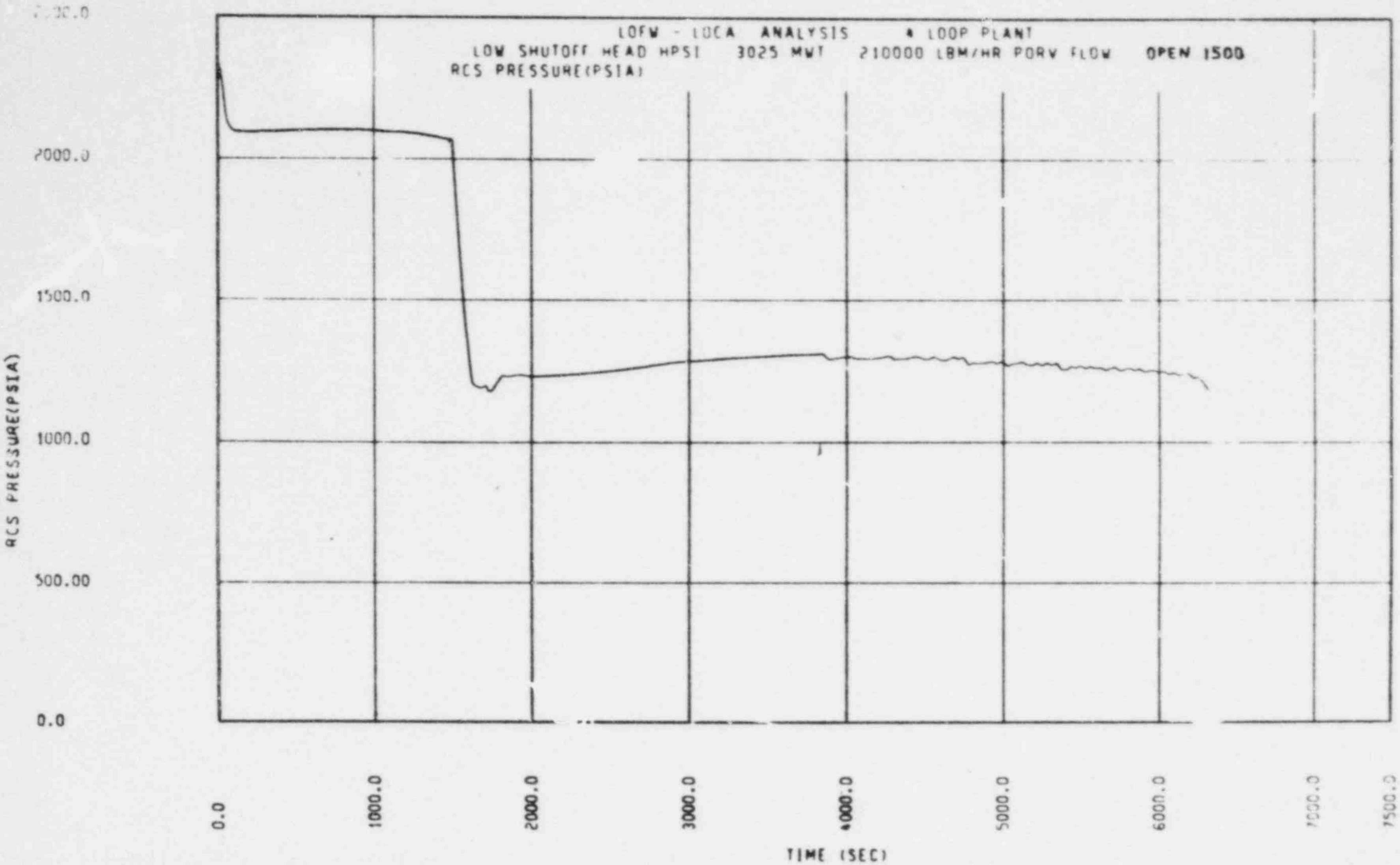

LOFW - LOCA ANALYSIS 4 LOOP PLANT
LOW SHUTOFF HEAD HPSI 3025 MWT 210000 LBM/HR PORV FLOW OPEN 1500
RCS PRESSURE(PSIA)
2000.0
1500.0
1000.0
500.00
0.0
RCS PRESSURE(PSIA)
0.0
1000.0
2000.0
3000.0
4000.0
5000.0
6000.0
7000.0
7500.0
TIME (SEC)

FIGURE D - 1

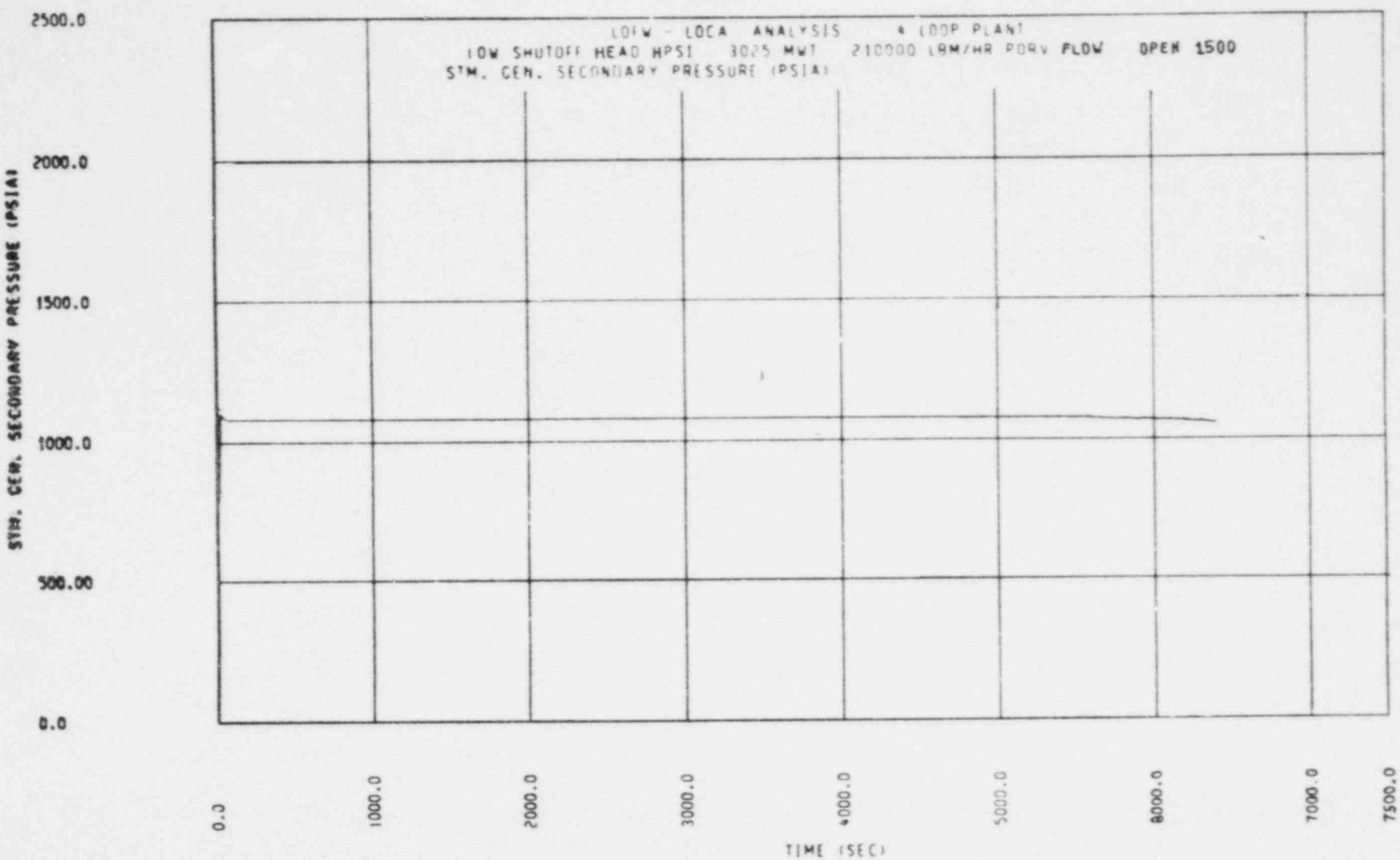

LOFW - LOCA ANALYSIS 4 LOOP PLANT
LOW SHUTOFF HEAD HPSI 3025 MWT 210000 LBM/HR PORV FLOW OPEN 1500
STM. GEN. SECONDARY PRESSURE (PSIA)
STM. GEN. SECONDARY PRESSURE (PSIA)
2500.0
2000.0
1500.0
1000.0
500.00
0.0
0.0
1000.0
2000.0
3000.0
4000.0
5000.0
6000.0
7000.0
7500.0
TIME (SEC)

FIGURE D - 2

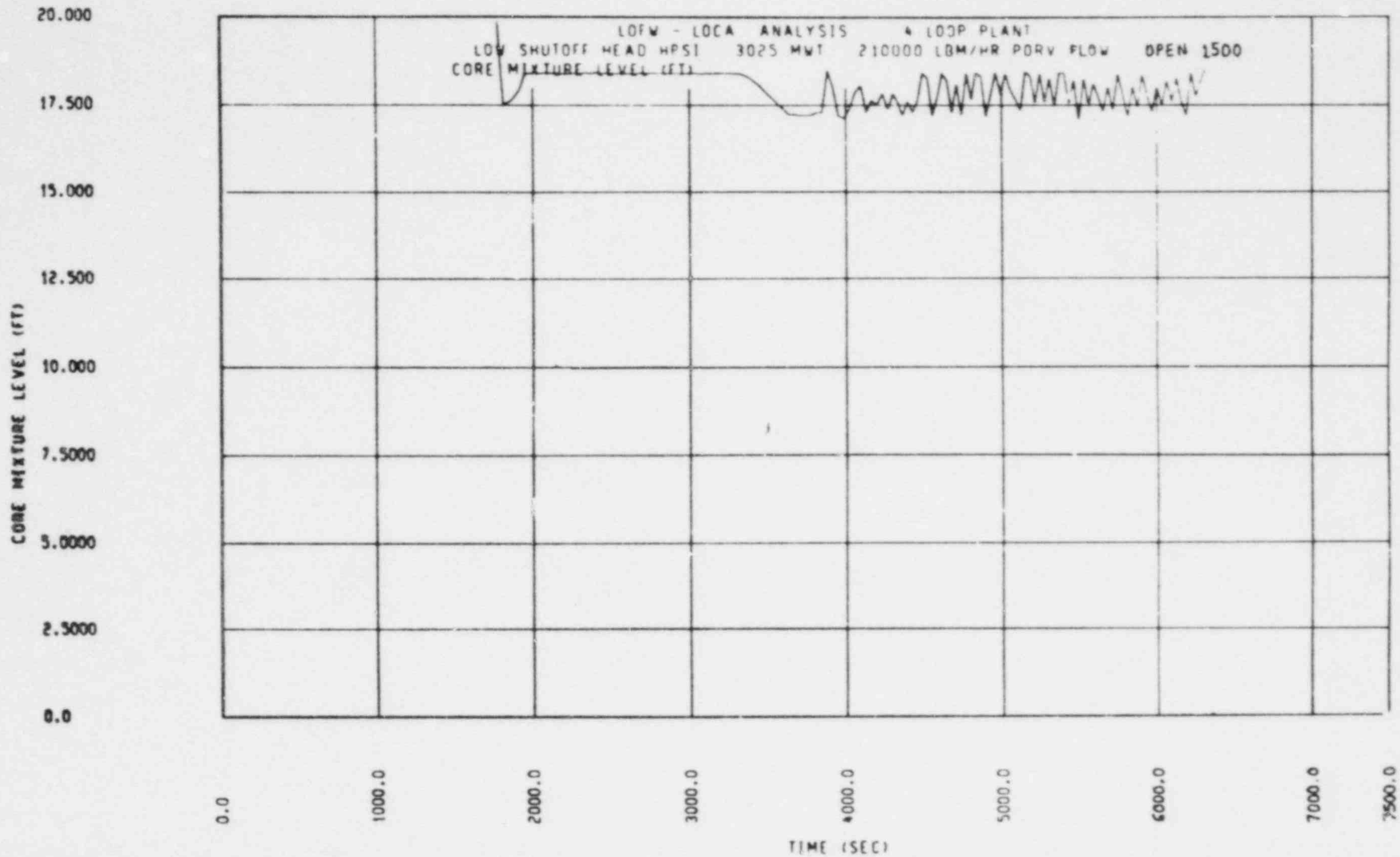
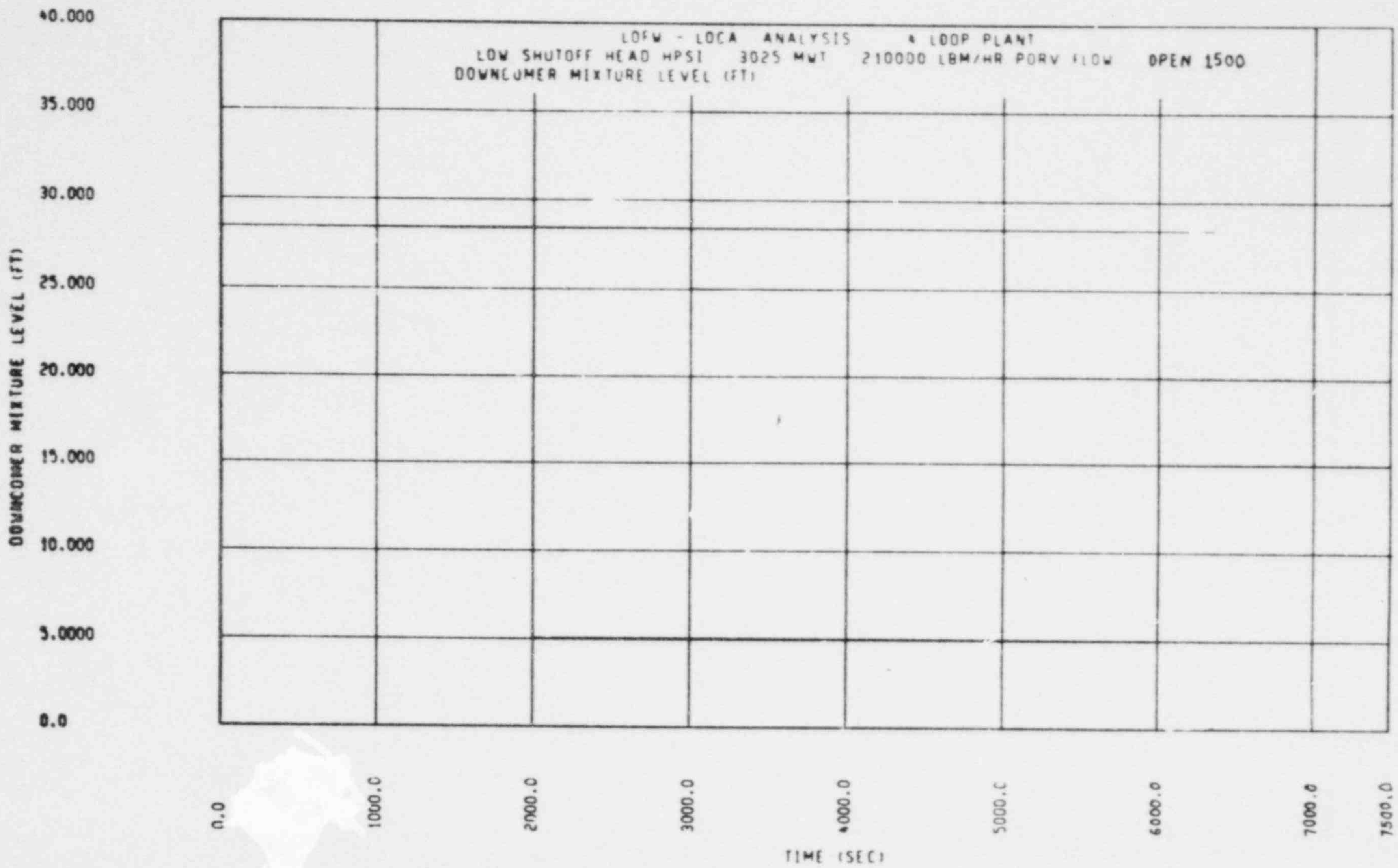

LOFW - LOCA ANALYSIS 4 LOOP PLANT
LOW SHUTOFF HEAD HPSI 3025 MWT 210000 LBM/HR PORV FLOW OPEN 1500
CORE MIXTURE LEVEL (FT)
20.000
17.500
15.000
12.500
10.000
7.5000
5.0000
2.5000
0.0
CORE MIXTURE LEVEL (FT)
0.0
1000.0
2000.0
3000.0
4000.0
5000.0
6000.0
7000.0
7500.0
TIME (SEC)

FIGURE D - 3

LOFW LOCA ANALYSIS 4 LOOP PLANT
LOW SHUTOFF HEAD HPSI 3025 MWT 210000 LBM/HR PORV FLOW OPEN 1500
UPPER HEAD MIXTURE LEVEL (FT)
10.000
8.0000
6.0000
4.0000
2.0000
0.0
UPPER HEAD MIXTURE LEVEL (FT)
0.0
1000.0
2000.0
3000.0
4000.0
5000.0
6000.0
7000.0
7500.0
TIME (SEC)

FIGURE D - 4



LOFW - LOCA ANALYSIS 4 LOOP PLANT
LOW SHUTOFF HEAD HPSI 3025 MWT 210000 LBM/HR PORV FLOW OPEN 1500
DOWNCOMER MIXTURE LEVEL (FT)
40.000
35.000
30.000
25.000
20.000
15.000
10.000
5.0000
0.0
DOWNCOMER MIXTURE LEVEL (FT)
0.0
1000.0
2000.0
3000.0
4000.0
5000.0
6000.0
7000.0
7500.0
TIME (SEC)

FIGURE D - 5

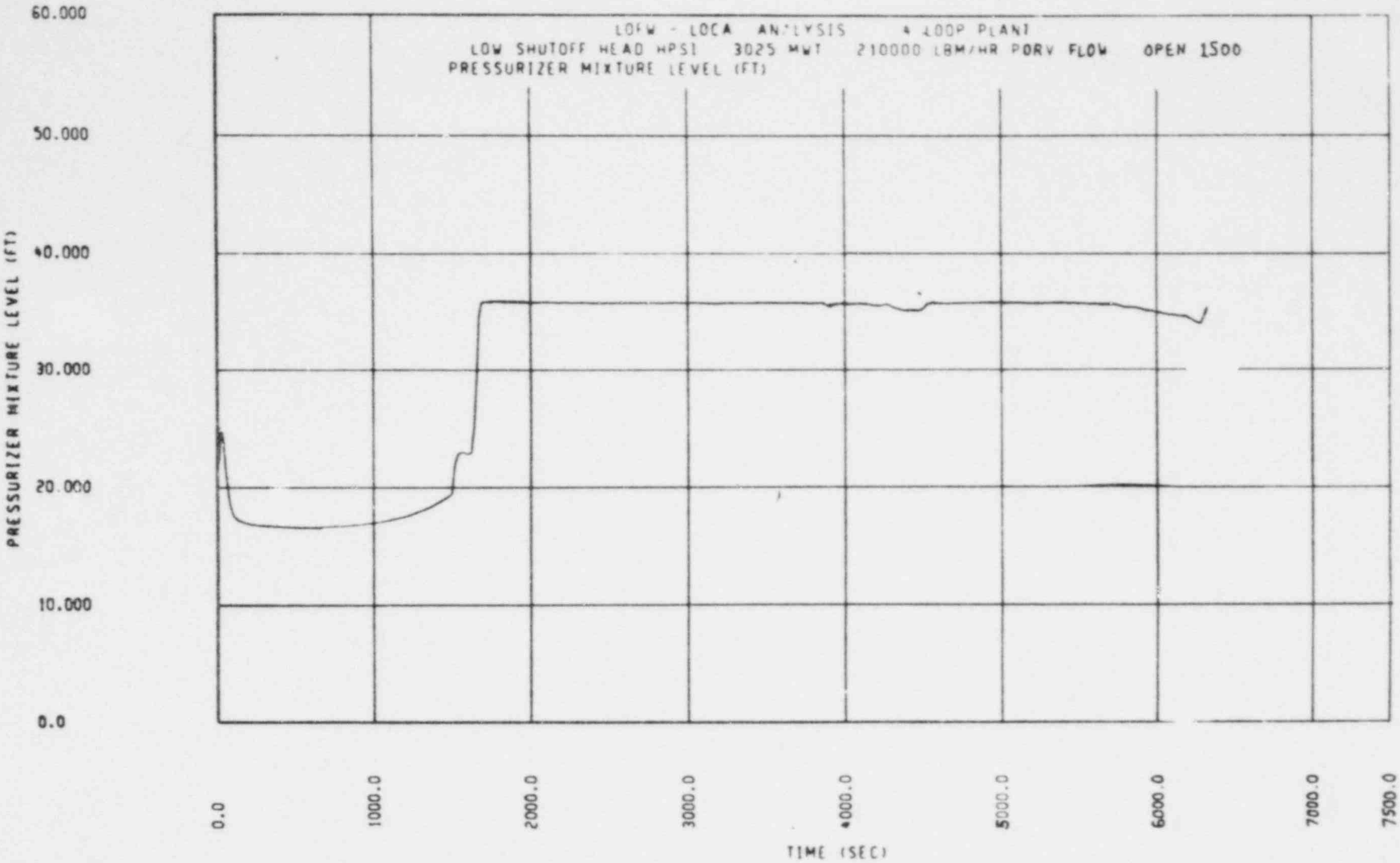
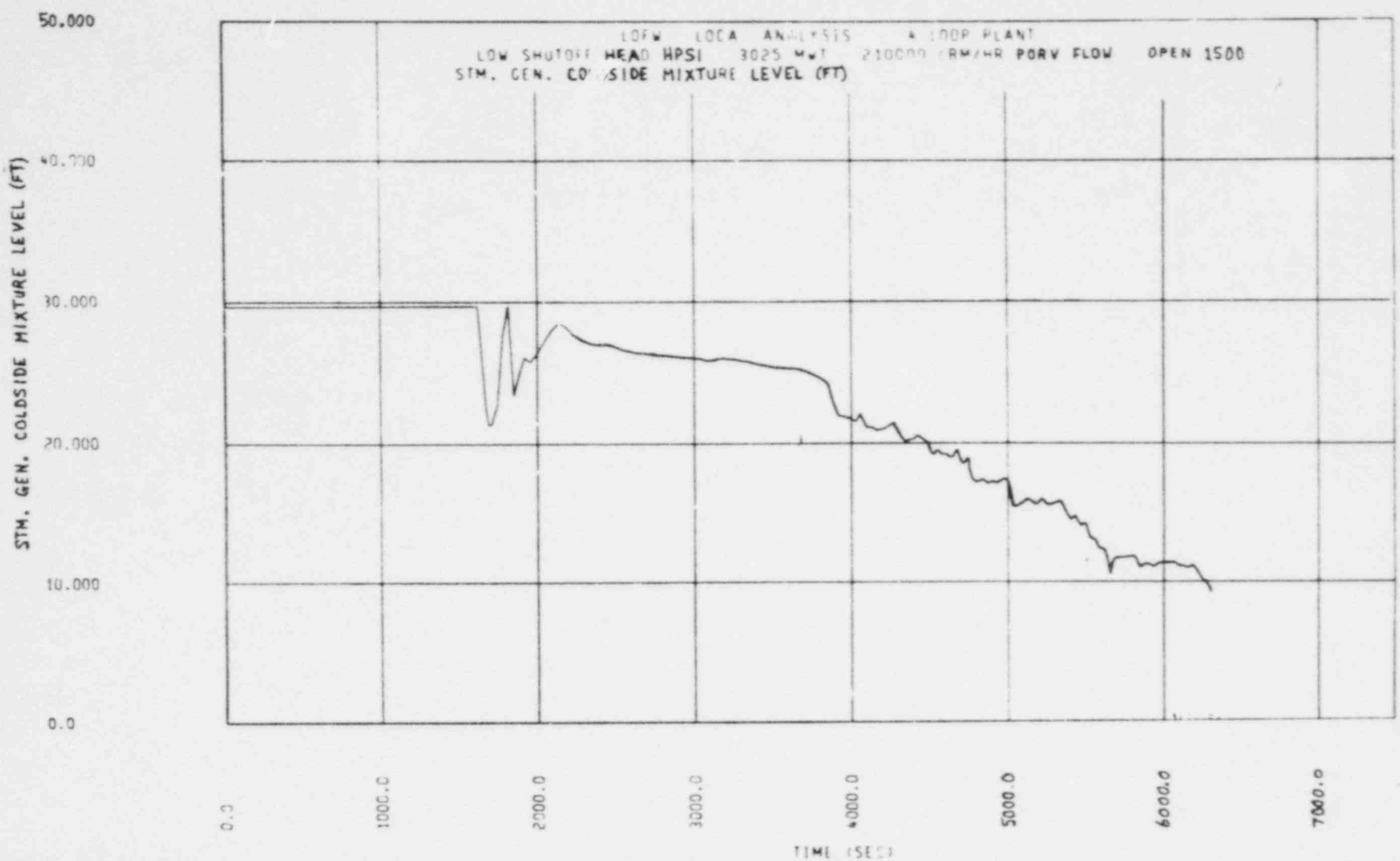

LOFW - LOCA ANALYSIS 4 LOOP PLANT
LOW SHUTOFF HEAD HPSI 3025 MWT 210000 LBM/HR PORV FLOW OPEN 1500
PRESSURIZER MIXTURE LEVEL (FT)
60.000
50.000
40.000
30.000
20.000
10.000
0.0
PRESSURIZER MIXTURE LEVEL (FT)
0.0
1000.0
2000.0
3000.0
4000.0
5000.0
6000.0
7000.0
7500.0
TIME (SEC)

FIGURE D - 6



LOFW LOCA ANALYSIS 4 LOOP PLANT
LOW SHUTOFF HEAD HPSI 3025 MWT 210000 LBM/HR PORV FLOW OPEN 1500
STM. GEN. COLDSIDE MIXTURE LEVEL (FT)
STM. GEN. COLDSIDE MIXTURE LEVEL (FT)
50.000
40.000
30.000
20.000
10.000
0.0
0.0
1000.0
2000.0
3000.0
4000.0
5000.0
6000.0
7000.0
TIME (SEC)

FIGURE D - 7

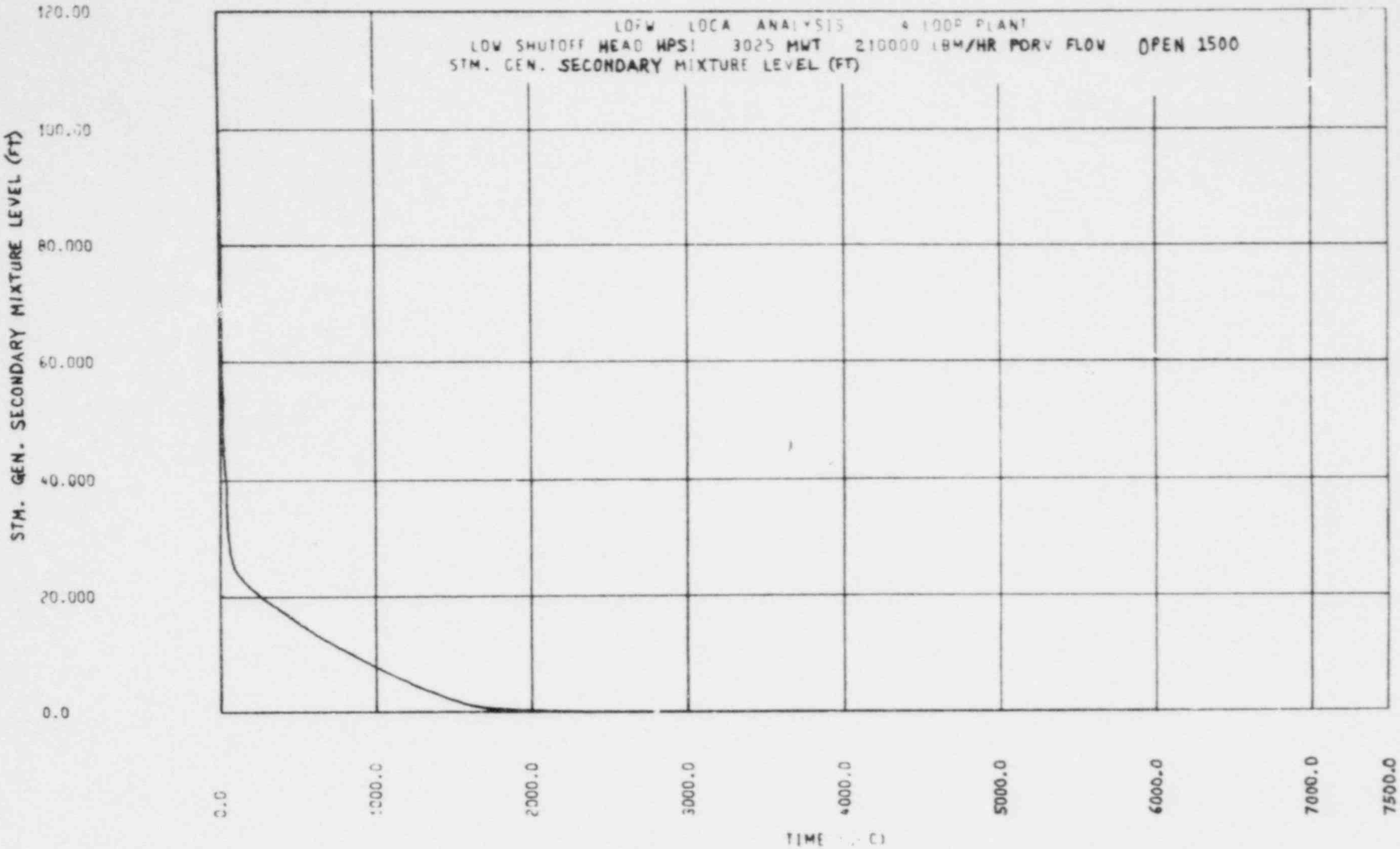

LOFW LOCA ANALYSIS 4 LOOP PLANT
LOW SHUTOFF HEAD HPSI 3025 MWT 210000 LBM/HR PORV FLOW OPEN 1500
STM. GEN. SECONDARY MIXTURE LEVEL (FT)
STM. GEN. SECONDARY MIXTURE LEVEL (FT)
120.00
100.00
80.000
60.000
40.000
20.000
0.0
0.0
1000.0
2000.0
3000.0
4000.0
5000.0
6000.0
7000.0
7500.0
TIME

FIGURE D - 8

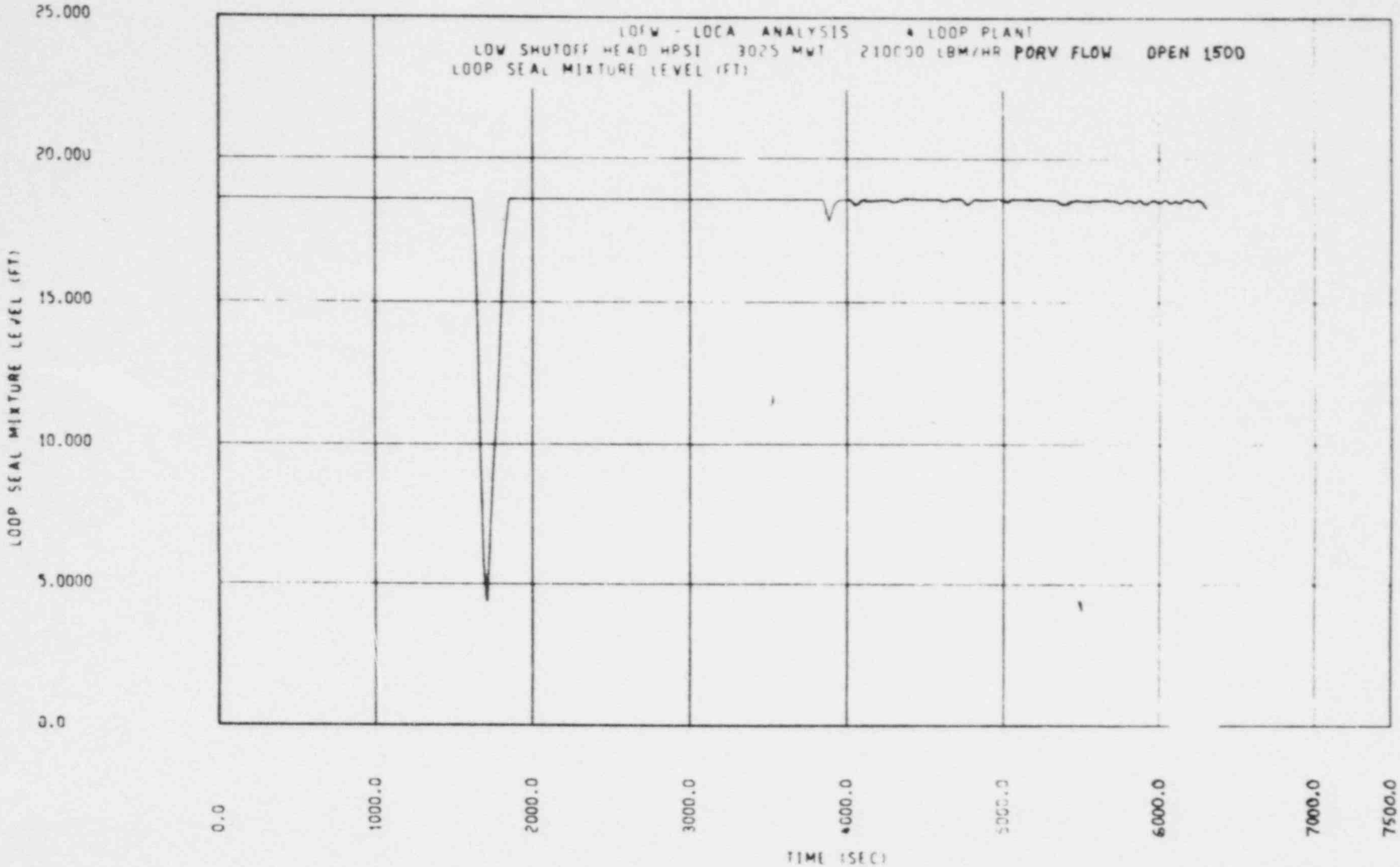

LOFW - LOCA ANALYSIS 4 LOOP PLANT
LOW SHUTOFF HEAD HPSI 3025 MWT 210000 LBM/HR PORV FLOW OPEN 1500
LOOP SEAL MIXTURE LEVEL (FT)
25.000
20.000
15.000
10.000
5.0000
0.0
LOOP SEAL MIXTURE LEVEL (FT)
0.0
1000.0
2000.0
3000.0
4000.0
5000.0
6000.0
7000.0
7500.0
TIME (SEC)

FIGURE D - 9

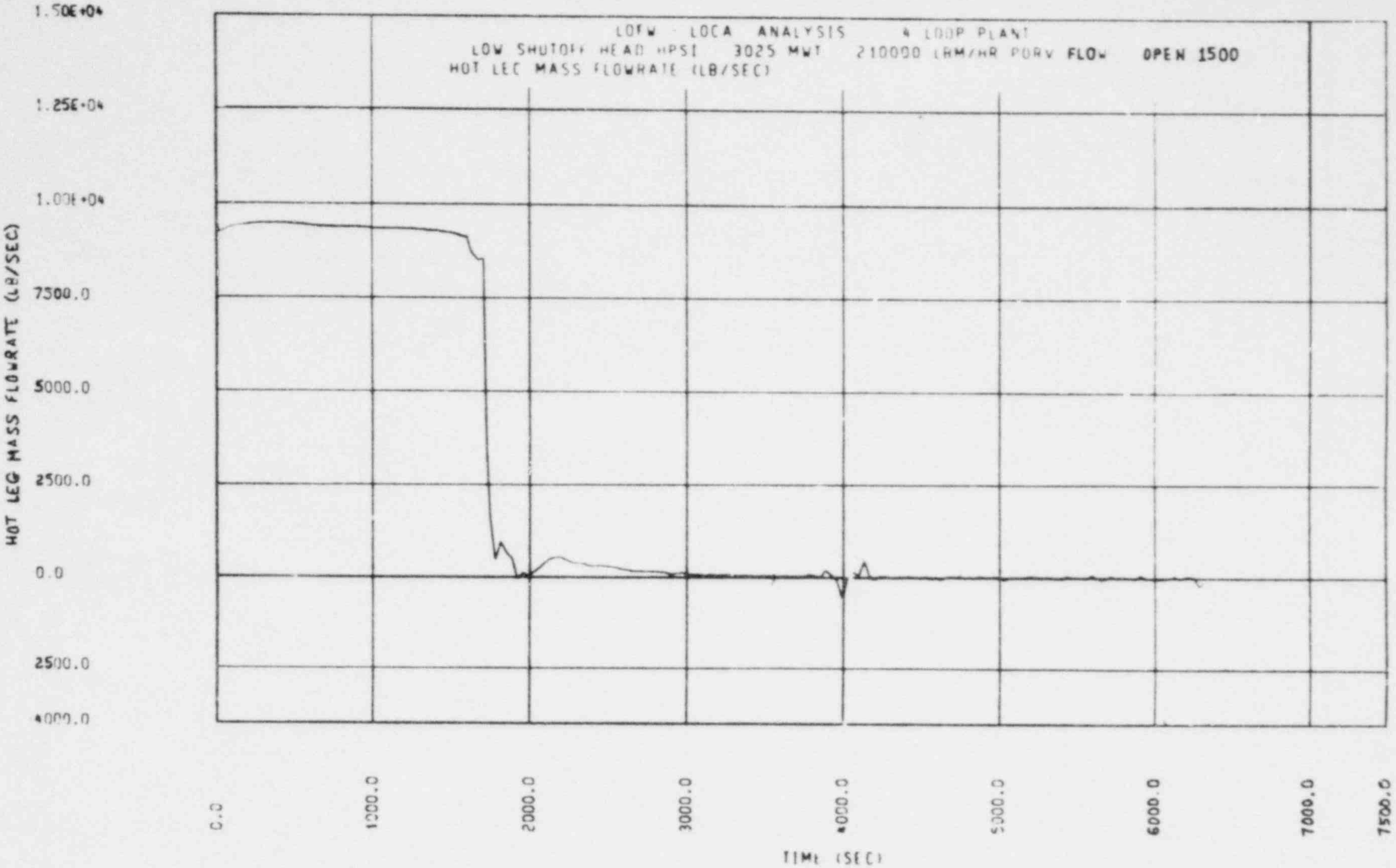
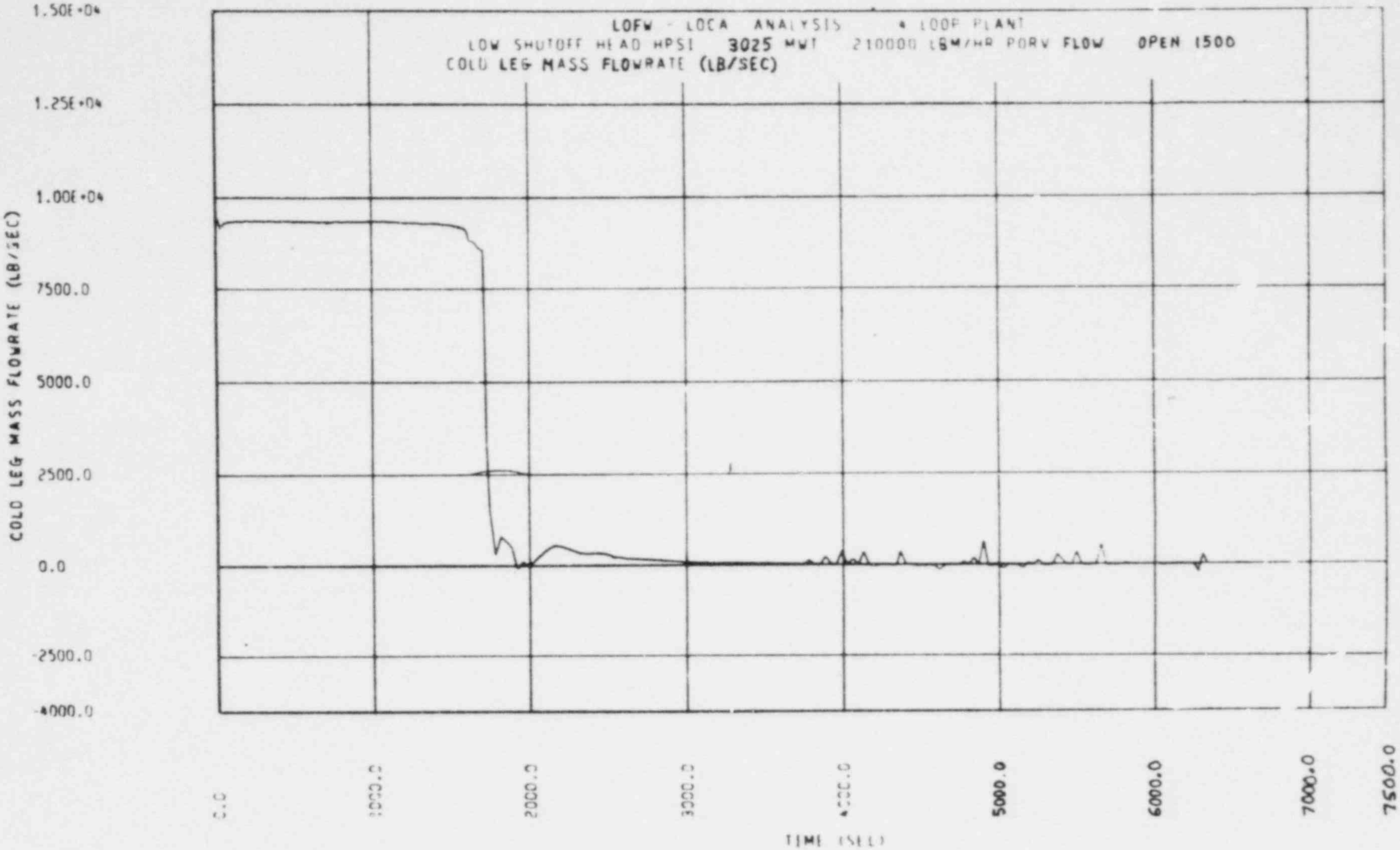

LOFW - LOCA ANALYSIS 4 LOOP PLANT
LOW SHUTOFF HEAD HPSI 3025 MWT 210000 LBM/HR PORV FLOW OPEN 1500
HOT LEG MASS FLOWRATE (LB/SEC)
HOT LEG MASS FLOWRATE (LB/SEC)
1.50E+04
1.25E+04
1.00E+04
7500.0
5000.0
2500.0
0.0
2500.0
4000.0
0.0
1000.0
2000.0
3000.0
4000.0
5000.0
6000.0
7000.0
7500.0
TIME (SEC)

FIGURE D - 10



LOFW - LOCA ANALYSIS 4 LOOP PLANT
LOW SHUTOFF HEAD HPSI 3025 MWT 210000 LBM/HR PORV FLOW OPEN 1500
COLD LEG MASS FLOWRATE (LB/SEC)
1.50E+04
1.25E+04
1.00E+04
7500.0
5000.0
2500.0
0.0
-2500.0
-4000.0
COLD LEG MASS FLOWRATE (LB/SEC)
0.0
1000.0
2000.0
3000.0
4000.0
5000.0
6000.0
7000.0
7500.0
TIME (SEC)

FIGURE D - 11

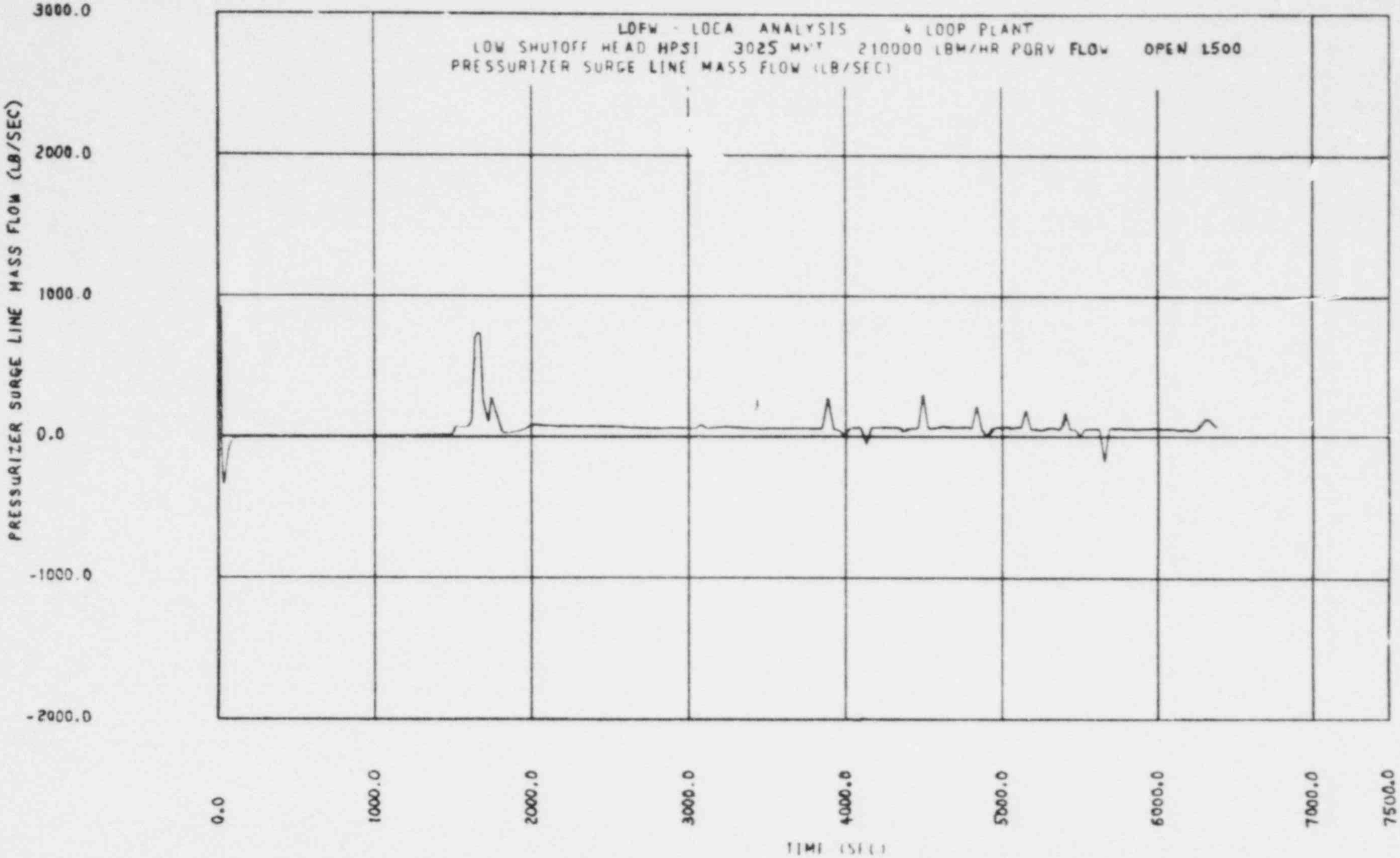

LOFW - LOCA ANALYSIS 4 LOOP PLANT
LOW SHUTOFF HEAD HPSI 3025 MWT 210000 LBM/HR PORV FLOW OPEN 1500
PRESSURIZER SURGE LINE MASS FLOW (LB/SEC)
PRESSURIZER SURGE LINE MASS FLOW (LB/SEC)
3000.0
2000.0
1000.0
0.0
-1000.0
-2000.0
0.0
1000.0
2000.0
3000.0
4000.0
5000.0
6000.0
7000.0
7500.0
TIME (SEC)

FIGURE D - 12

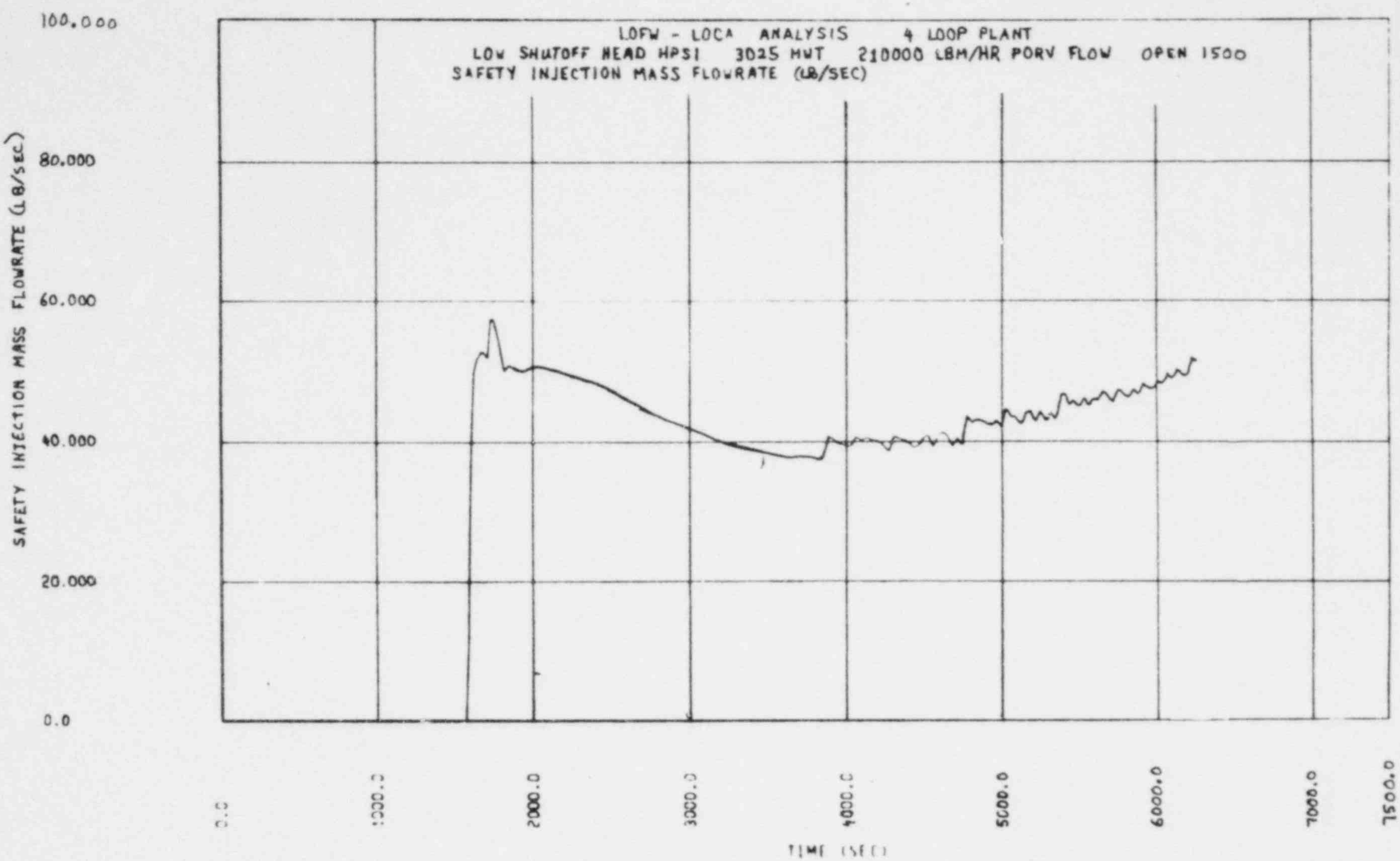

LOFW - LOCA ANALYSIS 4 LOOP PLANT
LOW SHUTOFF HEAD HPSI 3025 MWT 210000 LBM/HR PORV FLOW OPEN 1500
SAFETY INJECTION MASS FLOWRATE (LB/SEC)
100.000
80.000
60.000
40.000
20.000
0.0
SAFETY INJECTION MASS FLOWRATE (LB/SEC)
2000.0
3000.0
4000.0
5000.0
6000.0
7000.0
7500.0
TIME (SEC)

FIGURE D - 13

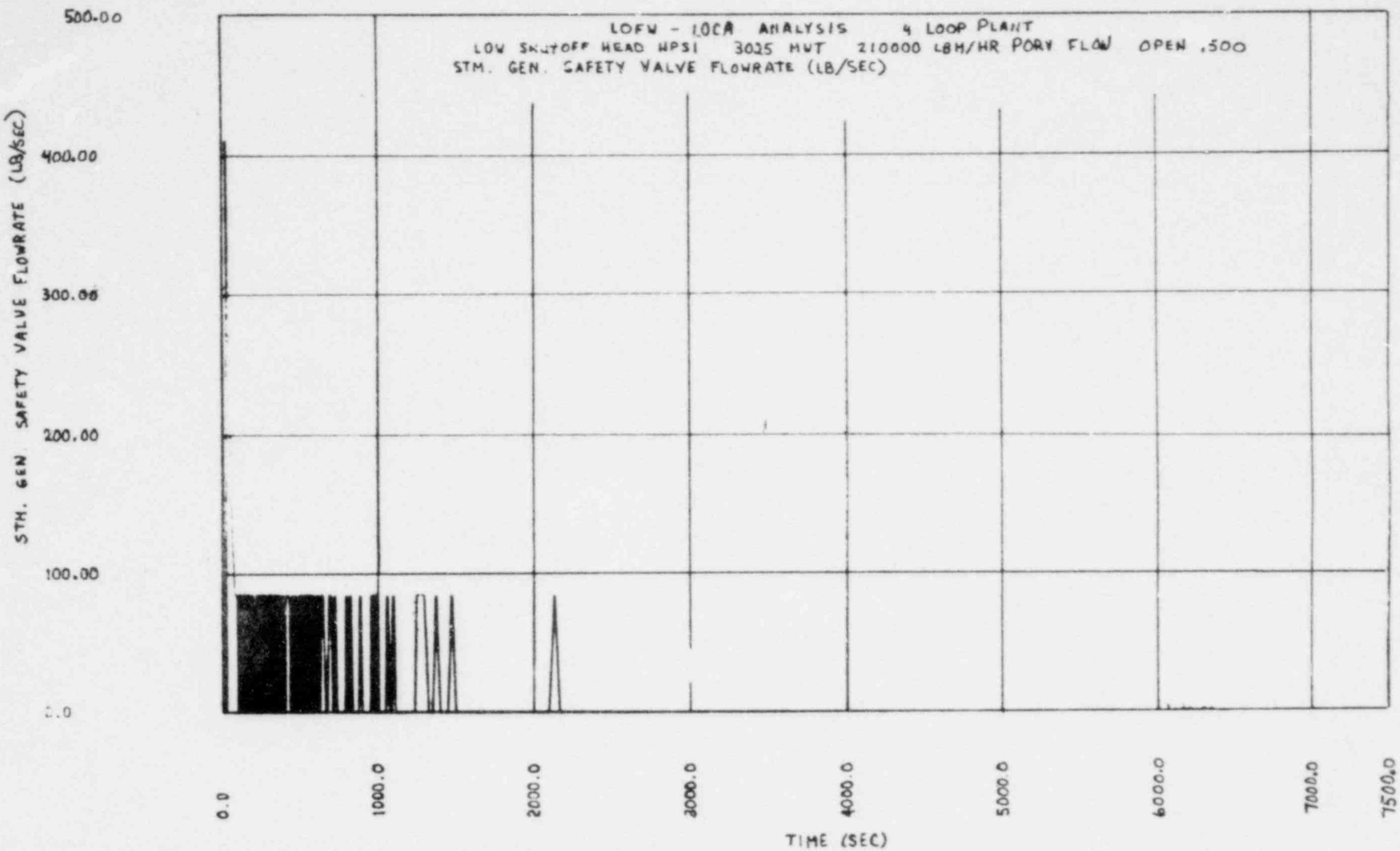

LOFW - LOCA ANALYSIS 4 LOOP PLANT
LOW SHUTOFF HEAD HPSI 3025 MWT 210000 LBM/HR PORV FLOW OPEN .500
STM. GEN. SAFETY VALVE FLOWRATE (LB/SEC)
500.00
400.00
300.00
200.00
100.00
0.0
STM. GEN SAFETY VALVE FLOWRATE (LB/SEC)
0.0
1000.0
2000.0
3000.0
4000.0
5000.0
6000.0
7000.0
7500.0
TIME (SEC)

FIGURE D - 14

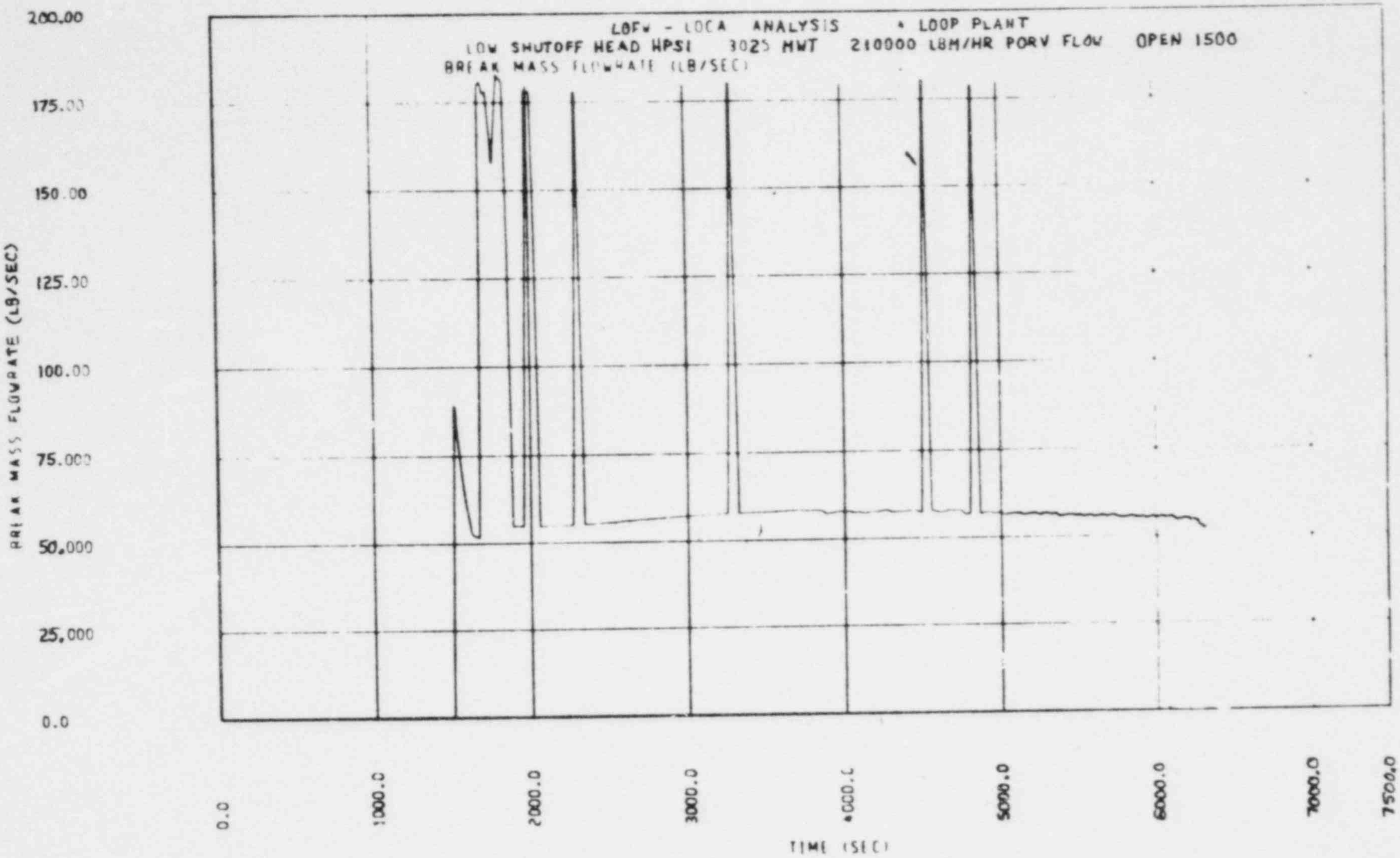

LOFW - LOCA ANALYSIS 4 LOOP PLANT
LOW SHUTOFF HEAD HPSI 3025 MWT 210000 LBM/HR PORV FLOW OPEN 1500
BREAK MASS FLOWRATE (LB/SEC)
200.00
175.00
150.00
125.00
100.00
75.000
50.000
25.000
0.0
BREAK MASS FLOWRATE (LB/SEC)
0.0
1000.0
2000.0
3000.0
4000.0
5000.0
6000.0
7000.0
7500.0
TIME (SEC)

FIGURE D - 15

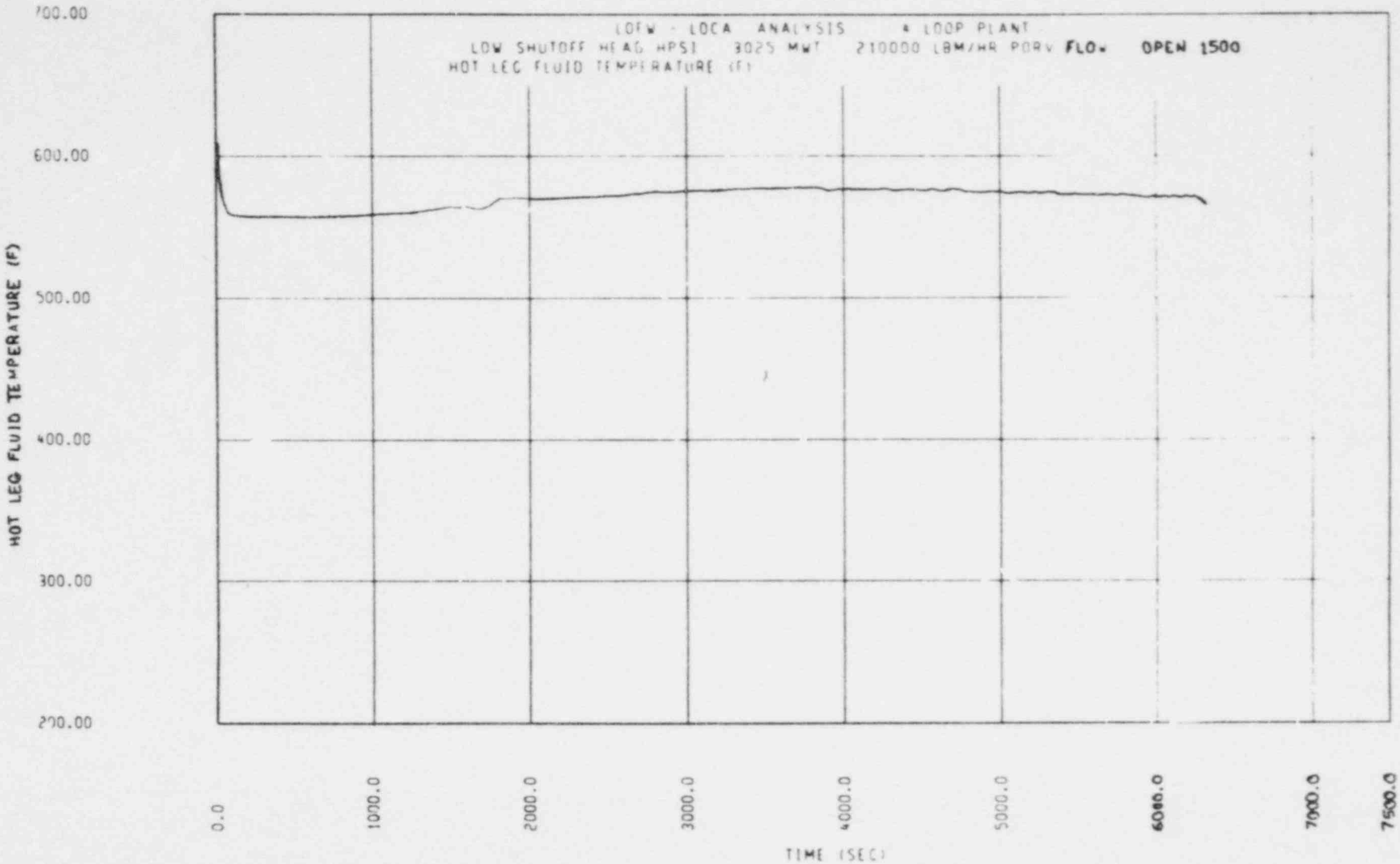

LOFW - LOCA ANALYSIS 4 LOOP PLANT
LOW SHUTOFF HEAD HPSI 3025 MWT 210000 LBM/HR PORV FLOW OPEN 1500
HOT LEG FLUID TEMPERATURE (F)
HOT LEG FLUID TEMPERATURE (F)
700.00
600.00
500.00
400.00
300.00
200.00
0.0
1000.0
2000.0
3000.0
4000.0
5000.0
6000.0
7000.0
7500.0
TIME (SEC)

FIGURE D - 16

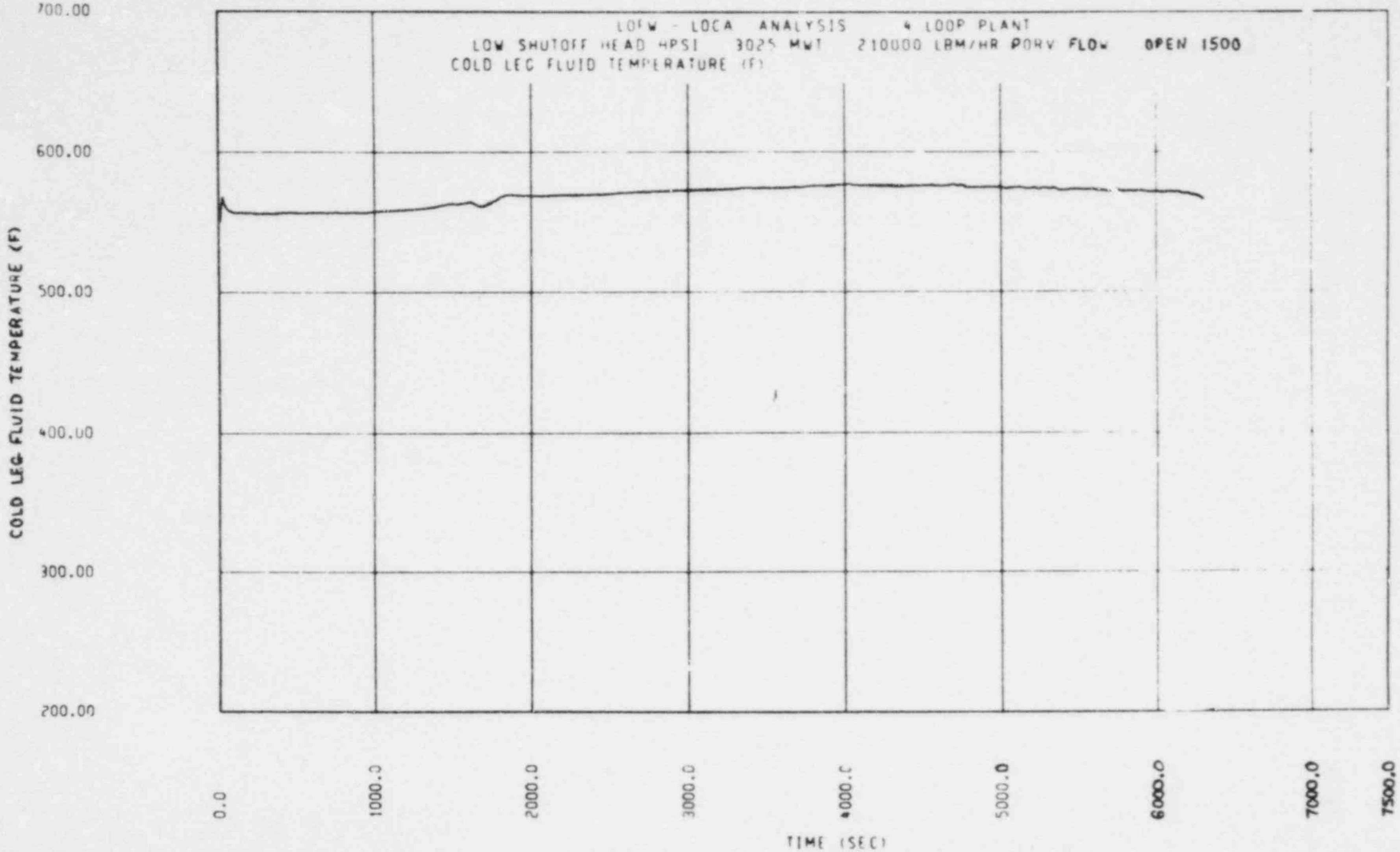

LOFW - LOCA ANALYSIS 4 LOOP PLANT
LOW SHUTOFF HEAD HPSI 3025 MWT 210000 LBM/HR PORV FLOW OPEN 1500
COLD LEG FLUID TEMPERATURE (F)
700.00
600.00
500.00
400.00
300.00
200.00
COLD LEG FLUID TEMPERATURE (F)
0.0
1000.0
2000.0
3000.0
4000.0
5000.0
6000.0
7000.0
7500.0
TIME (SEC)

FIGURE D - 17

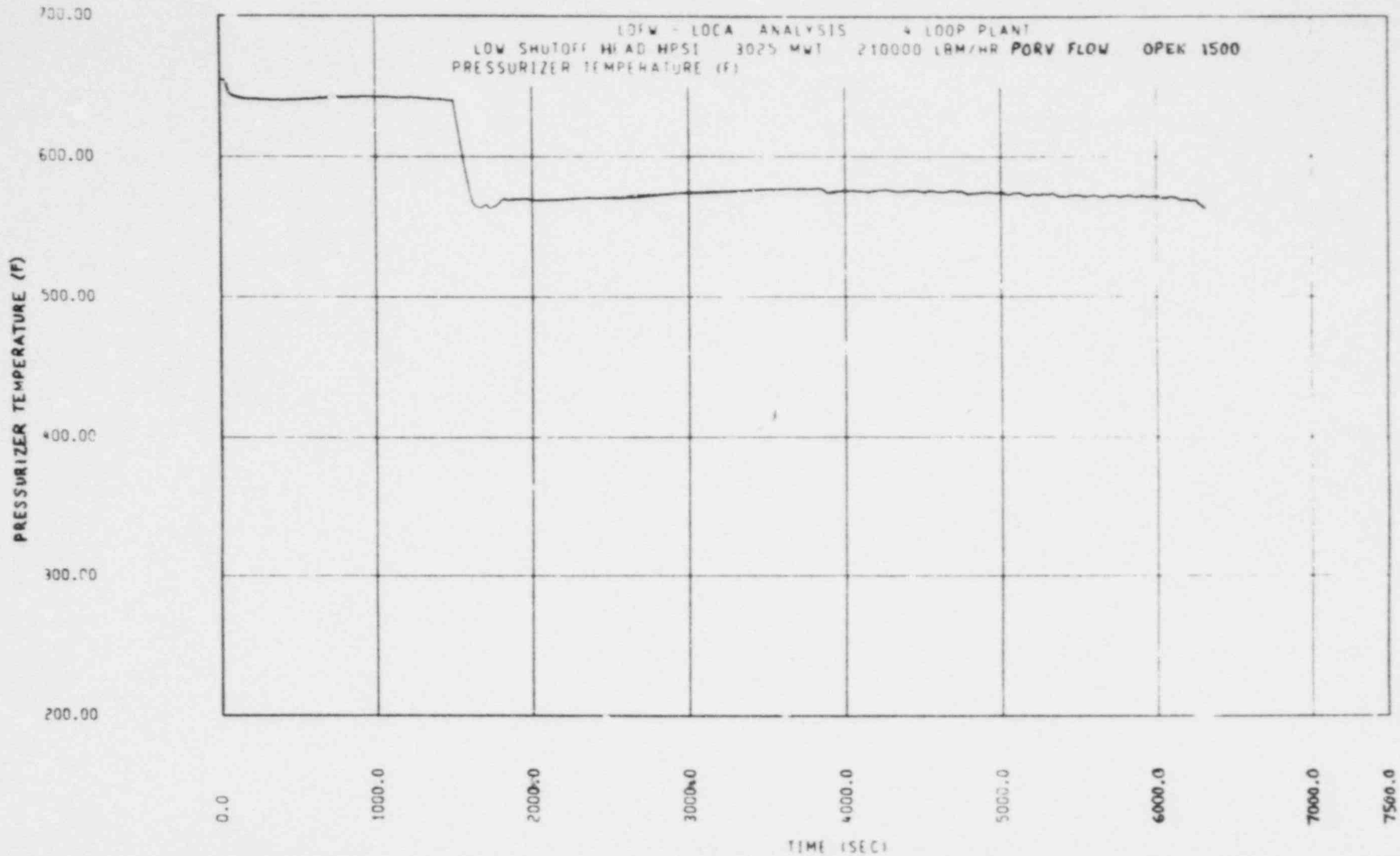

LOFW - LOCA ANALYSIS 4 LOOP PLANT
LOW SHUTOFF HEAD HPSI 3025 MWT 210000 LBM/HR PORV FLOW OPEK 1500
PRESSURIZER TEMPERATURE (F)
700.00
600.00
500.00
400.00
300.00
200.00
PRESSURIZER TEMPERATURE (F)
0.0
1000.0
2000.0
3000.0
4000.0
5000.0
6000.0
7000.0
7500.0
TIME (SEC)

FIGURE D - 18

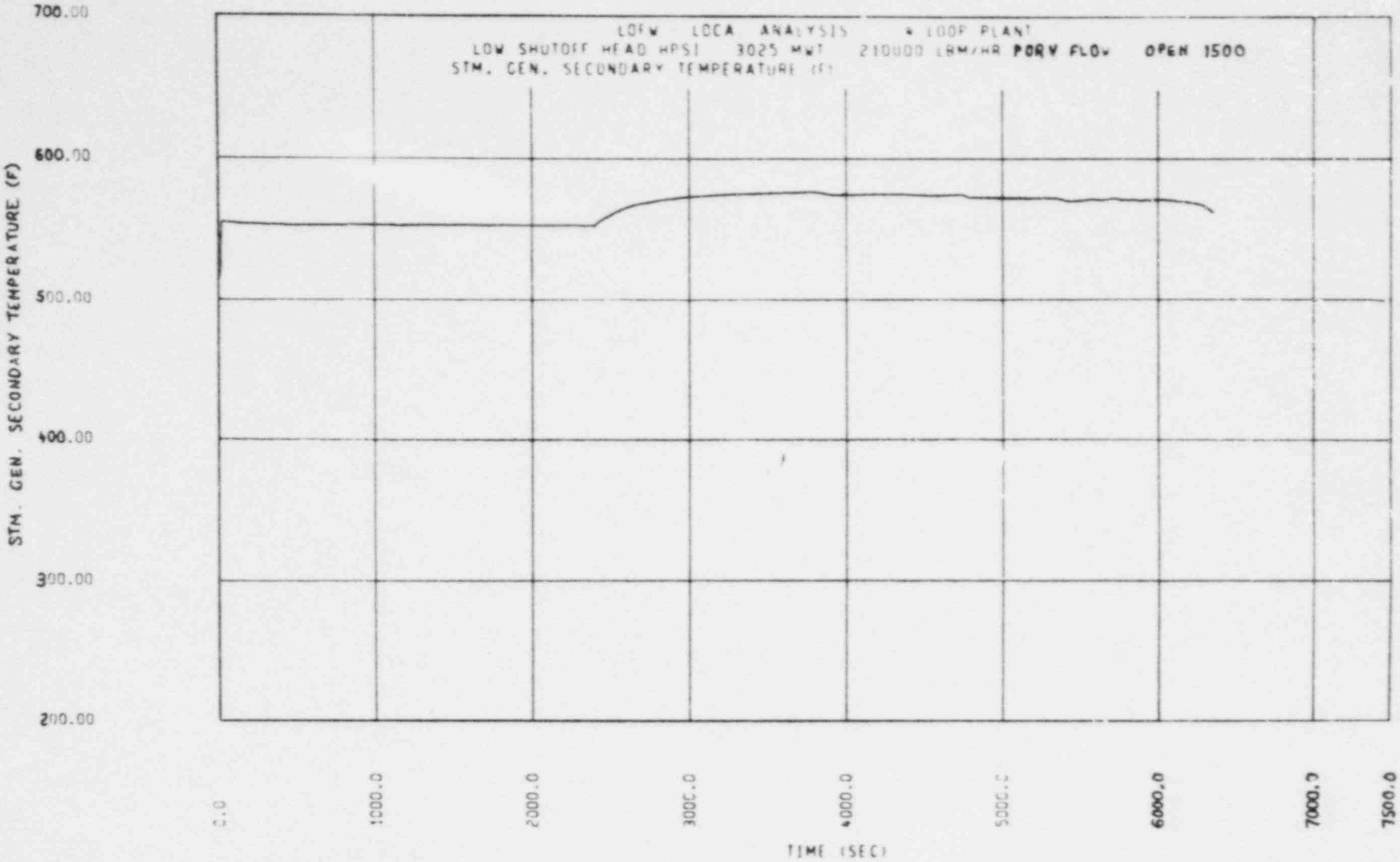

LOFW LOCA ANALYSIS 4 LOOP PLANT
LOW SHUTOFF HEAD HPSI 3025 MWT 210000 LBM/HR PORV FLOW OPEN 1500
STM. GEN. SECONDARY TEMPERATURE (F)
700.00
600.00
500.00
400.00
300.00
200.00
STM. GEN. SECONDARY TEMPERATURE (F)
0.0
1000.0
2000.0
3000.0
4000.0
5000.0
6000.0
7000.0
7500.0
TIME (SEC)

FIGURE D - 19

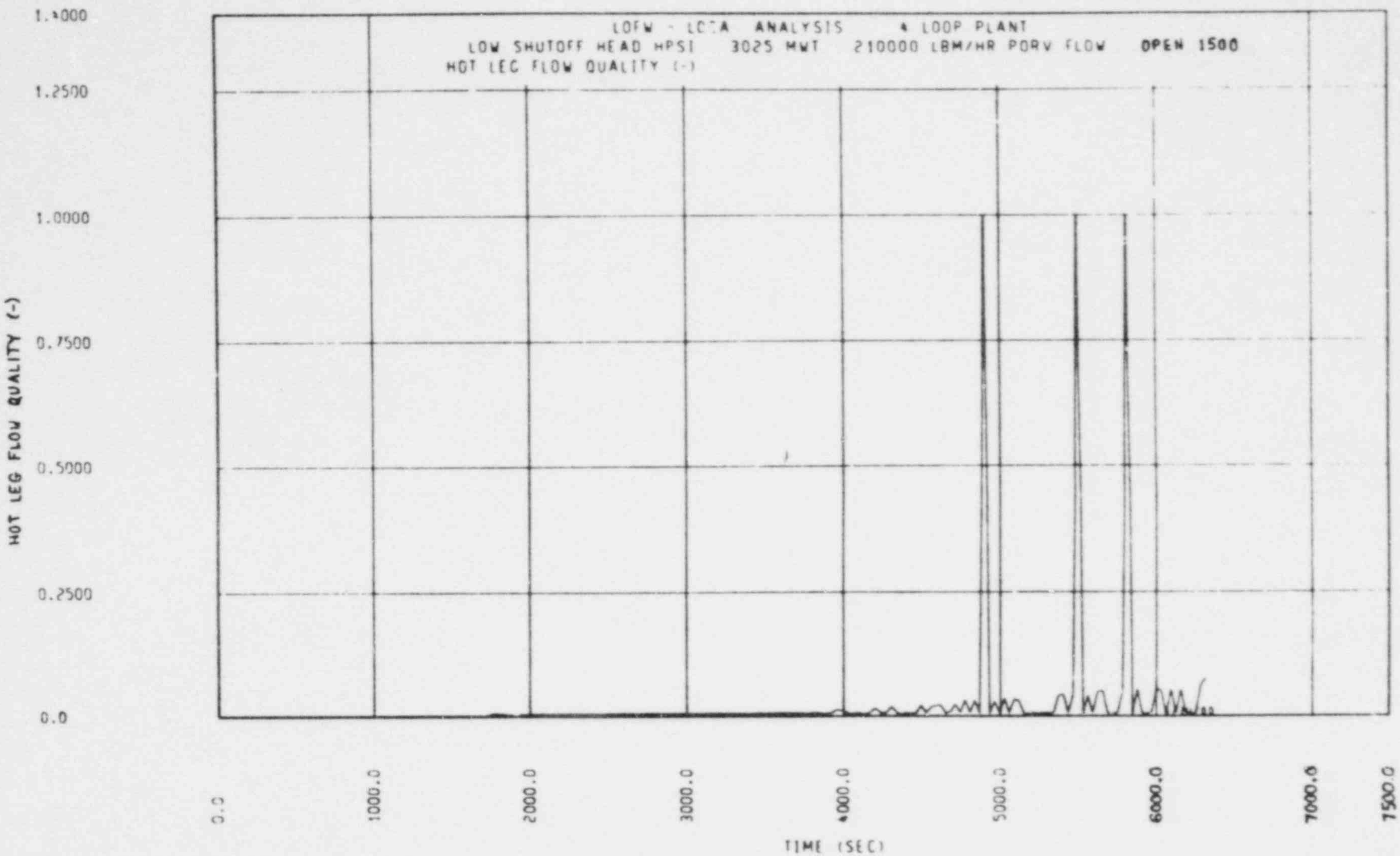
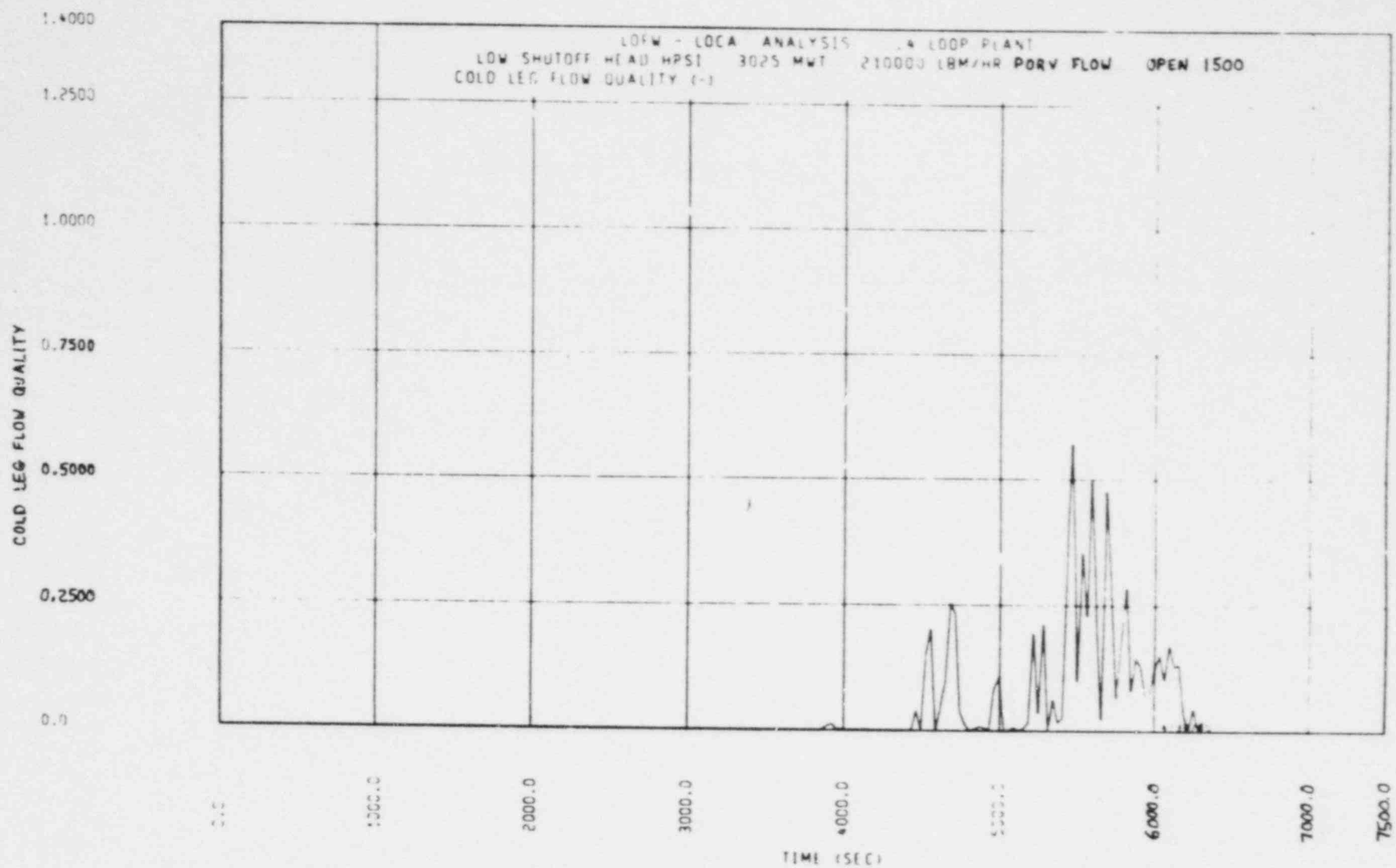
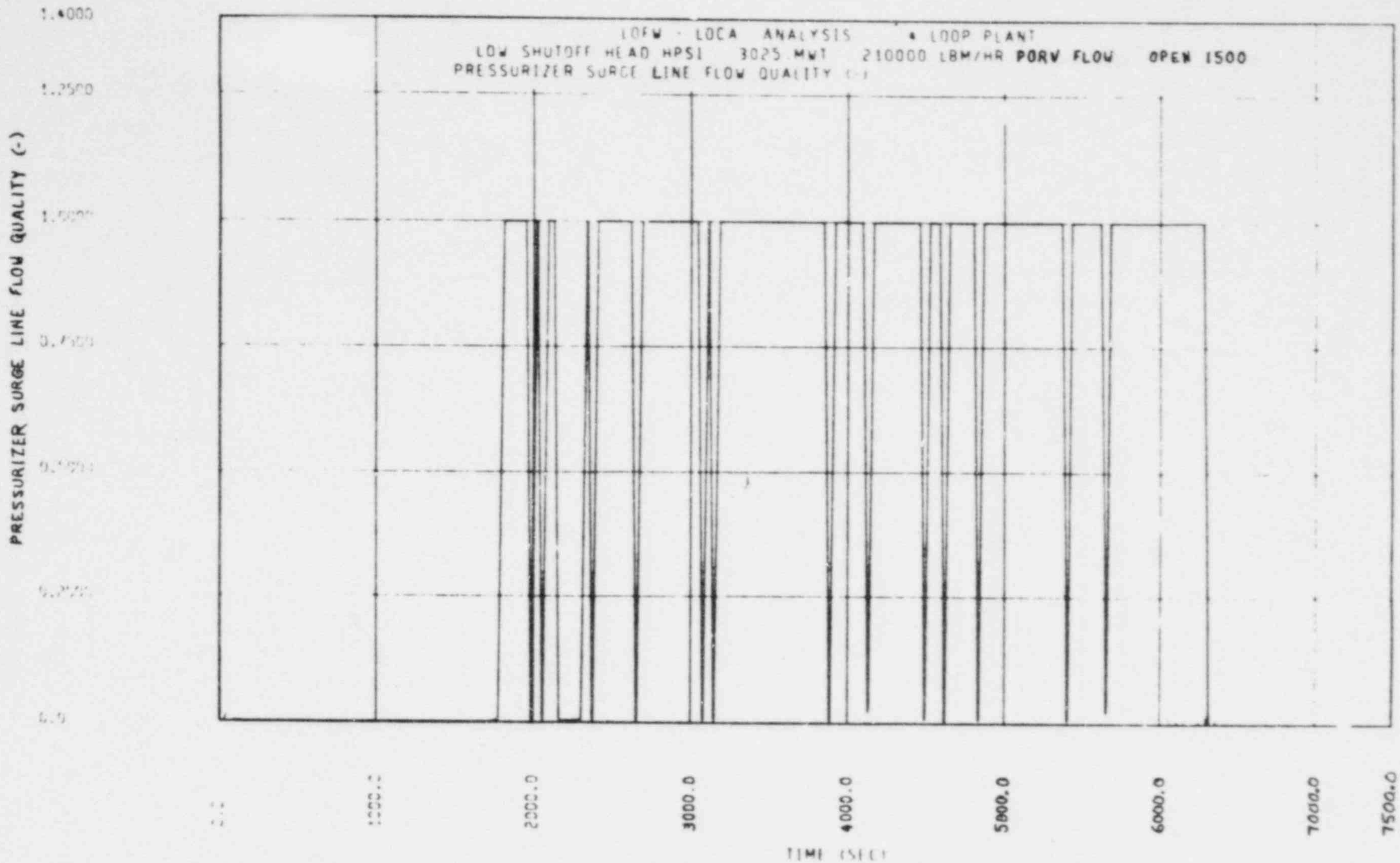

LOFW - LOCA ANALYSIS 4 LOOP PLANT
LOW SHUTOFF HEAD HPSI 3025 MWT 210000 LBM/HR PORV FLOW OPEN 1500
HOT LEG FLOW QUALITY (-)
HOT LEG FLOW QUALITY (-)
1.5000
1.2500
1.0000
0.7500
0.5000
0.2500
0.0
0.0
1000.0
2000.0
3000.0
4000.0
5000.0
6000.0
7000.0
7500.0
TIME (SEC)

FIGURE D - 20



LOFW - LOCA ANALYSIS 4 LOOP PLANT
LOW SHUTOFF HEAD HPSI 3025 MWT 210000 LBM/HR PORV FLOW OPEN 1500
COLD LEG FLOW QUALITY (-)
COLD LEG FLOW QUALITY
1.4000
1.2500
1.0000
0.7500
0.5000
0.2500
0.0
2000.0
3000.0
4000.0
6000.0
7000.0
7500.0
TIME (SEC)

FIGURE D - 21



LOFW - LOCA ANALYSIS 4 LOOP PLANT
LOW SHUTOFF HEAD HPSI 3025 MWT 210000 LBM/HR PORV FLOW OPEN 1500
PRESSURIZER SURGE LINE FLOW QUALITY
1.4000
1.2500
1.0000
0.7500
0.2500
0.0
2000.0
3000.0
4000.0
5000.0
6000.0
7000.0
7500.0
TIME (SEC)
PRESSURIZER SURGE LINE FLOW QUALITY (-)

FIGURE D - 22

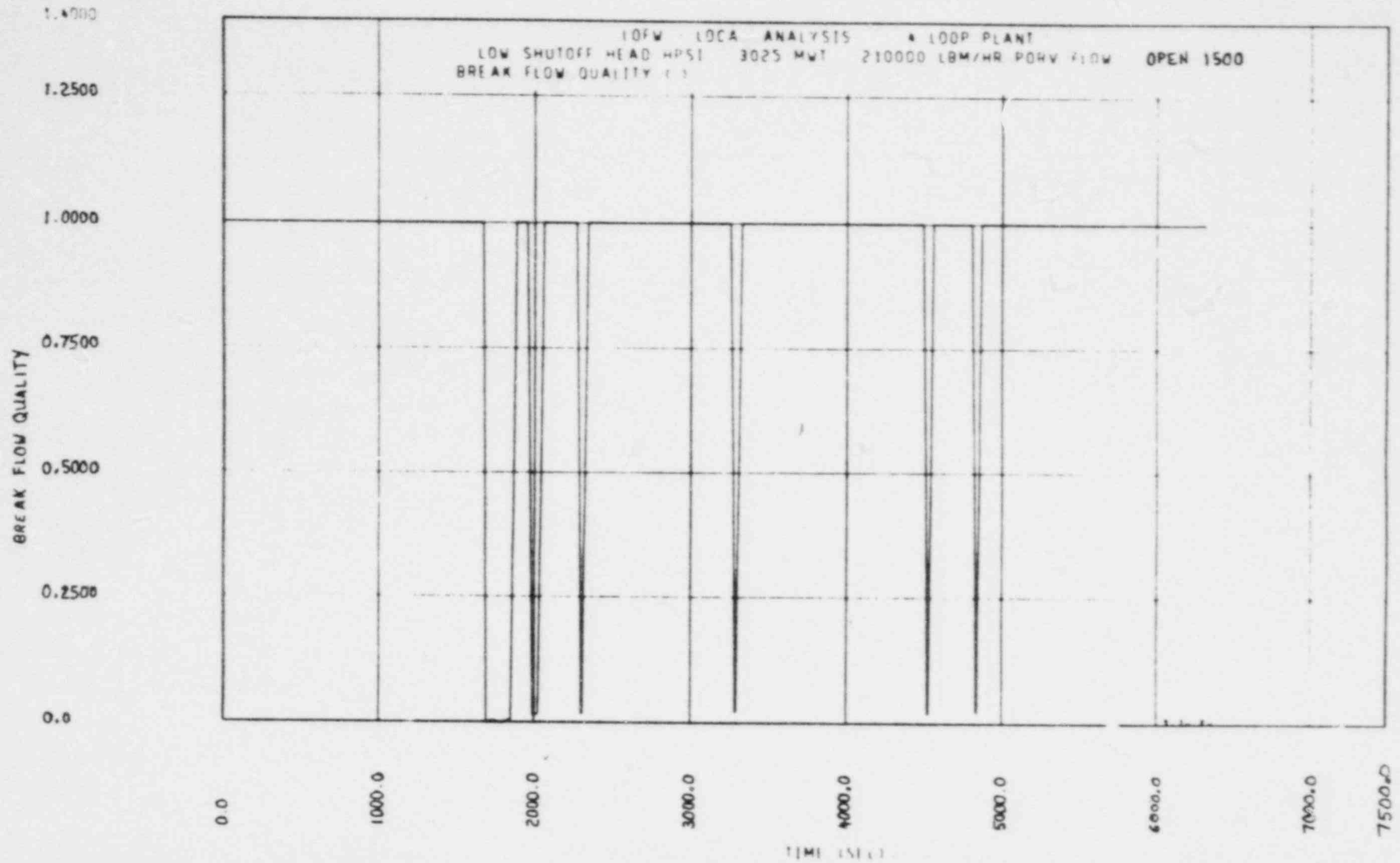

LOFW LOCA ANALYSIS 4 LOOP PLANT
LOW SHUTOFF HEAD HPSI 3025 MWT 210000 LBM/HR PORV FLOW OPEN 1500
BREAK FLOW QUALITY ( )
BREAK FLOW QUALITY
TIME (SEC)
1.4000
1.2500
1.0000
0.7500
0.5000
0.2500
0.0
0.0
1000.0
2000.0
3000.0
4000.0
5000.0
6000.0
7000.0
7500.0

FIGURE D - 23

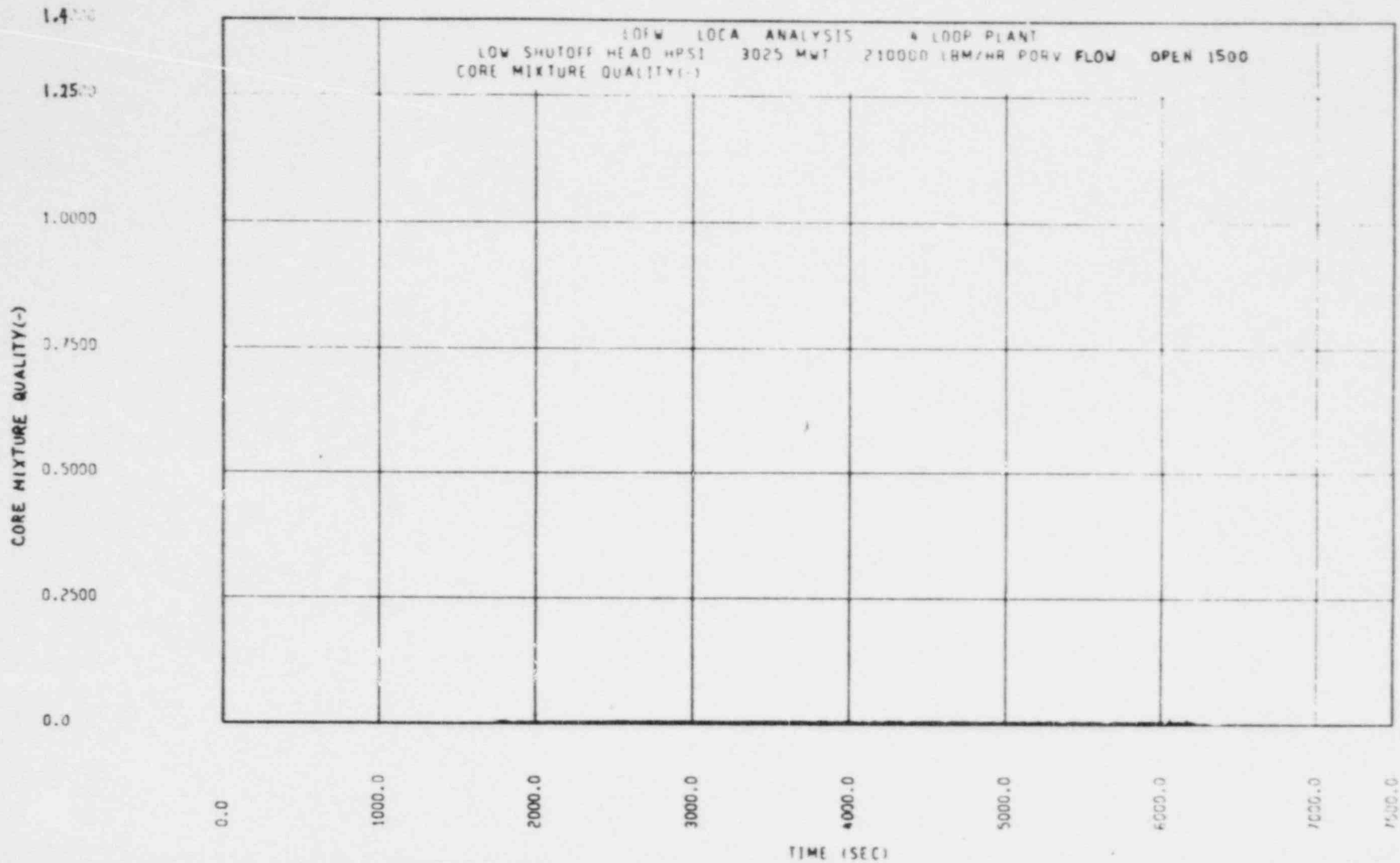

LOFW LOCA ANALYSIS 4 LOOP PLANT
LOW SHUTOFF HEAD HPSI 3025 MWT 210000 LBM/HR PORV FLOW OPEN 1500
CORE MIXTURE QUALITY(-)
1.25
1.0000
0.7500
0.5000
0.2500
0.0
CORE MIXTURE QUALITY(-)
0.0
1000.0
2000.0
3000.0
4000.0
5000.0
6000.0
7000.0
7500.0
TIME (SEC)

FIGURE D - 24

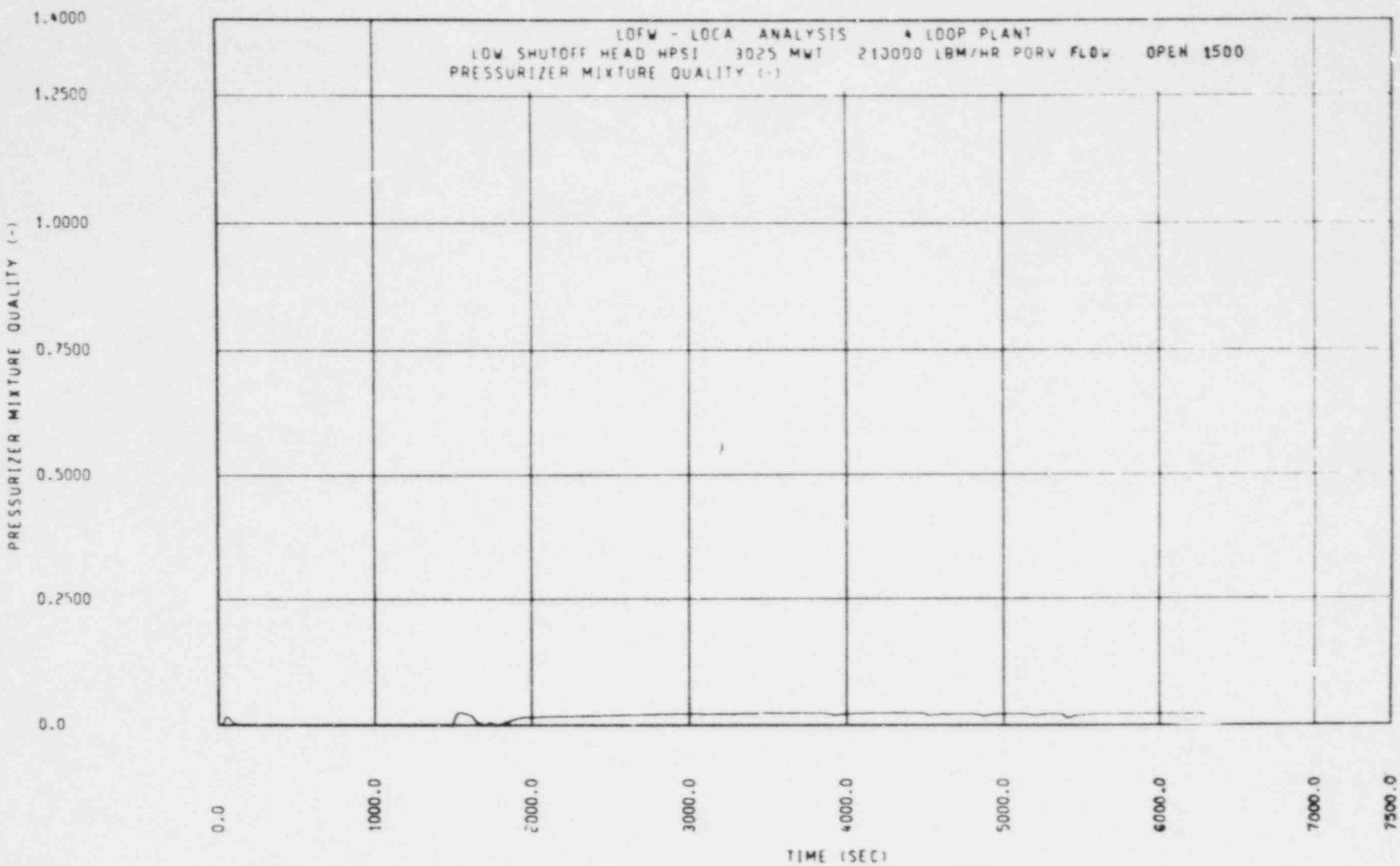
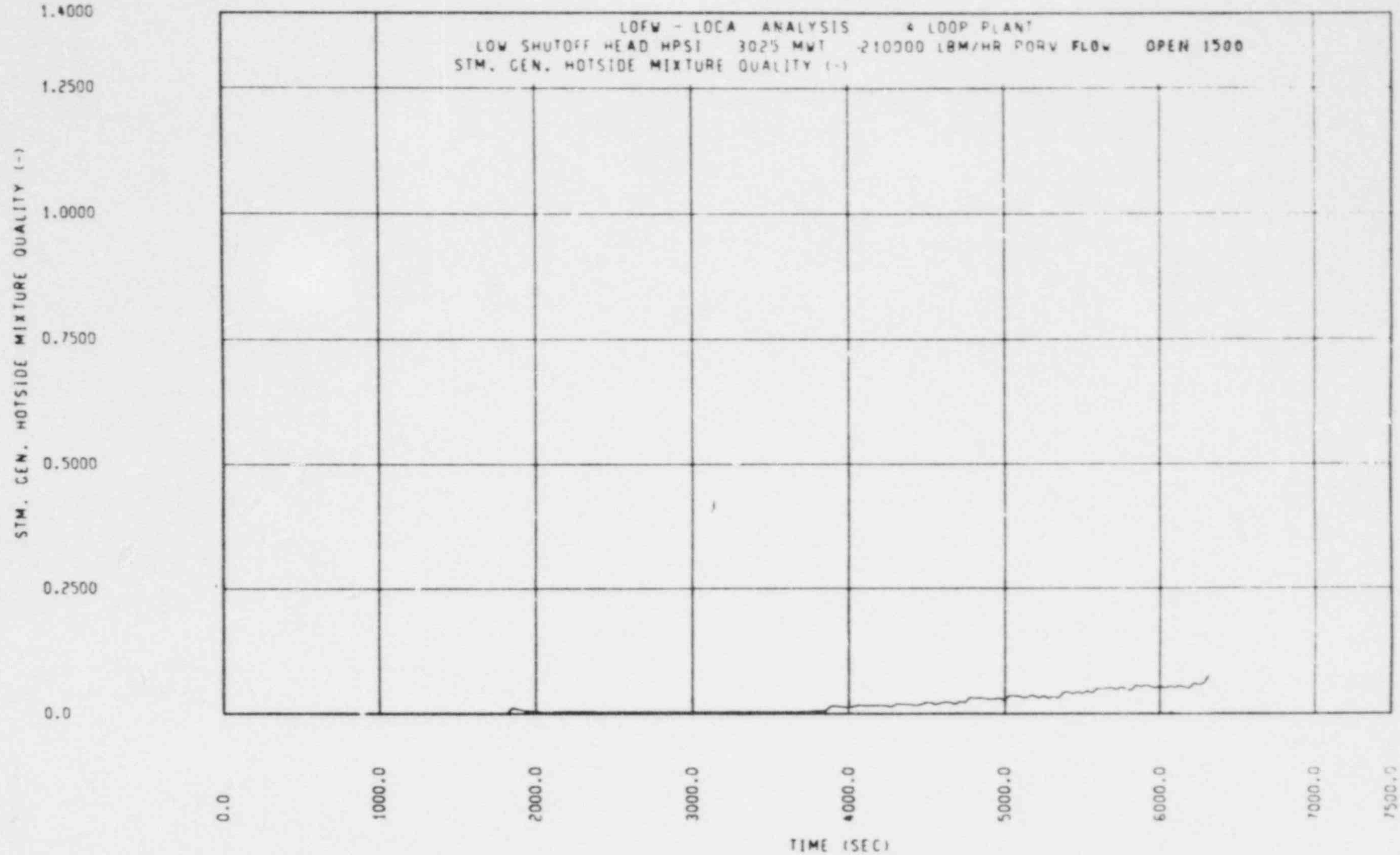

LOFW - LOCA ANALYSIS 4 LOOP PLANT
LOW SHUTOFF HEAD HPSI 3025 MWT 210000 LBM/HR PORV FLOW OPEN 1500
PRESSURIZER MIXTURE QUALITY (-)
PRESSURIZER MIXTURE QUALITY (-)
1.4000
1.2500
1.0000
0.7500
0.5000
0.2500
0.0
0.0
1000.0
2000.0
3000.0
4000.0
5000.0
6000.0
7000.0
7500.0
TIME (SEC)

FIGURE D - 25



LOFW - LOCA ANALYSIS 4 LOOP PLANT
LOW SHUTOFF HEAD HPSI 3025 MWT 210000 LBM/HR PORV FLOW OPEN 1500
STM. GEN. HOTSIDE MIXTURE QUALITY (-)
1.4000
1.2500
1.0000
0.7500
0.5000
0.2500
0.0
STM. GEN. HOTSIDE MIXTURE QUALITY (-)
0.0
1000.0
2000.0
3000.0
4000.0
5000.0
6000.0
7000.0
7500.0
TIME (SEC)

FIGURE D - 26

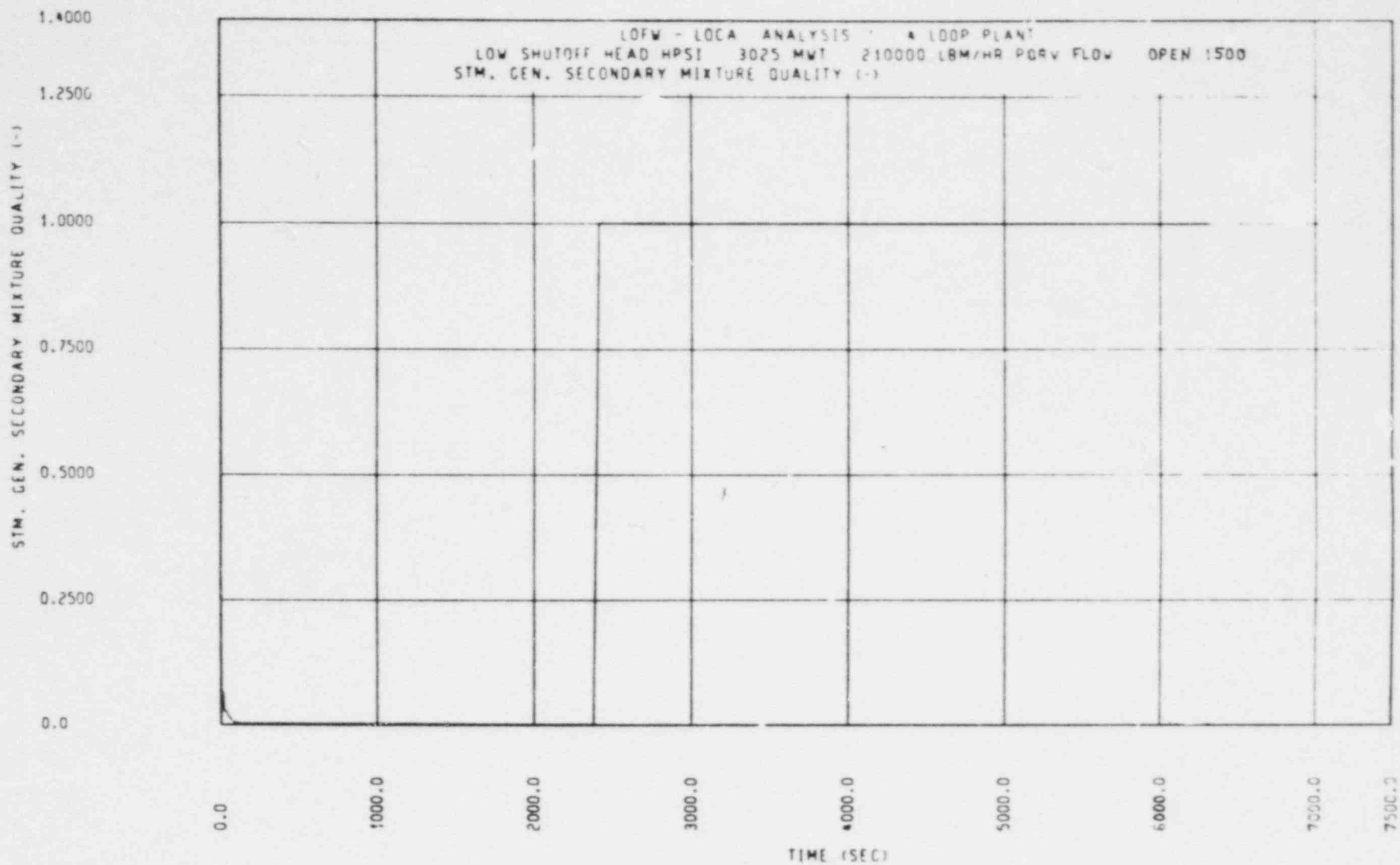

LOFW - LOCA ANALYSIS 4 LOOP PLANT
LOW SHUTOFF HEAD HPSI 3025 MWT 210000 LBM/HR PORV FLOW OPEN 1500
STM. GEN. SECONDARY MIXTURE QUALITY (-)
STM. GEN. SECONDARY MIXTURE QUALITY (-)
1.4000
1.2500
1.0000
0.7500
0.5000
0.2500
0.0
0.0
1000.0
2000.0
3000.0
4000.0
5000.0
6000.0
7000.0
7500.0
TIME (SEC)

FIGURE D - 27

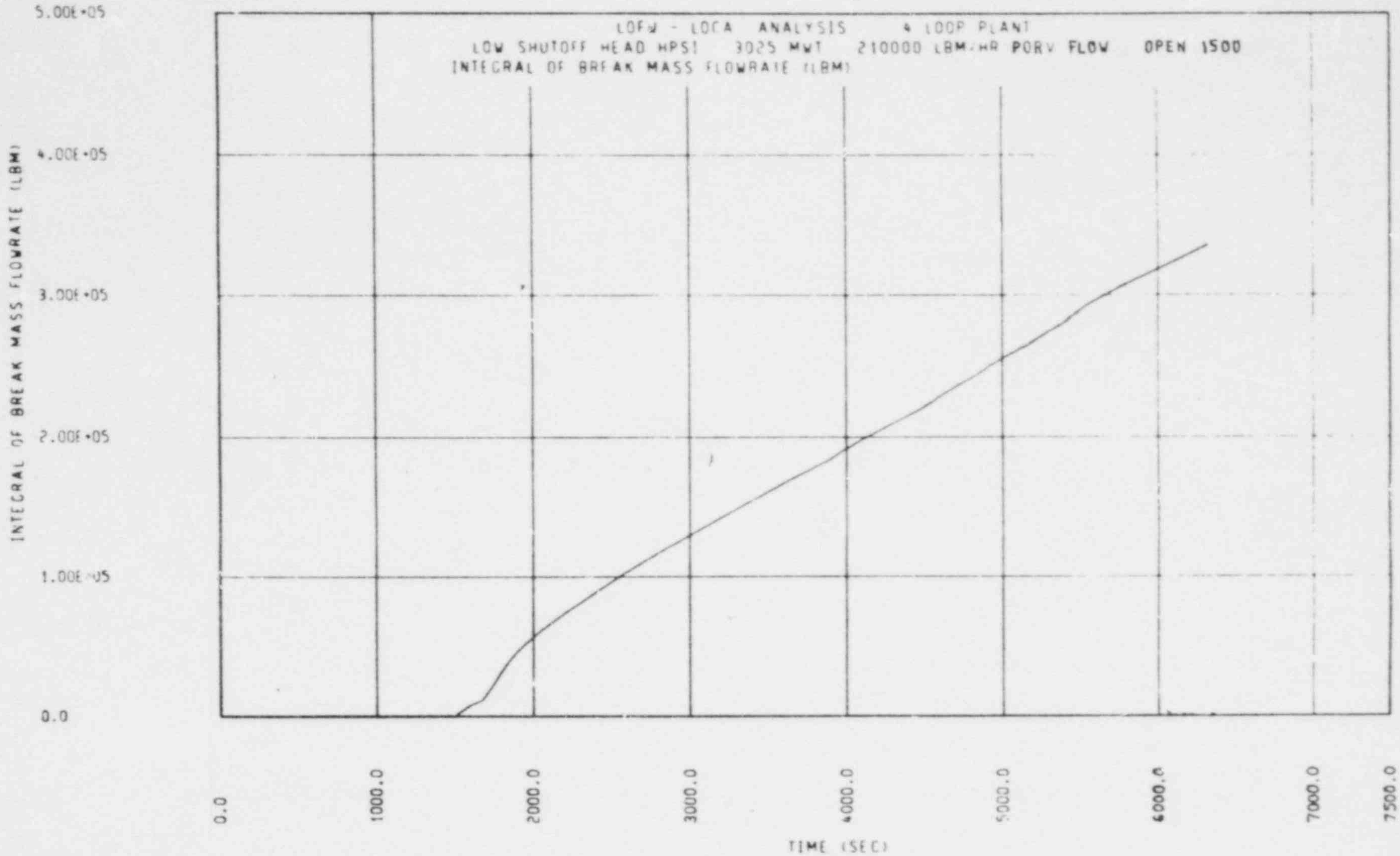
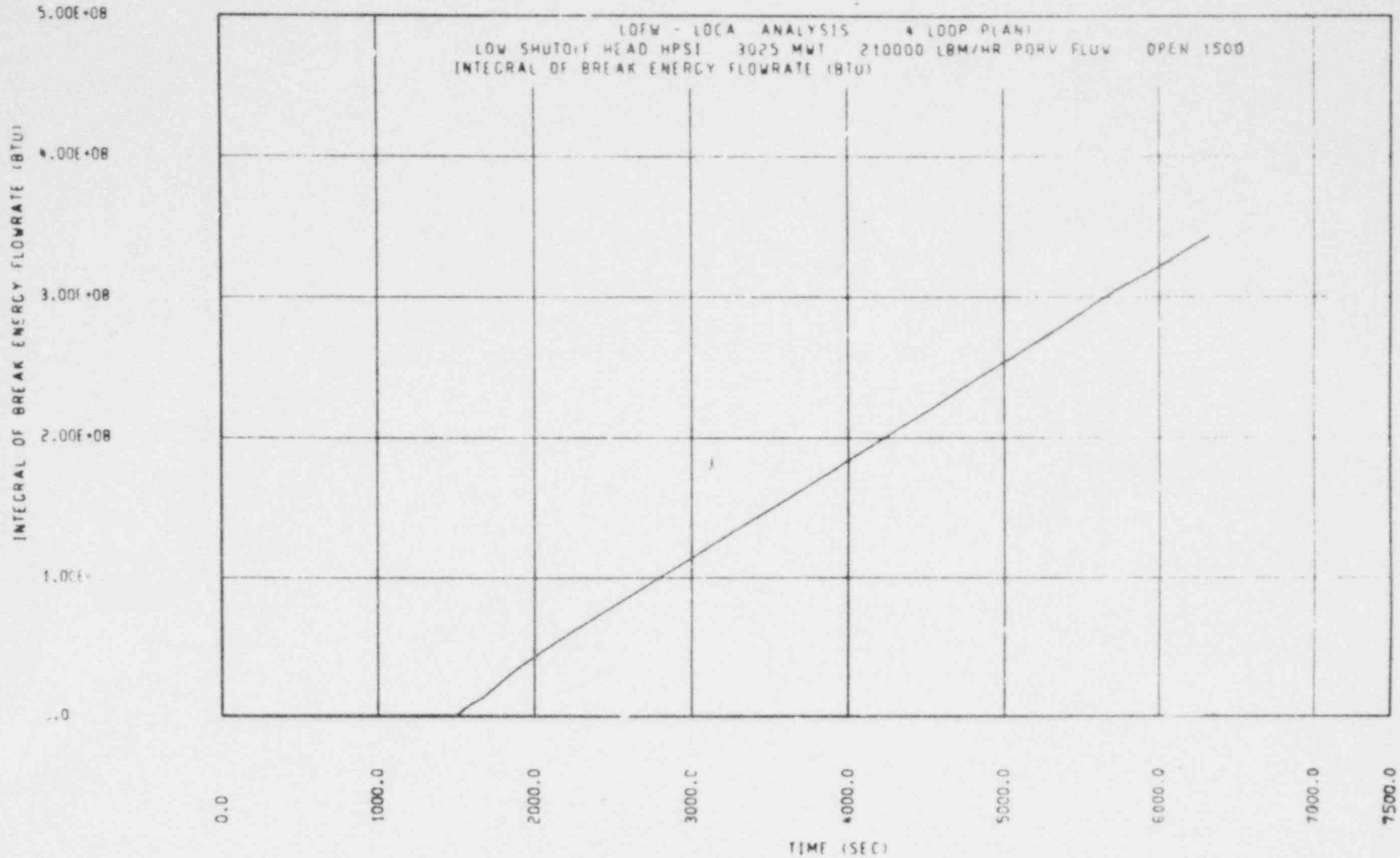

LOFW - LOCA ANALYSIS 4 LOOP PLANT
LOW SHUTOFF HEAD HPSI 3025 MWT 210000 LBM/HR PORV FLOW OPEN 1500
INTEGRAL OF BREAK MASS FLOWRATE (LBM)
INTEGRAL OF BREAK MASS FLOWRATE (LBM)
5.00E+05
4.00E+05
3.00E+05
2.00E+05
1.00E+05
0.0
0.0
1000.0
2000.0
3000.0
4000.0
5000.0
6000.0
7000.0
7500.0
TIME (SEC)

FIGURE D - 28



LOFW - LOCA ANALYSIS 4 LOOP PLANT
LOW SHUTOFF HEAD HPSI 3025 MWT 210000 LBM/HR PORV FLOW OPEN 1500
INTEGRAL OF BREAK ENERGY FLOWRATE (BTU)
5.00E+08
4.00E+08
3.00E+08
2.00E+08
0.0
INTEGRAL OF BREAK ENERGY FLOWRATE (BTU)
0.0
1000.0
2000.0
3000.0
4000.0
5000.0
6000.0
7000.0
7500.0
TIME (SEC)

FIGURE D - 29

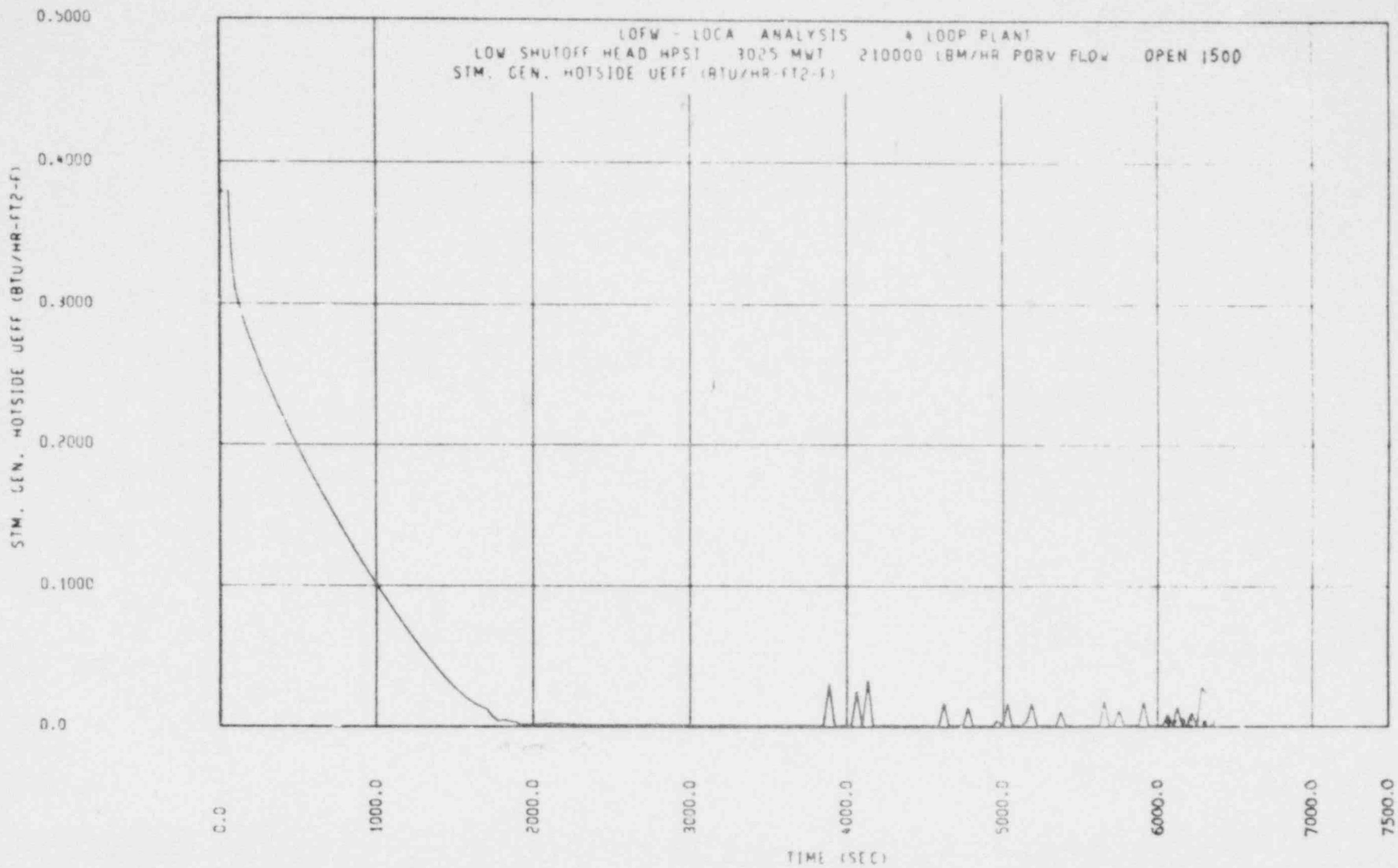
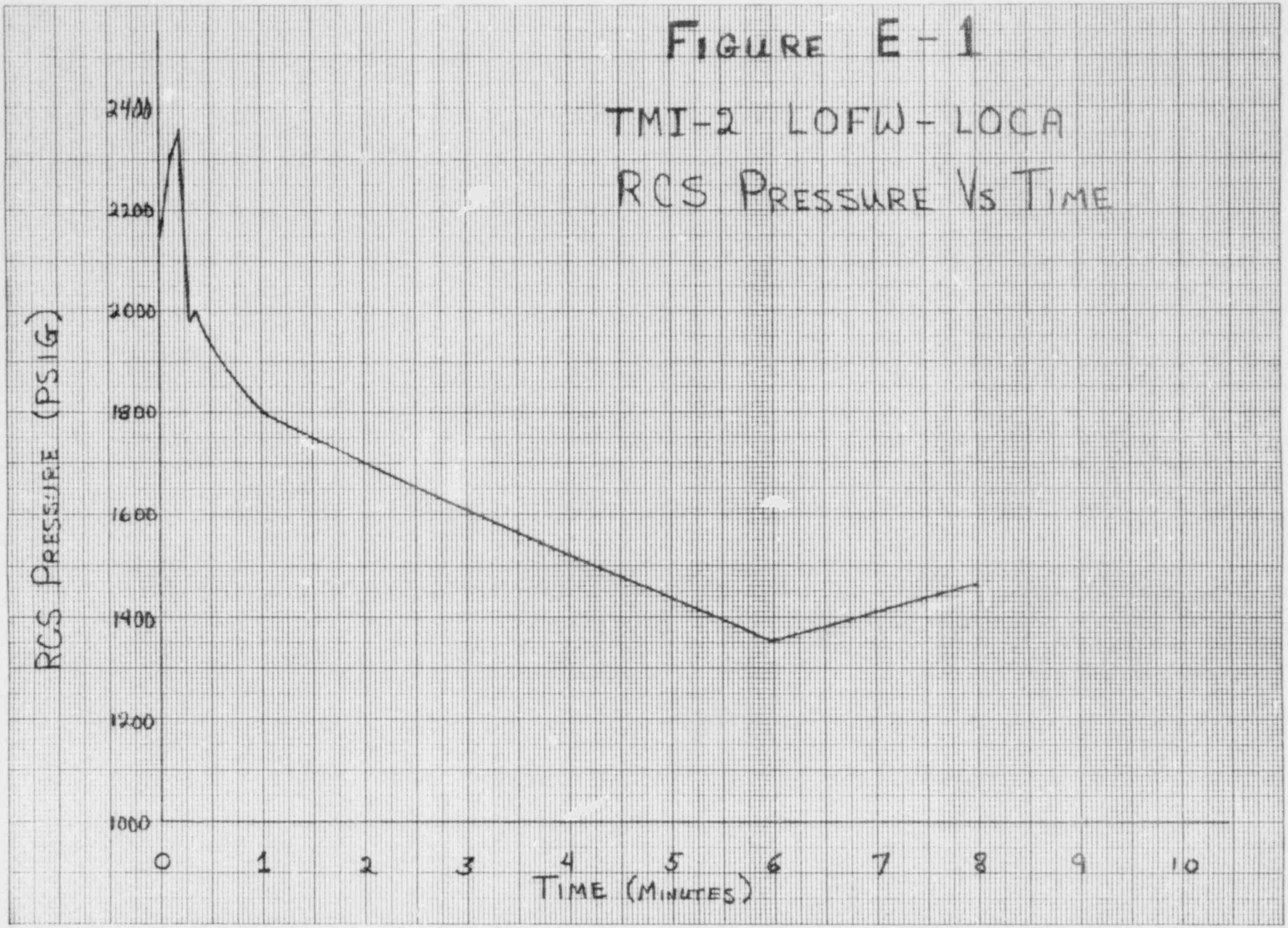

LOFW - LOCA ANALYSIS 4 LOOP PLANT
LOW SHUTOFF HEAD HPSI 3025 MWT 210000 LBM/HR PORV FLOW OPEN 1500
STM. GEN. HOTSIDE UEFF (BTU/HR-FT2-F)
0.5000
0.4000
0.3000
0.2000
0.1000
0.0
STM. GEN. HOTSIDE UEFF (BTU/HR-FT2-F)
0.0
1000.0
2000.0
3000.0
4000.0
5000.0
6000.0
7000.0
7500.0
TIME (SEC)

FIGURE D - 30

FIGURE E-1

TMI-2 LOFW-LOCA

RCS PRESSURE VS TIME



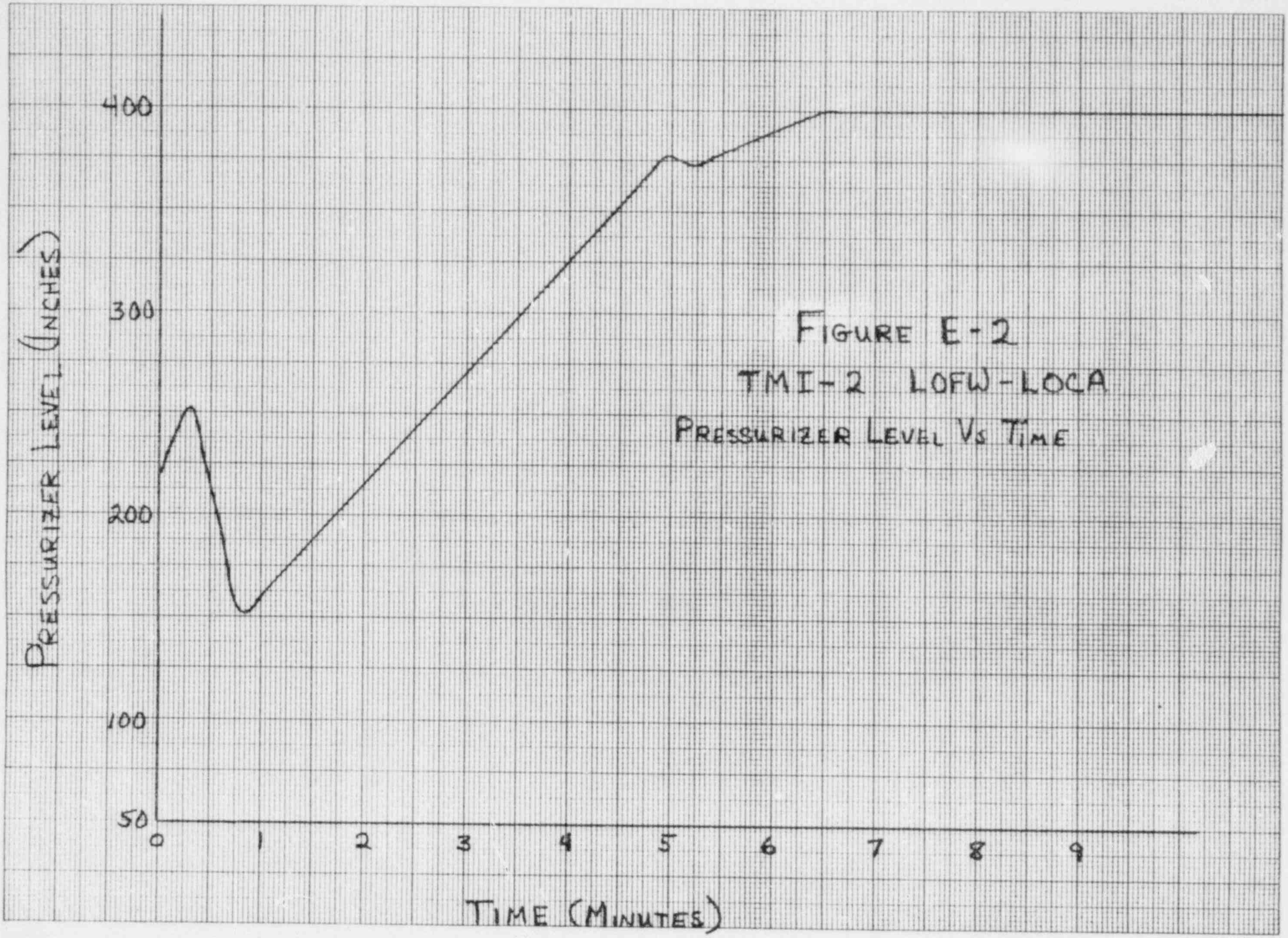


FIGURE E-2
TMI-2 LOFW-LOCA
PRESSURIZER LEVEL Vs TIME
PRESSURIZER LEVEL (INCHES)
400
300
200
100
50
0
1
2
3
4
5
6
7
8
9
TIME (MINUTES)

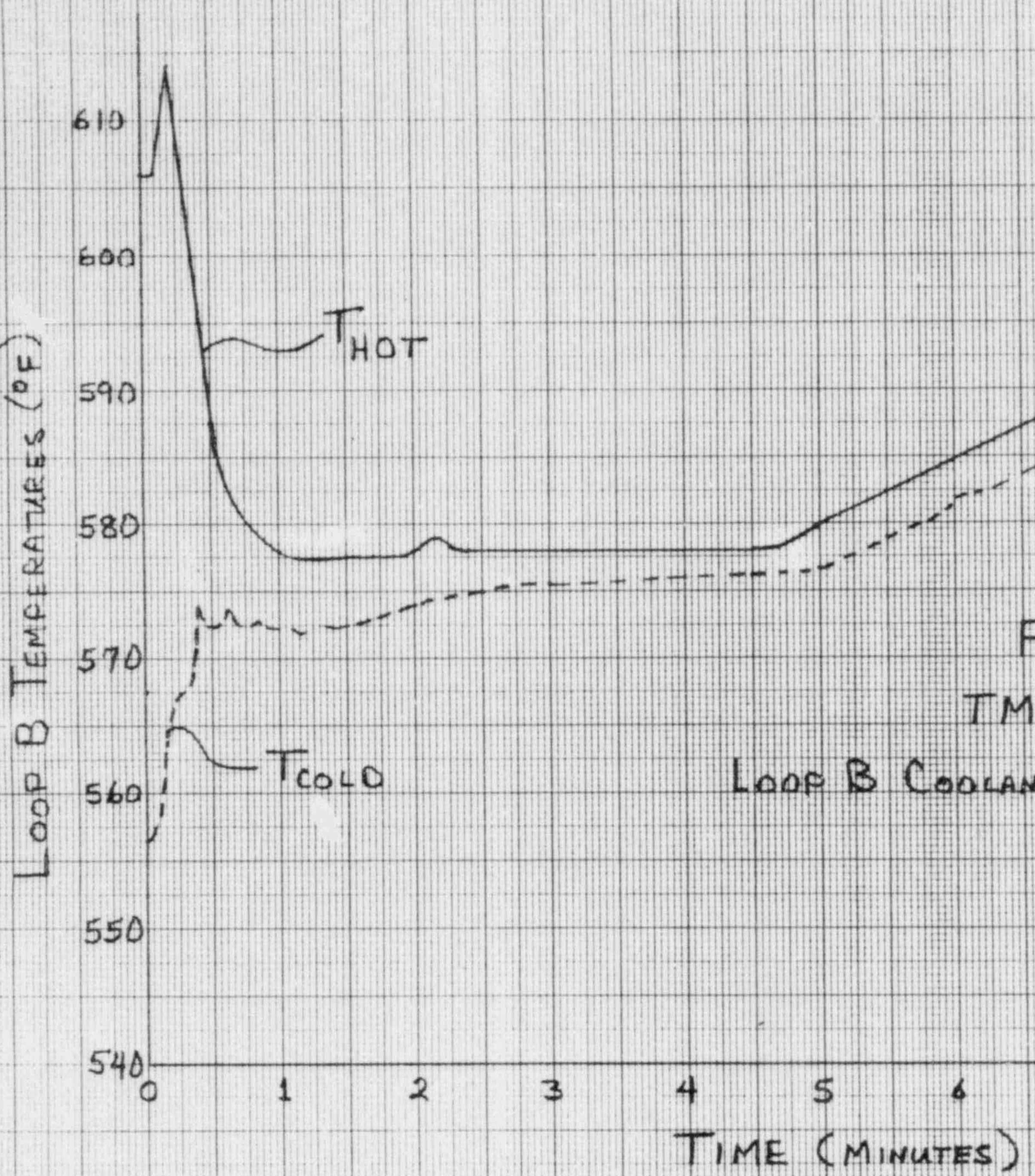


FIGURE E-3

TMI-2 LOFW-LOCA

LOOP B COOLANT TEMPERATURES VS TIME

APPENDIX II

REFERENCES

References

1. "Report on Small Break Accidents for Westinghouse NSSS Systems", WCAP-9600, Nuclear Safety department, June 1979.

2. "WFLASH - A Fortran-IV Computer Program for Simulation of Transients in a Multi-Loop PWR," WCAP-8200, by V. J. Esposito, K. Kesavan, and B. Maul, June 1974.

3. "Westinghouse Emergency Core Cooling System Small Break, October 1975 Model," WCAP-8970-P-A, by R. Skwarek, W. Johnson, P. Meyer, January 1979.