WCAP-9754

Westinghouse Class II

# Inadequate Core Cooling Studies of Scenarios With Feedwater Available, Using the NOTRUMP Computer Code

C. M. Thompson
R. H. Mark
G. E. Hill
S. Kellman

June, 1980

APPROVED: ______________________
T. M. Anderson, Manager
Nuclear Safety Department

WESTINGHOUSE PROPRIETARY DATA

This document contains information proprietary to Westinghouse Electric Corporation; it is submitted in confidence and is to be used solely for the purpose for which it is furnished and returned upon request. This document and such information is not to be reproduced, transmitted, disclosed or used otherwise in whole or in part without authorization of Westinghouse Electric Corporation, (Nuclear Energy Systems or a particular Division, as desired).

WESTINGHOUSE ELECTRIC CORPORATION
Nuclear Energy Systems
P. O. Box 355
Pittsburgh, Pennsylvania 15230

8007220503

This document contains material that is proprietary to the Westinghouse Electric Corporation. This proprietary information has been marked by means of brackets. The basis for marking the material proprietary is identified by marginal notes referring to the standards in Section 8 of the affidavit of R. A. Wiesemann of record "In the Matter of Acceptance Criteria for Emergency Core Cooling Systems for Light Water Cooled Nuclear Power Reactors (Docket No. RM-50-1)" at transcript pages 3706 through 3710 (February 24, 1972).

Due to the proprietary nature of the material contained in this report which was obtained at considerable Westinghouse expense and the release of which would seriously affect our competitive position, we request this information to be withheld from public disclosure in accordance with the Rules of Practice, 10 CFR 2.790, and that the information presented therein be safeguarded in accordance with 10 CFR 2.903. We believe that withholding this information will not adversely affect the public interest.

This information is for your internal use only and should not be released to persons or organizations outside the directorate of Regulation and the ACRS without prior approval of Westinghouse Electric Corporation. Should it become necessary to release this information to such persons as part of the review procedure, please contact Westinghouse Electric Corporation and they will make the necessary arrangements required to protect their proprietary interests.

# ACKNOWLEDGMENT

The authors would like to express their appreciation to the members of the Westinghouse Owner's Group Analytical Subcommittee, Safeguards Engineering and the Emergency Operating Instruction Task Team who reviewed and commented on the report.

# TABLE OF CONTENTS

## TABLE OF CONTENTS (Continued)

## LIST OF FIGURES

## LIST OF FIGURES (Continued)

Figure Number Title

## LIST OF FIGURES (Continued)

Reactor Vessel Diagrams

4 Inch Cold Leg Break Case Without Recovery Operations

# LIST OF FIGURES (Continued)

## LIST OF FIGURES (Continued)

## LIST OF FIGURES (Continued)

1 Inch Cold Leg Break Case
Recovery Operation: HHSI

# LIST OF FIGURES (Continued)

Figure Number Title

1 Inch Cold Leg Break Case
Recovery Operation: RCP Reactivation In
Broken Loop

## LIST OF FIGURES (Continued)

Figure Number Title

1 Inch Cold Leg Break Case
Recovery Operation: Open PORVs On Pressurizer

1 Inch Cold Leg Break Case
Recovery Operation: Open Steam Dump Valves

## LIST OF FIGURES (Continued)

4 Inch Cold Leg Break Case
Recovery Operation: RCP Reactivation In Broken Loop

## LIST OF FIGURES (Continued)

4 Inch Cold Leg Break Case
Recovery Operation: Open PORVs on Pressurizer

## LIST OF FIGURES (Continued)

4 Inch Cold Leg Break Case
Recovery Operation: Open Steam Dump Valves

## LIST OF FIGURES (Continued)

Pumps Running Transients

Four Inch Diameter Break; Pumps Running

System Inventory Transients

## LIST OF FIGURES (Continued)

# LIST OF TABLES

# I. INTRODUCTION

This report presents the results of the supplementary program performed to study inadequate core cooling (ICC) conditions*. This program, undertaken pro-actively by the Westinghouse Owner's group, is more comprehensive than the program completed on October 31, 1979[1] and is intended to investigate several scenarios and subsequent recovery steps that were not addressed in that submittal. The results presented here supersede those given in that earlier W-FLASH based analysis. The analyses discussed in this report utilized the NOTRUMP computer code along with a more detailed noding model (Figure 1).

Two cold leg break sizes were analyzed. A one inch and a four inch diameter break were selected in order to examine system behavior when natural circulation cooling and low pressure safety injection, respectively, are important occurrences. In order to achieve inadequate core cooling conditions, the loss of all high pressure safety injection was assumed. Other assumptions were that the reactor coolant pumps tripped at reactor coolant system pressure of 1250 psia and that offsite power was available so that credit for the steam dump system could be taken.

The expected response of currently available plant instrumentation to the onset of inadequate core cooling conditions is discussed along with relevant plots. The potential application of new instrumentation is also addressed. Furthermore, the effectiveness of several possible actions for recovery from an ICC condition is shown and discussed.

The analyses discussed in this report support the conclusion that a core exit thermocouple reading of 1200°F is a satisfactory criterion to alert the operator that action is required to cool the core before damage occurs, and therefore core exit thermocouples are acceptable instruments for the detection of ICC conditions. It is planned to use

---

* Inadequate core cooling, for the purpose of this report, is defined as a high temperature condition in the core such that operator action is required to cool the core before damage occurs.

these analyses in the development of Guidelines to restore core cooling during a small LOCA.

## II. MODEL DESCRIPTION

### A. NOTRUMP Computer Code[2]

The NOTRUMP code, originally developed for use in the analysis of steam generator behavior, was modified and expanded to permit treatment of LOCA's. The code is extremely flexible, allowing for the choice of several different drift-flux, heat transfer and break flow models. Other features of significance are the capability for horizontal stratified flow, node stacking for tracking mixture interfaces, natural convection and stratified node heat transfer models.

The NOTRUMP code has a wide range of plotting capabilities. Additionally, the code permits restarts with input modifications. The number of permissible restart points is large and restarts are accomplished easily; this feature makes the code an appropriate tool to be used in the study of recovery operations.

### B. Nodalization

Figure 1 shows the noding used to perform the ICC analyses. Specific features of this model are discussed below.

#### Vessel

The NOTRUMP model features a more detailed vessel noding arrangement than used in the earlier WFLASH analysis. In particular the core is separated from the upper plenum into [ ]$^{(a,c)}$ core nodes and [ ]$^{(a,c)}$ upper plenum node. Also, a separate node is used to represent the [ ]$^{(a,c)}$. The downcomer and lower plenum are separated into two nodes, nodes [ ]$^{(a,c)}$ respectively. Additionally [ ]$^{(a,c)}$ is a node of variable cross-sectional area which allows more appropriate modeling of the mixture level as a function of volume fraction. In order to better represent the flow path from downcomer to core for the ICC studies, the interface between nodes[ ]$^{(a,c)}$ is placed at the bottom of the flow skirt.

In order to investigate the response of core exit thermocouples, the flow communication between the core and the upper plenum is represented in greater detail than before. [ ]$^{(a,c)}$ represents the upper three feet of the active fuel and flow paths[ ]$^{(a,c)}$ connect the core to the upper plenum region. Flow path[ ]$^{(a,c)}$ represents the minimum flow area in the upper plenum, composed of open holes in the upper core plate and the flow area around the support columns. Flow path[ ]$^{(a,c)}$ represents the flow communication between the core and the guide tubes. To properly treat mixture elevation impact on flow as well as counter-current flow, flow paths[ ]$^{(a,c)}$ represent the flow area between the guide tube and the upper plenum while flow path[ ]$^{(a,c)}$ represents the flow between the guide tube and the upper head. This set of flow paths represents the actual flow communication that exists in a RESAR 412 PWR and is representative of all Westinghouse PRW's without upper head injection. Some of the unique features of this flow arrangement are discussed later together with the results of transient analyses.

## Core Fuel Model

The heat transport characteristics of the core are modeled using metal nodes which represent the lumping of $UO_2$ fuel and zircaloy clad. The specific heat and thermal conductivity utilized are those of $UO_2$ which comprises the largest part of initial stored energy. The power generation is simulated by critical heat links that feed the core metal nodes. The critical heat links deliver power in proportion to the power shape that is being modeled; after reactor trip, the heat transferred is modified by the appropriate decay fraction.

Figures 17 to 19 show the temperature transient for core nodes[ ]$^{(a,c)}$, respectively. These temperatures represent the average temperature for an average assembly at the elevation of the core node simulated.

## Reactor Coolant Loop Piping

A more detailed representation of the loop than the WFLASH model is used. In the determination of the number of nodes to be used in modeling the steam generator tubes the results of the study of natural circulation in steam generator tubes were considered. This study[3], performed for the Westinghouse Owner's Group, concluded that[ ](a,c) nodes were sufficient to model the density gradients in the steam generator tubes as well as to predict the onset and loss of natural circulation. Therefore, the tubes are divided into[ ](a,c) nodes. Individual nodes are used for the inlet plena of the steam generators in both loops, and the variable cross-sectional area model is utilized to model the area change that takes place within the plena. The steam generator outlet plena are combined with the downside of the loop seal piping into one node having a variable cross-sectional area. In addition, separate nodes are used to represent the hot and cold legs, reactor coolant pumps and the upside of the pump suction piping.

## Pressurizer Model

The pressurizer and surge line are modeled as one node having a variable cross-section. The mixture separation within the node is predicted using the[ ](a,c) while the[ ](a,c) is used in the treatment of the surge line flow path. The surge line is connected to the broken loop hot leg at the hot leg center line elevation. A continuous[2] flow path designation is also used to model the presence of a mixture interface at the surge line connection.

## Steam Generator Secondary System

A[ ](a,c) representation of the steam generator secondaries[ ](a,c), with the variable cross-sectional area option to model the area change between the tube region and the upper steam separator region, is used. Auxiliary feedwater is modeled employing best estimate flows and enthalpies. In order to model anticipated operator actions, full auxiliary feedwater is utilized if the secondary level is below the low-level setpoint and a 50 gpm flow per steam generator is used between the low-level and hi-level setpoints. Auxiliary feedwater is terminated when the high level is reached. A 50% load rejection steam dump system is also modeled. This model is used instead of the traditional safety valve model because best estimate conditions assume the availability of off-site power and the condenser. Two separate means for controlling the steam dump system are applied. The early part of the transient uses no-load $T_{ave}$ ($557^{o}$F) since this is the automatic mode; later control is switched to secondary header pressure. This latter option controls the secondary pressure to 1106 psia, about 100 psia under the safety valve setpoint, and can be used to simulate core recovery via cooldown.

## C. Flow Path Options Selected

Several special flow path and drift flux models are used in the vessel and loops. The core flow paths [ ]$^{(a,c)}$ use a modified version of the quenched core vertical flow model that is also used in the W-UHI evaluation model$^{2}$. The remaining vessel flow paths use the [

]$^{(a,c)}$ model is used. In addition the [

]$^{(a,c)}$.

Horizontal stratified flow path pairs are used to connect the hot and cold legs to the vessel. This option allows counter-current flow of steam and water to occur in the hot and cold legs as well as refluxing in the steam generator if conditions permit. The TRAC-P1 [

]$^{(a,c)}$. The flow path that represents the flow over the top of the tubes uses a special flow path option to restrict the liquid carry-over at the top of the tubes to [

]$^{(a,c)}$, thus allowing for proper phase separation in the steam generator tubes. The inverse of the preceding flow path option is applied at the bottom of the loop seals [ ]$^{(a,c)}$ and to the flow path between the downcomer and lower plenum.

Break flow is modeled[2] using the a modified Zaloudek correlation for subcooled liquid flow, the Moody correlation for two-phase flow and the Murdock and Baumann correlation for superheated steam flow.

### D. Model Limitations

There are a number of limitations to the model as applied to the ICC studies. Multidimensional effects in the upper plenum and core are neglected; only one core flow channel is modeled so that the response of thermocouples located above an average fuel assembly is examined. The effect of heat generated by the zirc-water reaction on pellet temperature is neglected as are the presence of non-condensible gas and its impact on steam generator heat transfer.

## III. TRANSIENT DESCRIPTION

In order to properly establish system conditions at the onset of ICC it was necessary to take a mechanistic approach. Small break transients were chosen in order to study events during which the operator could interact with the system. All transients were begun from a normal operating steady state condition and allowed to proceed to a condition of Inadequate Core Cooling. Table 1 lists best estimate input assumptions. The most obvious failure that would lead to severe consequences for a small LOCA was the loss of all high pressure safety injection. A total failure of all the high pressure safety injection is unrealistic since multiple failures are required; however that assumption was necessary in order to achieve ICC conditions. Reactor coolant pumps were also tripped in the analysis. While presently this is an unrealistic assumption (i.e., if no safety injection is available, current guidelines do not require RCP trip), it was a necessary action to examine natural circulation and refluxing.

Breaks in the cold leg were chosen since they represent the most restrictive steam vent path. Furthermore, for a cold leg break, less inventory (than in a hot leg break, for example) remains in the vessel at the time that steam can be vented from the break; this phenomenon reduces the amount of fluid available for use in ICC termination.

Two break sizes, of one inch and four inches in diameter, were examined. A one inch break depends heavily on primary to secondary heat transfer for removal of the decay heat and therefore relies on natural circulation flows. Also, since a one inch break relies principally on high pressure safety injection to maintain core cooling, an analysis without high pressure safety injection leads to ICC conditions before accumulator injection. Conversely, the four inch break relies on primary to secondary heat transfer for only a short period of time and most of the decay heat removal is through the break. A break of this latter size, resulting in rapid system depressurization, is expected to have some accumulator injection during a transient which leads to ICC.

## A. One Inch Diameter Cold Leg Break

Table 2 outlines the important events in the one inch transient while Figures 2 though 71 give a detailed depiction of the transient.

### 1. Early Events

The time period between break initiation and RCP trip is characterized by subcooled blowdown and the resulting system depressurization. Reactor trip occurs at 143 seconds, with a simultaneous turbine trip. The turbine throttle valves are assumed to close instantly and the steam dump valves open 3 seconds later. Initiation of the steam dump system stops the sudden pressurization of the steam generator secondaries and starts to control the steam flow to bring the primary system to 557$^{0}$F, no-load $T_{ave}$. During the time period from reactor trip to RCP trip the system is coming into equilibrium with the steam generators. Since no safety injection, (which under normal circumstances would have started at 155 seconds) is being delivered to the RCS, the initial system subcooling is lost; at RCP trip the system is still about $10^{o}F$ subcooled. The sudden loss of flow caused by the RCP trip raises the core enthalpy sufficiently to initiate steam generation in the upper core node almost immediately (Figure 21). Two phase flow starts to appear in the system at that time and two phase natural circulation begins at about 550 seconds (Figures 39 and 43). Two phase natural circulation increases as the hot part of the system voids and decreases as the cold side voids[3]. Around 1500 seconds the steam generators can no longer condense all of the steam flow and the downstream portions of the RCS begin to go two phase (Figures 63 and 65). Finally, at 4800 seconds liquid flow over the top of the steam generator tubes cannot be sustained and the two phase natural circulation period ends (Figure 62).

## 2. Refluxing Period

The loss of two phase natural circulation marks the beginning of the reflux period (Figures 37 and 41). From 4800 to 7800 seconds the mixture levels in the upper plenum and the hot legs are interfacing, i.e., in contact, and interacting. The flow between the hot legs and upper plenum is being controlled by the relationship between these mixture levels. Evidence of this occurrence is seen in Figures 37-40 which show an oscillating flow at the hot leg and vessel interface but a smooth flow between the hot leg and steam generator inlet plenum. Continuous refluxing between the steam generators and hot legs begins at 4800 seconds but continuous refluxing with the upper plenum does not occur until 7800 seconds when the upper plenum mixture level (Figure 5) falls below the hot leg. Refluxing continues as long as condensation is occurring in the steam generator tubes and a supply of steam is available for condensation. Several mechanisms may lead to the termination of refluxing, e.g. drop in primary pressure below that of the secondary system or dry out and resultant loss of steam flow. In the analysis being discussed, refluxing continues through core uncovery and into the development of ICC symptoms.

Figures 72 to 75 and 76 to 79 show the refluxing for the broken and intact loop hot legs, respectively. These figures are plotted from 8000 to 12000 seconds in order to obtain the necessary resolution. The figures show reversed (negative) liquid flow and normal positive steam flow. Thus a counter current flow situation, characteristic of refluxing, exists.

Figures 72 and 76 show a sharp reduction in reflux liquid flow from 9700 to 9900 seconds. This reduction results from the dry out of core node 3. When core [ ](a,c) uncovers, the heat load to the system drops and system pressure starts to decline. Note that the sharp transition is a result of the use of a finite number of nodes to model the core; in reality, a smoother transition would be expected in a PWR. Figures 80 and 81 show the core mixture and pressure transient to support the above discussion. Figure 82 shows the secondary pressure which remains nearly constant (i.e., secondary pressure is being controlled) during this time period. Thus the decrease in system pressure, which reduces $T_{SAT}$ leads to reduction in $\Delta T$ across the tubes; consequently the reflux rate drops due to the reduction in condensation. This gradual loss in steam generator heat transfer brings the system heat removal back in line with the core heat addition and the system stabilizes again around 9900 seconds.

The above process starts again at around 10250 seconds when core node 2 dries out and a significant reduction in core heat addition to the system occurs. This time the reduction in the reflux liquid flow is due to a reduction in the steam generation rate. Both the primary and secondary systems depressurize at nearly equal rates and therefore a constant $\Delta T$ across the tubes is maintained. The primary depressurization occurs due to the loss of heat load while the secondary depressurizes because of loss of heat load and continued auxiliary feedwater delivery. Thus from 10250 to about 10420 seconds depressurization is due to the loss of heat load and from 10420 to 12000 seconds the depressurization is due to the cooling of the secondary side by the auxiliary feedwater, resulting in the equal depressurization rate of the RCS and steam generator secondaries. When the core completely uncovers, past 12000 seconds, steam generation stops, terminating refluxing.

### 3. Approach to Inadequate Core Cooling Conditions

During the time period from 4800 to 7800 seconds the system above the hot legs is draining back into the vessel. Also, a net flow around the loops exists due to the head in the downside of the loop seals that is being supplied by condensation of steam in the cold side of the steam generator tubes. At 7800 seconds the drain period is almost over and the mixture level on the vessel falls below the hot legs. The reduction in the upper plenum mixture level at about 7800 seconds uncovers the guide tube lower flow paths [ ](a,c) and permits increased steam venting through the upper head to the break. This phenomenon has several effects on the total system and results in the steady decrease in core mixture height (Figure 7) which begins at 8000 seconds. First, less steam is delivered to the hot legs and the refluxing rate slows. Secondly, the delivery of steam to the loop seals is reduced and at 8000 seconds a gradual drop in the loop seal void fraction begins (Figures 25 and 26). The switch in steam flow from the loop to the guide tubes and out the break produces a readjustment in the ](a,c) RCS pressure drops. This occurrence allows the [ ](a,c) of the loop seal to come into static equilibrium with the [ ](a,c). Flow across the loop seals decreases nearly to zero and the break flow goes to all steam flow (Figure 71). Prior to this time the loops had been supplying liquid to the core and downcomer, to make up for the steam being released through the break. However, when the loop flows stop, the inventory in the core and downcomer begin to be depleted by the break. There is, in addition, a displacement of inventory from the vessel to the loop seals due to steam condensation in the cold side of the steam generator tubes. This causes a reduction in both the core and downcomer mixture heights.

The upper core node [ ](a,c) dries out at 9300 seconds (Figures 21 and 80) but this node is cooled by the liquid that enters the upper plenum due to the refluxing that is taking place (Figure 13). However, when core [ ](a,c) dries out at about 10250 seconds the temperatures in the upper core node and the upper plenum start to increase rapidly (Figure 14). This increase is due to a skewed to-the-bottom power shape that is used, i.e., [ ](a,c) generates the largest fraction of the total core power (approximately 33%). Therefore, the enthalpy rise up the core becomes large enough to boil all the reflux water in [ ](a,c) and to superheat the remaining steam. The upper core node exceeds 1200°F at about 11000 seconds. Since this temperature value is used as the primary indication that an inadequate core cooling condition exists, subsequent recovery operations are initiated at 11000 seconds. Note that 1200°F is based on the highest expected peak clad temperature for best estimate large break LOCA analyses. Thus temperatures greater than 1200°F indicate a deviation from best estimate predictions and hence the possibility of some degradation of safety systems.

At 11000 seconds, refluxing is still occurring (Figures 72 and 76) but the reflux water is being vaporized by the super heated steam leaving the core. Figures 11 through 14 show the fluid temperature distribution starting in core [ ](a,c) and ending in the upper plenum [ ](a,c). These figures show that nodes [ ](a,c) are hotter than node [ ](a,c) and that node [ ](a,c) is hotter than the upper plenum. The upper plenum is cooled by the entering reflux water. The upper core node is now cooled by steam flow that circulates from the upper plenum to the upper core node and back up the guide tube [ ](a,c). The guide tube node extends into the upper head [ ](a,c) and is in communication with the break through flow path [ ](a,c) which represents the head cooling jets. Therefore, the guide tube node is a low pressure region which creates a circulation flow field between the upper plenum, upper core node, and the guide tube. Thus, the refluxing and the circulation flows, coupled with the 1-D assumption that is inherent in the NOTRUMP code, allow the (average) lower core nodes to heat-up to higher temperatures than the (average) upper core node.

## 4. Core Exit Thermocouple Response

As discussed above, the 1-D assumption coupled with the reflux liquid flows and the particular flow path arrangement between the core and upper plenum modeled in NOTRUMP, delays the calculated heatup of the upper plenum and upper core nodes. The core exit thermocouples reside in the upper plenum approximately 1.3 feet above the active fuel line. Since those thermocouples are attached to the bottom of the support columns, the steam temperature in flow path[ ](a,c) would be expected to be representative of their temperature readings. At 11000 seconds, however, the flow in path[ ](a,c) is from the upper plenum to the upper core node due to the circulation flow discussed earlier. Based on the NOTRUMP results, the core exit thermocouples would not be predicted to reach 1200$^{\circ}$F until almost 12000 seconds. However the response of the upper core and upper plenum nodes, as applied to determine the thermocouple temperature, is unrealistic because 3-D effects which would keep most of the reflux liquid away from the core exit thermocouples are not modeled; hence the thermocouple temperature would be expected to reach 1200$^{\circ}$F earlier. The upper plenum and upper core nodes are treated as homogeneous below the mixture elevation and any liquid which enters these nodes is instantly distributed throughout the node. Yet during the refluxing phase the steam velocities are very low so that in reality, the low velocity liquid returning to the upper plenum would be expected to adhere to the inside barrel wall and flow down the outer fuel assemblies. In that case, then, a large number of fuel assemblies in the central region of the core would not be expected to be directly influenced by the reflux liquid. Furthermore, Figures 83 and 84 show that the guide tubes and support columns are distributed throughout the upper plenum and not lumped together as assumed in the NOTRUMP model. Therefore the circulation flow field that is calculated to occur in the NOTRUMP analysis would not be expected to exist in the same form. The inner locations, whether guide tubes, open holes or support columns, would have upflow while locations near the outer edge would have downflow. Thus, the thermocouples located near the core center would be expected to be in a flow field of superheated steam flowing up the core and out to the hot legs.

Another similar factor which, in this analysis, tends to yield high steam temperatures for the thermocouple locations later than would realistically be expected is that only one core flow channel is modeled. Thus only the enthalpy rise attributable to the average fuel assembly is seen. If several core flow channels had been modeled, the response of the hottest assemblies would be expected to lead to earlier core exit thermocouple readings of 1200$^{0}$F.

It should be noted (in comparison of the NOTRUMP core exit thermocouple response with the expected response) that the NOTRUMP prediction is conservative, with respect to system inventory, when used as an indicator to start core recovery actions. However, actual recovery actions may be required earlier than performed in these analyses, due to the expected response of core exit thermocouples located near hot assemblies.

5. Hot Leg Temperature Response

Figures 15 and 16, presenting the response of the resistance thermometers (RTD) in the broken and intact loop hot legs, show no discernible indication that inadequate core cooling is occurring. This is due partly to the equilibrium assumptions used in NOTRUMP. During the refluxing period the hot legs stay two phase and therefore equilibrium assumptions require that the hot legs be at the saturation temperature. In reality, during refluxing the hot leg would contain superheated steam and saturated water. The RTD's, in Westinghouse plants, are located in the upper 180$^{0}$ of the hot leg piping and would therefore measure the temperature of the superheated steam. Therefore, it may be possible to use RTD's as an indication of the onset of ICC; but it should be noted that lack of superheating would not necessarily be an indication that ICC conditions were not occurring.

B. Four Inch Diameter Cold Leg Break

Table 3 lists important events in the four inch transient, while Figures 85 through 161 show various parameters as functions of time. It should be noted that the transient required the assumptions of the loss of all high head safety injection and the isolation of all accumulators to reach ICC conditions.

### 1. Early Events

After break initiation, there is a rapid depressurization within the core and primary loops due to large break flow (Figure 85). Reactor trip occurs shortly thereafter (9.3 seconds), with a simultaneous turbine trip. After a 3 second delay, the steam dump system is activated automatically in the normal operating no-load $T_{ave}$ mode. Steam dump slows the rapid pressurization of the secondaries, incurred by the steam generator shutdown (turbine trip) and throttling of the main feedwater (Figures 86, 87). Complete loss of main feedwater occurrs 11 seconds after turbine trip (20.3 seconds) and following a further 3 second delay, auxiliary feedwater is initiated. The combined effect of the steam dump and cool auxiliary feedwater halts the pressurization of the secondaries.

Since complete loss of high-head safety injection is assumed (under normal circumstances a safety injection signal would have occurred at approximately 11.5 seconds after the break, with delivery of SI water some 8 seconds thereafter), the primary system rapidly reaches saturated conditions and voids start to appear 20-25 seconds into the transient. The sudden loss of core flow due to reactor coolant pump trip (30.9 seconds) immediately results in steam generation in the upper core nodes (Figures 110-113). Since more energy is being added to the system than is being removed by the break, the primary pressure levels off about 75-100 psi above the secondary pressure (Figure 85), as the steam generator remains a heat sink. During the time period following, the break flow is two phase and remains relatively constant (Figures 159, 160); the primary is steadily depleted of mass, and the loop flows take on aspects of natural circulation flows (Figures 128 and 132). The core temperatures drop below the no-load $T_{ave}$ and steam dump ended (240 seconds).

When enough primary system mass has been lost, the core begins to uncover (388 seconds, Figure 90), and continues to drop in mixture level until the blowing of the broken loop loop seal (460 seconds, Figure 114); during that period, all the decay heat is being removed from the core by the steam flow, and core temperatures are stable (Figures 97-100). Also during that time, the intact loop (in actuality, 3 loops) flow and broken loop flow remain in an approximate 3:1 ratio. After the broken loop loop seal blows, the core mixture level quickly recovers the core (493 seconds) as steam is rapidly vented through the broken loop to the break (Figure 90).

This occurrence results in a loss of symmetry between the broken and intact loops. The higher steam flows in the broken loop entrain much of the water in the steam generator inlet plenum and tubes, carrying liquid out of the steam generator, through the loop seal and into the pump; some of that entrained water passes into the cold leg and out the break. This is demonstrated by comparison of steam generator liquid flows for the broken (Figure 151a) and intact loops (Figure 153a) during the time period between 460 and 500 seconds of transient time. Thus less water exists in the broken loop steam generator inlet plenum than remains in the corresponding node on the intact loop side. Since the steam is now being vented, primary system pressure begins to drop once again, allowing more rapid steam generation in the core and resulting in the blowing of the intact loop loop seal (550 seconds, Figure 115). When this event occurs, water that resides in the intact loop loop seal is forced into the pump where some remains, and some continues on into the intact loop cold leg, into the downcomer and spills over into the broken loop cold leg. Some of this latter liquid is removed by the break but the remaining water enters the broken loop pump and loop seal, causing a further loss of symmetry between loop inventories (Figures 134-149). By 600 seconds, flows have stabilized once more, and flow symmetry once again exists, with the intact loop flow approximately 3 times that of the broken loop; in addition, the break flow has become single phase vapor (Figure 159).

### 2. Approach to Inadequate Core Cooling Conditions

At 722 seconds the core undergoes a second uncovery since primary inventory continues to be lost to the break. As core level drops, steam production decreases and break flow depressurizes the system until primary pressure drops below secondary pressure (750 seconds, Figures 85-87). At that time, auxiliary feedwater flow is throttled back due to increasing level in the steam generator secondary.

From 600 to 750 seconds, it is possible that a small amount of refluxing is occurring. If it exists however, it is overshadowed by the draining of the steam generator inlet plena back to the upper plenum through the hot legs. At 750 seconds with primary pressure below secondary pressure, refluxing becomes impossible since condensation can no longer occur inside the steam generator tubes. The steam generator inlet plena continue to drain, however, and at about 1050-1100 seconds the broken loop SG inlet plenum dries out (Figure 128a). After that time, the continued draining of the intact loop SG inlet plenum allows the pressure difference between the vessel downcomer and upper plenum to drop, since the head of water resisting flow in the intact loop is being reduced. As mentioned earlier, there is water trapped in the broken loop loop seal which could not drain as the inlet plenum drained. Consequently, the broken loop steam flow has to fall off to match conditions in the vessel until finally, the resisting head of water in the loop seal causes the flow in the broken loop to reverse (Figures 135, 137). During this time the intact loop flow (Figures 143, 145, 147) increases slightly to match the flow loss in the broken loop. Total steam flow is dropping slowly, however, as the core mixture level falls, decreasing steam production. With decreasing core mixture level, core node temperatures begin to increase (Figures 98-100). Between 1150 and 1225 seconds, the intact loop SG inlet plenum drains all its liquid into the upper plenum, and in turn, aids core cooling (Figure 132a). With the loss of this cooling water, the upper core temperatures begin to increase markedly.

At approximately 1300 seconds, the increasing core temperatures produce a $T_{ave}$ greater than no-load $T_{ave}$ and the steam dump system begins to vent the steam generator secondaries, causing an increase in auxiliary feedwater. The two effects combine to sharply depressurize the secondary (Figures 86 and 87) until, at 600 psia secondary pressure, the steam dump system is automatically isolated. These events occurring on the secondary side do not noticeably alter conditions in the primary loops, since the heat transfer coefficient between the steam generator tubes and the superheated steam on the primary side is relatively small, and the secondary to primary heat transfer is low.

At 1700 seconds when the maximum average fuel temperature of about 2200°F is attained (Figure 107), primary pressure drops below the low head safety injection shut-off head, initiating core recovery. Although the core recovers in this case with minimal operator actions, higher peak temperatures would be expected than are indicated by this analysis, since only the average core assembly is modeled and zirc-water eactions are neglected.

### 3. Core Exit Thermocouple Response

In the one inch break transient, considerable recirculation was found to occur between the upper core node, the upper plenum and the guide tubes. Three dimensional considerations, however, lead to the conclusion that the core exit thermocouples would indicate the core exit temperature under inadequate core cooling conditions.

For the four inch break case, however, since all core flows are upward and out the top of the core, the upper core node temperature would be expected to give a good estimate of the thermocouple reading. Note that at 1363 seconds, the upper core node temperature reaches 1200°F, before the core has completely uncovered.

### 4. Hot Leg Temperature Response

Figures 102 and 103 present the response of the resistance thermometers in the broken and intact loop hot legs, respectively. While the broken loop hot leg temperature shows only a slight rise at about the time the core exit thermocouples reach 1200°F, the intact loop hot leg temperature exhibits a sharp rise earlier (~ 1275 seconds) when the steam generator inlet plenum dries out. Therefore, in contrast to the one inch break, the intact loop RTD could be used as an indication of the onset of ICC for the four inch break.

## C. Four Inch Diameter Break With Accumulator Injection

Under normal circumstances, low primary pressure would have allowed accumulator injection at 1175 seconds into the transient. The inflow of cold accumulator water recovers the core and drops primary system pressure low enough to actuate low head safety injection approximately 25 seconds later (1201 sec.). At no time are there indications of ICC in this transient. Since ICC does not occur in this transient, no further details will be presented.

## D. Breaks With Reactor Coolant Pumps Running

This report has discussed the transients for one inch and four inch breaks in which the reactor coolant pumps were tripped. However, if the pumps are allowed to run indefinitely a much different transient results.

In the very early portion of the transient, the transient is the same as in the case of the pumps tripped, but diverges later in time. Initially, the system remains nearly homogeneous; the volumetric flow in both loops remains fairly constant; the constant flow rate results in continued heat removal from the primary system by the steam generators; since the primary to secondary heat transfer is very effective, the cold leg temperature is almost always equal to the secondary temperature. (This last occurrence has a clear effect on the transient.)

In the relatively early phase of the transient the primary system remains at a pressure just slightly higher than the secondary pressure. Thus the energy removed from the primary fluid as it passes through the steam generator tubes acts to reduce the quality of the fluid. Initially it returns all of the fluid to liquid conditions but as the transient continues it just reduces the enthalpy and thus the quality of the fluid.

The pressure continues to drop until the system has lost all of its liquid inventory. At this point the primary system pressure is nearly equal to the secondary pressure. Since the system pressure has been held nearly constant to this time, the break flow has only been dependent on the size of the break. For a four inch break the system empties at about 775 seconds. In the table below, the time required to empty the primary system has been extrapolated based on the ratio of the break areas, for a number of break sizes:

| Break Size | 4" | 2" | 1" | 1/2" |
|---|---|---|---|---|
| Time (sec) | 775 | 3100 | 12400. | 49600 |
| (hrs) |  | ~1. | ~3.5 | ~13.5 |

Of course as the breaks get very small as in the case of the one inch and one half inch breaks, the secondary system's depressurization could have a considerable effect in lengthening the time required for the system to empty.

Once the system has completely emptied, (i.e., all steam) the system pressure drops at a fairly steady rate as the system inventory is removed through the break. Although system inventory is being depleted the core continues to be cooled due to two situations mentioned earlier:

1. Loop volumetric flowrate is nearly constant (although it does increase slightly with decreasing fluid density).

2. The cold leg fluid temperature remains in equilibrium with the secondary fluid temperature.

Thus core heat is transferred from the primary system to the secondary system by a forced flow of superheated steam.

When the system pressure reaches 600 psi the accumulators begin to inject. Depending on the size of the break and the decay heat rate the accumulator flow will either cause an increase or a decrease in the system depressurization rate. The reason that the accumulator flow would cause an increase in the depressurization rate for larger small breaks is explained as follows:

1. The break is causing a fairly fast reduction in system inventory and pressure.

2. When the accumulators begin to inject they initially follow the rapid depressurization being caused by the break and the flow condenses steam in the loops. In the broken loop, this steam and much of the accumulator water is carried out of the break.

3. This results in an increase in system steam flow through the break, and in rapid condensation of the steam being pumped around the loops, which in turn causes rapid system depressurization.

The overall effect of this depressurization is to bring a large amount of liquid from the accumulators into the primary system, and recover the core. Once this has occurred the system pressure increases and the inventory begins to be depleted again.

In the case of smaller breaks, the slow depressurization prior to accumulator injection would initially be followed by the accumulators. This would limit injection to such a low rate that the injection would just reduce the steam superheat and the rate of primary system inventory depletion. Since primary system pressure is closely linked to primary system inventory the primary system depressurization would also be reduced.

One of the major differences between this case and the case in which the reactor coolant pumps are tripped is the method of core heat removal. In the case in which the pumps are tripped there are two mechanisms for removing core heat: core boil-off to the break and core and loop flow through the steam generators. Thus as long as either of these mechanisms is working the core will remain fairly cool. However, when the mixture height drops from the core and the loop flow diminishes, the core goes through a rapid temperature rise. With the pumps running, loop flows above keep the core cool. As inventory decreases, the loop mass flow rate decreases, and core exit temperature increases. Therefore the core temperature becomes dependent upon four system conditions: decay heat rate, system inventory (pressure), secondary temperature and pump flow rate.

Based upon a steady state flow assumption a set curves have been developed. These curves were developed by assuming the steady-state volumetric flow of steam at the secondary temperature to be entering the core. Then at a given system pressure the enthalpy rise up the core can be calculated based on the decay heat rate at the time the core was calculated to dryout. The result is the core exit temperature for various system pressures. The data has been plotted (Figure 306) as system pressure versus time with curves of constant temperature shown for the given conditions of steady-state volumetric flow and secondary pressure. Figure 306 shows that with the steam generator secondary at the steam dump setpoint the primary system pressure would be required to be at 142 psia for the core to have an exit temperature of 1200°F at 775 seconds. Thus, low head safety injection would clearly be injected before core exit temperatures reached 1200°F for any break size equal to or less than four inches in diameter. It should be noted that this estimate of time excludes the addition of accumulator inventory and the time required to depressurize to this pressure. Clearly if this had been taken into account even larger breaks could have been justified.

### 1. Four Inch Diameter Break With Reactor Coolant Pumps Running

For the period prior to the pump trip signal, this transient is identical to the case in which pumps were tripped. After the RCP trip signal the continued running of the pumps maintains large forward flows (Figure

310 through 313) through the loops. Since the RCP's are volumetric machines there is a fairly constant volumetric flow rate which maintains the large flows. The continued running of the pumps results in mixing of the fluid and therefore the system remains fairly homo- geneous. This impacts break flow by reducing the quality at the break, maintaining high break flows (Figure 326). The high break flows result in a rapid depletion of system inventory and eventually the system dries out; by 775 seconds into the transient virtually all the liquid has been boiled into steam, including the liquid in the loop seals.

With the loss of the liquid, core temperatures begin to rise and the primary system fluid begins to super heat. The break flow is now all steam which causes the system pressure to begin to drop. Eventually, the low head safety injection shut off pressure is reached and delivery to the system begins. The incoming subcooled SI water rapidly condenses steam and system pressure drops markedly which increases the SI delivery. The system begins to refill with the subcooled SI water and core cooling starts with the cooling of the lower core nodes as saturated rather than super heated steam becomes available.

The refilling process will continue with eventual recovery of the core. Thus core recovery was achieved without operator action or indications of ICC being generated. The highest expected core exit thermocouple reading, before core recovery, is less than 1000°F, well below the 1200°F ICC indication.

## IV. RECOVERY OPERATION DESCRIPTION

The following section provides a discussion of the methods used for core recovery, once inadequate core cooling conditions had occurred. These recovery techniques include:

- Actuation of High Head Safety Injection (HHSI)
- Reactivation of a Reactor Coolant Pump (RCP)
- Opening of all PORVs on the Pressurizer
- Opening of the Secondary System Steam Dump or Relief Valves

The first method, actuation of HHSI, is the most direct and effective way to cool the core. The second method, reactivation of an RCP, circulates the remaining fluid in the system, cooling the core for an additional period of time to permit other recovery actions; however, since the break continues to remove inventory, the system will continue to dry out unless water is provided by some means. In the analysis performed, the broken loop RCP was restarted. This choice is the result of model limitations and is not a necessary restriction. The remaining methods are utilized to depressurize the primary system to the point of actuation of the cold leg accumulators and low head safety injection (LHSI) system.

The one-inch and four-inch break analyses were performed utilizing the recovery methods once the upper core node had reached a temperature of 1200°F, as discussed above. The transients were run for a short time after core recovery.

Several parameters in all the recovery transients initially respond in the same way. When the recovery operation begins, the hot fluid residing in the core is forced into the upper plenum and hot legs which causes a sharp increase in fluid temperatures in those locations. Shortly thereafter the energy of the steam is dissipated and fluid temperatures return to saturation. A second parameter that responds similarly in recovery cases is system pressure. For non-depressurization cases, system pressure increases sharply following actuation of a recovery technique due to the initial surge of liquid into the bottom of the core which, in turn, causes a large increase in steam generation.

### A. One Inch Diameter Cold Leg Break

#### 1. Actuation of High Head Safety Injection

The high head safety injection system is actuated at 11060 seconds for the one inch break. By 11600 seconds the core is completely recovered (Figure 162). However, Figures 163 and 166 indicate that the core has begun to be cooled by about 11150 seconds. Thus, core cooling is re-established while the core is being recovered, within two minutes of operator action.

Figures 167 to 169 show the fluid temperatures in the upper plenum, broken and intact loop hot legs, respectively. As mentioned previously these temperatures show a sharp rise shortly after the safety injection begins, but drops rapidly thereafter. Figure 170 shows the rapid system repressurization when the core begins to be cooled, and the slow depressurization that follows. It should be noted that there is an initial depressurization due to steam condensation in the cold leg and downcomer. This effect can also be seen in core and downcomer mixture heights (Figures 162 and 171) in which injection initially increases downcomer height; but, the depressurization caused by condensation in the downcomer causes the core entrance flow to reverse and the core mixture height to drop slightly.

Although this case was not run to a steady state condition, the system would be expected to refill with safety injection water and single phase natural circulation to be restored, with the steam generators removing most of the decay heat; at that time, the safety injection flowrate would be reduced to match subcooled break flow, bringing the system to a stable condition.

## 2. Reactivation of Reactor Coolant Pump

Figures 172 and 173 present the RCP liquid and steam flows, respectively, after the RCP in the broken loop is reactivated at 11000 seconds. Liquid flow increases dramatically as soon as the pump is restarted, but decreases when the water remaining in the loop seal is depleted. The flow increases again when more water is supplied from the steam generator (Figure 174).

When the pump is reactivated, water remaining in the downcomer (Figure 185) is forced into the lower plenum and then into the core (Figure 176) as hot fluid residing in the core is forced into the upper plenum and hot legs. (Note the sharp increase in fluid temperatures in those locations in Figures 187 to 139.) The surge of water into the core and resultant steam generation lead to a rapid, short-lived repressurization of the system (Figure 186). Increased steam generation from the liquid entering the core causes the mixture height to increase dramatically, recovering the core at about 11020 seconds (Figures 179 to 181) and sharply reducing core temperatures (Figures 182 to 185). The core continues to be cooled by the frothy mixture generated as the core is being quenched.

The upper plenum steam and liquid flows to the broken loop (Figures 190, 191) as well as upper plenum void fraction (Figure 192) reflect the surges of liquid through the system just after the pump is restarted and the fairly quick stabilization of flow in that loop. Figures 193 and 194 indicate that, in the intact loop, steam flows from upper plenum to steam generator where it is condensed and returned to the upper plenum via refluxing.

However, as a caution, an important aspect of reactivating an RCP in the broken loop is the increased inventory lost to the break. Flowrates for break mass, steam and energy, plotted in Figures 195 to 197, respectively, make it clear that restarting the pump dramatically increases break flow and that this increase is mostly liquid, out to 11300 seconds.

Since an excessively long computer run would have been required, the recovery analysis was not carried out to a steady state condition. However, based on results of an analysis on a UHI plant[5], it is expected that the break would continue to remove liquid as the system slowly reached a state in which only steam remained in the core and broken loop. The pump would continue to circulate steam around the loop and cool the core. As the break removed more inventory, the system would depressurize and the steam would superheat. In this case, with the pump running, the core exit thermocouples would be expected to follow core fluid temperature. If the accumulator set pressure were reached before inadequate core cooling conditions had occurred, the accumulators would provide an extended period of core cooling; but if that were not to happen, inadequate core cooling conditions would recur and an additional method of core recovery would be required. The results of the UHI analysis indicate that inadequate core cooling is not reached prior to accumulator injection (2 hours after the pump is restarted). For this non-UHI case, then, the higher cold leg accumulator set pressure would result in earlier accumulator injection.

3. Opening of all PORVs on the Pressurizer

This case is initiated at 11000 seconds by opening all PORVs, providing the equivalent of an additional two inch break in the hot leg. This action permits the system to depressurize (Figure 198) at a much greater rate than with the PORVs closed. The decrease in pressure continues until the cold leg accumulator setpoint is reached (~11950 seconds), at which time the system undergoes a rapid depressurization and repressurization transient, typical of accumulator injection into a nearly empty system.

The injection affects both the primary and secondary systems. Accumulator water recovers the core and fills the guide tubes (Figure 206). The repressurization terminates accumulator injection and hot steam passing through the steam generator tubes causes heat transfer to take place from primary to secondary side once again (Figure 202). System pressure stabilizes somewhat as the guide tube and hot leg liquid drains back to the upper plenum, followed by the draining/core uncovery phenomena described in Section III.A.2. The transient is run long enough so that system pressure falls below the accumulator setpoint a second time which temporarily recovers the core; the depressurization that follows also actuates low head safety injection.

The impact of the steam discharge through the open PORVs is evident in Figure 199 (the flow rate through the pressurizer surge line). Steam flow entering the broken loop hot leg (Figure 200) increases sharply due to the increase in steam flow from the core. Note also the reverse hot leg flow, toward the pressurizer, as seen in Figure 201 (steam flow from the broken loop hot leg to the steam generator inlet plenum). In conjunction with the hot fluid from the core reaching the broken loop hot leg, there is a steep rise in fluid temperature (Figure 203); less effect is seen in the upper plenum (Figure 204) and in the intact loop hot leg (Figure 205) which are farther removed from the additional break.

In the vessel, both the core and downcomer mixture heights (Figures 206 and 207) show a slight rise initially as the system adjusts to an increased break flow and depressurization rate. This trend, however, soon reverses as both the core and downcomer mixture heights drop due to increased inventory loss through the PORVs. It is clear from these figures that the opening of the PORVs does not cause a fast recovery of the system. However, the increased core flow which is caused by the more rapid depressurization does reduce the heatup rate, as is evident from core node fluid temperatures in Figures 208 to 210. But node[ ](a,c) (Figure 211) shows an increase in heat-up rate, due mostly to increased flow from the lower core nodes. Since this increase would also be experienced by the core exit thermocouples, and the rate of core recovery for this transient is much slower than that for the other methods studied, this recovery method is considered to be the least desirable.

4. Opening of the Secondary System Steam Dump Valves

This recovery operation is begun at 11000 seconds by opening all the steam dump valves. Figures 212 and 213 exhibit the rapid depressurization of the broken and intact loop steam generator (SG) secondaries. The RCS pressure (Figure 214) follows the secondary pressure, but remains higher until the accumulators are actuated (at about 11150 seconds). The depressurization (and resultant cooldown) of the secondary side causes an increase in heat transfer across the steam generator tubes. Therefore the initial phenomenon of importance in this run is the rapid condensation of steam in the SG tubes, the effect of which is so strong that a momentary flow reversal occurs in the loop seal and pump (Figures 217 to 220).

The initial temperature rise in the upper core nodes (e.g. Figure 227) is due to the re-establishment of natural circulation flow, forcing hot fluid residing in the core into the upper plenum and hot legs (Figures 228, 229), as described early in the preceding recovery transients. During the early phase of this recovery operation, the core is slowly being recovered (Figure 221) from a number of sources, i.e., the frothy mixture that begins to flow through the core as mentioned above, steam generated in the lower plenum (Figure 223) as the system rapidly depressurizes, and water remaining in the downcomer that is forced into the lower plenum and core (Figure 222). With the increase in natural circulation flow, the core is completely cooled in less than 100 seconds after operator action (Figures 224-227).

When the accumulators begin to inject, the void fraction in the lower plenum (Figure 223) increases sharply because of the rapid local condensation and resultant depressurization that is associated with the injection; as a result of the depressurization, the mixture from the core flows into the downcomer (Figures 221, 222). But note that the void fraction drops dramatically to near zero when the subcooled accumulator water reaches the lower plenum.

Figures 231 to 233 present the total break mass, steam and energy flowrates. It can clearly be seen that opening the dump valves has a similar effect on break flow as restarting the RCP. Although the system is depressurizing, the break flow increases dramatically, primarily due to an increase in liquid break flow. Thus, the liquid inventory is slowly being depleted until the accumulator injects.

Although this run was not continued to a steady state, the system continues to depressurize and appears to be beginning to stabilize (Figure 214). It is expected that system pressure will drop until sufficient safety injection flow is entering the system to match liquid break flow.

### B. Four Inch Diameter Cold Leg Break

In terms of recovery, the four inch transient is unusual in two ways. First, even with the accumulators locked out, the low head safety injection is capable of recovering the core before any of the core nodes exceeds 2000°F. Secondly, the upper core node temperature is almost equal to that of the core node below it. This is considerably different from the one inch break where the upper core node is being cooled to a temperature nearly 800°F less than the core node below. These effects show that the inadequate core cooling condition is much more difficult to achieve for a larger small break, and that the core exit thermocouples will respond more rapidly for a larger break. Two obvious recovery techniques were not analyzed since they would clearly result in a rapid core recovery similar to that in the one inch break case, i.e., high head safety injection actuation and opening of the accumulator flow path.

### 1. Reactivation of a Reactor Coolant Pump

This recovery transient is initiated by restarting the reactor coolant pump in the broken loop at 1363 seconds, at which time the core exit thermocouples are reading 1200°F. This case is very different from the one inch case, mainly due to differences in system inventories. For this case there is little liquid remaining in either loop seal (Figures 234-235) so that pump reactivation simply serves to move steam around the broken loop (Figures 236-242). Since the intact loop is nearly empty, it provides the path of least resistance for the increased broken loop flow. Thus, the flow reverses in the intact loop to match the broken loop flow rate (Figures 243-249).

The operating reactor coolant pump supplies sufficient head to cause the upper head fluid to flow in the normal direction (Figure 250), but the pump has very little effect on the core flow (Figures 251-254), since there are a number of less resistive paths than the core, namely the intact loop and the upper head flow paths. In addition, the hot steam residing in the upper plenum is forced into the broken loop hot leg and then into the steam generator tubes. Initially in the recovery transient the secondary system is at a higher pressure and temperature than the primary (Figures 256-258). The increased flow in the tubes causes an increase in the primary to secondary heat transfer coefficient which, in turn, causes the secondary to follow the primary temperature more closely. As superheat in the core increases, the superheat in the broken loop hot leg increases, resulting in secondary temperature and pressure increase. Consequently, cold leg steam flow remains superheated (Figure 259) as it continues on into the intact loop. Before the pump is reactivated the flow in the intact loop is in a positive direction, causing the hot leg temperature to be superheated. However when the flow reverses, fluid temperature in the intact loop hot leg, now being fed by the broken loop cold leg, drops drastically, (Figure 260) serving to cool the fluid in the upper plenum when it enters that region (Figure 263).

For this case the system continues to heat (i.e. upper core node reaches 2000°F) until the system pressure decreases to the low head safety injection setpoint and the core is recovered (Figures 264-269). While the pump causes a substantial increase in break mass flow rate in the one inch case, little water remains in the loop seal in the four inch case to be supplied to the break. Figures 270-272 show that the break flow, mostly steam, is increased only momentarily.

2. Opening of All PORVs on the Pressurizer

For the four inch case the PORV flow area is only one fourth that of the break in comparison with the one inch case in which the PORV is four times as large as the break. For this reason, the effect on depressurization rate of opening the PORVs at 1363 seconds is not noticeable on the plot (Figure 273). However, the additional break does serve to increase depressurization sufficiently to cause an earlier initiation of low head SI and faster core recovery as is evident from the core and downcomer mixture heights and core temperature plots of Figures 285-290.

The impact of the flow of steam leaving the pressurizer when the PORVs are opened is seen in Figure 274, as well as in Figure 275, showing positive steam flow from upper plenum to broken loop hot leg, with an accompanying increase in hot leg fluid temperature (Figure 277). There is, however, little effect on the flow entering the hot leg from the steam generator (Figure 276) since the flow in the broken loop has been reversed for some time. Nor is there much effect on the intact loop (Figure 278), i.e., the hot leg temperature continues to follow the upper plenum temperature (Figures 279 and 280).

The break continues to be supplied by reverse flow entering the cold leg from the downcomer (Figure 281) and intact loop. The initiation of the recovery method has almost no effect on the break flow as is seen from Figures 282-284.

### 3. Opening of the Secondary System Steam Dump Valves

The opening of the steam dump valves for a four inch break does not have some of the dramatic effects on the system which were exhibited in the one inch transient. In this case the primary system pressure is about 200 psi less than the secondary pressure. Thus the secondary has to depressurize considerably before falling below the primary. Until that time the depressurization of the secondary has little effect on the primary system.

Figures 291 to 293 show the primary and secondary system pressures during the recovery transient. As mentioned previously the primary system is depressurizing at a steady rate until the secondary pressure becomes less than the primary pressure (at about 1400 seconds). At this time the heat transfer in the steam generators reverse and the secondary begins to cool the primary. At first this causes steam in the core to be forced into the upper plenum and hot legs. This can be seen by the sharp rise in the temperatures of the upper plenum and hot legs in the intact and broken loops (Figures 294-296) as well as the drop in core temperature (Figures 297-300).

When the secondary depressurizes significantly below the primary, the heat transfer from primary to secondary increases dramatically causing the primary system pressure to follow the secondary system pressure. This rapid depressurization continues until the primary system reaches the low head safety injection pump shutoff head. At that time the safety injection causes a steam condensation depressurization which results in primary system depressurization below the secondary pressure. The injection, quickly refills the downcomer (Figure 302), causing core mixture level to increase.

## V. DISCUSSION OF RESULTS

The analyses performed for the one-inch and four-inch diameter cold leg breaks demonstrated the need for the assumption of multiple failures in order to achieve inadequate core cooling conditions, i.e., the loss of all high head safety injection and additionally the loss of the accumulators (locked out) in the latter case. The results show that core exit thermocouples may be used as a reliable indication that ICC conditions are occurring.

For the one inch break the results indicate that most of the recovery techniques, initiated when core exit thermocouples reach 1200°F, are effective and provide long term cooling to the core:

> Restoration of high pressure safety injection results in beginning of core recovery in less than 2 minutes after operator action, and complete core recovery at 10 minutes.
>
> Opening of the secondary system steam dump valves leads to depressurization of the RCS and subsequent delivery by the low head safety injection system, and complete core recovery in less than 3 minutes after operator action.
>
> With inventory remaining in the system, reactivation of a reactor coolant pump leads to complete core recovery in 20 seconds after operator action; as discussed above, it is expected that the system will slowly depressurize and LHSI will be activated before core exit temperatures of 1200°F are achieved. Note: The case studied is conservative in that reactivation of the pump in the broken loop maximizes inventory lost to the break; the qualitative conclusions are applicable to cases in which pumps are restarted in any loop.

> Opening of the PORVs on the pressurizer appears to be the least desirable recovery method of those studied since the results indicate that core exit thermocouples would increase, to above 2000°F, before accumulator injection; accumulator injection led to complete core recovery about 15 minutes after PORV opening. Further analysis found that long term core recovery cannot be achieved via PORV blowdown, without high head safety injection

For the four inch break (RCP tripped; accumulators locked out) the results also indicate that most of the recovery techniques, initiated when core exit thermocouples reach 1200°F, are effective and provide long term cooling to the core:

> Although transients were not run for restoration of high head safety injection or for cold leg accumulator injection, both of the methods would result in rapid core recovery.
>
> As with the one inch break the opening of the steam dump valves seems to be second most effective method to restore sustained core cooling, (i.e., provide LHSI). Here, the core reaches a temperature of 1600°F, 350°F less than the case in which no action is taken and the core is cooled 140 seconds earlier.
>
> When compared to the case in which no recovery action is taken, opening the PORVs causes a reduction in the maximum core temperature (130°F) and in the time to cool the core (75 seconds). Note that in both instances LHSI is delivered.
>
> Since there is little inventory remaining the primary system the reactivation of a reactor coolant pump had very little effect. In fact, when compared to the case in which no recovery action is taken, the core remains in an inadequately cooled state for an additional 15 seconds and reaches a temperature nearly 150°F higher in the RCP reactivation transient. Note that core cooling would have occurred if more than one RCP had been restarted, forcing positive steam flow through the core from (an) intact loop(s).

Therefore, the effectiveness of recovery techniques is very dependent upon the system conditions at the time these techniques are initiated. Therefore, no single recovery method, other than correction of the failure that created the ICC condition, is best for all possible small break ICC scenarios.

Figures 327 through 336 show the system inventory as a function of time for the one and four inch ICC transients and all the recovery transients. All the recovery techniques, except restarting an RCP for the one inch transient, show an increase in system inventory. The sudden increases for the one inch PORV and steam dump transients are due to accumulator injection. The four inch recovery transient shows a much smoother increase in system inventory since the accumulators were locked out and only low pressure safety injection is active.

## VI. OTHER INDICATIONS OF SYSTEM CONDITIONS

The present analyses show that core exit thermocouples are acceptable instruments for the detection of ICC conditions. But there are other indications of system conditions that might be used by the operator such as equipment status, and loss of primary system subcooling, and containment parameters (e.g., pressure, radiation, sump level). Measurement of RCS void fraction by use of vessel level or RCP electrical current would also provide an indication of the approach to inadequate core cooling conditions, prior to the 1200$^{0}$F reading of the core exit thermocouples; further analysis would be required, however, to confirm the effectiveness of these indications and to determine the appropriate time for operator action. Figures 337 and 346 show the expected response for the Westinghouse vessel level gauge. In particular, the figures show a comparison between the core mixture elevation and the vessel level gauge prediction for the one inch, and four inch transients analyzed. With RCPs tripped, the trend of the vessel level gauge compares well with the calculated vessel level. This statement does not apply for the pumps running case (Figure 346), here the vessel level gauge trend corresponds to the increasing void fraction of the system.

A final note about thermocouples. The recirculation of fluid between the upper plenum and upper core nodes that occurred for the one inch break created a reverse flow field past the core exit thermocouples. This situation was primarily a result of guide tube flow communication with the break through the upper head. Note that the existing thermocouples will detect ICC but thermocouples attached to the guide tubes would have provided a direct measure of the core exit fluid temperature.

## VII. CONCLUSION

The analyses of transients with reactor coolant pumps running and tripped, discussed in this report, support the conclusion that a core exit thermocouple reading of 1200°F is a satisfactory criterion to alert the operator that action is required to cool the core before damage occurs. Therefore thermocouples, directly exposed to the mixed fluid exiting the core, are acceptable instruments for the detection of ICC conditions. It is recommended, therefore, that thermocouples centrally located above the core in the upper plenum, be utilized in order to avoid circulation/reflux interference as seen in the one-inch LOCA analysis.

While these analyses were performed for a 4 loop Westinghouse design, the results and recommendations of this study are generic in nature and therefore are also applicable to Westinghouse 2 and 3 loop design.

# VIII. REFERENCES

1. Westinghouse Owners Group, Report OG-18, October 30, 1979.

2. P. E. Meyer; G. K. Frick, "A Nodal Transient Model Boiler, Steam Generator, and General Network Code," WCAP-8913, Revision 2 Proprietary Class II, September 30, 1979.

3. R. D. Kelly, "Analytical Investigation of the Detailed Behavior or Fluid In Steam Generator Tubes Under Two-Phase Natural Circulation Conditions," WCAP-9721, Non-Proprietary, June 1980.

4. TRAC-P1: "An Advanced Best Estimate Computer Program for PWR LOCA Analysis," LA-7279-MS (NUREG/CR-0063).

5. R. H. Mark, et.al., "Inadequate Core Cooling Studies of Scenarios With Feedwater Available, for UHI Plants, Using the NOTRUMP Computer Code," WCAP-9763, Non-Proprietary, July 1980.

6. H. C. Yeh, and L. E. Hochreiter, "Mass Effluence During FLECHT Forced Reflood Experiments," Nuclear Engineering and Design (to be published).

## TABLE 1

## BEST ESTIMATE ASSUMPTIONS FOR THE NOTRUMP ICC ANALYSES

| | |
|---|---|
| Core Power: | 100% vs 102% |
| RCS Flow: | Best Estimate |
| RCS Enthalpies: | Best Estimate |
| Safety Injection: | Best Estimate |
| Auxiliary Feedwater: | Best Estimate, All Trains Are Operating |
| Protection Signals and Delay Times: | Both Are Best Estimate |
| Decay Heat: | ANS Finite vs 120% ANS Infinite |
| Secondary Pressure Control: | Steam Dump System vs Safety Valves |

## TABLE 2

## SIGNIFICANT EVENTS FOR THE ONE INCH DIAMETER COLD LEG BREAK

| EVENT | TIME (sec) |
|---|---|
| Break Initiation | 0 |
| Reactor Trip | 143 |
| Steam Generator Shutdown | 143 |
| Main Feedwater Termination | 154 |
| Initiation of Auxiliary Feedwater | 156 |
| Reactor Coolant Pump Trip | 376 |
| Transfer of Steam Dump Control from $T_{ave}$ to Pressure Header Control | 1500 |
| Loss of Two Phase Natural Circulation | 4800 |
| Beginning of Core Uncovery | 8900 |
| Core Exit T/C's > 1200°F | 11000 |
| Onset of Refluxing | 7800 |

## TABLE 3

## SIGNIFICANT EVENTS FOR THE FOUR INCH DIAMETER COLD LEG BREAK

| EVENT | TIME (sec) |
|---|---|
| Break Initiation | 0 |
| Reactor Trip | 9.3 |
| Steam Generator Shutdown | 9.3 |
| Main Feedwater Termination | 20.3 |
| Initiation of Auxiliary Feedwater | 23.3 |
| Reactor Coolant Pump Trip | 30.9 |
| Beginning of 1st Core Uncovery | 388 |
| Blowing of Broken Loop Loop Seal | 460 |
| Core Recovery | 493 |
| Blowing of Intact Loop Loop Seal | 550 |
| Beginning of 2nd Core Uncovery | 722 |
| Loss of Primary to Secondary Heat Transfer ($\text{Pressure}_{\text{secondary}} > \text{Pressure}_{\text{primary}}$) | 750 |
| Broken Loop Steam Generator Inlet Plenum Dryout | 1050-1100 |
| Intact Loop Steam Generator Inlet Plenum Dryout | 1150-1225 |
| Core exit thermocouples read 1200°F | 1363 |

[ ]$^{(a,c)}$ NOTRUMP MODEL

(a,c)

Figure 1

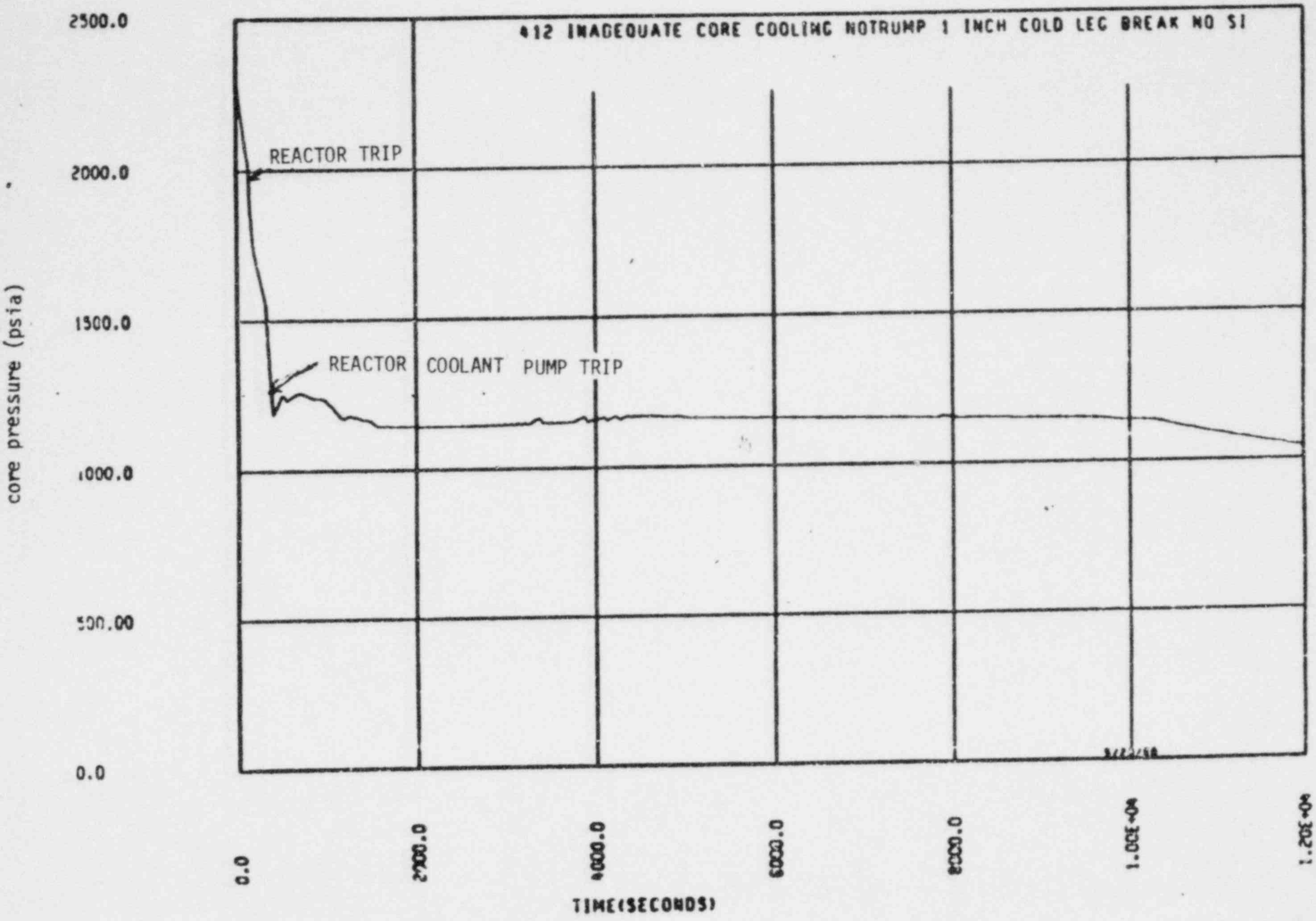

412 INADEQUATE CORE COOLING NOTRUMP 1 INCH COLD LEG BREAK NO SI
core pressure (psia)
2500.0
2000.0
1500.0
1000.0
500.00
0.0
REACTOR TRIP
REACTOR COOLANT PUMP TRIP
3/22/80
0.0
2000.0
4000.0
6000.0
8000.0
1.00E+04
1.20E+04
TIME(SECONDS)

Figure 2

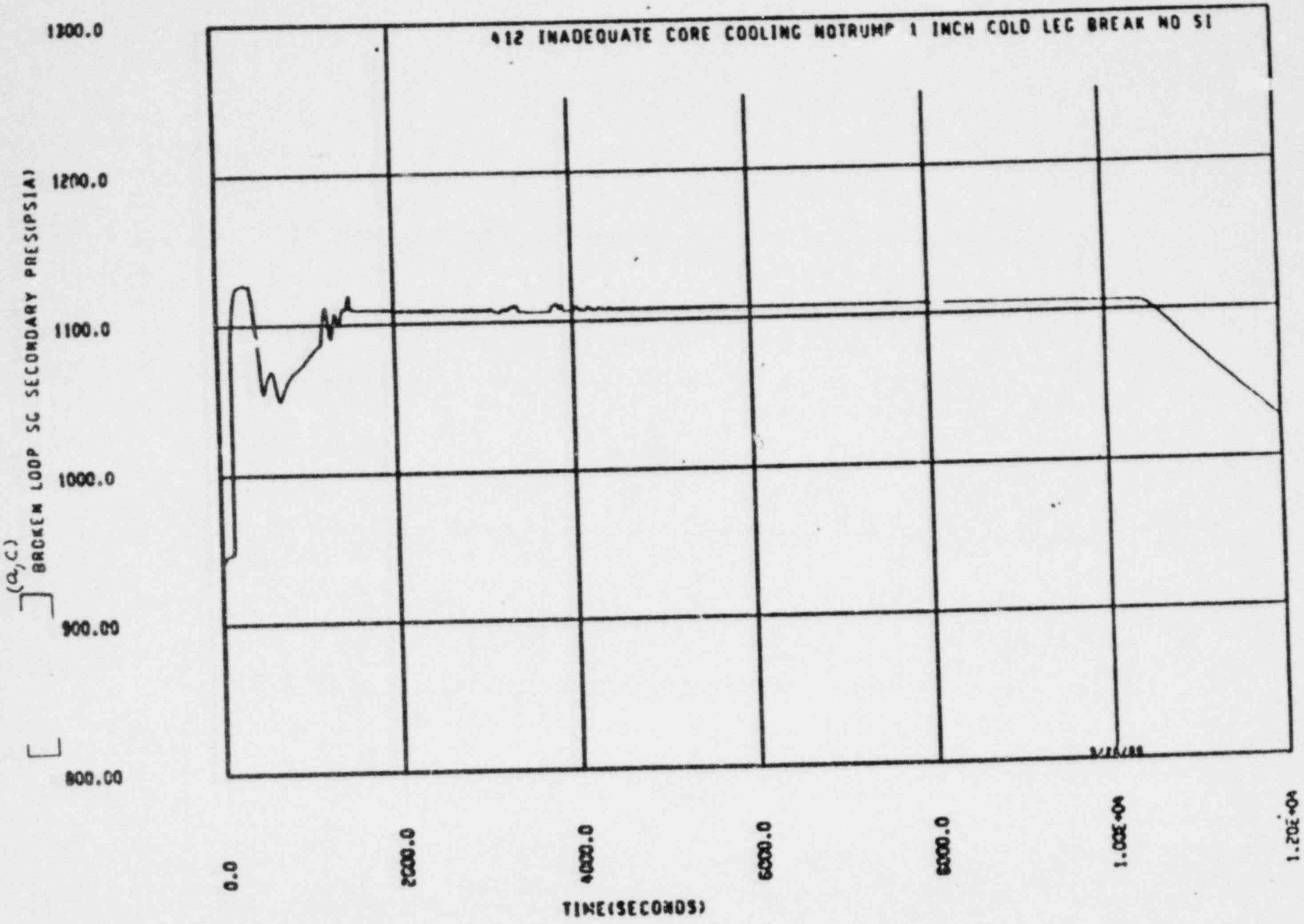

412 INADEQUATE CORE COOLING NOTRUMP 1 INCH COLD LEG BREAK NO SI
BROKEN LOOP SC SECONDARY PRES(PSIA)
[ ](a,c)
1300.0
1200.0
1100.0
1000.0
900.00
800.00
0.0
2000.0
4000.0
6000.0
8000.0
1.00E+04
1.20E+04
TIME(SECONDS)

Figure 3

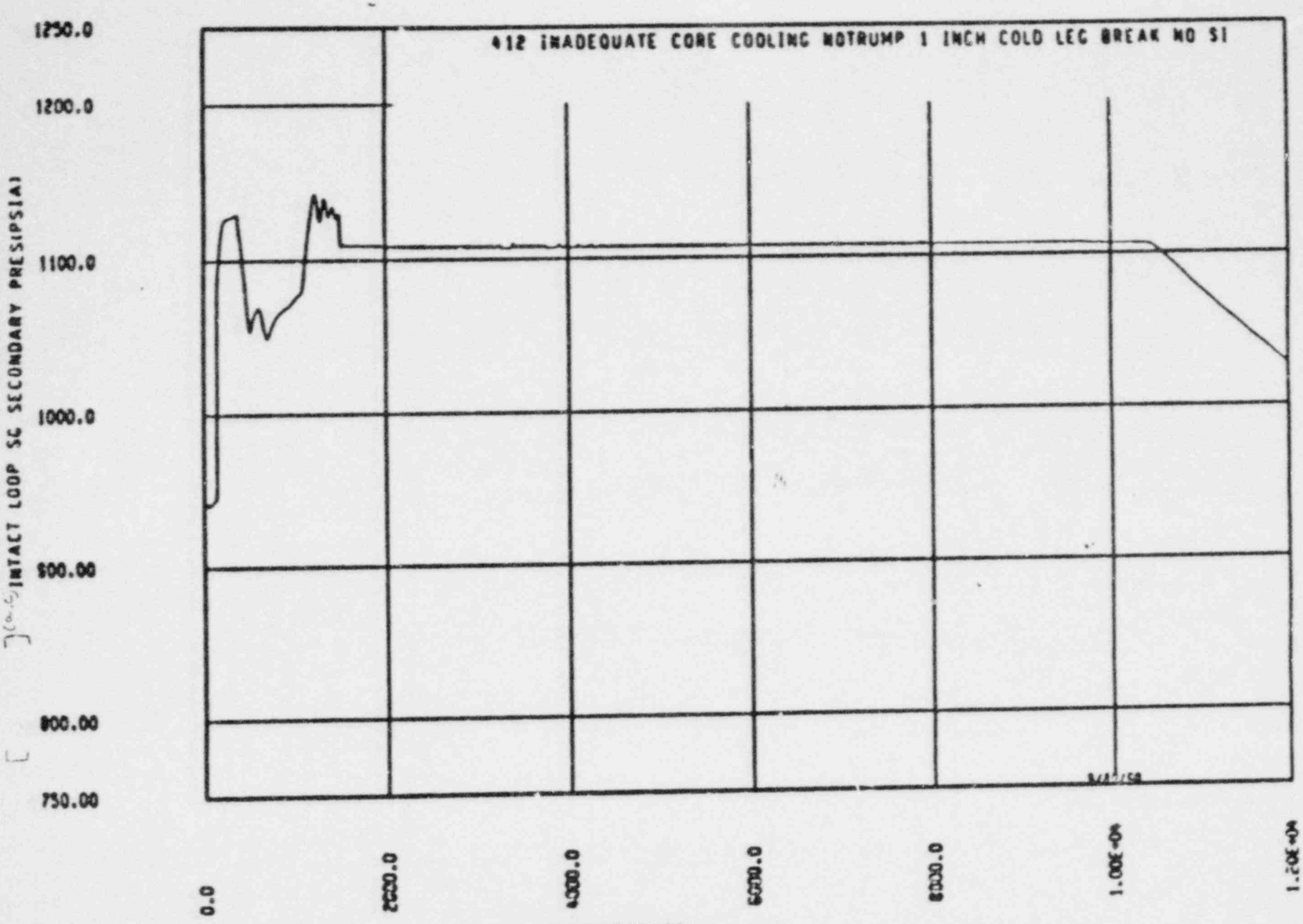

412 INADEQUATE CORE COOLING NOTRUMP 1 INCH COLD LEG BREAK NO SI
[ ](a,c)INTACT LOOP SG SECONDARY PRES(PSIA)
1250.0
1200.0
1100.0
1000.0
900.00
800.00
750.00
0.0
2000.0
4000.0
6000.0
8000.0
1.00E+04
1.20E+04
TIME(SECONDS)

Figure 4

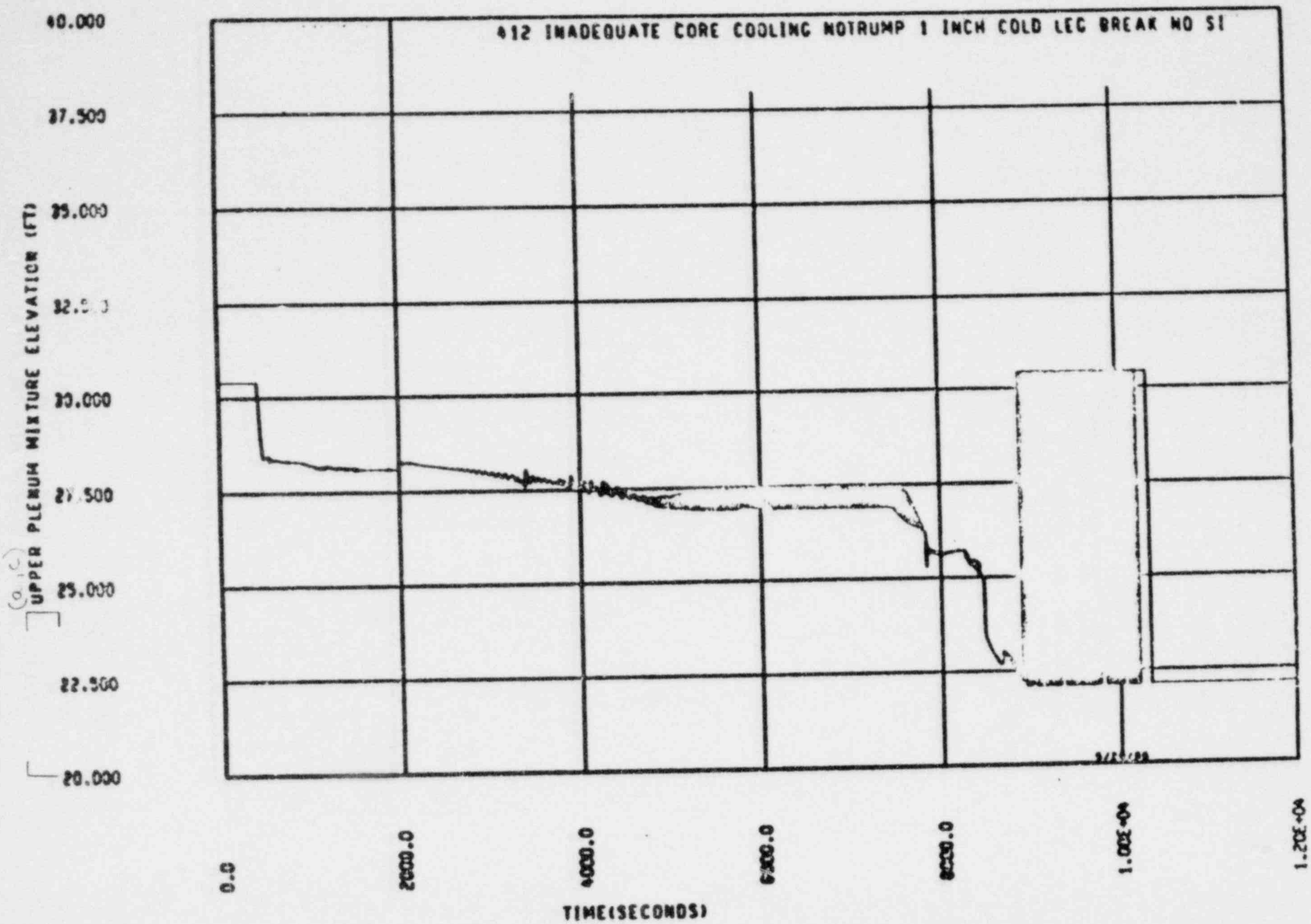

412 INADEQUATE CORE COOLING NOTRUMP 1 INCH COLD LEG BREAK NO SI
UPPER PLENUM MIXTURE ELEVATION (FT)
(a,c)
40.000
37.500
35.000
32.500
30.000
27.500
25.000
22.500
20.000
0.0
2000.0
4000.0
6000.0
8000.0
1.00E+04
1.20E+04
TIME(SECONDS)

Figure 5

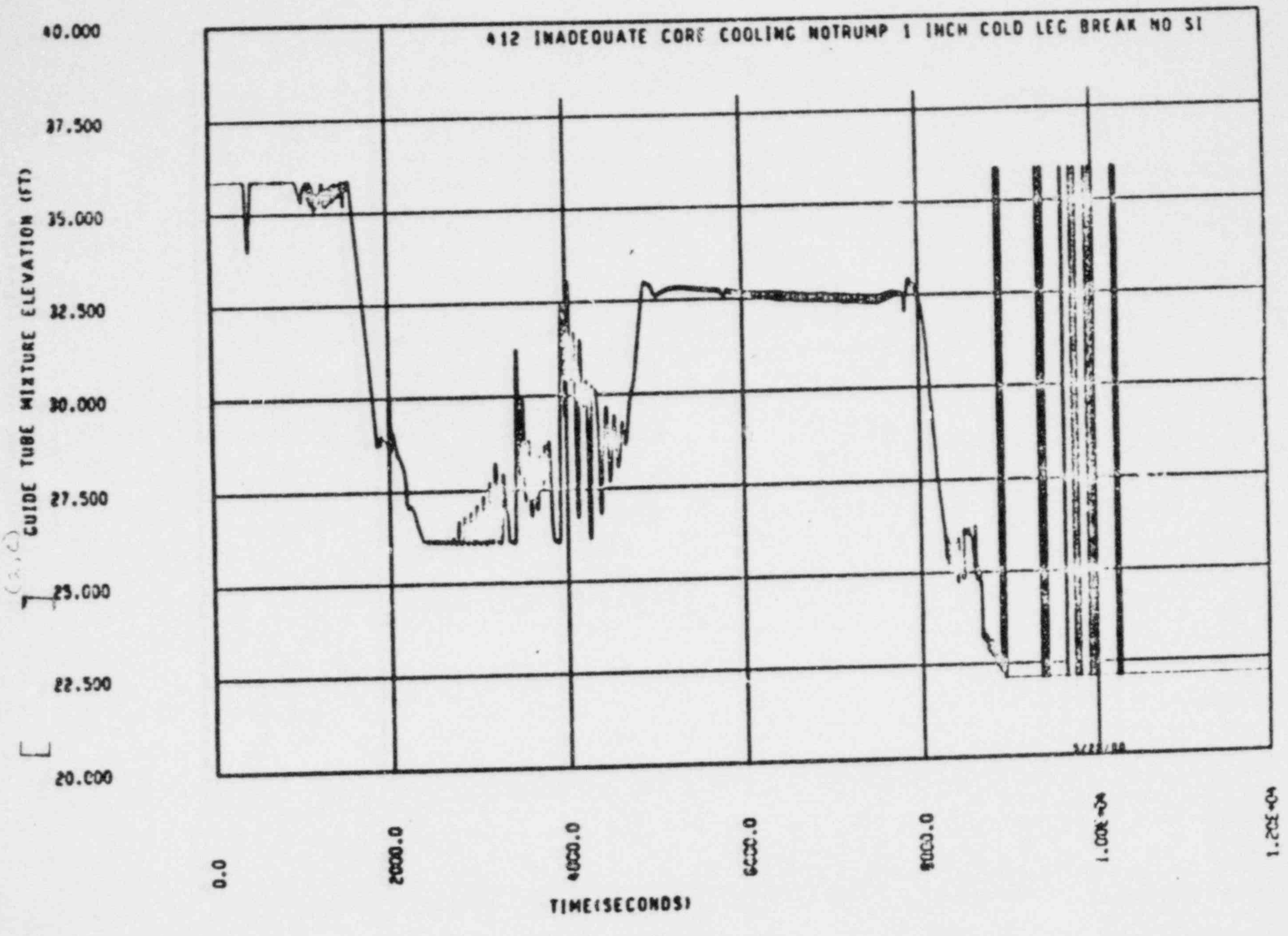

412 INADEQUATE CORE COOLING NOTRUMP 1 INCH COLD LEG BREAK NO SI
GUIDE TUBE MIXTURE ELEVATION (FT)
40.000
37.500
35.000
32.500
30.000
27.500
25.000
22.500
20.000
0.0
2000.0
4000.0
6000.0
8000.0
1.00E+04
1.20E+04
TIME(SECONDS)
(a,c)

Figure 6

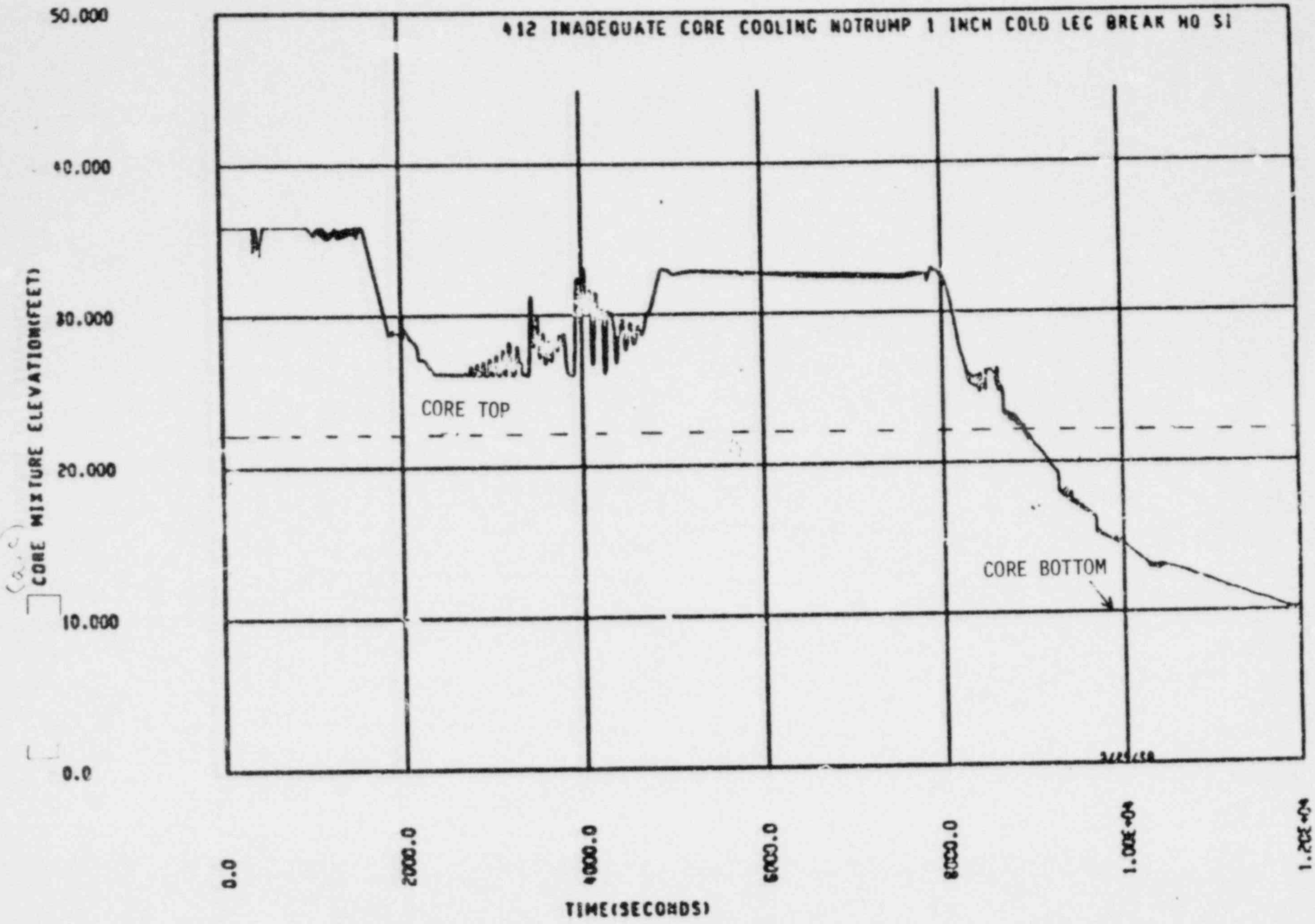

412 INADEQUATE CORE COOLING NOTRUMP 1 INCH COLD LEG BREAK NO SI
CORE MIXTURE ELEVATION(FEET)
(a,c)
50.000
40.000
30.000
20.000
10.000
0.0
CORE TOP
CORE BOTTOM
0.0
2000.0
4000.0
6000.0
8000.0
1.00E+04
1.20E+04
TIME(SECONDS)

Figure 7

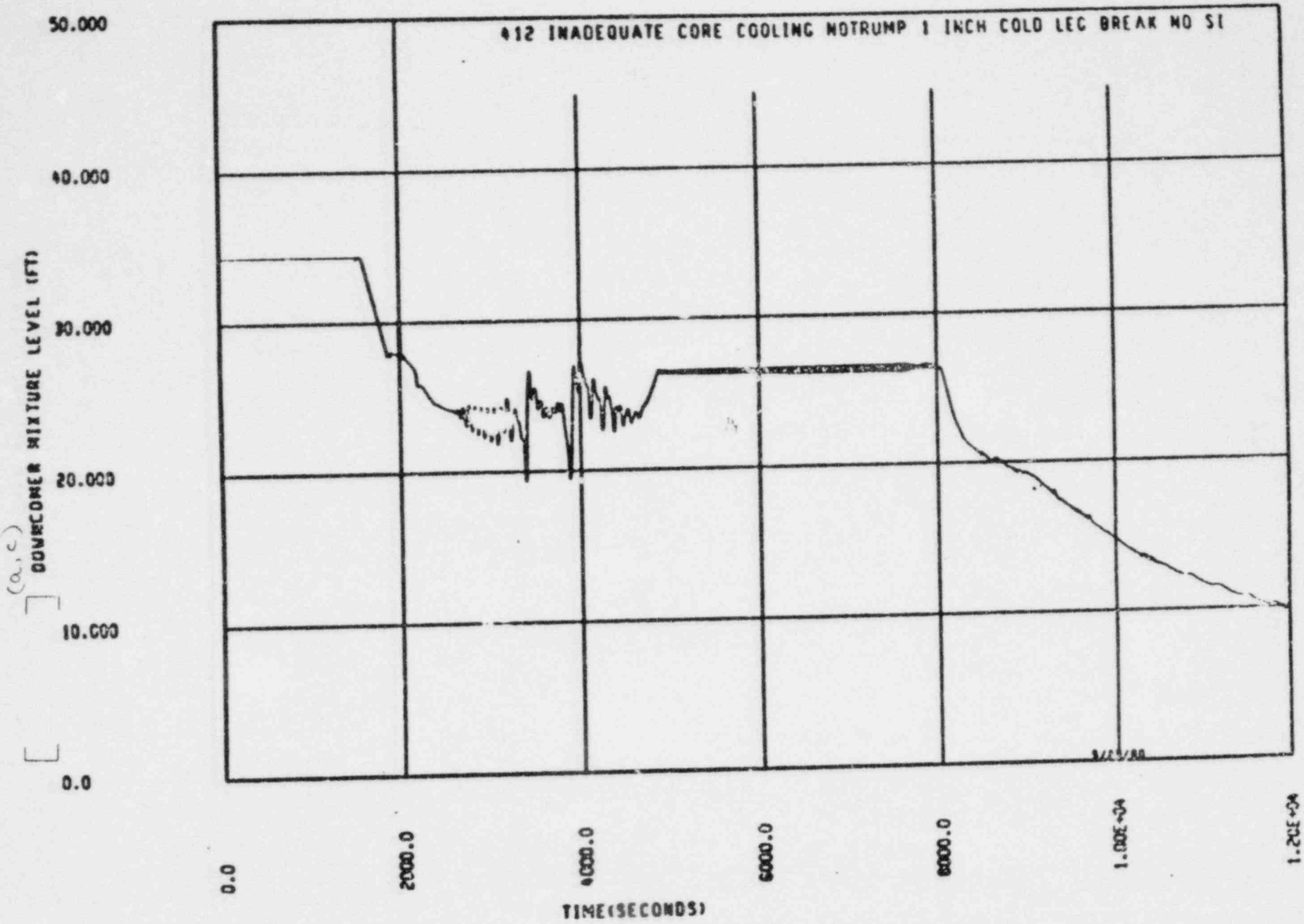

412 INADEQUATE CORE COOLING NOTRUMP 1 INCH COLD LEG BREAK NO SI
DOWNCOMER MIXTURE LEVEL (FT)
(a,c)
50.000
40.000
30.000
20.000
10.000
0.0
0.0
2000.0
4000.0
6000.0
8000.0
1.00E+04
1.20E+04
TIME(SECONDS)

Figure 8

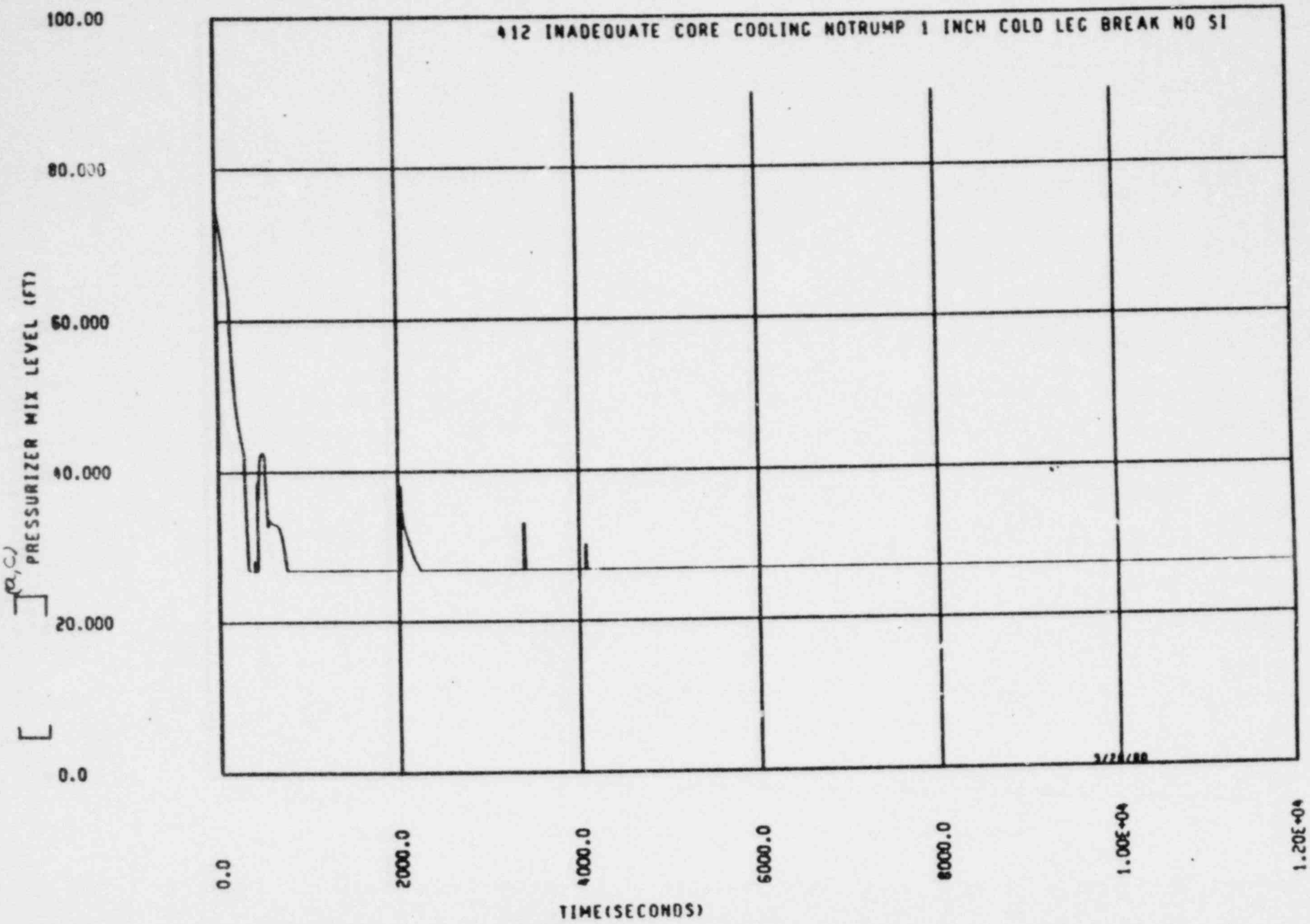
412 INADEQUATE CORE COOLING NOTRUMP 1 INCH COLD LEG BREAK NO SI
PRESSURIZER MIX LEVEL (FT)
100.00
80.000
60.000
40.000
20.000
0.0
TIME(SECONDS)
0.0
2000.0
4000.0
6000.0
8000.0
1.00E+04
1.20E+04
3/28/80
a,c

Figure 9

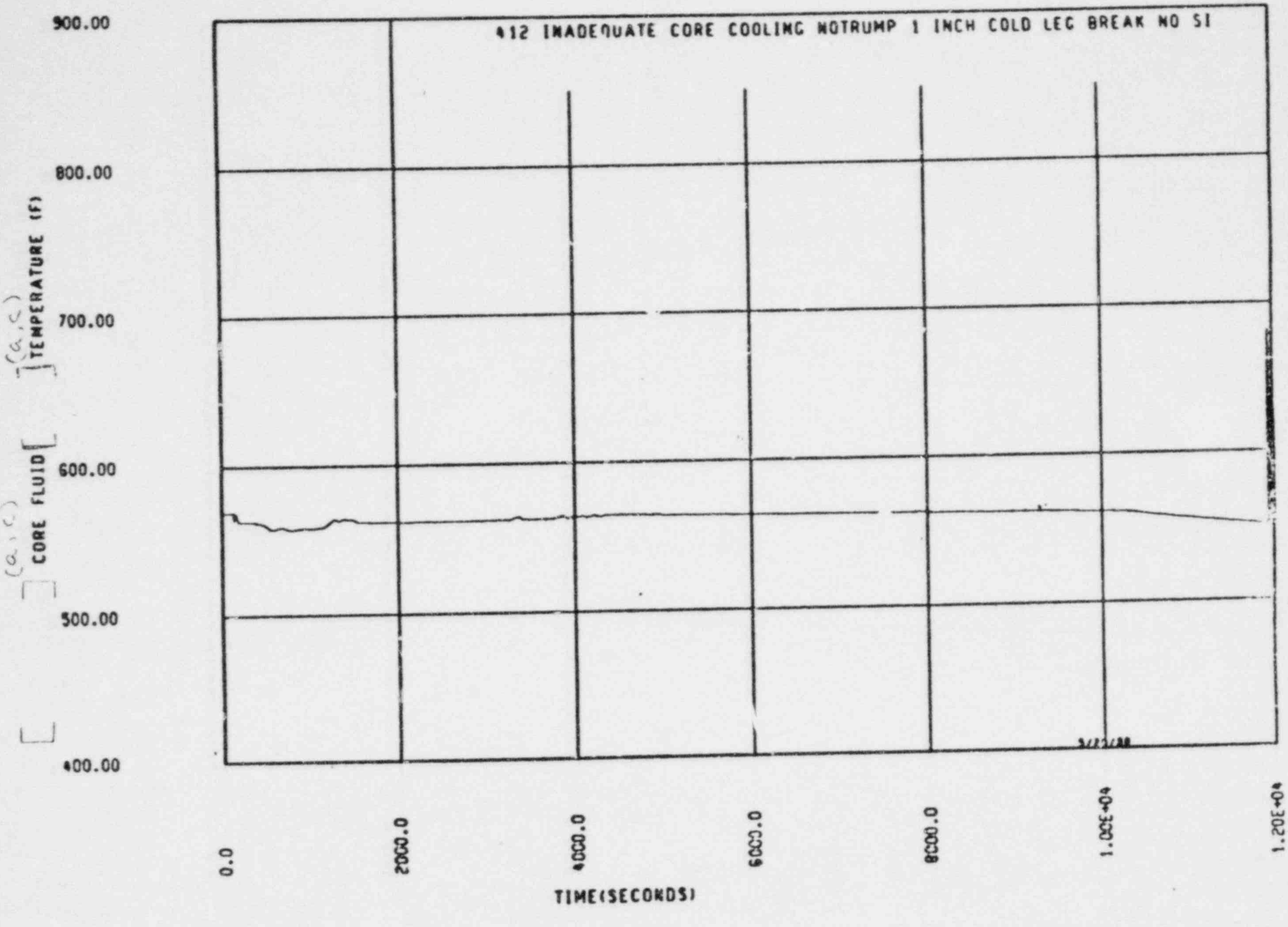

412 INADEQUATE CORE COOLING NOTRUMP 1 INCH COLD LEG BREAK NO SI
(a,c)
CORE FLUID
TEMPERATURE (F)
(a,c)
900.00
800.00
700.00
600.00
500.00
400.00
0.0
2000.0
4000.0
6000.0
8000.0
1.00E+04
1.20E+04
TIME(SECONDS)

Figure 10

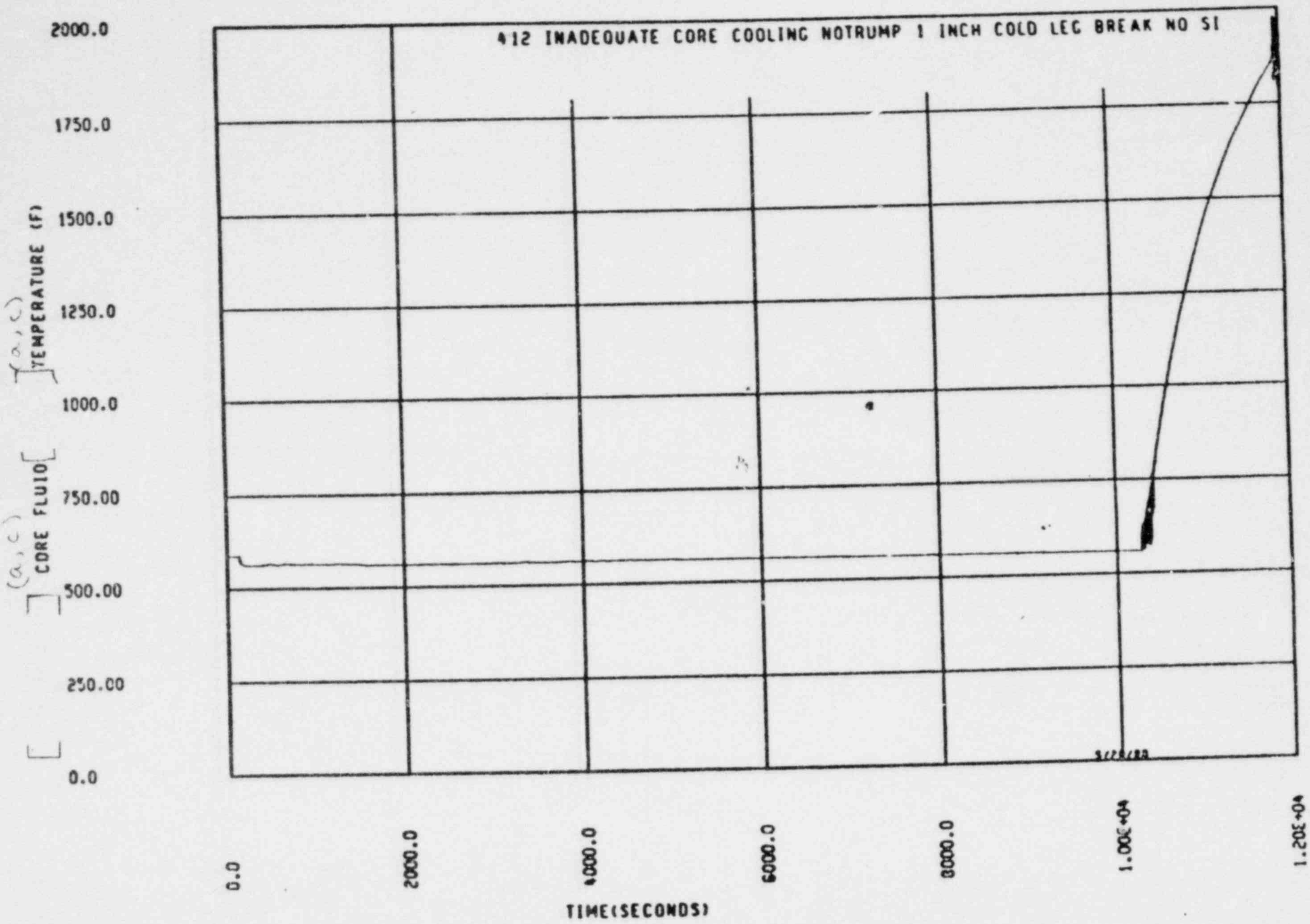

412 INADEQUATE CORE COOLING NOTRUMP 1 INCH COLD LEG BREAK NO SI
2000.0
1750.0
1500.0
1250.0
1000.0
750.00
500.00
250.00
0.0
CORE FLUID
TEMPERATURE (F)
(a,c)
(a,c)
0.0
2000.0
4000.0
6000.0
8000.0
1.00E+04
1.20E+04
TIME(SECONDS)

Figure 11

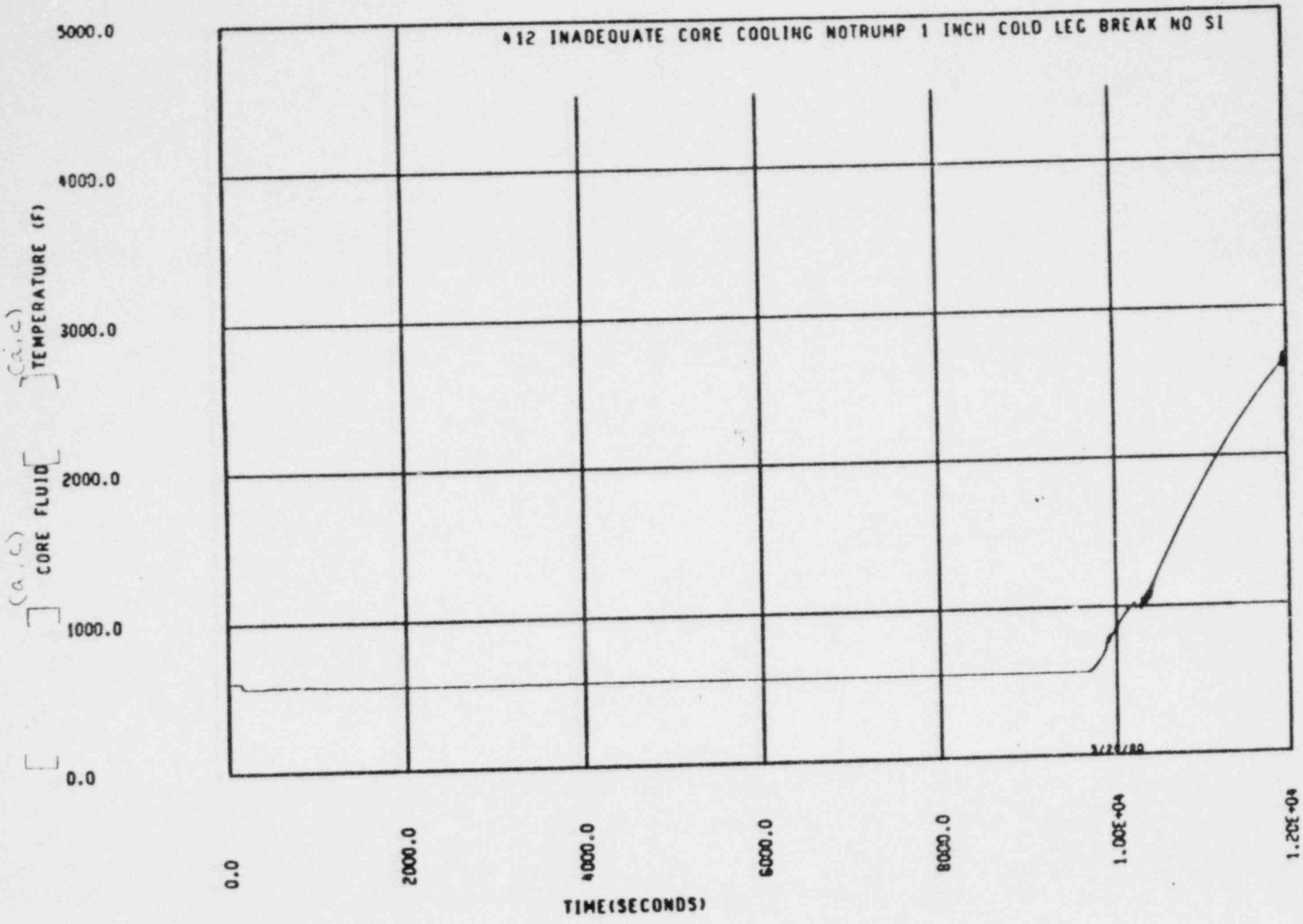

412 INADEQUATE CORE COOLING NOTRUMP 1 INCH COLD LEG BREAK NO SI
(a,c)
CORE FLUID
(a,c)
TEMPERATURE (F)
5000.0
4000.0
3000.0
2000.0
1000.0
0.0
0.0
2000.0
4000.0
6000.0
8000.0
1.00E+04
1.20E+04
TIME(SECONDS)

Figure 12

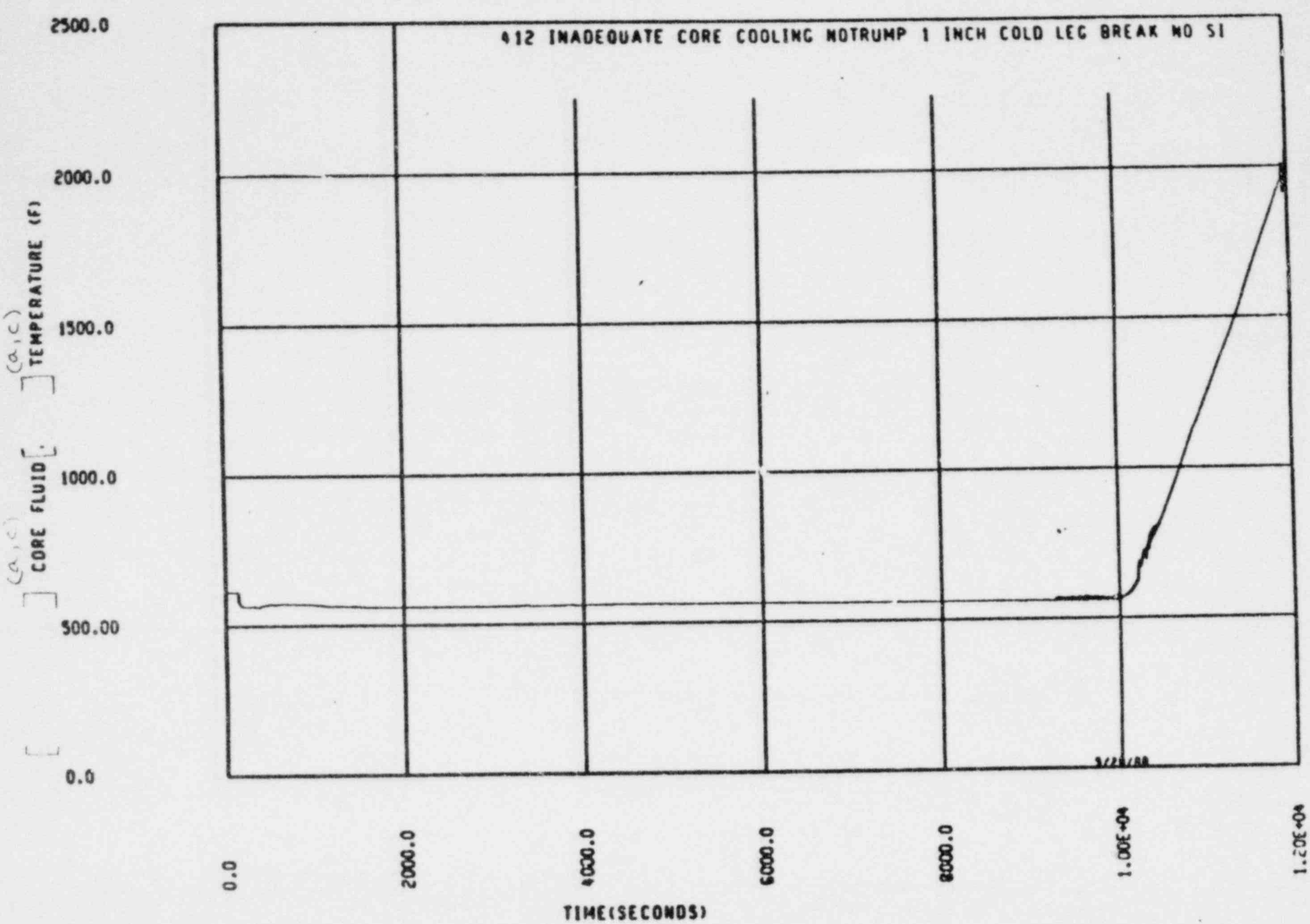

412 INADEQUATE CORE COOLING NOTRUMP 1 INCH COLD LEG BREAK NO SI
CORE FLUID
TEMPERATURE (F)
(a,c)
(a,c)
2500.0
2000.0
1500.0
1000.0
500.00
0.0
0.0
2000.0
4000.0
6000.0
8000.0
1.00E+04
1.20E+04
TIME(SECONDS)
5/23/88

Figure 13

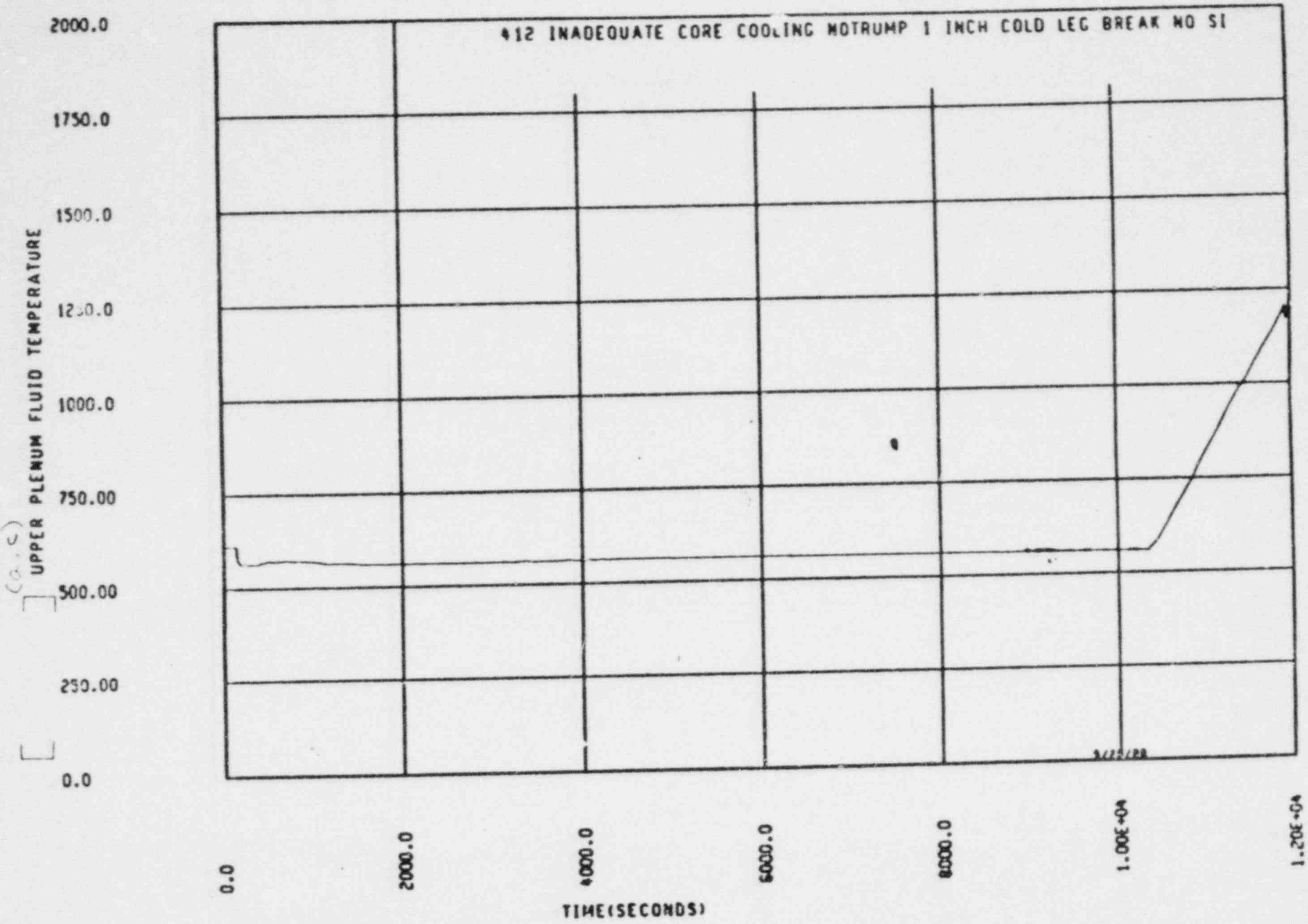
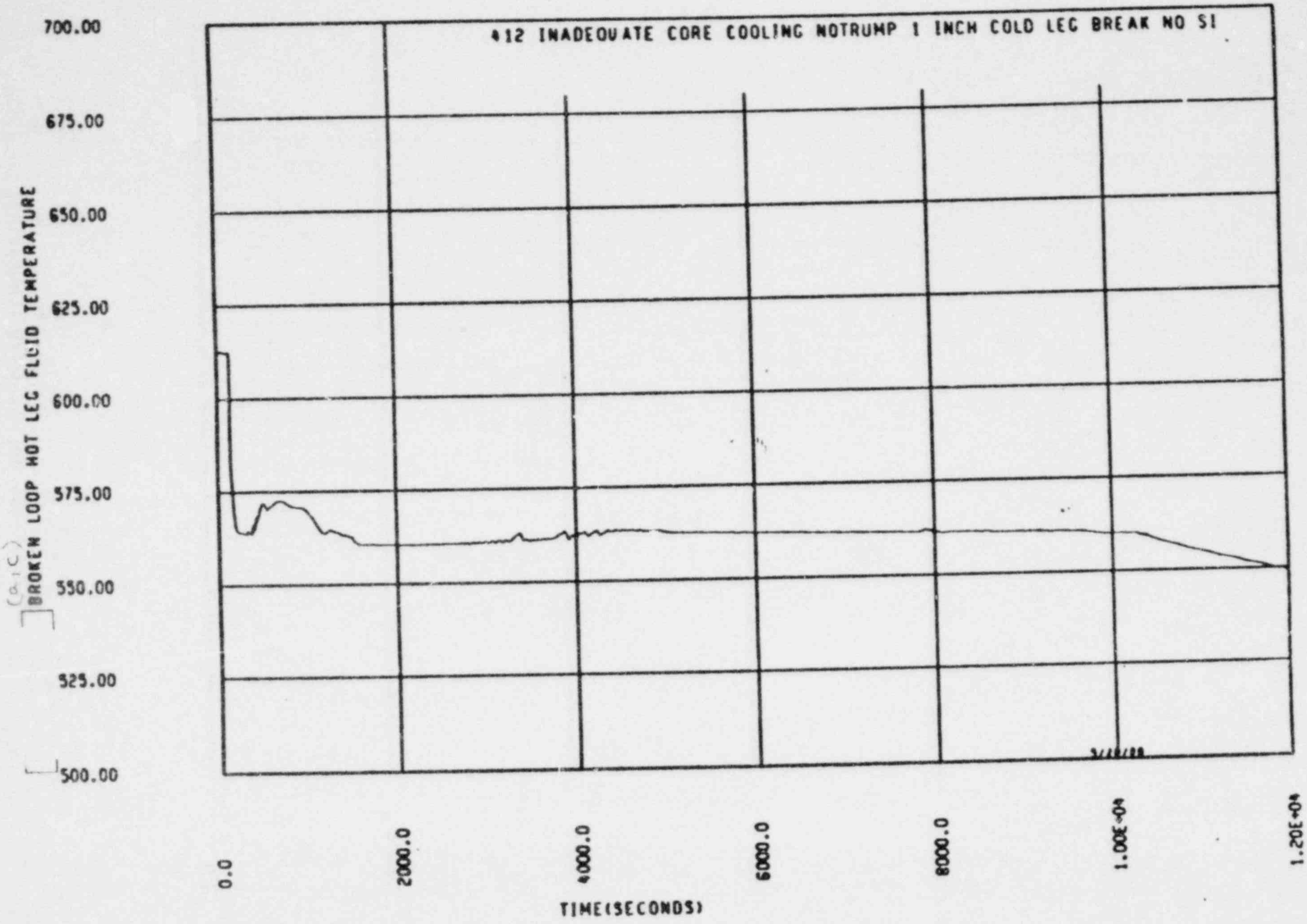

412 INADEQUATE CORE COOLING NOTRUMP 1 INCH COLD LEG BREAK NO SI
UPPER PLENUM FLUID TEMPERATURE
(a,c)
2000.0
1750.0
1500.0
1250.0
1000.0
750.00
500.00
250.00
0.0
0.0
2000.0
4000.0
6000.0
8000.0
1.00E+04
1.20E+04
TIME(SECONDS)

Figure 14



412 INADEQUATE CORE COOLING NOTRUMP 1 INCH COLD LEG BREAK NO SI
BROKEN LOOP HOT LEG FLUID TEMPERATURE
(a,c)
700.00
675.00
650.00
625.00
600.00
575.00
550.00
525.00
500.00
0.0
2000.0
4000.0
6000.0
8000.0
1.00E+04
1.20E+04
TIME(SECONDS)

Figure 15

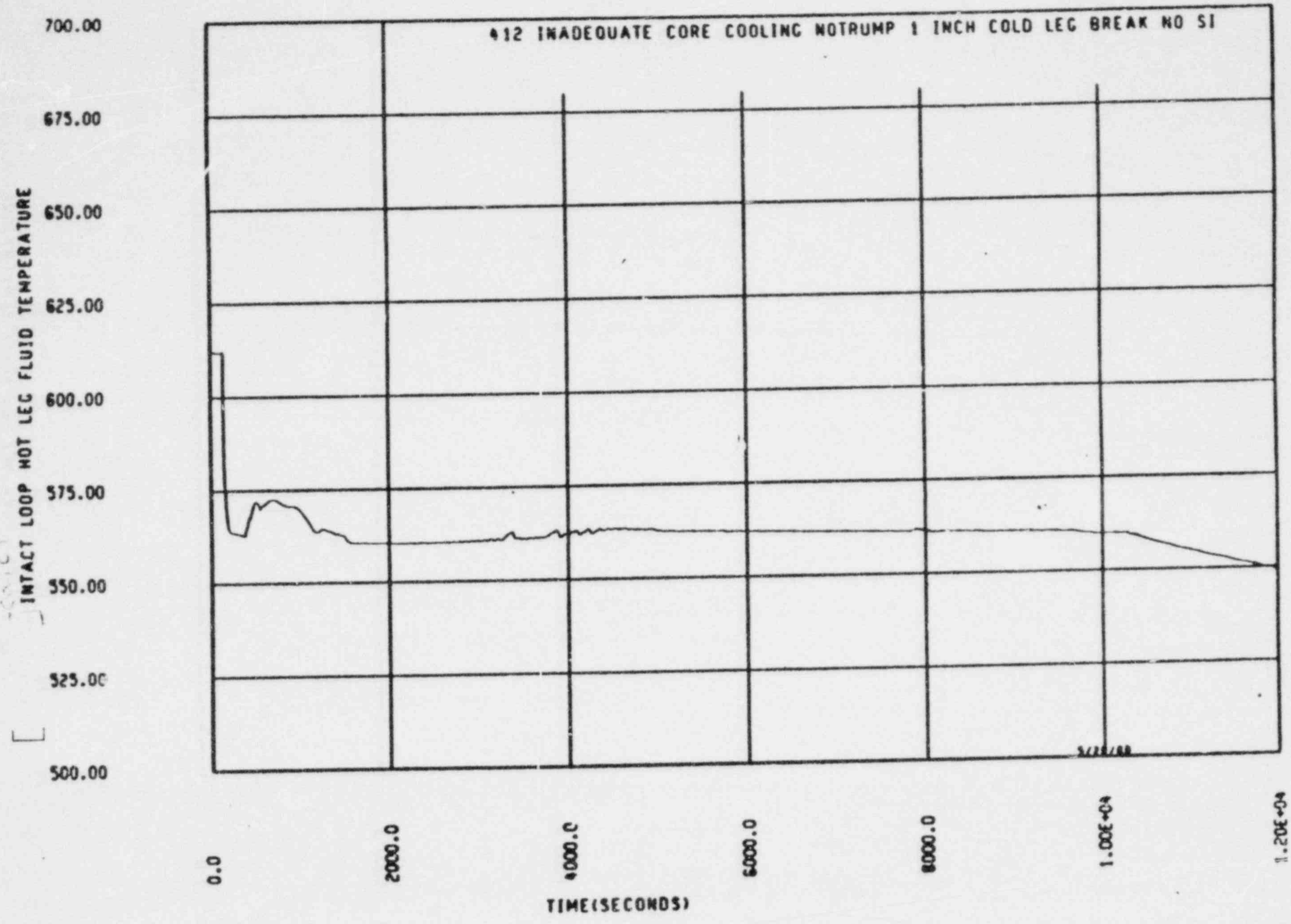

412 INADEQUATE CORE COOLING NOTRUMP 1 INCH COLD LEG BREAK NO SI
INTACT LOOP HOT LEG FLUID TEMPERATURE
700.00
675.00
650.00
625.00
600.00
575.00
550.00
525.00
500.00
0.0
2000.0
4000.0
6000.0
8000.0
1.00E+04
1.20E+04
TIME(SECONDS)

Figure 16

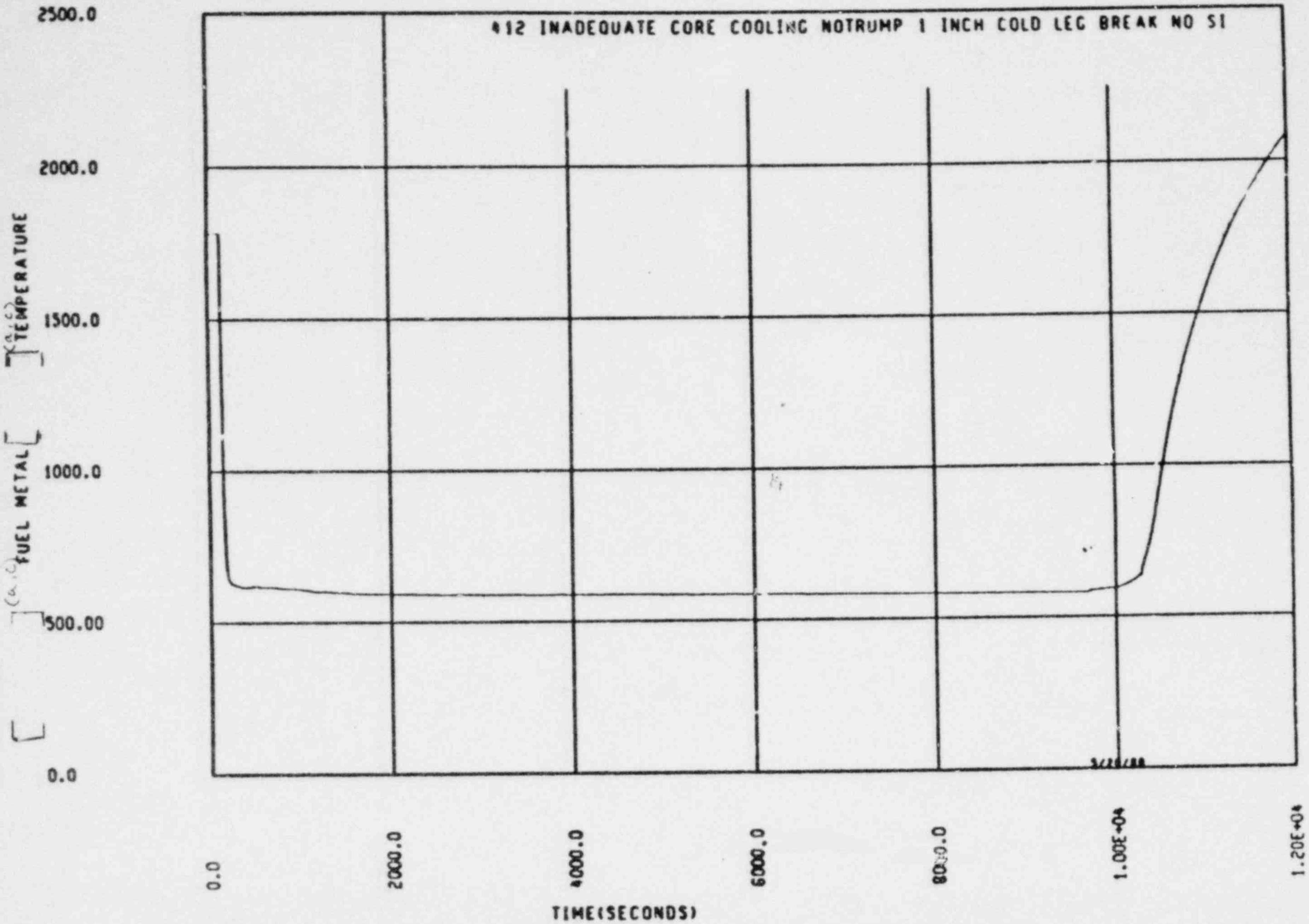

412 INADEQUATE CORE COOLING NOTRUMP 1 INCH COLD LEG BREAK NO SI
FUEL METAL TEMPERATURE
(a,c)
(a,c)
2500.0
2000.0
1500.0
1000.0
500.00
0.0
0.0
2000.0
4000.0
6000.0
8000.0
1.00E+04
1.20E+04
TIME(SECONDS)

Figure 17

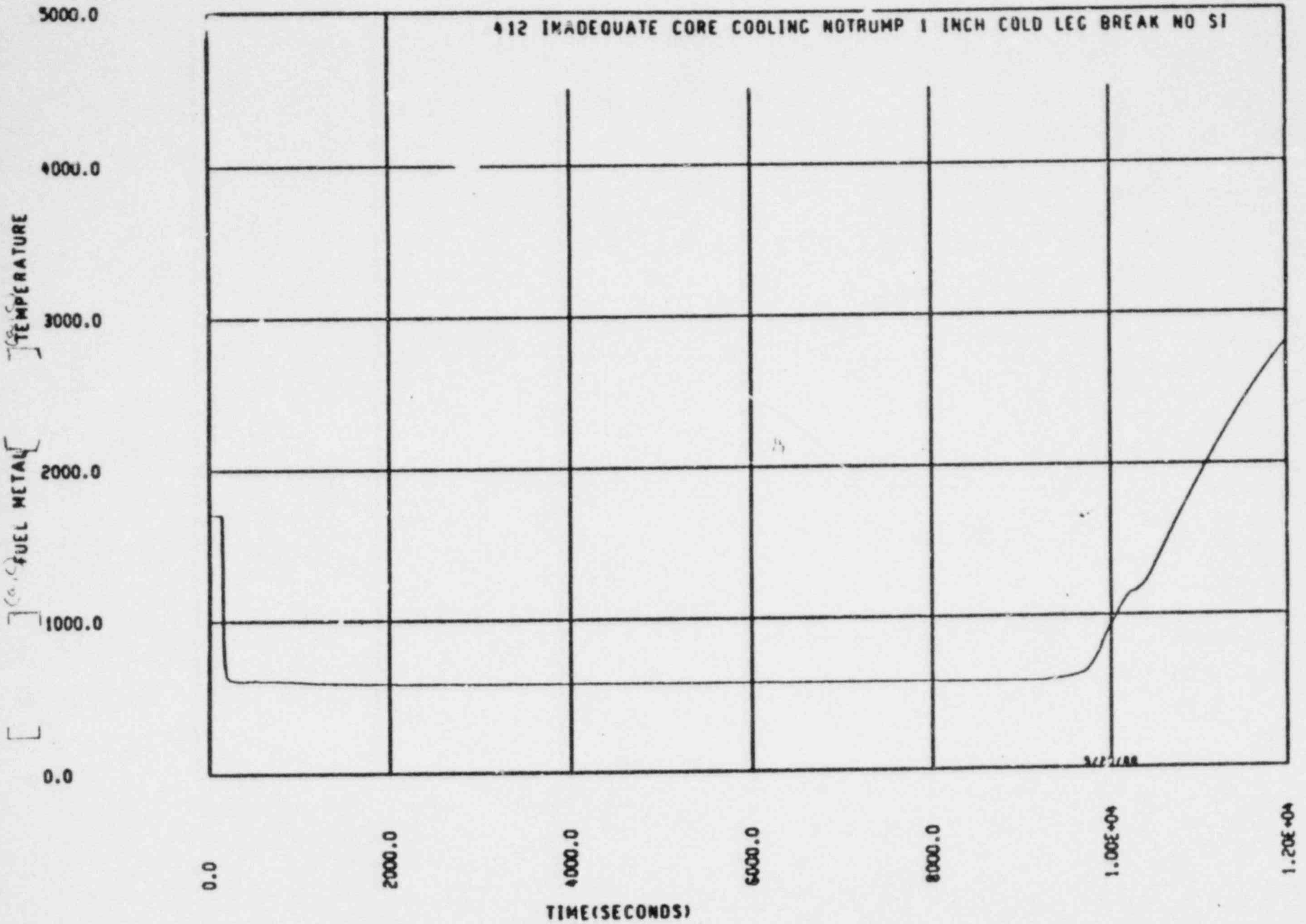

412 INADEQUATE CORE COOLING NOTRUMP 1 INCH COLD LEG BREAK NO SI
FUEL METAL TEMPERATURE
(a,c)
5000.0
4000.0
3000.0
2000.0
1000.0
0.0
0.0
2000.0
4000.0
6000.0
8000.0
1.00E+04
1.20E+04
TIME(SECONDS)

Figure 18

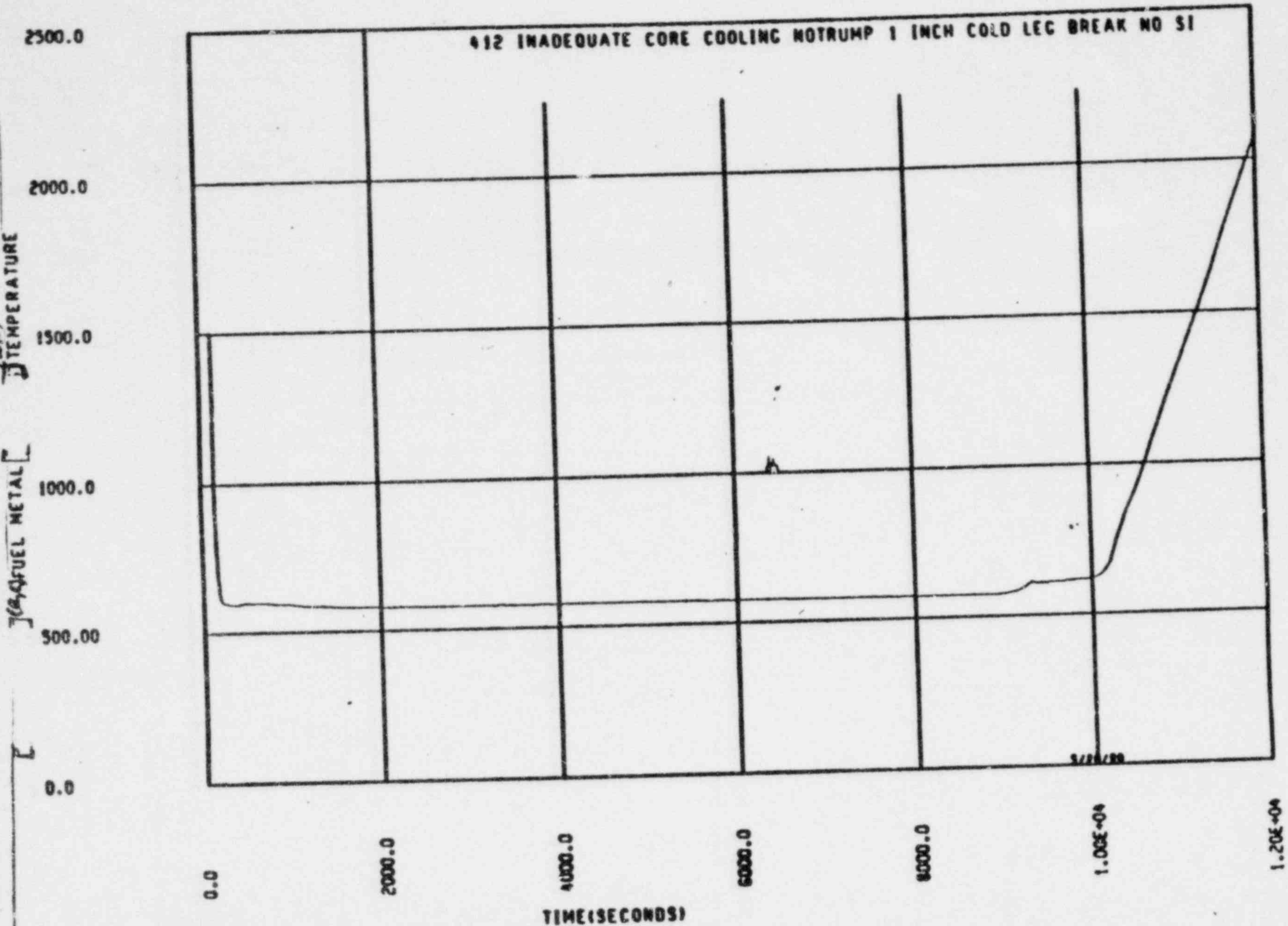

412 INADEQUATE CORE COOLING NOTRUMP 1 INCH COLD LEG BREAK NO SI
2500.0
2000.0
1500.0
1000.0
500.00
0.0
]$^{(a,c)}$FUEL METAL[ ]$^{(a,c)}$TEMPERATURE
[
0.0
2000.0
4000.0
6000.0
8000.0
1.00E+04
1.20E+04
TIME(SECONDS)

Figure 19

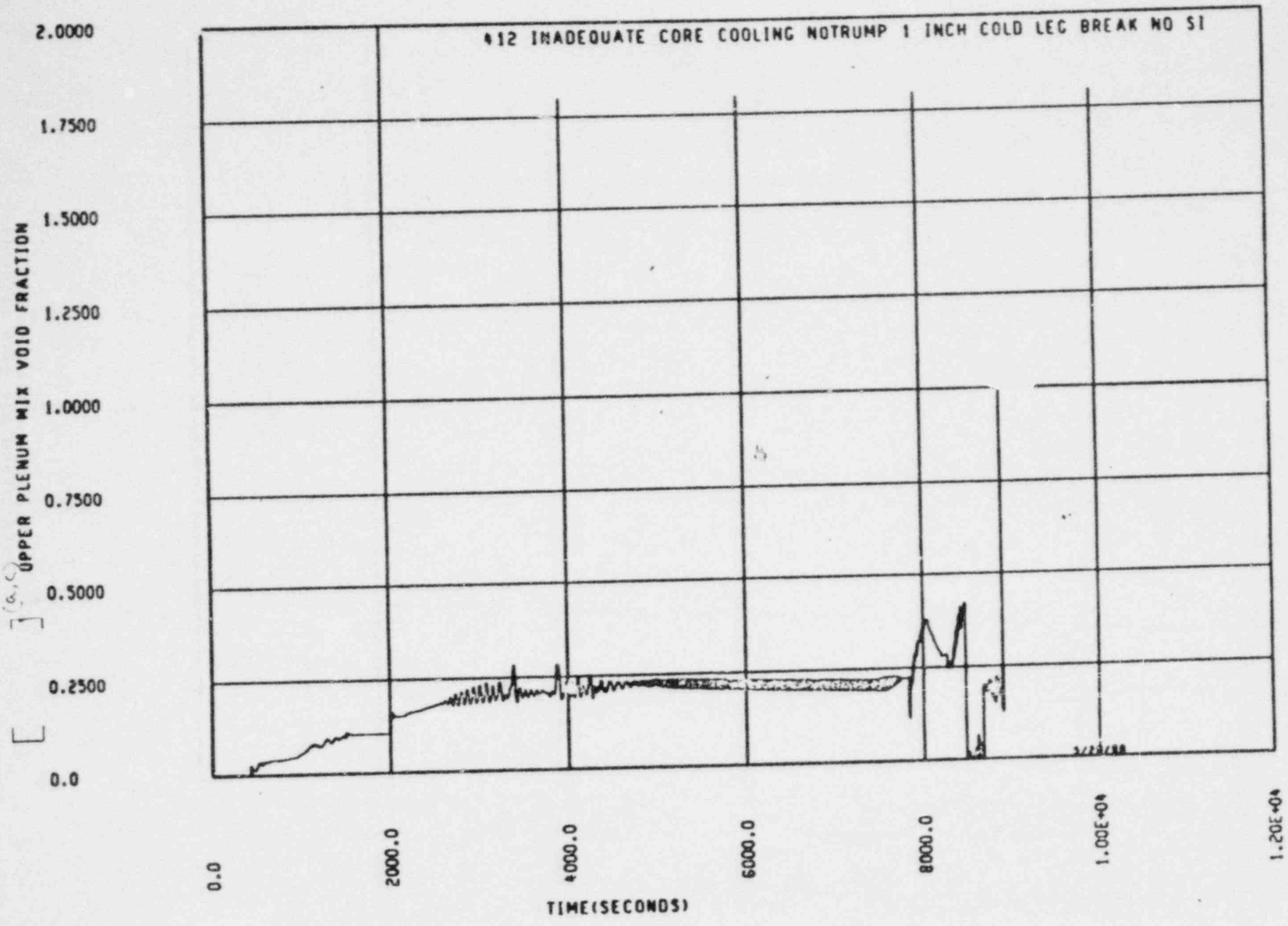

412 INADEQUATE CORE COOLING NOTRUMP 1 INCH COLD LEG BREAK NO SI
UPPER PLENUM MIX VOID FRACTION
2.0000
1.7500
1.5000
1.2500
1.0000
0.7500
0.5000
0.2500
0.0
0.0
2000.0
4000.0
6000.0
8000.0
1.00E+04
1.20E+04
TIME(SECONDS)
3/23/88
(a,c)

Figure 20

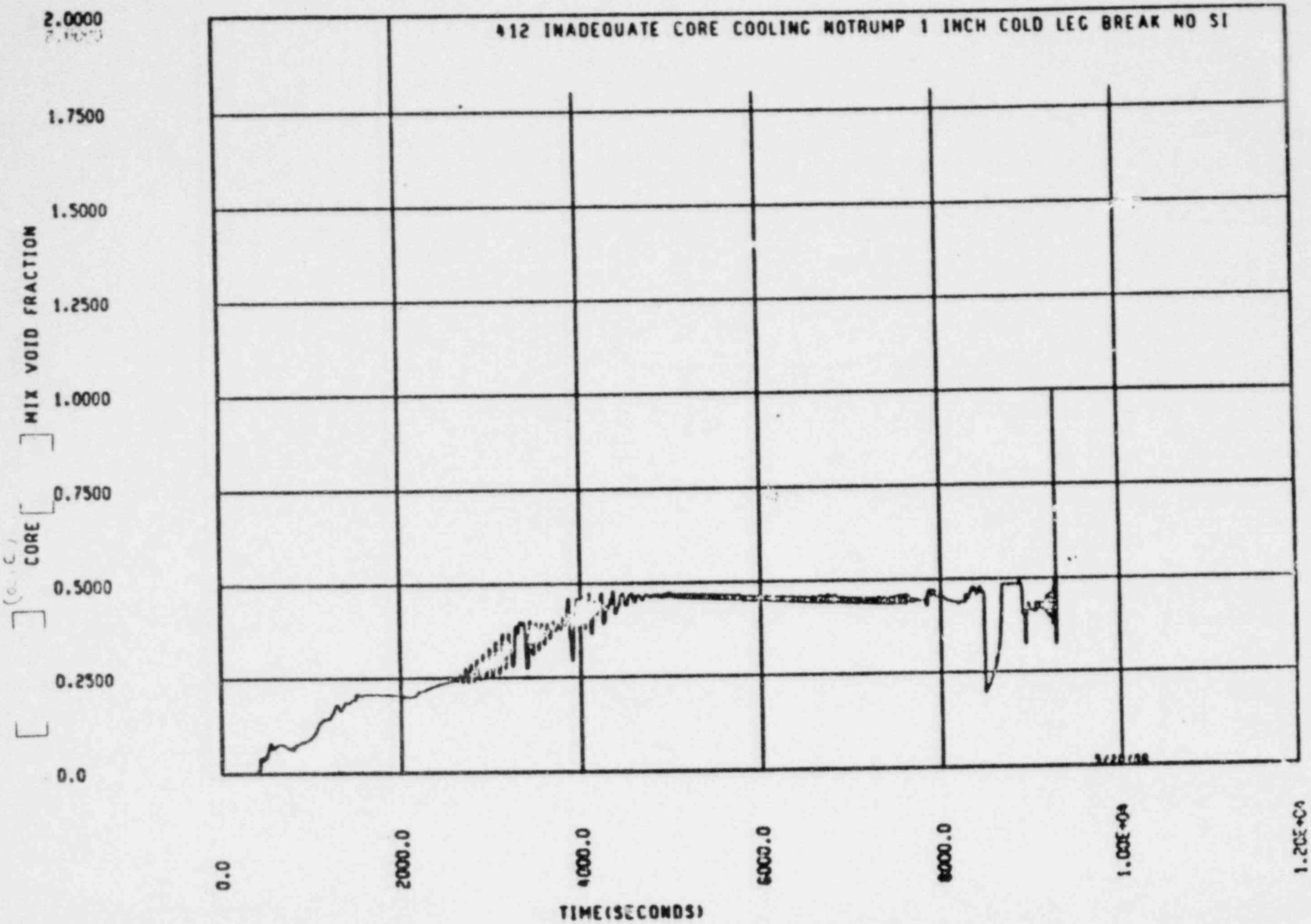

412 INADEQUATE CORE COOLING NOTRUMP 1 INCH COLD LEG BREAK NO SI
2.0000
1.7500
1.5000
1.2500
1.0000
0.7500
0.5000
0.2500
0.0
CORE MIX VOID FRACTION
(a,c)
0.0
2000.0
4000.0
6000.0
8000.0
1.00E+04
1.20E+04
TIME(SECONDS)
3/20/98

Figure 21

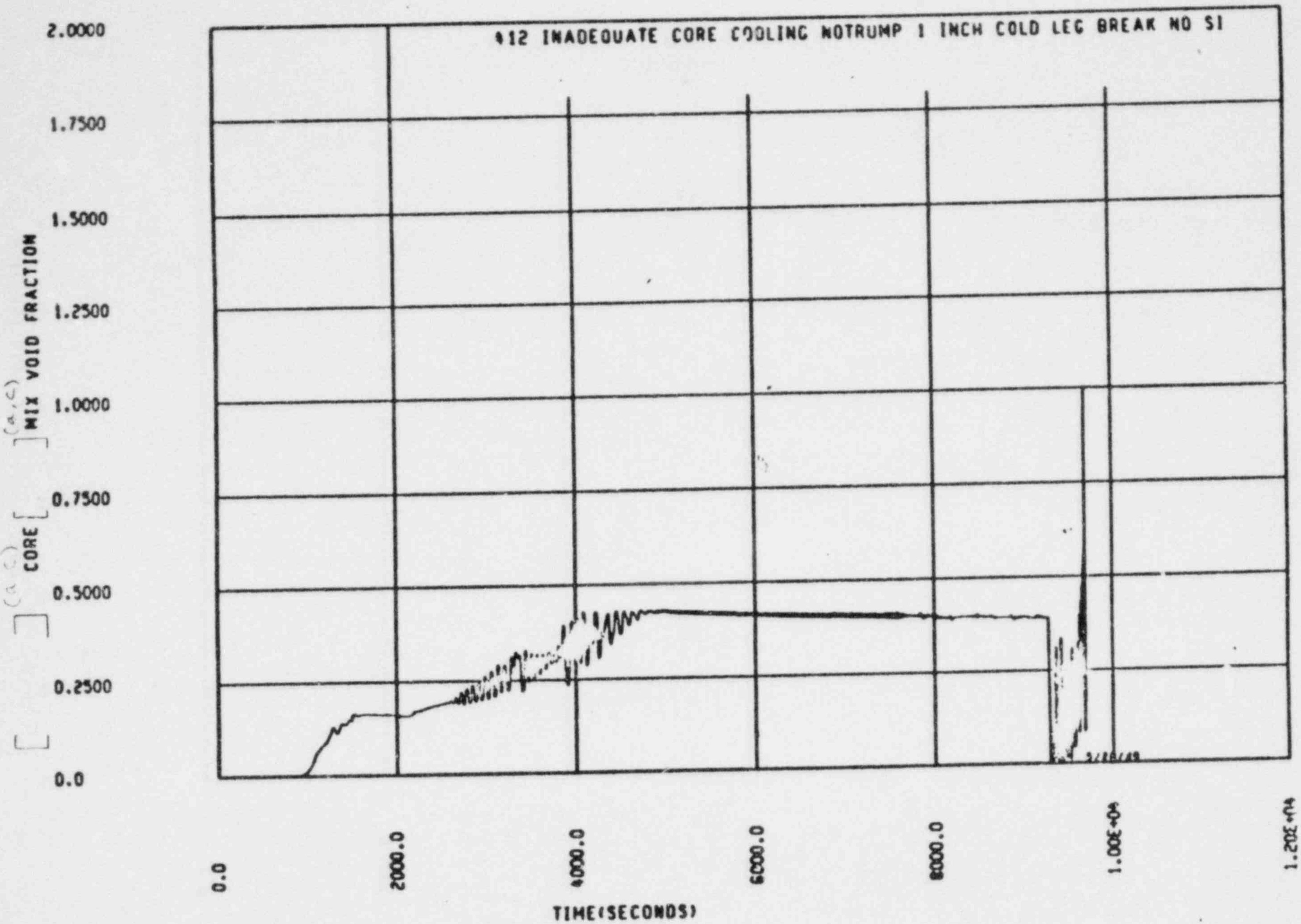

412 INADEQUATE CORE COOLING NOTRUMP 1 INCH COLD LEG BREAK NO SI
CORE MIX VOID FRACTION
(a,c)
(a,c)
2.0000
1.7500
1.5000
1.2500
1.0000
0.7500
0.5000
0.2500
0.0
0.0
2000.0
4000.0
6000.0
8000.0
1.00E+04
1.20E+04
TIME(SECONDS)

Figure 22

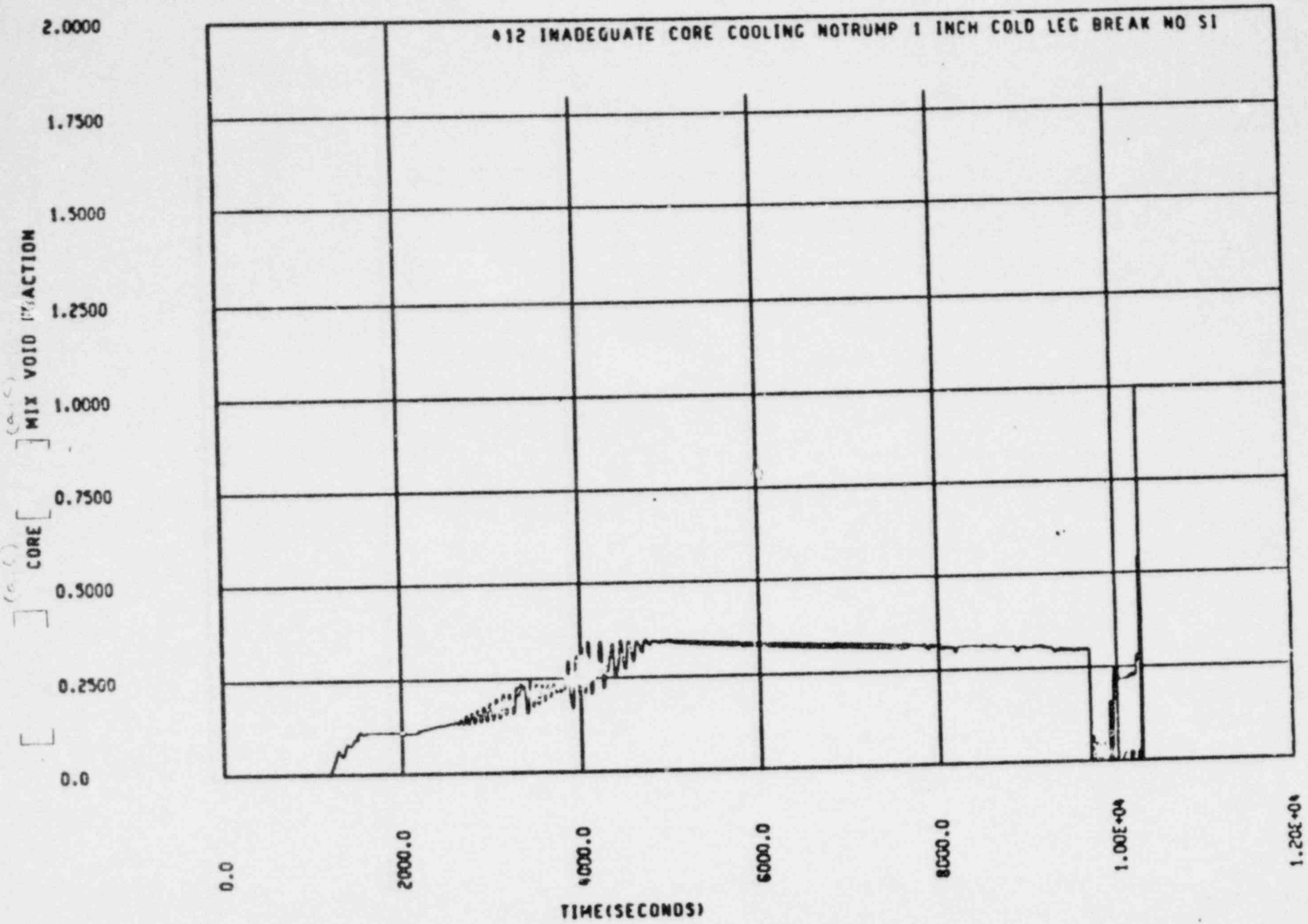

412 INADEQUATE CORE COOLING NOTRUMP 1 INCH COLD LEG BREAK NO SI
[ ] CORE [ ] MIX VOID FRACTION
(a,c)
(a,c)
2.0000
1.7500
1.5000
1.2500
1.0000
0.7500
0.5000
0.2500
0.0
0.0
2000.0
4000.0
6000.0
8000.0
1.00E+04
1.20E+04
TIME(SECONDS)

Figure 23

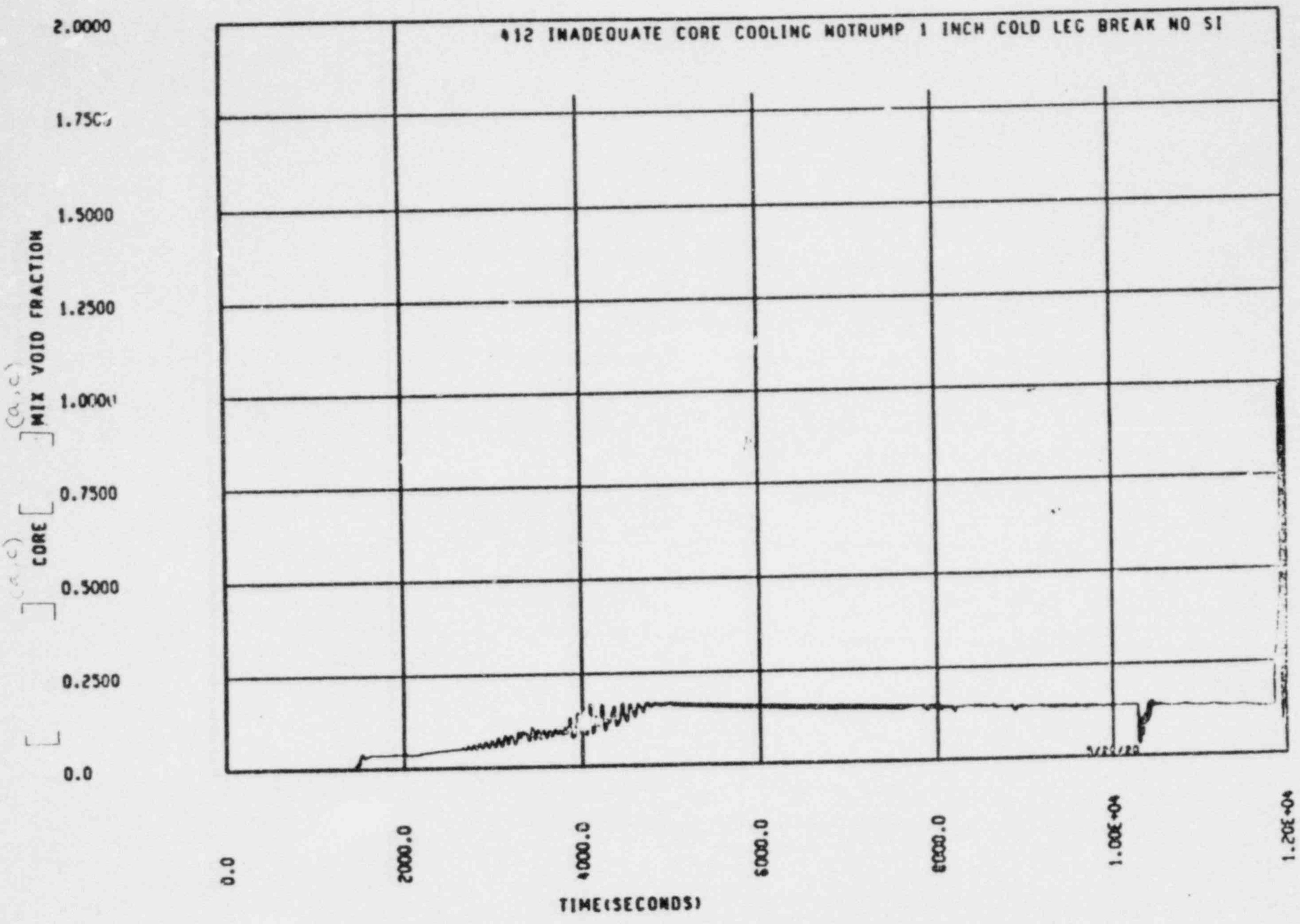

412 INADEQUATE CORE COOLING NOTRUMP 1 INCH COLD LEG BREAK NO SI
2.0000
1.750
1.5000
1.2500
1.0000
0.7500
0.5000
0.2500
0.0
CORE
MIX VOID FRACTION
(a,c)
(a,c)
0.0
2000.0
4000.0
6000.0
8000.0
1.00E+04
1.20E+04
TIME(SECONDS)

Figure 24

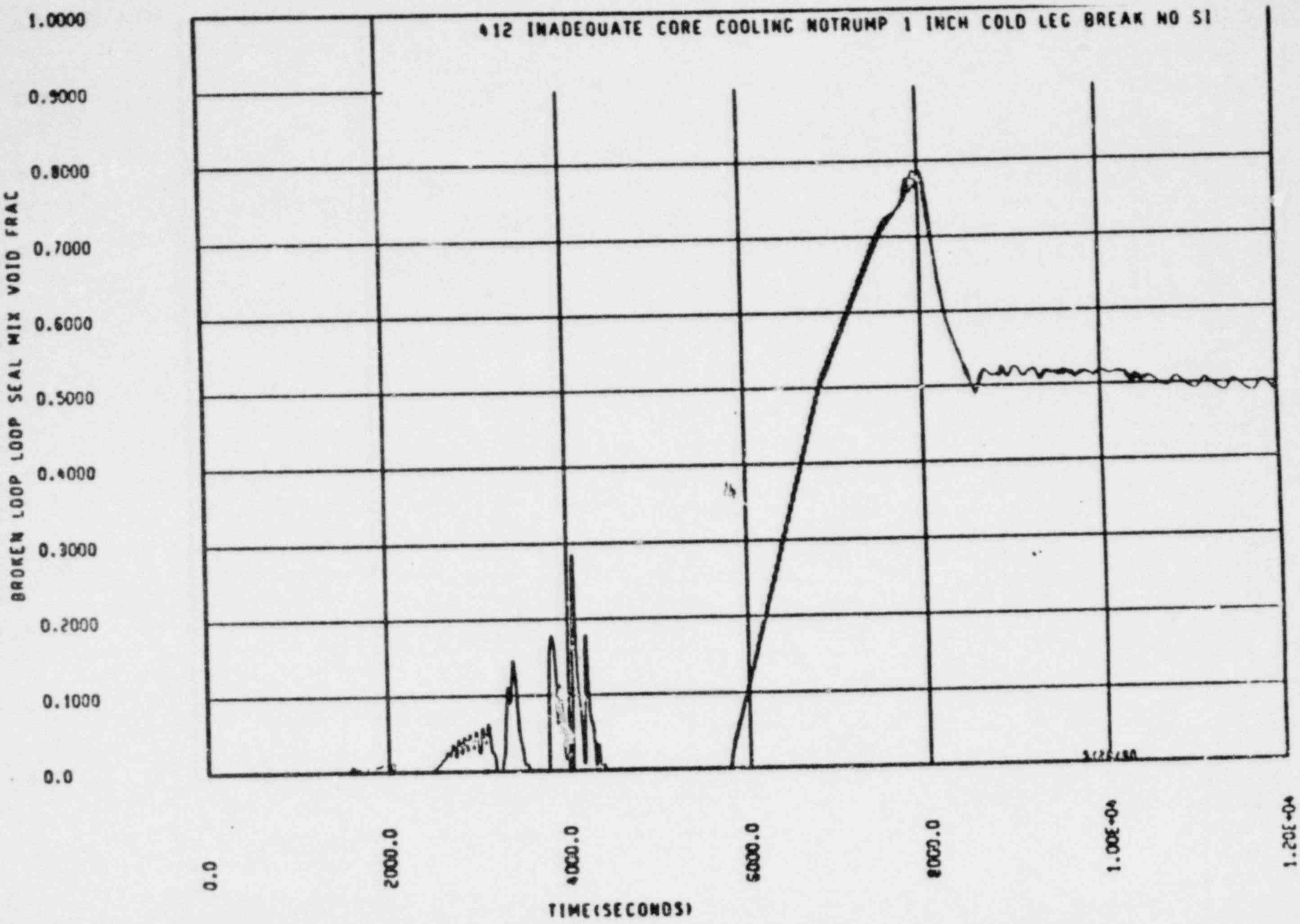

412 INADEQUATE CORE COOLING NOTRUMP 1 INCH COLD LEG BREAK NO SI
BROKEN LOOP LOOP SEAL MIX VOID FRAC
1.0000
0.9000
0.8000
0.7000
0.6000
0.5000
0.4000
0.3000
0.2000
0.1000
0.0
0.0
2000.0
4000.0
6000.0
8000.0
1.00E+04
1.20E+04
TIME(SECONDS)

Figure 25

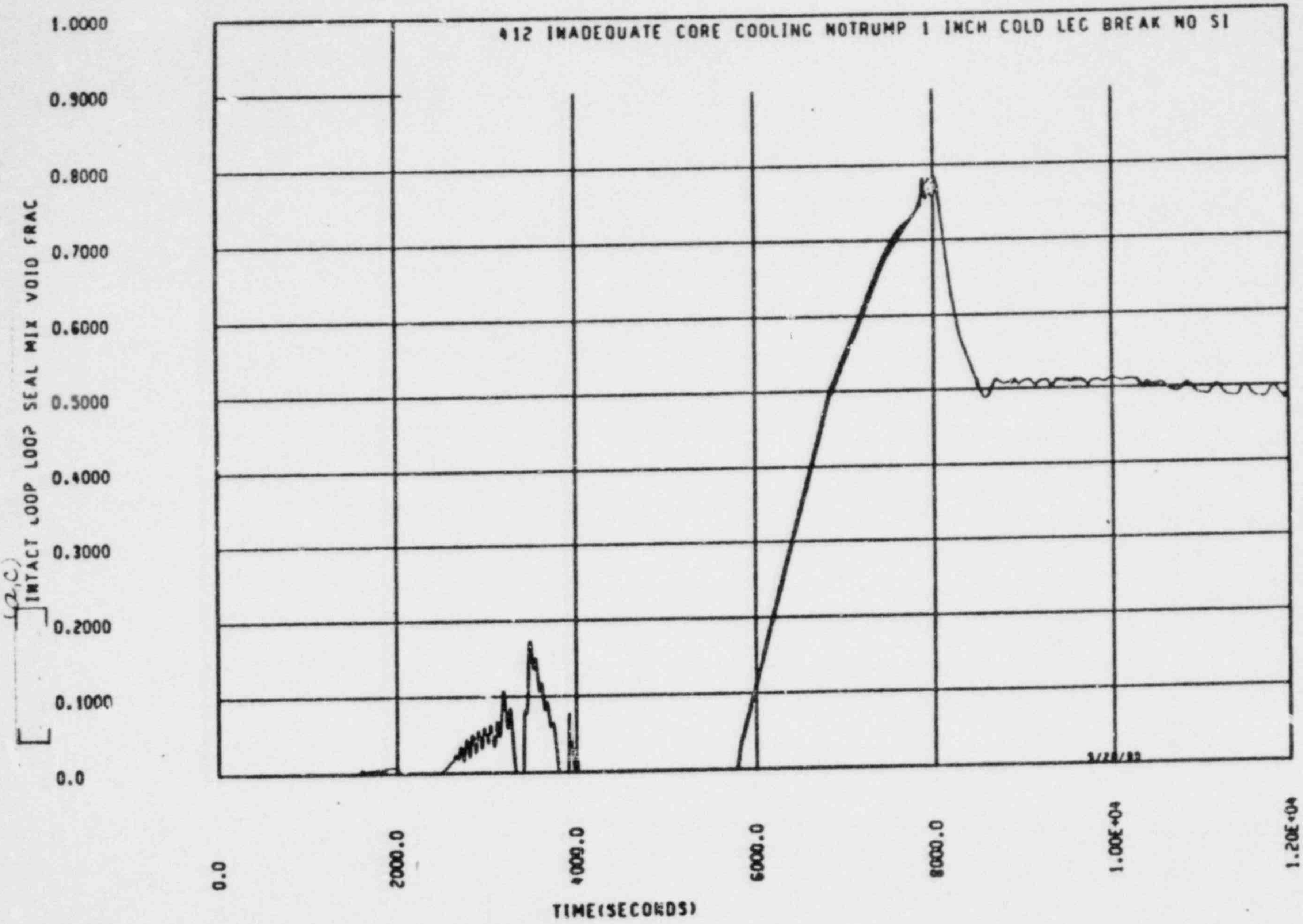

412 INADEQUATE CORE COOLING NOTRUMP 1 INCH COLD LEG BREAK NO SI
INTACT LOOP LOOP SEAL MIX VOID FRAC
a,c
1.0000
0.9000
0.8000
0.7000
0.6000
0.5000
0.4000
0.3000
0.2000
0.1000
0.0
0.0
2000.0
4000.0
6000.0
8000.0
1.00E+04
1.20E+04
TIME(SECONDS)
5/28/83

Figure 26

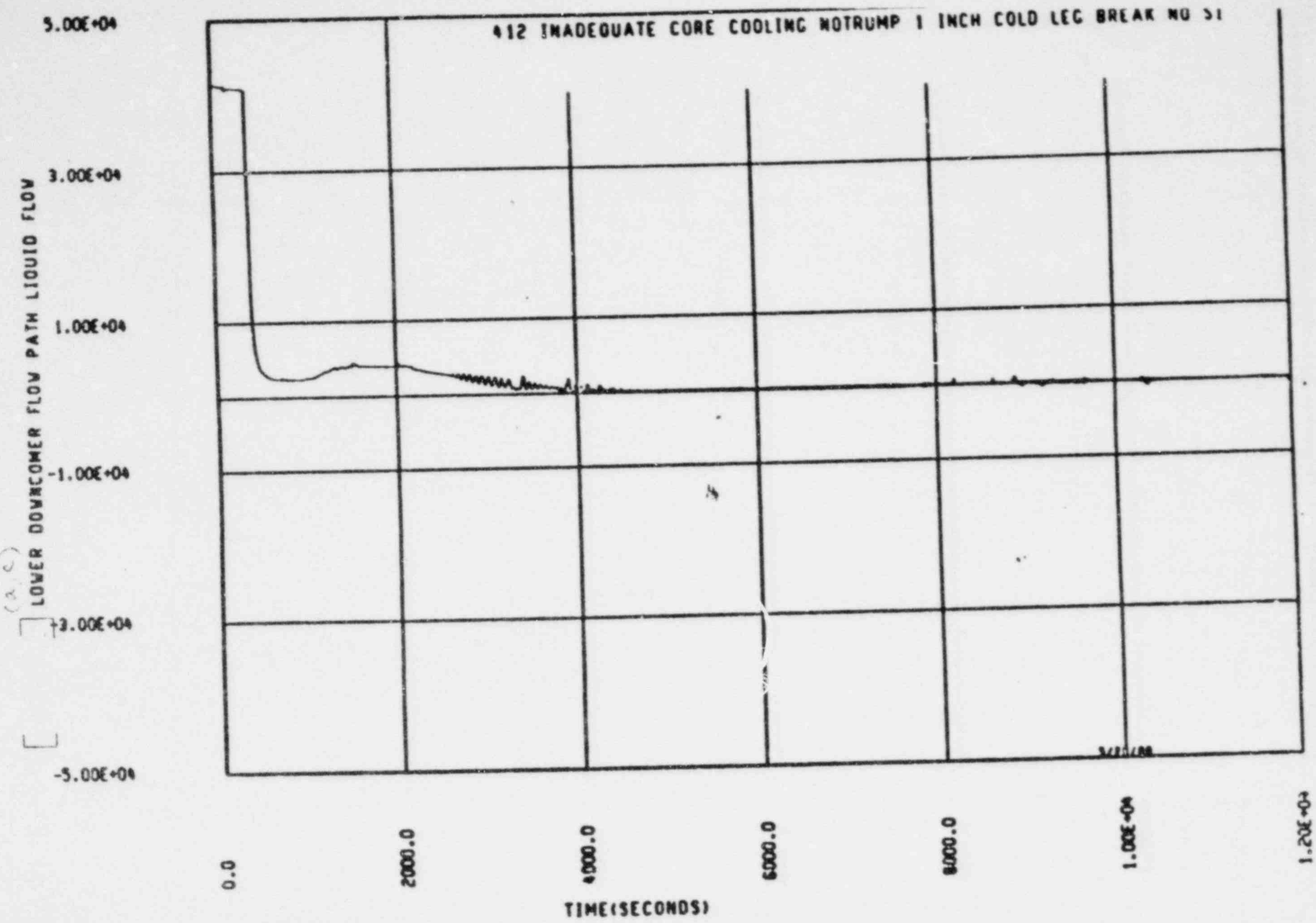

412 INADEQUATE CORE COOLING NOTRUMP 1 INCH COLD LEG BREAK NO SI
LOWER DOWNCOMER FLOW PATH LIQUID FLOW
(a,c)
5.00E+04
3.00E+04
1.00E+04
-1.00E+04
-3.00E+04
-5.00E+04
0.0
2000.0
4000.0
6000.0
8000.0
1.00E+04
1.20E+04
TIME(SECONDS)

Figure 27

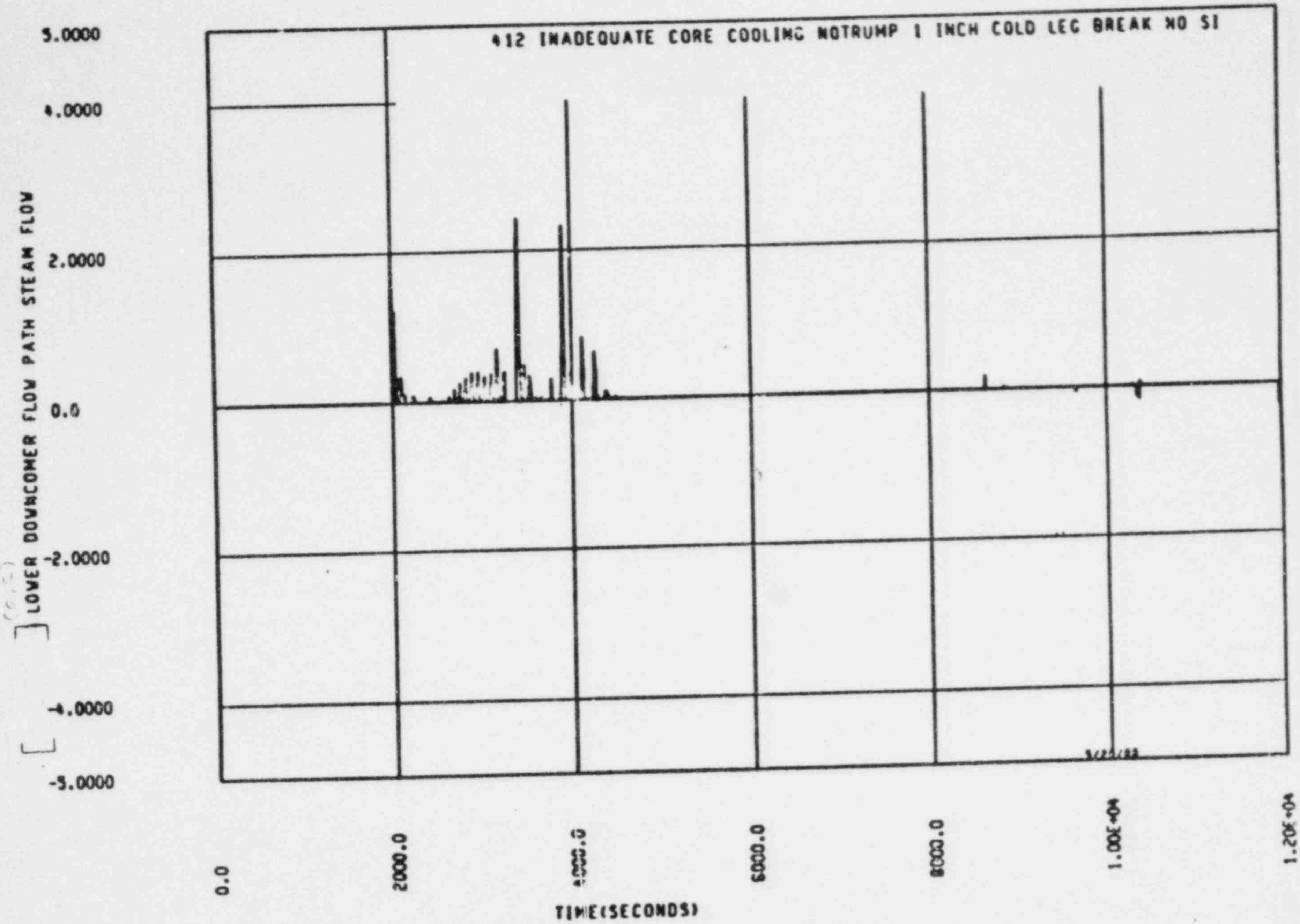

412 INADEQUATE CORE COOLING NOTRUMP 1 INCH COLD LEG BREAK NO SI
LOWER DOWNCOMER FLOW PATH STEAM FLOW
(a,c)
5.0000
4.0000
2.0000
0.0
-2.0000
-4.0000
-5.0000
0.0
2000.0
4000.0
6000.0
8000.0
1.000E+04
1.200E+04
TIME(SECONDS)
5/23/83

Figure 28

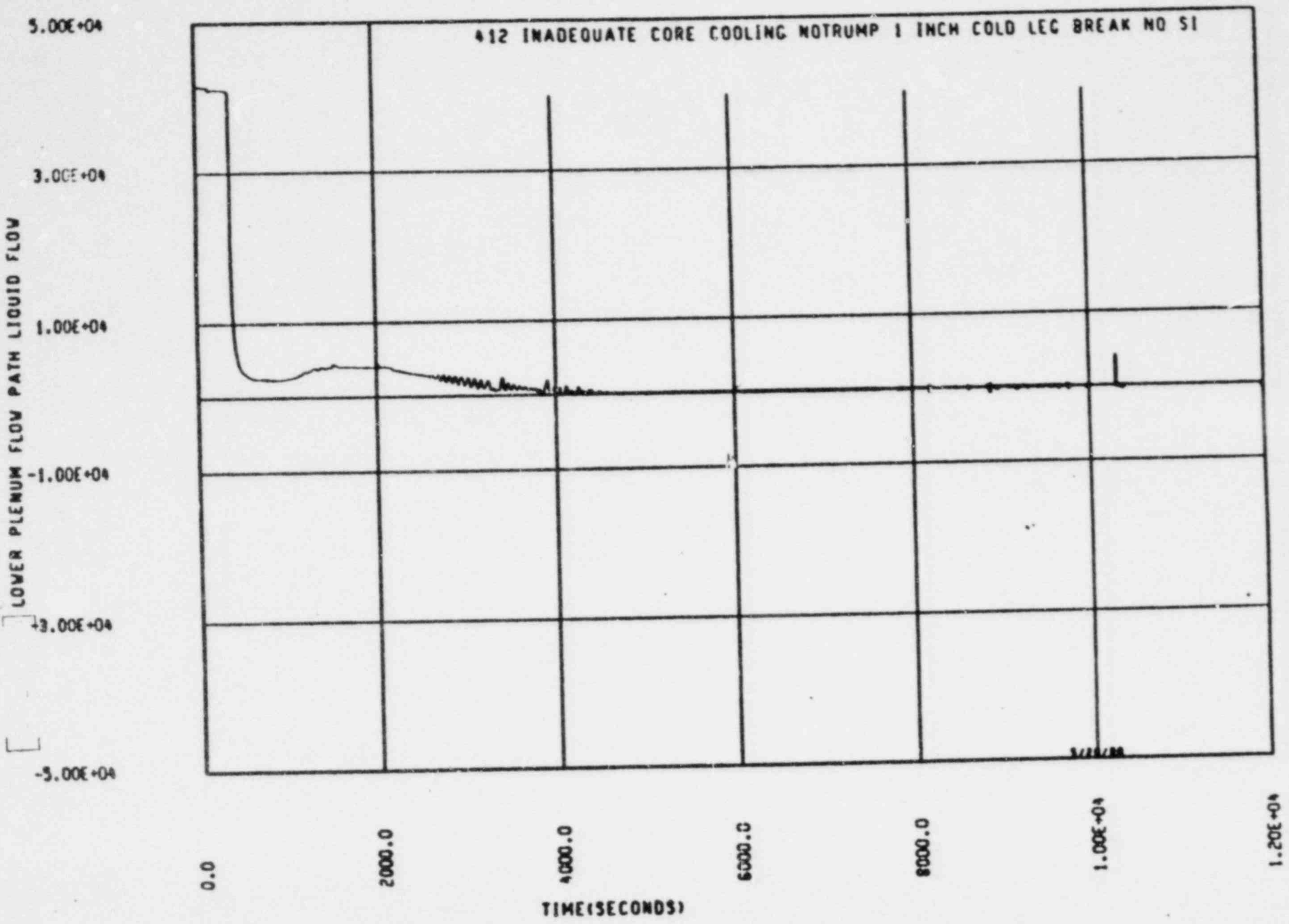

412 INADEQUATE CORE COOLING NOTRUMP 1 INCH COLD LEG BREAK NO SI
LOWER PLENUM FLOW PATH LIQUID FLOW
(a,c)
5.00E+04
3.00E+04
1.00E+04
-1.00E+04
-3.00E+04
-5.00E+04
0.0
2000.0
4000.0
6000.0
8000.0
1.00E+04
1.20E+04
TIME(SECONDS)

Figure 29

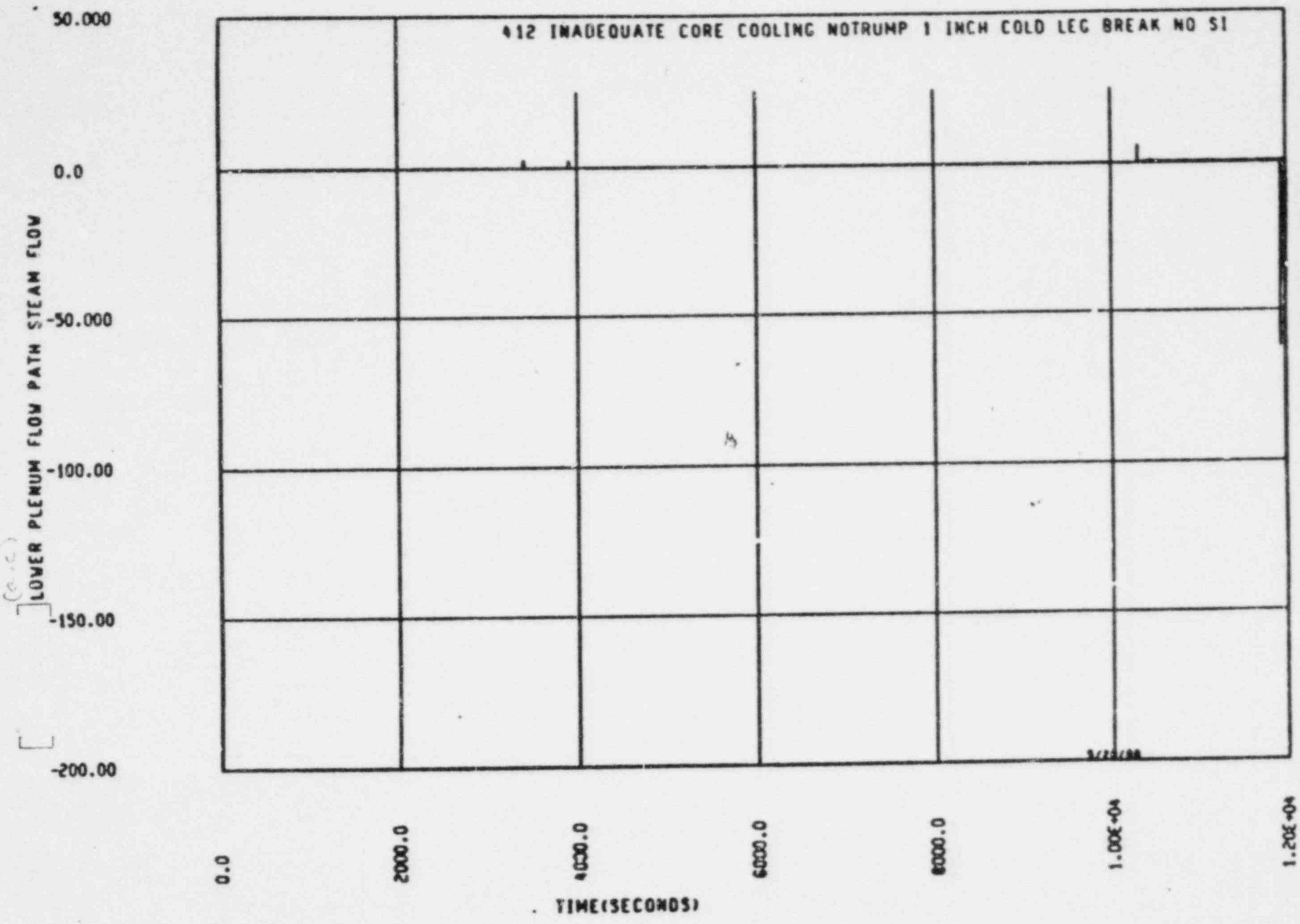

412 INADEQUATE CORE COOLING NOTRUMP 1 INCH COLD LEG BREAK NO SI
LOWER PLENUM FLOW PATH STEAM FLOW [ ]
(a,c)
50.000
0.0
-50.000
-100.00
-150.00
-200.00
0.0
2000.0
4000.0
6000.0
8000.0
1.00E+04
1.20E+04
TIME(SECONDS)

Figure 3Q

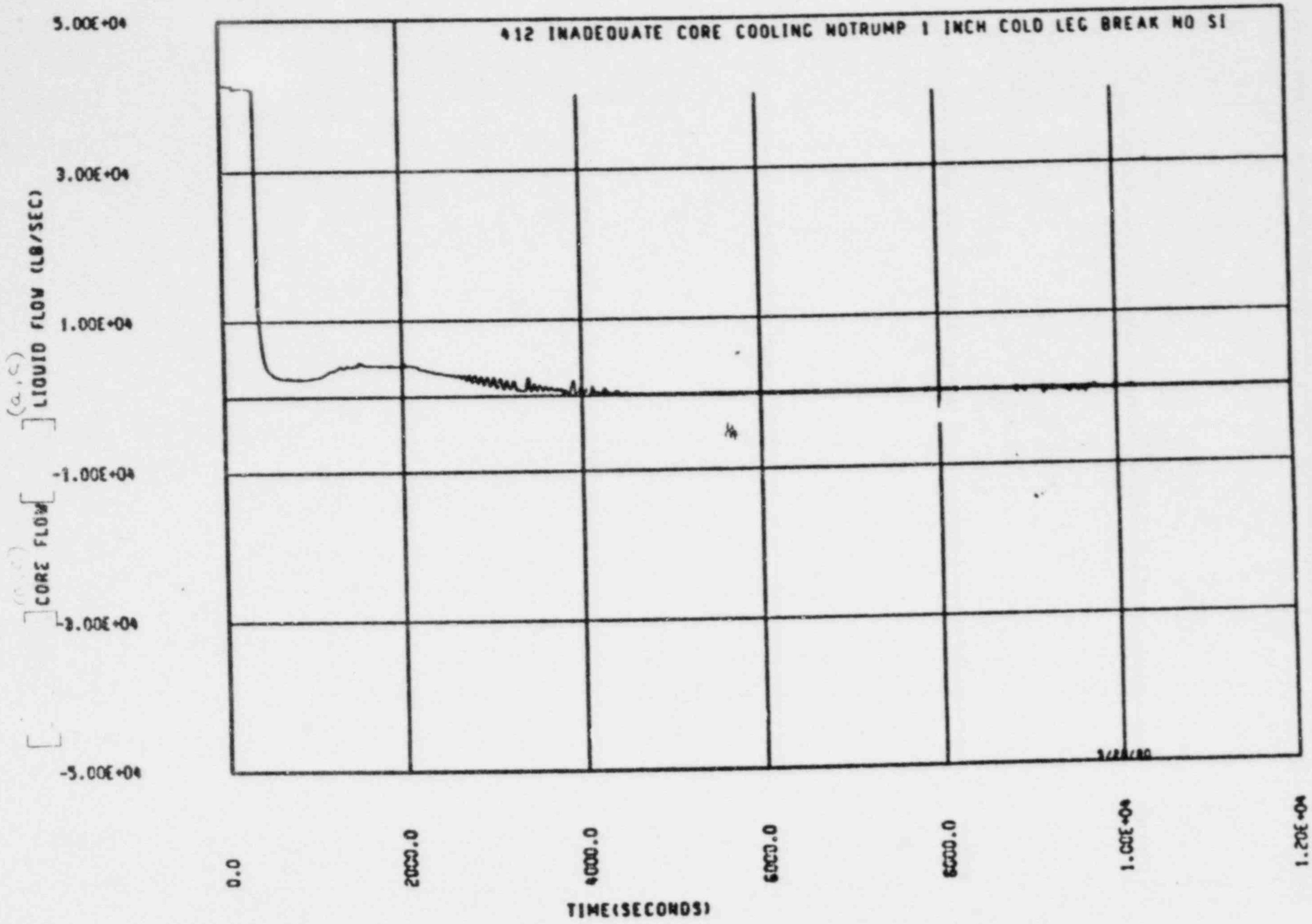
412 INADEQUATE CORE COOLING NOTRUMP 1 INCH COLD LEG BREAK NO SI
5.00E+04
3.00E+04
1.00E+04
-1.00E+04
-3.00E+04
-5.00E+04
CORE FLOW (a,c) LIQUID FLOW (LB/SEC) (a,c)
0.0
2000.0
4000.0
6000.0
8000.0
1.00E+04
1.20E+04
TIME(SECONDS)
3/28/80

Figure 31

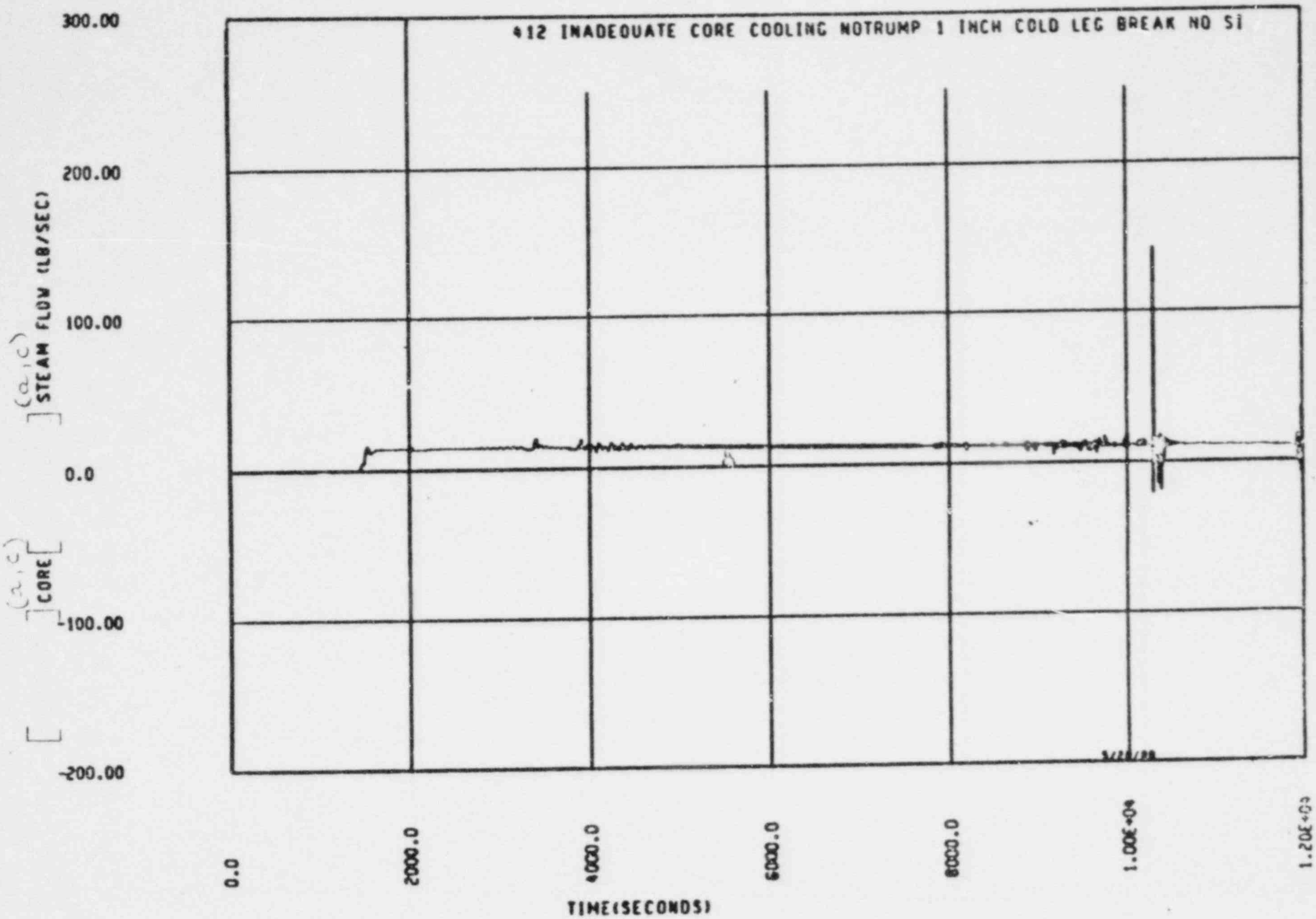

412 INADEQUATE CORE COOLING NOTRUMP 1 INCH COLD LEG BREAK NO SI
300.00
200.00
100.00
0.0
-100.00
-200.00
STEAM FLOW (LB/SEC)
CORE
(a,c)
(a,c)
0.0
2000.0
4000.0
6000.0
8000.0
1.00E+04
1.20E+04
TIME(SECONDS)
5/28/98

Figure 32

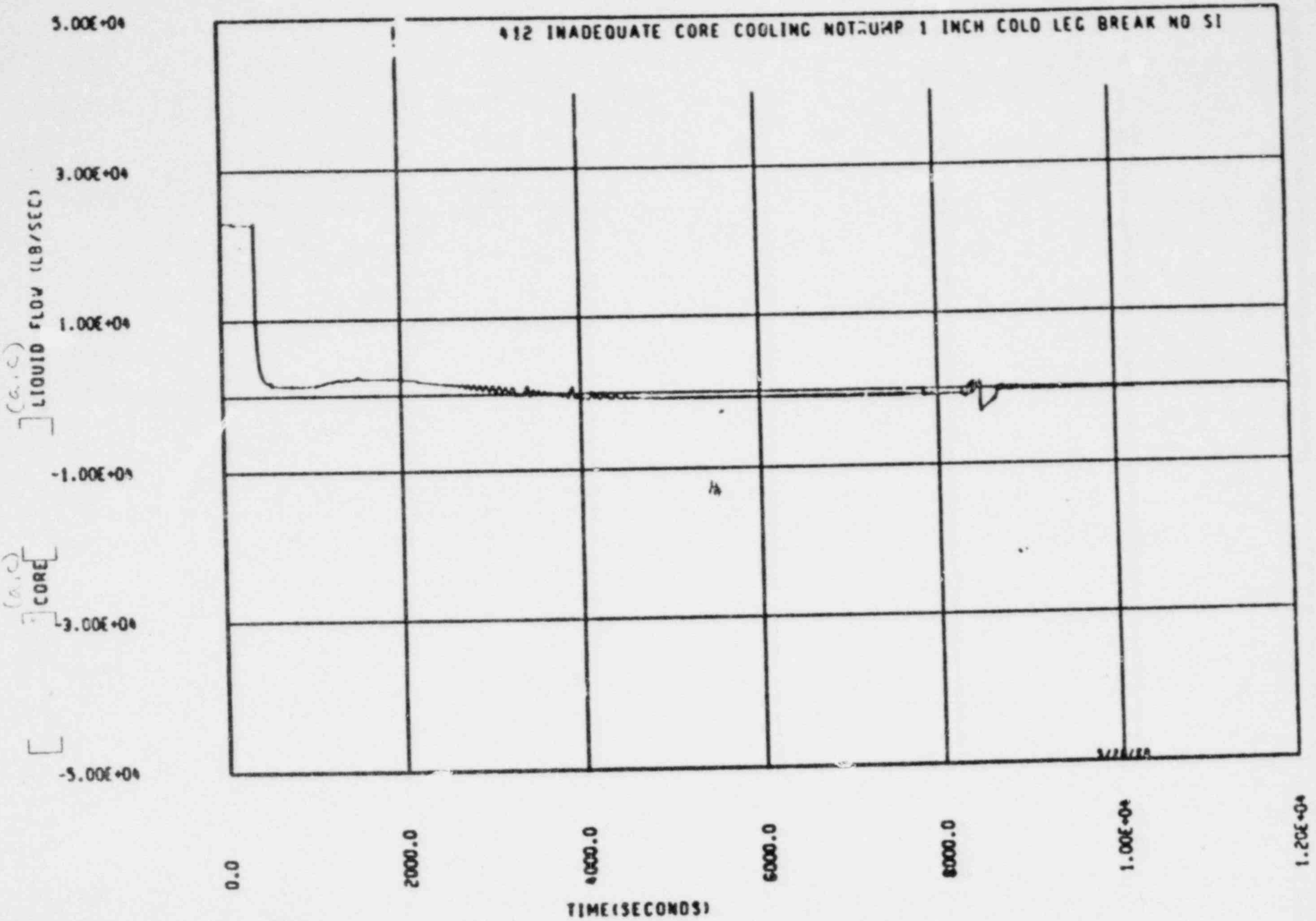

412 INADEQUATE CORE COOLING NOTRUMP 1 INCH COLD LEG BREAK NO SI
5.00E+04
3.00E+04
1.00E+04
-1.00E+04
-3.00E+04
-5.00E+04
(a,c)
LIQUID FLOW (LB/SEC)
(a,c)
CORE
0.0
2000.0
4000.0
6000.0
8000.0
1.00E+04
1.20E+04
TIME(SECONDS)

Figure 33

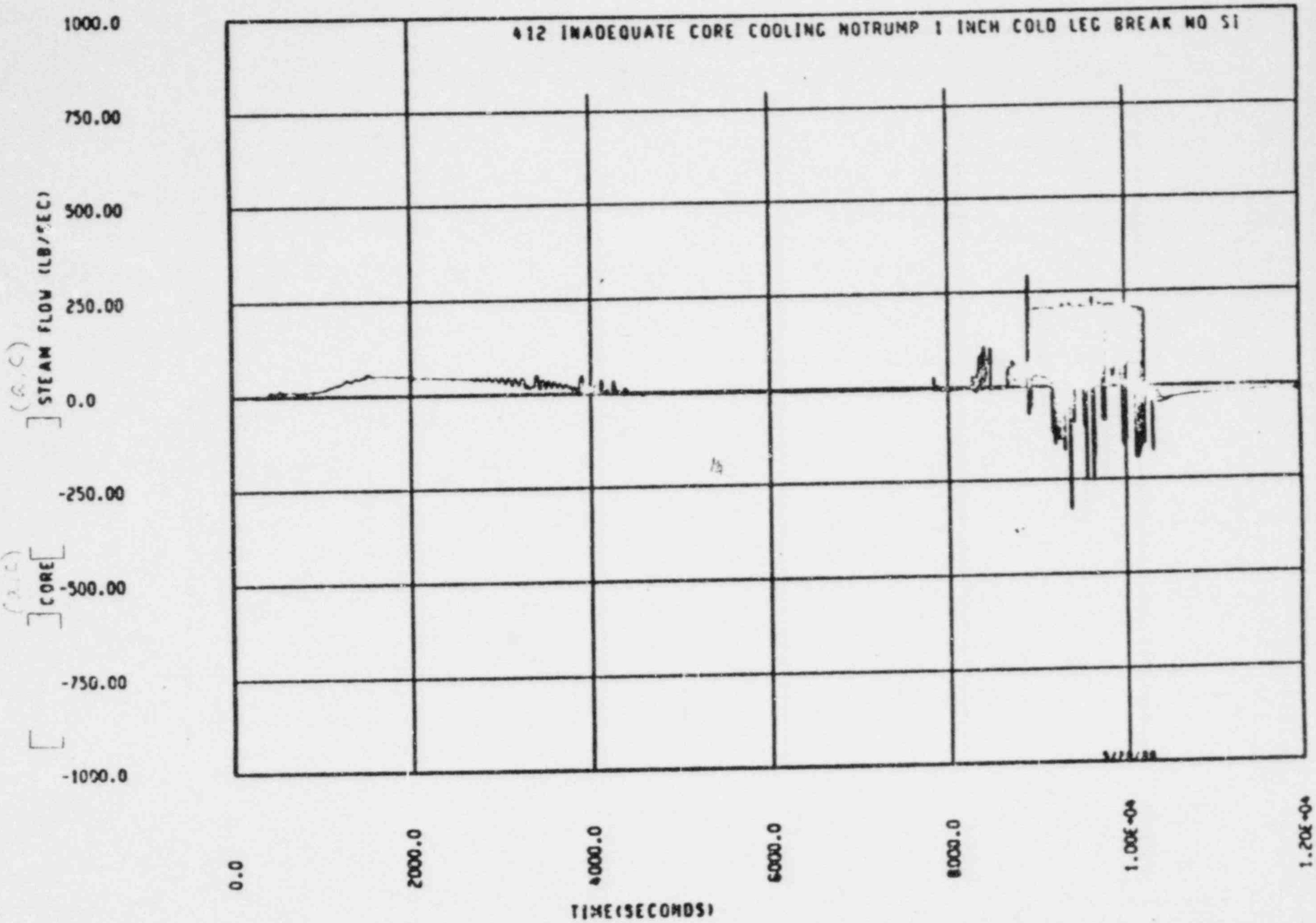

412 INADEQUATE CORE COOLING NOTRUMP 1 INCH COLD LEG BREAK NO SI
1000.0
750.00
500.00
250.00
0.0
-250.00
-500.00
-750.00
-1000.0
STEAM FLOW (LB/SEC)
CORE
(a,c)
(a,c)
0.0
2000.0
4000.0
6000.0
8000.0
1.00E+04
1.20E+04
TIME(SECONDS)

Figure 34

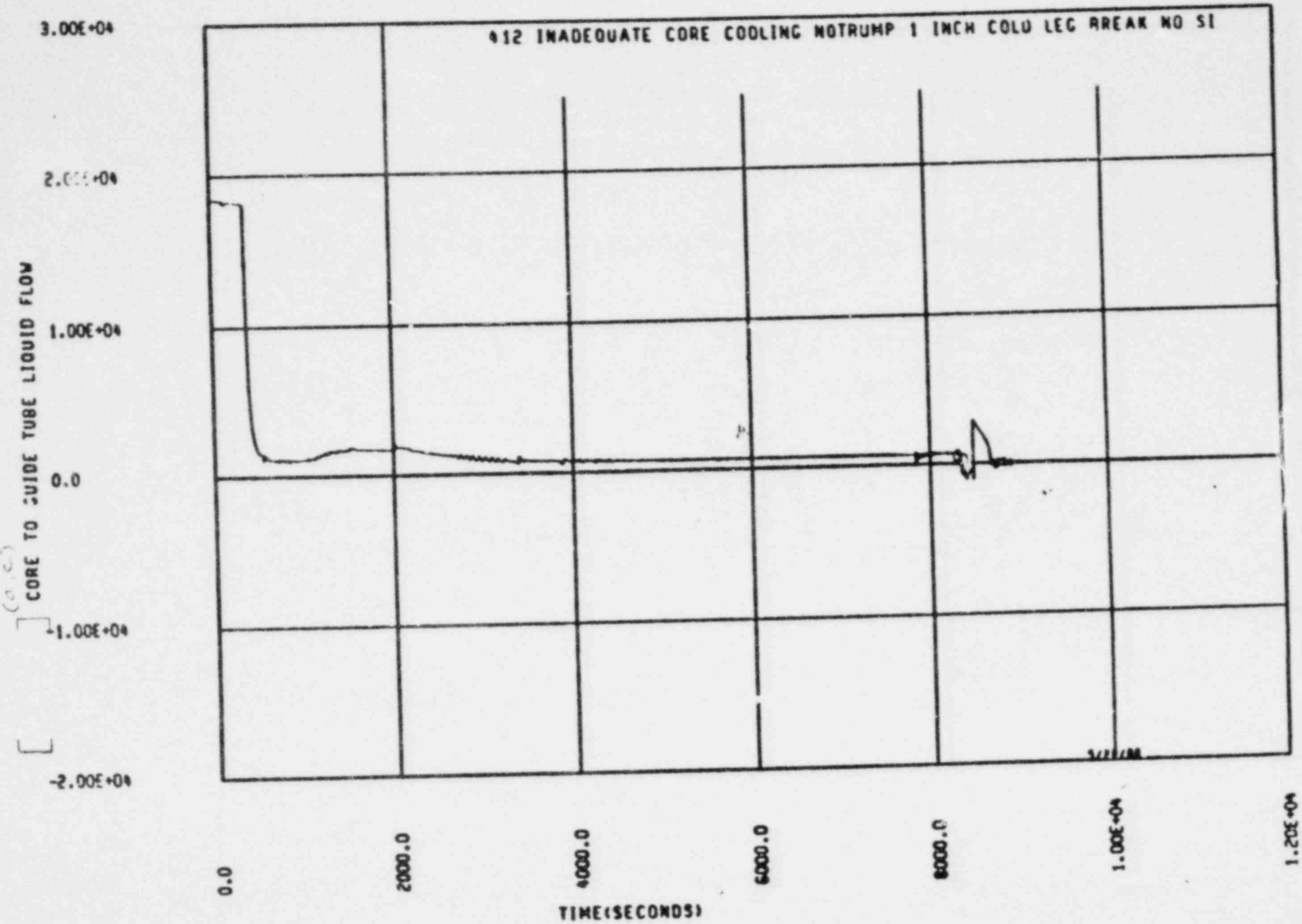

412 INADEQUATE CORE COOLING NOTRUMP 1 INCH COLD LEG BREAK NO SI
CORE TO GUIDE TUBE LIQUID FLOW
(a,c)
3.00E+04
2.00E+04
1.00E+04
0.0
-1.00E+04
-2.00E+04
0.0
2000.0
4000.0
6000.0
8000.0
1.00E+04
1.20E+04
TIME(SECONDS)

Figure 35

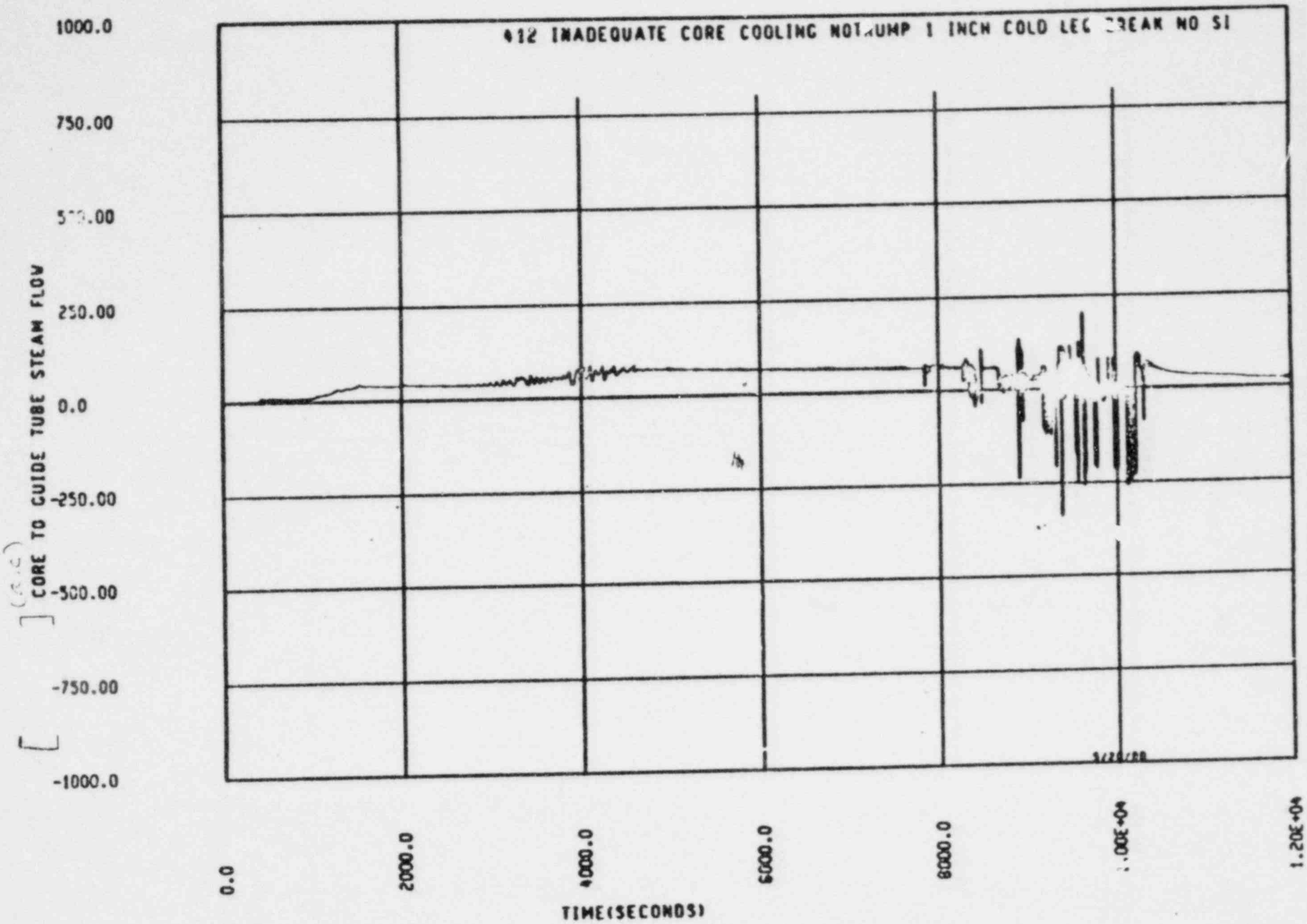

412 INADEQUATE CORE COOLING NOTRUMP 1 INCH COLD LEG BREAK NO SI
1000.0
750.00
500.00
250.00
0.0
-250.00
-500.00
-750.00
-1000.0
CORE TO GUIDE TUBE STEAM FLOW
(a,c)
0.0
2000.0
4000.0
6000.0
8000.0
1.00E+04
1.20E+04
TIME(SECONDS)

Figure 36

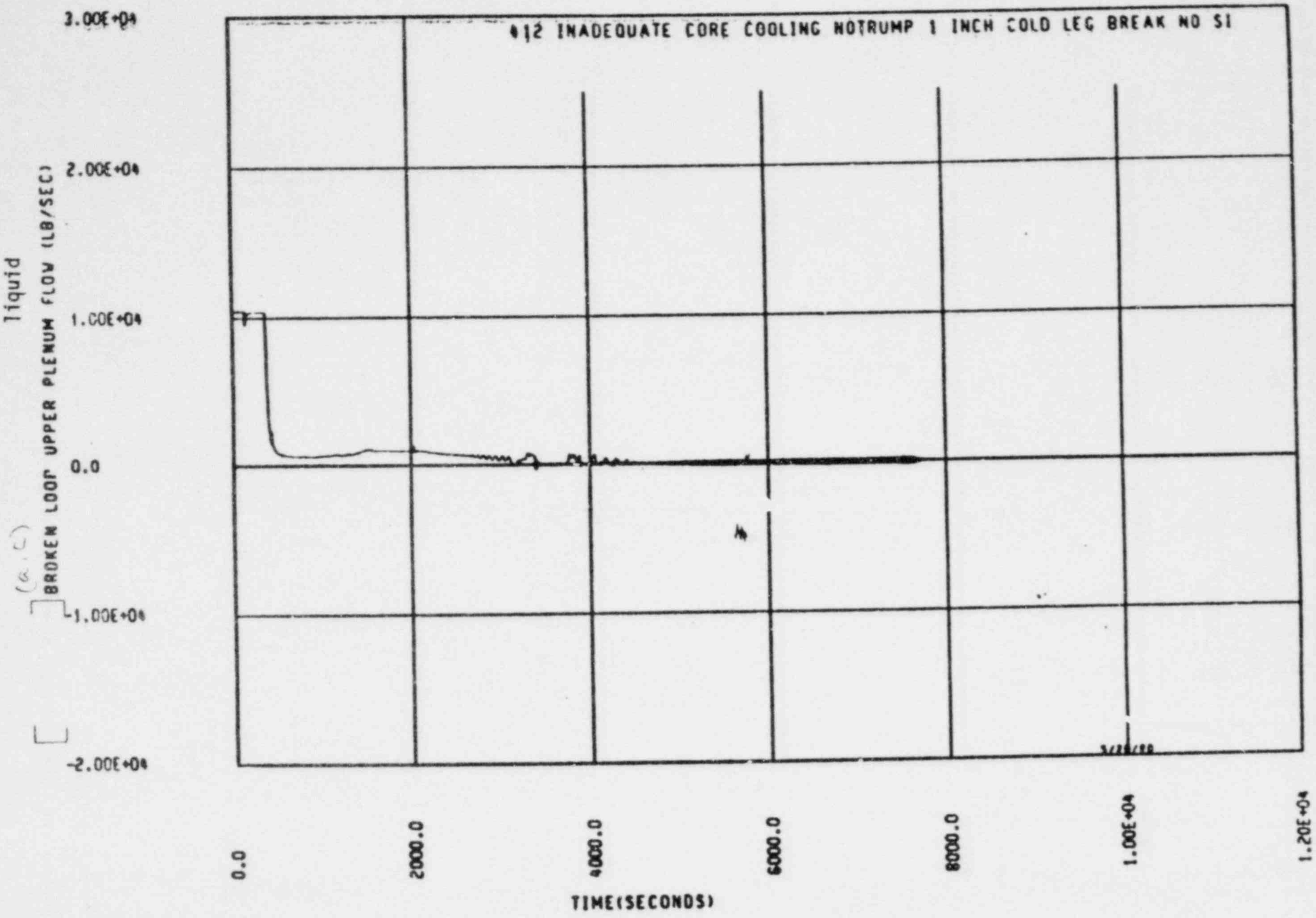
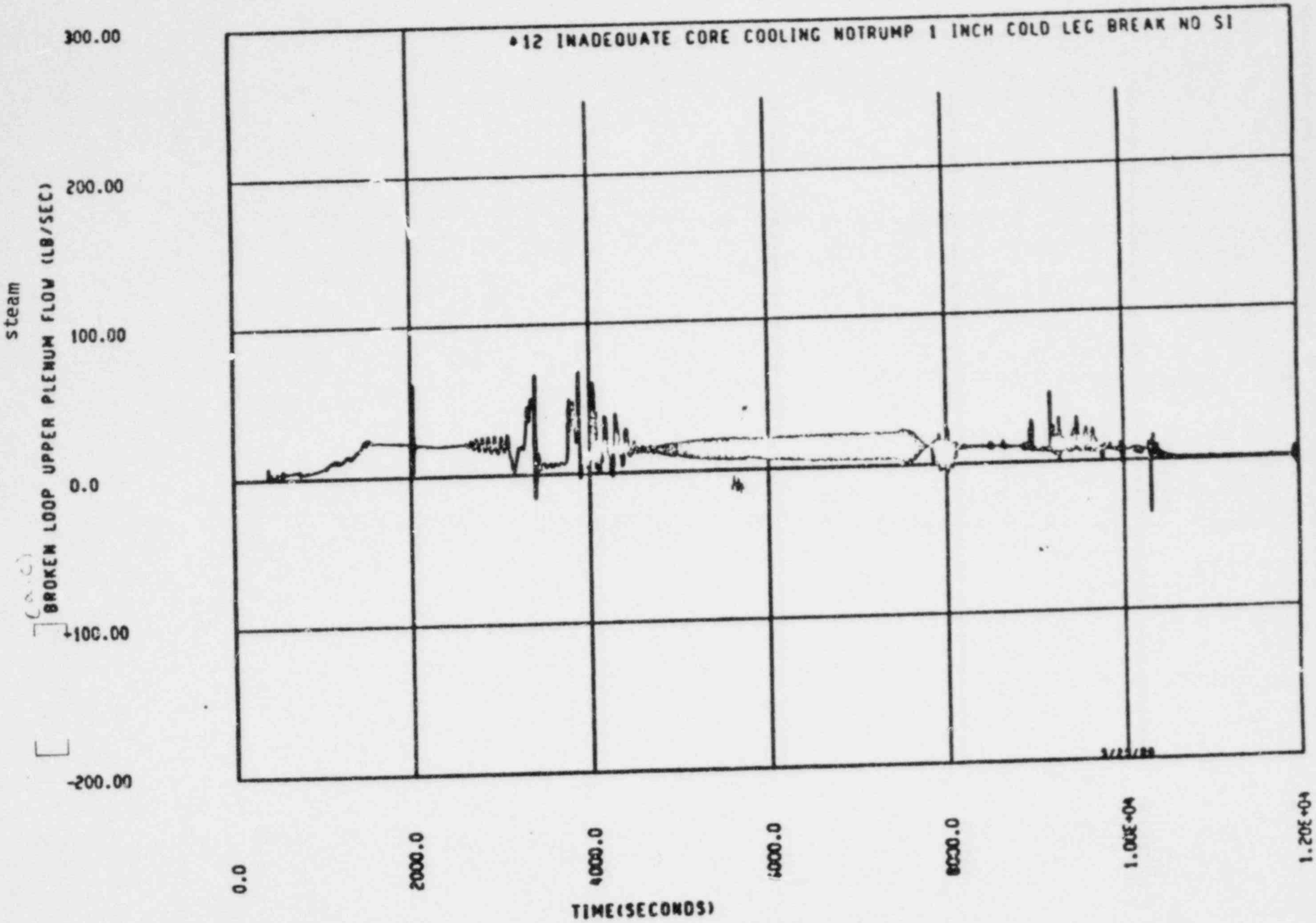

4|2 INADEQUATE CORE COOLING NOTRUMP 1 INCH COLD LEG BREAK NO SI
liquid
BROKEN LOOP UPPER PLENUM FLOW (LB/SEC)
(a,c)
3.00E+04
2.00E+04
1.00E+04
0.0
-1.00E+04
-2.00E+04
0.0
2000.0
4000.0
6000.0
8000.0
1.00E+04
1.20E+04
TIME(SECONDS)

Figure 37



#12 INADEQUATE CORE COOLING NOTRUMP 1 INCH COLD LEG BREAK NO SI
steam
BROKEN LOOP UPPER PLENUM FLOW (LB/SEC)
(a,c)
300.00
200.00
100.00
0.0
-100.00
-200.00
0.0
2000.0
4000.0
6000.0
8000.0
1.000E+04
1.200E+04
TIME(SECONDS)

Figure 38

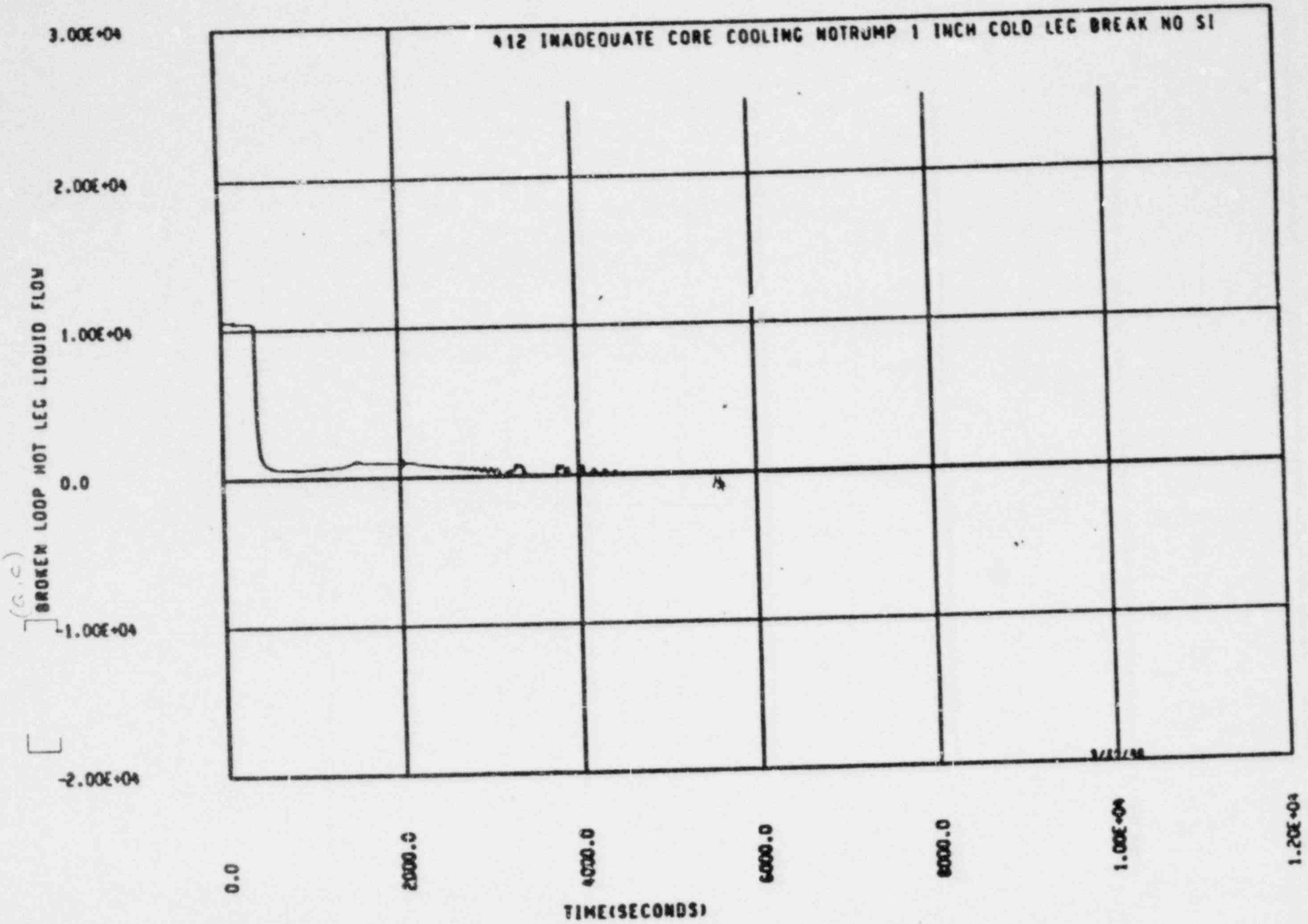

412 INADEQUATE CORE COOLING NOTRUMP 1 INCH COLD LEG BREAK NO SI
BROKEN LOOP HOT LEG LIQUID FLOW
(a,c)
3.00E+04
2.00E+04
1.00E+04
0.0
-1.00E+04
-2.00E+04
0.0
2000.0
4000.0
6000.0
8000.0
1.00E+04
1.20E+04
TIME(SECONDS)

Figure 39

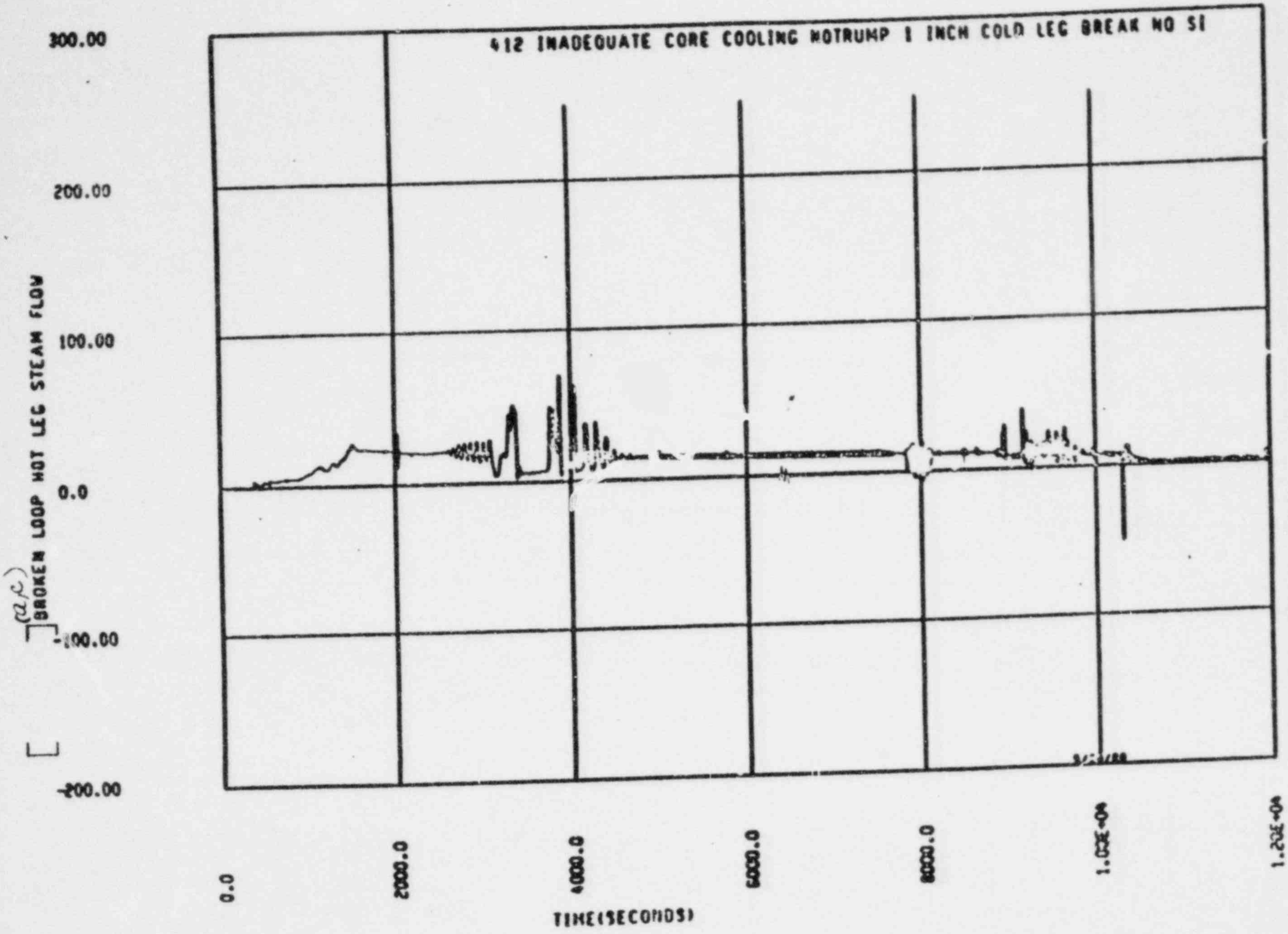

412 INADEQUATE CORE COOLING NOTRUMP 1 INCH COLD LEG BREAK NO SI
300.00
200.00
100.00
0.0
-100.00
-200.00
BROKEN LOOP HOT LEG STEAM FLOW
(a,c)
0.0
2000.0
4000.0
6000.0
8000.0
1.00E+04
1.20E+04
TIME(SECONDS)

Figure 40

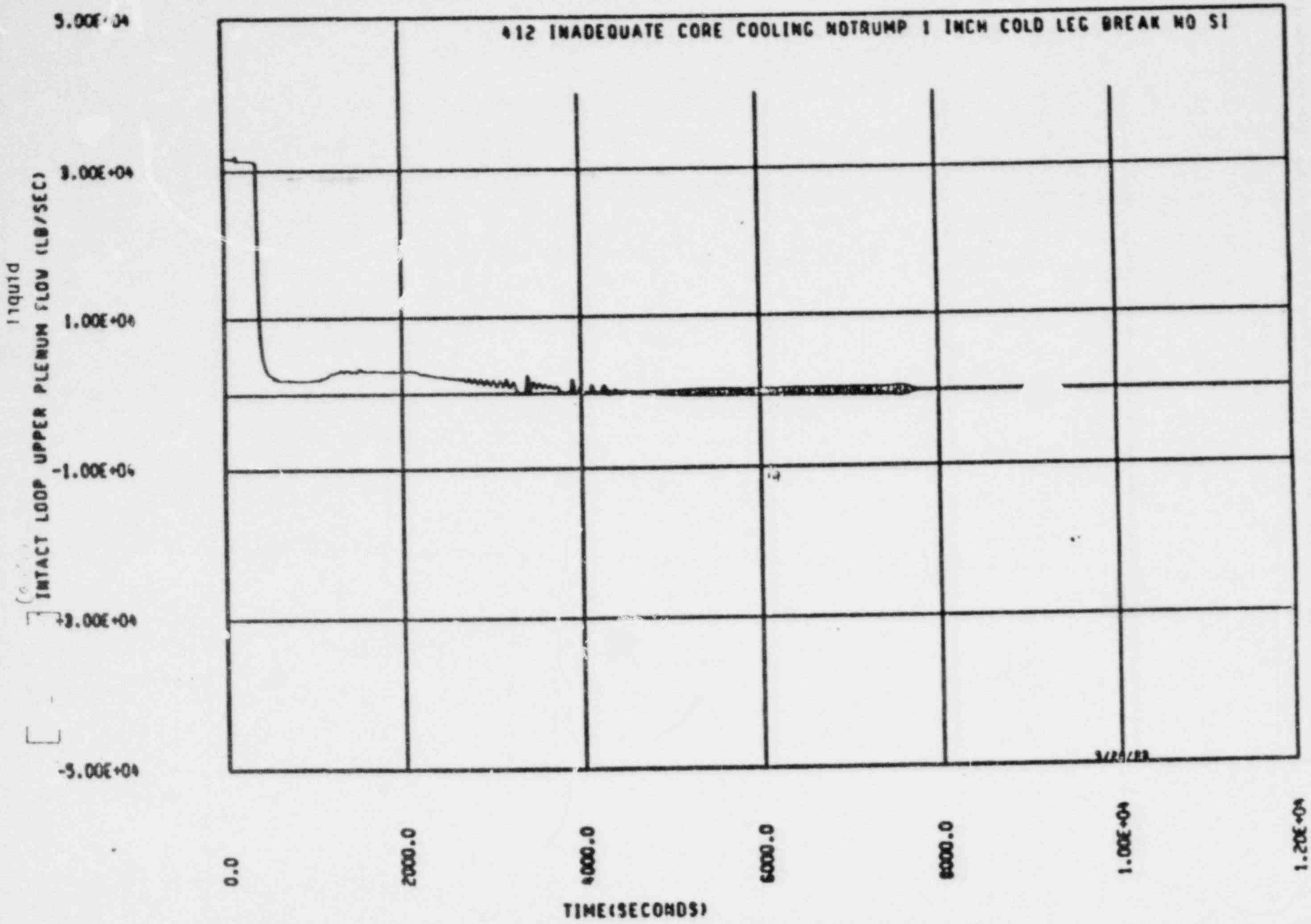

412 INADEQUATE CORE COOLING NOTRUMP 1 INCH COLD LEG BREAK NO SI
liquid
INTACT LOOP UPPER PLENUM FLOW (LB/SEC)
5.00E+04
3.00E+04
1.00E+04
-1.00E+04
-3.00E+04
-5.00E+04
0.0
2000.0
4000.0
6000.0
8000.0
1.00E+04
1.20E+04
TIME(SECONDS)

Figure 41

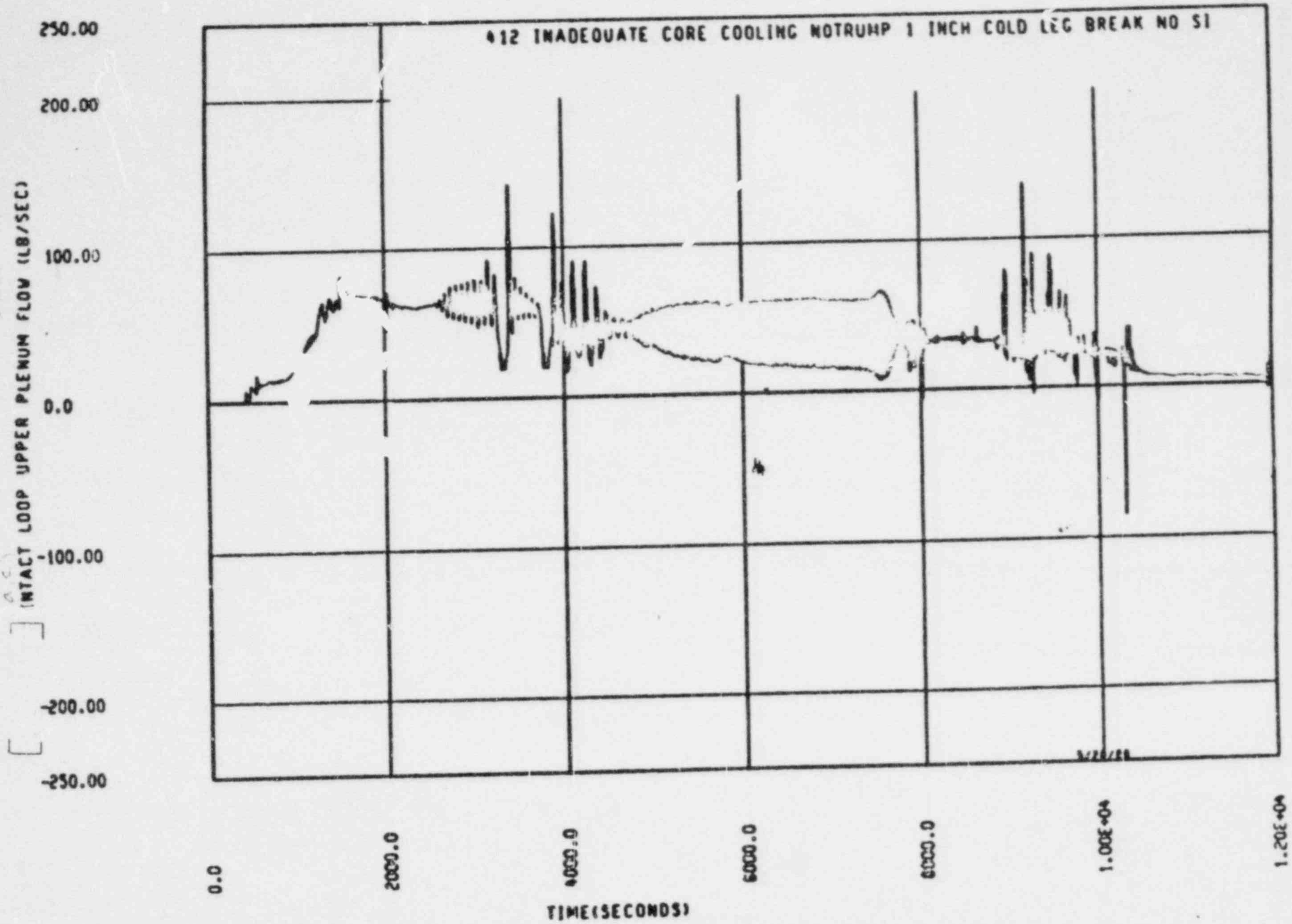

412 INADEQUATE CORE COOLING NOTRUMP 1 INCH COLD LEG BREAK NO SI
INTACT LOOP UPPER PLENUM FLOW (LB/SEC)
250.00
200.00
100.00
0.0
-100.00
-200.00
-250.00
0.0
2000.0
4000.0
6000.0
8000.0
1.00E+04
1.20E+04
TIME(SECONDS)

Figure 42

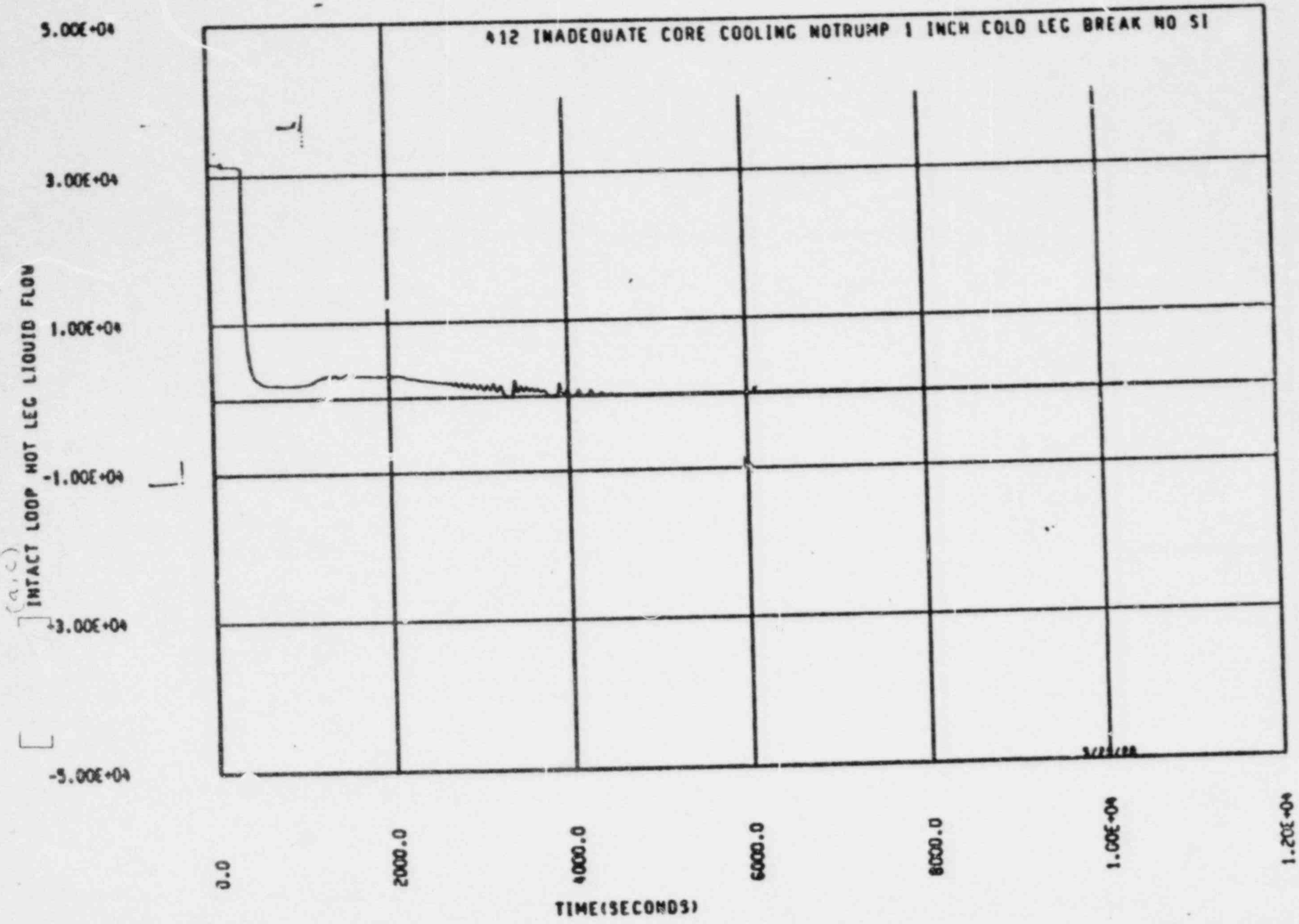

412 INADEQUATE CORE COOLING NOTRUMP 1 INCH COLD LEG BREAK NO SI
INTACT LOOP HOT LEG LIQUID FLOW
(a,c)
5.00E+04
3.00E+04
1.00E+04
-1.00E+04
-3.00E+04
-5.00E+04
0.0
2000.0
4000.0
6000.0
8000.0
1.00E+04
1.20E+04
TIME(SECONDS)

Figure 43

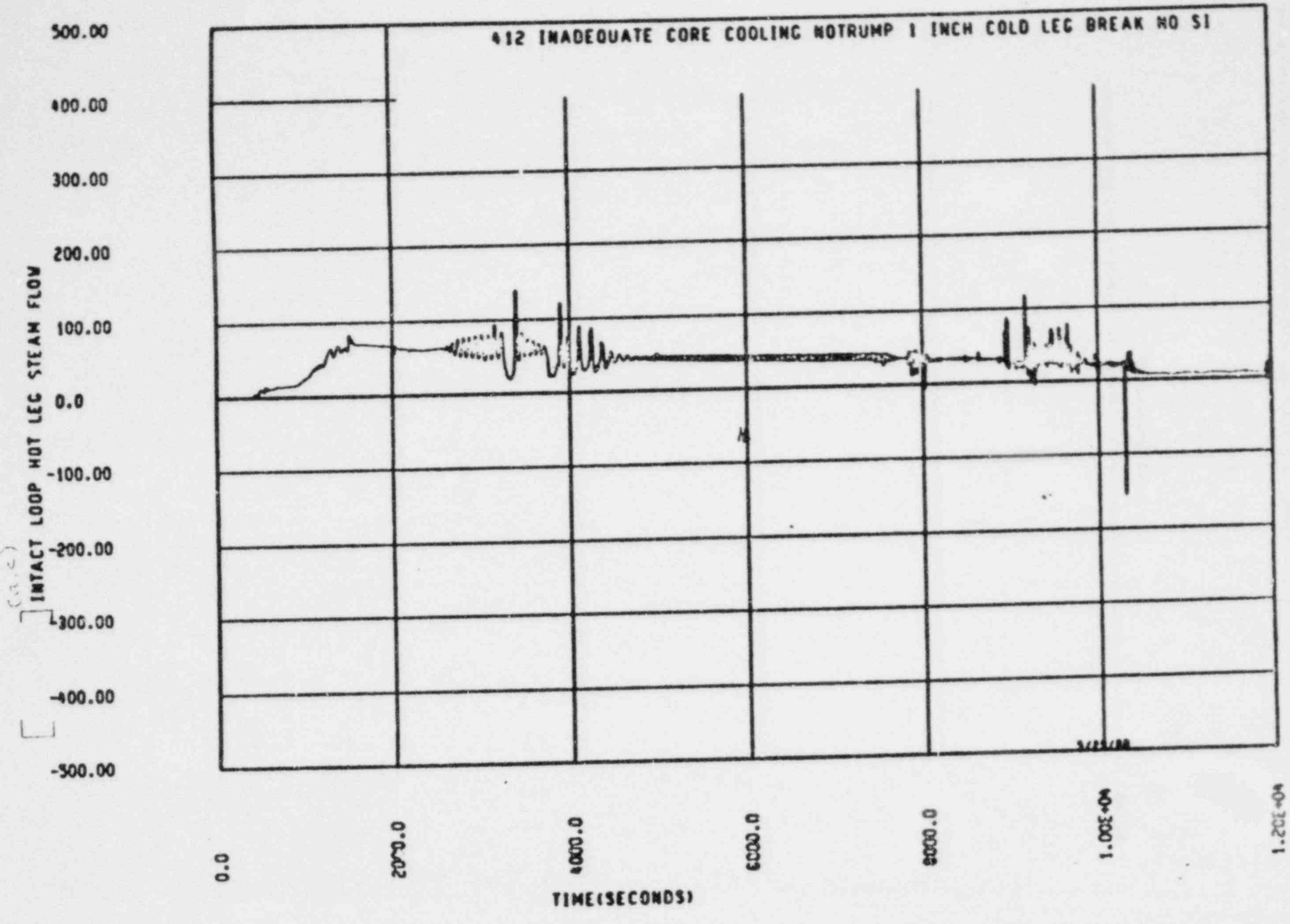

412 INADEQUATE CORE COOLING NOTRUMP 1 INCH COLD LEG BREAK NO SI
INTACT LOOP HOT LEG STEAM FLOW
(a,c)
500.00
400.00
300.00
200.00
100.00
0.0
-100.00
-200.00
-300.00
-400.00
-500.00
0.0
2000.0
4000.0
6000.0
8000.0
1.000E+04
1.200E+04
TIME(SECONDS)
5/25/88

Figure 44

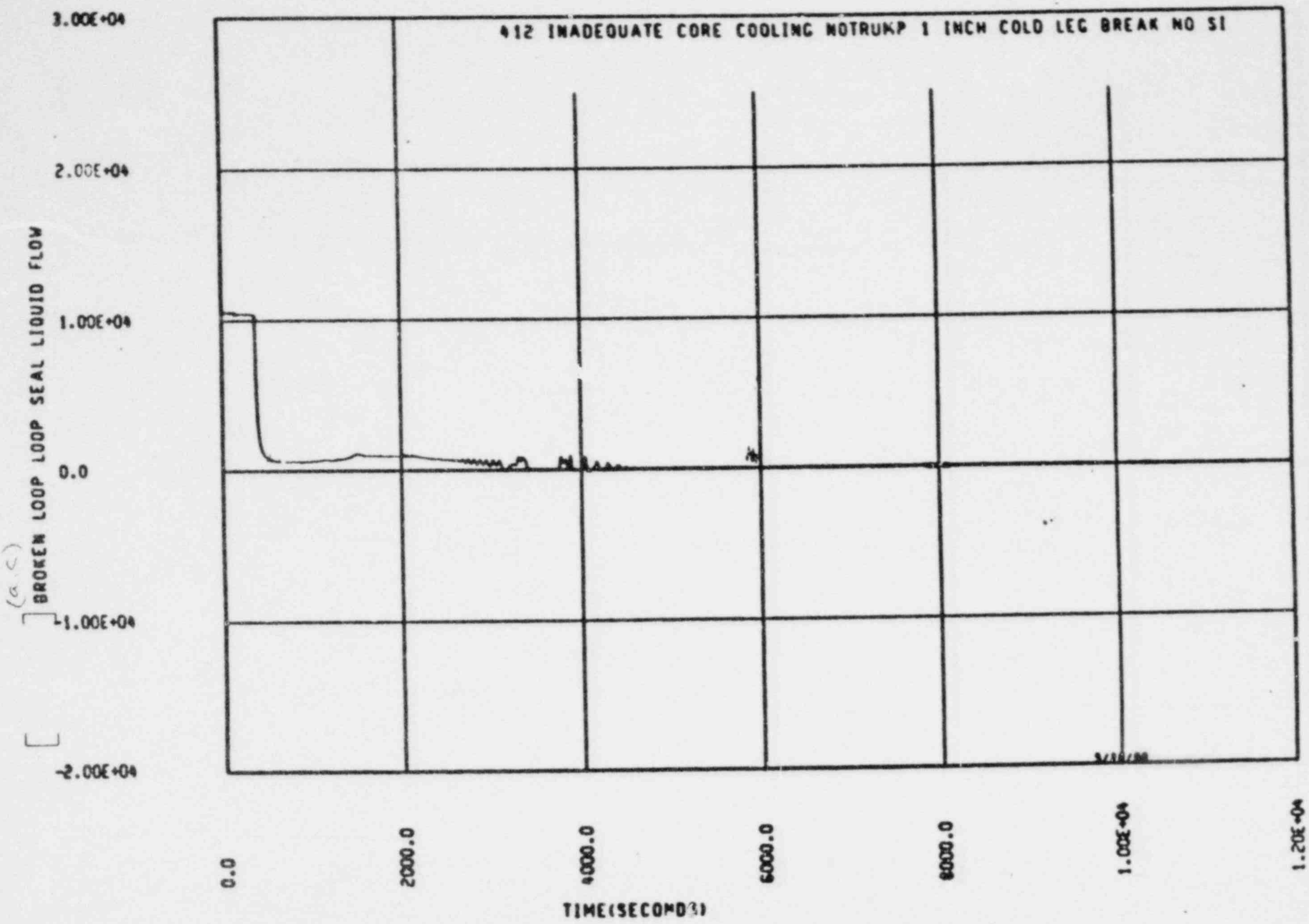

412 INADEQUATE CORE COOLING NOTRUMP 1 INCH COLD LEG BREAK NO SI
BROKEN LOOP LOOP SEAL LIQUID FLOW
(a,c)
3.00E+04
2.00E+04
1.00E+04
0.0
-1.00E+04
-2.00E+04
0.0
2000.0
4000.0
6000.0
8000.0
1.00E+04
1.20E+04
TIME(SECONDS)

Figure 45

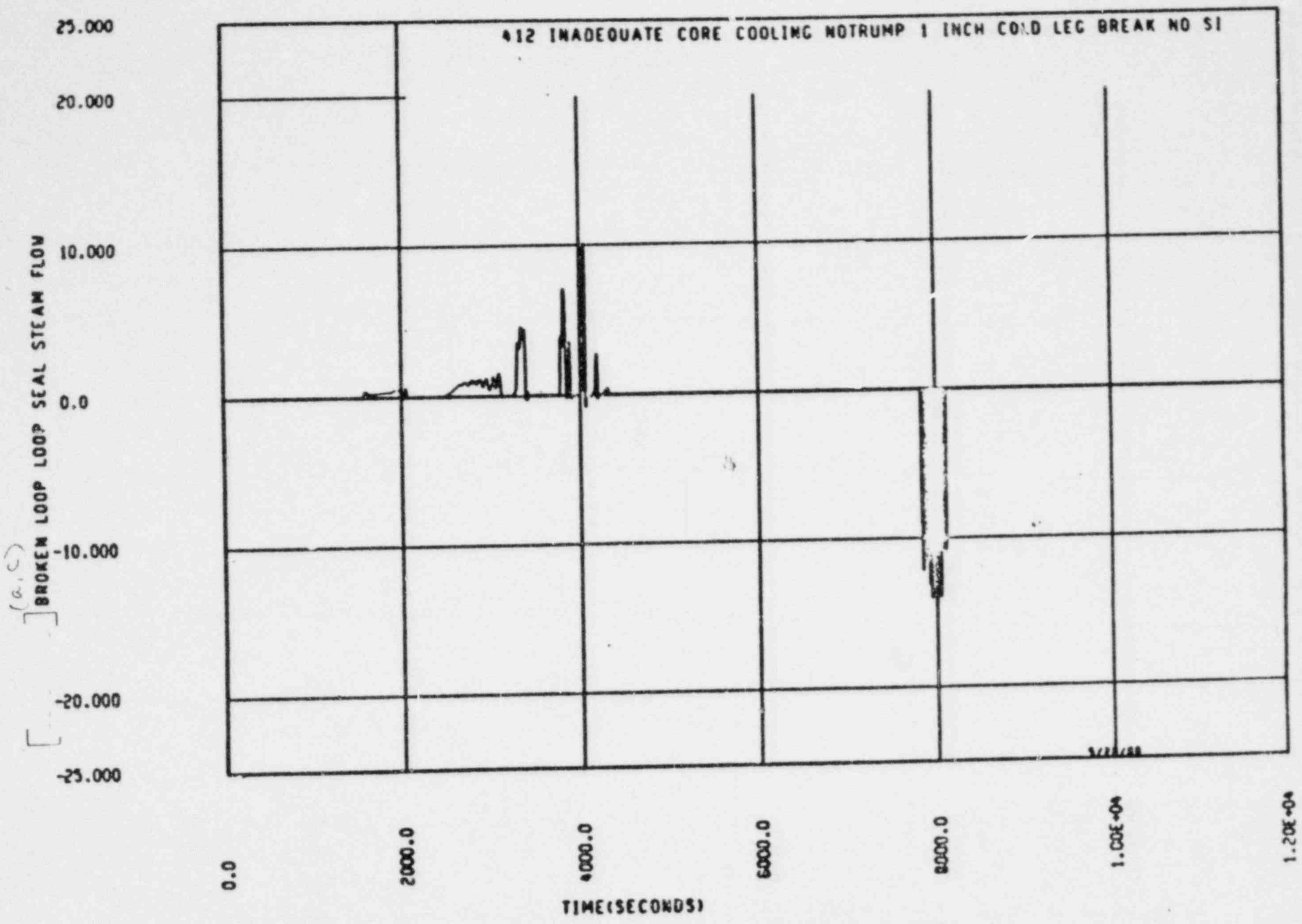

412 INADEQUATE CORE COOLING NOTRUMP 1 INCH COLD LEG BREAK NO SI
BROKEN LOOP LOOP SEAL STEAM FLOW
(a,c)
25.000
20.000
10.000
0.0
-10.000
-20.000
-25.000
0.0
2000.0
4000.0
6000.0
8000.0
1.00E+04
1.20E+04
TIME(SECONDS)

Figure 46

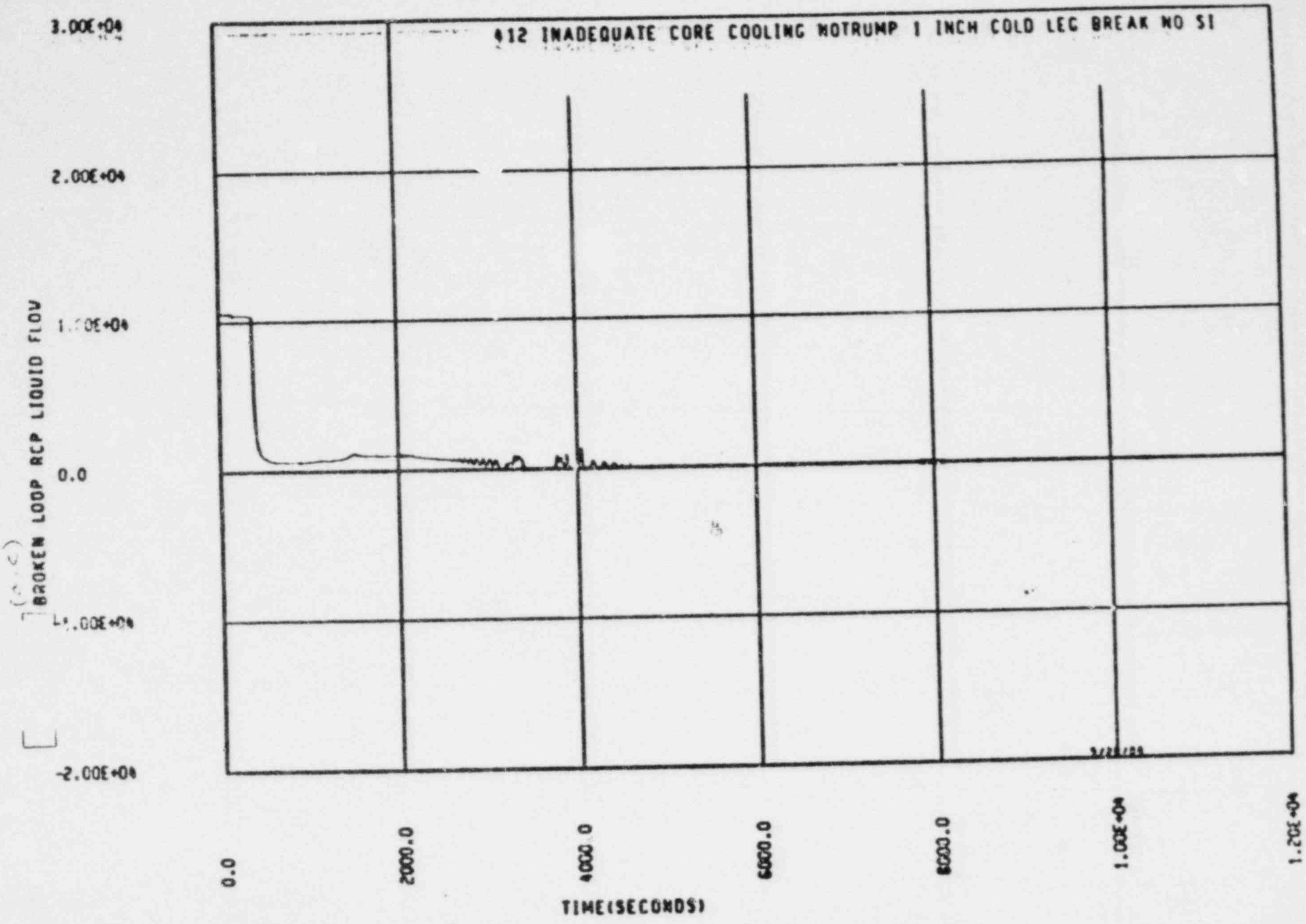

412 INADEQUATE CORE COOLING NOTRUMP 1 INCH COLD LEG BREAK NO SI
BROKEN LOOP RCP LIQUID FLOW
(a,c)
3.00E+04
2.00E+04
1.00E+04
0.0
-1.00E+04
-2.00E+04
0.0
2000.0
4000.0
6000.0
8000.0
1.00E+04
1.20E+04
TIME(SECONDS)

Figure 47

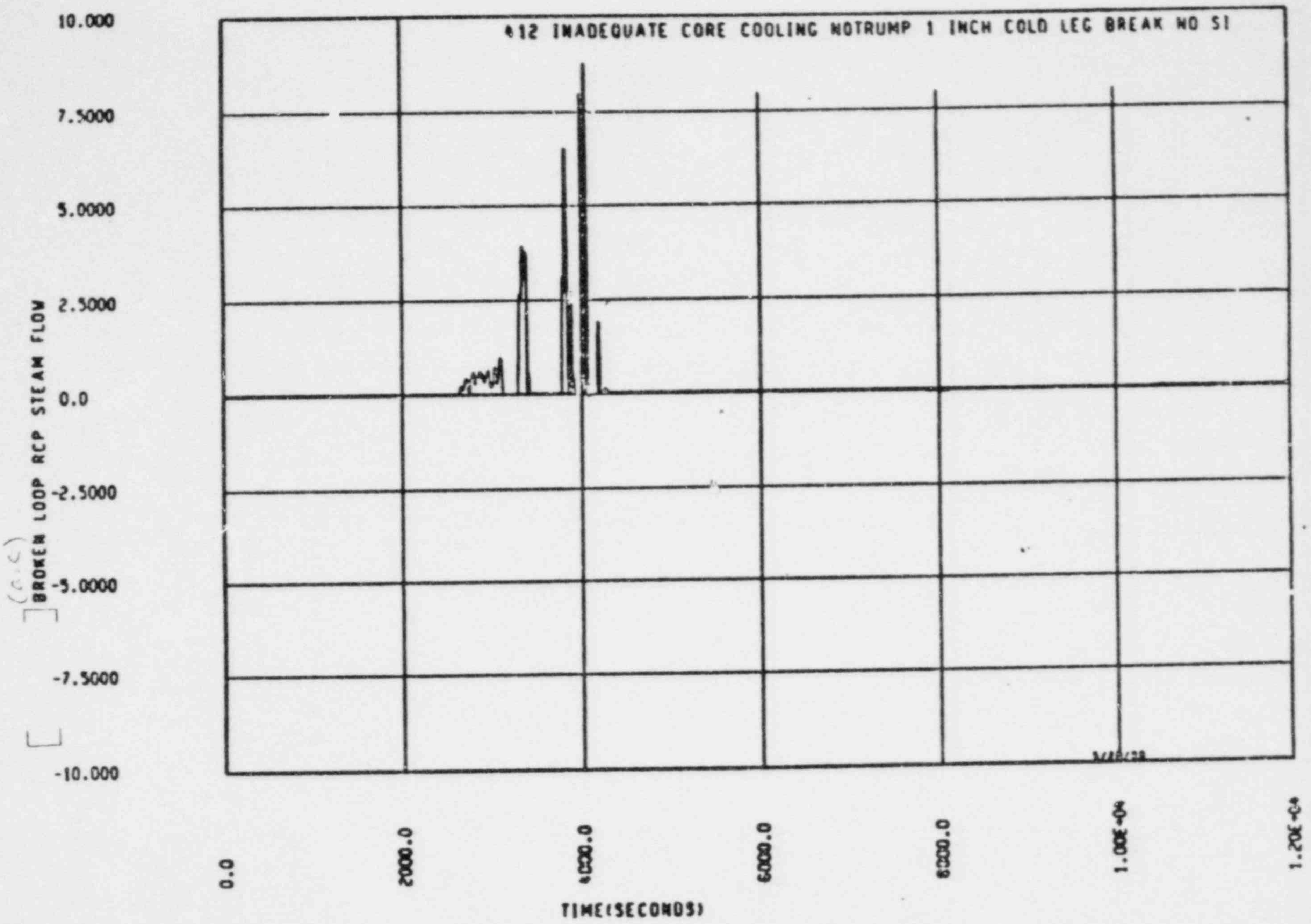

412 INADEQUATE CORE COOLING NOTRUMP 1 INCH COLD LEG BREAK NO SI
(a,c)
BROKEN LOOP RCP STEAM FLOW
10.000
7.5000
5.0000
2.5000
0.0
-2.5000
-5.0000
-7.5000
-10.000
0.0
2000.0
4000.0
6000.0
8000.0
1.00E+04
1.20E+04
TIME(SECONDS)

Figure 48

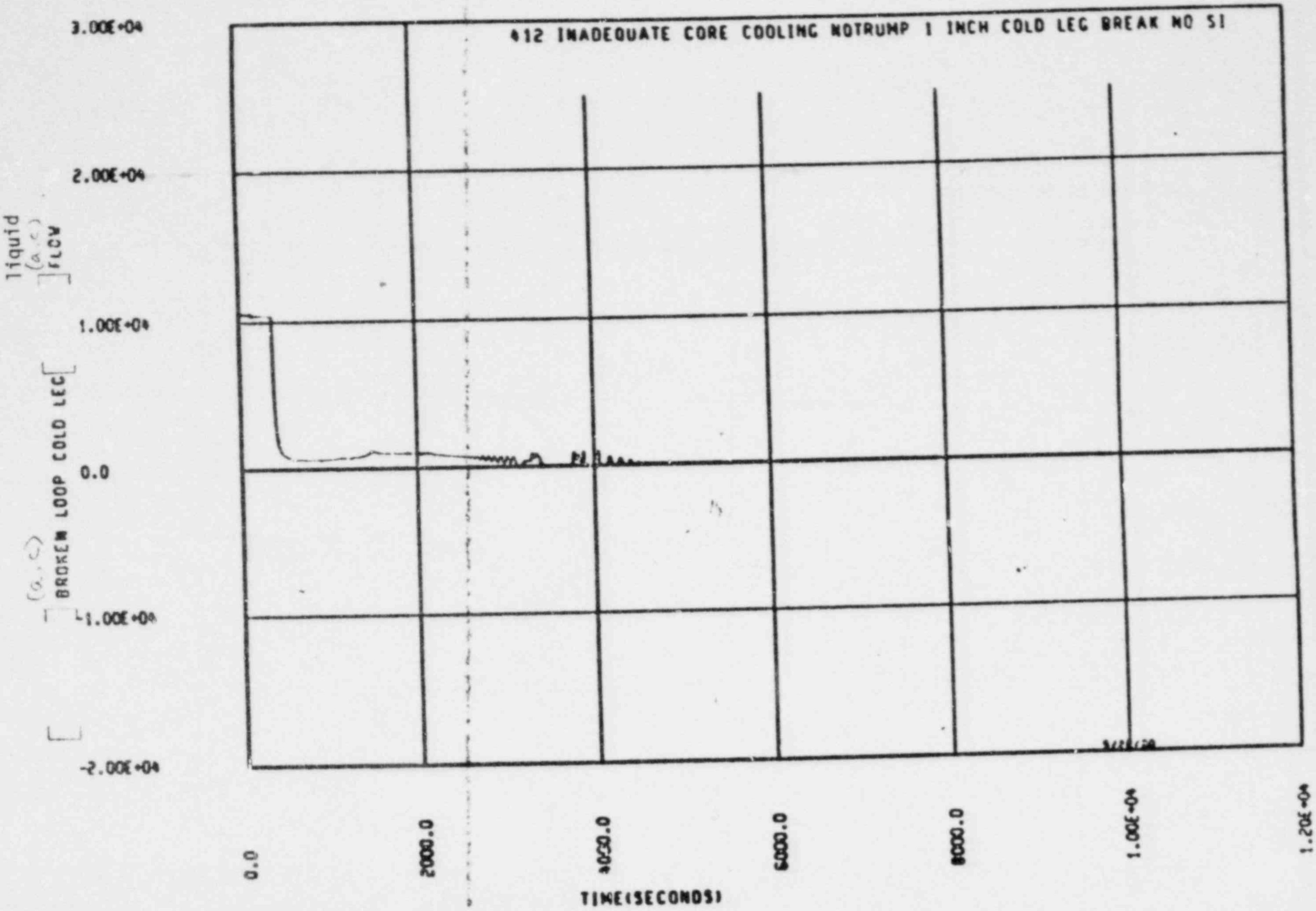

412 INADEQUATE CORE COOLING NOTRUMP 1 INCH COLD LEG BREAK NO SI
(a,c)
BROKEN LOOP COLD LEG liquid
(a,c)
FLOW
3.00E+04
2.00E+04
1.00E+04
0.0
-1.00E+04
-2.00E+04
0.0
2000.0
4000.0
6000.0
8000.0
1.00E+04
1.20E+04
TIME(SECONDS)

Figure 49

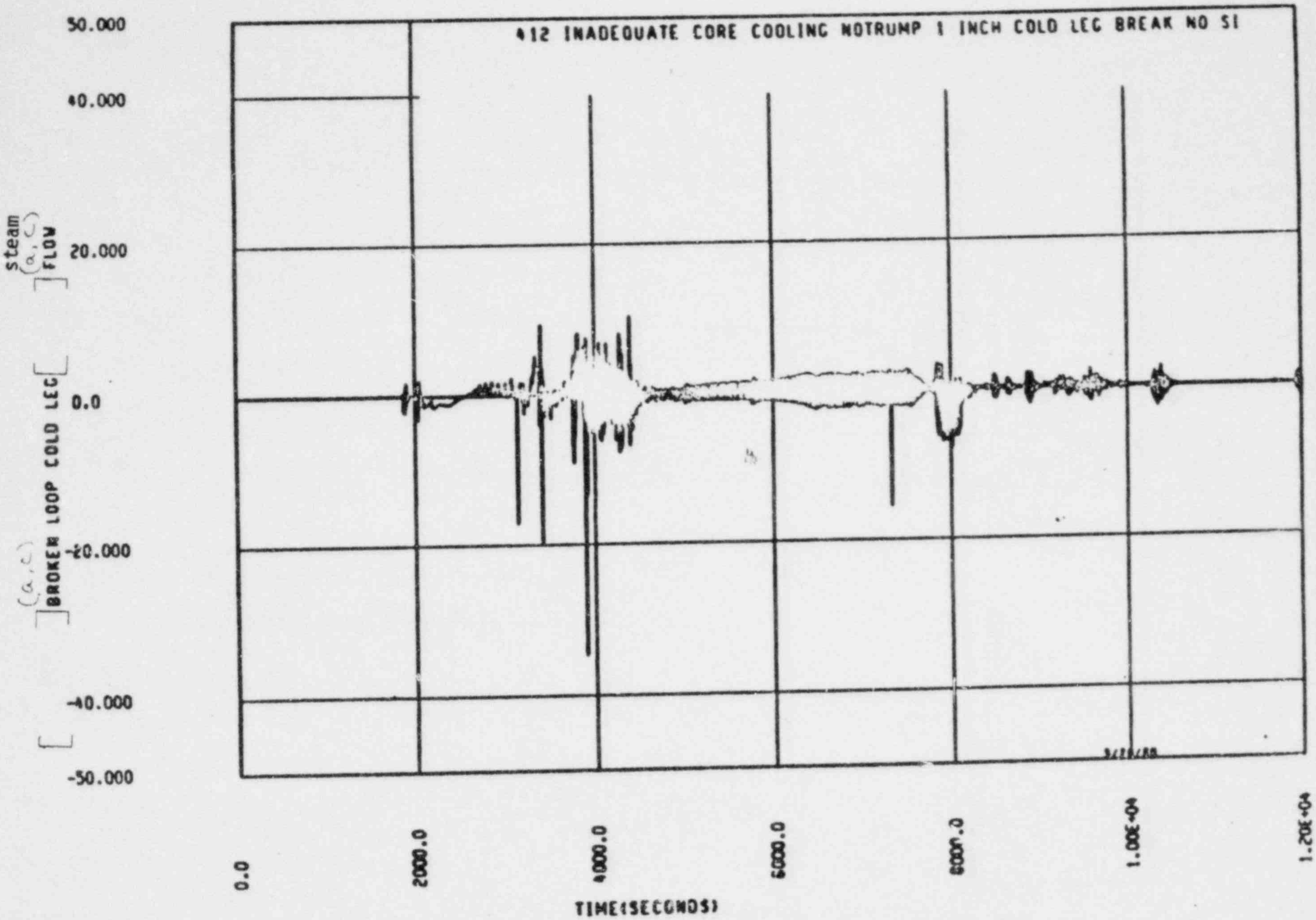

412 INADEQUATE CORE COOLING NOTRUMP 1 INCH COLD LEG BREAK NO SI
steam (a,c) FLOW
(a,c) BROKEN LOOP COLD LEG
50.000
40.000
20.000
0.0
-20.000
-40.000
-50.000
0.0
2000.0
4000.0
6000.0
8000.0
1.00E+04
1.20E+04
TIME(SECONDS)

Figure 50

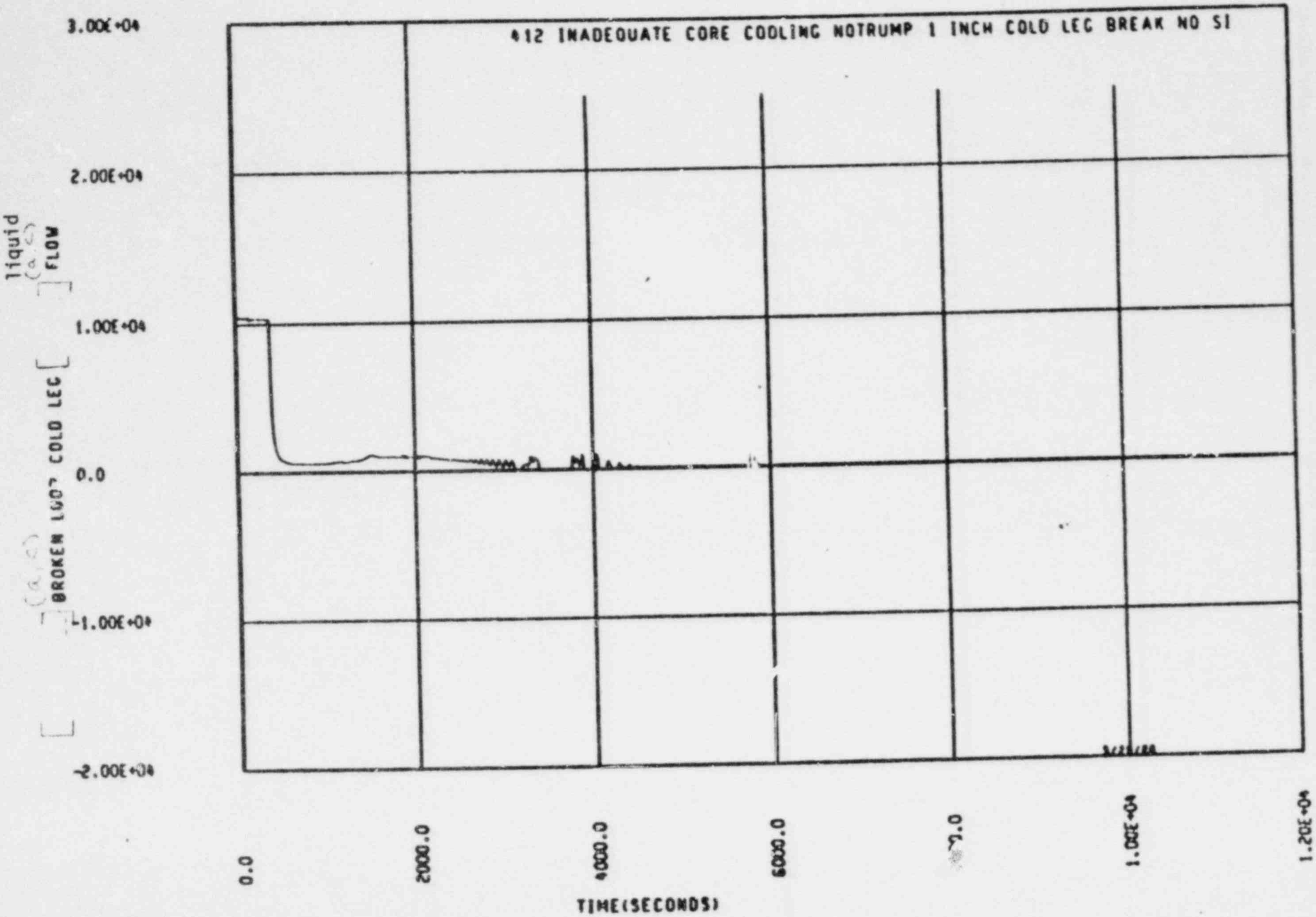

412 INADEQUATE CORE COOLING NOTRUMP 1 INCH COLD LEG BREAK NO SI
liquid
(a,c)
[ ] BROKEN LOOP COLD LEG [ ] FLOW
(a,c)
3.00E+04
2.00E+04
1.00E+04
0.0
-1.00E+04
-2.00E+04
0.0
2000.0
4000.0
6000.0
[illegible].0
1.00E+04
1.20E+04
TIME(SECONDS)

Figure 51

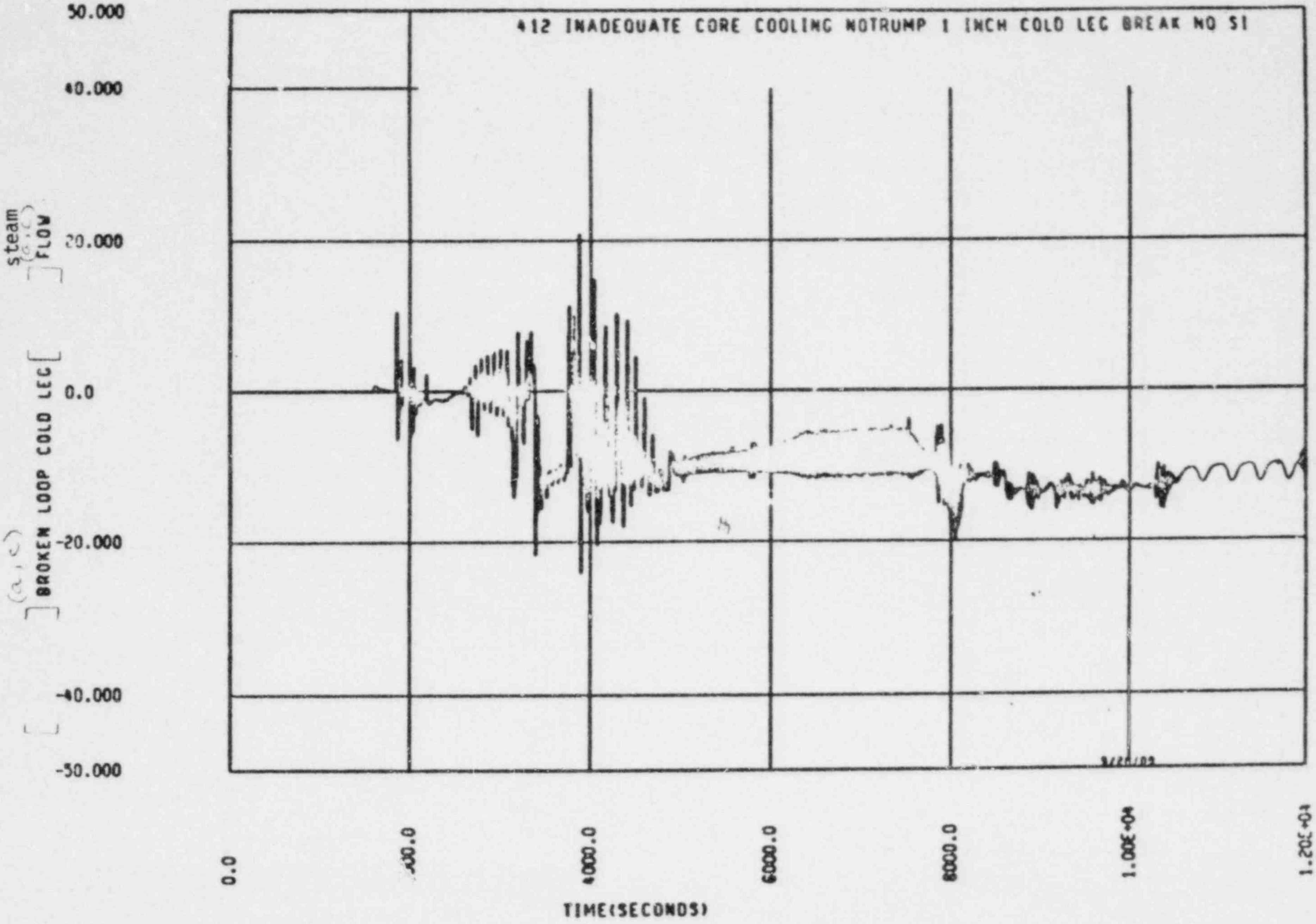

412 INADEQUATE CORE COOLING NOTRUMP 1 INCH COLD LEG BREAK NO SI
50.000
40.000
20.000
0.0
-20.000
-40.000
-50.000
BROKEN LOOP COLD LEG steam FLOW
(a,c)
(a,c)
0.0
000.0
4000.0
6000.0
8000.0
1.00E+04
1.20E+04
TIME(SECONDS)

Figure 52

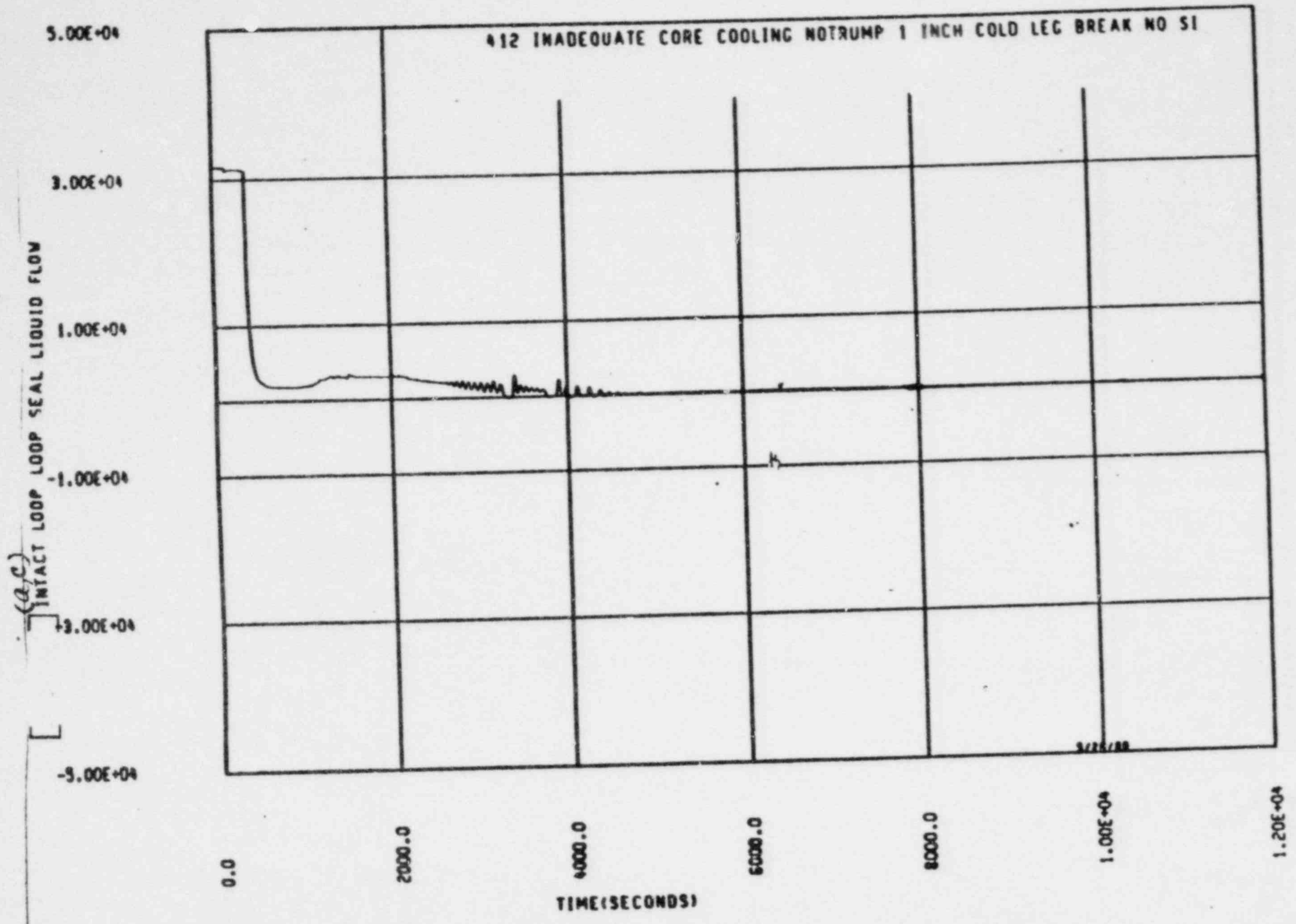

412 INADEQUATE CORE COOLING NOTRUMP 1 INCH COLD LEG BREAK NO SI
INTACT LOOP LOOP SEAL LIQUID FLOW
(a,c)
5.00E+04
3.00E+04
1.00E+04
-1.00E+04
-3.00E+04
-5.00E+04
0.0
2000.0
4000.0
6000.0
8000.0
1.00E+04
1.20E+04
TIME(SECONDS)

Figure 53

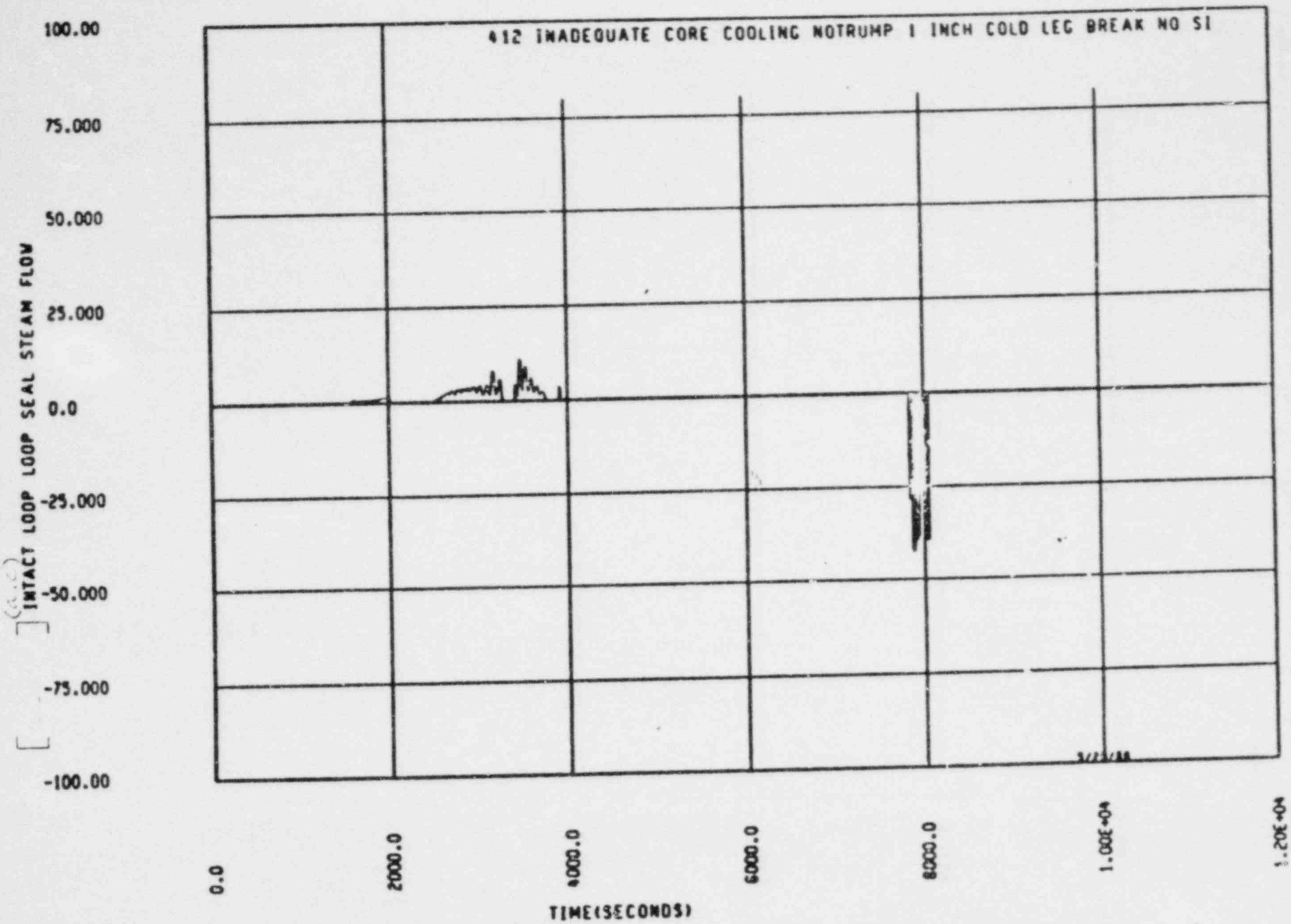

412 INADEQUATE CORE COOLING NOTRUMP 1 INCH COLD LEG BREAK NO SI
INTACT LOOP LOOP SEAL STEAM FLOW
(a,c)
100.00
75.000
50.000
25.000
0.0
-25.000
-50.000
-75.000
-100.00
0.0
2000.0
4000.0
6000.0
8000.0
1.000E+04
1.200E+04
TIME(SECONDS)

Figure 54

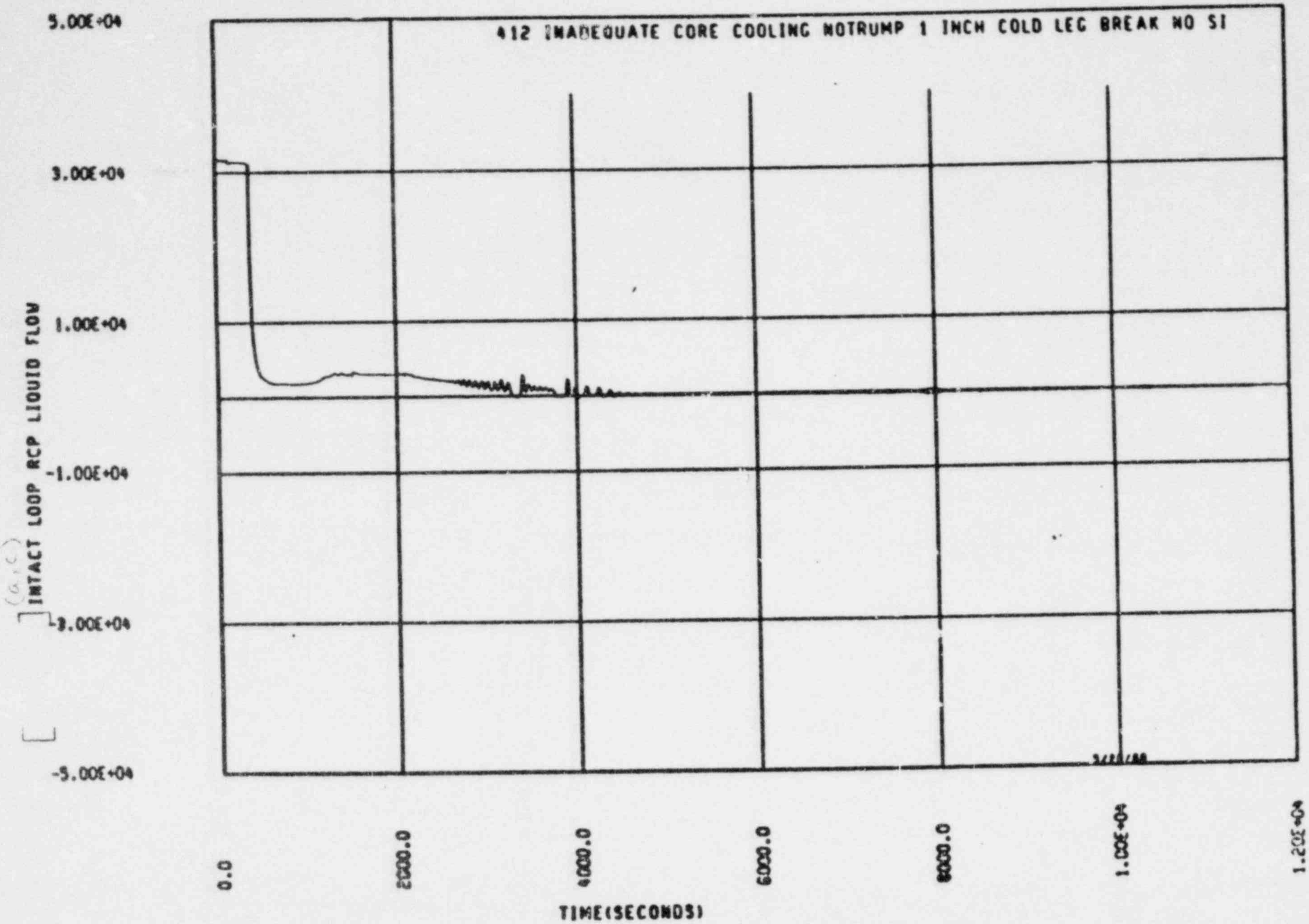

412 INADEQUATE CORE COOLING NOTRUMP 1 INCH COLD LEG BREAK NO SI
INTACT LOOP RCP LIQUID FLOW
(a,c)
5.00E+04
3.00E+04
1.00E+04
-1.00E+04
-3.00E+04
-5.00E+04
0.0
2000.0
4000.0
6000.0
8000.0
1.00E+04
1.20E+04
TIME(SECONDS)

Figure 55

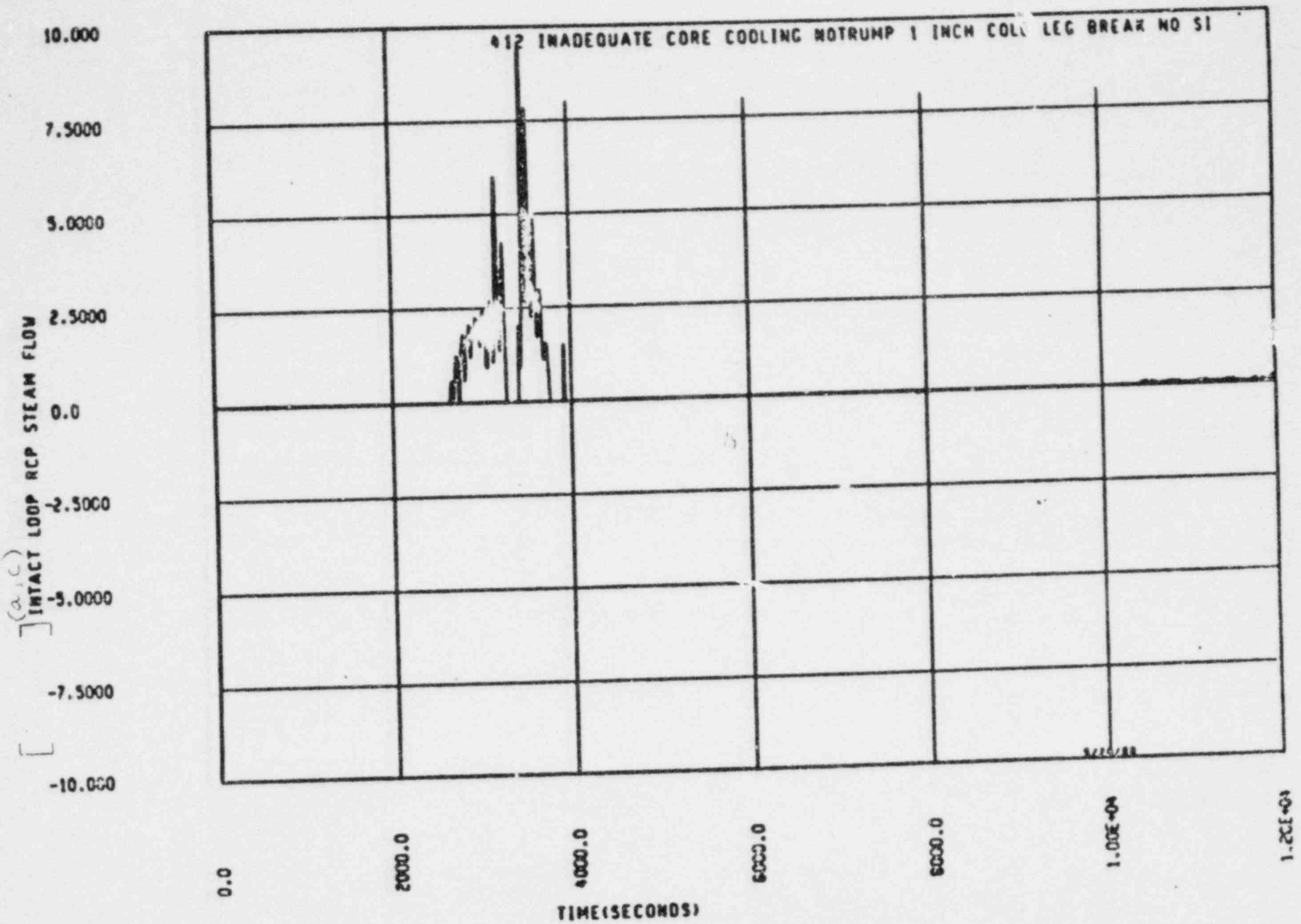

412 INADEQUATE CORE COOLING NOTRUMP 1 INCH COLD LEG BREAK NO SI
10.000
7.5000
5.0000
2.5000
0.0
-2.5000
-5.0000
-7.5000
-10.000
INTACT LOOP RCP STEAM FLOW
(a,c)
0.0
2000.0
4000.0
6000.0
8000.0
1.00E+04
1.20E+04
TIME(SECONDS)

Figure 56

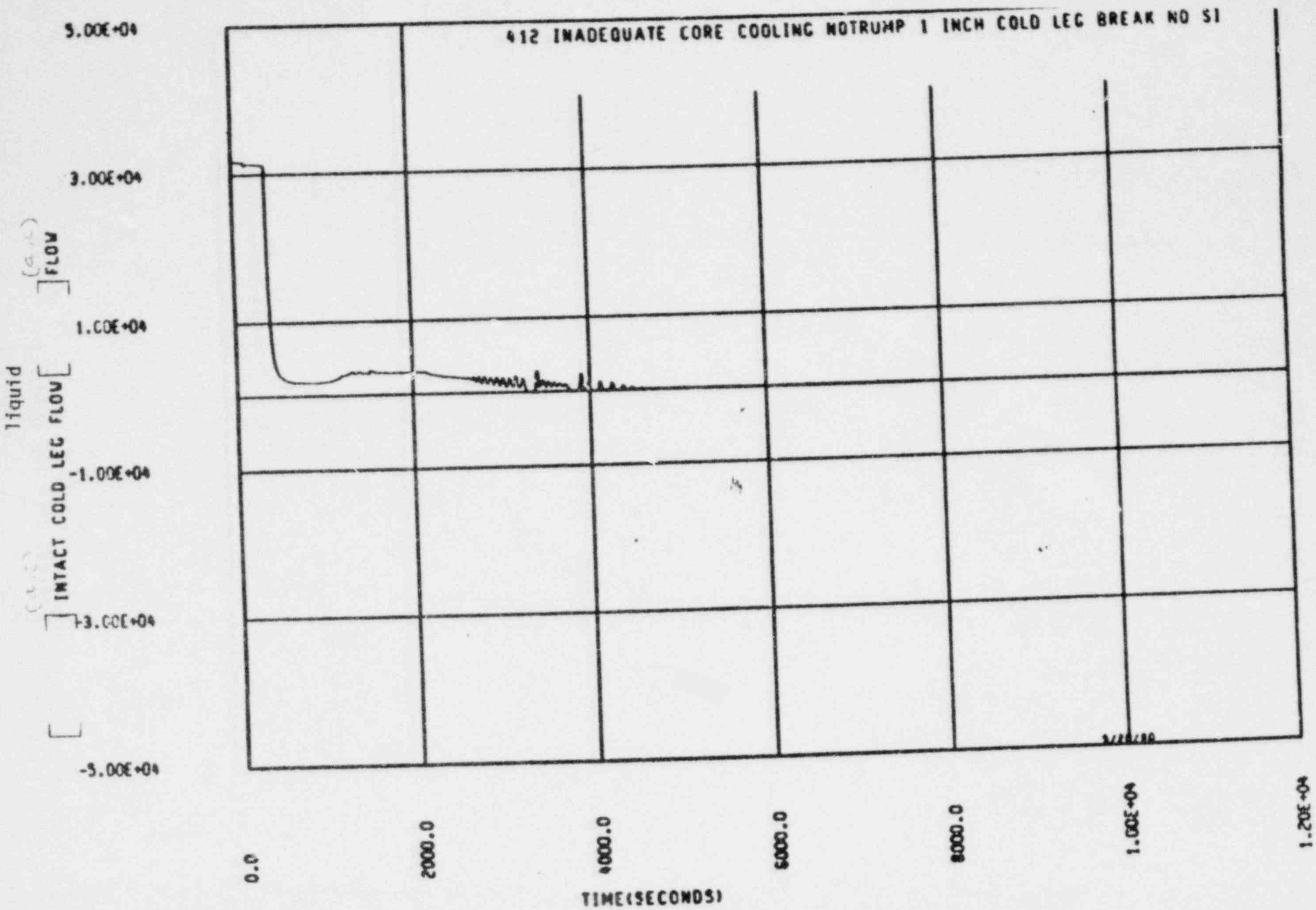

412 INADEQUATE CORE COOLING NOTRUMP 1 INCH COLD LEG BREAK NO SI
5.00E+04
3.00E+04
1.00E+04
-1.00E+04
-3.00E+04
-5.00E+04
liquid INTACT COLD LEG FLOW FLOW
(a,c)
0.0
2000.0
4000.0
6000.0
8000.0
1.00E+04
1.20E+04
TIME(SECONDS)

Figure 57

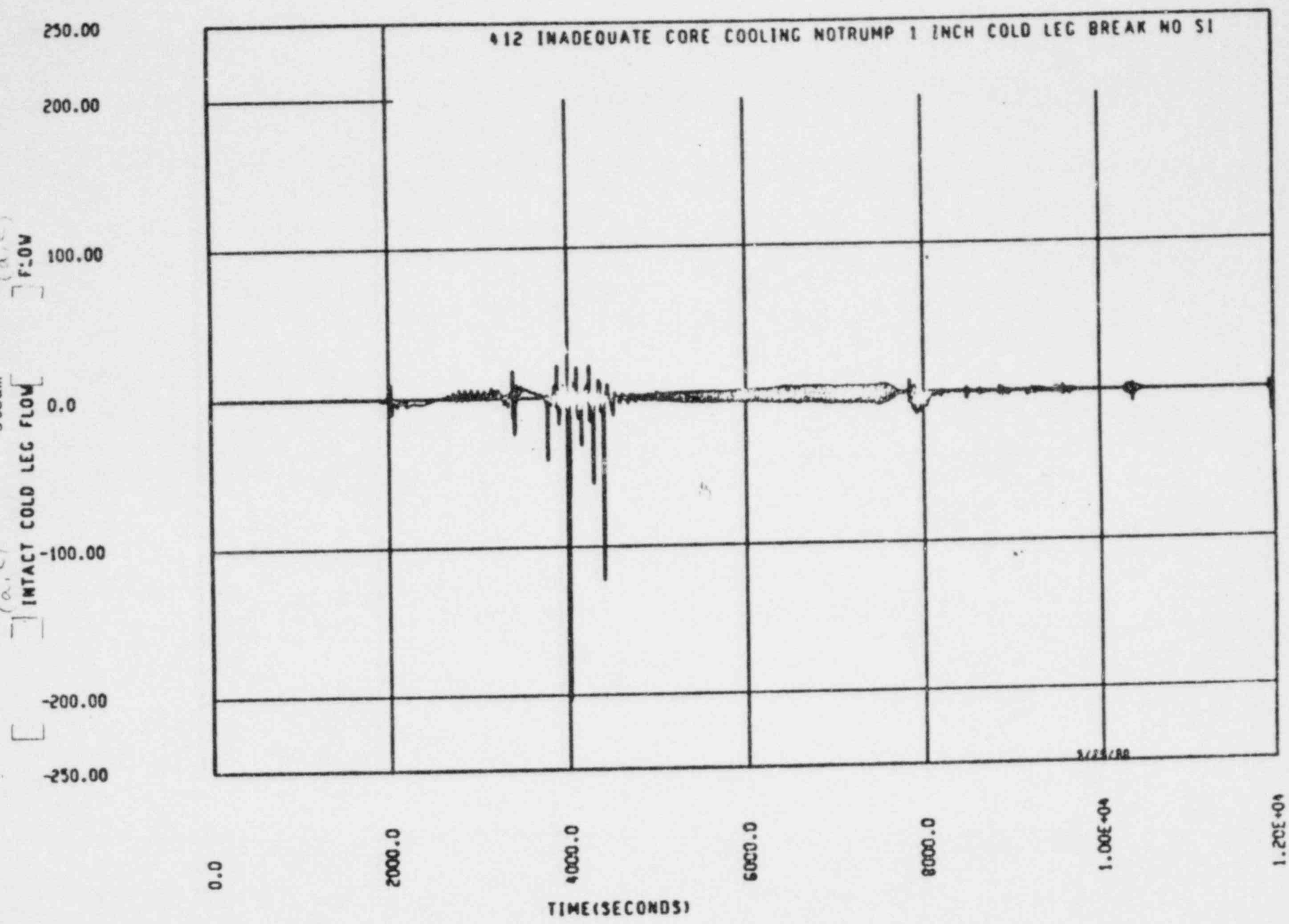

412 INADEQUATE CORE COOLING NOTRUMP 1 INCH COLD LEG BREAK NO SI
250.00
200.00
100.00
0.0
-100.00
-200.00
-250.00
INTACT COLD LEG FLOW
steam
FLOW
(a,c)
(a,c)
0.0
2000.0
4000.0
6000.0
8000.0
1.00E+04
1.20E+04
TIME(SECONDS)

Figure 58

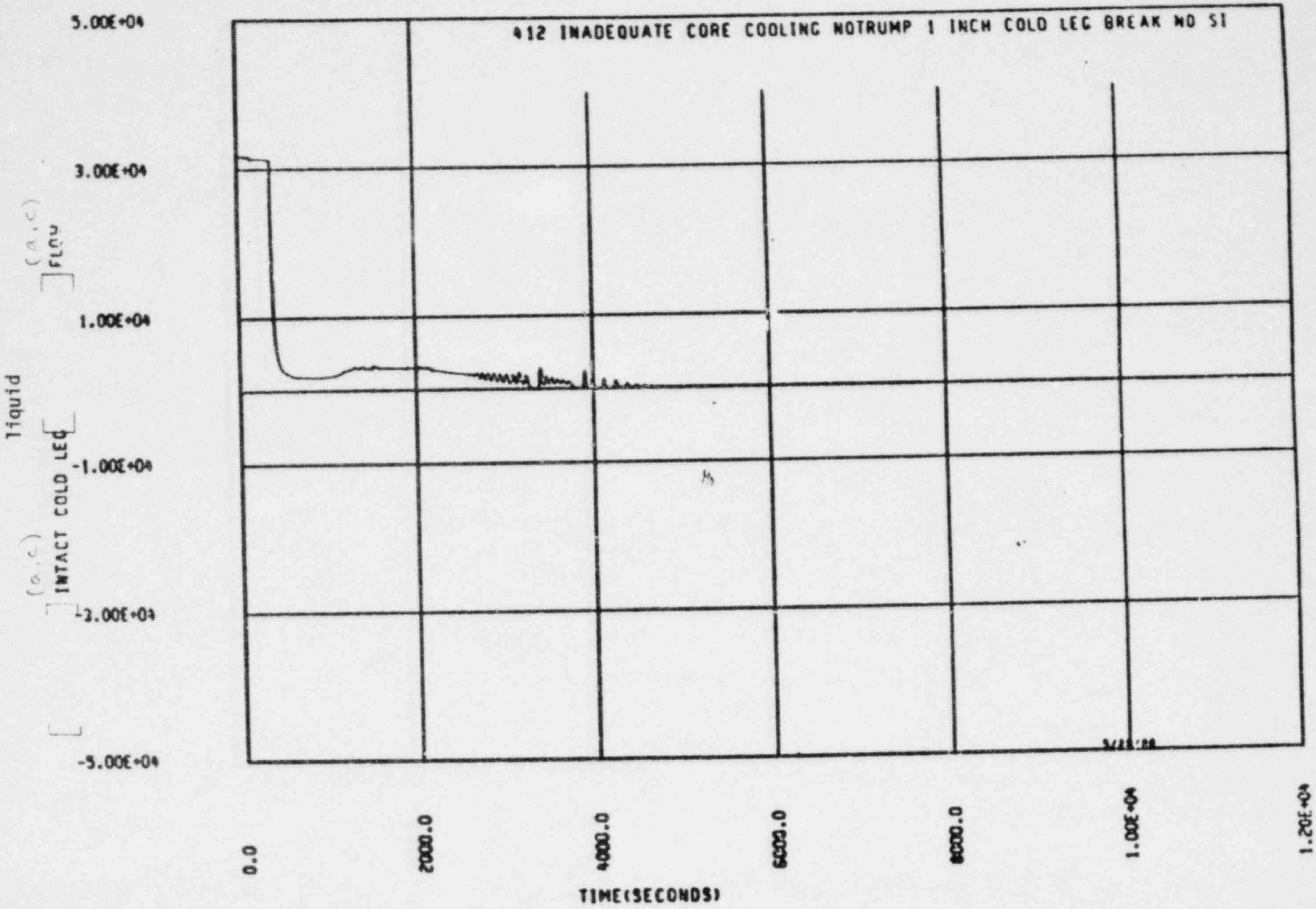

412 INADEQUATE CORE COOLING NOTRUMP 1 INCH COLD LEG BREAK NO SI
5.00E+04
3.00E+04
1.00E+04
-1.00E+04
-2.00E+04
-5.00E+04
liquid
INTACT COLD LEG
FLOW
(a,c)
(a,c)
0.0
2000.0
4000.0
6000.0
8000.0
1.00E+04
1.20E+04
TIME(SECONDS)

Figure 59

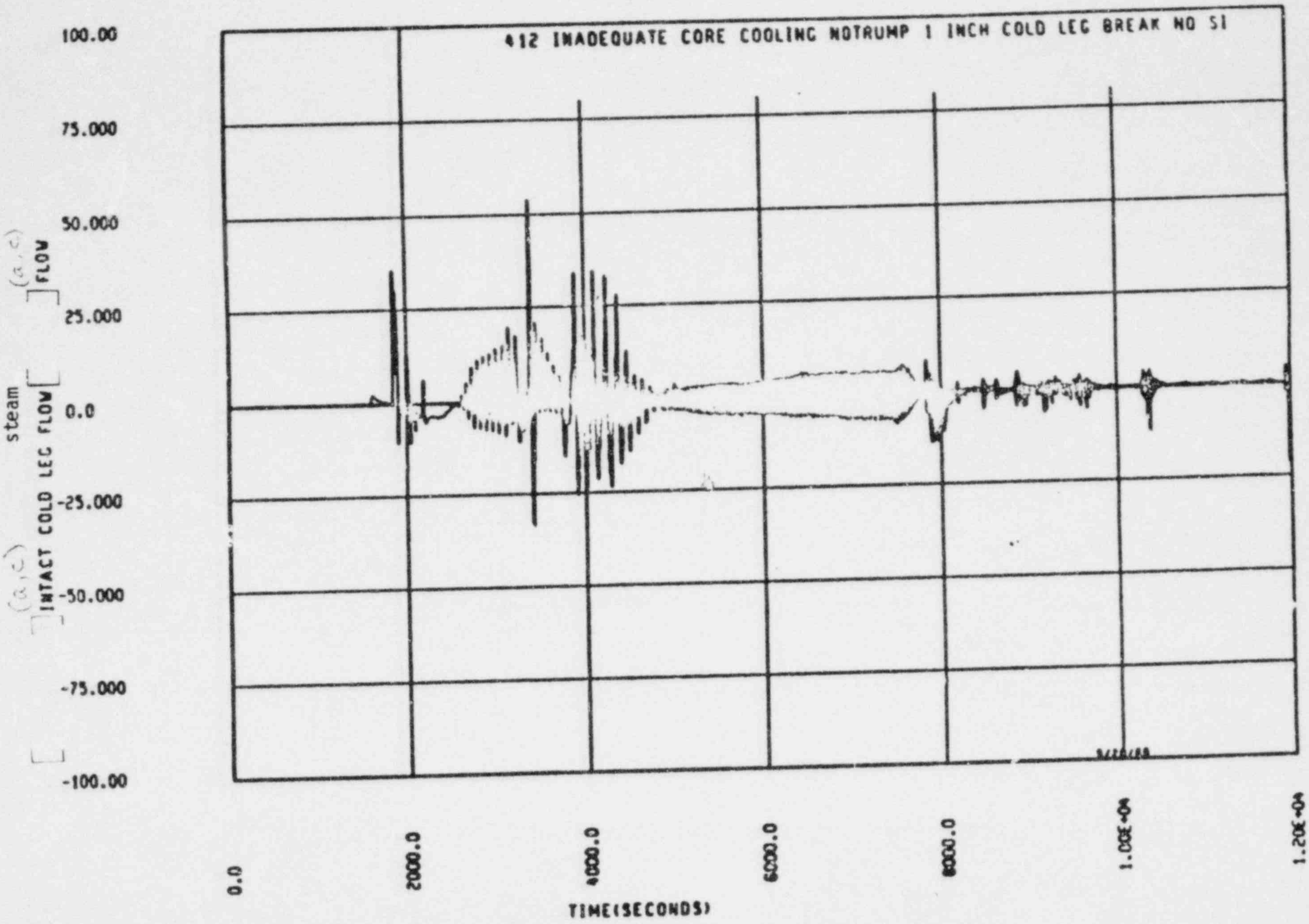

412 INADEQUATE CORE COOLING NOTRUMP 1 INCH COLD LEG BREAK NO SI
100.00
75.000
50.000
25.000
0.0
-25.000
-50.000
-75.000
-100.00
(a,c)
INTACT COLD LEG FLOW
steam
FLOW
(a,c)
0.0
2000.0
4000.0
6000.0
8000.0
1.00E+04
1.20E+04
TIME(SECONDS)

Figure 60

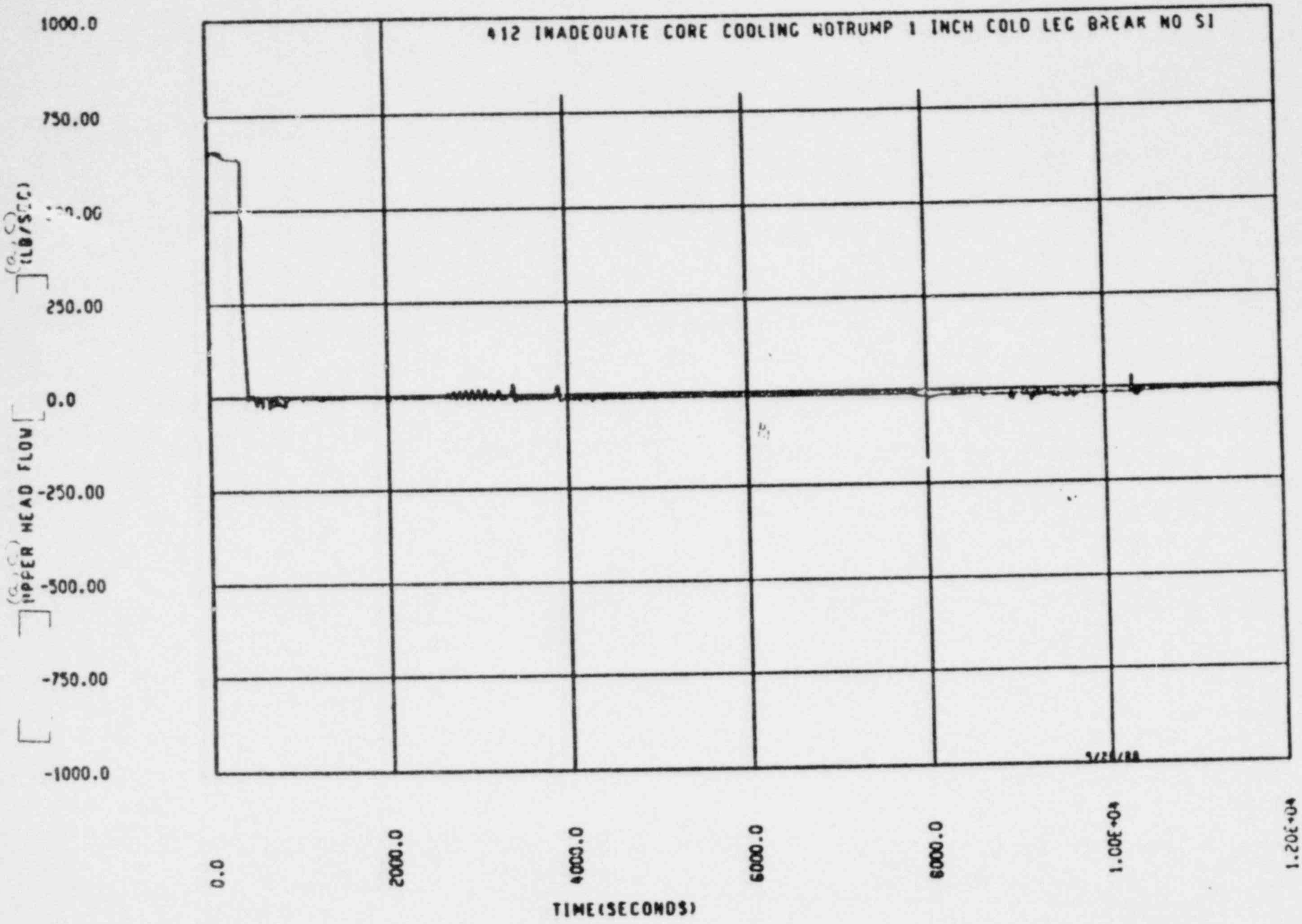

412 INADEQUATE CORE COOLING NOTRUMP 1 INCH COLD LEG BREAK NO SI
1000.0
750.00
500.00
250.00
0.0
-250.00
-500.00
-750.00
-1000.0
UPPER HEAD FLOW (LB/SEC)
(a,c)
(a,c)
0.0
2000.0
4000.0
6000.0
8000.0
1.00E+04
1.20E+04
TIME(SECONDS)
5/26/88

Figure 61

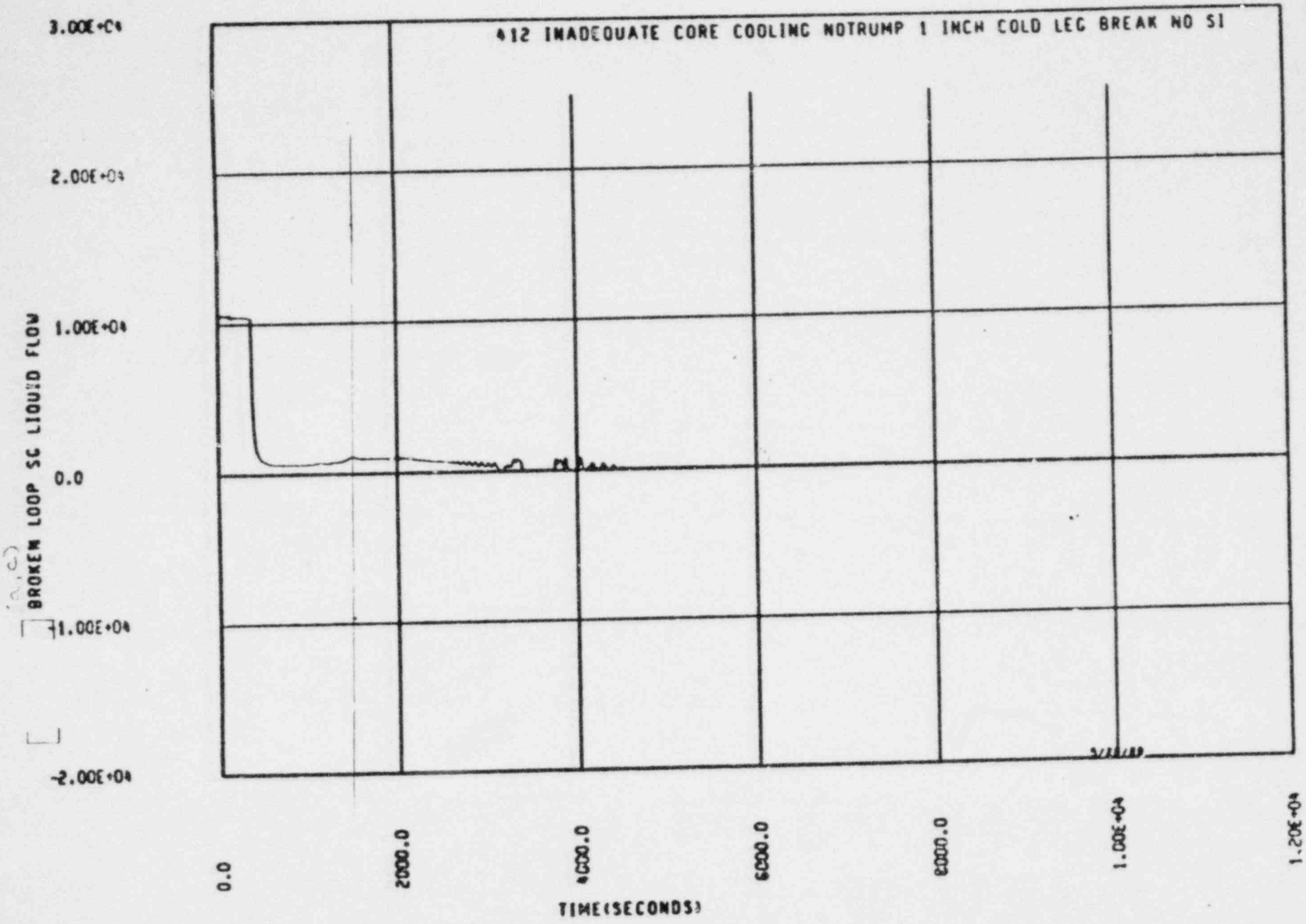

412 INADEQUATE CORE COOLING NOTRUMP 1 INCH COLD LEG BREAK NO SI
BROKEN LOOP SG LIQUID FLOW
3.00E+04
2.00E+04
1.00E+04
0.0
-1.00E+04
-2.00E+04
a,c
0.0
2000.0
4000.0
6000.0
8000.0
1.00E+04
1.20E+04
TIME(SECONDS)

Figure 62

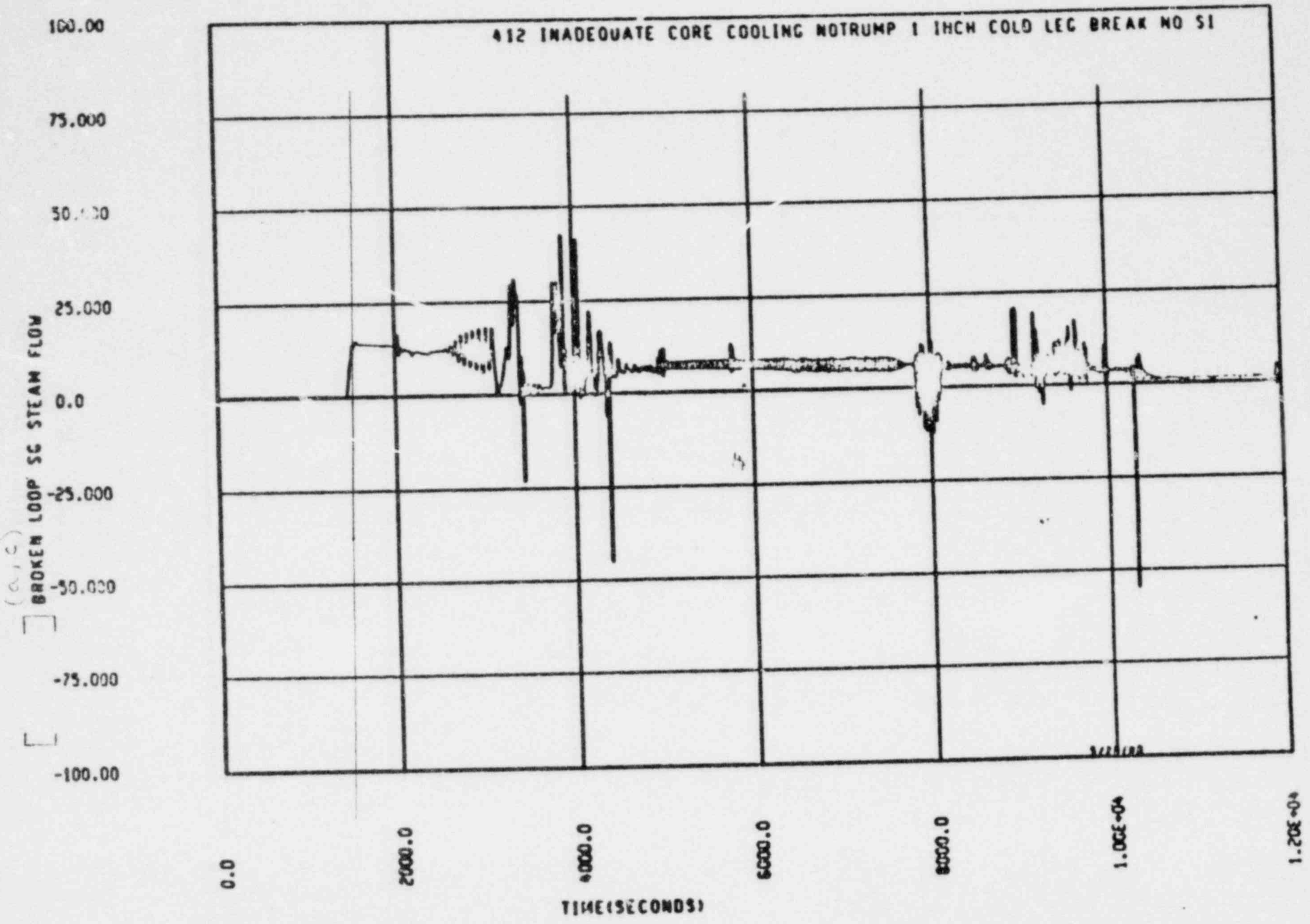

412 INADEQUATE CORE COOLING NOTRUMP 1 INCH COLD LEG BREAK NO SI
100.00
75.000
50.000
25.000
0.0
-25.000
-50.000
-75.000
-100.00
BROKEN LOOP SG STEAM FLOW
(a,c)
0.0
2000.0
4000.0
6000.0
8000.0
1.00E+04
1.20E+04
TIME(SECONDS)

Figure 63

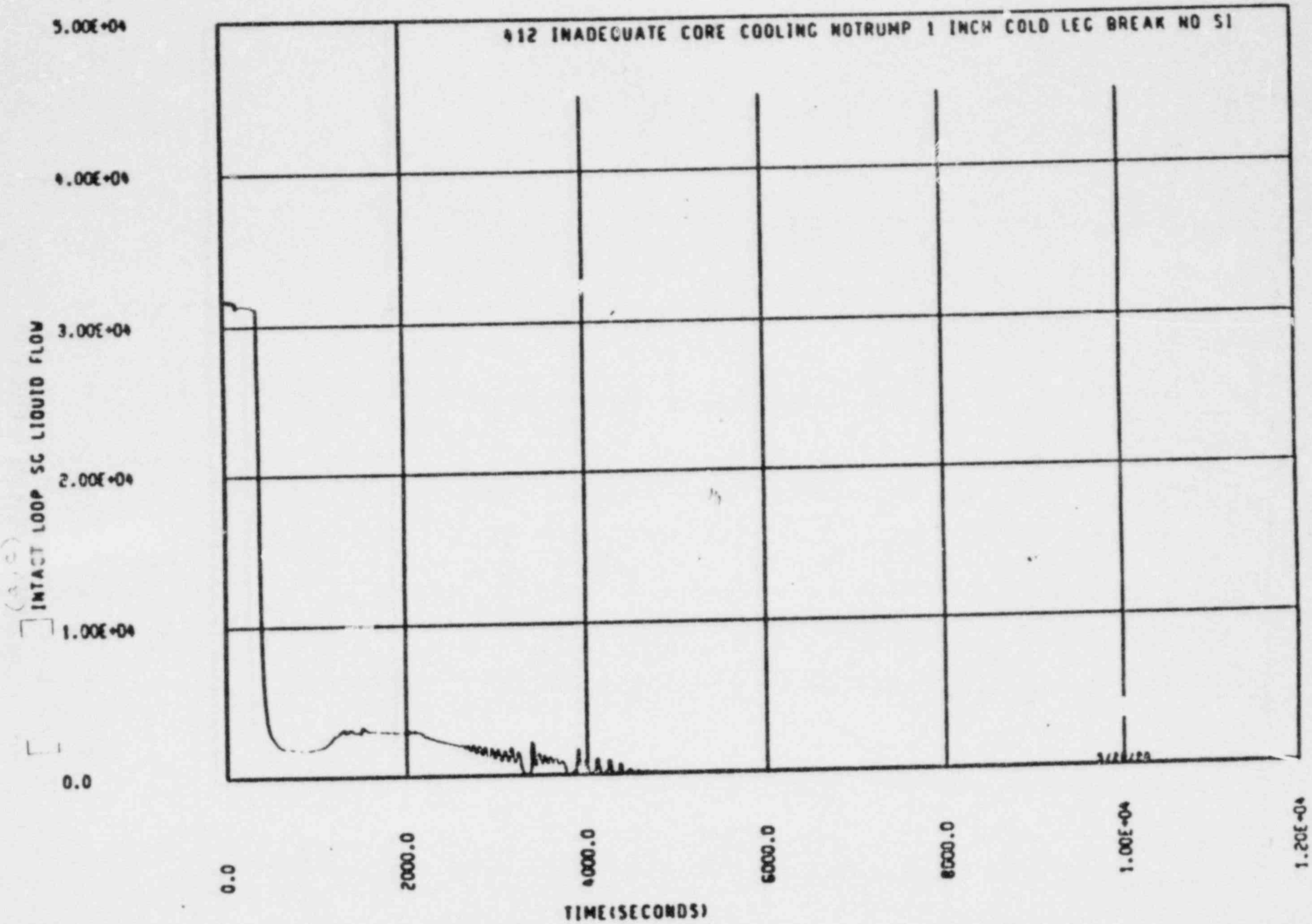

412 INADEQUATE CORE COOLING NOTRUMP 1 INCH COLD LEG BREAK NO SI
INTACT LOOP SG LIQUID FLOW
(a,c)
5.00E+04
4.00E+04
3.00E+04
2.00E+04
1.00E+04
0.0
0.0
2000.0
4000.0
6000.0
8000.0
1.00E+04
1.20E+04
TIME(SECONDS)

Figure 64

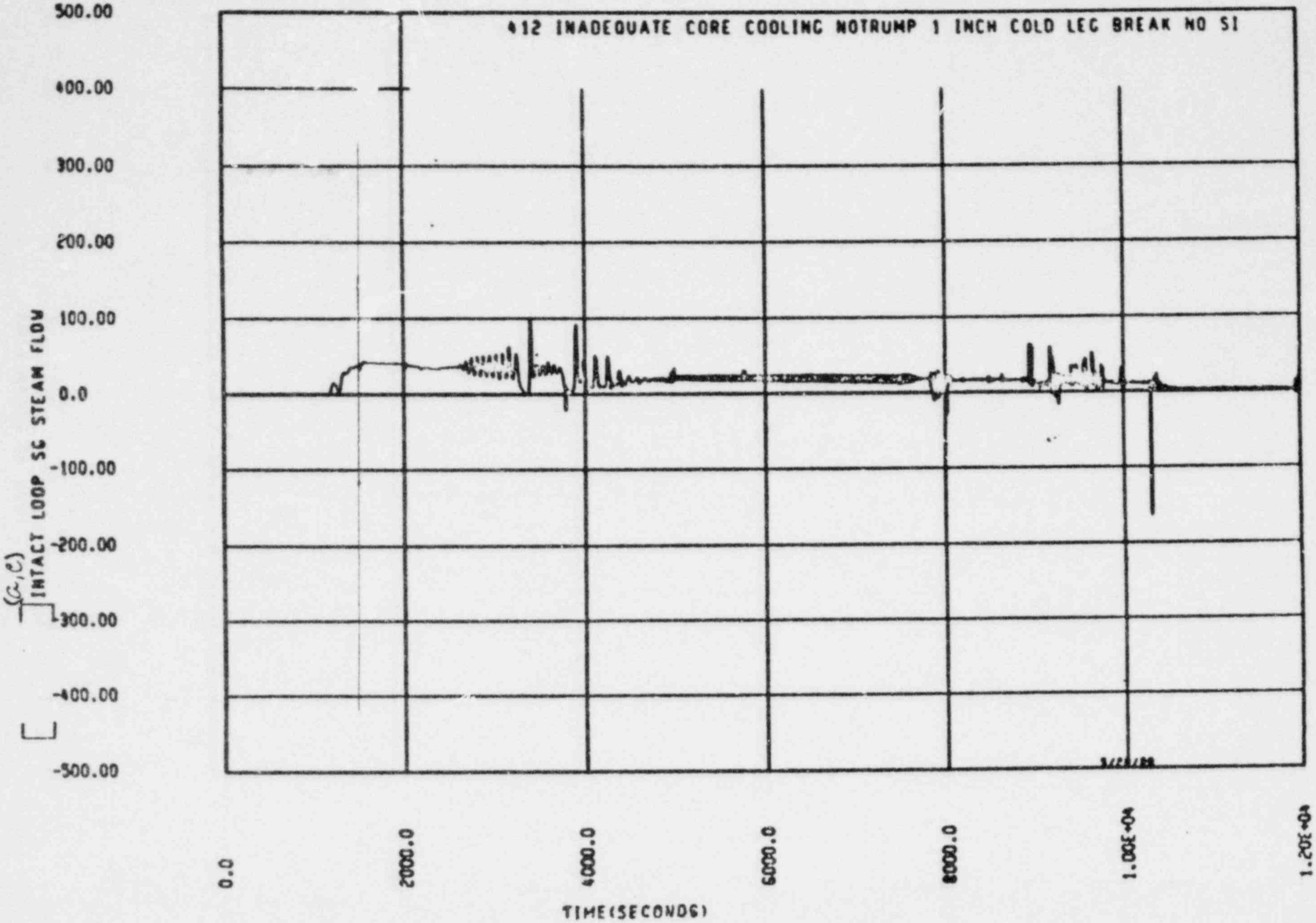

412 INADEQUATE CORE COOLING NOTRUMP 1 INCH COLD LEG BREAK NO SI
INTACT LOOP SG STEAM FLOW
(a,c)
500.00
400.00
300.00
200.00
100.00
0.0
-100.00
-200.00
-300.00
-400.00
-500.00
0.0
2000.0
4000.0
6000.0
8000.0
1.00E+04
1.20E+04
TIME(SECONDS)

Figure 65

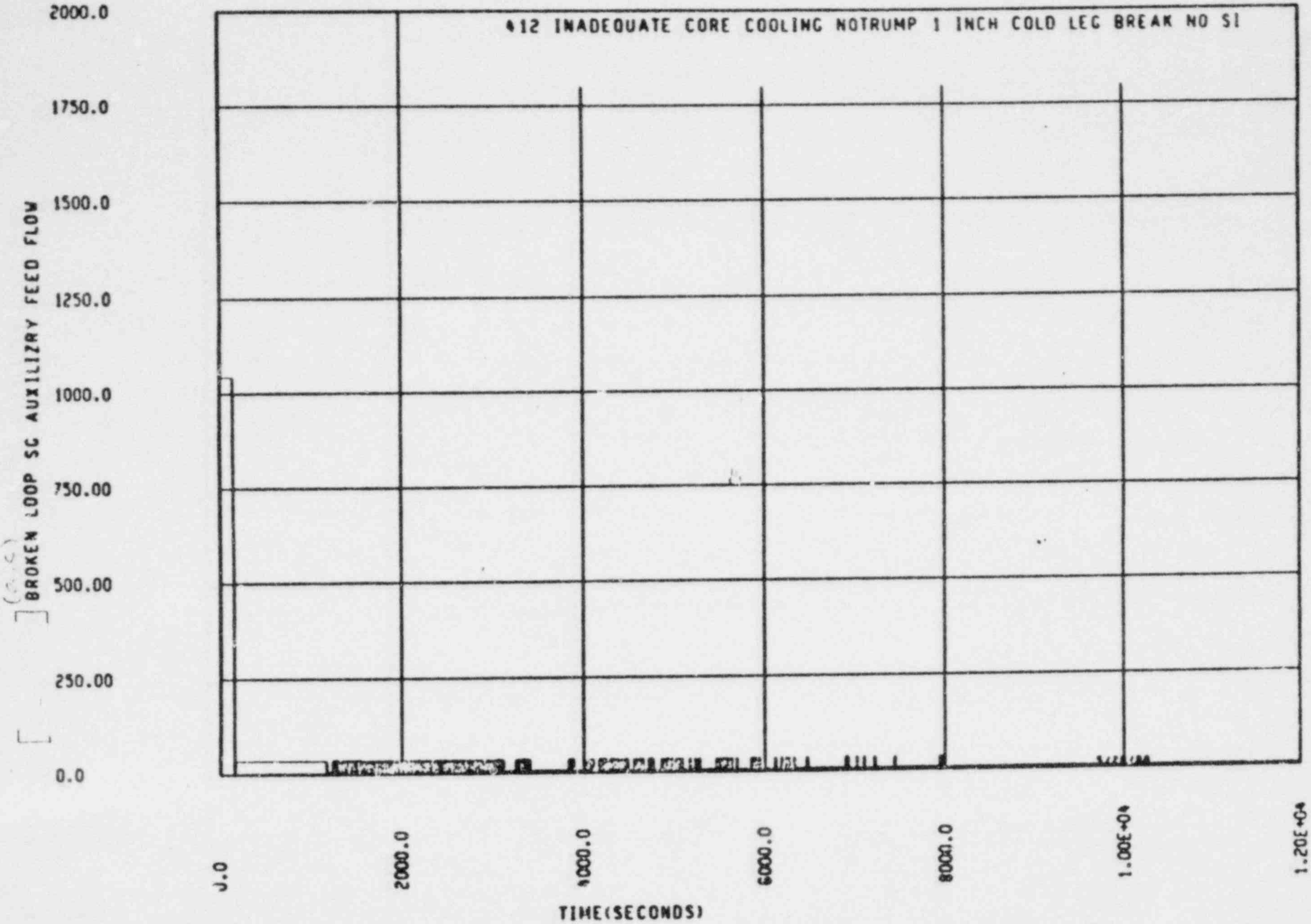

412 INADEQUATE CORE COOLING NOTRUMP 1 INCH COLD LEG BREAK NO SI
BROKEN LOOP SG AUXILIZRY FEED FLOW
2000.0
1750.0
1500.0
1250.0
1000.0
750.00
500.00
250.00
0.0
0.0
2000.0
4000.0
6000.0
8000.0
1.00E+04
1.20E+04
TIME(SECONDS)

Figure 66

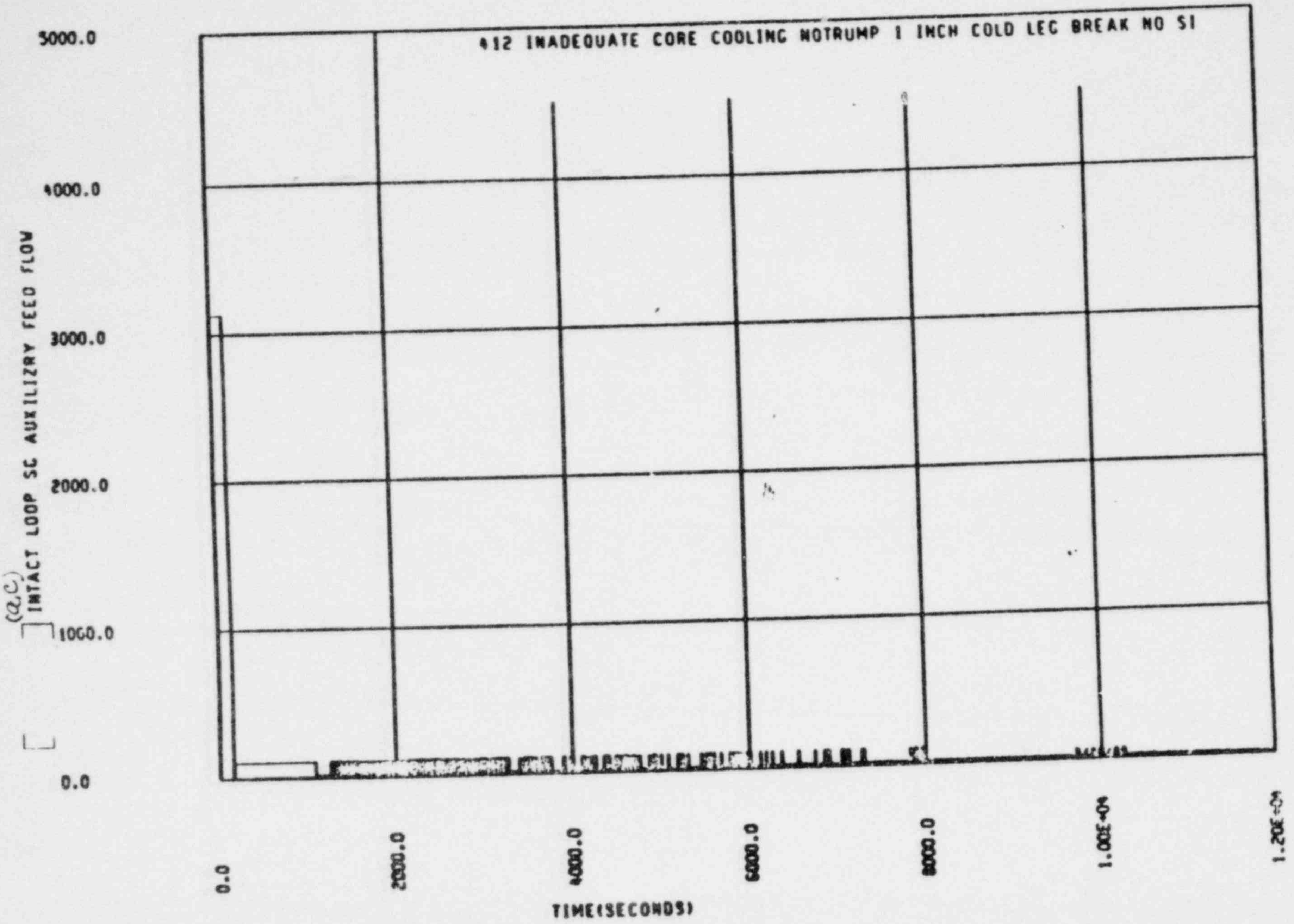

412 INADEQUATE CORE COOLING NOTRUMP 1 INCH COLD LEG BREAK NO SI
(a,c)
INTACT LOOP SG AUXILIZRY FEED FLOW
5000.0
4000.0
3000.0
2000.0
1000.0
0.0
0.0
2000.0
4000.0
6000.0
8000.0
1.00E+04
1.20E+04
TIME(SECONDS)

Figure 67

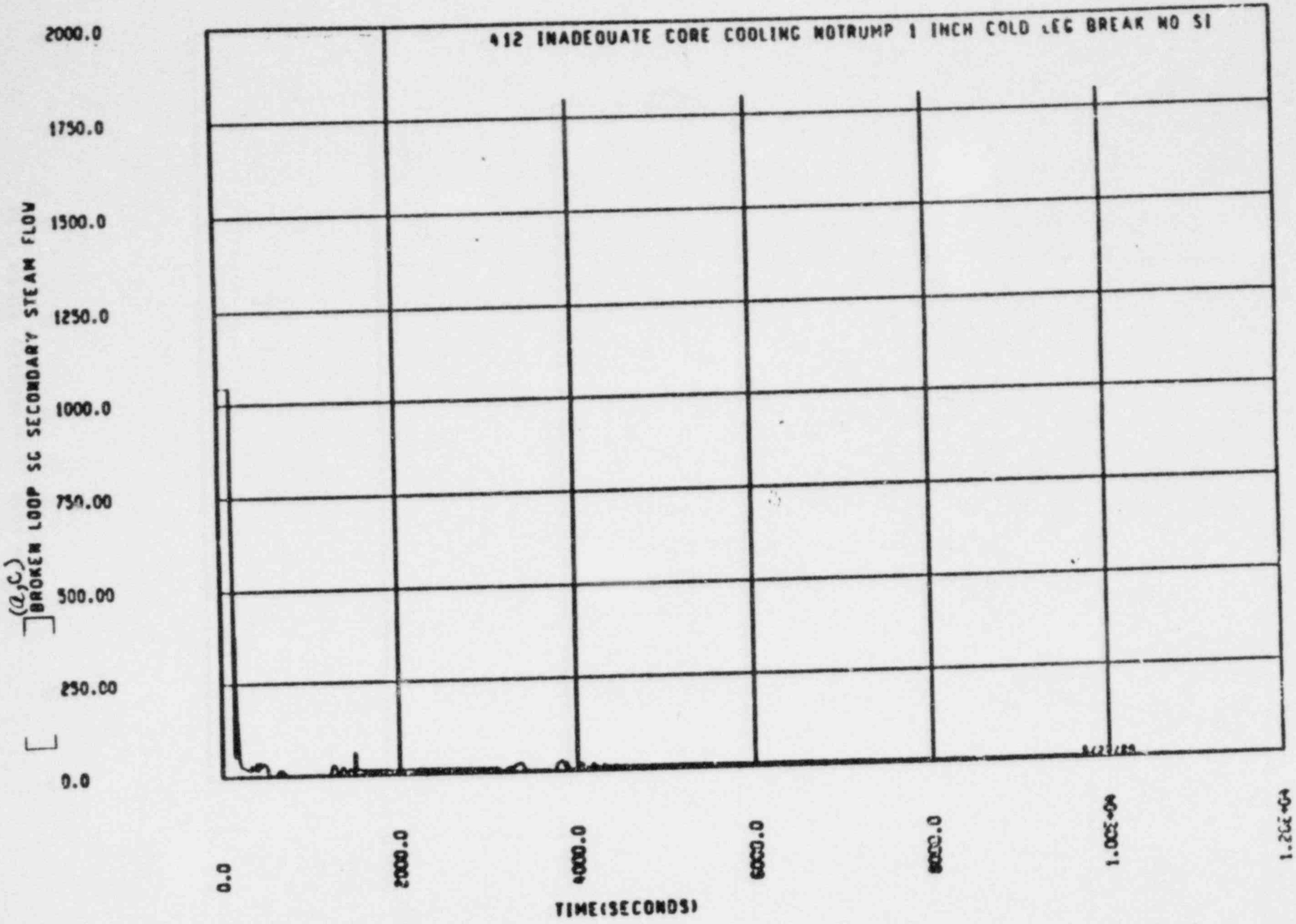

412 INADEQUATE CORE COOLING NOTRUMP 1 INCH COLD LEG BREAK NO SI
BROKEN LOOP SG SECONDARY STEAM FLOW
(a,c)
2000.0
1750.0
1500.0
1250.0
1000.0
750.00
500.00
250.00
0.0
0.0
2000.0
4000.0
6000.0
8000.0
1.00E+04
1.20E+04
TIME(SECONDS)

Figure 68

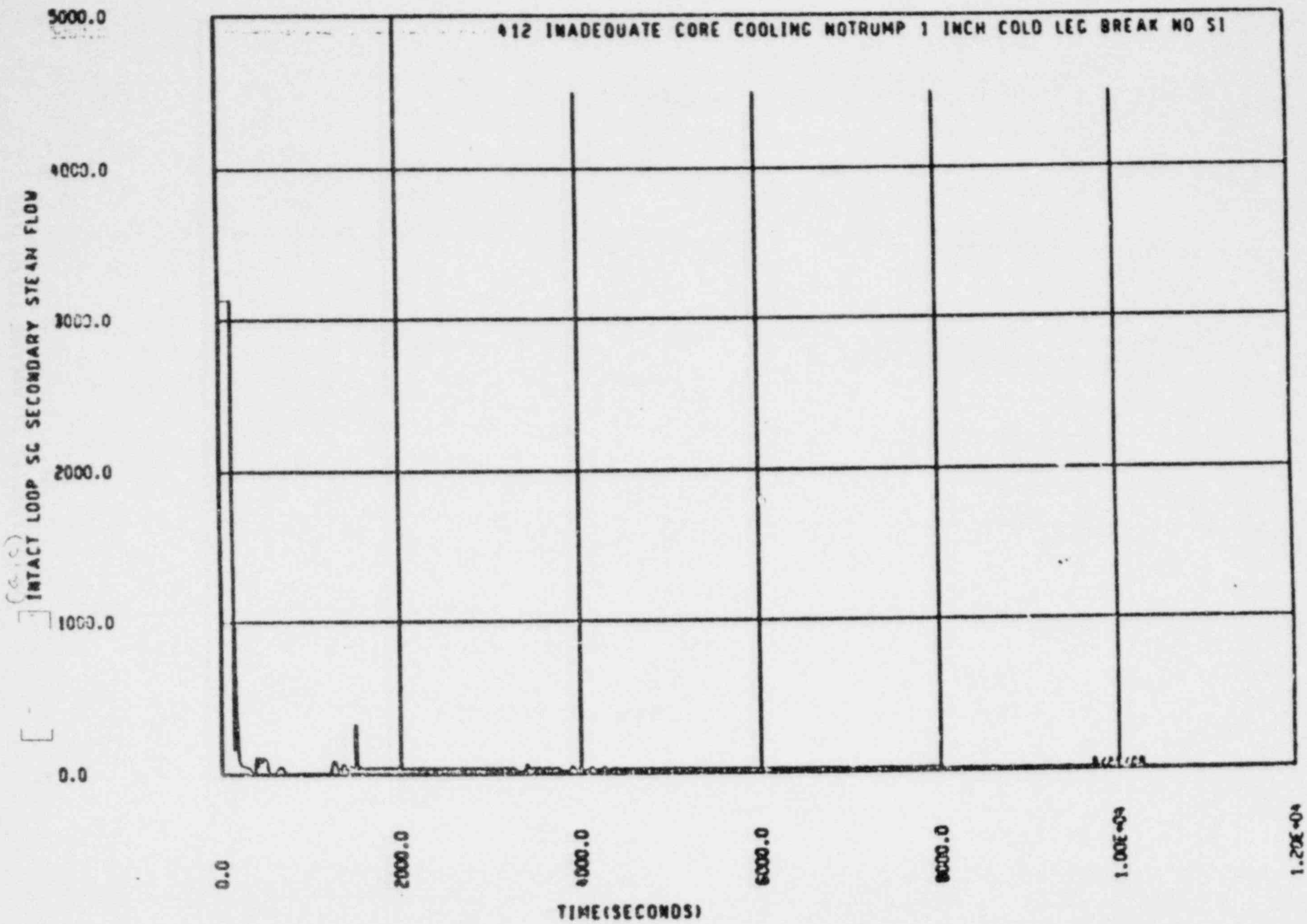

412 INADEQUATE CORE COOLING NOTRUMP 1 INCH COLD LEG BREAK NO SI
INTACT LOOP SC SECONDARY STEAM FLOW
(a,c)
5000.0
4000.0
3000.0
2000.0
1000.0
0.0
0.0
2000.0
4000.0
6000.0
8000.0
1.00E+04
1.20E+04
TIME(SECONDS)

Figure 69

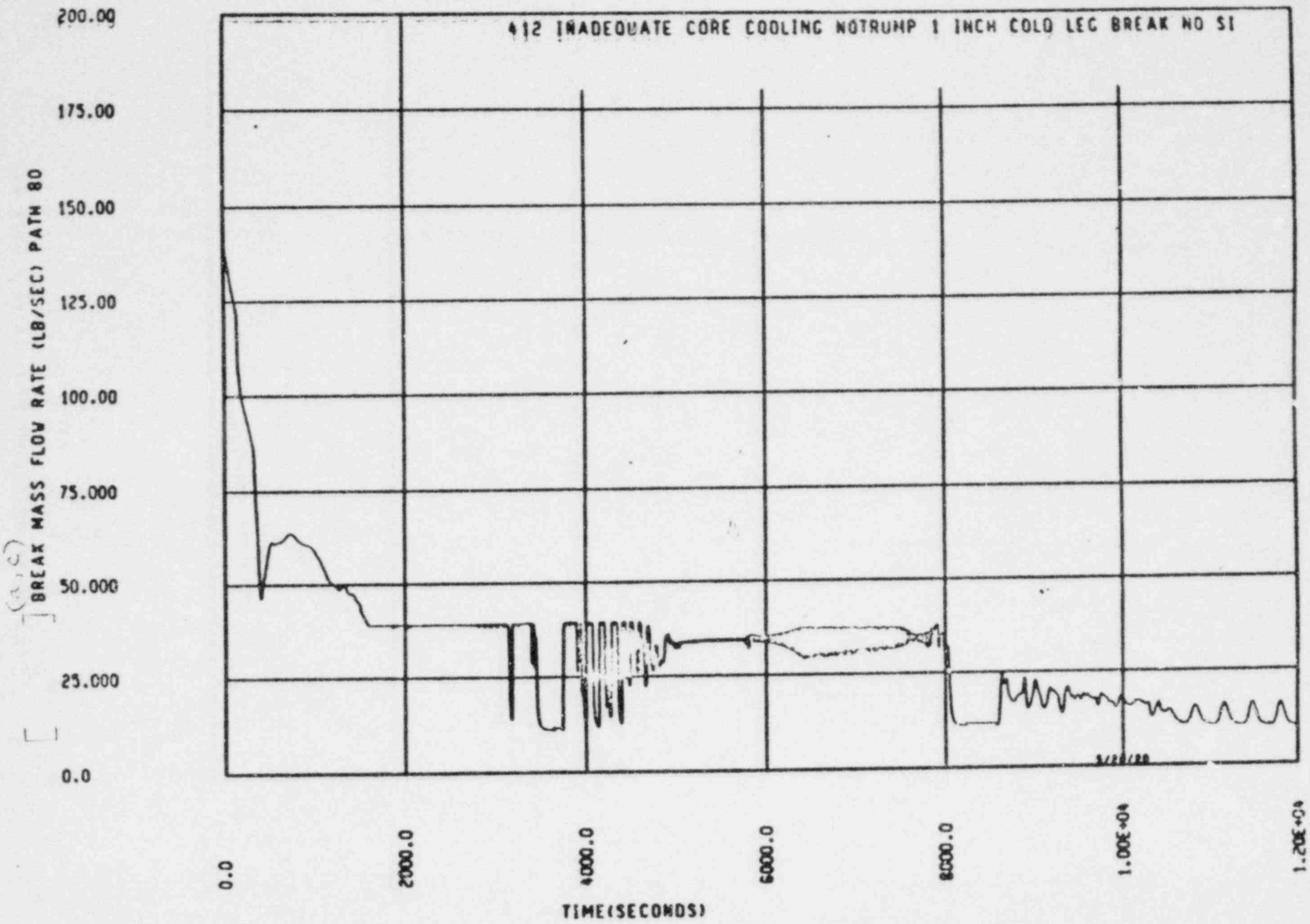

412 INADEQUATE CORE COOLING NOTRUMP 1 INCH COLD LEG BREAK NO SI
BREAK MASS FLOW RATE (LB/SEC) PATH 80
(a,c)
200.00
175.00
150.00
125.00
100.00
75.000
50.000
25.000
0.0
0.0
2000.0
4000.0
6000.0
8000.0
1.00E+04
1.20E+04
TIME(SECONDS)

Figure 70

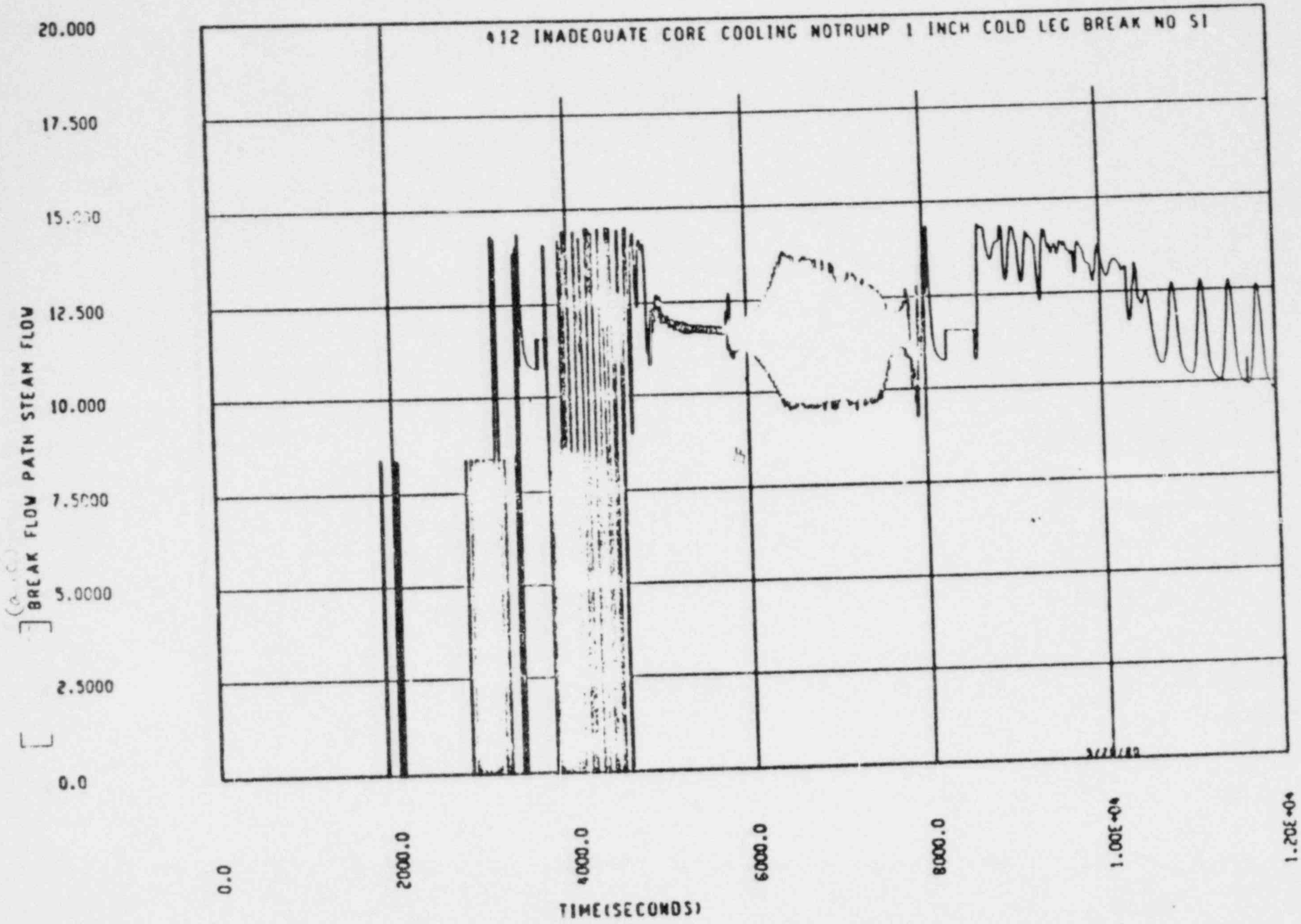

412 INADEQUATE CORE COOLING NOTRUMP 1 INCH COLD LEG BREAK NO SI
BREAK FLOW PATH STEAM FLOW
(a,c)
20.000
17.500
15.000
12.500
10.000
7.5000
5.0000
2.5000
0.0
0.0
2000.0
4000.0
6000.0
8000.0
1.00E+04
1.20E+04
TIME(SECONDS)

Figure 71

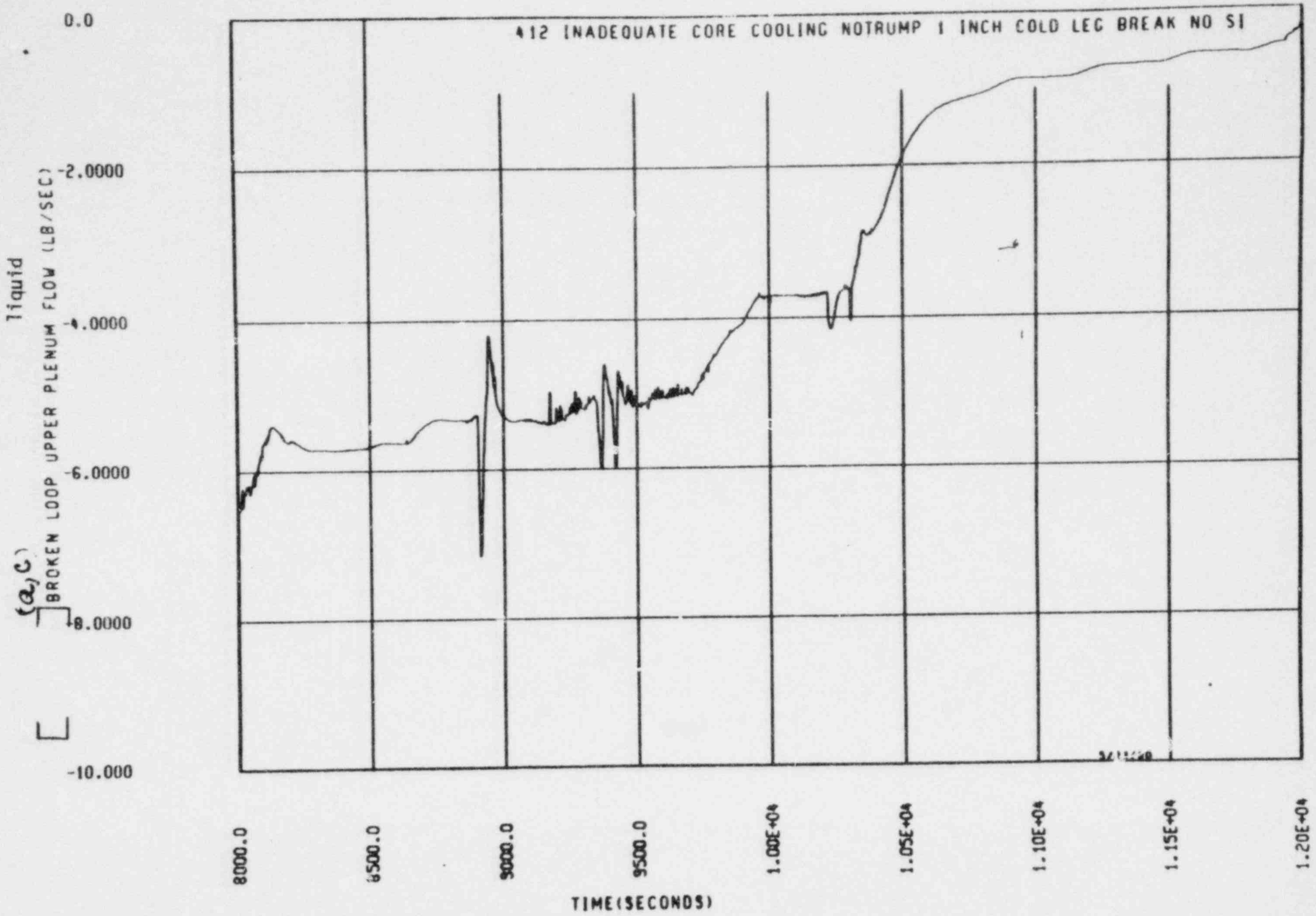

412 INADEQUATE CORE COOLING NOTRUMP 1 INCH COLD LEG BREAK NO SI
liquid
BROKEN LOOP UPPER PLENUM FLOW (LB/SEC)
(a,c)
0.0
-2.0000
-4.0000
-6.0000
-8.0000
-10.000
8000.0
8500.0
9000.0
9500.0
1.00E+04
1.05E+04
1.10E+04
1.15E+04
1.20E+04
TIME(SECONDS)

Figure 72

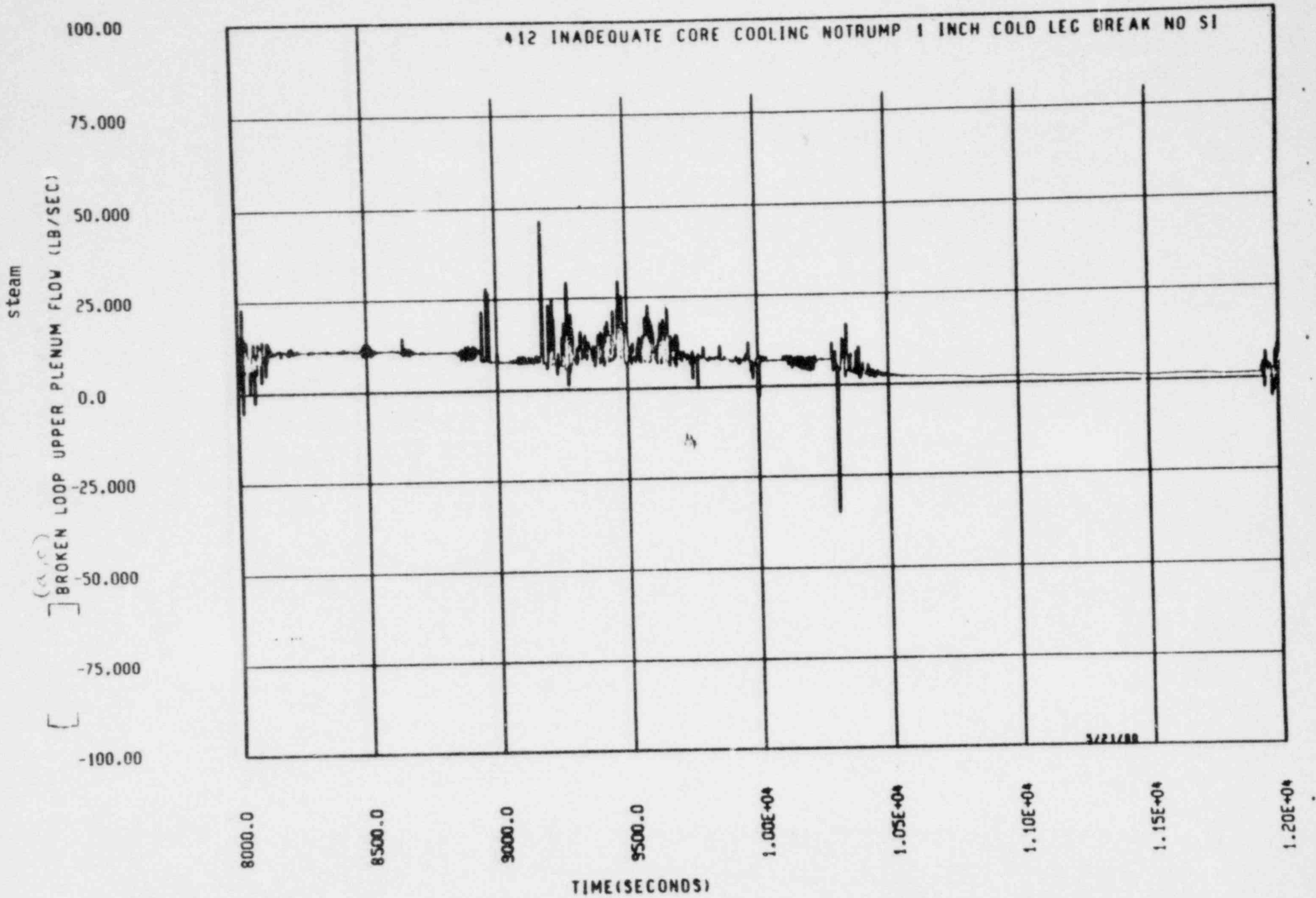

412 INADEQUATE CORE COOLING NOTRUMP 1 INCH COLD LEG BREAK NO SI
5/21/80
steam
BROKEN LOOP UPPER PLENUM FLOW (LB/SEC)
(a,c)
100.00
75.000
50.000
25.000
0.0
-25.000
-50.000
-75.000
-100.00
8000.0
8500.0
9000.0
9500.0
1.00E+04
1.05E+04
1.10E+04
1.15E+04
1.20E+04
TIME(SECONDS)

Figure 73

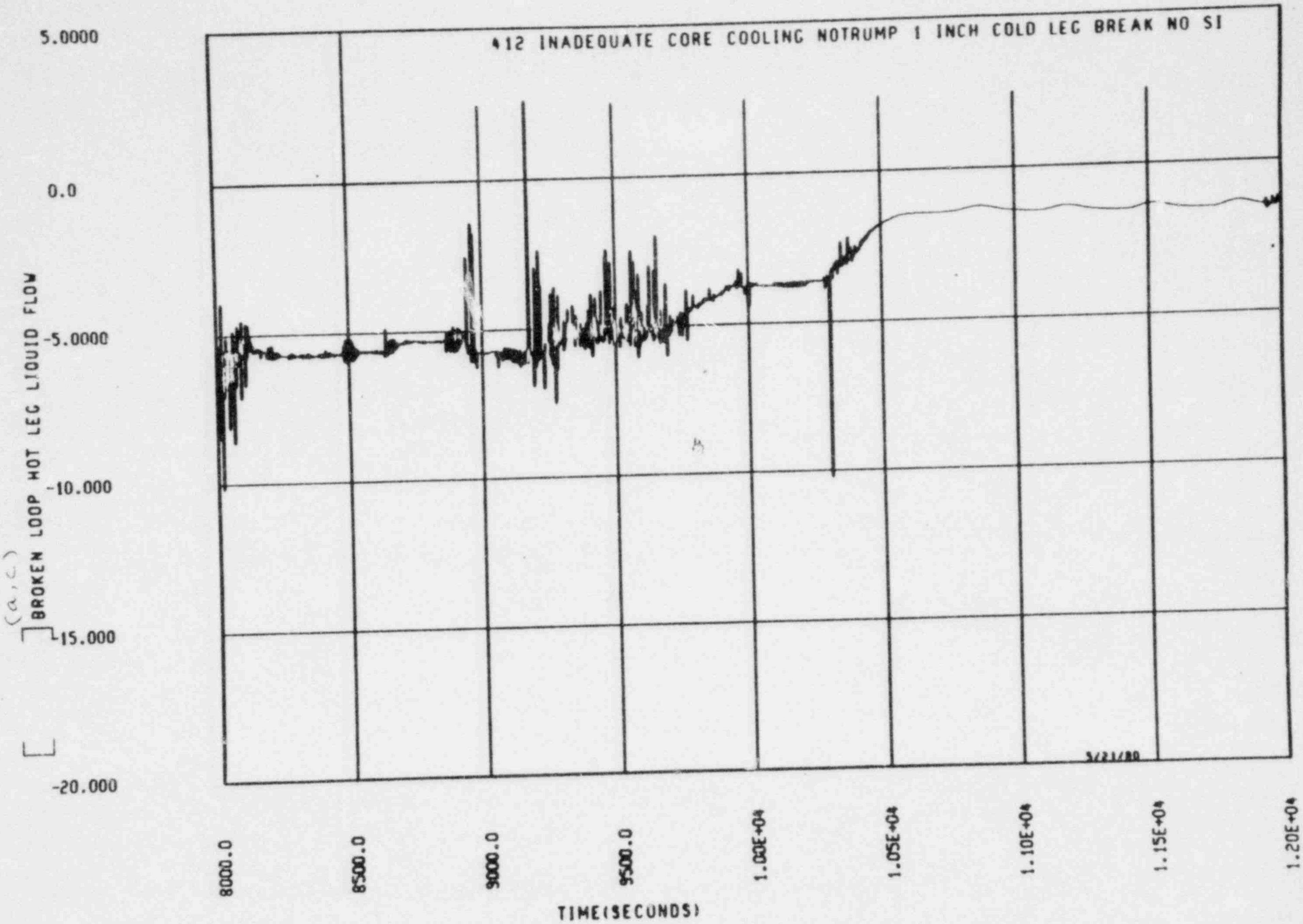

412 INADEQUATE CORE COOLING NOTRUMP 1 INCH COLD LEG BREAK NO SI
5.0000
0.0
-5.0000
-10.000
-15.000
-20.000
BROKEN LOOP HOT LEG LIQUID FLOW
(a,c)
8000.0
8500.0
9000.0
9500.0
1.00E+04
1.05E+04
1.10E+04
1.15E+04
1.20E+04
TIME(SECONDS)
5/21/80

Figure 74

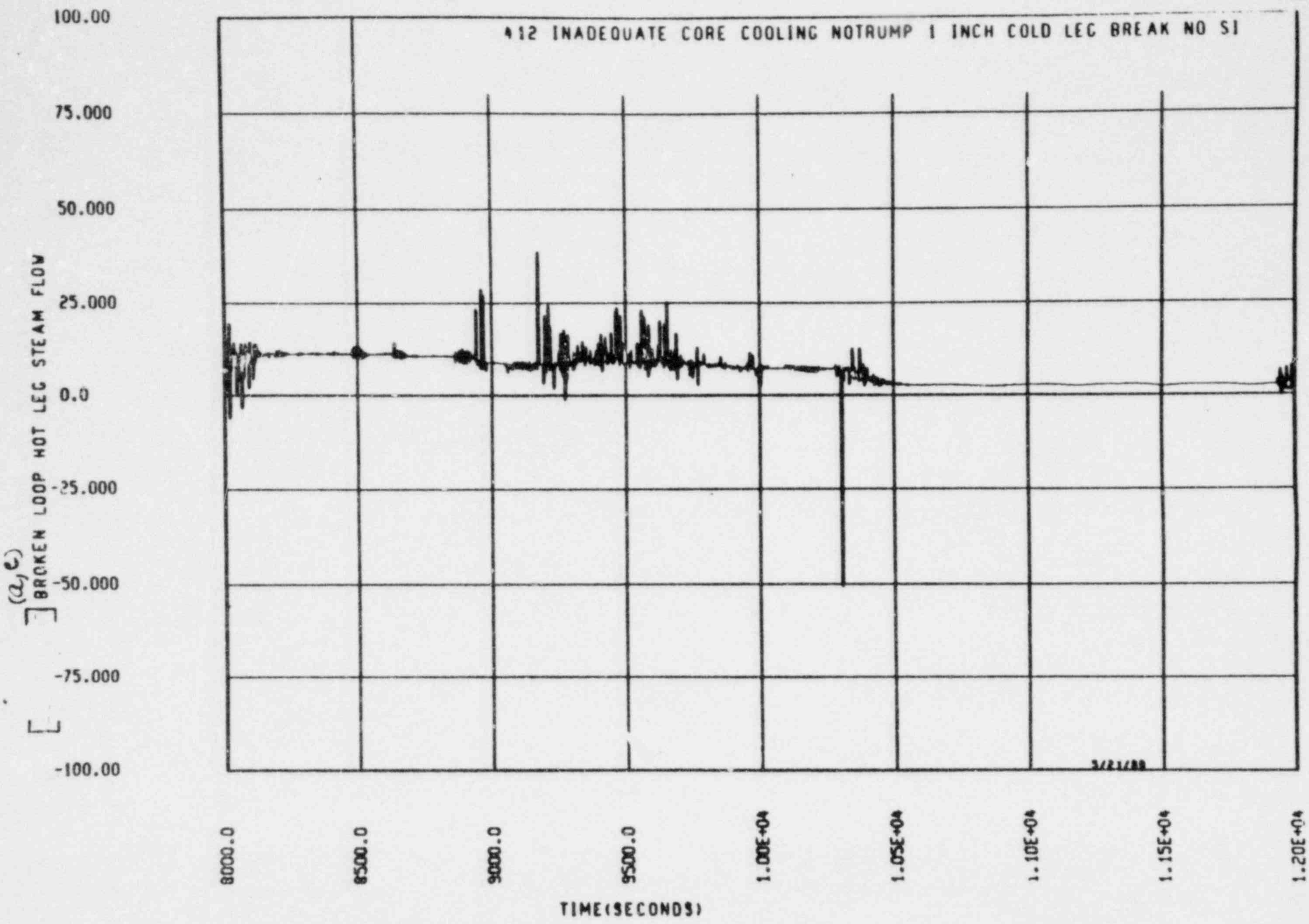

412 INADEQUATE CORE COOLING NOTRUMP 1 INCH COLD LEG BREAK NO SI
BROKEN LOOP HOT LEG STEAM FLOW
(a,c)
100.00
75.000
50.000
25.000
0.0
-25.000
-50.000
-75.000
-100.00
8000.0
8500.0
9000.0
9500.0
1.00E+04
1.05E+04
1.10E+04
1.15E+04
1.20E+04
TIME(SECONDS)

Figure 75

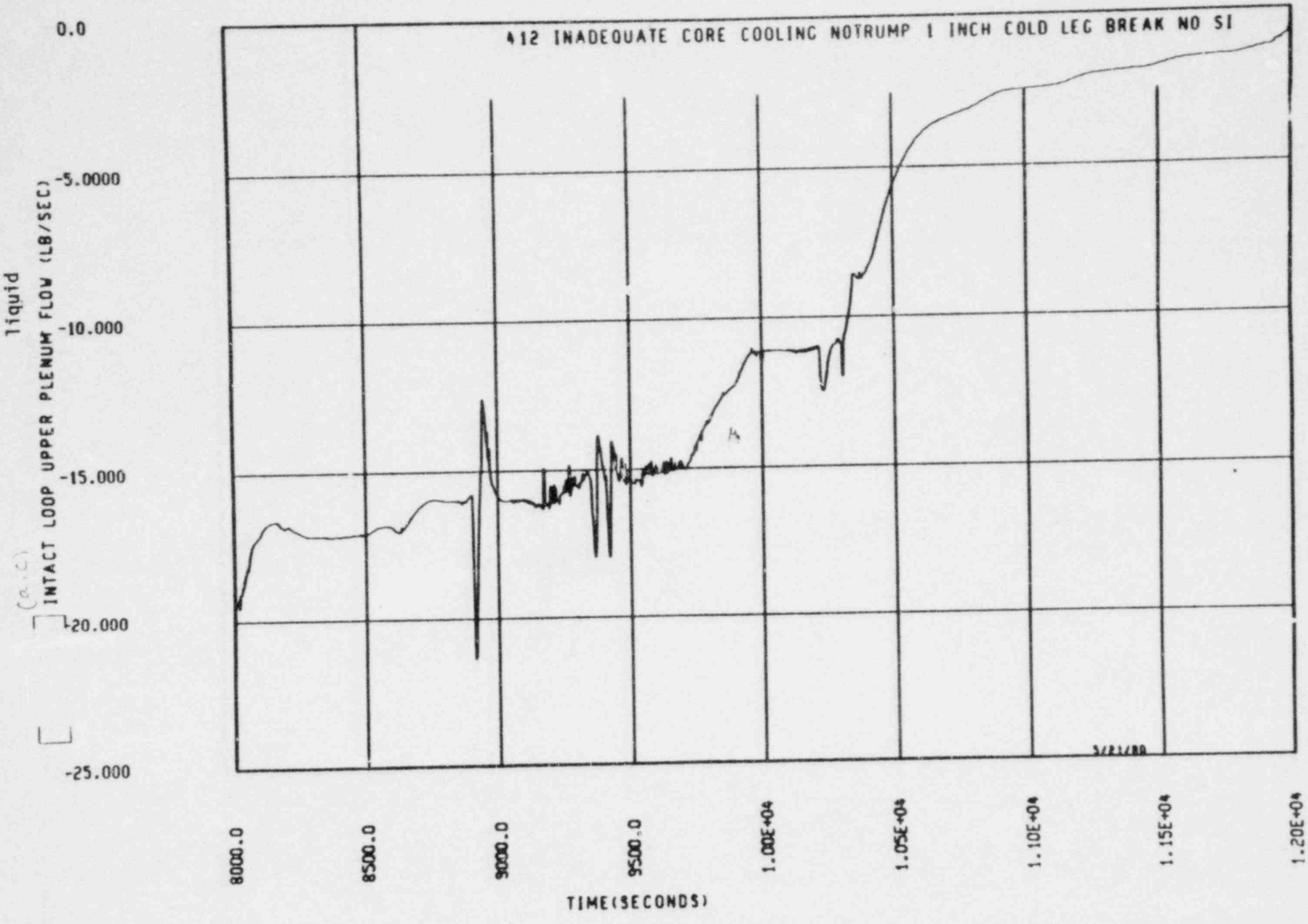

412 INADEQUATE CORE COOLINC NOTRUMP 1 INCH COLD LEG BREAK NO SI
liquid
INTACT LOOP UPPER PLENUM FLOW (LB/SEC)
(a,c)
0.0
-5.0000
-10.000
-15.000
-20.000
-25.000
8000.0
8500.0
9000.0
9500.0
1.00E+04
1.05E+04
1.10E+04
1.15E+04
1.20E+04
TIME(SECONDS)
5/21/80

Figure 76

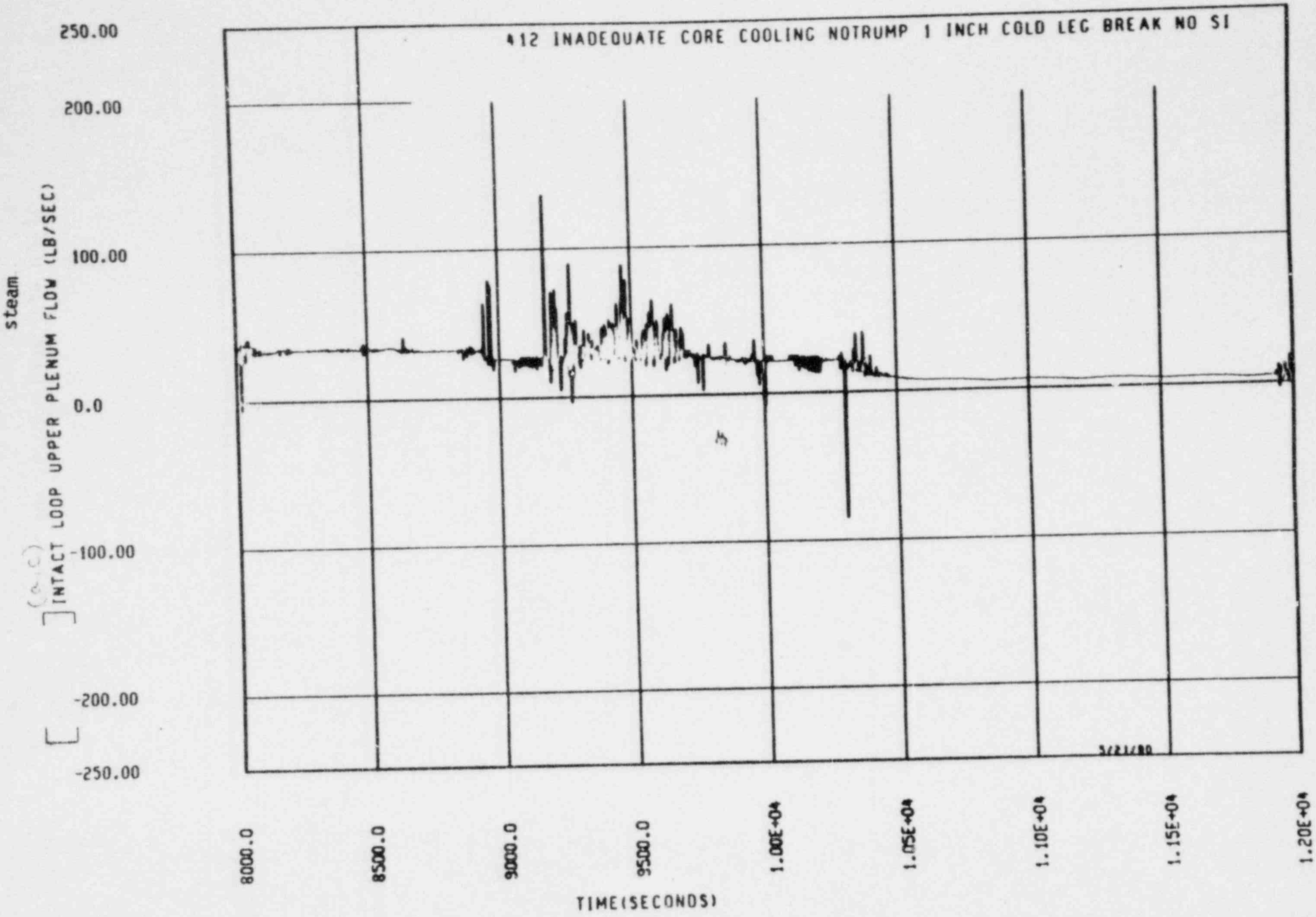

412 INADEQUATE CORE COOLING NOTRUMP 1 INCH COLD LEG BREAK NO SI
steam
(a,c)
INTACT LOOP UPPER PLENUM FLOW (LB/SEC)
250.00
200.00
100.00
0.0
-100.00
-200.00
-250.00
8000.0
8500.0
9000.0
9500.0
1.00E+04
1.05E+04
1.10E+04
1.15E+04
1.20E+04
TIME(SECONDS)
5/21/80

Figure 77

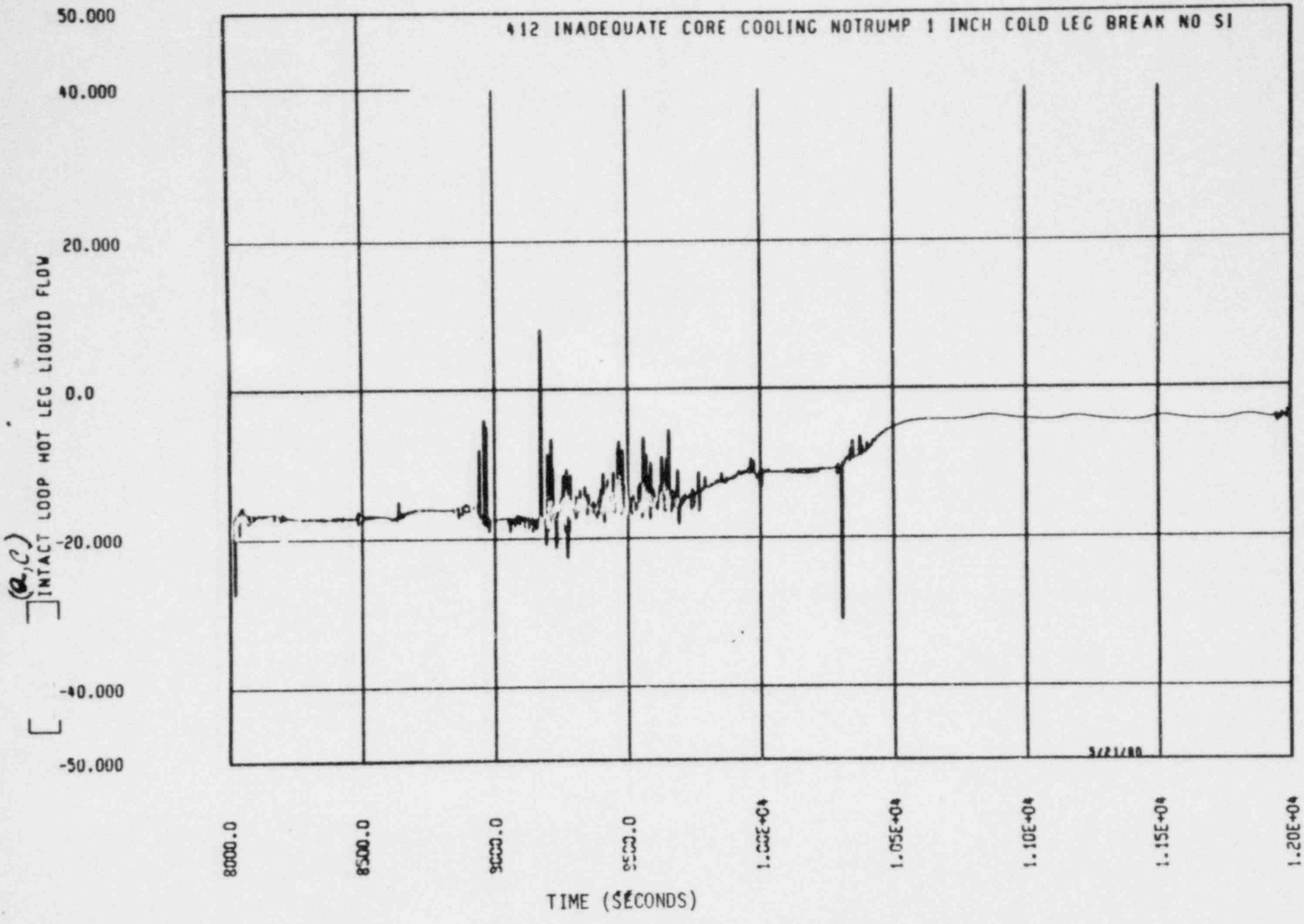

412 INADEQUATE CORE COOLING NOTRUMP 1 INCH COLD LEG BREAK NO SI
INTACT LOOP HOT LEG LIQUID FLOW
(a,c)
50.000
40.000
20.000
0.0
-20.000
-40.000
-50.000
8000.0
8500.0
9000.0
9500.0
1.00E+04
1.05E+04
1.10E+04
1.15E+04
1.20E+04
TIME (SECONDS)
5/21/80

Figure 78

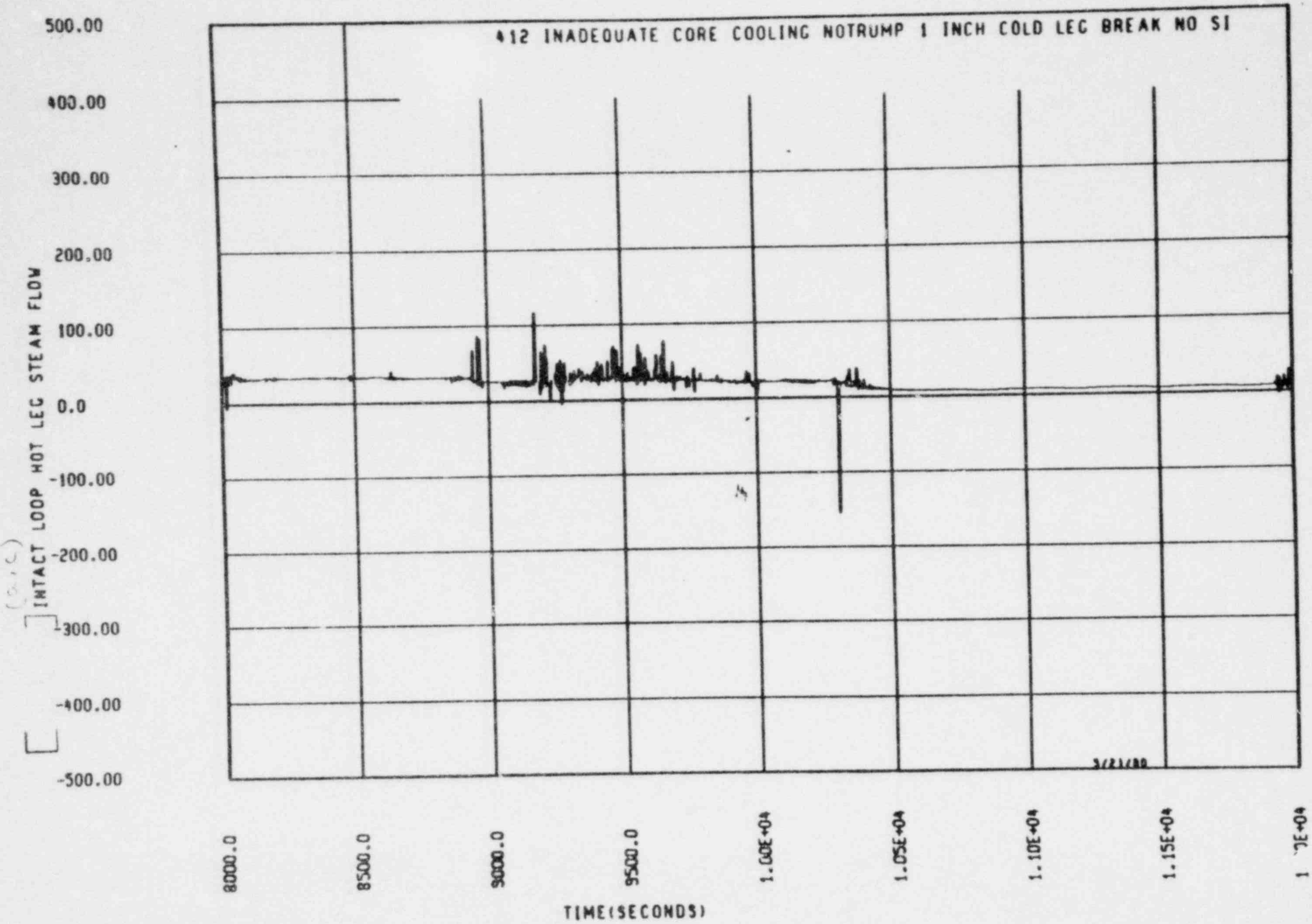

412 INADEQUATE CORE COOLING NOTRUMP 1 INCH COLD LEG BREAK NO SI
INTACT LOOP HOT LEG STEAM FLOW
(a,c)
500.00
400.00
300.00
200.00
100.00
0.0
-100.00
-200.00
-300.00
-400.00
-500.00
TIME(SECONDS)
8000.0
8500.0
9000.0
9500.0
1.00E+04
1.05E+04
1.10E+04
1.15E+04
1 'JE+04
3/21/80

Figure 79


50.000
40.000
30.000
20.000
10.000
0.0
CORE MIXTURE ELEVATION(FEET)
(a,c)

Figure 80

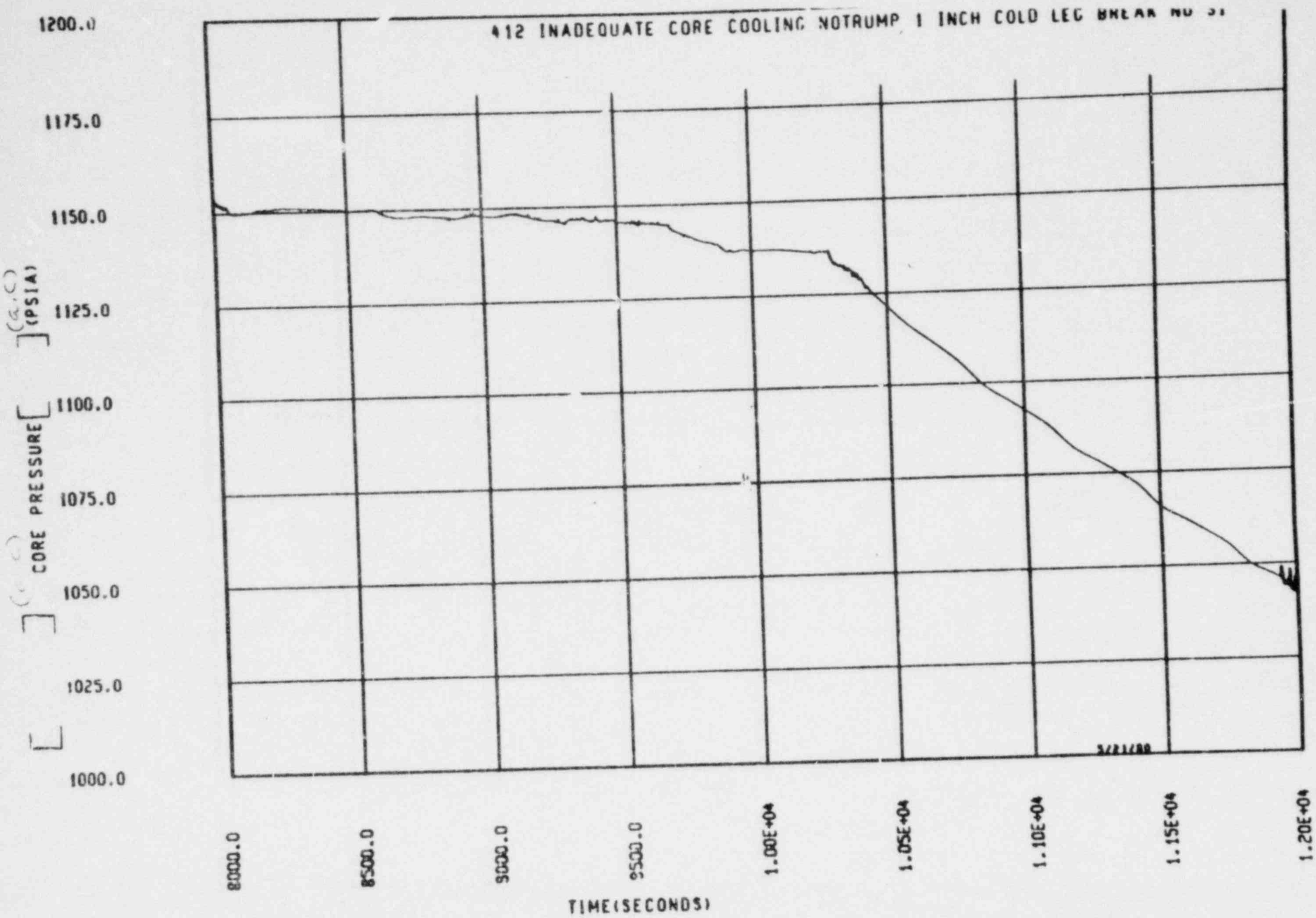
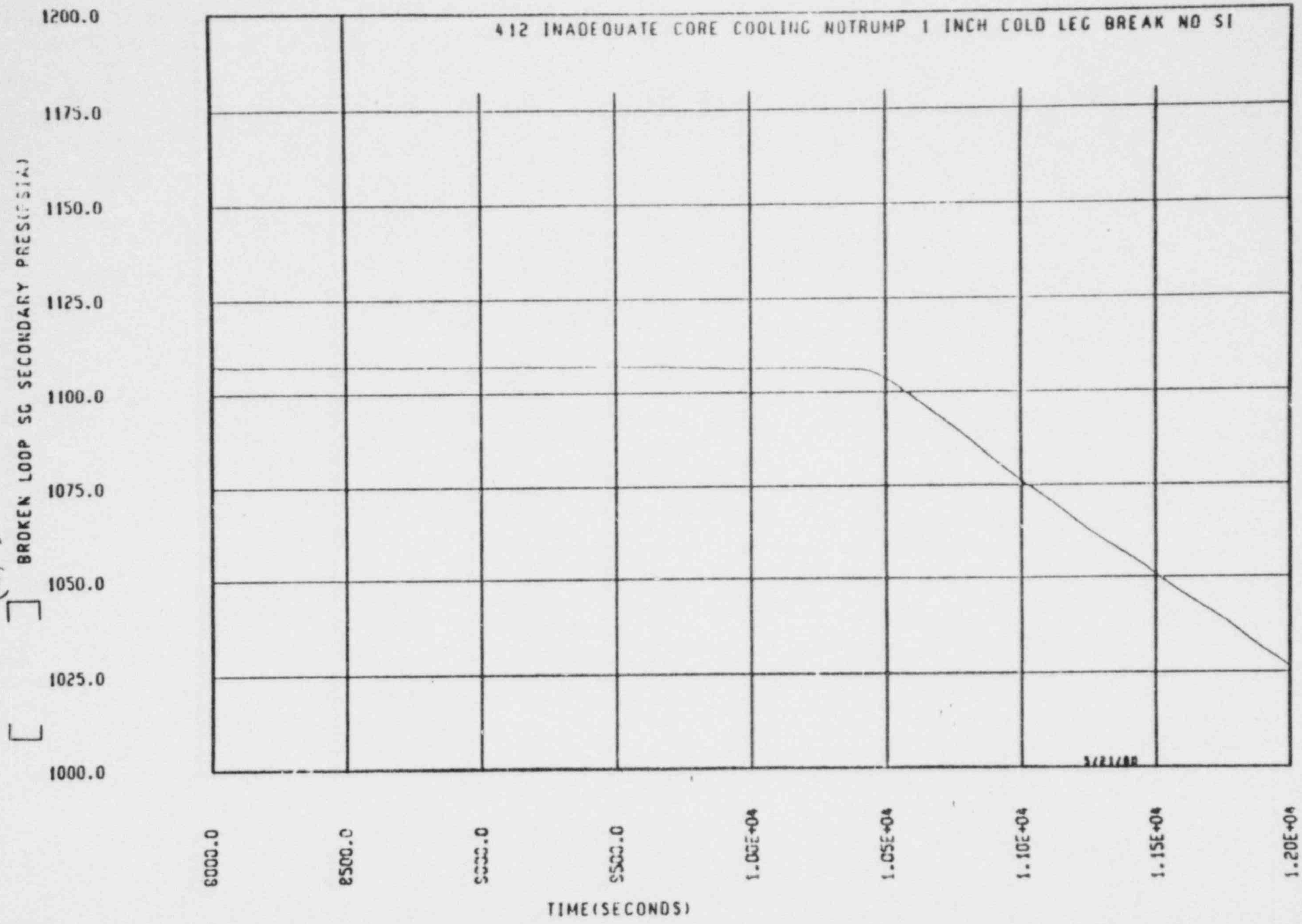
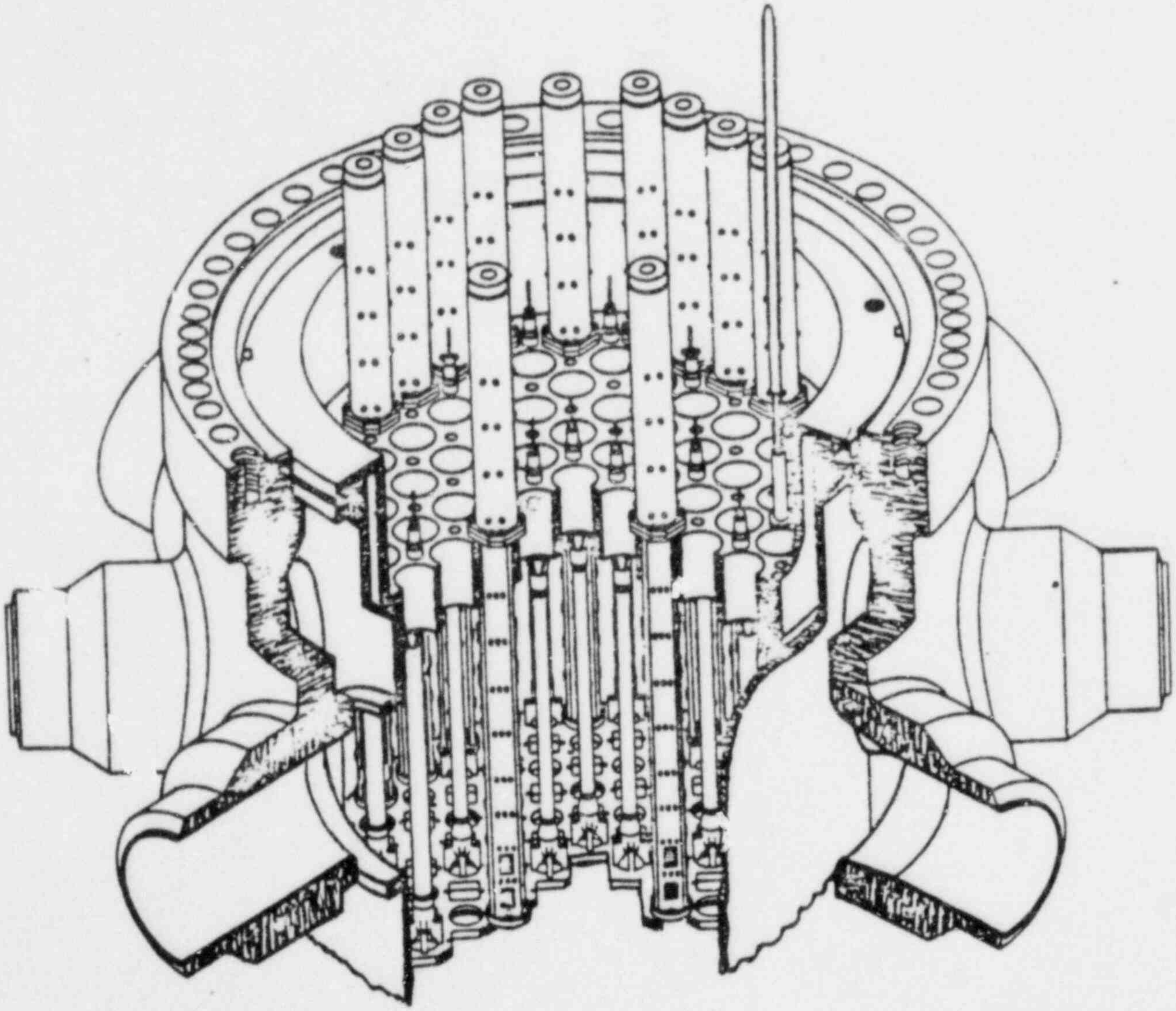

412 INADEQUATE CORE COOLING NOTRUMP 1 INCH COLD LEG BREAK NO SI
CORE PRESSURE (PSIA)
(a,c)
1200.0
1175.0
1150.0
1125.0
1100.0
1075.0
1050.0
1025.0
1000.0
8000.0
8500.0
9000.0
9500.0
1.00E+04
1.05E+04
1.10E+04
1.15E+04
1.20E+04
TIME(SECONDS)
5/21/80

Figure 81


412 INADEQUATE CORE COOLING NOTRUMP 1 INCH COLD LEG BREAK NO SI
BROKEN LOOP SG SECONDARY PRES(PSIA)
1200.0
1175.0
1150.0
1125.0
1100.0
1075.0
1050.0
1025.0
1000.0
8000.0
8500.0
9000.0
9500.0
1.00E+04
1.05E+04
1.10E+04
1.15E+04
1.20E+04
TIME(SECONDS)
5/21/80

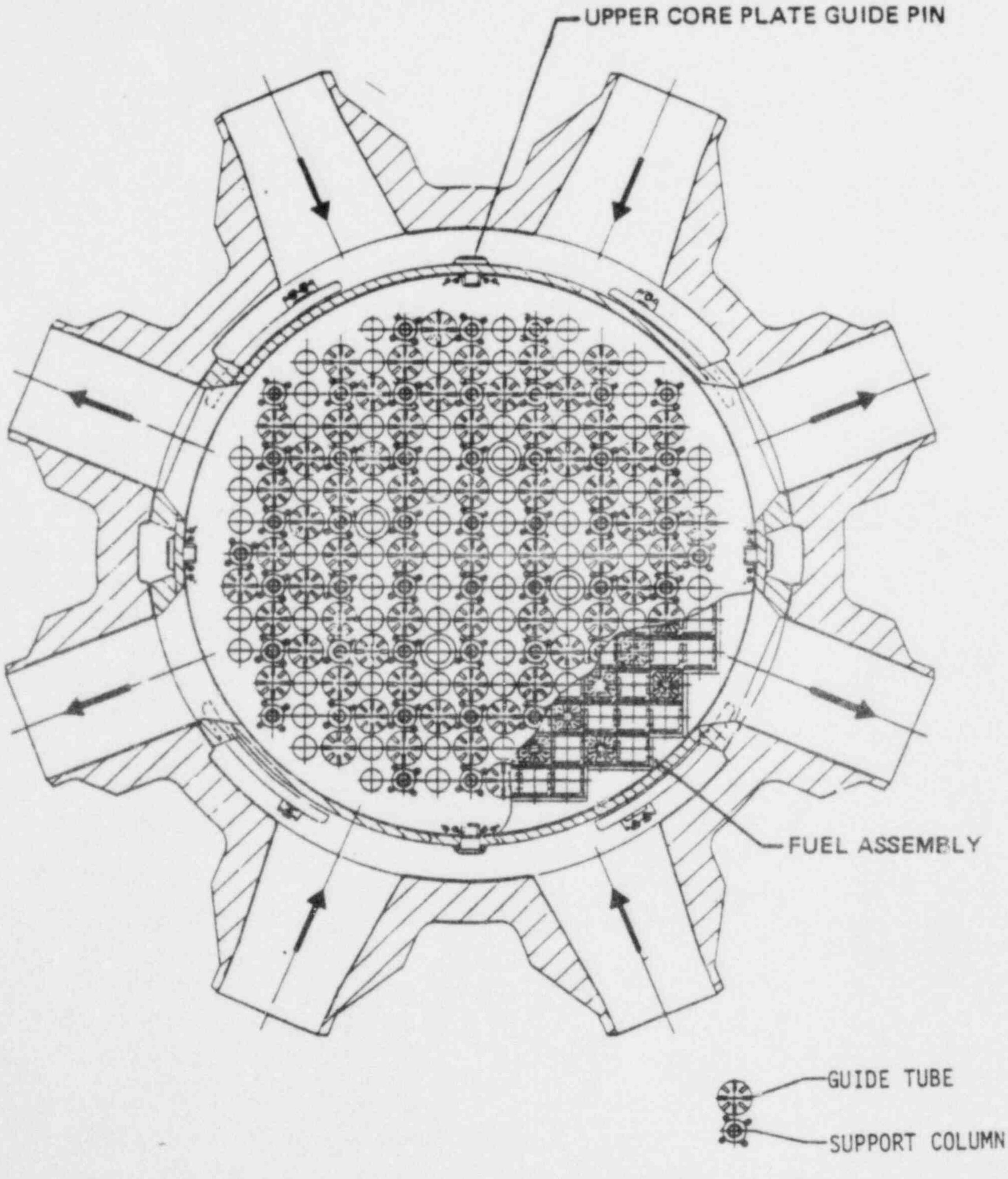
(a,c)

Figure 82



Upper Core Plate, Inlet & Outlet Nozzles, Support Column, Guide Tube and Upper Support Plate

Figure 83



Typical 4 Loop Plant Upper Plenum Geometry

FIGURE 84

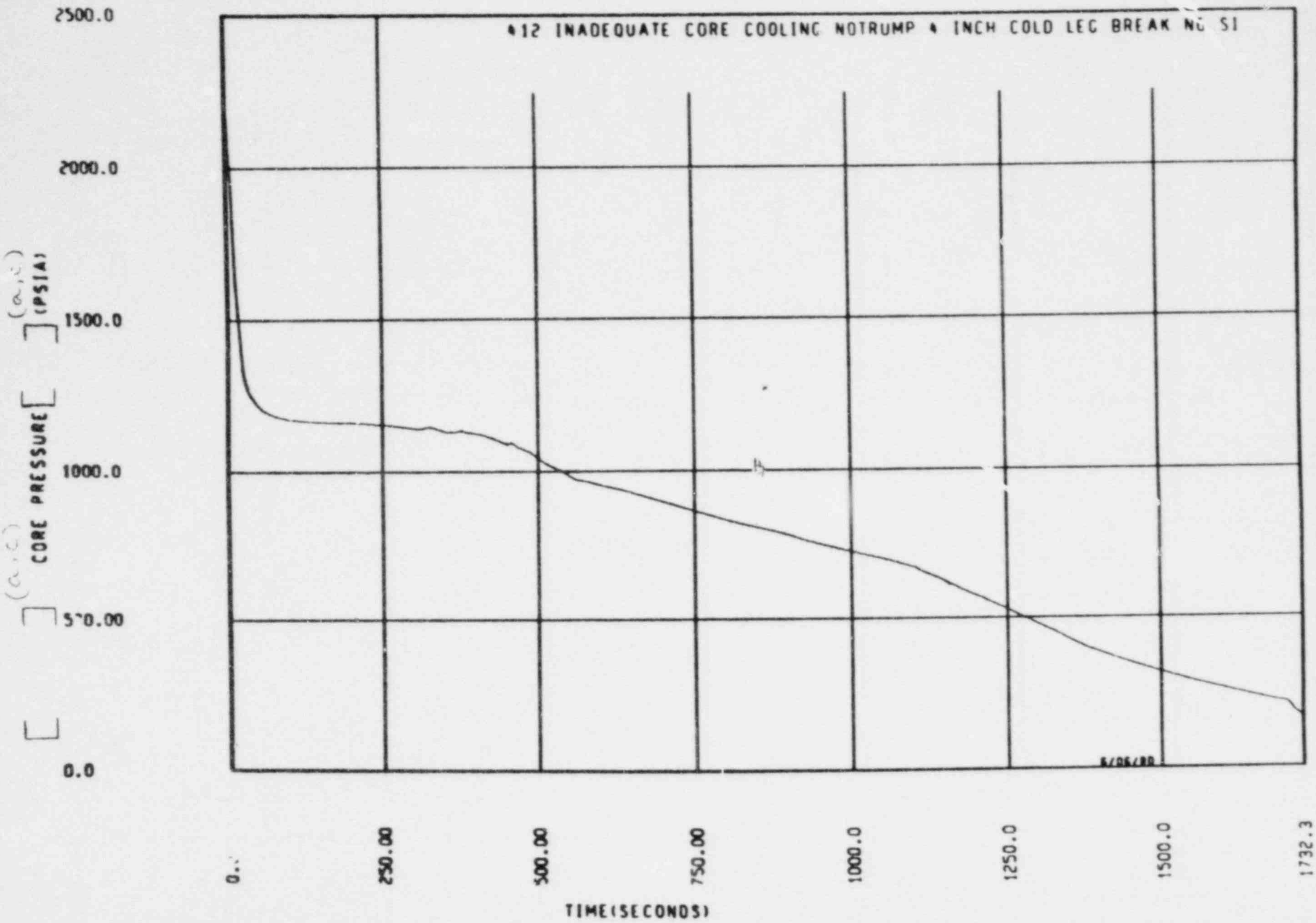

412 INADEQUATE CORE COOLING NOTRUMP 4 INCH COLD LEG BREAK NO SI
2500.0
2000.0
1500.0
1000.0
500.00
0.0
(a,c)
CORE PRESSURE
(PSIA)
(a,c)
0.
250.00
500.00
750.00
1000.0
1250.0
1500.0
1732.3
TIME(SECONDS)
6/06/80

Figure 85

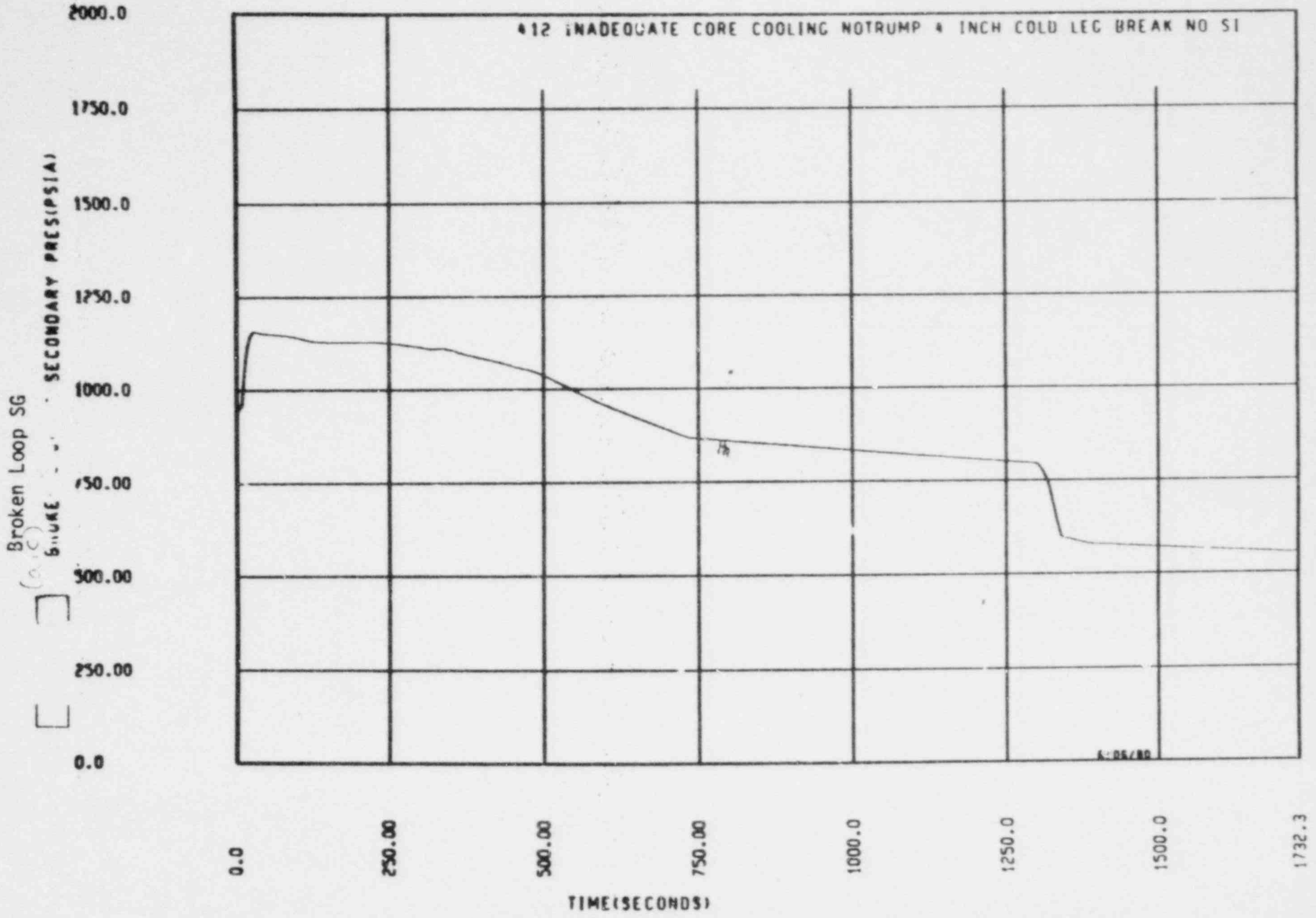

412 INADEQUATE CORE COOLING NOTRUMP 4 INCH COLD LEG BREAK NO SI
Broken Loop SG
(a,c)
BROKE . . SECONDARY PRES(PSIA)
2000.0
1750.0
1500.0
1250.0
1000.0
750.00
500.00
250.00
0.0
0.0
250.00
500.00
750.00
1000.0
1250.0
1500.0
1732.3
TIME(SECONDS)
6/06/80

Figure 86

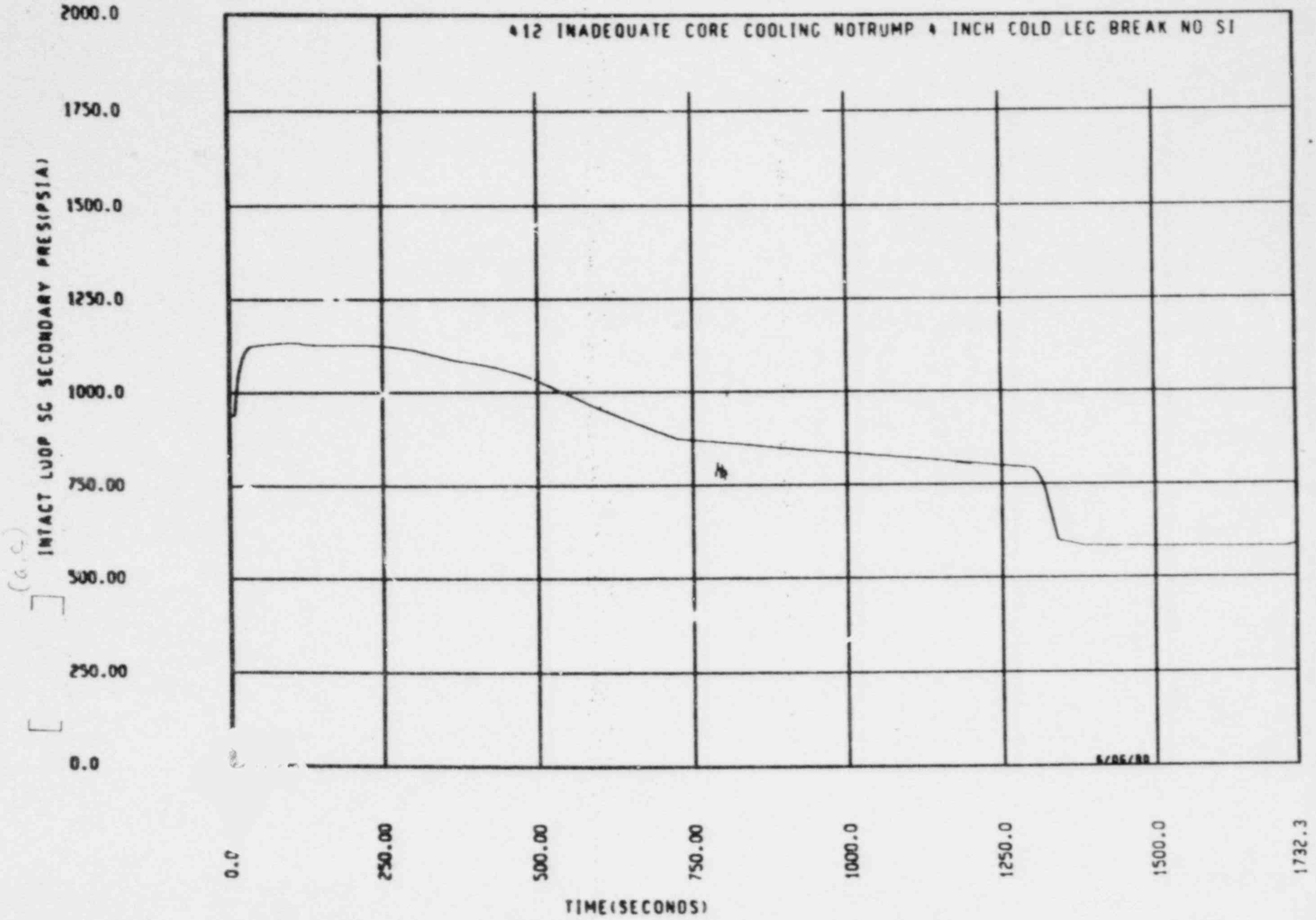

412 INADEQUATE CORE COOLING NOTRUMP 4 INCH COLD LEG BREAK NO SI
INTACT LOOP SG SECONDARY PRES(PSIA)
2000.0
1750.0
1500.0
1250.0
1000.0
750.00
500.00
250.00
0.0
0.0
250.00
500.00
750.00
1000.0
1250.0
1500.0
1732.3
TIME(SECONDS)
6/06/80
(a,c)

Figure 87

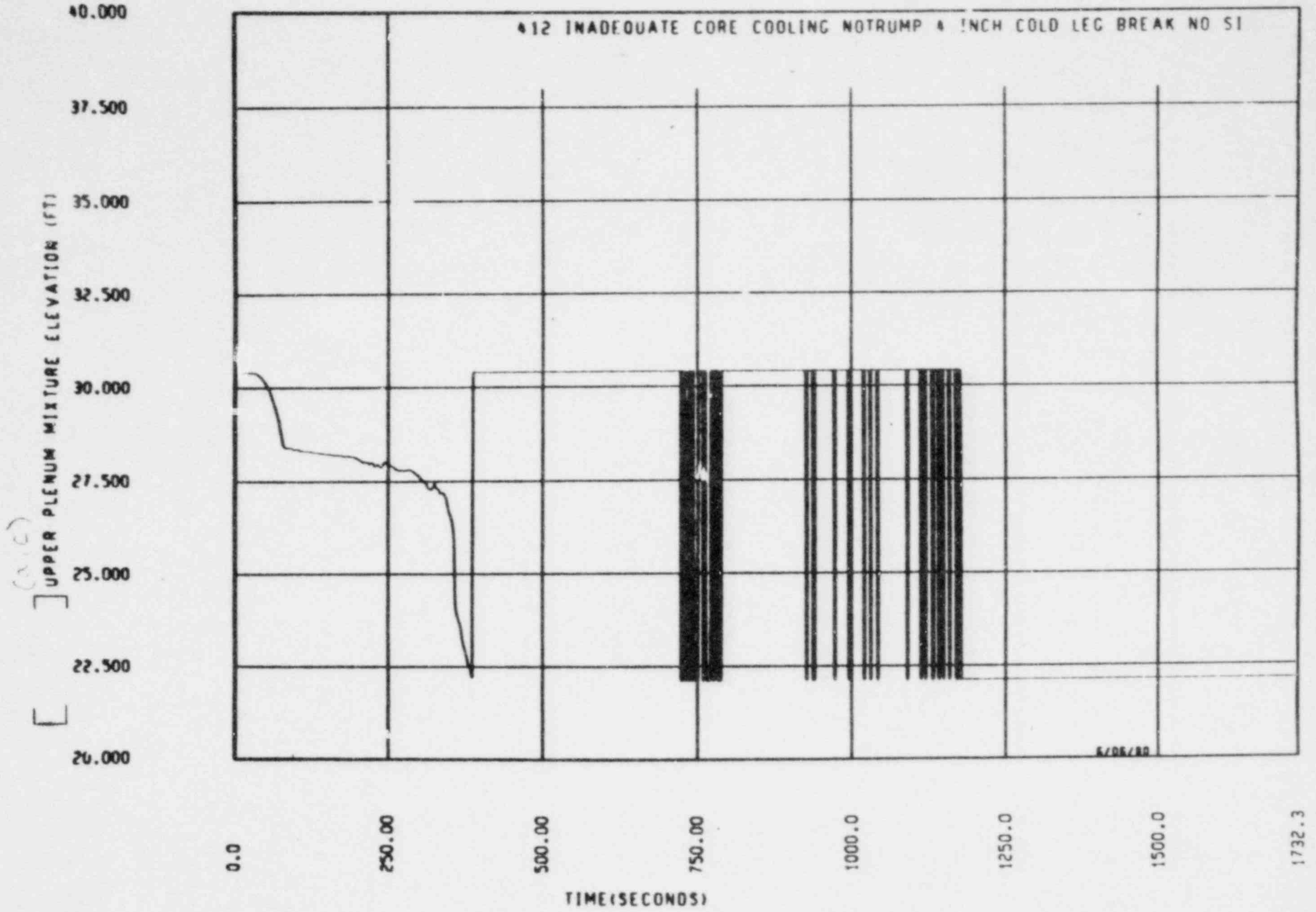

412 INADEQUATE CORE COOLING NOTRUMP 4 INCH COLD LEG BREAK NO SI
UPPER PLENUM MIXTURE ELEVATION (FT)
(a,c)
40.000
37.500
35.000
32.500
30.000
27.500
25.000
22.500
20.000
0.0
250.00
500.00
750.00
1000.0
1250.0
1500.0
1732.3
TIME(SECONDS)
6/06/80

Figure 88

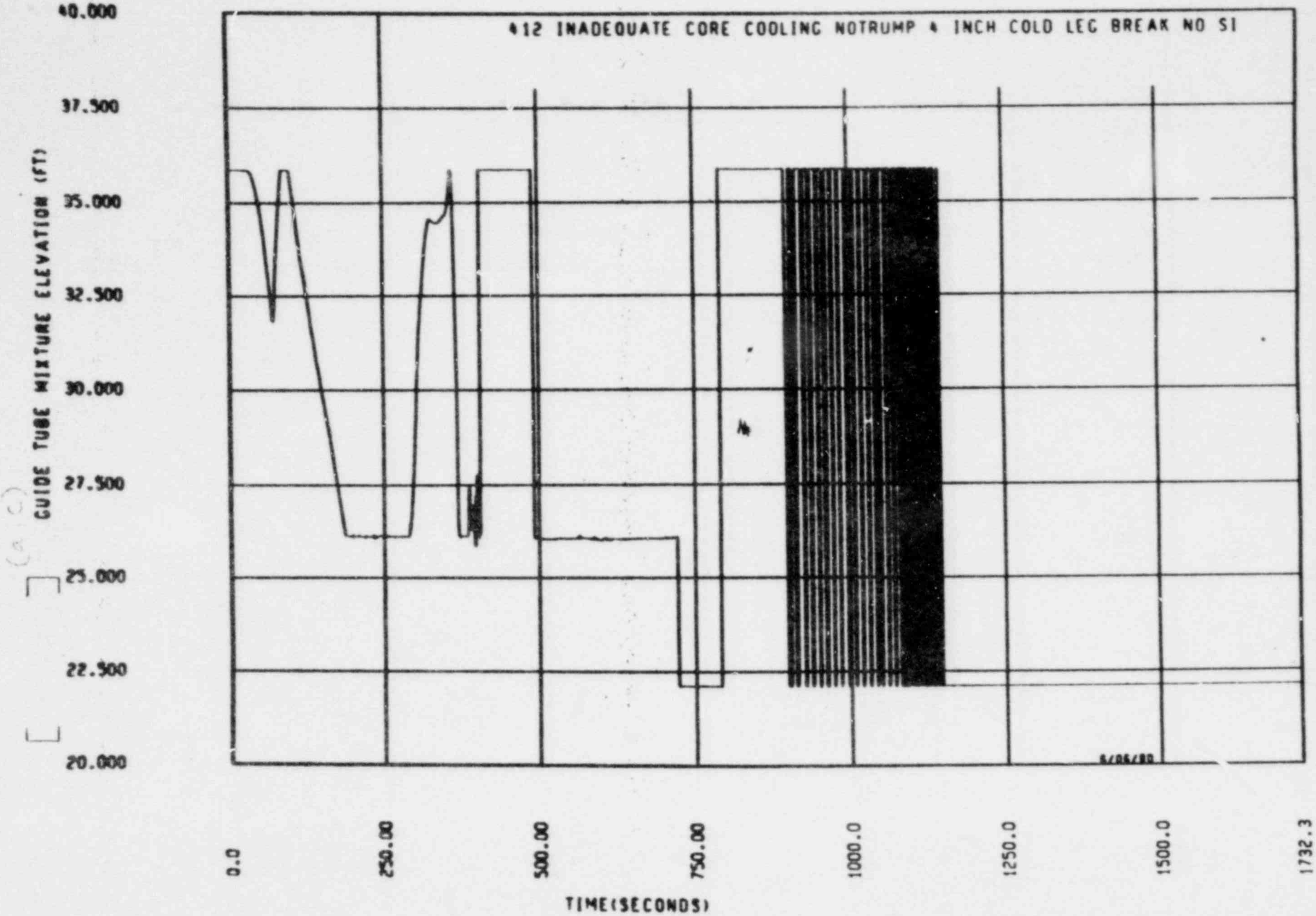

412 INADEQUATE CORE COOLING NOTRUMP 4 INCH COLD LEG BREAK NO SI
GUIDE TUBE MIXTURE ELEVATION (FT)
40.000
37.500
35.000
32.500
30.000
27.500
25.000
22.500
20.000
(a,c)
0.0
250.00
500.00
750.00
1000.0
1250.0
1500.0
1732.3
TIME(SECONDS)
6/06/80

Figure 89

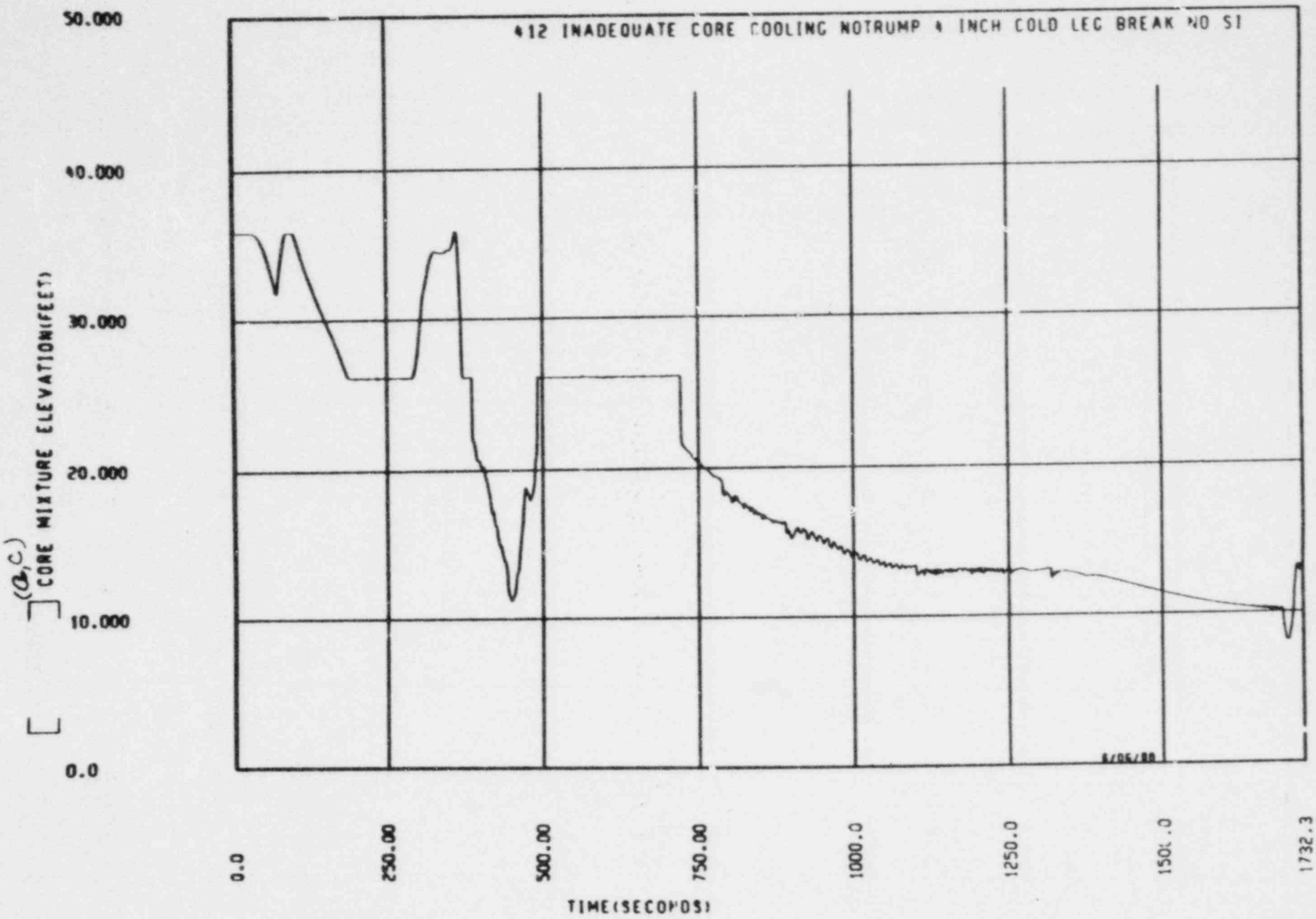

412 INADEQUATE CORE COOLING NOTRUMP 4 INCH COLD LEG BREAK NO SI
CORE MIXTURE ELEVATION(FEET)
(a,c)
50.000
40.000
30.000
20.000
10.000
0.0
0.0
250.00
500.00
750.00
1000.0
1250.0
1500.0
1732.3
TIME(SECONDS)
6/06/80

Figure 90

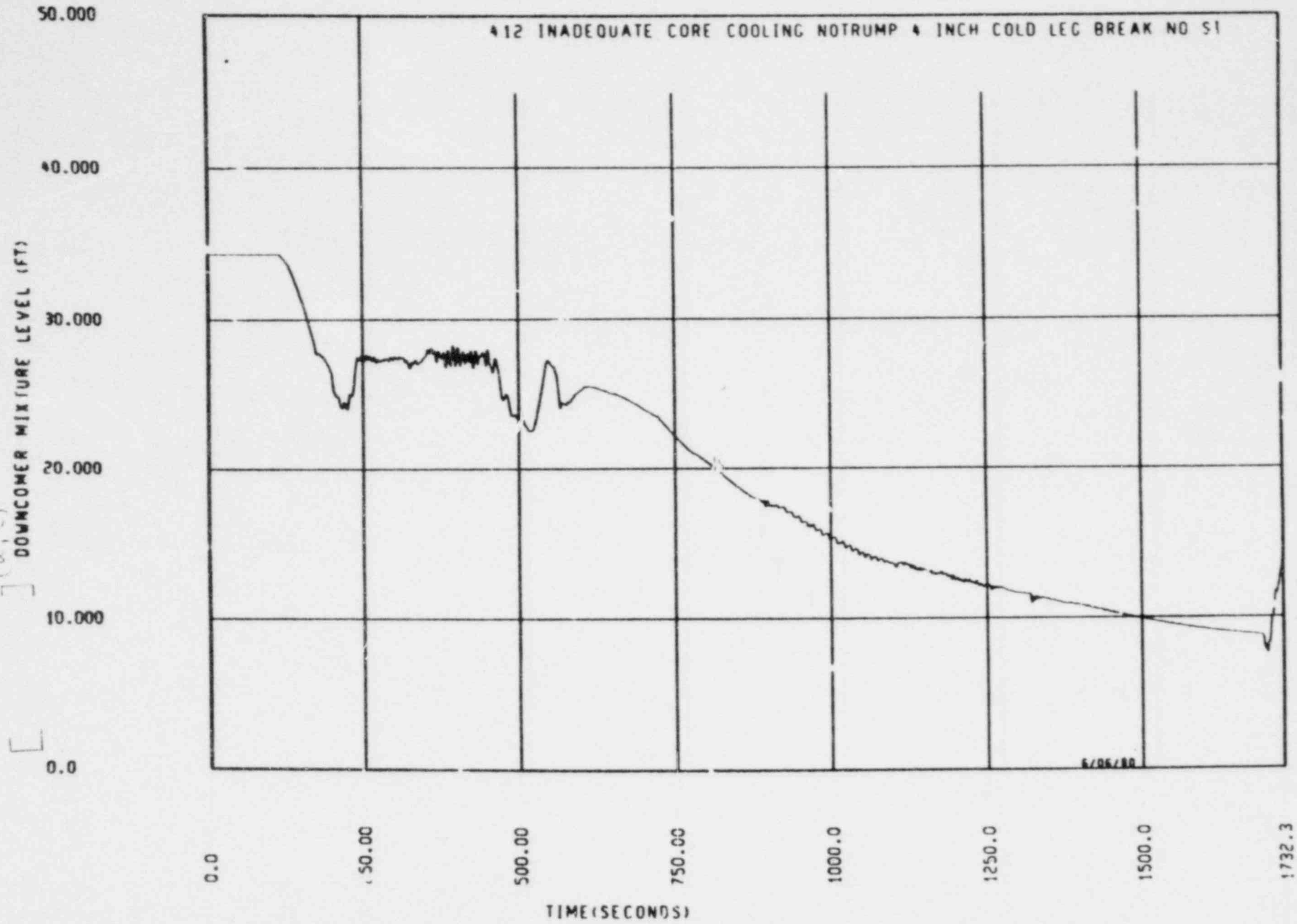
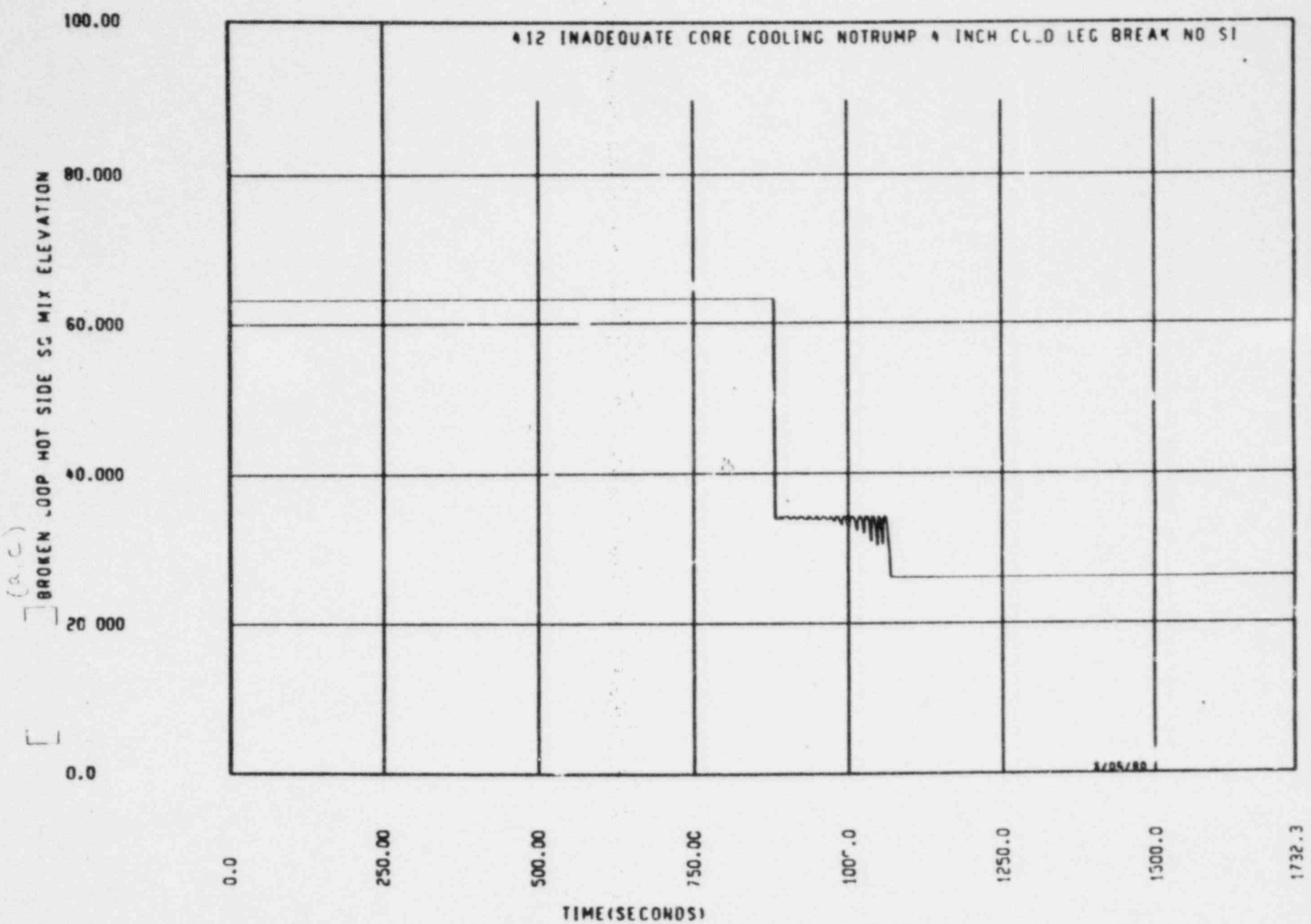

412 INADEQUATE CORE COOLING NOTRUMP 4 INCH COLD LEG BREAK NO SI
DOWNCOMER MIXTURE LEVEL (FT)
50.000
40.000
30.000
20.000
10.000
0.0
TIME(SECONDS)
0.0
250.00
500.00
750.00
1000.0
1250.0
1500.0
1732.3
6/06/80
(a,c)

Figure 91



412 INADEQUATE CORE COOLING NOTRUMP 4 INCH COLD LEG BREAK NO SI
BROKEN LOOP HOT SIDE SG MIX ELEVATION
(a,c)
100.00
80.000
60.000
40.000
20 000
0.0
0.0
250.00
500.00
750.00
1000.0
1250.0
1500.0
1732.3
TIME(SECONDS)
3/05/80

Figure 92

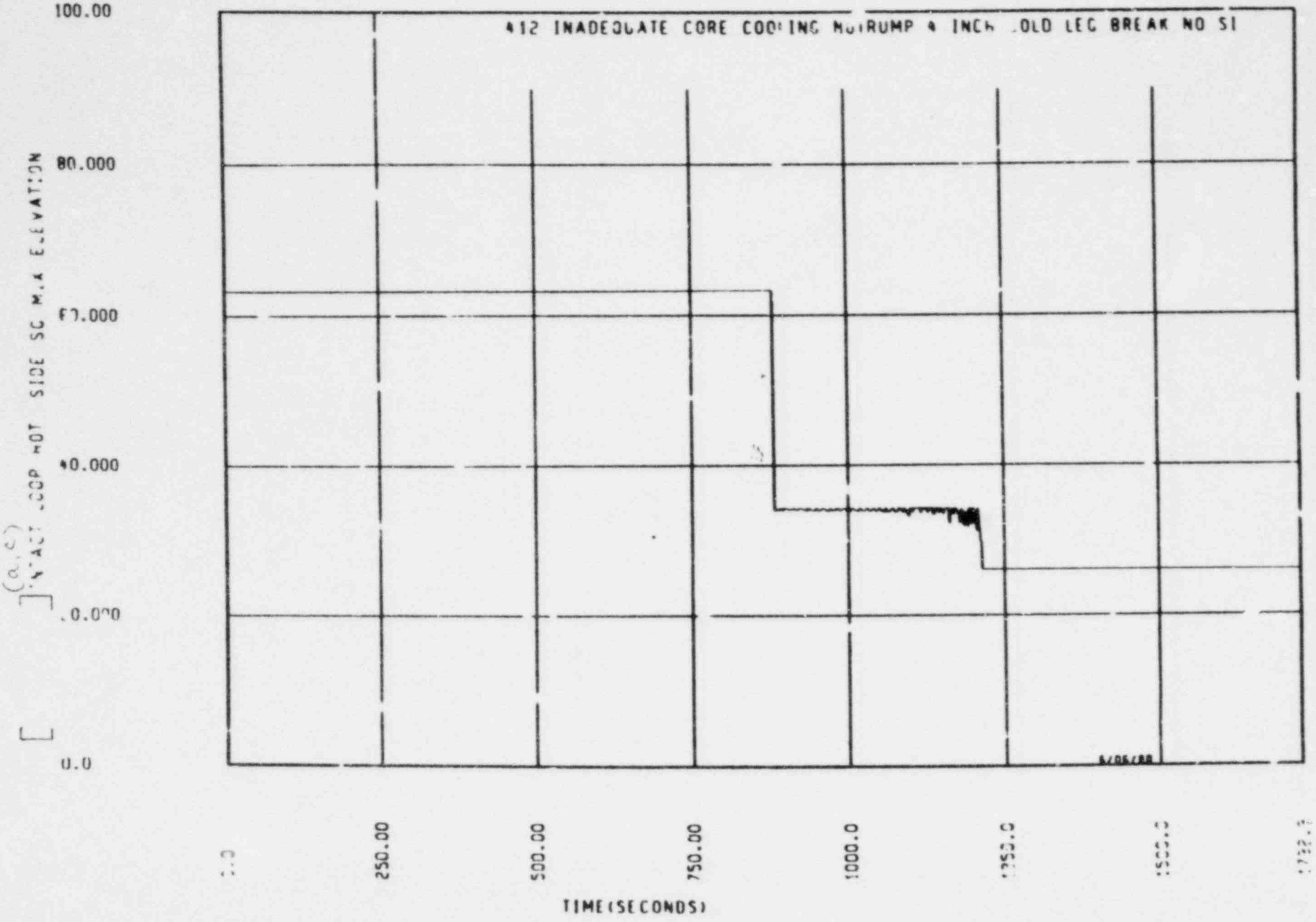

412 INADEQUATE CORE COOLING NOPUMP 4 INCH COLD LEG BREAK NO SI
100.00
80.000
60.000
40.000
20.000
0.0
(a,c)
W'ACT LOOP HOT SIDE SG MIX ELEVATION
0.0
250.00
500.00
750.00
1000.0
1250.0
1500.0
1750.0
TIME(SECONDS)
6/05/88

Figure 93

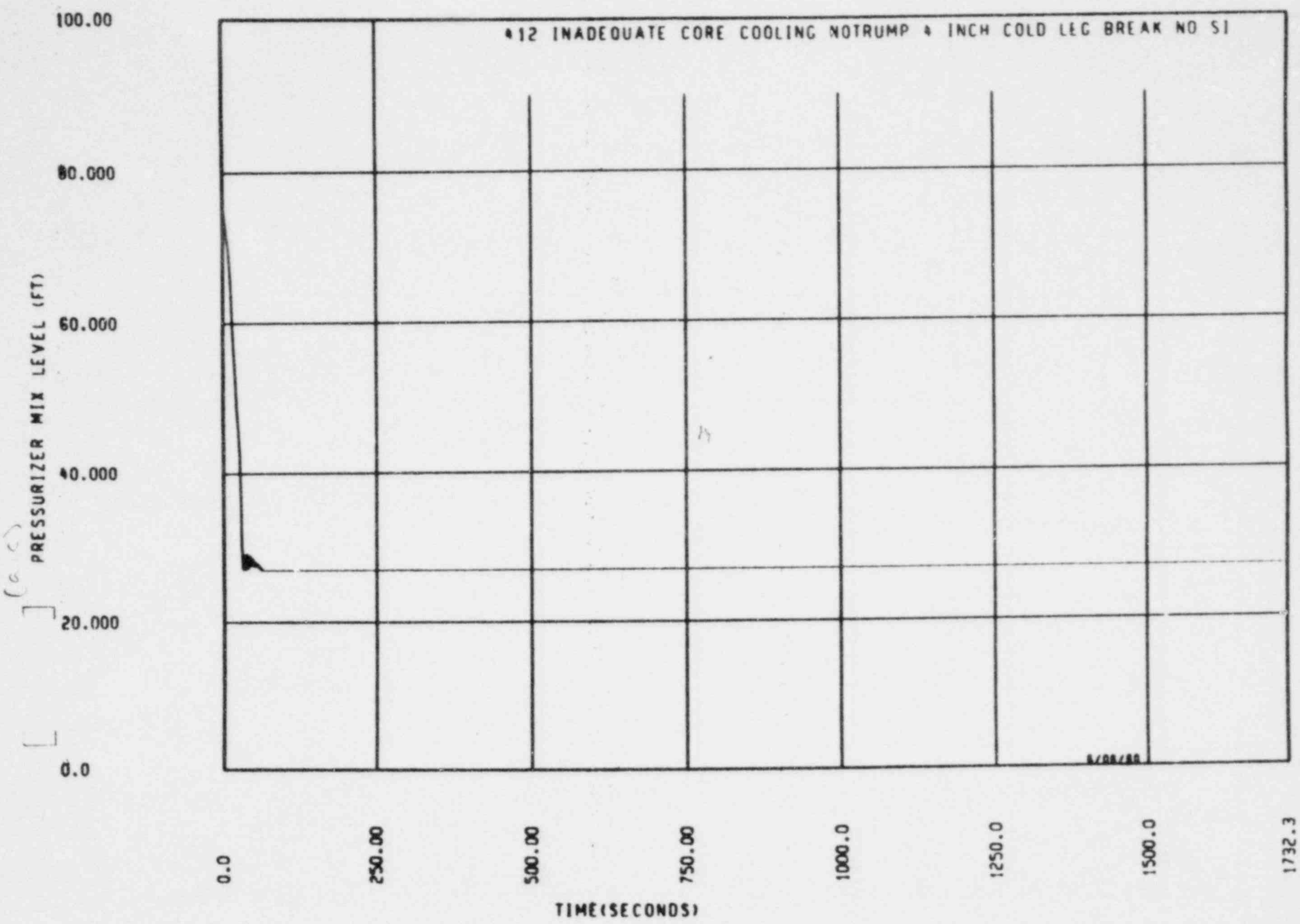
412 INADEQUATE CORE COOLING NOTRUMP 4 INCH COLD LEG BREAK NO SI
PRESSURIZER MIX LEVEL (FT)
100.00
80.000
60.000
40.000
20.000
0.0
(a,c)
TIME(SECONDS)
0.0
250.00
500.00
750.00
1000.0
1250.0
1500.0
1732.3

Figure 94

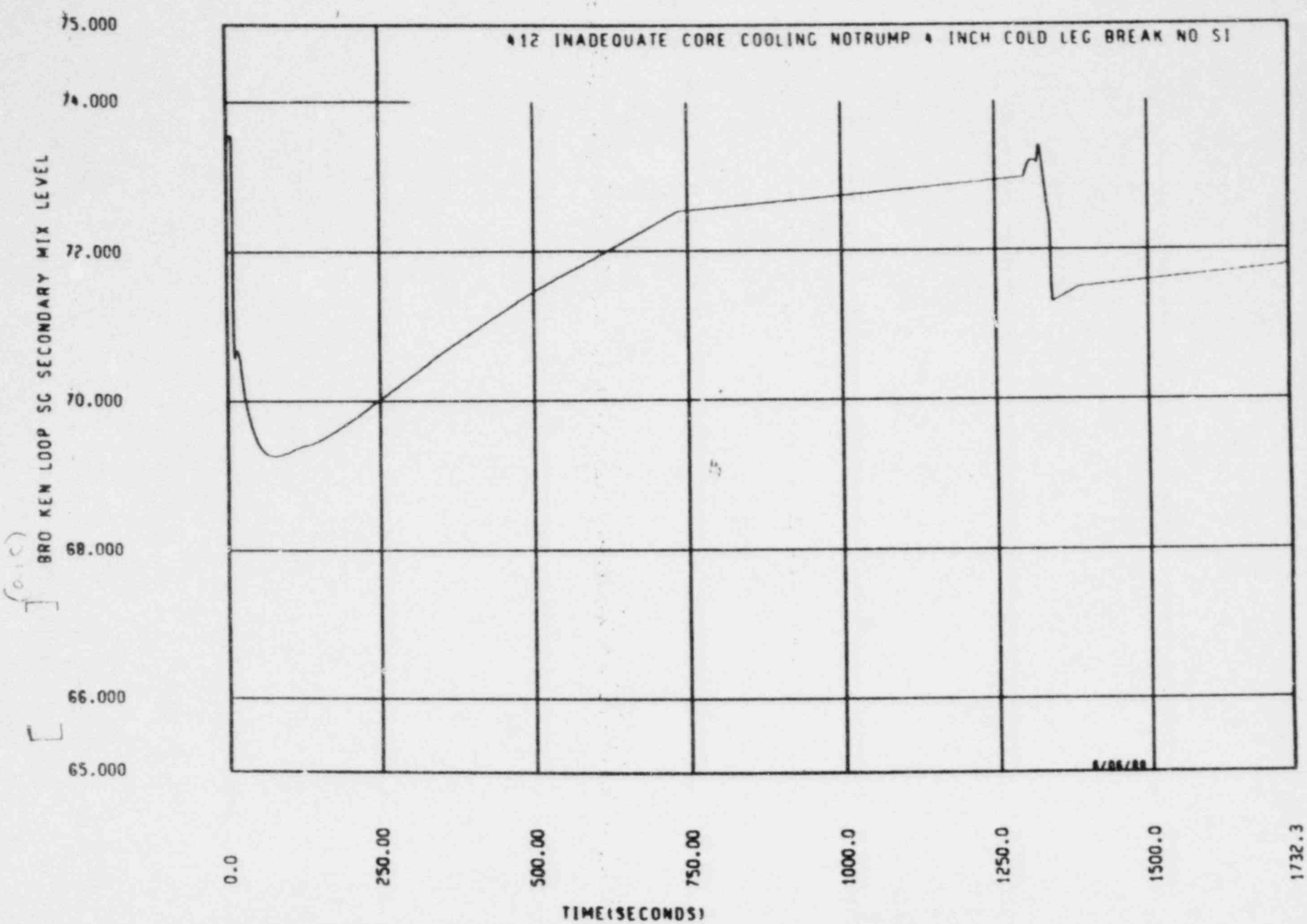

412 INADEQUATE CORE COOLING NOTRUMP 4 INCH COLD LEG BREAK NO SI
BRO KEN LOOP SC SECONDARY MIX LEVEL
(a,c)
75.000
74.000
72.000
70.000
68.000
66.000
65.000
0.0
250.00
500.00
750.00
1000.0
1250.0
1500.0
1732.3
TIME(SECONDS)

Figure 95

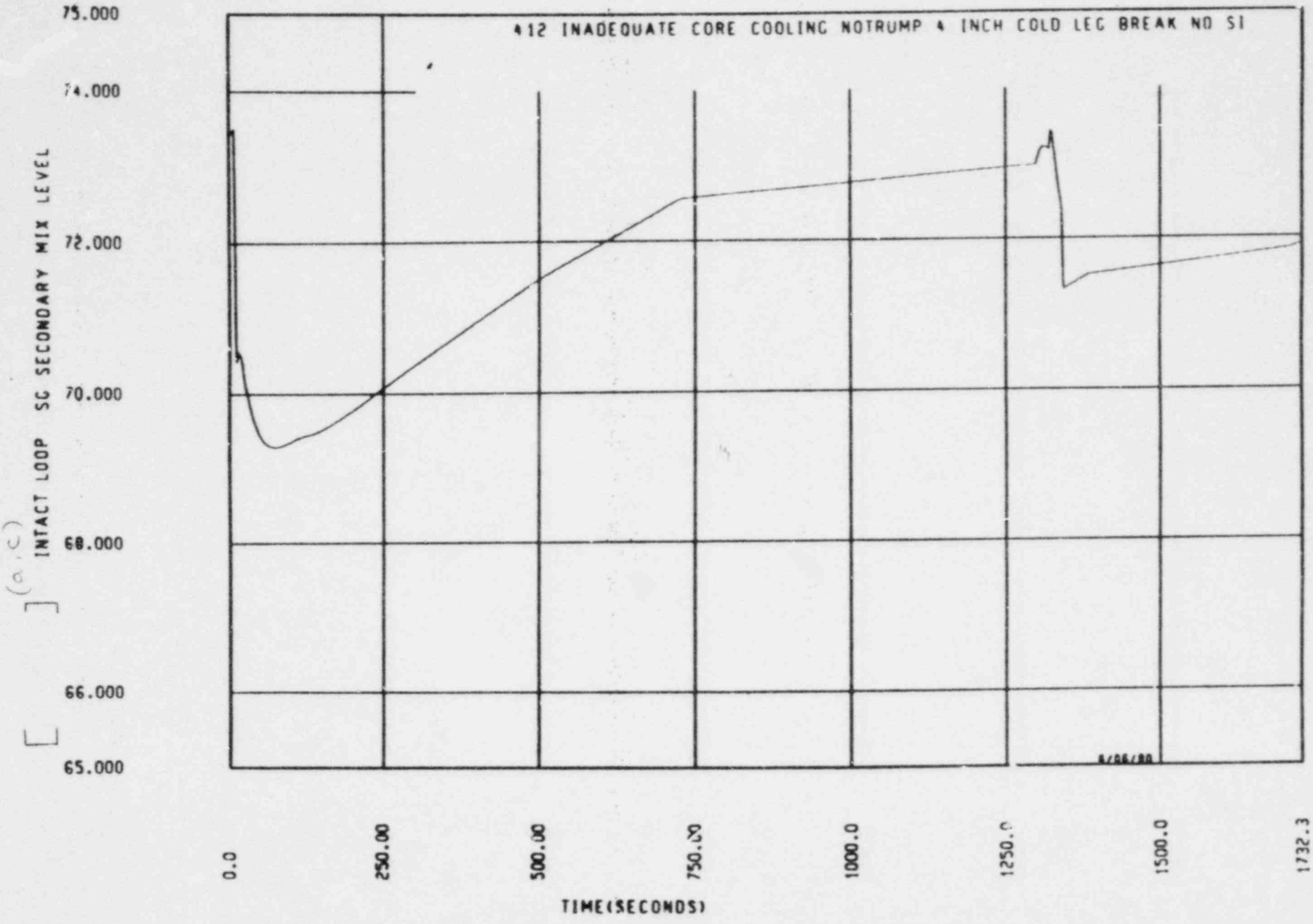

412 INADEQUATE CORE COOLING NOTRUMP 4 INCH COLD LEG BREAK NO SI
INTACT LOOP SG SECONDARY MIX LEVEL
[ ](a,c)
75.000
74.000
72.000
70.000
68.000
66.000
65.000
0.0
250.00
500.00
750.00
1000.0
1250.0
1500.0
1732.3
TIME(SECONDS)
6/06/80

Figure 96

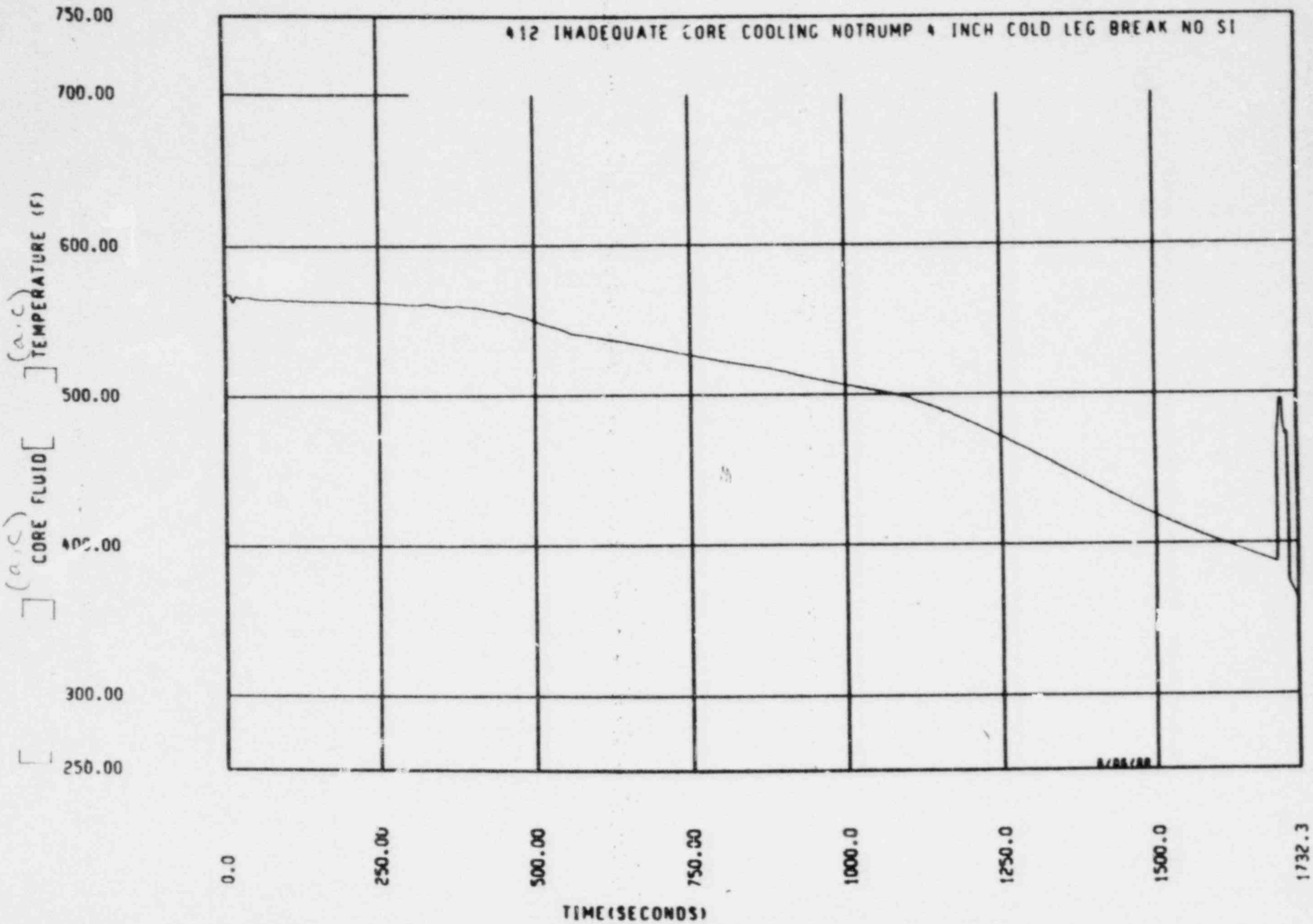

412 INADEQUATE CORE COOLING NOTRUMP 4 INCH COLD LEG BREAK NO SI
750.00
700.00
600.00
500.00
400.00
300.00
250.00
] (a,c) CORE FLUID [ ] (a,c) TEMPERATURE (F)
0.0
250.00
500.00
750.00
1000.0
1250.0
1500.0
1732.3
TIME(SECONDS)

Figure 97

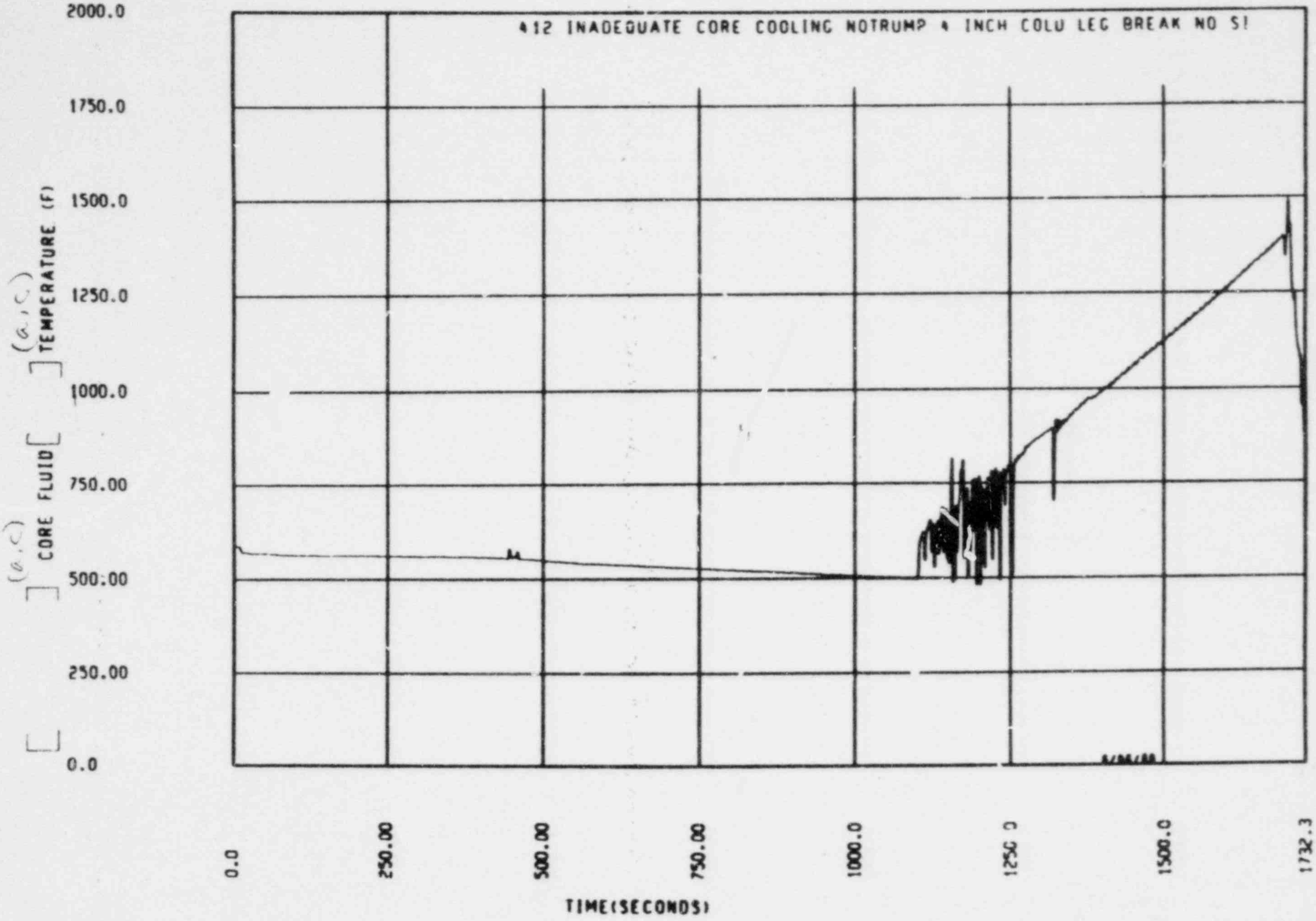

412 INADEQUATE CORE COOLING NOTRUMP 4 INCH COLU LEG BREAK NO SI
2000.0
1750.0
1500.0
1250.0
1000.0
750.00
500.00
250.00
0.0
[ ] CORE FLUID [ ] TEMPERATURE (F)
(a,c)
(a,c)
0.0
250.00
500.00
750.00
1000.0
1250.0
1500.0
1732.3
TIME(SECONDS)

Figure 98

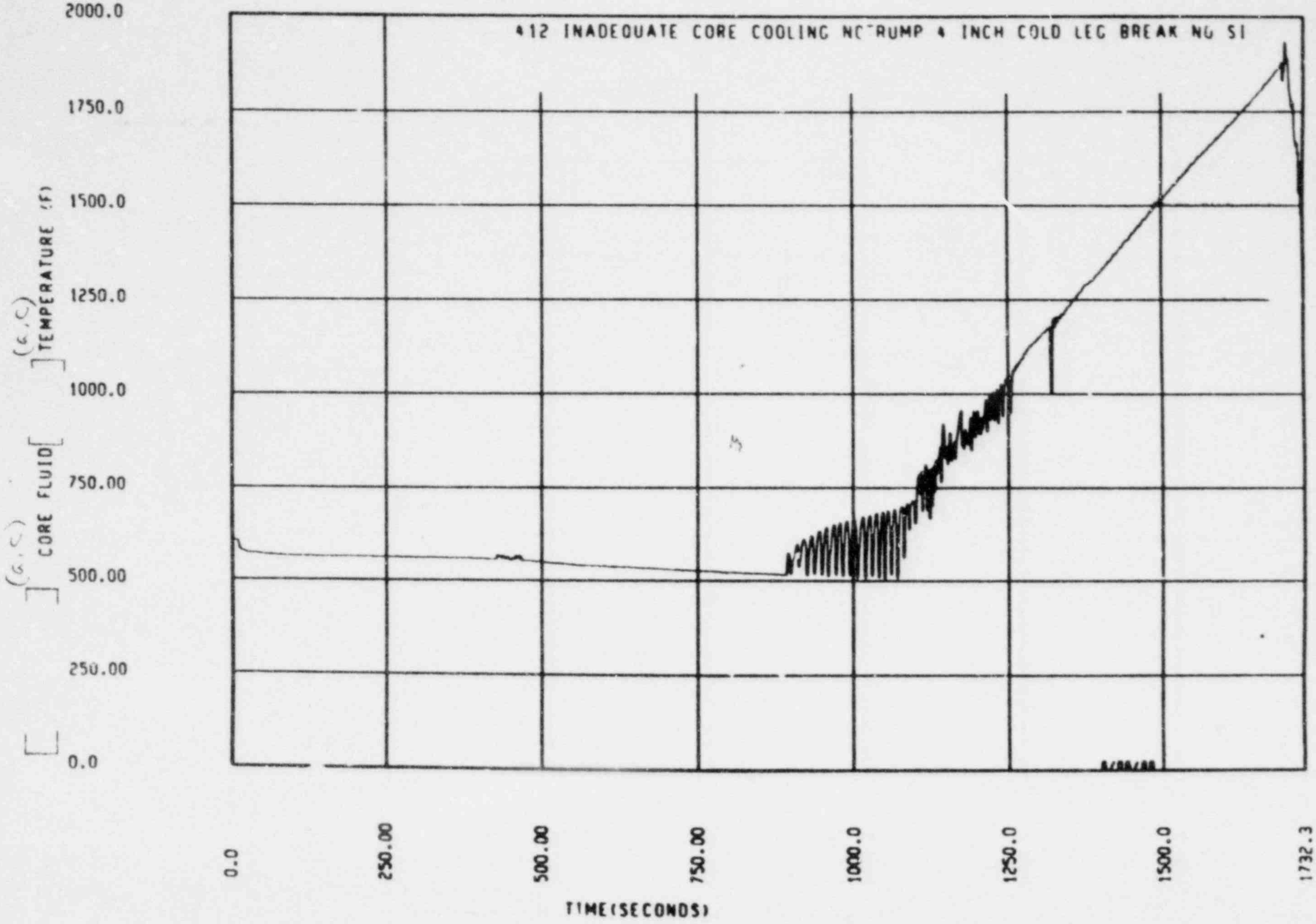

412 INADEQUATE CORE COOLING NO RUMP 4 INCH COLD LEG BREAK NO SI
CORE FLUID TEMPERATURE (F)
(a,c)
(a,c)
2000.0
1750.0
1500.0
1250.0
1000.0
750.00
500.00
250.00
0.0
0.0
250.00
500.00
750.00
1000.0
1250.0
1500.0
1732.3
TIME(SECONDS)

Figure 99

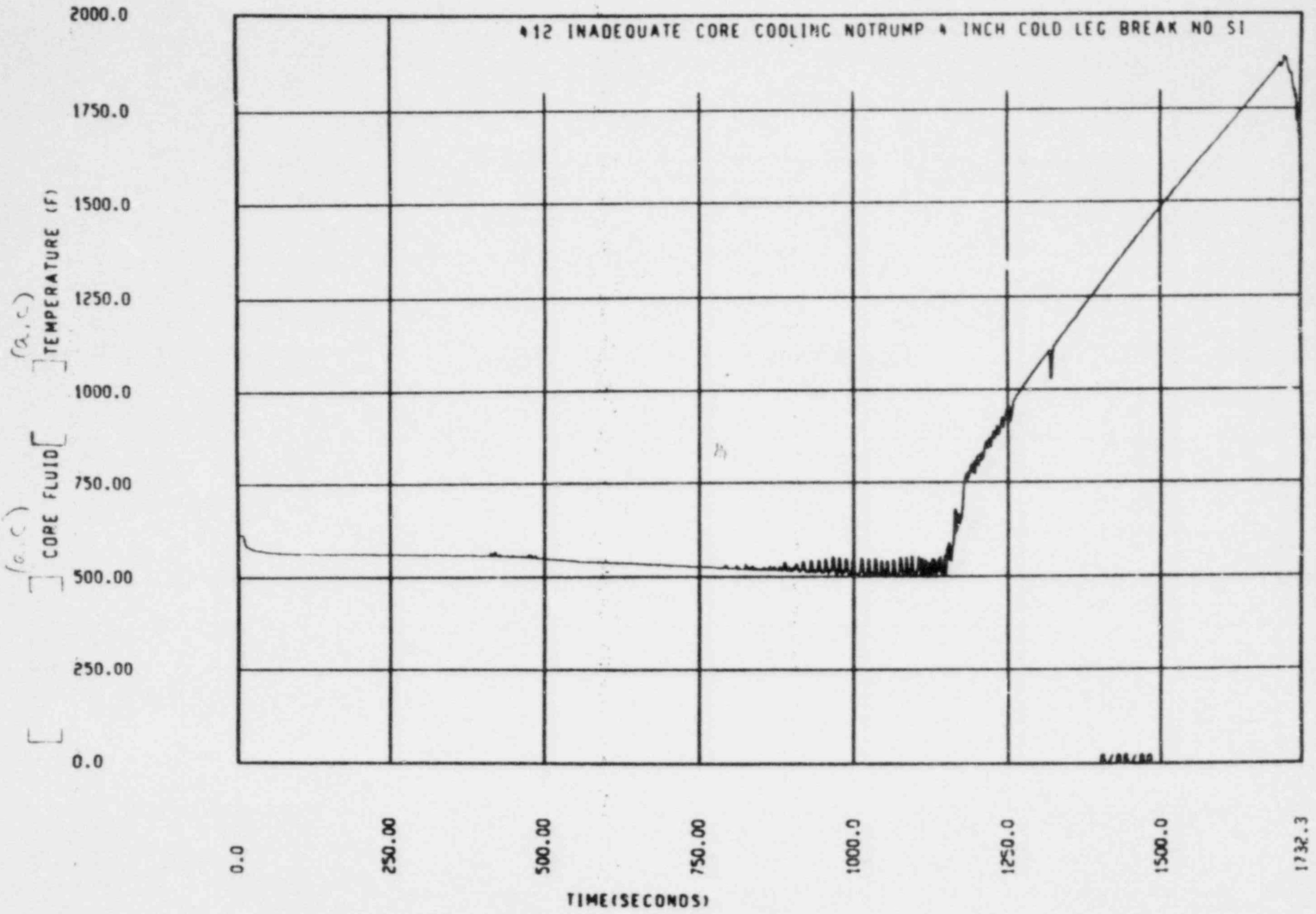

412 INADEQUATE CORE COOLING NOTRUMP 4 INCH COLD LEG BREAK NO SI
(a,c)
CORE FLUID
(a,c)
TEMPERATURE (F)
2000.0
1750.0
1500.0
1250.0
1000.0
750.00
500.00
250.00
0.0
0.0
250.00
500.00
750.00
1000.0
1250.0
1500.0
1732.3
TIME(SECONDS)

Figure 100

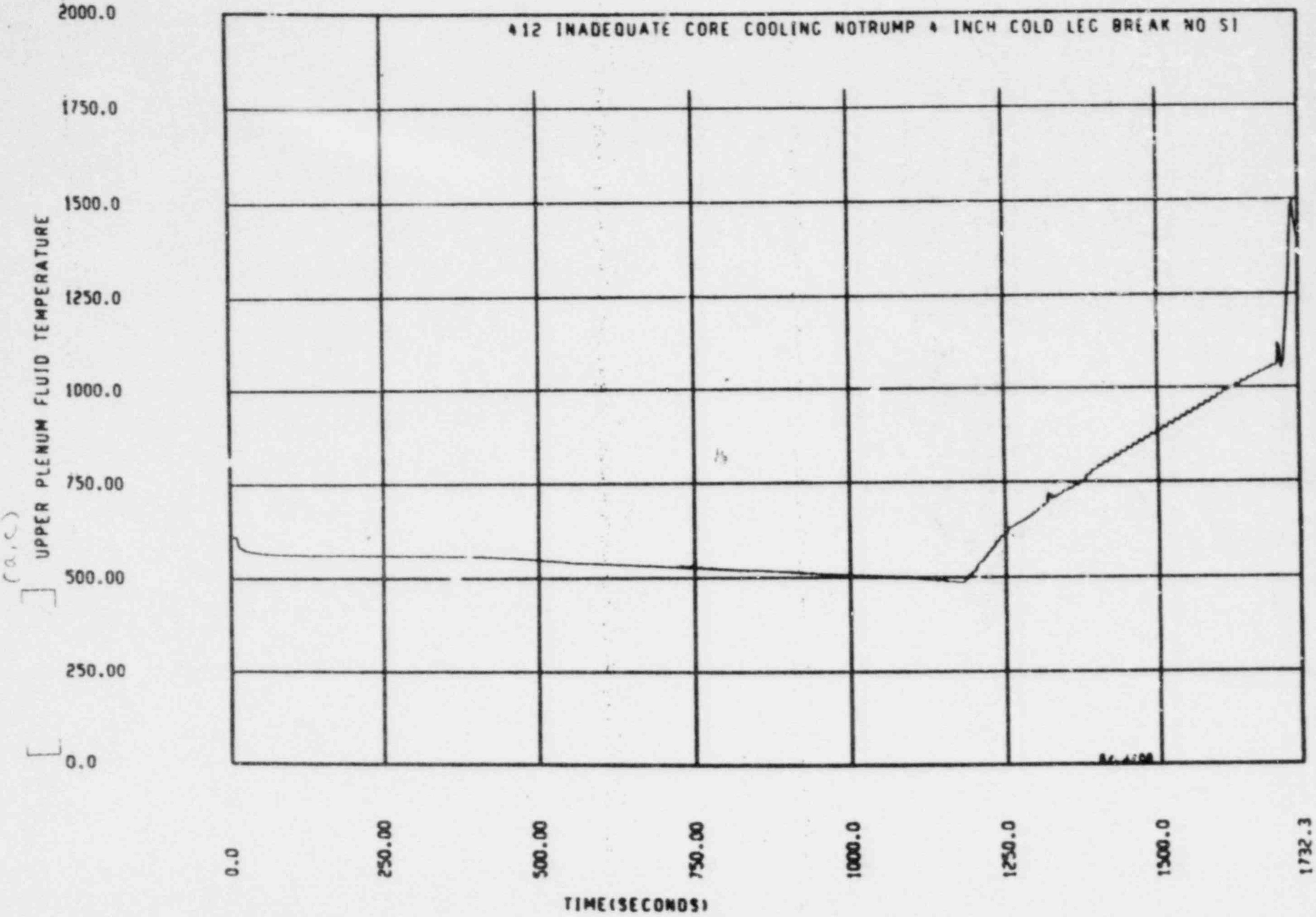

412 INADEQUATE CORE COOLING NOTRUMP 4 INCH COLD LEG BREAK NO SI
UPPER PLENUM FLUID TEMPERATURE
(a,c)
2000.0
1750.0
1500.0
1250.0
1000.0
750.00
500.00
250.00
0.0
0.0
250.00
500.00
750.00
1000.0
1250.0
1500.0
1732.3
TIME(SECONDS)

Figure 101

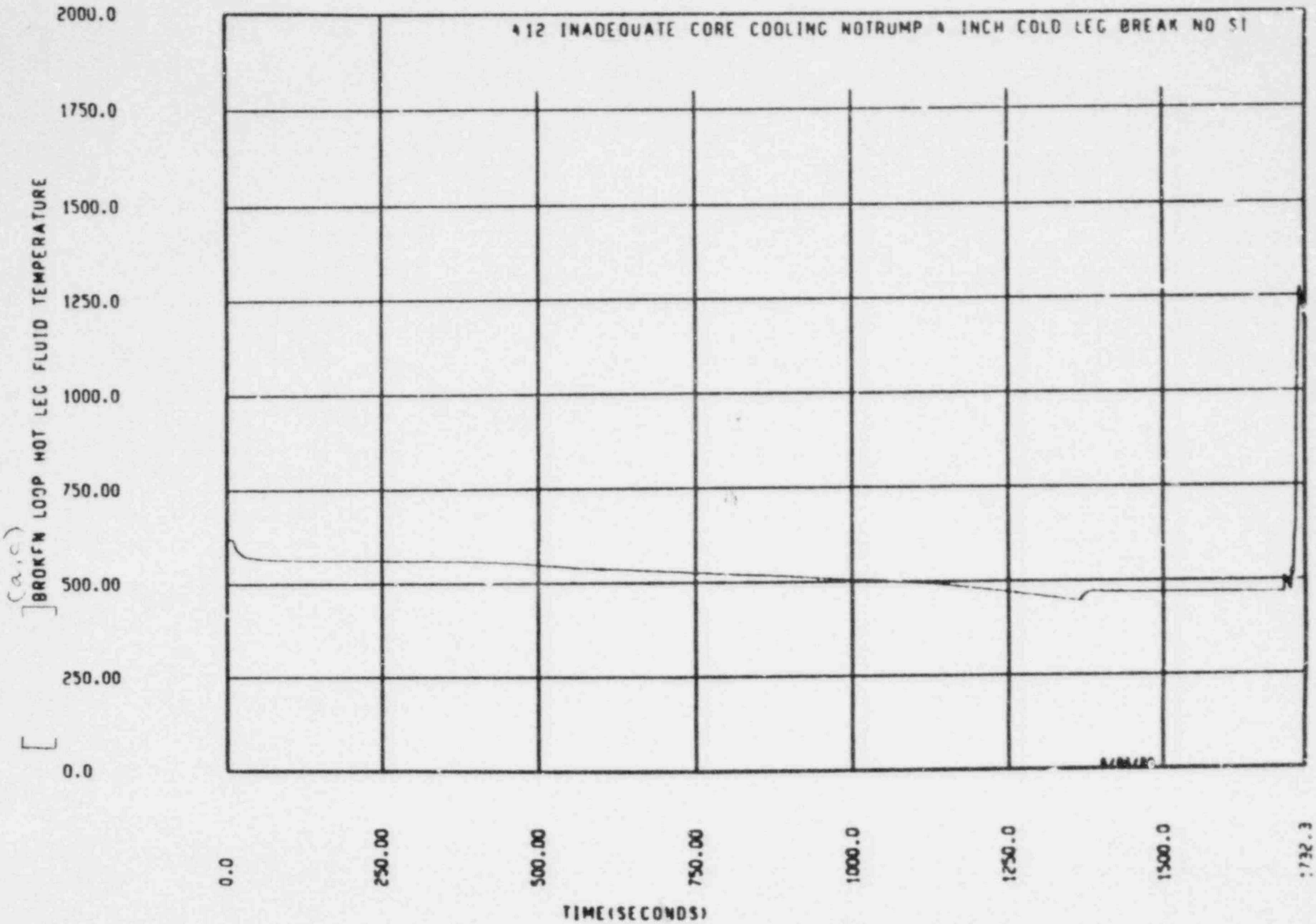

412 INADEQUATE CORE COOLING NOTRUMP 4 INCH COLD LEG BREAK NO SI
(a,c)
BROKEN LOOP HOT LEG FLUID TEMPERATURE
2000.0
1750.0
1500.0
1250.0
1000.0
750.00
500.00
250.00
0.0
0.0
250.00
500.00
750.00
1000.0
1250.0
1500.0
1732.3
TIME(SECONDS)

Figure 102

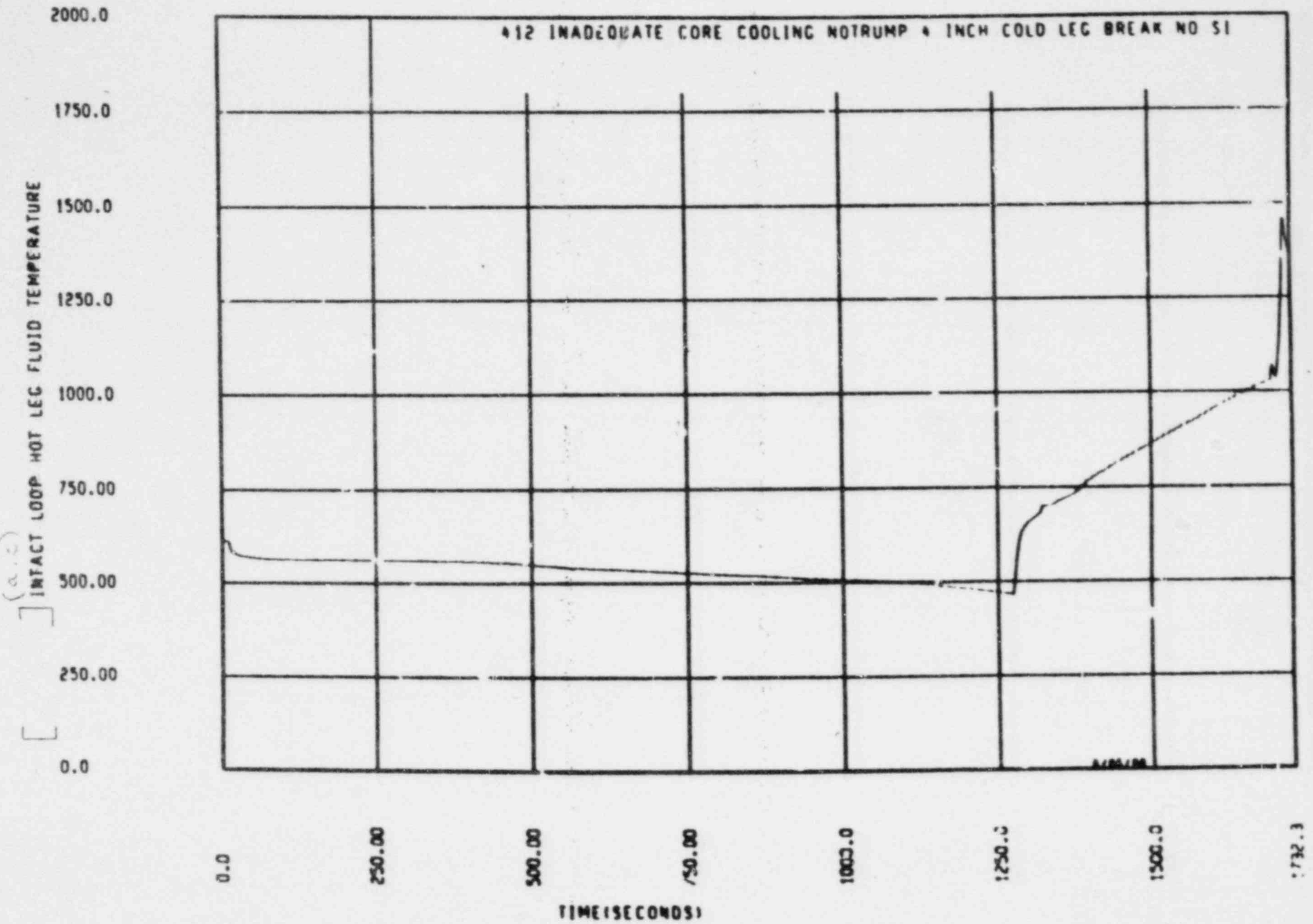

412 INADEQUATE CORE COOLING NOTRUMP 4 INCH COLD LEG BREAK NO SI
INTACT LOOP HOT LEG FLUID TEMPERATURE
(a,c)
2000.0
1750.0
1500.0
1250.0
1000.0
750.00
500.00
250.00
0.0
0.0
250.00
500.00
750.00
1000.0
1250.0
1500.0
1732.3
TIME(SECONDS)

Figure 103

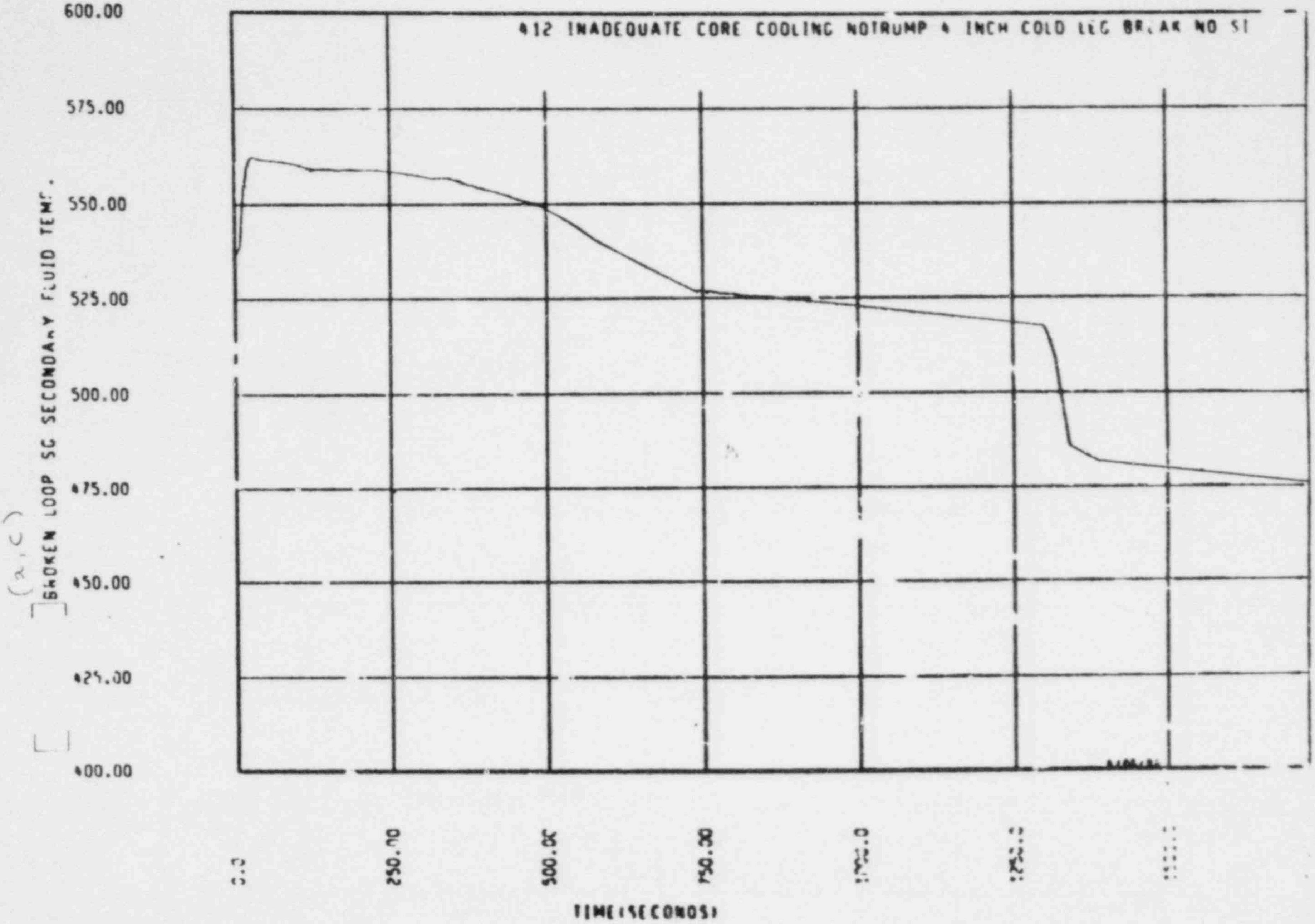

412 INADEQUATE CORE COOLING NOTRUMP 4 INCH COLD LEG BREAK NO SI
BROKEN LOOP SG SECONDARY FLUID TEMP.
(a,c)
600.00
575.00
550.00
525.00
500.00
475.00
450.00
425.00
400.00
0.0
250.00
500.00
750.00
1000.0
1250.0
1500.0
TIME(SECONDS)

Figure 104

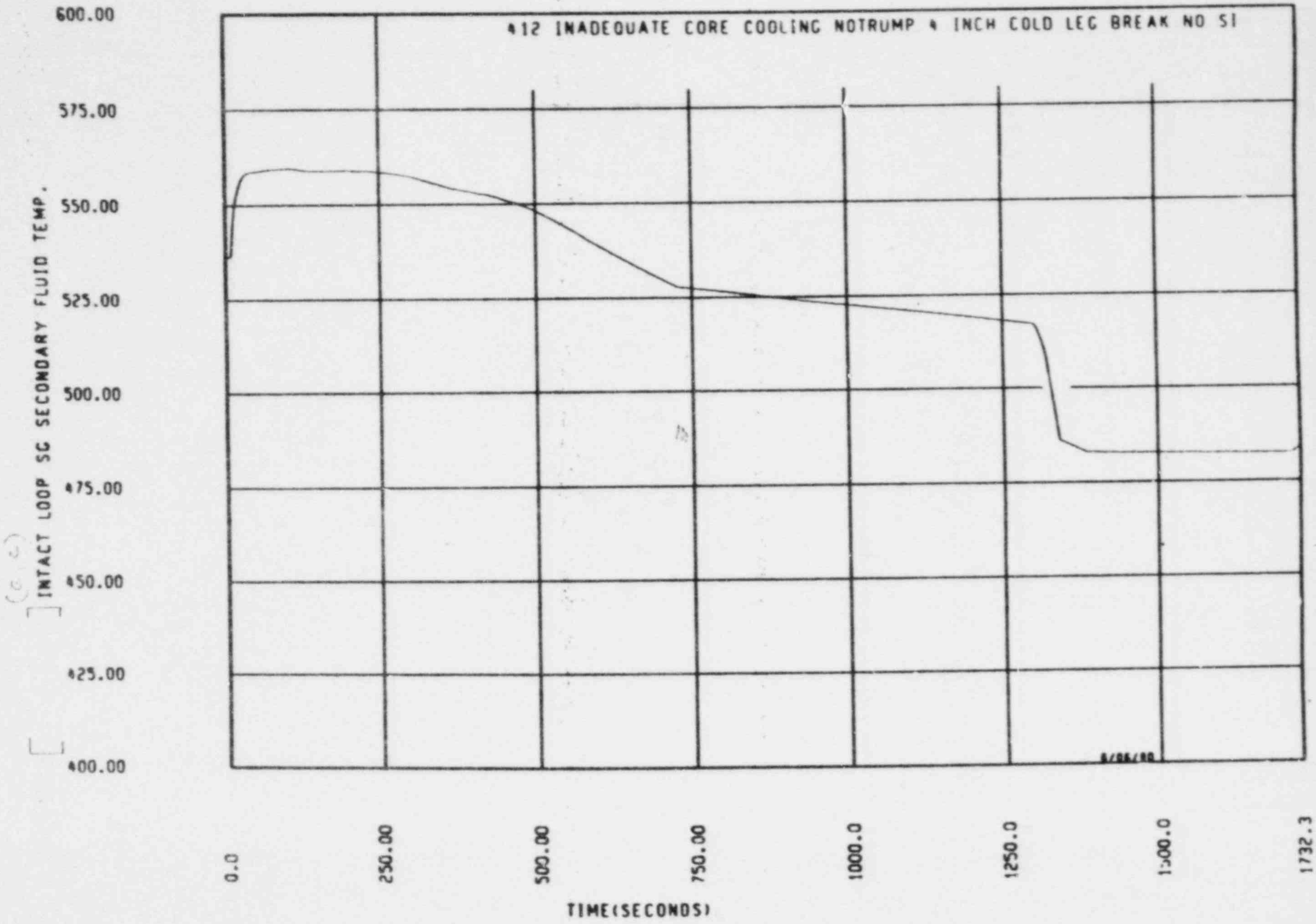

412 INADEQUATE CORE COOLING NOTRUMP 4 INCH COLD LEG BREAK NO SI
INTACT LOOP SG SECONDARY FLUID TEMP.
(a,c)
600.00
575.00
550.00
525.00
500.00
475.00
450.00
425.00
400.00
0.0
250.00
500.00
750.00
1000.0
1250.0
1500.0
1732.3
TIME(SECONDS)

Figure 105

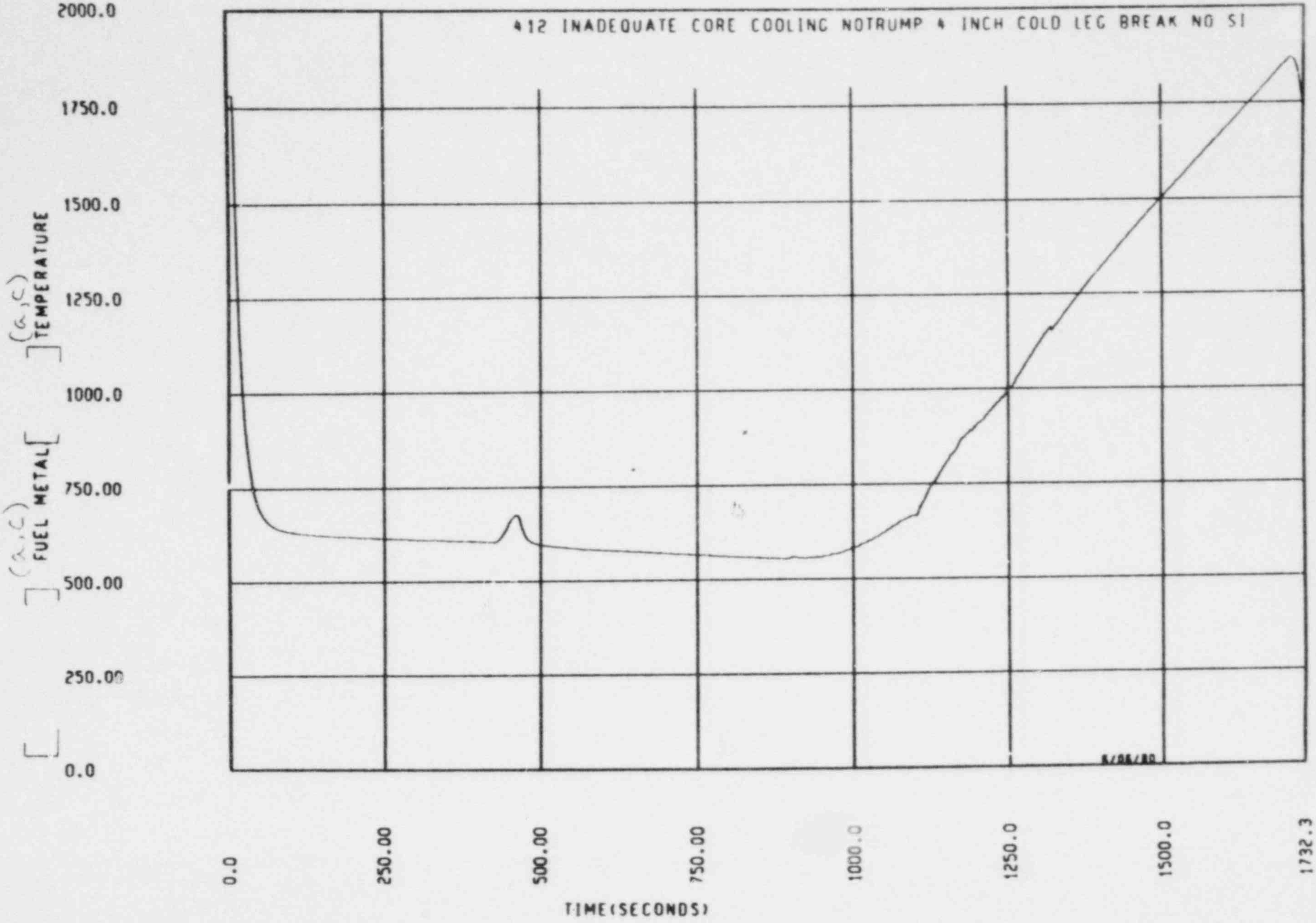

412 INADEQUATE CORE COOLINC NOTRUMP 4 INCH COLD LEG BREAK NO SI
(a,c)
TEMPERATURE
(a,c)
FUEL METAL
2000.0
1750.0
1500.0
1250.0
1000.0
750.00
500.00
250.00
0.0
0.0
250.00
500.00
750.00
1000.0
1250.0
1500.0
1732.3
TIME(SECONDS)

Figure 106

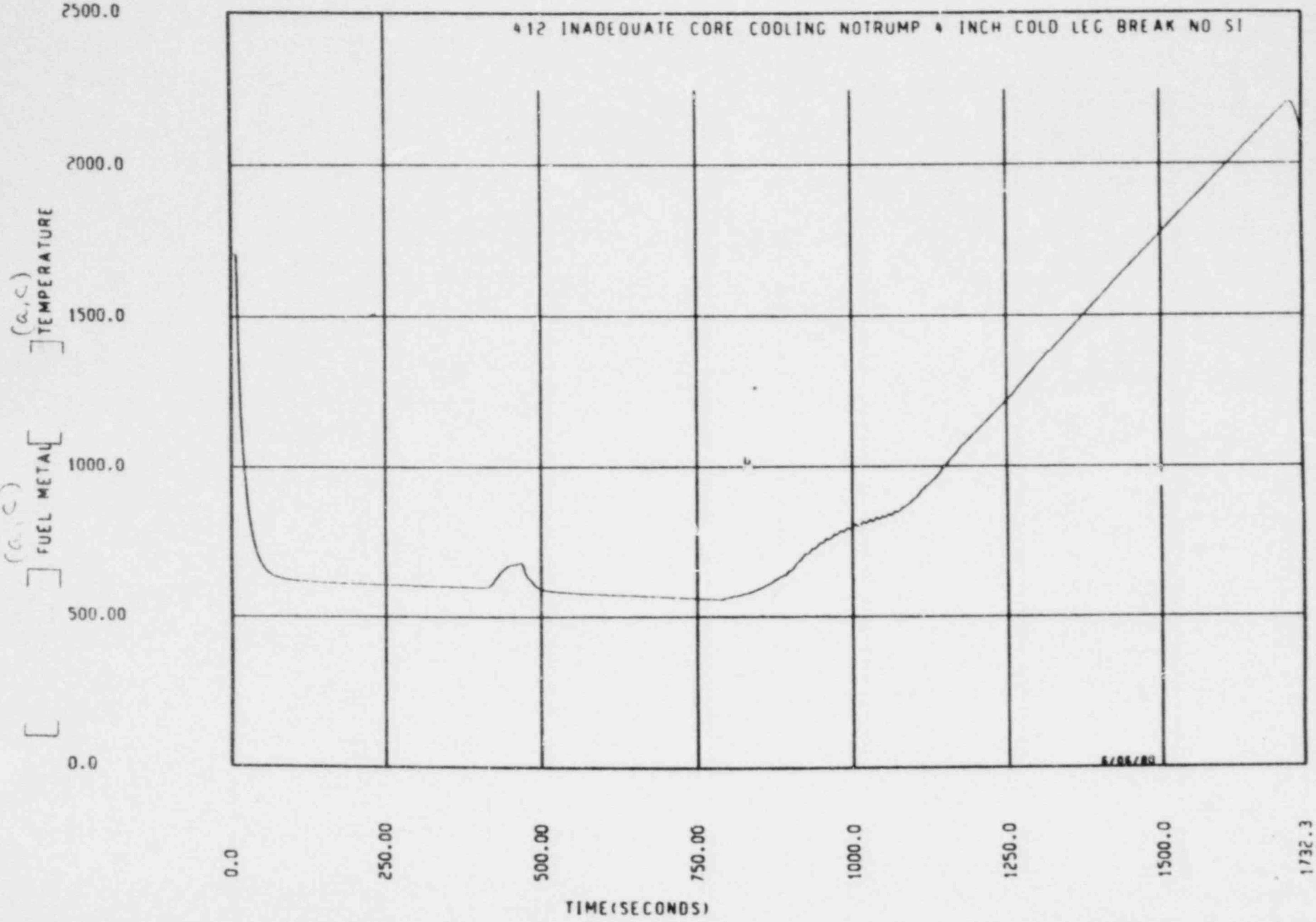

412 INADEQUATE CORE COOLING NOTRUMP 4 INCH COLD LEG BREAK NO SI
(a,c)
TEMPERATURE
(a,c)
FUEL METAL
2500.0
2000.0
1500.0
1000.0
500.00
0.0
0.0
250.00
500.00
750.00
1000.0
1250.0
1500.0
1732.3
TIME(SECONDS)
6/06/80

Figure 107

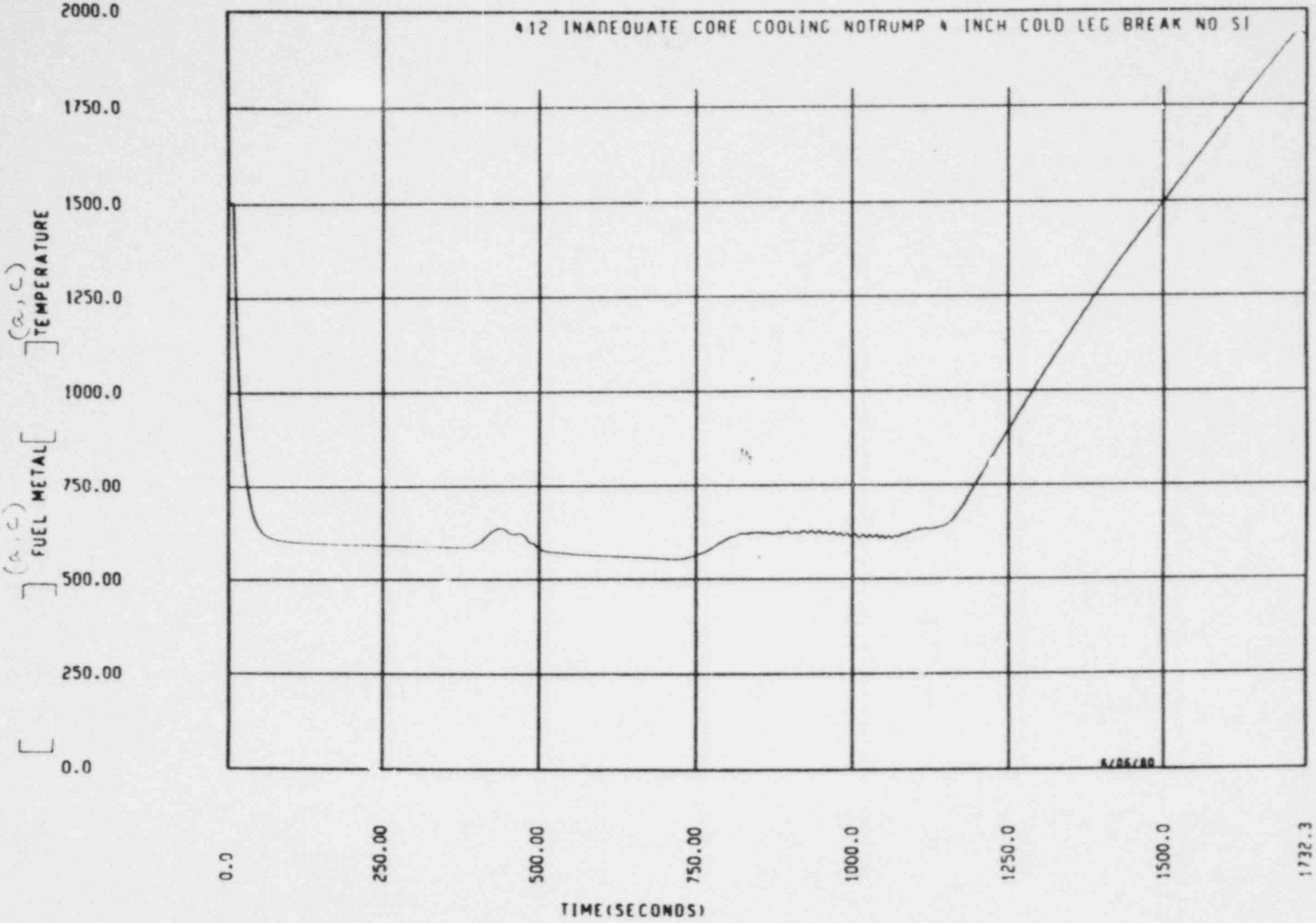

412 INADEQUATE CORE COOLING NOTRUMP 4 INCH COLD LEG BREAK NO SI
[ ]^(a,c) FUEL METAL [ ]^(a,c) TEMPERATURE
2000.0
1750.0
1500.0
1250.0
1000.0
750.00
500.00
250.00
0.0
0.0
250.00
500.00
750.00
1000.0
1250.0
1500.0
1732.3
TIME(SECONDS)

Figure 108

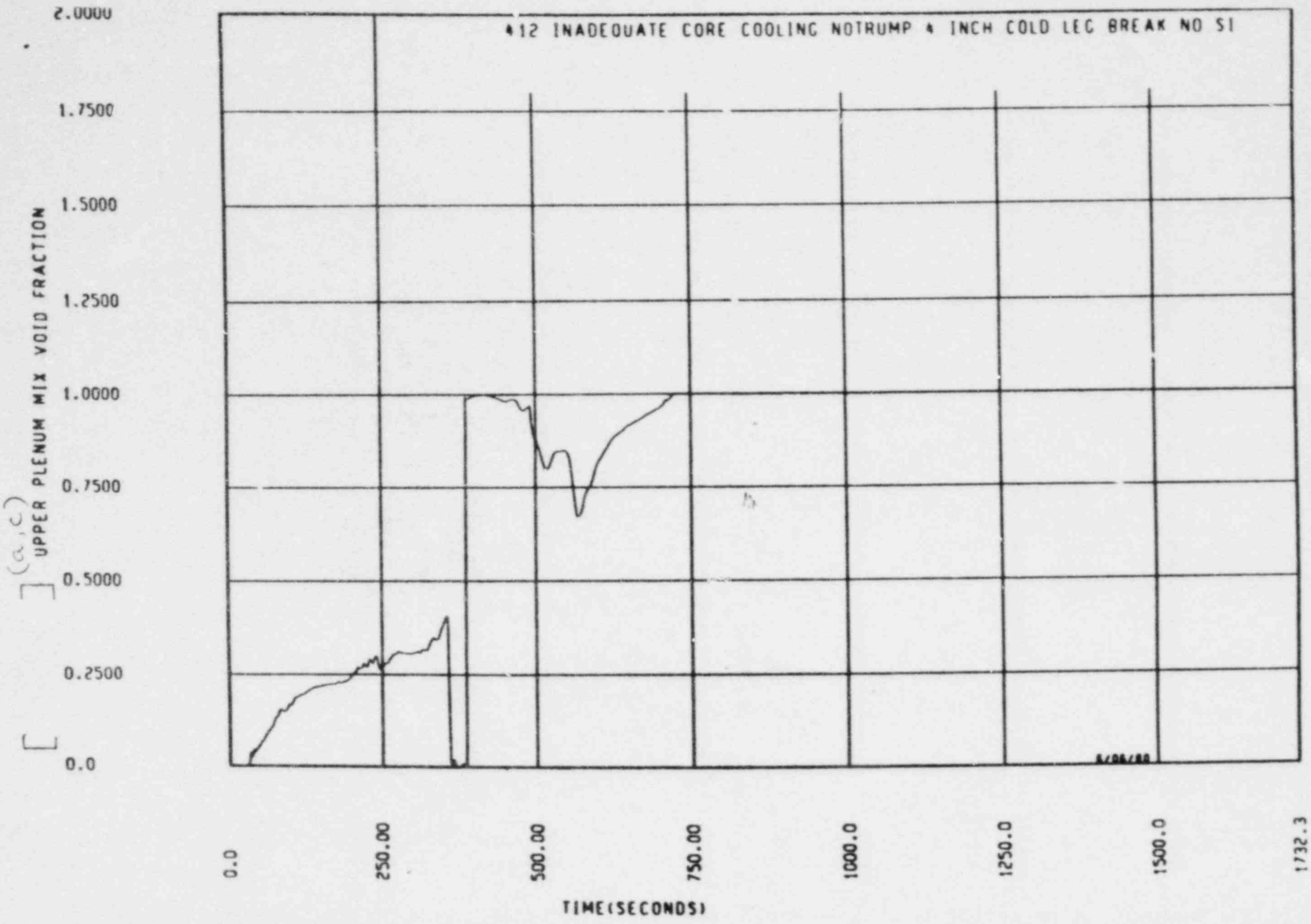

412 INADEQUATE CORE COOLING NOTRUMP 4 INCH COLD LEG BREAK NO SI
UPPER PLENUM MIX VOID FRACTION
[ ](a,c)
2.0000
1.7500
1.5000
1.2500
1.0000
0.7500
0.5000
0.2500
0.0
0.0
250.00
500.00
750.00
1000.0
1250.0
1500.0
1732.3
TIME(SECONDS)

Figure 109

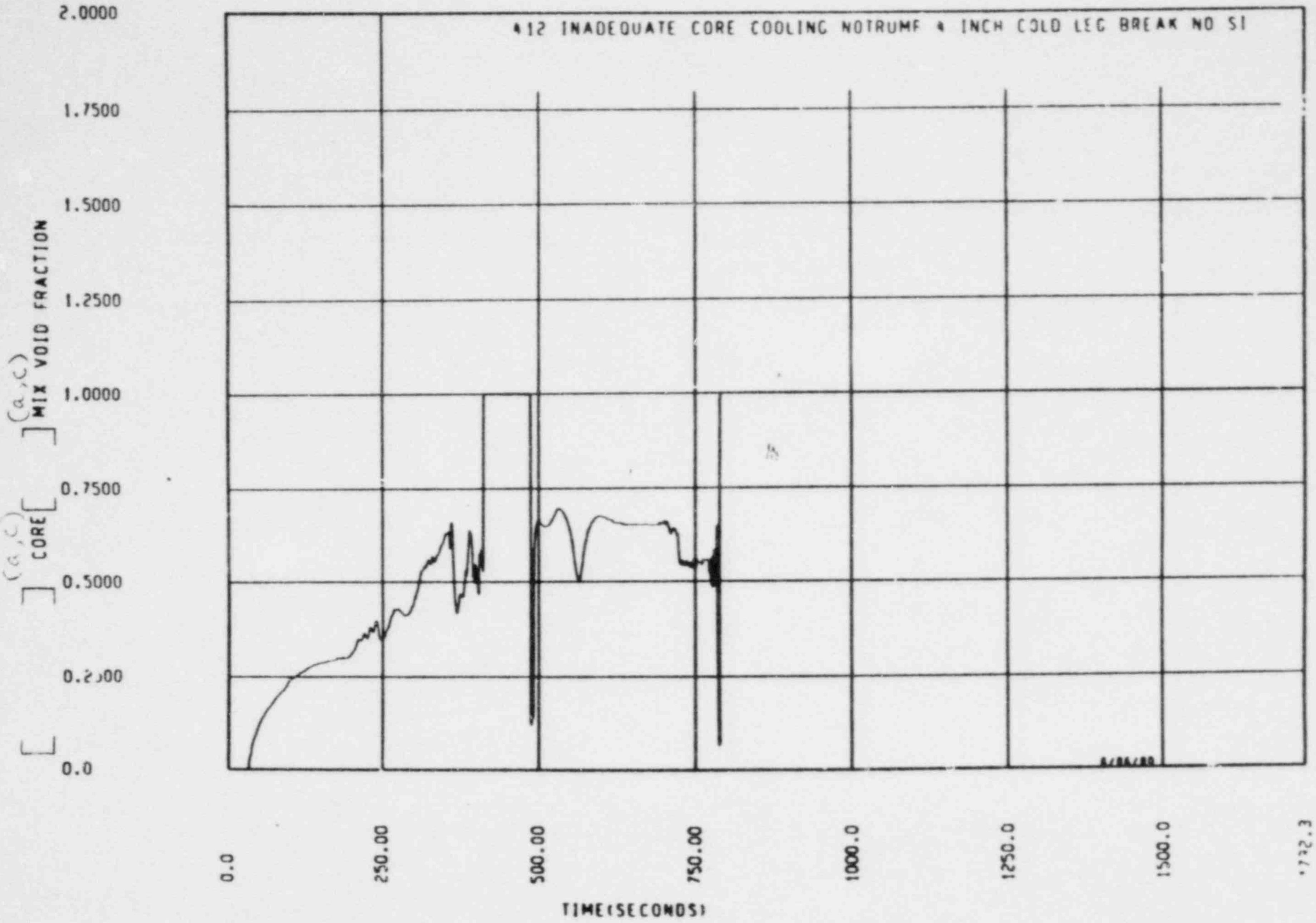

412 INADEQUATE CORE COOLING NOTRUMF 4 INCH COLD LEG BREAK NO SI
[ ]^(a,c) CORE [ ]^(a,c) MIX VOID FRACTION
2.0000
1.7500
1.5000
1.2500
1.0000
0.7500
0.5000
0.2500
0.0
0.0
250.00
500.00
750.00
1000.0
1250.0
1500.0
1732.3
TIME(SECONDS)

Figure 110

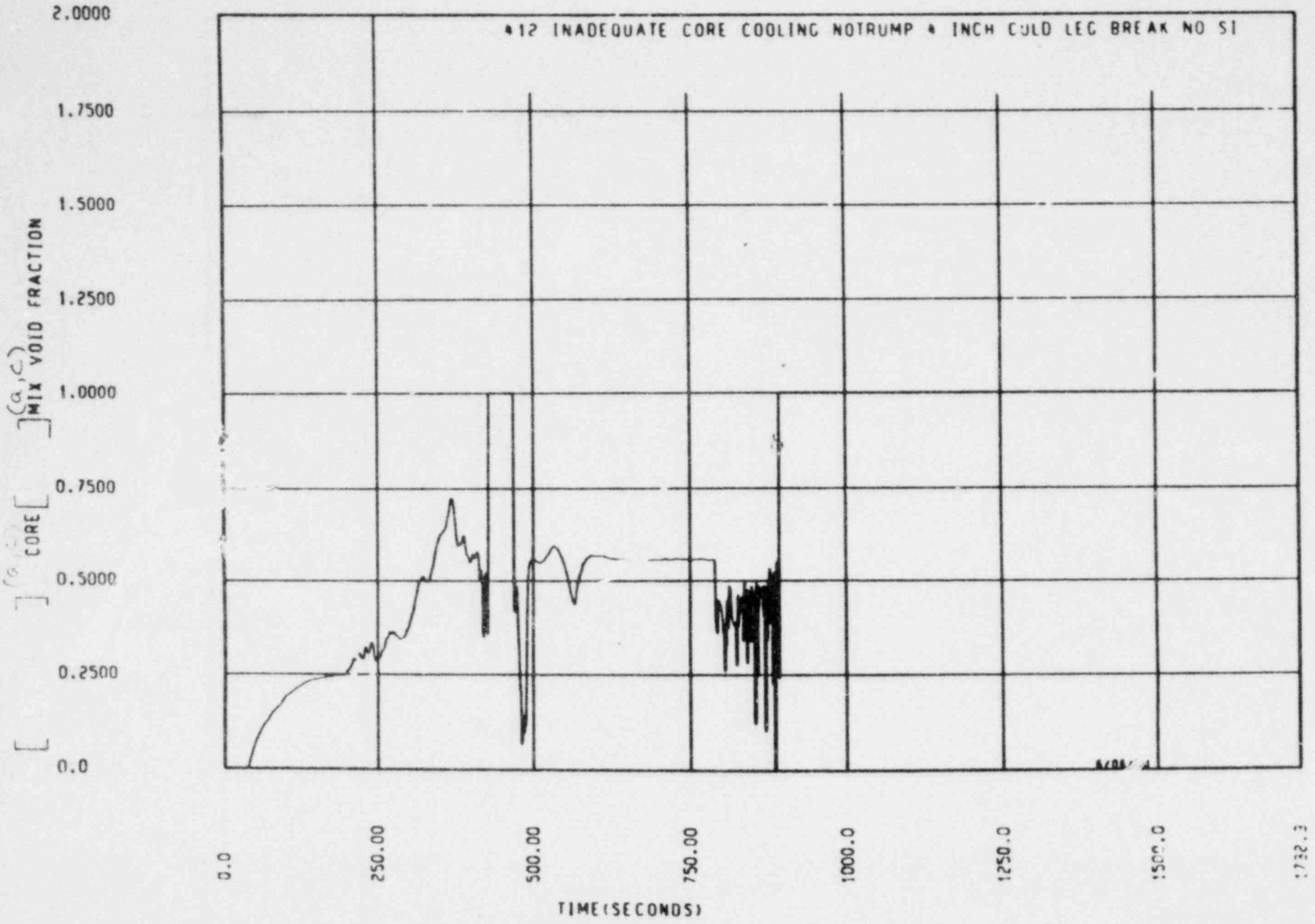

412 INADEQUATE CORE COOLING NOTRUMP 4 INCH COLD LEG BREAK NO SI
[ ]CORE[ ]MIX VOID FRACTION(a,c)
(a,c)
2.0000
1.7500
1.5000
1.2500
1.0000
0.7500
0.5000
0.2500
0.0
0.0
250.00
500.00
750.00
1000.0
1250.0
1500.0
1732.3
TIME(SECONDS)

Figure 111

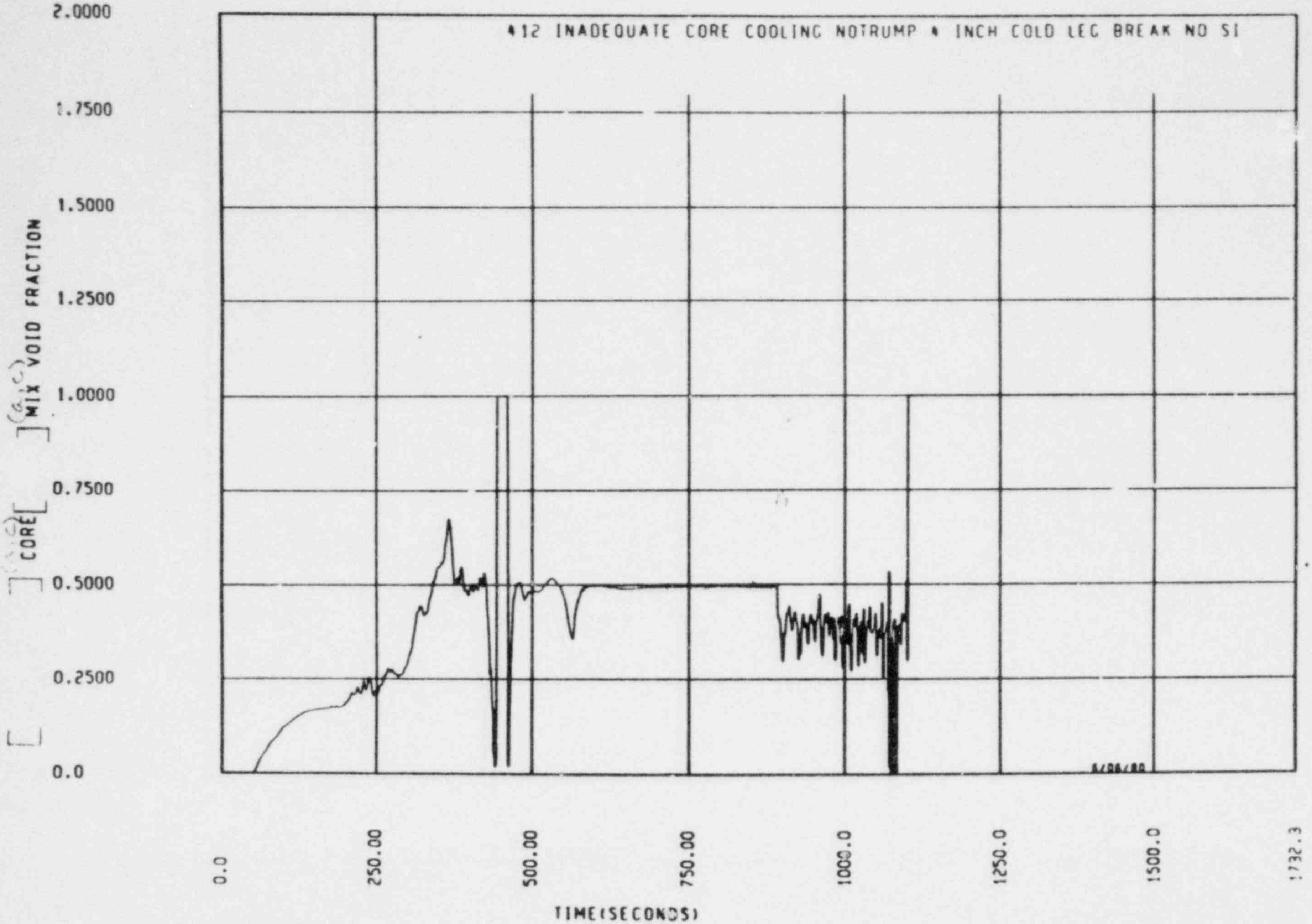

412 INADEQUATE CORE COOLING NOTRUMP 4 INCH COLD LEG BREAK NO SI
CORE MIX VOID FRACTION
(a,c)
(a,c)
2.0000
1.7500
1.5000
1.2500
1.0000
0.7500
0.5000
0.2500
0.0
0.0
250.00
500.00
750.00
1000.0
1250.0
1500.0
1732.3
TIME(SECONDS)

Figure 112

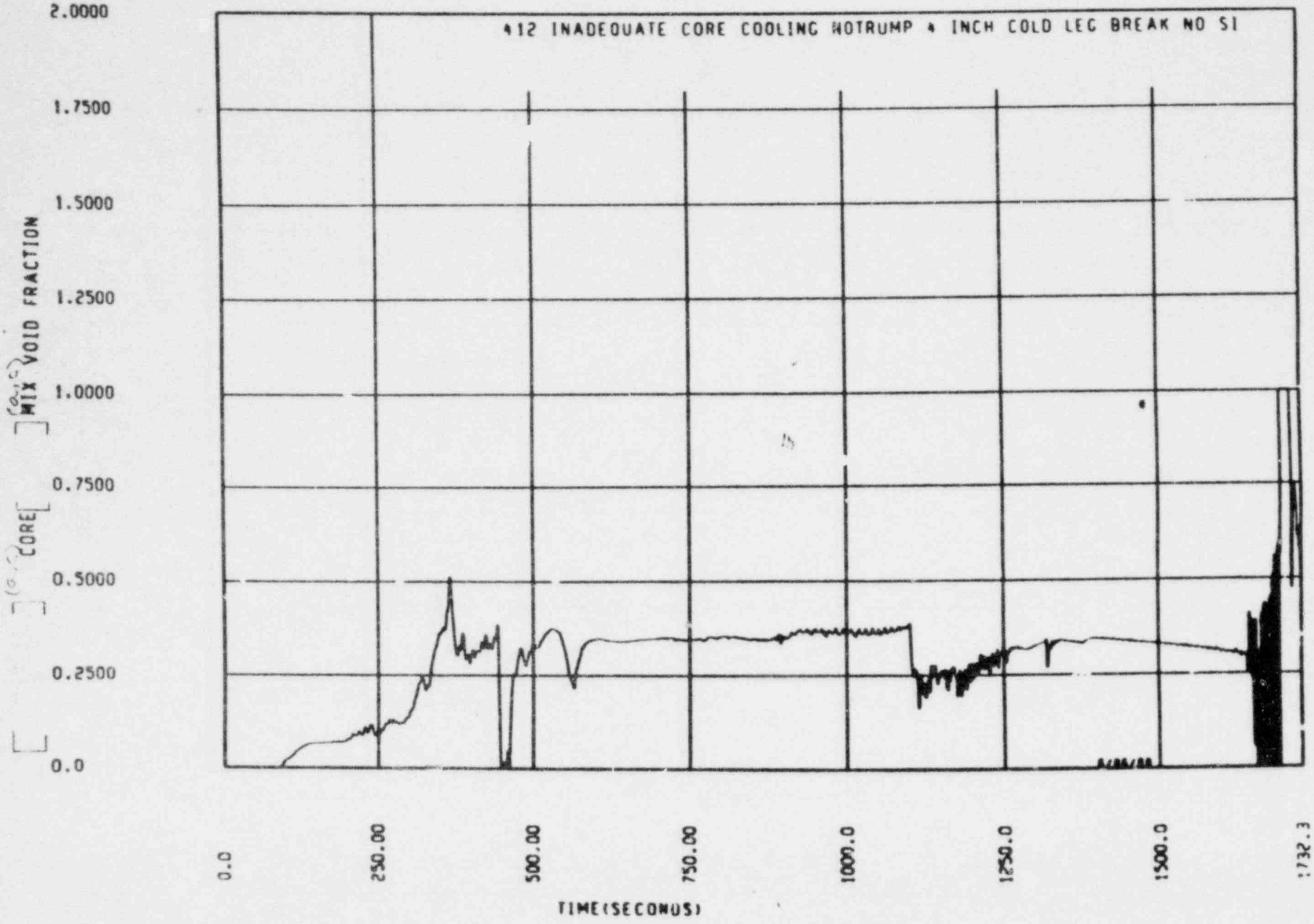

412 INADEQUATE CORE COOLING NOTRUMP 4 INCH COLD LEG BREAK NO SI
2.0000
1.7500
1.5000
1.2500
1.0000
0.7500
0.5000
0.2500
0.0
CORE MIX VOID FRACTION
(a,c)
0.0
250.00
500.00
750.00
1000.0
1250.0
1500.0
1732.3
TIME(SECONDS)

Figure 113

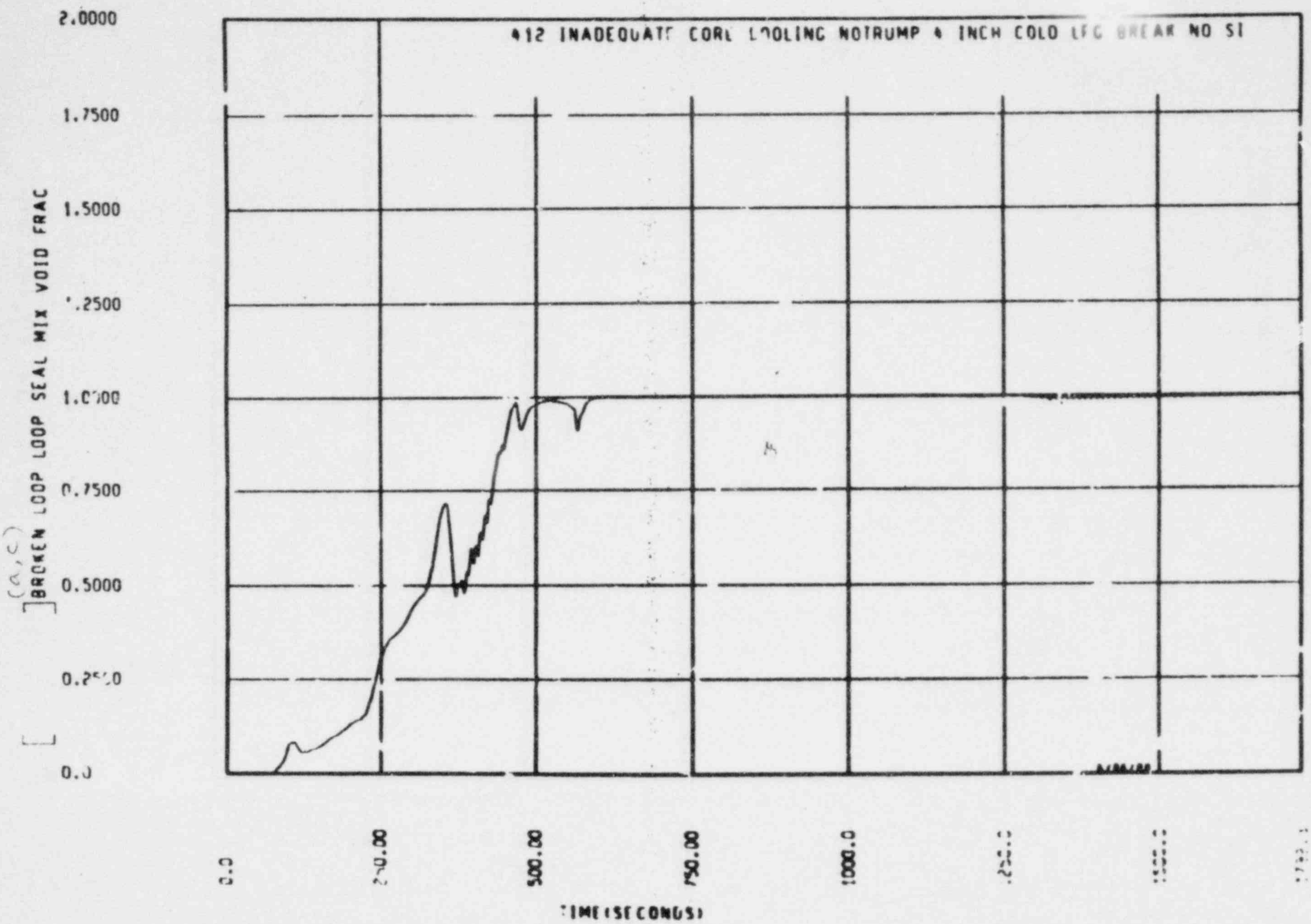

412 INADEQUATE CORE COOLING NOTRUMP 4 INCH COLD LEG BREAK NO SI
(a,c)
BROKEN LOOP LOOP SEAL MIX VOID FRAC
2.0000
1.7500
1.5000
1.2500
1.0000
0.7500
0.5000
0.2500
0.0
0.0
250.00
500.00
750.00
1000.0
1250.0
1500.0
1750.0
TIME(SECONDS)

Figure 114

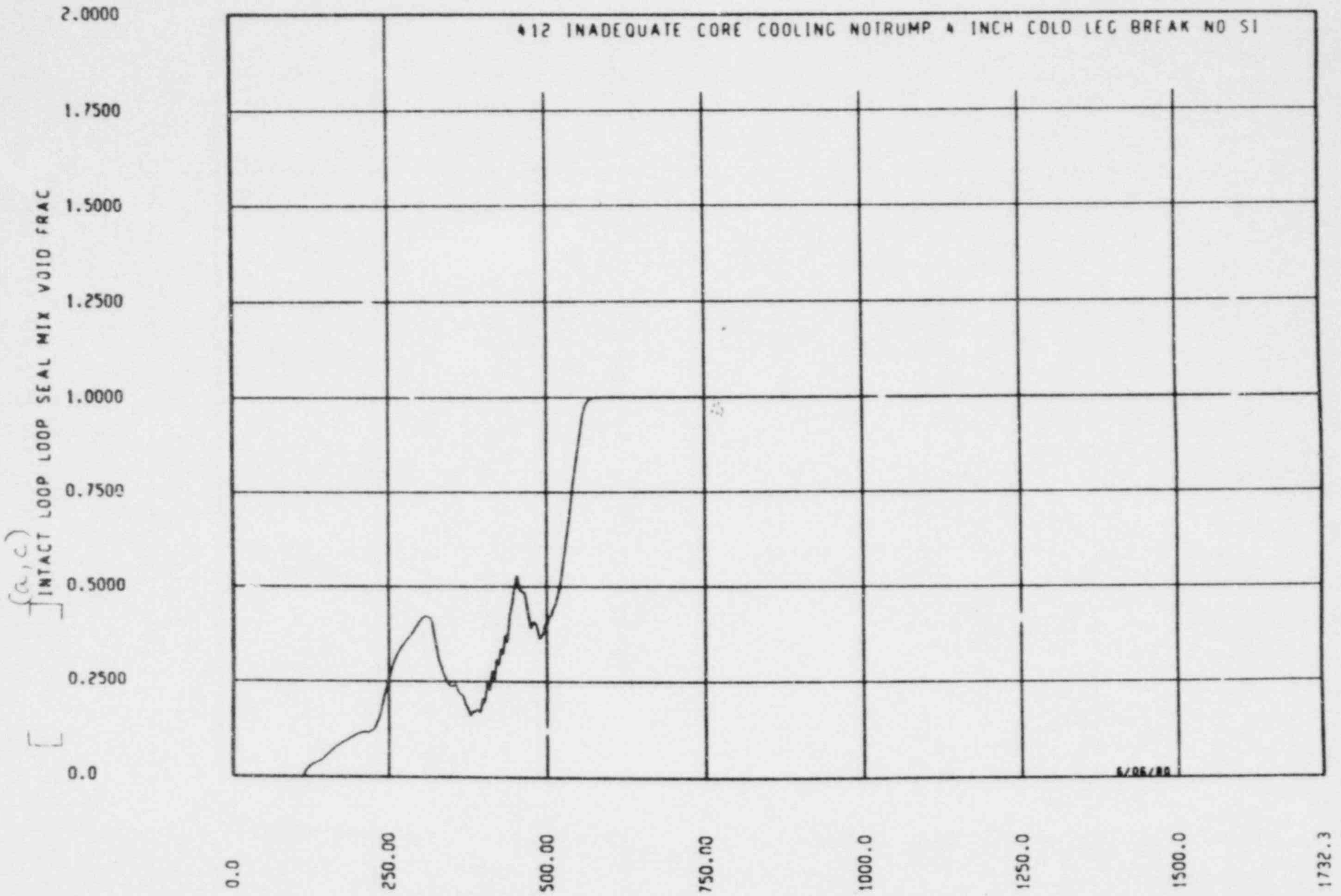

412 INADEQUATE CORE COOLING NOTRUMP 4 INCH COLD LEG BREAK NO SI
INTACT LOOP LOOP SEAL MIX VOID FRAC
(a,c)
2.0000
1.7500
1.5000
1.2500
1.0000
0.7500
0.5000
0.2500
0.0
0.0
250.00
500.00
750.00
1000.0
1250.0
1500.0
1732.3
TIME(SECONDS)
6/06/80

Figure 115

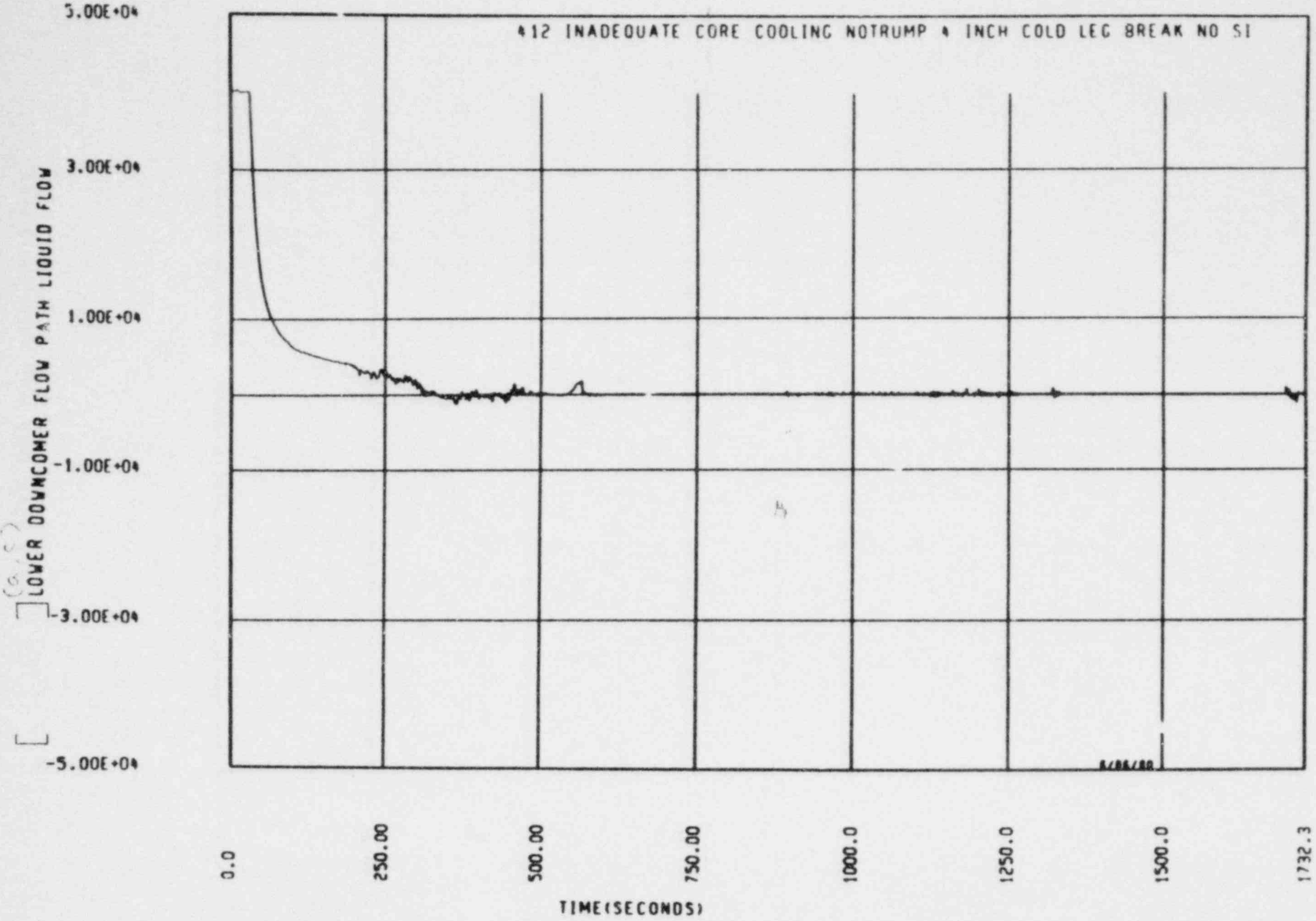

412 INADEQUATE CORE COOLING NOTRUMP 4 INCH COLD LEG BREAK NO SI
LOWER DOWNCOMER FLOW PATH LIQUID FLOW [ ]
(a,c)
5.00E+04
3.00E+04
1.00E+04
-1.00E+04
-3.00E+04
-5.00E+04
0.0
250.00
500.00
750.00
1000.0
1250.0
1500.0
1732.3
TIME(SECONDS)
8/06/80

Figure 116

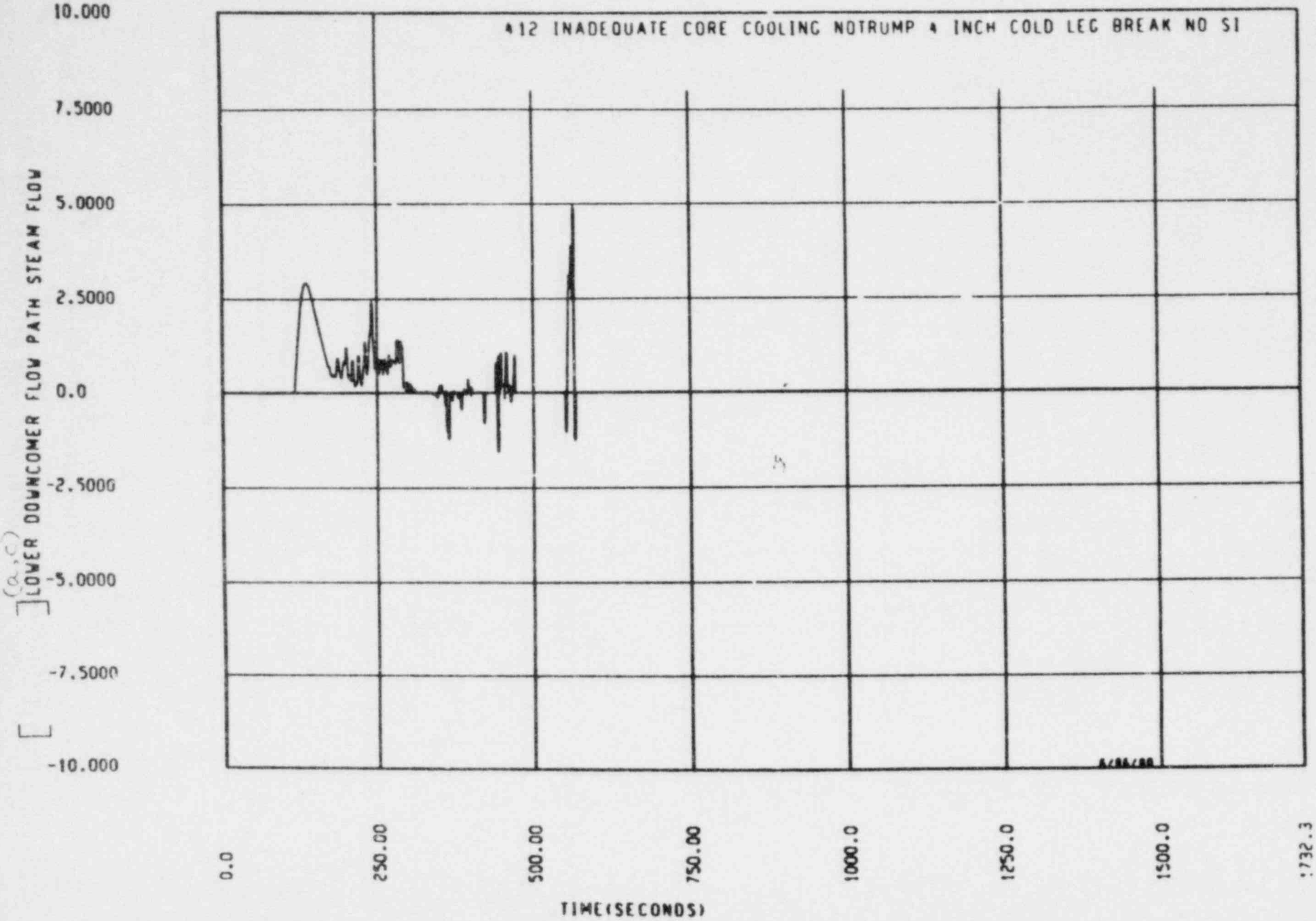

412 INADEQUATE CORE COOLING NOTRUMP 4 INCH COLD LEG BREAK NO SI
LOWER DOWNCOMER FLOW PATH STEAM FLOW
(a,c)
10.000
7.5000
5.0000
2.5000
0.0
-2.5000
-5.0000
-7.5000
-10.000
0.0
250.00
500.00
750.00
1000.0
1250.0
1500.0
1732.3
TIME(SECONDS)

Figure 117

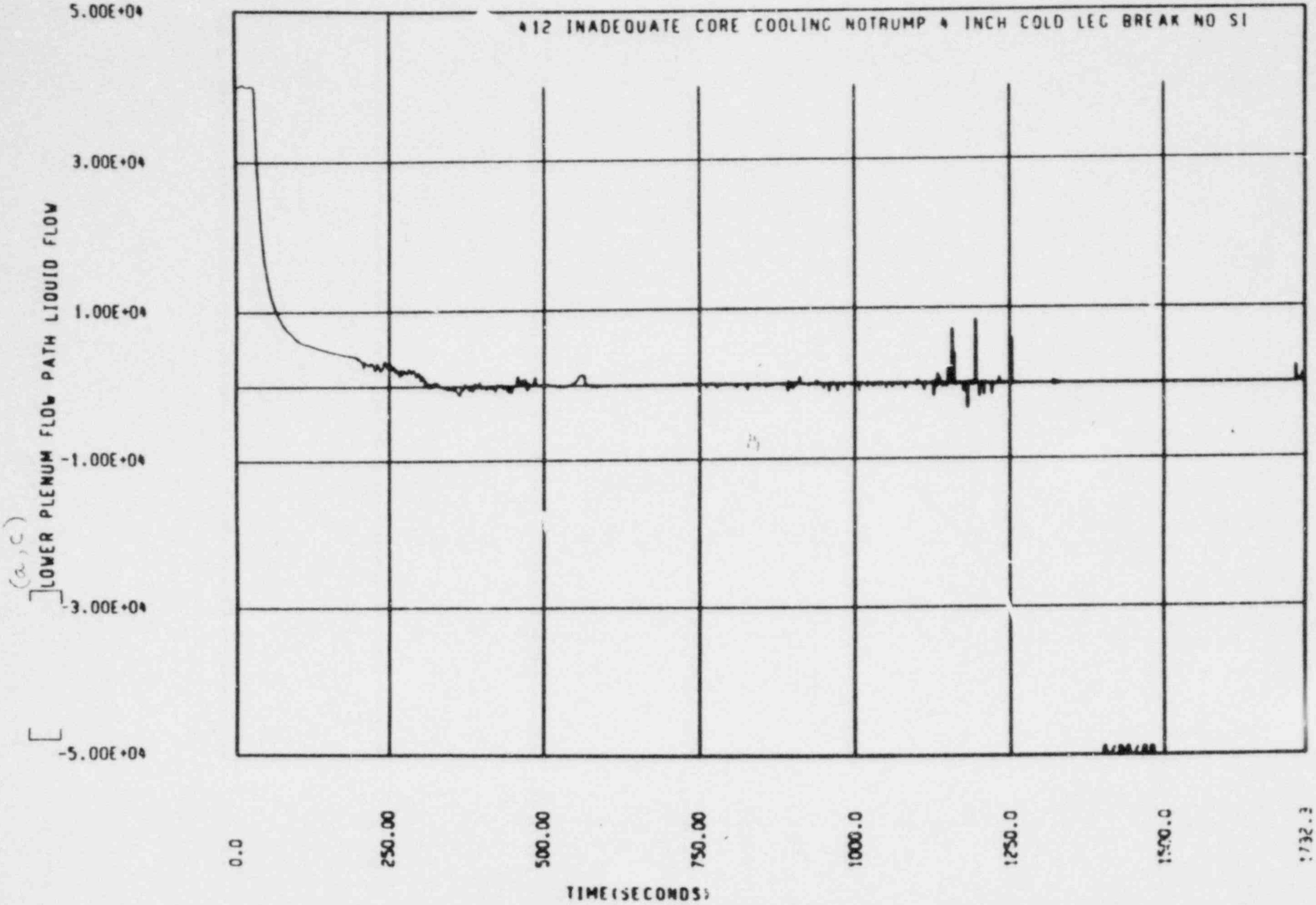

412 INADEQUATE CORE COOLING NOTRUMP 4 INCH COLD LEG BREAK NO SI
LOWER PLENUM FLOW PATH LIQUID FLOW
(a,c)
5.00E+04
3.00E+04
1.00E+04
-1.00E+04
-3.00E+04
-5.00E+04
0.0
250.00
500.00
750.00
1000.0
1250.0
1500.0
1732.3
TIME(SECONDS)

Figure 118

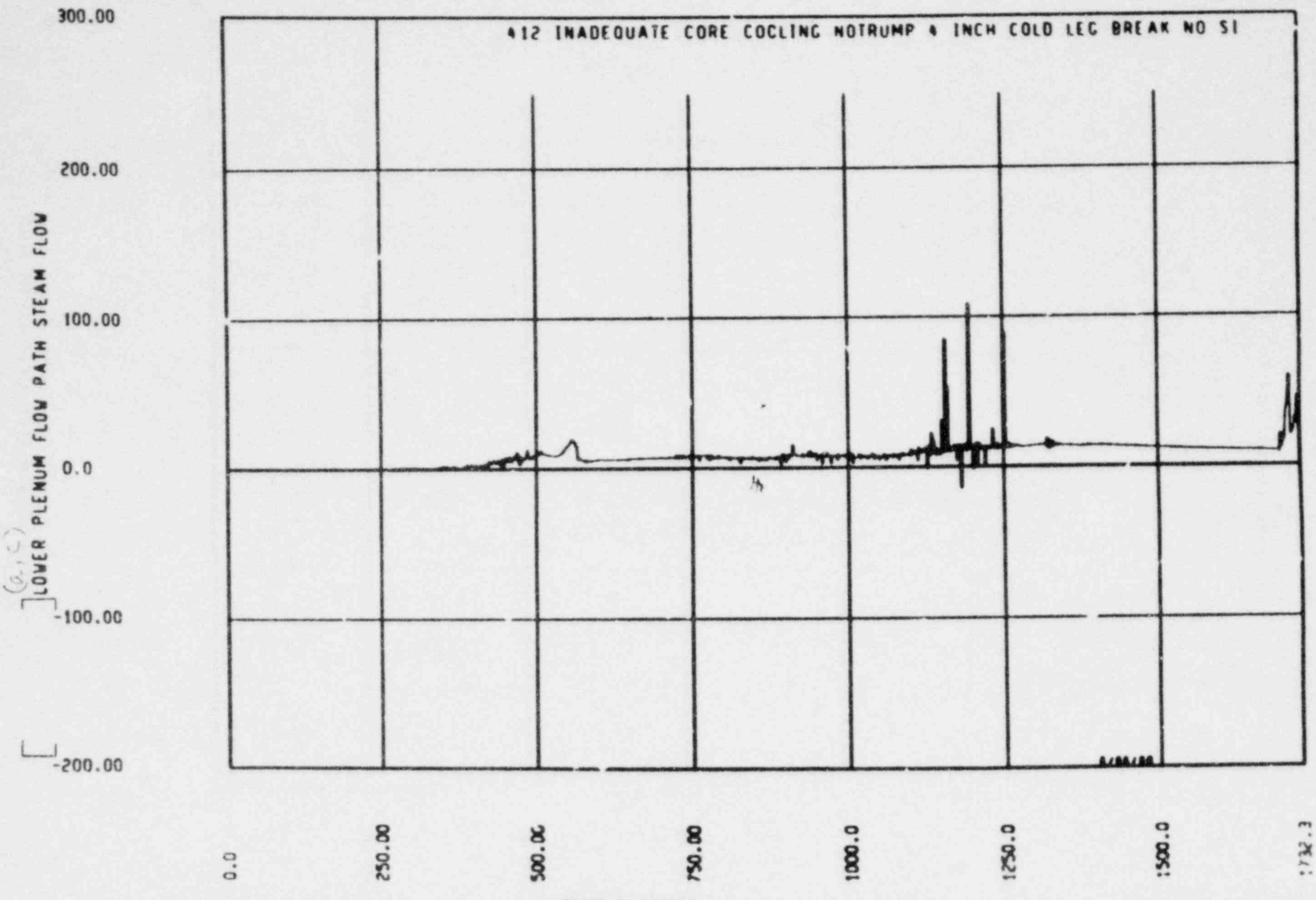

412 INADEQUATE CORE COCLING NOTRUMP 4 INCH COLD LEG BREAK NO SI
300.00
200.00
100.00
0.0
-100.00
-200.00
LOWER PLENUM FLOW PATH STEAM FLOW
(a,c)
0.0
250.00
500.0C
750.00
1000.0
1250.0
1500.0
1732.3
TIME(SECONDS)

Figure 119

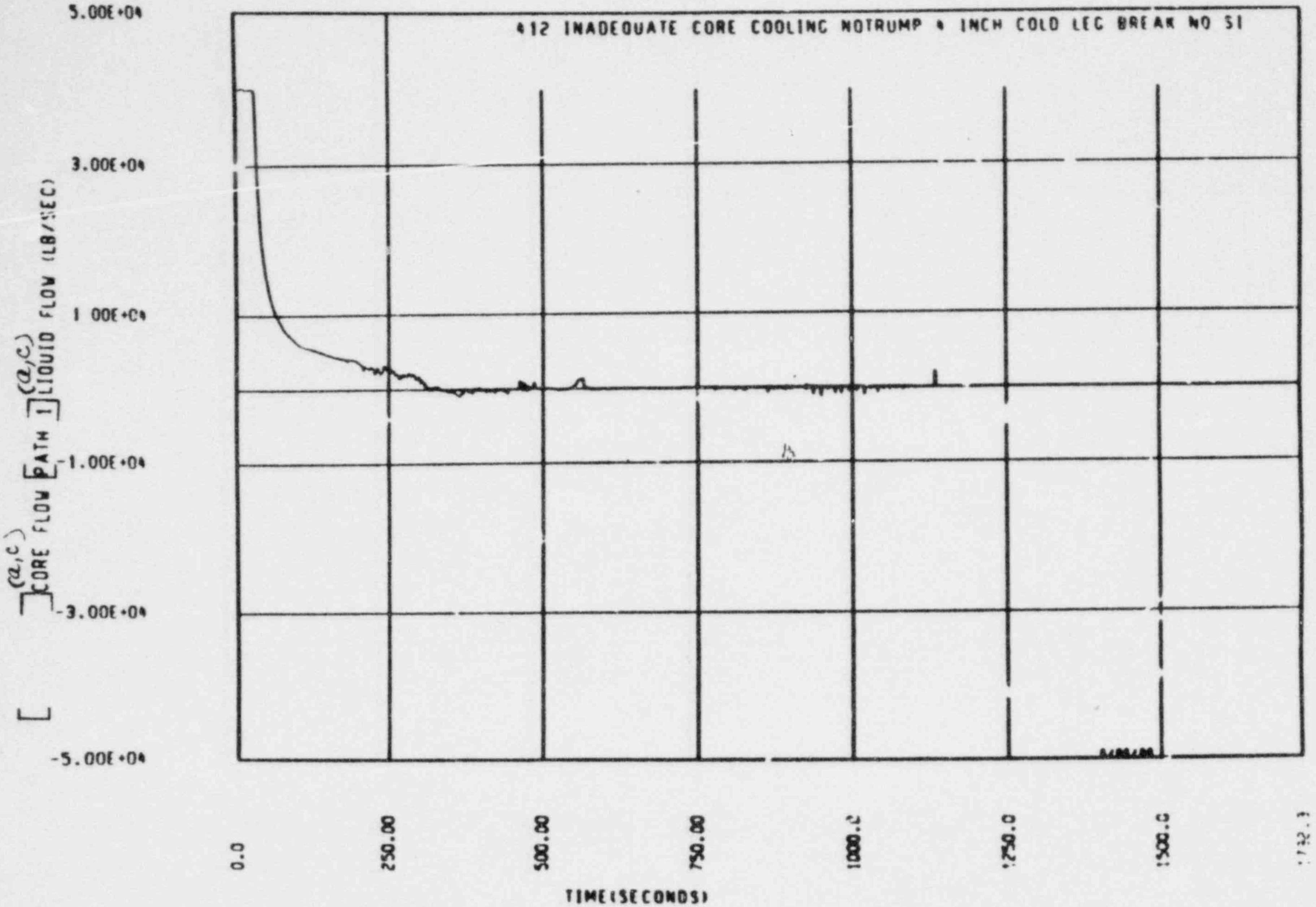

412 INADEQUATE CORE COOLING NOTRUMP 4 INCH COLD LEG BREAK NO SI
5.00E+04
3.00E+04
1.00E+04
-1.00E+04
-3.00E+04
-5.00E+04
[ ]$^{(a,c)}$ CORE FLOW [PATH 1]$^{(a,c)}$ LIQUID FLOW (LB/SEC)
0.0
250.00
500.00
750.00
1000.0
1250.0
1500.0
1732.3
TIME(SECONDS)

Figure 120

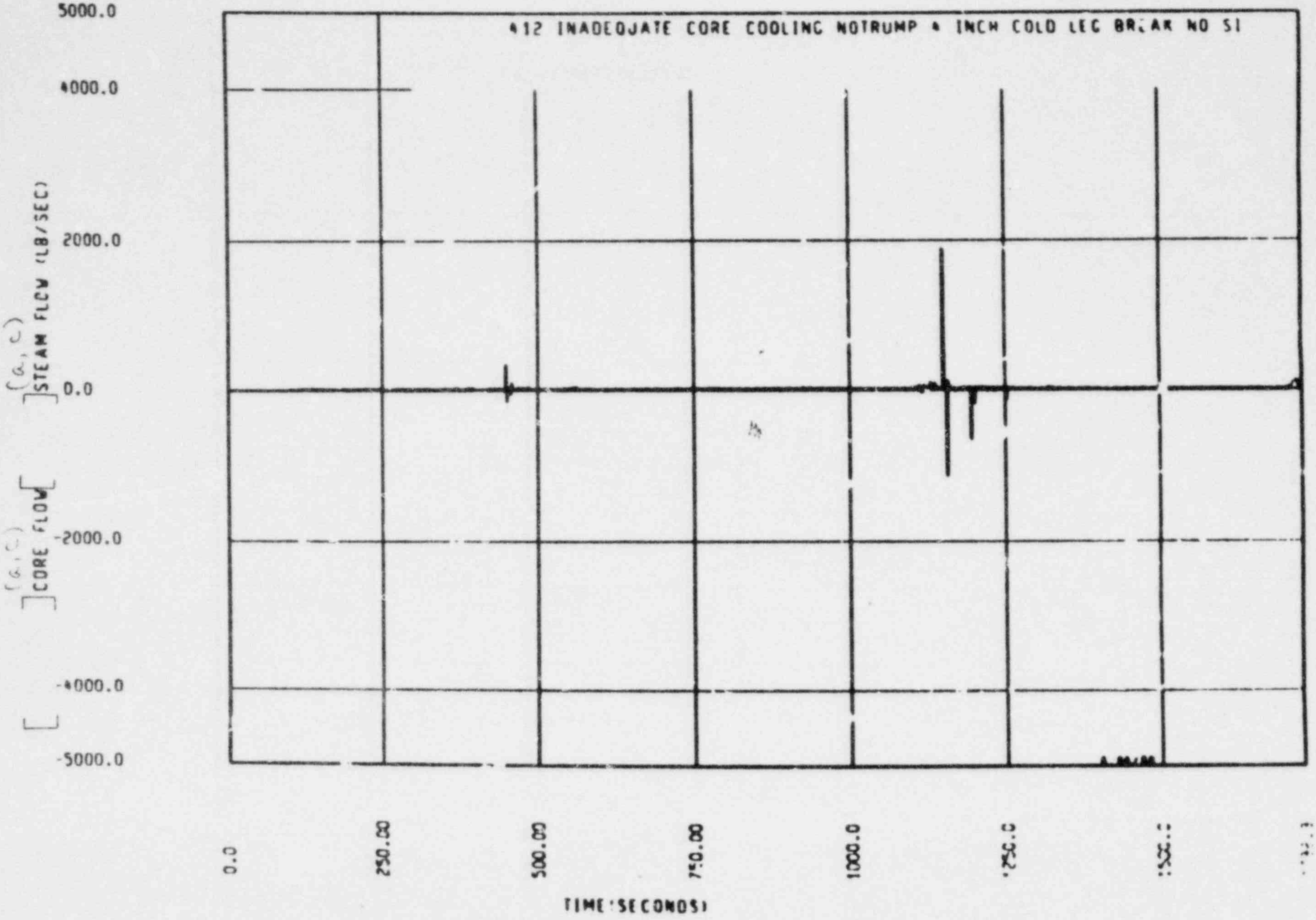

412 INADEQUATE CORE COOLING NOTRUMP 4 INCH COLD LEG BREAK NO SI
5000.0
4000.0
2000.0
0.0
-2000.0
-4000.0
-5000.0
STEAM FLOW (LB/SEC)
(a,c)
CORE FLOW
(a,c)
0.0
250.00
500.00
750.00
1000.0
1250.0
1500.0
1750.0
TIME (SECONDS)

Figure 121

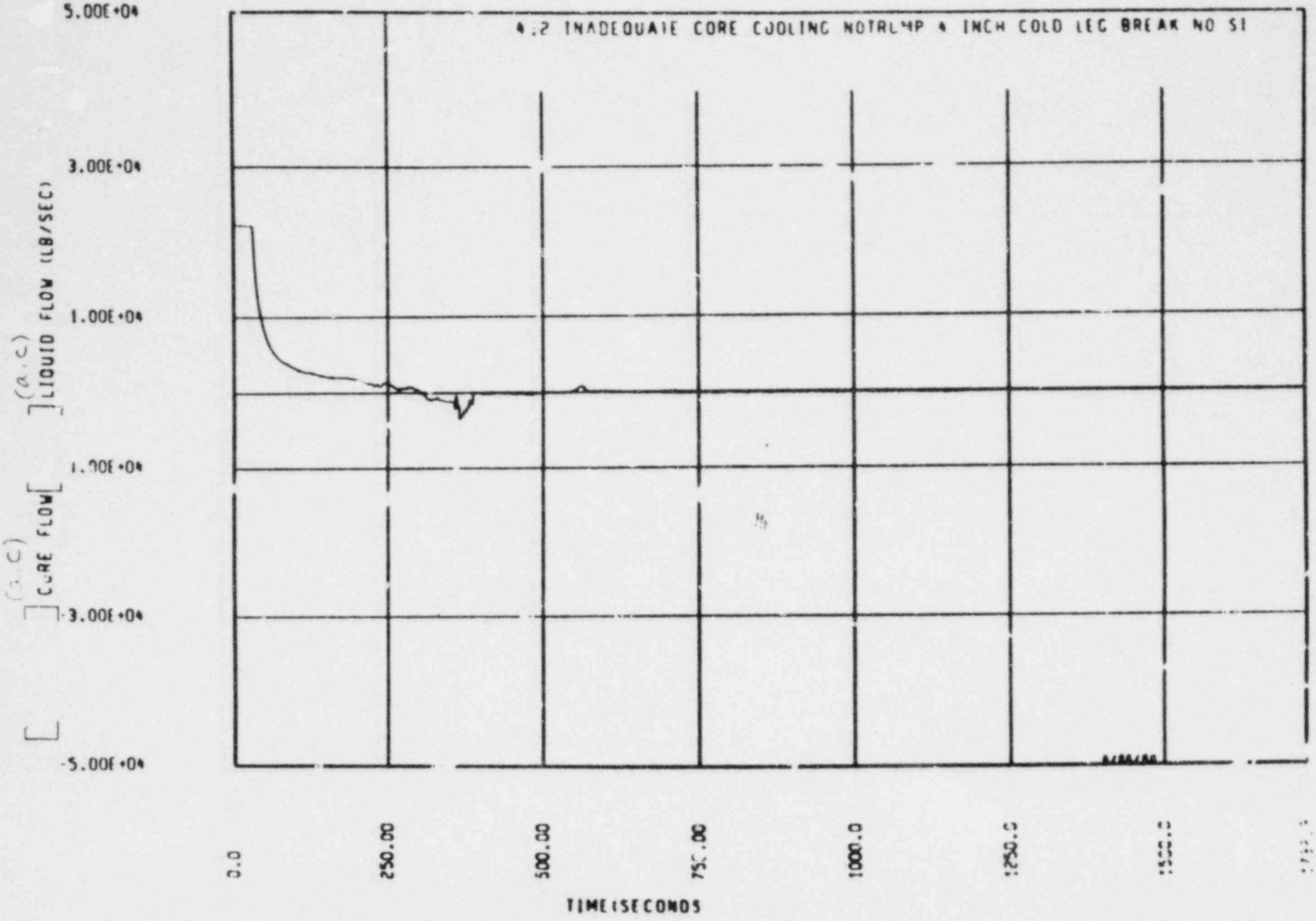

4.2 INADEQUATE CORE COOLING NOTRUMP 4 INCH COLD LEG BREAK NO SI
5.00E+04
3.00E+04
1.00E+04
1.00E+04
-3.00E+04
-5.00E+04
(a,c)
LIQUID FLOW (LB/SEC)
(a,c)
CORE FLOW
0.0
250.00
500.00
750.00
1000.0
1250.0
1500.0
1750.0
TIME(SECONDS

Figure 122

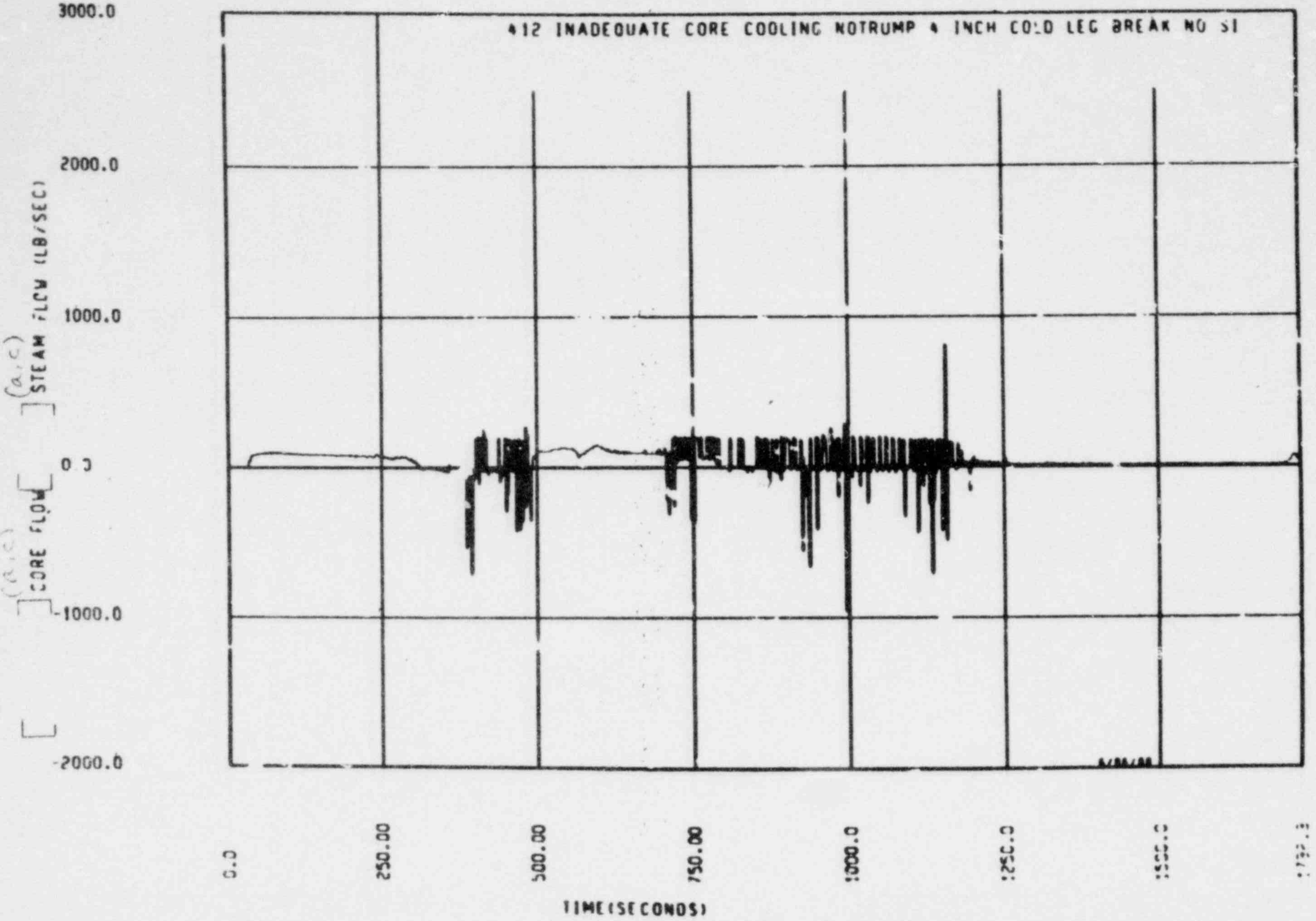

412 INADEQUATE CORE COOLING NOTRUMP 4 INCH COLD LEG BREAK NO SI
3000.0
2000.0
1000.0
0.0
-1000.0
-2000.0
(a,c)
STEAM FLOW (LB/SEC)
(a,c)
CORE FLOW
0.0
250.00
500.00
750.00
1000.0
1250.0
1500.0
1732.3
TIME(SECONDS)

Figure 123

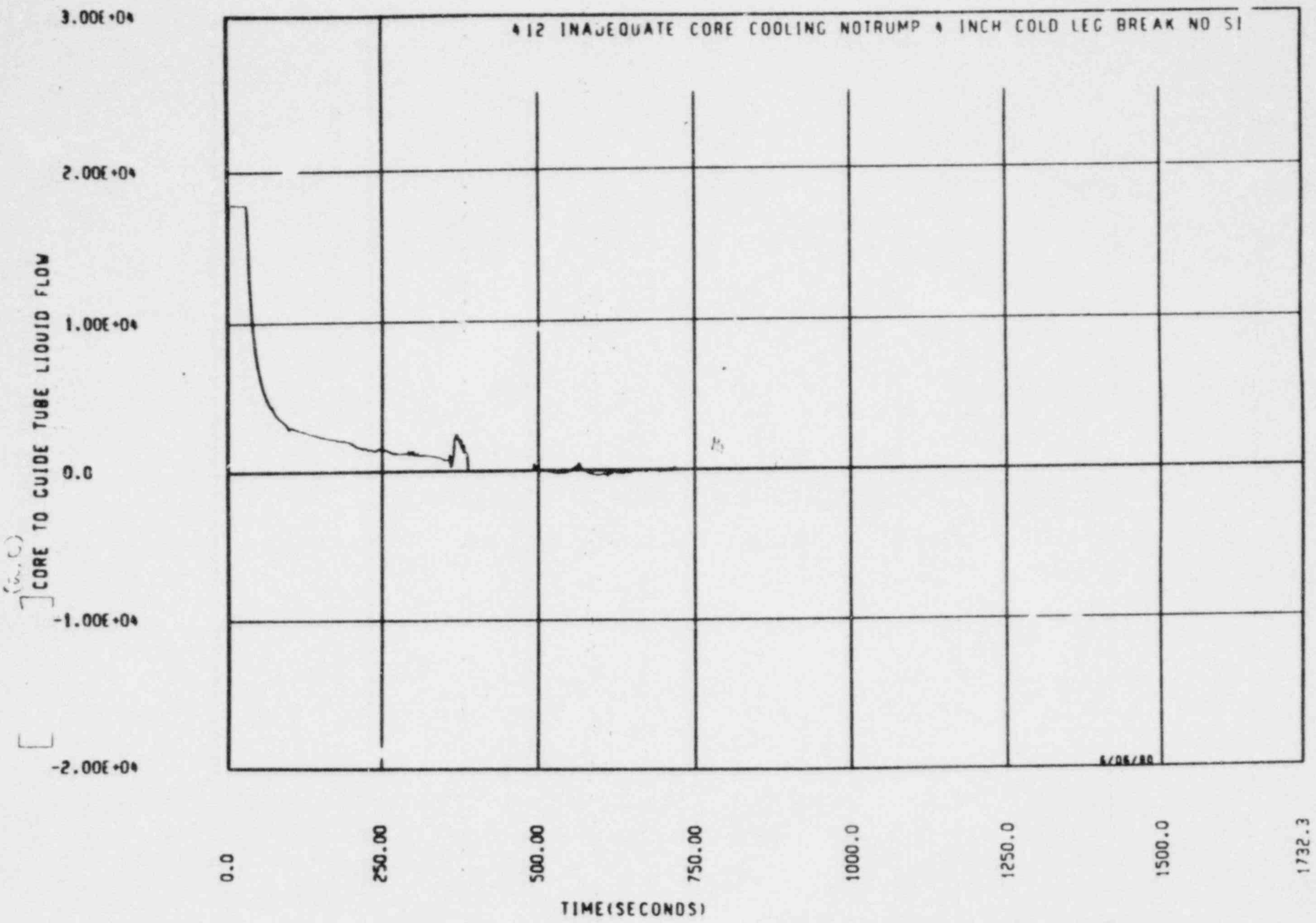

412 INADEQUATE CORE COOLING NOTRUMP 4 INCH COLD LEG BREAK NO SI
CORE TO GUIDE TUBE LIQUID FLOW
(a,c)
3.00E+04
2.00E+04
1.00E+04
0.0
-1.00E+04
-2.00E+04
0.0
250.00
500.00
750.00
1000.0
1250.0
1500.0
1732.3
TIME(SECONDS)
6/06/80

Figure 124

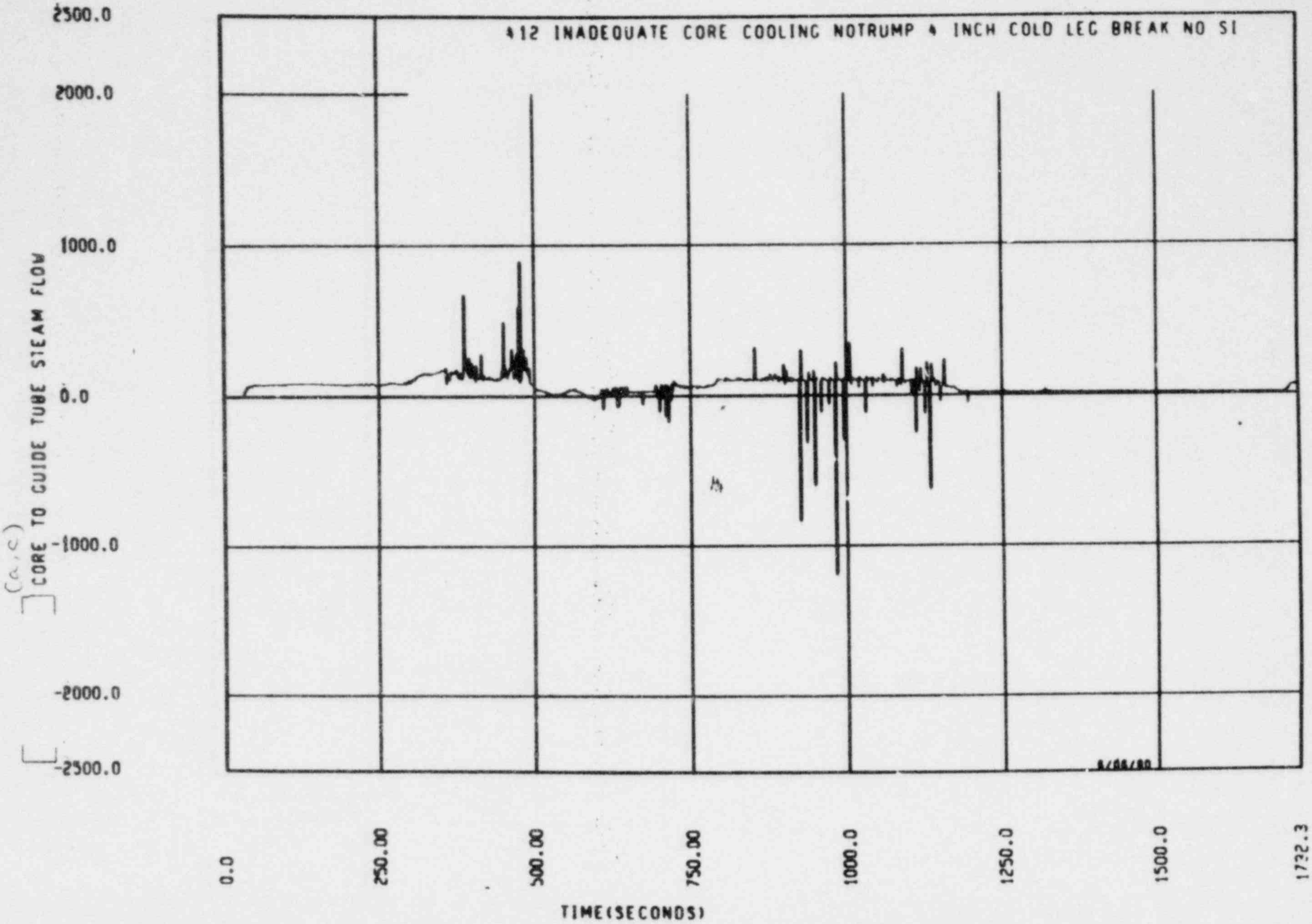

412 INADEQUATE CORE COOLING NOTRUMP 4 INCH COLD LEG BREAK NO SI
CORE TO GUIDE TUBE STEAM FLOW
(a,c)
2500.0
2000.0
1000.0
0.0
-1000.0
-2000.0
-2500.0
0.0
250.00
500.00
750.00
1000.0
1250.0
1500.0
1732.3
TIME(SECONDS)
8/06/80

Figure 125

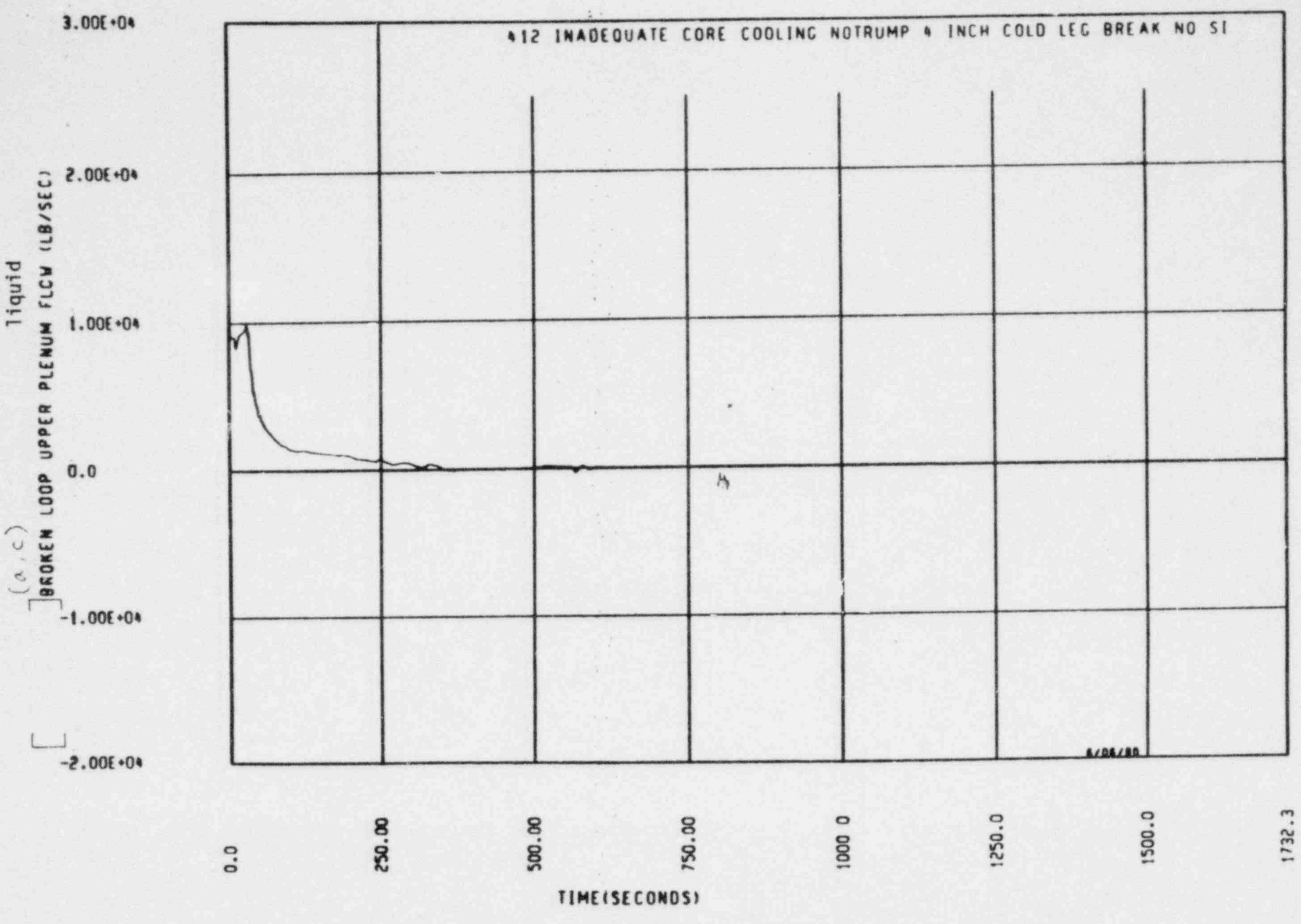

412 INADEQUATE CORE COOLING NOTRUMP 4 INCH COLD LEG BREAK NO SI
liquid
BROKEN LOOP UPPER PLENUM FLCW (LB/SEC)
(a,c)
3.00E+04
2.00E+04
1.00E+04
0.0
-1.00E+04
-2.00E+04
0.0
250.00
500.00
750.00
1000 0
1250.0
1500.0
1732.3
TIME(SECONDS)

Figure 126

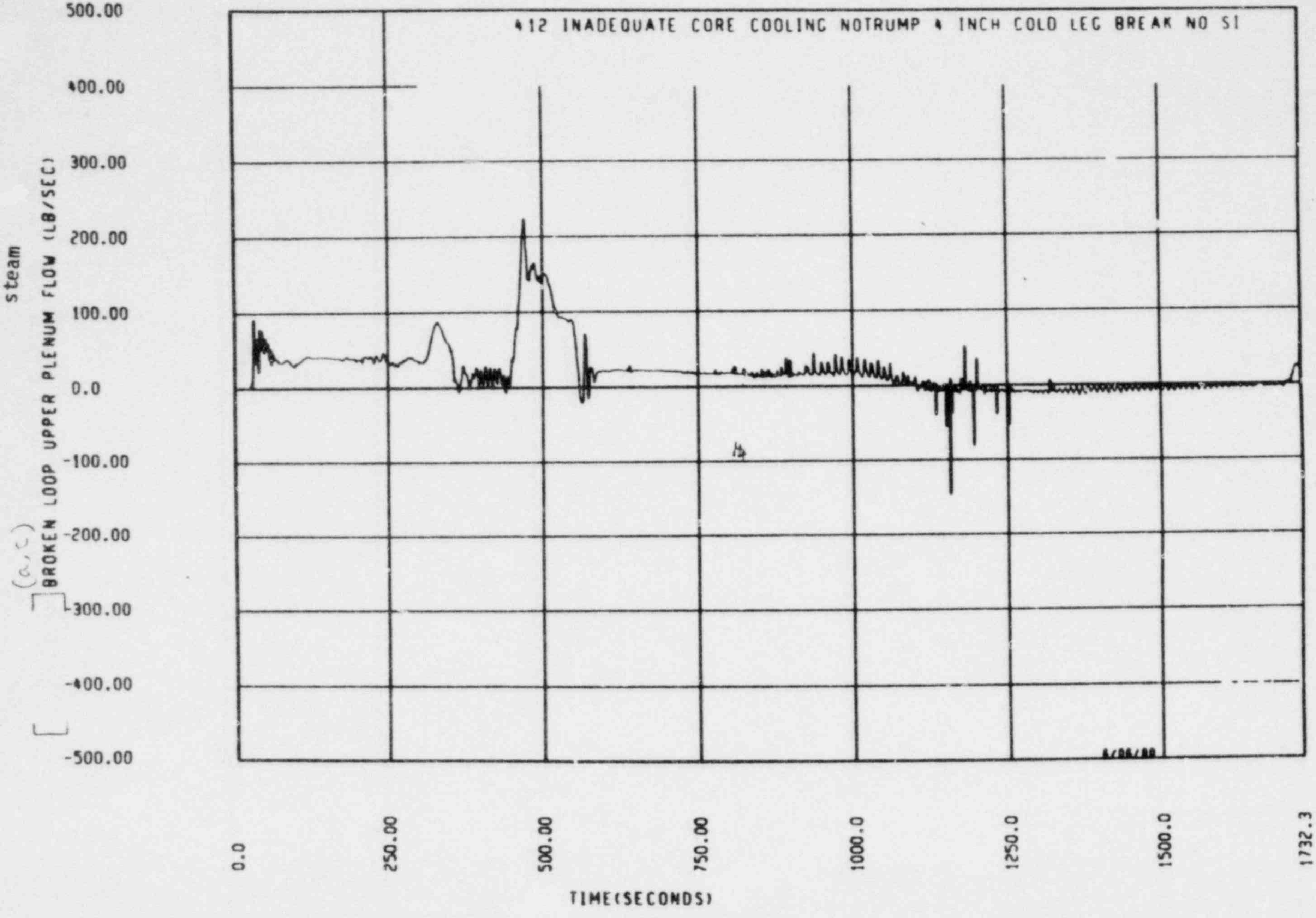

412 INADEQUATE CORE COOLING NOTRUMP 4 INCH COLD LEG BREAK NO SI
steam
BROKEN LOOP UPPER PLENUM FLOW (LB/SEC)
(a,c)
500.00
400.00
300.00
200.00
100.00
0.0
-100.00
-200.00
-300.00
-400.00
-500.00
0.0
250.00
500.00
750.00
1000.0
1250.0
1500.0
1732.3
TIME(SECONDS)

Figure 127

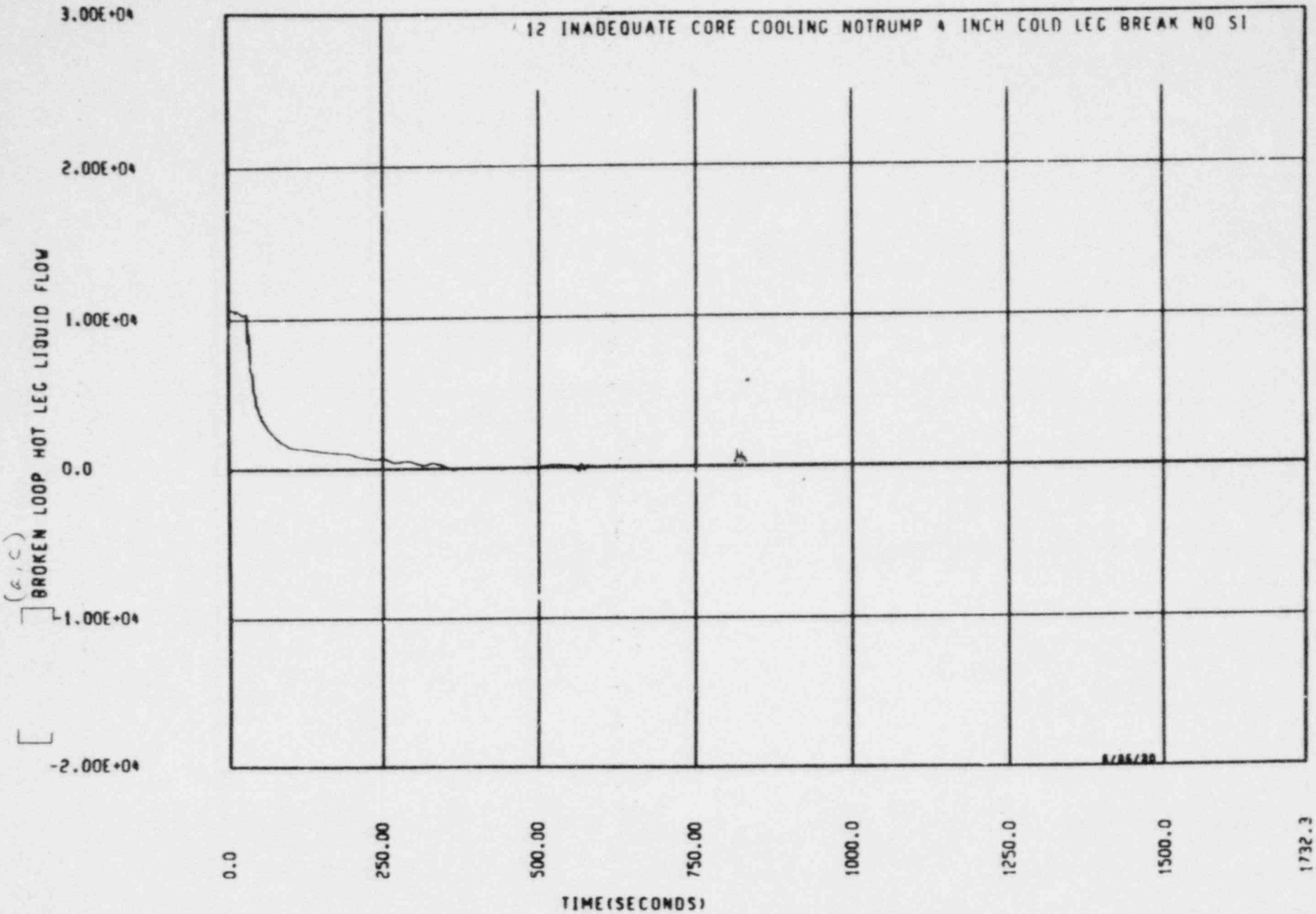

12 INADEQUATE CORE COOLING NOTRUMP 4 INCH COLD LEG BREAK NO SI
BROKEN LOOP HOT LEG LIQUID FLOW
(a,c)
3.00E+04
2.00E+04
1.00E+04
0.0
-1.00E+04
-2.00E+04
0.0
250.00
500.00
750.00
1000.0
1250.0
1500.0
1732.3
TIME(SECONDS)

Figure 128

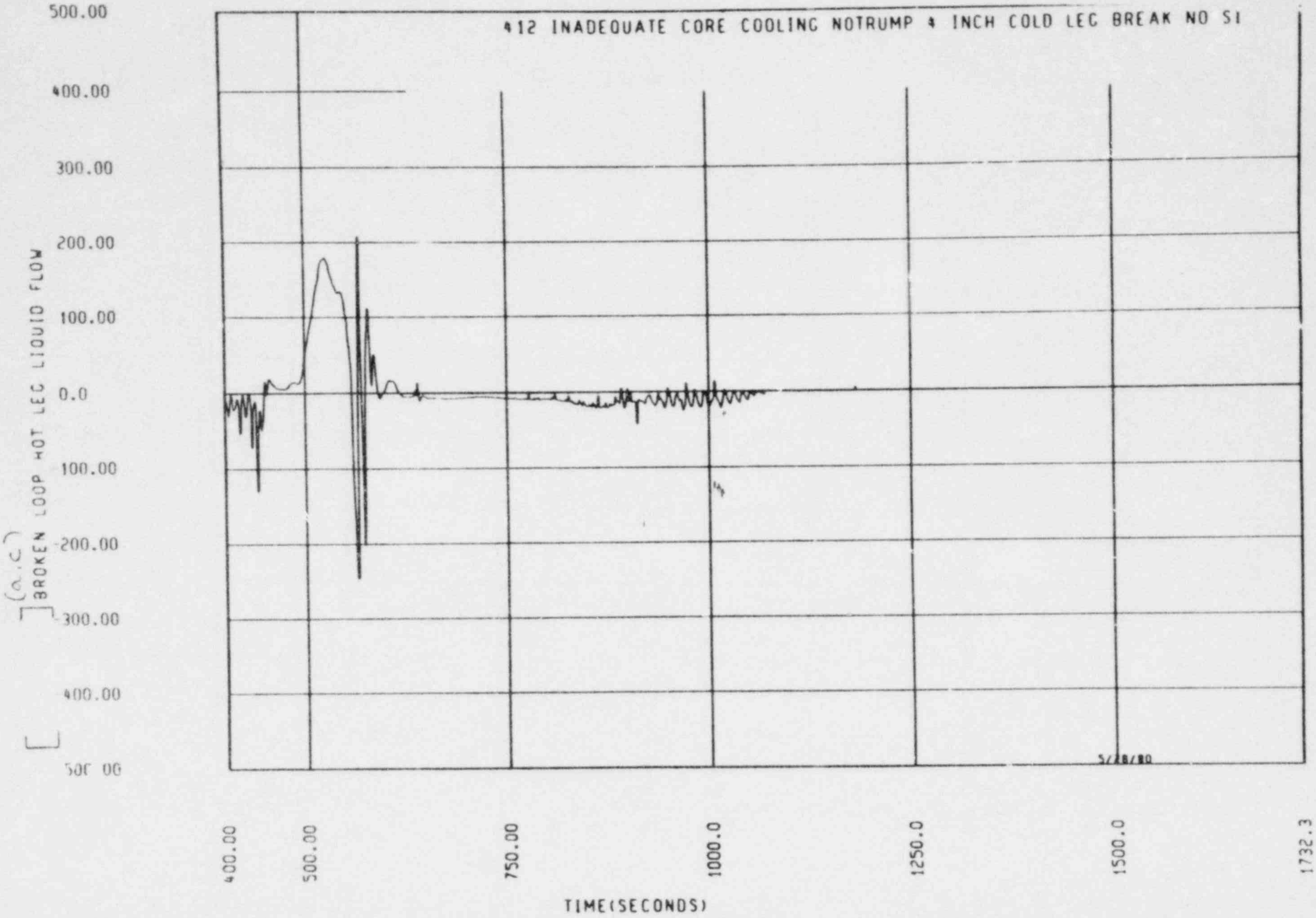

412 INADEQUATE CORE COOLING NOTRUMP 4 INCH COLD LEG BREAK NO SI
500.00
400.00
300.00
200.00
100.00
0.0
100.00
-200.00
-300.00
400.00
500 00
BROKEN LOOP HOT LEG LIQUID FLOW
(a,c)
400.00
500.00
750.00
1000.0
1250.0
1500.0
1732.3
TIME(SECONDS)
5/28/80

Figure 128a

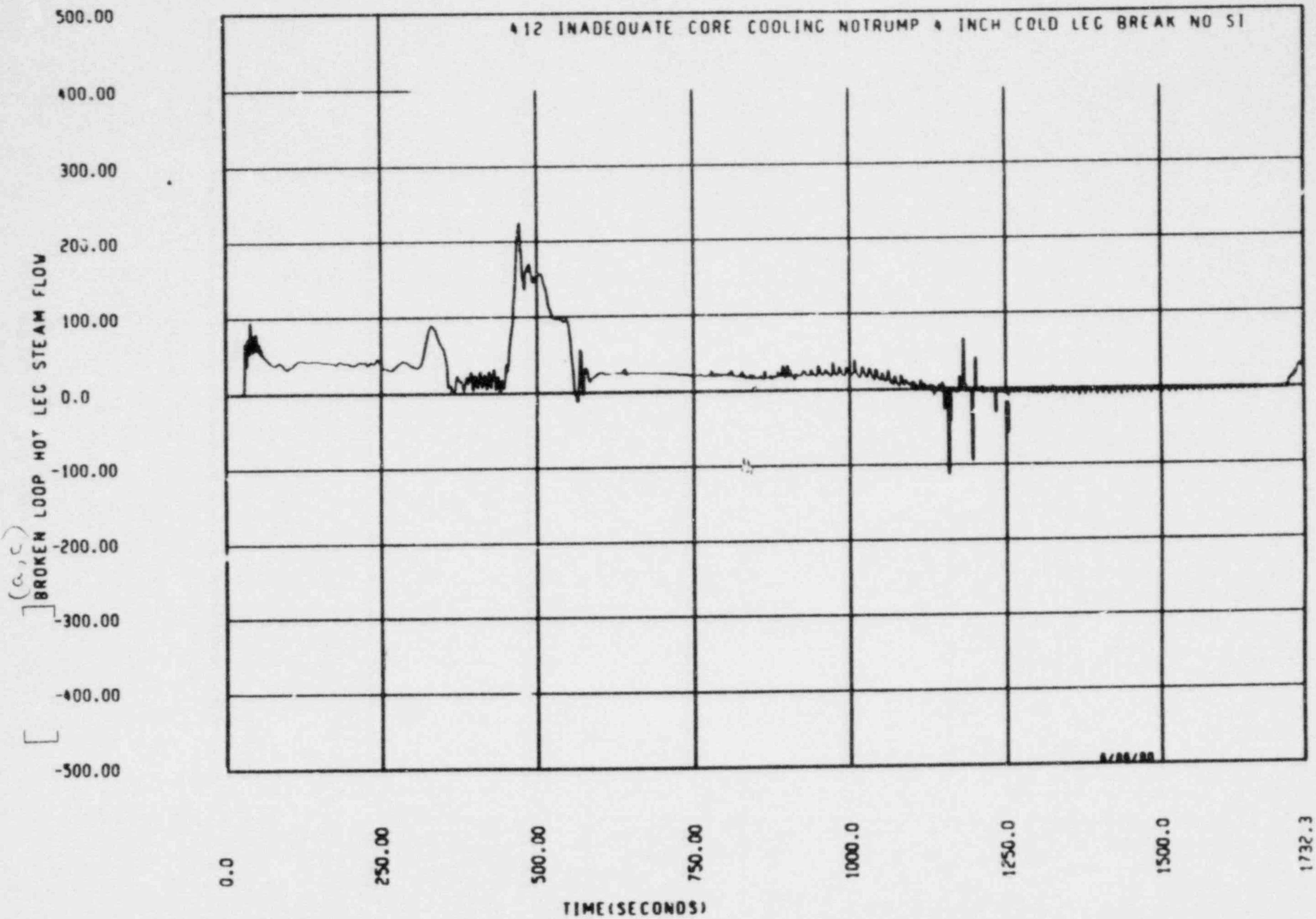

412 INADEQUATE CORE COOLING NOTRUMP 4 INCH COLD LEG BREAK NO SI
BROKEN LOOP HOT LEG STEAM FLOW
(a,c)
500.00
400.00
300.00
200.00
100.00
0.0
-100.00
-200.00
-300.00
-400.00
-500.00
0.0
250.00
500.00
750.00
1000.0
1250.0
1500.0
1732.3
TIME(SECONDS)

Figure 129

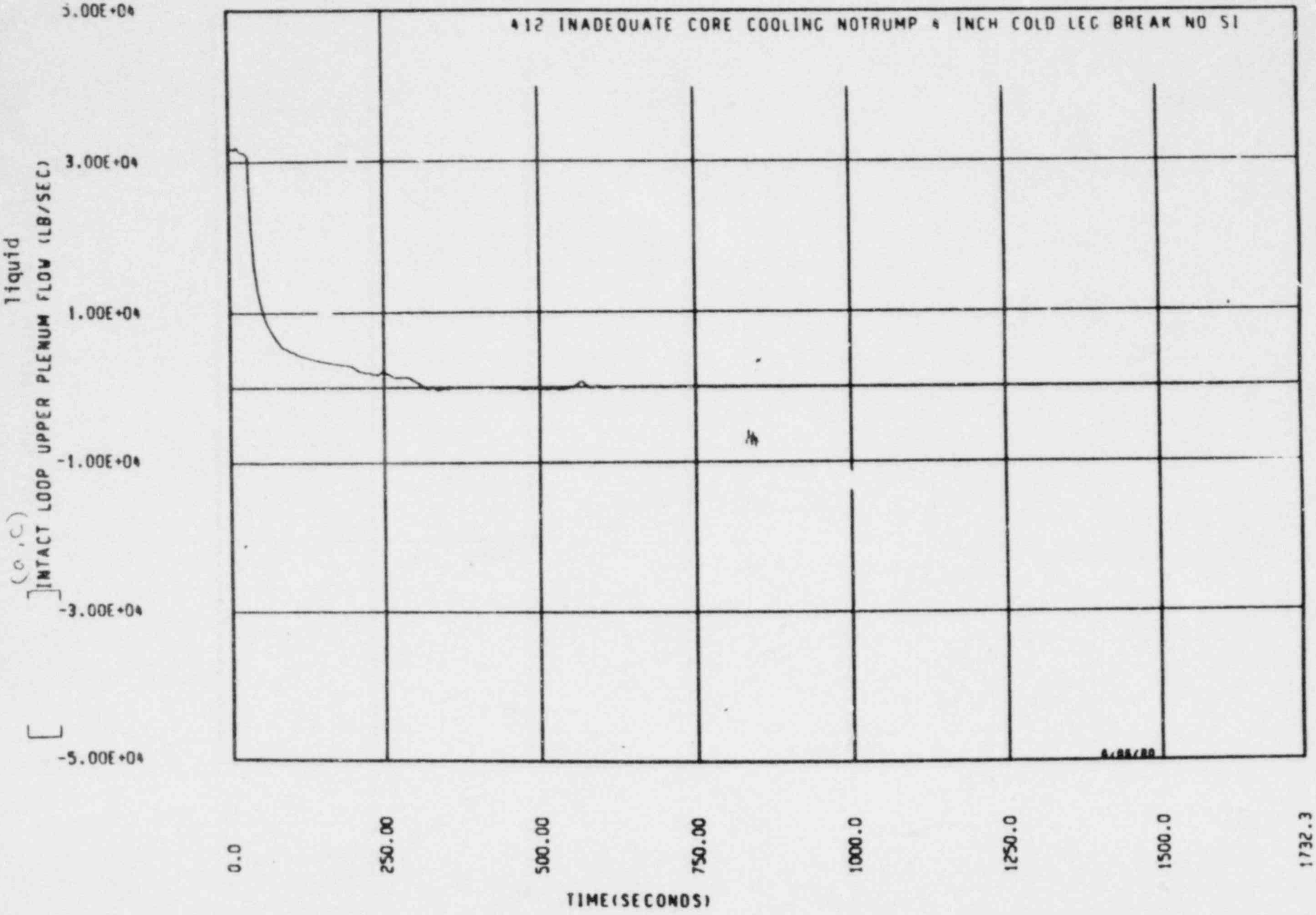

412 INADEQUATE CORE COOLING NOTRUMP 4 INCH COLD LEG BREAK NO SI
liquid
INTACT LOOP UPPER PLENUM FLOW (LB/SEC)
(a,c)
5.00E+04
3.00E+04
1.00E+04
-1.00E+04
-3.00E+04
-5.00E+04
0.0
250.00
500.00
750.00
1000.0
1250.0
1500.0
1732.3
TIME(SECONDS)

Figure 130

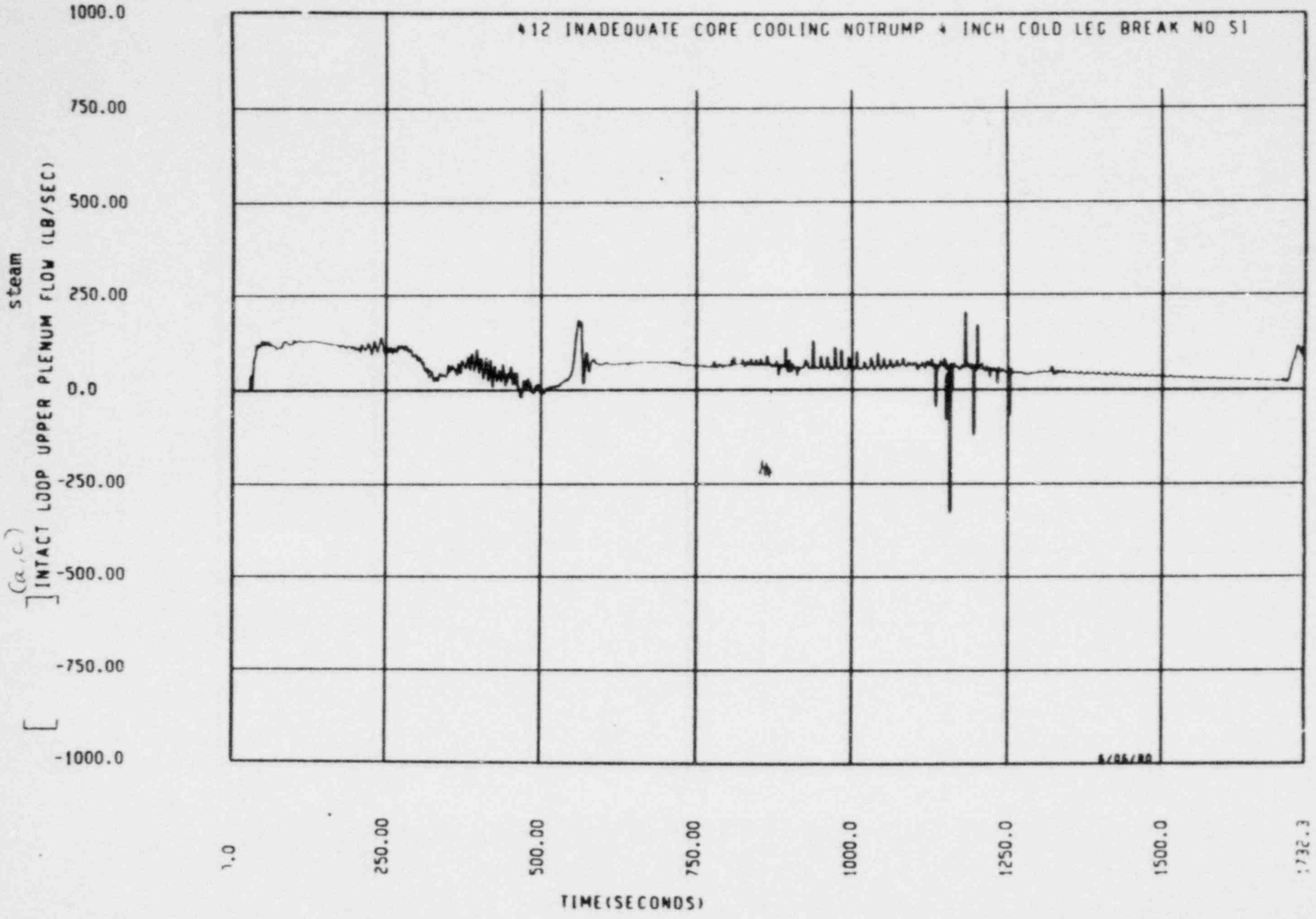

412 INADEQUATE CORE COOLING NOTRUMP 4 INCH COLD LEG BREAK NO SI
steam
INTACT LOOP UPPER PLENUM FLOW (LB/SEC)
(a,c)
1000.0
750.00
500.00
250.00
0.0
-250.00
-500.00
-750.00
-1000.0
1.0
250.00
500.00
750.00
1000.0
1250.0
1500.0
1732.3
TIME(SECONDS)

Figure 131

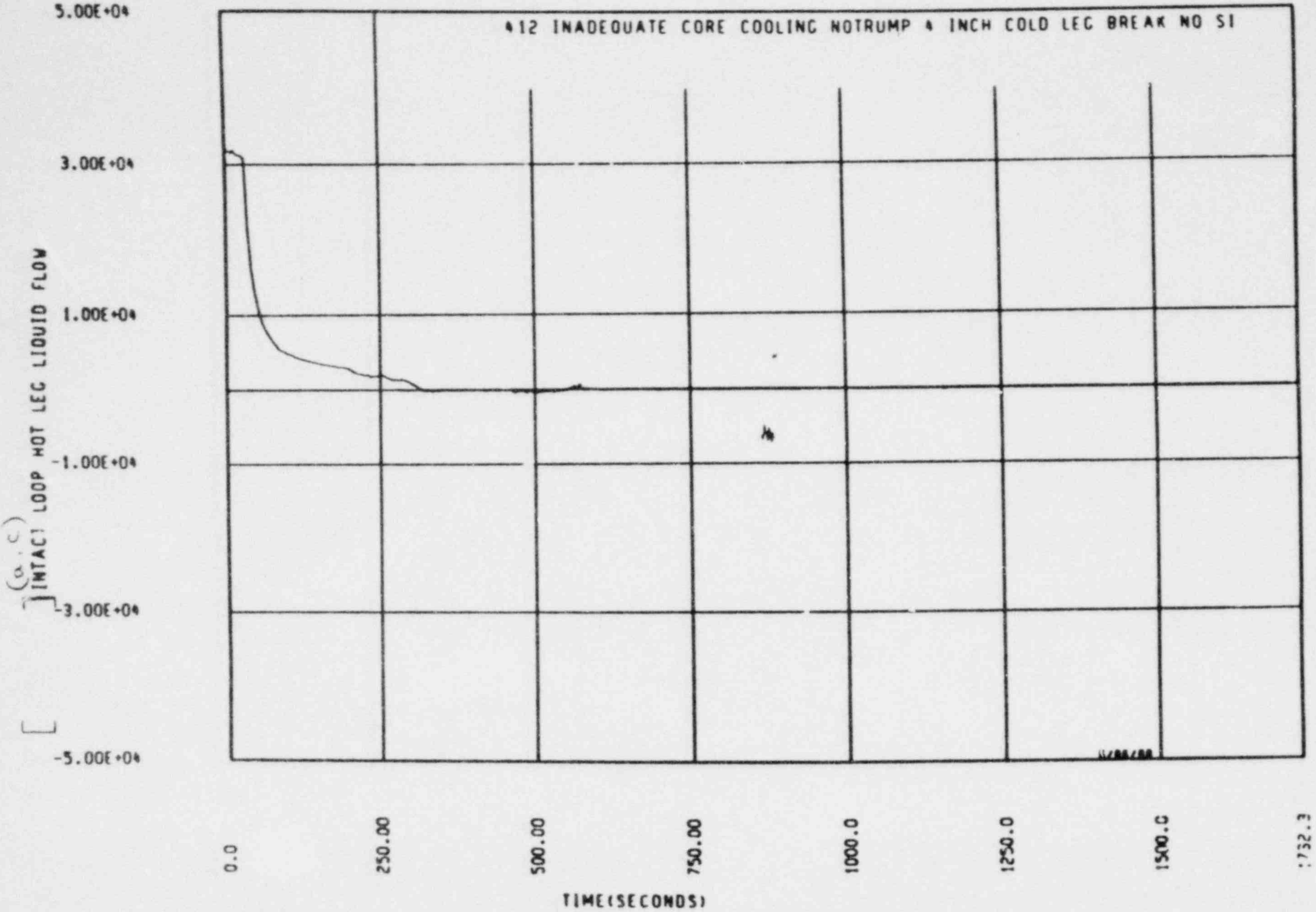

412 INADEQUATE CORE COOLING NOTRUMP 4 INCH COLD LEG BREAK NO SI
INTACT LOOP HOT LEG LIQUID FLOW
(a, c)
5.00E+04
3.00E+04
1.00E+04
-1.00E+04
-3.00E+04
-5.00E+04
0.0
250.00
500.00
750.00
1000.0
1250.0
1500.0
1732.3
TIME(SECONDS)

Figure 132

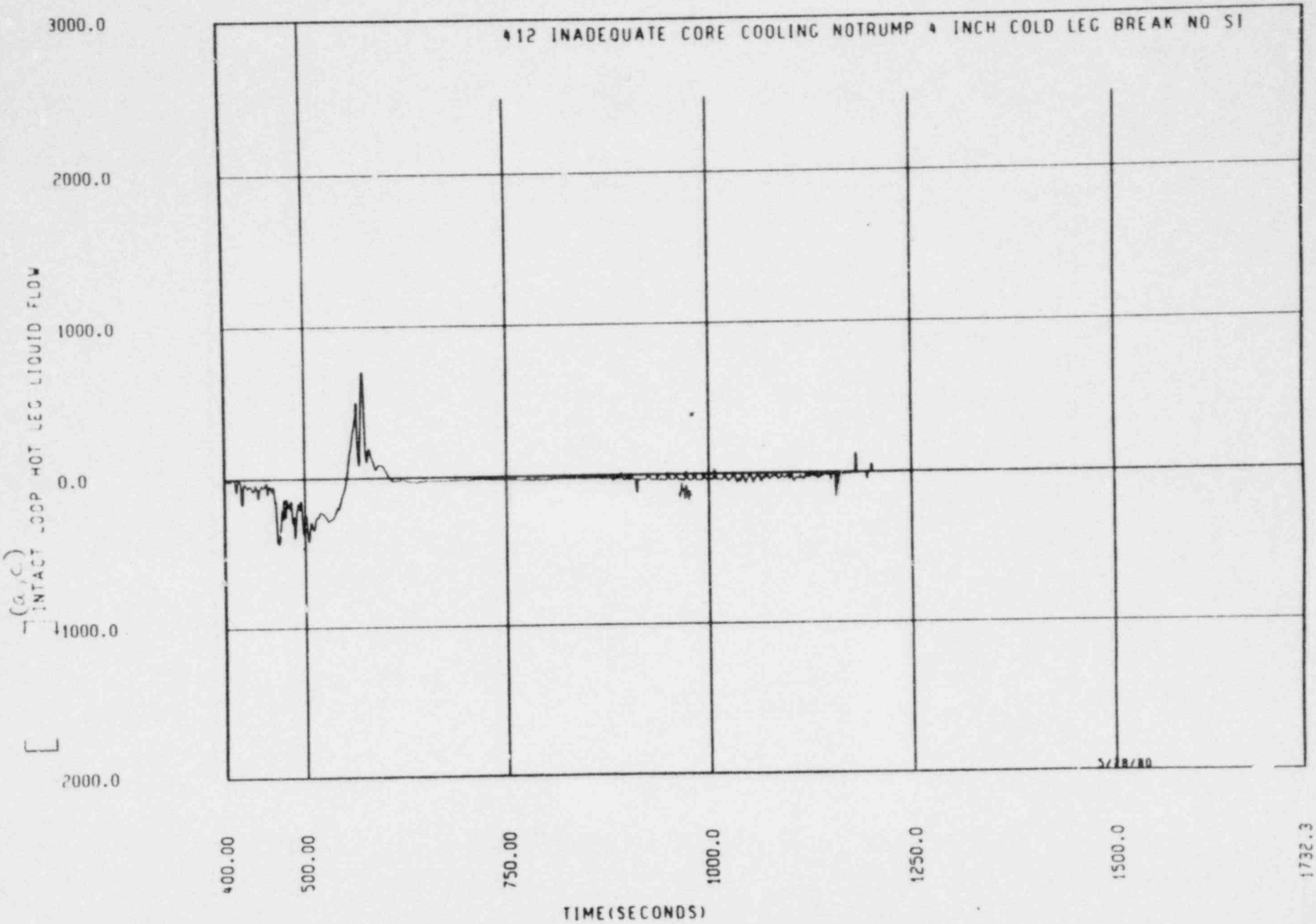

412 INADEQUATE CORE COOLING NOTRUMP 4 INCH COLD LEG BREAK NO SI
3000.0
2000.0
1000.0
0.0
1000.0
2000.0
INTACT LOOP HOT LEG LIQUID FLOW
(a,c)
400.00
500.00
750.00
1000.0
1250.0
1500.0
1732.3
TIME(SECONDS)
5/28/80

Figure 132a

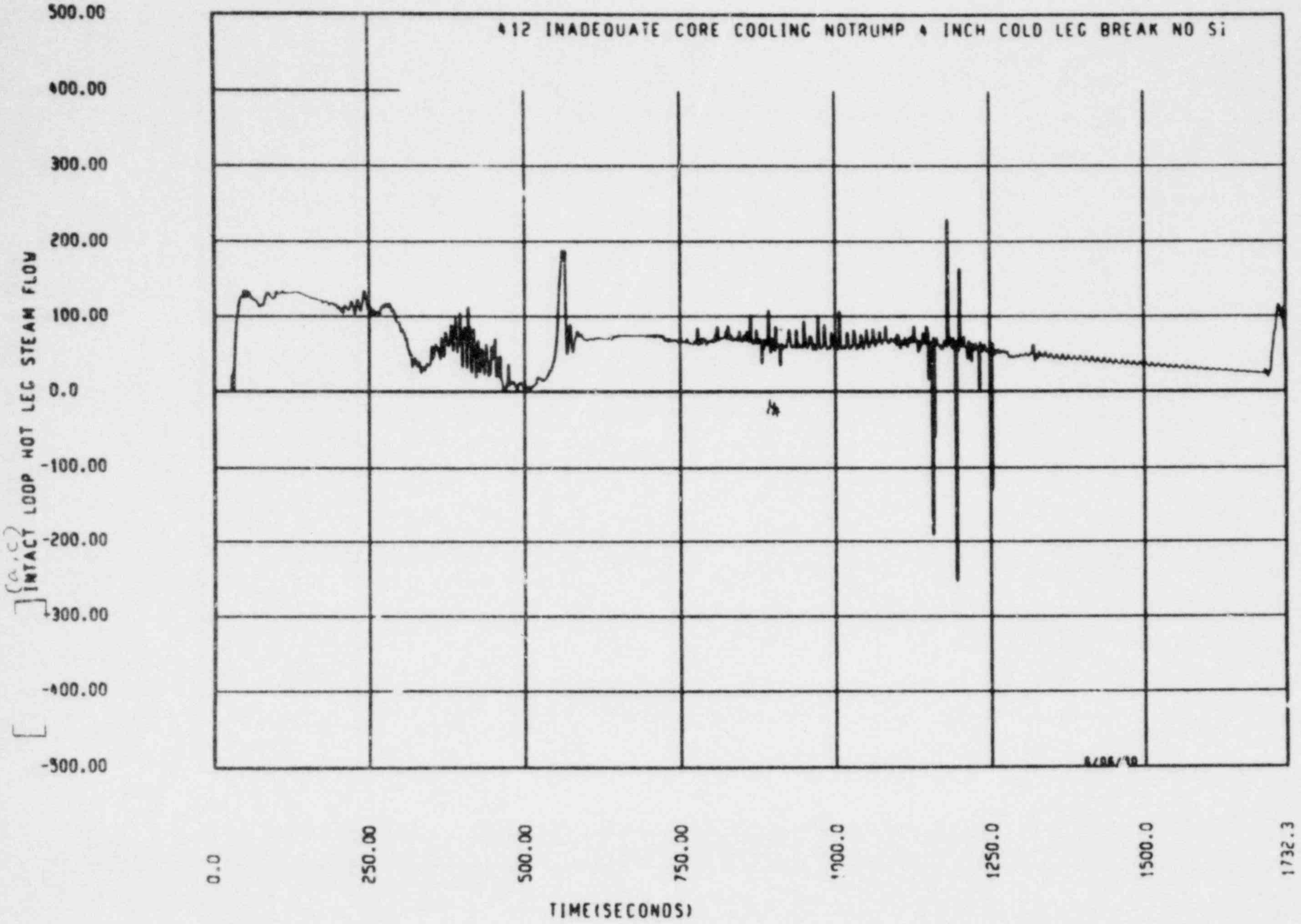

412 INADEQUATE CORE COOLING NOTRUMP 4 INCH COLD LEG BREAK NO SI
INTACT LOOP HOT LEG STEAM FLOW
(a,c)
500.00
400.00
300.00
200.00
100.00
0.0
-100.00
-200.00
-300.00
-400.00
-500.00
0.0
250.00
500.00
750.00
1000.0
1250.0
1500.0
1732.3
TIME(SECONDS)
8/06/80

Figure 133

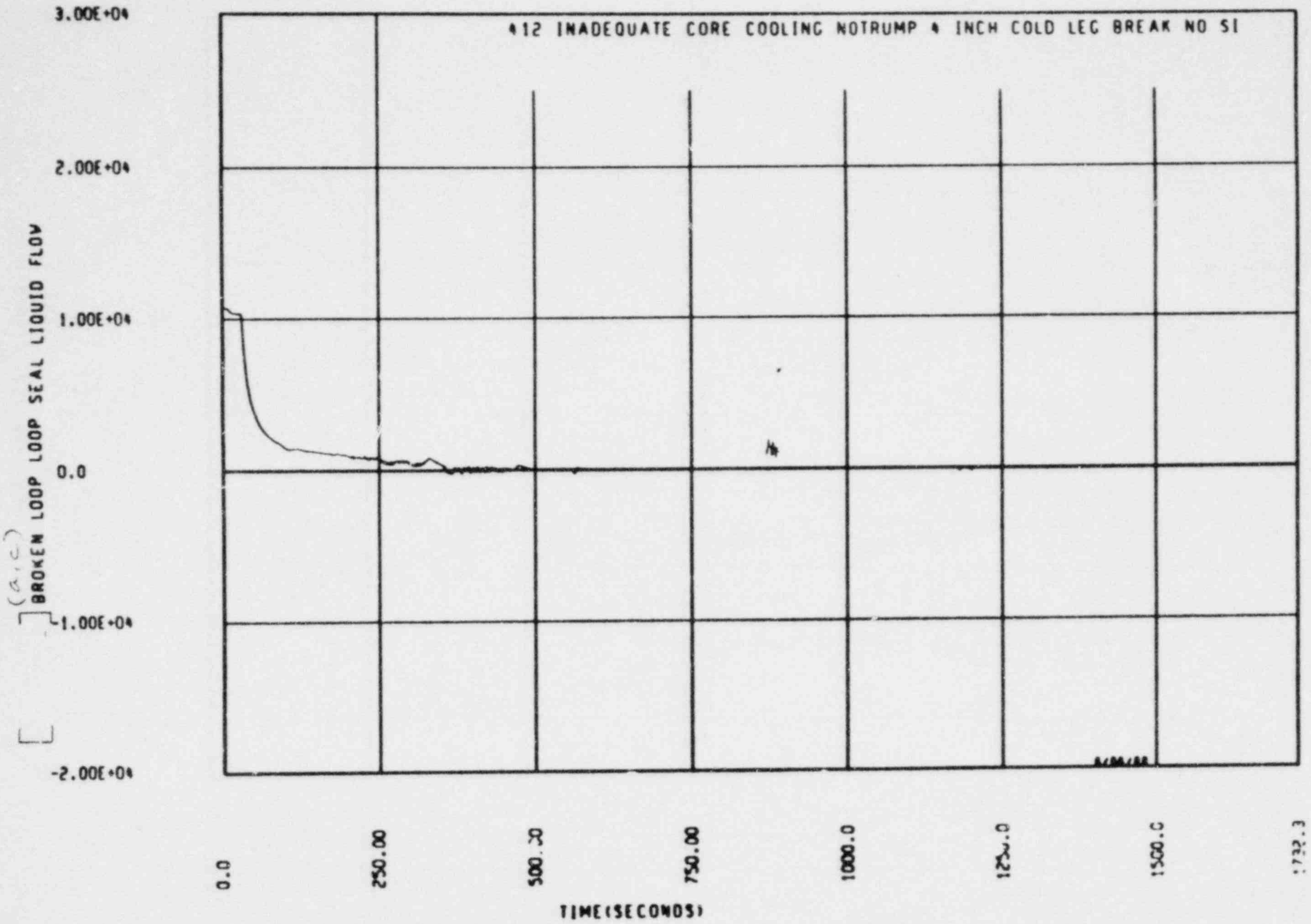

412 INADEQUATE CORE COOLING NOTRUMP 4 INCH COLD LEG BREAK NO SI
BROKEN LOOP LOOP SEAL LIQUID FLOW
(a,c)
3.00E+04
2.00E+04
1.00E+04
0.0
-1.00E+04
-2.00E+04
0.0
250.00
500.00
750.00
1000.0
1250.0
1500.0
1732.3
TIME(SECONDS)

Figure 134

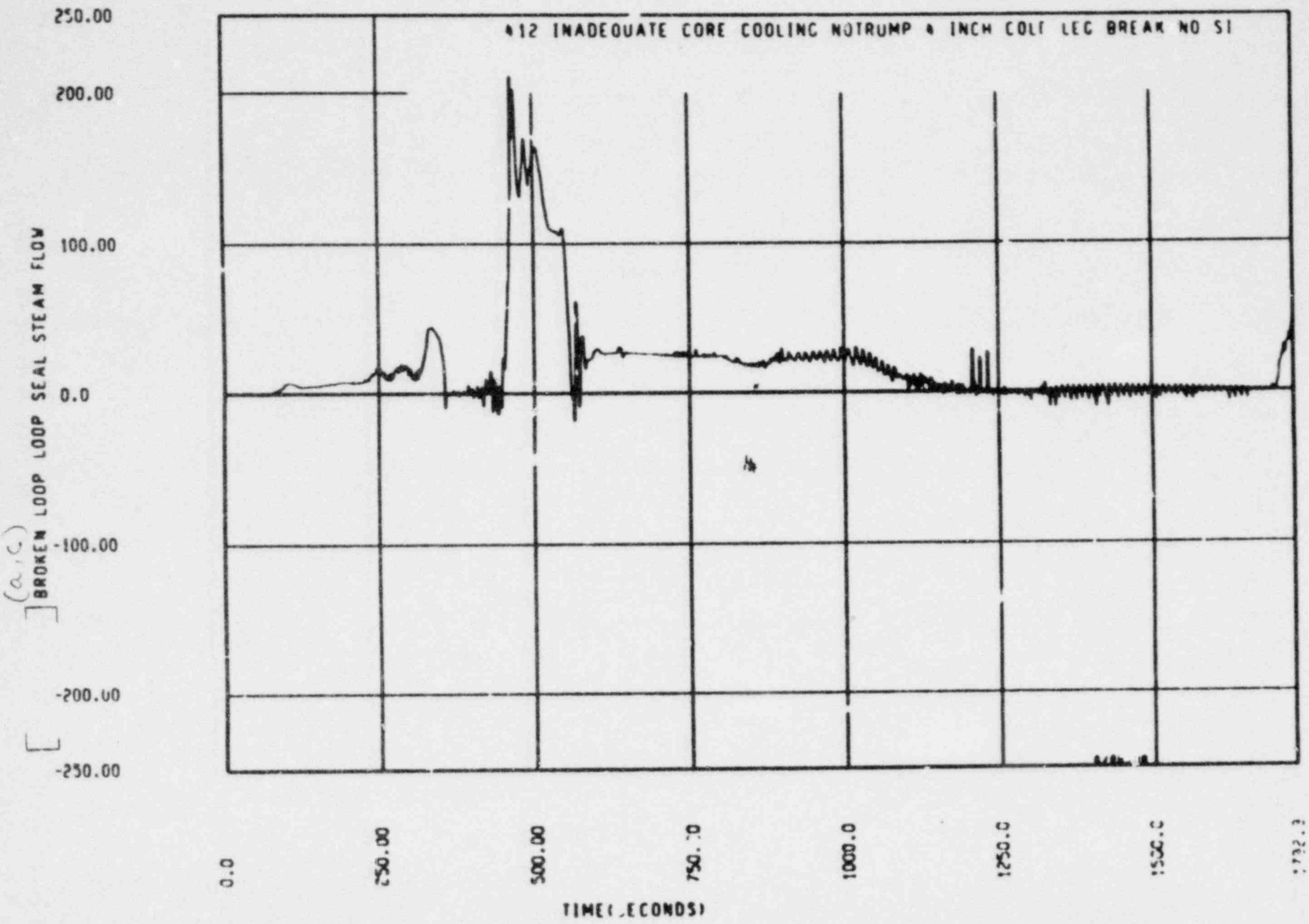

412 INADEQUATE CORE COOLING NOTRUMP 4 INCH COLD LEG BREAK NO SI
BROKEN LOOP LOOP SEAL STEAM FLOW
(a,c)
250.00
200.00
100.00
0.0
-100.00
-200.00
-250.00
0.0
250.00
500.00
750.00
1000.0
1250.0
1500.0
1732.3
TIME(SECONDS)

Figure 135

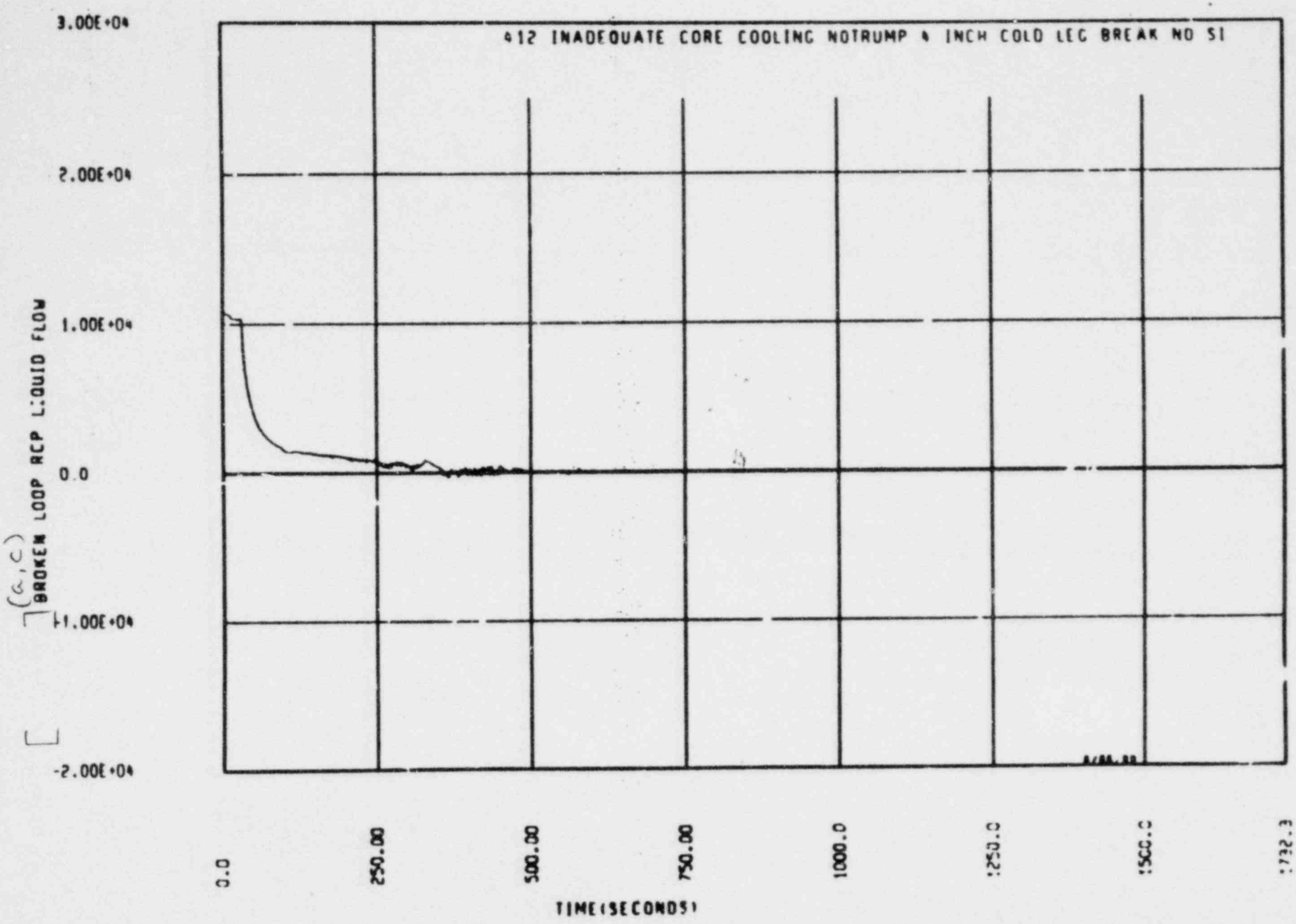

412 INADEQUATE CORE COOLING NOTRUMP 4 INCH COLD LEG BREAK NO SI
3.00E+04
2.00E+04
1.00E+04
0.0
-1.00E+04
-2.00E+04
BROKEN LOOP RCP LIQUID FLOW
(a,c)
0.0
250.00
500.00
750.00
1000.0
1250.0
1500.0
1732.3
TIME(SECONDS)

Figure 136

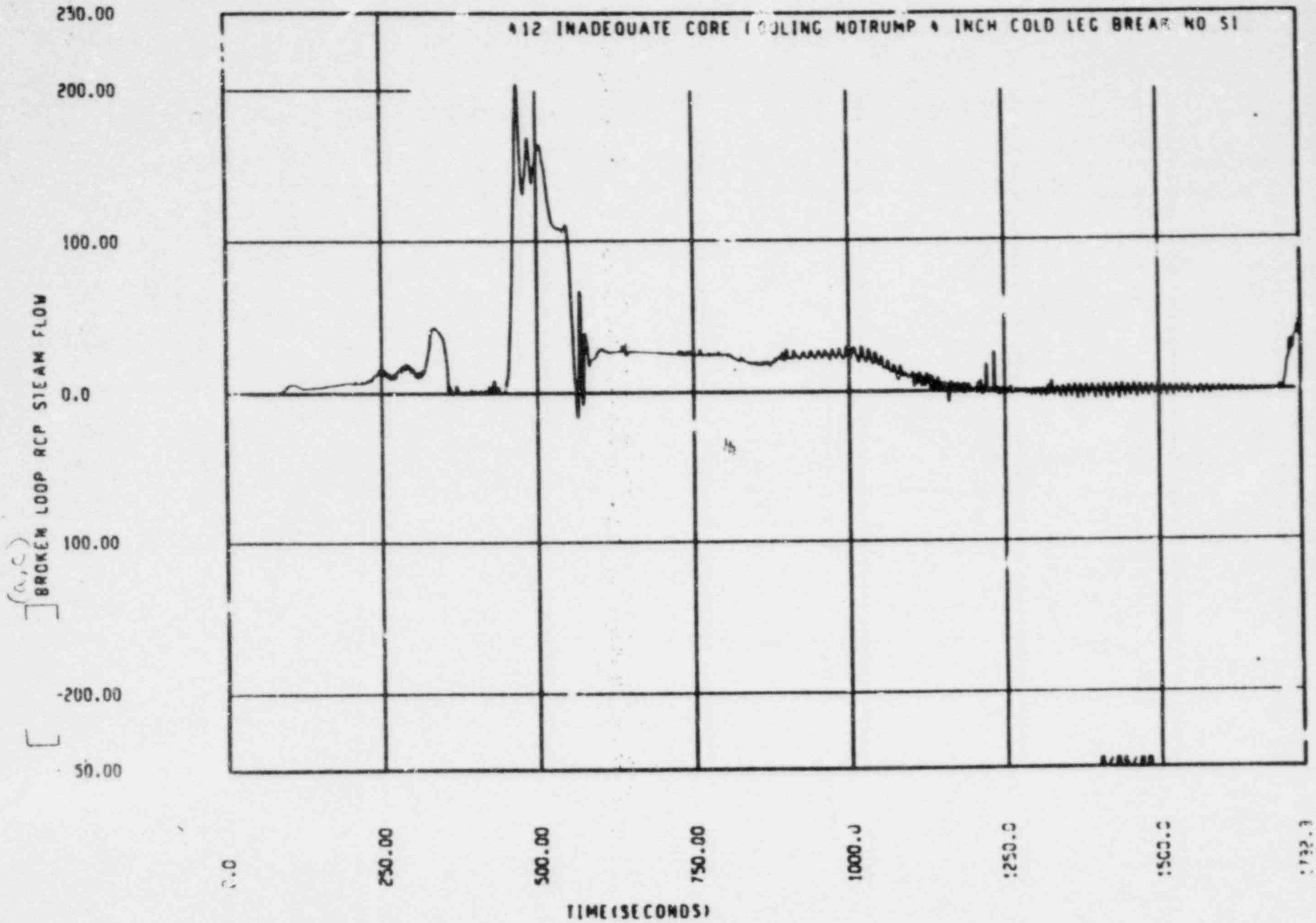

412 INADEQUATE CORE COOLING NOTRUMP 4 INCH COLD LEG BREAK NO SI
BROKEN LOOP RCP STEAM FLOW
(a,c)
230.00
200.00
100.00
0.0
100.00
-200.00
50.00
0.0
250.00
500.00
750.00
1000.0
1250.0
1500.0
1732.3
TIME(SECONDS)

Figure 137

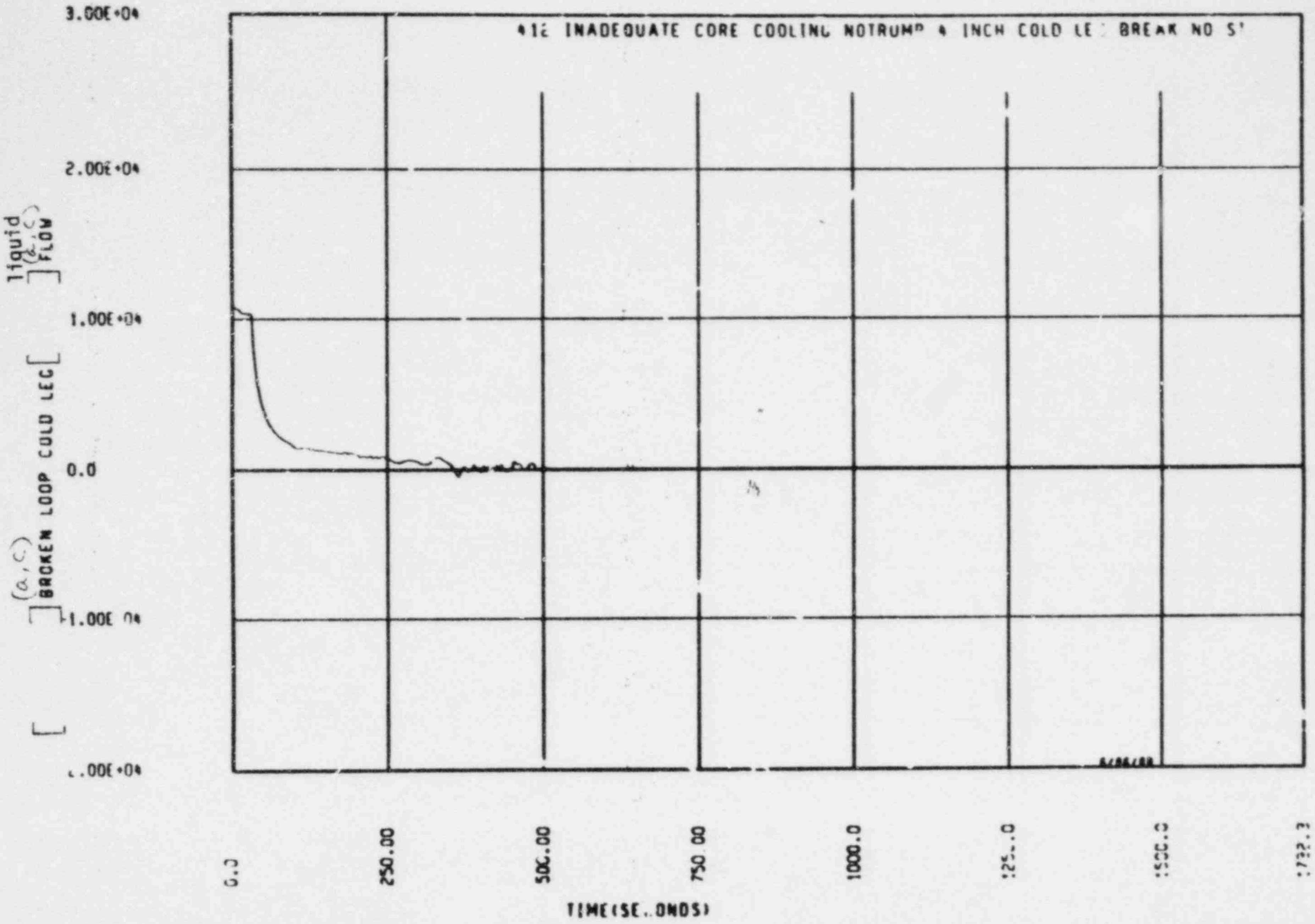

412 INADEQUATE CORE COOLING NOTRUMP 4 INCH COLD LEG BREAK NO SI
3.00E+04
2.00E+04
1.00E+04
0.0
-1.00E+04
-2.00E+04
[ ](a,c) BROKEN LOOP COLD LEG [ liquid ](a,c) FLOW
0.0
250.00
500.00
750.00
1000.0
1250.0
1500.0
1732.3
TIME(SECONDS)

Figure 138

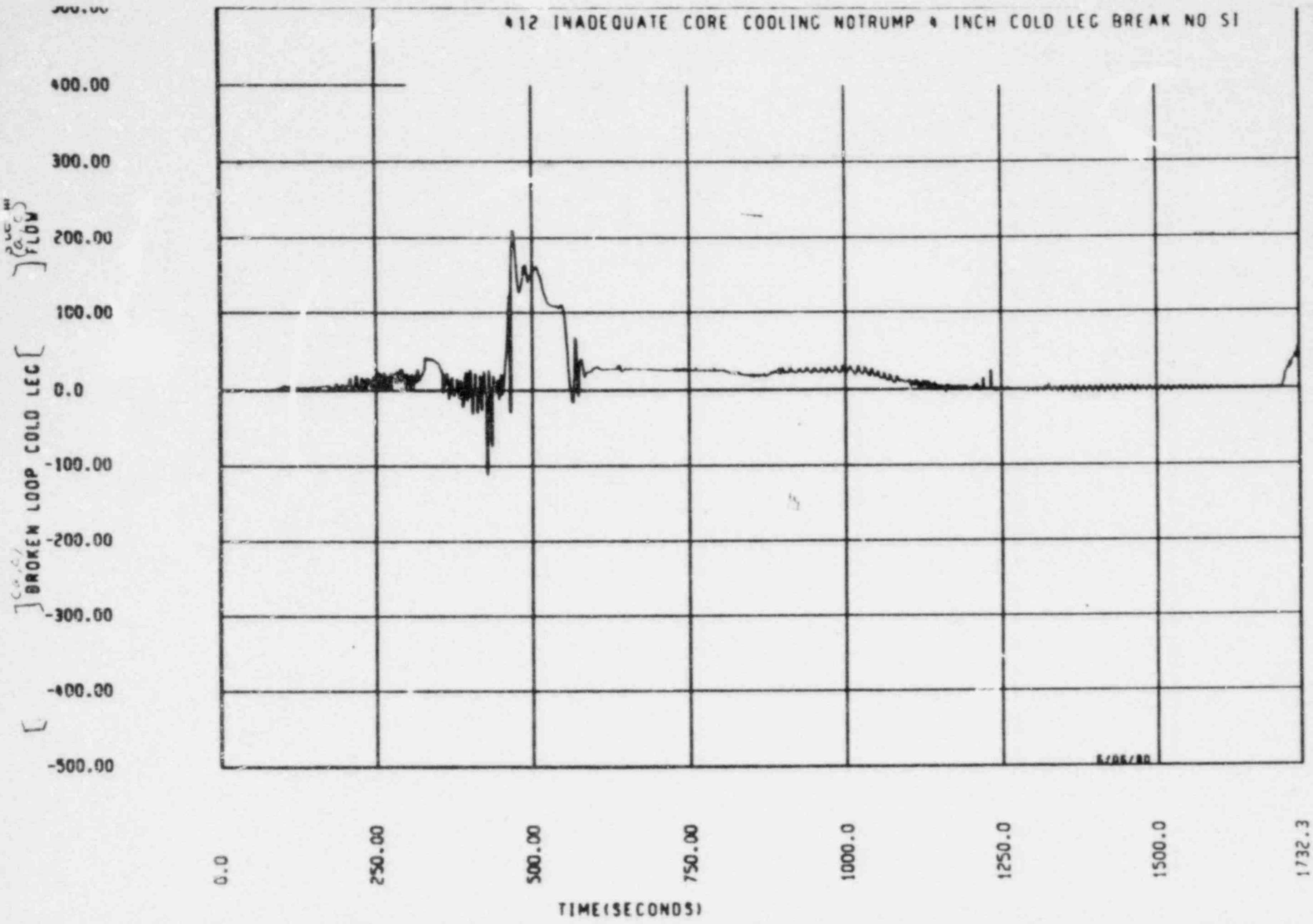
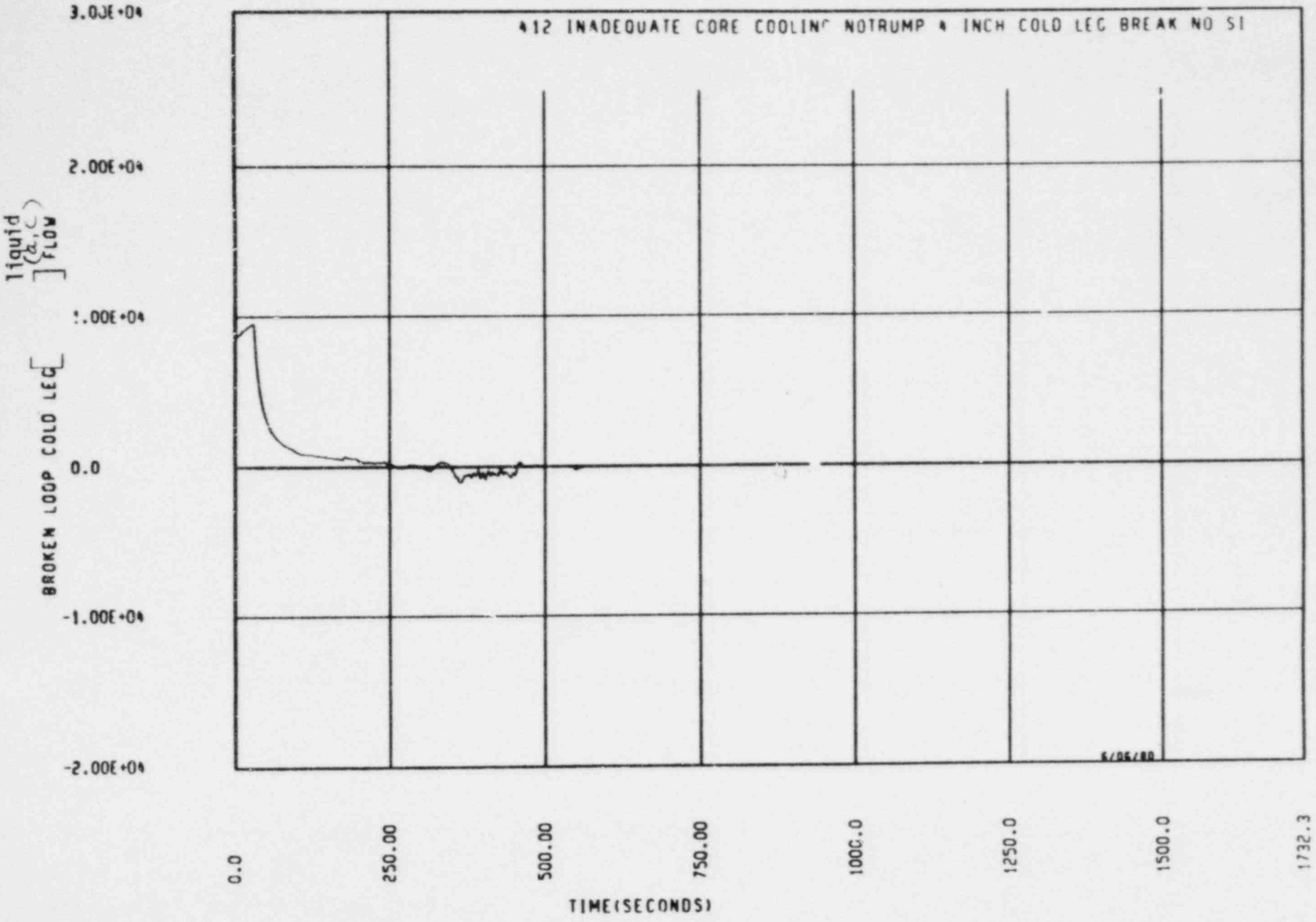

412 INADEQUATE CORE COOLING NOTRUMP 4 INCH COLD LEG BREAK NO SI
400.00
300.00
200.00
100.00
0.0
-100.00
-200.00
-300.00
-400.00
-500.00
BROKEN LOOP COLD LEG FLOW
a,c
0.0
250.00
500.00
750.00
1000.0
1250.0
1500.0
1732.3
TIME(SECONDS)
6/06/80

Figure 139



412 INADEQUATE CORE COOLIN^ NOTRUMP 4 INCH COLD LEG BREAK NO SI
BROKEN LOOP COLD LEG[
liquid
(a,c)
] FLOW
3.0E+04
2.00E+04
1.00E+04
0.0
-1.00E+04
-2.00E+04
0.0
250.00
500.00
750.00
1000.0
1250.0
1500.0
1732.3
TIME(SECONDS)
5/05/80

Figure 140

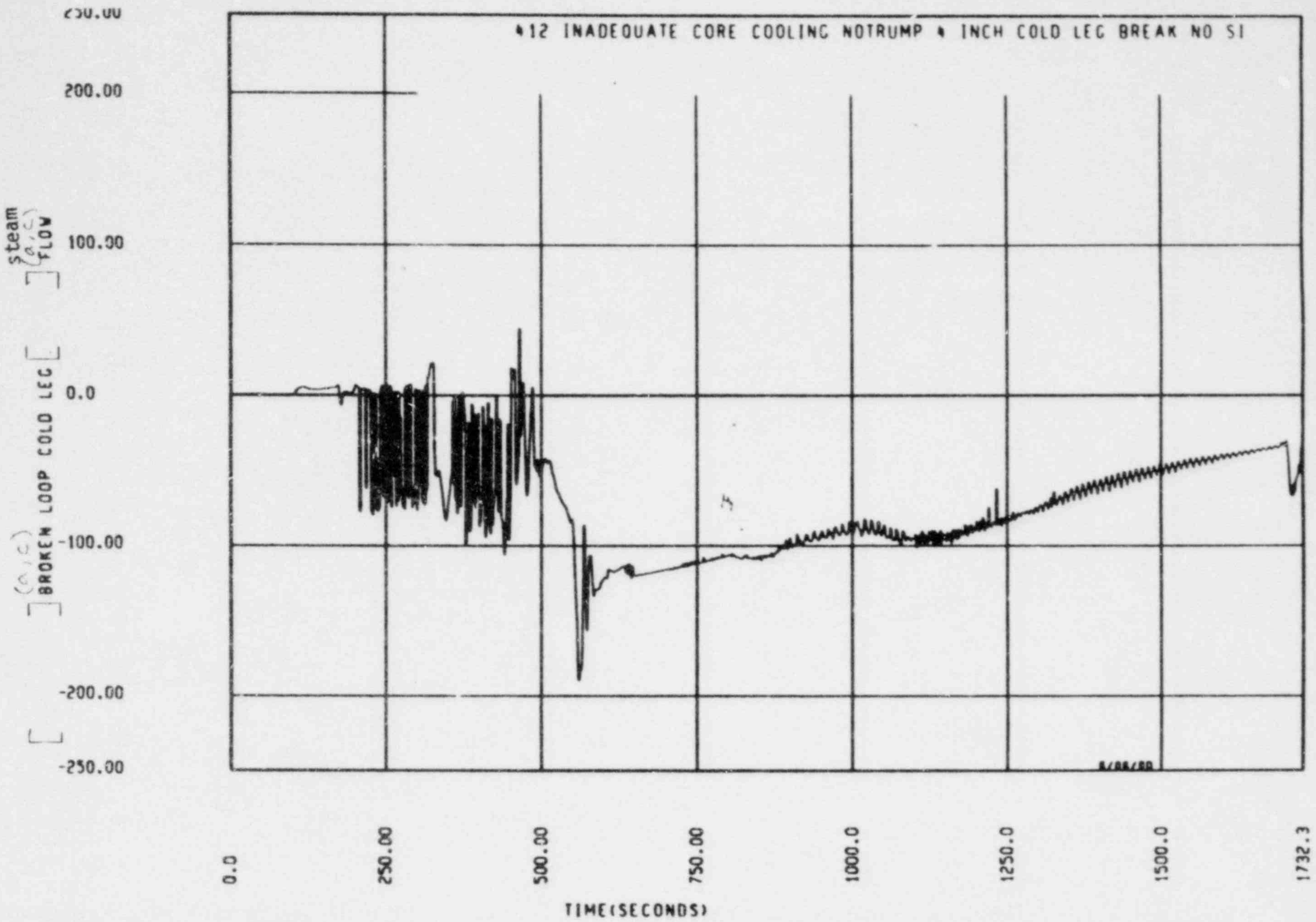

412 INADEQUATE CORE COOLING NOTRUMP 4 INCH COLD LEG BREAK NO SI
BROKEN LOOP COLD LEG [ ] steam [ ] FLOW
(a,c)
(a,c)
250.00
200.00
100.00
0.0
-100.00
-200.00
-250.00
0.0
250.00
500.00
750.00
1000.0
1250.0
1500.0
1732.3
TIME(SECONDS)

Figure 141

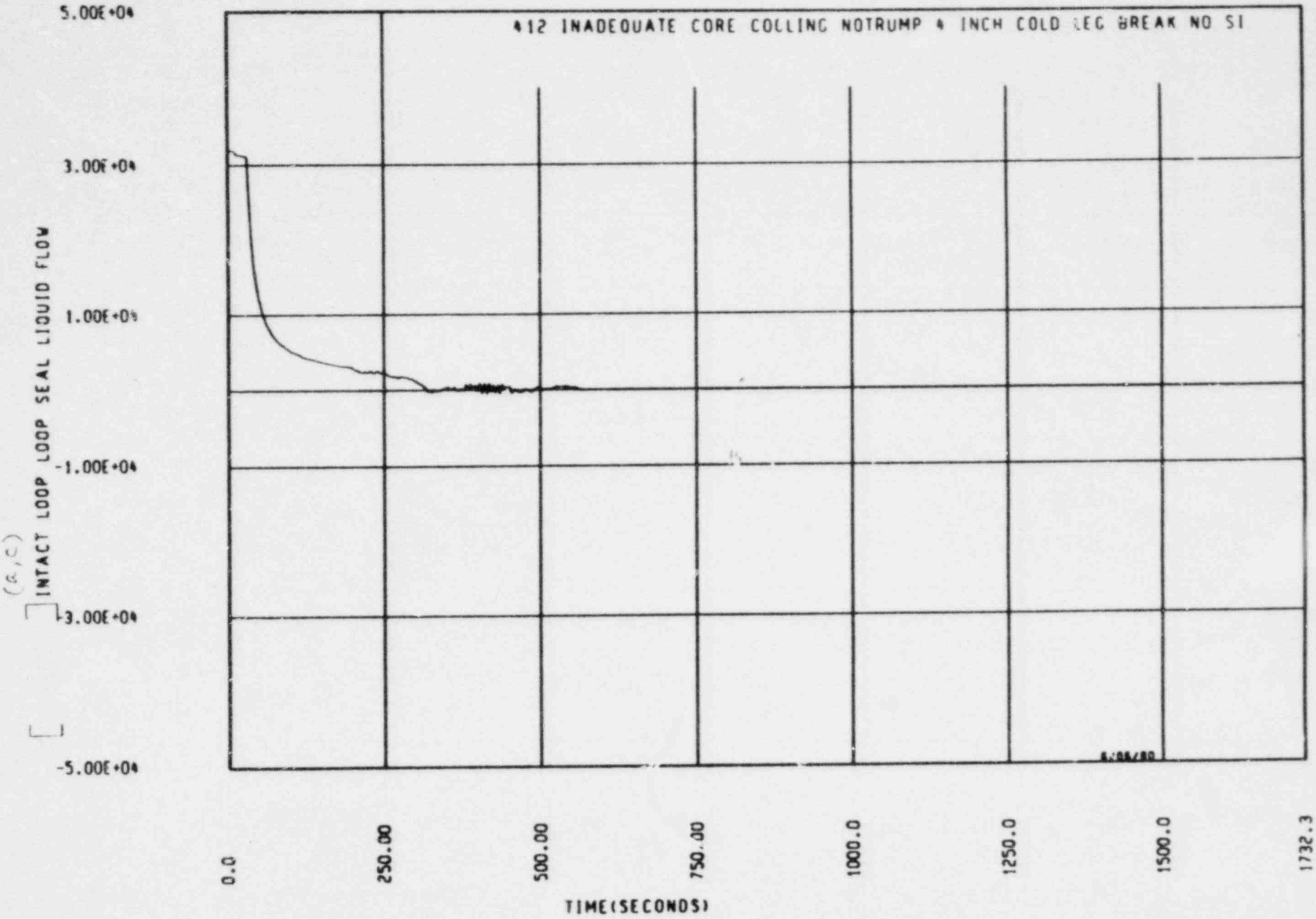

412 INADEQUATE CORE COLLING NOTRUMP 4 INCH COLD LEG BREAK NO SI
INTACT LOOP LOOP SEAL LIQUID FLOW
(a,c)
5.00E+04
3.00E+04
1.00E+04
-1.00E+04
-3.00E+04
-5.00E+04
0.0
250.00
500.00
750.00
1000.0
1250.0
1500.0
1732.3
TIME(SECONDS)
6/06/80

Figure 142

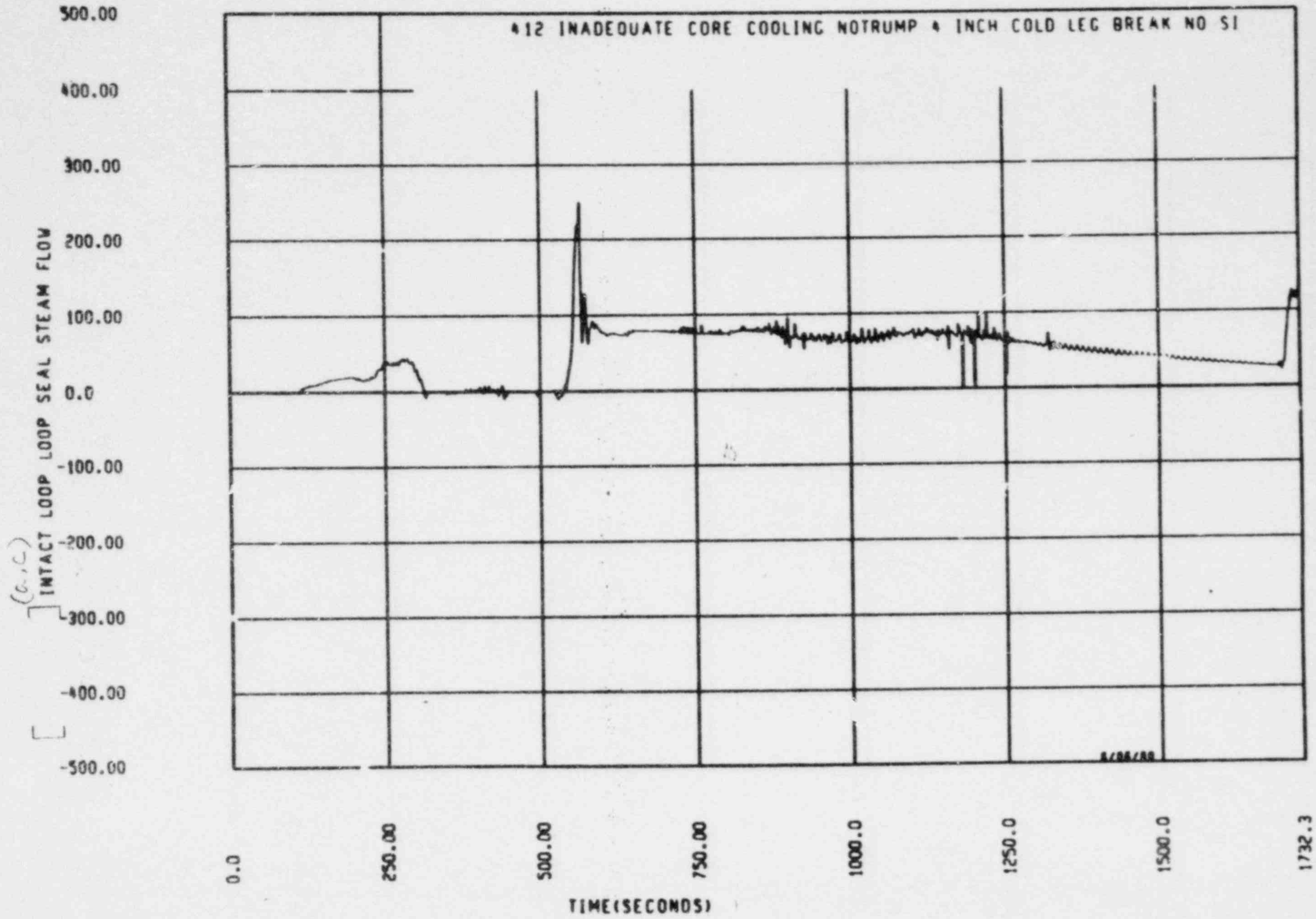

412 INADEQUATE CORE COOLING NOTRUMP 4 INCH COLD LEG BREAK NO SI
INTACT LOOP LOOP SEAL STEAM FLOW
(a,c)
500.00
400.00
300.00
200.00
100.00
0.0
-100.00
-200.00
-300.00
-400.00
-500.00
0.0
250.00
500.00
750.00
1000.0
1250.0
1500.0
1732.3
TIME(SECONDS)

Figure 143

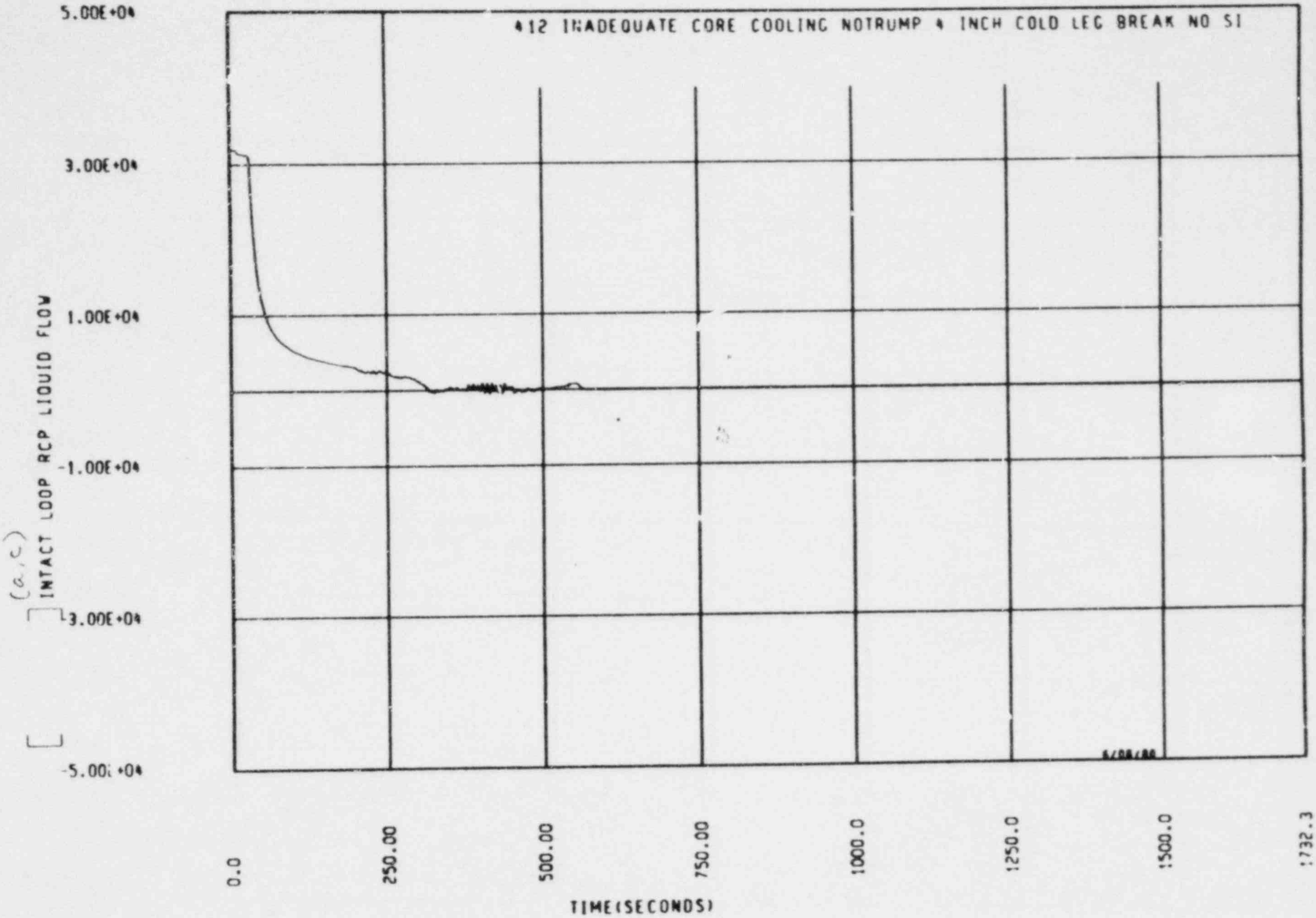

412 INADEQUATE CORE COOLING NOTRUMP 4 INCH COLD LEG BREAK NO SI
INTACT LOOP RCP LIQUID FLOW
(a,c)
5.00E+04
3.00E+04
1.00E+04
-1.00E+04
3.00E+04
-5.00E+04
0.0
250.00
500.00
750.00
1000.0
1250.0
1500.0
1732.3
TIME(SECONDS)

Figure 144

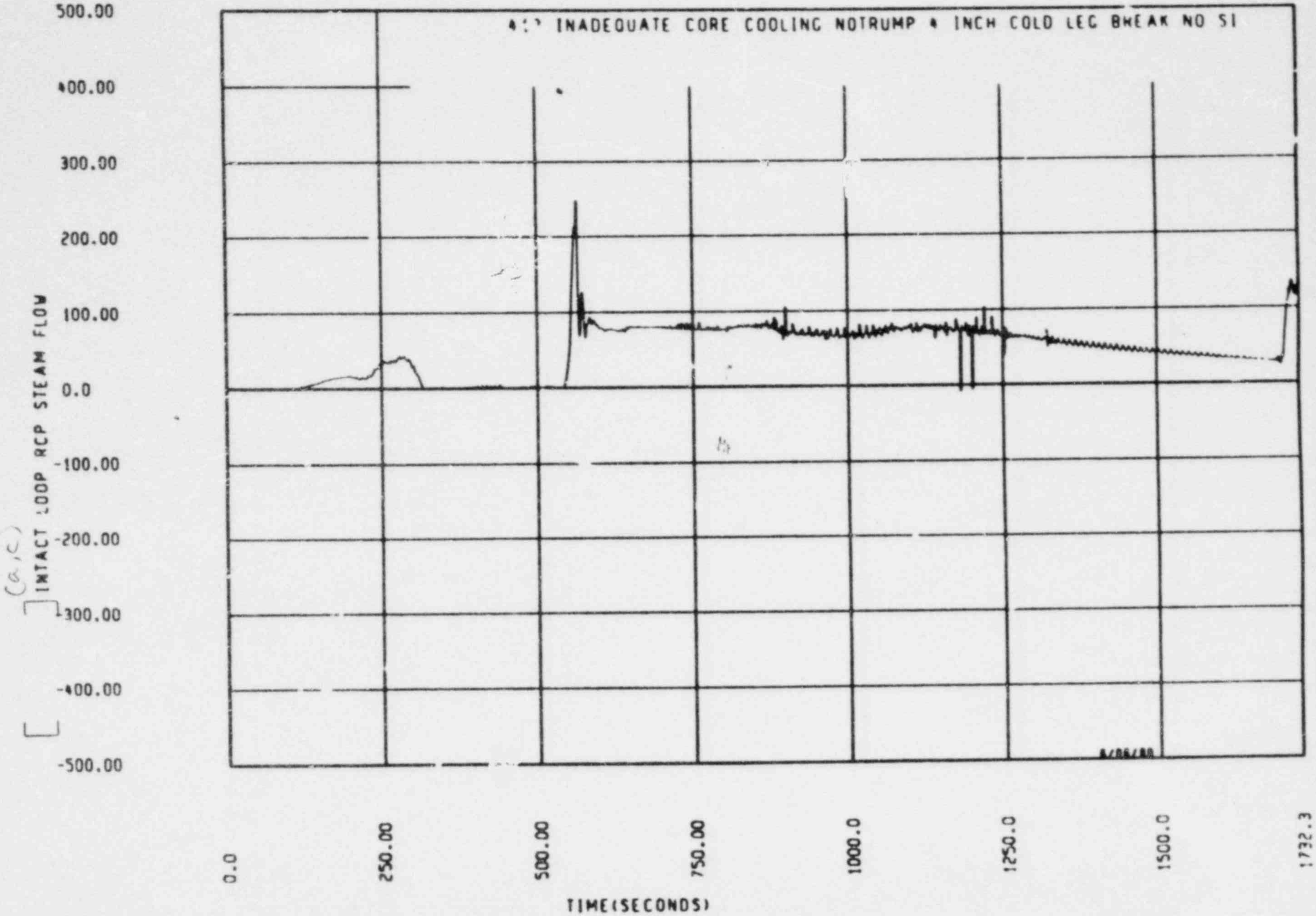

4.? INADEQUATE CORE COOLING NOTRUMP 4 INCH COLD LEG BREAK NO SI
[ ] INTACT LOOP RCP STEAM FLOW (a,c)
500.00
400.00
300.00
200.00
100.00
0.0
-100.00
-200.00
-300.00
-400.00
-500.00
0.0
250.00
500.00
750.00
1000.0
1250.0
1500.0
1732.3
TIME(SECONDS)
8/06/80

Figure 145

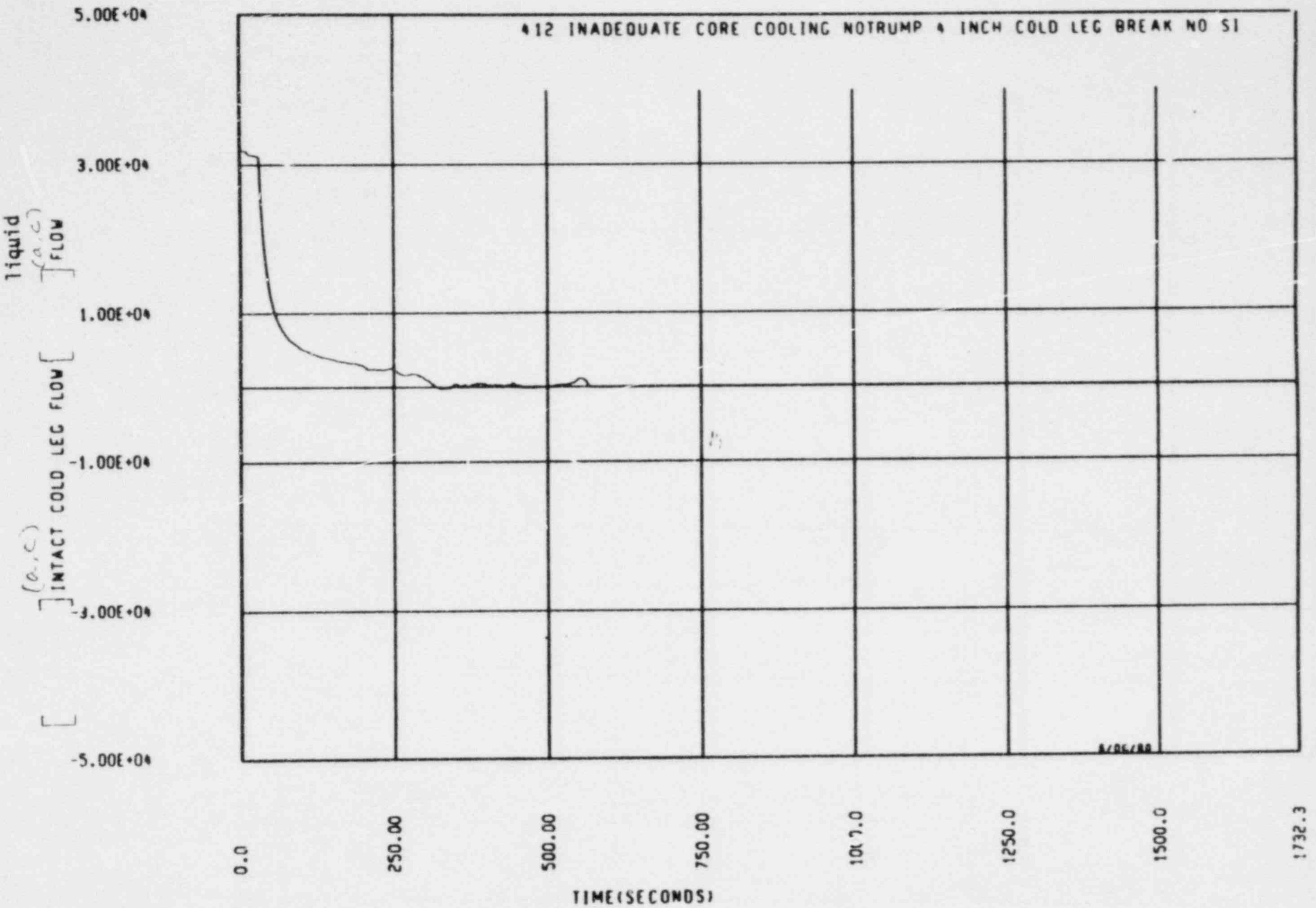

412 INADEQUATE CORE COOLING NOTRUMP 4 INCH COLD LEG BREAK NO SI
5.00E+04
3.00E+04
1.00E+04
-1.00E+04
-3.00E+04
-5.00E+04
(a,c)
INTACT COLD LEG FLOW
liquid
(a,c)
FLOW
0.0
250.00
500.00
750.00
1017.0
1250.0
1500.0
1732.3
TIME(SECONDS)

Figure 146

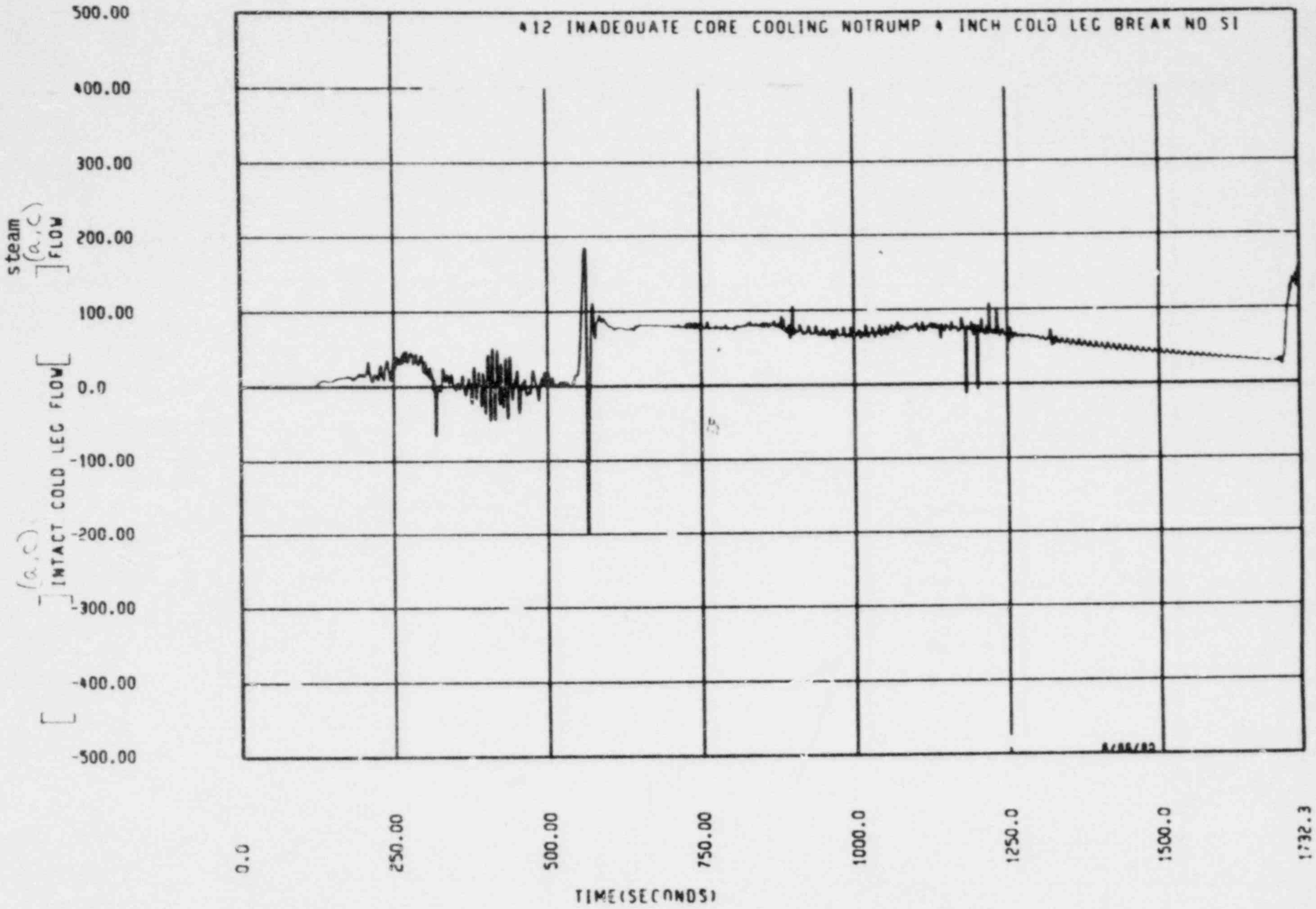
412 INADEQUATE CORE COOLING NOTRUMP 4 INCH COLD LEG BREAK NO SI
500.00
400.00
300.00
200.00
100.00
0.0
-100.00
-200.00
-300.00
-400.00
-500.00
INTACT COLD LEG FLOW
steam
FLOW
(a,c)
(a,c)
0.0
250.00
500.00
750.00
1000.0
1250.0
1500.0
1732.3
TIME(SECONDS)

Figure 147

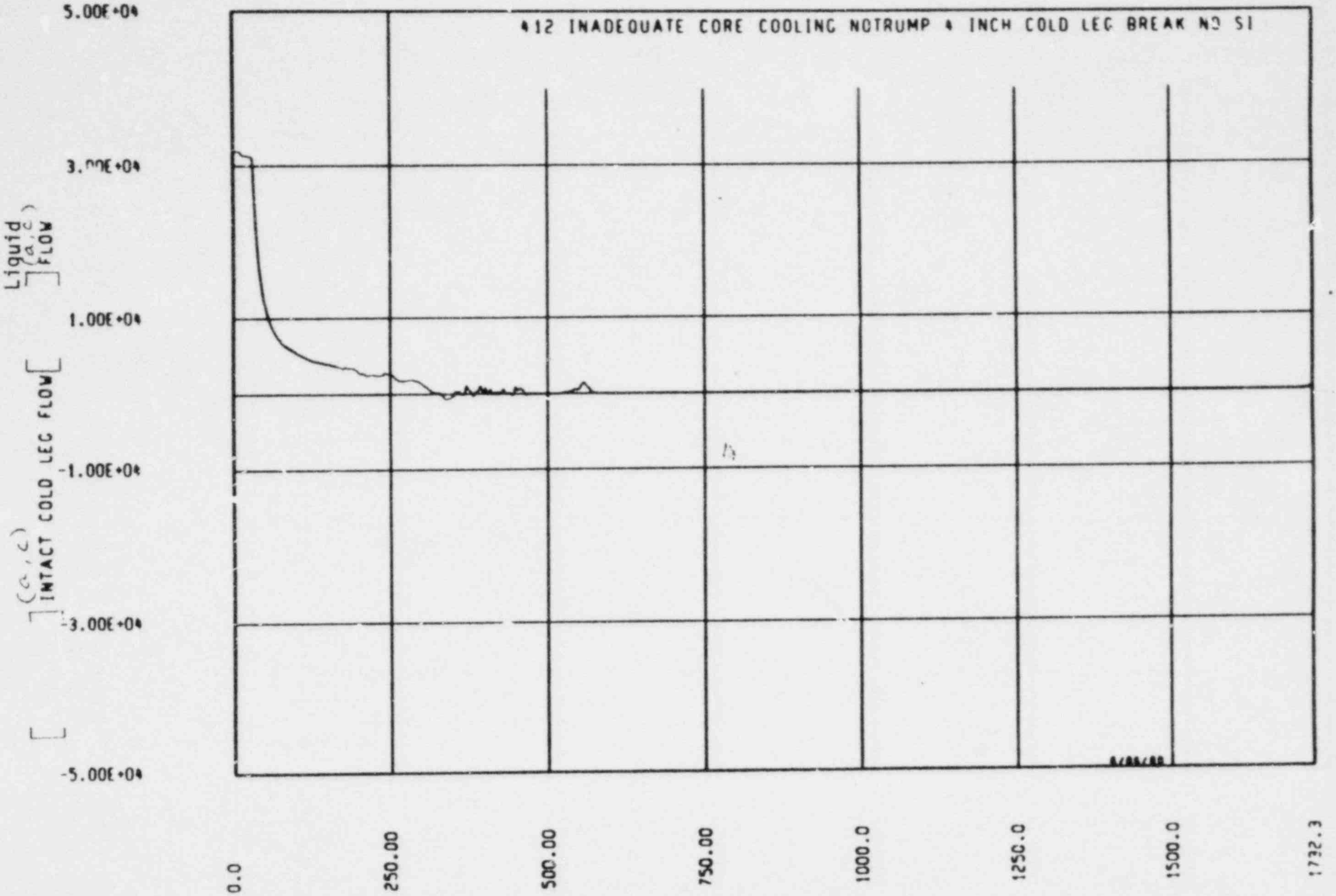

412 INADEQUATE CORE COOLING NOTRUMP 4 INCH COLD LEG BREAK NO SI
5.00E+04
3.00E+04
1.00E+04
-1.00E+04
-3.00E+04
-5.00E+04
Liquid
(a,c)
FLOW
INTACT COLD LEG FLOW
(a,c)
0.0
250.00
500.00
750.00
1000.0
1250.0
1500.0
1732.3
TIME(SECONDS)

Figure 148

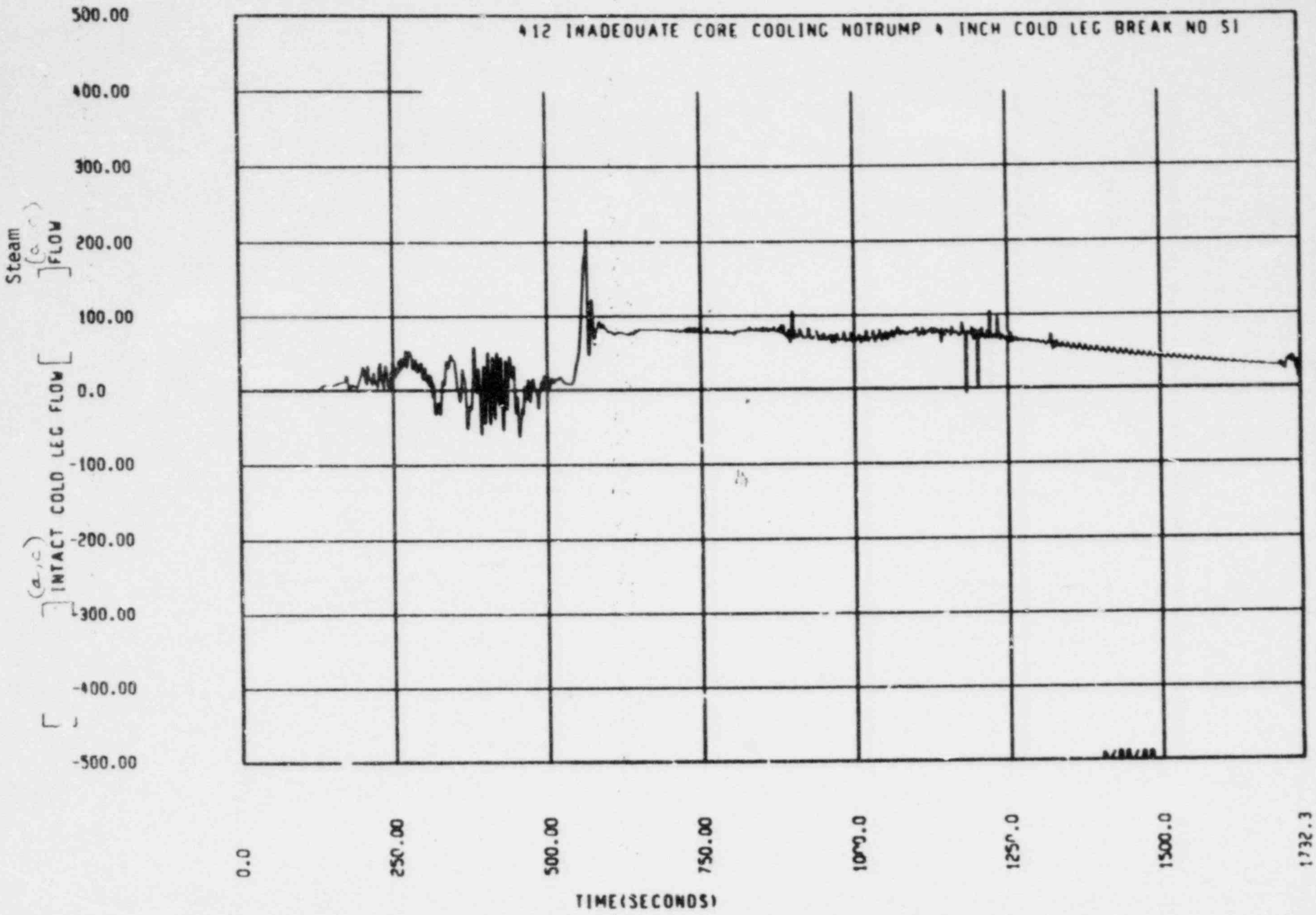

412 INADEQUATE CORE COOLING NOTRUMP 4 INCH COLD LEG BREAK NO SI
Steam
(a,c)
FLOW
INTACT COLD LEG FLOW
(a,c)
500.00
400.00
300.00
200.00
100.00
0.0
-100.00
-200.00
-300.00
-400.00
-500.00
0.0
250.00
500.00
750.00
1000.0
1250.0
1500.0
1732.3
TIME(SECONDS)

Figure 149

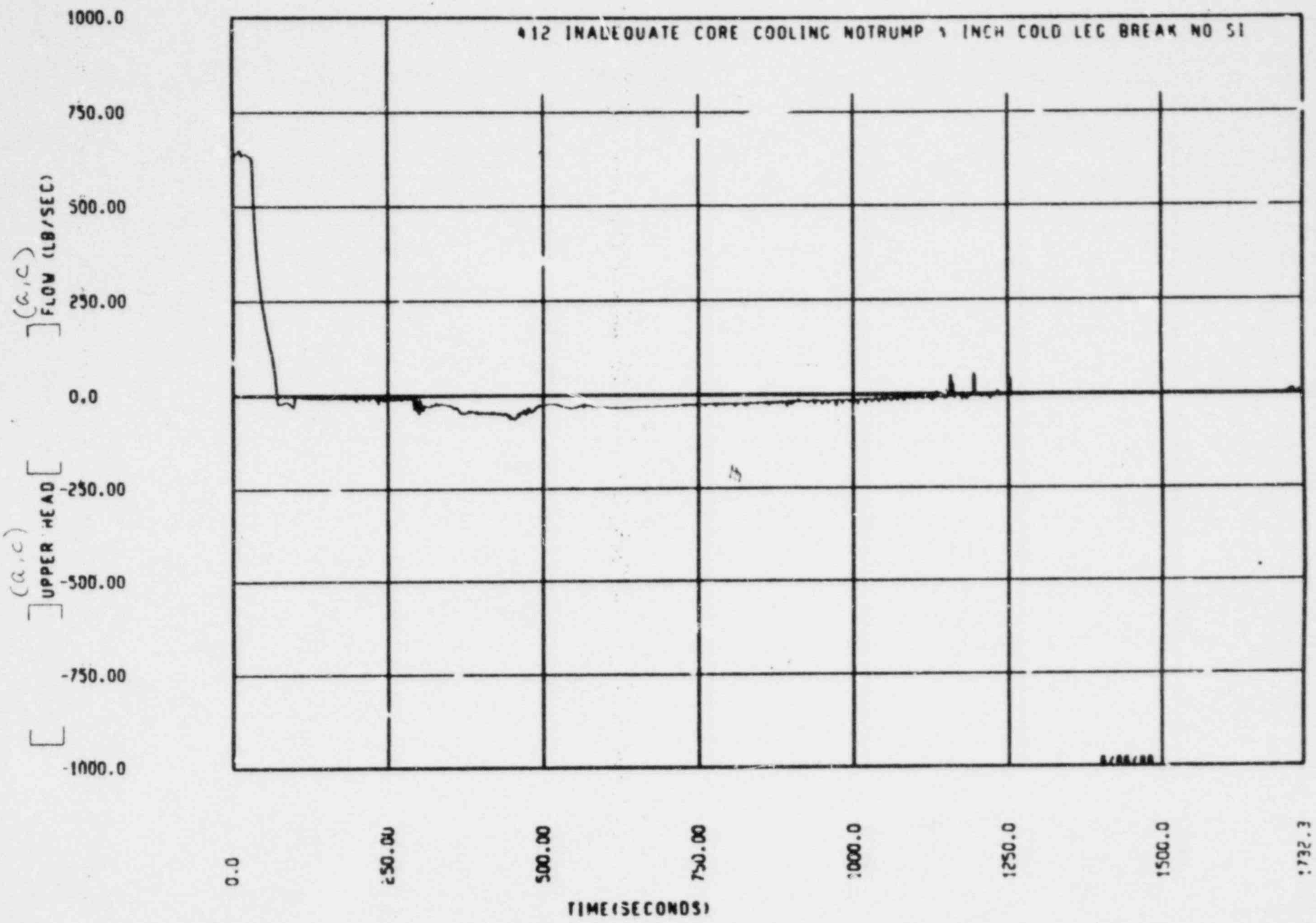

412 INADEQUATE CORE COOLING NOTRUMP ¾ INCH COLD LEG BREAK NO SI
(a,c)
FLOW (LB/SEC)
(a,c)
UPPER HEAD
1000.0
750.00
500.00
250.00
0.0
-250.00
-500.00
-750.00
-1000.0
0.0
250.00
500.00
750.00
1000.0
1250.0
1500.0
1732.3
TIME(SECONDS)

Figure 150

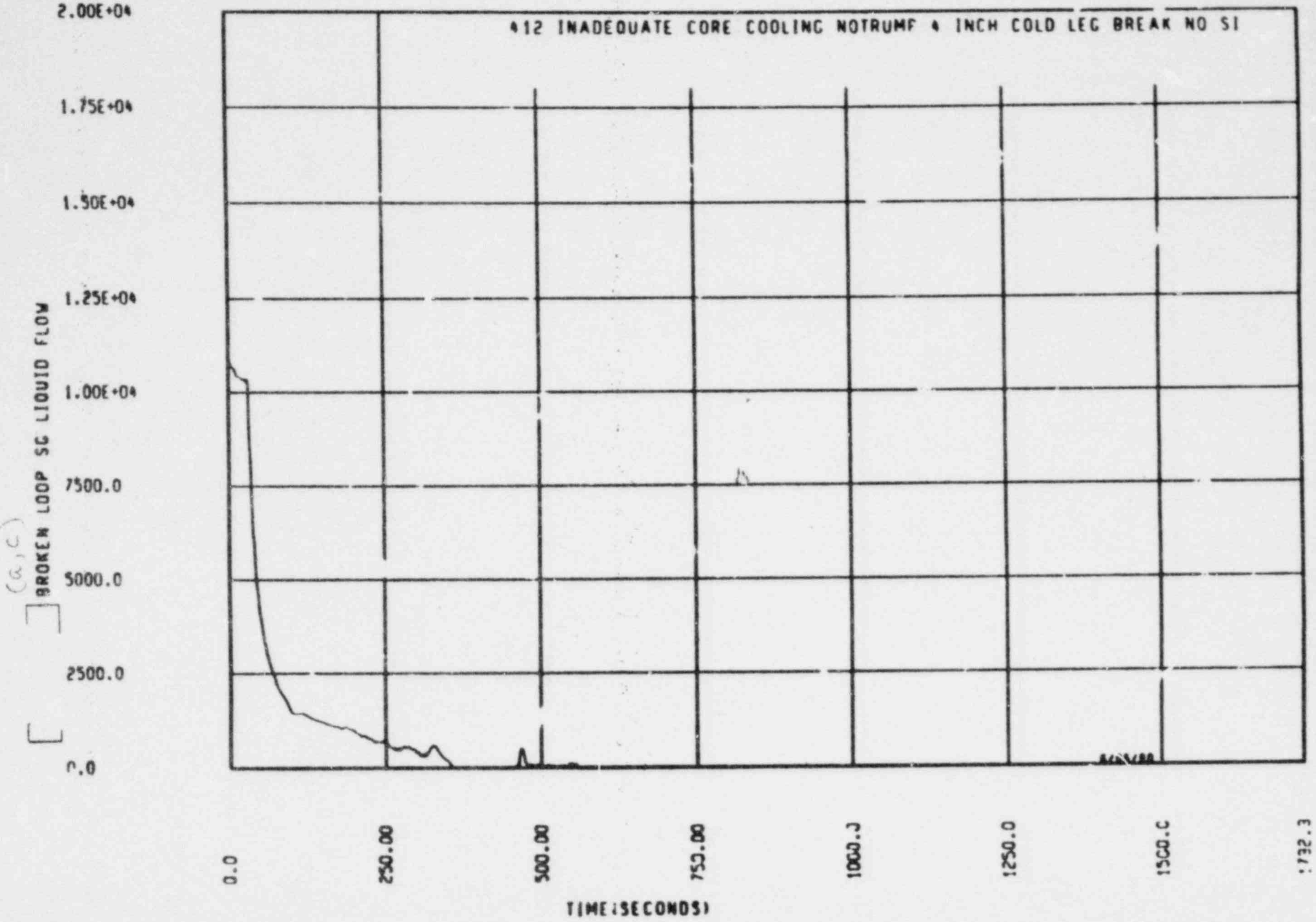

412 INADEQUATE CORE COOLING NOTRUMF 4 INCH COLD LEG BREAK NO SI
BROKEN LOOP SG LIQUID FLOW
(a,c)
2.00E+04
1.75E+04
1.50E+04
1.25E+04
1.00E+04
7500.0
5000.0
2500.0
0.0
0.0
250.00
500.00
750.00
1000.0
1250.0
1500.0
1732.3
TIME (SECONDS)

Figure 151

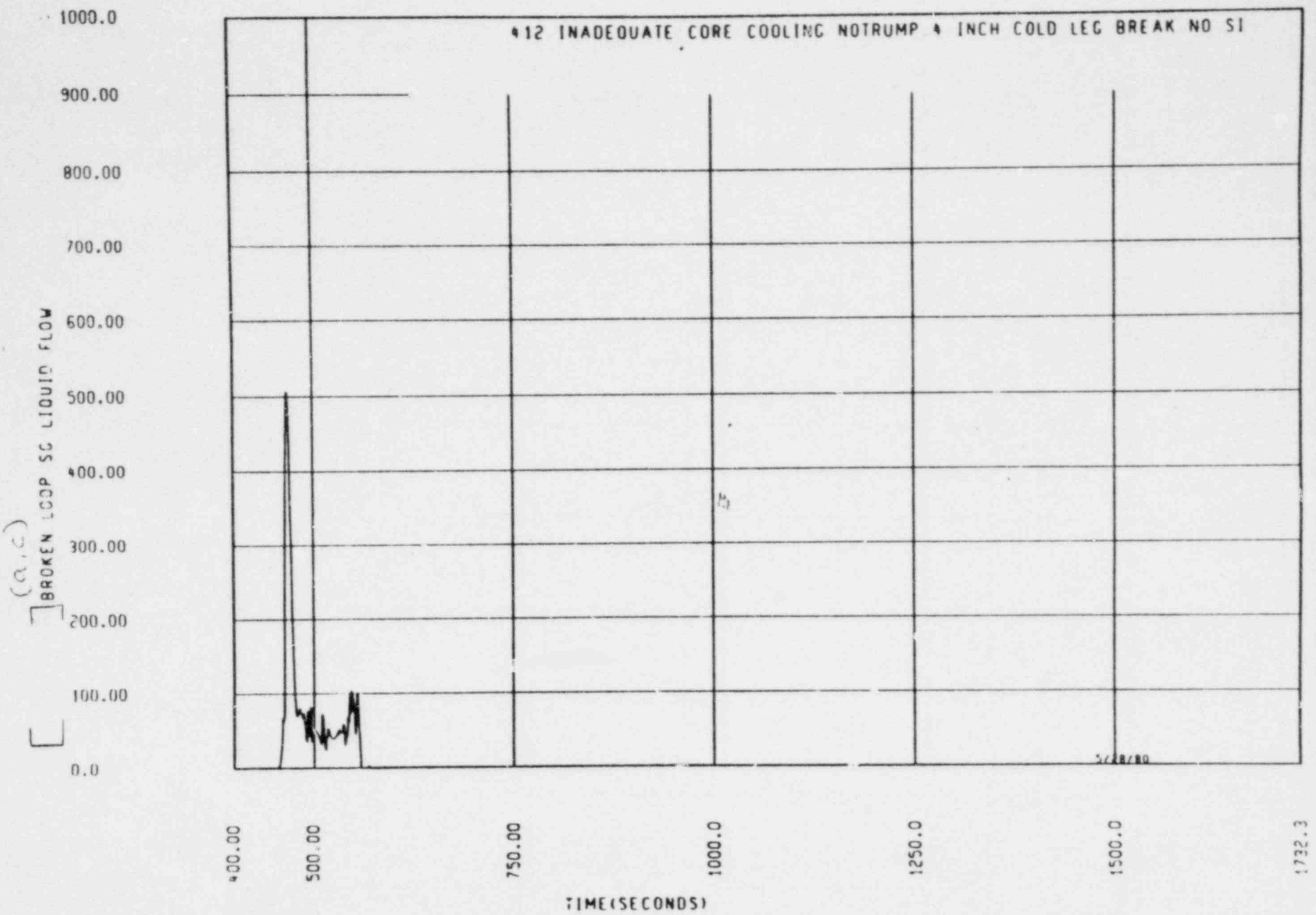

412 INADEQUATE CORE COOLING NOTRUMP 4 INCH COLD LEG BREAK NO SI
(a,c)
BROKEN LOOP SC LIQUID FLOW
1000.0
900.00
800.00
700.00
600.00
500.00
400.00
300.00
200.00
100.00
0.0
400.00
500.00
750.00
1000.0
1250.0
1500.0
1732.3
TIME(SECONDS)
5/28/80

Figure 151a

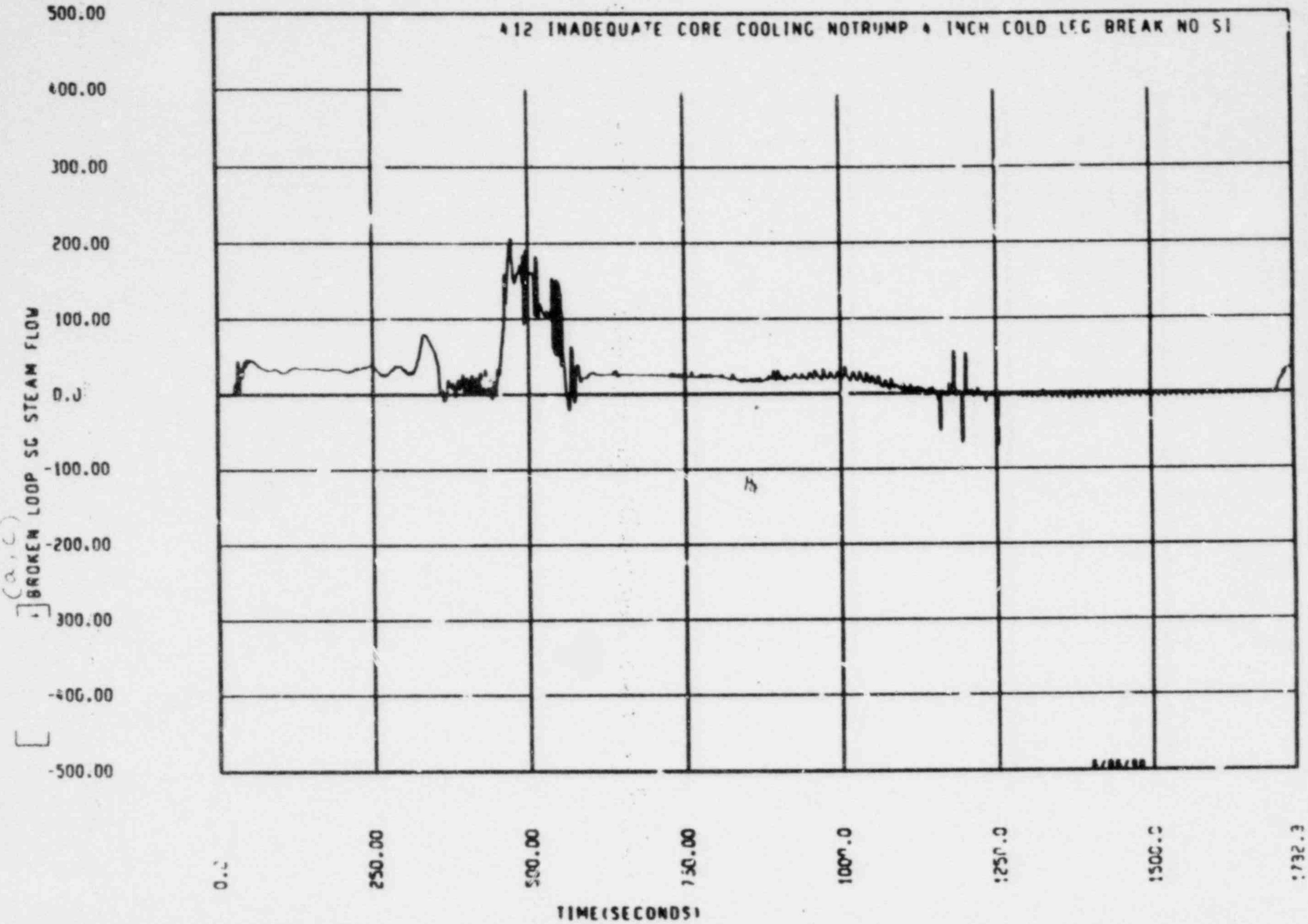

412 INADEQUATE CORE COOLING NOTRUMP 4 INCH COLD LEG BREAK NO SI
BROKEN LOOP SG STEAM FLOW
(a,c)
500.00
400.00
300.00
200.00
100.00
0.0
-100.00
-200.00
-300.00
-400.00
-500.00
0.0
250.00
500.00
750.00
1000.0
1250.0
1500.0
1732.3
TIME(SECONDS)

Figure 152

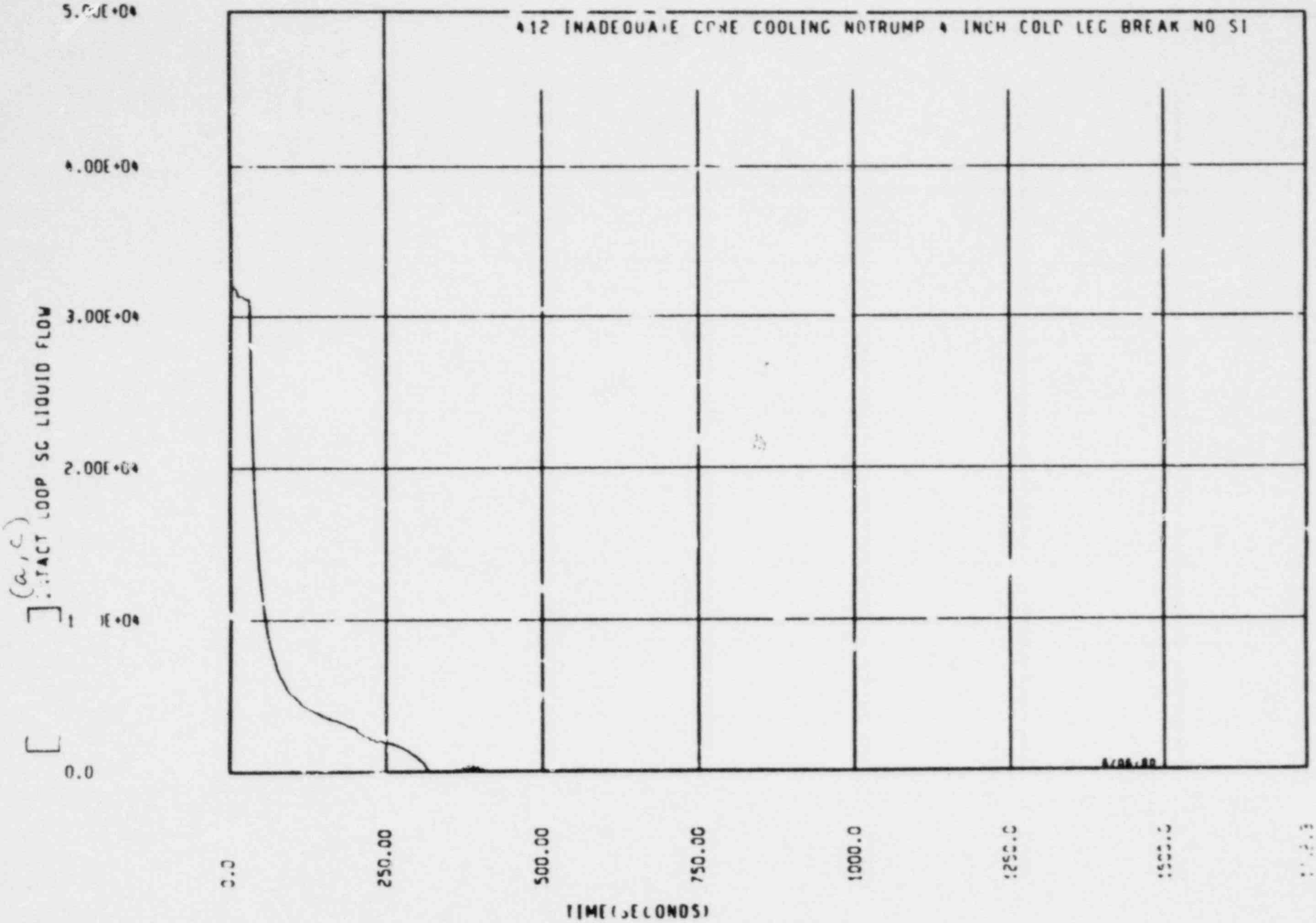

412 INADEQUATE CORE COOLING NOTRUMP 4 INCH COLD LEG BREAK NO SI
5.00E+04
4.00E+04
3.00E+04
2.00E+04
1.00E+04
0.0
INTACT LOOP SG LIQUID FLOW
(a,c)
0.0
250.00
500.00
750.00
1000.0
1250.0
1500.0
1750.0
TIME(SECONDS)

Figure 153

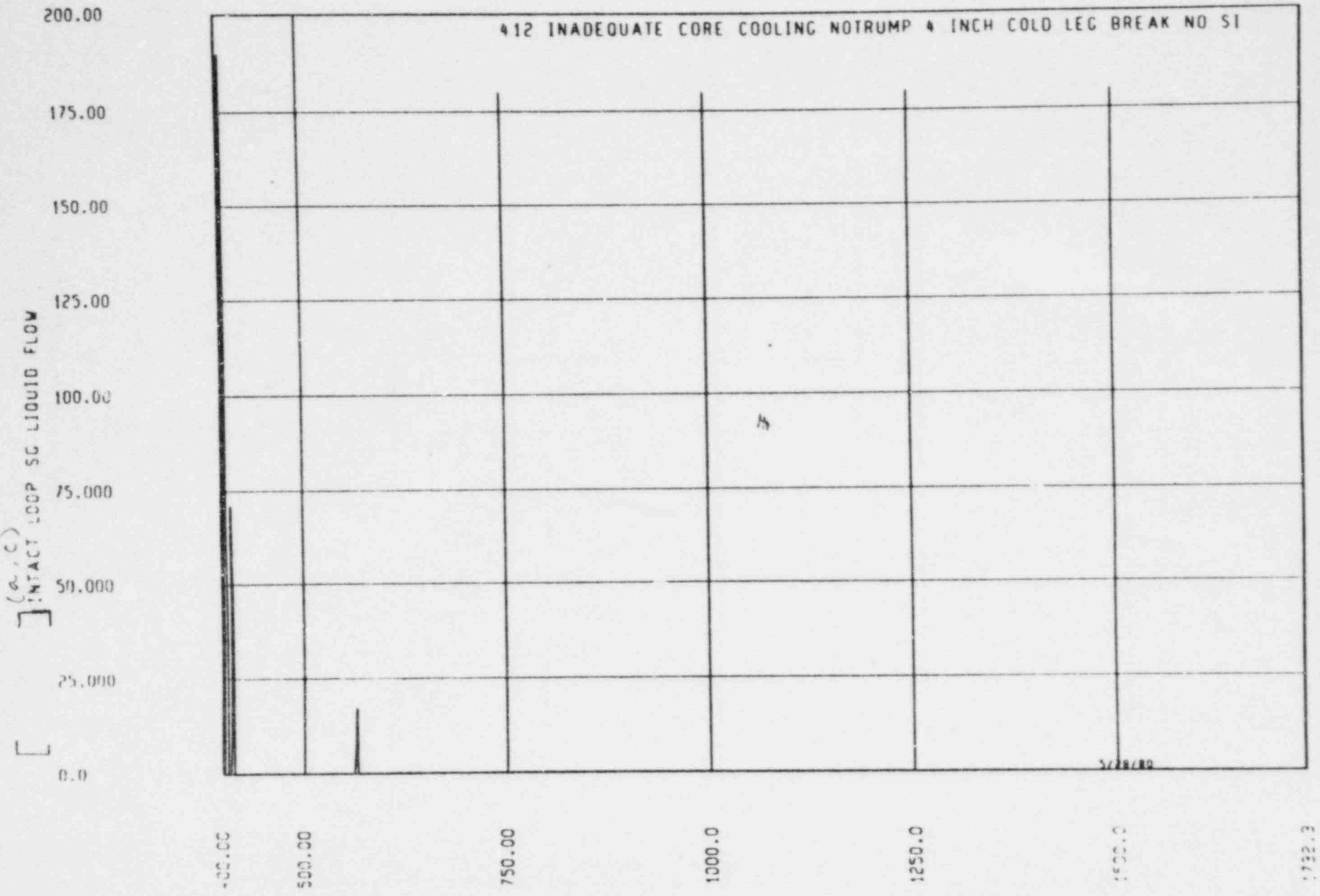

412 INADEQUATE CORE COOLING NOTRUMP 4 INCH COLD LEG BREAK NO SI
[ INTACT LOOP SG LIQUID FLOW ](a,c)
200.00
175.00
150.00
125.00
100.00
75.000
50.000
25.000
0.0
400.00
500.00
750.00
1000.0
1250.0
1500.0
1733.3
5/28/80
TIME(SECONDS)

Figure 153a

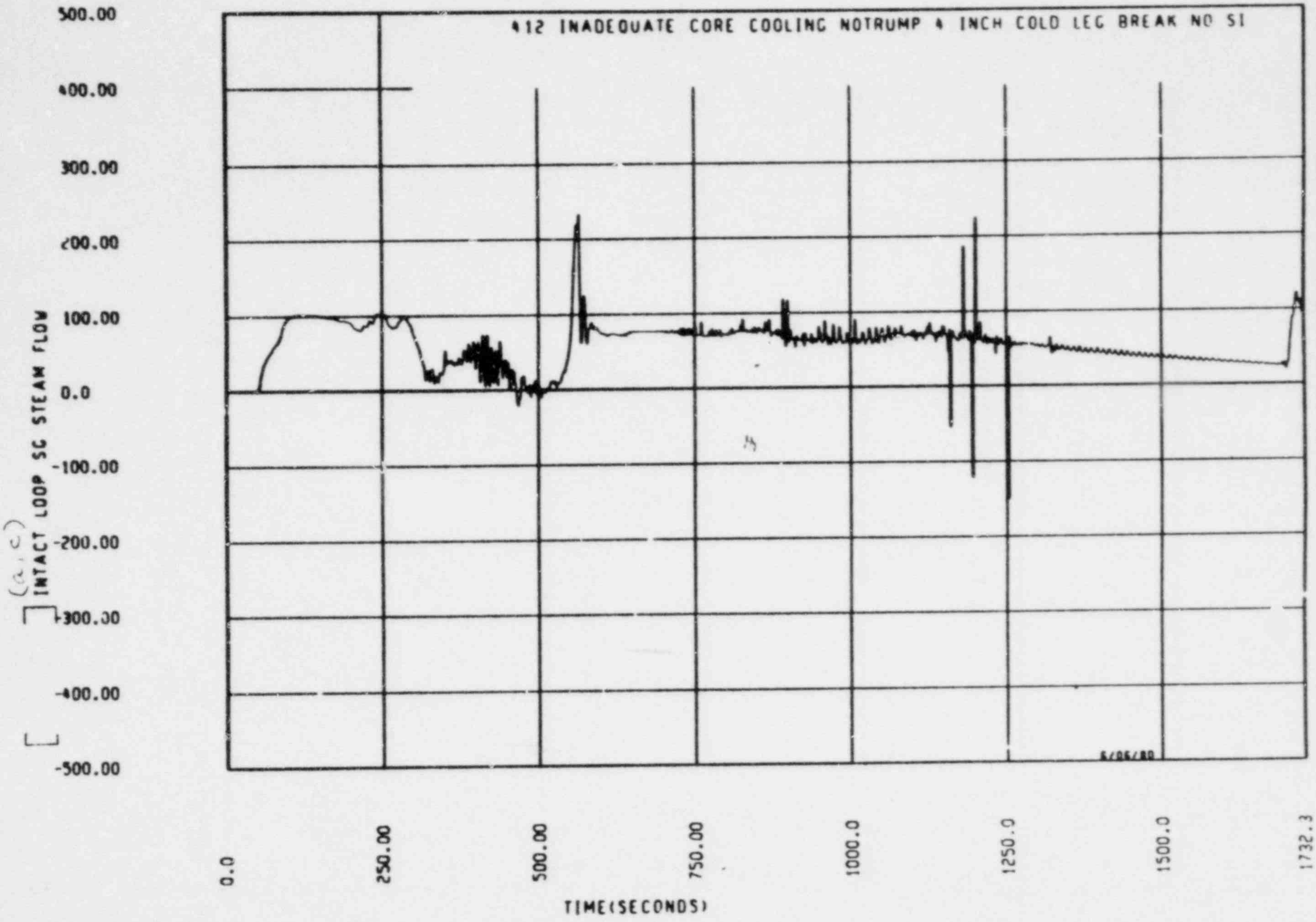

412 INADEQUATE CORE COOLING NOTRUMP 4 INCH COLD LEG BREAK NO SI
INTACT LOOP SG STEAM FLOW [ ]
(a,c)
500.00
400.00
300.00
200.00
100.00
0.0
-100.00
-200.00
-300.00
-400.00
-500.00
0.0
250.00
500.00
750.00
1000.0
1250.0
1500.0
1732.3
TIME(SECONDS)
6/06/80

Figure 154

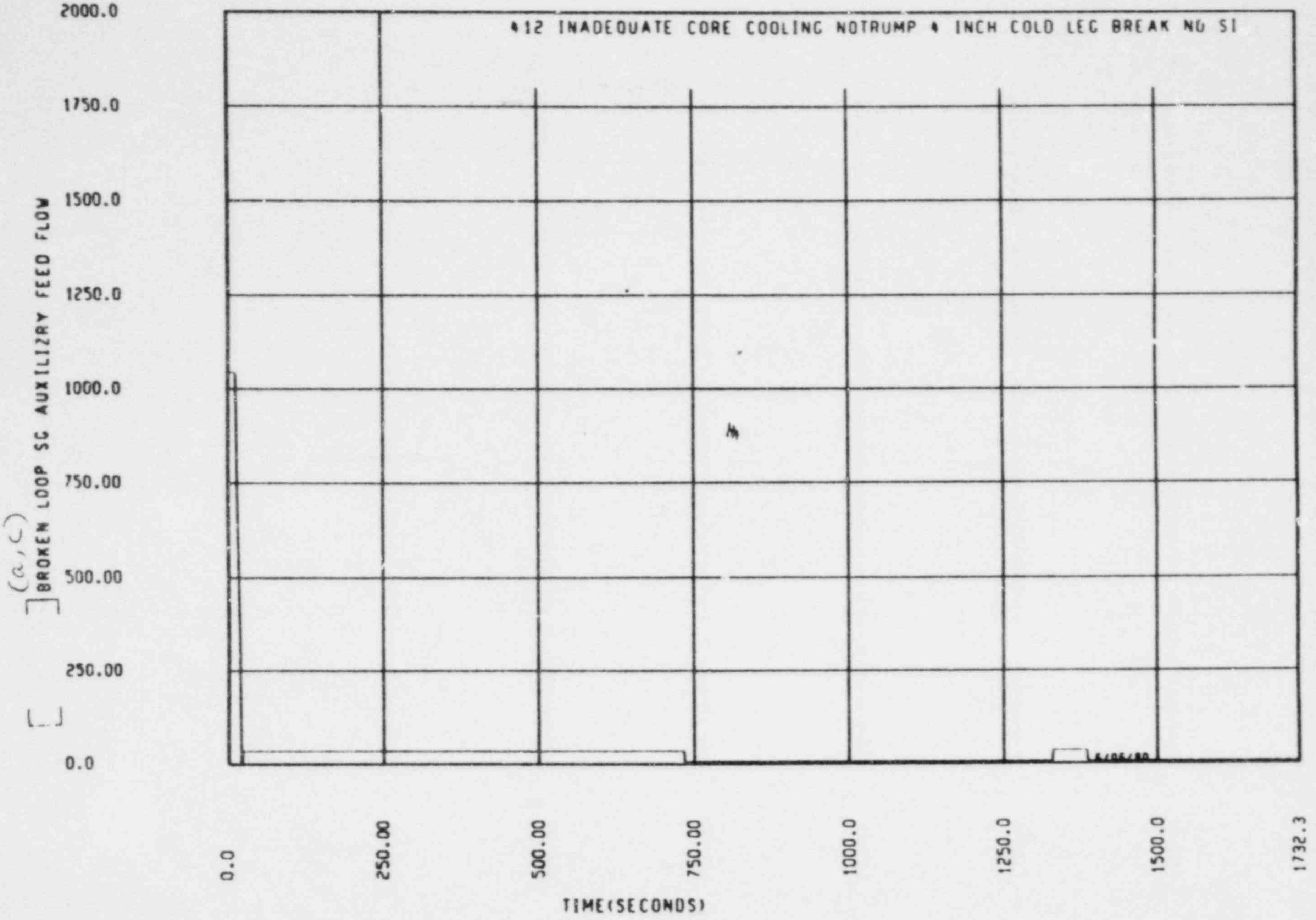

412 INADEQUATE CORE COOLING NOTRUMP 4 INCH COLD LEG BREAK NO SI
BROKEN LOOP SG AUXILIZRY FEED FLOW
(a,c)
2000.0
1750.0
1500.0
1250.0
1000.0
750.00
500.00
250.00
0.0
0.0
250.00
500.00
750.00
1000.0
1250.0
1500.0
1732.3
TIME(SECONDS)

Figure 155

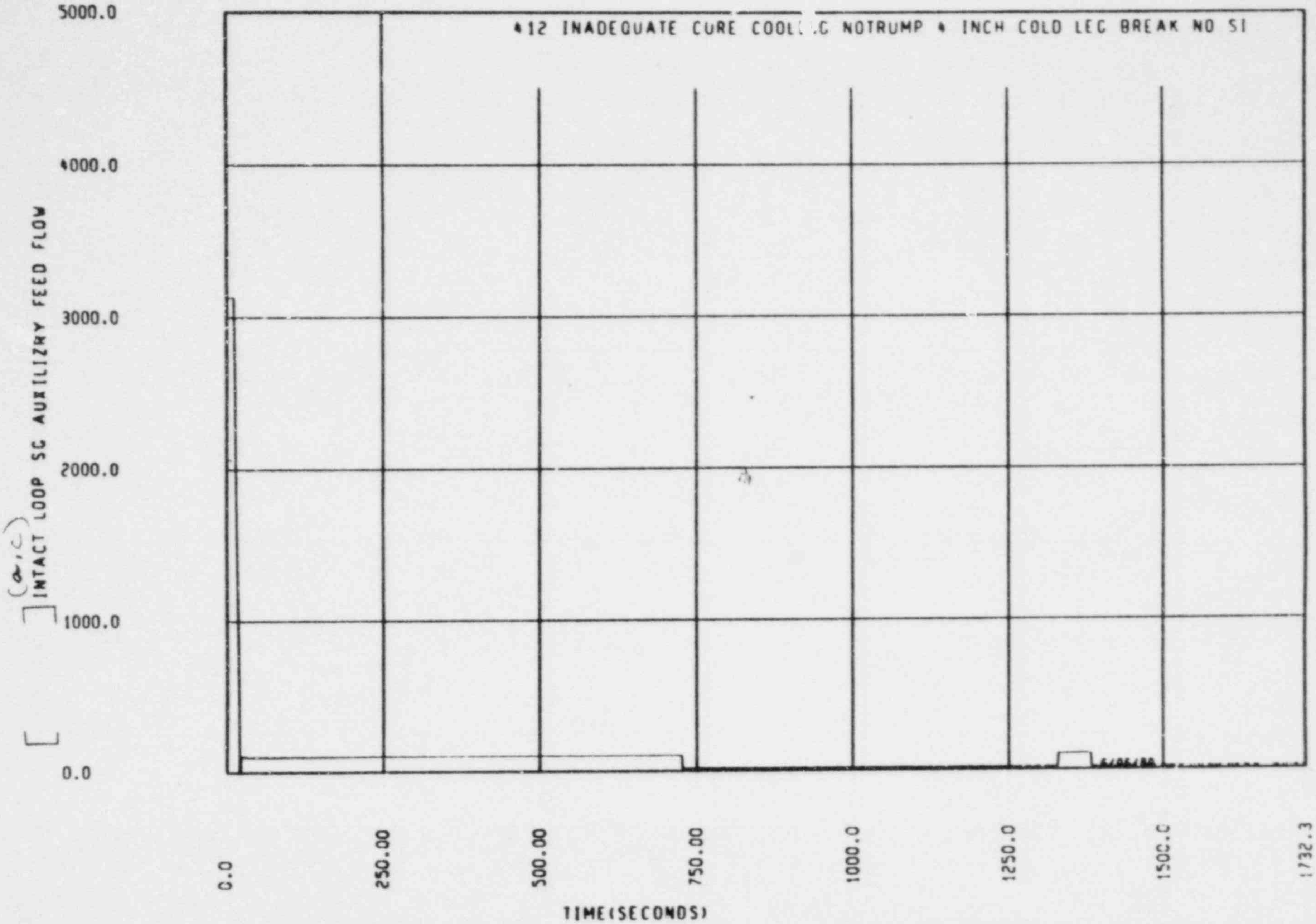

412 INADEQUATE CORE COOLING NOTRUMP 4 INCH COLD LEG BREAK NO SI
(a,c)
INTACT LOOP SG AUXILIZRY FEED FLOW
5000.0
4000.0
3000.0
2000.0
1000.0
0.0
0.0
250.00
500.00
750.00
1000.0
1250.0
1500.0
1732.3
TIME(SECONDS)

Figure 156

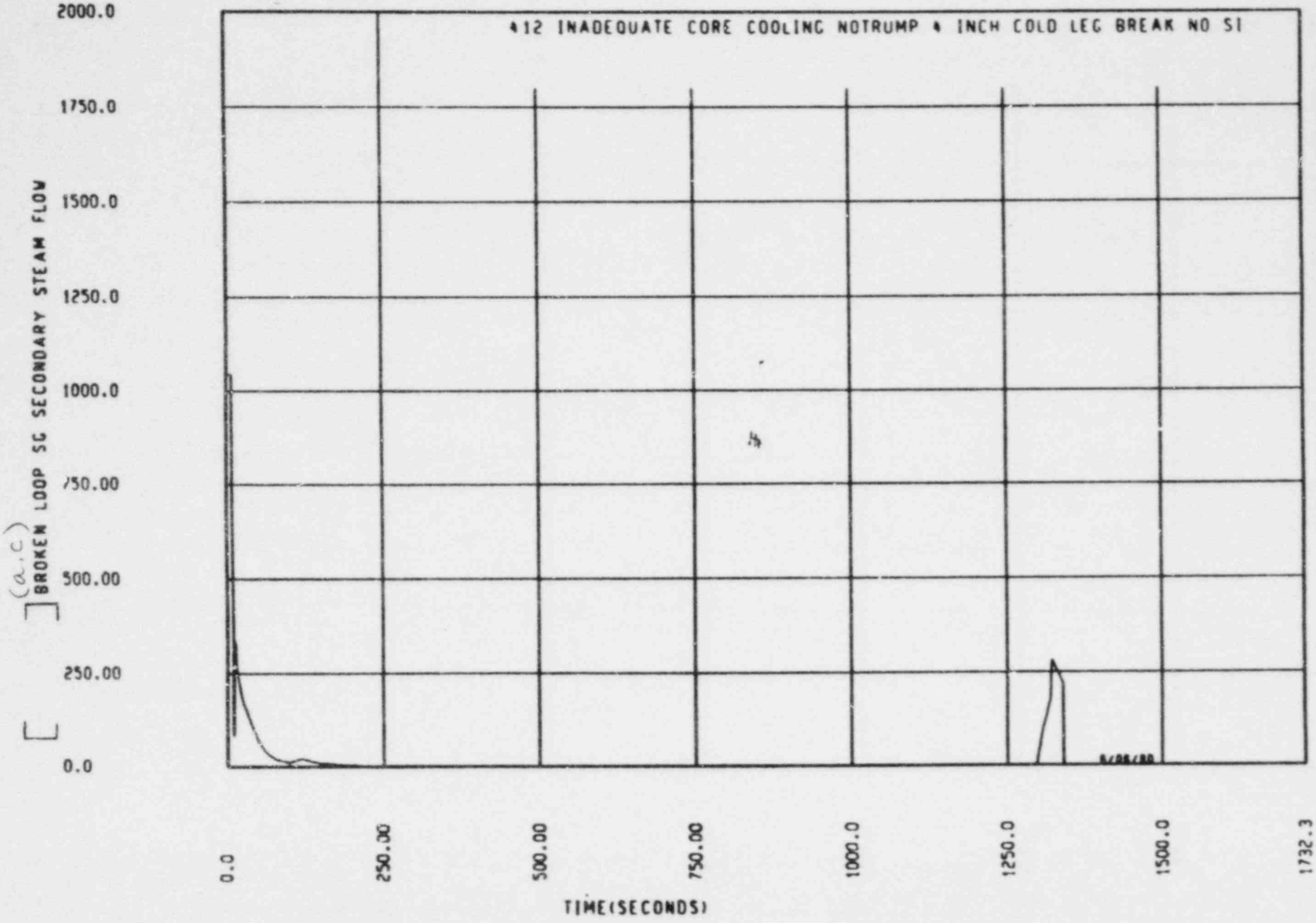

412 INADEQUATE CORE COOLING NOTRUMP 4 INCH COLD LEG BREAK NO SI
(a.c)
BROKEN LOOP SG SECONDARY STEAM FLOW
2000.0
1750.0
1500.0
1250.0
1000.0
750.00
500.00
250.00
0.0
0.0
250.00
500.00
750.00
1000.0
1250.0
1500.0
1732.3
TIME(SECONDS)

Figure 157

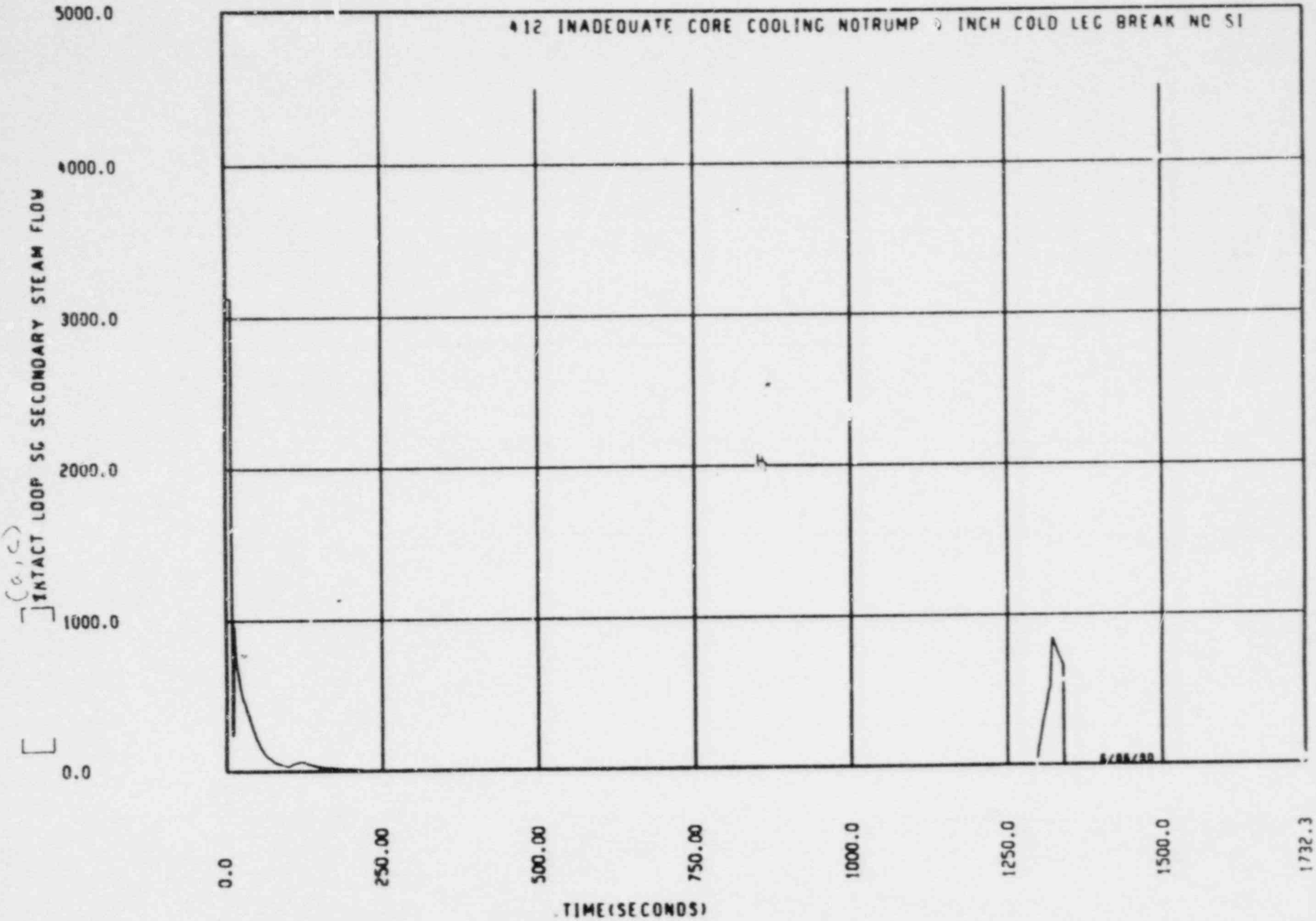

412 INADEQUATE CORE COOLING NOTRUMP ◌ INCH COLD LEG BREAK NC SI
(a,c)
INTACT LOOP SG SECONDARY STEAM FLOW
5000.0
4000.0
3000.0
2000.0
1000.0
0.0
0.0
250.00
500.00
750.00
1000.0
1250.0
1500.0
1732.3
TIME(SECONDS)

Figure 158

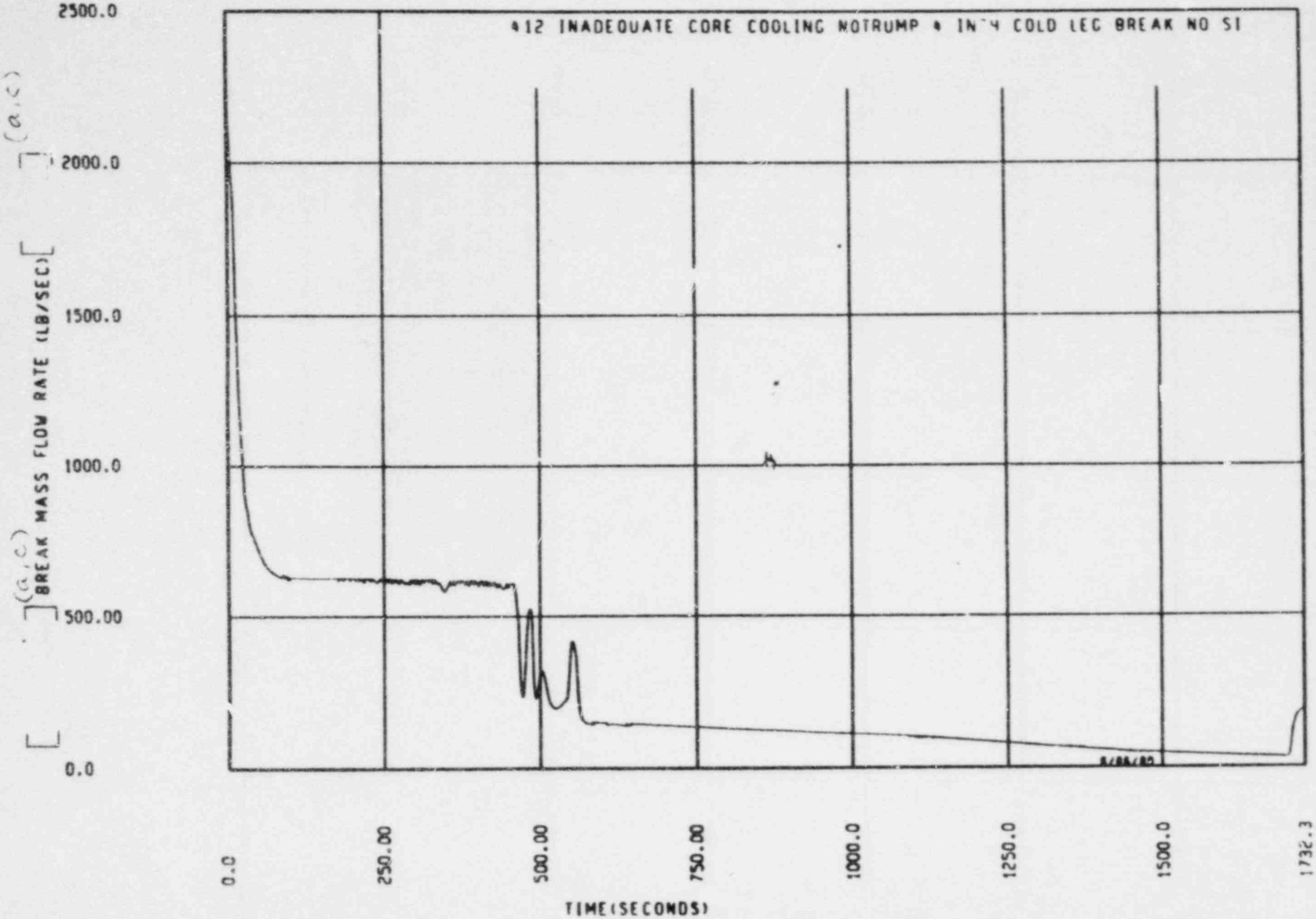
412 INADEQUATE CORE COOLING NOTRUMP 4 IN"4 COLD LEG BREAK NO SI
BREAK MASS FLOW RATE (LB/SEC)
(a,c)
(a,c)
2500.0
2000.0
1500.0
1000.0
500.00
0.0
0.0
250.00
500.00
750.00
1000.0
1250.0
1500.0
1732.3
TIME(SECONDS)

Figure 159

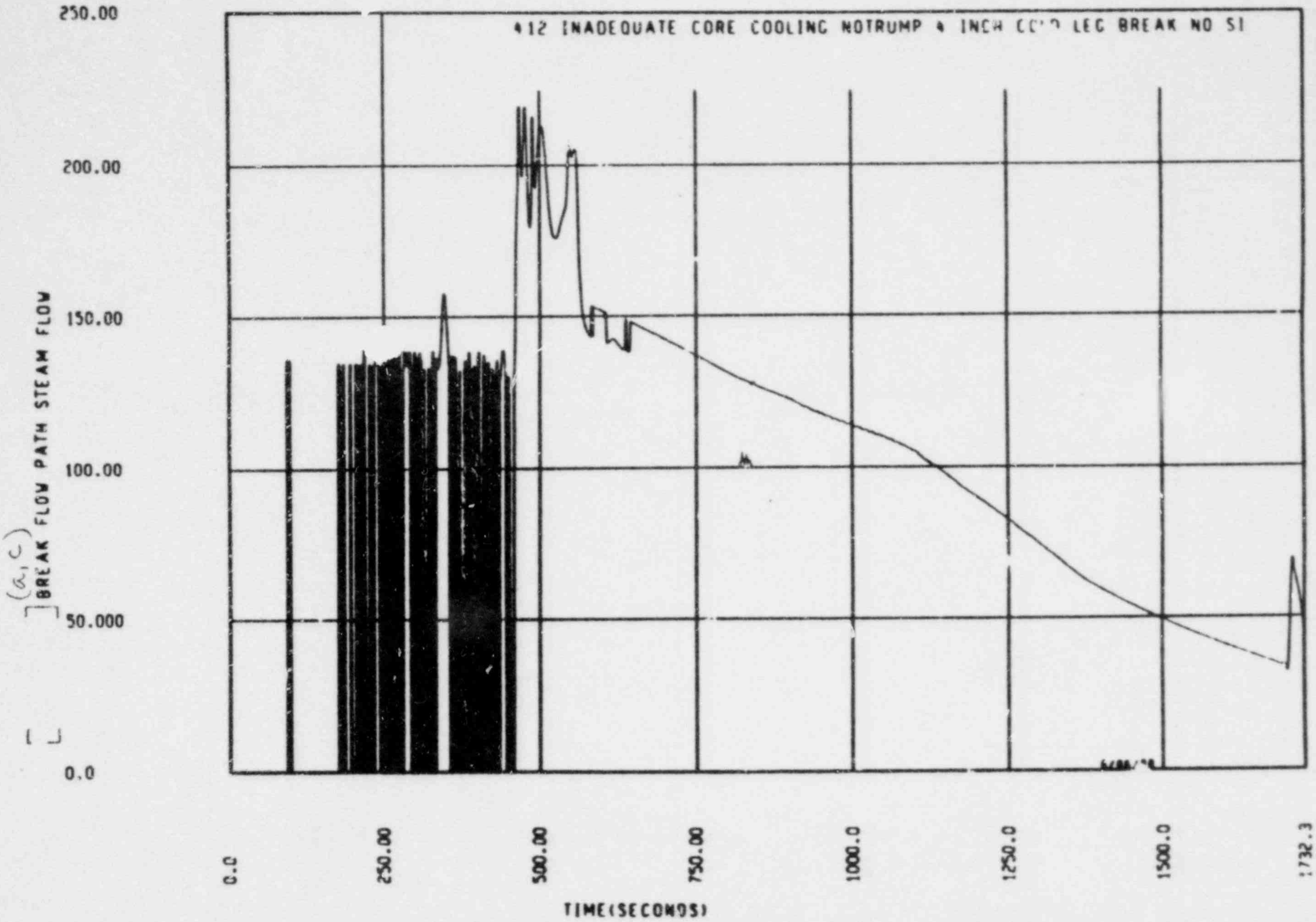

412 INADEQUATE CORE COOLING NOTRUMP 4 INCH CC'D LEG BREAK NO SI
BREAK FLOW PATH STEAM FLOW
(a,c)
250.00
200.00
150.00
100.00
50.000
0.0
0.0
250.00
500.00
750.00
1000.0
1250.0
1500.0
1732.3
TIME(SECONDS)

Figure 160

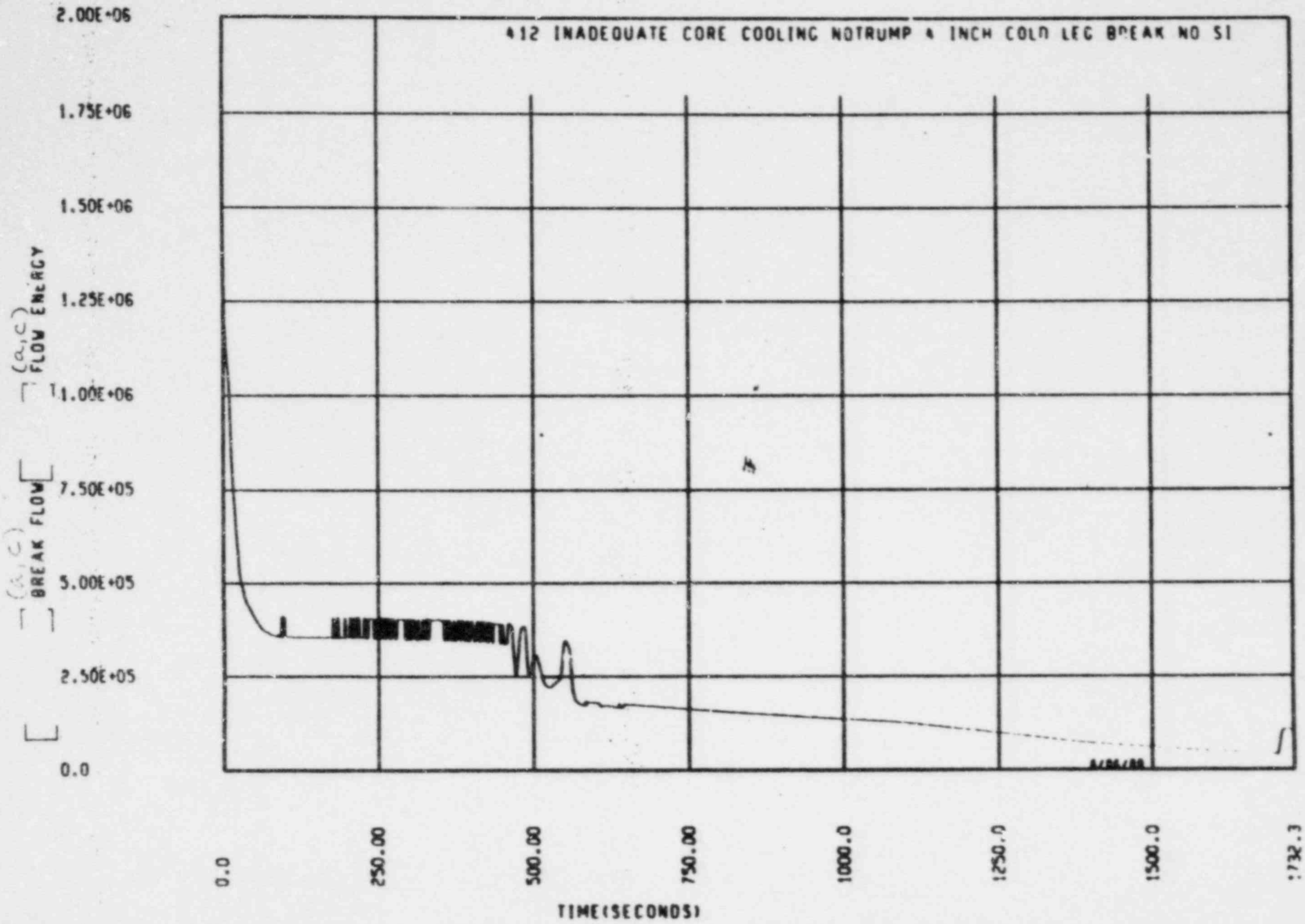

412 INADEQUATE CORE COOLING NOTRUMP 4 INCH COLD LEG BREAK NO SI
(a,c) FLOW ENERGY
(a,c) BREAK FLOW
2.00E+06
1.75E+06
1.50E+06
1.25E+06
1.00E+06
7.50E+05
5.00E+05
2.50E+05
0.0
0.0
250.00
500.00
750.00
1000.0
1250.0
1500.0
1732.3
TIME(SECONDS)

Figure 161

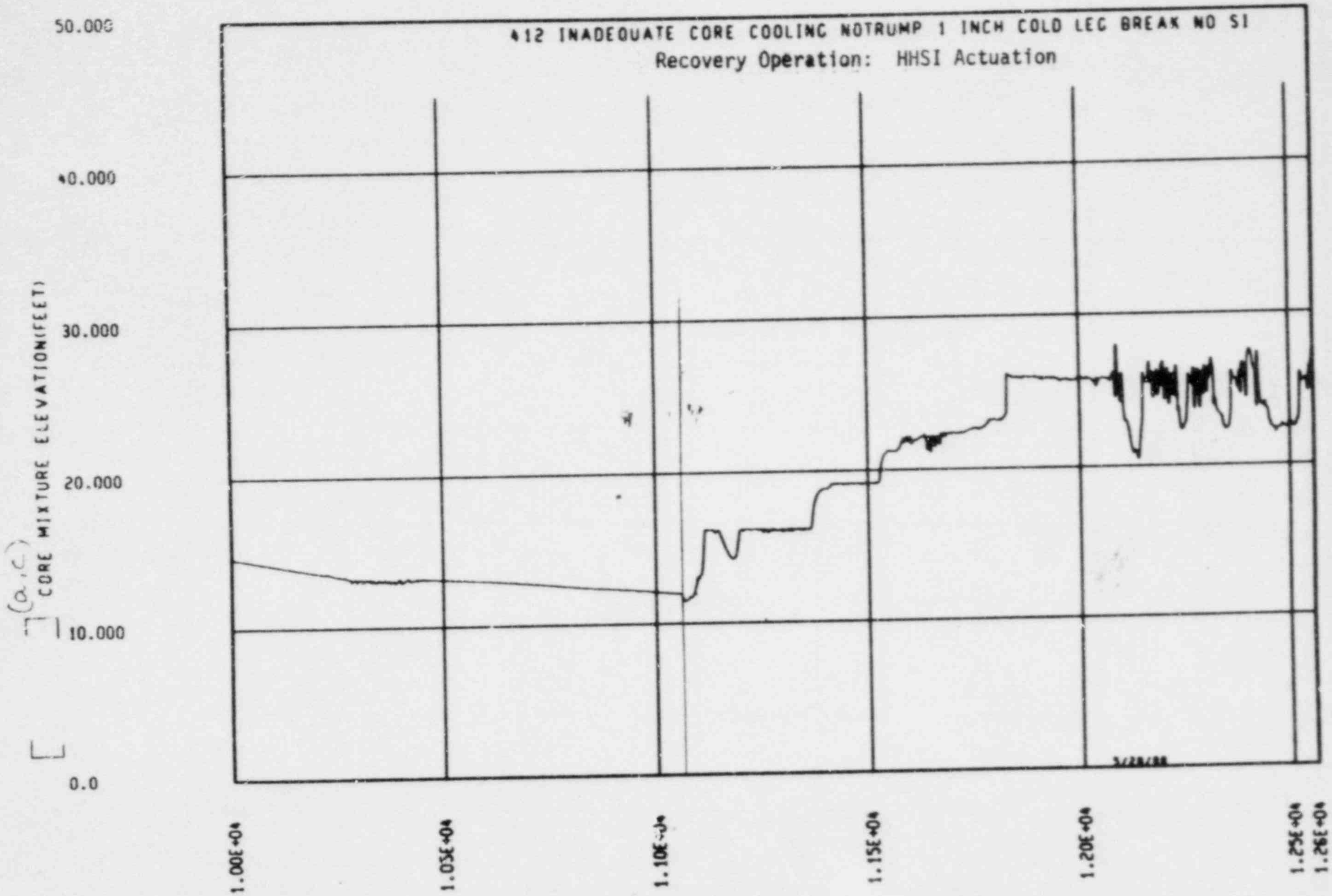

412 INADEQUATE CORE COOLING NOTRUMP 1 INCH COLD LEG BREAK NO SI
Recovery Operation: HHSI Actuation
CORE MIXTURE ELEVATION(FEET)
(a,c)
50.000
40.000
30.000
20.000
10.000
0.0
1.00E+04
1.05E+04
1.10E+04
1.15E+04
1.20E+04
1.25E+04
1.26E+04
TIME(SECONDS)

Figure 162

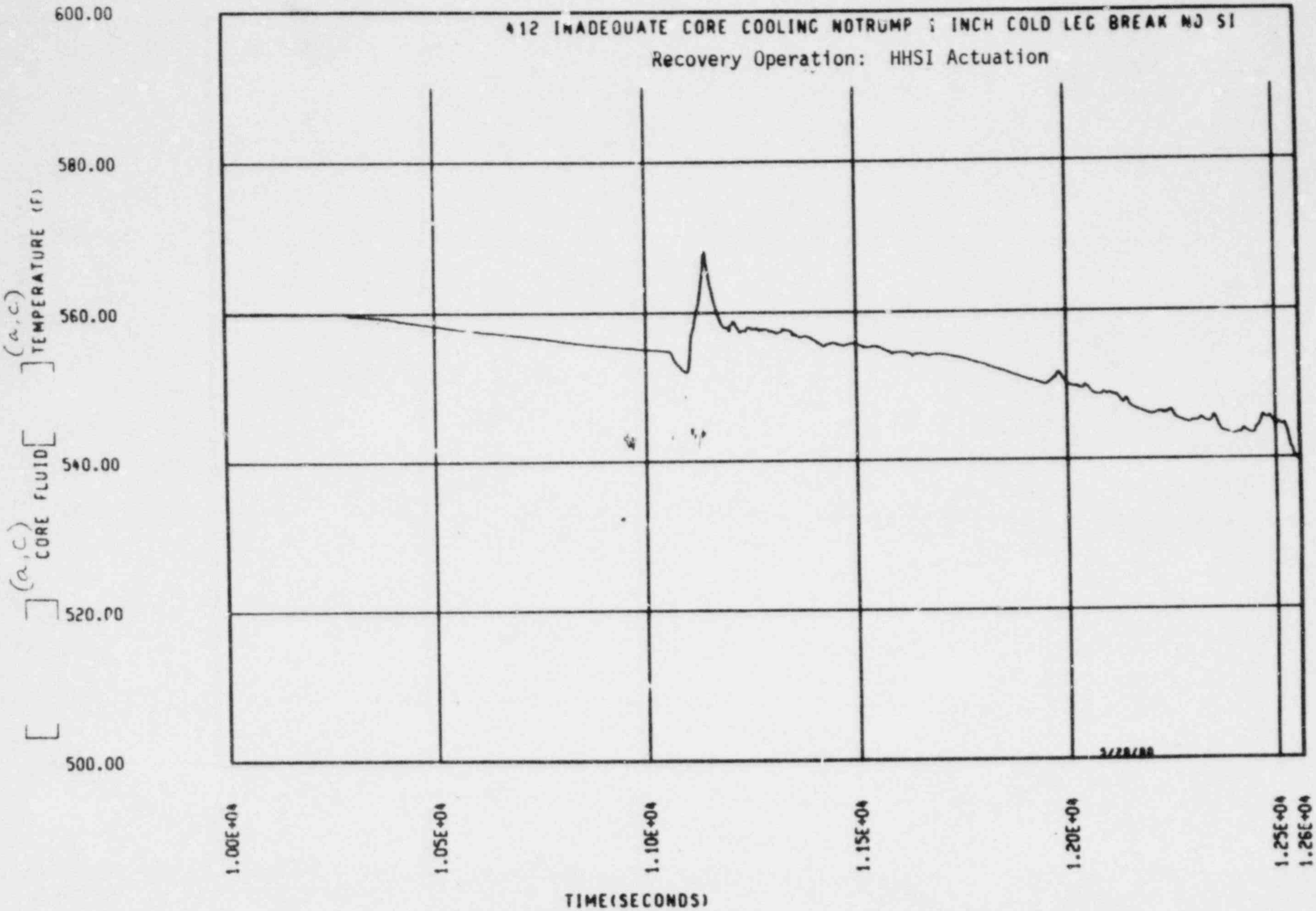

412 INADEQUATE CORE COOLING NOTRUMP : INCH COLD LEG BREAK NO SI
Recovery Operation: HHSI Actuation
(a,c)
CORE FLUID
(a,c)
TEMPERATURE (F)
600.00
580.00
560.00
540.00
520.00
500.00
1.00E+04
1.05E+04
1.10E+04
1.15E+04
1.20E+04
1.25E+04
1.26E+04
TIME(SECONDS)

Figure 163

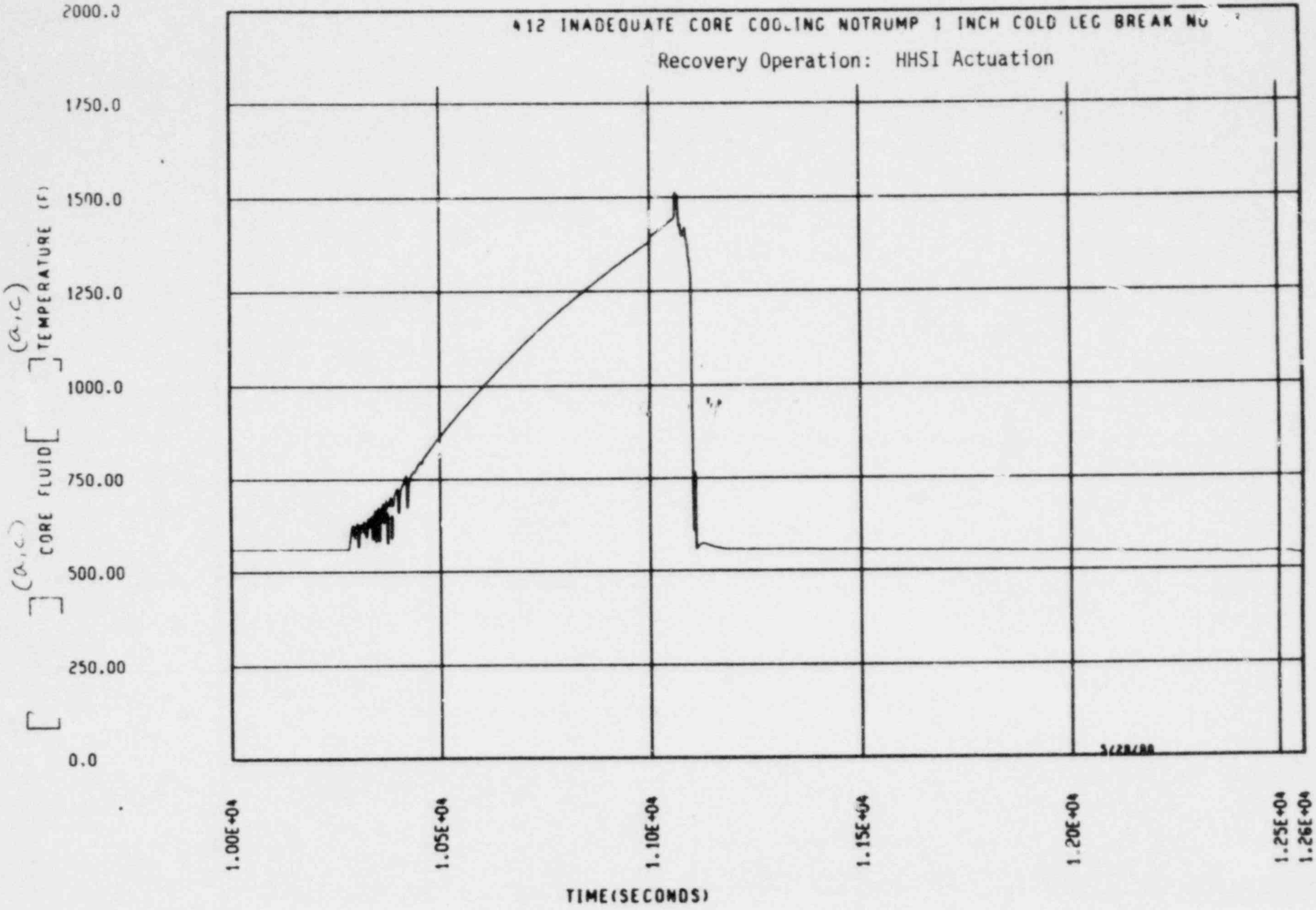

412 INADEQUATE CORE COOLING NOTRUMP 1 INCH COLD LEG BREAK NO
Recovery Operation: HHSI Actuation
(a,c)
(a,c)
CORE FLUID TEMPERATURE (F)
2000.0
1750.0
1500.0
1250.0
1000.0
750.00
500.00
250.00
0.0
1.00E+04
1.05E+04
1.10E+04
1.15E+04
1.20E+04
1.25E+04
1.26E+04
TIME(SECONDS)

Figure 164

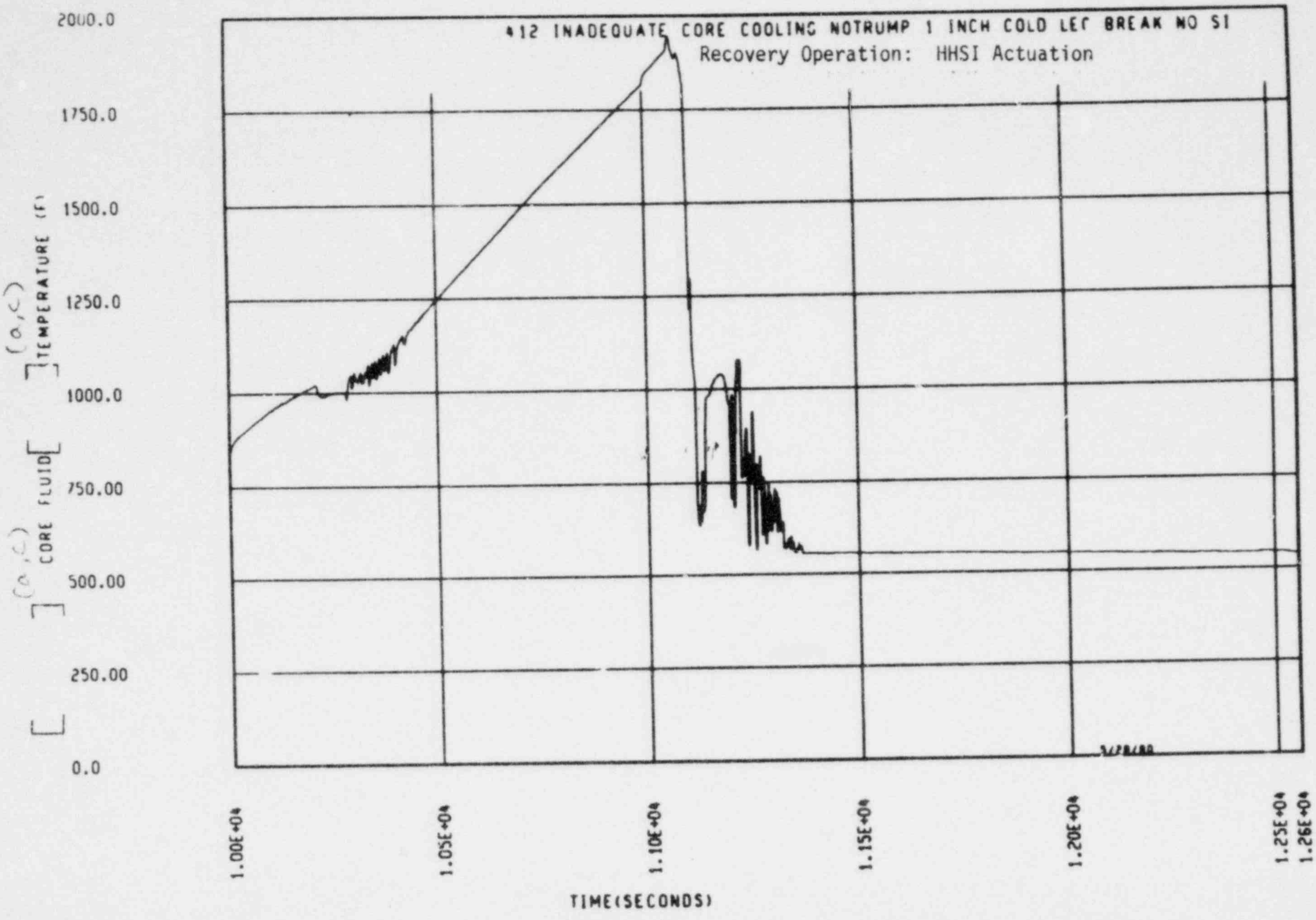

412 INADEQUATE CORE COOLING NOTRUMP 1 INCH COLD LEG BREAK NO SI
Recovery Operation: HHSI Actuation
2000.0
1750.0
1500.0
1250.0
1000.0
750.00
500.00
250.00
0.0
CORE FLUID TEMPERATURE (F)
(a,c)
(a,c)
1.00E+04
1.05E+04
1.10E+04
1.15E+04
1.20E+04
1.25E+04
1.26E+04
TIME(SECONDS)

Figure 165

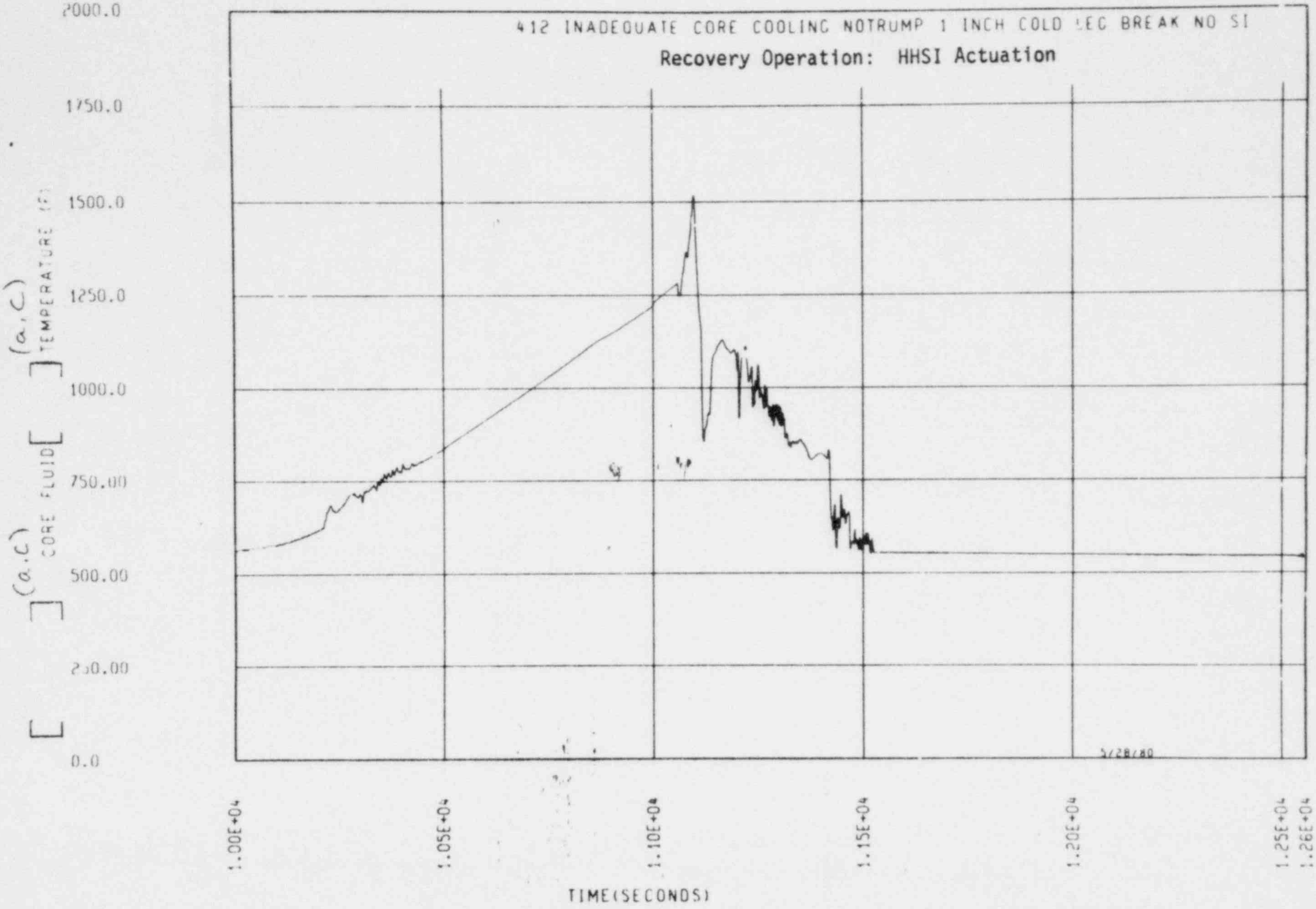

412 INADEQUATE CORE COOLING NOTRUMP 1 INCH COLD LEG BREAK NO SI
Recovery Operation: HHSI Actuation
2000.0
1750.0
1500.0
1250.0
1000.0
750.00
500.00
250.00
0.0
[ ] (a,c) CORE FLUID [ ] TEMPERATURE (F) [ ] (a,c)
1.00E+04
1.05E+04
1.10E+04
1.15E+04
1.20E+04
1.25E+04
1.26E+04
TIME(SECONDS)
5/28/80

Figure 166

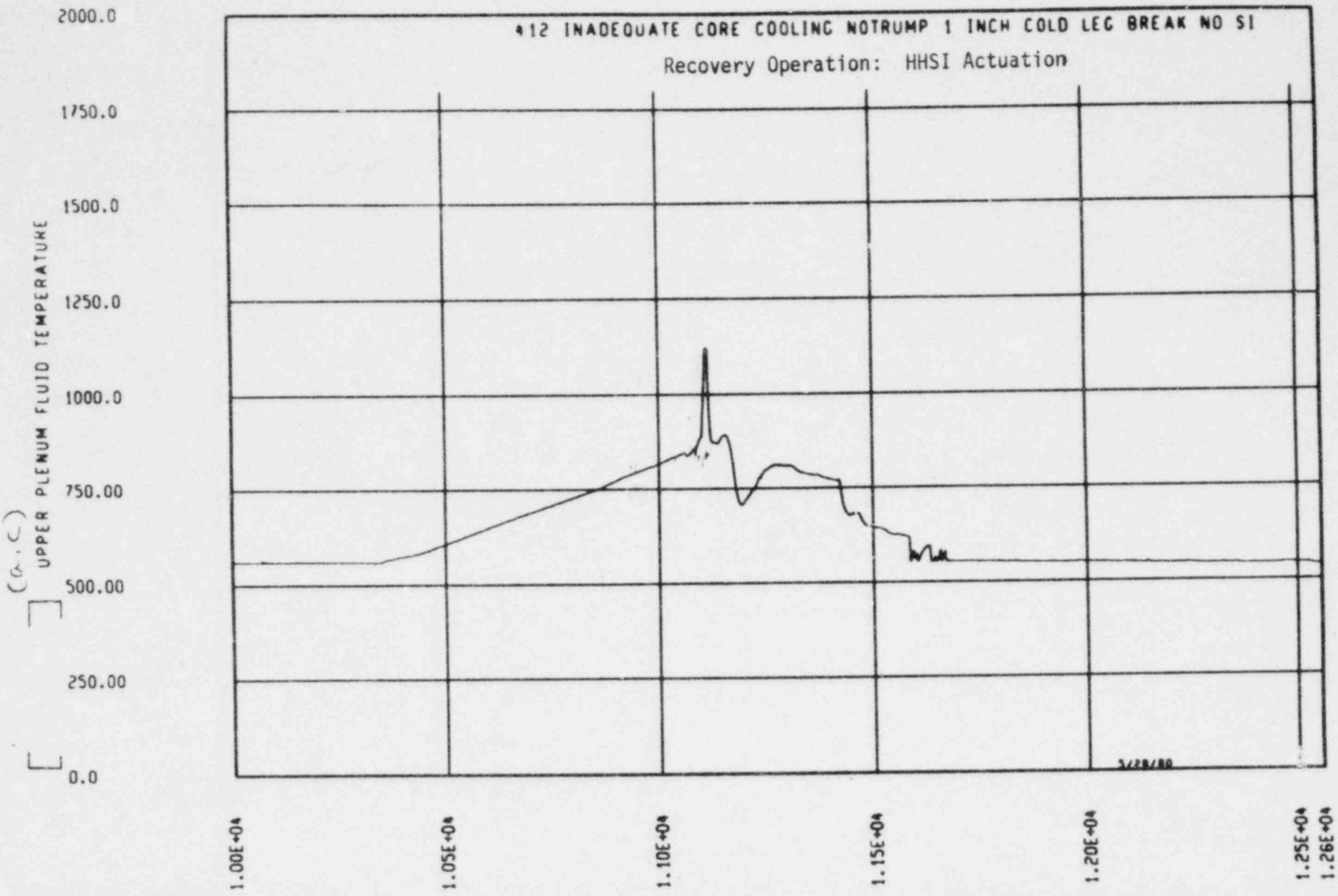
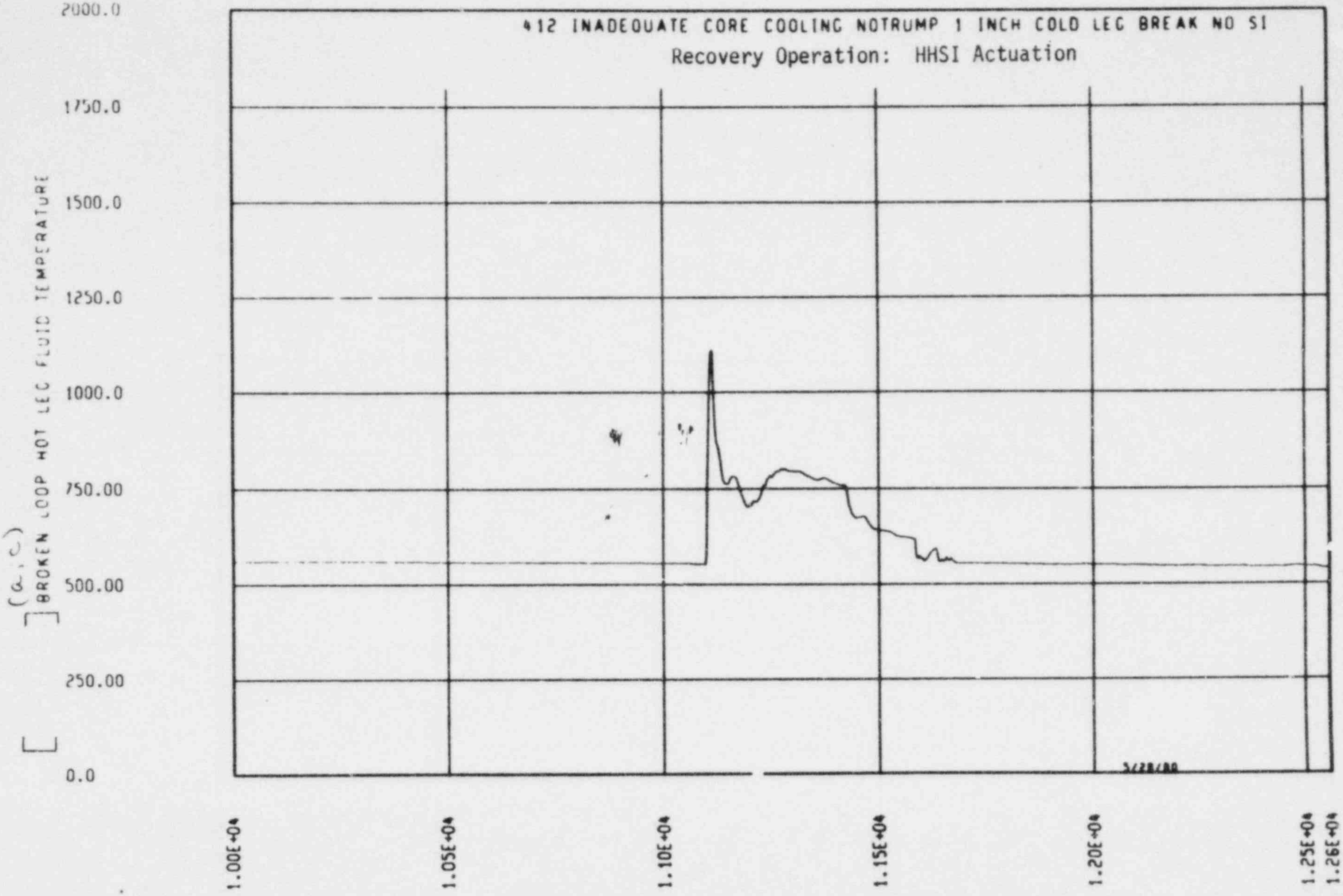

412 INADEQUATE CORE COOLING NOTRUMP 1 INCH COLD LEG BREAK NO SI
Recovery Operation: HHSI Actuation
UPPER PLENUM FLUID TEMPERATURE
(a,c)
2000.0
1750.0
1500.0
1250.0
1000.0
750.00
500.00
250.00
0.0
1.00E+04
1.05E+04
1.10E+04
1.15E+04
1.20E+04
1.25E+04
1.26E+04
TIME(SECONDS)
5/28/80

Figure 167



TIME(SECONDS)

Figure 168

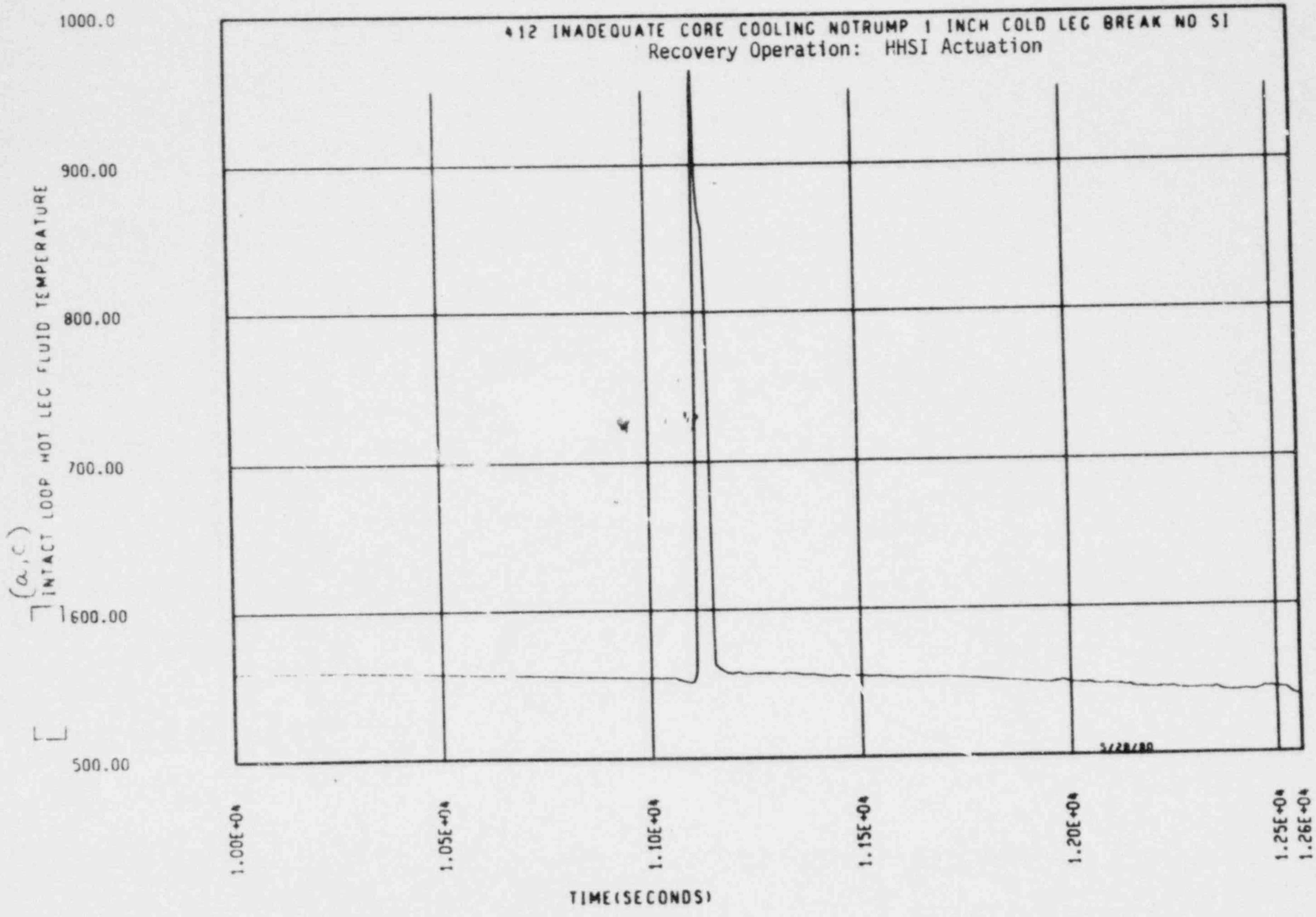

412 INADEQUATE CORE COOLING NOTRUMP 1 INCH COLD LEG BREAK NO SI
Recovery Operation: HHSI Actuation
1000.0
900.00
800.00
700.00
600.00
500.00
INTACT LOOP HOT LEG FLUID TEMPERATURE
(a,c)
1.00E+04
1.05E+04
1.10E+04
1.15E+04
1.20E+04
1.25E+04
1.26E+04
TIME(SECONDS)
5/28/80

Figure 169

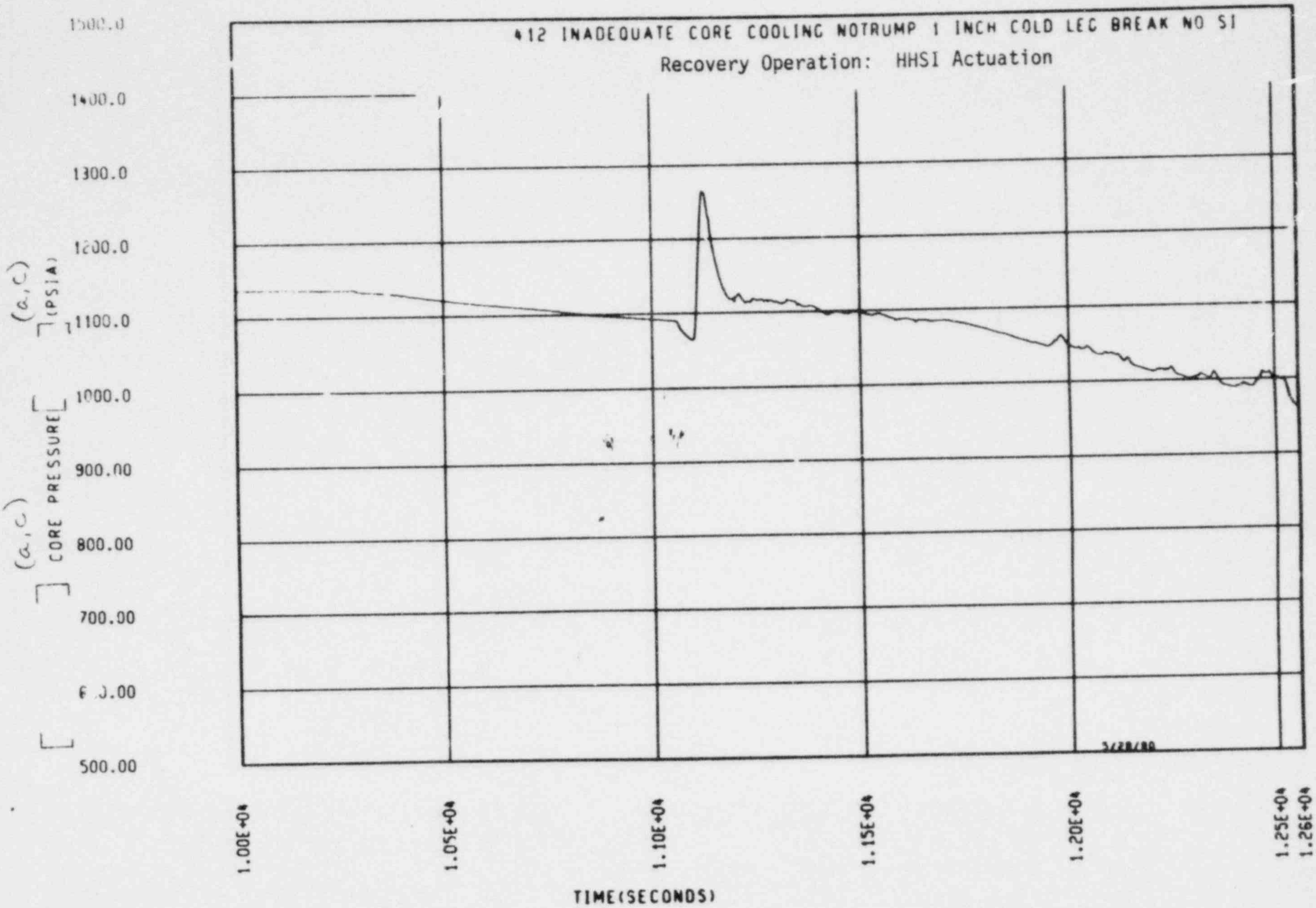
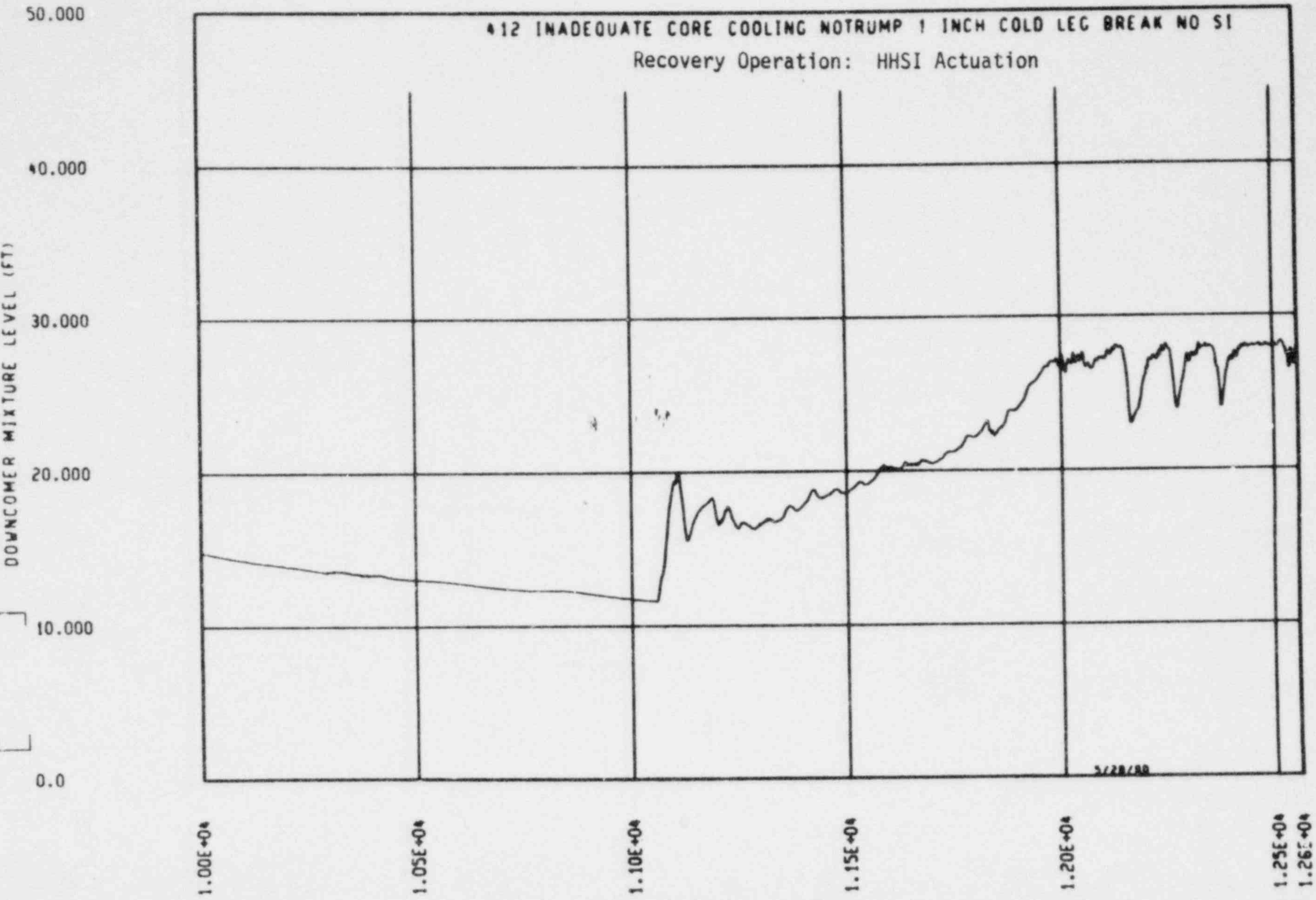

412 INADEQUATE CORE COOLING NOTRUMP 1 INCH COLD LEG BREAK NO SI
Recovery Operation: HHSI Actuation
1500.0
1400.0
1300.0
1200.0
1100.0
1000.0
900.00
800.00
700.00
600.00
500.00
CORE PRESSURE (PSIA)
(a,c)
(a,c)
1.00E+04
1.05E+04
1.10E+04
1.15E+04
1.20E+04
1.25E+04
1.26E+04
TIME(SECONDS)
5/28/80

Figure 170


4.12 INADEQUATE CORE COOLING NOTRUMP 1 INCH COLD LEG BREAK NO SI

Recovery Operation: HHSI Actuation

5/28/80

[ ](a,c)

Figure 171

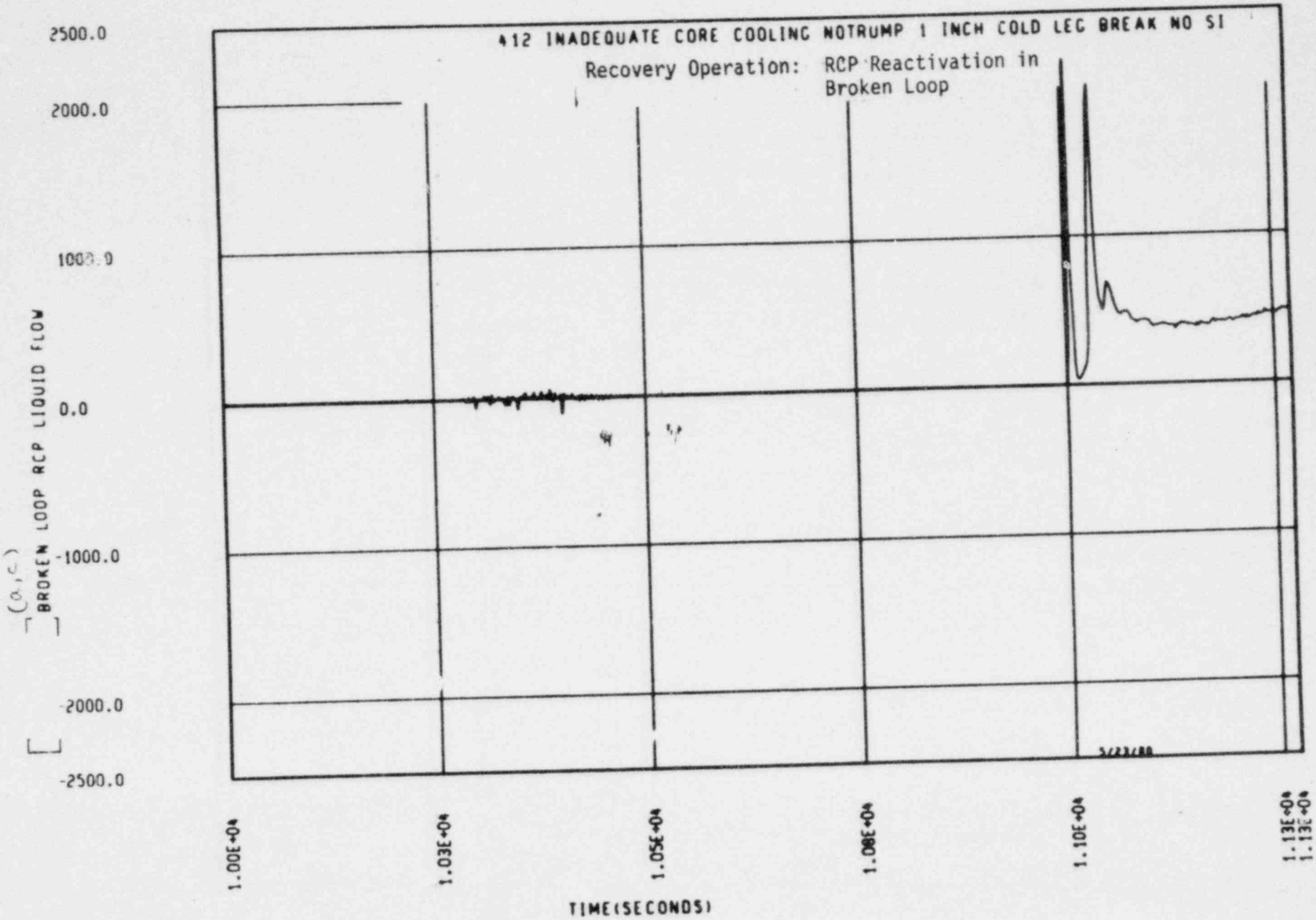

412 INADEQUATE CORE COOLING NOTRUMP 1 INCH COLD LEG BREAK NO SI
Recovery Operation: RCP Reactivation in Broken Loop
2500.0
2000.0
1000.0
0.0
-1000.0
-2000.0
-2500.0
BROKEN LOOP RCP LIQUID FLOW
(a,c)
1.00E+04
1.03E+04
1.05E+04
1.08E+04
1.10E+04
1.13E+04
1.13E+04
TIME(SECONDS)
5/23/80

Figure 172

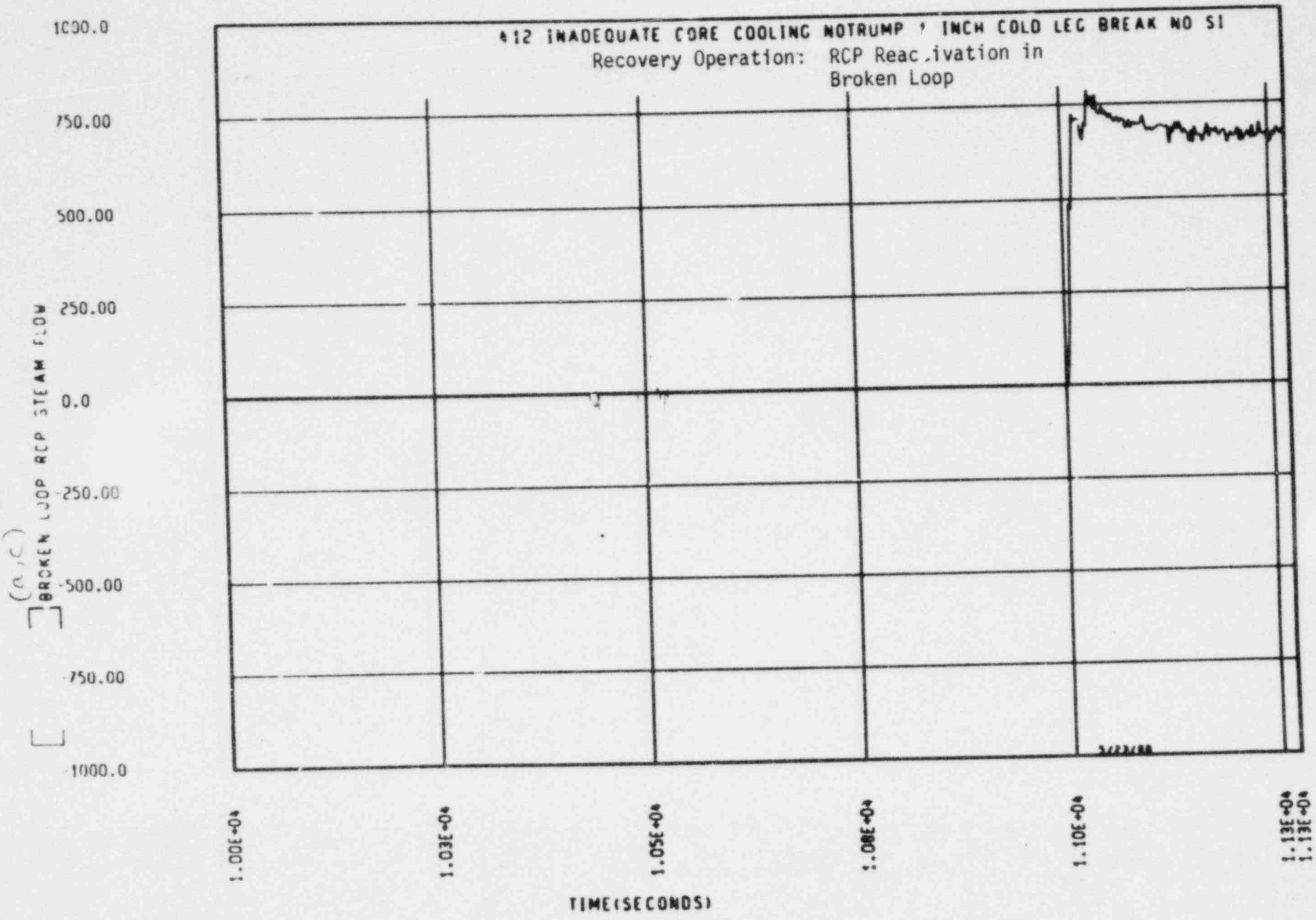

412 INADEQUATE CORE COOLING NOTRUMP ? INCH COLD LEG BREAK NO SI
Recovery Operation: RCP Reac.ivation in Broken Loop
1000.0
750.00
500.00
250.00
0.0
-250.00
-500.00
-750.00
-1000.0
BROKEN LOOP RCP STEAM FLOW
(a,c)
1.00E+04
1.03E+04
1.05E+04
1.08E+04
1.10E+04
1.13E+04
1.13E+04
TIME(SECONDS)
5/23/88

Figure 173

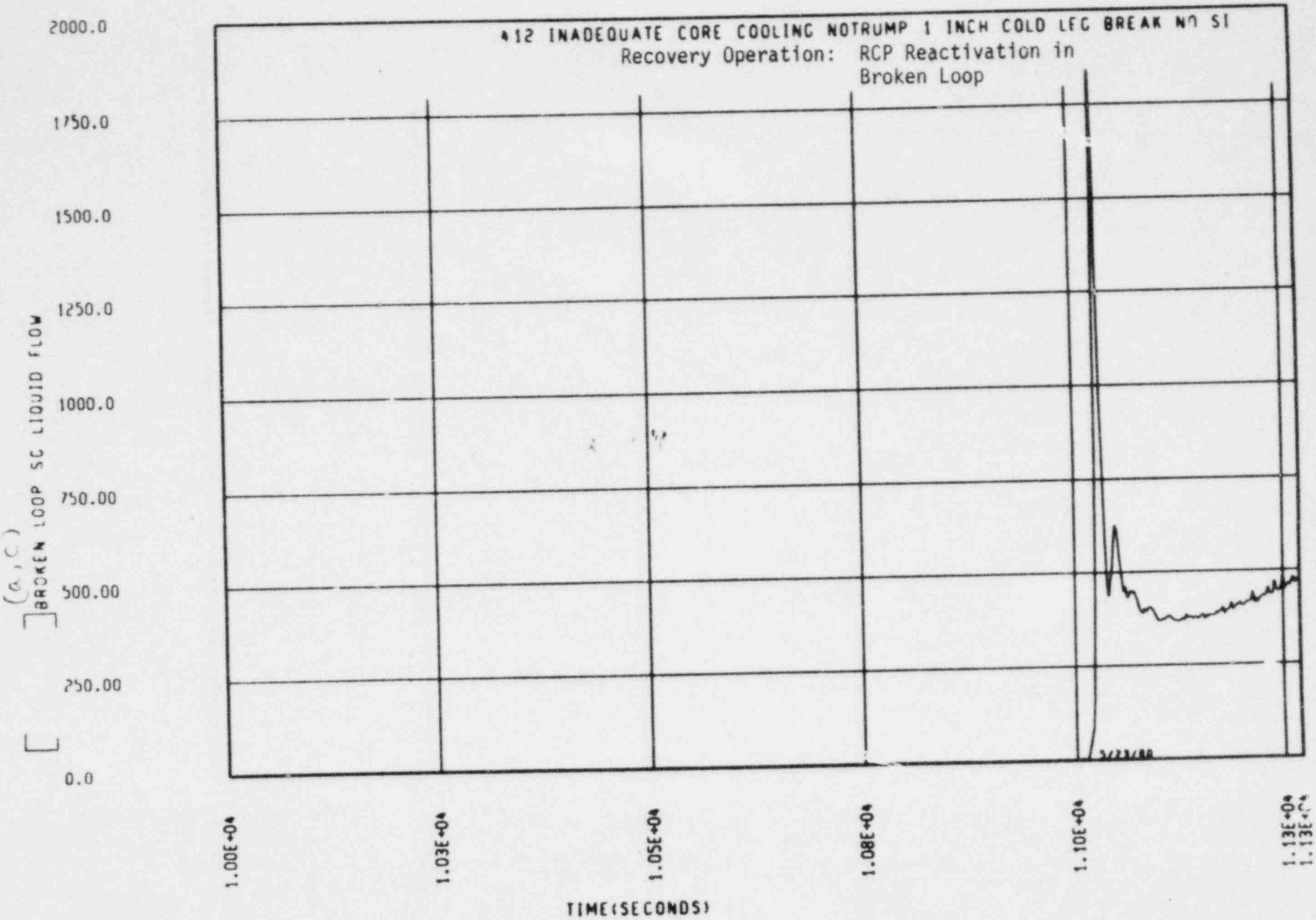

412 INADEQUATE CORE COOLING NOTRUMP 1 INCH COLD LEG BREAK NO SI
Recovery Operation: RCP Reactivation in
Broken Loop
2000.0
1750.0
1500.0
1250.0
1000.0
750.00
500.00
250.00
0.0
BROKEN LOOP SC LIQUID FLOW
(a,c)
1.00E+04
1.03E+04
1.05E+04
1.08E+04
1.10E+04
1.13E+04
1.13E+04
TIME(SECONDS)
3/23/80

Figure 174

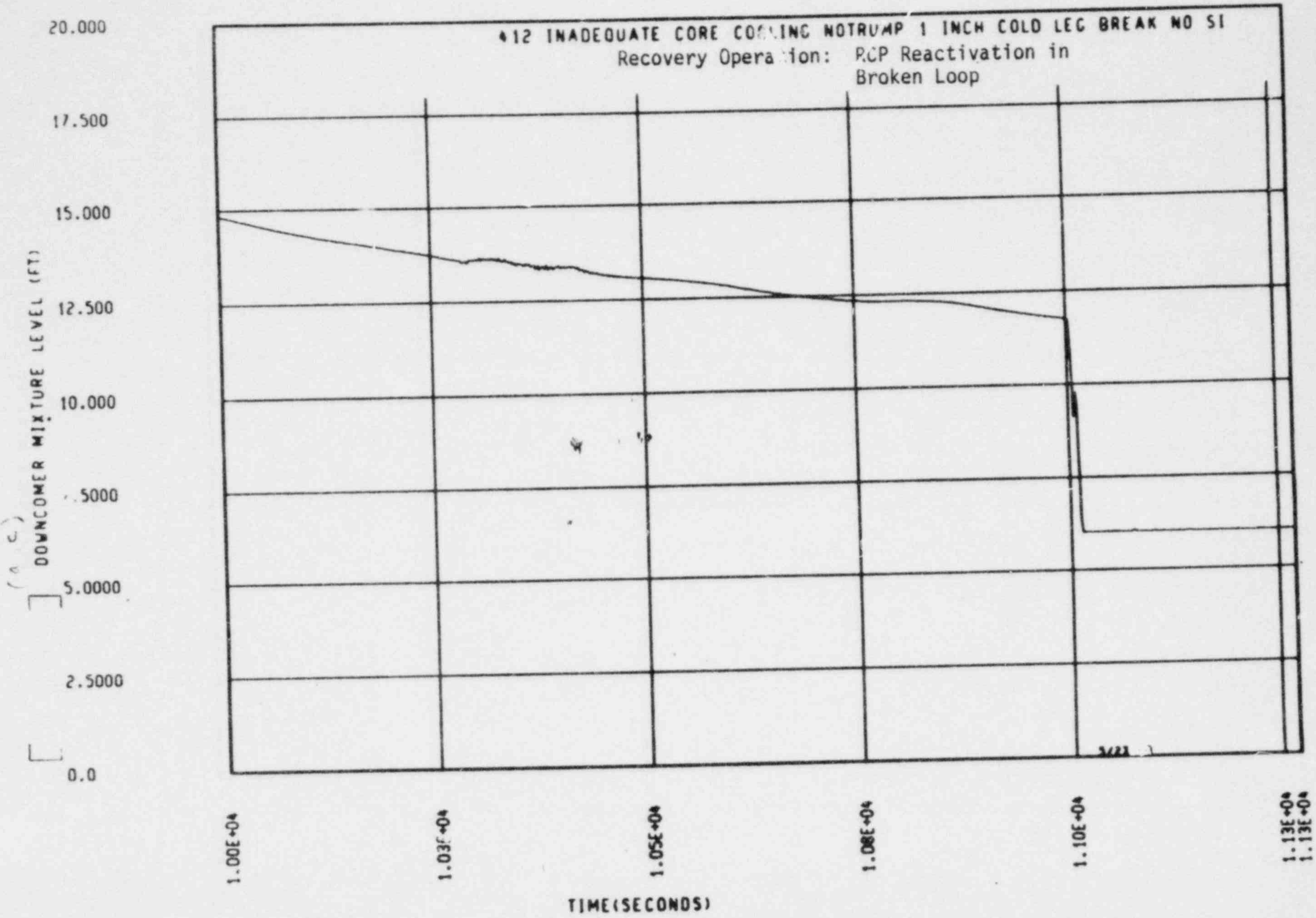

412 INADEQUATE CORE COOLING NOTRUMP 1 INCH COLD LEG BREAK NO SI
Recovery Operation: RCP Reactivation in
Broken Loop
DOWNCOMER MIXTURE LEVEL (FT)
(a,c)
20.000
17.500
15.000
12.500
10.000
7.5000
5.0000
2.5000
0.0
1.00E+04
1.03E+04
1.05E+04
1.08E+04
1.10E+04
1.13E+04
1.13E+04
TIME(SECONDS)

Figure 125

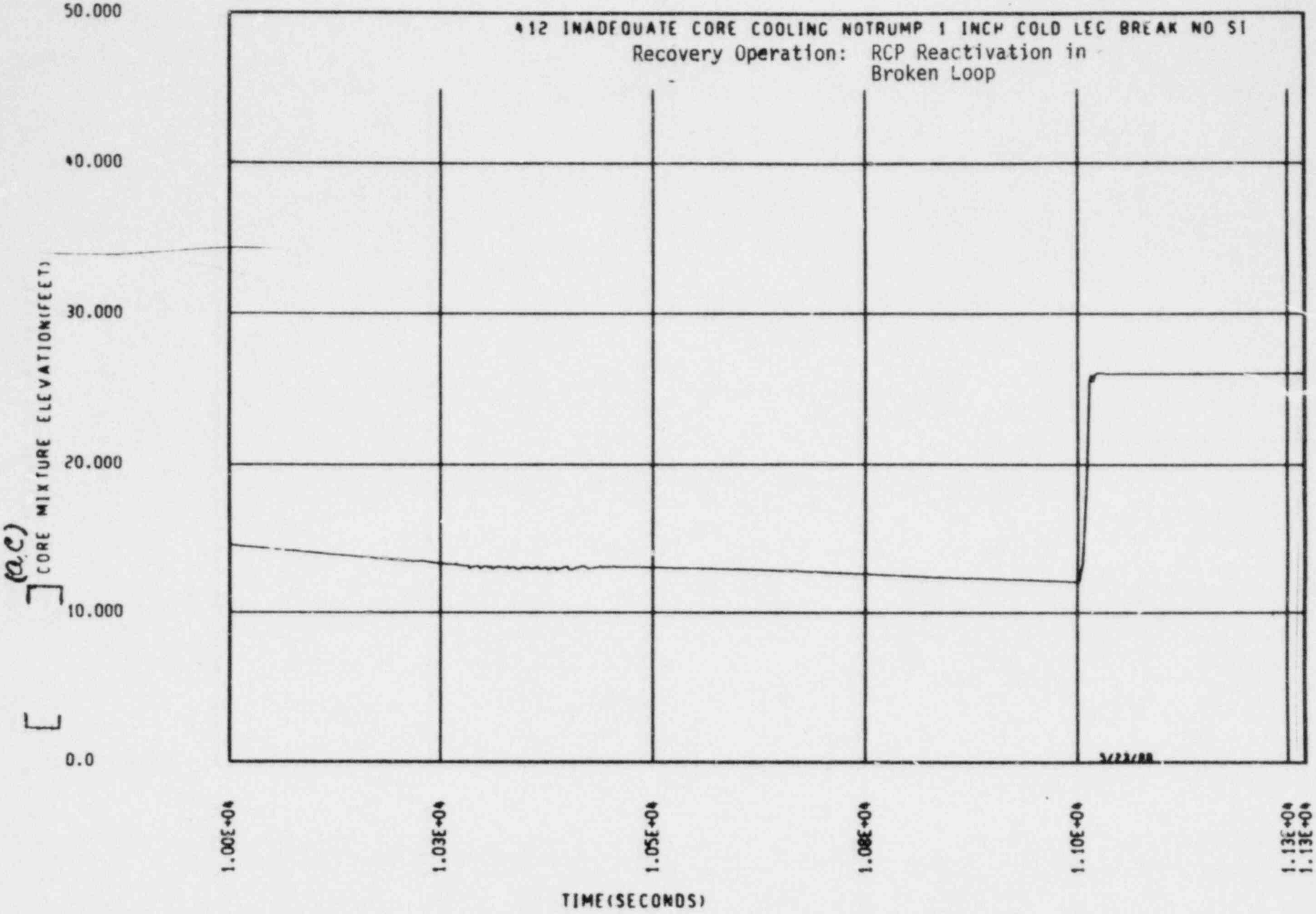

412 INADEQUATE CORE COOLING NOTRUMP 1 INCH COLD LEG BREAK NO SI
Recovery Operation: RCP Reactivation in Broken Loop
CORE MIXTURE ELEVATION(FEET)
(a,c)
50.000
40.000
30.000
20.000
10.000
0.0
1.00E+04
1.03E+04
1.05E+04
1.08E+04
1.10E+04
1.13E+04
1.13E+04
TIME(SECONDS)
5/23/88

Figure 176

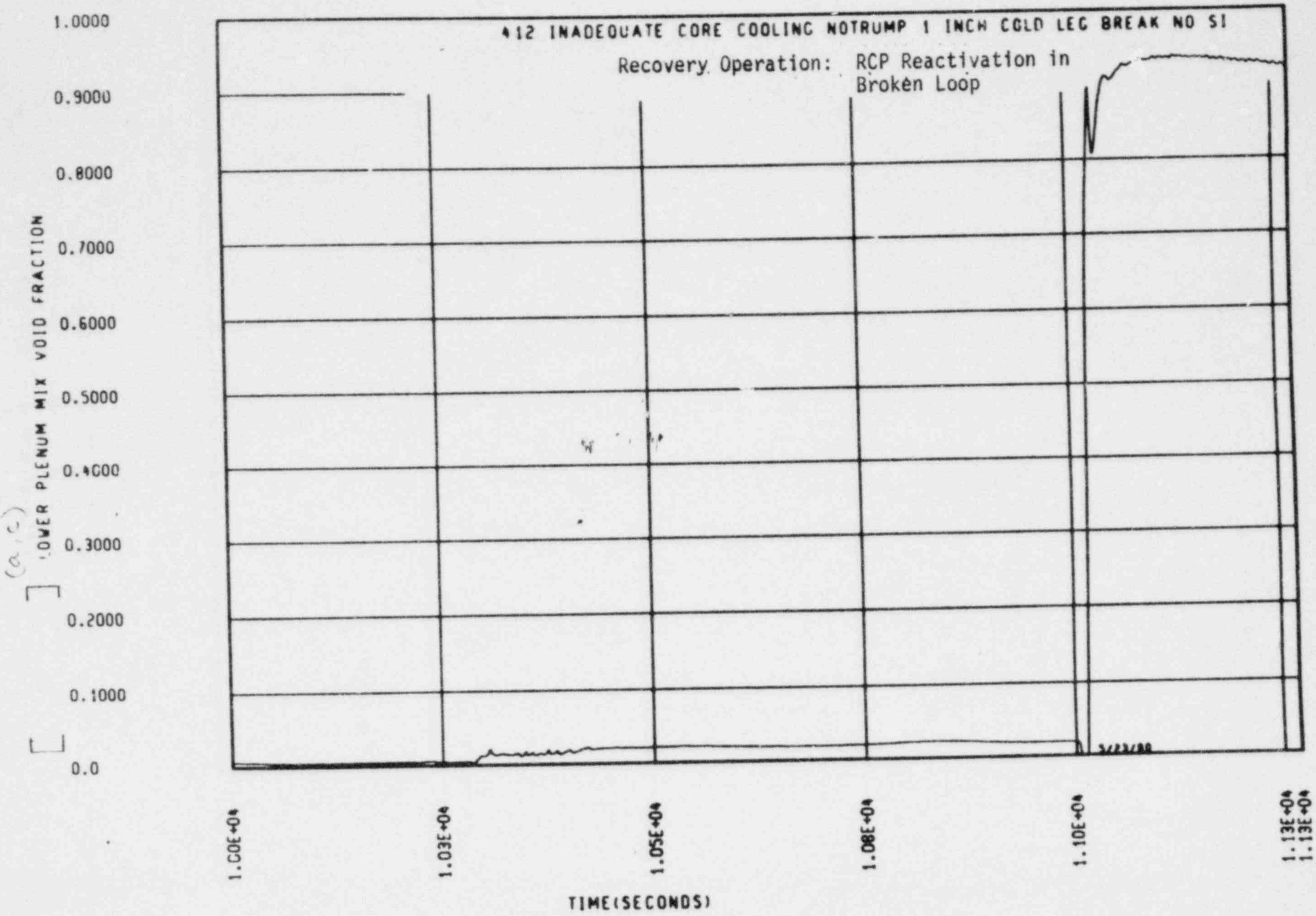

412 INADEQUATE CORE COOLING NOTRUMP 1 INCH COLD LEG BREAK NO SI
Recovery Operation: RCP Reactivation in Broken Loop
LOWER PLENUM MIX VOID FRACTION
(a,c)
1.0000
0.9000
0.8000
0.7000
0.6000
0.5000
0.4000
0.3000
0.2000
0.1000
0.0
1.00E+04
1.03E+04
1.05E+04
1.08E+04
1.10E+04
1.13E+04
1.13E+04
TIME(SECONDS)
5/23/80

Figure 177

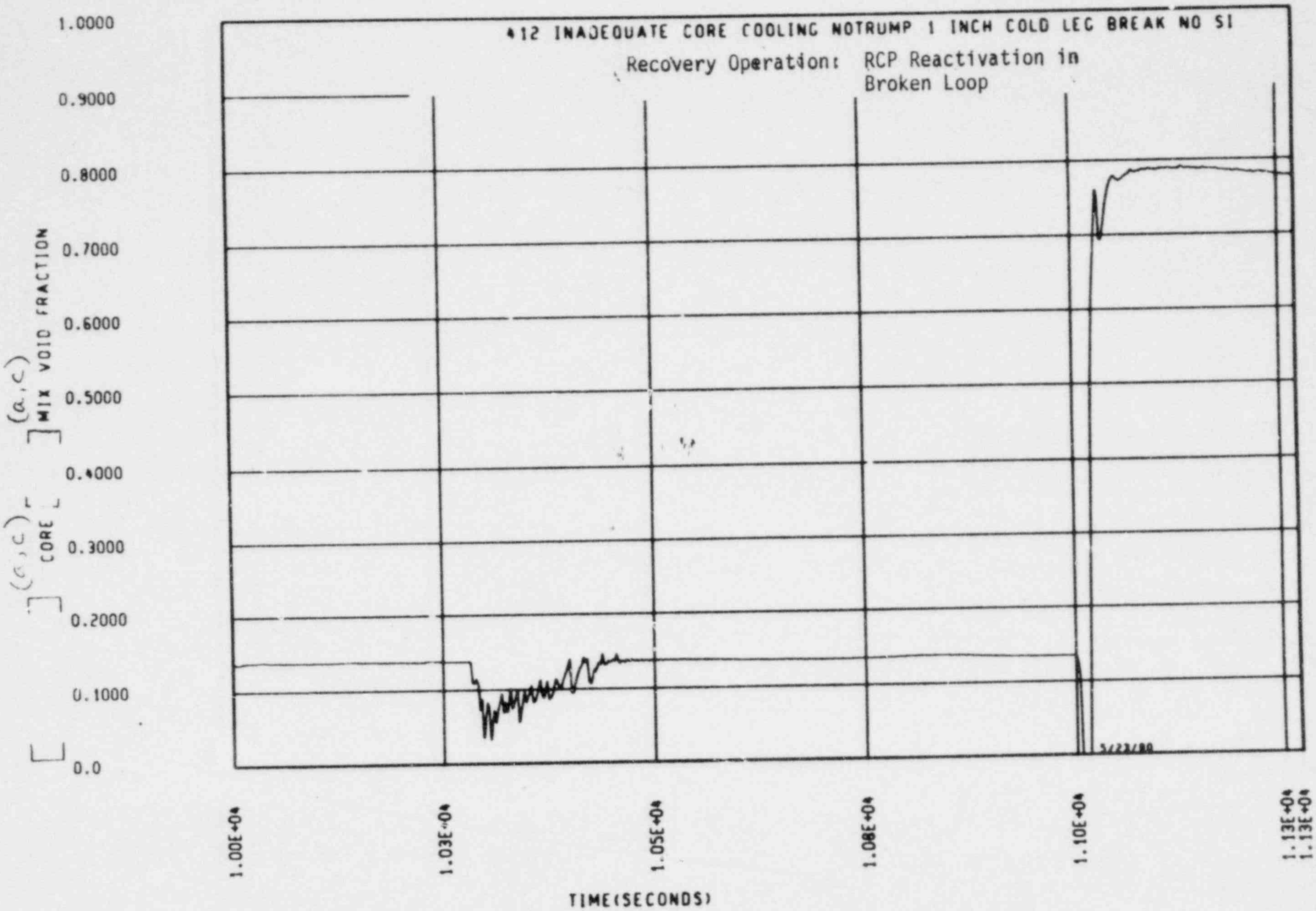

412 INADEQUATE CORE COOLING NOTRUMP 1 INCH COLD LEG BREAK NO SI
Recovery Operation: RCP Reactivation in Broken Loop
(a,c)
CORE
(a,c)
MIX VOID FRACTION
1.0000
0.9000
0.8000
0.7000
0.6000
0.5000
0.4000
0.3000
0.2000
0.1000
0.0
1.00E+04
1.03E+04
1.05E+04
1.08E+04
1.10E+04
1.13E+04
1.13E+04
TIME(SECONDS)
5/23/80

Figure 178

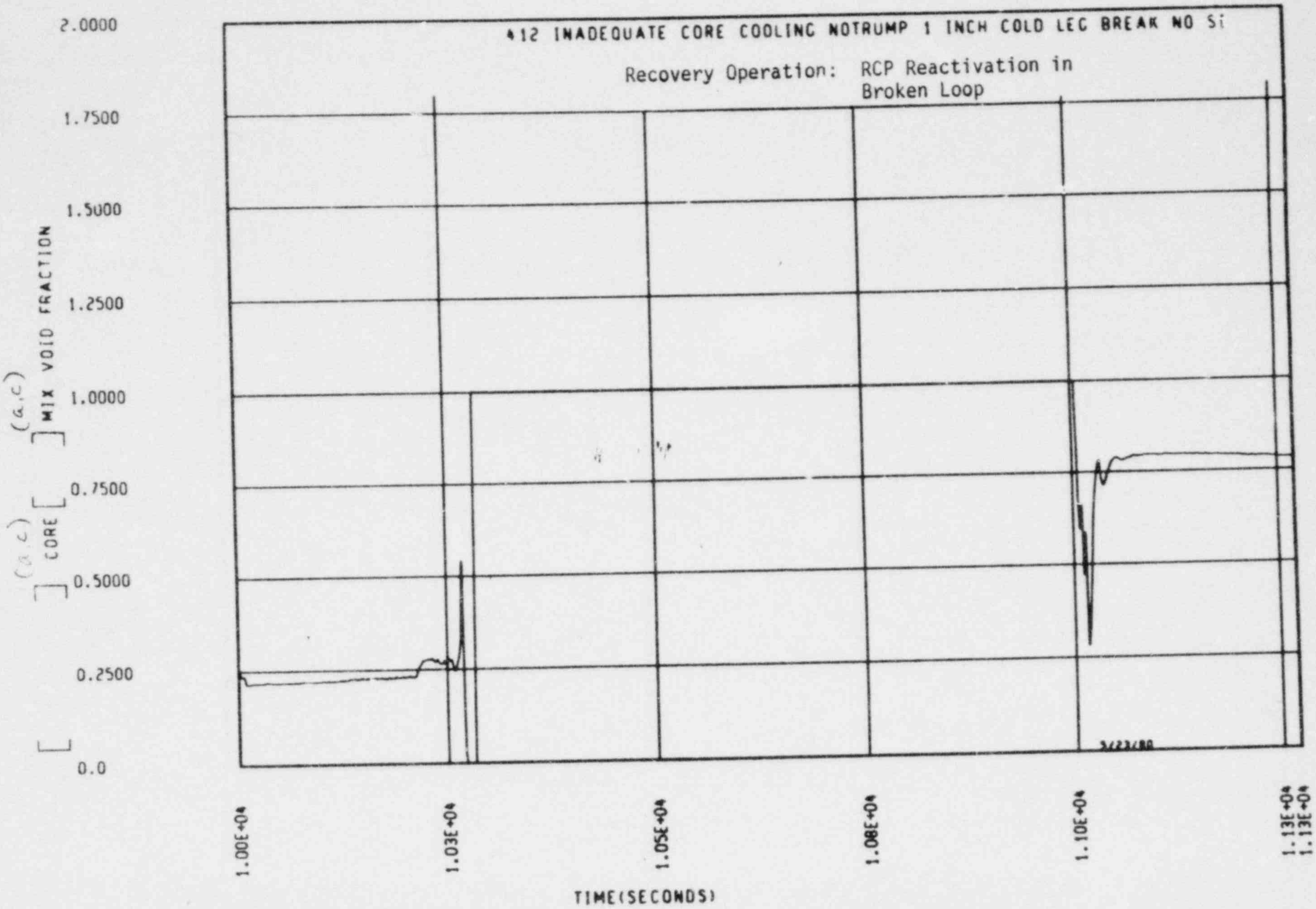

412 INADEQUATE CORE COOLING NOTRUMP 1 INCH COLD LEG BREAK NO SI
Recovery Operation: RCP Reactivation in Broken Loop
(a,c)
MIX VOID FRACTION
(a,c)
CORE
2.0000
1.7500
1.5000
1.2500
1.0000
0.7500
0.5000
0.2500
0.0
1.00E+04
1.03E+04
1.05E+04
1.08E+04
1.10E+04
1.13E+04
1.13E+04
TIME(SECONDS)
5/23/80

Figure 179

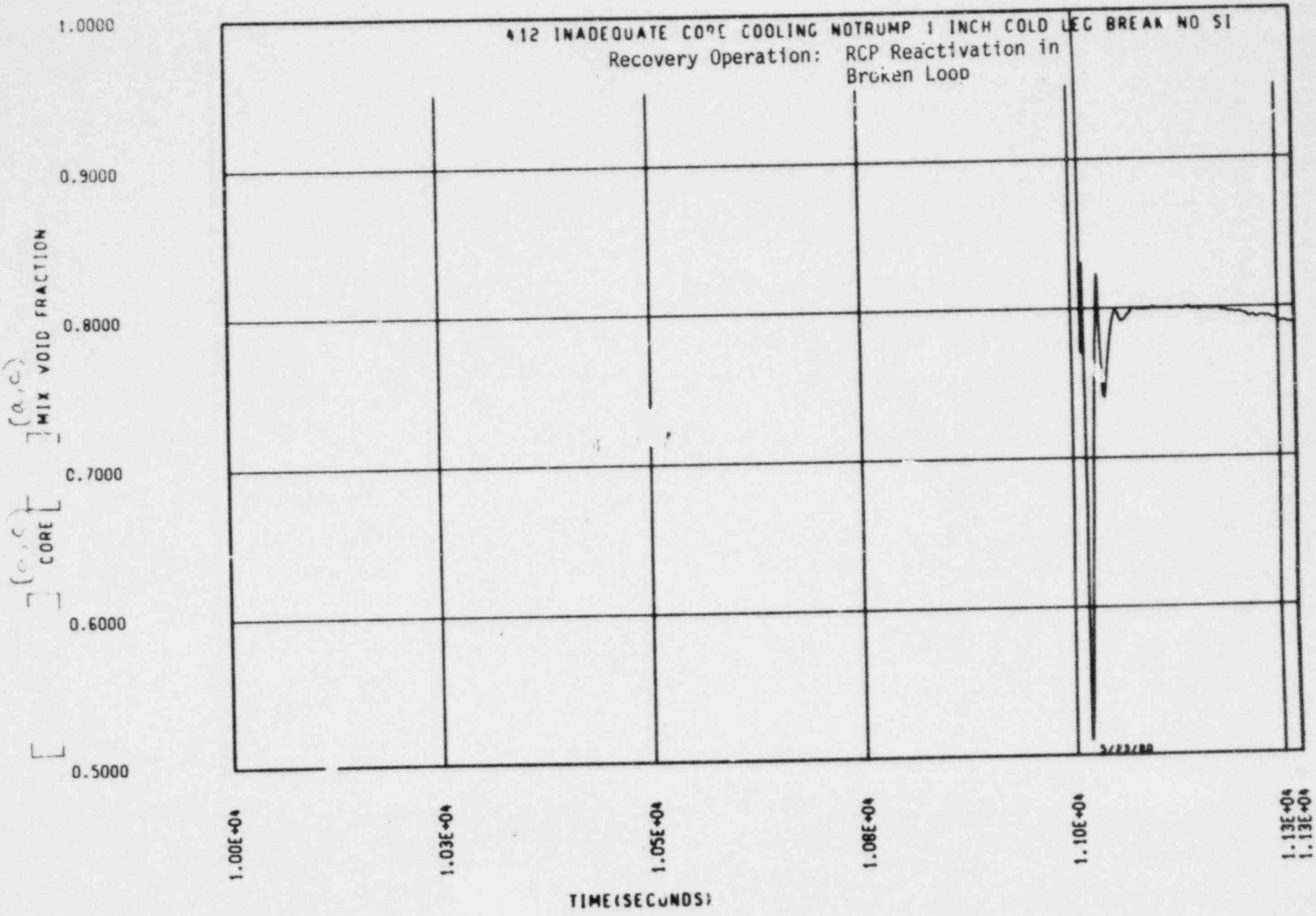

412 INADEQUATE CORE COOLING NOTRUMP 1 INCH COLD LEG BREAK NO SI
Recovery Operation: RCP Reactivation in Broken Loop
CORE MIX VOID FRACTION
(a,c)
(a,c)
1.0000
0.9000
0.8000
0.7000
0.6000
0.5000
1.00E+04
1.03E+04
1.05E+04
1.08E+04
1.10E+04
1.13E+04
1.13E+04
TIME(SECONDS)
5/23/80

Figure 180

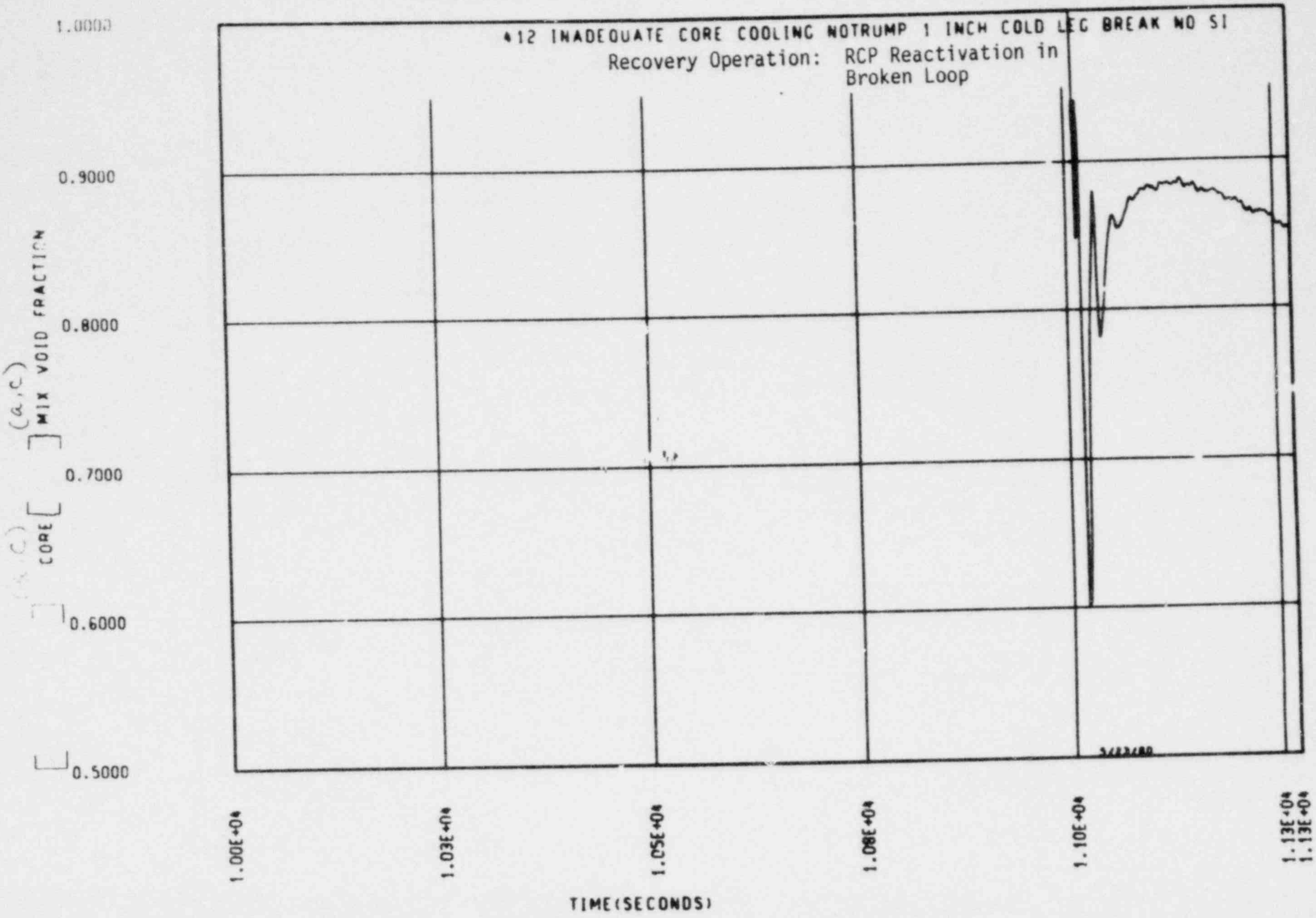

412 INADEQUATE CORE COOLING NOTRUMP 1 INCH COLD LEG BREAK NO SI
Recovery Operation: RCP Reactivation in Broken Loop
CORE MIX VOID FRACTION
(a,c)
(a,c)
1.0000
0.9000
0.8000
0.7000
0.6000
0.5000
1.00E+04
1.03E+04
1.05E+04
1.08E+04
1.10E+04
1.13E+04
1.13E+04
TIME(SECONDS)
5/23/80

Figure 181

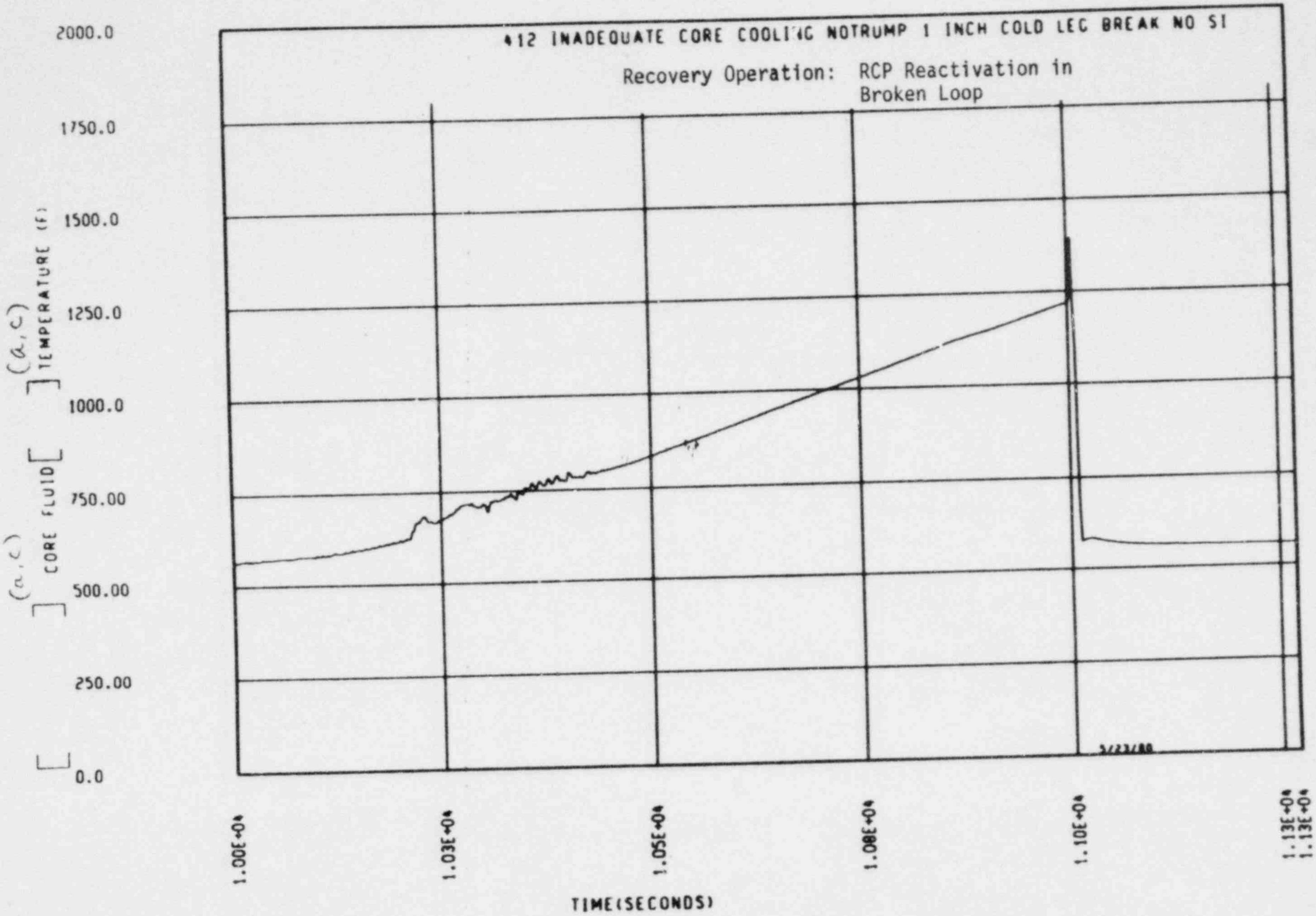

412 INADEQUATE CORE COOLING NOTRUMP 1 INCH COLD LEG BREAK NO SI
Recovery Operation: RCP Reactivation in Broken Loop
CORE FLUID TEMPERATURE (F)
(a,c)
(a,c)
2000.0
1750.0
1500.0
1250.0
1000.0
750.00
500.00
250.00
0.0
1.00E+04
1.03E+04
1.05E+04
1.08E+04
1.10E+04
1.13E+04
1.13E+04
TIME(SECONDS)
5/23/80

Figure 182

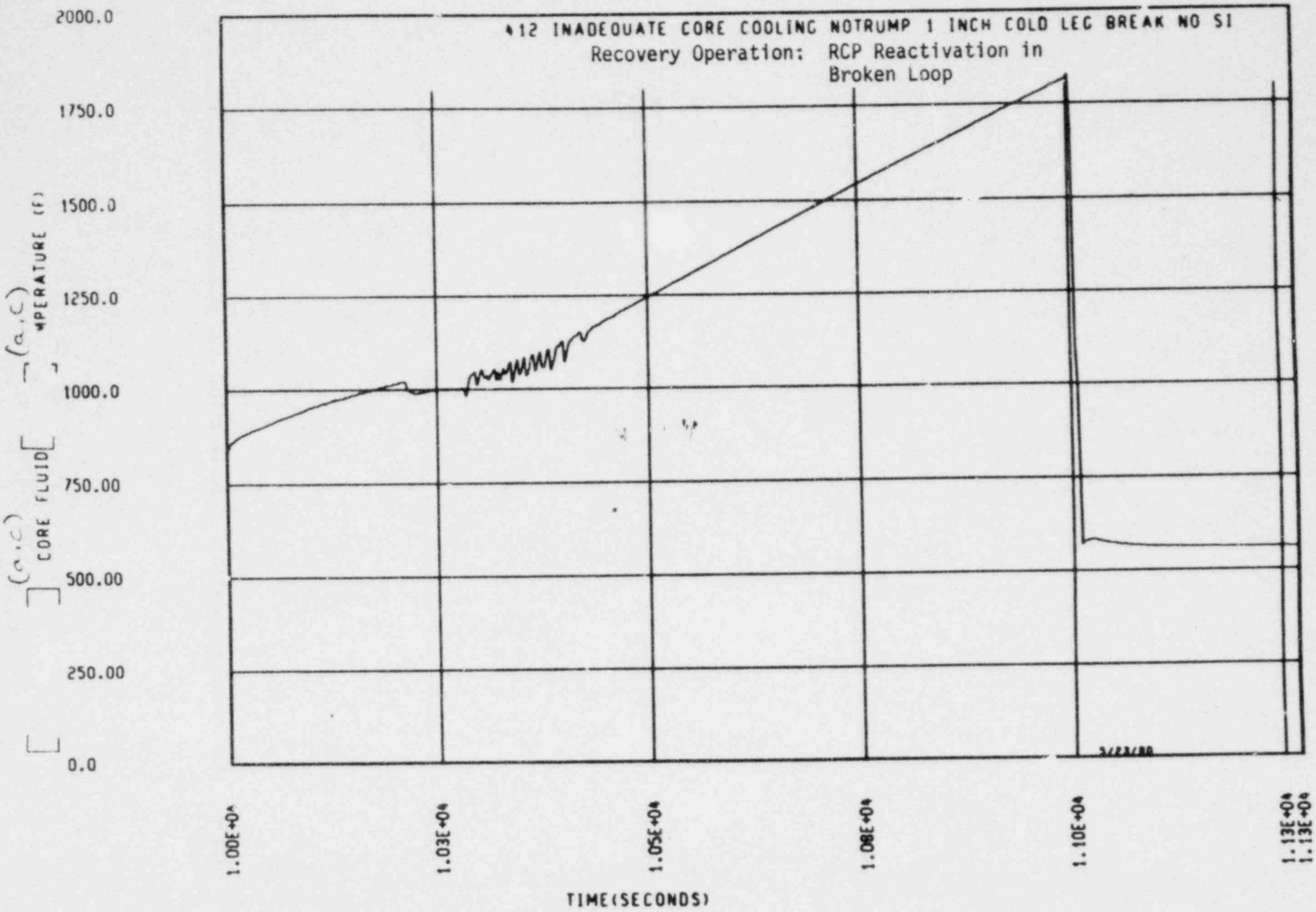

412 INADEQUATE CORE COOLING NOTRUMP 1 INCH COLD LEG BREAK NO SI
Recovery Operation: RCP Reactivation in Broken Loop
CORE FLUID
TEMPERATURE (F)
(a,c)
(a,c)
2000.0
1750.0
1500.0
1250.0
1000.0
750.00
500.00
250.00
0.0
1.00E+04
1.03E+04
1.05E+04
1.08E+04
1.10E+04
1.13E+04
1.13E+04
TIME(SECONDS)
5/23/80

Figure 183

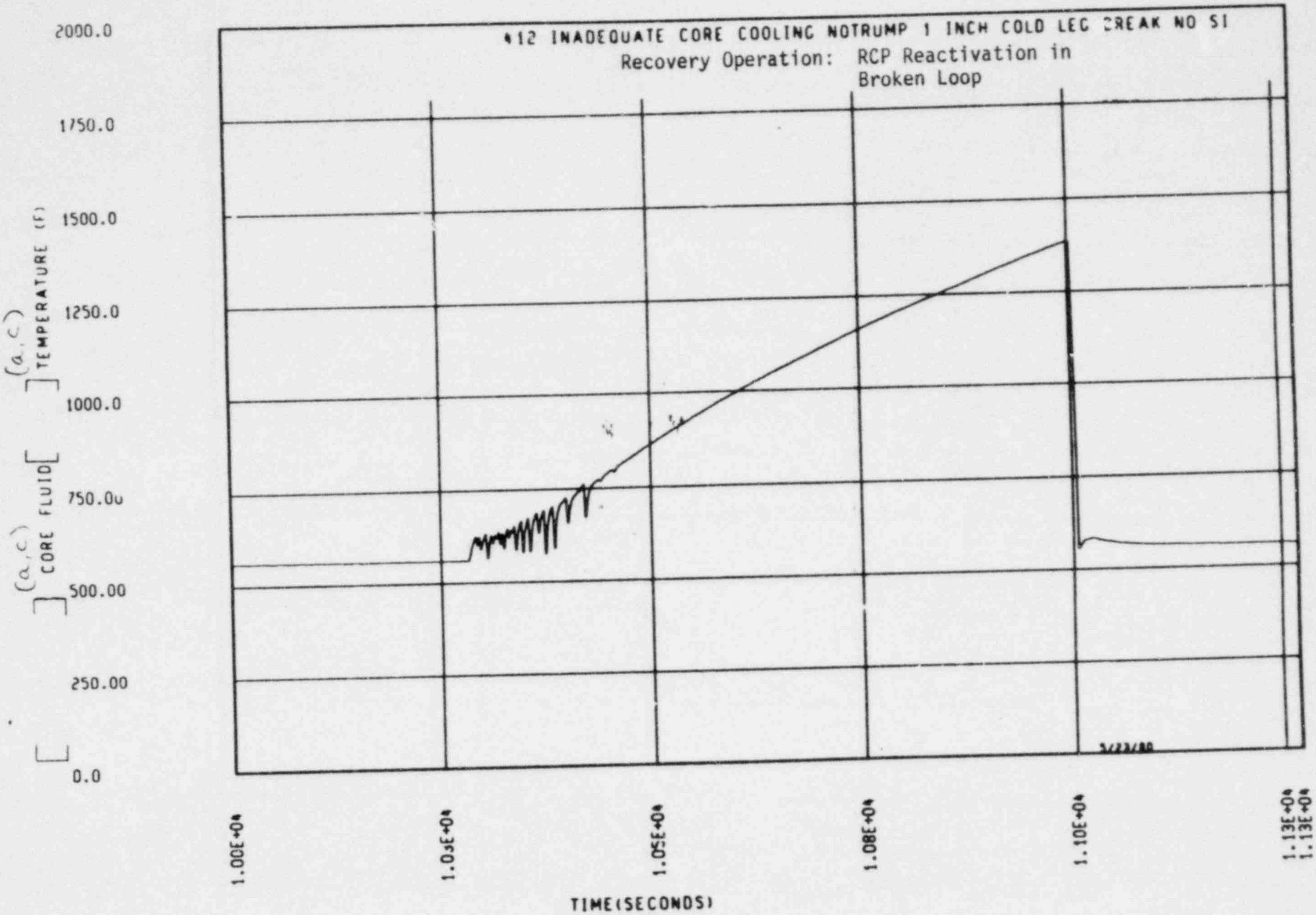

412 INADEQUATE CORE COOLING NOTRUMP 1 INCH COLD LEG BREAK NO SI
Recovery Operation: RCP Reactivation in Broken Loop
(a,c)
CORE FLUID
(a,c)
TEMPERATURE (F)
2000.0
1750.0
1500.0
1250.0
1000.0
750.00
500.00
250.00
0.0
1.00E+04
1.03E+04
1.05E+04
1.08E+04
1.10E+04
1.13E+04
1.13E+04
TIME(SECONDS)
5/23/80

Figure 184

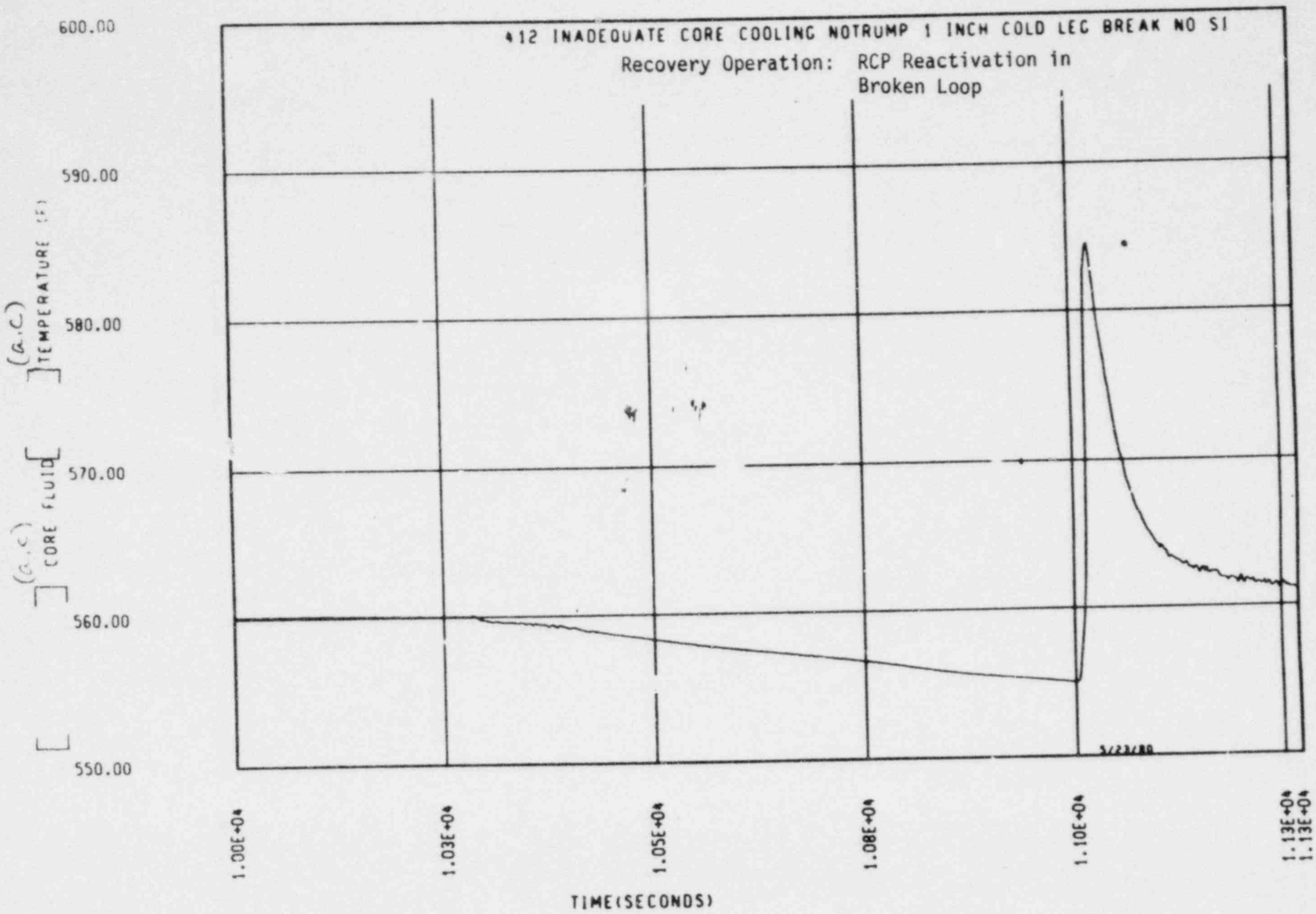

412 INADEQUATE CORE COOLING NOTRUMP 1 INCH COLD LEG BREAK NO SI
Recovery Operation: RCP Reactivation in Broken Loop
(a,c)
CORE FLUID
(a,c)
TEMPERATURE (F)
600.00
590.00
580.00
570.00
560.00
550.00
1.00E+04
1.03E+04
1.05E+04
1.08E+04
1.10E+04
1.13E+04
1.13E+04
TIME(SECONDS)
5/23/80

Figure 185

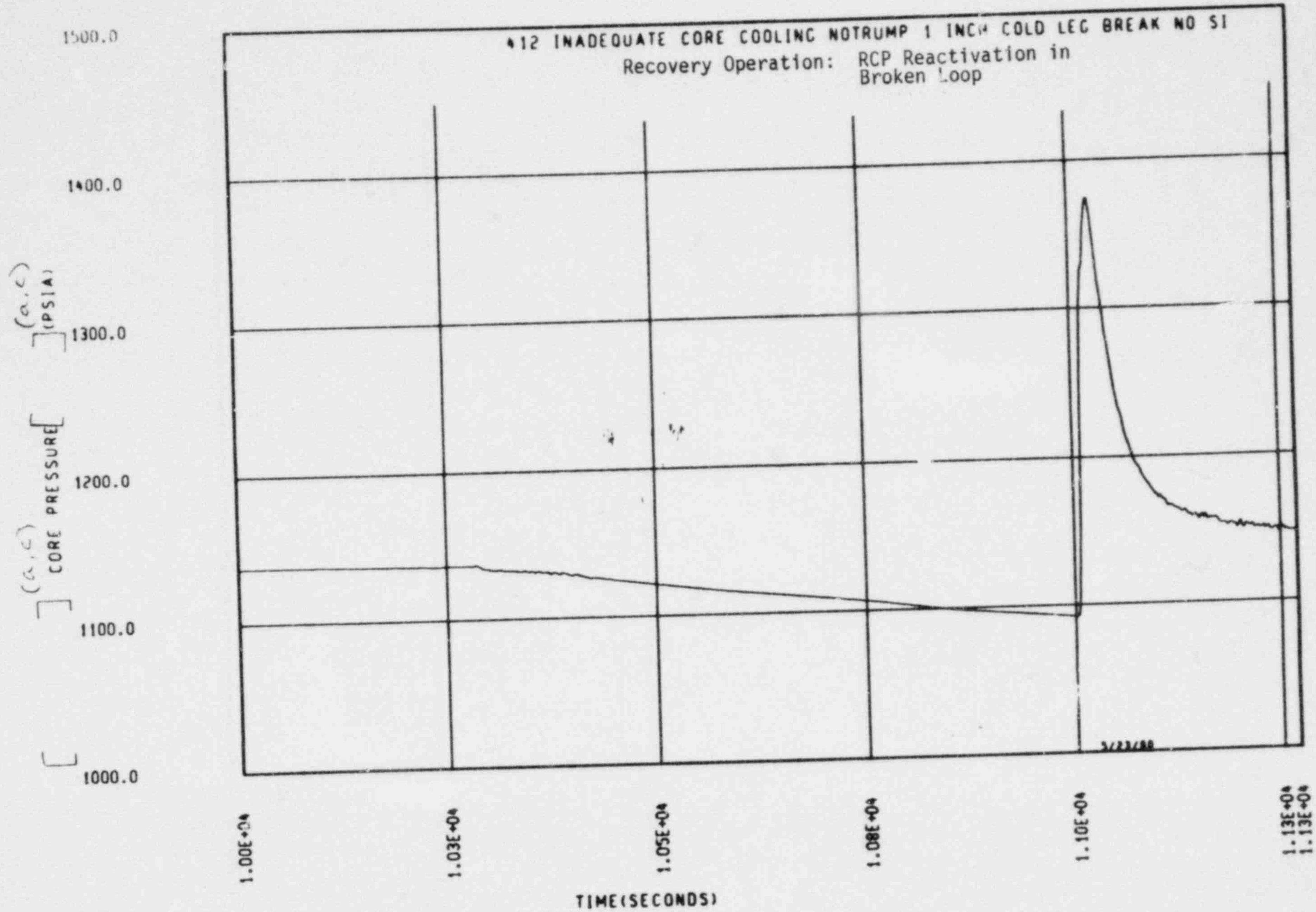
412 INADEQUATE CORE COOLING NOTRUMP 1 INCH COLD LEG BREAK NO SI
Recovery Operation: RCP Reactivation in Broken Loop
1500.0
1400.0
1300.0
1200.0
1100.0
1000.0
CORE PRESSURE (PSIA)
(a,c)
(a,c)
1.00E+04
1.03E+04
1.05E+04
1.08E+04
1.10E+04
1.13E+04
1.13E+04
TIME(SECONDS)
5/23/88

Figure 186

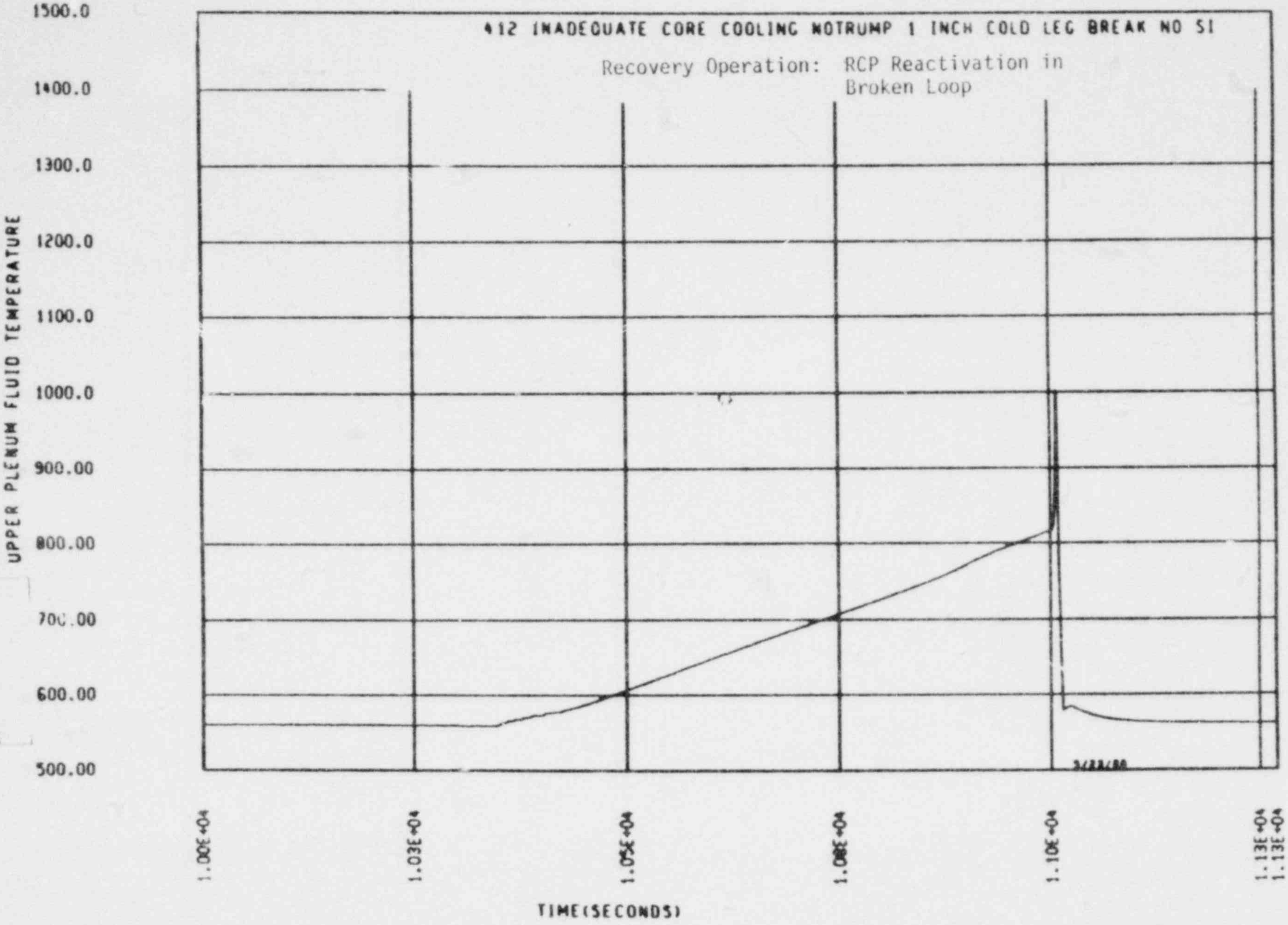
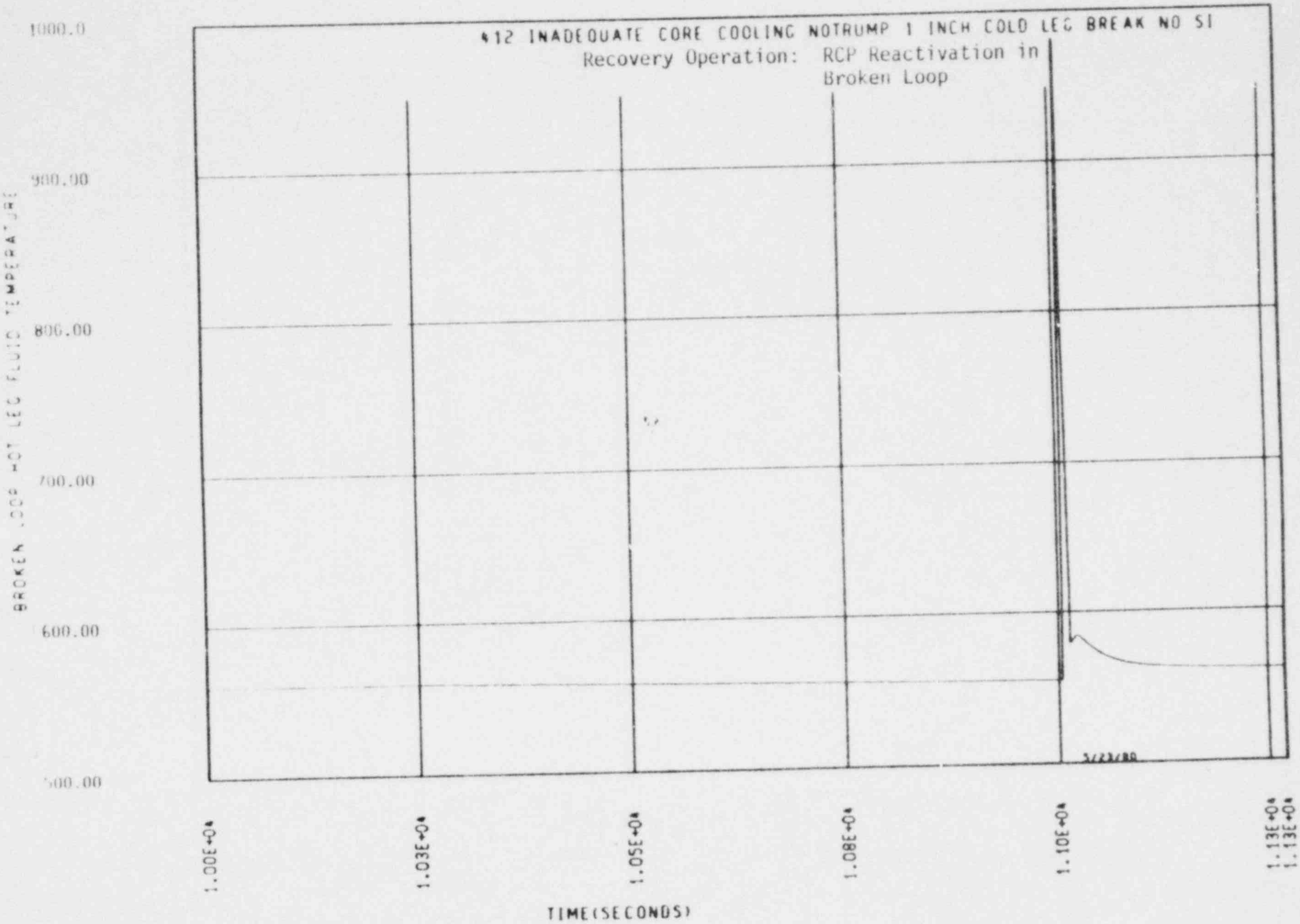

412 INADEQUATE CORE COOLING NOTRUMP 1 INCH COLD LEG BREAK NO SI
Recovery Operation: RCP Reactivation in Broken Loop
UPPER PLENUM FLUID TEMPERATURE
1500.0
1400.0
1300.0
1200.0
1100.0
1000.0
900.00
800.00
700.00
600.00
500.00
1.00E+04
1.03E+04
1.05E+04
1.08E+04
1.10E+04
1.13E+04
1.13E+04
TIME(SECONDS)
3/23/80

Figure 187



412 INADEQUATE CORE COOLING NOTRUMP 1 INCH COLD LEG BREAK NO SI
Recovery Operation: RCP Reactivation in Broken Loop

Figure 188

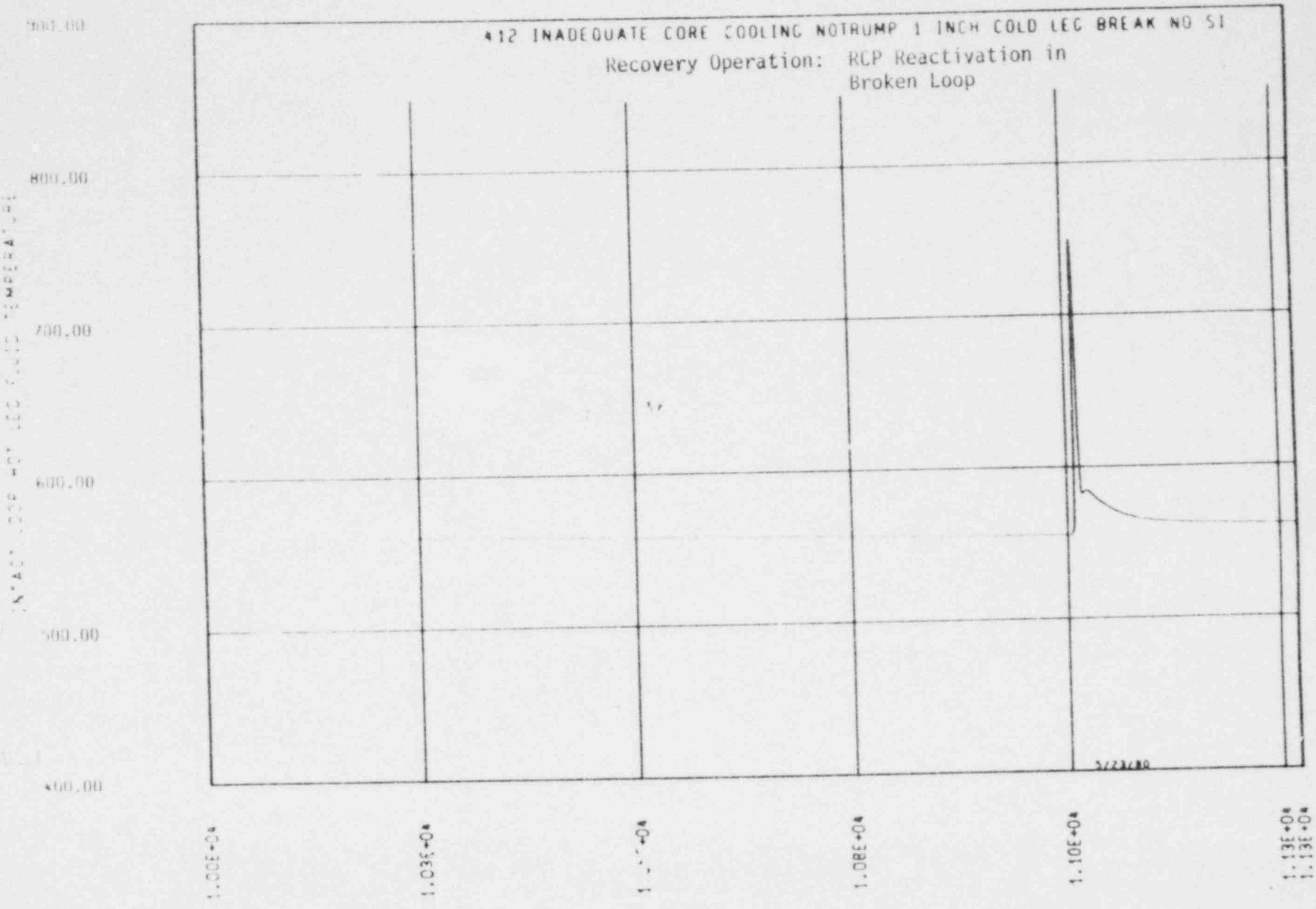

412 INADEQUATE CORE COOLING NOTRUMP 1 INCH COLD LEG BREAK NO SI
Recovery Operation: RCP Reactivation in Broken Loop
900.00
800.00
700.00
600.00
500.00
400.00
1.00E+04
1.03E+04
1.08E+04
1.10E+04
1.13E+04
1.13E+04
5/23/80
TIME(SECONDS)

Figure 189

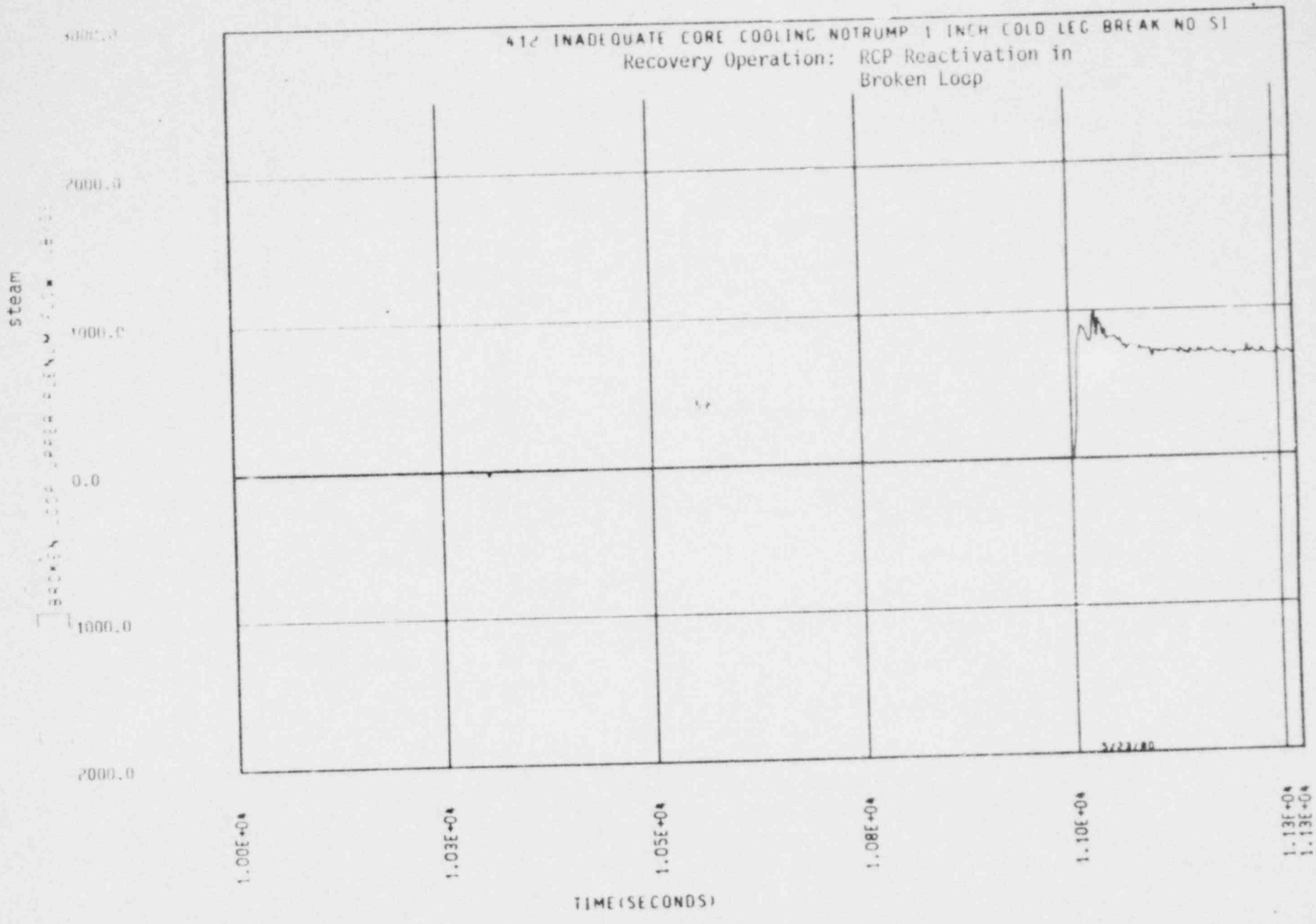

412 INADEQUATE CORE COOLING NOTRUMP 1 INCH COLD LEG BREAK NO SI
Recovery Operation: RCP Reactivation in Broken Loop
steam
BROKEN LOOP UPPER PLENUM FLOW (LB/SEC)
3000.0
2000.0
1000.0
0.0
1000.0
2000.0
1.00E+04
1.03E+04
1.05E+04
1.08E+04
1.10E+04
1.13E+04
1.13E+04
TIME(SECONDS)
5/23/80

Figure 190

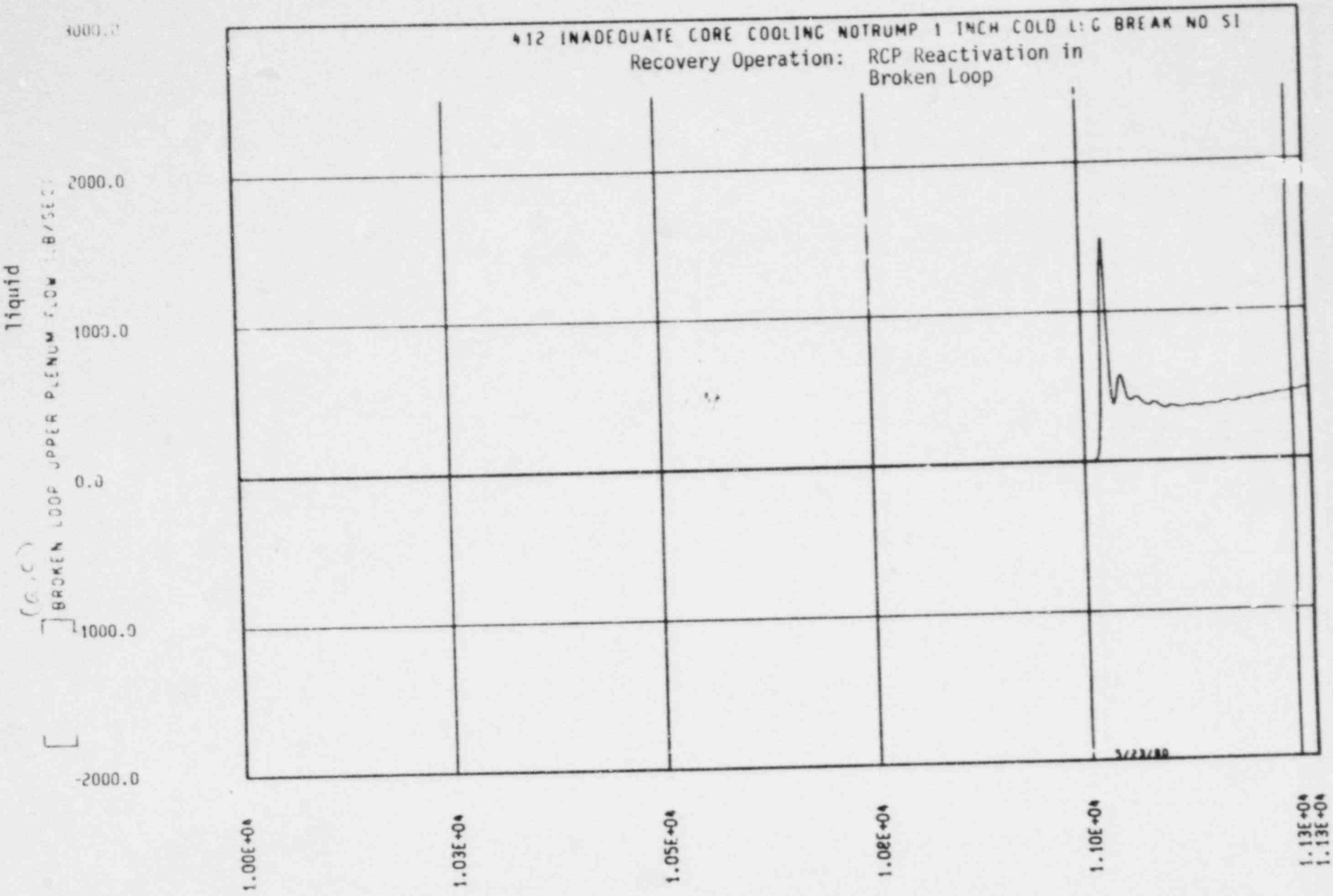

412 INADEQUATE CORE COOLING NOTRUMP 1 INCH COLD L:G BREAK NO SI
Recovery Operation: RCP Reactivation in Broken Loop
BROKEN LOOP UPPER PLENUM FLOW (LB/SEC)
liquid
(a,c)
4000.0
2000.0
1000.0
0.0
-1000.0
-2000.0
1.00E+04
1.03E+04
1.05E+04
1.08E+04
1.10E+04
1.13E+04
1.13E+04
5/23/80
TIME(SECONDS)

Figure 191

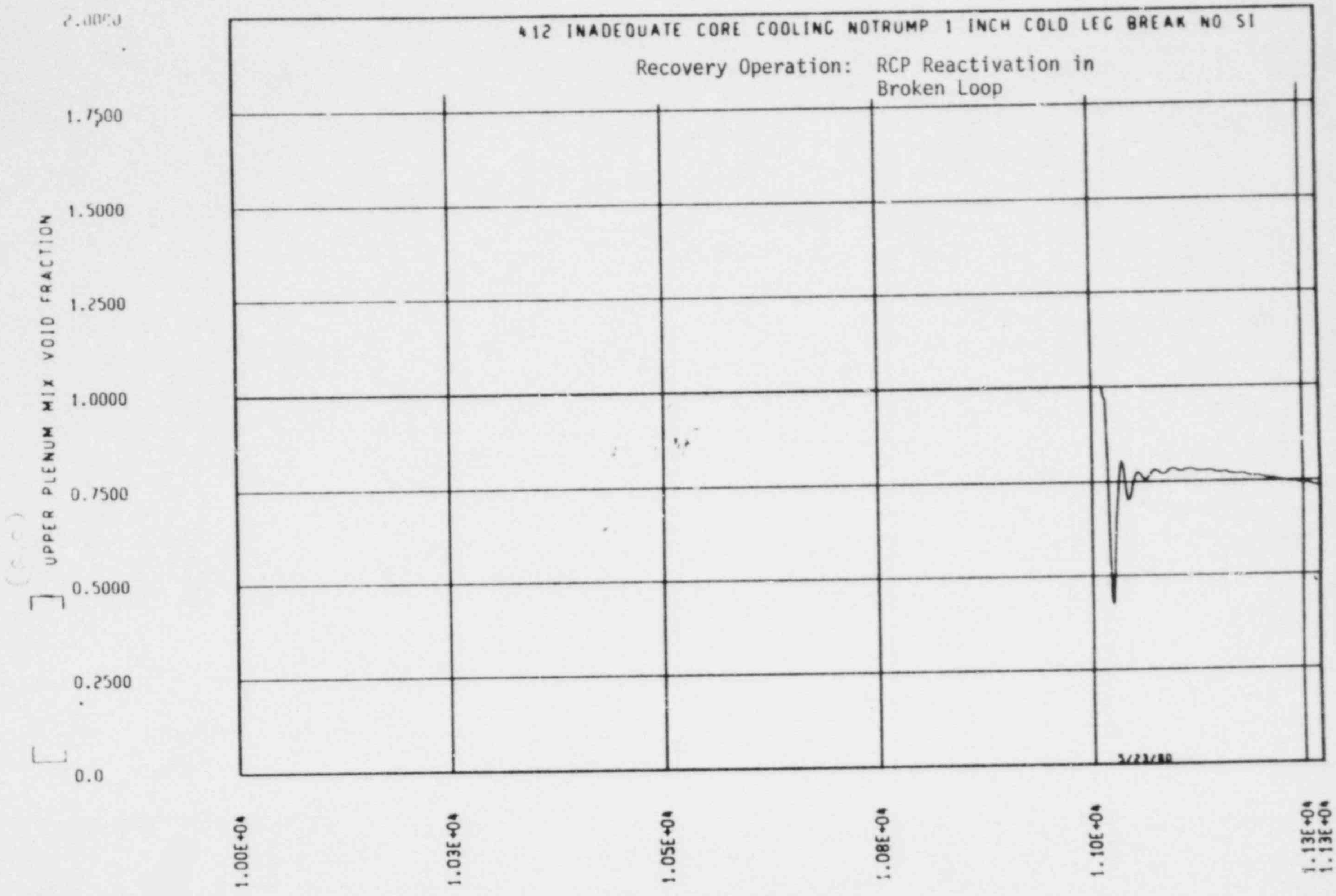

412 INADEQUATE CORE COOLING NOTRUMP 1 INCH COLD LEG BREAK NO SI
Recovery Operation: RCP Reactivation in Broken Loop
UPPER PLENUM MIX VOID FRACTION
2.0000
1.7500
1.5000
1.2500
1.0000
0.7500
0.5000
0.2500
0.0
TIME(SECONDS)
1.00E+04
1.03E+04
1.05E+04
1.08E+04
1.10E+04
1.13E+04
1.13E+04
5/23/80

Figure 192

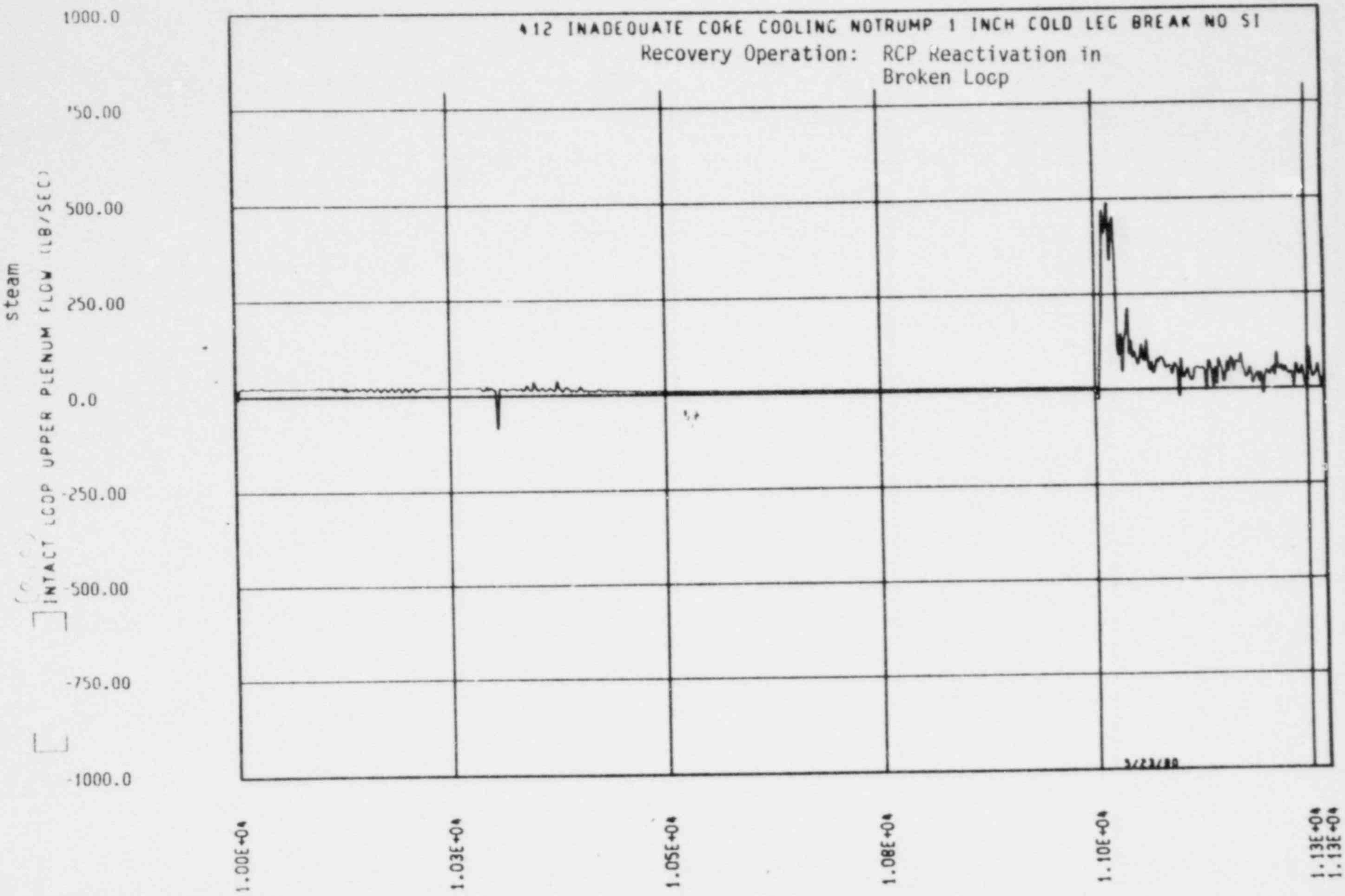

412 INADEQUATE CORE COOLING NOTRUMP 1 INCH COLD LEG BREAK NO SI
Recovery Operation: RCP Reactivation in Broken Loop
steam
INTACT LOOP UPPER PLENUM FLOW (LB/SEC)
1000.0
750.00
500.00
250.00
0.0
-250.00
-500.00
-750.00
-1000.0
1.00E+04
1.03E+04
1.05E+04
1.08E+04
1.10E+04
1.13E+04
1.13E+04
TIME(SECONDS)
5/23/80

Figure 193

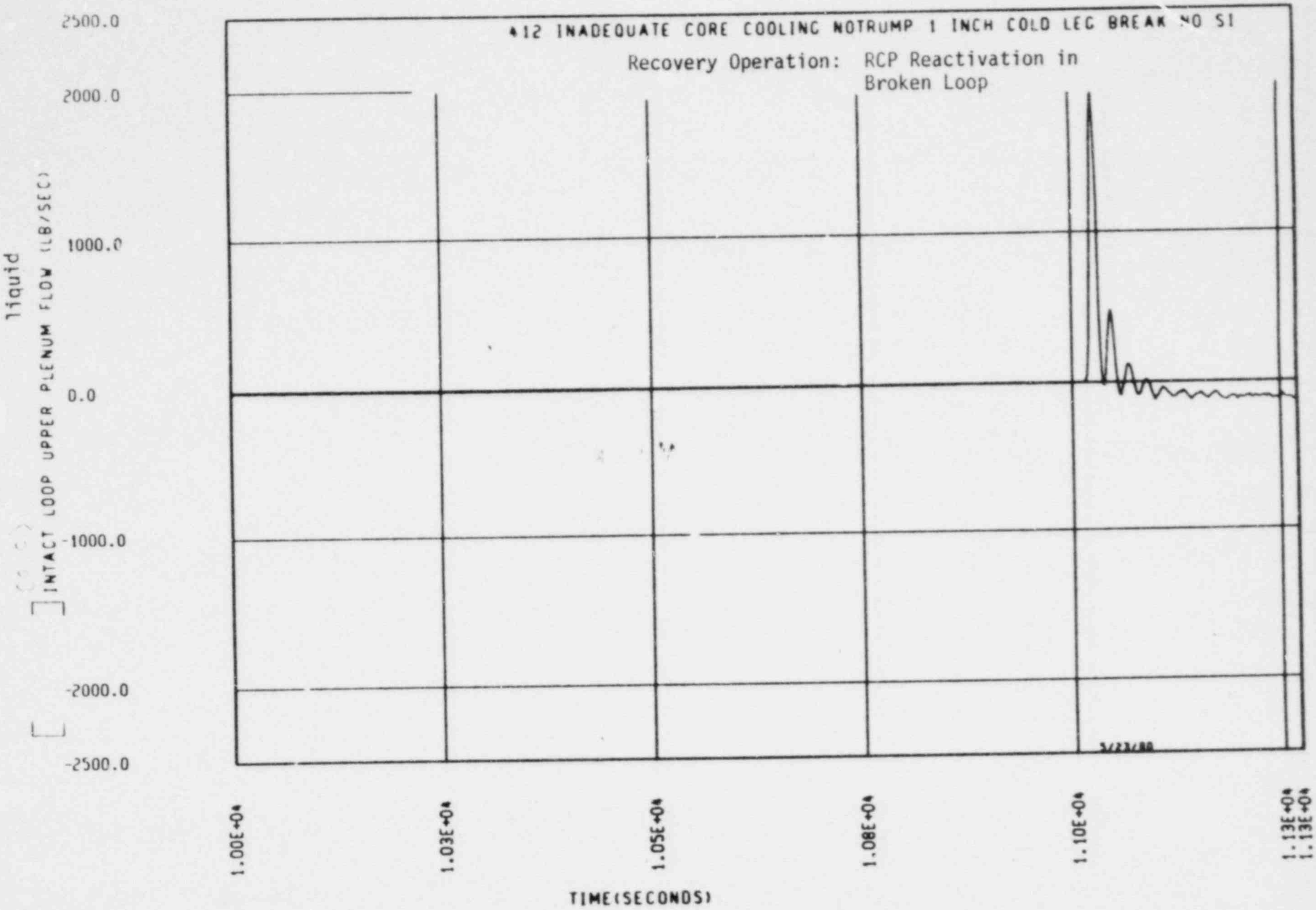

4.12 INADEQUATE CORE COOLING NOTRUMP 1 INCH COLD LEG BREAK NO SI
Recovery Operation: RCP Reactivation in Broken Loop
liquid
INTACT LOOP UPPER PLENUM FLOW (LB/SEC)
2500.0
2000.0
1000.0
0.0
-1000.0
-2000.0
-2500.0
1.00E+04
1.03E+04
1.05E+04
1.08E+04
1.10E+04
1.13E+04
1.13E+04
TIME(SECONDS)
5/23/80

Figure 194

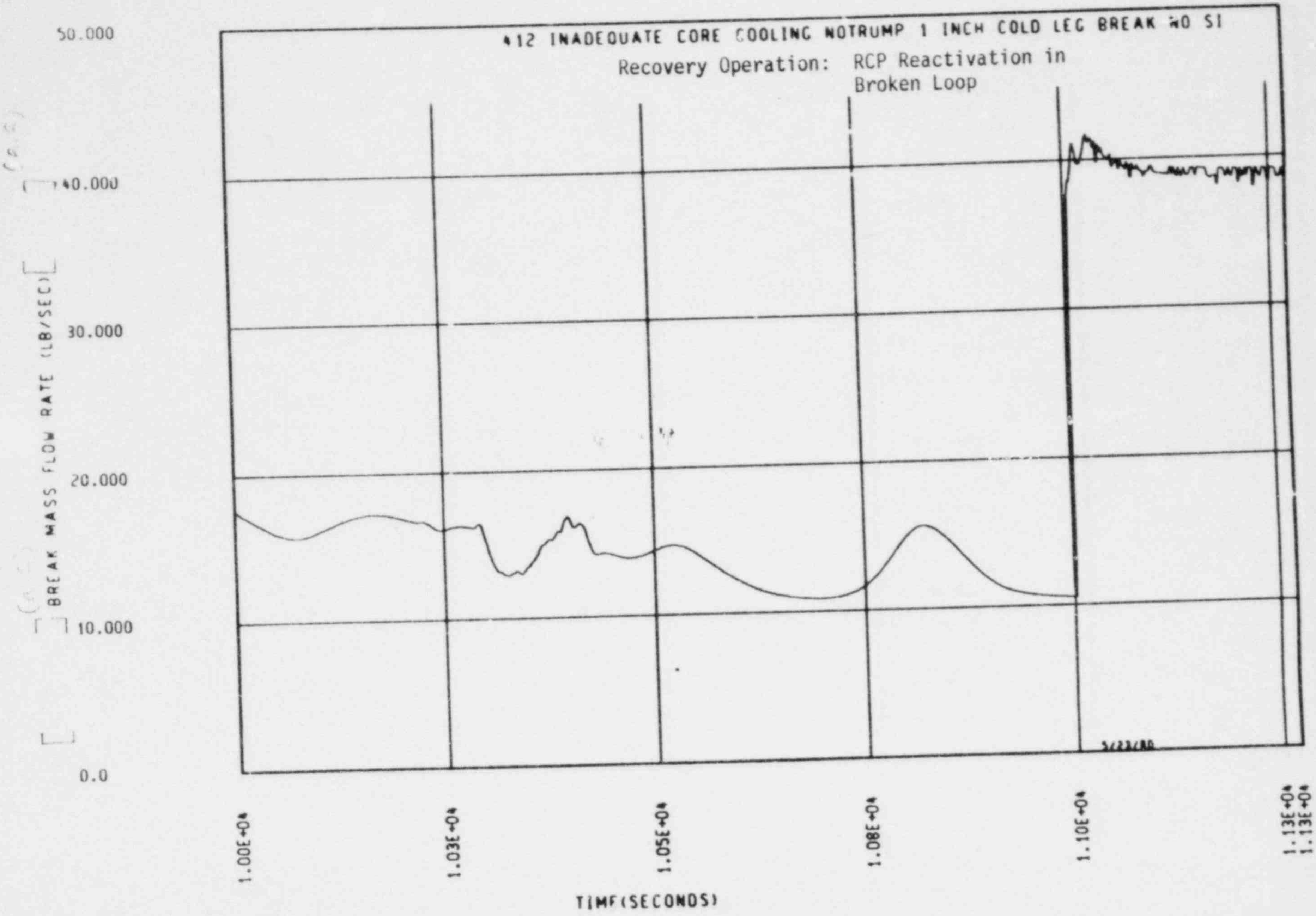
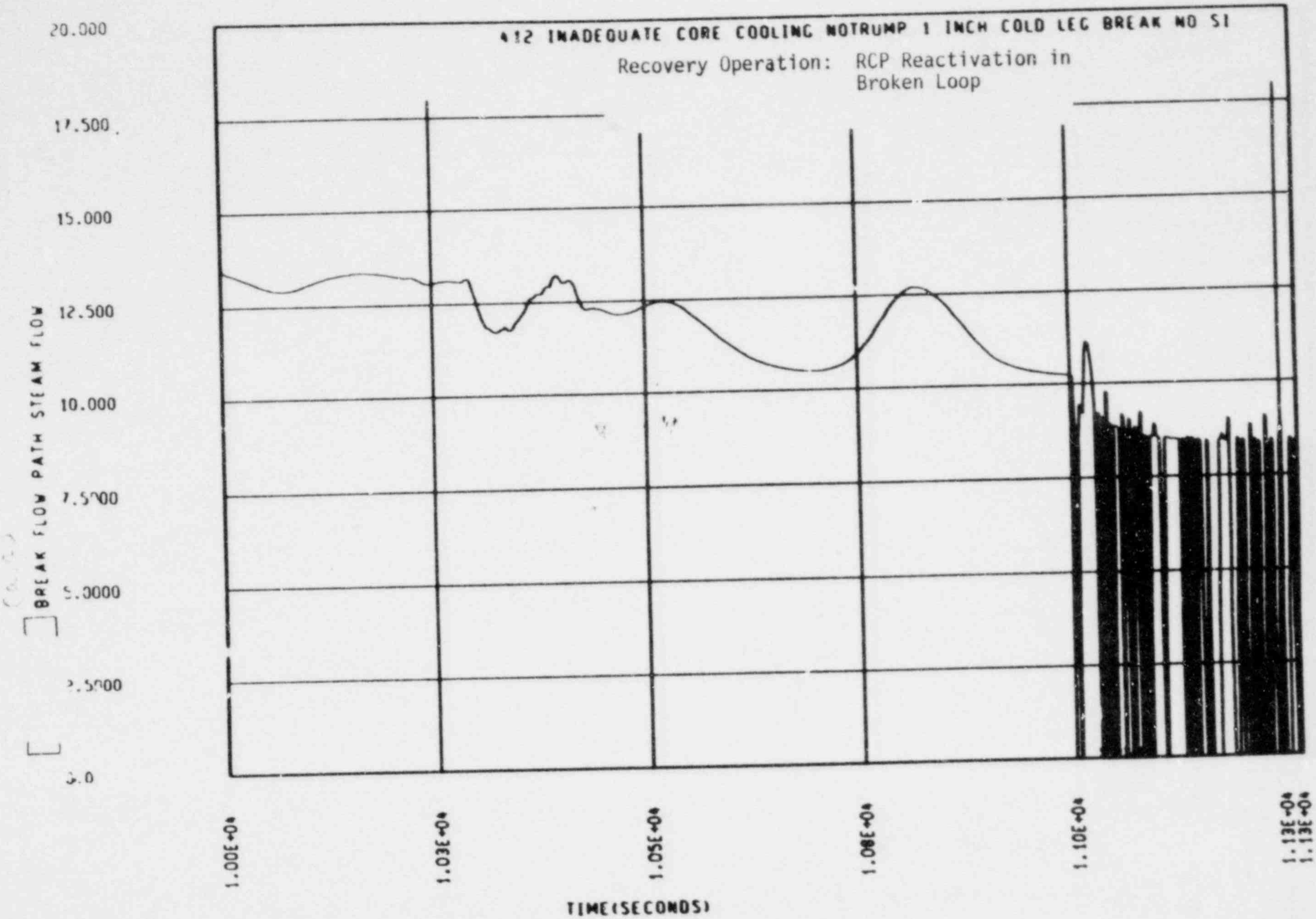

412 INADEQUATE CORE COOLING NOTRUMP 1 INCH COLD LEG BREAK NO SI
Recovery Operation: RCP Reactivation in Broken Loop
50.000
40.000
30.000
20.000
10.000
0.0
BREAK MASS FLOW RATE (LB/SEC)
1.00E+04
1.03E+04
1.05E+04
1.08E+04
1.10E+04
1.13E+04
1.13E+04
TIME(SECONDS)
5/23/80

Figure 195



412 INADEQUATE CORE COOLING NOTRUMP 1 INCH COLD LEG BREAK NO SI
Recovery Operation: RCP Reactivation in Broken Loop
BREAK FLOW PATH STEAM FLOW
20.000
17.500
15.000
12.500
10.000
7.5000
5.0000
2.5000
0.0
1.00E+04
1.03E+04
1.05E+04
1.08E+04
1.10E+04
1.13E+04
1.13E+04
TIME(SECONDS)

Figure 196

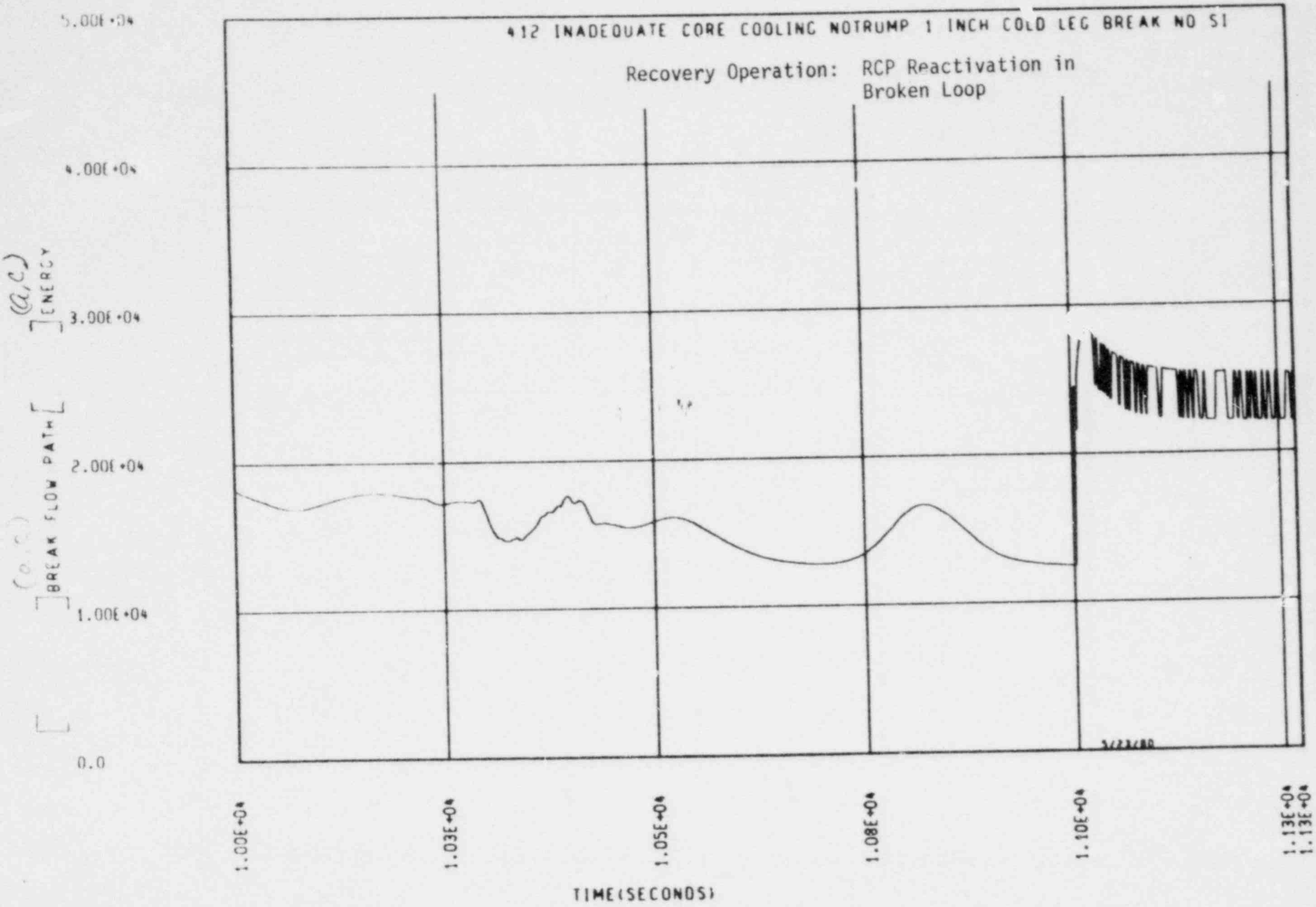

412 INADEQUATE CORE COOLING NOTRUMP 1 INCH COLD LEG BREAK NO SI
Recovery Operation: RCP Reactivation in Broken Loop
5.00E+04
4.00E+04
3.00E+04
2.00E+04
1.00E+04
0.0
BREAK FLOW PATH ENERGY
(a,c)
(a,c)
1.00E+04
1.03E+04
1.05E+04
1.08E+04
1.10E+04
1.13E+04
1.13E+04
TIME(SECONDS)
5/23/80

Figure 197

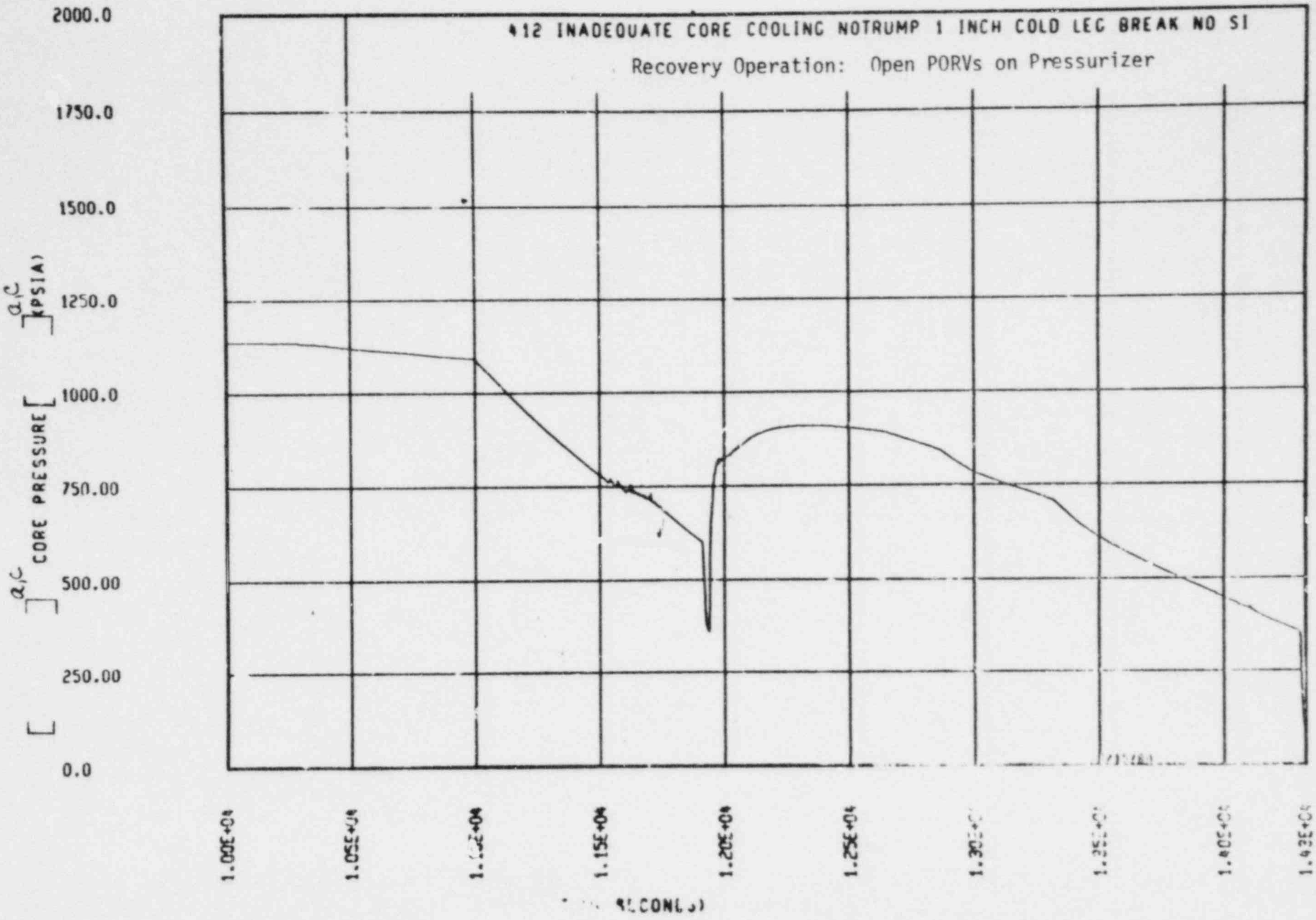

412 INADEQUATE CORE COOLING NOTRUMP 1 INCH COLD LEG BREAK NO SI
Recovery Operation: Open PORVs on Pressurizer
CORE PRESSURE (PSIA)
a,c
a,c
2000.0
1750.0
1500.0
1250.0
1000.0
750.00
500.00
250.00
0.0
1.00E+04
1.05E+04
1.10E+04
1.15E+04
1.20E+04
1.25E+04
1.30E+04
1.35E+04
1.40E+04
1.43E+04
SECONDS)

Figure 198

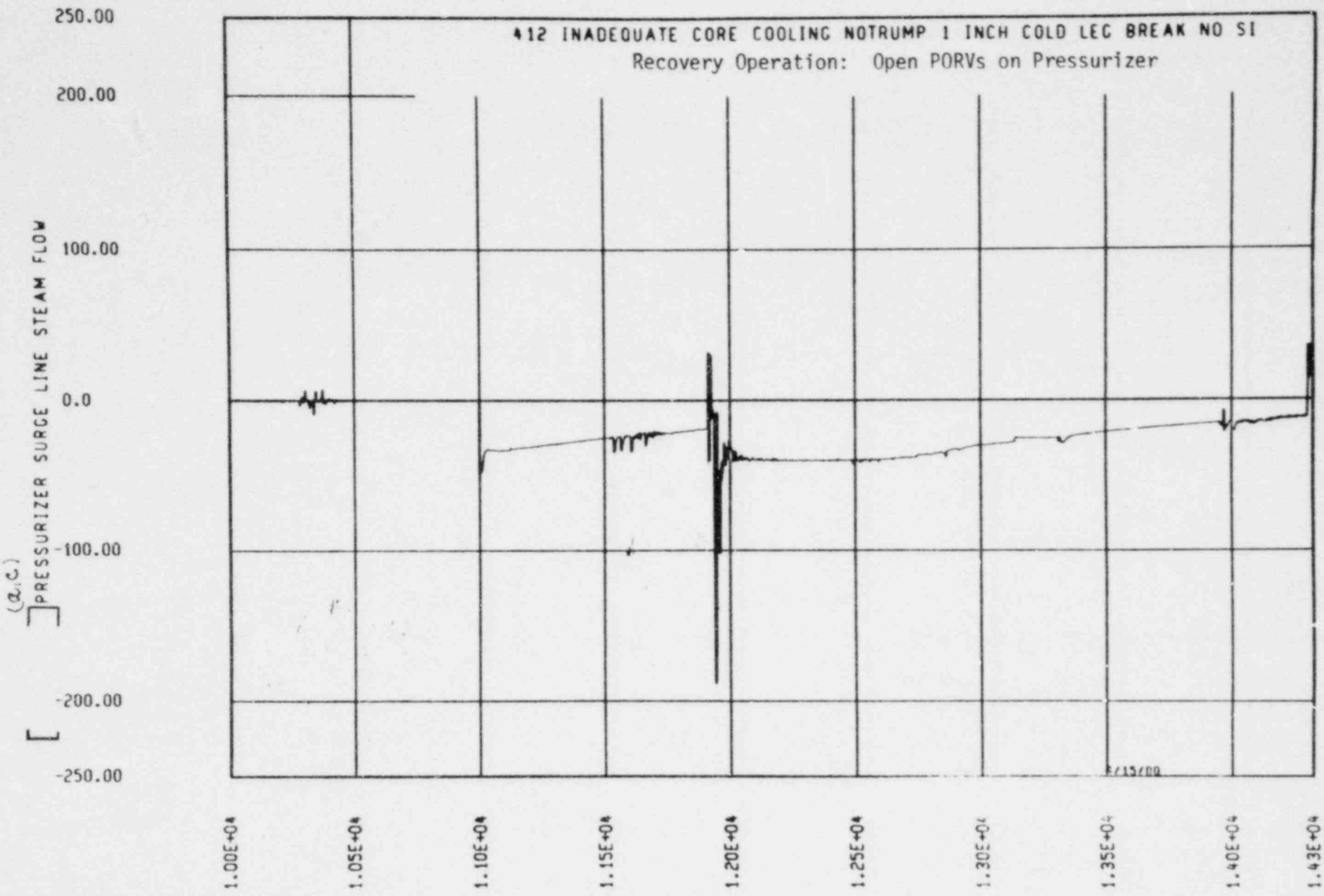

412 INADEQUATE CORE COOLING NOTRUMP 1 INCH COLD LEG BREAK NO SI
Recovery Operation: Open PORVs on Pressurizer

Figure 199

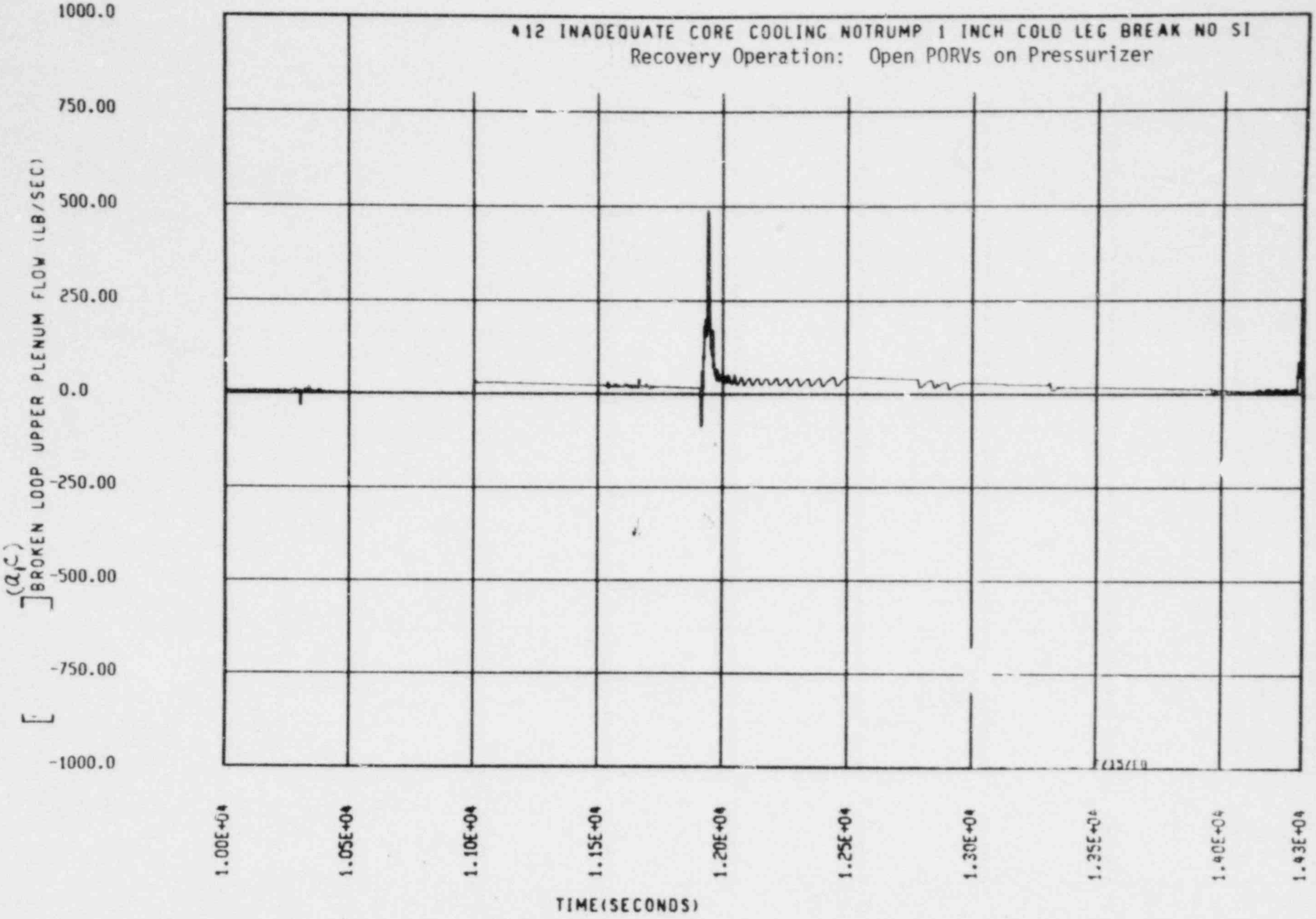

412 INADEQUATE CORE COOLING NOTRUMP 1 INCH COLD LEG BREAK NO SI
Recovery Operation: Open PORVs on Pressurizer
BROKEN LOOP UPPER PLENUM FLOW (LB/SEC)
(a,c)
1000.0
750.00
500.00
250.00
0.0
-250.00
-500.00
-750.00
-1000.0
1.00E+04
1.05E+04
1.10E+04
1.15E+04
1.20E+04
1.25E+04
1.30E+04
1.35E+04
1.40E+04
1.43E+04
TIME(SECONDS)

Figure 200

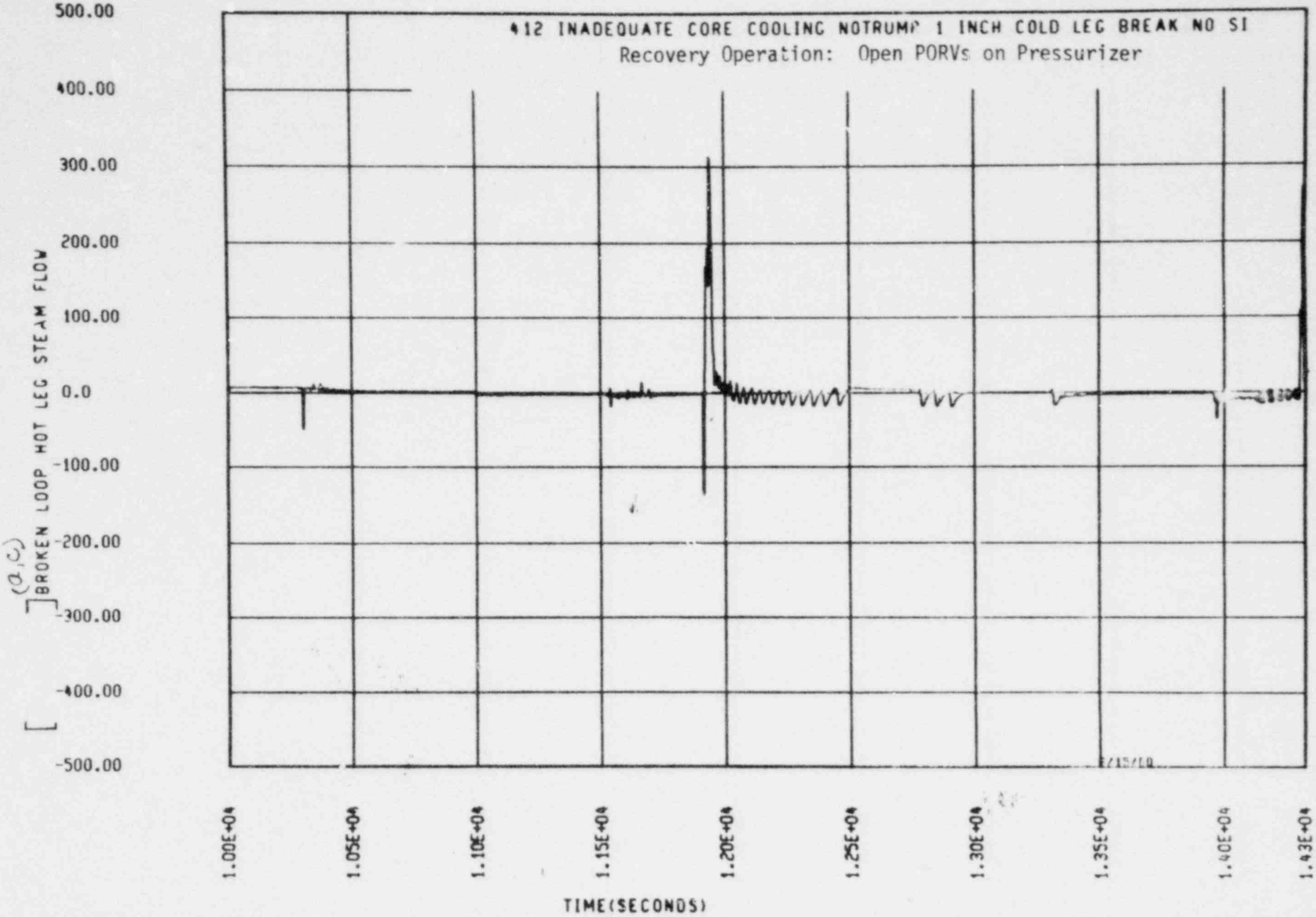

412 INADEQUATE CORE COOLING NOTRUMP 1 INCH COLD LEG BREAK NO SI
Recovery Operation: Open PORVs on Pressurizer
BROKEN LOOP HOT LEG STEAM FLOW
(a,c)
500.00
400.00
300.00
200.00
100.00
0.0
-100.00
-200.00
-300.00
-400.00
-500.00
1.00E+04
1.05E+04
1.10E+04
1.15E+04
1.20E+04
1.25E+04
1.30E+04
1.35E+04
1.40E+04
1.43E+04
TIME(SECONDS)

Figure 201

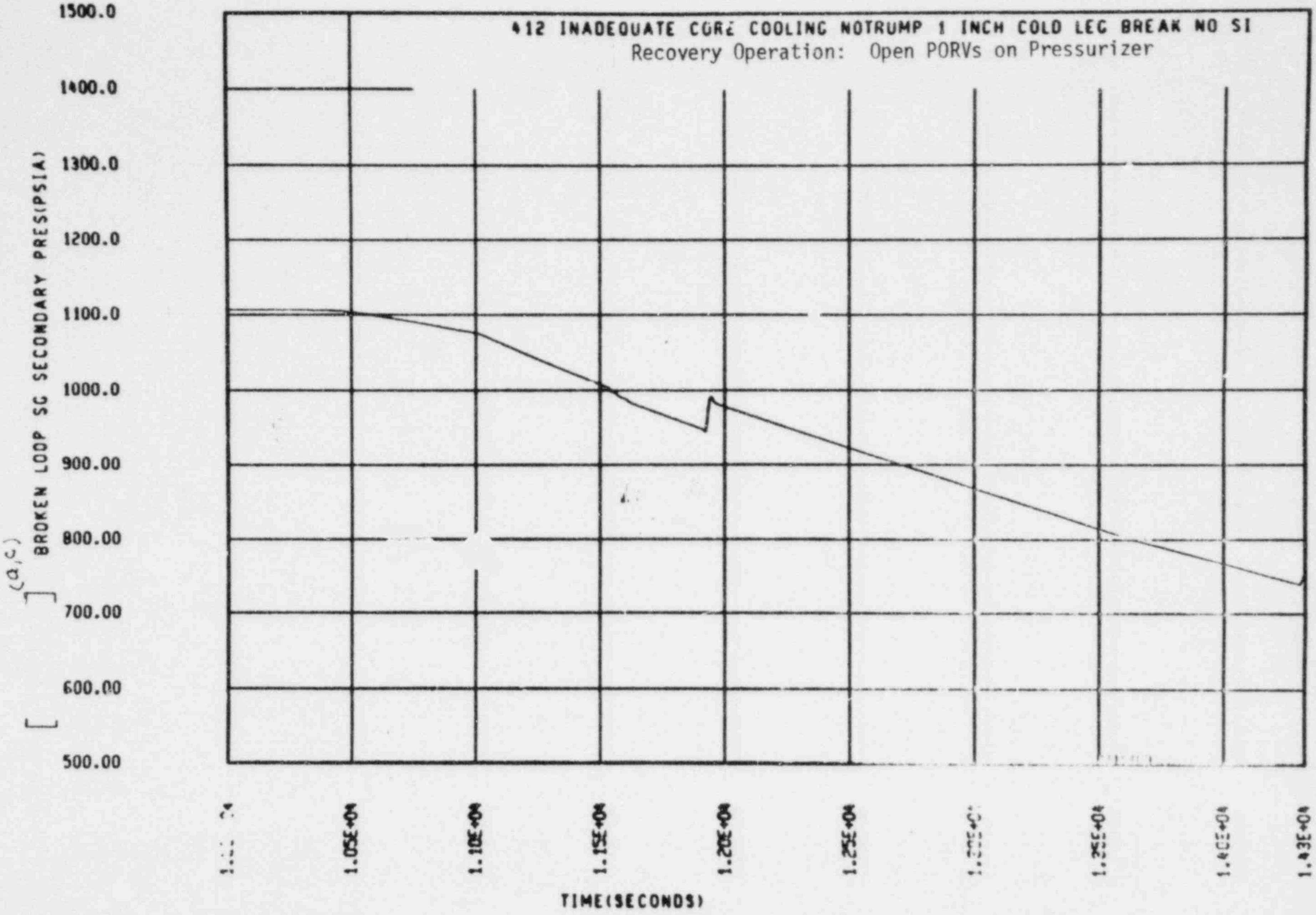

412 INADEQUATE CORE COOLING NOTRUMP 1 INCH COLD LEG BREAK NO SI
Recovery Operation: Open PORVs on Pressurizer
BROKEN LOOP SG SECONDARY PRES(PSIA)
[ ]^(a,c)
1500.0
1400.0
1300.0
1200.0
1100.0
1000.0
900.00
800.00
700.00
600.00
500.00
1.05E+04
1.10E+04
1.15E+04
1.20E+04
1.25E+04
1.30E+04
1.35E+04
1.40E+04
1.43E+04
TIME(SECONDS)

Figure 202

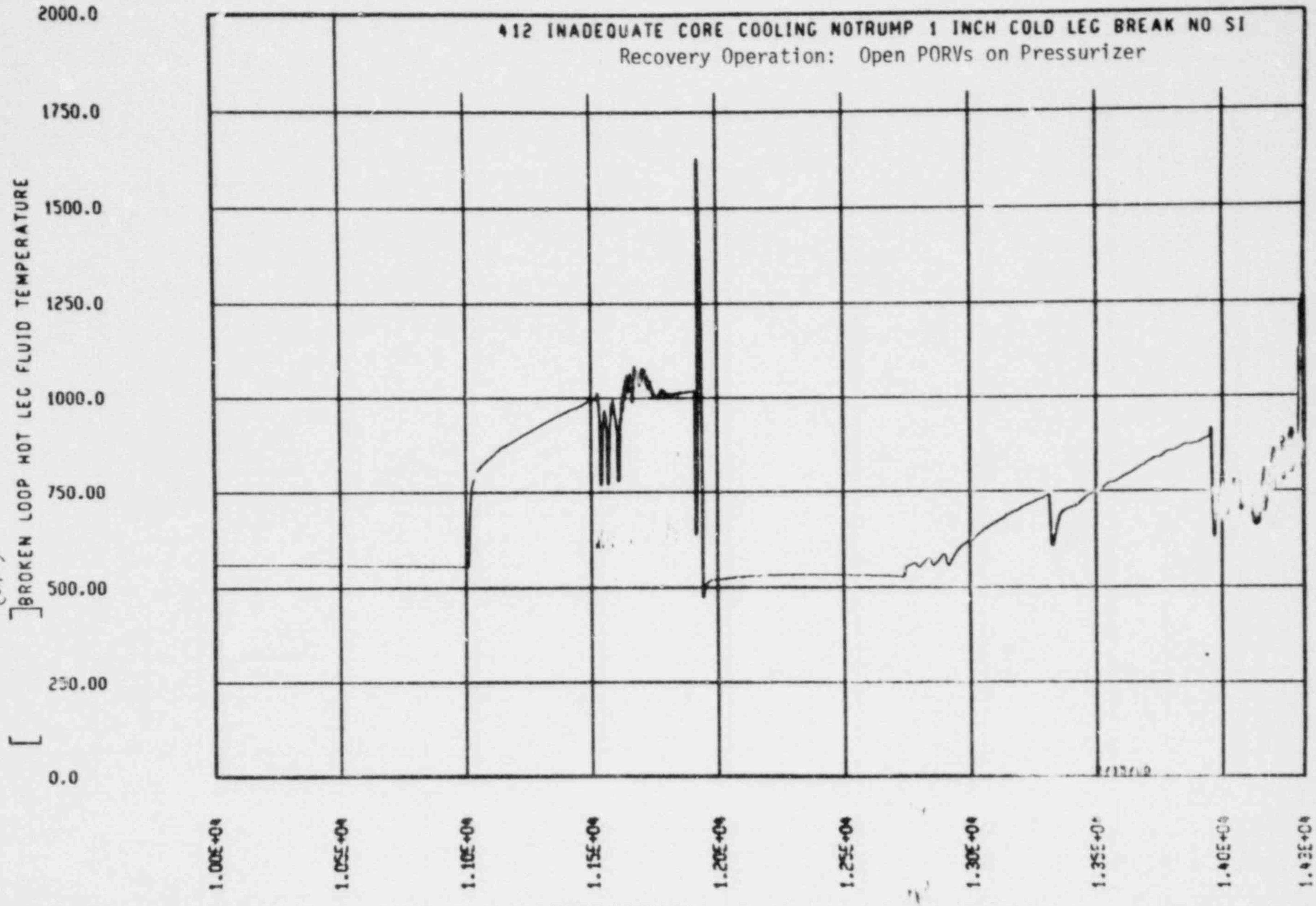

412 INADEQUATE CORE COOLING NOTRUMP 1 INCH COLD LEG BREAK NO SI
Recovery Operation: Open PORVs on Pressurizer
[
]BROKEN LOOP HOT LEG FLUID TEMPERATURE
(a,c)
2000.0
1750.0
1500.0
1250.0
1000.0
750.00
500.00
250.00
0.0
1.00E+04
1.05E+04
1.10E+04
1.15E+04
1.20E+04
1.25E+04
1.30E+04
1.35E+04
1.40E+04
1.43E+04
TIME(SECONDS)

Figure 203

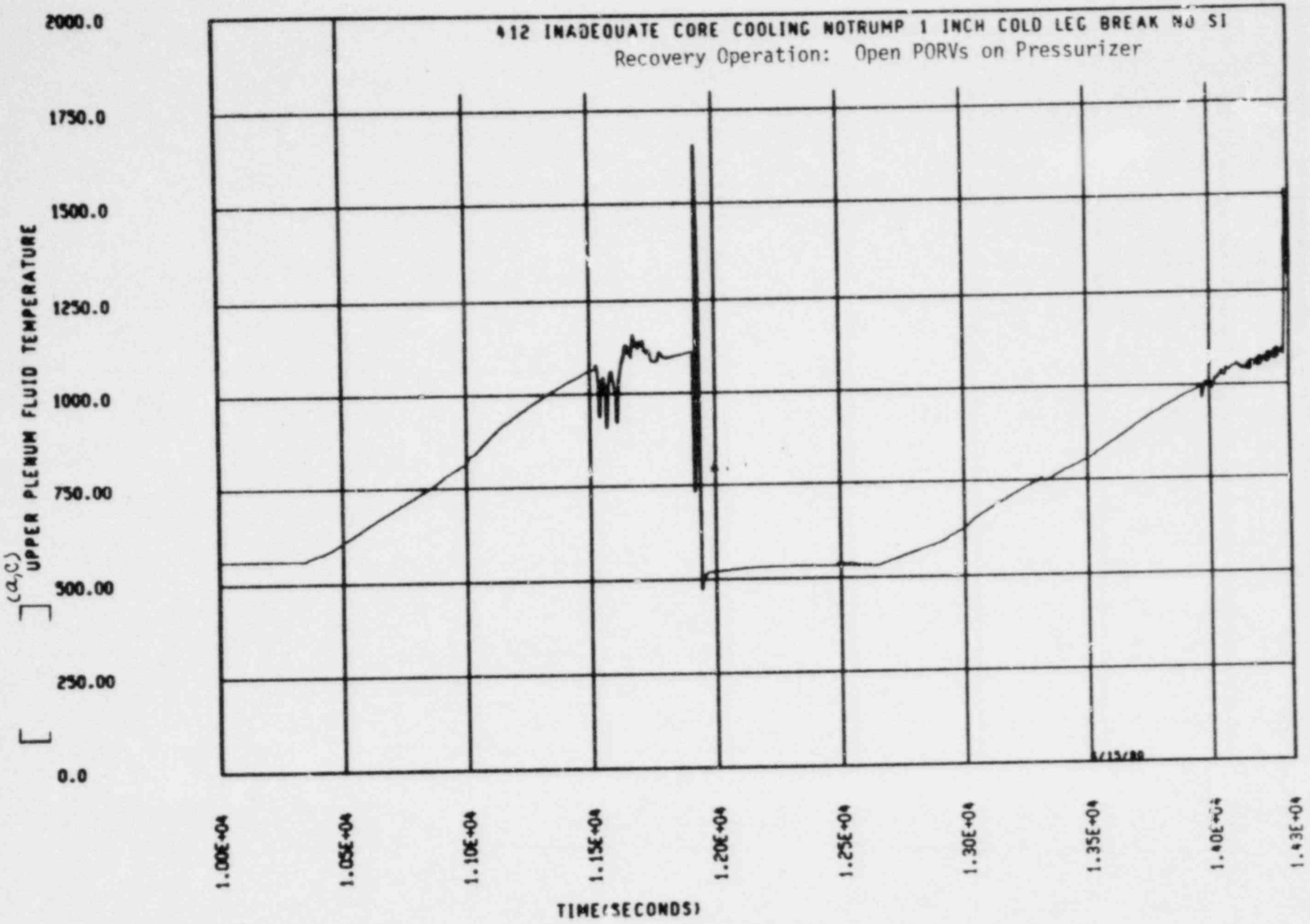

412 INADEQUATE CORE COOLING NOTRUMP 1 INCH COLD LEG BREAK NO SI
Recovery Operation: Open PORVs on Pressurizer
UPPER PLENUM FLUID TEMPERATURE
(a,c)
2000.0
1750.0
1500.0
1250.0
1000.0
750.00
500.00
250.00
0.0
1.00E+04
1.05E+04
1.10E+04
1.15E+04
1.20E+04
1.25E+04
1.30E+04
1.35E+04
1.40E+04
1.43E+04
TIME(SECONDS)

Figure 204

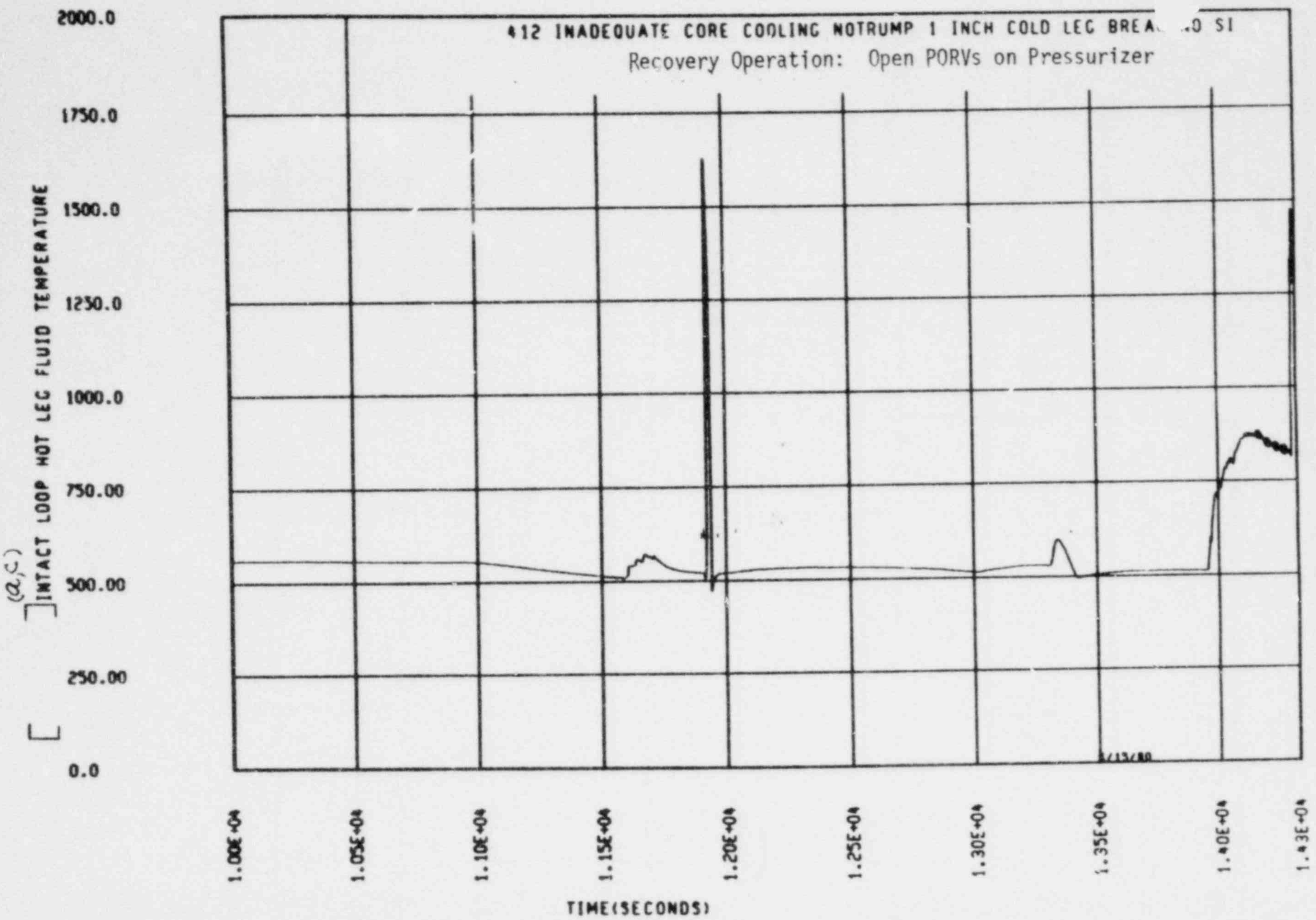

412 INADEQUATE CORE COOLING NOTRUMP 1 INCH COLD LEG BREA .O SI
Recovery Operation: Open PORVs on Pressurizer
(a,c)
INTACT LOOP HOT LEG FLUID TEMPERATURE
2000.0
1750.0
1500.0
1250.0
1000.0
750.00
500.00
250.00
0.0
1.00E+04
1.05E+04
1.10E+04
1.15E+04
1.20E+04
1.25E+04
1.30E+04
1.35E+04
1.40E+04
1.43E+04
TIME(SECONDS)
3/13/80

Figure 205

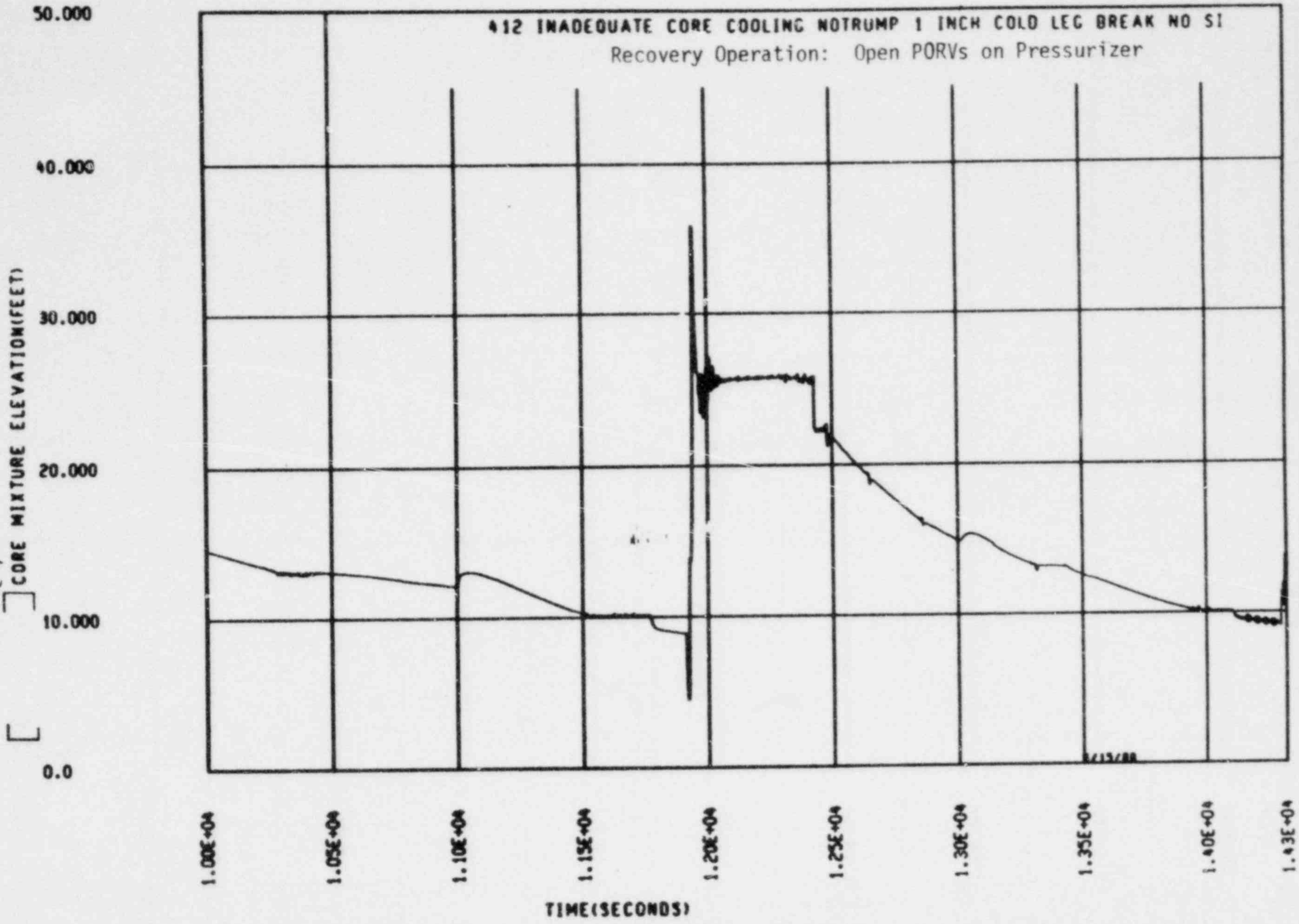

412 INADEQUATE CORE COOLING NOTRUMP 1 INCH COLD LEG BREAK NO SI
Recovery Operation: Open PORVs on Pressurizer
50.000
40.000
30.000
20.000
10.000
0.0
(a,c)
CORE MIXTURE ELEVATION(FEET)
1.00E+04
1.05E+04
1.10E+04
1.15E+04
1.20E+04
1.25E+04
1.30E+04
1.35E+04
1.40E+04
1.43E+04
TIME(SECONDS)

Figure 206

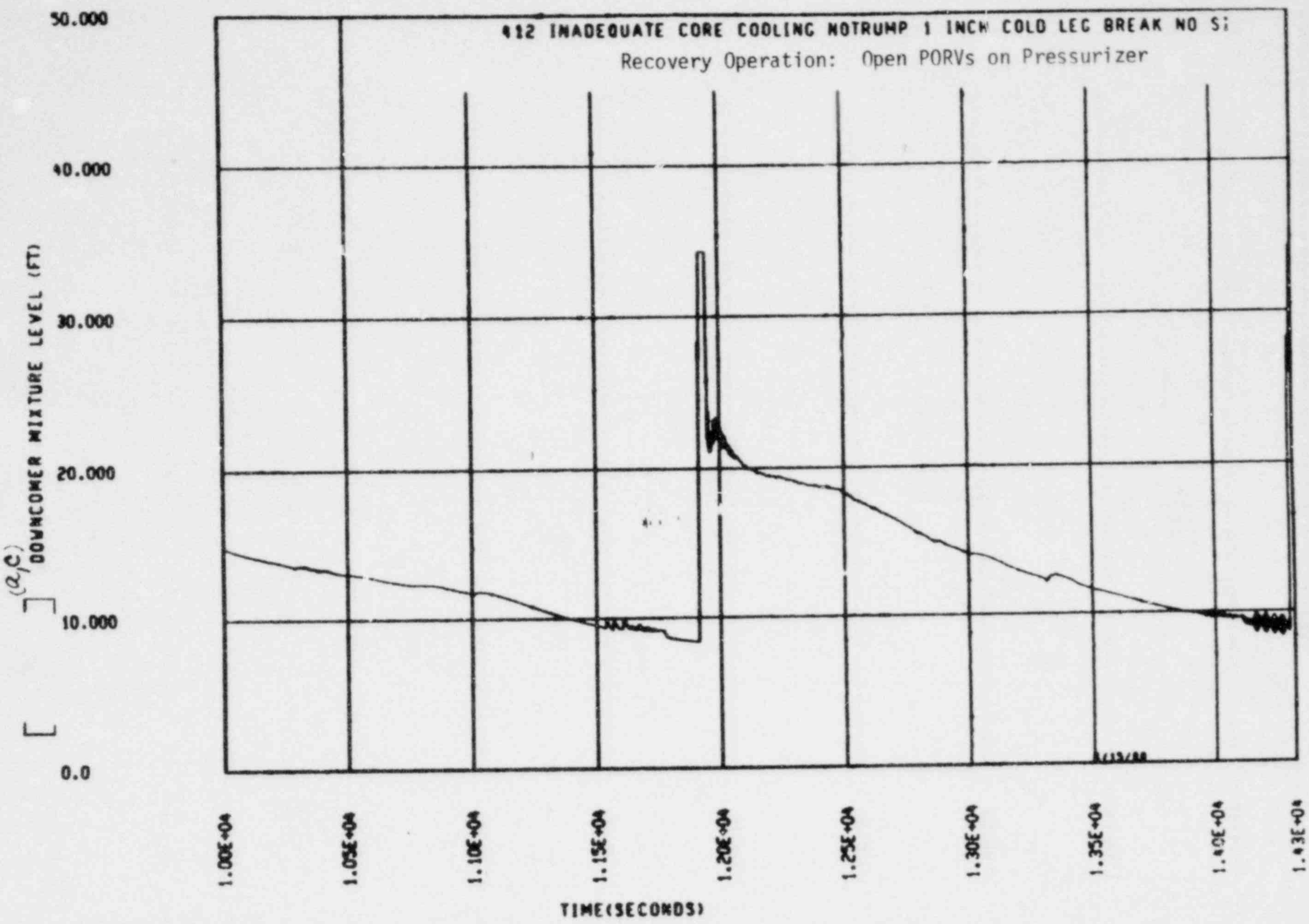

412 INADEQUATE CORE COOLING NOTRUMP 1 INCH COLD LEG BREAK NO SI
Recovery Operation: Open PORVs on Pressurizer
DOWNCOMER MIXTURE LEVEL (FT)
(a,c)
50.000
40.000
30.000
20.000
10.000
0.0
1.00E+04
1.05E+04
1.10E+04
1.15E+04
1.20E+04
1.25E+04
1.30E+04
1.35E+04
1.40E+04
1.43E+04
TIME(SECONDS)

Figure 207

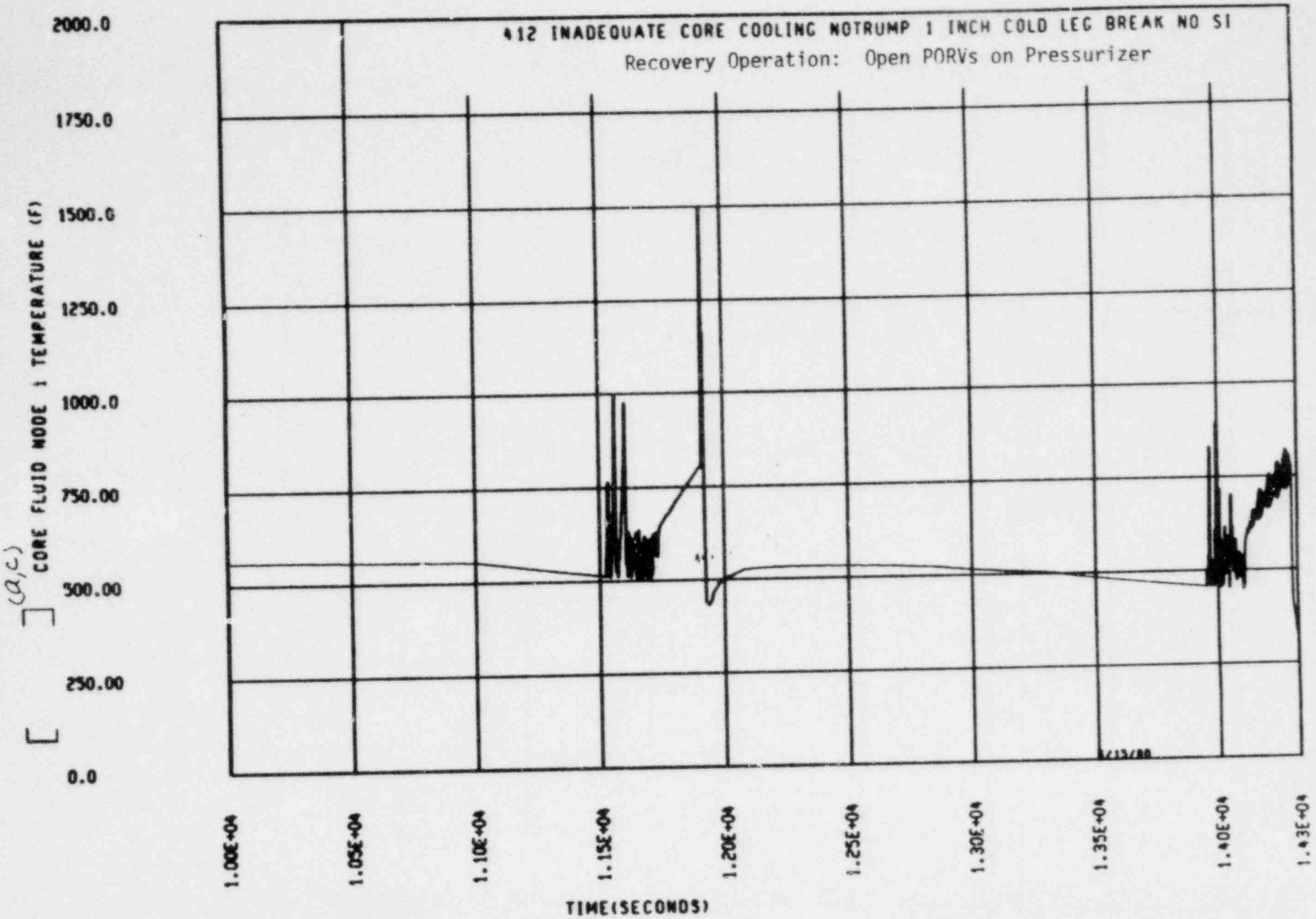

412 INADEQUATE CORE COOLING NOTRUMP 1 INCH COLD LEG BREAK NO SI
Recovery Operation: Open PORVs on Pressurizer
CORE FLUID NODE 1 TEMPERATURE (F)
(a,c)
2000.0
1750.0
1500.0
1250.0
1000.0
750.00
500.00
250.00
0.0
1.00E+04
1.05E+04
1.10E+04
1.15E+04
1.20E+04
1.25E+04
1.30E+04
1.35E+04
1.40E+04
1.43E+04
TIME(SECONDS)

Figure 208

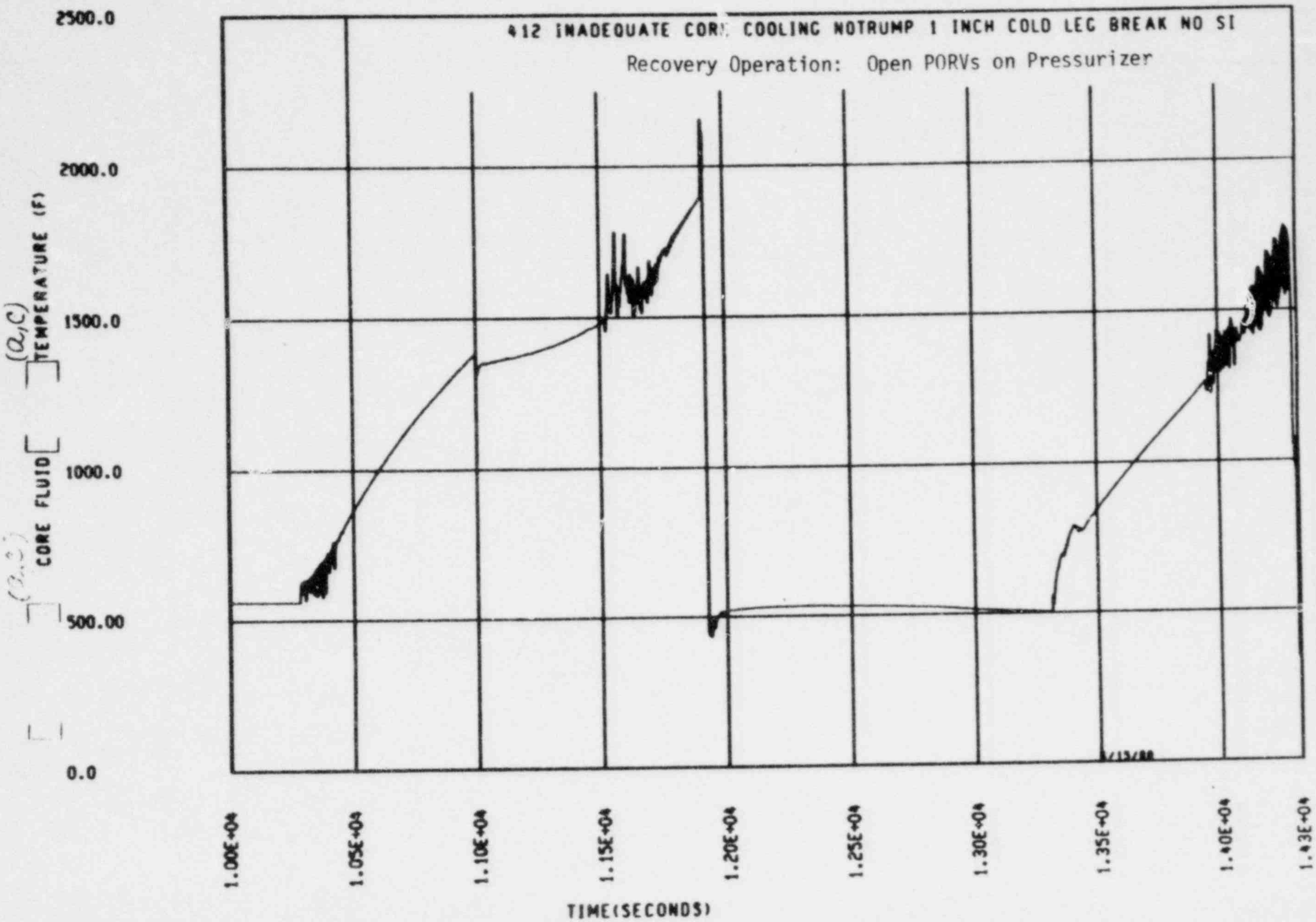

412 INADEQUATE CORE COOLING NOTRUMP 1 INCH COLD LEG BREAK NO SI
Recovery Operation: Open PORVs on Pressurizer
CORE FLUID TEMPERATURE (F)
(a,c)
(a,c)
2500.0
2000.0
1500.0
1000.0
500.00
0.0
1.00E+04
1.05E+04
1.10E+04
1.15E+04
1.20E+04
1.25E+04
1.30E+04
1.35E+04
1.40E+04
1.43E+04
TIME(SECONDS)
/13/88

Figure 209

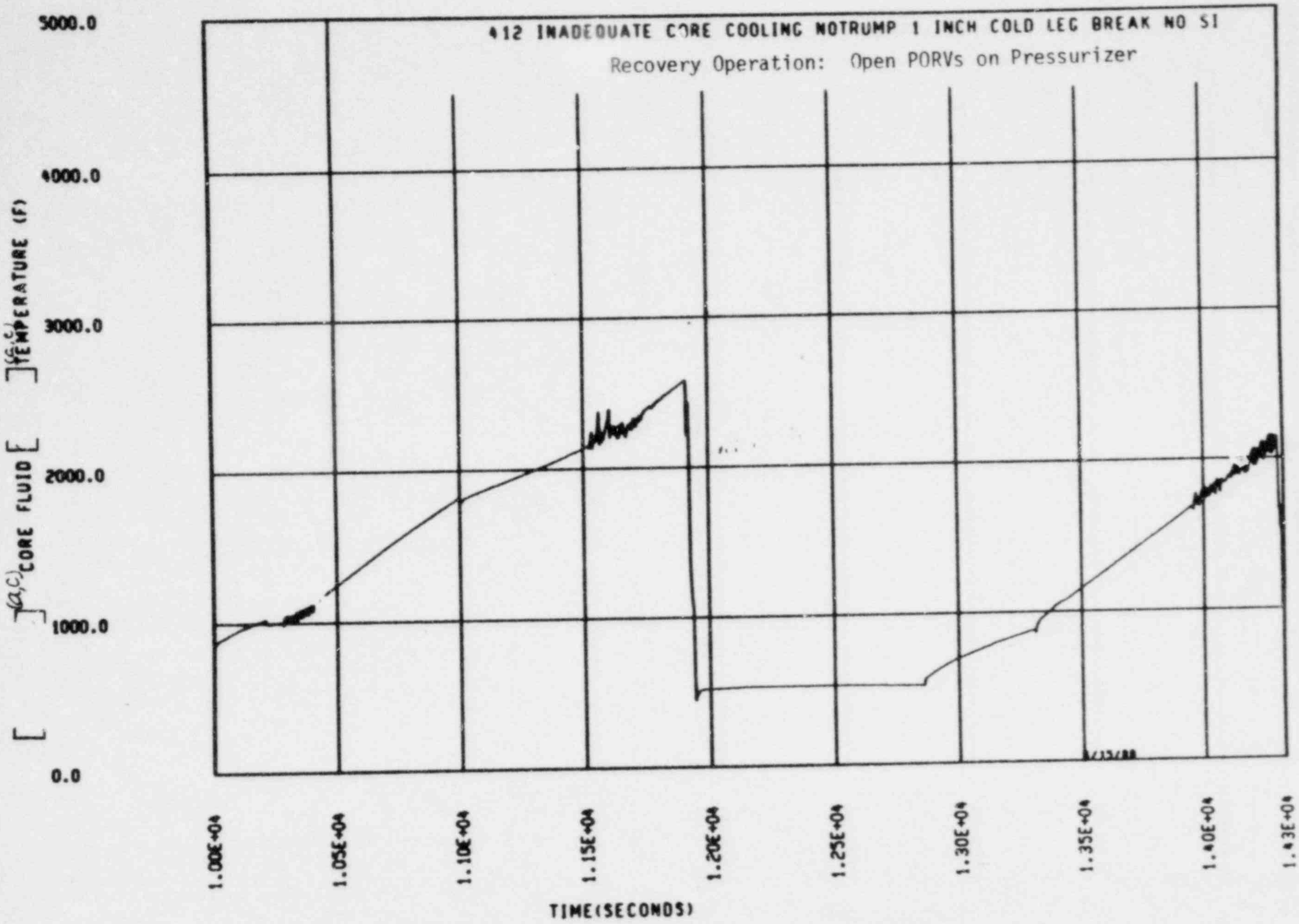

412 INADEQUATE CORE COOLING NOTRUMP 1 INCH COLD LEG BREAK NO SI
Recovery Operation: Open PORVs on Pressurizer
(a,c) CORE FLUID (a,c) TEMPERATURE (F)
5000.0
4000.0
3000.0
2000.0
1000.0
0.0
1.00E+04
1.05E+04
1.10E+04
1.15E+04
1.20E+04
1.25E+04
1.30E+04
1.35E+04
1.40E+04
1.43E+04
TIME(SECONDS)

Figure 210

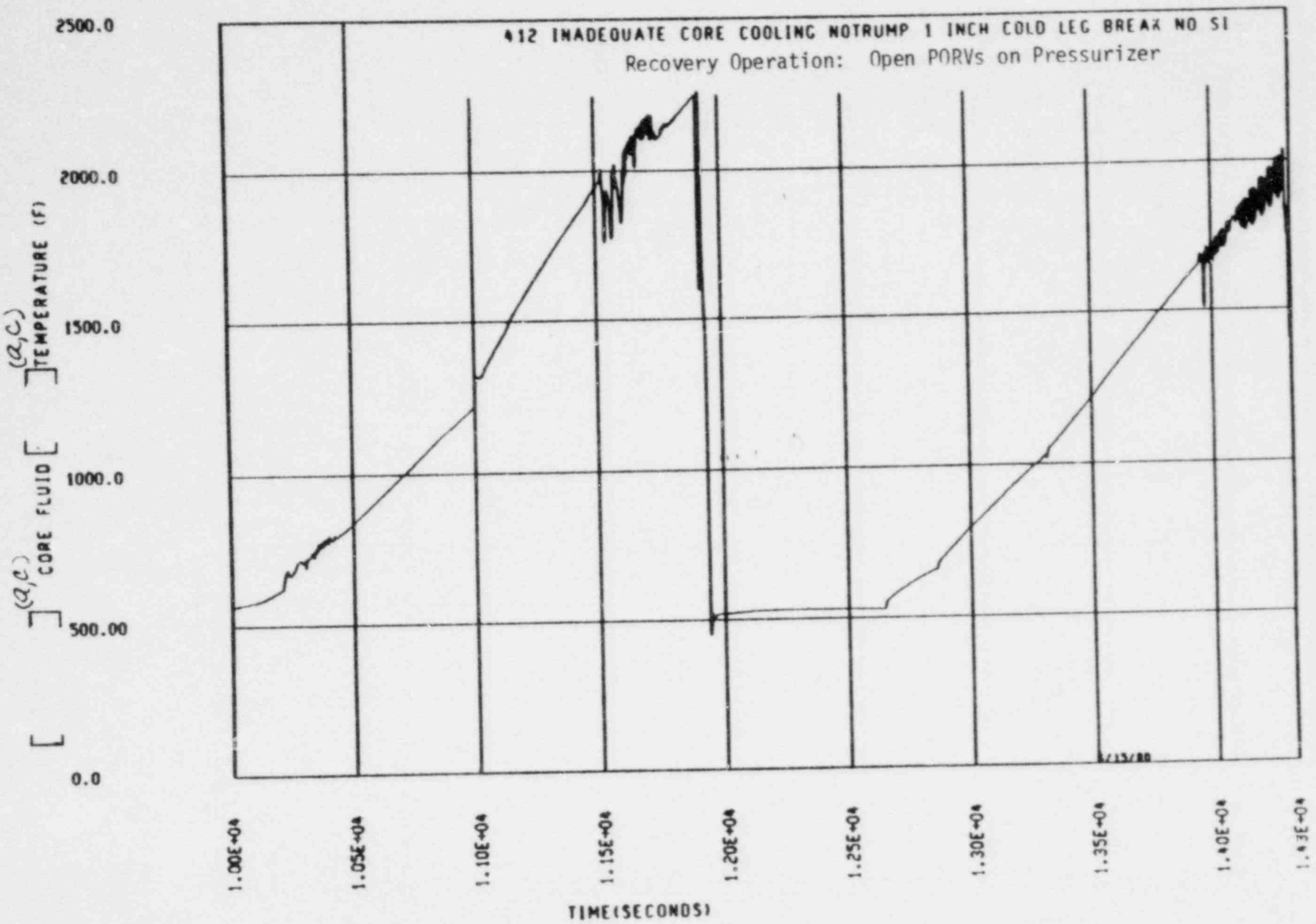

412 INADEQUATE CORE COOLING NOTRUMP 1 INCH COLD LEG BREAK NO SI
Recovery Operation: Open PORVs on Pressurizer
(a,c)
CORE FLUID
(a,c)
TEMPERATURE (F)
2500.0
2000.0
1500.0
1000.0
500.00
0.0
1.00E+04
1.05E+04
1.10E+04
1.15E+04
1.20E+04
1.25E+04
1.30E+04
1.35E+04
1.40E+04
1.43E+04
TIME(SECONDS)
/13/80

Figure 211

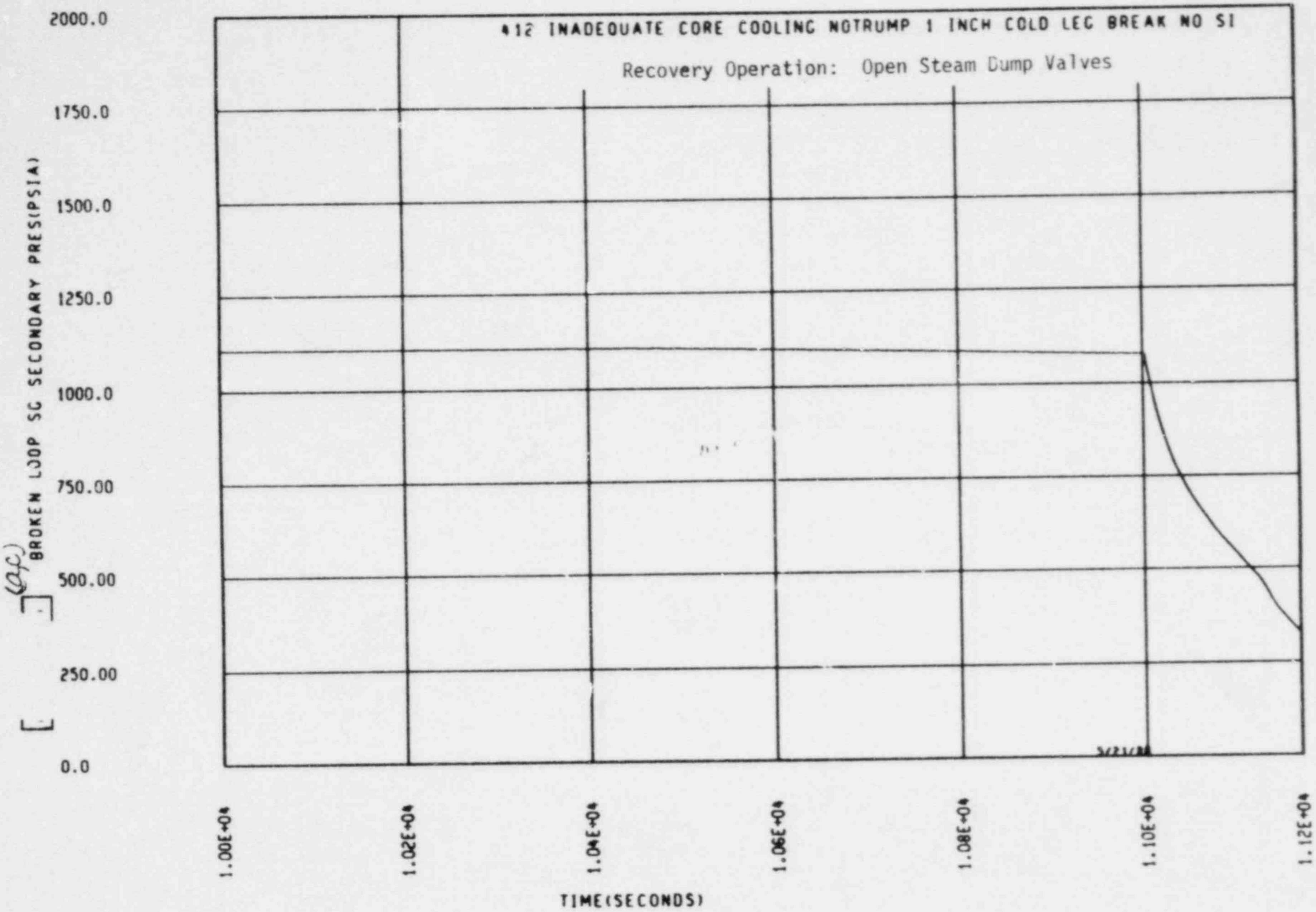

412 INADEQUATE CORE COOLING NOTRUMP 1 INCH COLD LEG BREAK NO SI
Recovery Operation: Open Steam Dump Valves
BROKEN LOOP SC SECONDARY PRES(PSIA)
(a,c)
2000.0
1750.0
1500.0
1250.0
1000.0
750.00
500.00
250.00
0.0
1.00E+04
1.02E+04
1.04E+04
1.06E+04
1.08E+04
1.10E+04
1.12E+04
TIME(SECONDS)

Figure 212

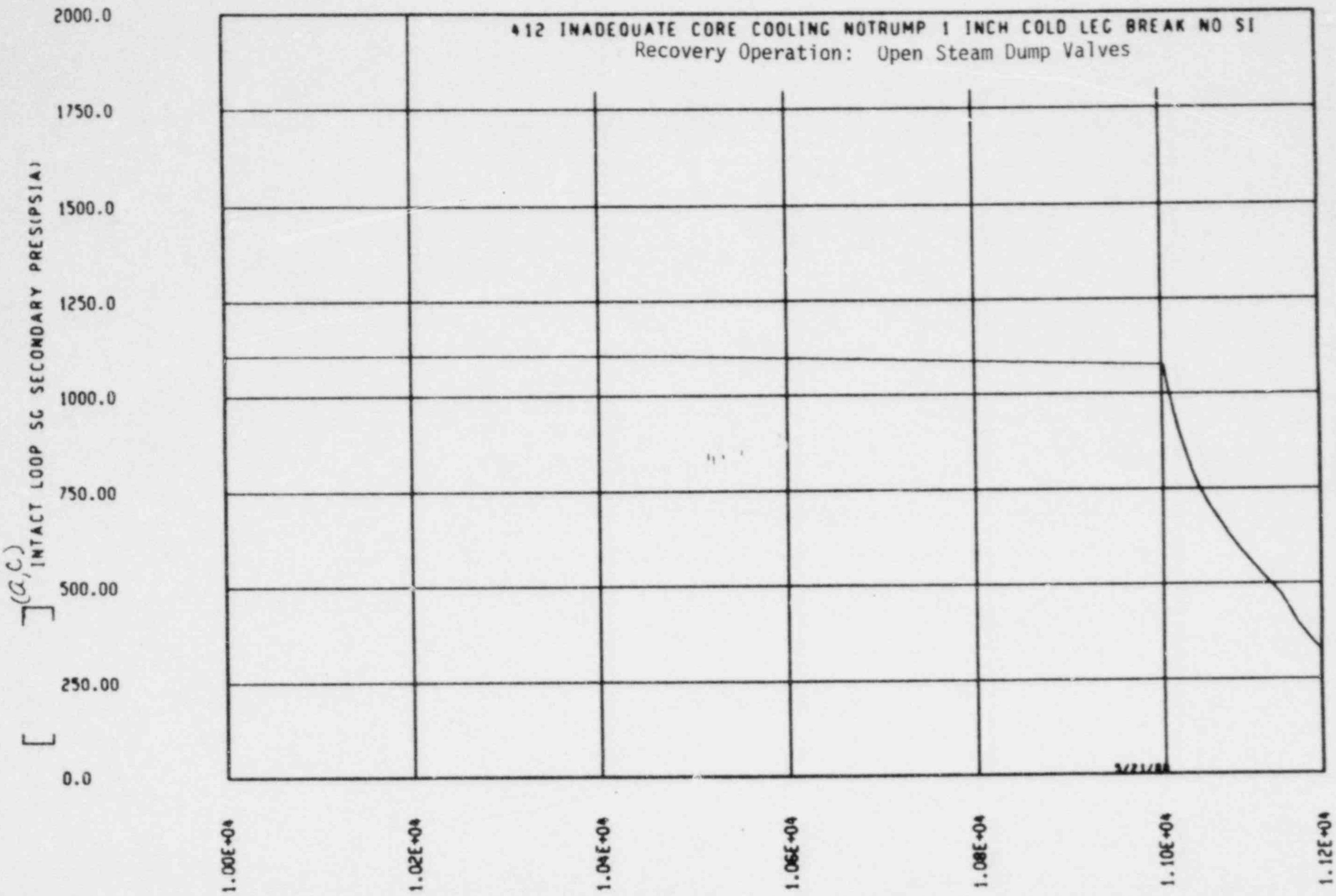

412 INADEQUATE CORE COOLING NOTRUMP 1 INCH COLD LEG BREAK NO SI
Recovery Operation: Open Steam Dump Valves
INTACT LOOP SG SECONDARY PRES(PSIA)
(a,c)
2000.0
1750.0
1500.0
1250.0
1000.0
750.00
500.00
250.00
0.0
1.00E+04
1.02E+04
1.04E+04
1.06E+04
1.08E+04
1.10E+04
1.12E+04
5/21/84
TIME(SECONDS)

Figure 213

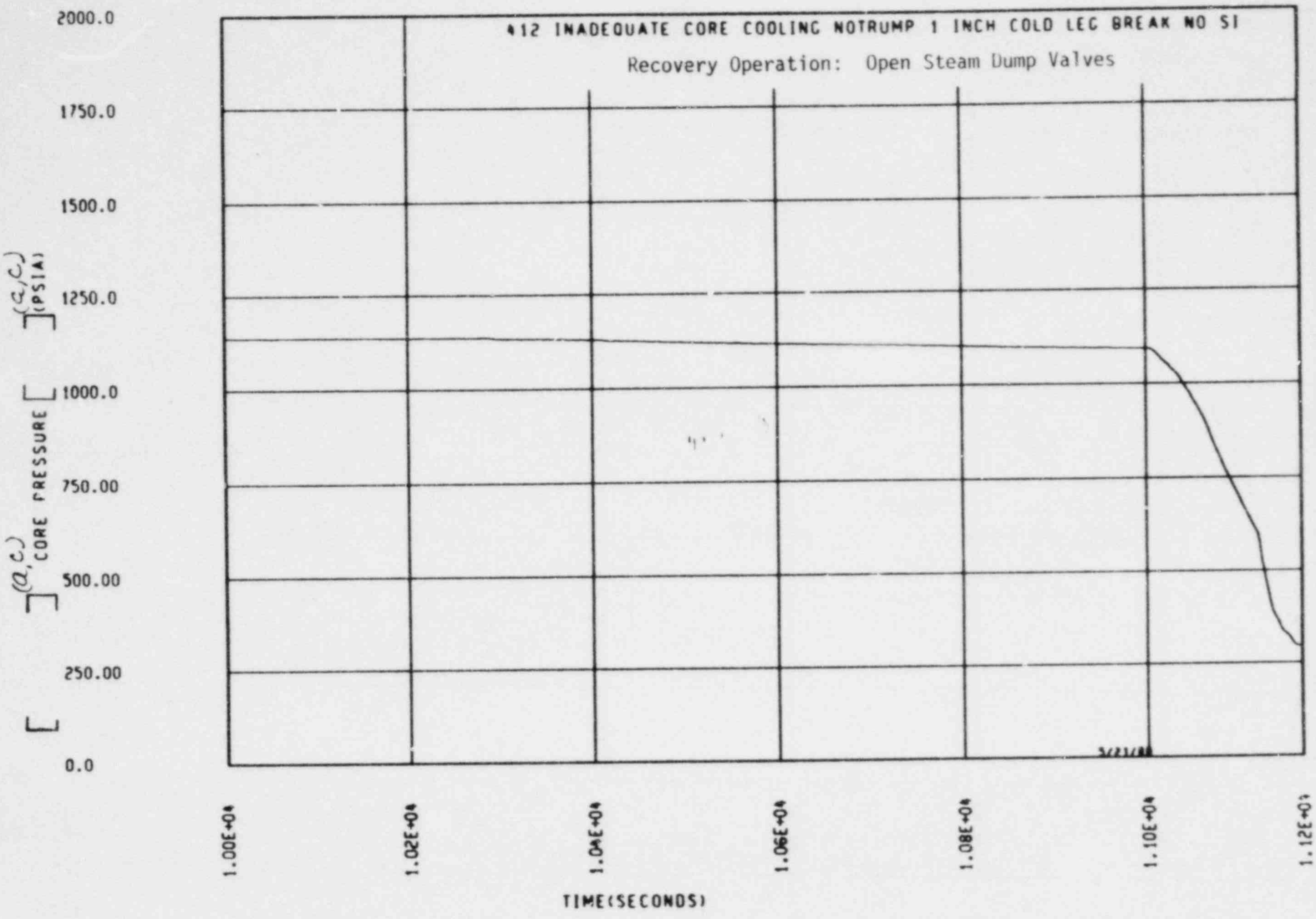

412 INADEQUATE CORE COOLING NOTRUMP 1 INCH COLD LEG BREAK NO SI
Recovery Operation: Open Steam Dump Valves
2000.0
1750.0
1500.0
1250.0
1000.0
750.00
500.00
250.00
0.0
(a,c) CORE PRESSURE (PSIA) (a,c)
1.00E+04
1.02E+04
1.04E+04
1.06E+04
1.08E+04
1.10E+04
1.12E+04
TIME(SECONDS)

Figure 214

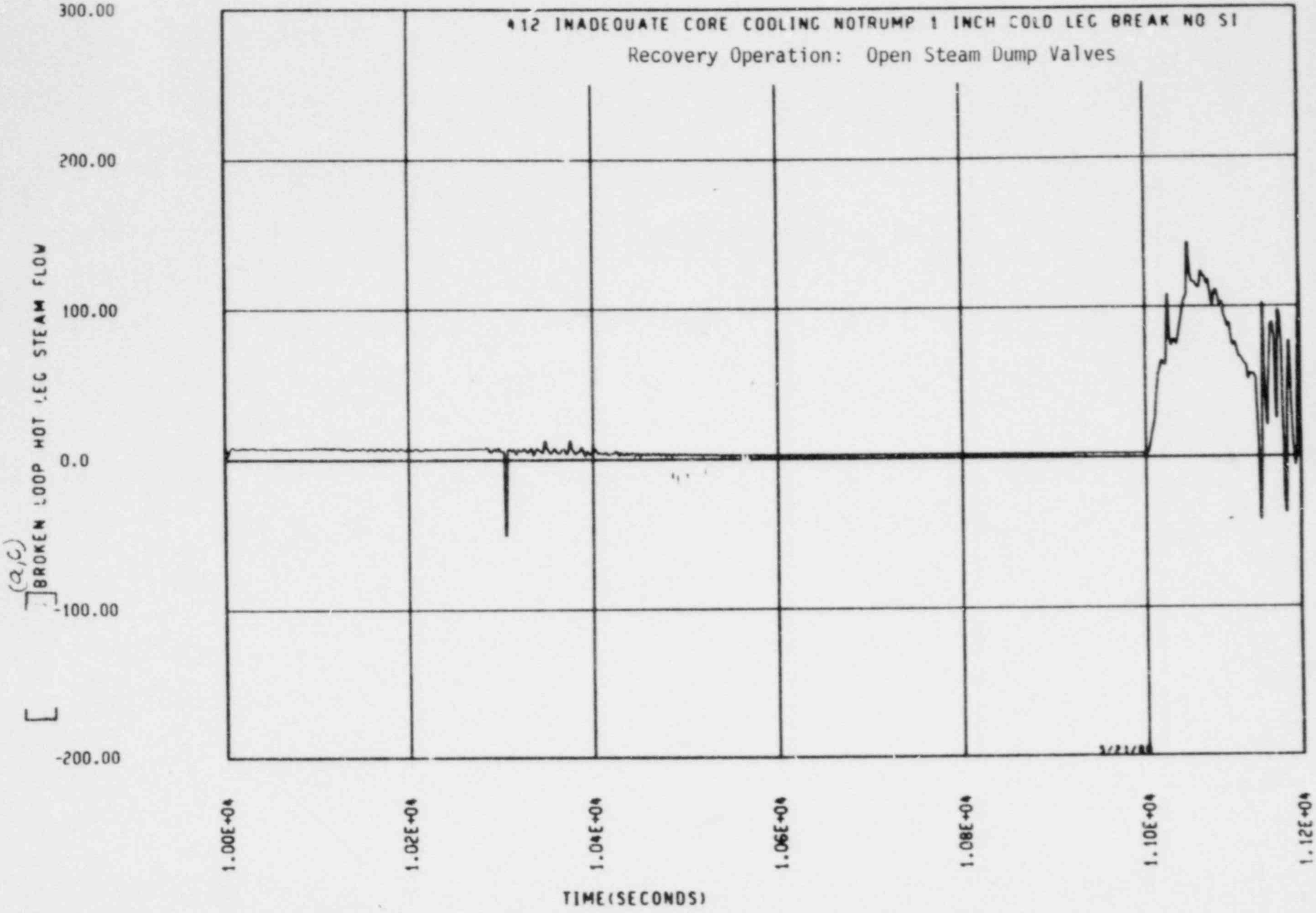

412 INADEQUATE CORE COOLING NOTRUMP 1 INCH COLD LEG BREAK NO SI
Recovery Operation: Open Steam Dump Valves
]BROKEN LOOP HOT LEG STEAM FLOW
[
(a,c)
300.00
200.00
100.00
0.0
-100.00
-200.00
1.00E+04
1.02E+04
1.04E+04
1.06E+04
1.08E+04
1.10E+04
1.12E+04
TIME(SECONDS)
3/21/80

Figure 215

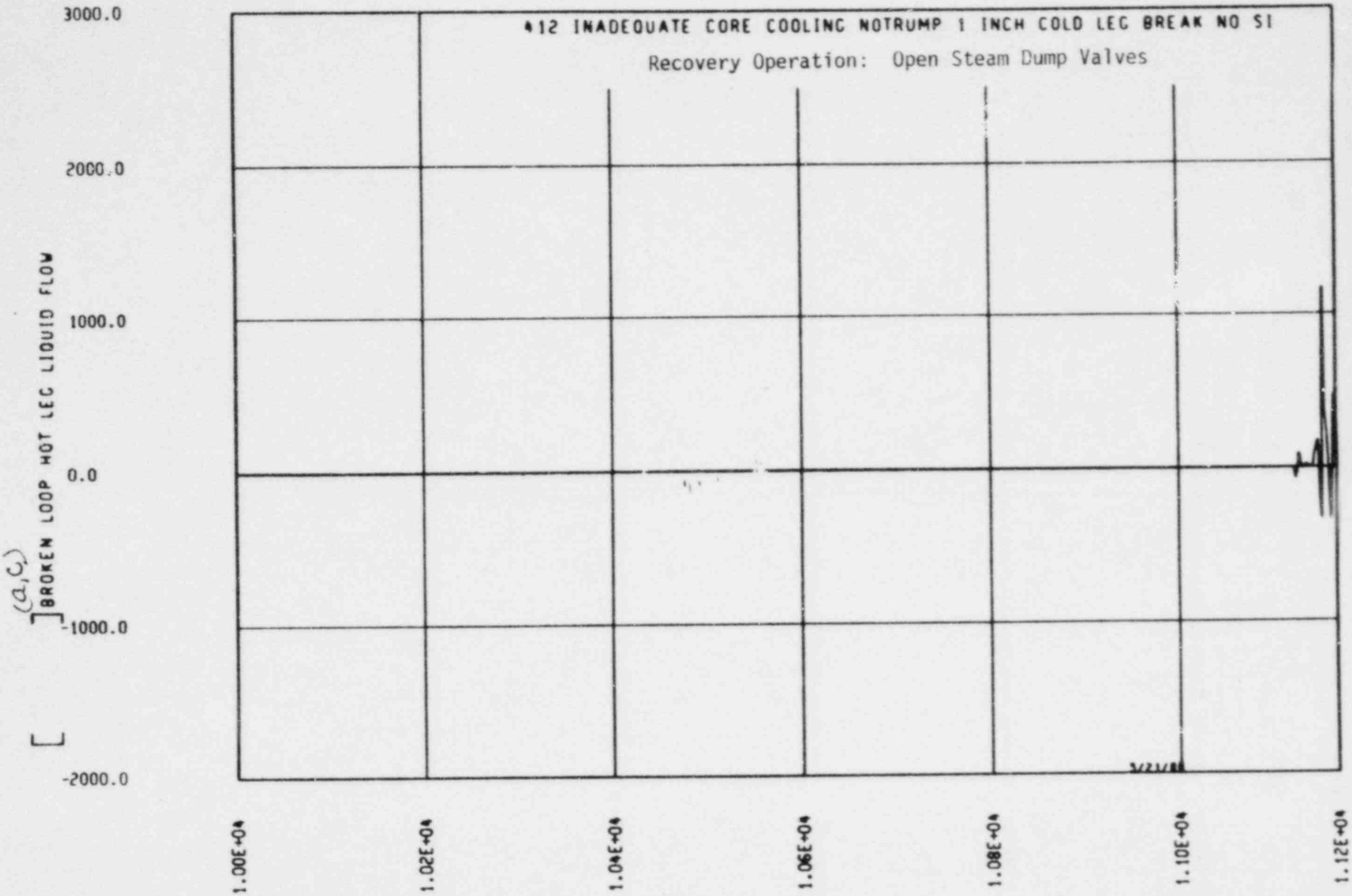

412 INADEQUATE CORE COOLING NOTRUMP 1 INCH COLD LEG BREAK NO SI
Recovery Operation: Open Steam Dump Valves
[
]BROKEN LOOP HOT LEG LIQUID FLOW
(a,c)
3000.0
2000.0
1000.0
0.0
-1000.0
-2000.0
1.00E+04
1.02E+04
1.04E+04
1.06E+04
1.08E+04
1.10E+04
1.12E+04
5/21/8
TIME(SECONDS)

Figure 216

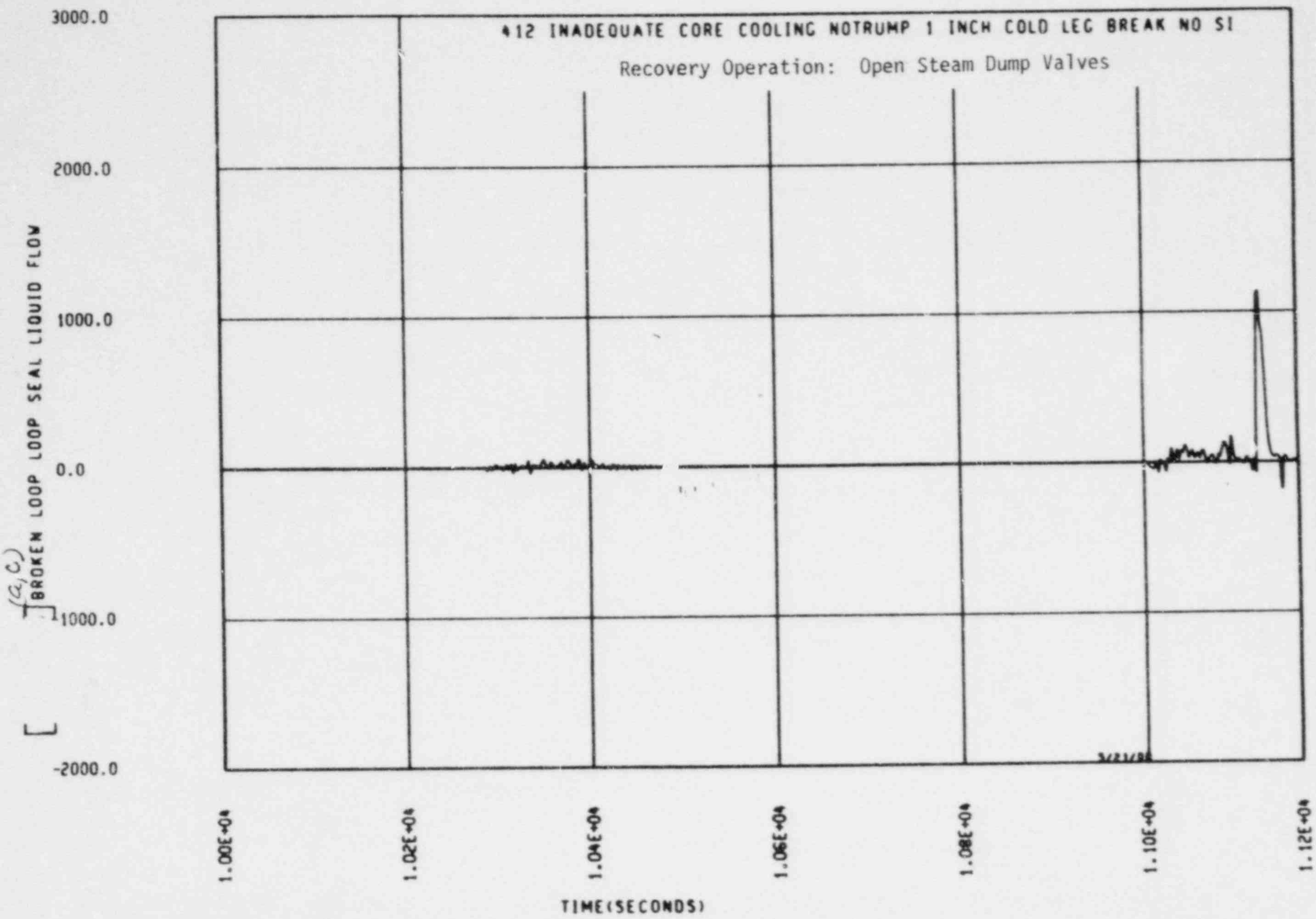

412 INADEQUATE CORE COOLING NOTRUMP 1 INCH COLD LEG BREAK NO SI
Recovery Operation: Open Steam Dump Valves
(a,c)
BROKEN LOOP LOOP SEAL LIQUID FLOW
3000.0
2000.0
1000.0
0.0
-1000.0
-2000.0
1.00E+04
1.02E+04
1.04E+04
1.06E+04
1.08E+04
1.10E+04
1.12E+04
TIME(SECONDS)

Figure 217

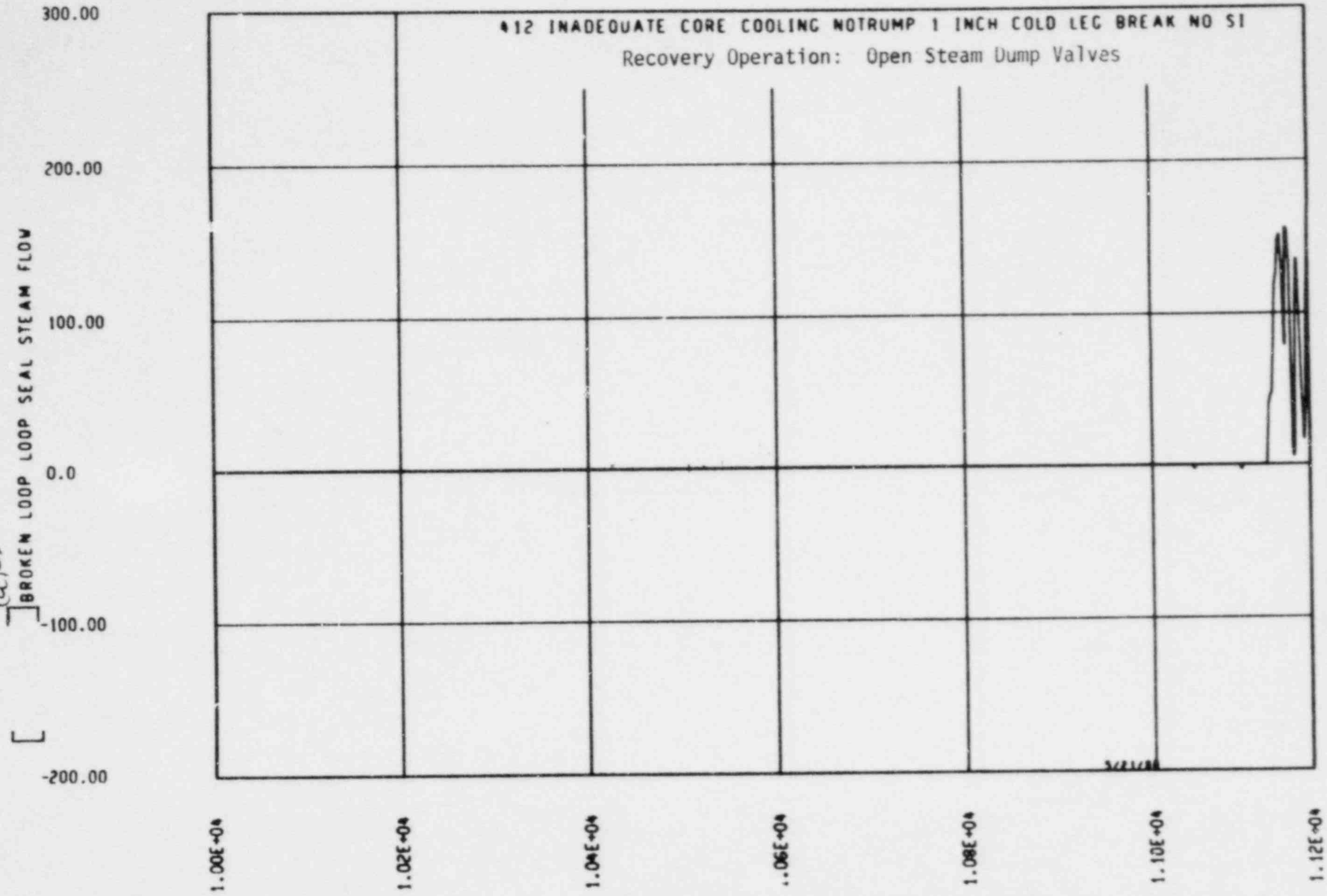

412 INADEQUATE CORE COOLING NOTRUMP 1 INCH COLD LEG BREAK NO SI
Recovery Operation: Open Steam Dump Valves
300.00
200.00
100.00
0.0
-100.00
-200.00
BROKEN LOOP LOOP SEAL STEAM FLOW
(a,c)
1.00E+04
1.02E+04
1.04E+04
.06E+04
1.08E+04
1.10E+04
1.12E+04
TIME(SECONDS)

Figure 218

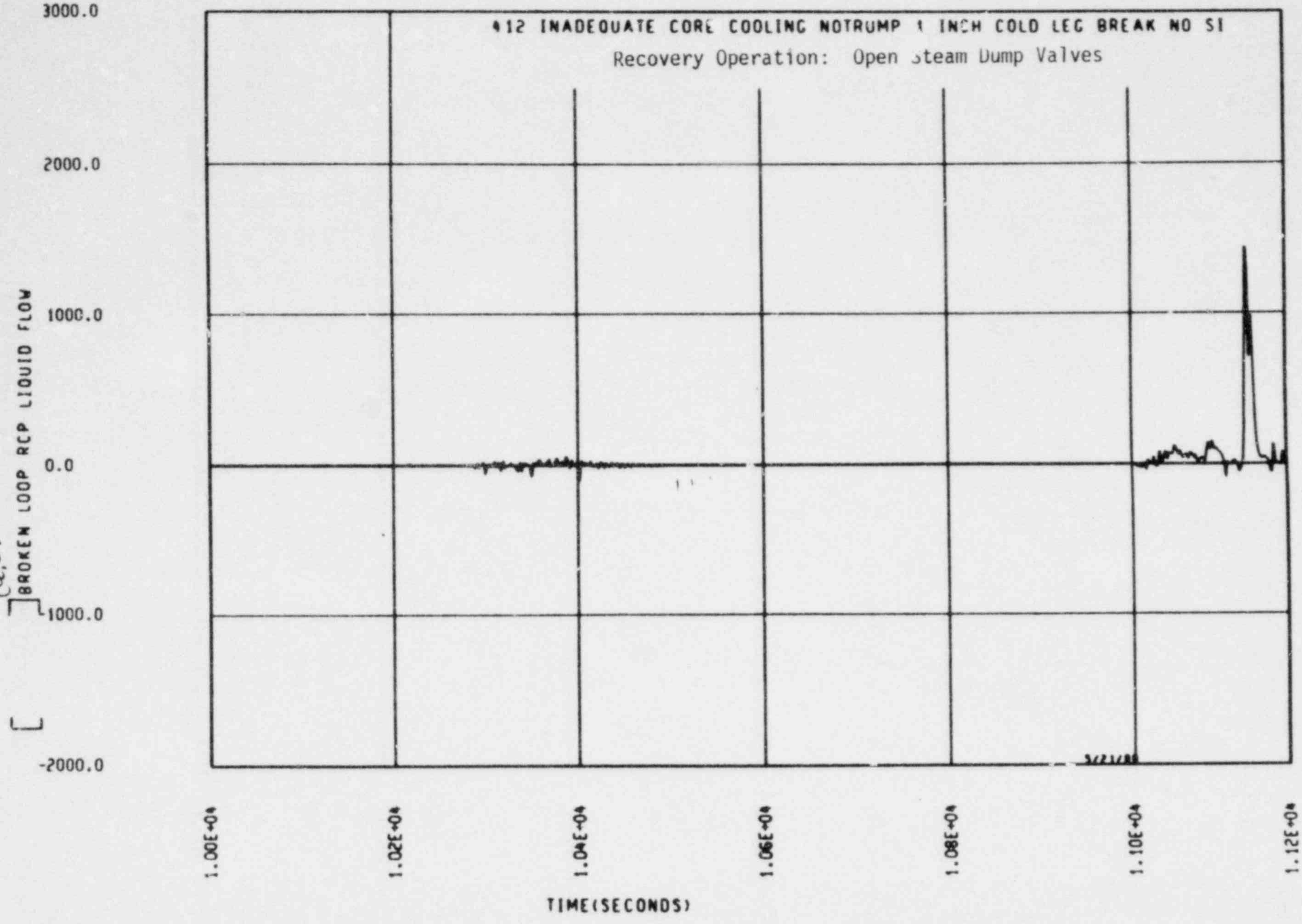

412 INADEQUATE CORE COOLING NOTRUMP 1 INCH COLD LEG BREAK NO SI
Recovery Operation: Open Steam Dump Valves
3000.0
2000.0
1000.0
0.0
1000.0
-2000.0
(a,c)
BROKEN LOOP RCP LIQUID FLOW
1.00E+04
1.02E+04
1.04E+04
1.06E+04
1.08E+04
1.10E+04
1.12E+04
5/21/88
TIME(SECONDS)

Figure 219

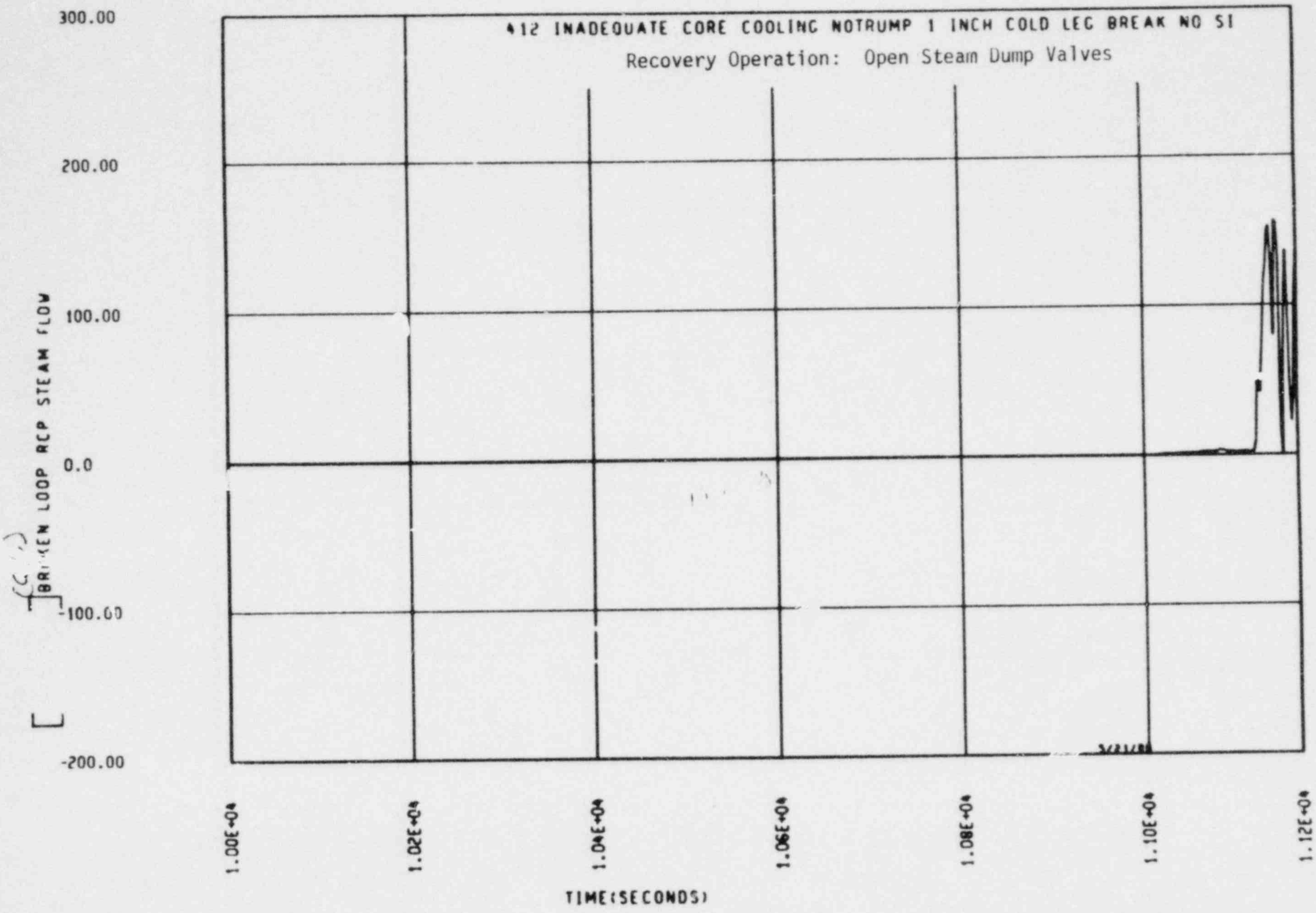

412 INADEQUATE CORE COOLING NOTRUMP 1 INCH COLD LEG BREAK NO SI
Recovery Operation: Open Steam Dump Valves
300.00
200.00
100.00
0.0
-100.00
-200.00
BROKEN LOOP RCP STEAM FLOW
(c)
1.00E+04
1.02E+04
1.04E+04
1.06E+04
1.08E+04
1.10E+04
1.12E+04
TIME(SECONDS)
5/21/80

Figure 220

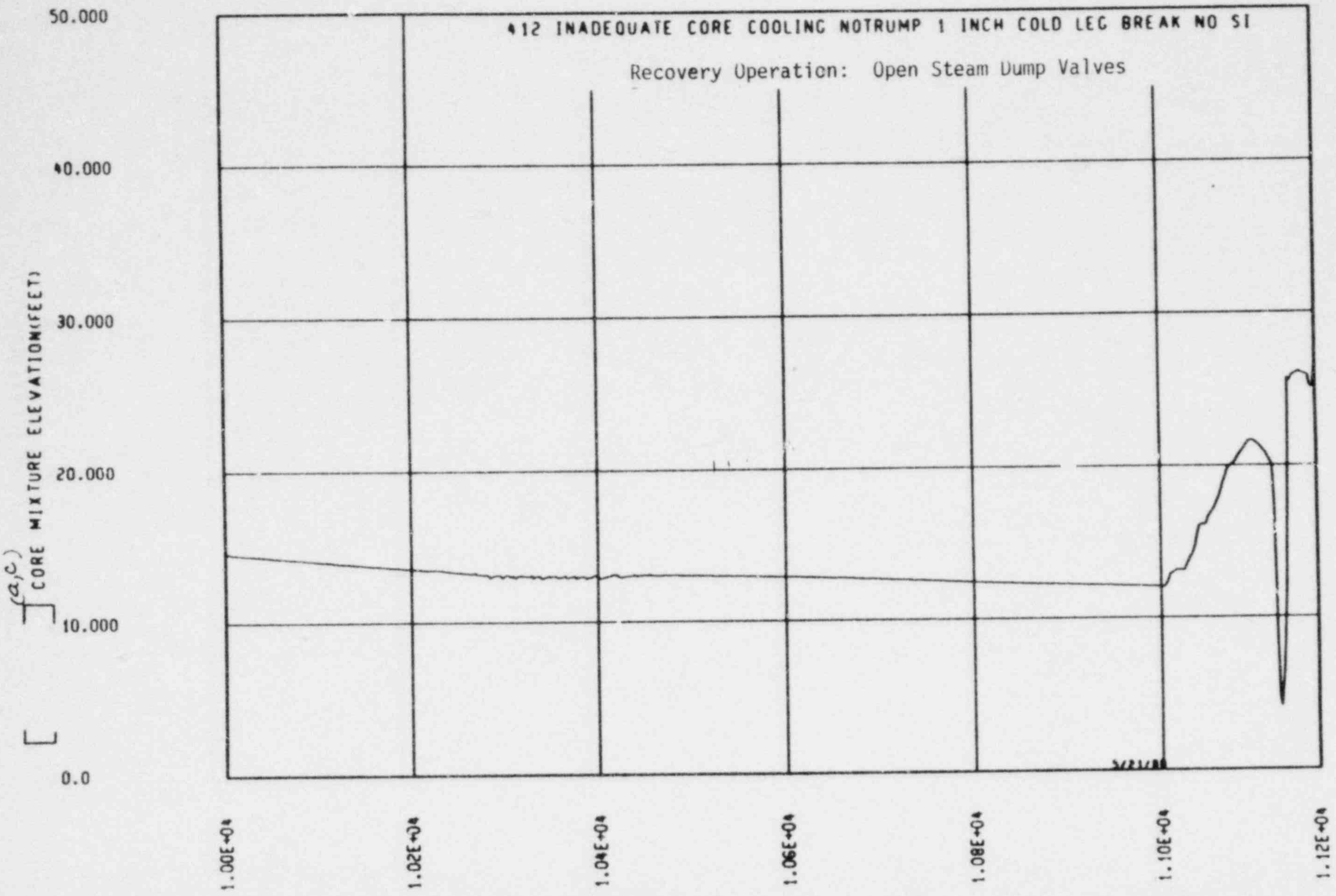

412 INADEQUATE CORE COOLING NOTRUMP 1 INCH COLD LEG BREAK NO SI
Recovery Operation: Open Steam Dump Valves
50.000
40.000
30.000
20.000
10.000
0.0
CORE MIXTURE ELEVATION(FEET)
(a,c)
1.00E+04
1.02E+04
1.04E+04
1.06E+04
1.08E+04
1.10E+04
1.12E+04
TIME(SECONDS)
5/21/80

Figure 221

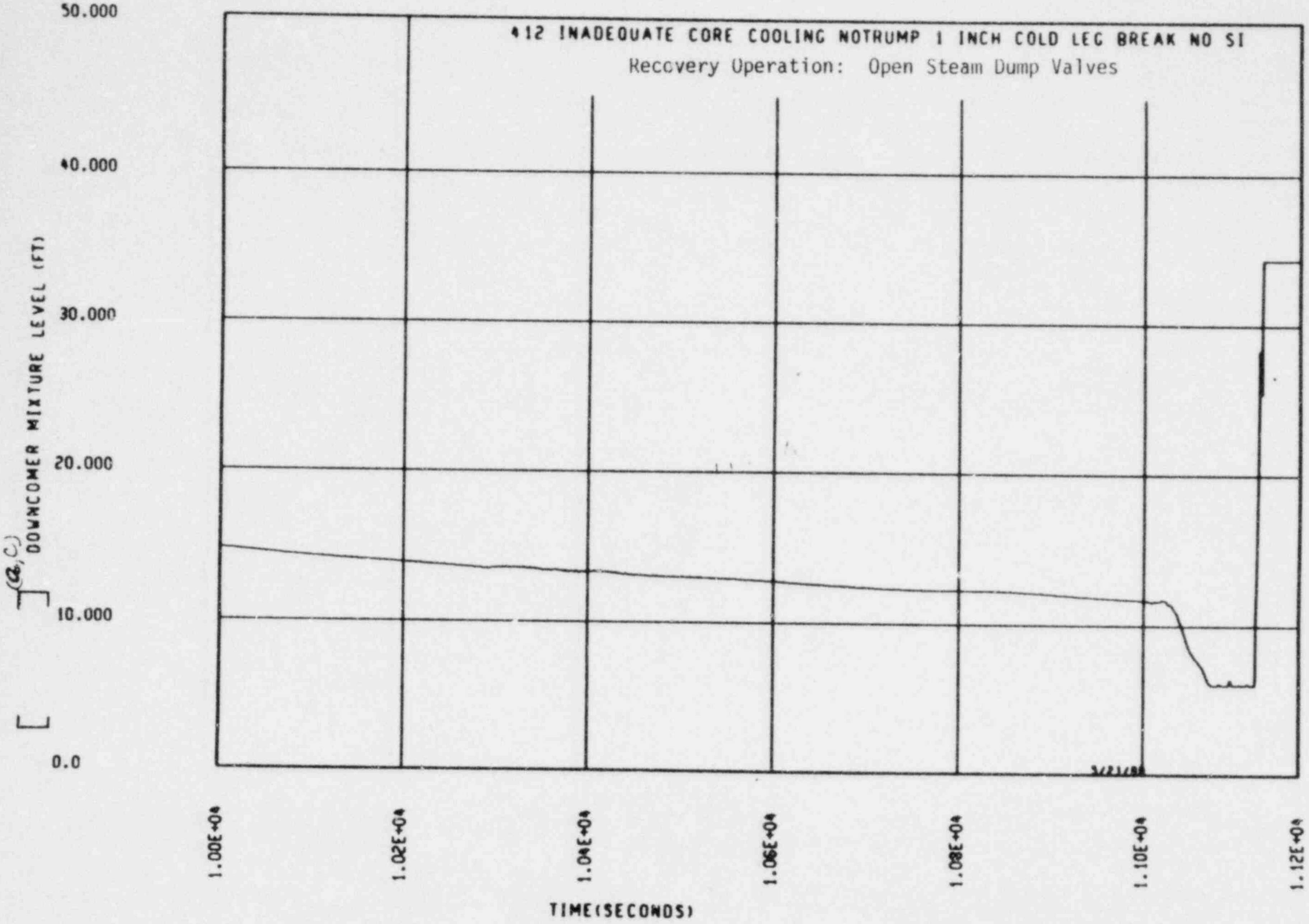

412 INADEQUATE CORE COOLING NOTRUMP 1 INCH COLD LEG BREAK NO SI
Recovery Operation: Open Steam Dump Valves
DOWNCOMER MIXTURE LEVEL (FT)
(a,c)
50.000
40.000
30.000
20.000
10.000
0.0
1.00E+04
1.02E+04
1.04E+04
1.06E+04
1.08E+04
1.10E+04
1.12E+04
TIME(SECONDS)
5/21/84

Figure 222

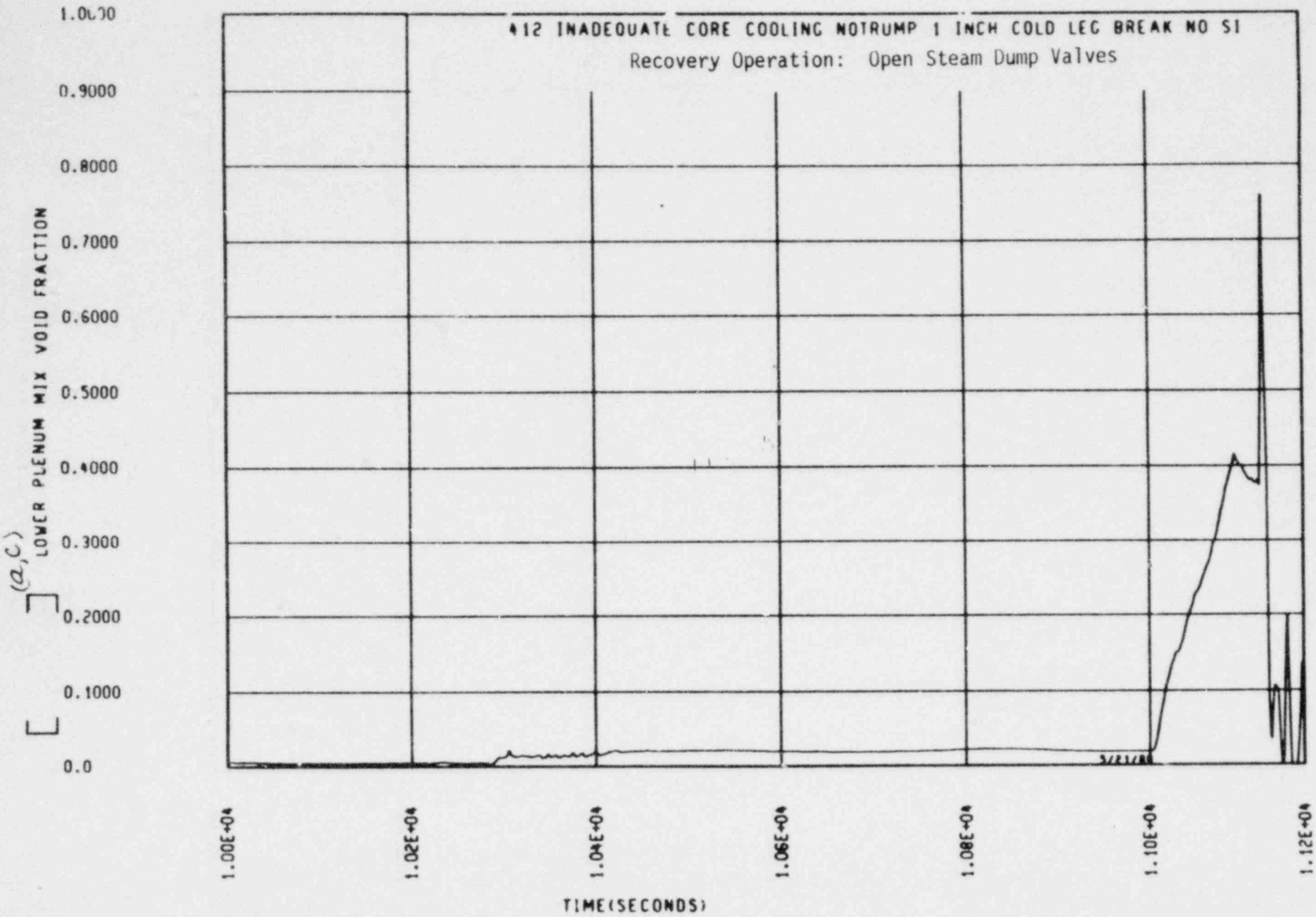

412 INADEQUATE CORE COOLING NOTRUMP 1 INCH COLD LEG BREAK NO SI
Recovery Operation: Open Steam Dump Valves
LOWER PLENUM MIX VOID FRACTION
(a,c)
1.0000
0.9000
0.8000
0.7000
0.6000
0.5000
0.4000
0.3000
0.2000
0.1000
0.0
1.00E+04
1.02E+04
1.04E+04
1.06E+04
1.08E+04
1.10E+04
1.12E+04
TIME(SECONDS)

Figure 223

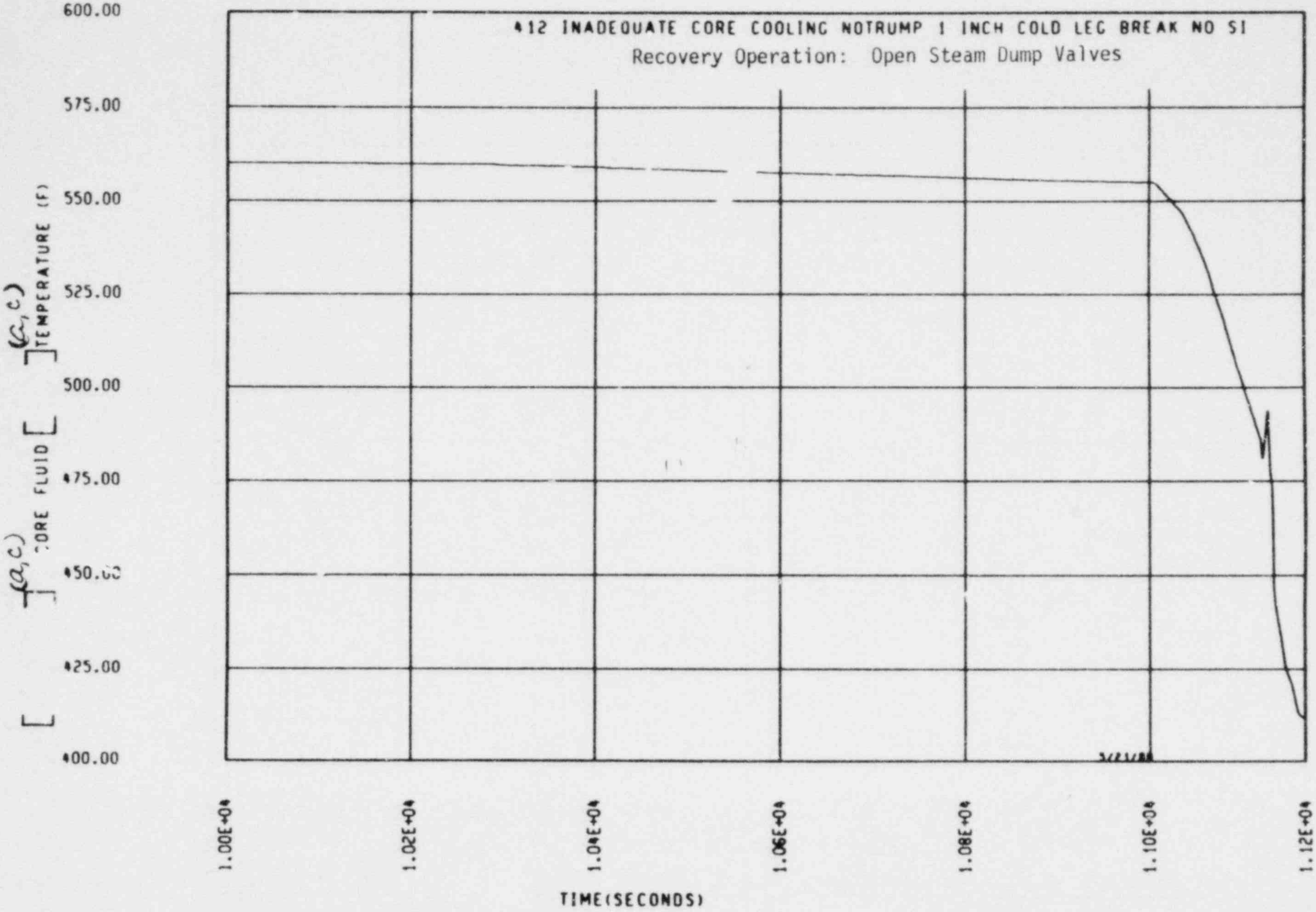

412 INADEQUATE CORE COOLING NOTRUMP 1 INCH COLD LEG BREAK NO SI
Recovery Operation: Open Steam Dump Valves
600.00
575.00
550.00
525.00
500.00
475.00
450.00
425.00
400.00
[ ] CORE FLUID [ ] TEMPERATURE (F)
(a,c)
(a,c)
1.00E+04
1.02E+04
1.04E+04
1.06E+04
1.08E+04
1.10E+04
1.12E+04
TIME(SECONDS)
3/21/88

Figure 224

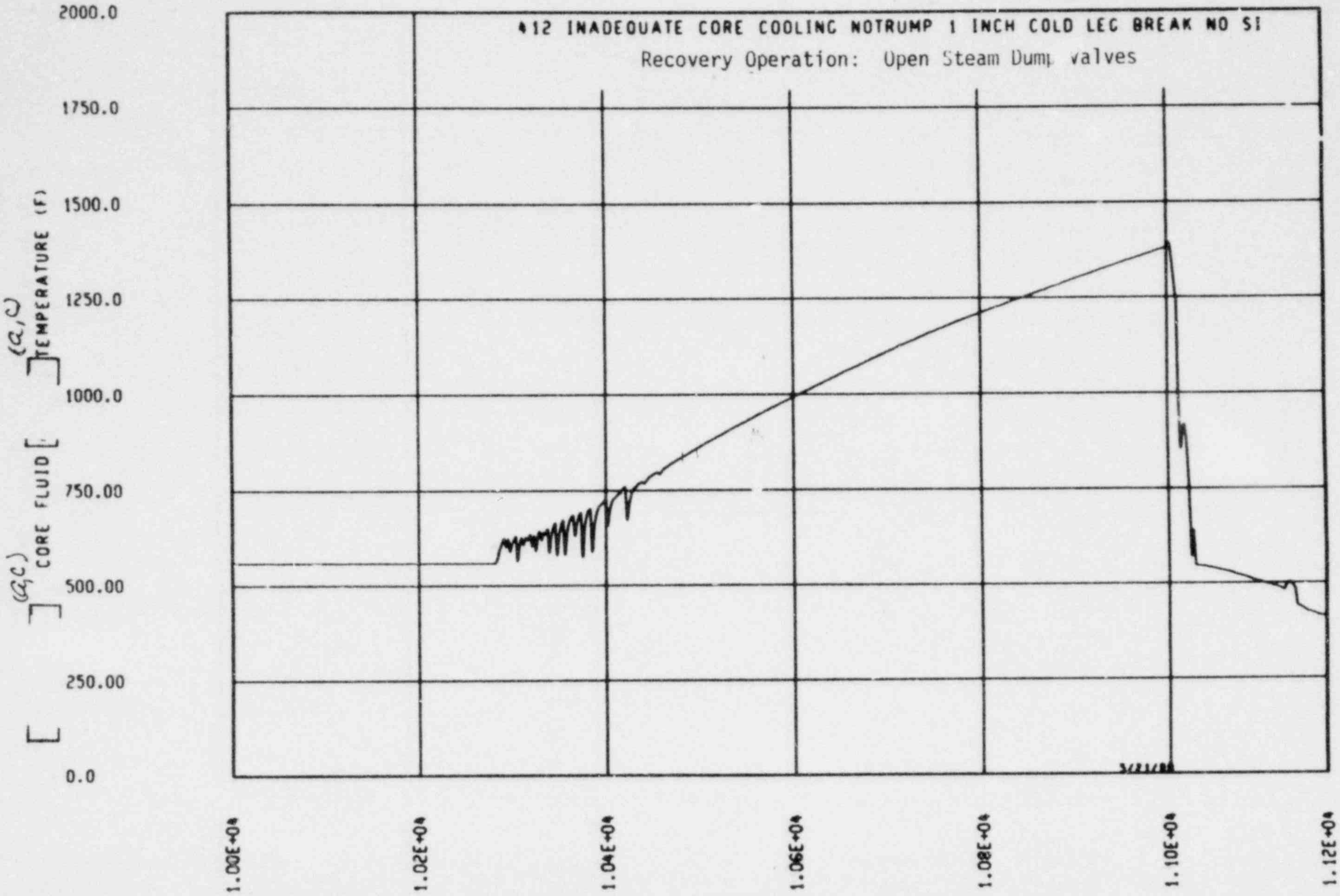

412 INADEQUATE CORE COOLING NOTRUMP 1 INCH COLD LEG BREAK NO SI
Recovery Operation: Open Steam Dump valves
CORE FLUID TEMPERATURE (F)
(a,c)
(a,c)
2000.0
1750.0
1500.0
1250.0
1000.0
750.00
500.00
250.00
0.0
1.00E+04
1.02E+04
1.04E+04
1.06E+04
1.08E+04
1.10E+04
1.12E+04
TIME(SECONDS)
3/21/88

Figure 225

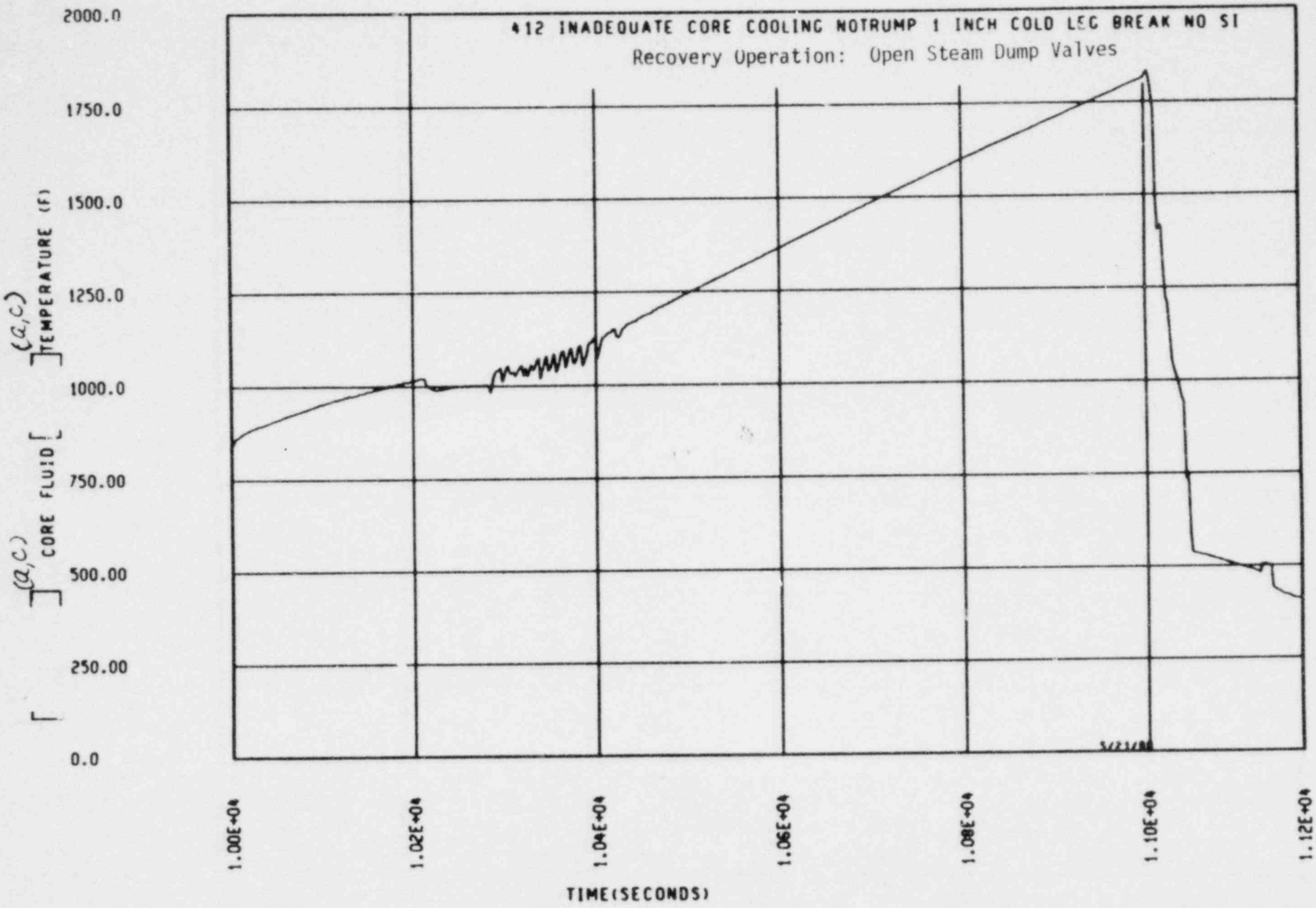

412 INADEQUATE CORE COOLING NOTRUMP 1 INCH COLD LEG BREAK NO SI
Recovery Operation: Open Steam Dump Valves
[ CORE FLUID [ ]TEMPERATURE (F)
(a,c)
(a,c)
2000.0
1750.0
1500.0
1250.0
1000.0
750.00
500.00
250.00
0.0
1.00E+04
1.02E+04
1.04E+04
1.06E+04
1.08E+04
1.10E+04
1.12E+04
TIME(SECONDS)
5/23/88

Figure 226

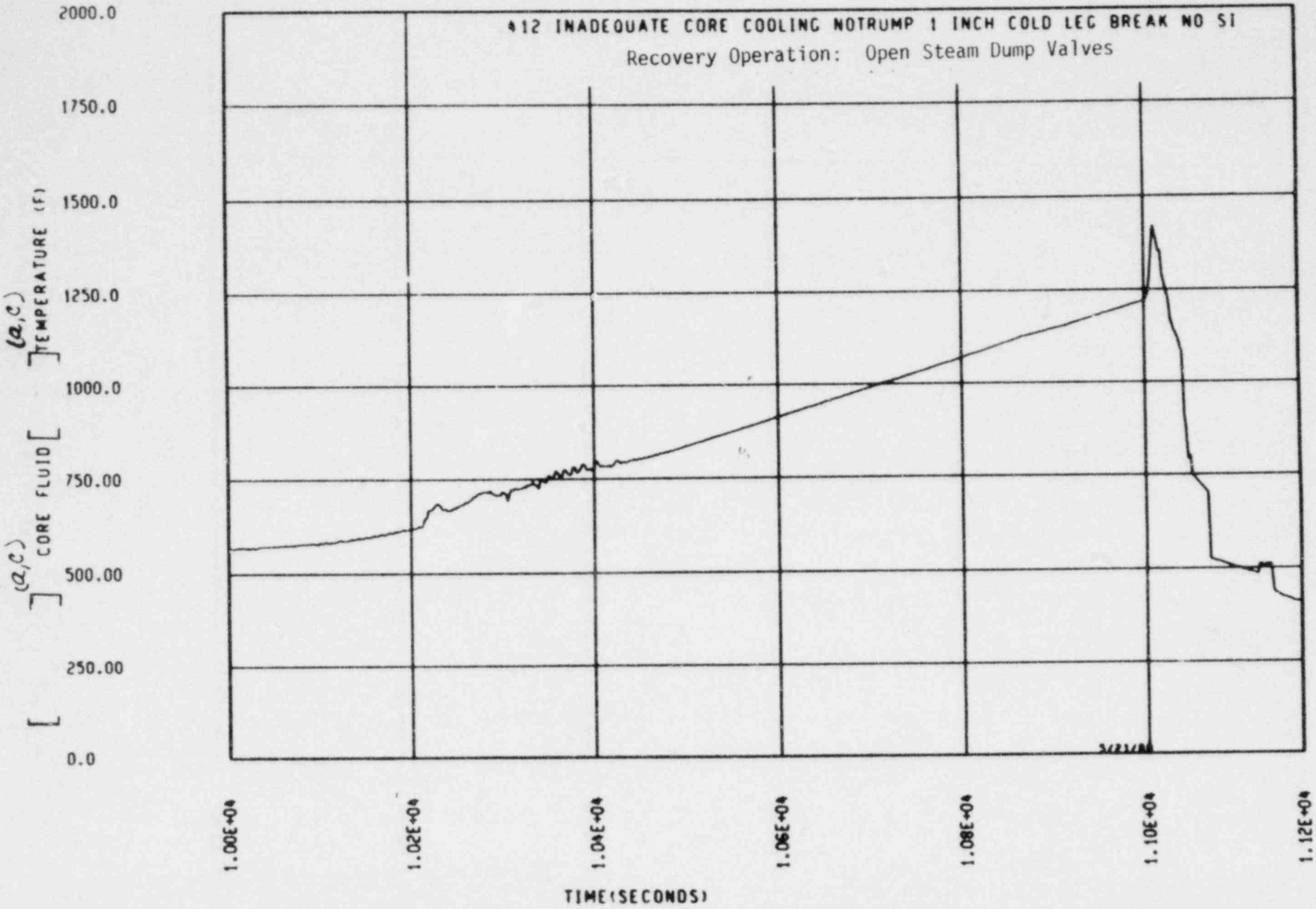

412 INADEQUATE CORE COOLING NOTRUMP 1 INCH COLD LEG BREAK NO SI
Recovery Operation: Open Steam Dump Valves
[ ]$^{(a,c)}$ CORE FLUID [ ]TEMPERATURE (F)$^{(a,c)}$
2000.0
1750.0
1500.0
1250.0
1000.0
750.00
500.00
250.00
0.0
1.00E+04
1.02E+04
1.04E+04
1.06E+04
1.08E+04
1.10E+04
1.12E+04
TIME(SECONDS)

Figure 227

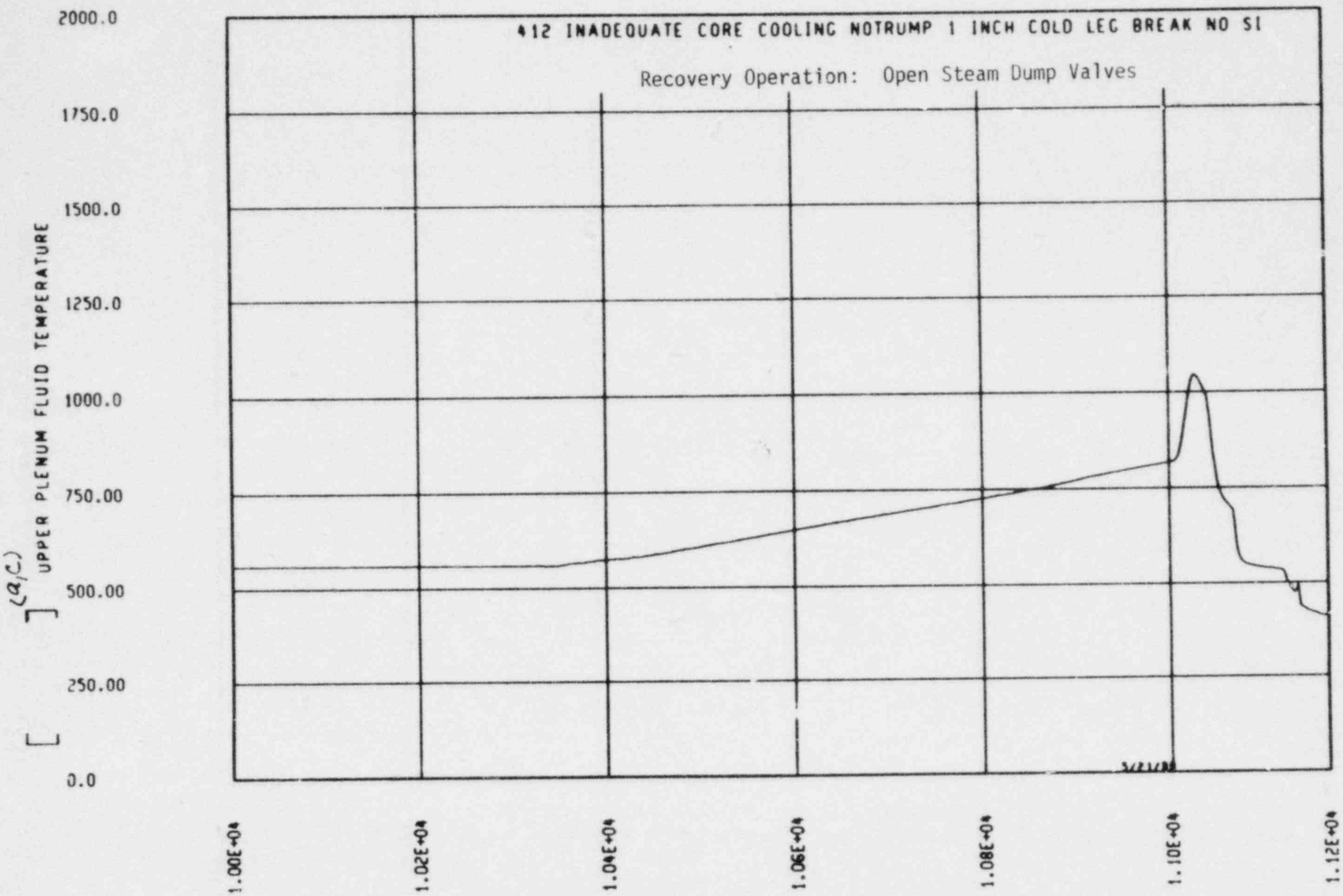

412 INADEQUATE CORE COOLING NOTRUMP 1 INCH COLD LEG BREAK NO SI
Recovery Operation: Open Steam Dump Valves
UPPER PLENUM FLUID TEMPERATURE
(a,c)
2000.0
1750.0
1500.0
1250.0
1000.0
750.00
500.00
250.00
0.0
1.00E+04
1.02E+04
1.04E+04
1.06E+04
1.08E+04
1.10E+04
1.12E+04
TIME(SECONDS)

Figure 228

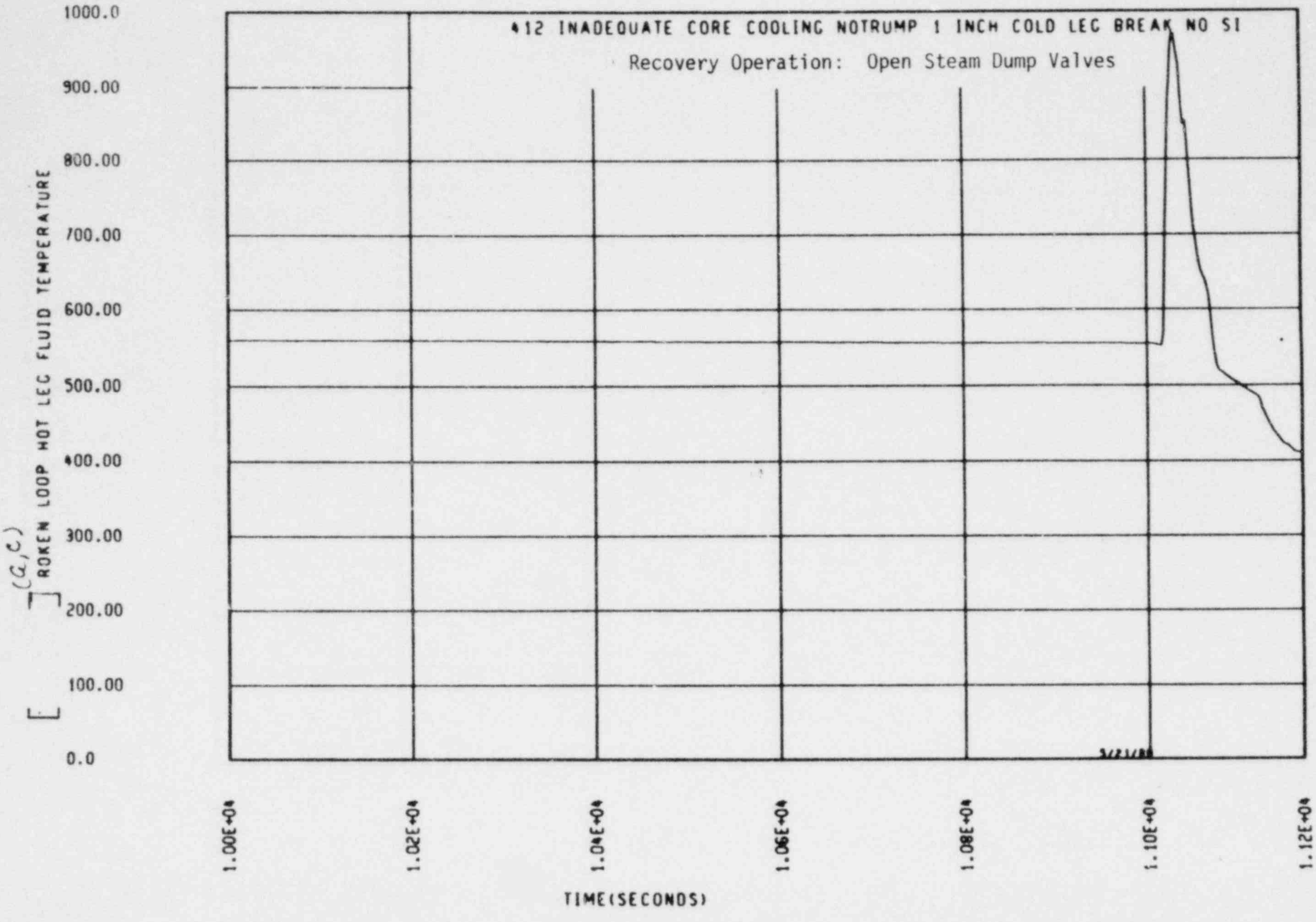

412 INADEQUATE CORE COOLING NOTRUMP 1 INCH COLD LEG BREAK NO SI
Recovery Operation: Open Steam Dump Valves
ROKEN LOOP HOT LEG FLUID TEMPERATURE
(a,c)
1000.0
900.00
800.00
700.00
600.00
500.00
400.00
300.00
200.00
100.00
0.0
1.00E+04
1.02E+04
1.04E+04
1.06E+04
1.08E+04
1.10E+04
1.12E+04
TIME(SECONDS)

Figure 229

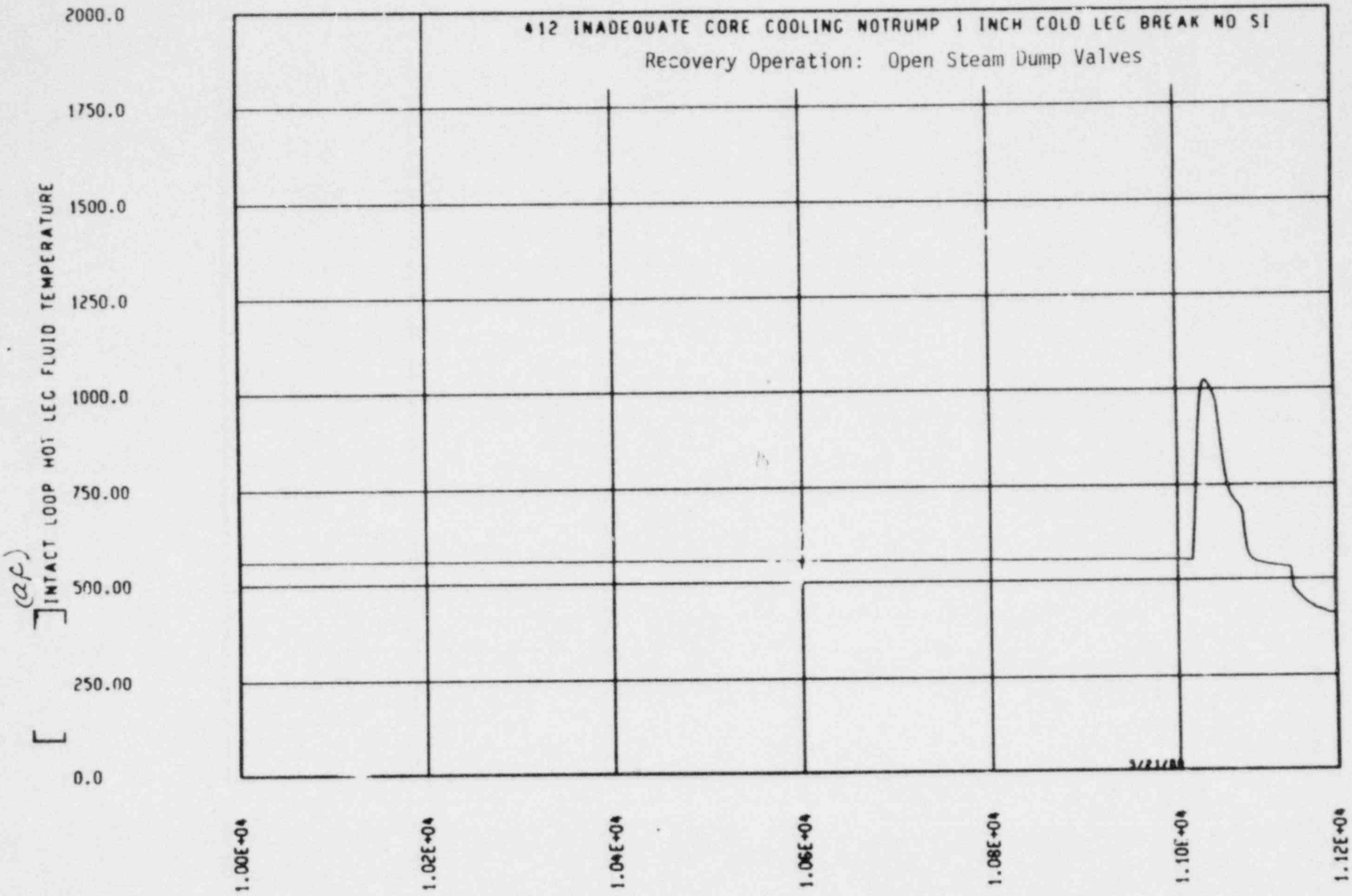

412 INADEQUATE CORE COOLING NOTRUMP 1 INCH COLD LEG BREAK NO SI
Recovery Operation: Open Steam Dump Valves
INTACT LOOP HOT LEG FLUID TEMPERATURE
(a,c)
2000.0
1750.0
1500.0
1250.0
1000.0
750.00
500.00
250.00
0.0
1.00E+04
1.02E+04
1.04E+04
1.06E+04
1.08E+04
1.10E+04
1.12E+04
TIME(SE ONDS)
5/21/88

Figure 230

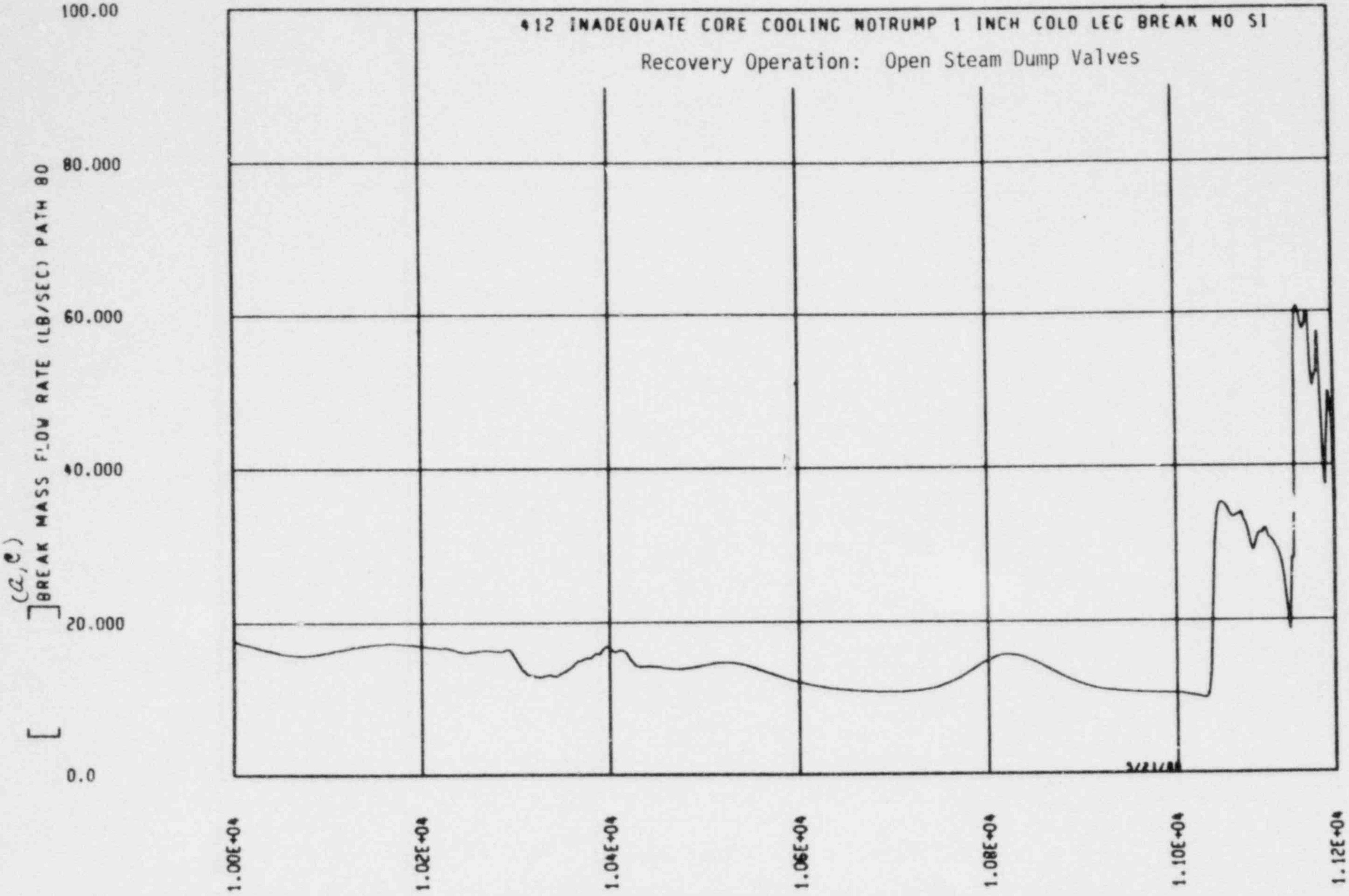

412 INADEQUATE CORE COOLING NOTRUMP 1 INCH COLD LEG BREAK NO SI
Recovery Operation: Open Steam Dump Valves
(a,c)
BREAK MASS FLOW RATE (LB/SEC) PATH 80
100.00
80.000
60.000
40.000
20.000
0.0
1.00E+04
1.02E+04
1.04E+04
1.06E+04
1.08E+04
1.10E+04
1.12E+04
TIME(SECONDS)

Figure 231

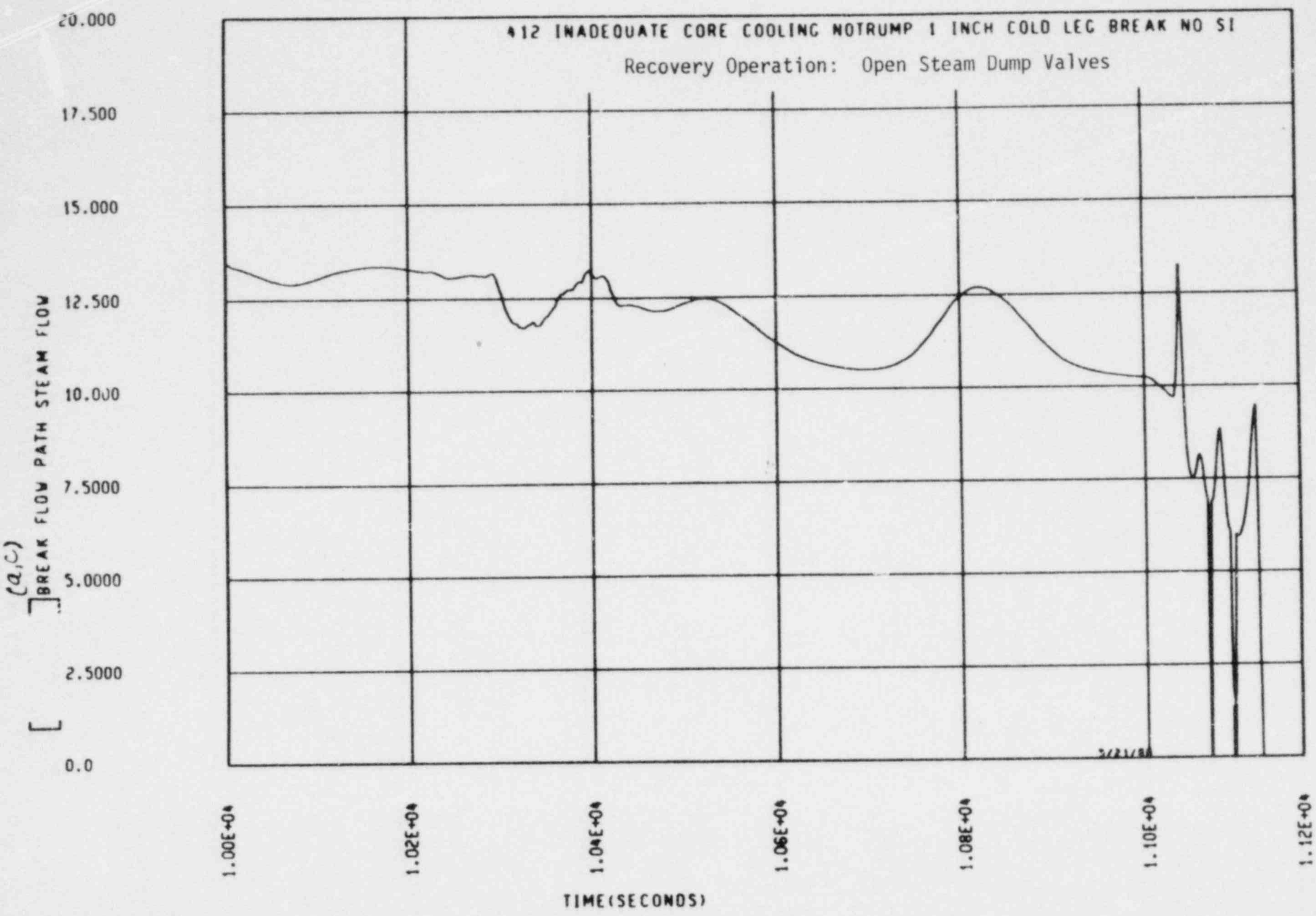
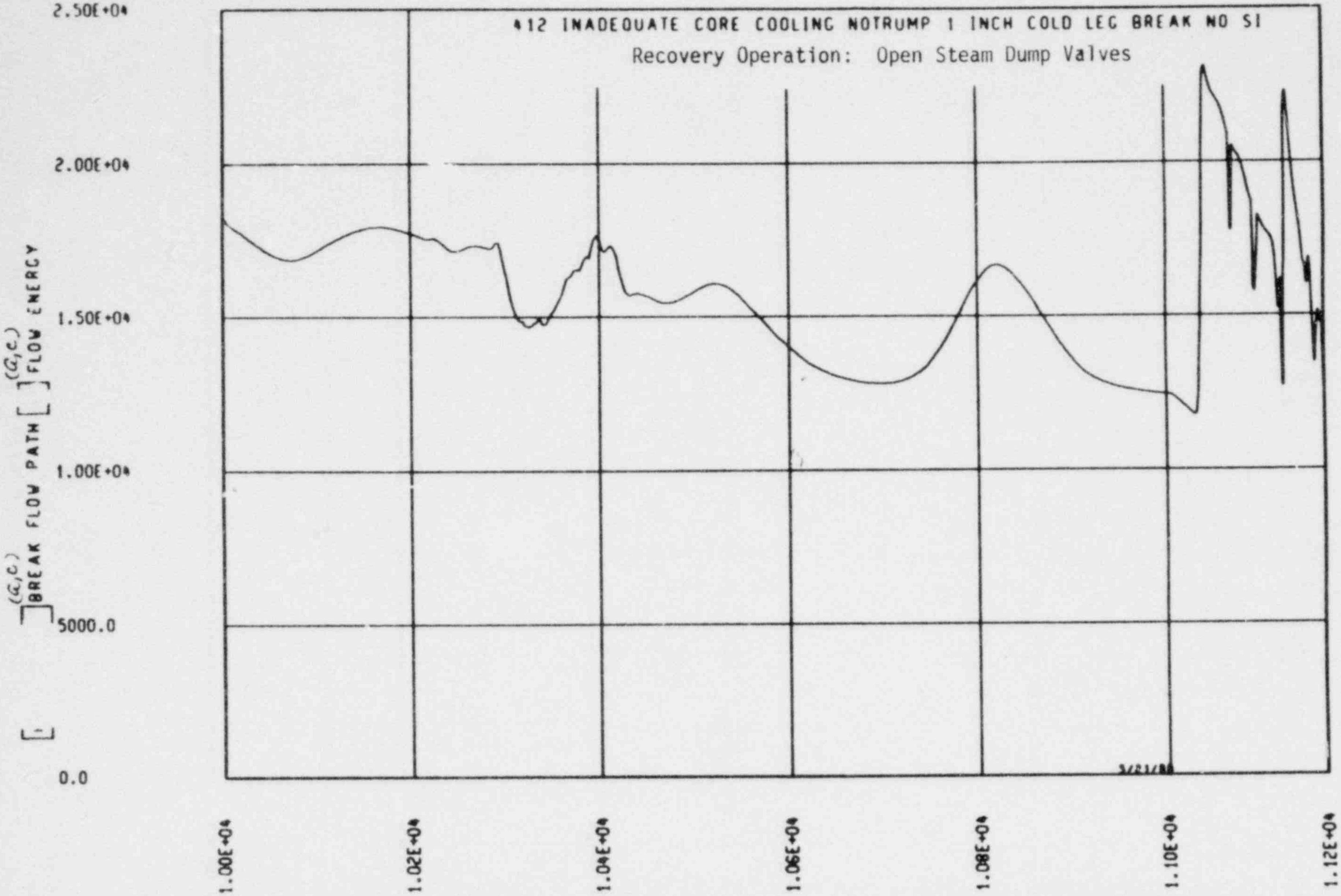

412 INADEQUATE CORE COOLING NOTRUMP 1 INCH COLD LEG BREAK NO SI
Recovery Operation: Open Steam Dump Valves
20.000
17.500
15.000
12.500
10.000
7.5000
5.0000
2.5000
0.0
[ ]BREAK FLOW PATH STEAM FLOW (a,c)
1.00E+04
1.02E+04
1.04E+04
1.06E+04
1.08E+04
1.10E+04
1.12E+04
TIME(SECONDS)
3/21/88

Figure 232



TIME(SECONDS)

Figure 233

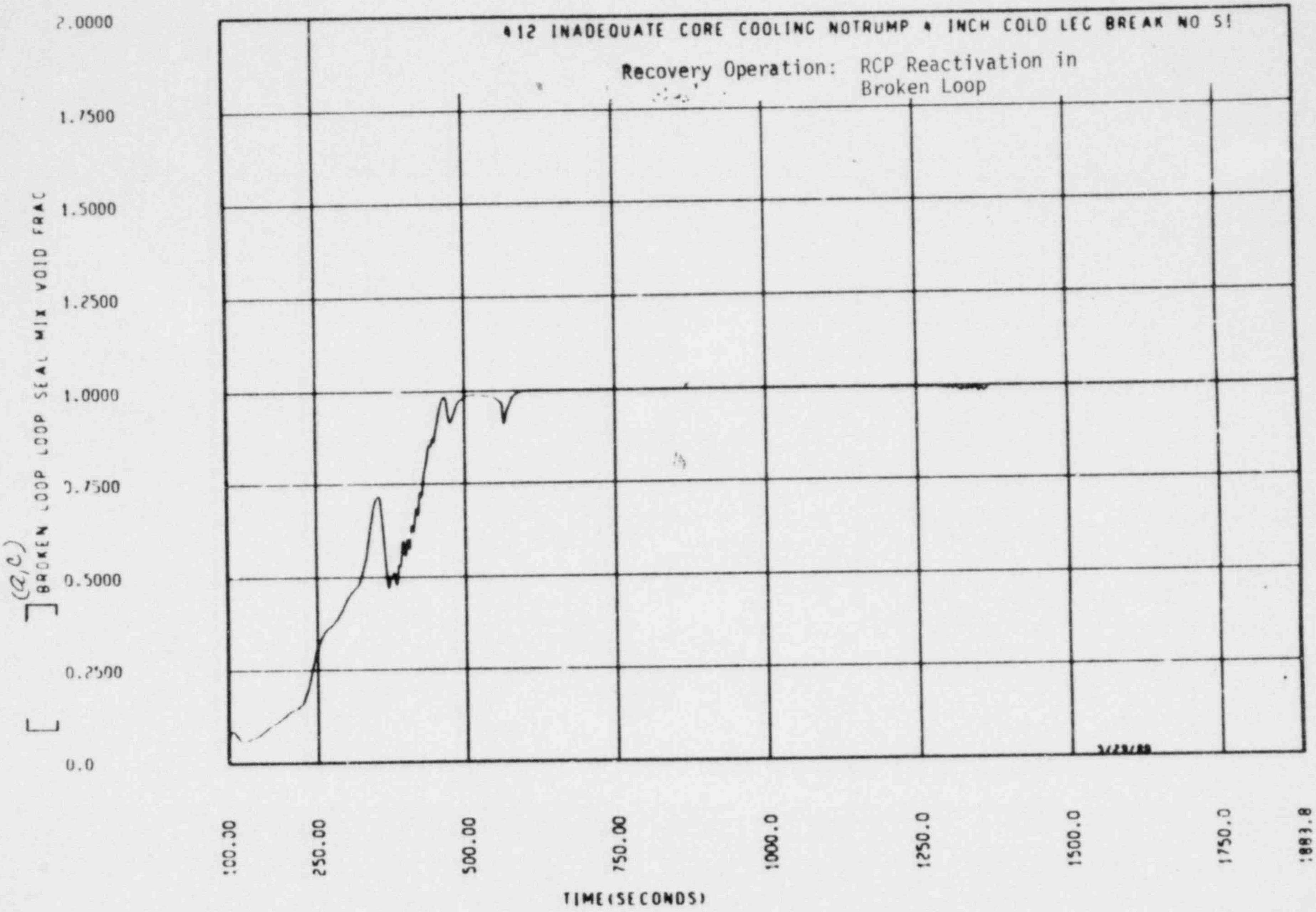
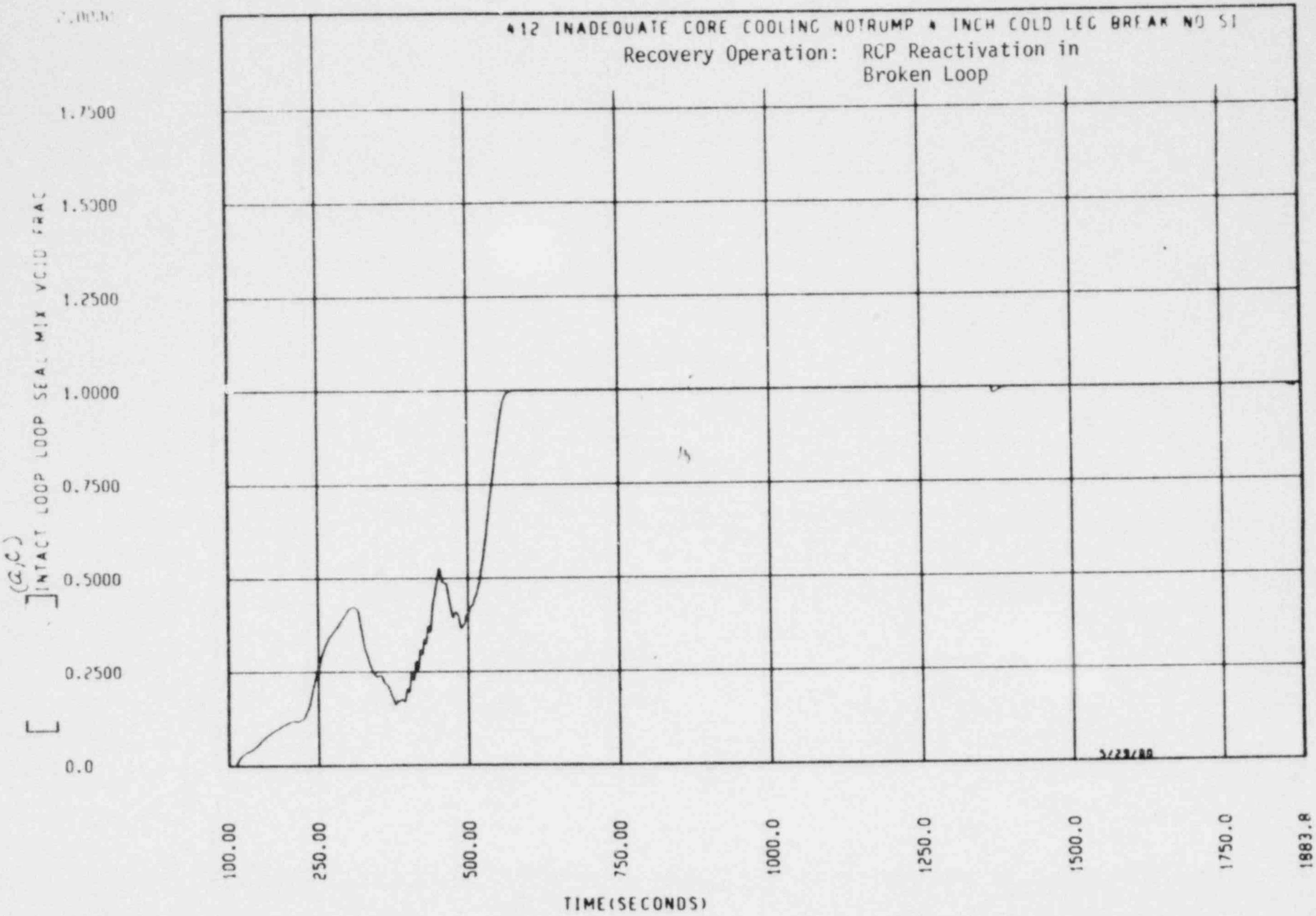
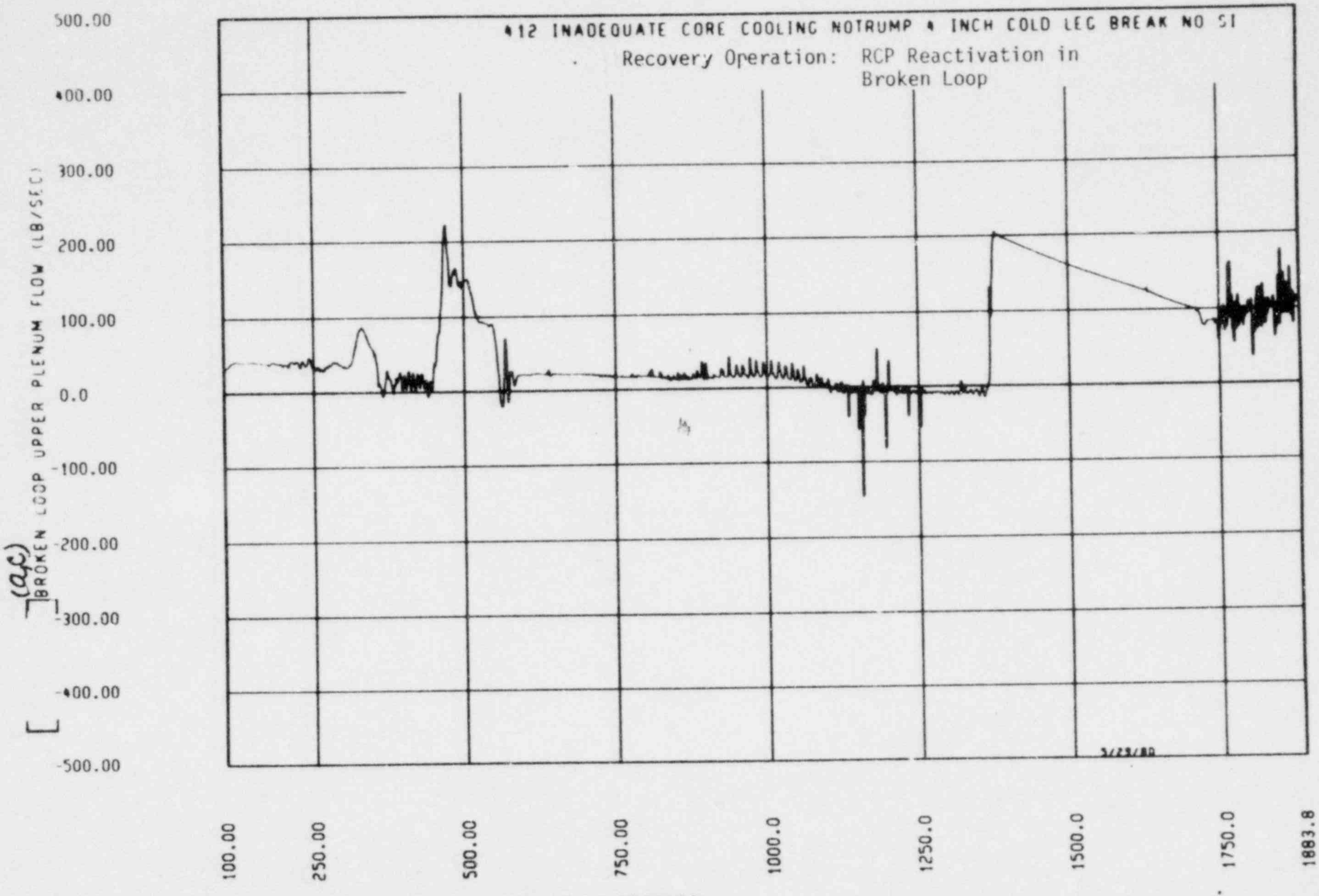

412 INADEQUATE CORE COOLING NOTRUMP 4 INCH COLD LEG BREAK NO SI
Recovery Operation: RCP Reactivation in Broken Loop
BROKEN LOOP LOOP SEAL MIX VOID FRAC
(a,c)
2.0000
1.7500
1.5000
1.2500
1.0000
0.7500
0.5000
0.2500
0.0
100.00
250.00
500.00
750.00
1000.0
1250.0
1500.0
1750.0
1883.8
TIME(SECONDS)

Figure 234



412 INADEQUATE CORE COOLING NOTRUMP 4 INCH COLD LEG BREAK NO SI
Recovery Operation: RCP Reactivation in
Broken Loop

Figure 235



412 INADEQUATE CORE COOLING NOTRUMP 4 INCH COLD LEG BREAK NO SI
Recovery Operation: RCP Reactivation in Broken Loop
BROKEN LOOP UPPER PLENUM FLOW (LB/SEC)
(a,c)
500.00
400.00
300.00
200.00
100.00
0.0
-100.00
-200.00
-300.00
-400.00
-500.00
100.00
250.00
500.00
750.00
1000.0
1250.0
1500.0
1750.0
1883.8
TIME(SECONDS)
5/29/80

Figure 236

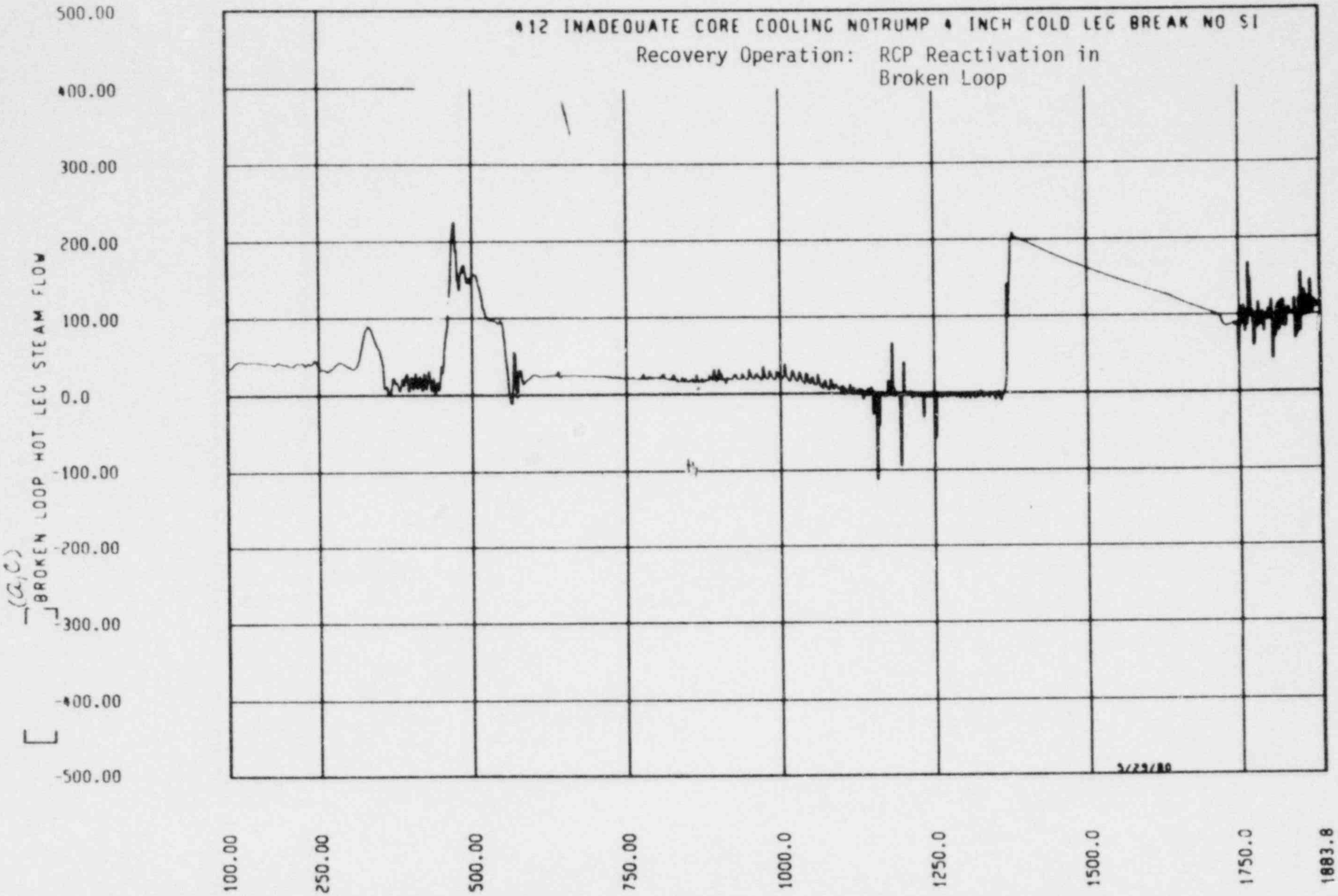

412 INADEQUATE CORE COOLING NOTRUMP 4 INCH COLD LEG BREAK NO SI
Recovery Operation: RCP Reactivation in Broken Loop
BROKEN LOOP HOT LEG STEAM FLOW
(a,c)
500.00
400.00
300.00
200.00
100.00
0.0
-100.00
-200.00
-300.00
-400.00
-500.00
100.00
250.00
500.00
750.00
1000.0
1250.0
1500.0
1750.0
1883.8
TIME(SECONDS)
5/29/80

Figure 237

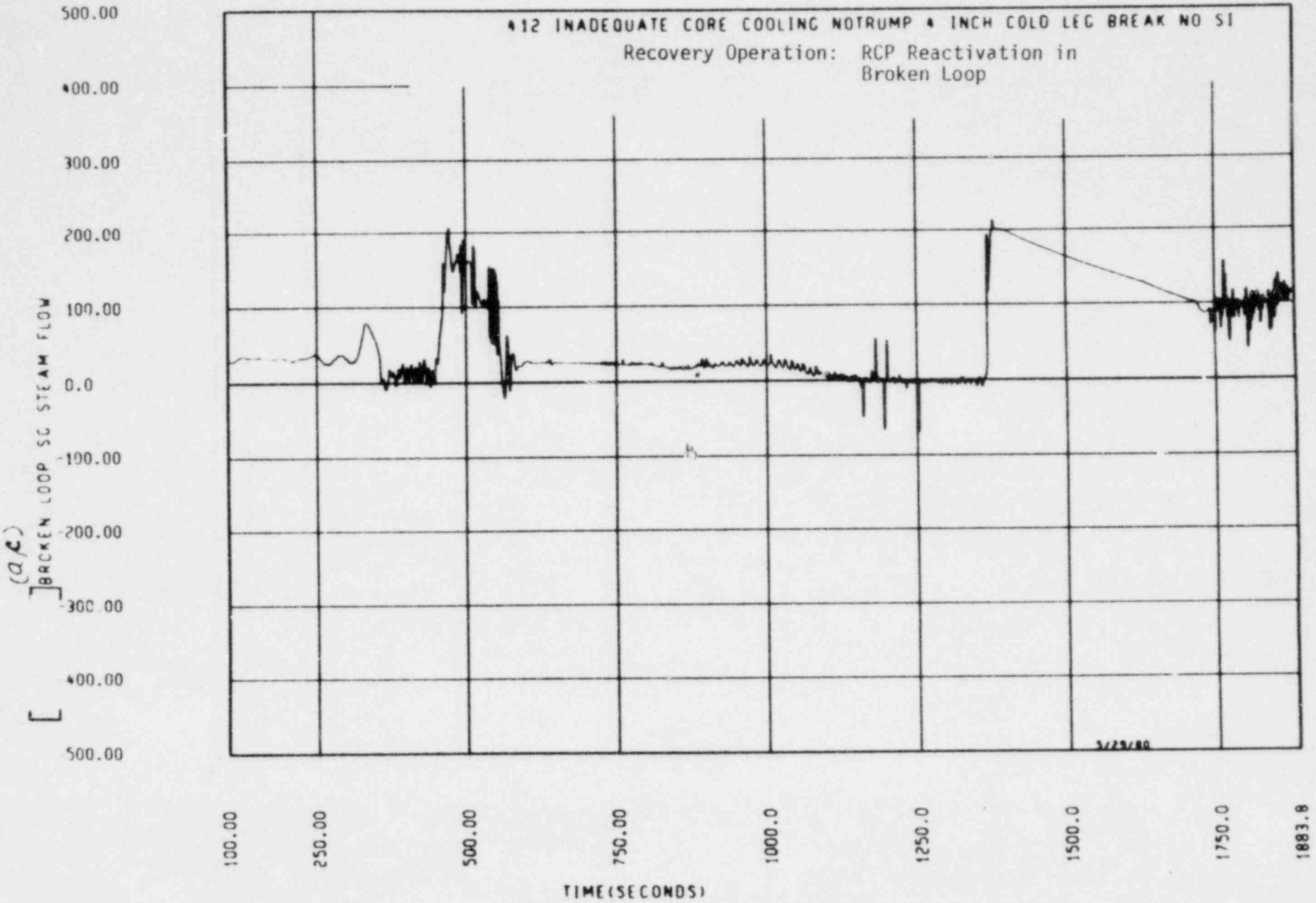

412 INADEQUATE CORE COOLING NOTRUMP 4 INCH COLD LEG BREAK NO SI
Recovery Operation: RCP Reactivation in Broken Loop
BRCKEN LOOP SC STEAM FLOW
(a,c)
500.00
400.00
300.00
200.00
100.00
0.0
-100.00
-200.00
-300.00
-400.00
-500.00
100.00
250.00
500.00
750.00
1000.0
1250.0
1500.0
1750.0
1883.8
TIME(SECONDS)
5/29/80

Figure 238

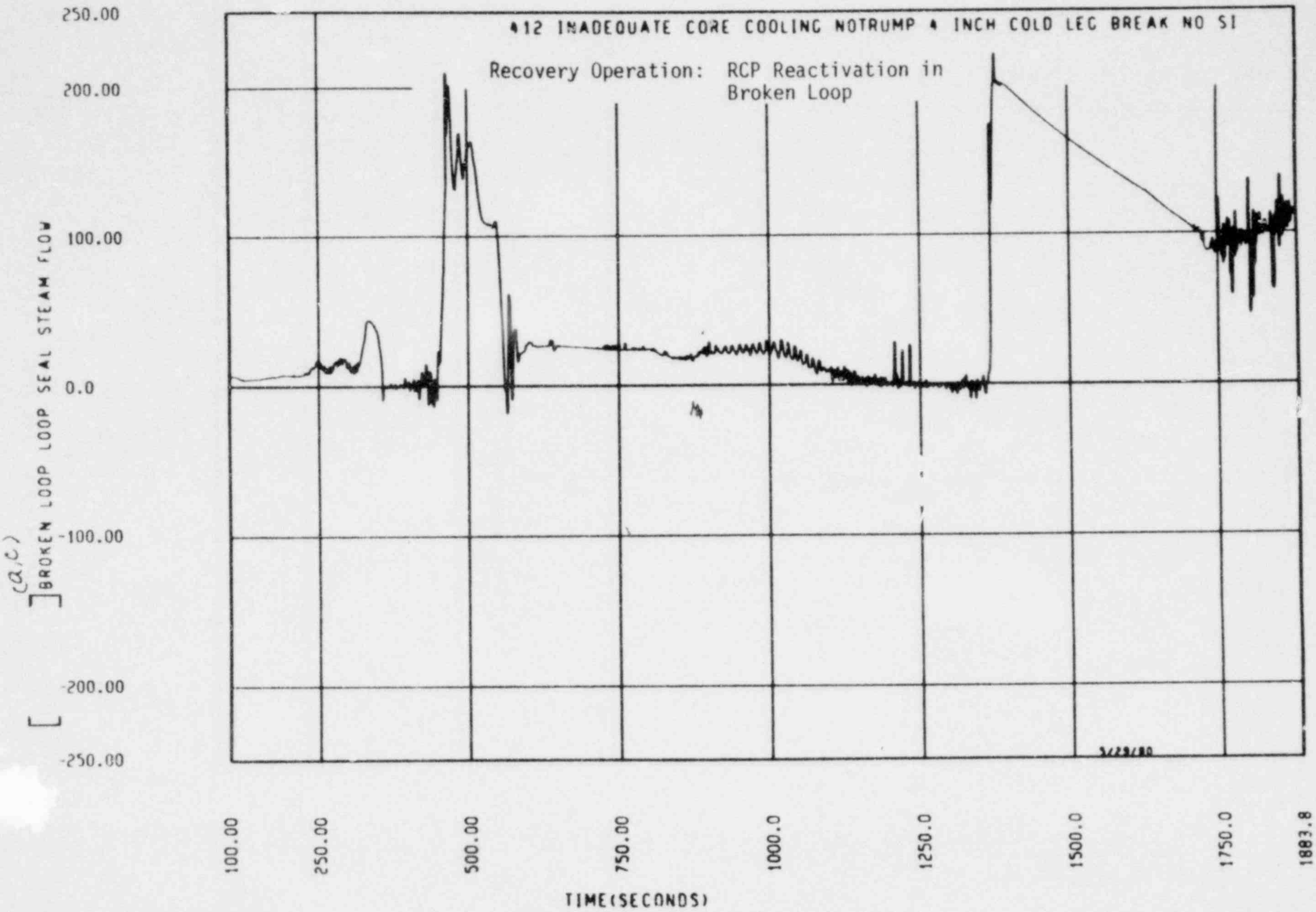

412 INADEQUATE CORE COOLING NOTRUMP 4 INCH COLD LEG BREAK NO SI
Recovery Operation: RCP Reactivation in Broken Loop
5/29/80
[
]BROKEN LOOP LOOP SEAL STEAM FLOW
(a,c)
250.00
200.00
100.00
0.0
-100.00
-200.00
-250.00
100.00
250.00
500.00
750.00
1000.0
1250.0
1500.0
1750.0
1883.8
TIME(SECONDS)

Figure 239

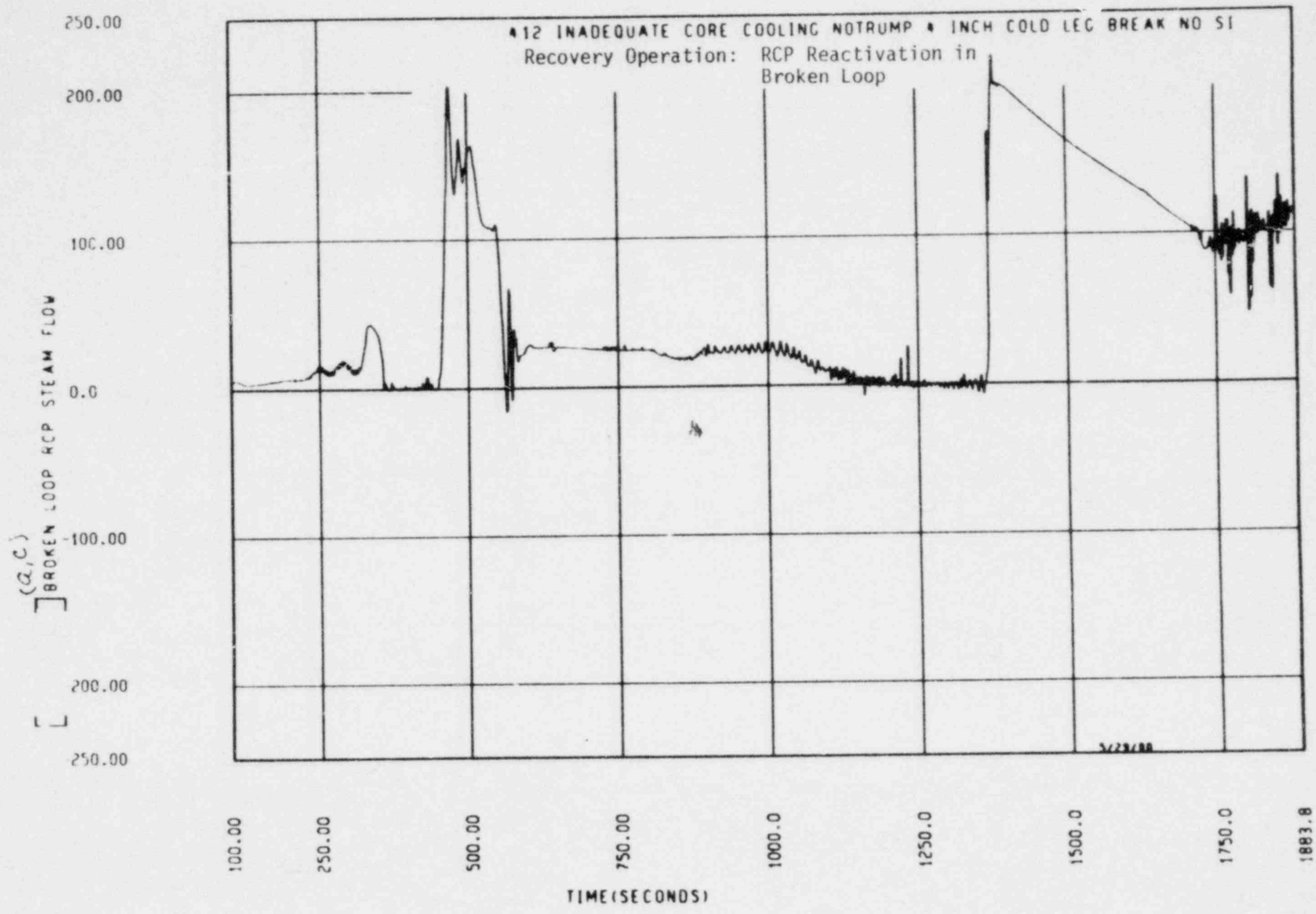

412 INADEQUATE CORE COOLING NOTRUMP 4 INCH COLD LEG BREAK NO SI
Recovery Operation: RCP Reactivation in Broken Loop
250.00
200.00
100.00
0.0
-100.00
200.00
250.00
BROKEN LOOP RCP STEAM FLOW
(a,c)
100.00
250.00
500.00
750.00
1000.0
1250.0
1500.0
1750.0
1883.8
TIME(SECONDS)
5/23/80

Figure 240

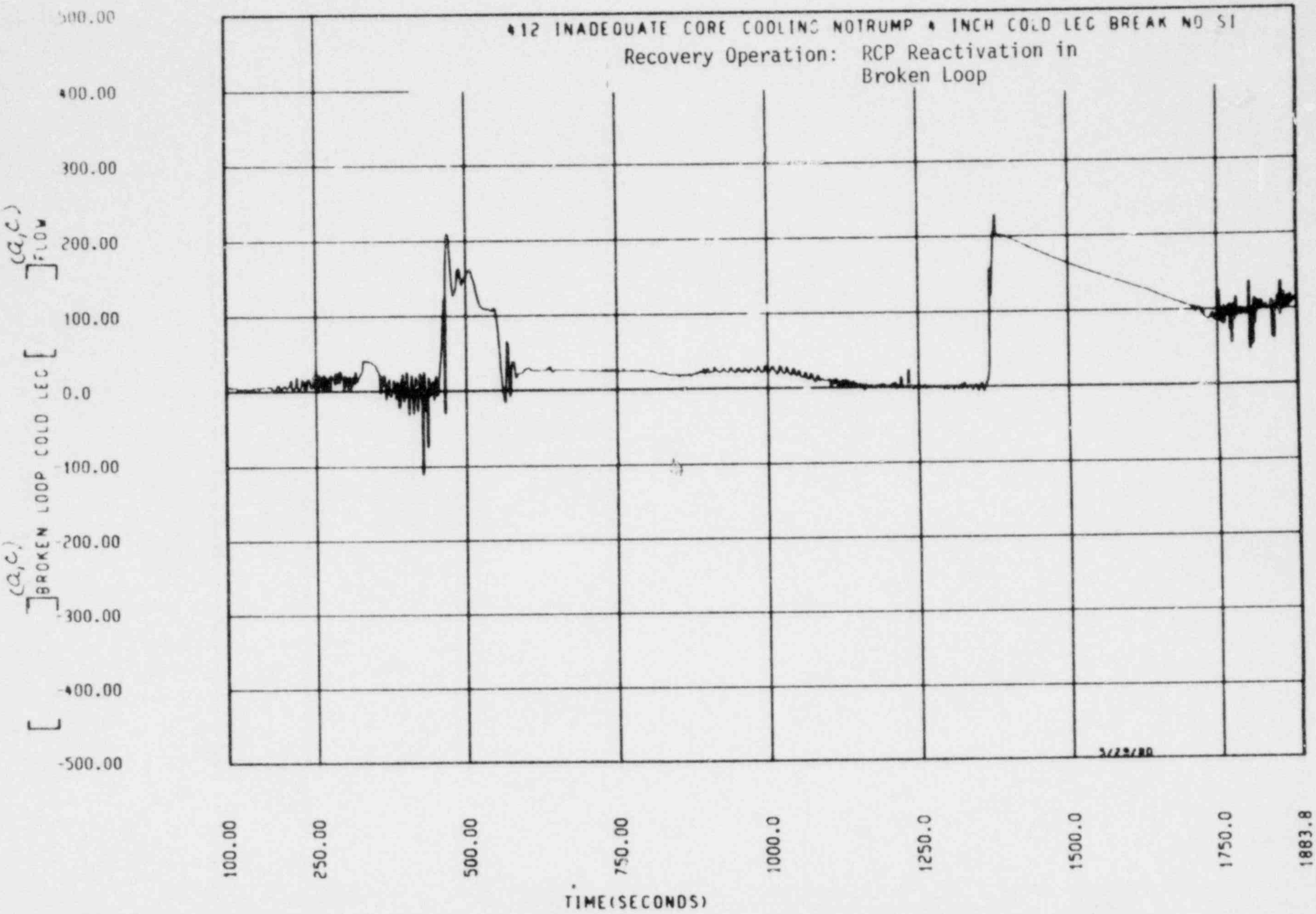
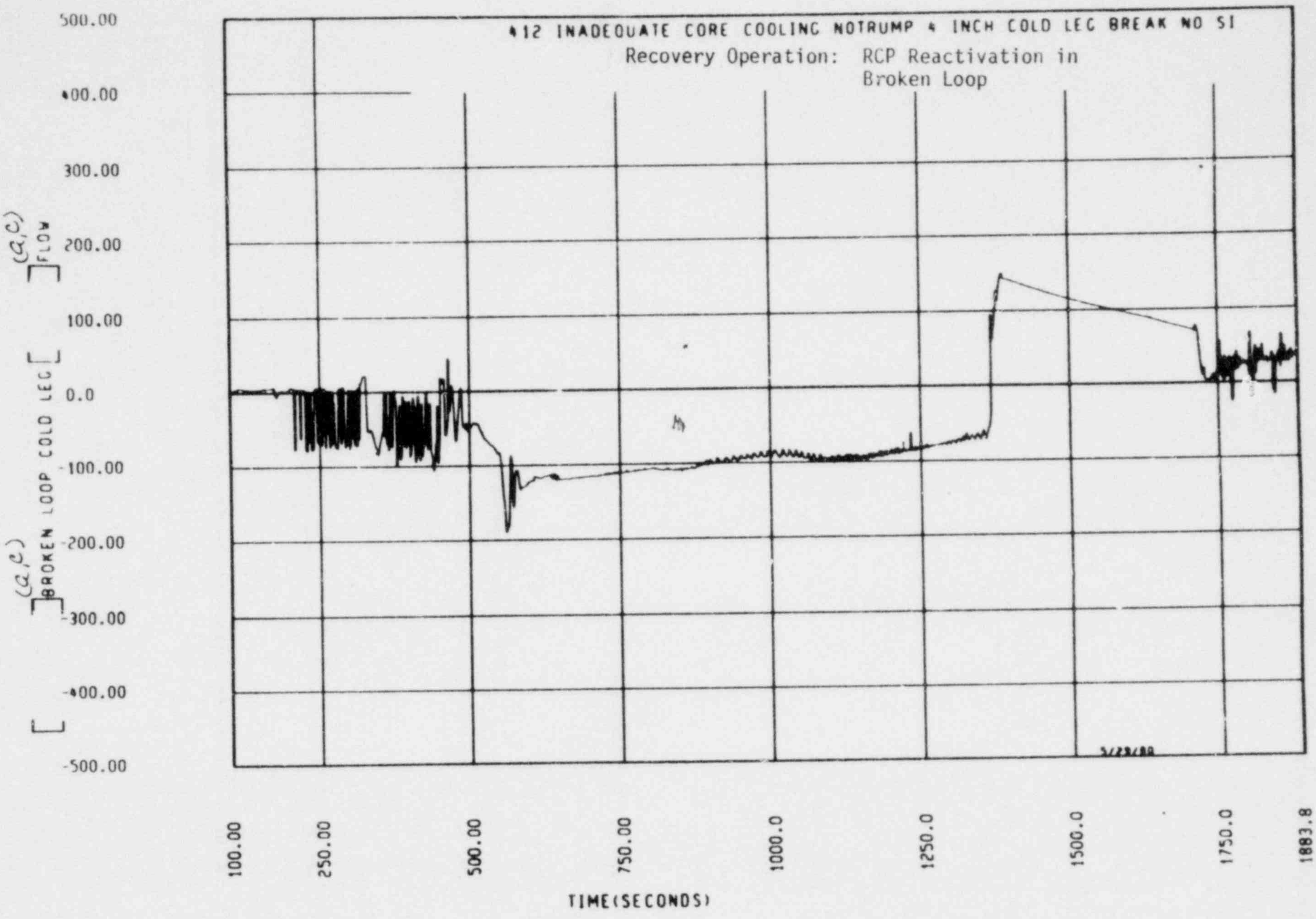

412 INADEQUATE CORE COOLING NOTRUMP 4 INCH COLD LEG BREAK NO SI
Recovery Operation: RCP Reactivation in Broken Loop
500.00
400.00
300.00
200.00
100.00
0.0
-100.00
-200.00
-300.00
-400.00
-500.00
BROKEN LOOP COLD LEG [ ] FLOW [ ]
(a,c)
(a,c)
100.00
250.00
500.00
750.00
1000.0
1250.0
1500.0
1750.0
1883.8
TIME(SECONDS)
5/29/80

Figure 241


4.12 INADEQUATE CORE COOLING NOTRUMP 4 INCH COLD LEG BREAK NO SI

Recovery Operation: RCP Reactivation in Broken Loop

5/29/80

Figure 242

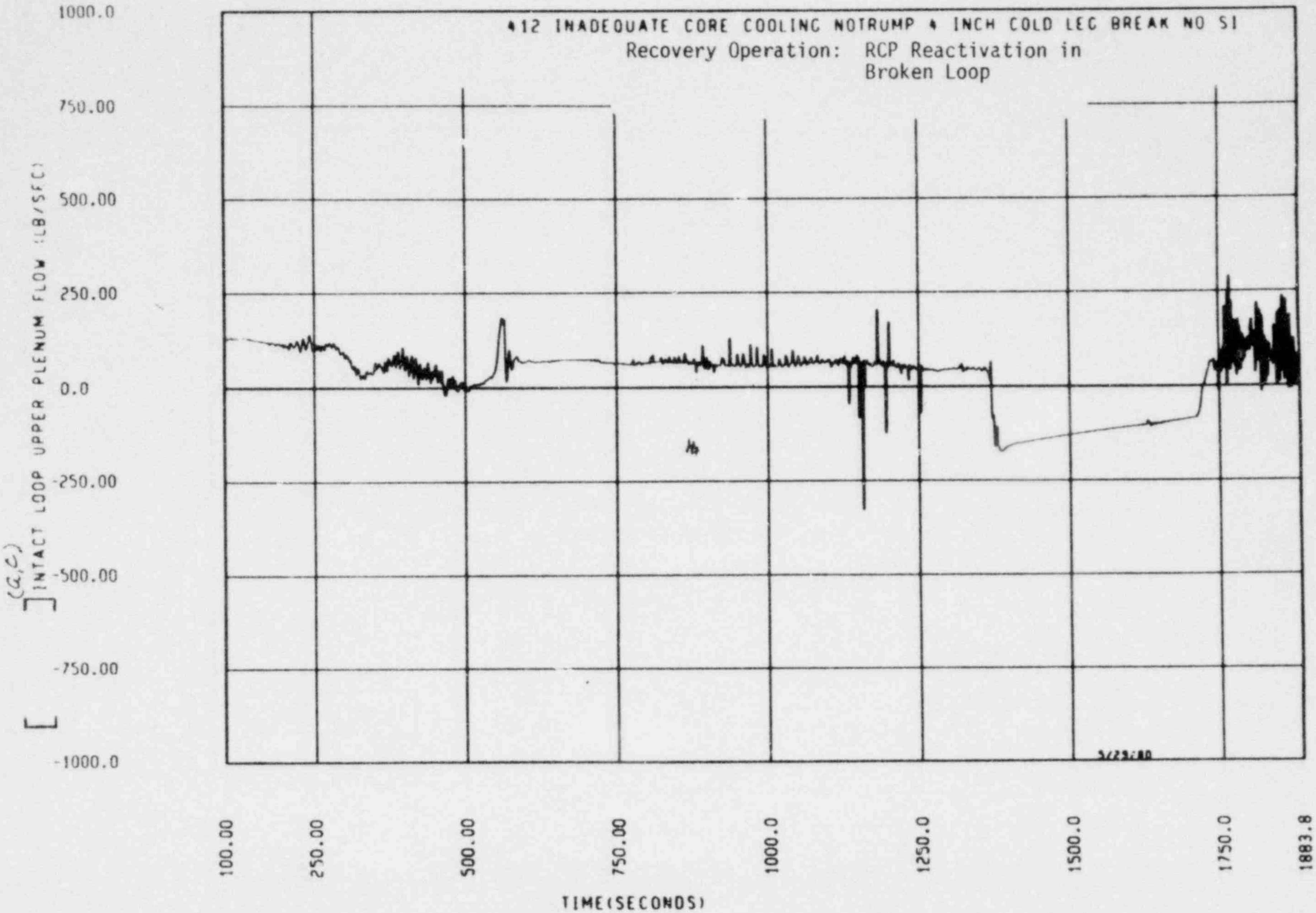

412 INADEQUATE CORE COOLING NOTRUMP 4 INCH COLD LEG BREAK NO SI
Recovery Operation: RCP Reactivation in Broken Loop
INTACT LOOP UPPER PLENUM FLOW (LB/SEC)
(a,c)
1000.0
750.00
500.00
250.00
0.0
-250.00
-500.00
-750.00
-1000.0
100.00
250.00
500.00
750.00
1000.0
1250.0
1500.0
1750.0
1883.8
TIME(SECONDS)
5/29/80

Figure 243

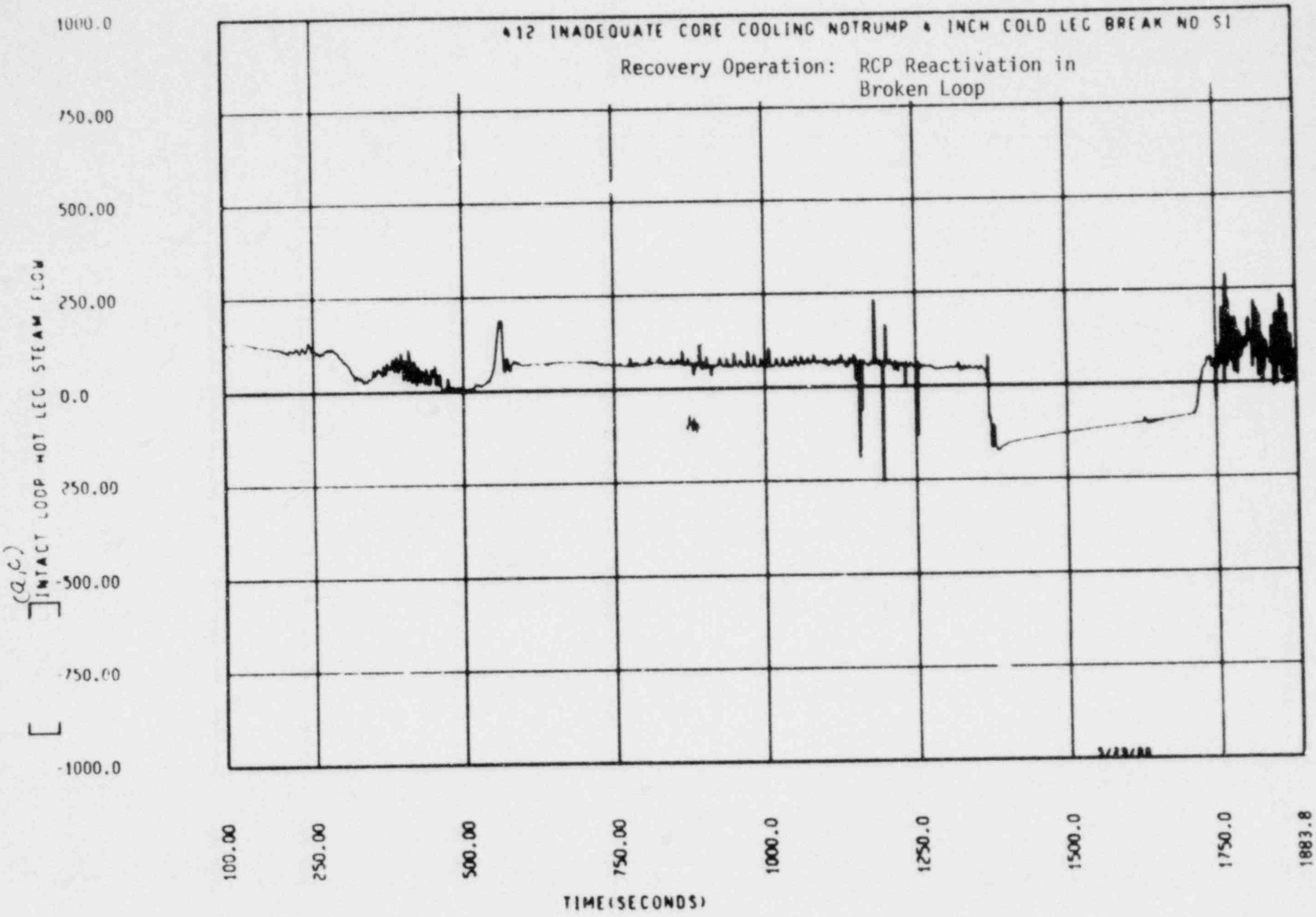

412 INADEQUATE CORE COOLING NOTRUMP 4 INCH COLD LEG BREAK NO SI
Recovery Operation: RCP Reactivation in Broken Loop
INTACT LOOP HOT LEG STEAM FLOW
(a,c)
1000.0
750.00
500.00
250.00
0.0
-250.00
-500.00
-750.00
-1000.0
100.00
250.00
500.00
750.00
1000.0
1250.0
1500.0
1750.0
1883.8
TIME(SECONDS)

Figure 244

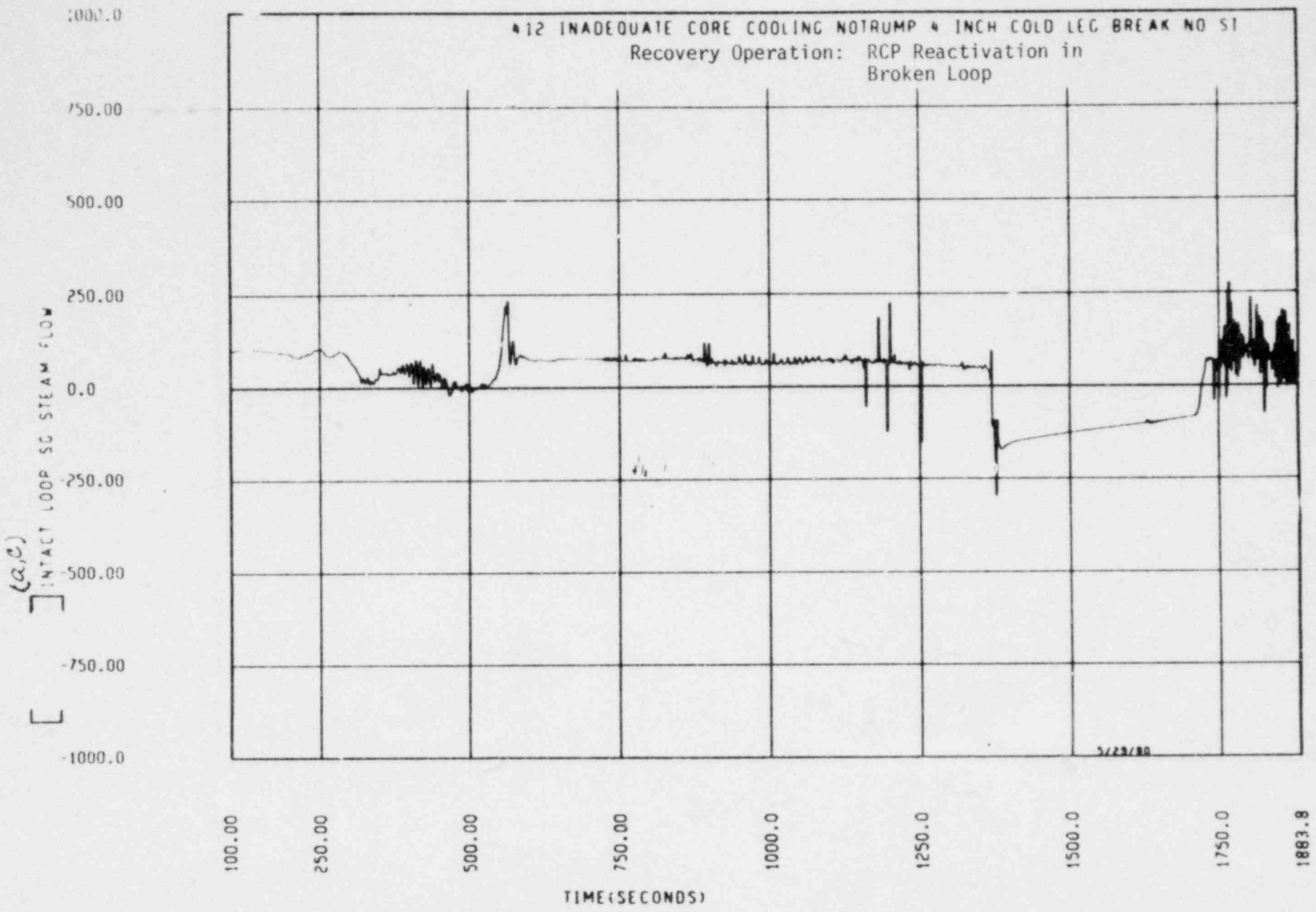

412 INADEQUATE CORE COOLING NOTRUMP 4 INCH COLD LEG BREAK NO SI
Recovery Operation: RCP Reactivation in Broken Loop
INTACT LOOP SG STEAM FLOW
(a,c)
1000.0
750.00
500.00
250.00
0.0
-250.00
-500.00
-750.00
-1000.0
100.00
250.00
500.00
750.00
1000.0
1250.0
1500.0
1750.0
1883.8
TIME(SECONDS)
5/29/80

Figure 245

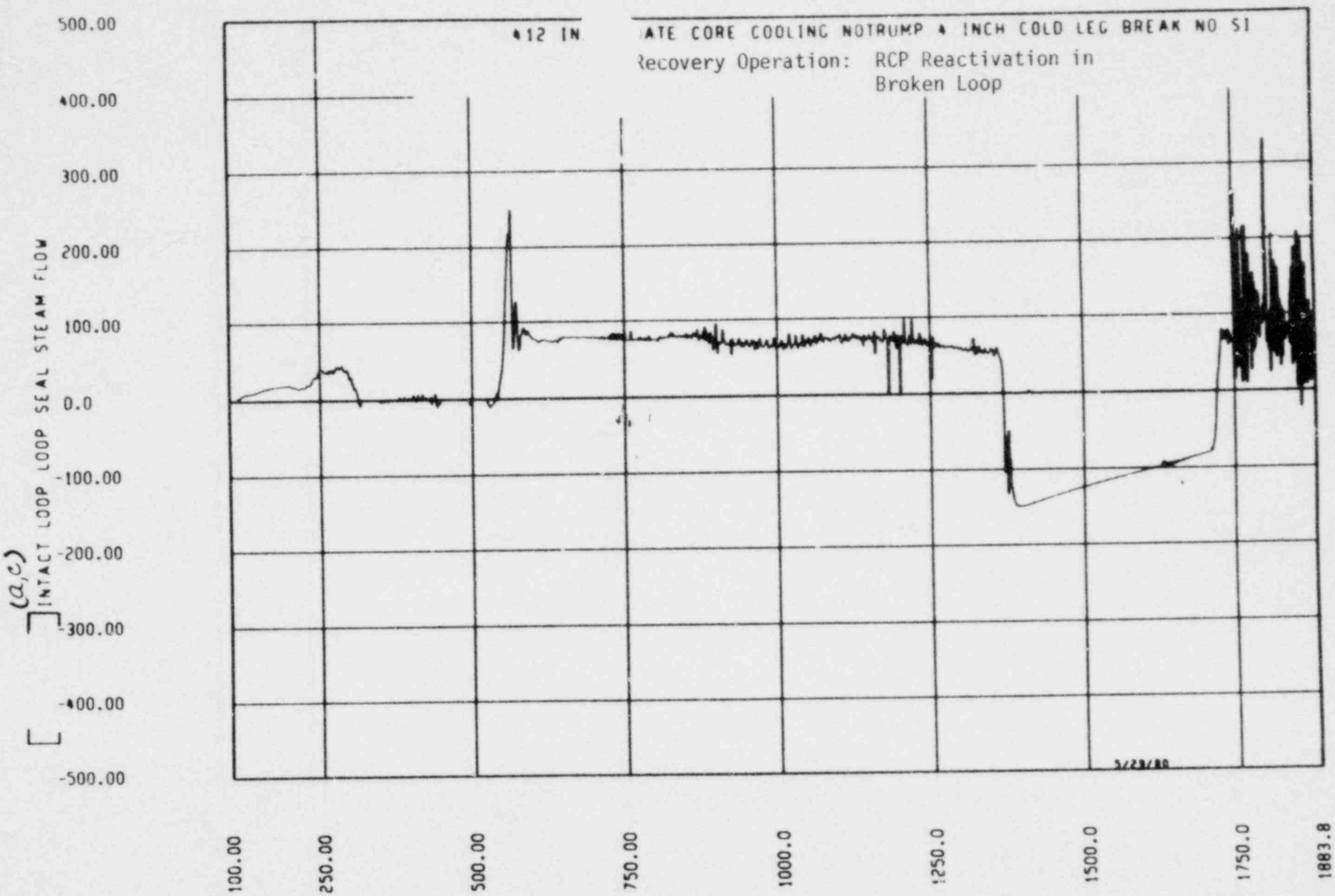

412 IN
ATE CORE COOLING NOTRUMP 4 INCH COLD LEG BREAK NO SI
ecovery Operation: RCP Reactivation in Broken Loop
INTACT LOOP LOOP SEAL STEAM FLOW
(a,c)
500.00
400.00
300.00
200.00
100.00
0.0
-100.00
-200.00
-300.00
-400.00
-500.00
100.00
250.00
500.00
750.00
1000.0
1250.0
1500.0
1750.0
1883.8
TIME(SECONDS)
5/29/80

Figure 246

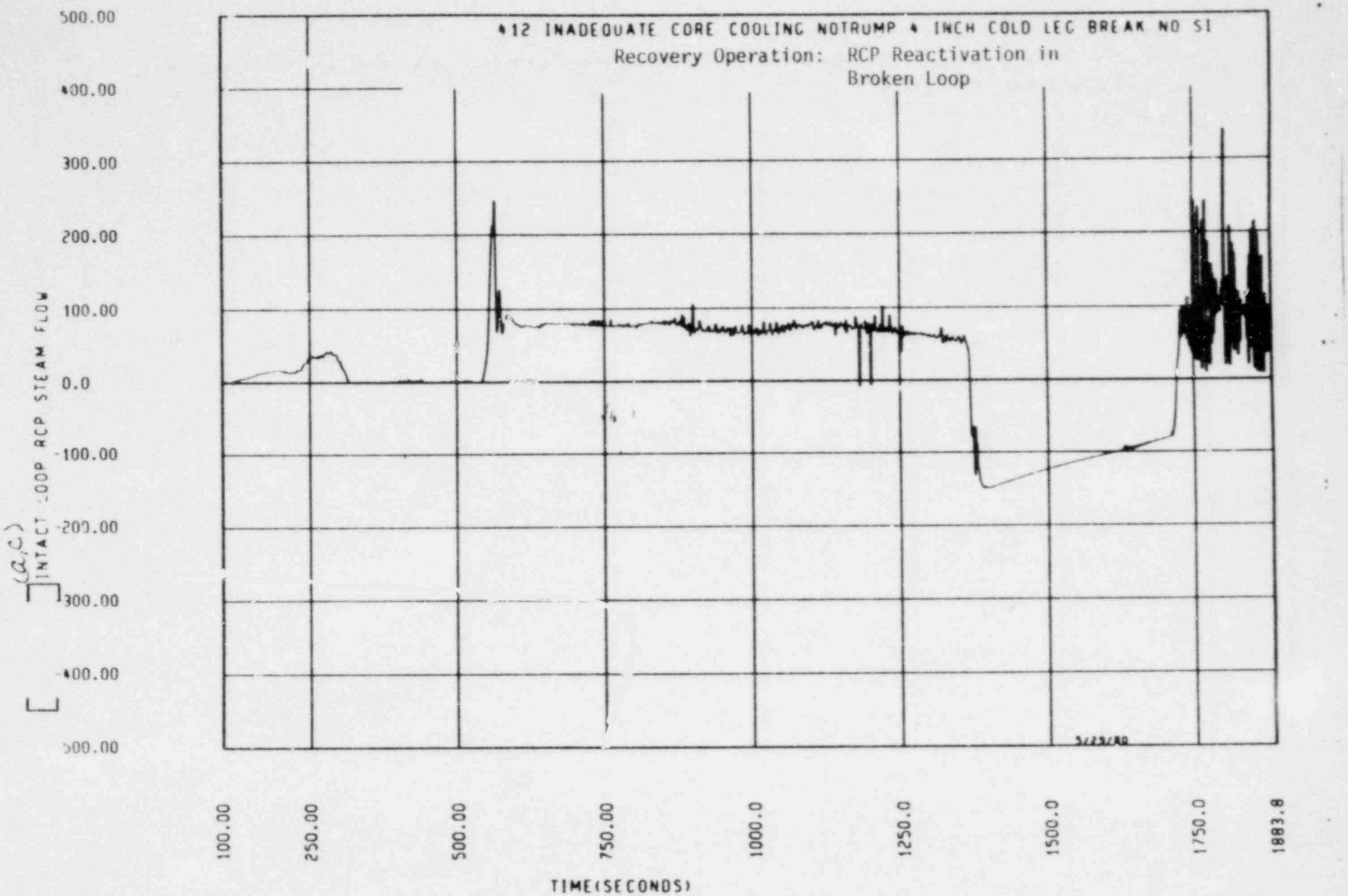

412 INADEQUATE CORE COOLING NOTRUMP 4 INCH COLD LEG BREAK NO SI
Recovery Operation: RCP Reactivation in
Broken Loop
INTACT LOOP RCP STEAM FLOW
(a,c)
500.00
400.00
300.00
200.00
100.00
0.0
-100.00
-200.00
-300.00
-400.00
-500.00
100.00
250.00
500.00
750.00
1000.0
1250.0
1500.0
1750.0
1883.8
5/23/80
TIME(SECONDS)

Figure 247

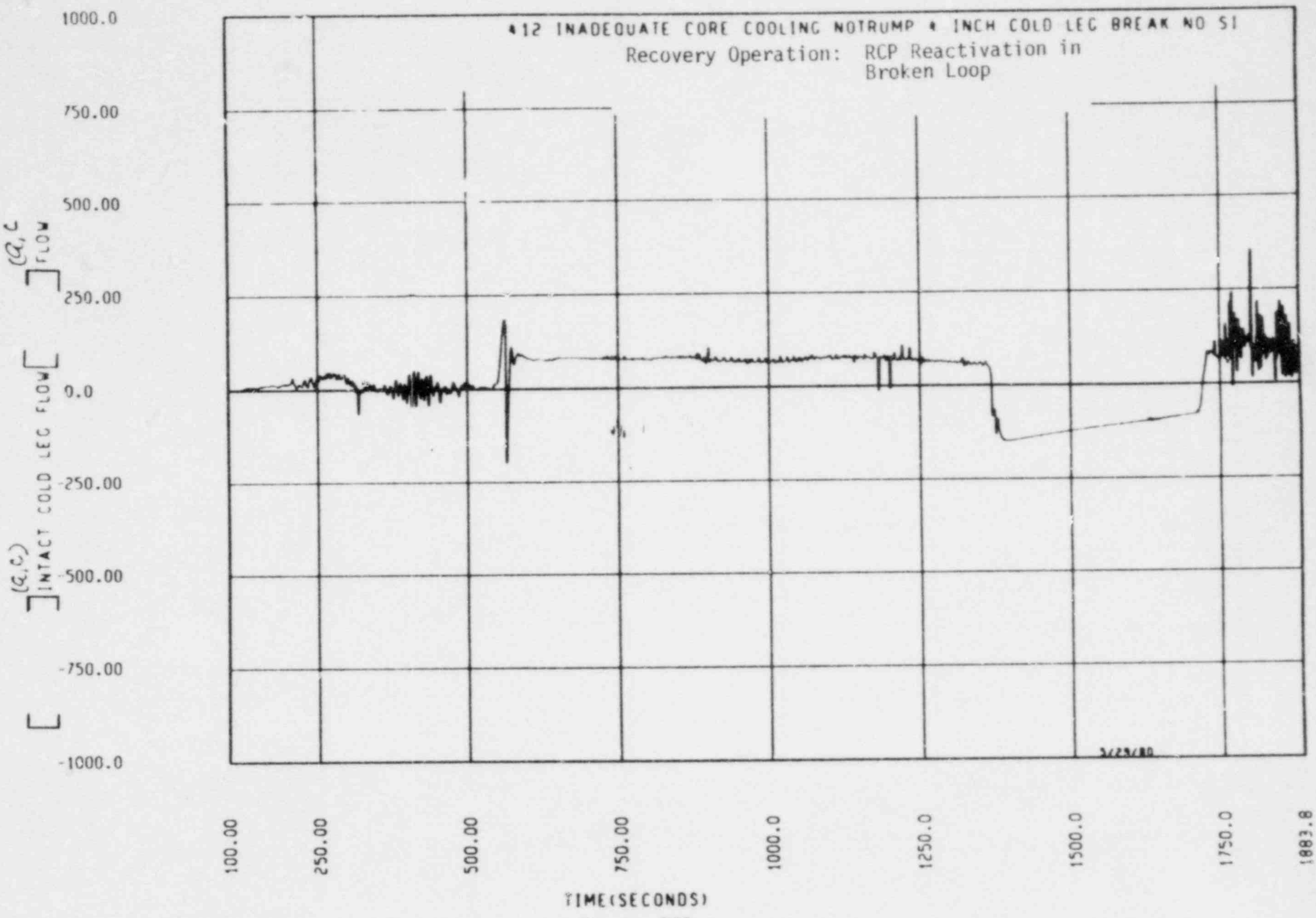

412 INADEQUATE CORE COOLING NOTRUMP 4 INCH COLD LEG BREAK NO SI
Recovery Operation: RCP Reactivation in Broken Loop
(a,c)
INTACT COLD LEG FLOW
FLOW
(a,c)
1000.0
750.00
500.00
250.00
0.0
-250.00
-500.00
-750.00
-1000.0
100.00
250.00
500.00
750.00
1000.0
1250.0
1500.0
1750.0
1883.8
TIME(SECONDS)
5/29/80

Figure 248

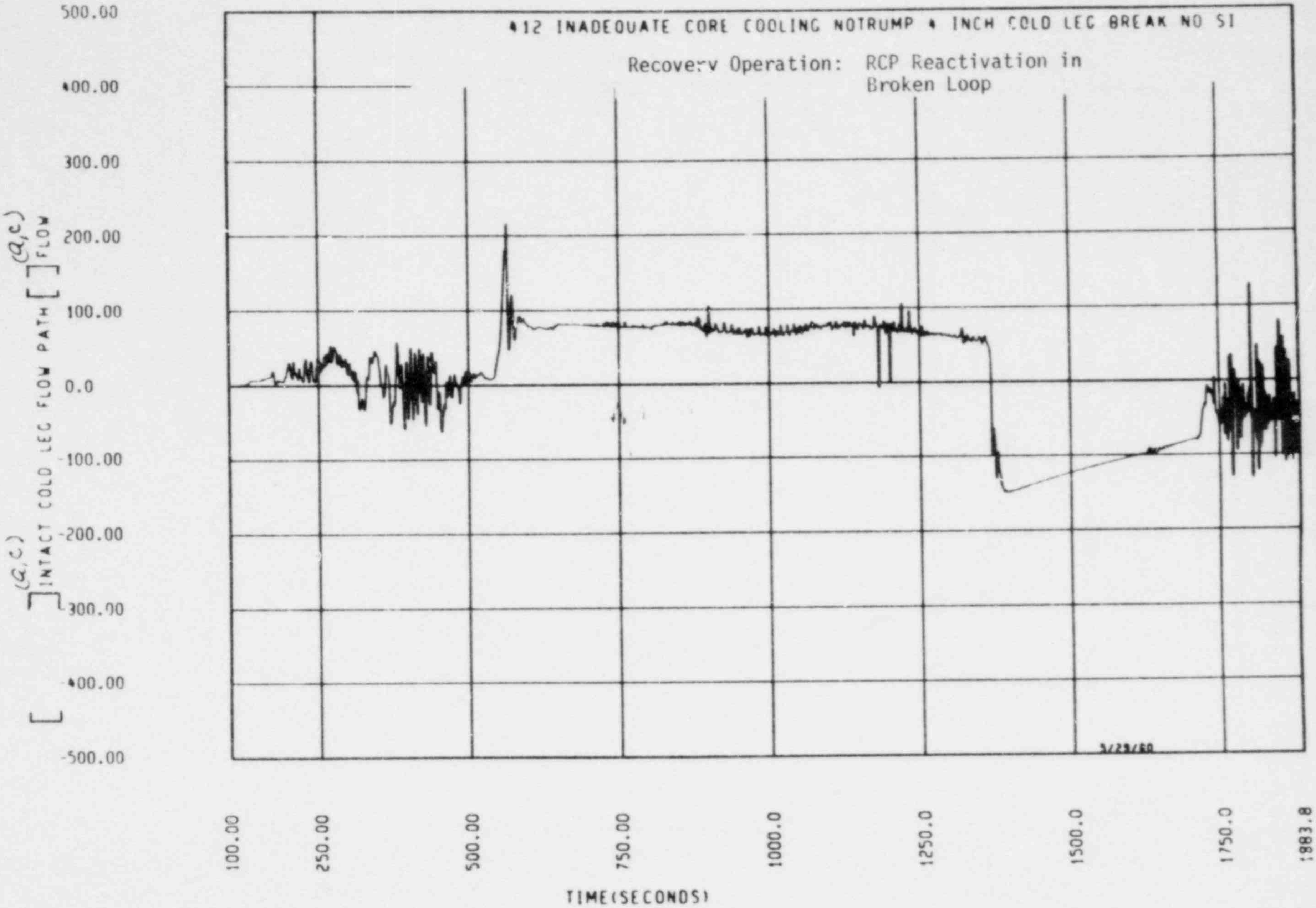

412 INADEQUATE CORE COOLING NOTRUMP 4 INCH COLD LEG BREAK NO SI
Recovery Operation: RCP Reactivation in Broken Loop
[ ]INTACT COLD LEG FLOW PATH [ ]FLOW
(a,c)
(a,c)
500.00
400.00
300.00
200.00
100.00
0.0
-100.00
-200.00
-300.00
-400.00
-500.00
100.00
250.00
500.00
750.00
1000.0
1250.0
1500.0
1750.0
1883.8
TIME(SECONDS)
5/29/80

Figure 249

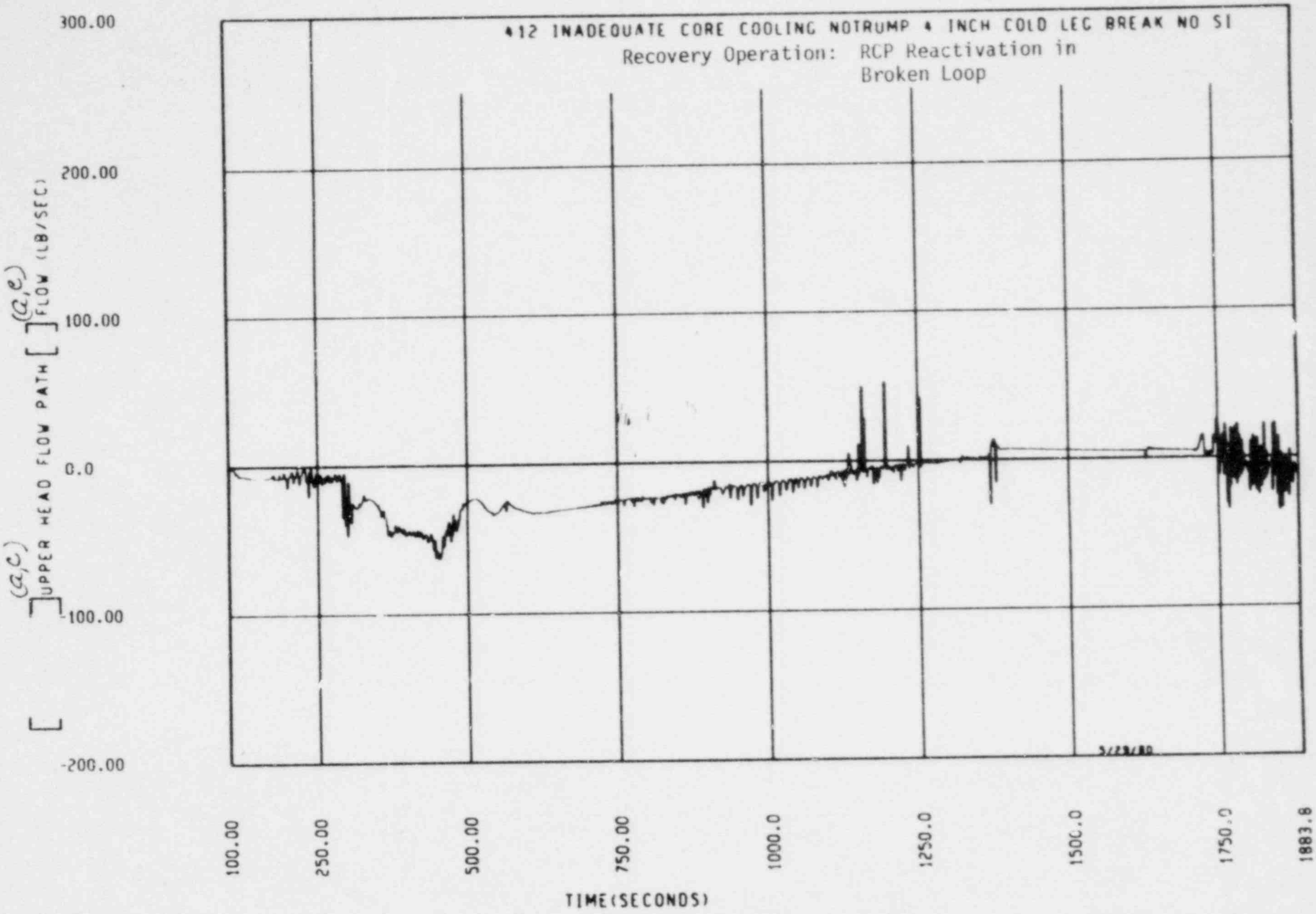

412 INADEQUATE CORE COOLING NOTRUMP 4 INCH COLD LEG BREAK NO SI
Recovery Operation: RCP Reactivation in Broken Loop
(a,c) UPPER HEAD FLOW PATH [ ] FLOW (LB/SEC) (a,e)
[ ]
300.00
200.00
100.00
0.0
-100.00
-200.00
100.00
250.00
500.00
750.00
1000.0
1250.0
1500.0
1750.0
1883.8
TIME(SECONDS)
5/29/80

Figure 250

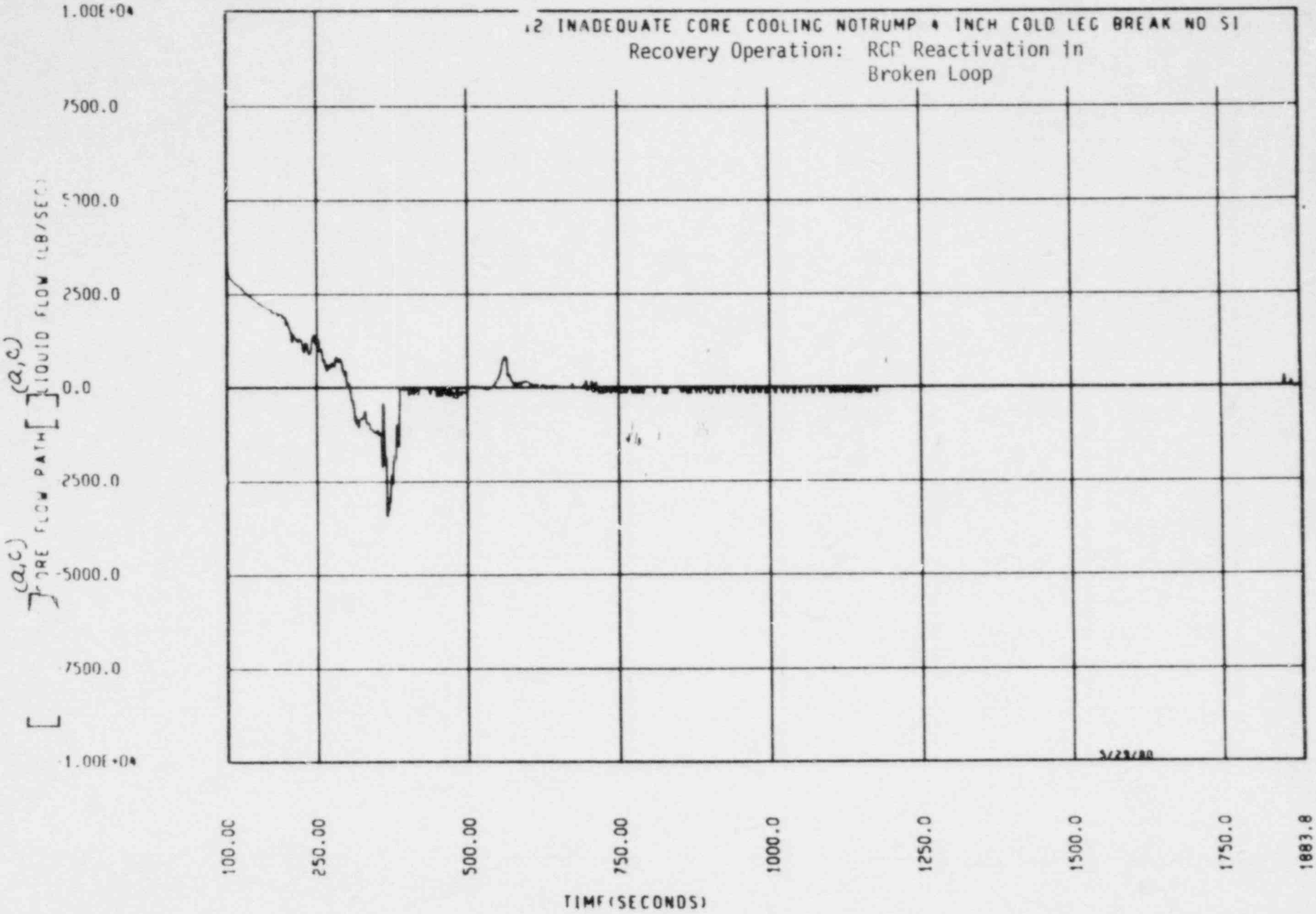

.2 INADEQUATE CORE COOLING NOTRUMP 4 INCH COLD LEG BREAK NO SI
Recovery Operation: RCP Reactivation in
Broken Loop
1.00E+04
7500.0
5000.0
2500.0
0.0
-2500.0
-5000.0
-7500.0
-1.00E+04
CORE FLOW PATH LIQUID FLOW (LB/SEC)
(a,c)
(a,c)
100.00
250.00
500.00
750.00
1000.0
1250.0
1500.0
1750.0
1883.8
TIME (SECONDS)
5/23/80

Figure 251

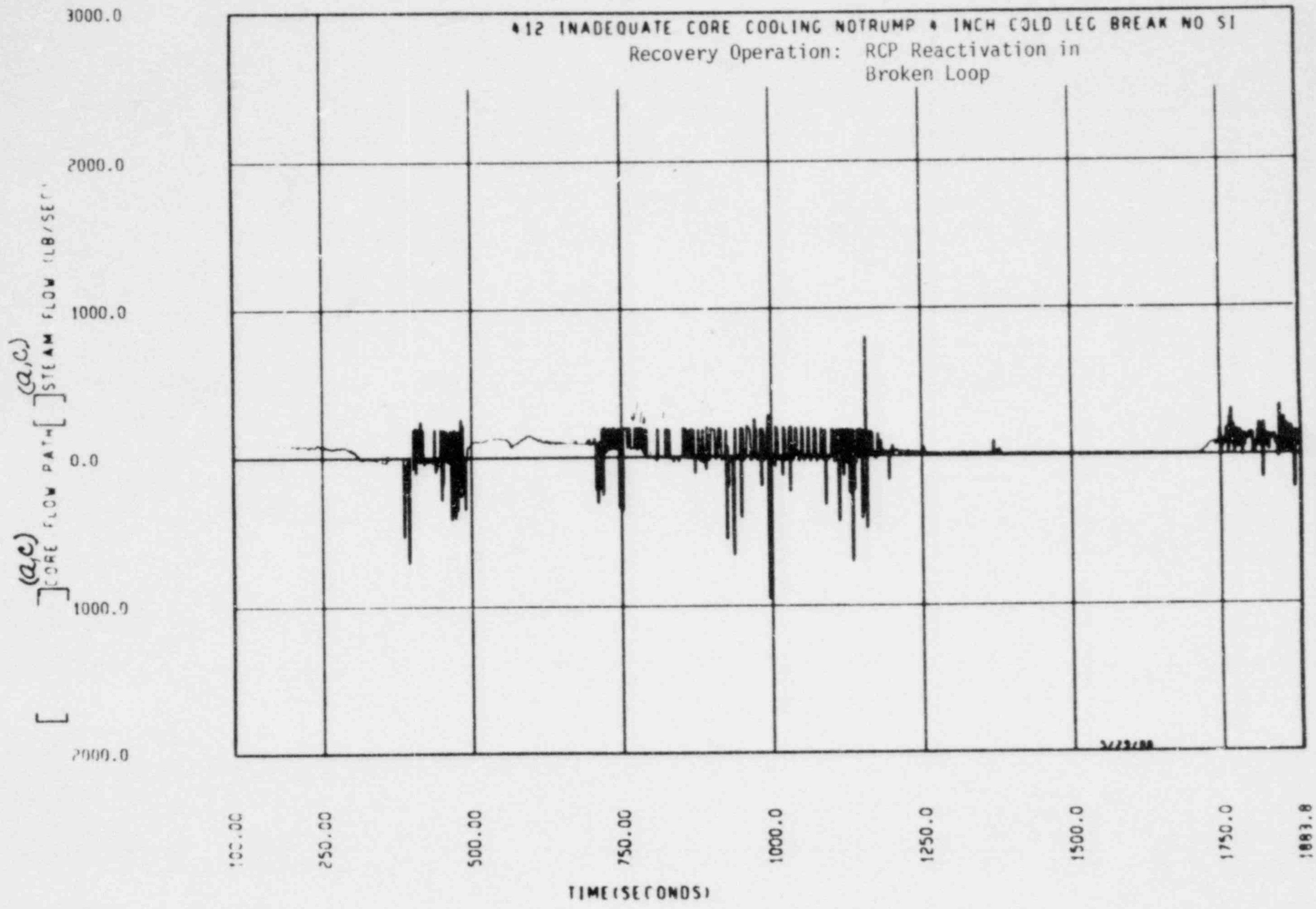

412 INADEQUATE CORE COOLING NOTRUMP 4 INCH COLD LEG BREAK NO SI
Recovery Operation: RCP Reactivation in
Broken Loop
3000.0
2000.0
1000.0
0.0
1000.0
2000.0
(a,c)
CORE FLOW PATH
(a,c)
STEAM FLOW (LB/SEC)
100.00
250.00
500.00
750.00
1000.0
1250.0
1500.0
1750.0
1883.8
TIME(SECONDS)

Figure 252

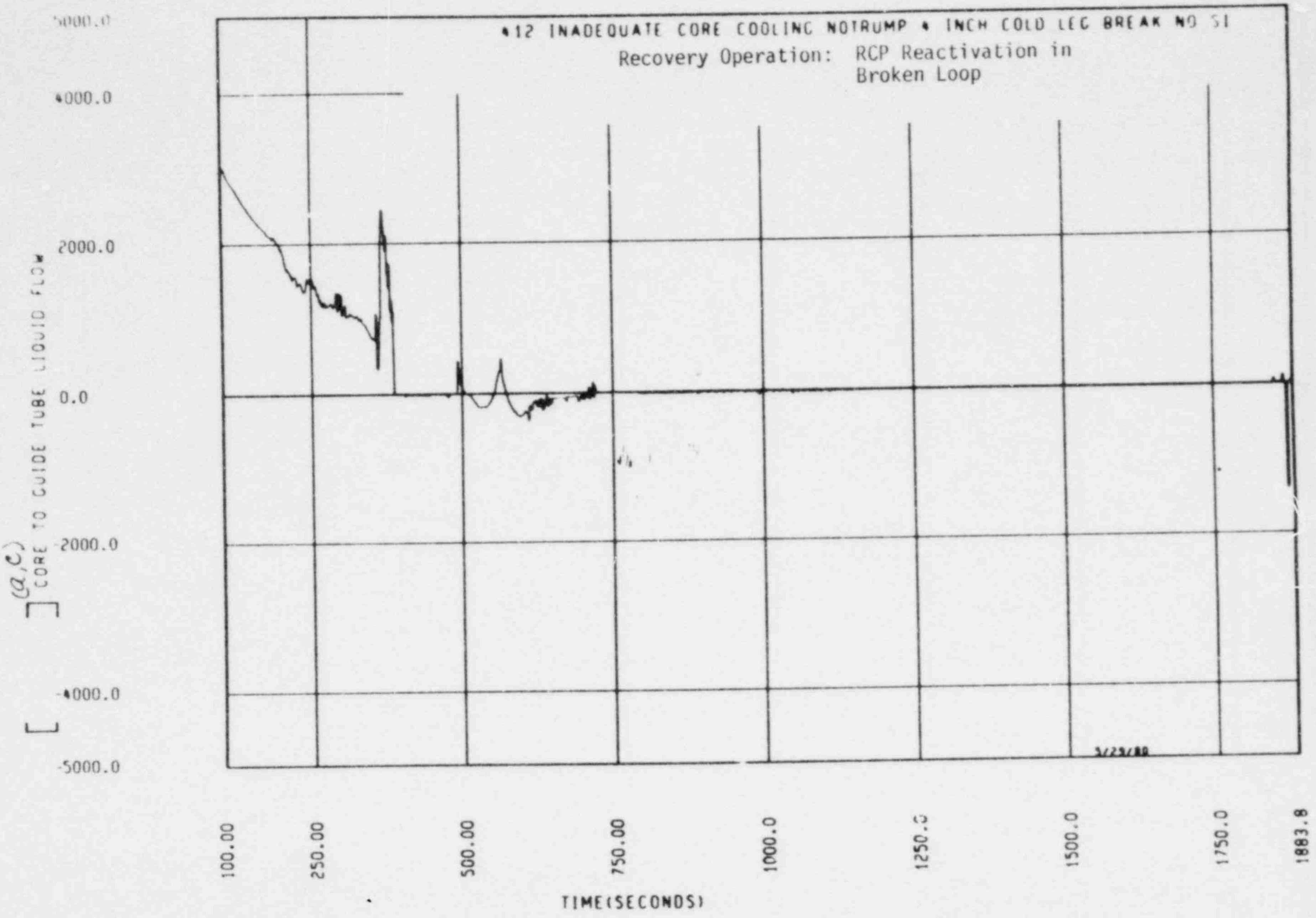

412 INADEQUATE CORE COOLING NOTRUMP 4 INCH COLD LEG BREAK NO SI
Recovery Operation: RCP Reactivation in Broken Loop
5000.0
4000.0
2000.0
0.0
-2000.0
-4000.0
-5000.0
CORE TO GUIDE TUBE LIQUID FLOW
(a,c)
100.00
250.00
500.00
750.00
1000.0
1250.0
1500.0
1750.0
1883.8
TIME(SECONDS)
5/29/80

Figure 253

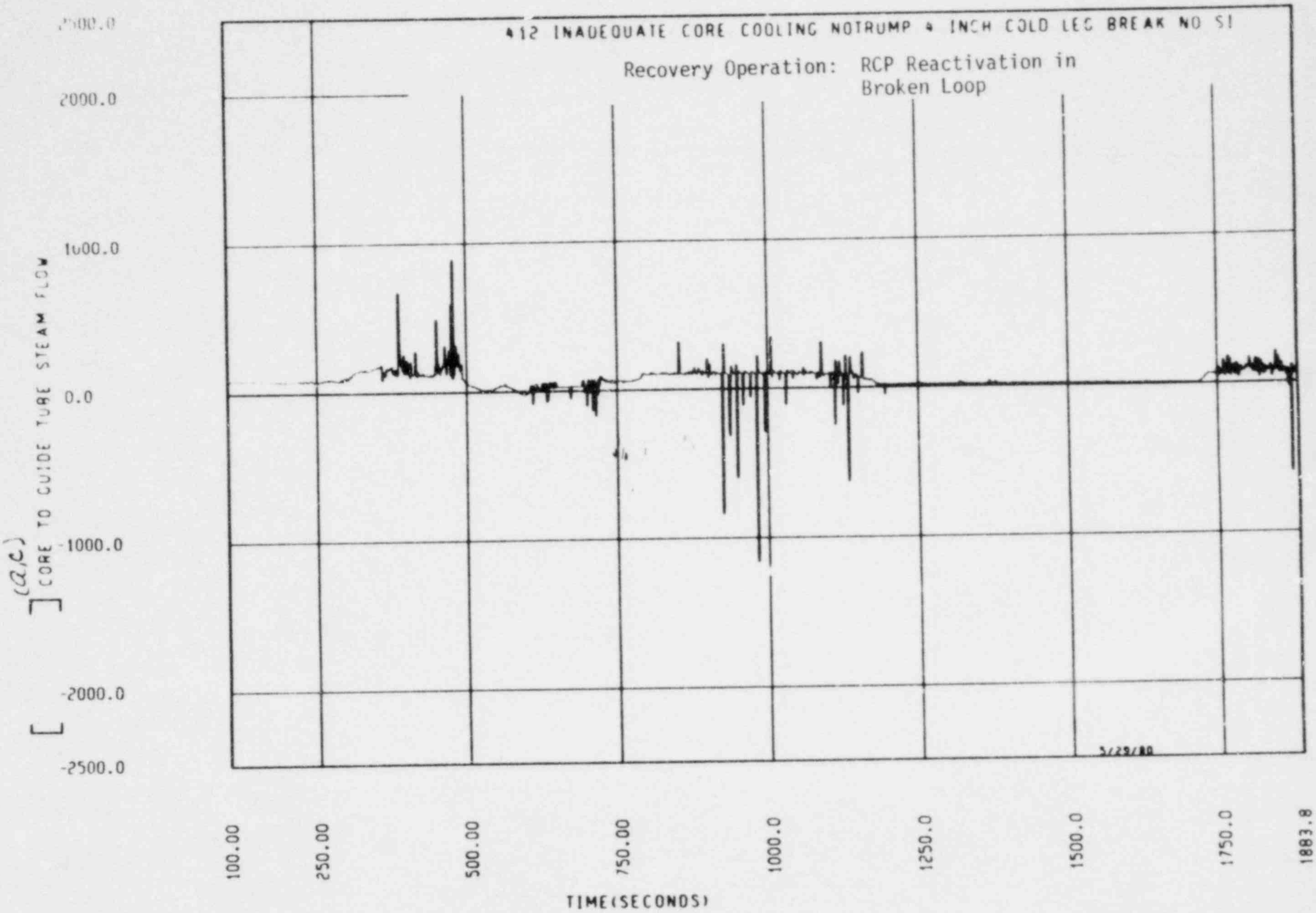

412 INADEQUATE CORE COOLING NOTRUMP 4 INCH COLD LEG BREAK NO SI
Recovery Operation: RCP Reactivation in Broken Loop
2500.0
2000.0
1000.0
0.0
-1000.0
-2000.0
-2500.0
CORE TO GUIDE TUBE STEAM FLOW
(a,c)
100.00
250.00
500.00
750.00
1000.0
1250.0
1500.0
1750.0
1883.8
TIME(SECONDS)
5/29/80

Figure 254

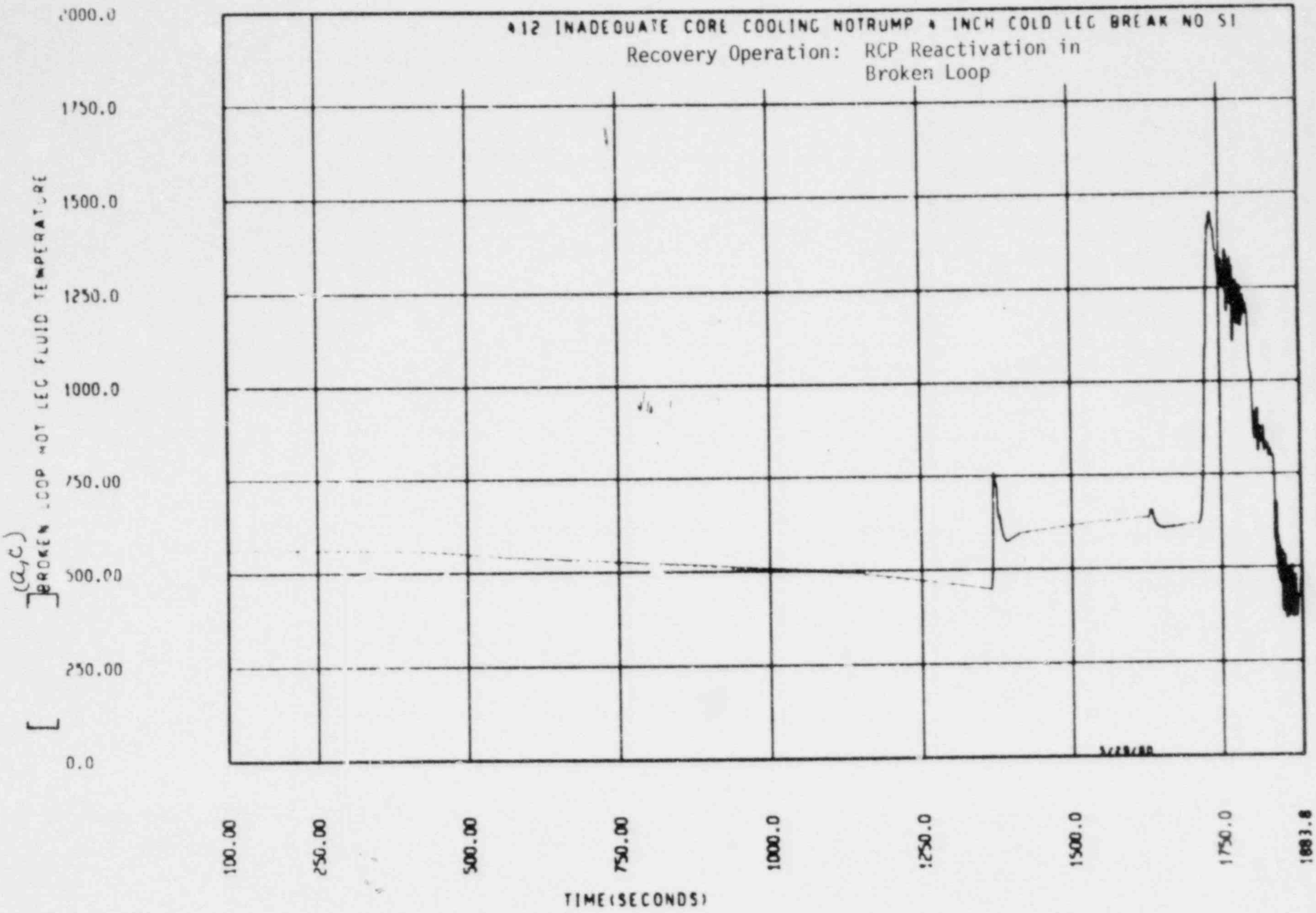

412 INADEQUATE CORE COOLING NOTRUMP 4 INCH COLD LEG BREAK NO SI
Recovery Operation: RCP Reactivation in Broken Loop
BROKEN LOOP HOT LEG FLUID TEMPERATURE
(a,c)
2000.0
1750.0
1500.0
1250.0
1000.0
750.00
500.00
250.00
0.0
100.00
250.00
500.00
750.00
1000.0
1250.0
1500.0
1750.0
1883.8
TIME(SECONDS)

Figure 255

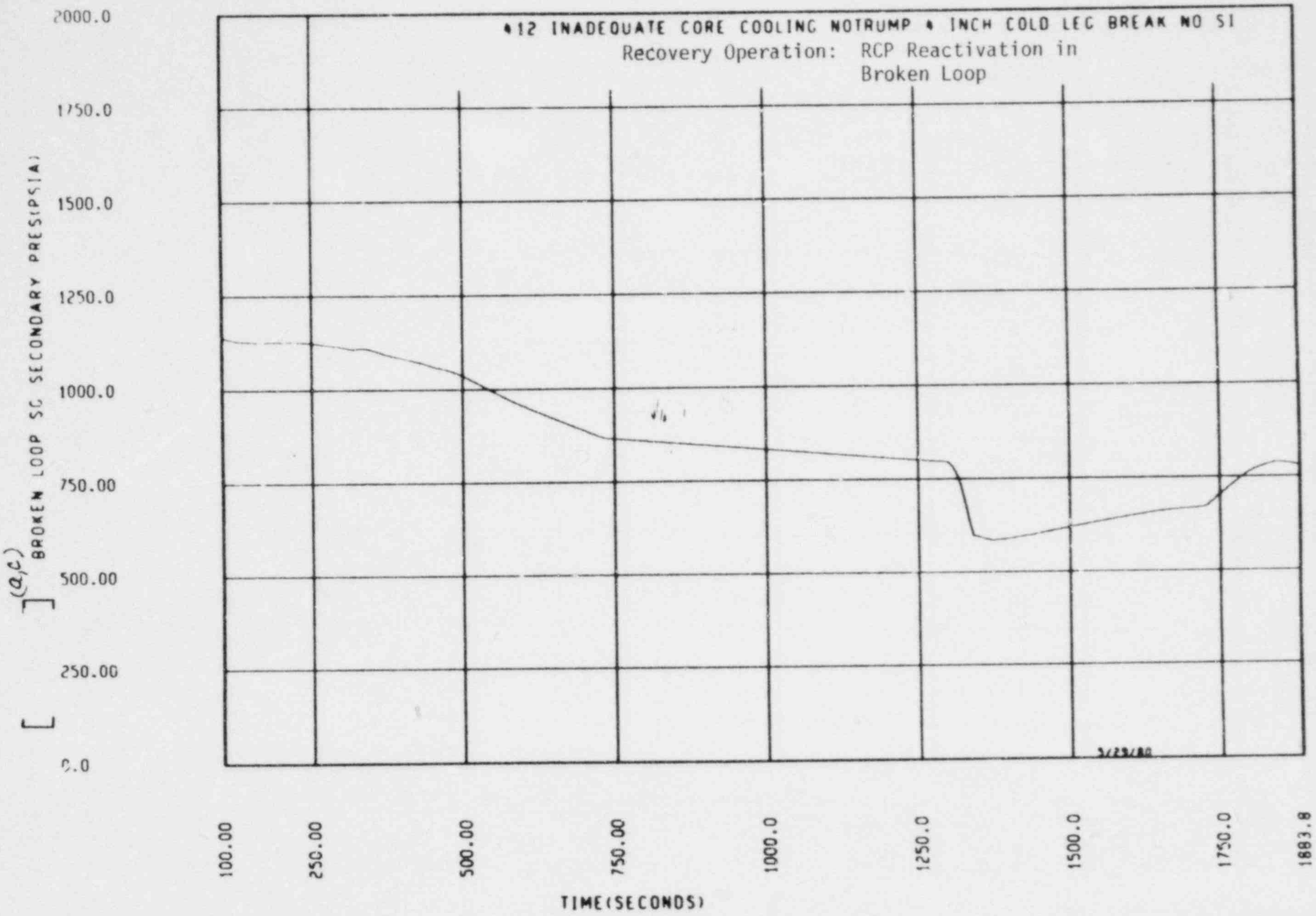

412 INADEQUATE CORE COOLING NOTRUMP 4 INCH COLD LEG BREAK NO SI
Recovery Operation: RCP Reactivation in Broken Loop
5/23/80
BROKEN LOOP SG SECONDARY PRES(PSIA)
[ ](a,c)
2000.0
1750.0
1500.0
1250.0
1000.0
750.00
500.00
250.00
0.0
100.00
250.00
500.00
750.00
1000.0
1250.0
1500.0
1750.0
1883.8
TIME(SECONDS)

Figure 256

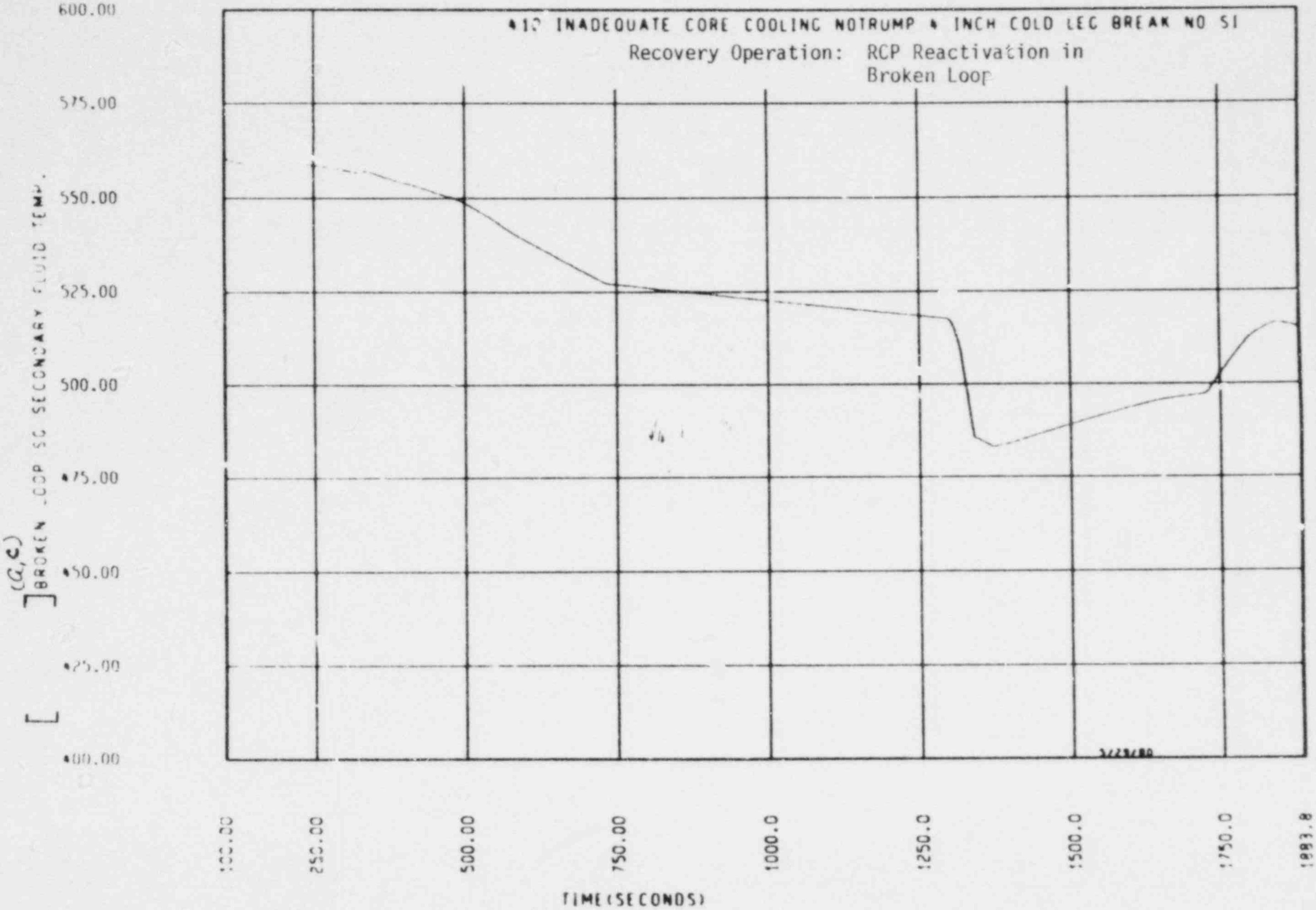
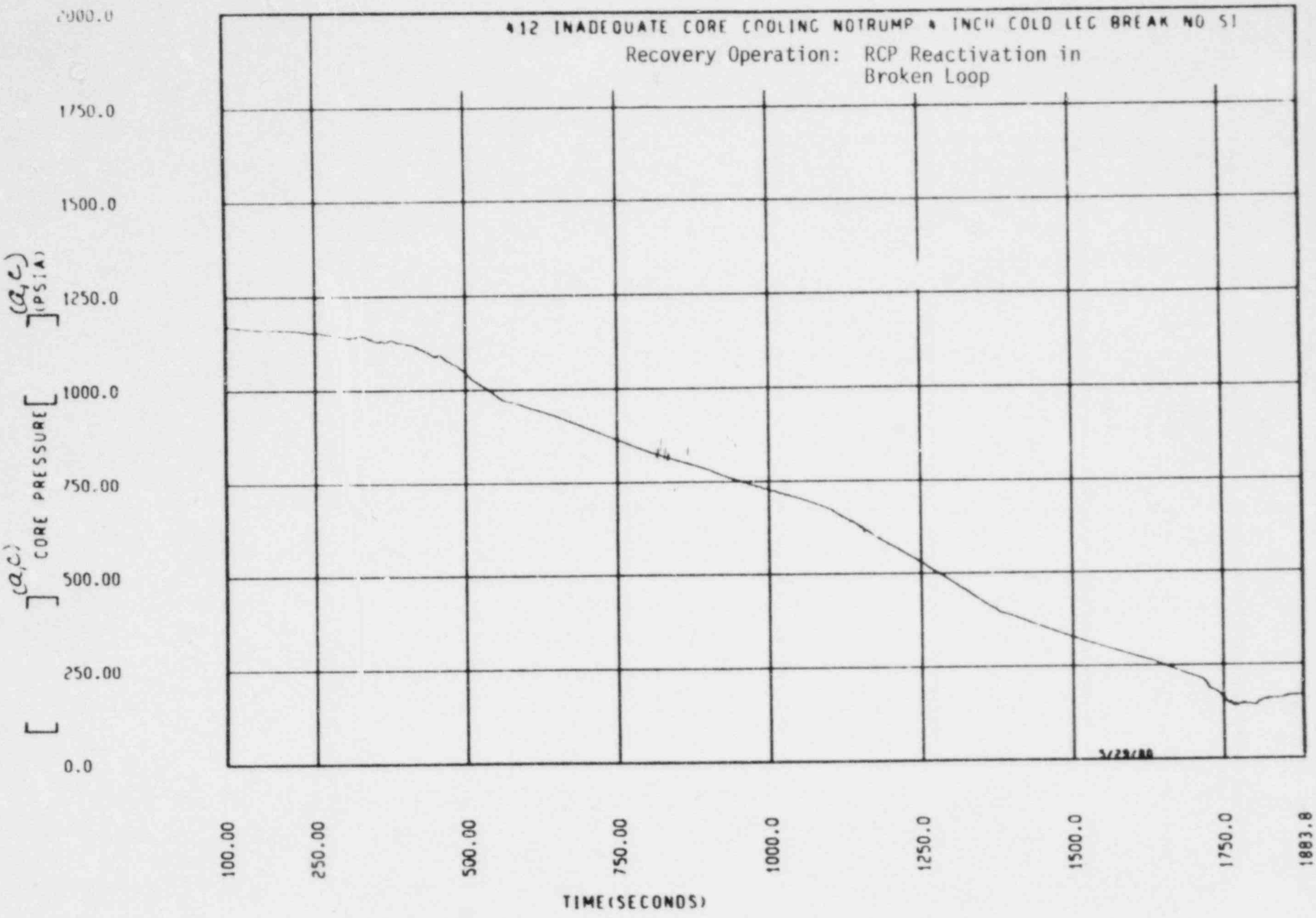

412 INADEQUATE CORE COOLING NOTRUMP 4 INCH COLD LEG BREAK NO SI
Recovery Operation: RCP Reactivation in Broken Loop
BROKEN LOOP SG SECONDARY FLUID TEMP.
(a,c)
600.00
575.00
550.00
525.00
500.00
475.00
450.00
425.00
400.00
100.00
250.00
500.00
750.00
1000.0
1250.0
1500.0
1750.0
1883.8
TIME (SECONDS)
5/29/80

Figure 257



Recovery Operation: RCP Reactivation in Broken Loop

Figure 258

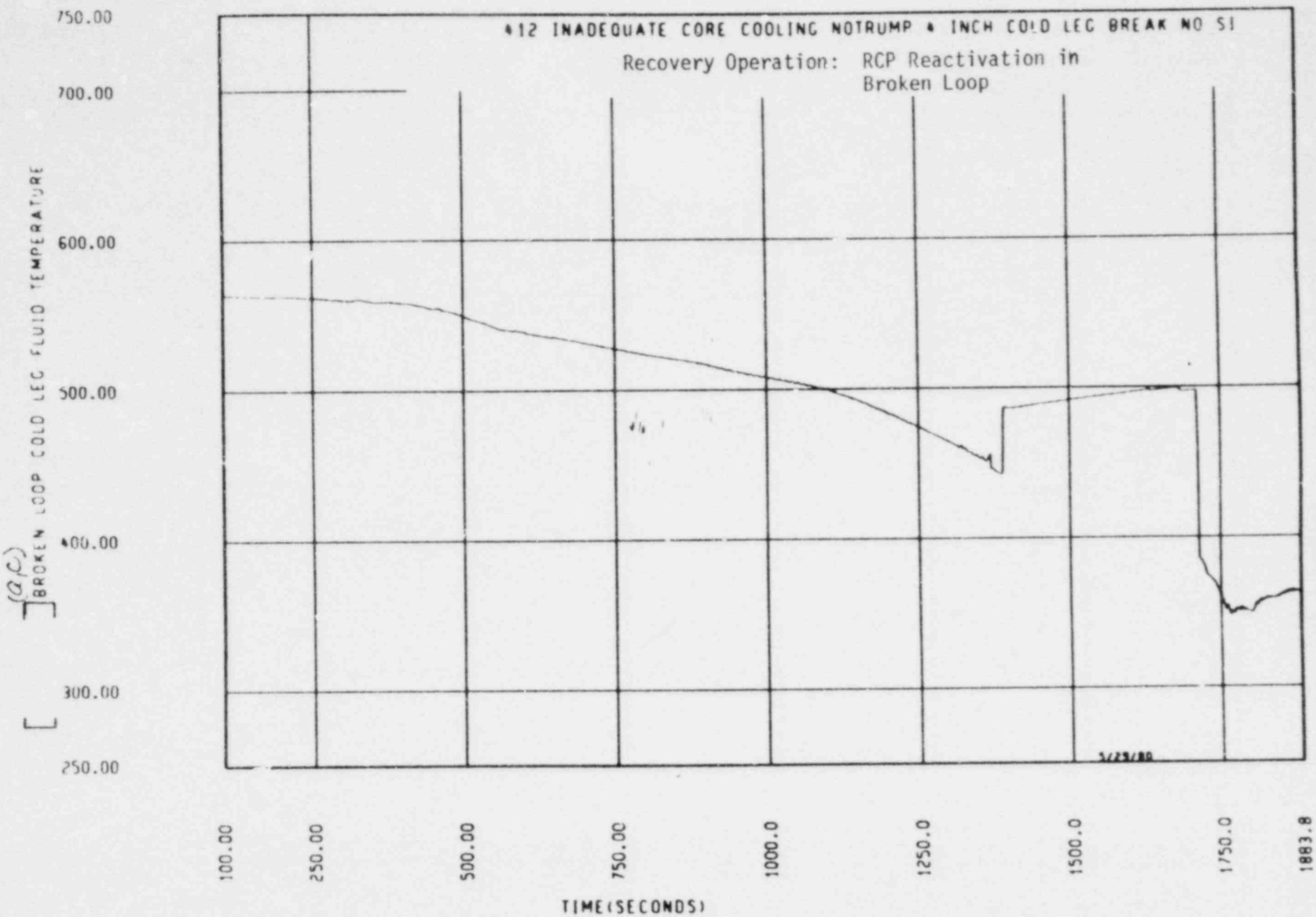

412 INADEQUATE CORE COOLING NOTRUMP 4 INCH COLD LEG BREAK NO SI
Recovery Operation: RCP Reactivation in Broken Loop
BROKEN LOOP COLD LEG FLUID TEMPERATURE
(a,c)
750.00
700.00
600.00
500.00
400.00
300.00
250.00
100.00
250.00
500.00
750.00
1000.0
1250.0
1500.0
1750.0
1883.8
TIME(SECONDS)
5/29/80

Figure 259

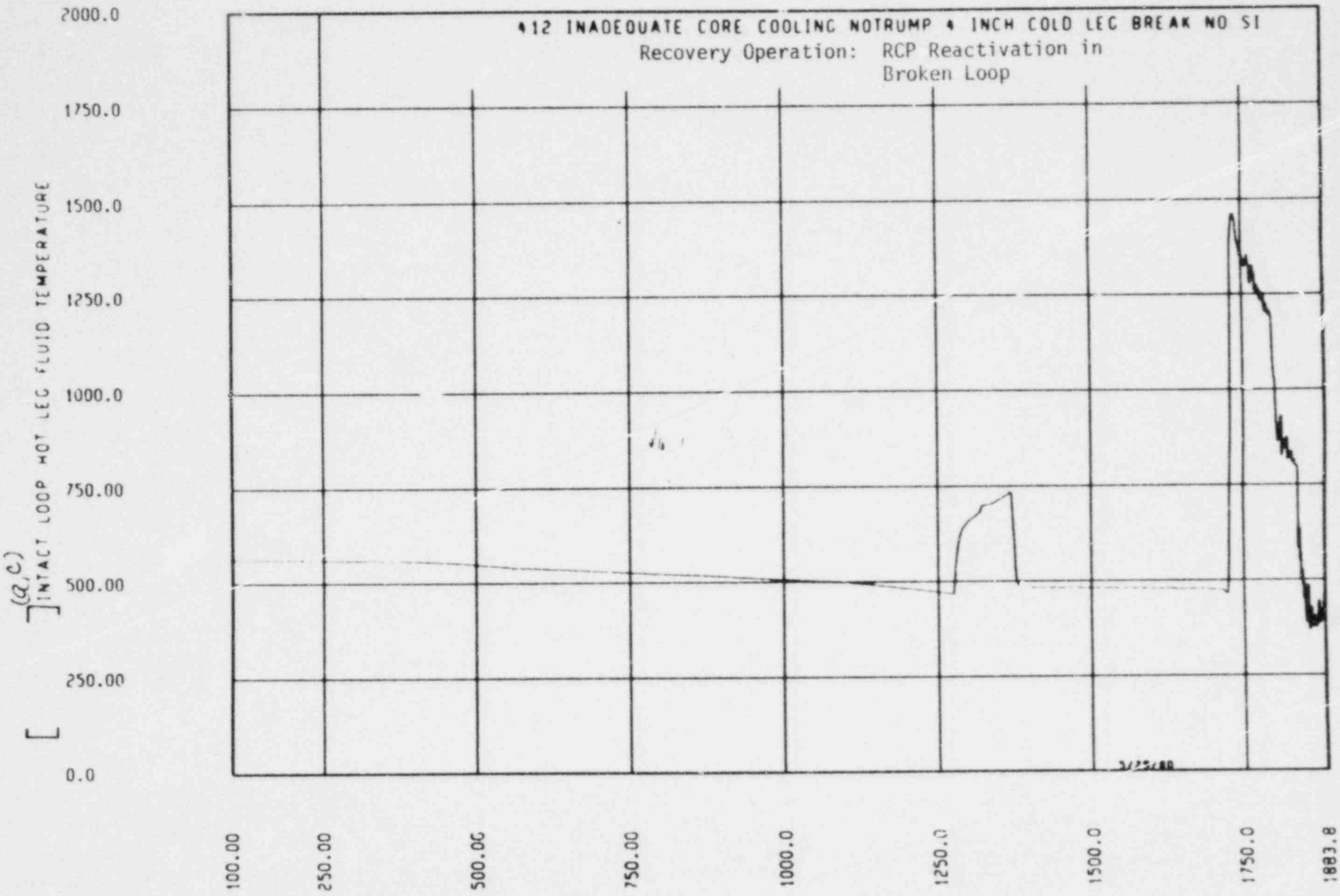

412 INADEQUATE CORE COOLING NOTRUMP 4 INCH COLD LEG BREAK NO SI
Recovery Operation: RCP Reactivation in Broken Loop
INTACT LOOP HOT LEG FLUID TEMPERATURE
(a,c)
2000.0
1750.0
1500.0
1250.0
1000.0
750.00
500.00
250.00
0.0
100.00
250.00
500.00
750.00
1000.0
1250.0
1500.0
1750.0
1883.8
3/25/88
TIME(SECONDS)

Figure 260

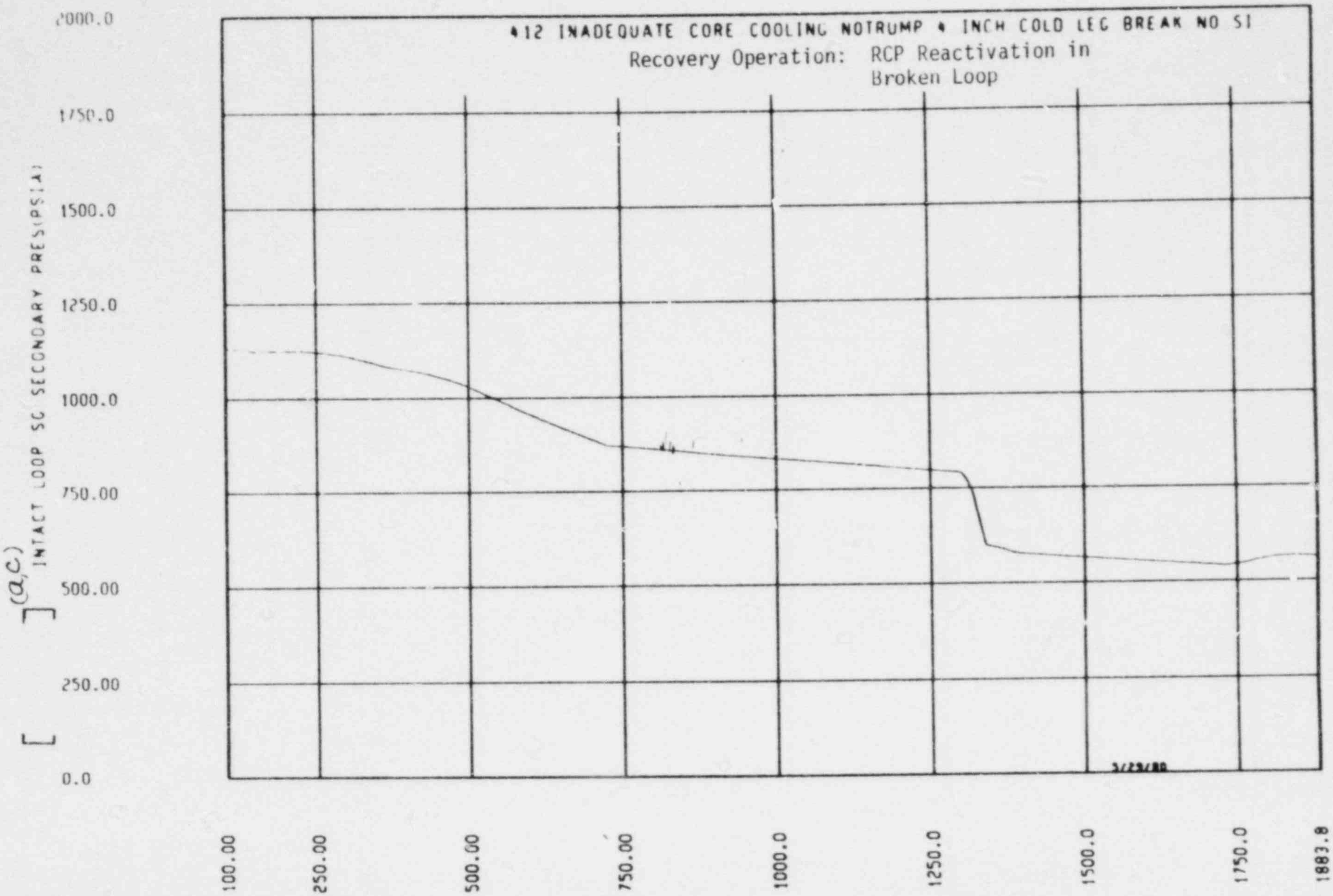

412 INADEQUATE CORE COOLING NOTRUMP 4 INCH COLD LEG BREAK NO SI
Recovery Operation: RCP Reactivation in
Broken Loop
[ ](a,c)
INTACT LOOP SG SECONDARY PRES(PSIA)
2000.0
1750.0
1500.0
1250.0
1000.0
750.00
500.00
250.00
0.0
100.00
250.00
500.00
750.00
1000.0
1250.0
1500.0
1750.0
1883.8
5/29/80
TIME(SECONDS)

Figure 261

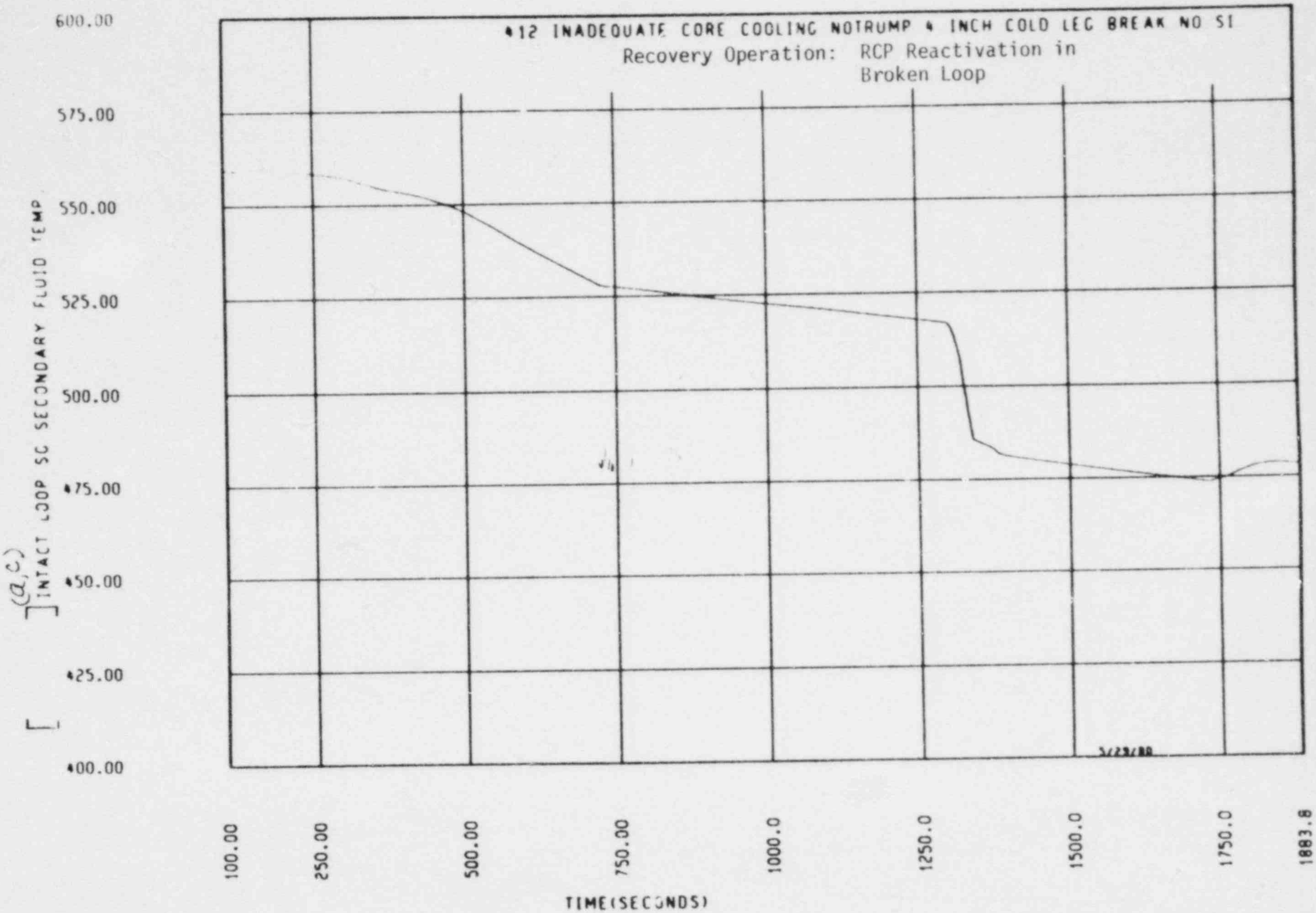
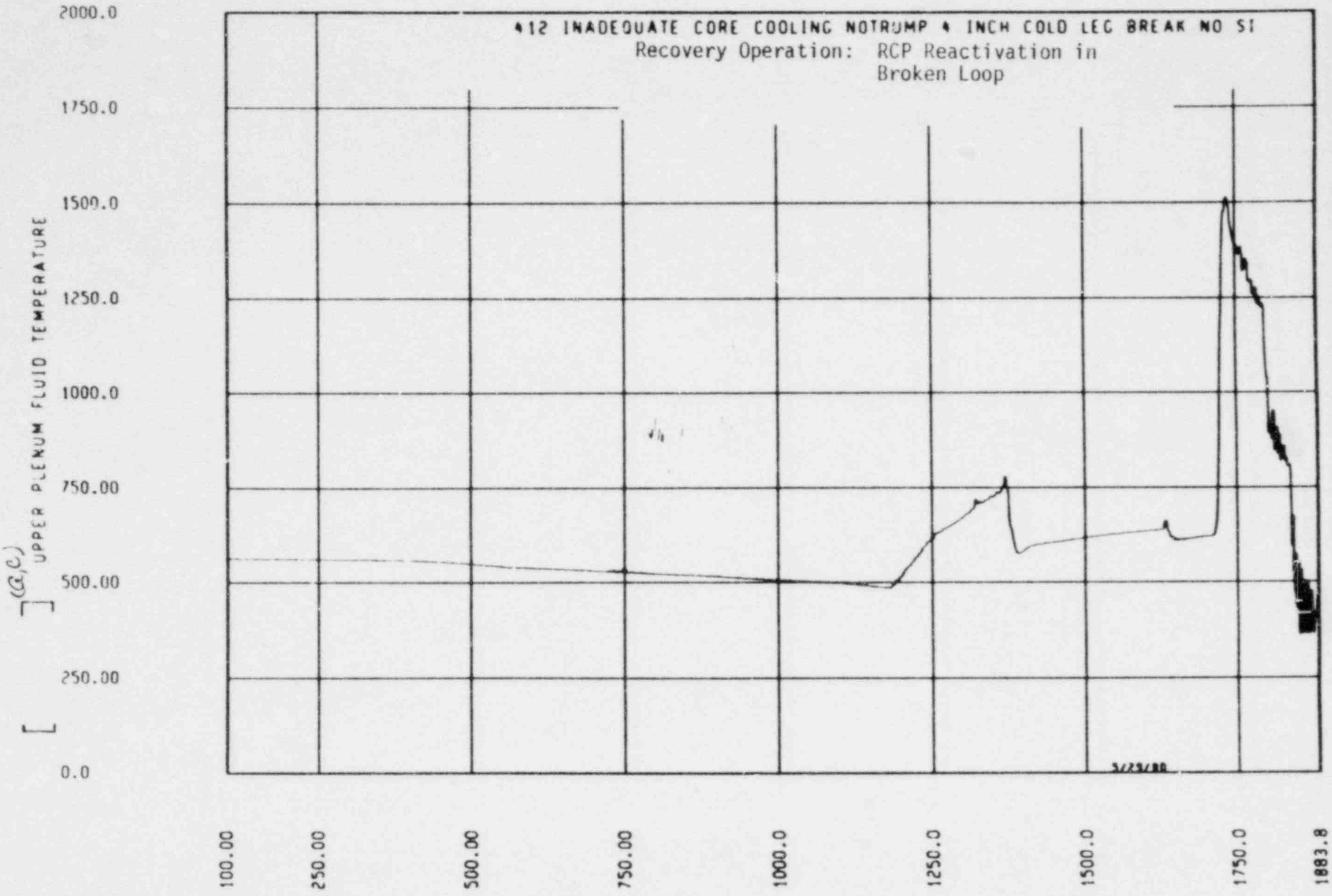

412 INADEQUATE CORE COOLING NOTRUMP 4 INCH COLD LEG BREAK NO SI
Recovery Operation: RCP Reactivation in Broken Loop
INTACT LOOP SG SECONDARY FLUID TEMP
(a,c)
600.00
575.00
550.00
525.00
500.00
475.00
450.00
425.00
400.00
100.00
250.00
500.00
750.00
1000.0
1250.0
1500.0
1750.0
1883.8
TIME(SECONDS)
5/23/88

Figure 262



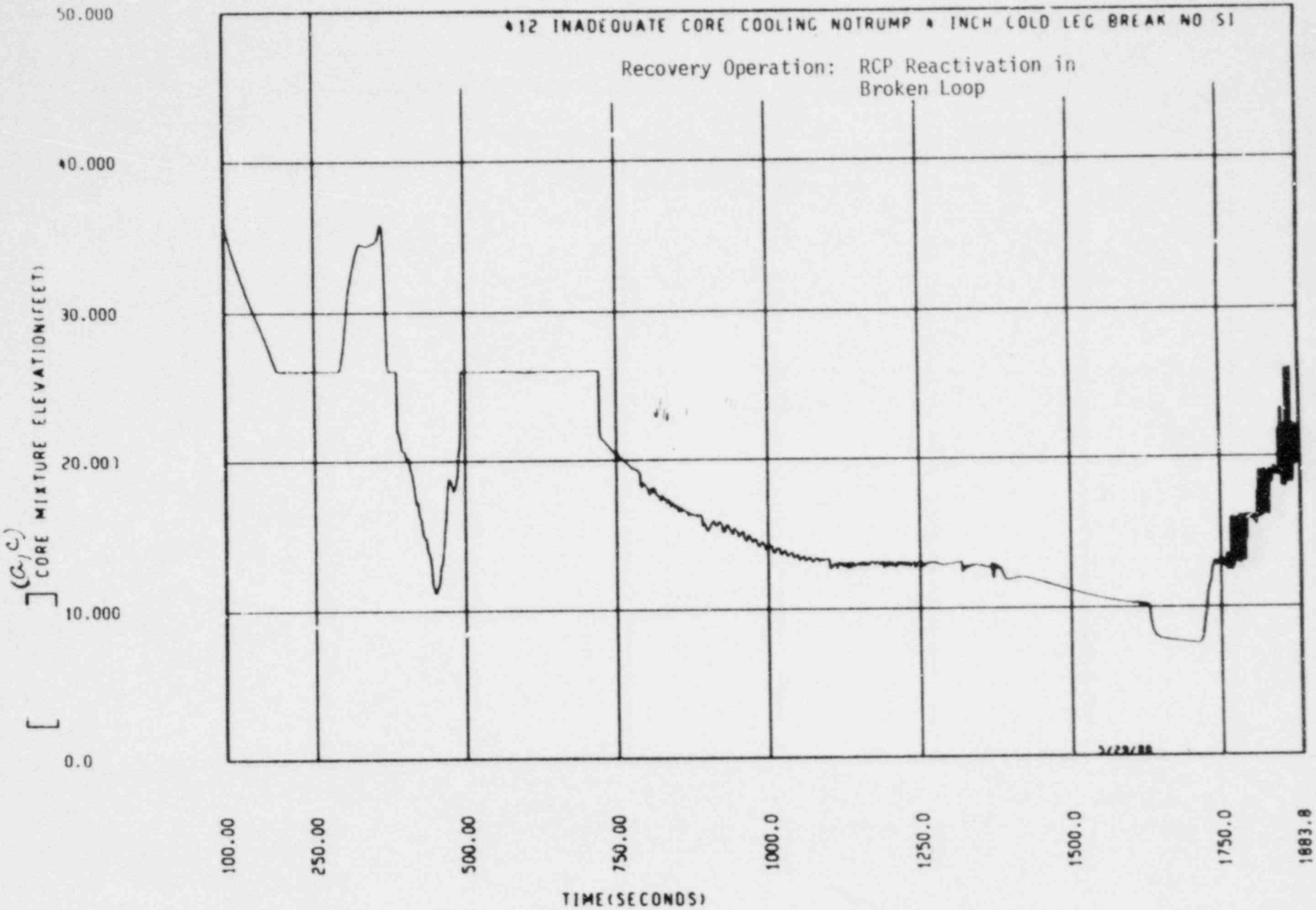

412 INADEQUATE CORE COOLING NOTRUMP 4 INCH COLD LEG BREAK NO SI
Recovery Operation: RCP Reactivation in Broken Loop
CORE MIXTURE ELEVATION(FEET)
(a,c)
50.000
40.000
30.000
20.001
10.000
0.0
100.00
250.00
500.00
750.00
1000.0
1250.0
1500.0
1750.0
1883.8
TIME(SECONDS)
5/29/88

Figure 264

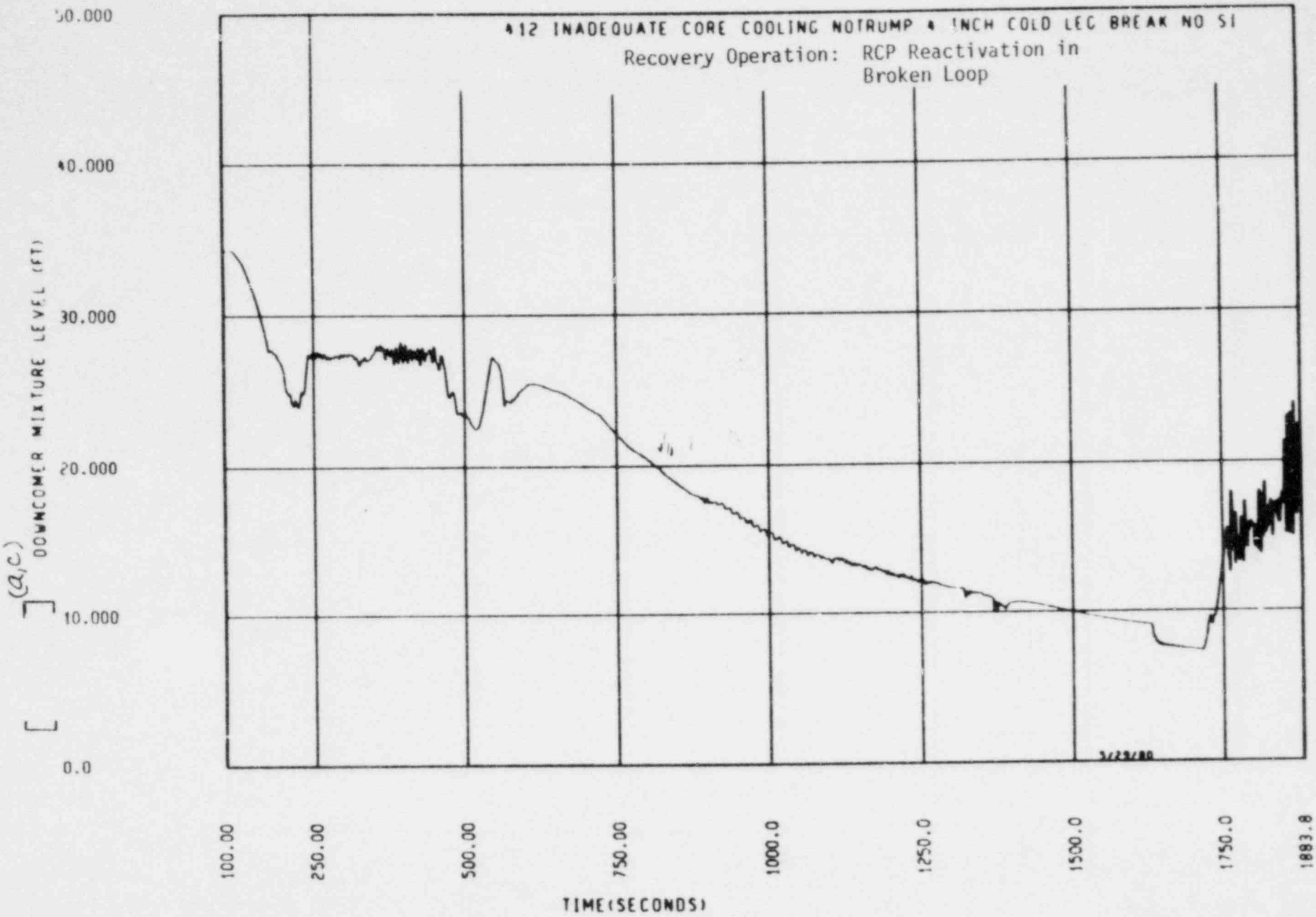

412 INADEQUATE CORE COOLING NOTRUMP 4 INCH COLD LEG BREAK NO SI
Recovery Operation: RCP Reactivation in Broken Loop
DOWNCOMER MIXTURE LEVEL (FT)
(a,c)
50.000
40.000
30.000
20.000
10.000
0.0
100.00
250.00
500.00
750.00
1000.0
1250.0
1500.0
1750.0
1883.8
TIME(SECONDS)
5/29/80

Figure 265

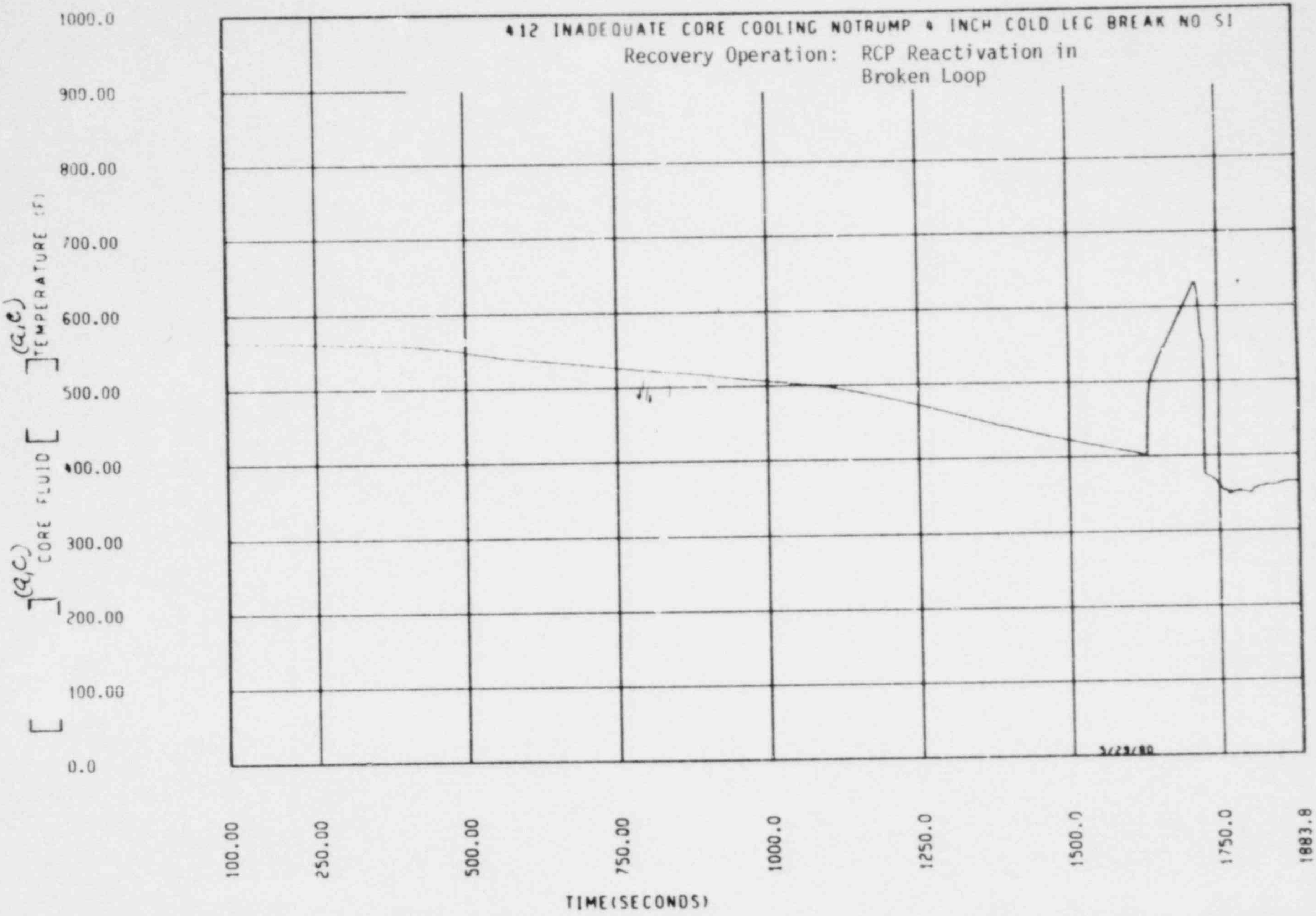

412 INADEQUATE CORE COOLING NOTRUMP 4 INCH COLD LEG BREAK NO SI
Recovery Operation: RCP Reactivation in Broken Loop
1000.0
900.00
800.00
700.00
600.00
500.00
400.00
300.00
200.00
100.00
0.0
(a,c)
TEMPERATURE (F)
CORE FLUID
(a,c)
100.00
250.00
500.00
750.00
1000.0
1250.0
1500.0
1750.0
1883.8
TIME(SECONDS)
5/29/80

Figure 266 .

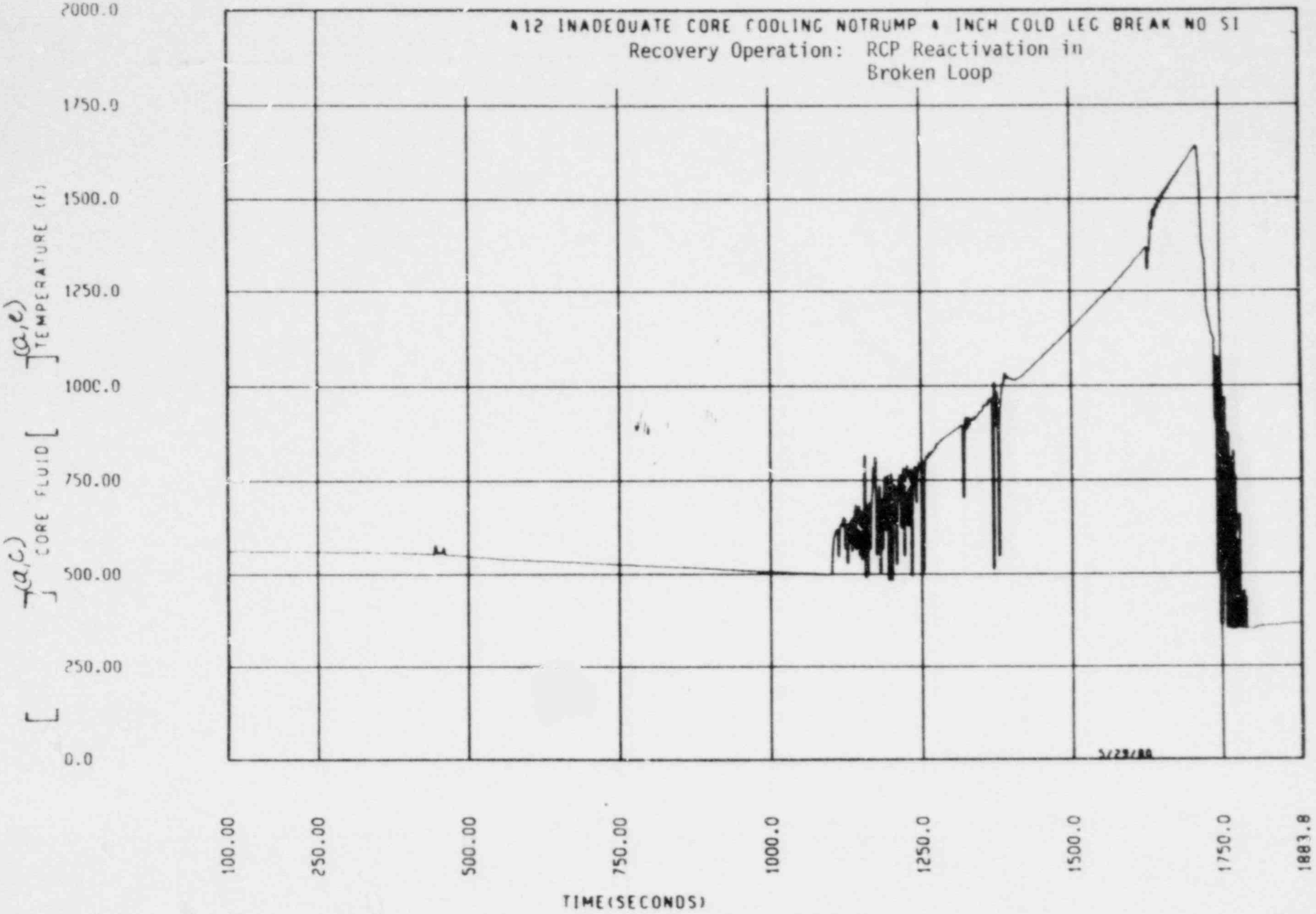

412 INADEQUATE CORE COOLING NOTRUMP 4 INCH COLD LEG BREAK NO SI
Recovery Operation: RCP Reactivation in
Broken Loop
(a,e)
TEMPERATURE (F)
CORE FLUID
(a,c)
2000.0
1750.0
1500.0
1250.0
1000.0
750.00
500.00
250.00
0.0
100.00
250.00
500.00
750.00
1000.0
1250.0
1500.0
1750.0
1883.8
TIME(SECONDS)
5/29/80

Figure 267

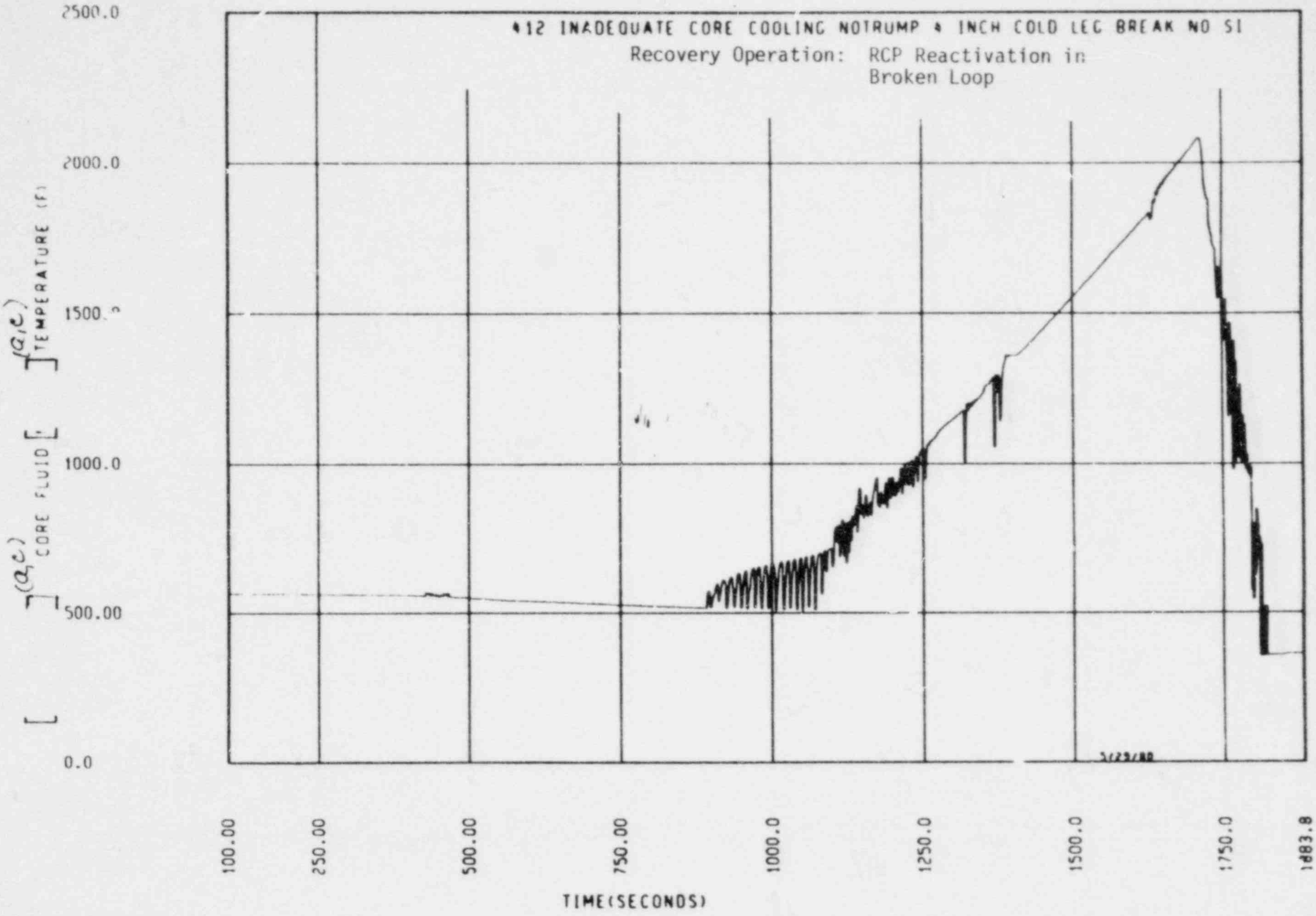

412 INADEQUATE CORE COOLING NOTRUMP 4 INCH COLD LEG BREAK NO SI
Recovery Operation: RCP Reactivation in Broken Loop
2500.0
2000.0
1500.0
1000.0
500.00
0.0
[ ]
]$^{(a,c)}$ CORE FLUID [ ] TEMPERATURE (F) ]$^{(a,c)}$
100.00
250.00
500.00
750.00
1000.0
1250.0
1500.0
1750.0
1883.8
TIME(SECONDS)
5/29/80

Figure 268

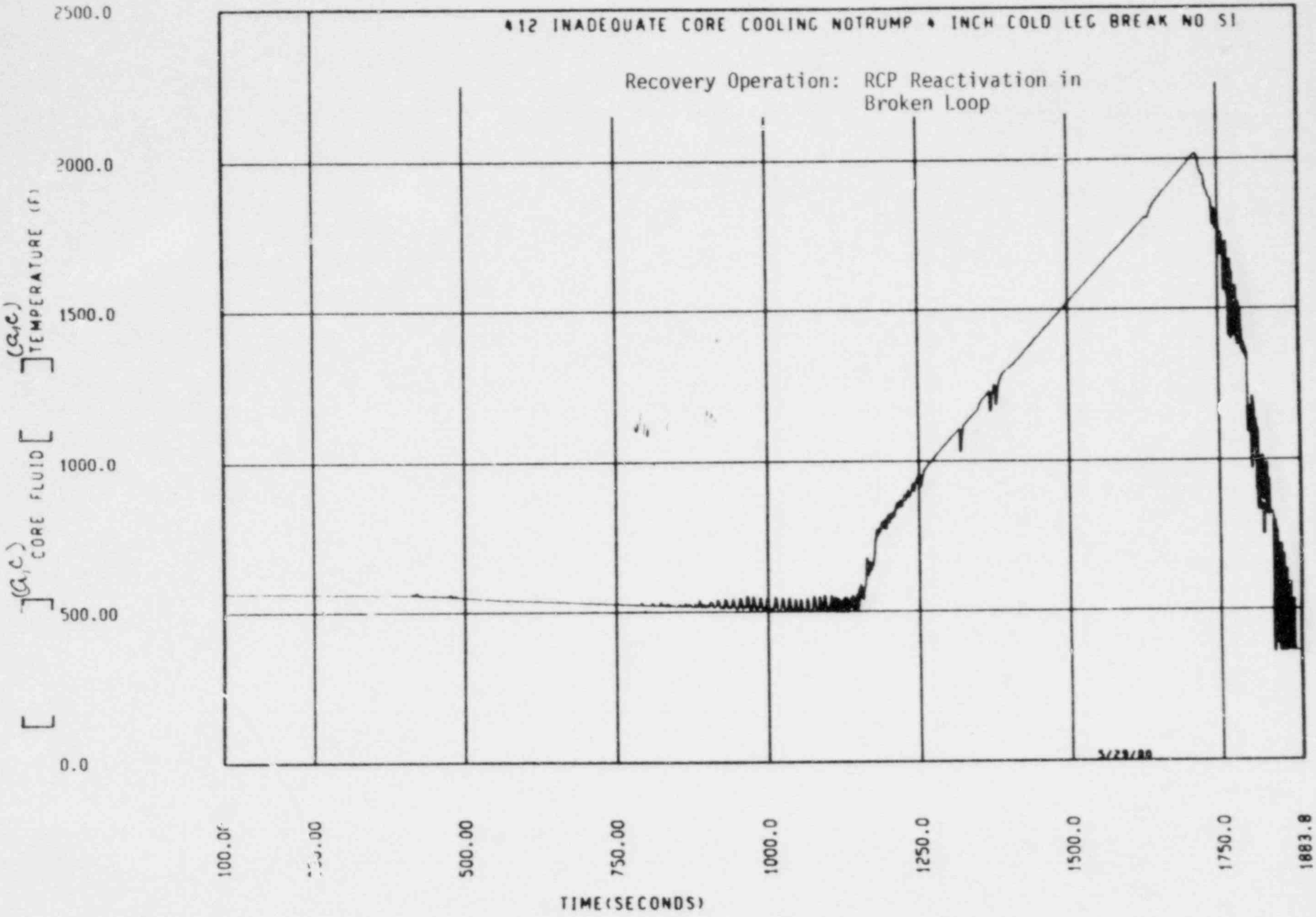

412 INADEQUATE CORE COOLING NOTRUMP 4 INCH COLD LEG BREAK NO SI
Recovery Operation: RCP Reactivation in Broken Loop
CORE FLUID TEMPERATURE (F)
(a,c)
(a,c)
2500.0
2000.0
1500.0
1000.0
500.00
0.0
100.00
500.00
750.00
1000.0
1250.0
1500.0
1750.0
1883.8
TIME(SECONDS)
5/29/80

Figure 269

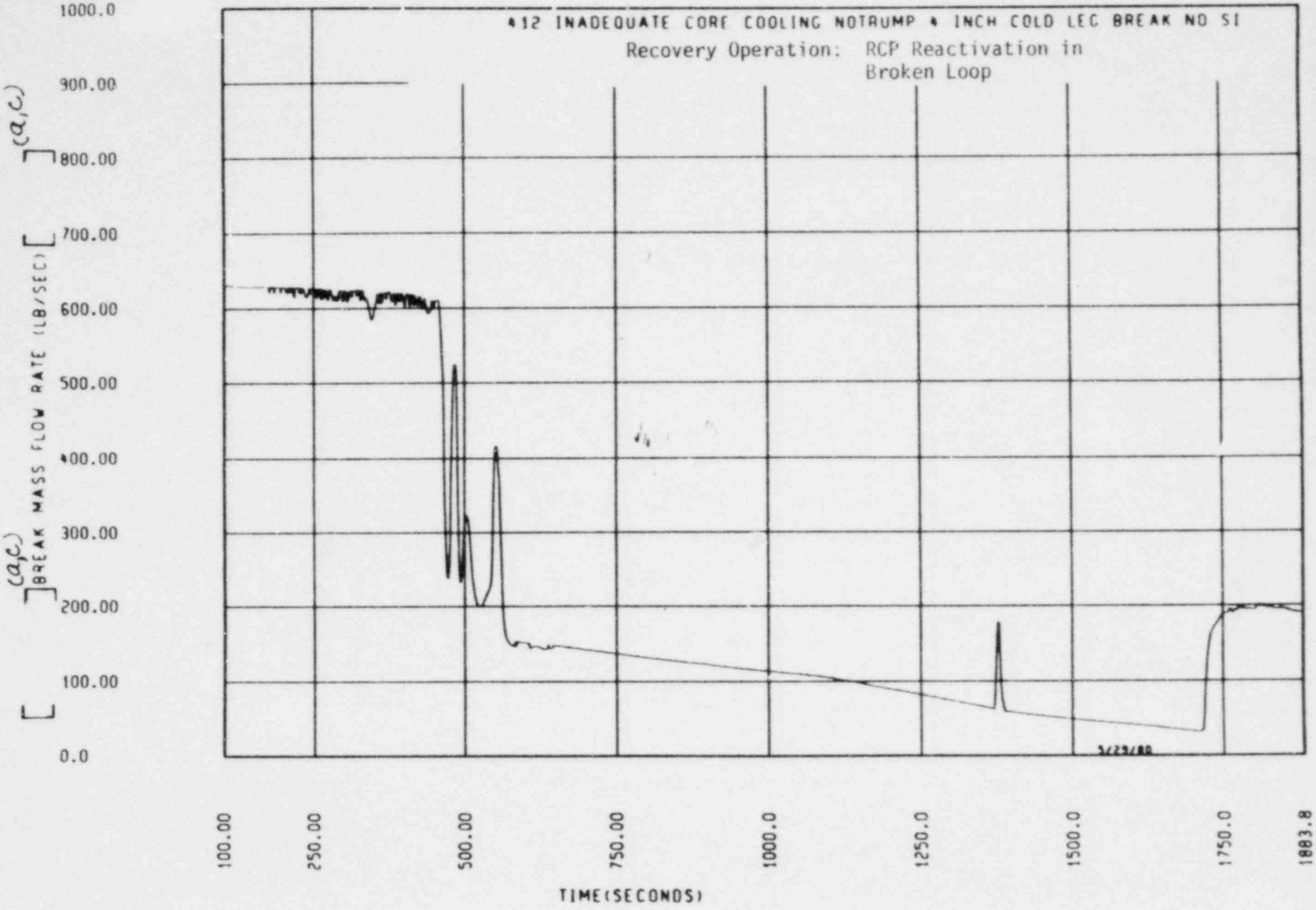

412 INADEQUATE CORE COOLING NOTRUMP 4 INCH COLD LEG BREAK NO SI
Recovery Operation: RCP Reactivation in Broken Loop
5/29/80
BREAK MASS FLOW RATE (LB/SEC)
(a,c)
(a,c)
1000.0
900.00
800.00
700.00
600.00
500.00
400.00
300.00
200.00
100.00
0.0
100.00
250.00
500.00
750.00
1000.0
1250.0
1500.0
1750.0
1883.8
TIME(SECONDS)

Figure 270

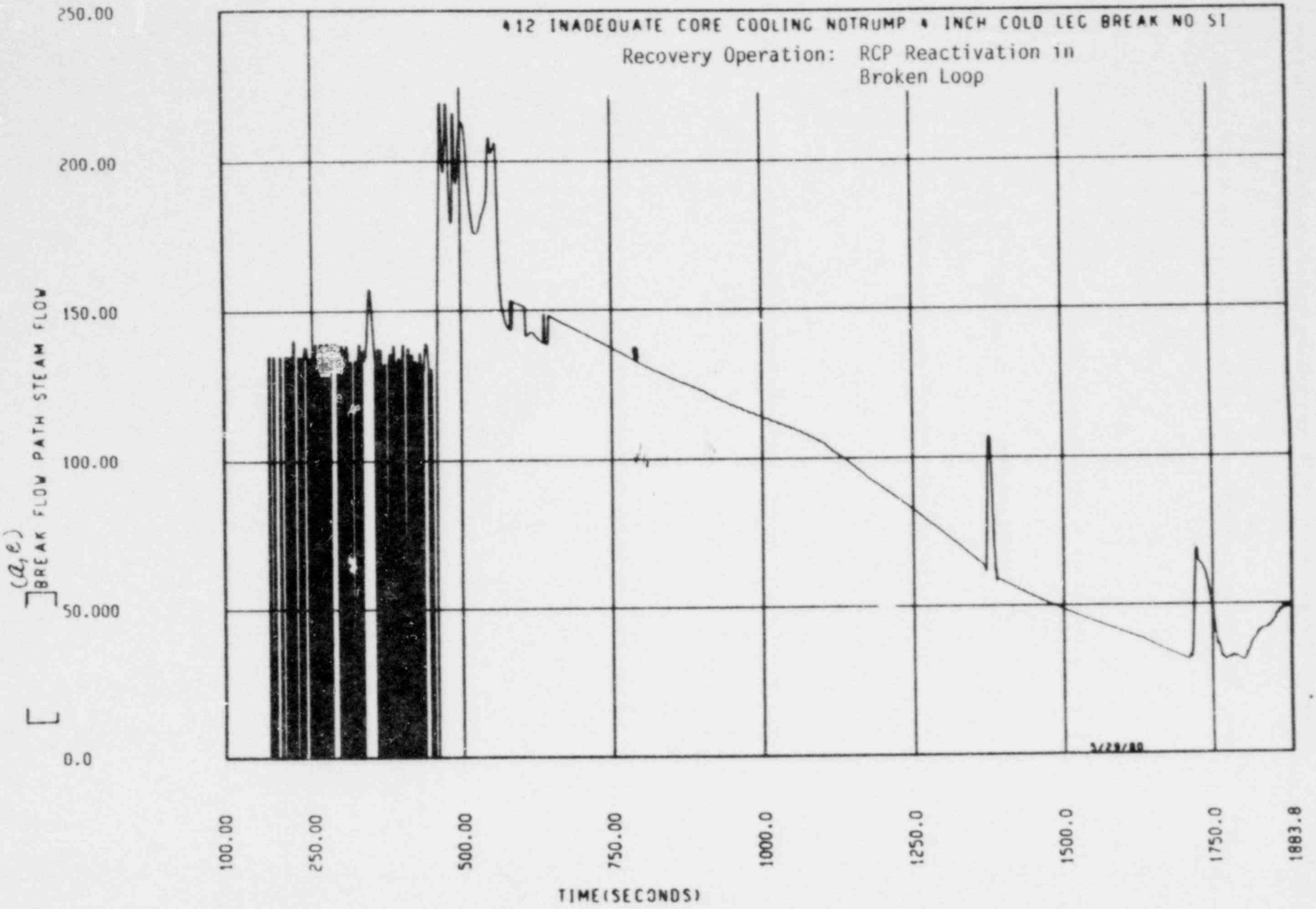

412 INADEQUATE CORE COOLING NOTRUMP 4 INCH COLD LEG BREAK NO SI
Recovery Operation: RCP Reactivation in
Broken Loop
(a,e)
BREAK FLOW PATH STEAM FLOW
250.00
200.00
150.00
100.00
50.000
0.0
100.00
250.00
500.00
750.00
1000.0
1250.0
1500.0
1750.0
1883.8
TIME(SECONDS)
5/29/80

Figure 271

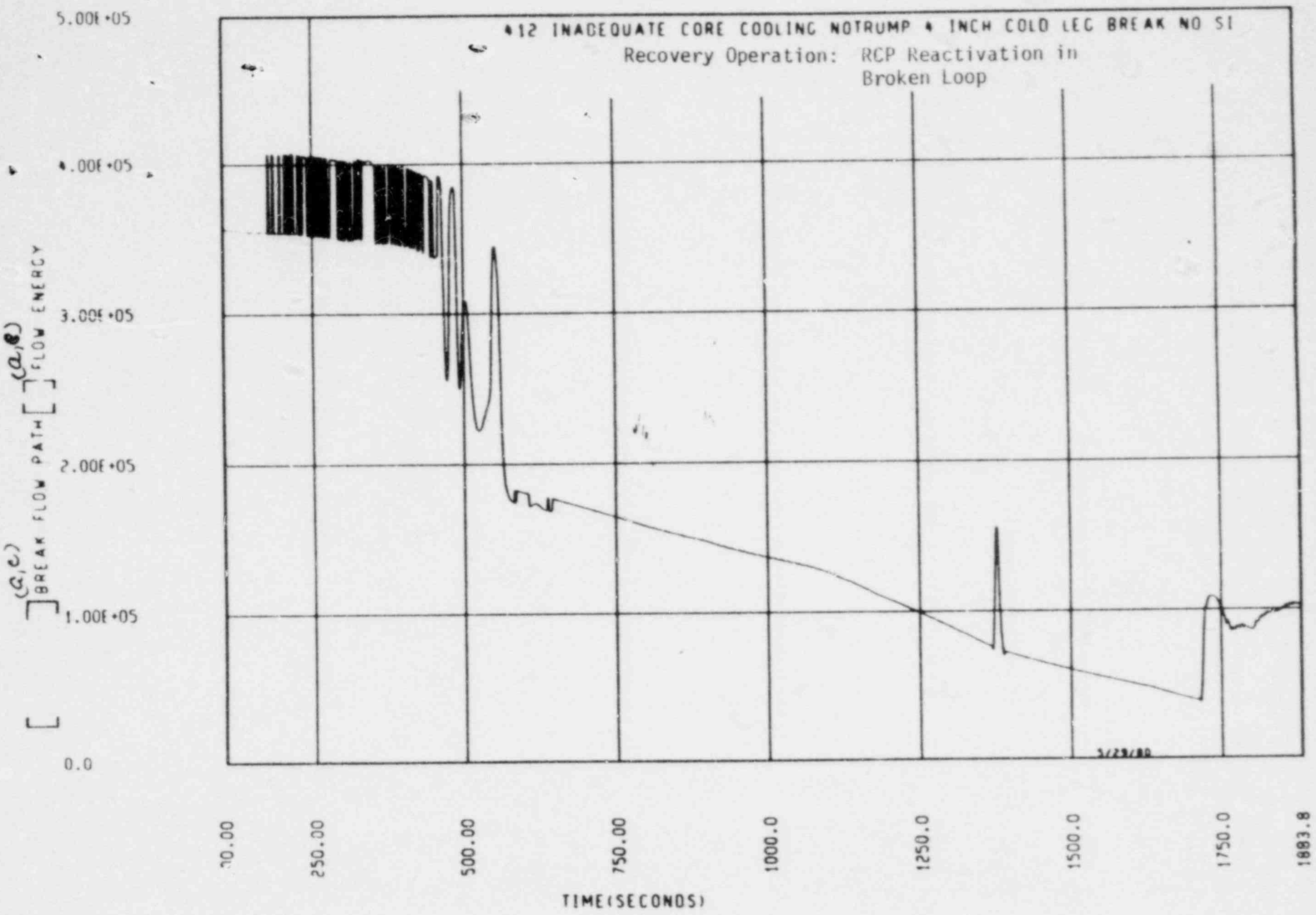

412 INADEQUATE CORE COOLING NOTRUMP 4 INCH COLD LEG BREAK NO SI
Recovery Operation: RCP Reactivation in Broken Loop
(a,c) BREAK FLOW PATH [ ] (a,c) FLOW ENERGY [ ]
5.00E+05
4.00E+05
3.00E+05
2.00E+05
1.00E+05
0.0
0.00
250.00
500.00
750.00
1000.0
1250.0
1500.0
1750.0
1883.8
TIME(SECONDS)
5/29/80

Figure 272

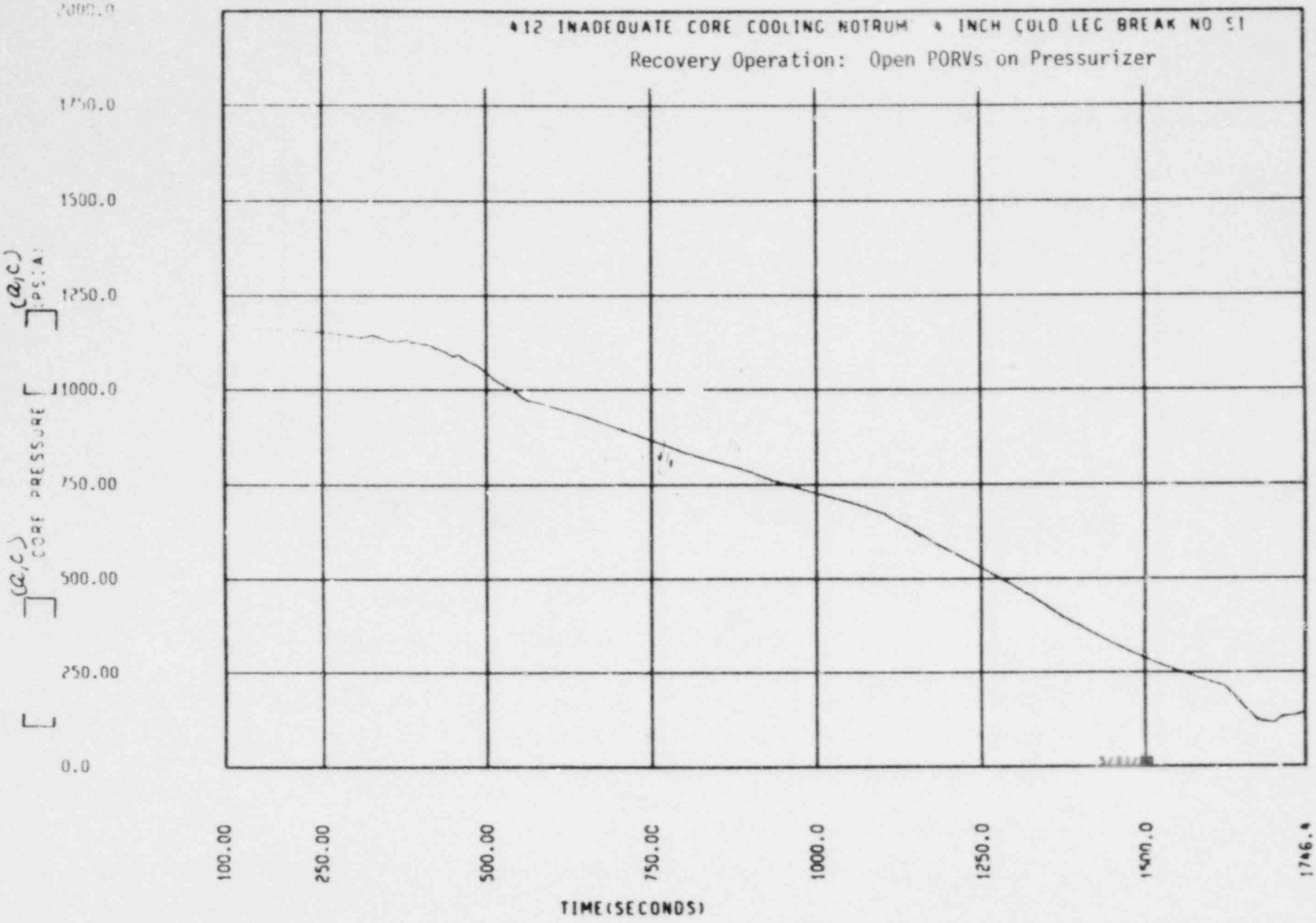

412 INADEQUATE CORE COOLING NOTRUM 4 INCH COLD LEG BREAK NO SI
Recovery Operation: Open PORVs on Pressurizer
CORE PRESSURE (PSIA)
(a,c)
(a,c)
2000.0
1750.0
1500.0
1250.0
1000.0
750.00
500.00
250.00
0.0
100.00
250.00
500.00
750.00
1000.0
1250.0
1500.0
1746.4
TIME(SECONDS)

Figure 273

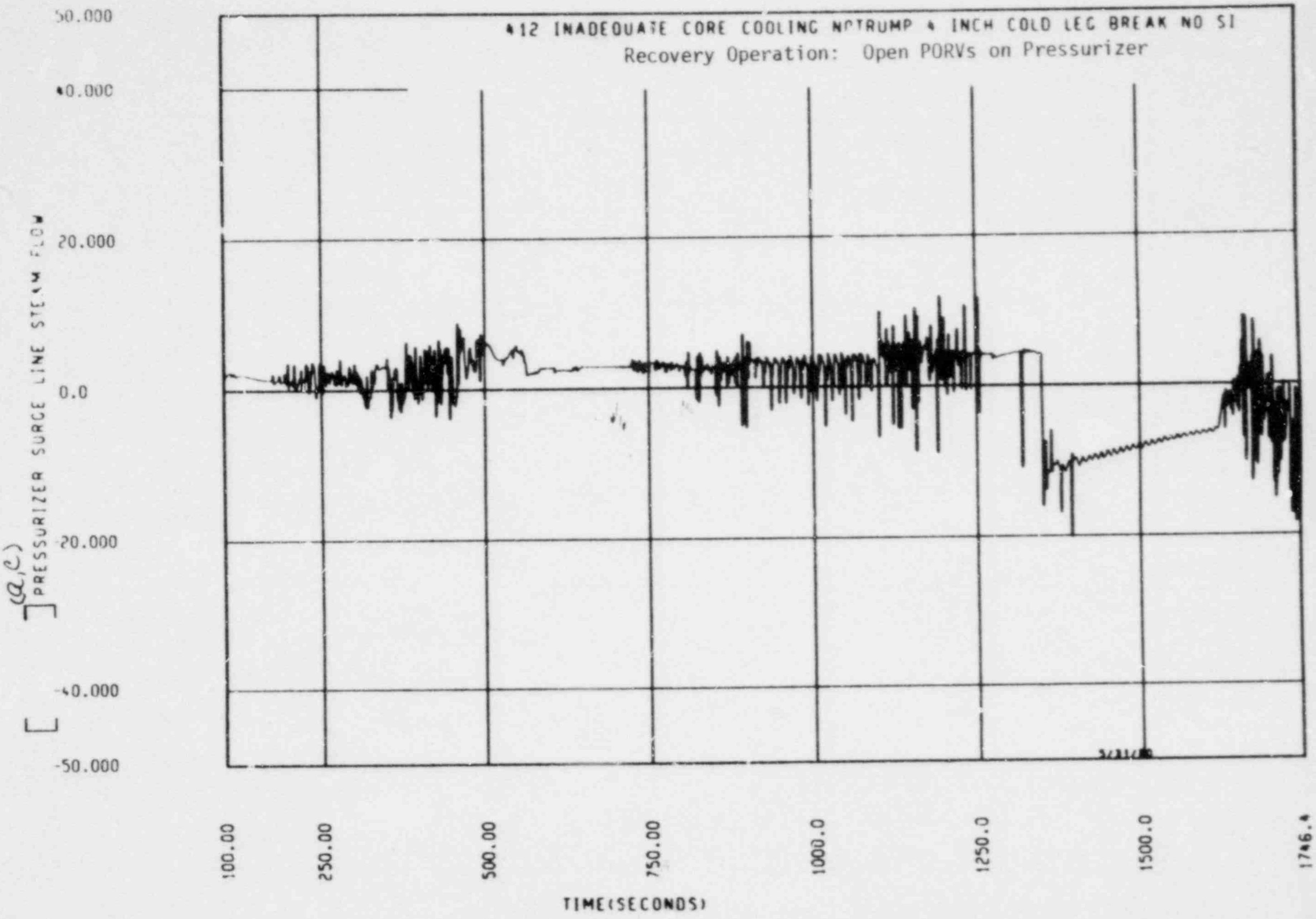

412 INADEQUATE CORE COOLING NOTRUMP 4 INCH COLD LEG BREAK NO SI
Recovery Operation: Open PORVs on Pressurizer
50.000
40.000
20.000
0.0
-20.000
-40.000
-50.000
PRESSURIZER SURGE LINE STEAM FLOW
(a,c)
100.00
250.00
500.00
750.00
1000.0
1250.0
1500.0
1746.4
TIME(SECONDS)

Figure 274

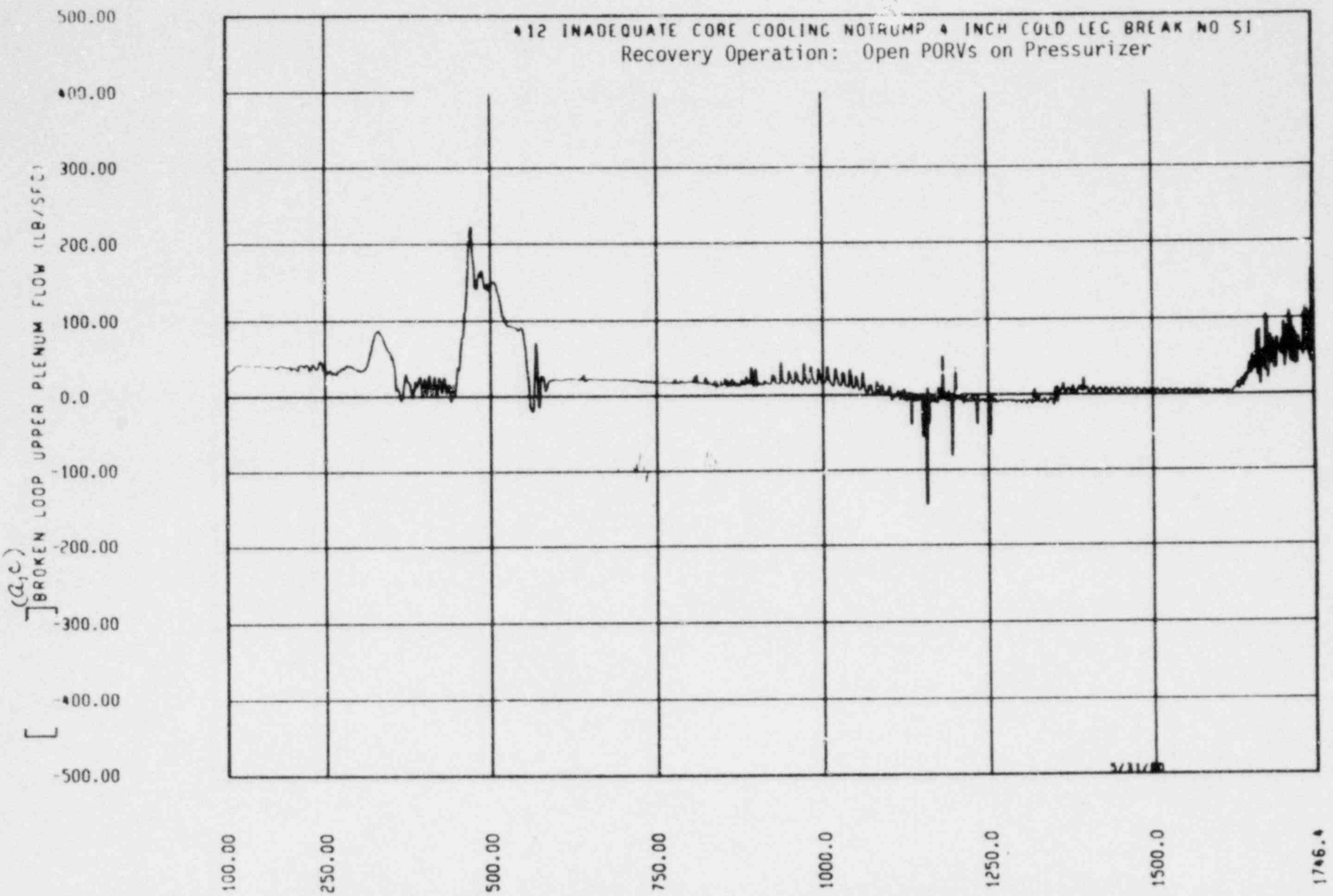

412 INADEQUATE CORE COOLING NOTRUMP 4 INCH COLD LEG BREAK NO SI
Recovery Operation: Open PORVs on Pressurizer
BROKEN LOOP UPPER PLENUM FLOW (LB/SFC)
(a,c)
500.00
400.00
300.00
200.00
100.00
0.0
-100.00
-200.00
-300.00
-400.00
-500.00
100.00
250.00
500.00
750.00
1000.0
1250.0
1500.0
1746.4
TIME(SECONDS)
5/31/

Figure 275

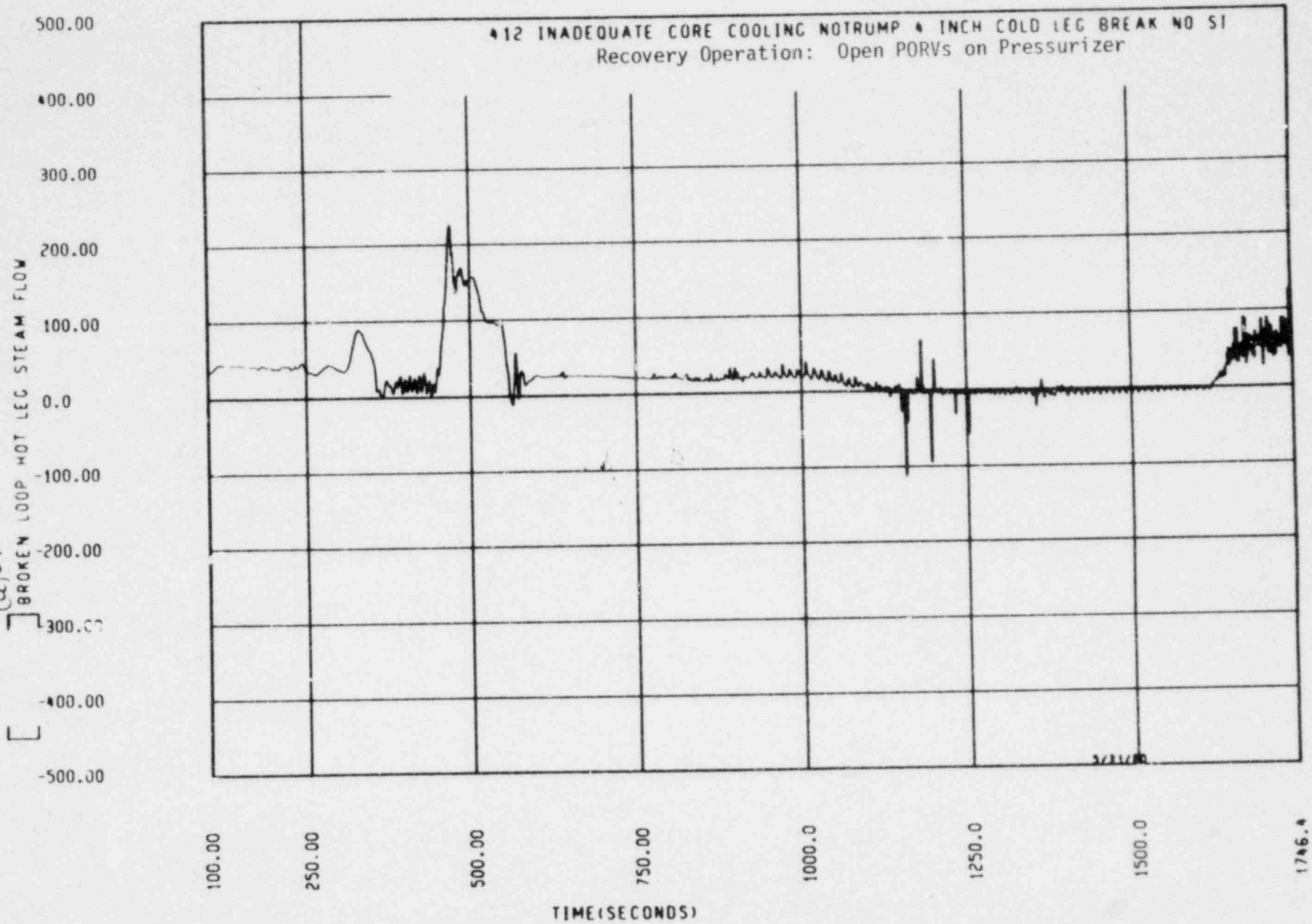

412 INADEQUATE CORE COOLING NOTRUMP 4 INCH COLD LEG BREAK NO SI
Recovery Operation: Open PORVs on Pressurizer
BROKEN LOOP HOT LEG STEAM FLOW
(a,c)
500.00
400.00
300.00
200.00
100.00
0.0
-100.00
-200.00
-300.00
-400.00
-500.00
100.00
250.00
500.00
750.00
1000.0
1250.0
1500.0
1746.4
TIME(SECONDS)

Figure 276

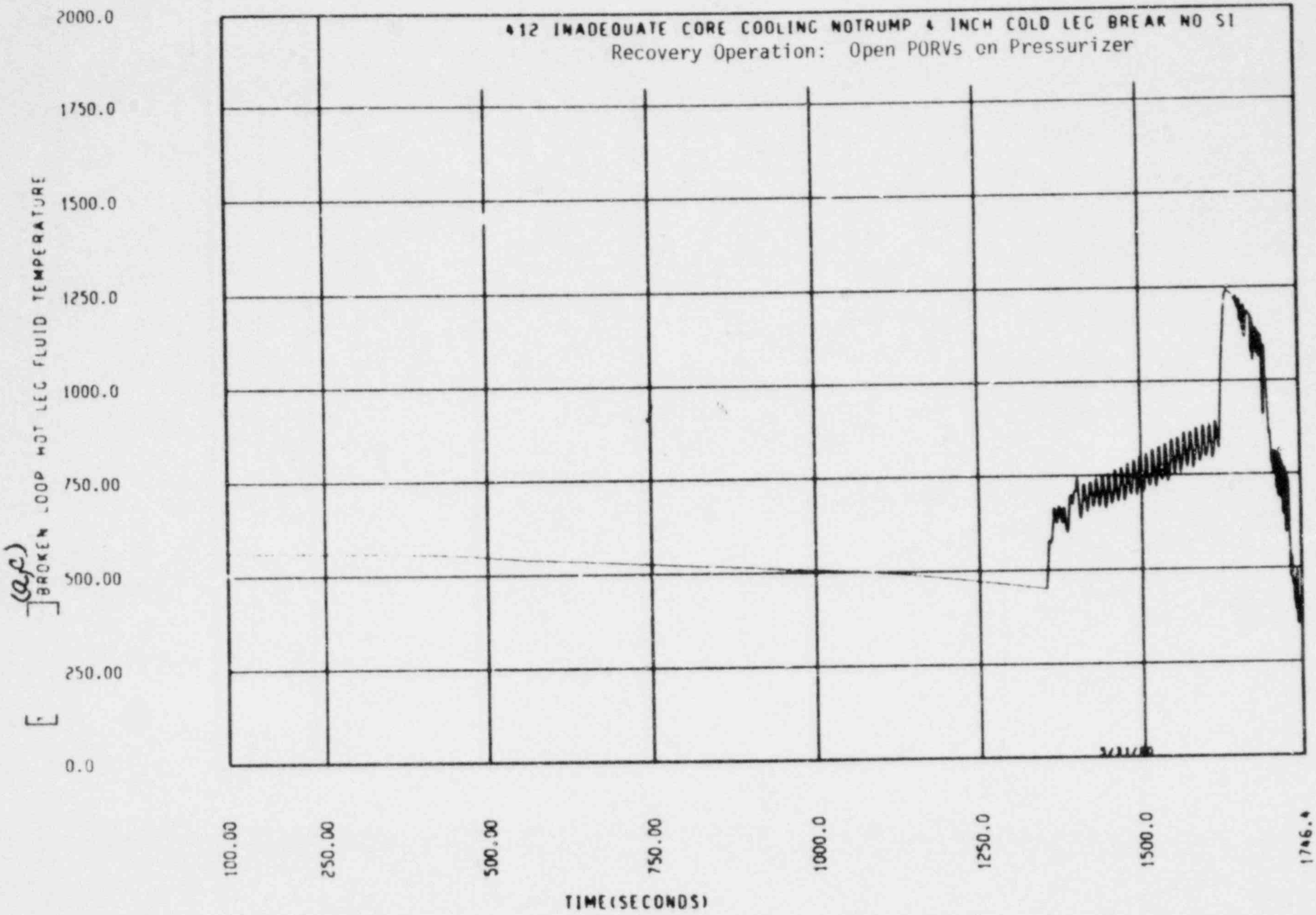
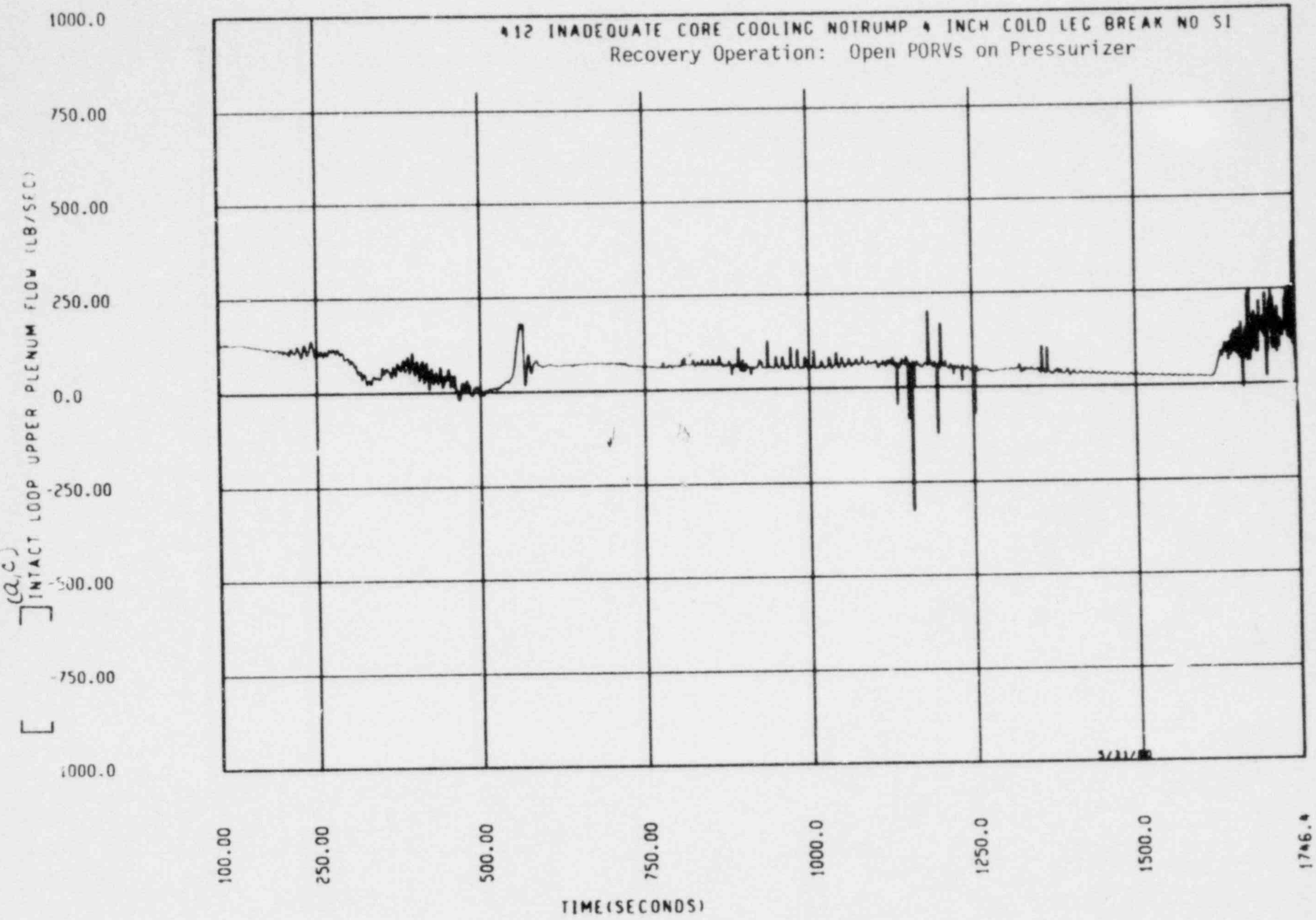

412 INADEQUATE CORE COOLING NOTRUMP 4 INCH COLD LEG BREAK NO SI
Recovery Operation: Open PORVs on Pressurizer
BROKEN LOOP HOT LEG FLUID TEMPERATURE
(a,c)
2000.0
1750.0
1500.0
1250.0
1000.0
750.00
500.00
250.00
0.0
100.00
250.00
500.00
750.00
1000.0
1250.0
1500.0
1746.4
TIME(SECONDS)

Figure 277



412 INADEQUATE CORE COOLING NOTRUMP 4 INCH COLD LEG BREAK NO SI
Recovery Operation: Open PORVs on Pressurizer

Figure 278

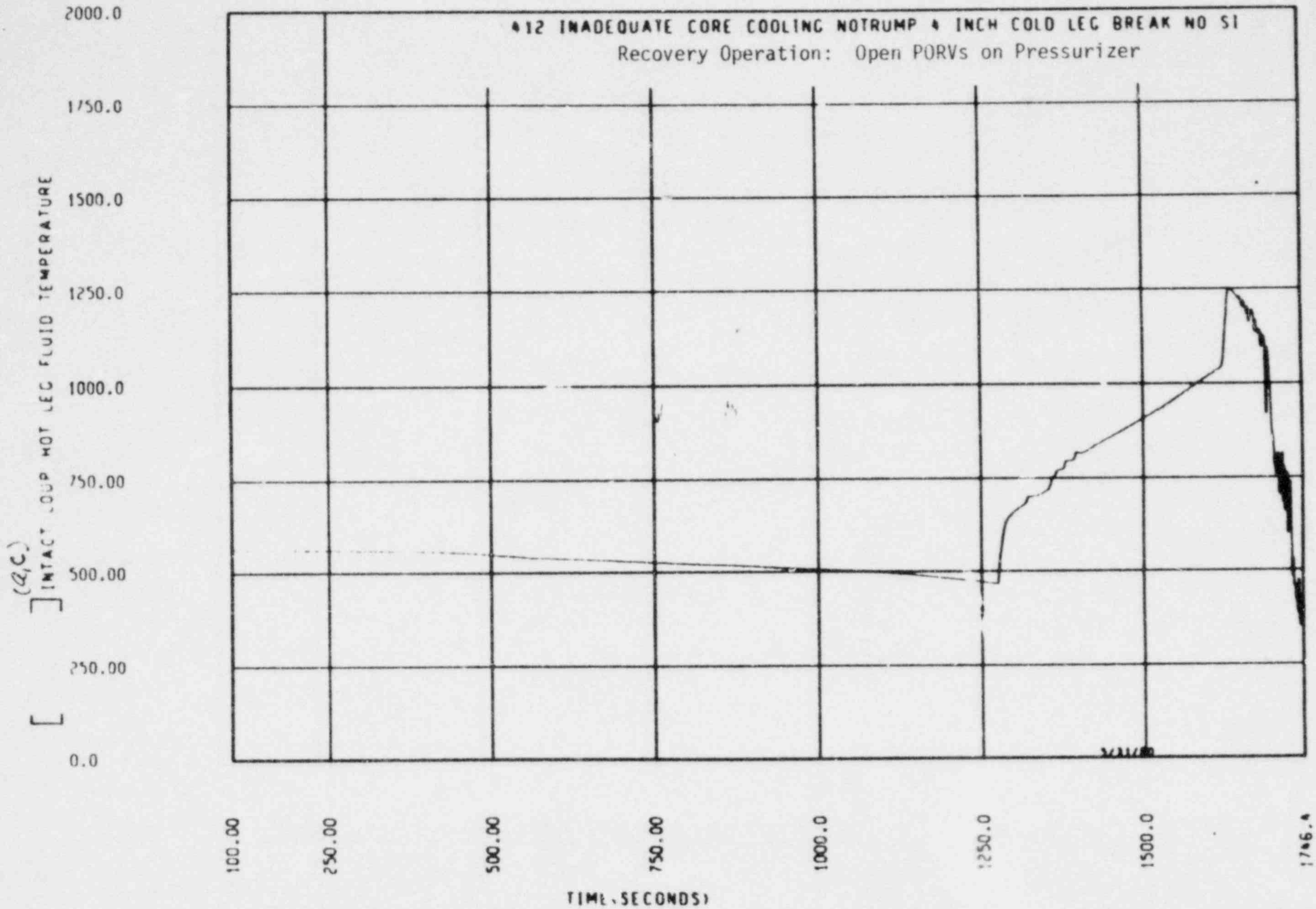

412 INADEQUATE CORE COOLING NOTRUMP 4 INCH COLD LEG BREAK NO SI
Recovery Operation: Open PORVs on Pressurizer
INTACT LOOP HOT LEG FLUID TEMPERATURE
(a,c)
2000.0
1750.0
1500.0
1250.0
1000.0
750.00
500.00
250.00
0.0
100.00
250.00
500.00
750.00
1000.0
1250.0
1500.0
1746.4
TIME,SECONDS)

Figure 279

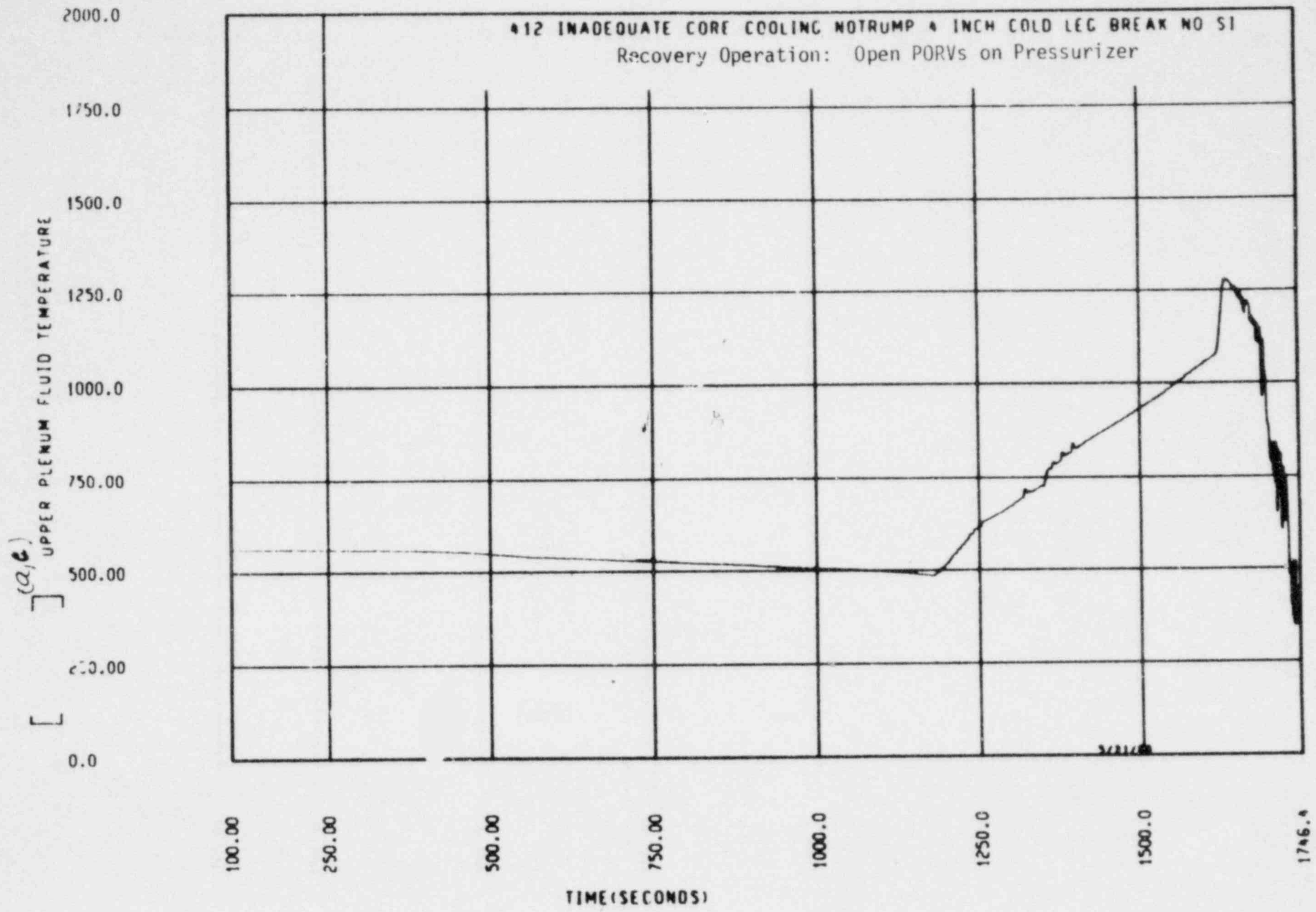

412 INADEQUATE CORE COOLING NOTRUMP 4 INCH COLD LEG BREAK NO SI
Recovery Operation: Open PORVs on Pressurizer
UPPER PLENUM FLUID TEMPERATURE
(a,c)
2000.0
1750.0
1500.0
1250.0
1000.0
750.00
500.00
250.00
0.0
100.00
250.00
500.00
750.00
1000.0
1250.0
1500.0
1746.4
TIME(SECONDS)

Figure 280

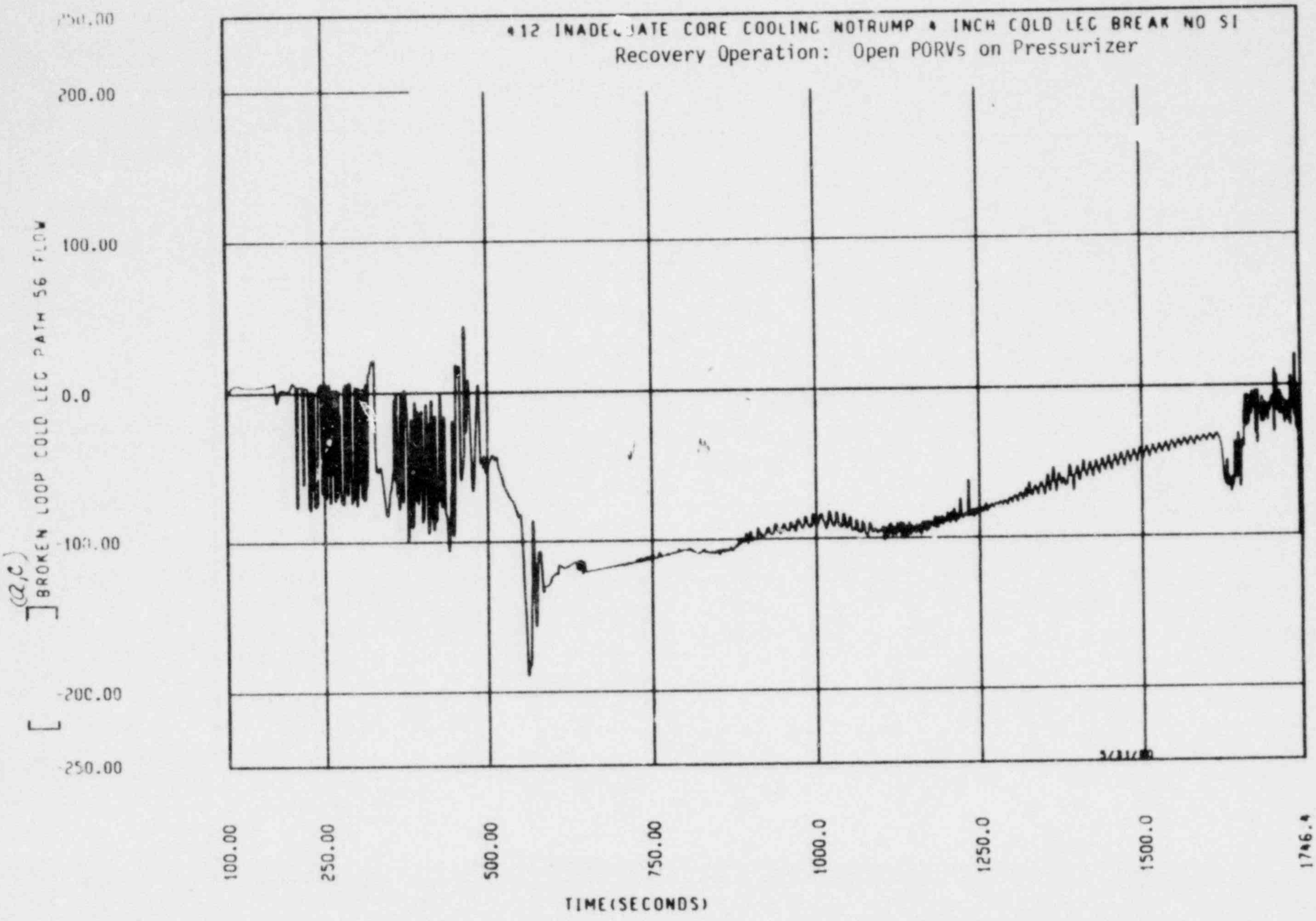

412 INADEQUATE CORE COOLING NOTRUMP 4 INCH COLD LEG BREAK NO SI
Recovery Operation: Open PORVs on Pressurizer
250.00
200.00
100.00
0.0
-100.00
-200.00
-250.00
BROKEN LOOP COLD LEG PATH 56 FLOW
(a,c)
100.00
250.00
500.00
750.00
1000.0
1250.0
1500.0
1746.4
TIME(SECONDS)

Figure 281

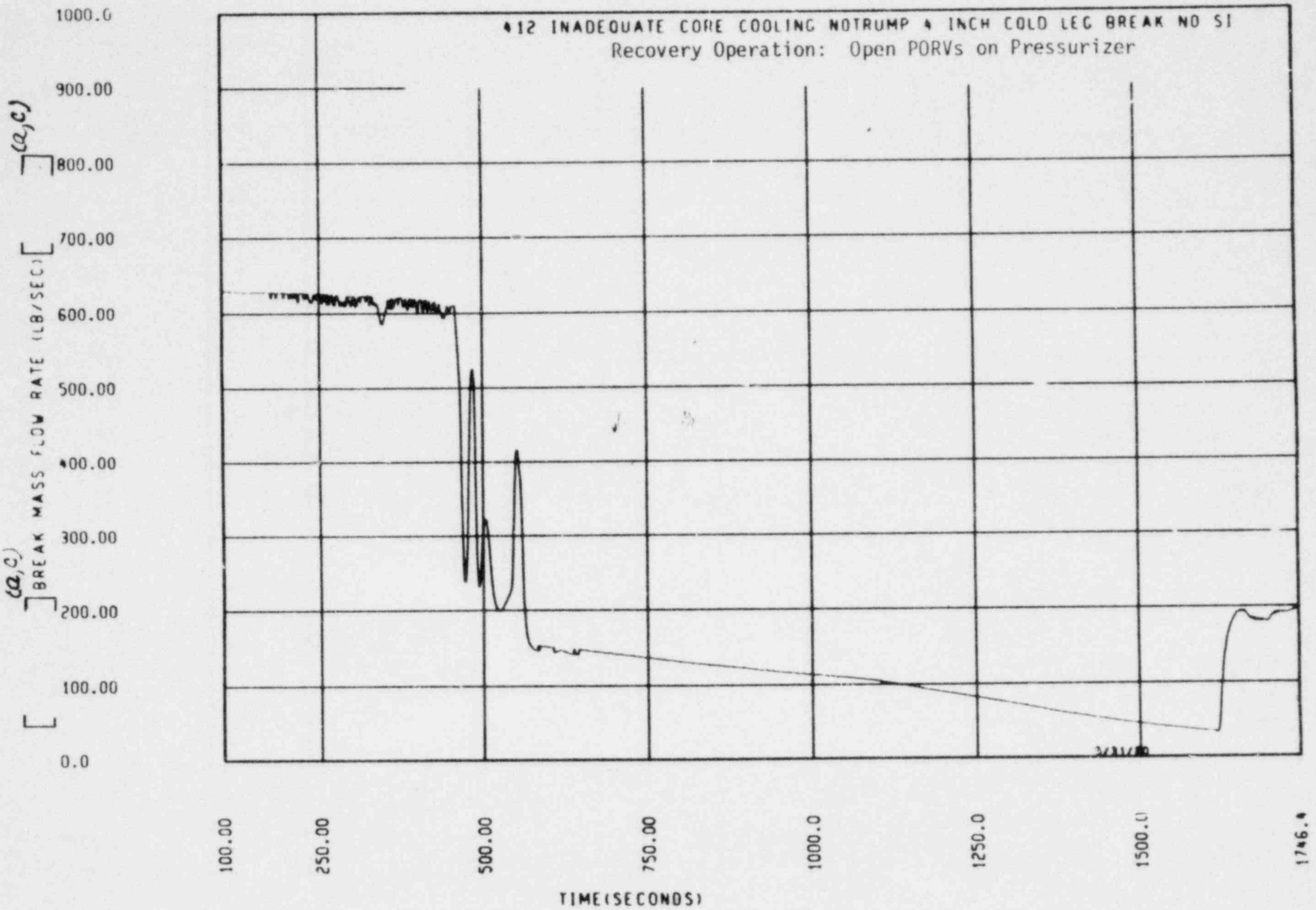

412 INADEQUATE CORE COOLING NOTRUMP 4 INCH COLD LEG BREAK NO SI
Recovery Operation: Open PORVs on Pressurizer
BREAK MASS FLOW RATE (LB/SEC)
(a,c)
(a,c)
1000.0
900.00
800.00
700.00
600.00
500.00
400.00
300.00
200.00
100.00
0.0
100.00
250.00
500.00
750.00
1000.0
1250.0
1500.0
1746.4
TIME(SECONDS)

Figure 282

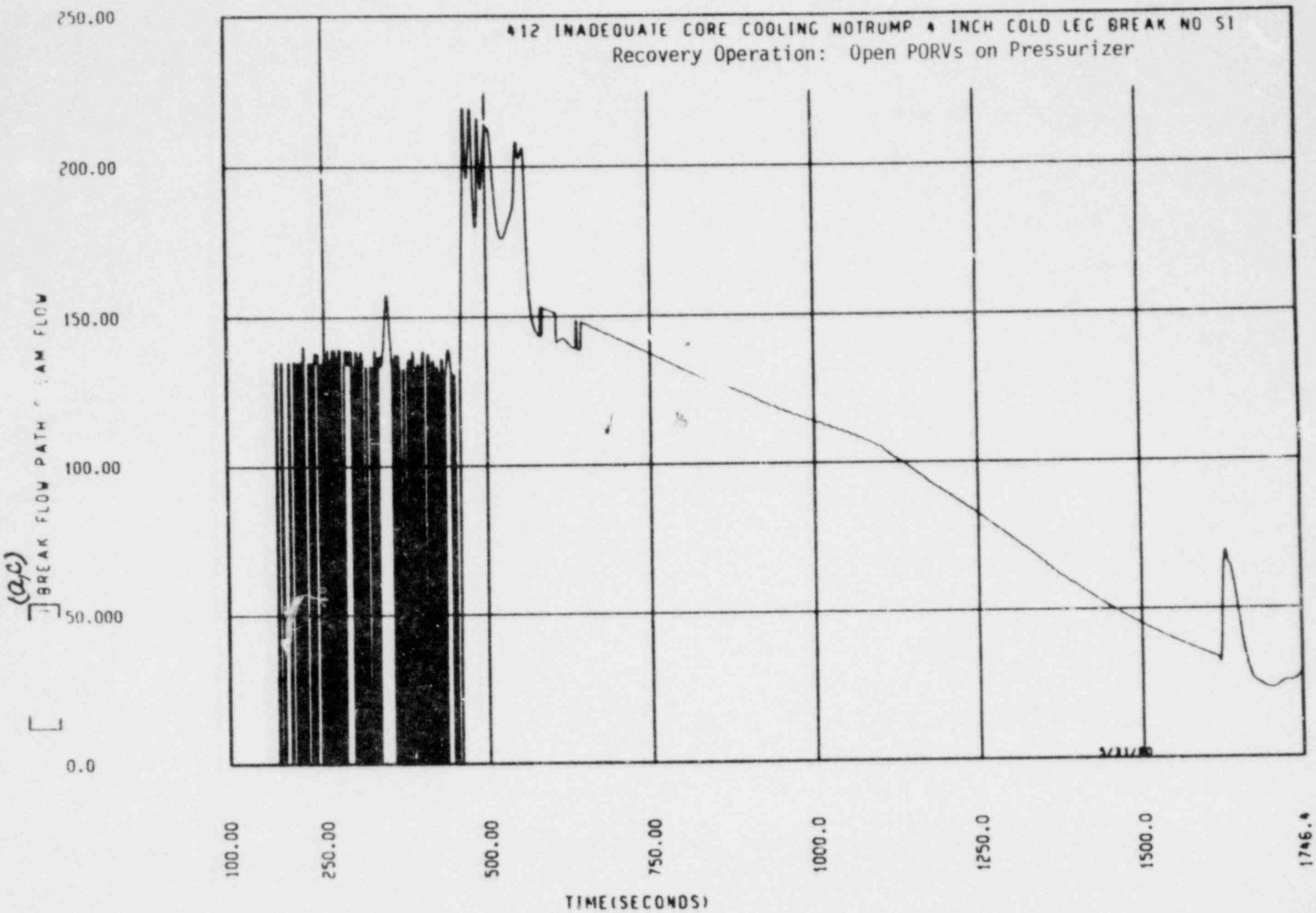
412 INADEQUATE CORE COOLING NOTRUMP 4 INCH COLD LEG BREAK NO SI
Recovery Operation: Open PORVs on Pressurizer
(a,c)
BREAK FLOW PATH STEAM FLOW
250.00
200.00
150.00
100.00
50.000
0.0
100.00
250.00
500.00
750.00
1000.0
1250.0
1500.0
1746.4
TIME(SECONDS)

Figure 283

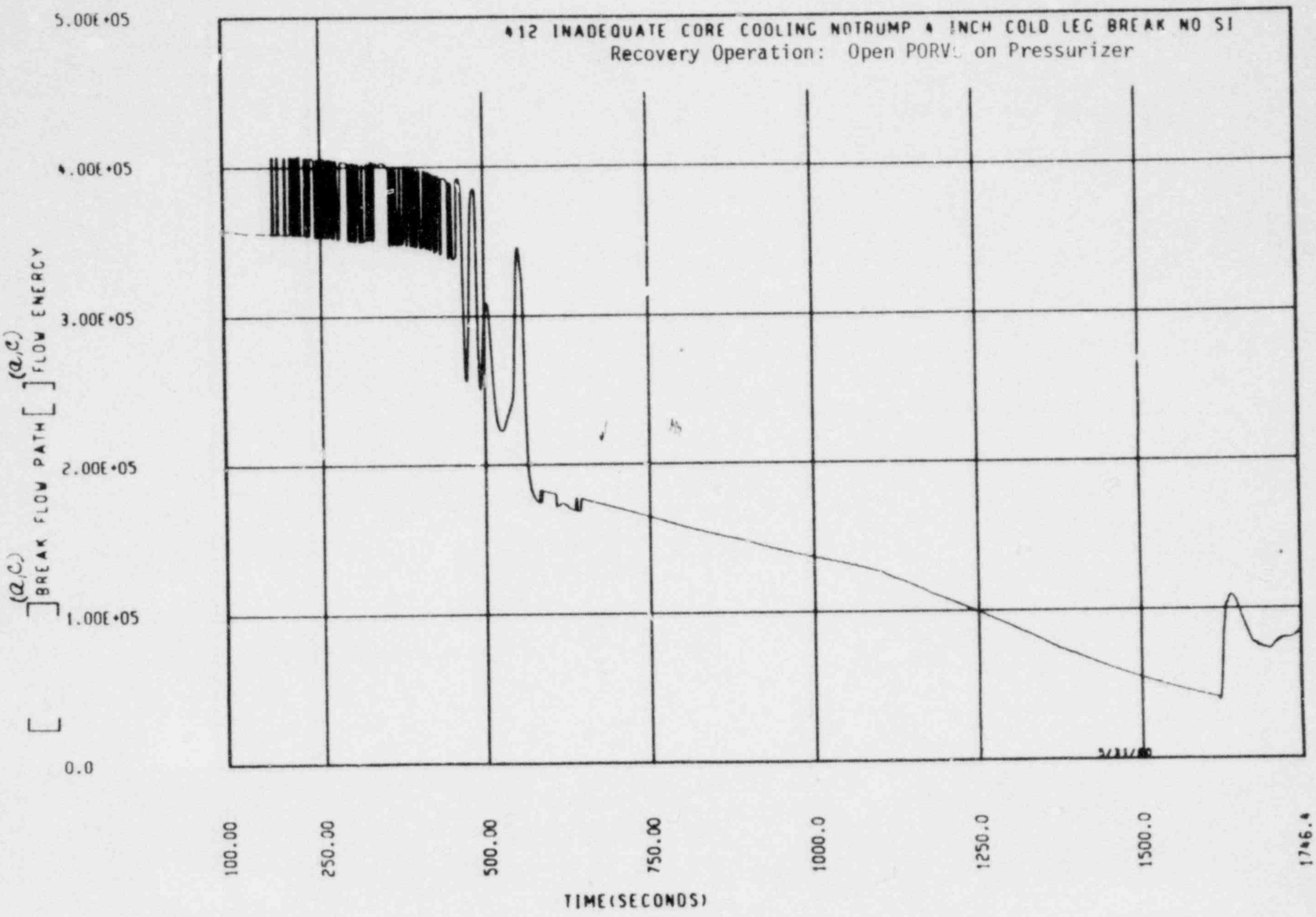

412 INADEQUATE CORE COOLING NOTRUMP 4 INCH COLD LEG BREAK NO SI
Recovery Operation: Open PORVs on Pressurizer
[ ]BREAK FLOW PATH [ ]FLOW ENERGY
(a,c)
(a,c)
5.00E+05
4.00E+05
3.00E+05
2.00E+05
1.00E+05
0.0
100.00
250.00
500.00
750.00
1000.0
1250.0
1500.0
1746.4
TIME(SECONDS)

Figure 284

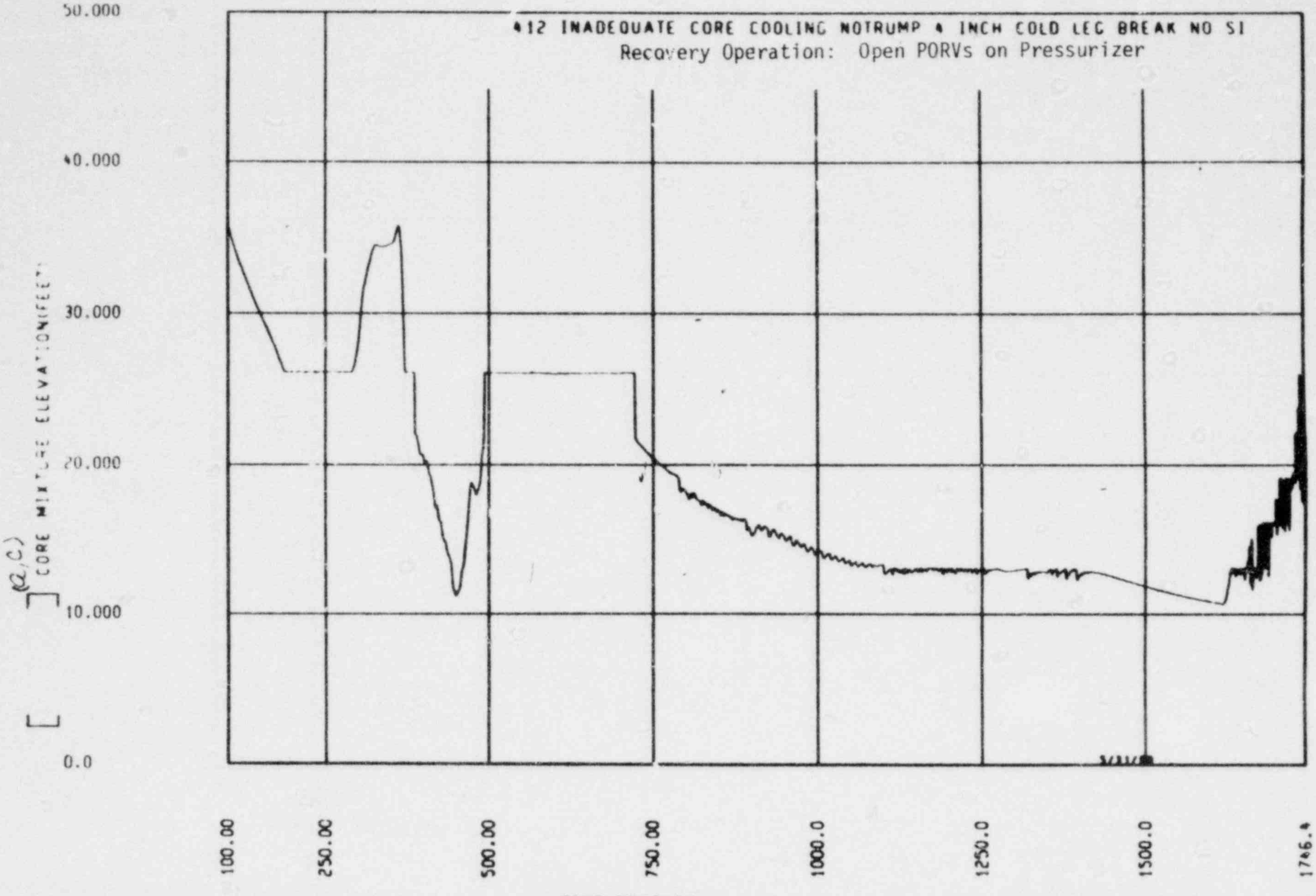

412 INADEQUATE CORE COOLING NOTRUMP 4 INCH COLD LEG BREAK NO SI
Recovery Operation: Open PORVs on Pressurizer

Figure 285

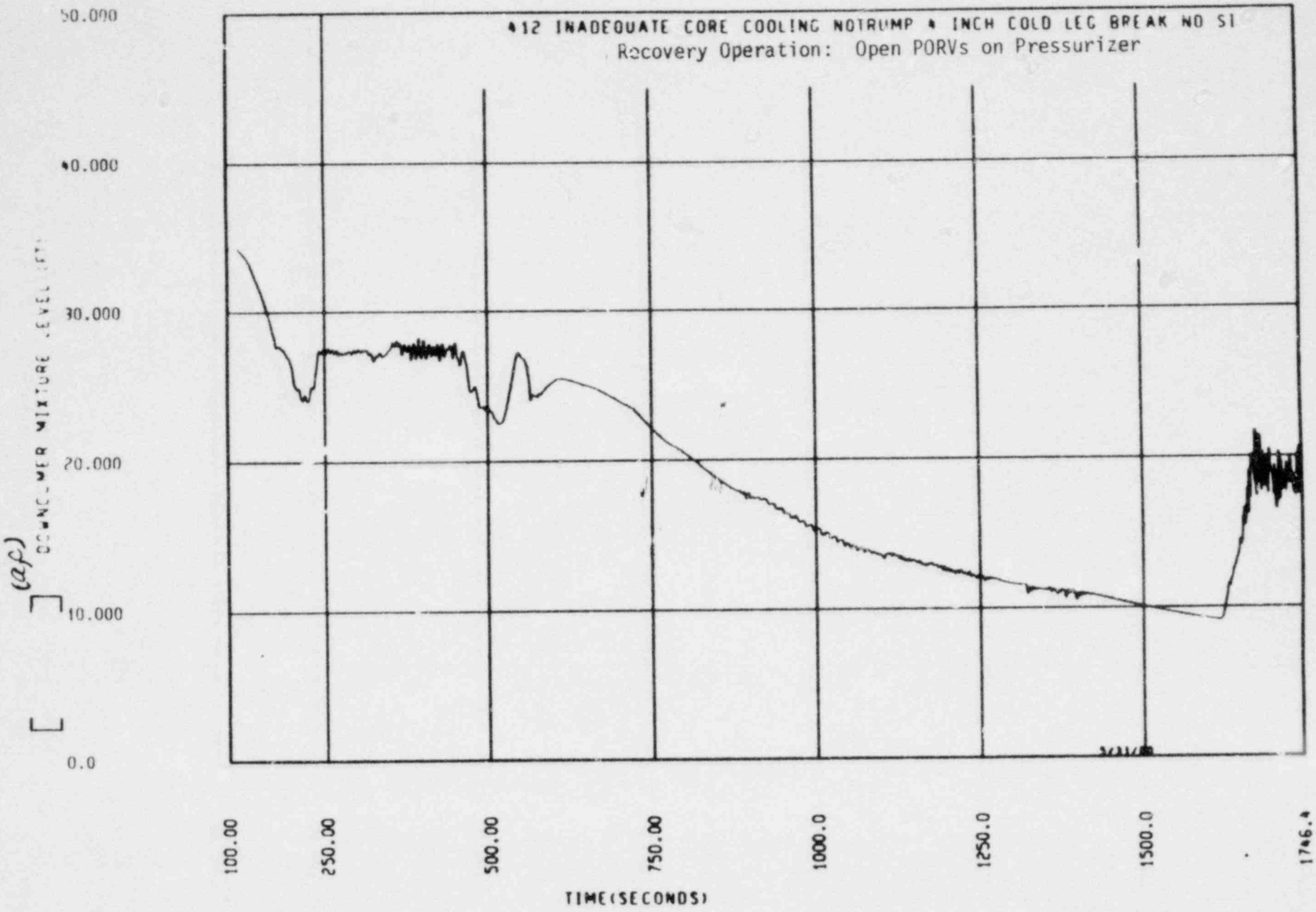

412 INADEQUATE CORE COOLING NOTRUMP 4 INCH COLD LEG BREAK NO SI
Recovery Operation: Open PORVs on Pressurizer
DOWNCOMER MIXTURE LEVEL (FT)
(a,c)
50.000
40.000
30.000
20.000
10.000
0.0
100.00
250.00
500.00
750.00
1000.0
1250.0
1500.0
1746.4
TIME(SECONDS)

Figure 286

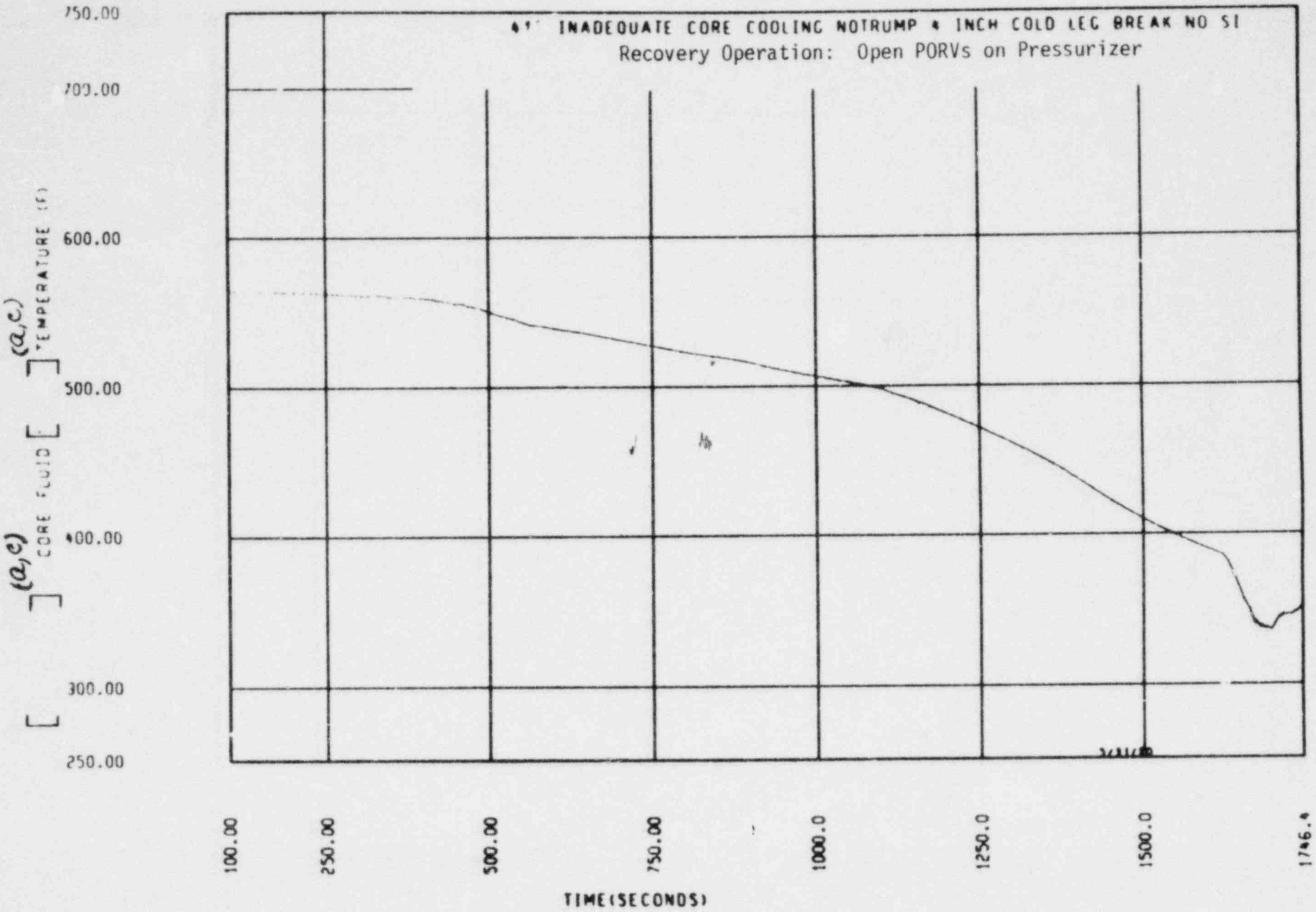

41' INADEQUATE CORE COOLING NOTRUMP 4 INCH COLD LEG BREAK NO SI
Recovery Operation: Open PORVs on Pressurizer
750.00
700.00
600.00
500.00
400.00
300.00
250.00
(a,c)
(a,c)
CORE FLUID TEMPERATURE (F)
100.00
250.00
500.00
750.00
1000.0
1250.0
1500.0
1746.4
TIME(SECONDS)

Figure 287

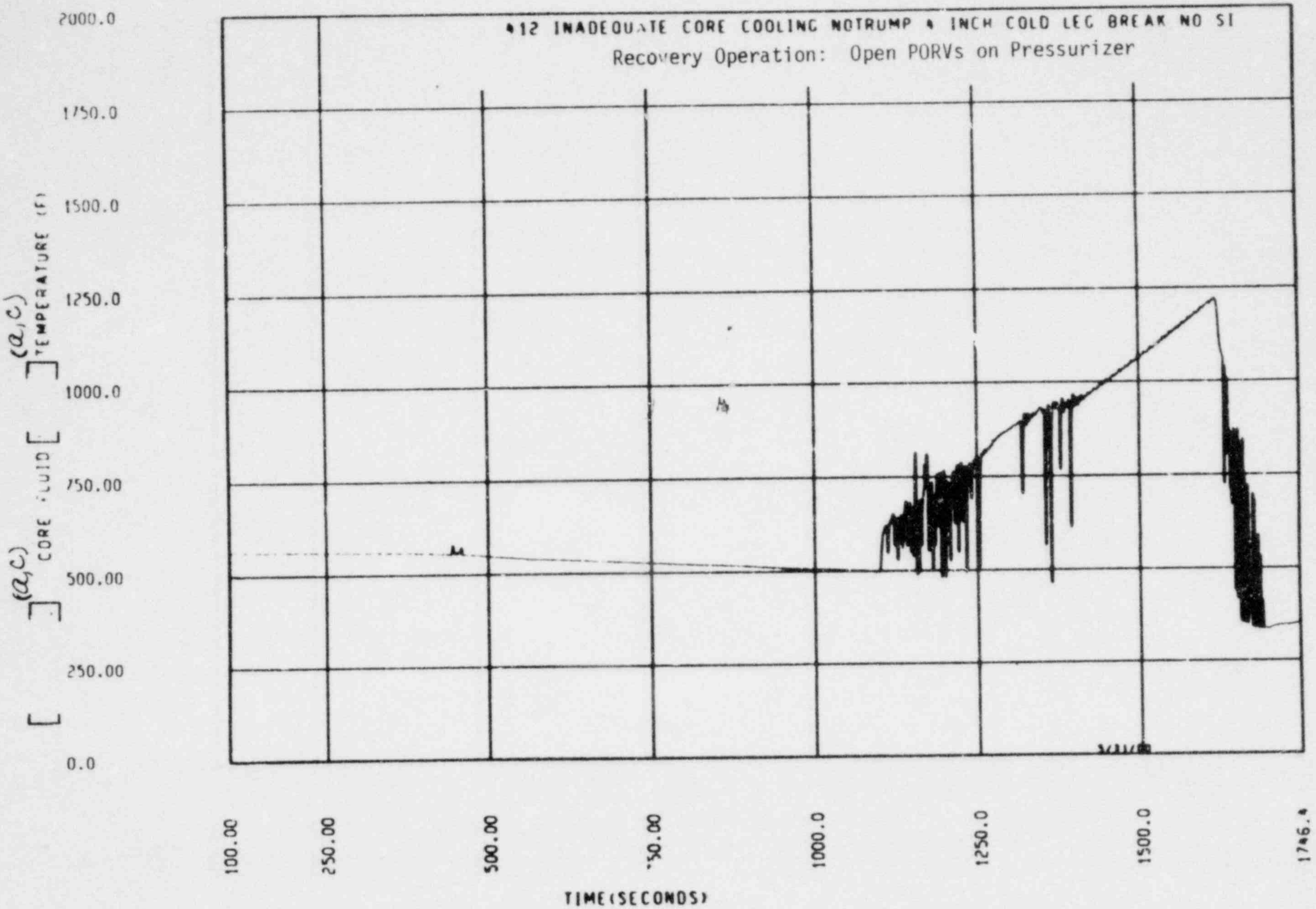

412 INADEQUATE CORE COOLING NOTRUMP 4 INCH COLD LEG BREAK NO SI
Recovery Operation: Open PORVs on Pressurizer
CORE FLUID
TEMPERATURE (F)
(a,c)
(a,c)
2000.0
1750.0
1500.0
1250.0
1000.0
750.00
500.00
250.00
0.0
100.00
250.00
500.00
750.00
1000.0
1250.0
1500.0
1746.4
TIME(SECONDS)

Figure 288

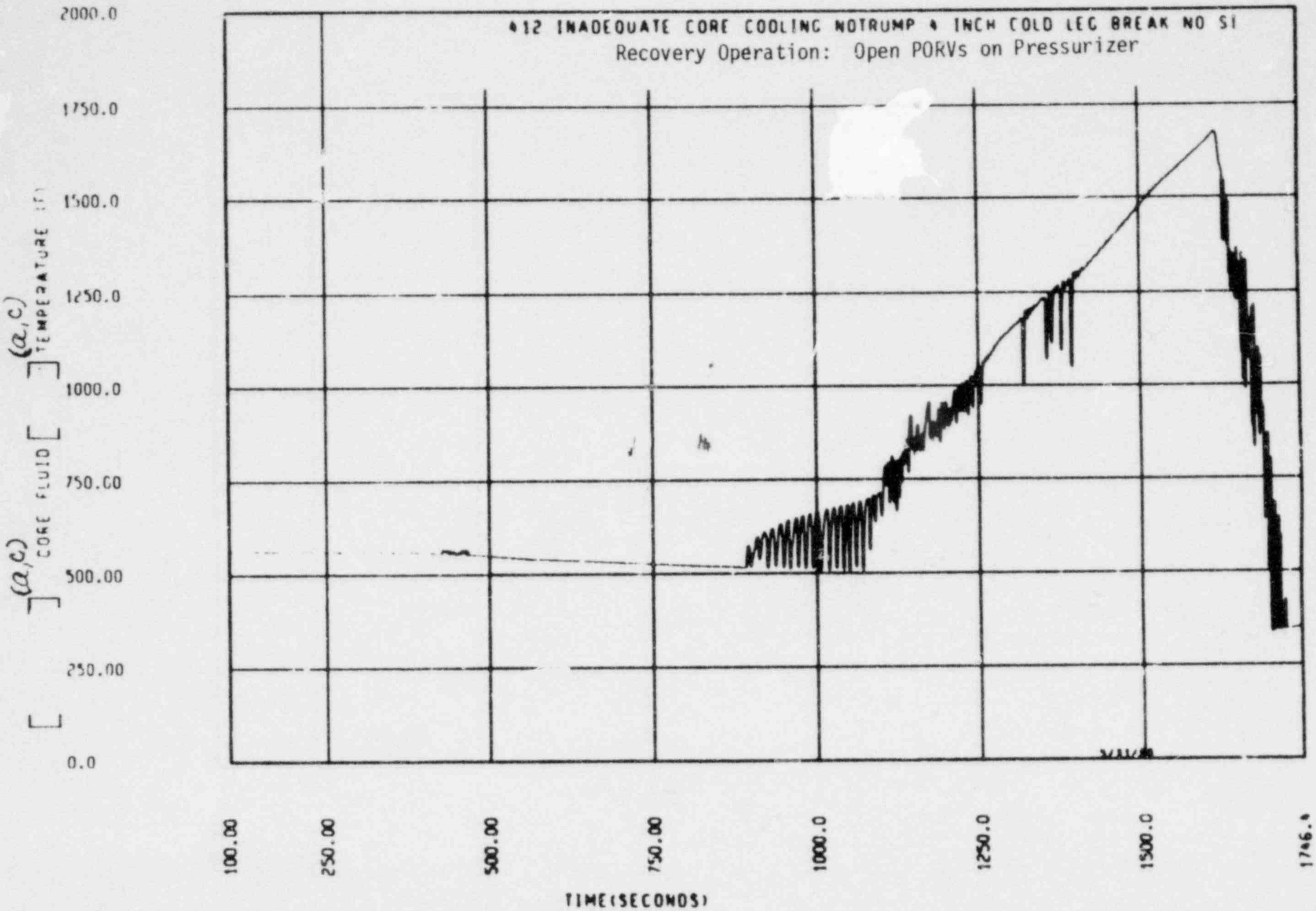

412 INADEQUATE CORE COOLING NOTRUMP 4 INCH COLD LEG BREAK NO SI
Recovery Operation: Open PORVs on Pressurizer
(a,c)
CORE FLUID
(a,c)
TEMPERATURE (F)
2000.0
1750.0
1500.0
1250.0
1000.0
750.00
500.00
250.00
0.0
100.00
250.00
500.00
750.00
1000.0
1250.0
1500.0
1746.4
TIME(SECONDS)

Figure 289

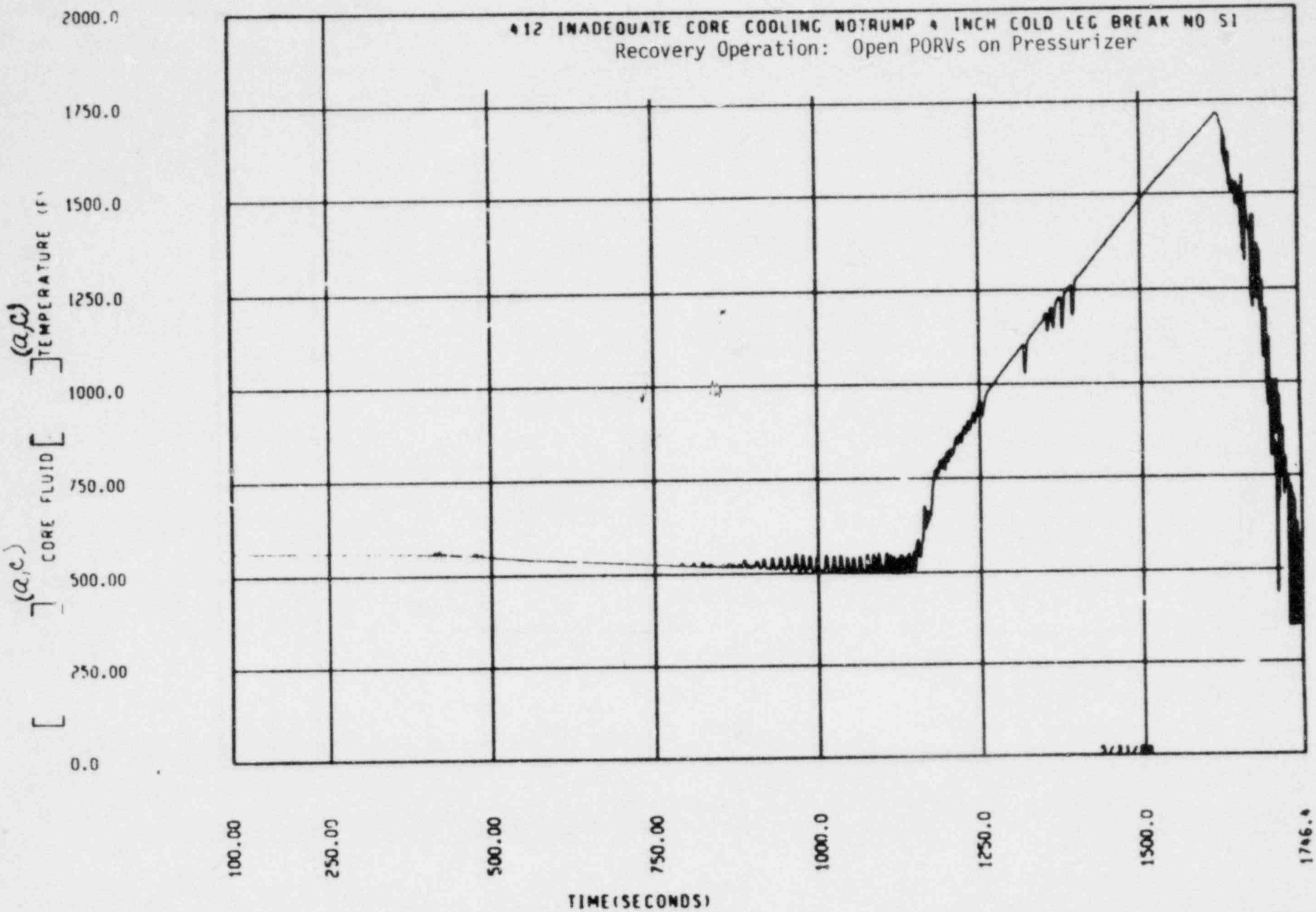

412 INADEQUATE CORE COOLING NOTRUMP 4 INCH COLD LEG BREAK NO SI
Recovery Operation: Open PORVs on Pressurizer
(a,c)
(a,c)
CORE FLUID
TEMPERATURE (F)
2000.0
1750.0
1500.0
1250.0
1000.0
750.00
500.00
250.00
0.0
100.00
250.00
500.00
750.00
1000.0
1250.0
1500.0
1746.4
TIME(SECONDS)

Figure 290

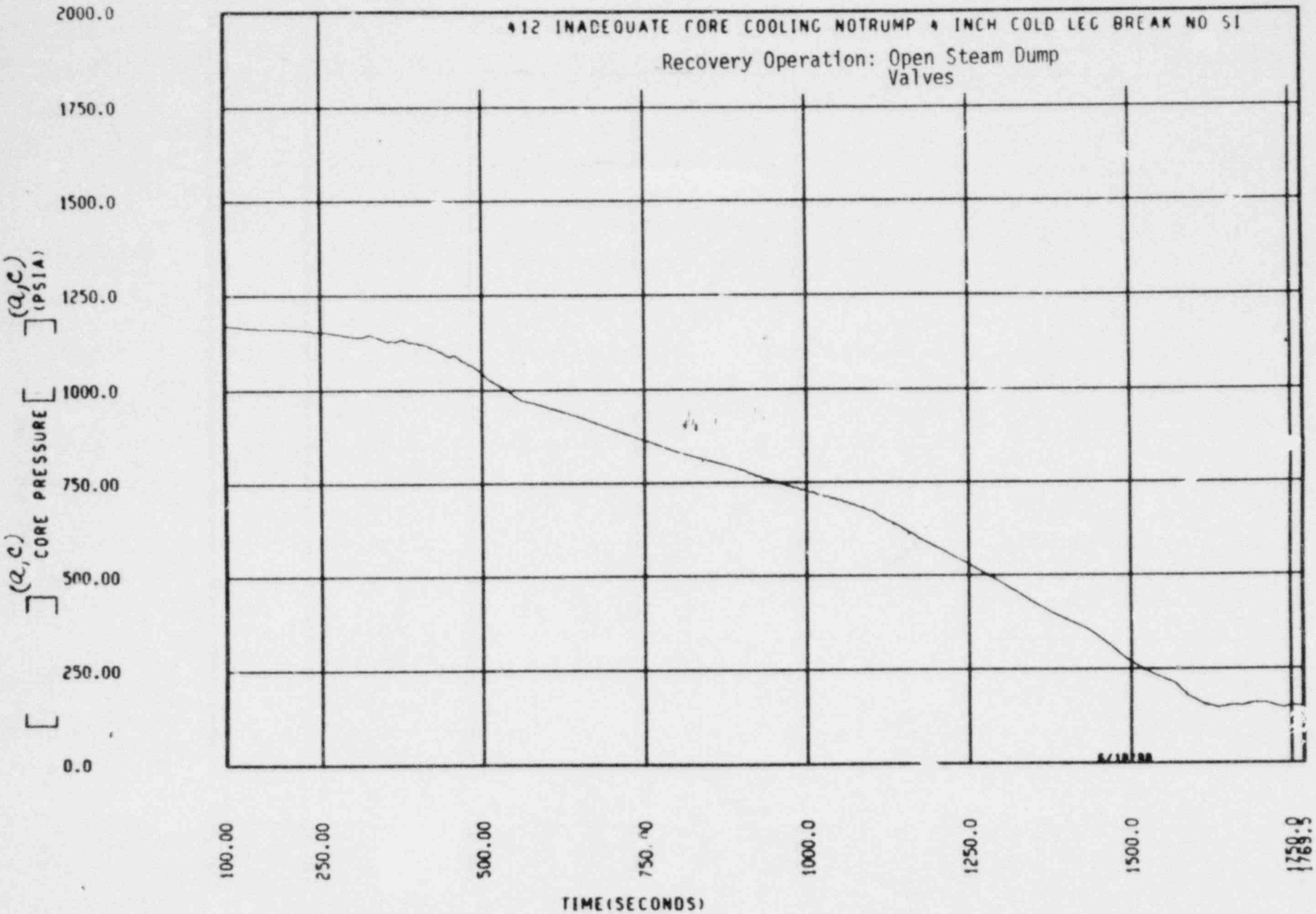

412 INADEQUATE CORE COOLING NOTRUMP 4 INCH COLD LEG BREAK NO SI
Recovery Operation: Open Steam Dump Valves
(a,c)
CORE PRESSURE
(PSIA)
(a,c)
2000.0
1750.0
1500.0
1250.0
1000.0
750.00
500.00
250.00
0.0
100.00
250.00
500.00
750.00
1000.0
1250.0
1500.0
1750.0
1769.5
TIME(SECONDS)

Figure 291

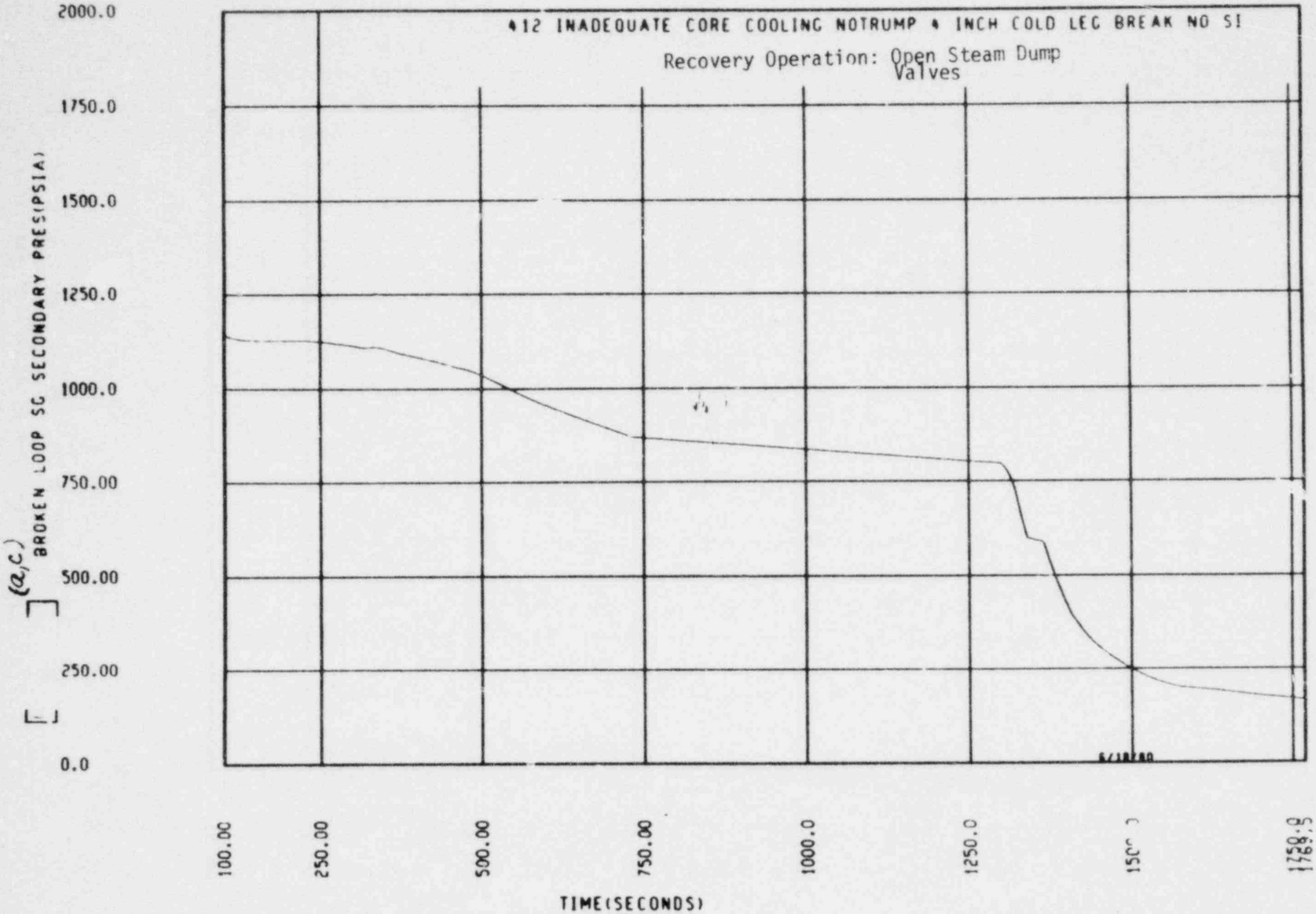
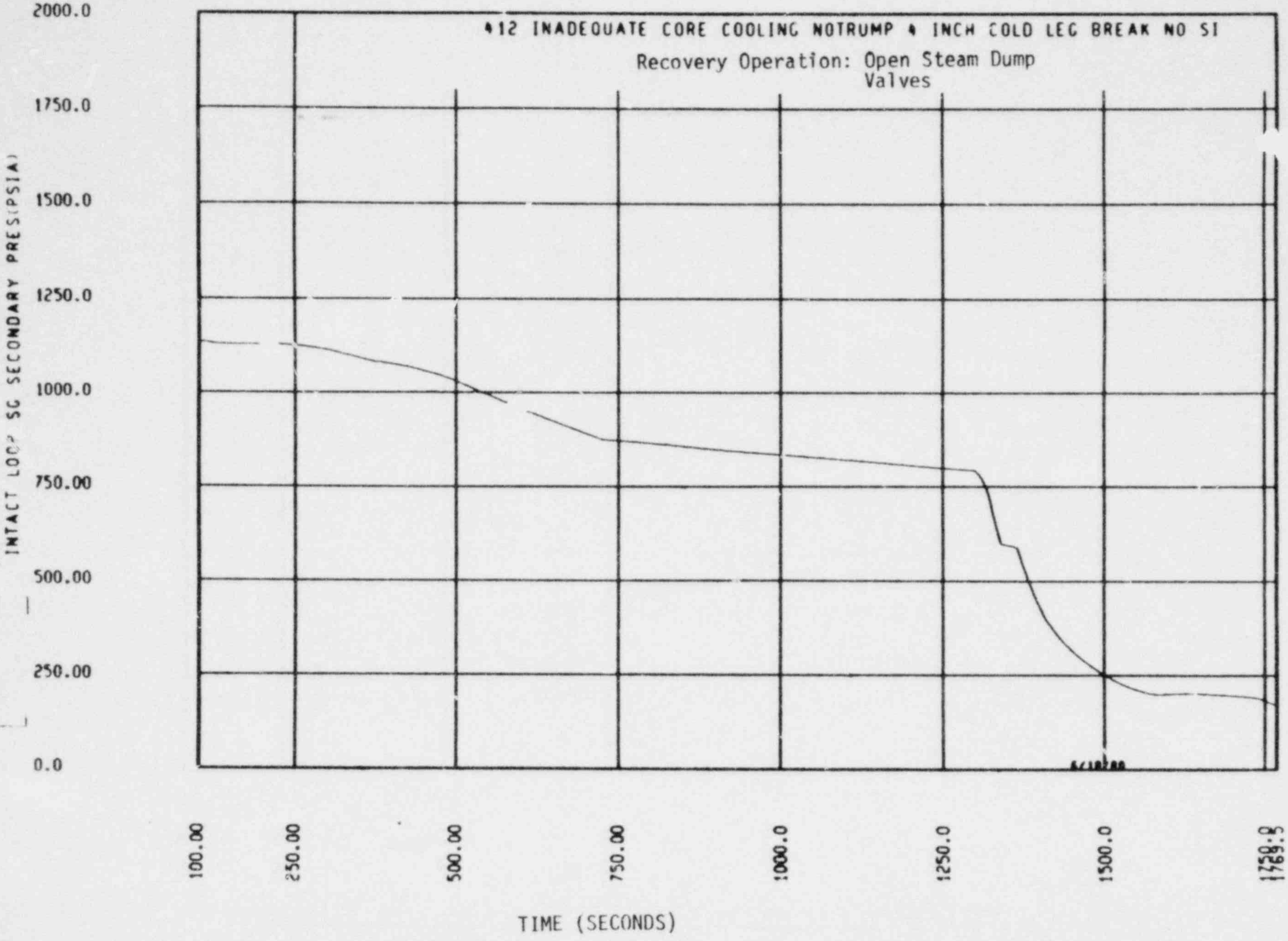

412 INADEQUATE CORE COOLING NOTRUMP 4 INCH COLD LEG BREAK NO SI
Recovery Operation: Open Steam Dump Valves
BROKEN LOOP SG SECONDARY PRES(PSIA)
(a,c)
2000.0
1750.0
1500.0
1250.0
1000.0
750.00
500.00
250.00
0.0
100.00
250.00
500.00
750.00
1000.0
1250.0
1500.0
1750.0
1769.5
6/18/80
TIME(SECONDS)

Figure 292



(a,c)

Figure 293

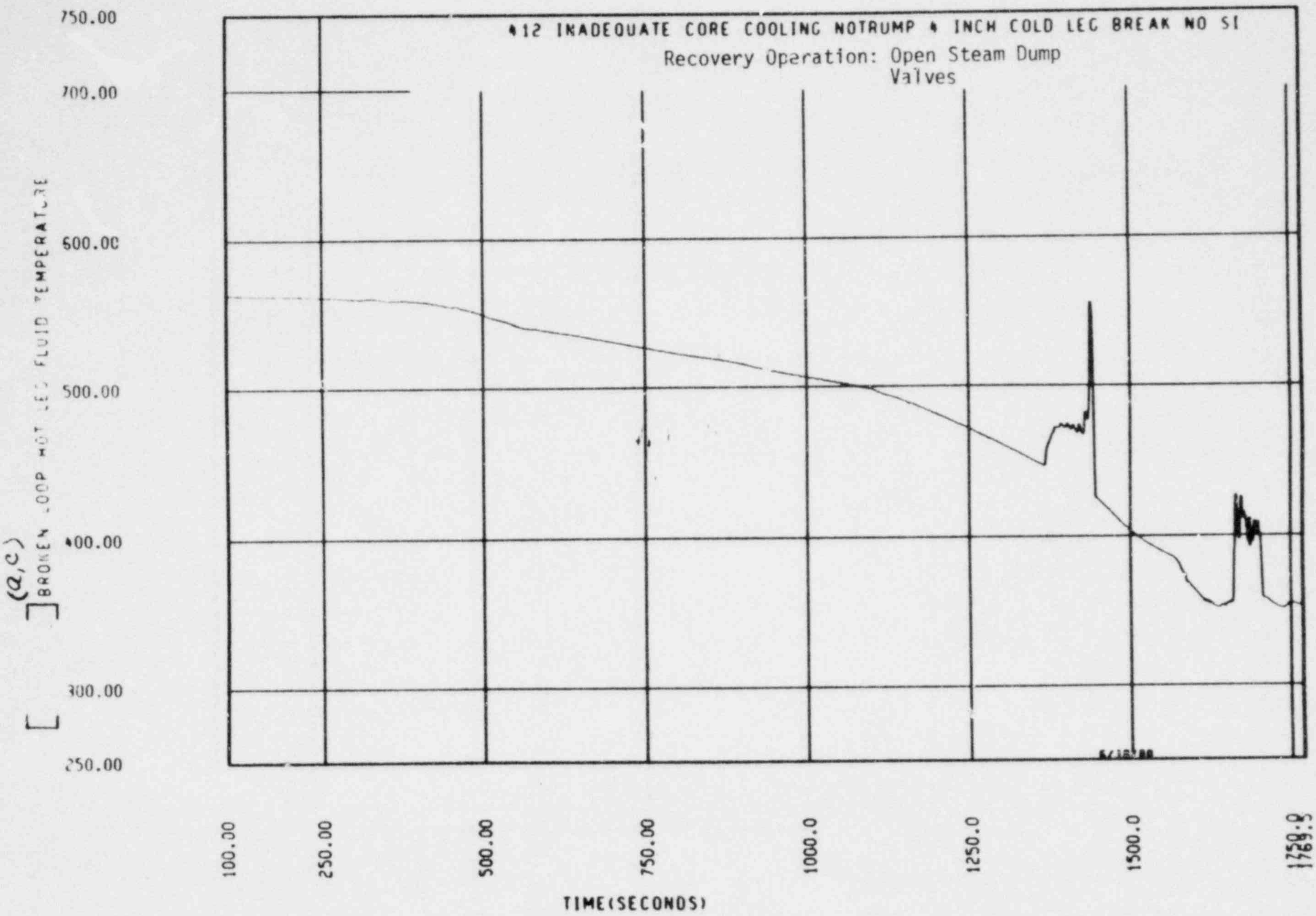

412 INADEQUATE CORE COOLING NOTRUMP 4 INCH COLD LEG BREAK NO SI
Recovery Operation: Open Steam Dump Valves
(a,c)
BROKEN LOOP HOT LEG FLUID TEMPERATURE
750.00
700.00
600.00
500.00
400.00
300.00
250.00
100.00
250.00
500.00
750.00
1000.0
1250.0
1500.0
1750.0
1769.5
TIME(SECONDS)

Figure 294

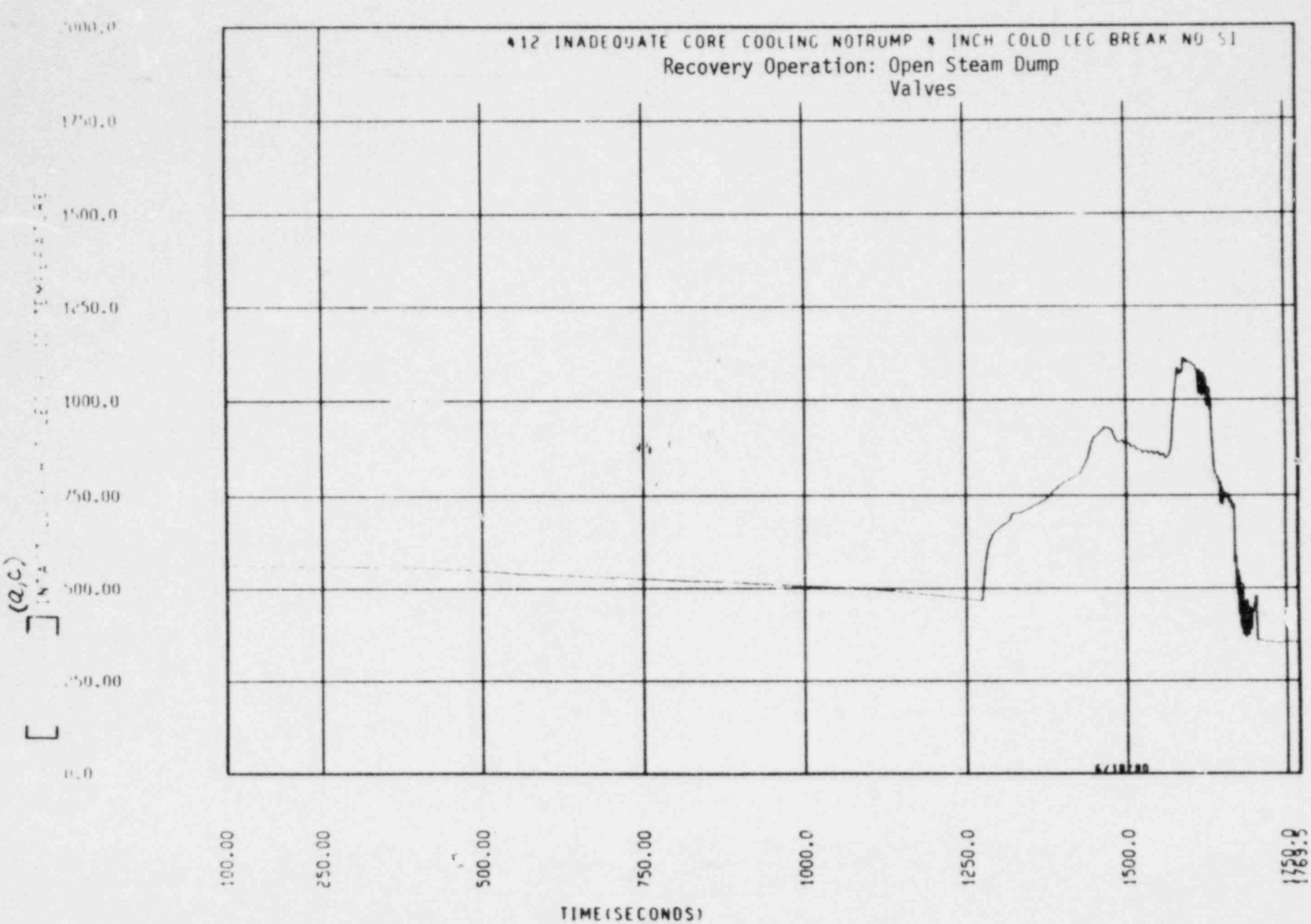

412 INADEQUATE CORE COOLING NOTRUMP 4 INCH COLD LEG BREAK NO SI
Recovery Operation: Open Steam Dump
Valves
2000.0
1750.0
1500.0
1250.0
1000.0
750.00
500.00
250.00
0.0
(a,c)
100.00
250.00
500.00
750.00
1000.0
1250.0
1500.0
1750.0
1769.5
6/18/80
TIME(SECONDS)

Figure 295

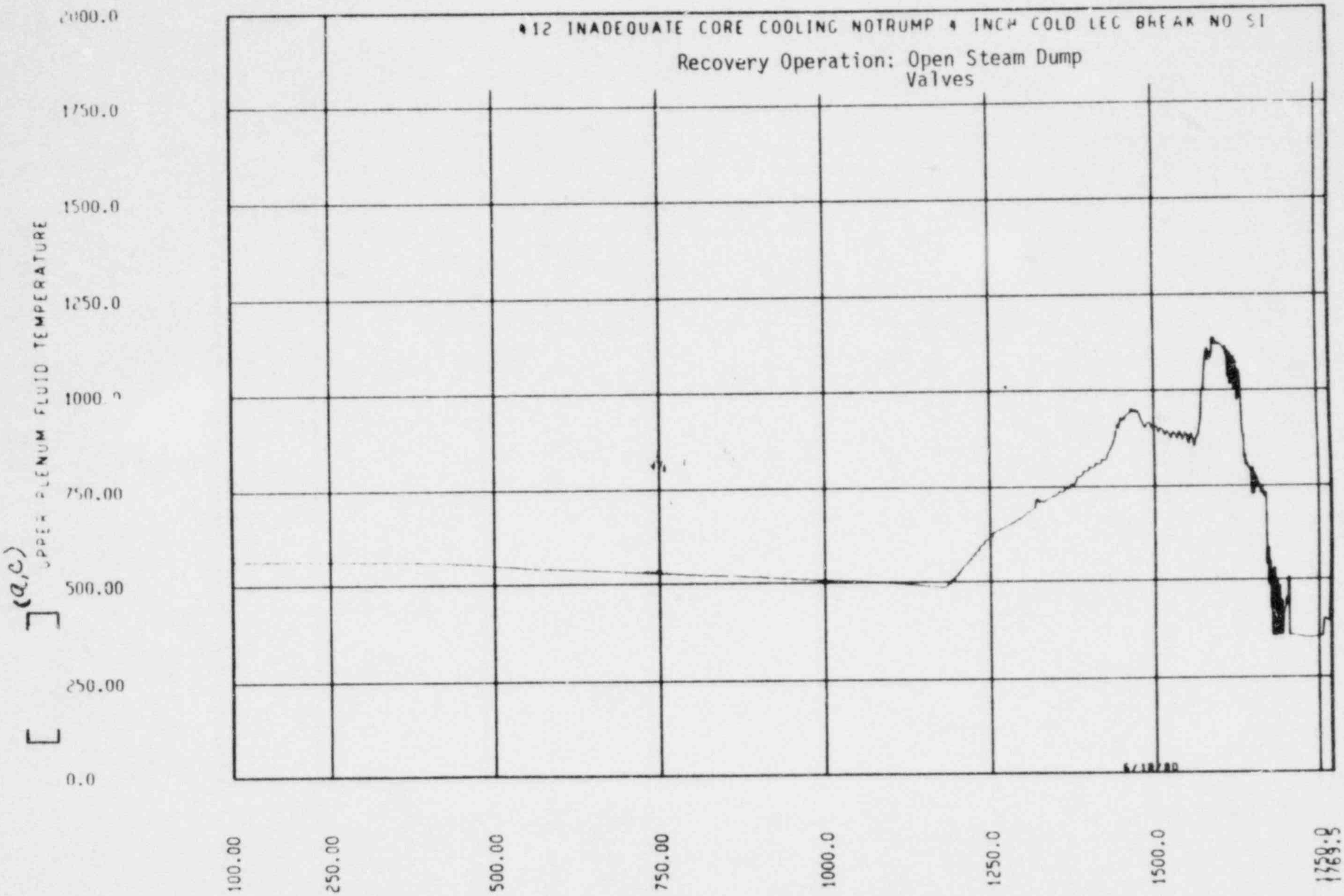

412 INADEQUATE CORE COOLING NOTRUMP 4 INCH COLD LEG BREAK NO SI
Recovery Operation: Open Steam Dump Valves
UPPER PLENUM FLUID TEMPERATURE
[ ](a,c)
2000.0
1750.0
1500.0
1250.0
1000.0
750.00
500.00
250.00
0.0
100.00
250.00
500.00
750.00
1000.0
1250.0
1500.0
1750.0
1769.5
TIME(SECONDS)
6/18/80

Figure 296

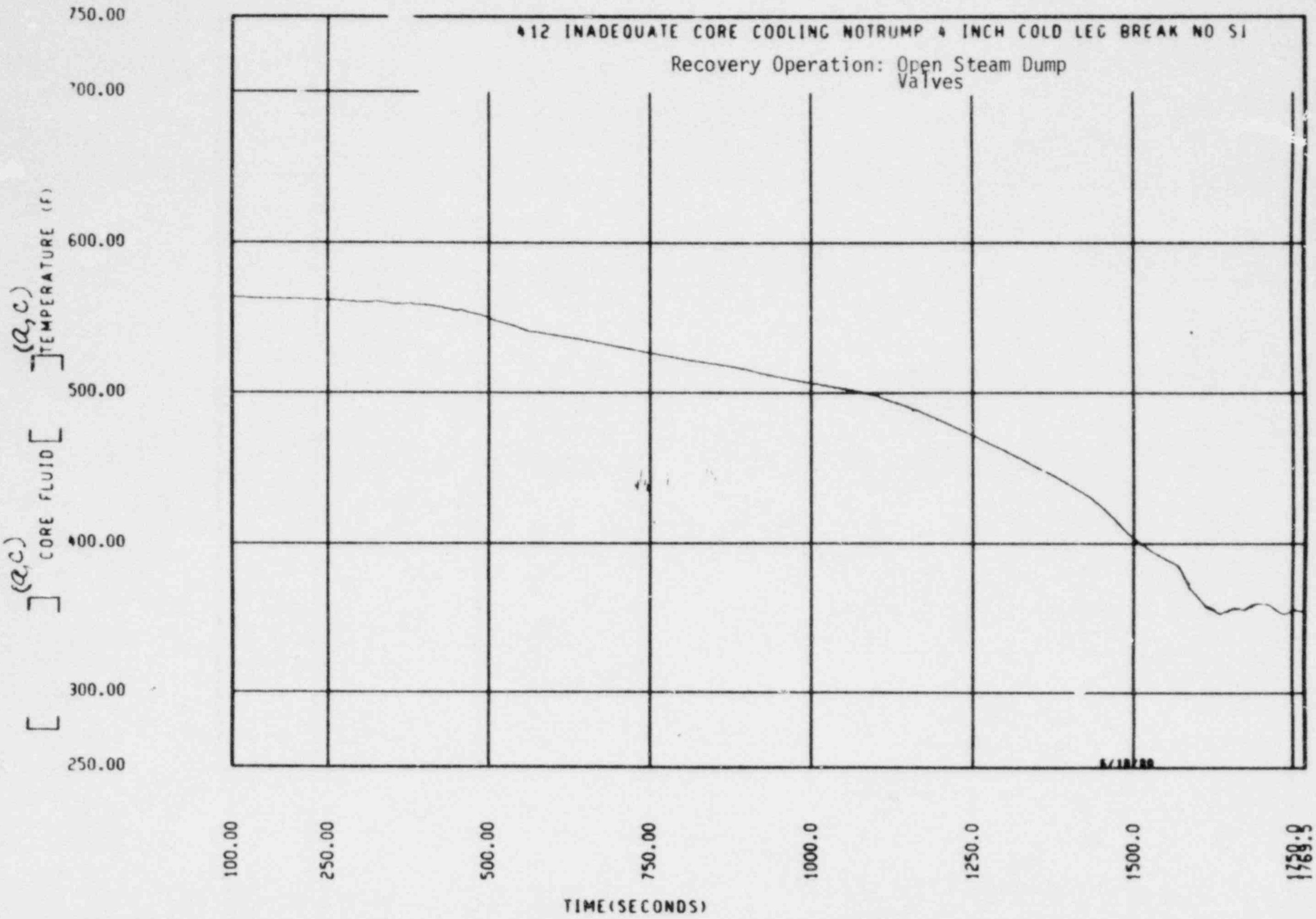
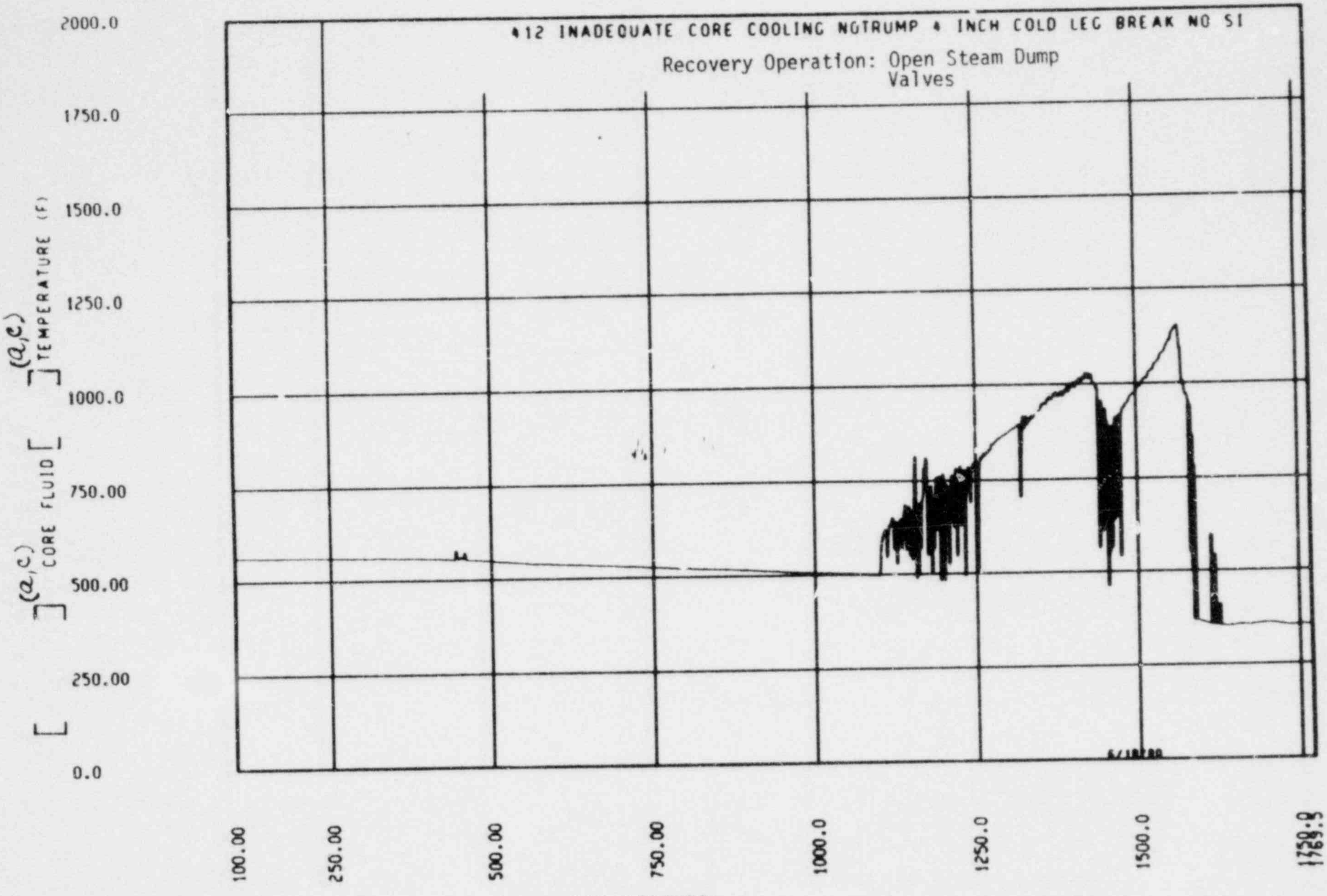

412 INADEQUATE CORE COOLING NOTRUMP 4 INCH COLD LEG BREAK NO SI
Recovery Operation: Open Steam Dump Valves
(a,c)
CORE FLUID
(a,c)
TEMPERATURE (F)
750.00
700.00
600.00
500.00
400.00
300.00
250.00
100.00
250.00
500.00
750.00
1000.0
1250.0
1500.0
1750.0
1769.5
TIME(SECONDS)

Figure 297



412 INADEQUATE CORE COOLING NOTRUMP 4 INCH COLD LEG BREAK NO SI
Recovery Operation: Open Steam Dump Valves
[ ]^(a,c) CORE FLUID [ ]^(a,c) TEMPERATURE (F)
2000.0
1750.0
1500.0
1250.0
1000.0
750.00
500.00
250.00
0.0
100.00
250.00
500.00
750.00
1000.0
1250.0
1500.0
1750.0
1769.5
TIME(' ECONDS)

Figure 298

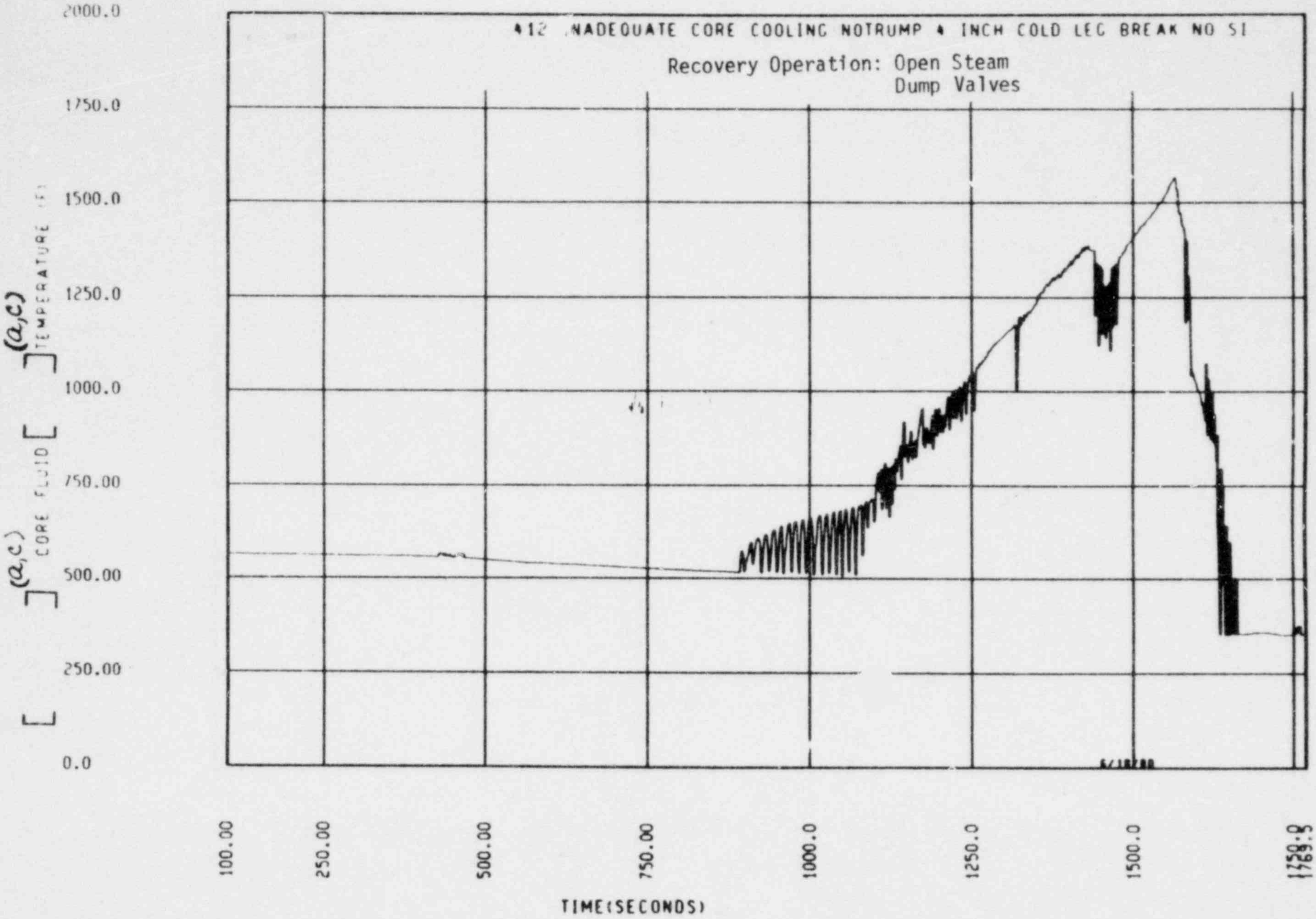
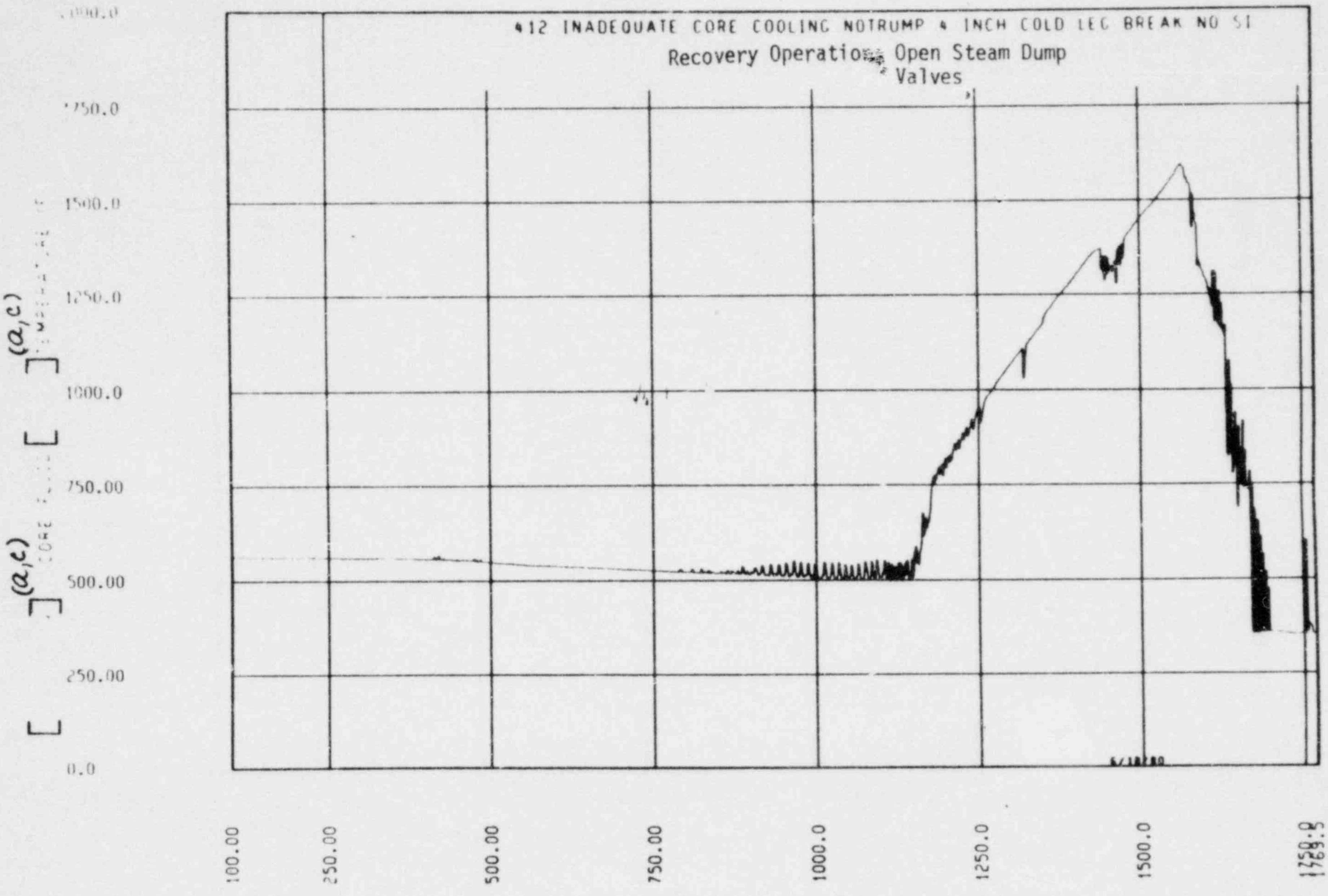
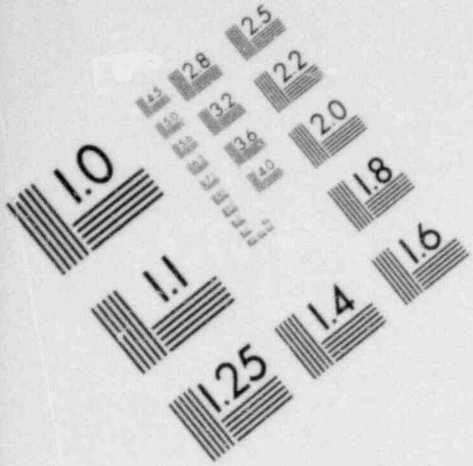

412 INADEQUATE CORE COOLING NOTRUMP 4 INCH COLD LEG BREAK NO SI
Recovery Operation: Open Steam Dump Valves
[ ]$^{(a,c)}$ CORE FLUID [ ]$^{(a,c)}$ TEMPERATURE (F)
2000.0
1750.0
1500.0
1250.0
1000.0
750.00
500.00
250.00
0.0
100.00
250.00
500.00
750.00
1000.0
1250.0
1500.0
1750.0
1769.5
TIME(SECONDS)

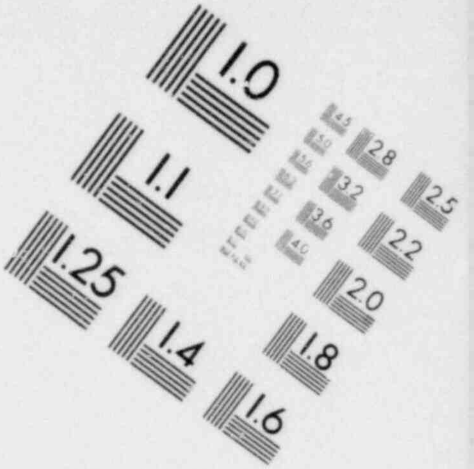
Figure 299



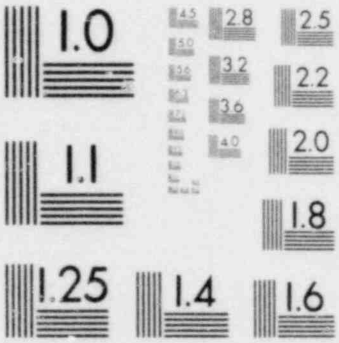
TIME(SECONDS)

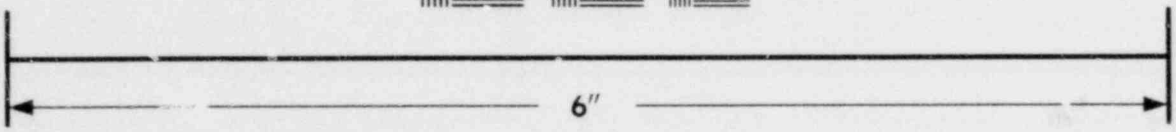
Figure 300



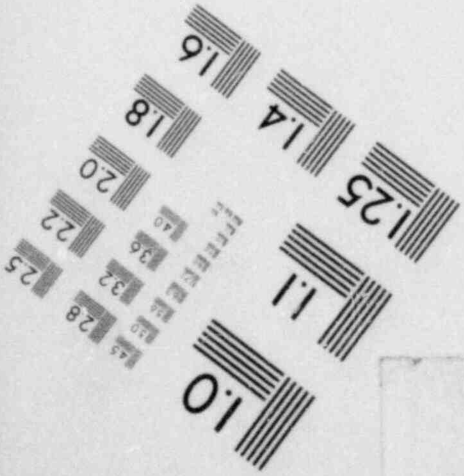


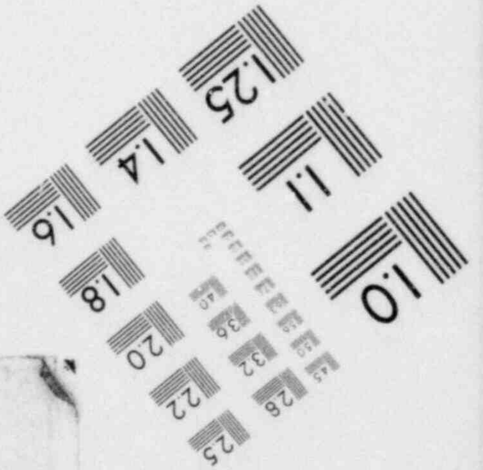
# IMAGE EVALUATION TEST TARGET (MT-3)

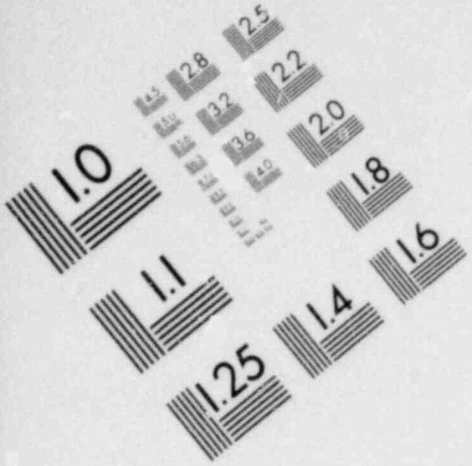


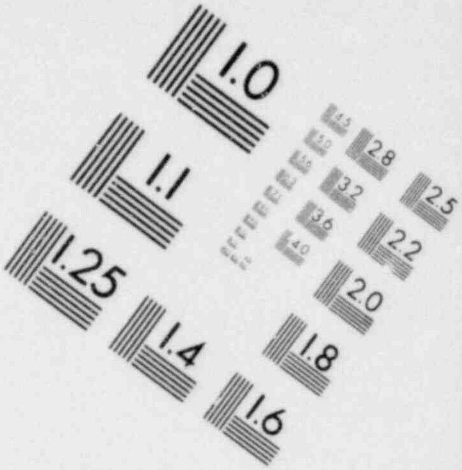


# MICROCOPY RESOLUTION TEST CHART

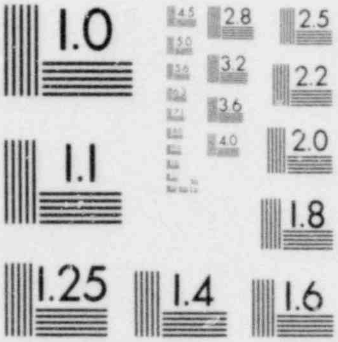


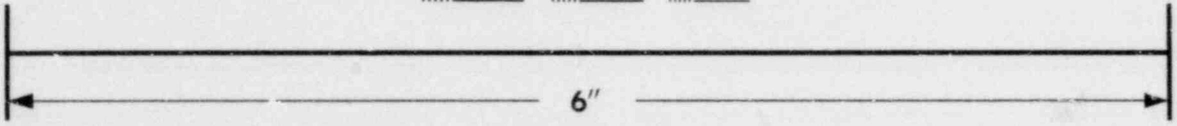




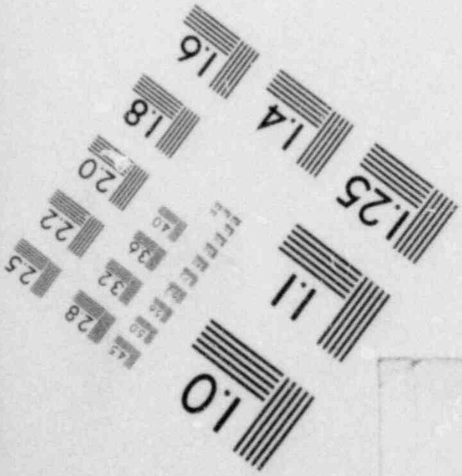


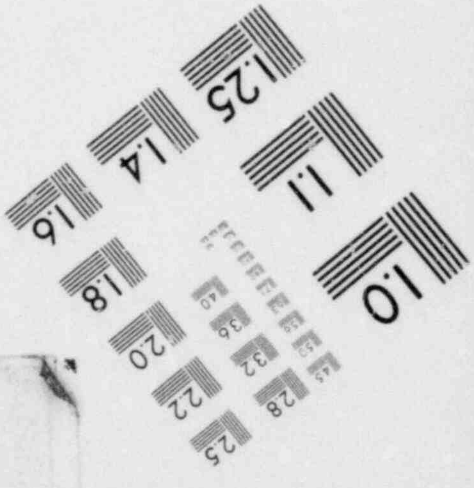
# IMAGE EVALUATION
# TEST TARGET (MT-3)





# MICROCOPY RESOLUTION TEST CHART





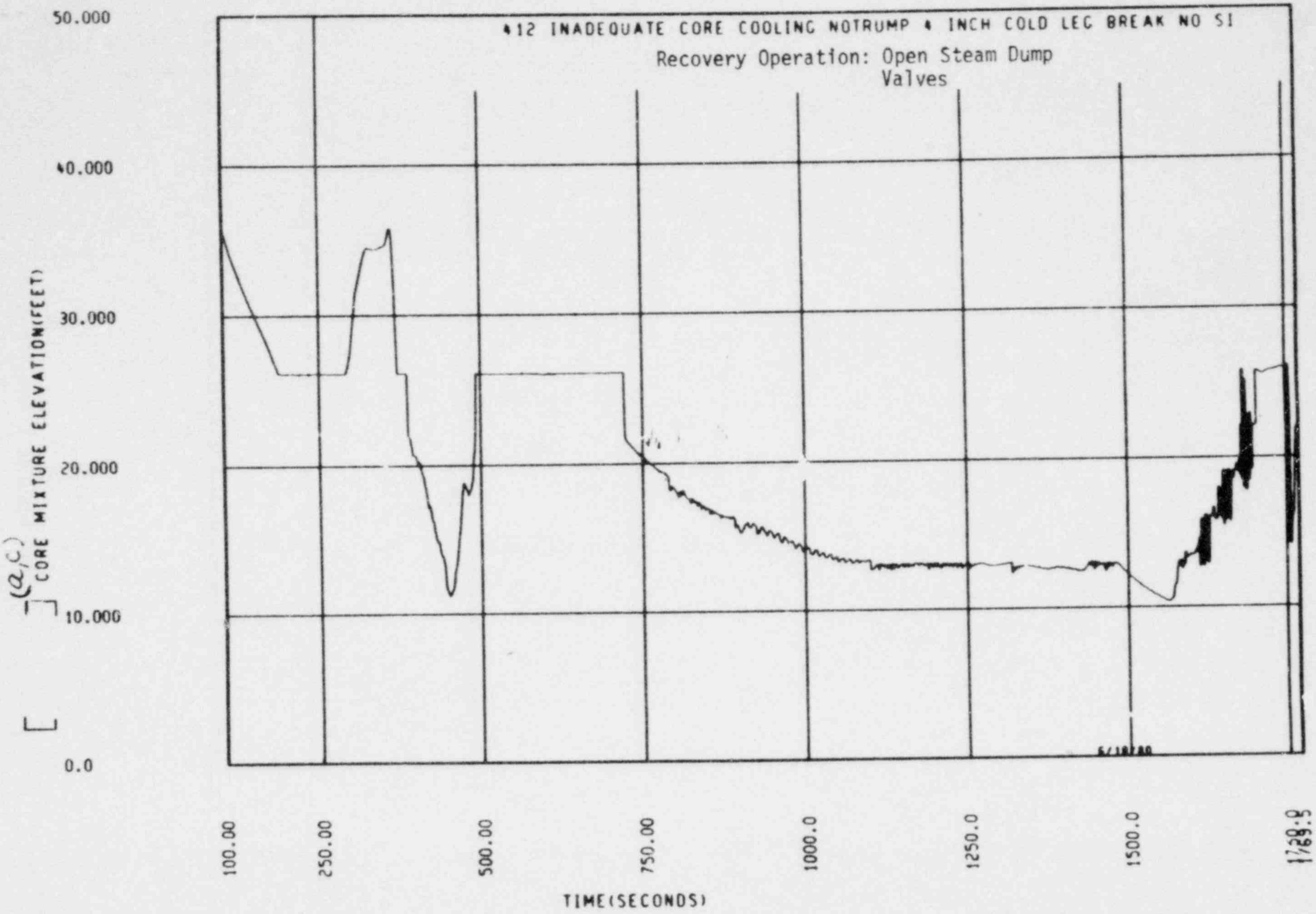

412 INADEQUATE CORE COOLING NOTRUMP 4 INCH COLD LEG BREAK NO SI
Recovery Operation: Open Steam Dump Valves
CORE MIXTURE ELEVATION(FEET)
(a,c)
50.000
40.000
30.000
20.000
10.000
0.0
100.00
250.00
500.00
750.00
1000.0
1250.0
1500.0
1720.0
1769.5
TIME(SECONDS)
5/18/80

Figure 301

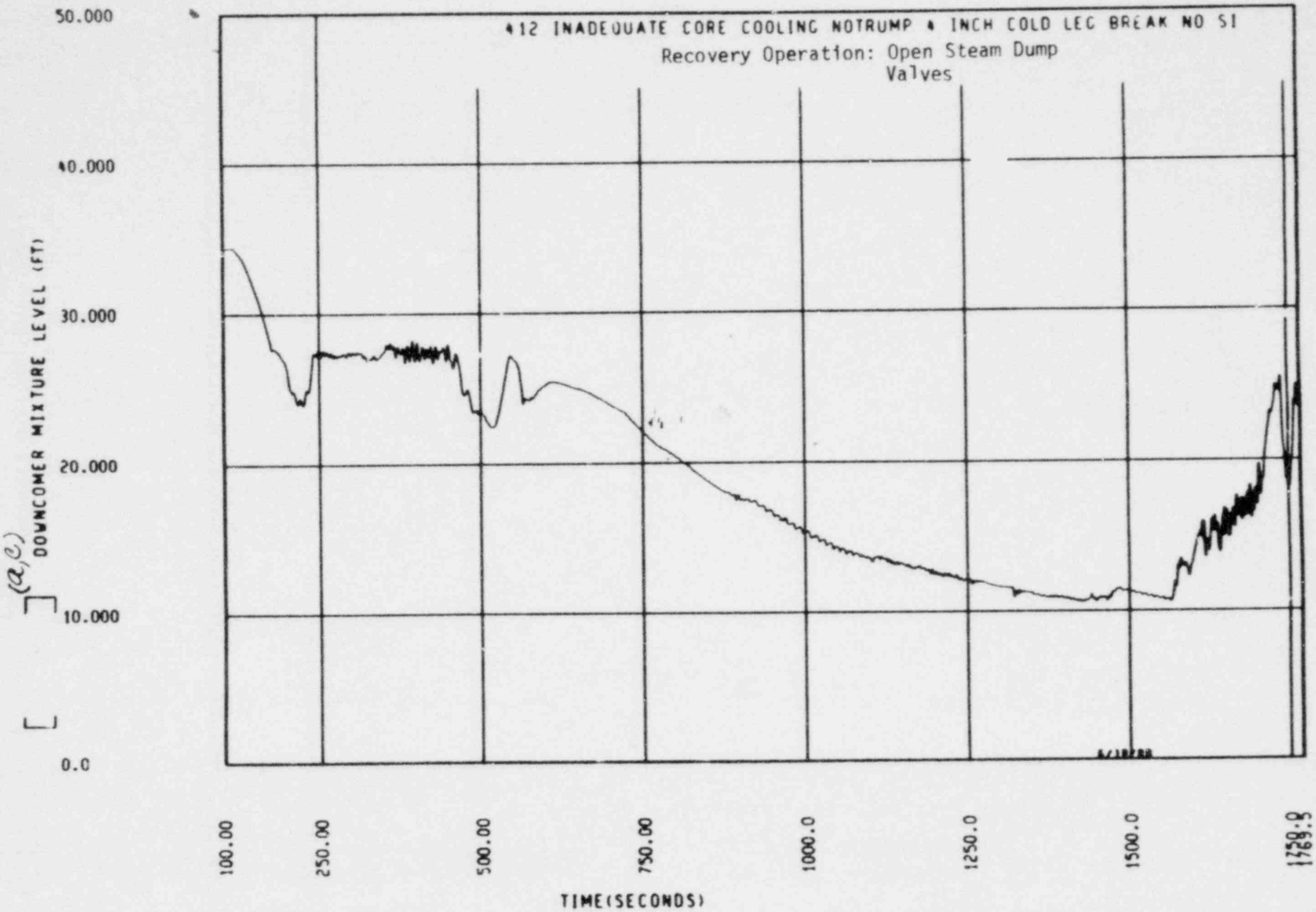

412 INADEQUATE CORE COOLING NOTRUMP 4 INCH COLD LEG BREAK NO SI
Recovery Operation: Open Steam Dump Valves
DOWNCOMER MIXTURE LEVEL (FT)
(a,c)
50.000
40.000
30.000
20.000
10.000
0.0
100.00
250.00
500.00
750.00
1000.0
1250.0
1500.0
1750.0
1769.5
TIME(SECONDS)

Figure 302

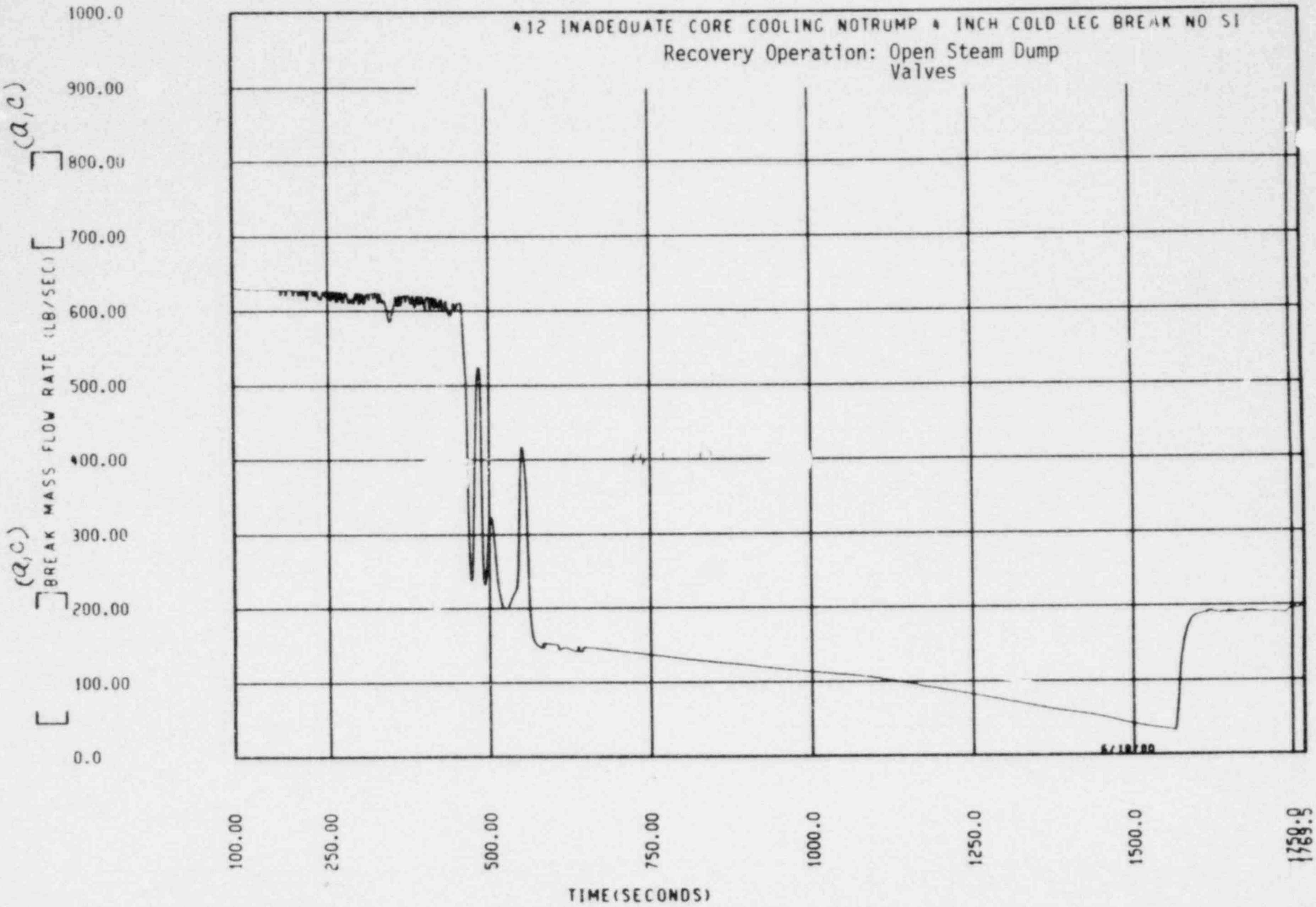

412 INADEQUATE CORE COOLING NOTRUMP 4 INCH COLD LEG BREAK NO SI
Recovery Operation: Open Steam Dump Valves
BREAK MASS FLOW RATE (LB/SEC)
(a,c)
(a,c)
1000.0
900.00
800.00
700.00
600.00
500.00
400.00
300.00
200.00
100.00
0.0
100.00
250.00
500.00
750.00
1000.0
1250.0
1500.0
1750.0
1769.5
TIME(SECONDS)
6/18/80

Figure 303

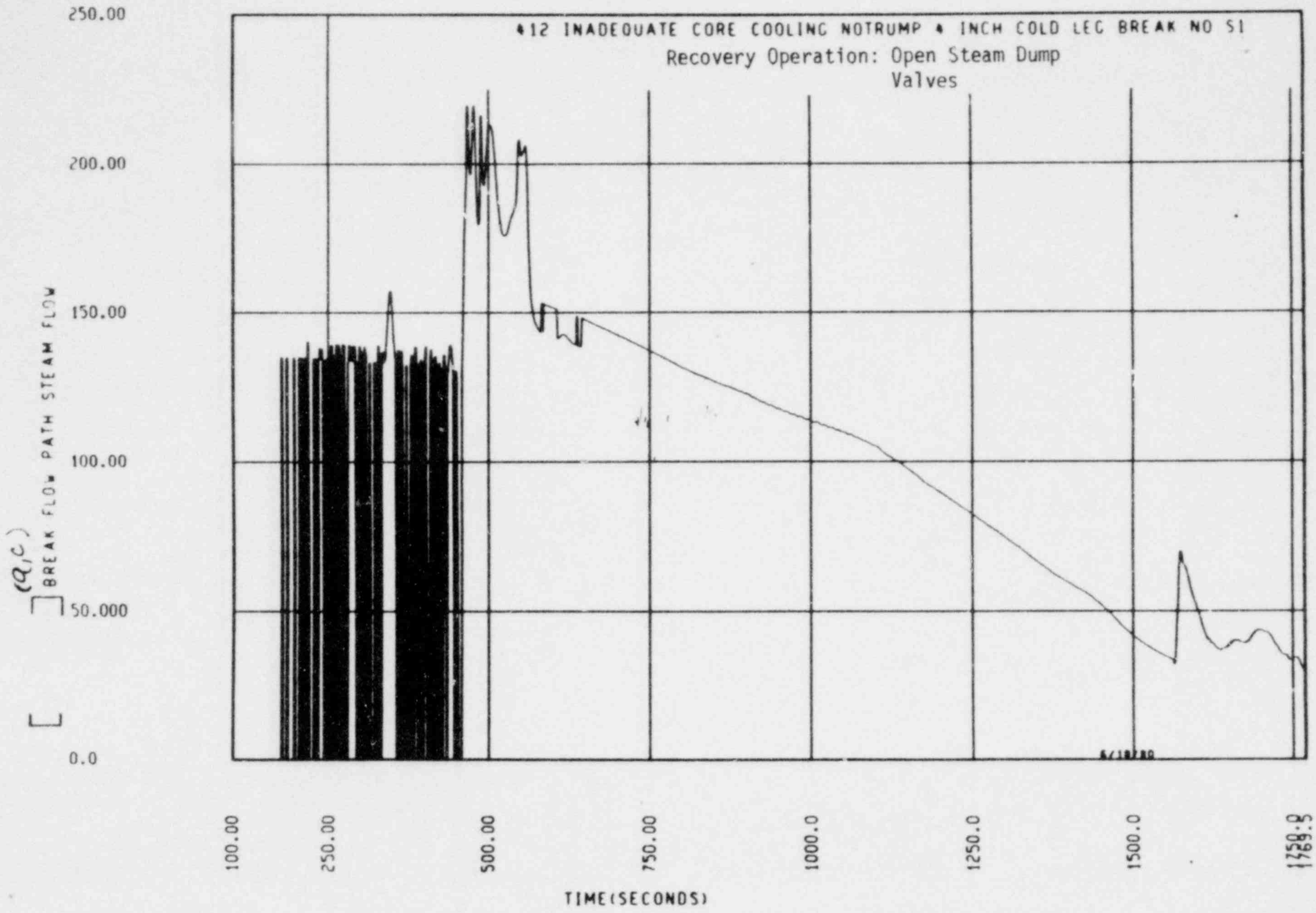

412 INADEQUATE CORE COOLING NOTRUMP 4 INCH COLD LEG BREAK NO SI
Recovery Operation: Open Steam Dump
Valves
BREAK FLOW PATH STEAM FLOW
(a,c)
250.00
200.00
150.00
100.00
50.000
0.0
100.00
250.00
500.00
750.00
1000.0
1250.0
1500.0
1750.0
1769.5
TIME(SECONDS)
6/18/80

Figure 304

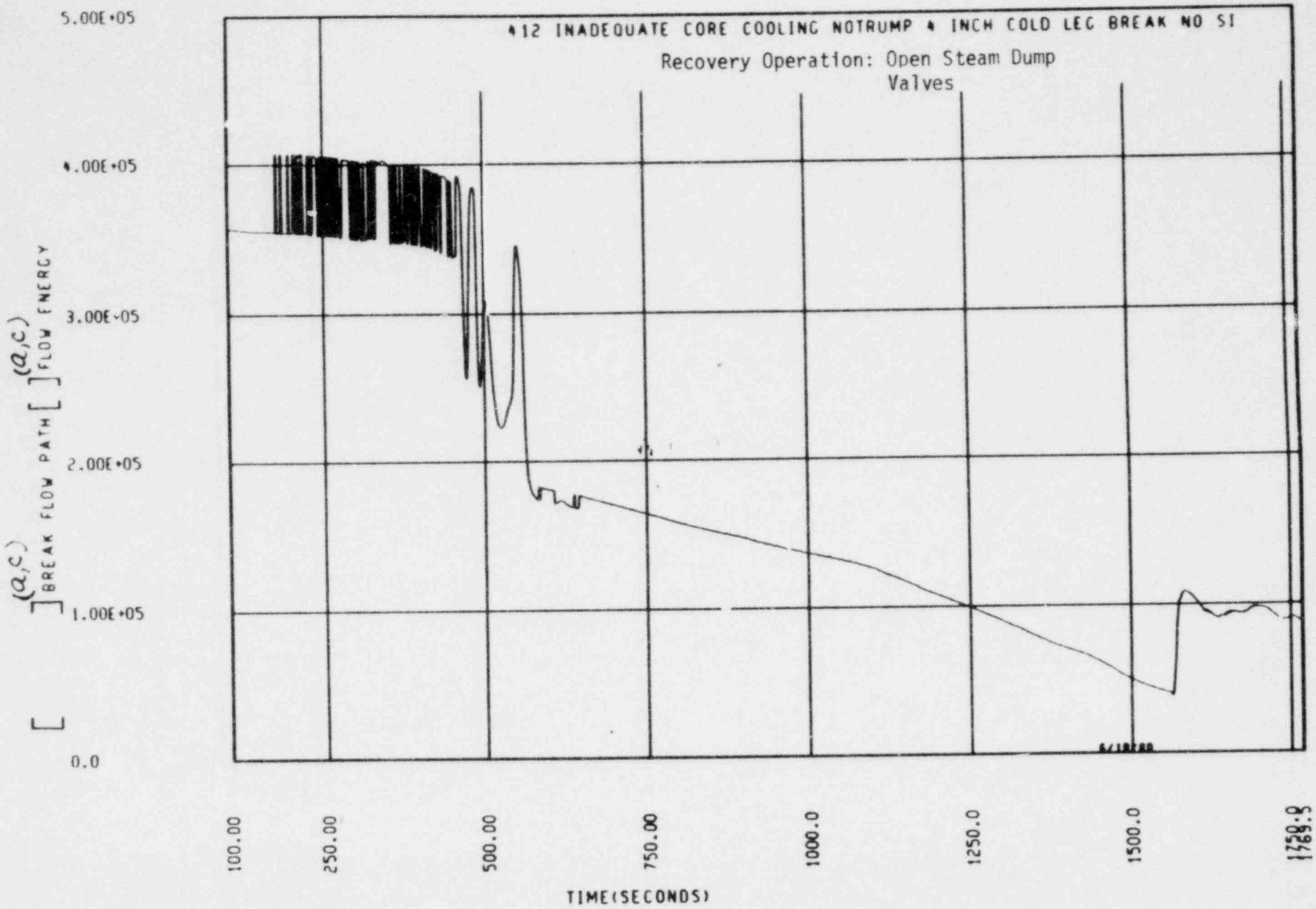

412 INADEQUATE CORE COOLING NOTRUMP 4 INCH COLD LEG BREAK NO SI
Recovery Operation: Open Steam Dump Valves
[ ]BREAK FLOW PATH [ ]FLOW ENERGY
(a,c)
(a,c)
5.00E+05
4.00E+05
3.00E+05
2.00E+05
1.00E+05
0.0
100.00
250.00
500.00
750.00
1000.0
1250.0
1500.0
1750.0
1769.5
TIME(SECONDS)

Figure 305

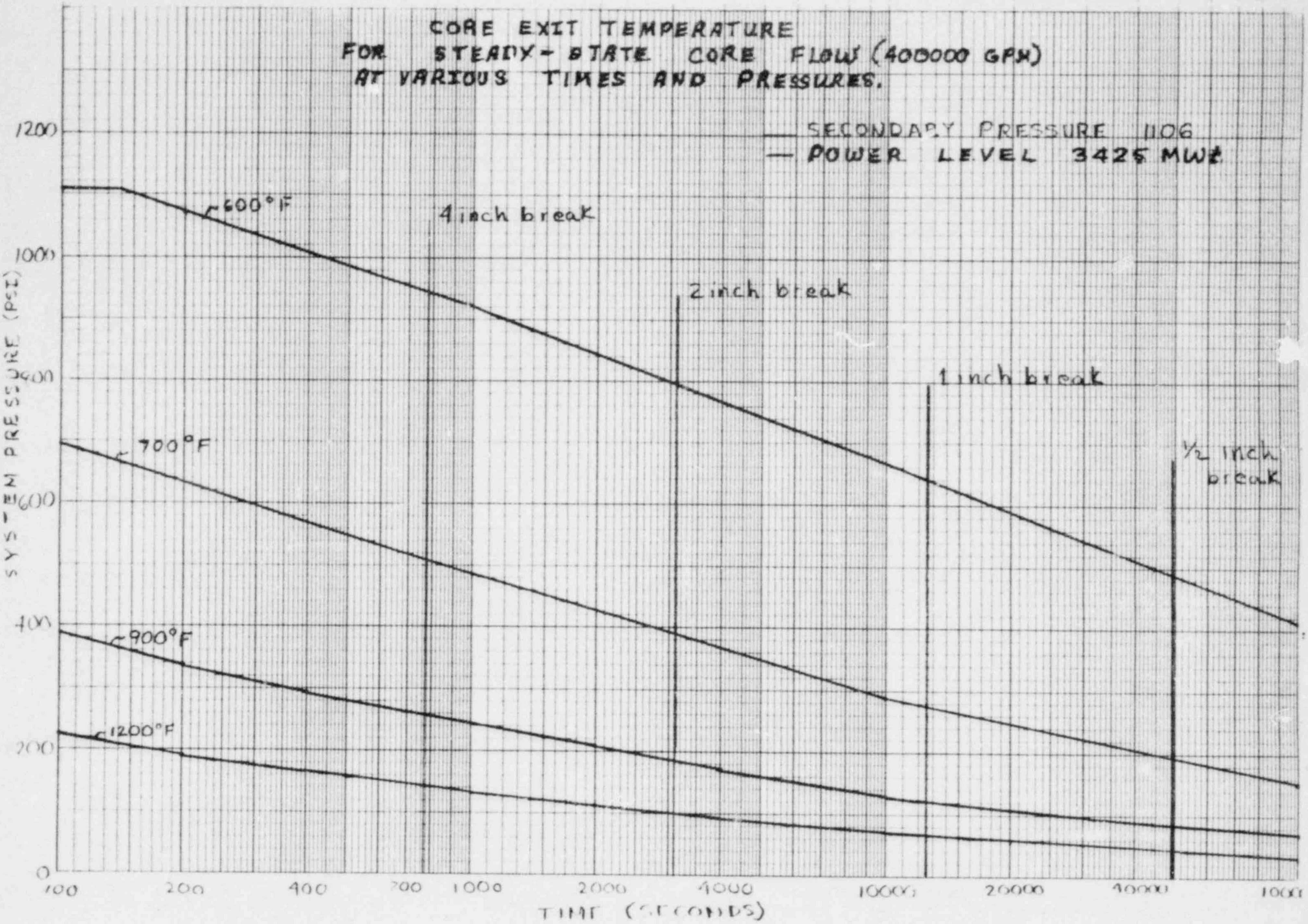

CORE EXIT TEMPERATURE
FOR STEADY-STATE CORE FLOW (400000 GPM)
AT VARIOUS TIMES AND PRESSURES.
— SECONDARY PRESSURE 1106
— POWER LEVEL 3425 MWt
600°F
700°F
900°F
1200°F
4 inch break
2 inch break
1 inch break
½ inch break
SYSTEM PRESSURE (PSI)
1200
1000
800
600
400
200
0
100
200
400
700
1000
2000
4000
10000
20000
40000
1000
TIME (SECONDS)

Figure 306

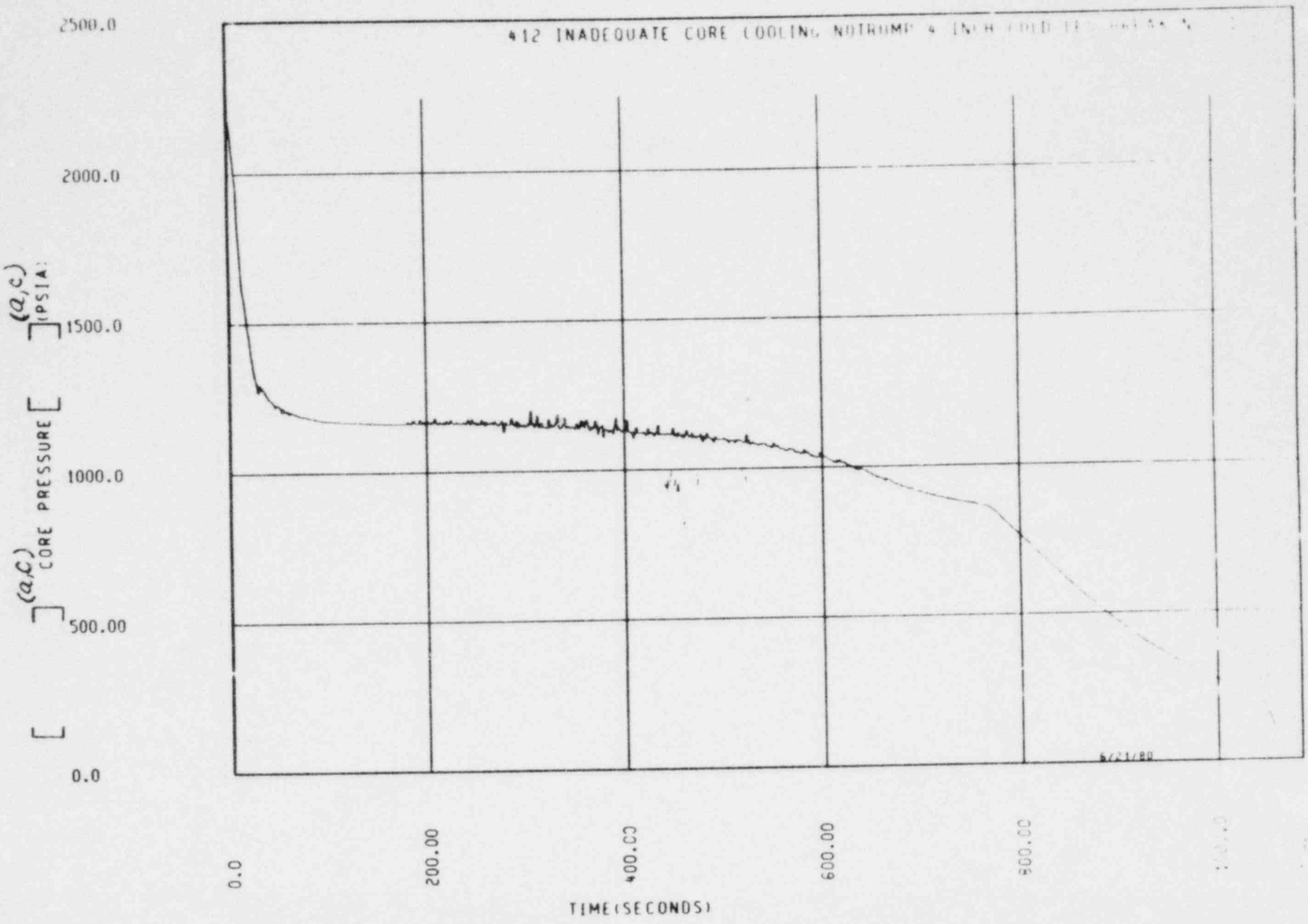

412 INADEQUATE CORE COOLING NOTRUMP 4 INCH COLD LEG BREAK
2500.0
2000.0
1500.0
1000.0
500.00
0.0
(a,c)
CORE PRESSURE
(PSIA)
(a,c)
0.0
200.00
400.00
600.00
800.00
1000.0
TIME(SECONDS)
6/21/80

Figure 307

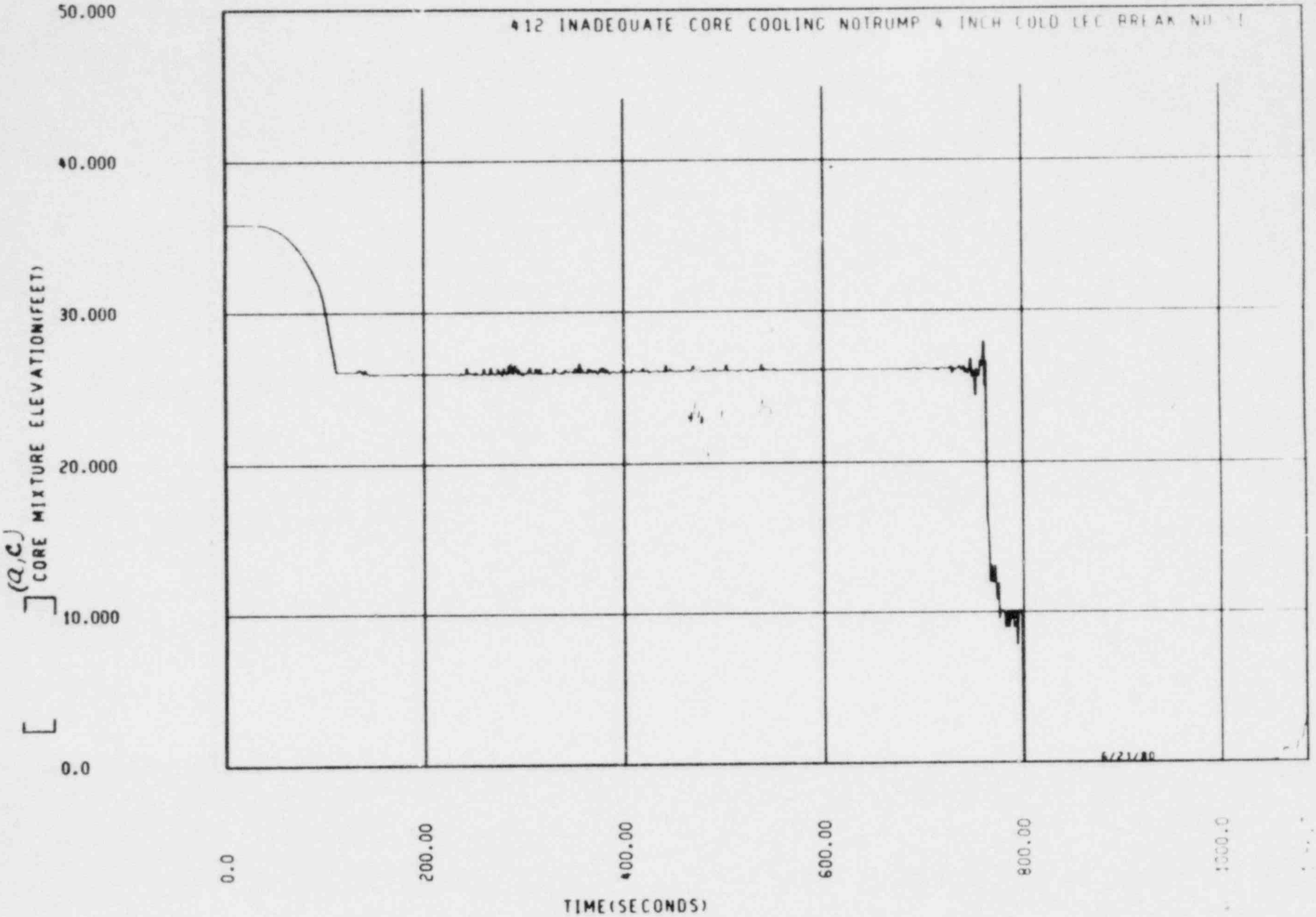

412 INADEQUATE CORE COOLING NOTRUMP 4 INCH COLD LEG BREAK NO 31
(a,c)
CORE MIXTURE ELEVATION(FEET)
50.000
40.000
30.000
20.000
10.000
0.0
0.0
200.00
400.00
600.00
800.00
1000.0
TIME(SECONDS)
6/23/80

Figure 308

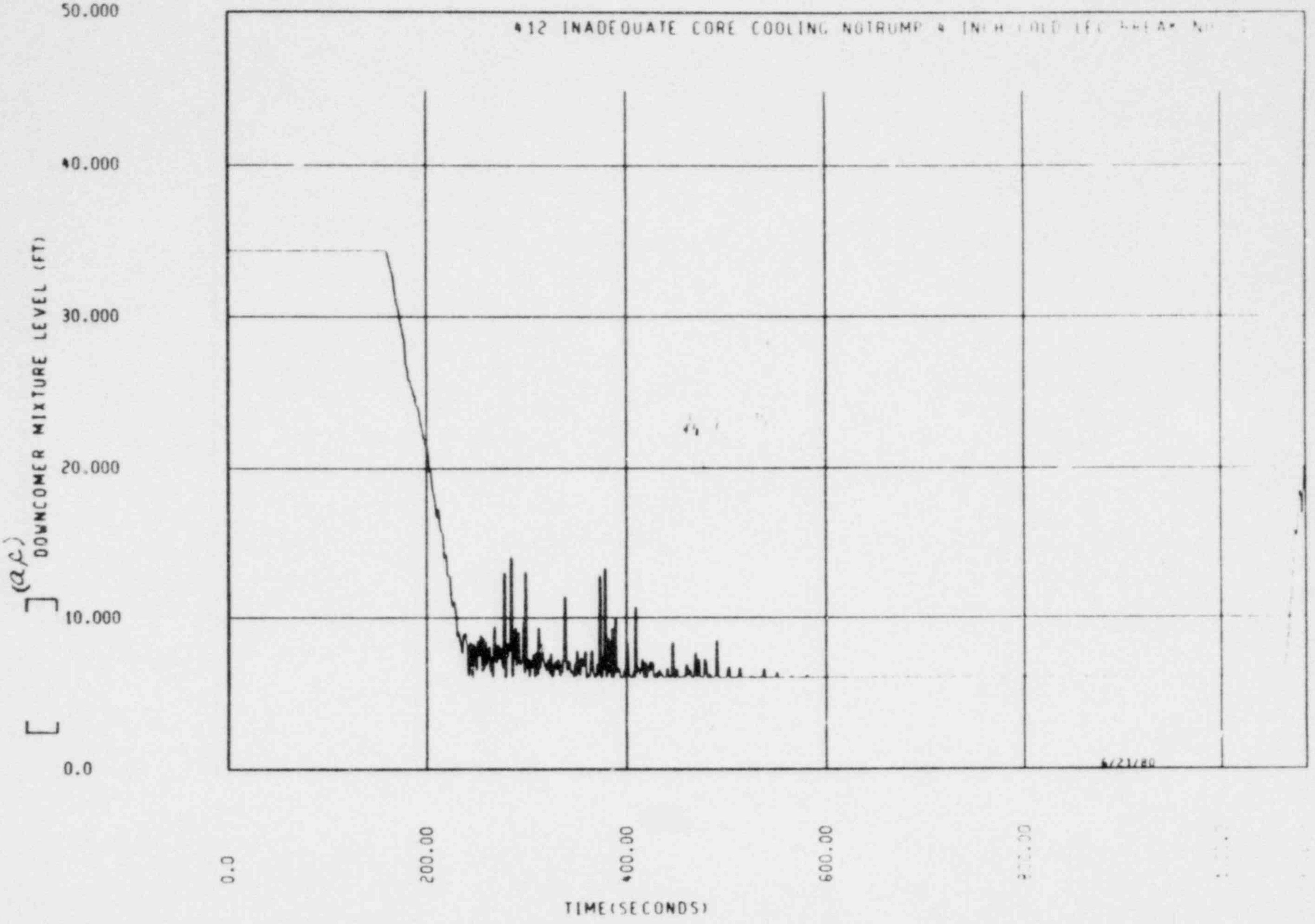

412 INADEQUATE CORE COOLING NOTRUMP 4 INCH COLD LEG BREAK NO
DOWNCOMER MIXTURE LEVEL (FT)
[ ](a,c)
50.000
40.000
30.000
20.000
10.000
0.0
0.0
200.00
400.00
600.00
TIME(SECONDS)
6/21/80

Figure 309

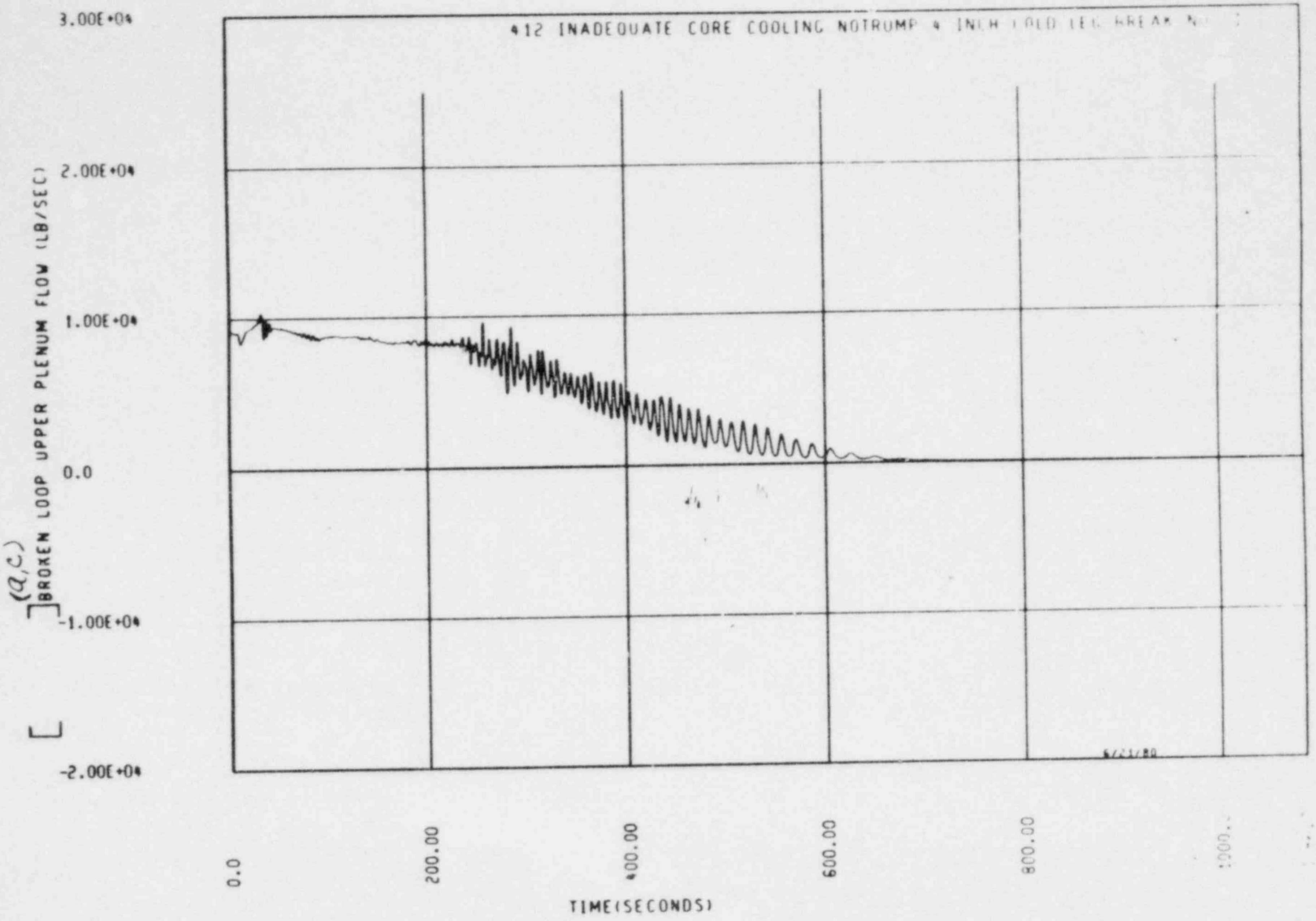

412 INADEQUATE CORE COOLING NOTRUMP 4 INCH COLD LEG BREAK
BROKEN LOOP UPPER PLENUM FLOW (LB/SEC)
(a,c)
3.00E+04
2.00E+04
1.00E+04
0.0
-1.00E+04
-2.00E+04
0.0
200.00
400.00
600.00
800.00
1000.
TIME(SECONDS)
6/21/80

Figure 310

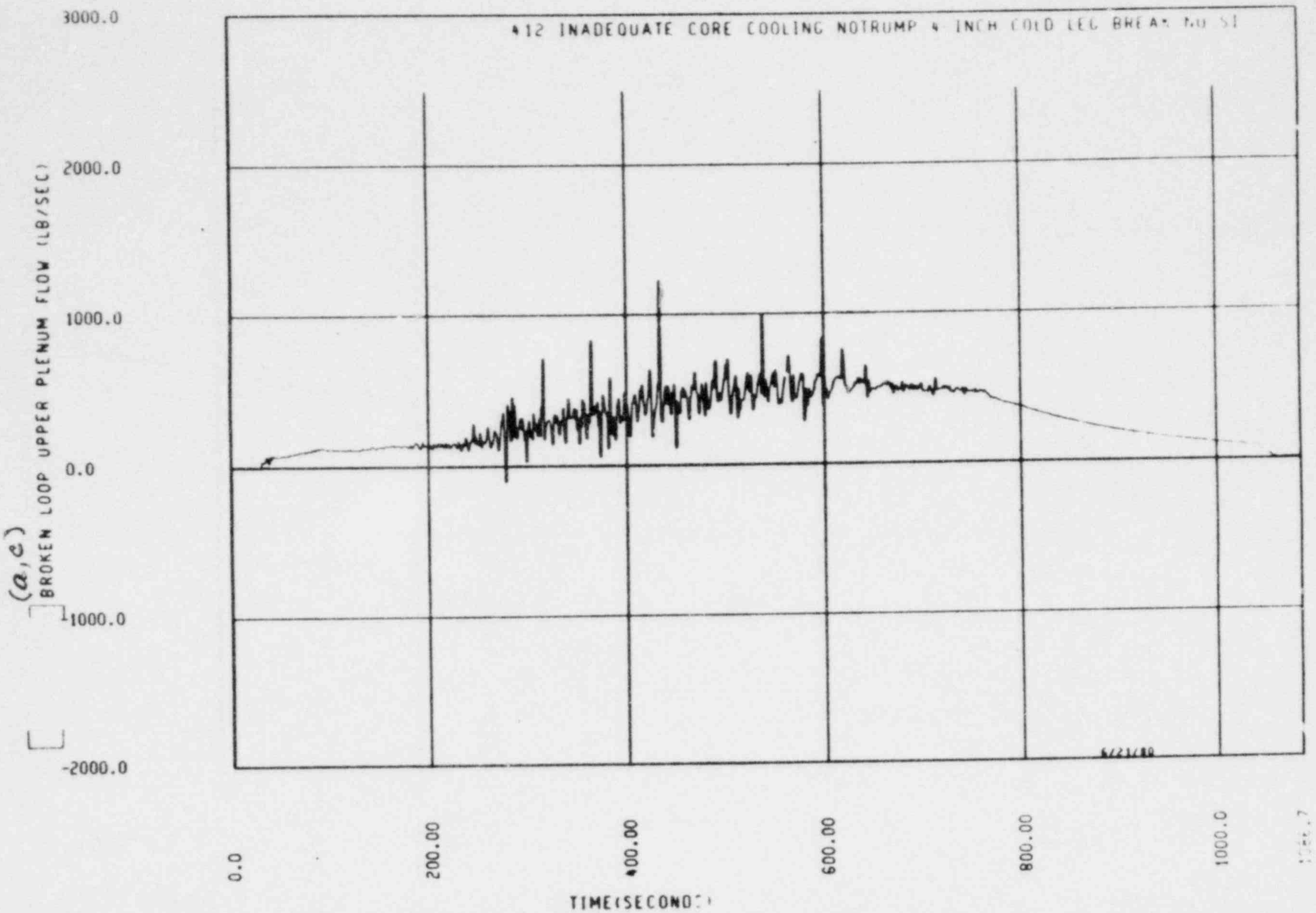
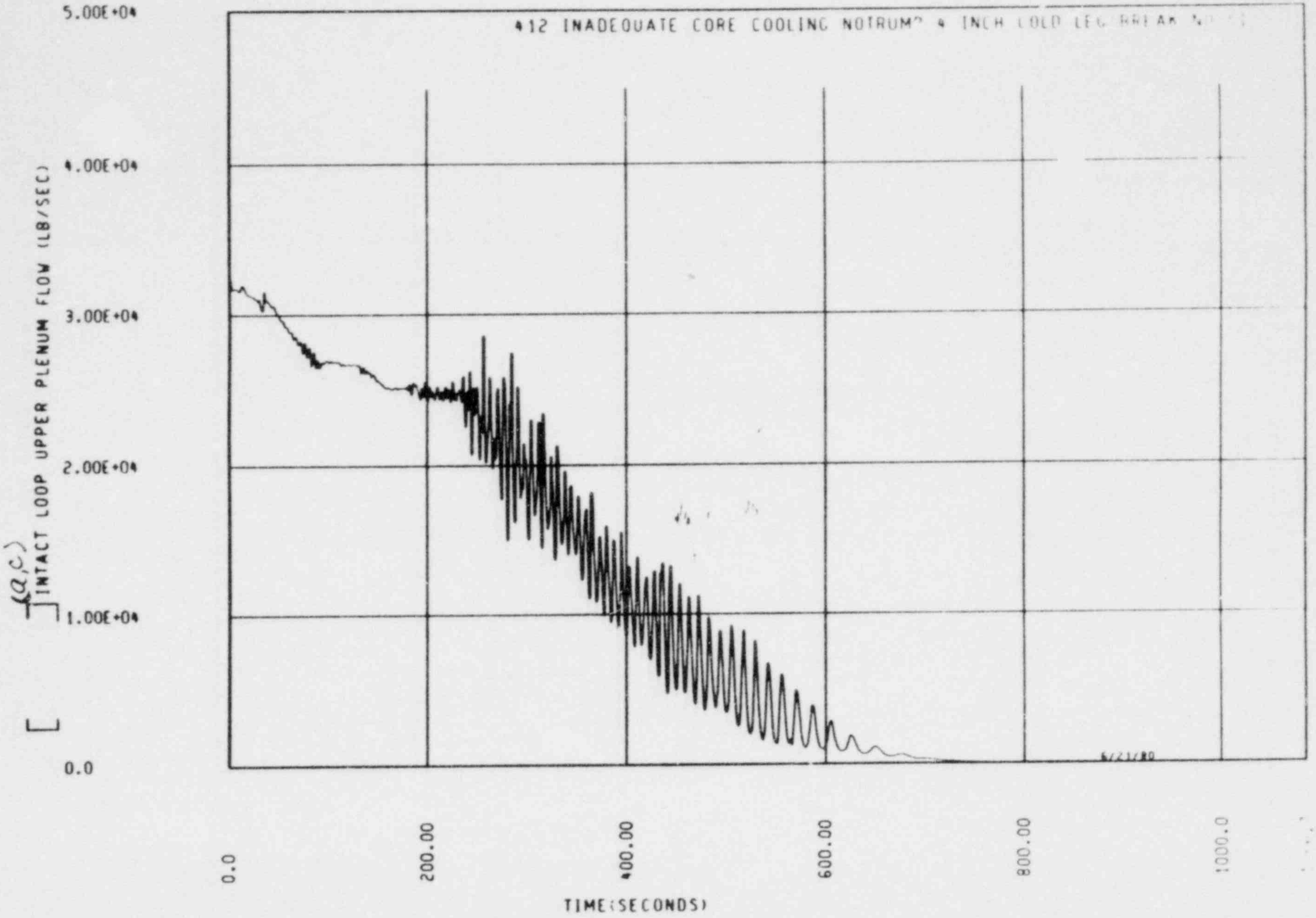

412 INADEQUATE CORE COOLING NOTRUMP 4 INCH COLD LEG BREAK NO SI
BROKEN LOOP UPPER PLENUM FLOW (LB/SEC)
(a,c)
3000.0
2000.0
1000.0
0.0
1000.0
-2000.0
0.0
200.00
400.00
600.00
800.00
1000.0
TIME(SECONDS)
6/21/80

Figure 311



(a,c)

Figure 312

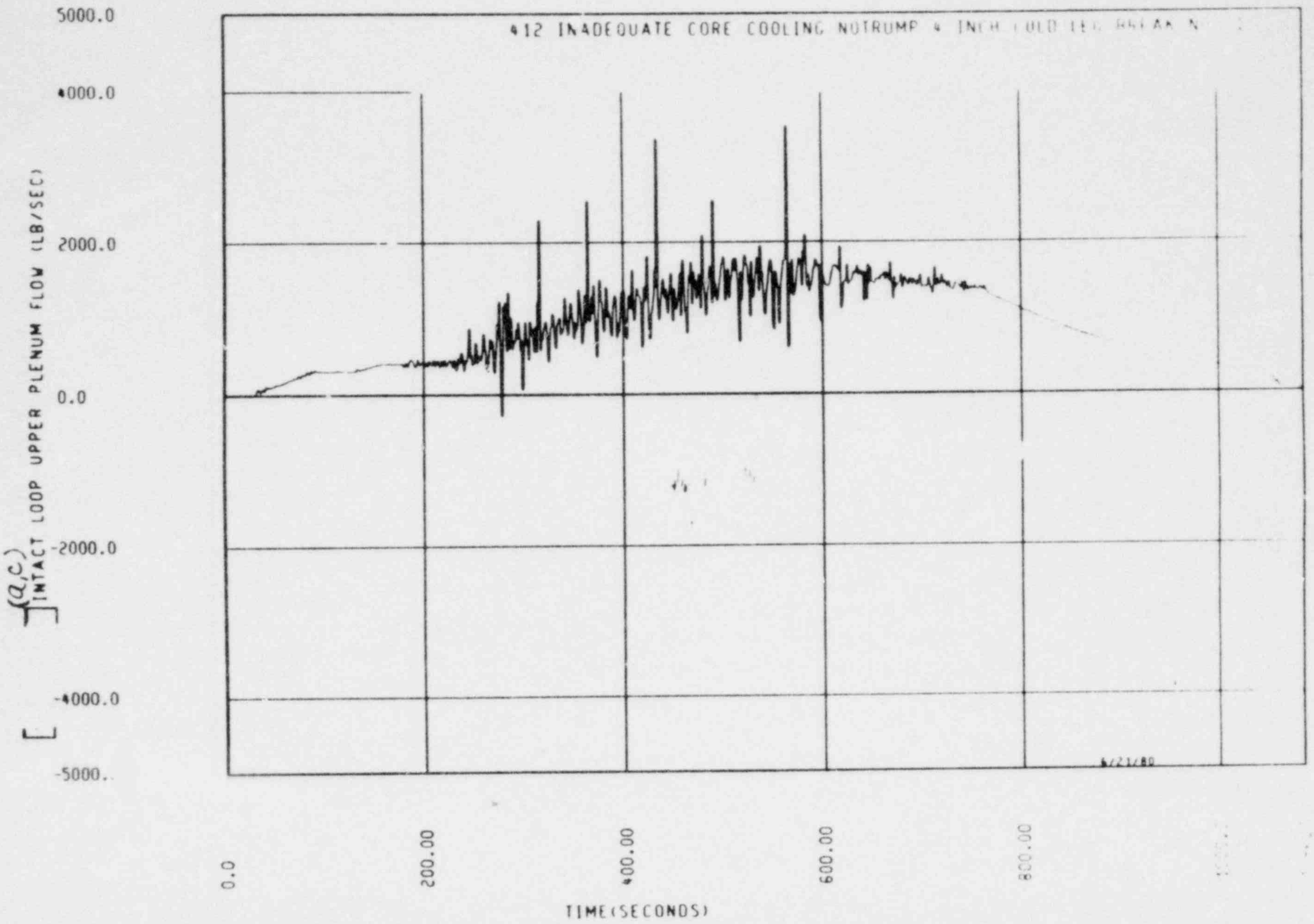

412 INADEQUATE CORE COOLING NOTRUMP 4 INCH COLD LEG BREAK N
(a,c)
INTACT LOOP UPPER PLENUM FLOW (LB/SEC)
5000.0
4000.0
2000.0
0.0
-2000.0
-4000.0
-5000.
0.0
200.00
400.00
600.00
800.00
1000.0
TIME(SECONDS)
6/21/80

Figure 313

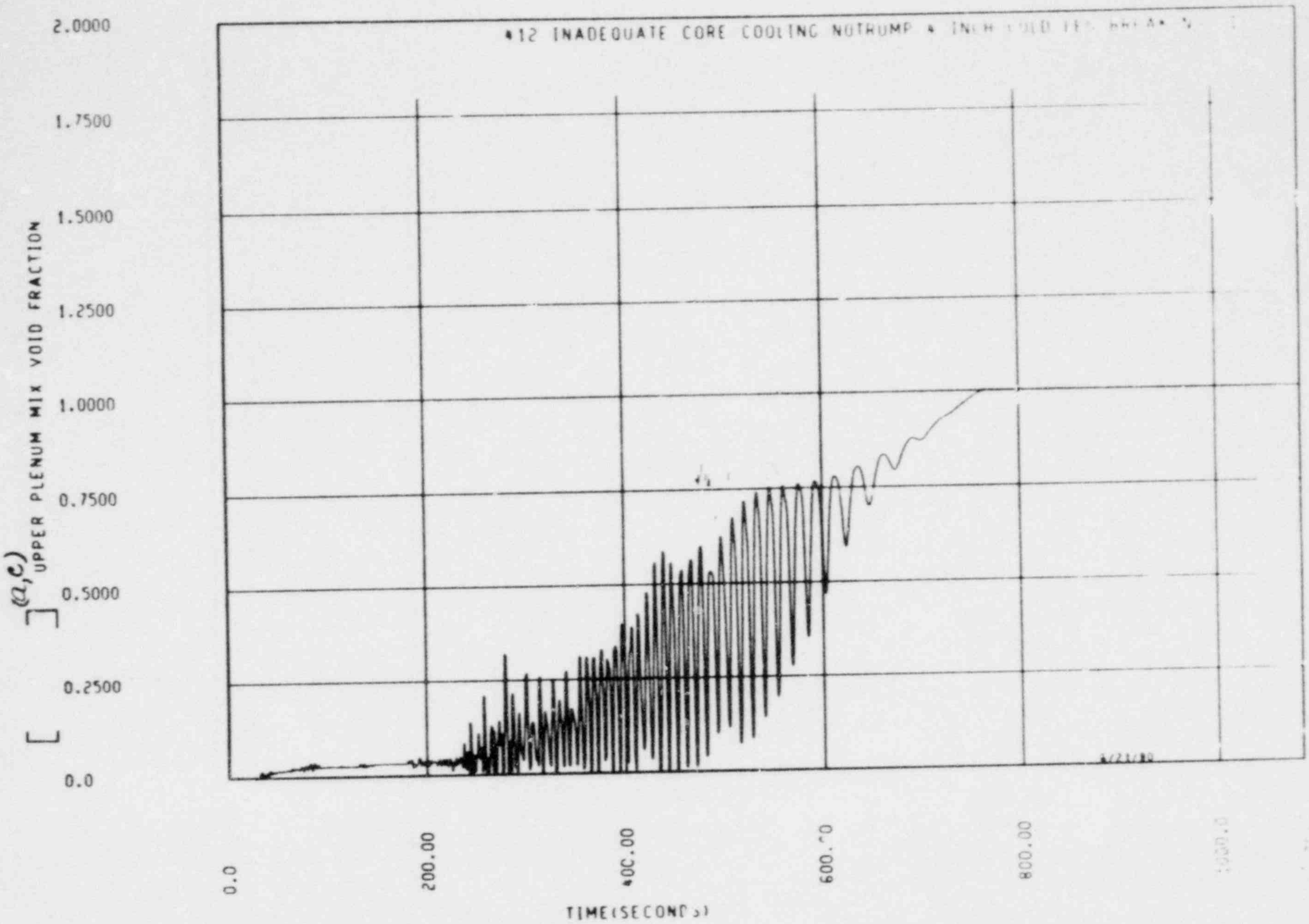
#12 INADEQUATE CORE COOLING NOTRUMP 4 INCH COLD LEG BREAK
UPPER PLENUM MIX VOID FRACTION
(a,c)
2.0000
1.7500
1.5000
1.2500
1.0000
0.7500
0.5000
0.2500
0.0
0.0
200.00
400.00
600.00
800.00
1000.0
TIME(SECONDS)

Figure 314

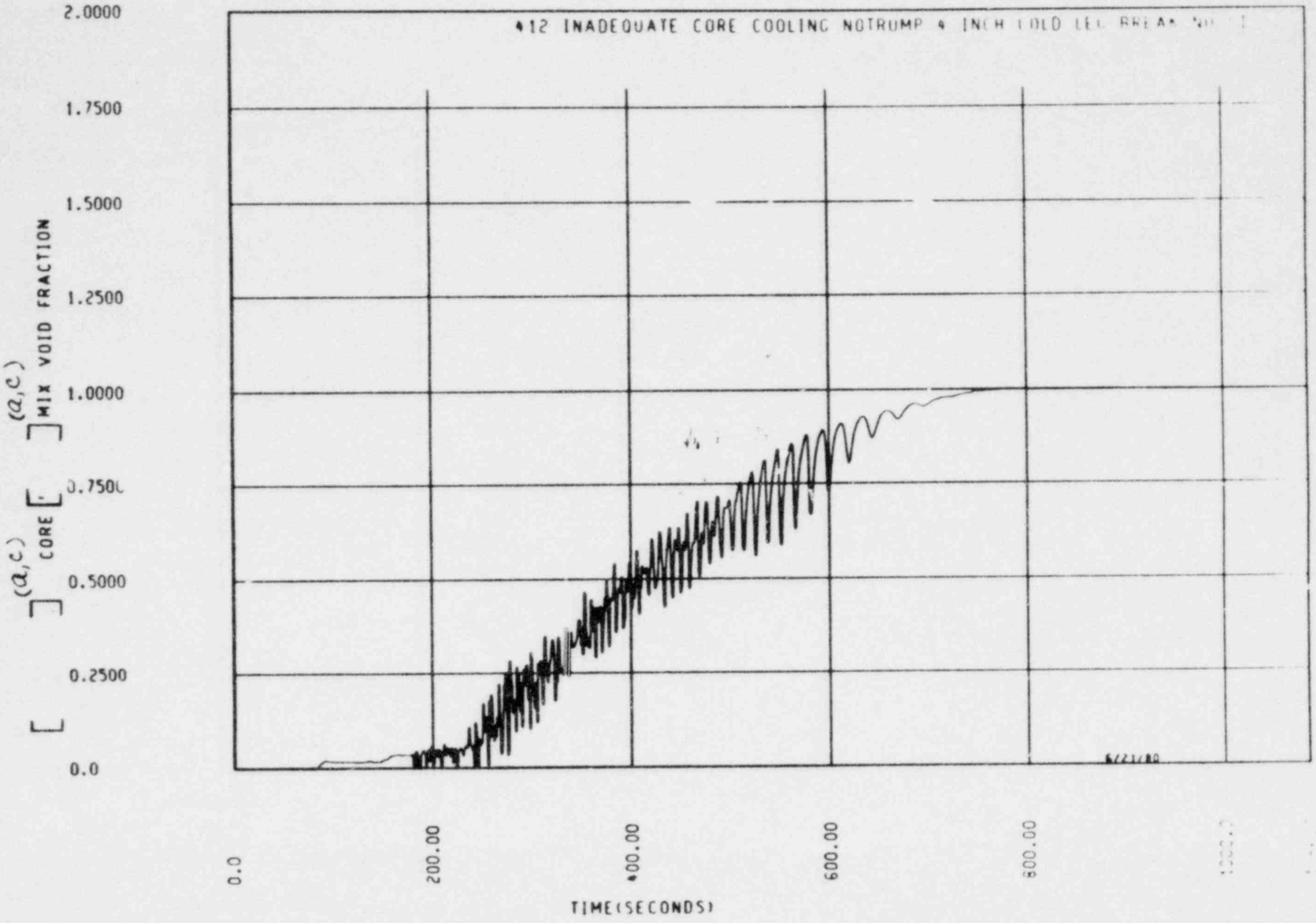
412 INADEQUATE CORE COOLING NOTRUMP 4 INCH COLD LEG BREAK NO
[ ](a,c) CORE [ ] ](a,c) MIX VOID FRACTION
2.0000
1.7500
1.5000
1.2500
1.0000
0.7500
0.5000
0.2500
0.0
0.0
200.00
400.00
600.00
800.00
1000.0
TIME(SECONDS)
6/21/80

Figure 315

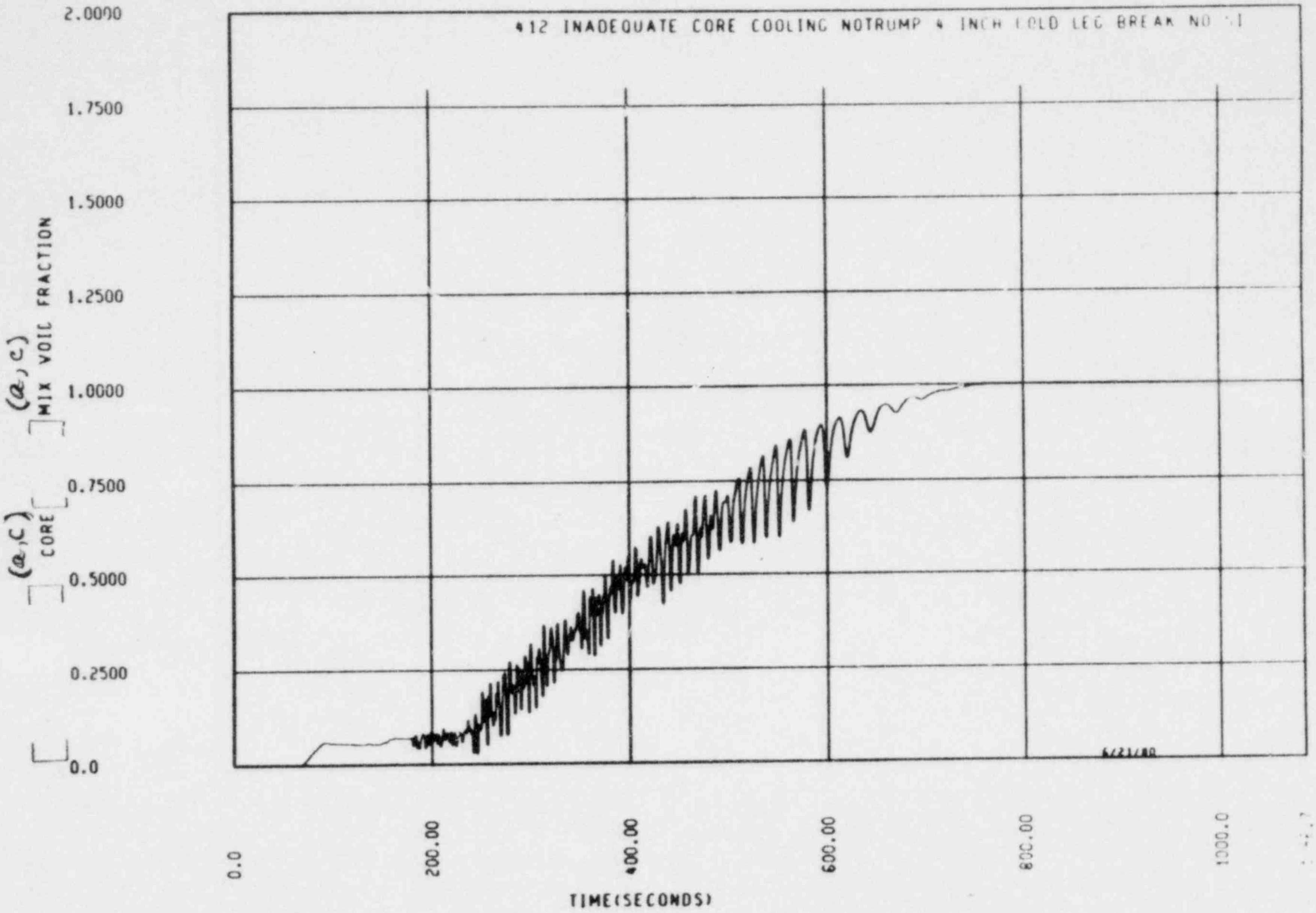

412 INADEQUATE CORE COOLING NOTRUMP 4 INCH COLD LEG BREAK NO
(a,c) MIX VOID FRACTION
(a,c) CORE
2.0000
1.7500
1.5000
1.2500
1.0000
0.7500
0.5000
0.2500
0.0
0.0
200.00
400.00
600.00
800.00
1000.0
TIME(SECONDS)
6/21/80

Figure 316

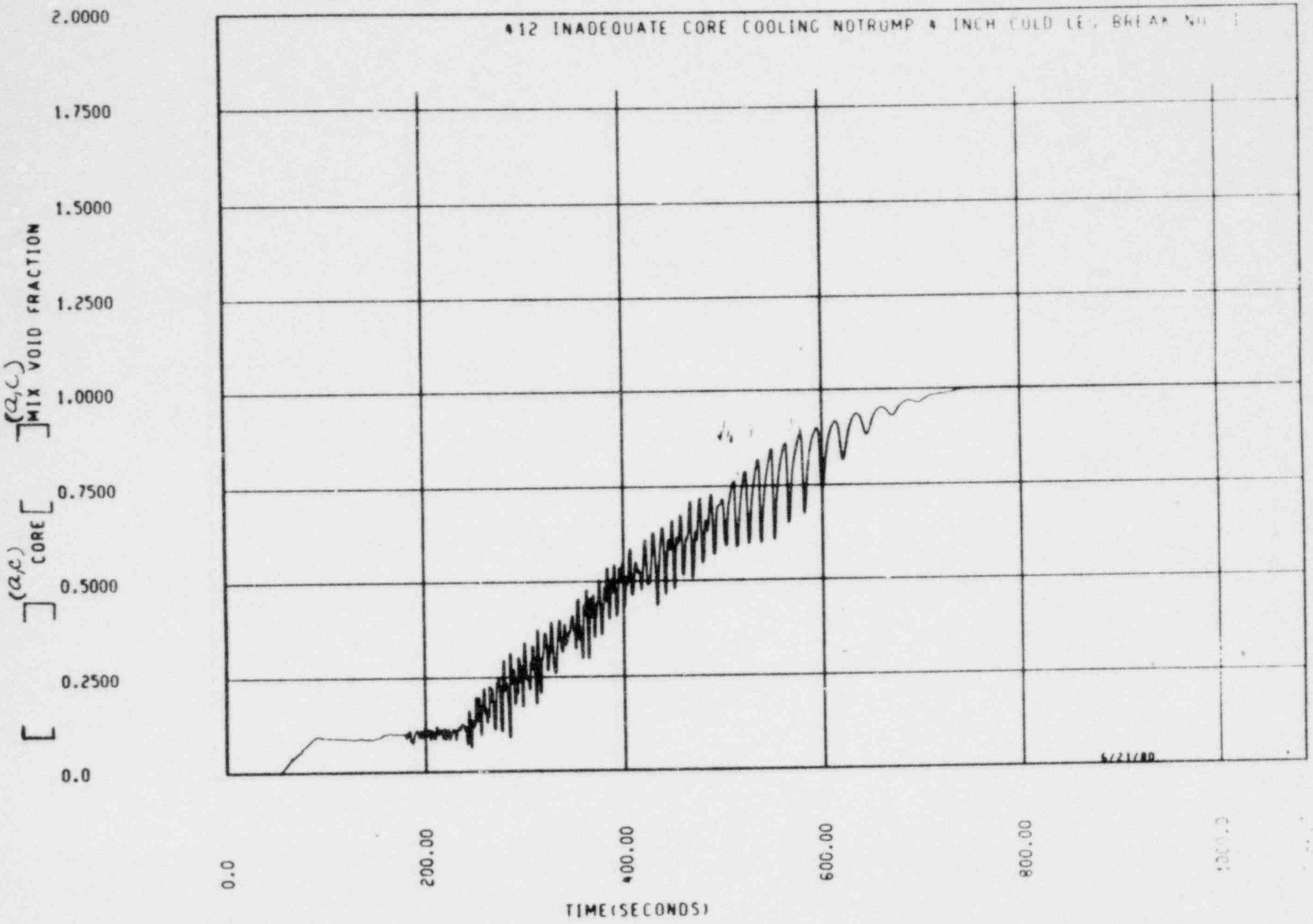

412 INADEQUATE CORE COOLING NOTRUMP 4 INCH COLD LEG BREAK
(a,c)
MIX VOID FRACTION
(a,c)
CORE
2.0000
1.7500
1.5000
1.2500
1.0000
0.7500
0.5000
0.2500
0.0
0.0
200.00
400.00
600.00
800.00
1000.0
TIME(SECONDS)
6/21/80

Figure 317

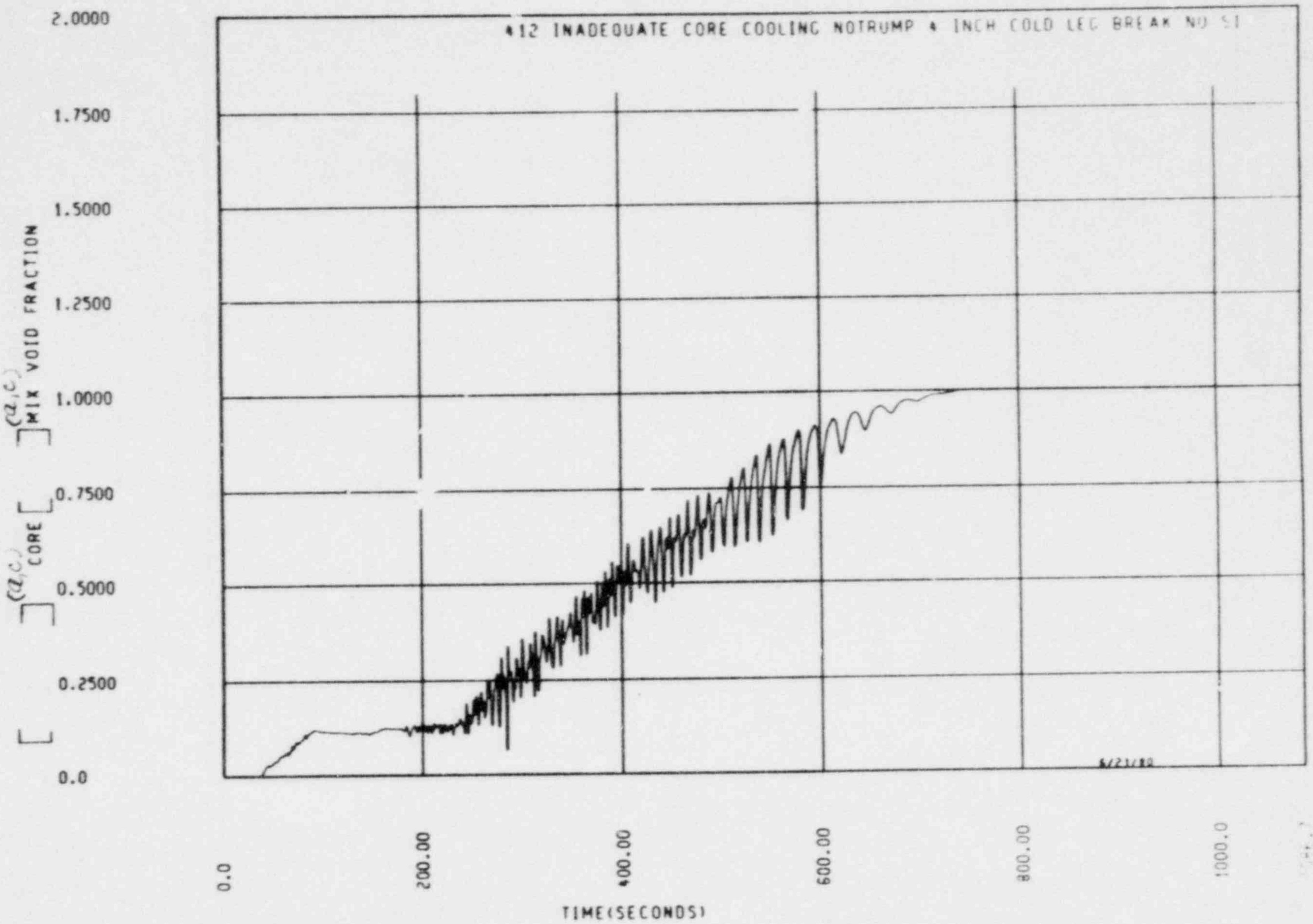

412 INADEQUATE CORE COOLING NOTRUMP 4 INCH COLD LEG BREAK NO SI
[ ]$^{(a,c)}$ CORE [ ]$^{(a,c)}$ MIX VOID FRACTION
2.0000
1.7500
1.5000
1.2500
1.0000
0.7500
0.5000
0.2500
0.0
0.0
200.00
400.00
600.00
800.00
1000.0
TIME(SECONDS)
6/21/80

Figure 318

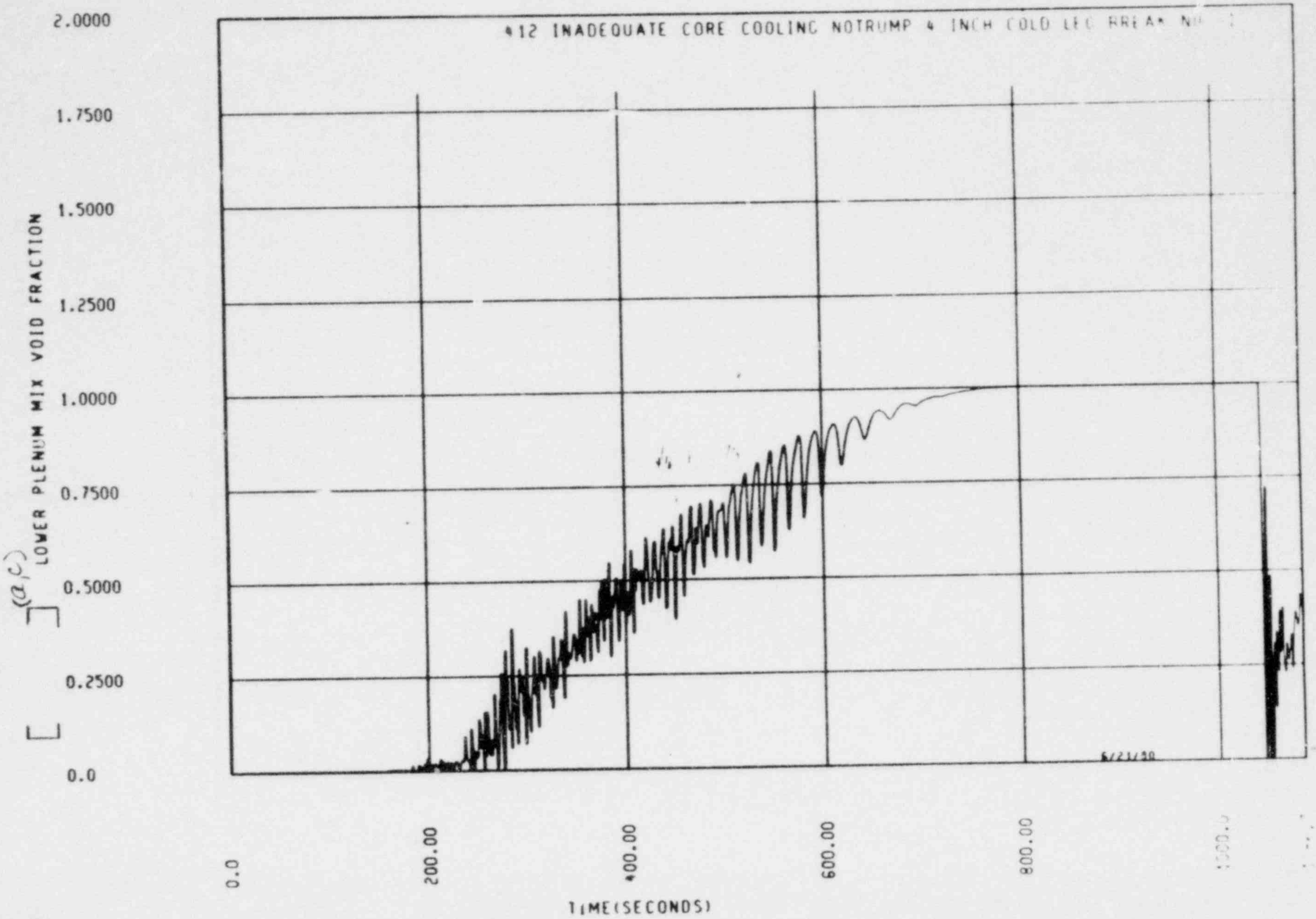

412 INADEQUATE CORE COOLING NOTRUMP 4 INCH COLD LEG BREAK NO
LOWER PLENUM MIX VOID FRACTION
(a,c)
2.0000
1.7500
1.5000
1.2500
1.0000
0.7500
0.5000
0.2500
0.0
0.0
200.00
400.00
600.00
800.00
1000.0
TIME(SECONDS)
6/21/80

Figure 319

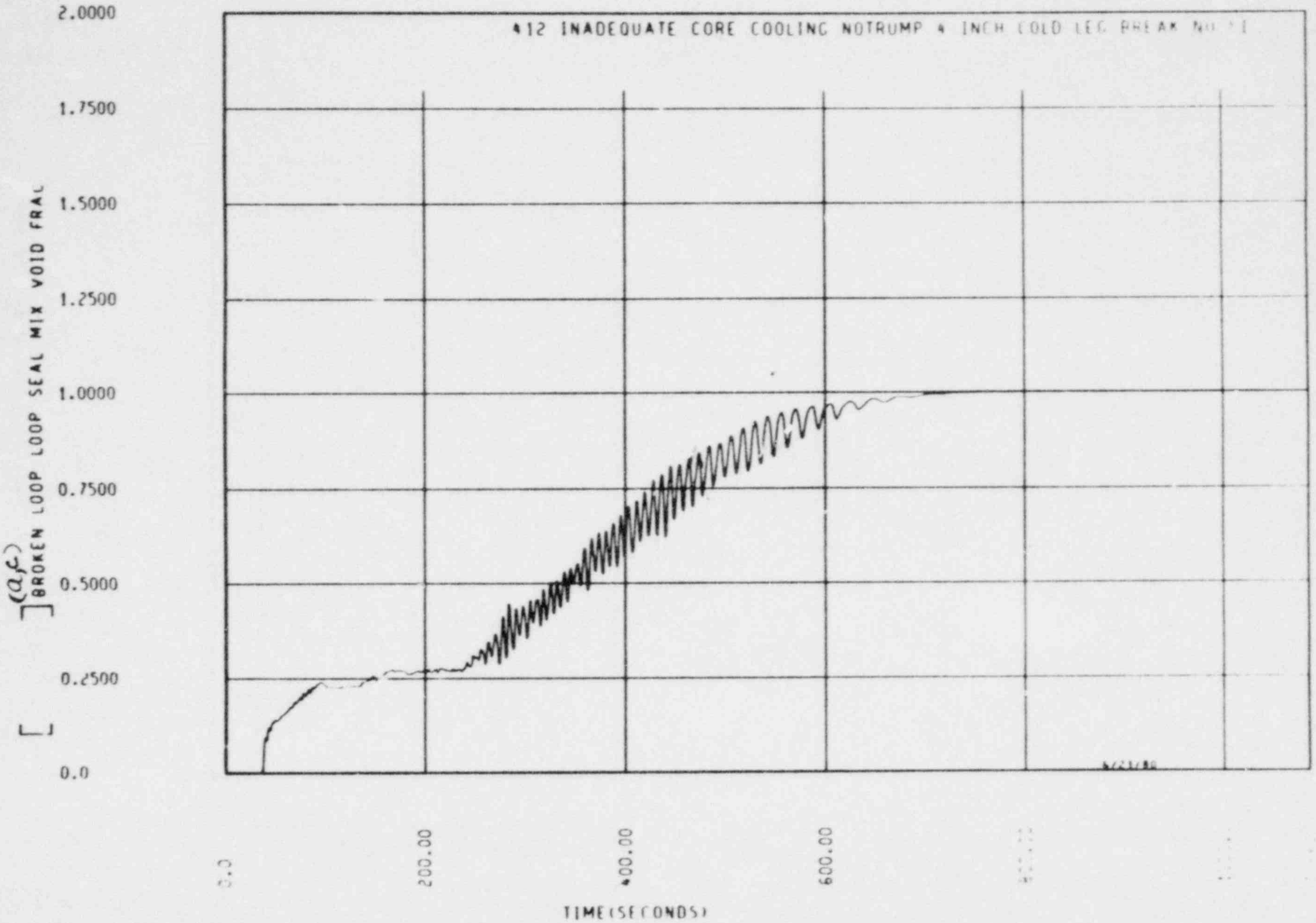

412 INADEQUATE CORE COOLING NOTRUMP 4 INCH COLD LEG BREAK NO 1
[ ](a,c) BROKEN LOOP LOOP SEAL MIX VOID FRAC
2.0000
1.7500
1.5000
1.2500
1.0000
0.7500
0.5000
0.2500
0.0
0.0
200.00
400.00
600.00
TIME(SECONDS)
6/23/80

Figure 320

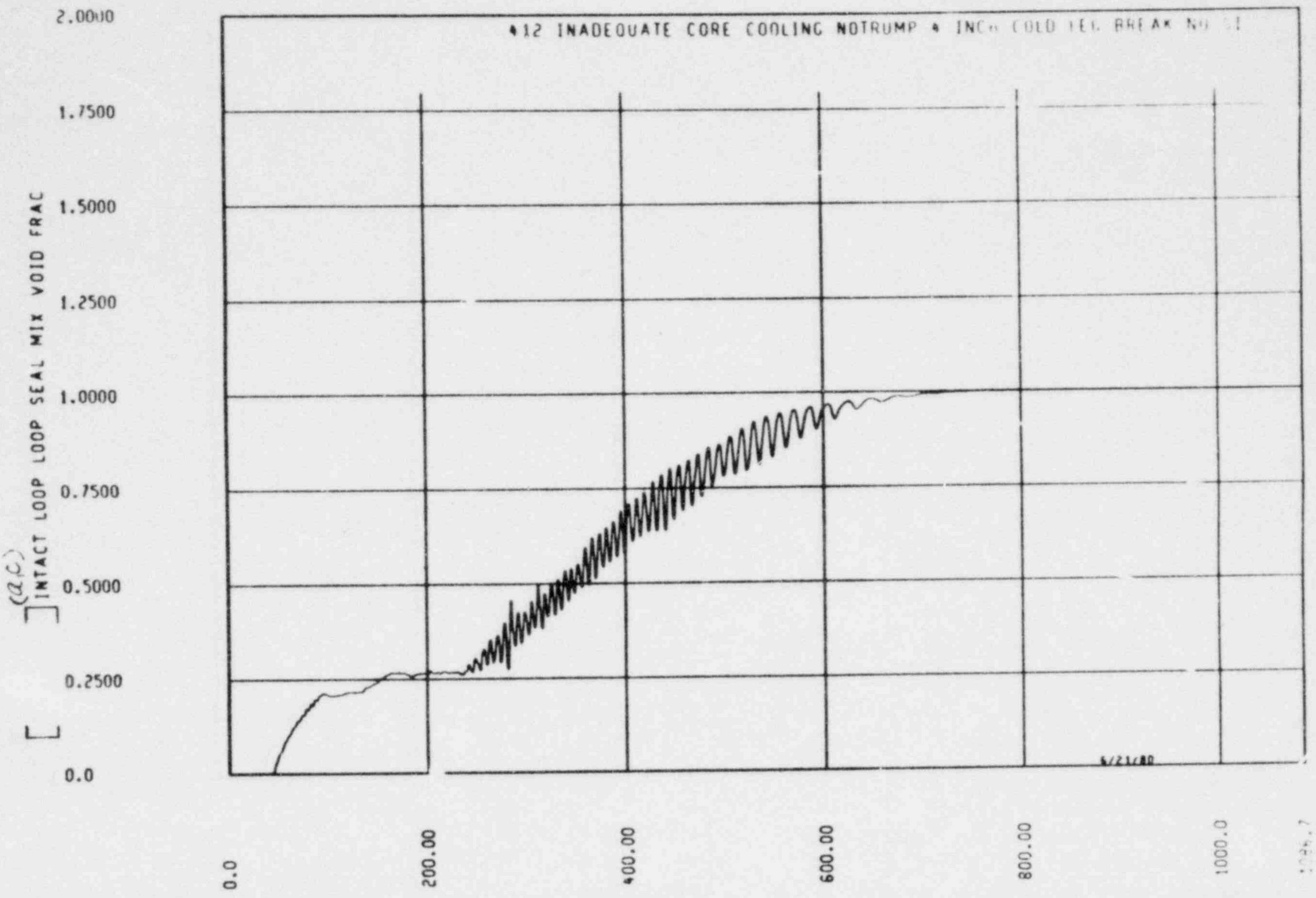
412 INADEQUATE CORE COOLING NOTRUMP 4 INCH COLD LEG BREAK NO SI
[ ](a,c) INTACT LOOP LOOP SEAL MIX VOID FRAC
2.0000
1.7500
1.5000
1.2500
1.0000
0.7500
0.5000
0.2500
0.0
0.0
200.00
400.00
600.00
800.00
1000.0
1086.7
6/21/80
TIME(SECONDS)

Figure 321

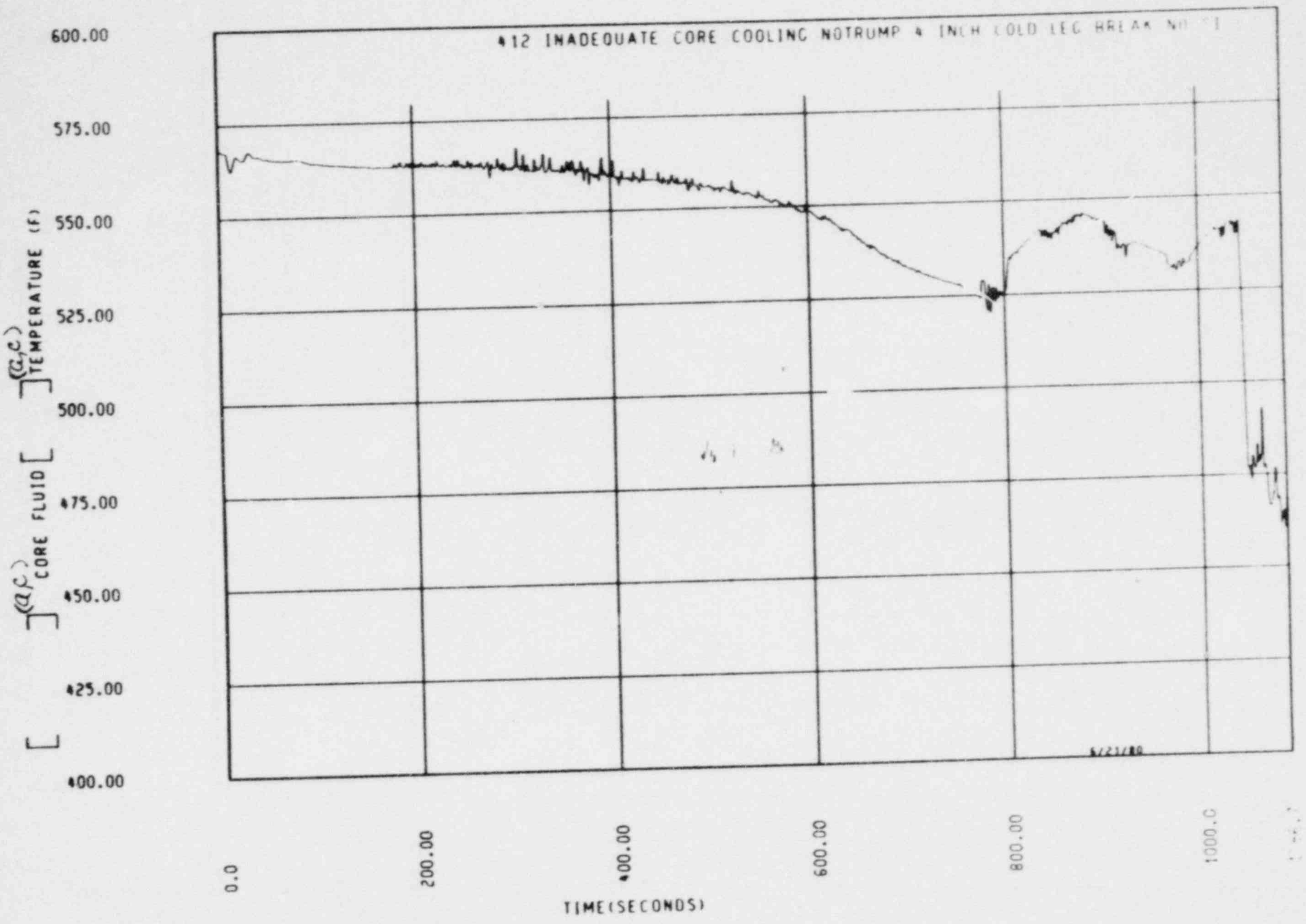

412 INADEQUATE CORE COOLING NOTRUMP 4 INCH COLD LEG BREAK NO SI
[ CORE FLUID ](a,c) [ TEMPERATURE (F) ](a,c)
600.00
575.00
550.00
525.00
500.00
475.00
450.00
425.00
400.00
0.0
200.00
400.00
600.00
800.00
1000.0
TIME(SECONDS)
6/23/80

Figure 322

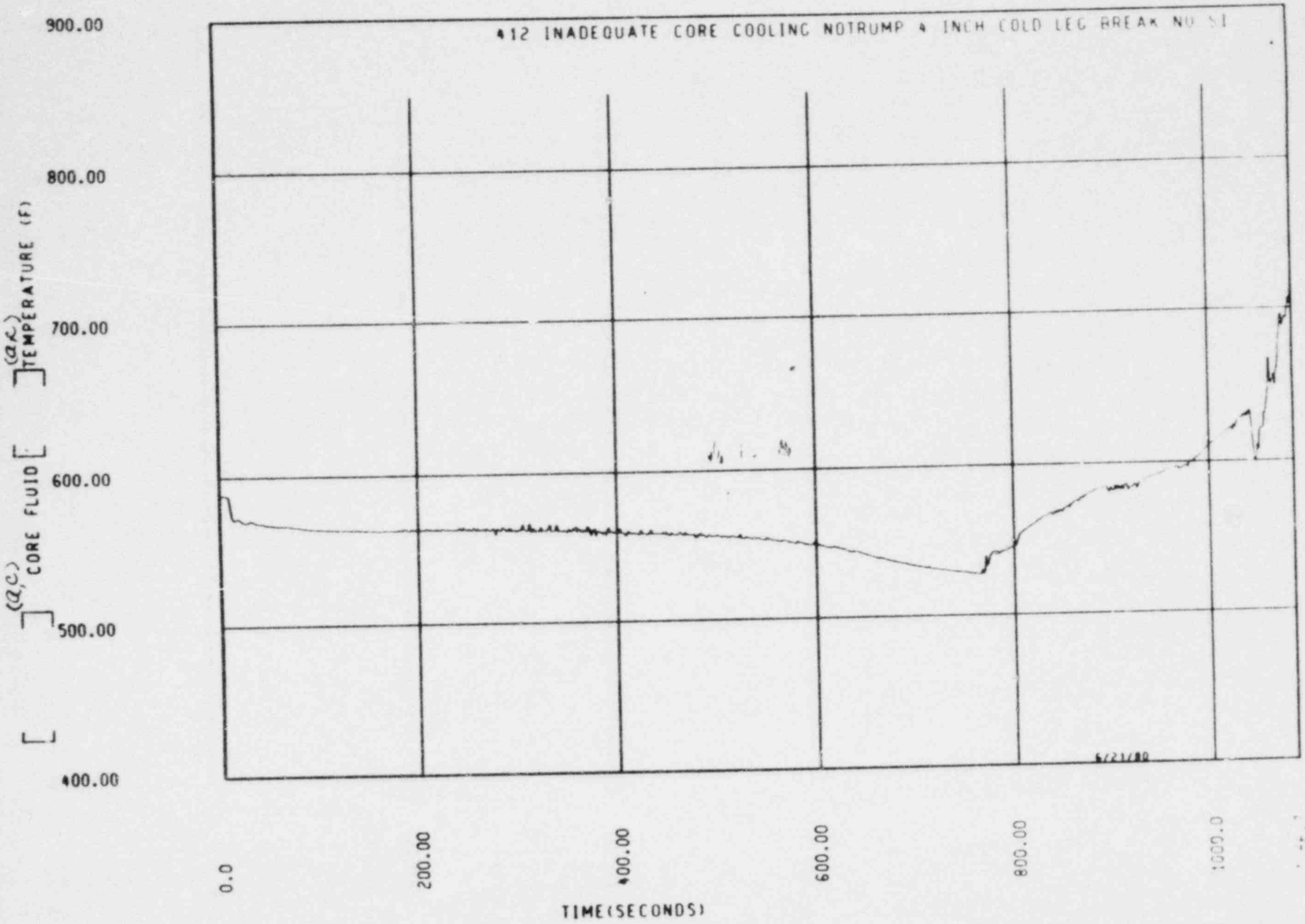

412 INADEQUATE CORE COOLING NOTRUMP 4 INCH COLD LEG BREAK NO SI
(a,c) CORE FLUID (a,c) TEMPERATURE (F)
900.00
800.00
700.00
600.00
500.00
400.00
0.0
200.00
400.00
600.00
800.00
1000.0
TIME(SECONDS)
6/23/80

Figure 323

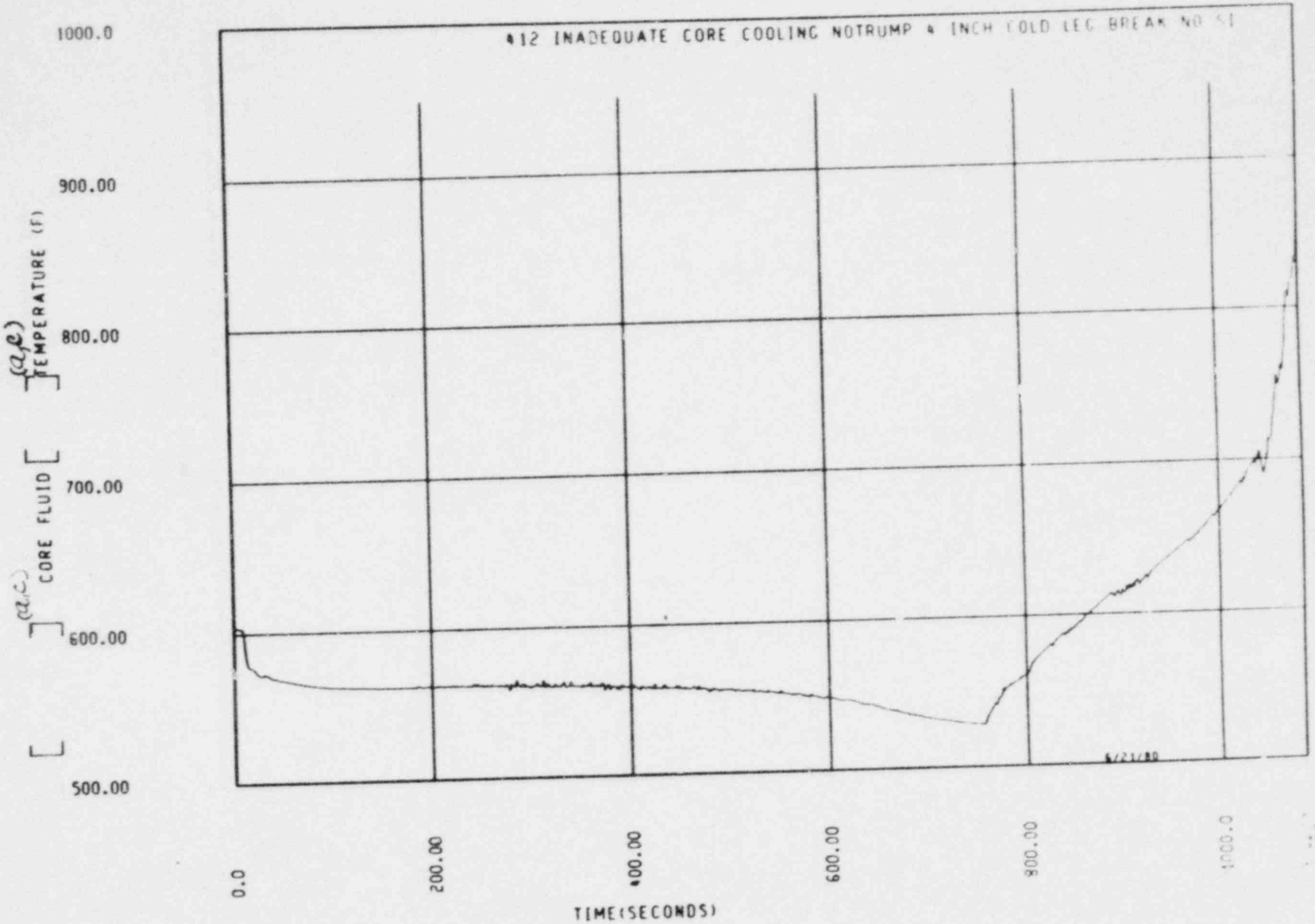

412 INADEQUATE CORE COOLING NOTRUMP 4 INCH COLD LEG BREAK NO SI
1000.0
900.00
800.00
700.00
600.00
500.00
(a,e)
CORE FLUID TEMPERATURE (F)
(a,c)
0.0
200.00
400.00
600.00
800.00
1000.0
TIME(SECONDS)
6/23/80

Figure 324

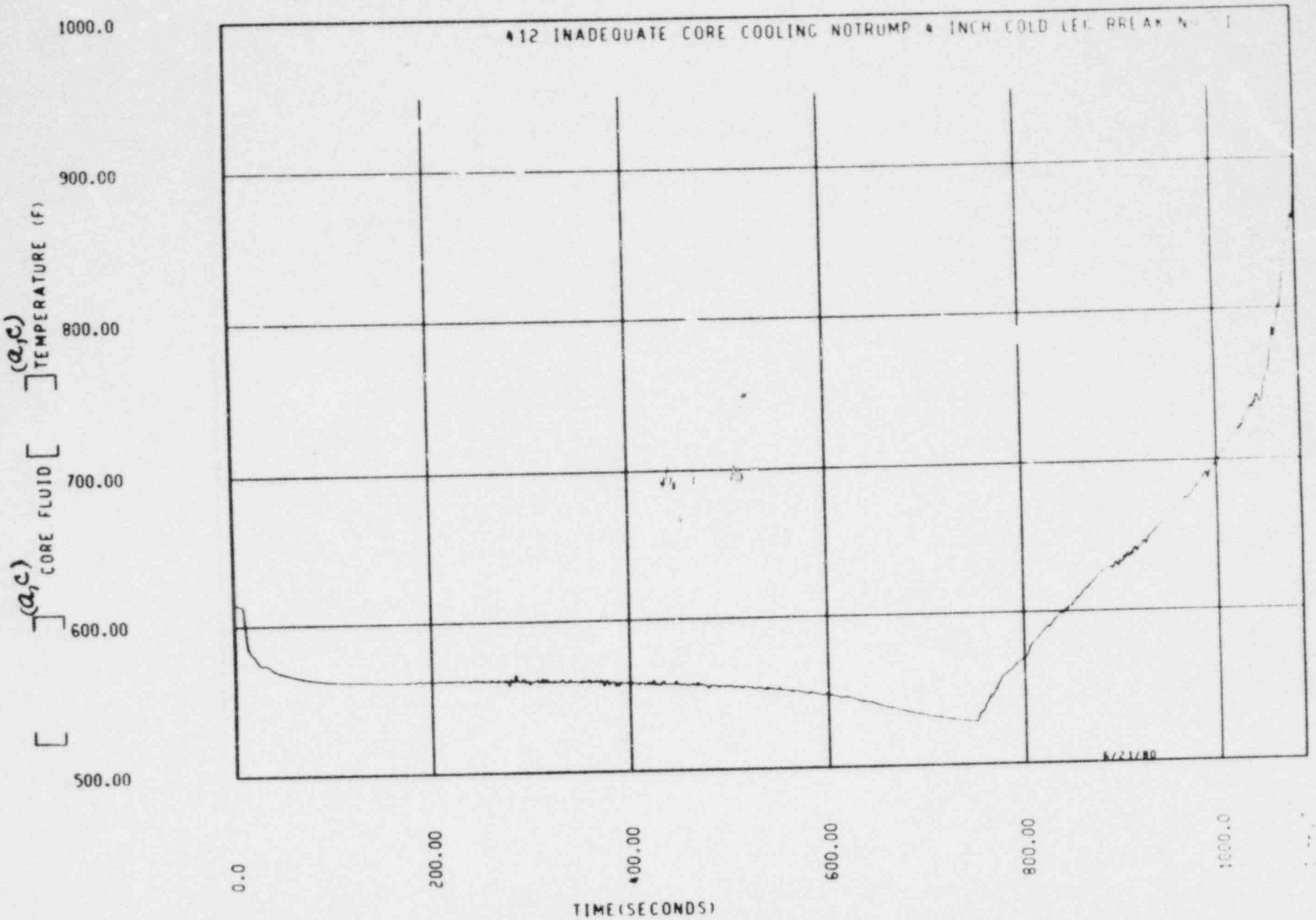

412 INADEQUATE CORE COOLING NOTRUMP 4 INCH COLD LEG BREAK
CORE FLUID TEMPERATURE (F)
(a,c)
(a,c)
1000.0
900.00
800.00
700.00
600.00
500.00
0.0
200.00
400.00
600.00
800.00
1000.0
TIME(SECONDS)
6/23/80

Figure 325

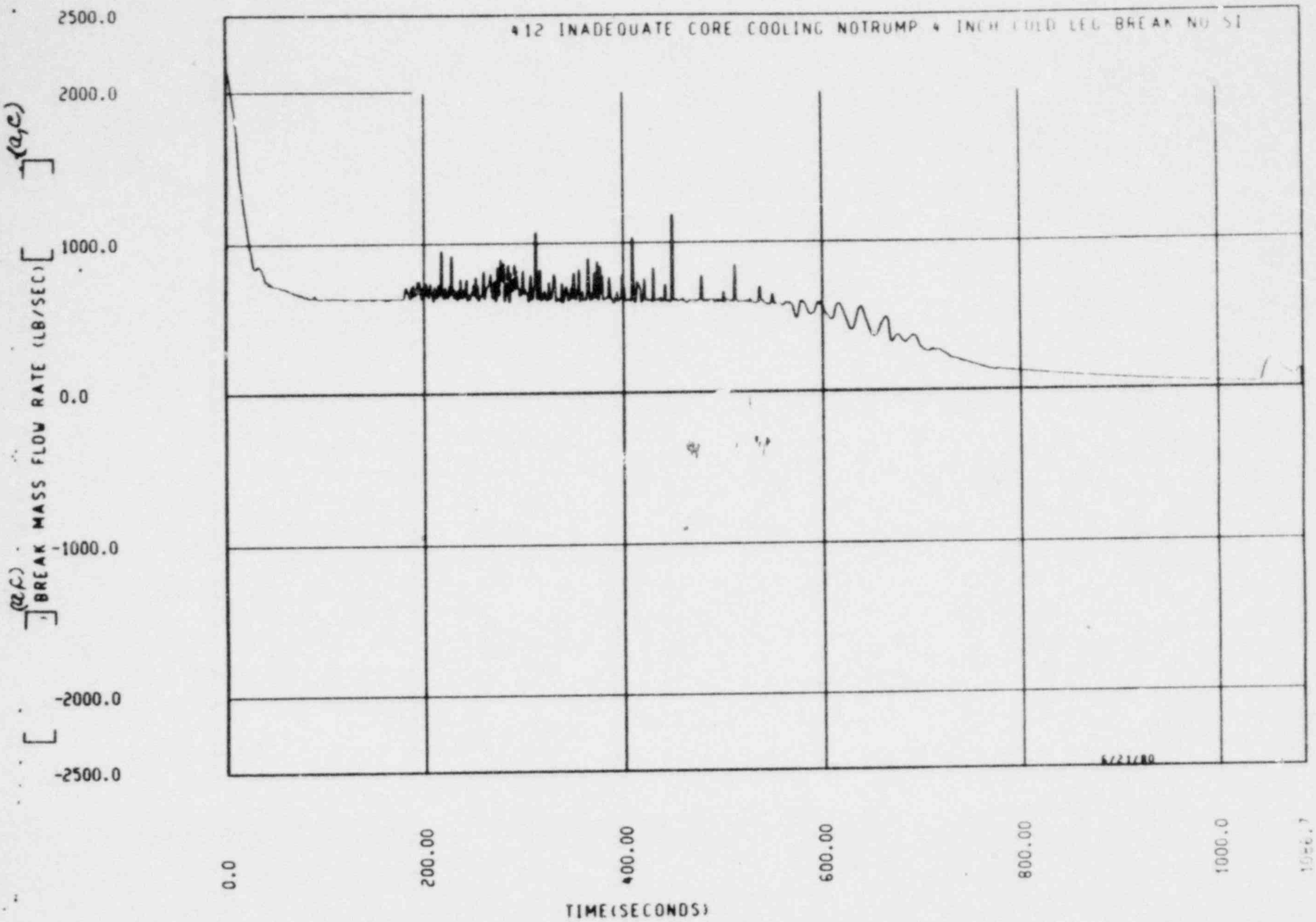

412 INADEQUATE CORE COOLING NOTRUMP 4 INCH COLD LEG BREAK NO SI
BREAK MASS FLOW RATE (LB/SEC)
(a,c)
(a,c)
2500.0
2000.0
1000.0
0.0
-1000.0
-2000.0
-2500.0
0.0
200.00
400.00
600.00
800.00
1000.0
1066.7
TIME(SECONDS)
6/21/80

Figure 326

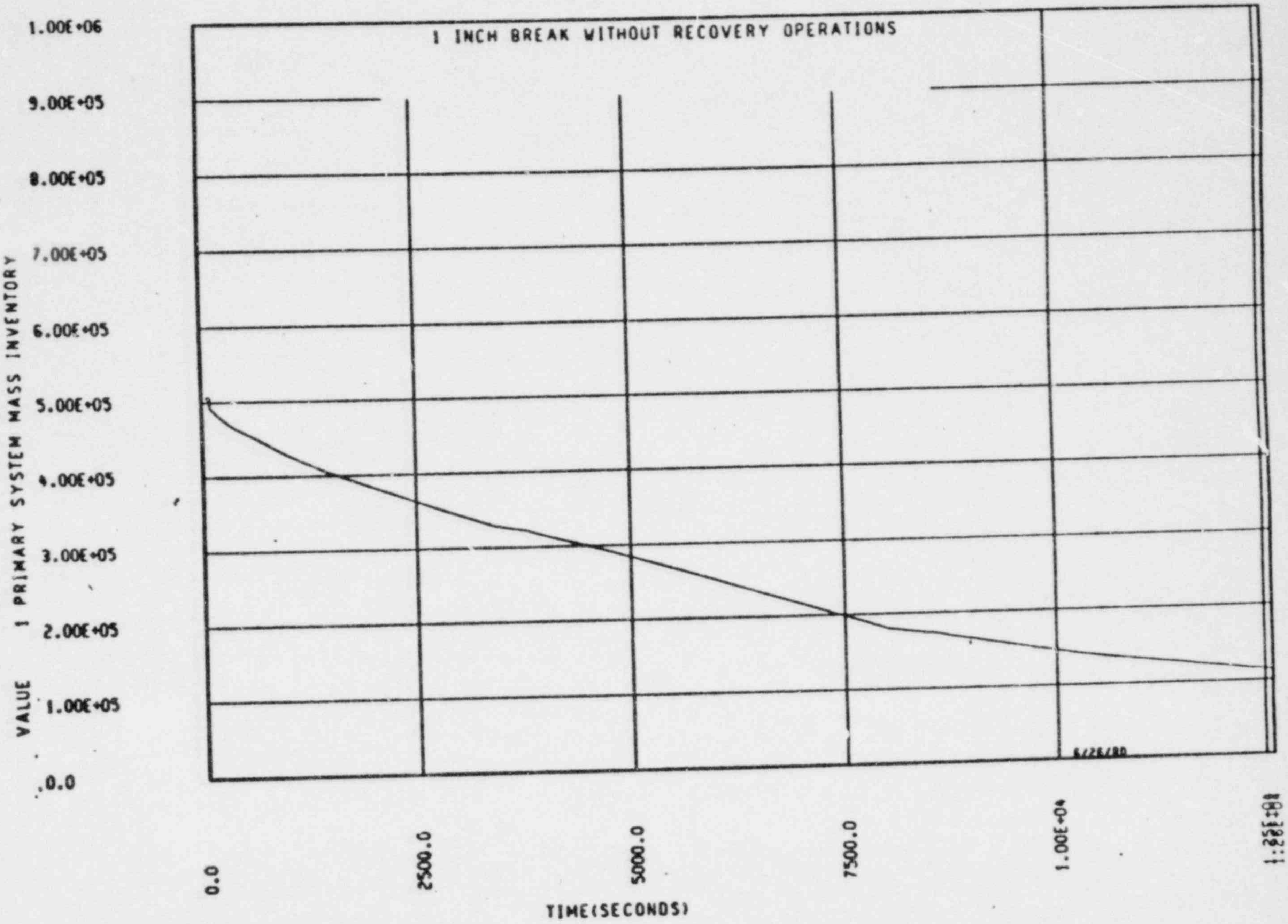

1 INCH BREAK WITHOUT RECOVERY OPERATIONS
VALUE 1 PRIMARY SYSTEM MASS INVENTORY
1.00E+06
9.00E+05
8.00E+05
7.00E+05
6.00E+05
5.00E+05
4.00E+05
3.00E+05
2.00E+05
1.00E+05
0.0
0.0
2500.0
5000.0
7500.0
1.00E+04
1.25E+04
TIME(SECONDS)
6/26/80

Figure 327

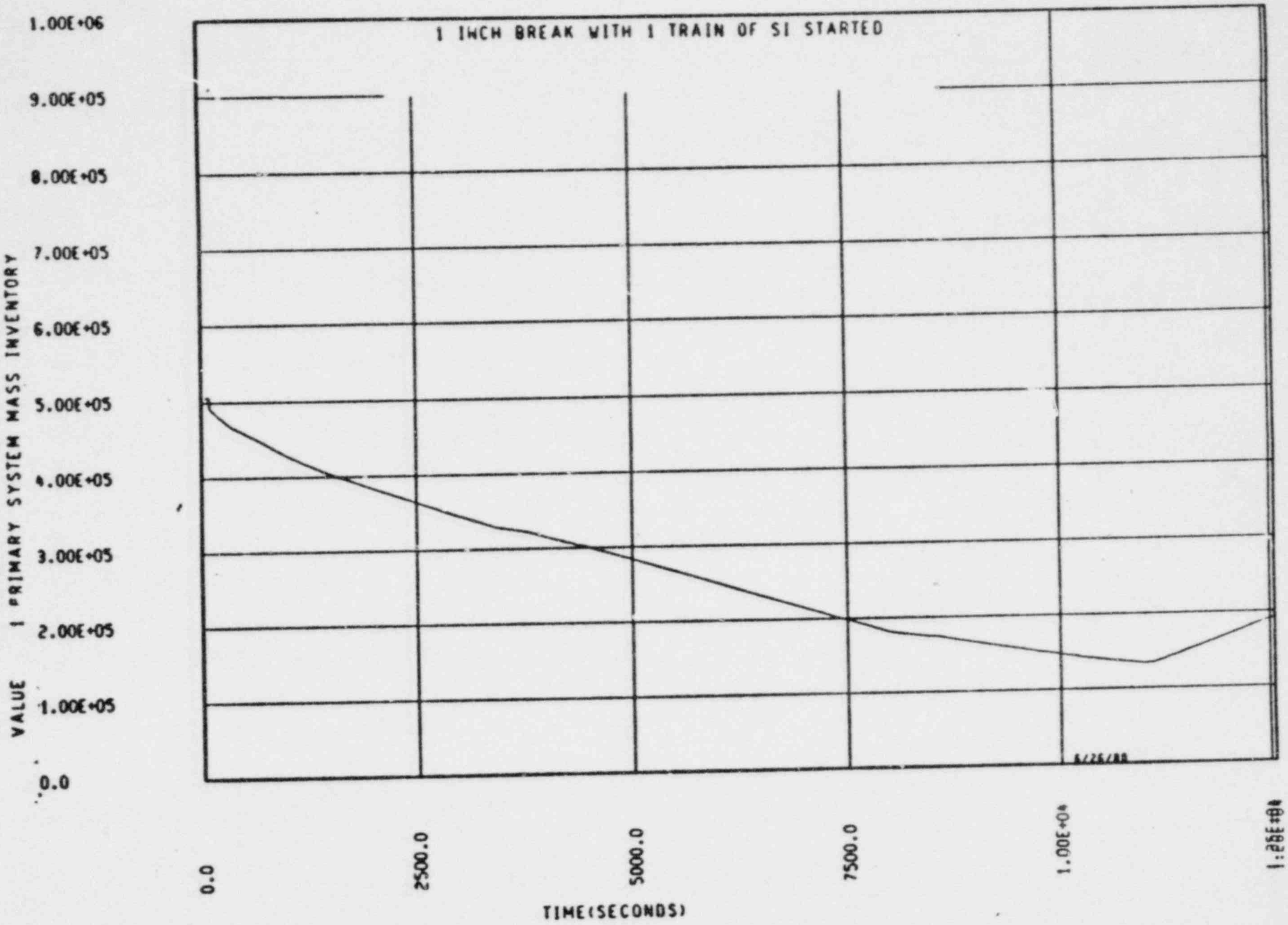

1 INCH BREAK WITH 1 TRAIN OF SI STARTED
VALUE 1 PRIMARY SYSTEM MASS INVENTORY
1.00E+06
9.00E+05
8.00E+05
7.00E+05
6.00E+05
5.00E+05
4.00E+05
3.00E+05
2.00E+05
1.00E+05
0.0
0.0
2500.0
5000.0
7500.0
1.00E+04
1.25E+04
TIME(SECONDS)

Figure 328

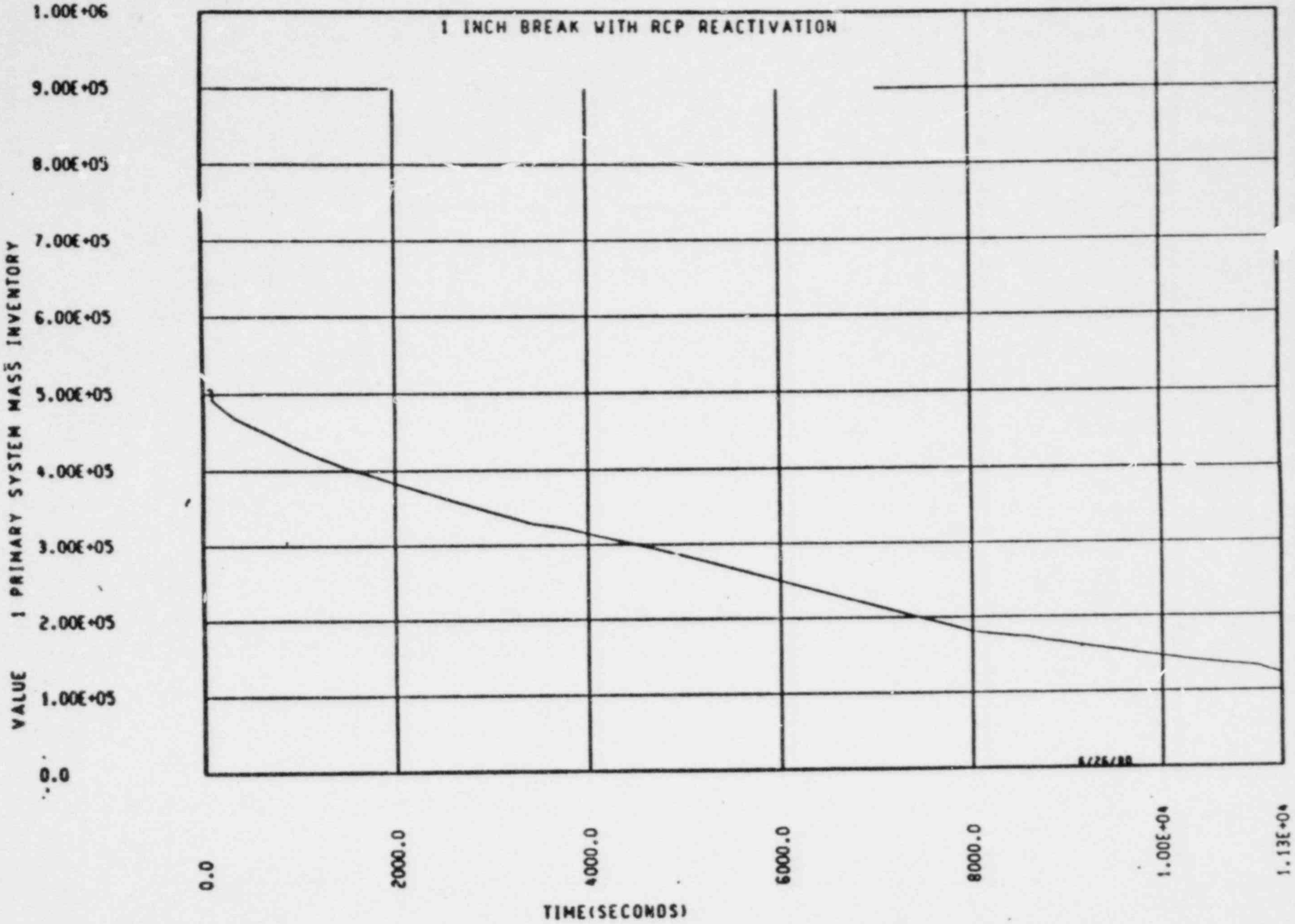

1 INCH BREAK WITH RCP REACTIVATION
VALUE 1 PRIMARY SYSTEM MASS INVENTORY
1.00E+06
9.00E+05
8.00E+05
7.00E+05
6.00E+05
5.00E+05
4.00E+05
3.00E+05
2.00E+05
1.00E+05
0.0
0.0
2000.0
4000.0
6000.0
8000.0
1.00E+04
1.13E+04
6/26/88
TIME(SECONDS)

Figure 329

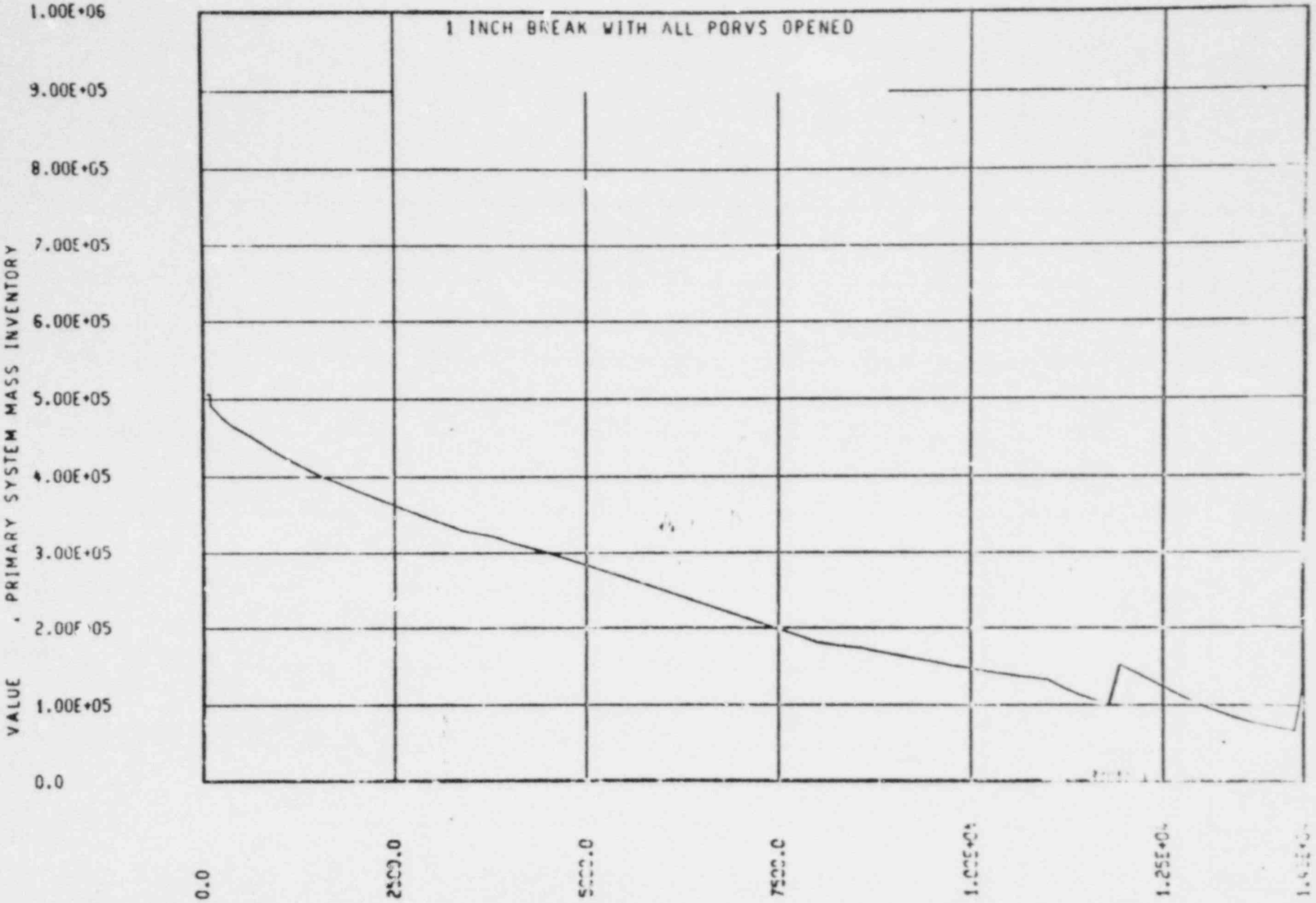
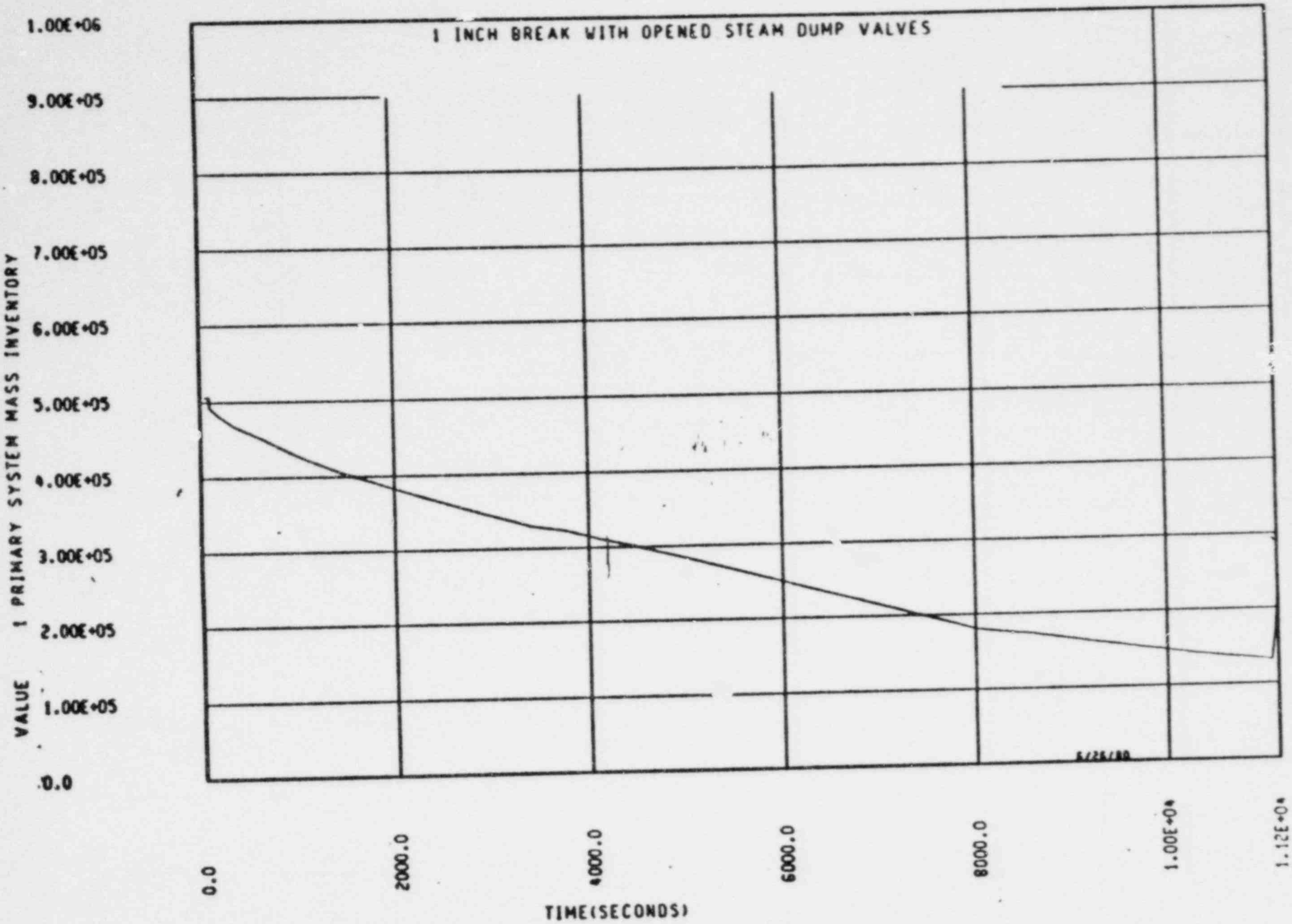

1 INCH BREAK WITH ALL PORVS OPENED
VALUE , PRIMARY SYSTEM MASS INVENTORY
1.00E+06
9.00E+05
8.00E+05
7.00E+05
6.00E+05
5.00E+05
4.00E+05
3.00E+05
2.00E+05
1.00E+05
0.0
0.0
2500.0
5000.0
7500.0
1.00E+04
1.25E+04
1.43E+04
TIME(SECONDS)

Figure 30



1 INCH BREAK WITH OPENED STEAM DUMP VALVES
VALUE 1 PRIMARY SYSTEM MASS INVENTORY
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
1.00E+04
1.12E+04
TIME(SECONDS)
6/26/80

Figure 331

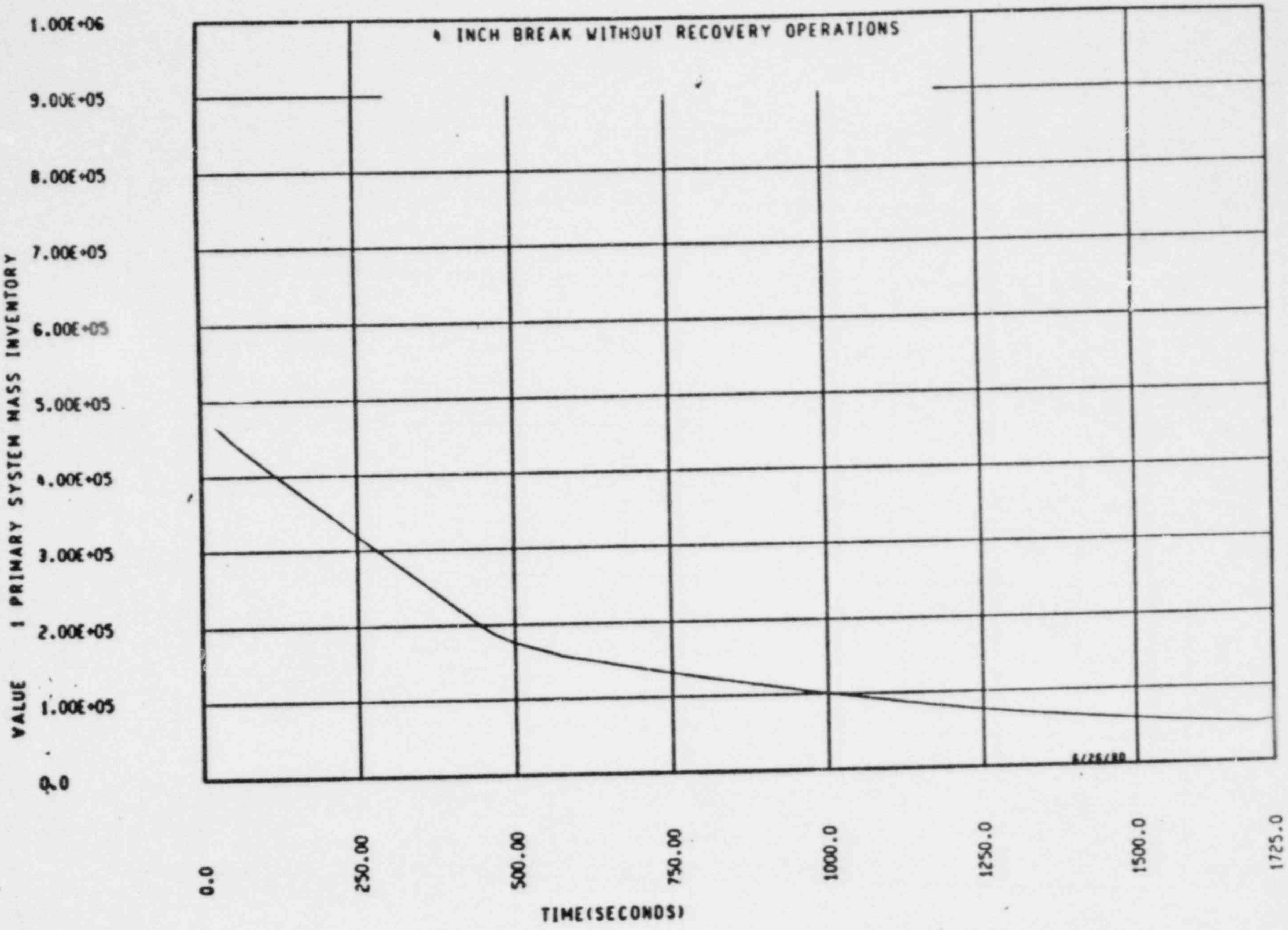

4 INCH BREAK WITHOUT RECOVERY OPERATIONS
VALUE 1 PRIMARY SYSTEM MASS INVENTORY
1.00E+06
9.00E+05
8.00E+05
7.00E+05
6.00E+05
5.00E+05
4.00E+05
3.00E+05
2.00E+05
1.00E+05
0.0
0.0
250.00
500.00
750.00
1000.0
1250.0
1500.0
1725.0
TIME(SECONDS)
8/26/80

Figure 332

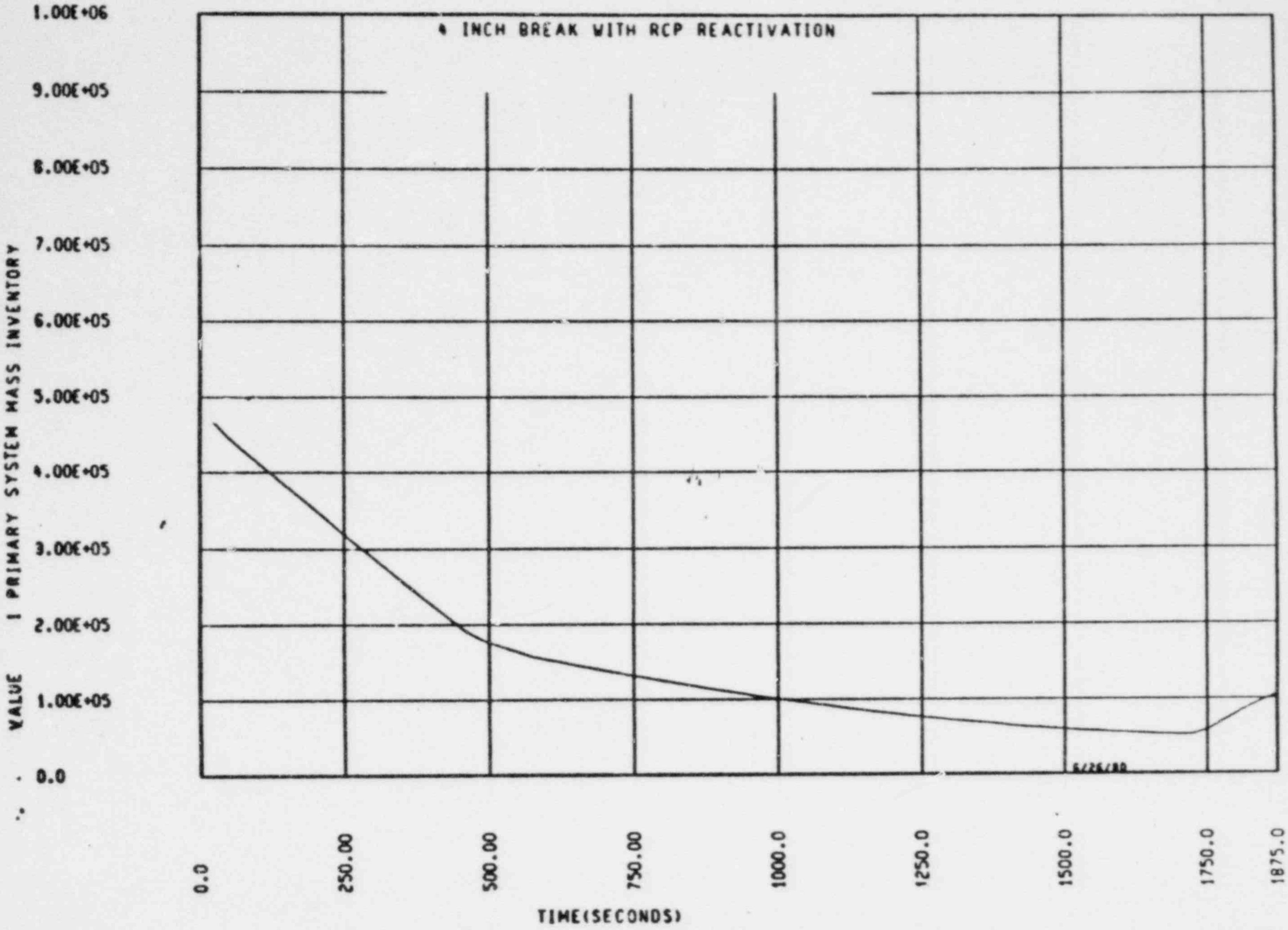

4 INCH BREAK WITH RCP REACTIVATION
VALUE I PRIMARY SYSTEM MASS INVENTORY
1.00E+06
9.00E+05
8.00E+05
7.00E+05
6.00E+05
5.00E+05
4.00E+05
3.00E+05
2.00E+05
1.00E+05
0.0
0.0
250.00
500.00
750.00
1000.0
1250.0
1500.0
1750.0
1875.0
TIME(SECONDS)
6/26/80

Figure 333

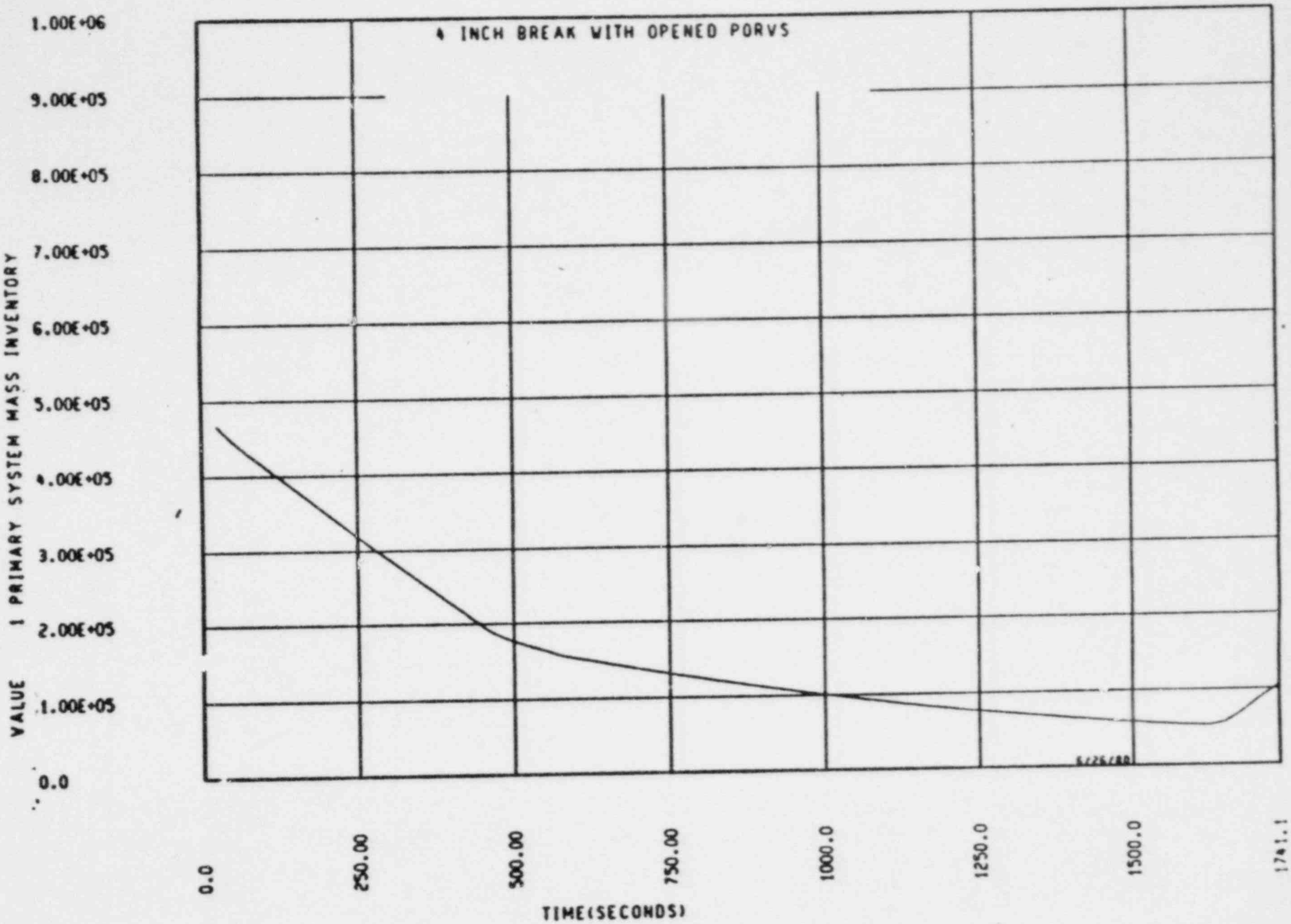

4 INCH BREAK WITH OPENED PORVS
VALUE 1 PRIMARY SYSTEM MASS INVENTORY
1.00E+06
9.00E+05
8.00E+05
7.00E+05
6.00E+05
5.00E+05
4.00E+05
3.00E+05
2.00E+05
1.00E+05
0.0
0.0
250.00
500.00
750.00
1000.0
1250.0
1500.0
1741.1
TIME(SECONDS)
6/26/80

Figure 334

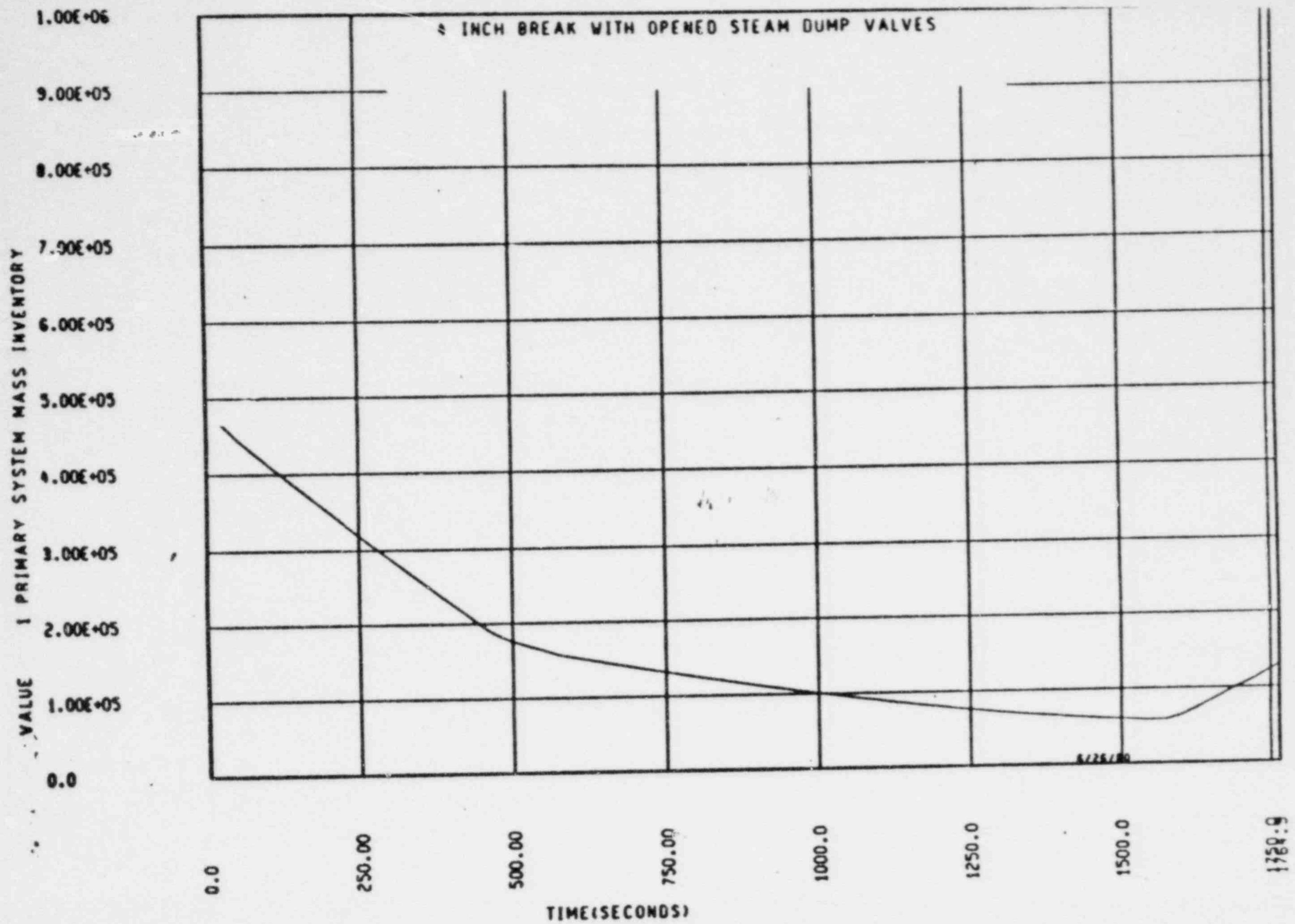
4 INCH BREAK WITH OPENED STEAM DUMP VALVES
VALUE    1 PRIMARY SYSTEM MASS INVENTORY
1.00E+06
9.00E+05
8.00E+05
7.00E+05
6.00E+05
5.00E+05
4.00E+05
3.00E+05
2.00E+05
1.00E+05
0.0
0.0
250.00
500.00
750.00
1000.0
1250.0
1500.0
1750.0
1764.9
TIME(SECONDS)
6/25/80

Figure 335

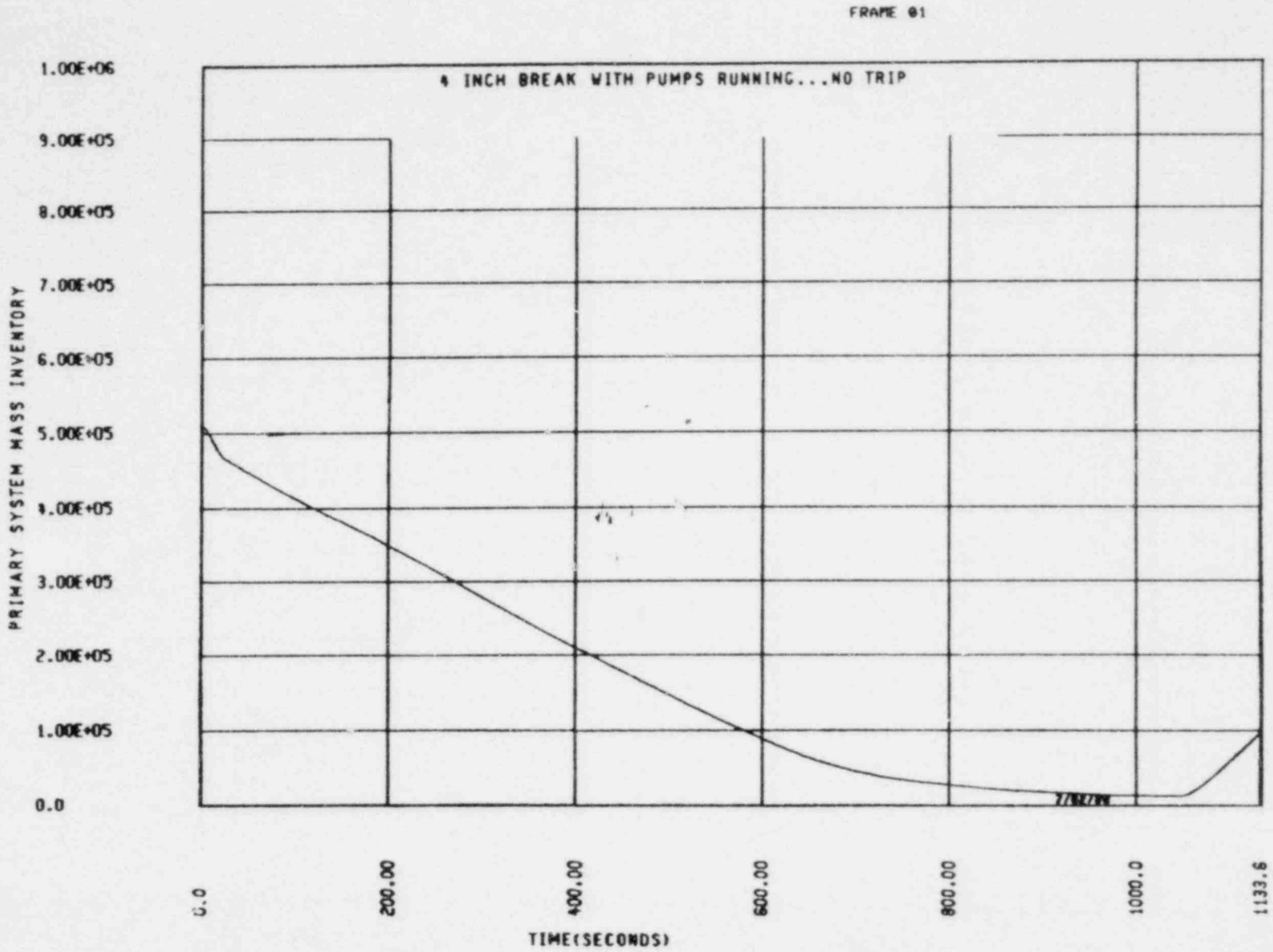

FRAME 01
4 INCH BREAK WITH PUMPS RUNNING...NO TRIP
PRIMARY SYSTEM MASS INVENTORY
1.00E+06
9.00E+05
8.00E+05
7.00E+05
6.00E+05
5.00E+05
4.00E+05
3.00E+05
2.00E+05
1.00E+05
0.0
0.0
200.00
400.00
600.00
800.00
1000.0
1133.6
TIME(SECONDS)

Figure 336

(a,c)

Figure 337

(a,c)

TIME(SECONDS)

Figure 338

Figure 339

(a,c

Figure 340

(a,c)

Figure 343

(a,c)

Figure 344

(a,c)

Figure 345

(a,c)

Figure 346