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International Agreement Report

RELAP5/MOD2 Post-Test Calculation of the OECD LOFT Experiment LP-SB-2

Prepared by
J. Perez, R. Mendizabal

Consejo de Seguridad Nuclear (C.S.N.)
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Office of Nuclear Regulatory Research
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April 1992

Prepared as part of
The Agreement on Research Participation and Technical Exchange
under the International Thermal-Hydraulic Code Assessment
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ABSTRACT

This document presents the analysis of the OECD LOFT LP-SB-2 experiment performed by the Consejo de Seguridad Nuclear of Spain working group making use of RELAP5/MOD2 in the frame of the Spanish LOFT Project.

LP-SB-2 experiment studies the effect of a delayed pump trip in a small break LOCA scenario with a 3 inches equivalent diameter break in the hot leg of a commercial PWR.

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EXECUTIVE SUMMARY

Experiment LP-SB-2 was conducted on July 14, 1983 in the LOFT facility at the Idaho National Engineering Laboratory.

The LP-SB-2 experiment simulated a 7.6 cm (3 inch) equivalent diameter break in a hot leg pipe of a PWR plant. Experiment LP-SB-2 addresses the analysis of a small break loss of coolant accident with the break at the mid plane of the intact loop hot leg. LP-SB-2 was one of a pair of experiments aimed to address the effects of early and delayed pump trip on system behaviour. The primary coolant pumps were allowed to operate until tripped when the primary system pressure had decreased to 3.16 MPa in experiment LP-SB-2.

The main objective of this calculation was to assess the code in the challenging conditions of a small break scenario.

Our aim was to simulate the major physical phenomena of the transient that took place until the beginning of the plant recovery.

The code used to simulate the LP-SB-2 experiment was RELAP5/MOD2 Cycle 36.04 installed on a CYBER 810.

The input data was based on that used in previous LP-SB-1 calculations.

The major conclusions are:

i) The two phase head multipliers used in the calculation caused that pumps degraded later and in a smoother way than in the experiment.

ii) RELAP5/MOD2 failed to calculate onset of the stratified flow in the hot leg.

iii) The code could not account for the liquid entrainment and vapor pull-through in the break tee due to the delayed detection of stratified flow conditions. So break uncovery was not detected and primary mass inventory was finally underpredicted.

iv) RELAP5/MOD2 choked flow model underpredicted the break line velocities.

FOREWORD

This report represents one of the assessment/application calculations submitted in fulfilment of the bilateral agreement for cooperation in thermalhydraulic activities between the Consejo de Seguridad Nuclear of Spain (CSN) and the United States Nuclear Regulatoy Commission (US-NRC) in the form of Spanish contribution to the International Code Assessment and Applications Program (ICAP) of the US-NRC whose main purpose is the validation of the TRAC and RELAP system codes.

The Consejo de Seguridad Nuclear has promoted a coordinated Spanish Nuclear Industry effort (ICAP-SPAIN) aiming to satisfy the requirements of this agreement and to improve the quality of the technical support groups at the Spanish Utilities, Spanish Research Establishments, Regulatory Staff and Engineering Companies, for safety purposes.

This ICAP-SPAIN national program includes agreements between CSN and each of the following organizations:

- Unidad Eléctrica (UNESA)
- Unión Iberoamericana de Tecnología Eléctrica (UITESA)
- Empresa Nacional del Uranio (ENUSA)
- TECNATOM
- LOFT-ESPAÑA

The program is executed by 12 working groups and a generic code review group and is coordinated by the "Comité de Coordinación". This committee has approved the distribution of this document for ICAP purposes.

1. INTRODUCTION

Thermal-hydraulic research has required close interaction between experimental and analytical work. A number of separate-effect experiments have been performed to help in the validation of best estimate computer codes. Analogously the overall results of code calculations are assessed using data from integral test facilities. The analyses show that the codes generally provide accurate calculations of the Loss of Coolant Accident (LOCA). Areas where model improvements are needed have also been identified by these tests. In particular the Loss of Fluid Test (LOFT) facility was adapted to study some small breaks. The motivation of one of these is explained hereafter.

An analysis performed after TMI showed that one of the key factors in the core damage was the tripping of the primary circuit pumps. The USNRC requested the reactor vendors to carry out an analysis of this problem. The conflict between the results of these investigations led to a recommendation to carry out experiments on this program in order to clarify the criteria for pump trip. The experiments LP-SB-1 and LP-SB-2 modelled small breaks in the hot leg. They differ in time of pump trip which is early in the former and delayed in the later of these tests. In this paper the results obtained in a post test analysis of the experiment LP-SB-2 by the CSN working group, part of the Spanish LOFT project are set down. The calculations with RELAP5/MOD2 Cycle 36.04 were carried out on a CYBER 810 in Madrid.

2. DESCRIPTION OF THE LOFT INSTALLATION

The experimental LOFT installation simulates a four loop 1000 MW commercial PWR. It has a thermal power of 50 MW. The installation consists of a vessel scaled 1/47 in volume, an intact circuit with an active steam generator, a pressurizer, two pumps in parallel and a broken loop, connected by recirculation lines to the intact circuit in order to maintain a temperature of this broken circuit near to that of the coolant at core inlet at the beginning of the experiment. More detailed information on the LOFT system configuration is provided in (1).

A LOFT piping schematic with instrumentation for experiment LP-SB-1 and LP-SB-2, and an axonometric projection of the LOFT system configuration are shown respectively in Figures

3. RELAP5/MOD2 MODEL OF LOFT FACILITY

The code used for this calculation was RELAP5/MOD2 Cycle 36.04.

The input data was based on that used in previous LP-SB-1 (8) calculations. The splitting in two volumes of the break line was eliminated because it induces big break flow oscillations.

Figure 3 shows the final nodalization.

4. EXPERIMENT LP-SB-2

Experiment LP-SB-2 was conducted on July 14, 1983 in the LOFT facility at the Idaho National Engineering Laboratory.

The LP-SB-2 experiment simulated a 7.6 cm (3 inch.) equivalent diameter break in the midplane of the hot leg pipe of a PWR plant. LP-SB-2 was one of a pair of experiments aimed to address the effects of early and delayed pump trip on system behaviour. The primary coolant pumps were tripped early in experiment LP-SB-1 and were allowed to operate until tripped when the primary system pressure had decreased to 3.16 MPa in this experiment.

A detailed description of the experiment is found in (2).

4.1 Steady state calculations

To accelerate the achievement of steady-state conditions the following variables were controlled.

(i) Liquid level in the "downcomer" of the steam generator.
(ii) Primary mass flow.
(iii) Liquid level in the pressurizer.

In addition the upper part of the pressurizer was connected to a dummy volume to maintain the desired pressure in the primary side.

Under this situation the code achieved steady-state conditions in 191 secs. Then a calculation without controls for 25 secs was carried out to demonstrate that a true steady state had been reached. These stationary state conditions are compared with the initial conditions of the plant in Table 1. The Figures 4 - 7 show significant parameters during the null transient.

4.2 Transient boundary conditions

4.2.1 Decay Heat Data

Reactor power after scram was specified by means of a table. During the first 2 seconds of the transient, data were taken from the RELAP5/MOD1 input deck used for the pretest prediction of LP-SB-2 (3). After that, data contained in (4) were used until the end of the transient.

4.2.2 Pumps injection flow

The pumps injection flow was simulated assuming a constant flow of 0.0475 l/s, to each pump (2,5).

4.2.3 Auxiliary Feedwater Flow

An auxiliary feedwater flow of 0.5 l/s (5) was manually initiated at 63.8 seconds and turned off at 1864. seconds.

4.2.4 High Pressure Injection System

The HPIS was effective in experiment LP-SB-2 when the intact loop hot leg pressure had fallen to 7.99 MPa (2).

4.2.5 Secondary Side Steam Control Valve

Descriptive data of the steam bypass valve were not available. Its function was assumed by the steam control valve. After 80 seconds it was latched closed to a flow area of 0.0925% of its fully opened value, throughout the transient.

4.2.6 Operational setpoints

The operational setpoints measured during the experiment, and those used in the RELAP5/MOD2 calculation are given in table 2.(2)

5. POST TEST CALCULATION

The calculation was run for 2500 secs. This was considered to be sufficient to obtain the most significant data. Table 3 shows the event chronology.

5.1 Code Performance

Two thousand and five hundred seconds of transient required about 230,000 cpu seconds (Fig. 8). This corresponds to a cpu/real time ratio of about 92. The user-specified minimum allowable time step throughout the calculation was 1.E-7 seconds and the maximum time step was set to 0.05 seconds. The code used the maximum value through the whole transient (Fig. 9).

The model consisted of 115 hydrodynamic volumes, 121 junctions and 122 heat structures with 658 mesh points.

The grid time for this run was 40. ms per volume per advancement.

5.2 Chronology of events

The predicted timing of significant events is compared with measurements during the LP-SB-2 transient in Table 3.

The opening of the valve in the ILHL break line was the beginning of the transient.

The reactor scram occurred 1.6 seconds later than in the experiment.

One second after the reactor scram, closure of steam control valve was initiated. Isolation of the main feedwater took 2.5 seconds.

In our simulation, the main steam control valve assumed also the function of the steam bypass valve. It was fully closed at 17.8 seconds, 3 seconds later than in the experiment, and then was let to reopen at around 24 seconds (Fig. 10). The valve stem position was ~4% of the fully opened value. After 80 seconds this valve was latched closed to a minimum flow area of 0.0925% of its fully opened value trying to simulate the experimental leakage of this valve.

The HPIS initiated at 38 sec., 4 seconds before than in the experiment.

The break line reached saturated conditions at 50 seconds. This marks the end of subcooled blowdown.(Fig. 11)

The auxiliary feedwater was initiated at 65.4 seconds and turned off at 1865 seconds.

The pumps degraded later (662 sec. vs. 582 sec.) and less sharply than in the experiment.

In the experiment, the break line was uncovered at ~1192 sec. That did not appear in the simulation. From then on the break mass flow rate was overpredicted.

Around 1700 seconds the primary coolant system pressure fell bellow the secondary system pressure (1290 seconds in the experiment). (Fig. 12)

The minimum primary mass inventory was estimated to be reached at between 2100 and 2500 seconds in the experiment. At this time in the simulation, the break mass flow rate was still ~0.5 kg/sec. higher than the sum of HPIS and pumps injection mass flow rates.

The pumps trip set-point was not reached in the simulation. The pumps were tripped at 2853 sec in the experiment.

5.3 Secondary side pressure

The closure of the steam control valve produced an increase on the secondary side pressure. This short-term behaviour was very well reproduced in the calculation (Fig. 13). Globally, the pressure was slightly underpredicted (Fig 14). Due to the secondary role played by the steam generator this did not affect significantly the results.

The energy removal from the steam generator was through the steam valve leakage (around 3 x 10-2 kg/sec. from 500 seconds on) and heat losses through the shell. The minimum flow area of the main steam valve was restricted to 0.0925% of its fully-open value.

5.4 Primary side pressure

The primary pressure was in agreement with the experiment during the subcooled blowdown (~50 seconds) (Fig. 15). The rate of depressurisation was approximately well predicted. However, the simulation did not account for the increase in the rate of depressurisation due to the break uncovery. The result was that primary pressure was overpredicted from 1400 seconds on.

5.5 Temperatures

The subcooled blowdown ended at ~50 sec. (Fig. 11) both in the experiment and the calculation. From then on the loop temperatures (fig. 16 and 17) followed the pressure trend, being well reproduced until the break uncovery, and overpredicted afterwards. The maximum in the cold leg temperature at ~100 (likely due to the heat transfer degradation in the steam generator) was not reproduced in the calculation.

The pressurizer temperature history shows (fig. 18) a sharp initial decrease. After the emptying of the component, around 33 seconds, the steam became superheated and its temperature began to increase. That is due to the radiative heat transfer from the pressurizer wall.

5.6 Density distribution

The calculation showed a very uniform voiding rate in the intact loop (fig. 19 and 20). The calculated loop densities decreased almost linearly through the transient (fig. 21, 22 and 23),and were underpredicted from 1500. sec. on, when loop flow stagnated as quoted in 5.8 .

The core was always covered by a two phase mixture (fig. 24) with a vapour quality continuously increasing.

5.7 Break line density and break mass flow rate

The break line density was overpredicted through the whole transient (fig. 25). This fact has been reported in other LP-SB-2 simulations with RELAP5/MOD2 (6,7). The low measured density may be caused by strong flashing in the break pipe, bubble concentration at the break piping inlet or intensive vapor pull through (2).

The code offtake model was active from ~2100. sec. on, when the hot leg flow became stratified. So the hot leg and break line void fractions were coincident until that time (fig. 26).

The break mass flow rate (fig. 27) was well reproduced until the break uncovery. As stated in (2) the subcooled blowdown ended at a break mass flow rate of about 4 kg/s with a smooth transition into saturated break flow. The calculated blowdown ended at about the same time but abruptly and at a break mass flow rate of ~3kg/s. The code did not account for break uncovery and after 1200 sec. overpredicted the break mass flow rate in ~40% .

The break flow was choked from the beginning of the transient. The break line density overprediction implies that the critical velocity was basically underpredicted by the code.

5.8 Loop flow

Pumps behaviour played a very important role in the loop flow through the whole transient.

The two phase head multipliers used in the calculation were those from L3-6 data. Both pumps degraded at 662 sec., 80 sec. later than in the experiment, and in a smoother way (Fig. 28). The use of head multipliers derived from (9) should enhance this result. A detailed study about pumps behaviour will be found in (6).

Figures 29 to 32 show measured and calculated coolant velocities in the hot leg, cold leg, core inlet and core outlet respectively. It can be seen that around 1300 sec. the flow through the core ceased. The loop flow stopped at about 2000 sec. The simulation did not show flow stagnation. Some suggestions to justify this behaviour are given in (7).

Hot leg flow stratified between 1100 and 1400 sec. Figure 33 shows flow regimes found by the code. Stratification happened at ~2100 sec. in the calculation.The code switched from bubbly to slug flow when the void fraction reached 0.5 and from slug to annular-mist for α= 0.8.

5.9 Primary system mass inventory

Figure 34 compares the measured and calculated primary system mass inventory. Although not accurately known from the experimental data, minimum primary mass inventory was estimated to have occurred between 2100 and 2500 seconds. Until ~1900 sec. the calculated mass was into the experimental uncertainty band. In the lapse between 1900 and the end of the calculation the mass was under the lower margin.

The experimental difference between the HPIS plus pumps injection and the break mass flow rate is compared with the calculated one in Fig. 35 .This balance was slightly overpredicted in the transition from subcooled to saturated break flow (50 to 400 sec.). After the break uncovery, it was underpredicted.

The HPIS flow rate was well reproduced globally (Fig. 36).

6. CONCLUSIONS

The major conclusions are:

i) The two phase head multipliers used in the calculation caused that pumps degraded later and in a smoother way than in the experiment.

ii) RELAP5/MOD2 failed to calculate onset of the stratified flow in the hot leg.

iii) The code could not account for the liquid entrainment and vapor pull-through in the break tee due to the delayed detection of stratified flow conditions. So break uncovery was not detected and primary mass inventory was finally underpredicted.

iv) RELAP5/MOD2 choked flow model underpredicted the break line velocities.

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TABLE 1

INITIAL CONDITIONS FOR EXPERIMENT LP-SB-2

	MEASURED	CALCULATED
PRIMARY COOLANT SYSTEM		
Core ΔT (K)	18.6 ± 1.7	19.74
Hot leg pressure	14.95 ± 0.11	15.06
Cold leg temperature (K)	557.2 ± 1.5	558.98
Mass flow rate (kgs-1)	480.0 ± 3.2	480.01
REACTOR VESSEL		
Power level (MW)	49.1 ± 1.2	49.12
STEAM GENERATOR SECONDARY SIDE		
Liquid level (m)	3.13 ± 0.01	3.13
Water temperature (K)	539.5 ± 4.4	544.46
Pressure (MPa)	5.6 ± 0.09	5.6
Mass flow rate (kgs-1)	26.7 ± 0.8	25.75
PRESSURIZER		
Liquid volume (m3)	0.6462 ± 0.002	0.590
Steam volume (m3)	0.356 ± 0.002	0.397
Water temperature (K)	615.8 ± 8.2	615.16
Pressure (MPa)	15.08 ± 0.16	15.08
Liquid level (m)	1.109 ± 0.003	1.108
BROKEN LOOP		
Cold leg temperature (K)	555.9 ± 6.3	558.02

TABLE 2

OPERATIONAL SETPOINTS FOR EXPERIMENT LP-SB-2

Action	Reference	Measured Setpoint
Small-break valve Opened	Time	0.
Reactor scrammed	ILHL pressure (MPa)	14.28± 0.02
Main feedwater Shut off	ILHL pressure (MPa)	14.28± 0.02
Main steam control valve started to close	Time after reactor scram (seconds)	1.0± 0.2
Primary coolant pumps tripped	ILHL pressure (MPa)	3.161±0.018
HPIS Flow) initiated	ILHL pressure (MPa)	8.07± 0.05
Auxiliary feed-water initiated	Time after reactor scram (seconds)	62.± 0.2
Auxiliary feed-water terminated	Time after reactor scram (seconds)	1862.2± 0.3

TABLE 3

LP-SB-2 CHRONOLOGY OF EVENTS

EVENT	PLANT (SECONDS)	RELAP5 (SECONDS)
Small-break valve opened	0.0	0.0
Reactor scramed	1.8 ±0.05	3.4
Main feedwater shut off	1.8 ±0.2	3.4
Main steam control valve started to close	2.8 ±0.2	4.4
Main feedwater isolated	4.3 ±0.05	5.8
Main steam control valve fully closed	14.8 ±0.2	17.8
Pressurizer liquid level below indicating range	36.4±0.2	32.
HPIS flow initiated	42.4±0.2	38.0
Subcooled blowdown ended	50.2±1.0	50.
Auxiliary feedwater initiated	63.8±0.2	65.4
Pump two-phase performance degradation observed	582.2±0.2	662.
Break started to uncover	1192.5±2.5	950.*
Primary system pressure becomes less than secondary system pressure	1290.0±45.	1687.
Auxiliary feedwater shut off	1864.0±0.2	1865.0
HPIS flow rate exceeded break flow rate	2284.0±200.	
Primary coolant pumps tripped	2852.8±0.2	
Primary coolant pump 1 coastdown completed	2883.2±0.2	
Primary coolant pump 2 coastdown completed	2883.8±0.2	

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* Collapsed level under the HL pipe midplane

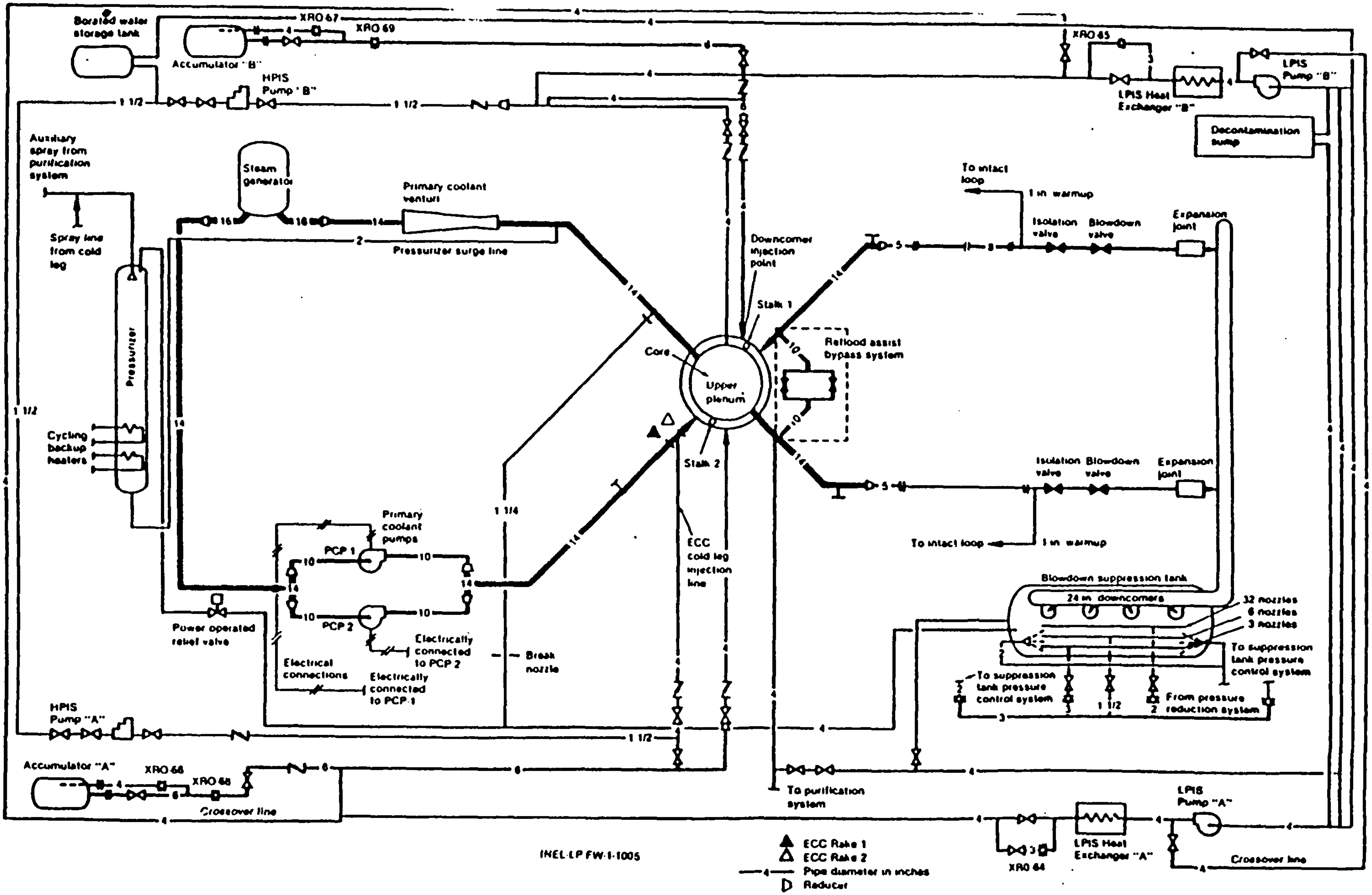


FIG. 1 LOFT piping schematic.

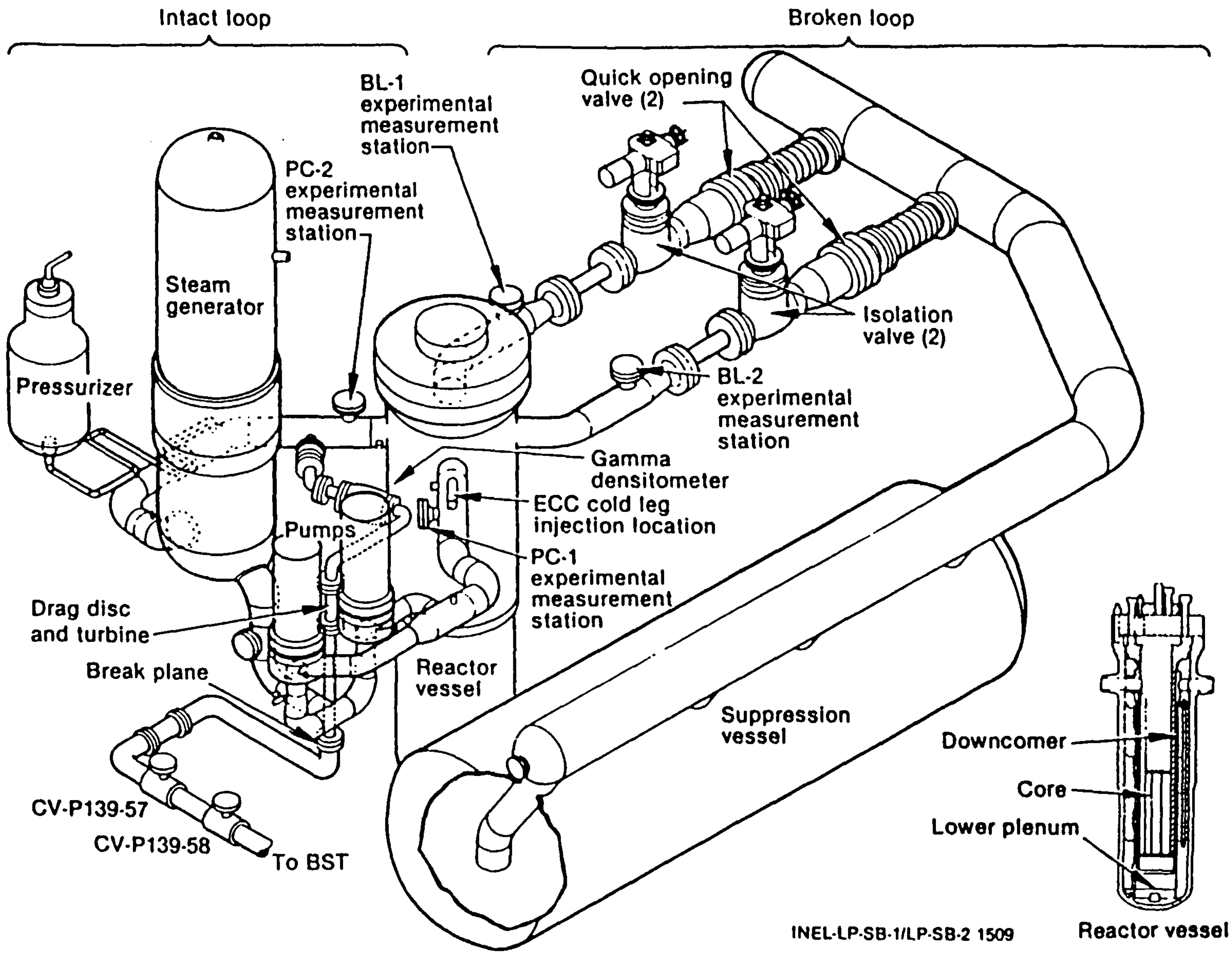


FIG. 2 Axonometric projection of the LOFT system configuration for Experiments LP-SB-1 and LP-SB-2.

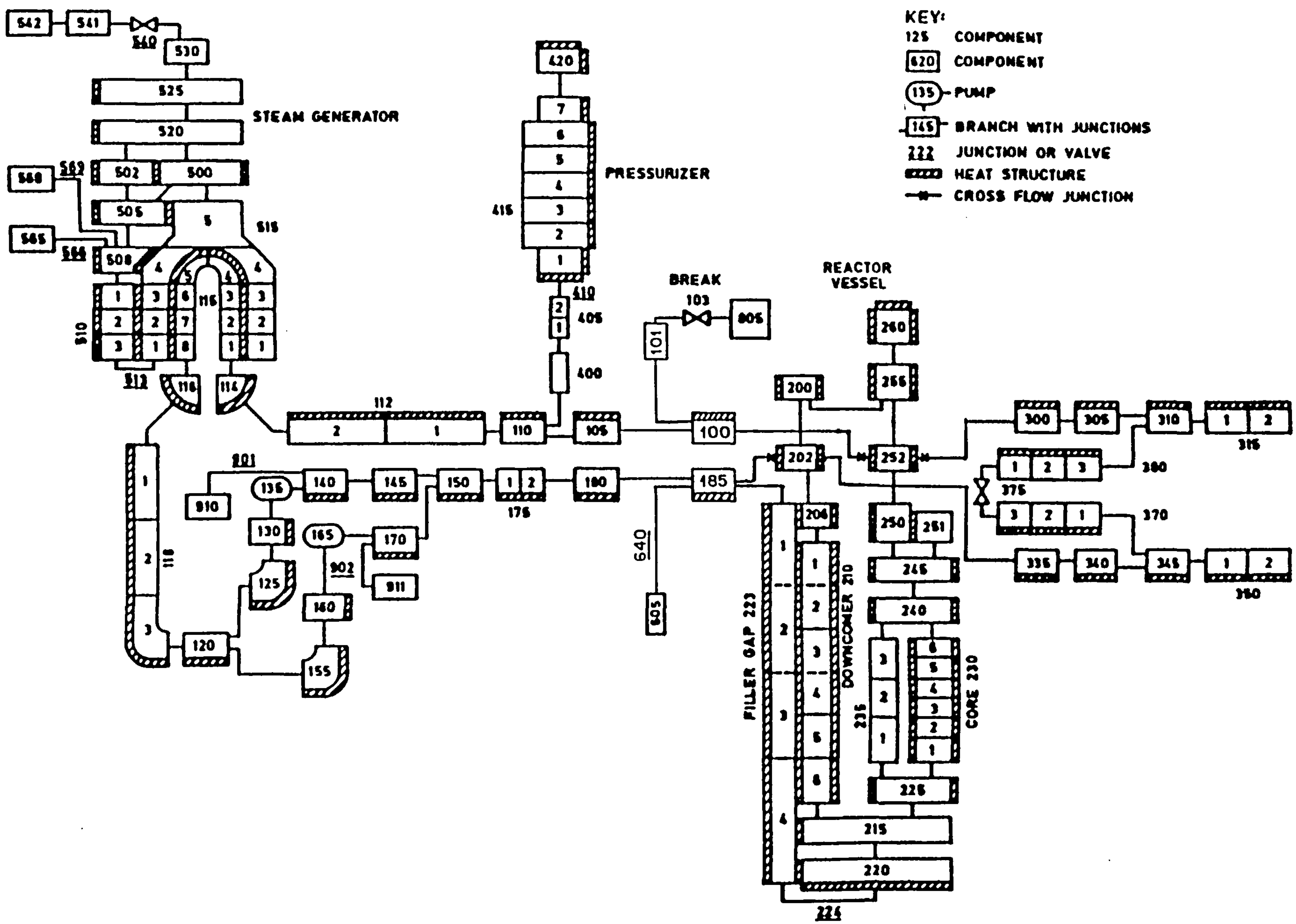


FIG. 3 RELAP 5 NODING DIAGRAM FOR LOFT LP-SB-2 CALCULATION

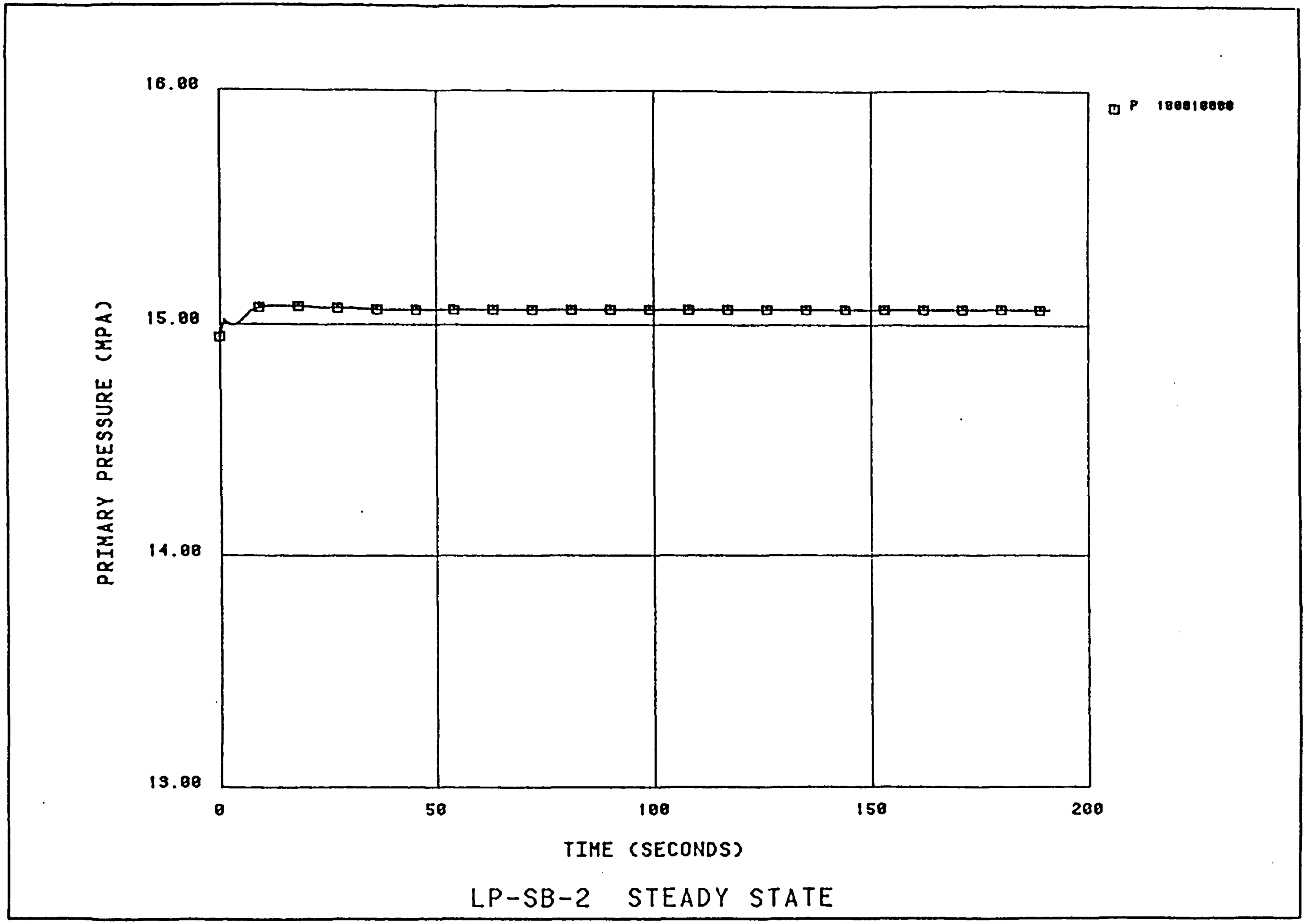
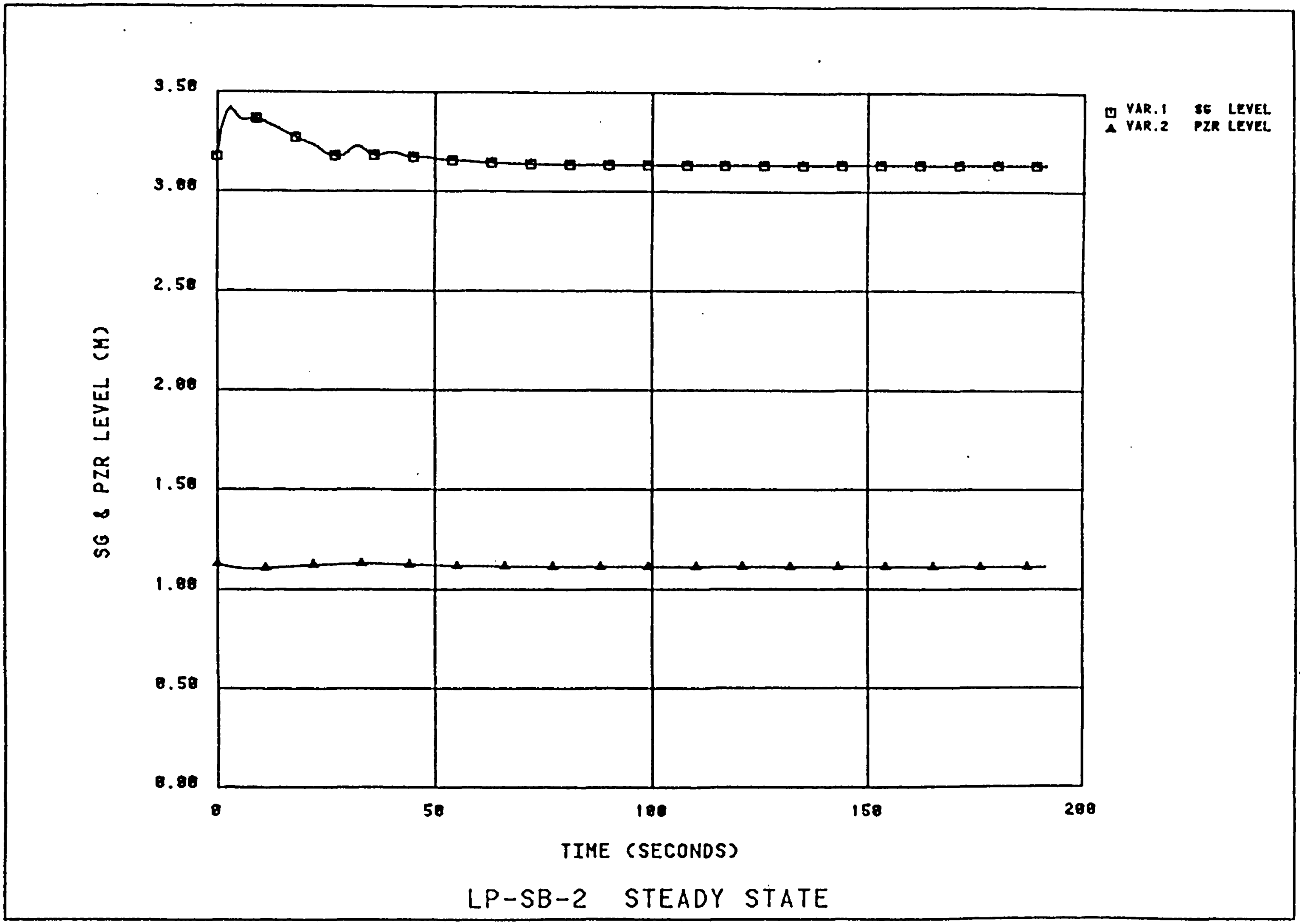

16.00
15.00
14.00
13.00
PRIMARY PRESSURE (MPA)
0
50
100
150
200
TIME (SECONDS)
P 100010000
LP-SB-2 STEADY STATE

FIG. 4



3.50
3.00
2.50
2.00
1.50
1.00
0.50
0.00
SG & PZR LEVEL (M)
0
50
100
150
200
TIME (SECONDS)
VAR.1 SG LEVEL
VAR.2 PZR LEVEL
LP-SB-2 STEADY STATE

FIG. 5

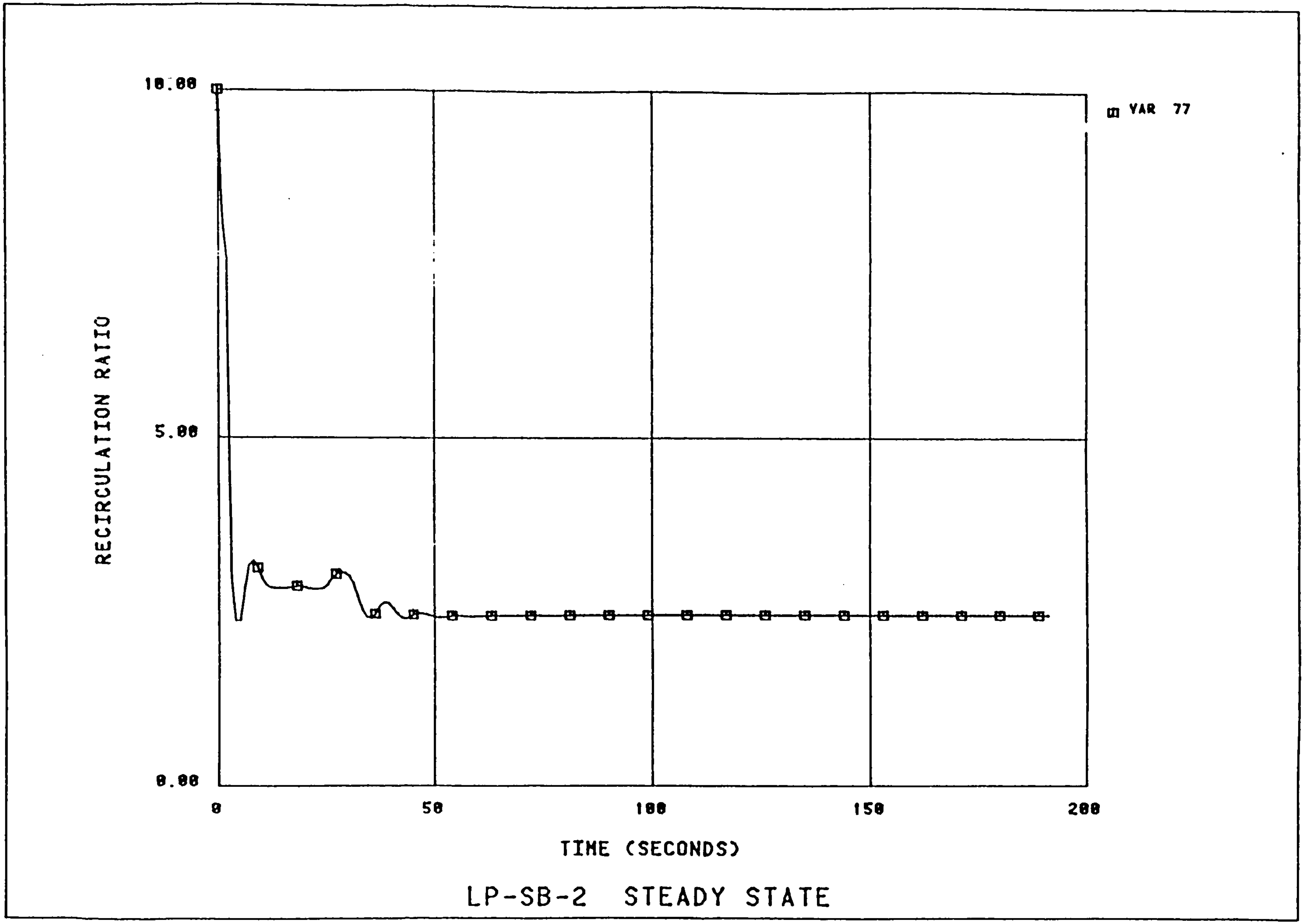

10.00
5.00
0.00
RECIRCULATION RATIO
0
50
100
150
200
TIME (SECONDS)
VAR 77
LP-SB-2 STEADY STATE

FIG. 6

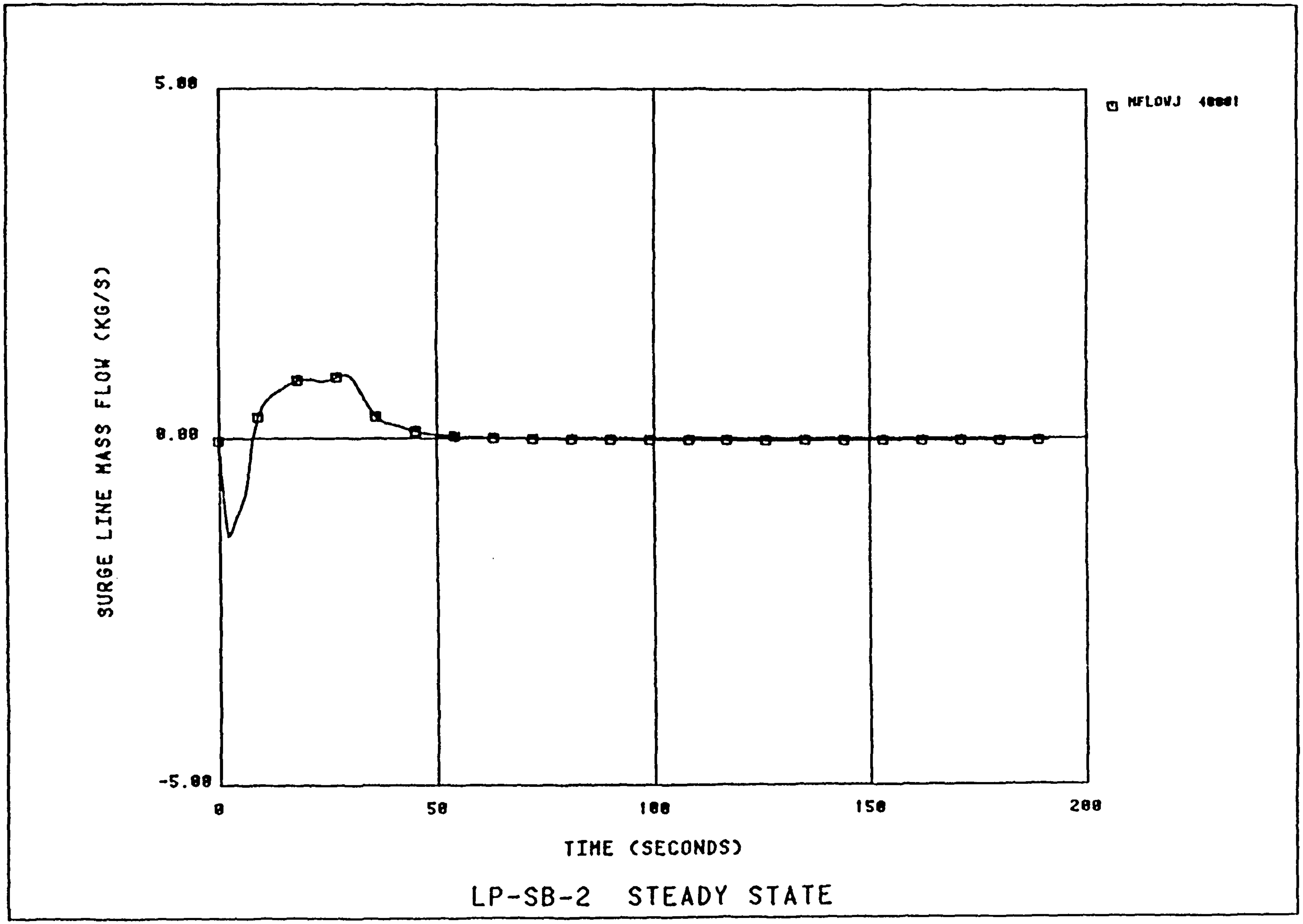
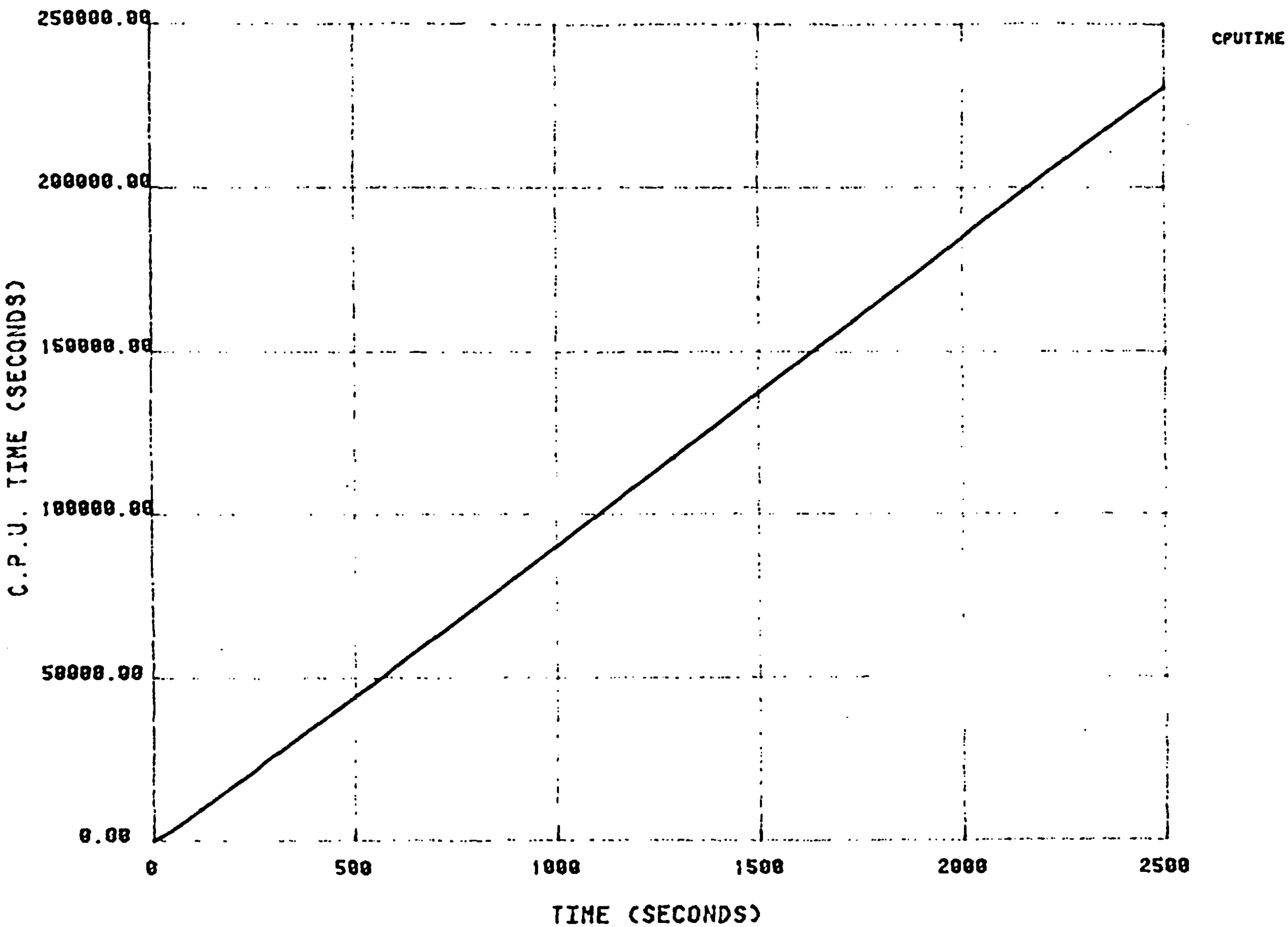

5.00
0.00
-5.00
SURGE LINE MASS FLOW (KG/S)
0
50
100
150
200
TIME (SECONDS)
MFLOWJ 40001
LP-SB-2 STEADY STATE

FIG. 7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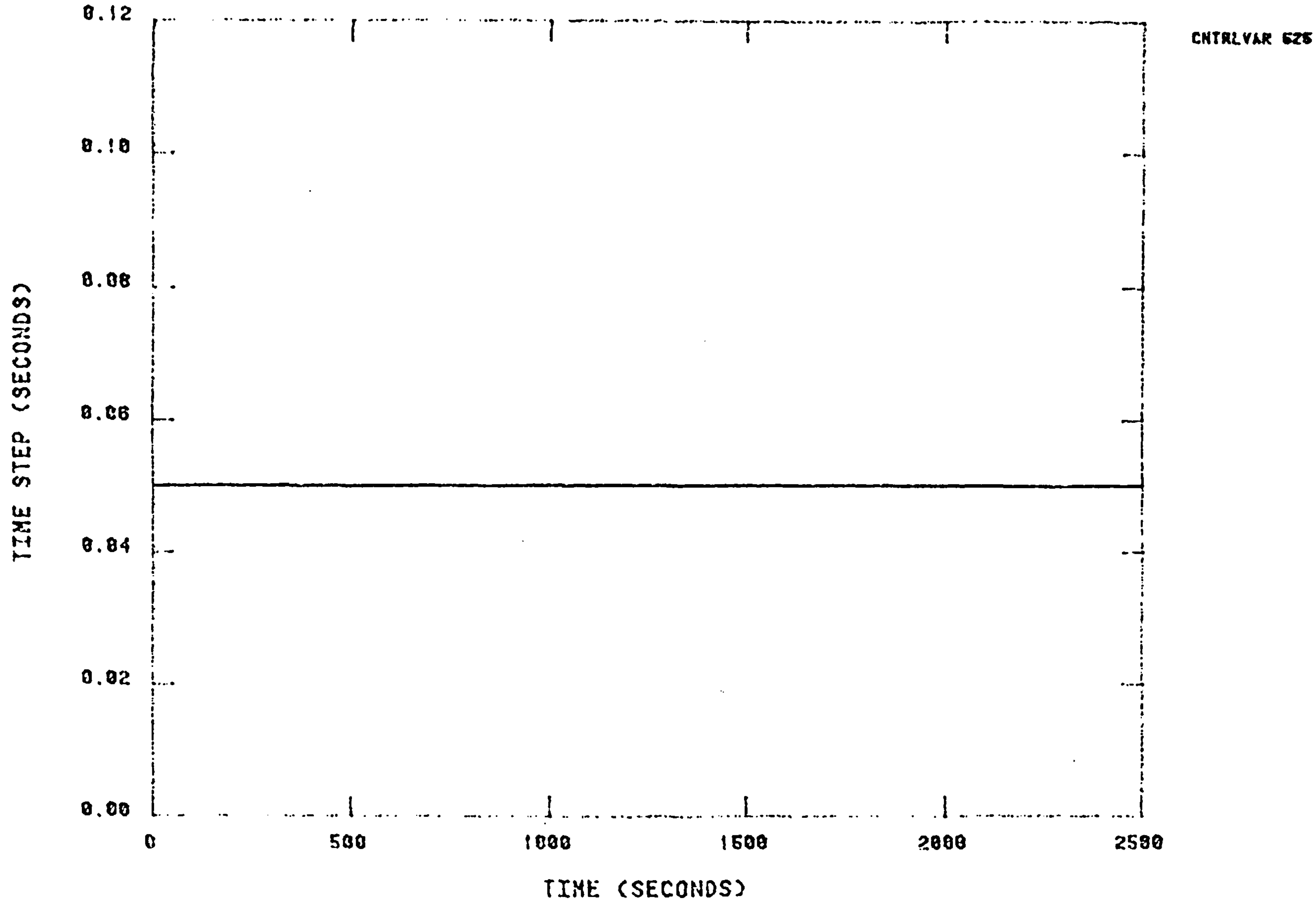
C.P.U. TIME (SECONDS)
250000.00
200000.00
150000.00
100000.00
50000.00
0.00
0
500
1000
1500
2000
2500
TIME (SECONDS)

LP-SB-2.

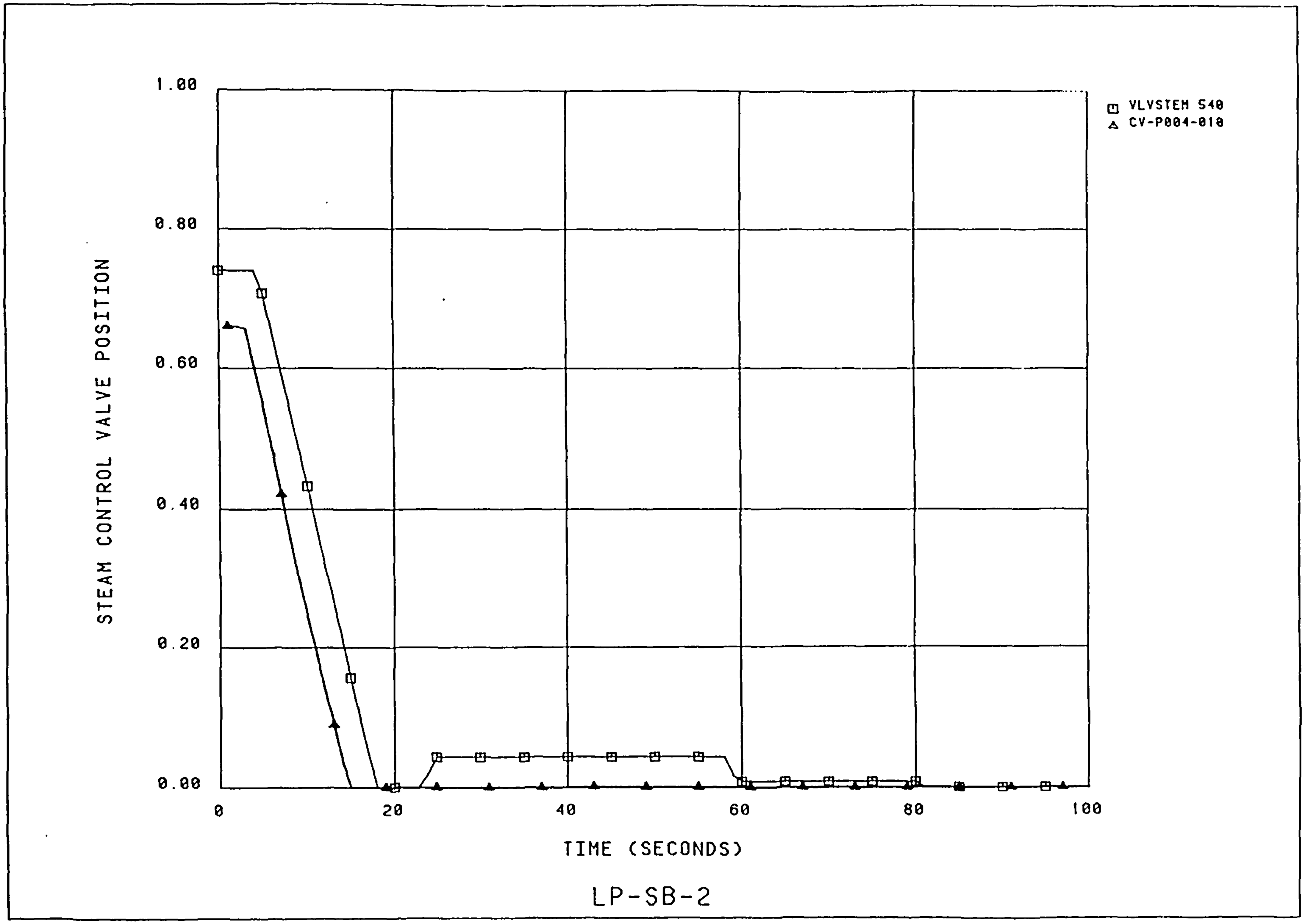
FIG 8

02



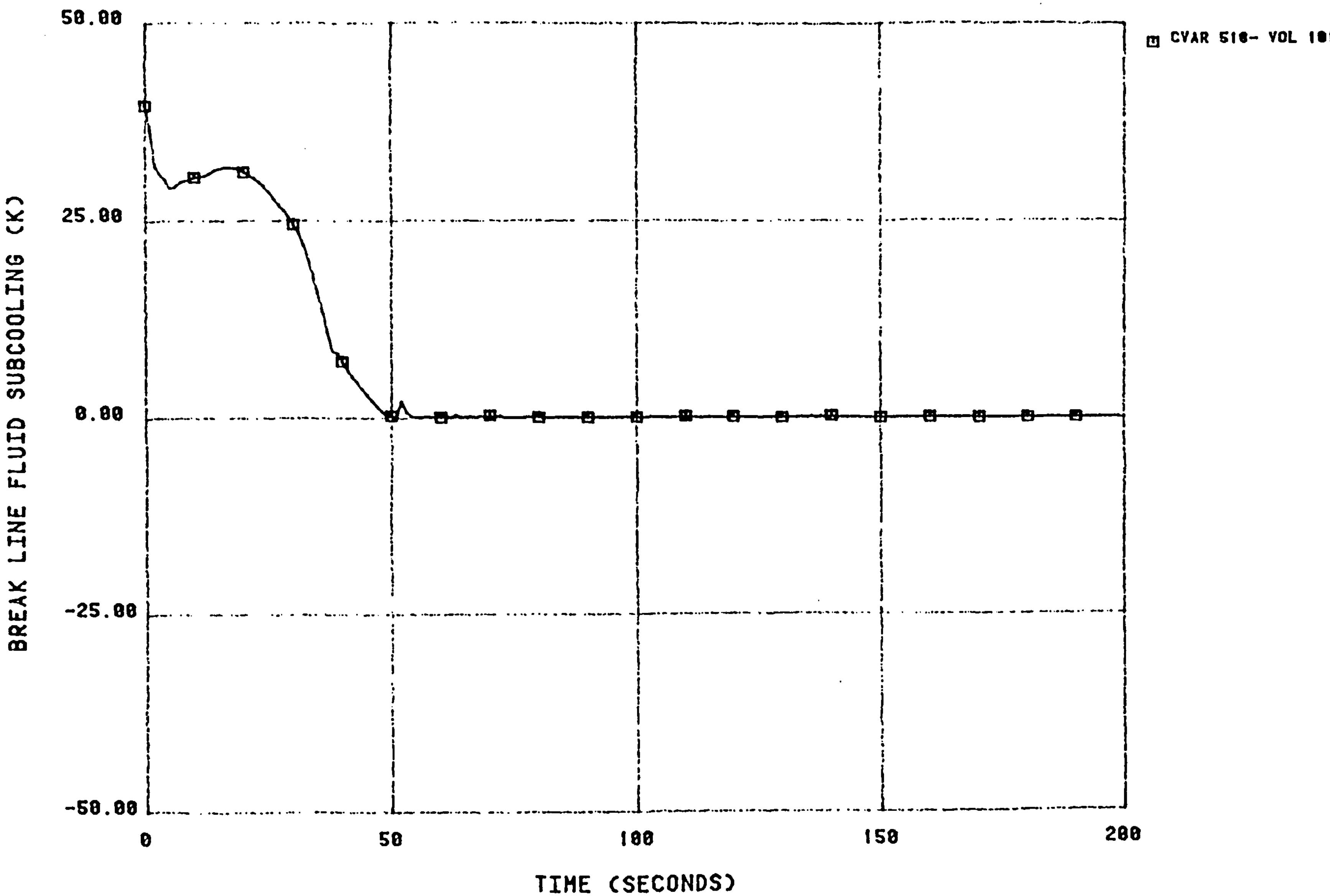
LP-SB-2.

FIG. 9



1.00
0.80
0.60
0.40
0.20
0.00
STEAM CONTROL VALVE POSITION
0
20
40
60
80
100
TIME (SECONDS)
VLVSTEM 540
CV-P004-010
LP-SB-2

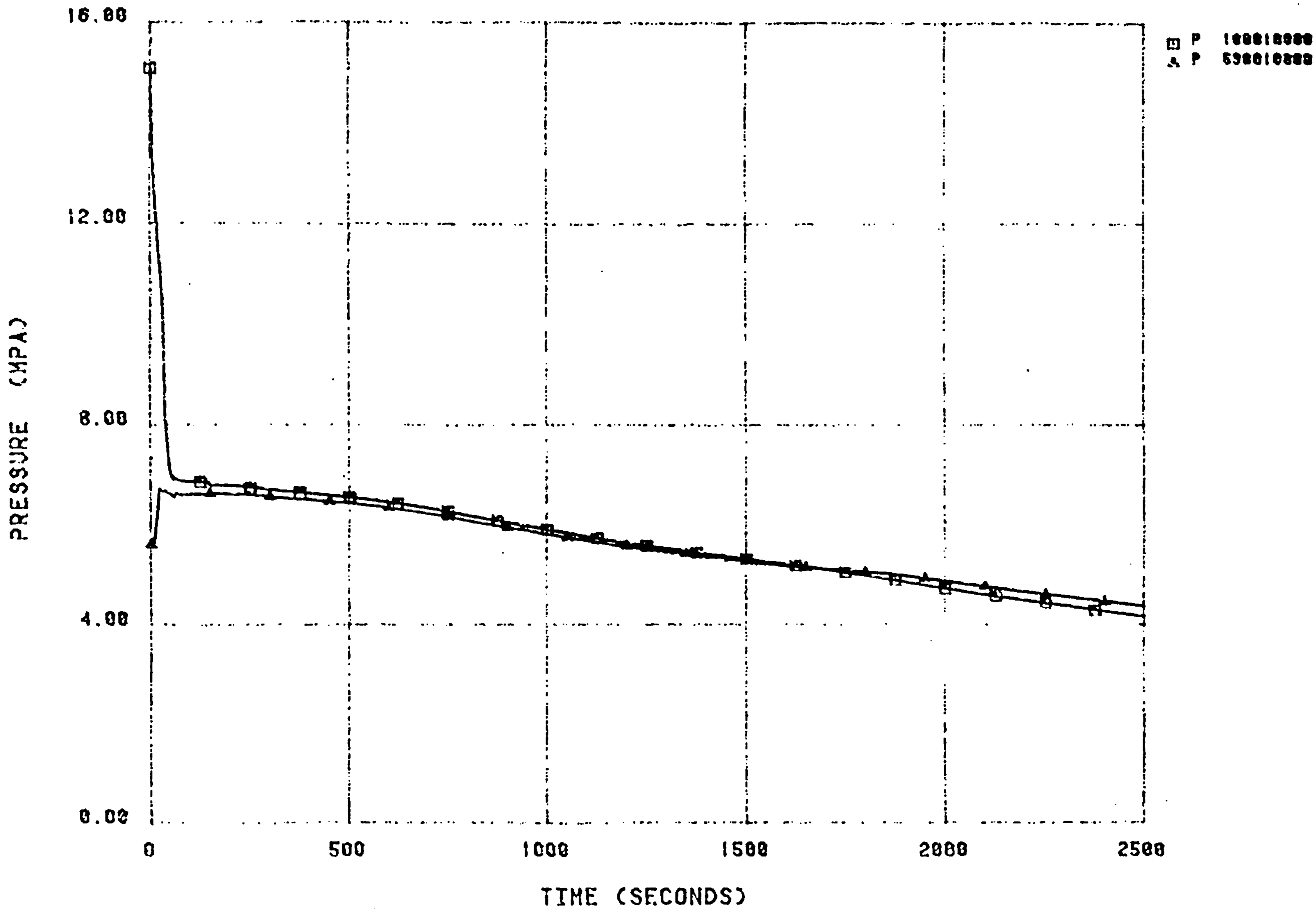
FIG. 10



50.00
25.00
0.00
-25.00
-50.00
BREAK LINE FLUID SUBCOOLING (K)
0
50
100
150
200
TIME (SECONDS)
CVAR 510- VOL 101

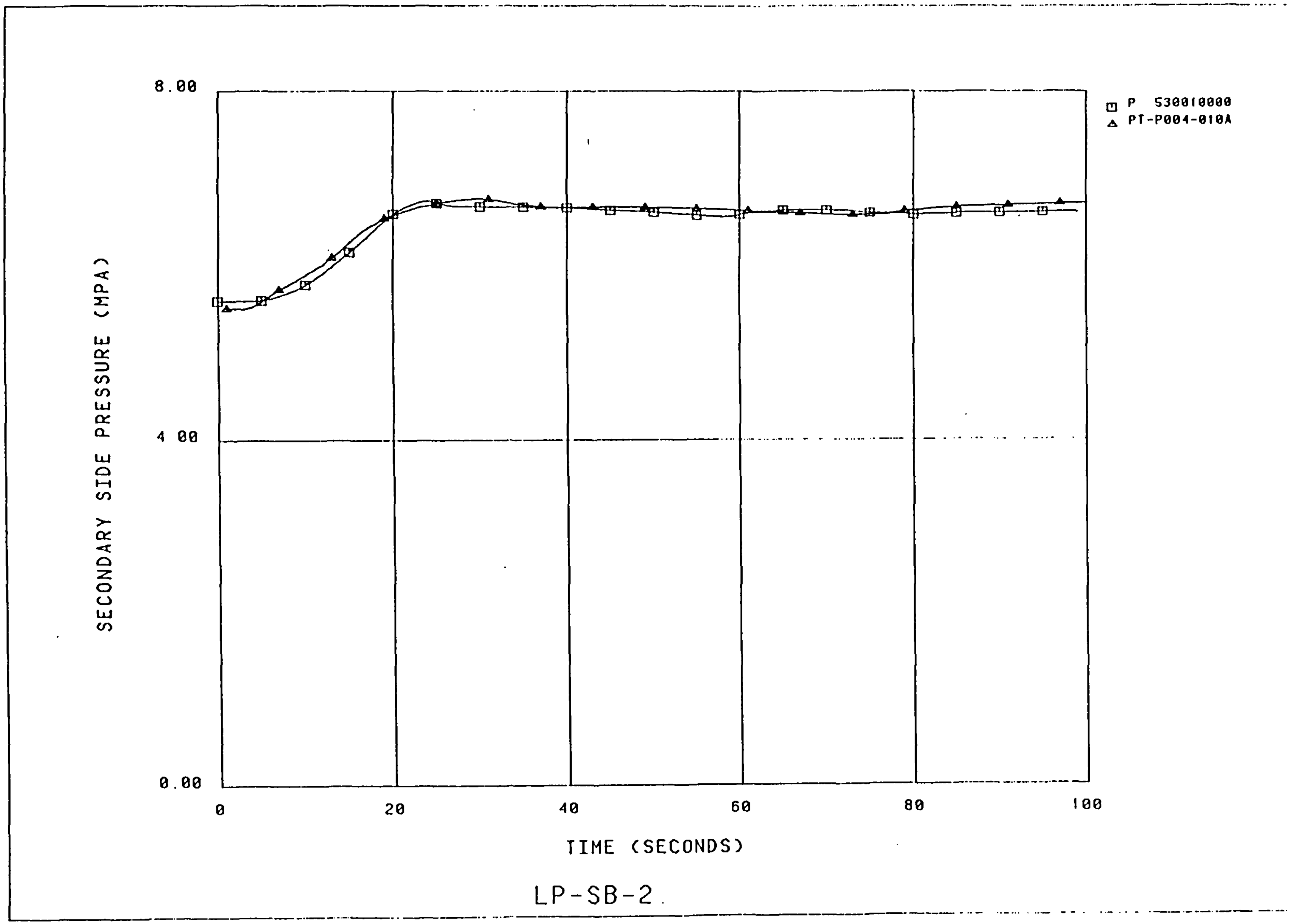
LP-SB-2.

FIG. 11


16.00
12.00
8.00
4.00
0.00
PRESSURE (MPA)
0
500
1000
1500
2000
2500
TIME (SECONDS)
P 100010000
P 530010000

LP-SB-2.

FIG 12



8.00
4.00
0.00
SECONDARY SIDE PRESSURE (MPA)
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PT-P004-010A
0
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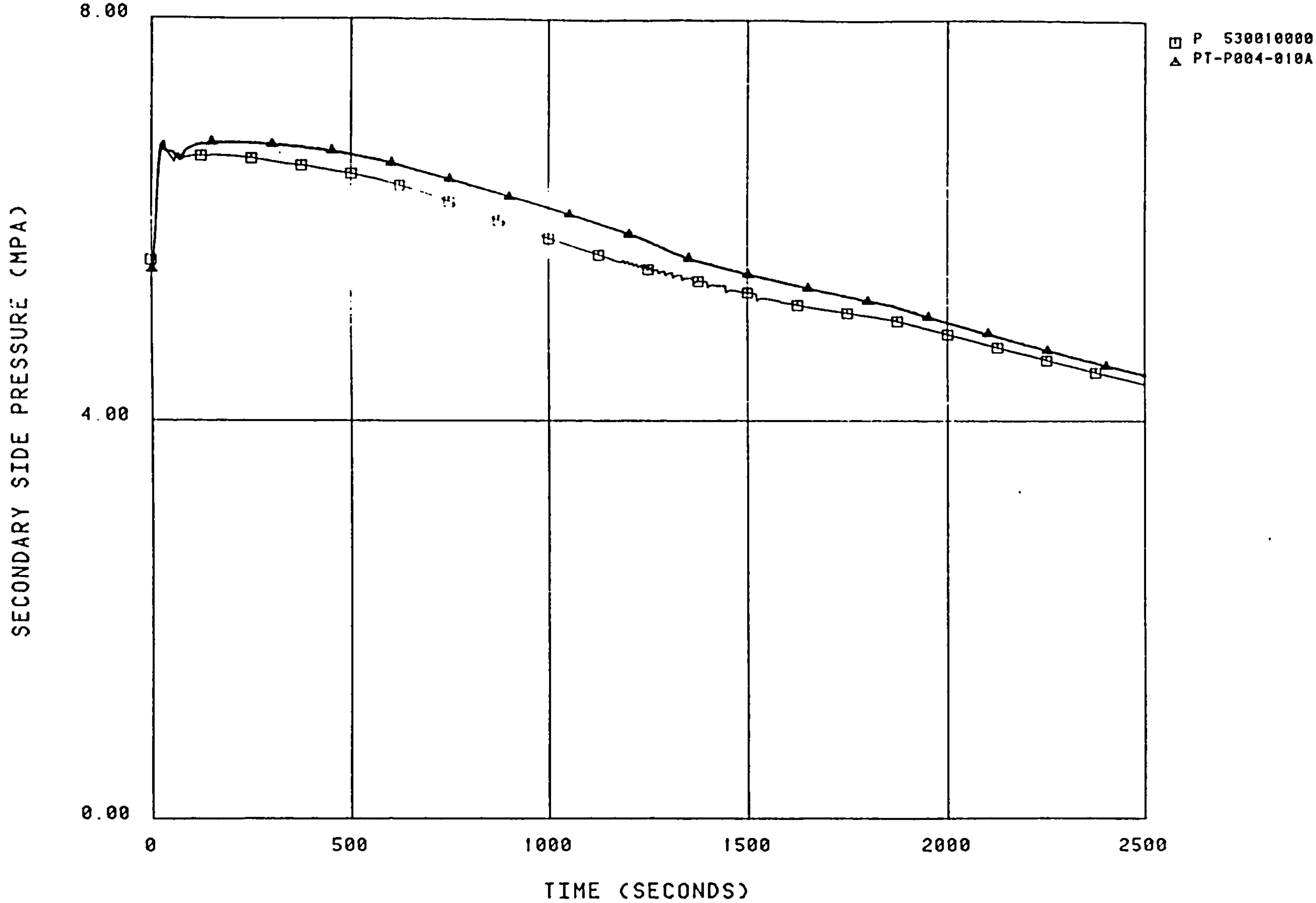
40
60
80
100
TIME (SECONDS)
LP-SB-2

FIG. 13


8.00
4.00
0.00
0
500
1000
1500
2000
2500
SECONDARY SIDE PRESSURE (MPA)
TIME (SECONDS)
P 530010000
PT-P004-010A

LP-SB-2

FIG. 14

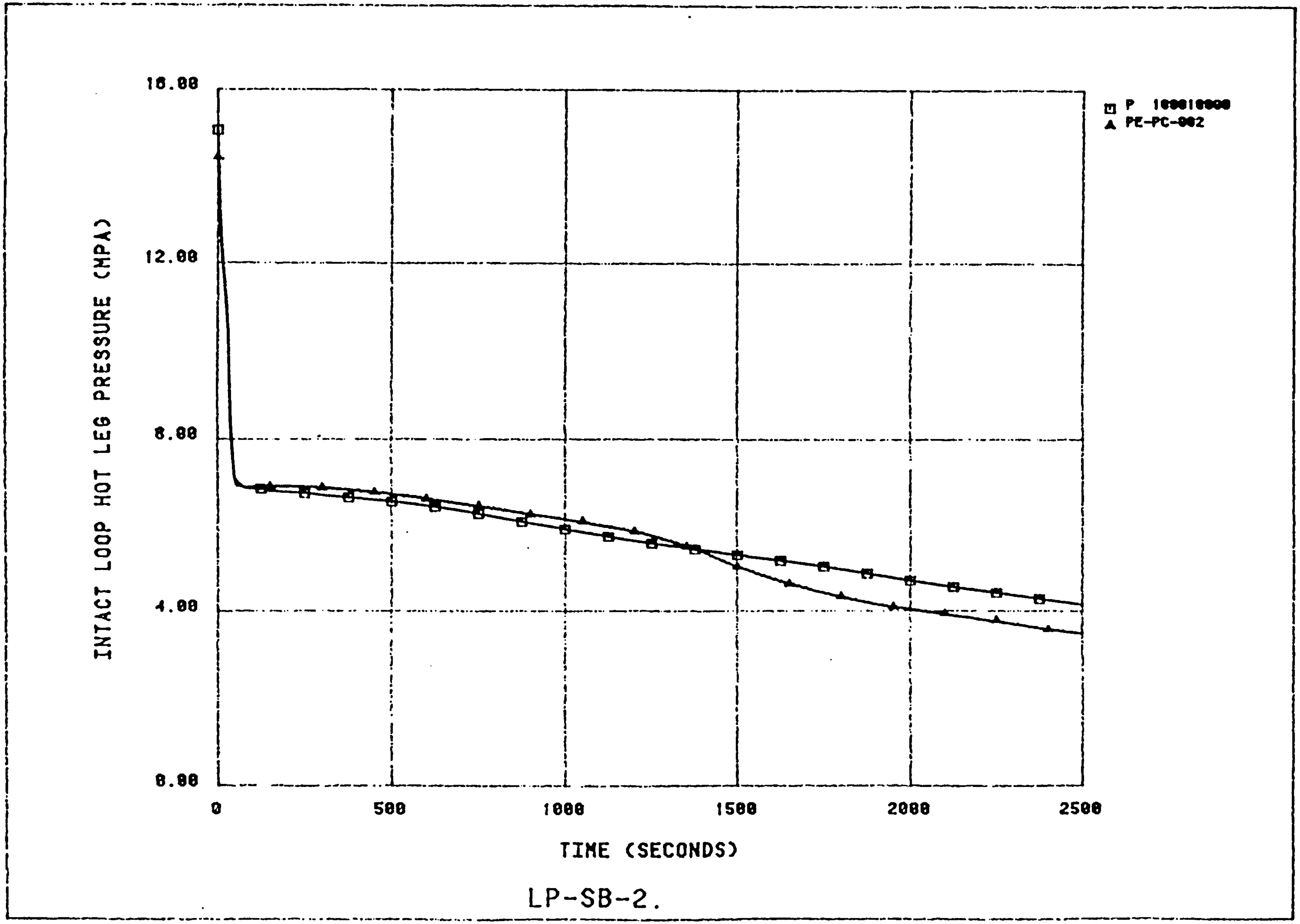
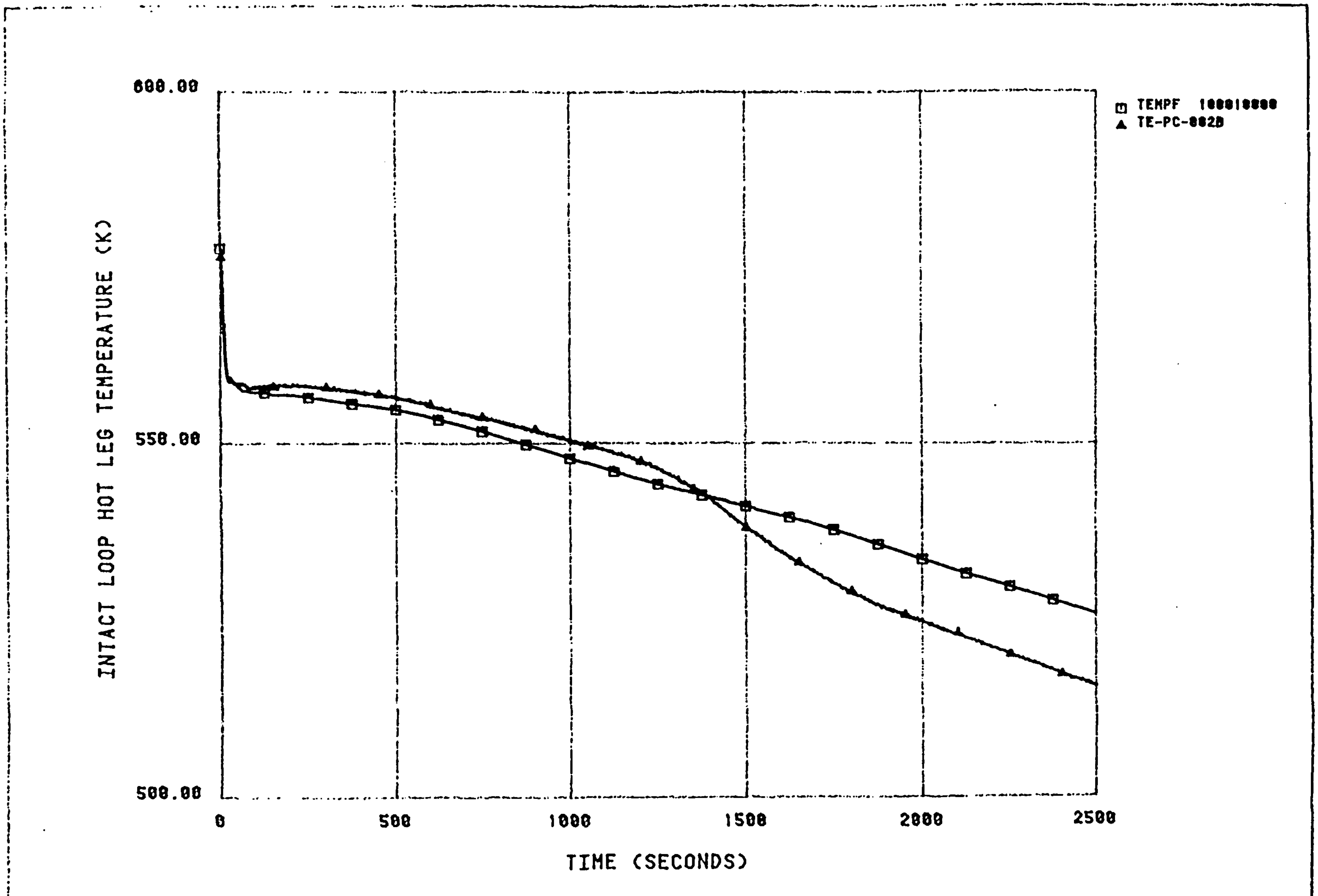
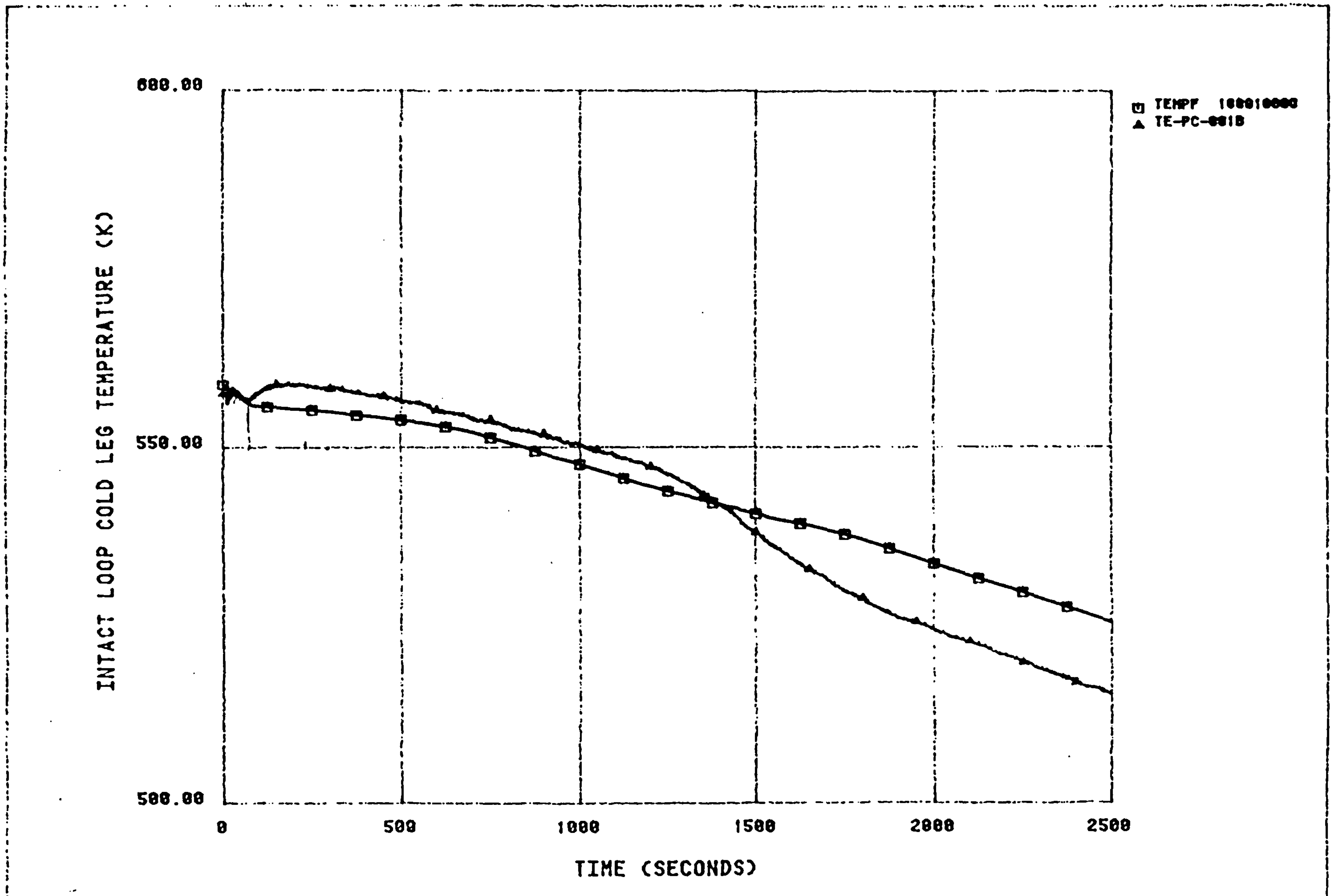

16.00
12.00
8.00
4.00
0.00
INTACT LOOP HOT LEG PRESSURE (MPA)
0
500
1000
1500
2000
2500
TIME (SECONDS)
P 100010000
PE-PC-002
LP-SB-2.

FIG. 15


600.00
550.00
500.00
INTACT LOOP HOT LEG TEMPERATURE (K)
0
500
1000
1500
2000
2500
TIME (SECONDS)
TEMPF 100010000
TE-PC-002B

LP-SB-2.

FIG. 16


600.00
550.00
500.00
INTACT LOOP COLD LEG TEMPERATURE (K)
0
500
1000
1500
2000
2500
TIME (SECONDS)
TEMPF 100010000
TE-PC-001B

LP-SB-2.

FIG. 17

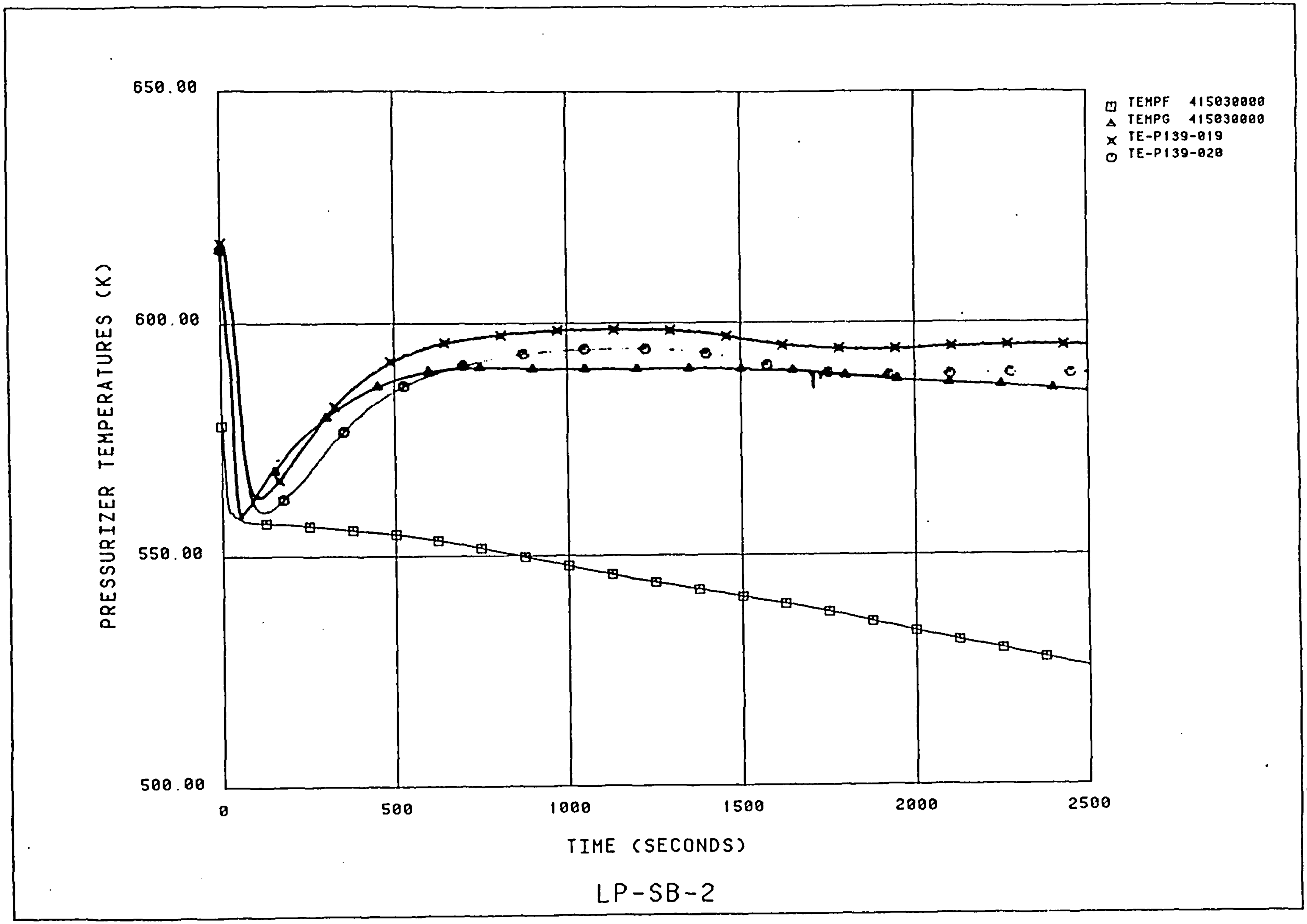
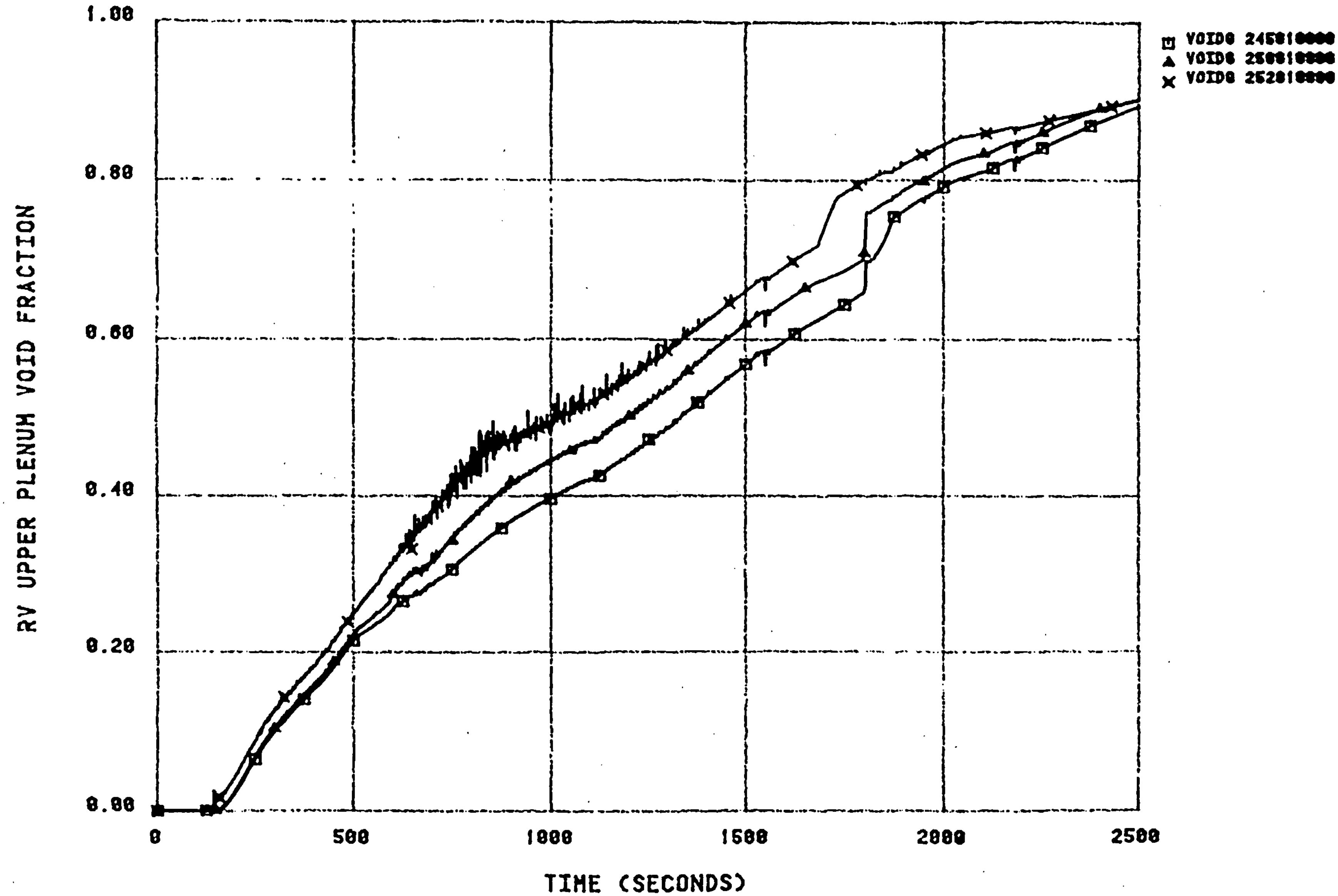
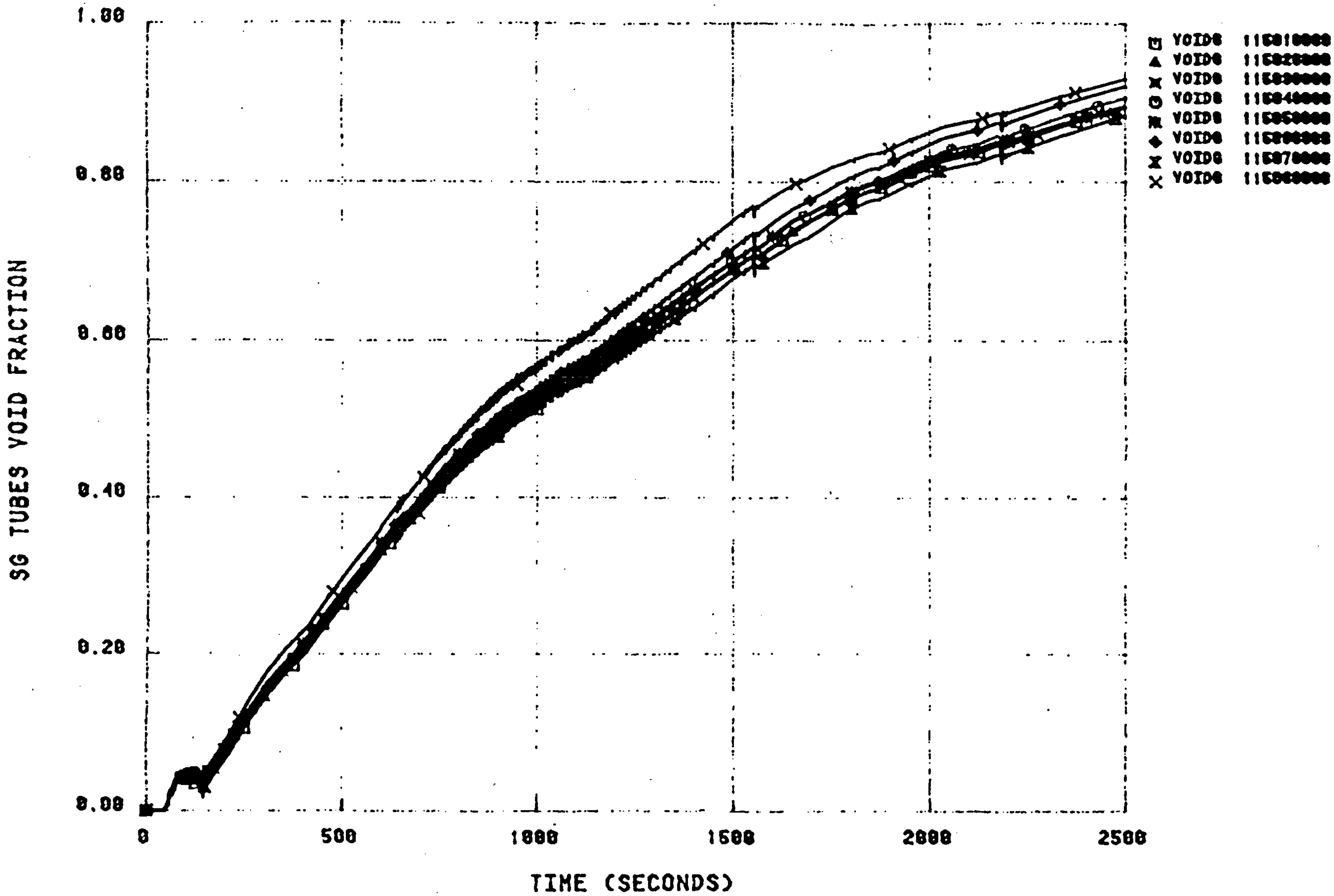

650.00
600.00
550.00
500.00
PRESSURIZER TEMPERATURES (K)
0
500
1000
1500
2000
2500
TIME (SECONDS)
TEMPF 415030000
TEMPG 415030000
TE-P139-019
TE-P139-020
LP-SB-2

FIG. 18


RV UPPER PLENUM VOID FRACTION
TIME (SECONDS)
1.00
0.80
0.60
0.40
0.20
0.00
0
500
1000
1500
2000
2500
VOIDG 245010000
VOIDG 250010000
VOIDG 252010000

LP-SB-2.

FIG. 19


SG TUBES VOID FRACTION
1.00
0.80
0.60
0.40
0.20
0.00
0
500
1000
1500
2000
2500
TIME (SECONDS)
VOIDG 115010000
VOIDG 115020000
VOIDG 115030000
VOIDG 115040000
VOIDG 115050000
VOIDG 115060000
VOIDG 115070000
VOIDG 115080000

LP-SB-2.

FIG. 2Ø

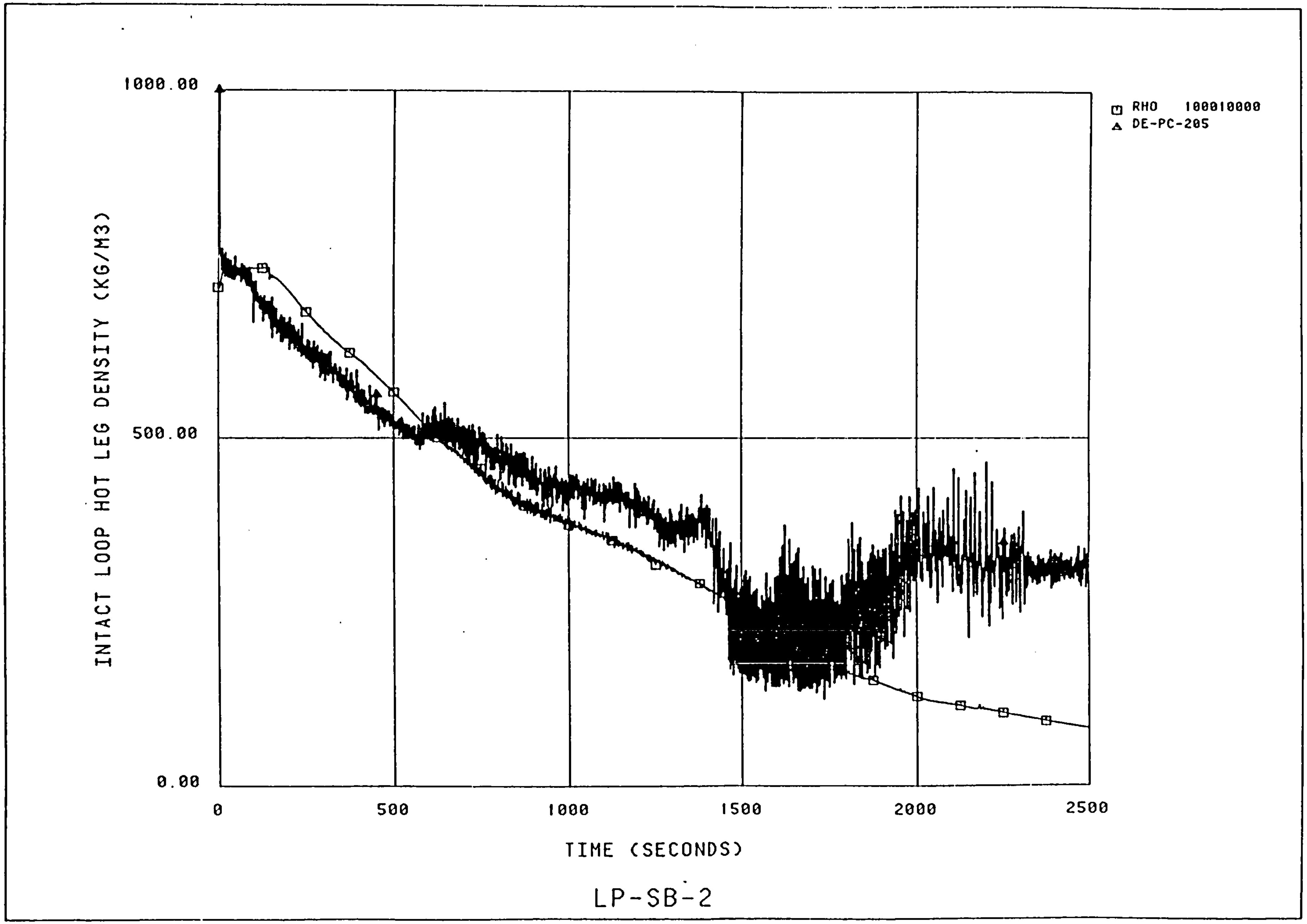

1000.00
500.00
0.00
0
500
1000
1500
2000
2500
INTACT LOOP HOT LEG DENSITY (KG/M3)
TIME (SECONDS)
RHO 100010000
DE-PC-205
LP-SB-2

FIG. 21

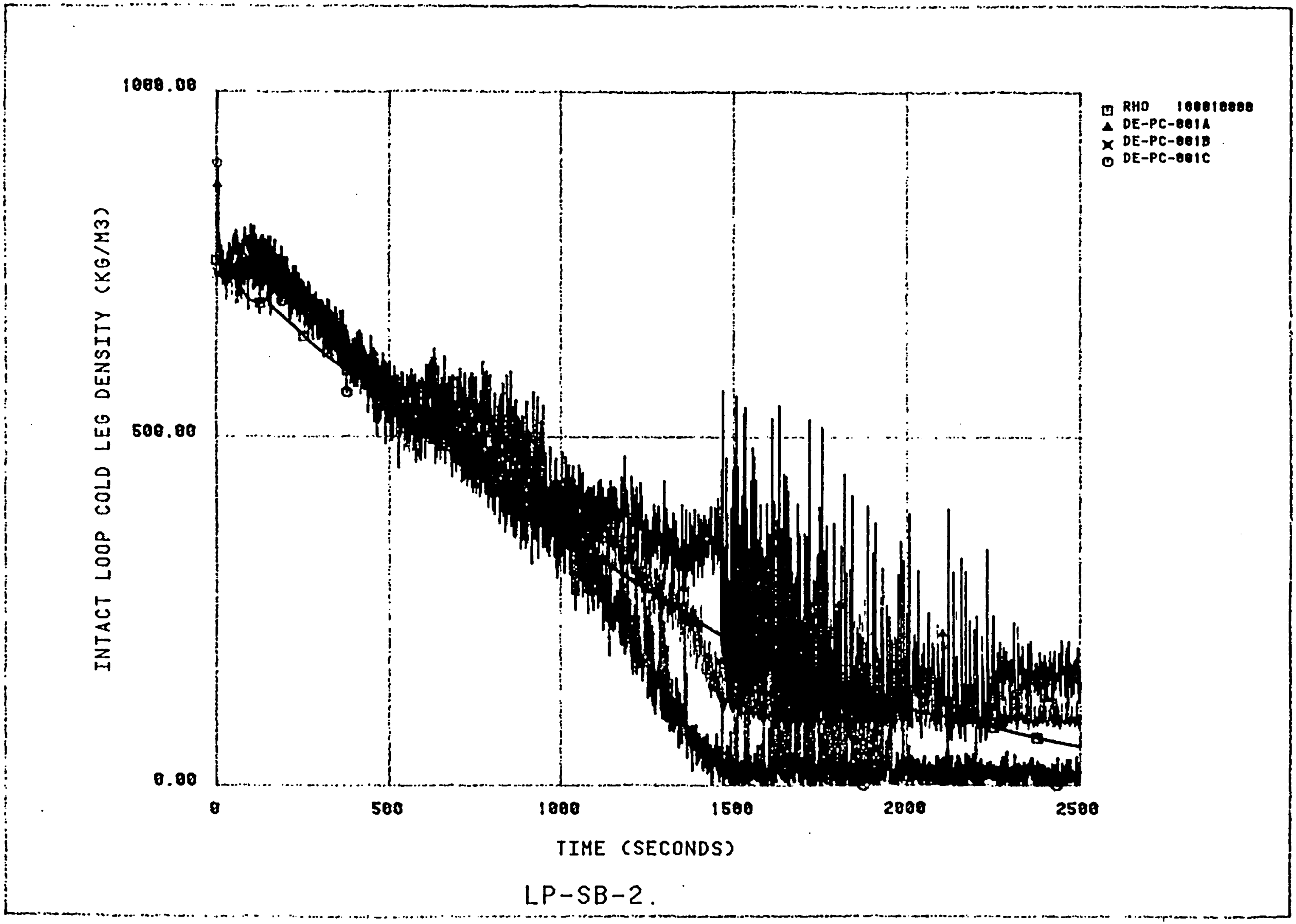
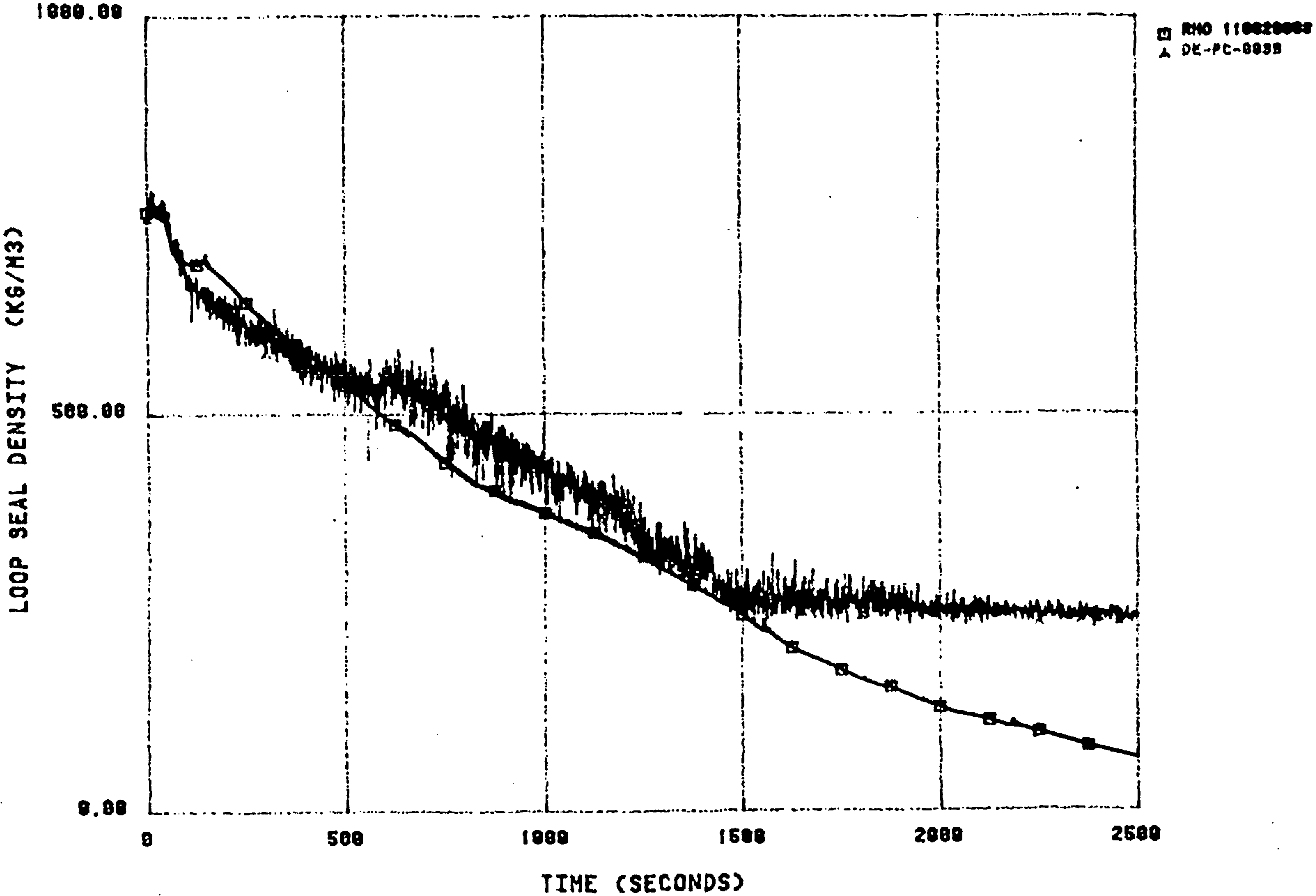

INTACT LOOP COLD LEG DENSITY (KG/M3)
1000.00
500.00
0.00
0
500
1000
1500
2000
2500
TIME (SECONDS)
RHO 100010000
DE-PC-001A
DE-PC-001B
DE-PC-001C
LP-SB-2.

FIG. 22


1000.00
500.00
0.00
LOOP SEAL DENSITY (KG/M3)
0
500
1000
1500
2000
2500
TIME (SECONDS)
RHO
DE-PC-003B

LP-SB-2.

FIG. 23

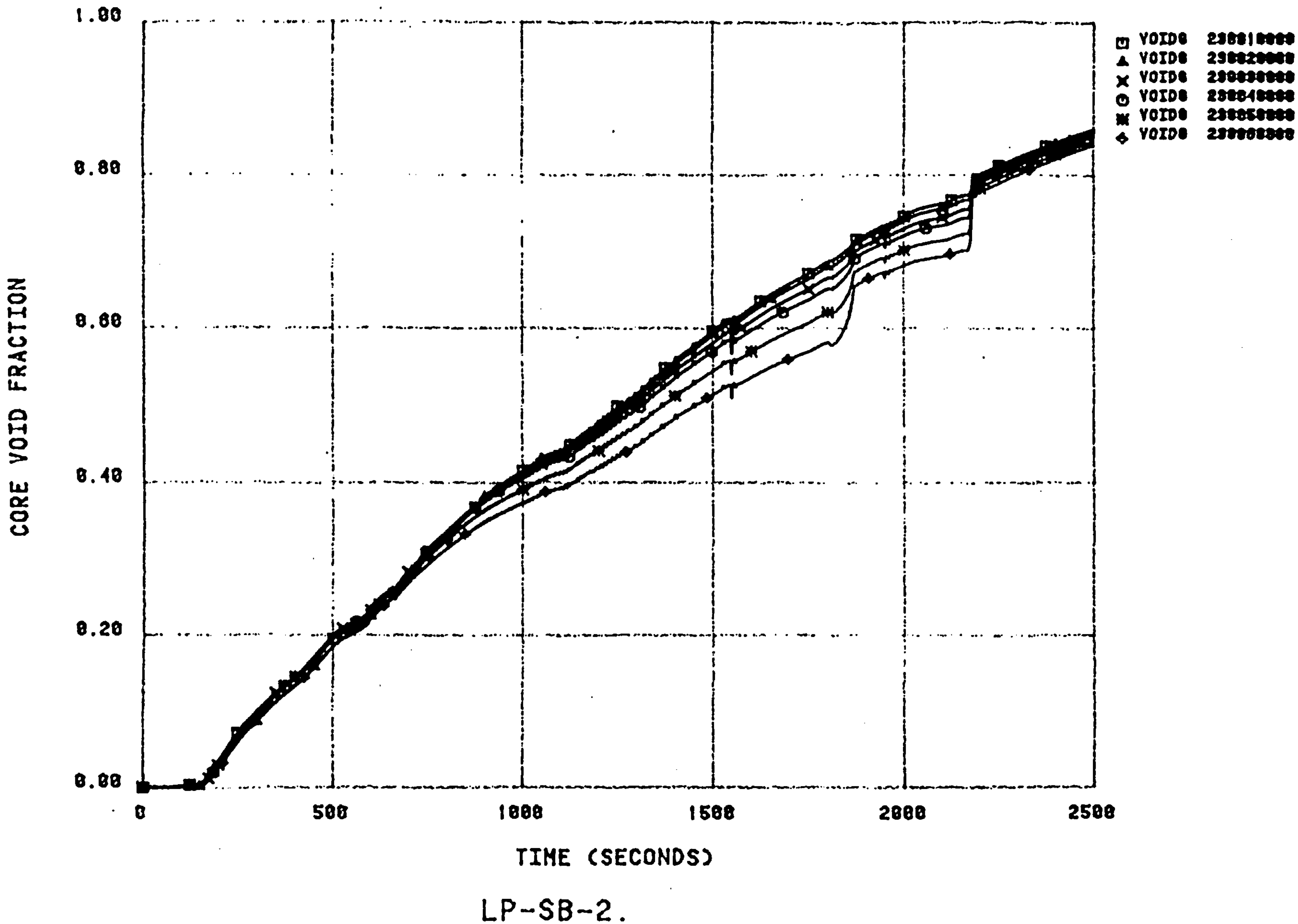

1.00
0.80
0.60
0.40
0.20
0.00
CORE VOID FRACTION
0
500
1000
1500
2000
2500
TIME (SECONDS)
VOIDG 230010000
VOIDG 230020000
VOIDG 230030000
VOIDG 230040000
VOIDG 230050000
VOIDG 230060000
LP-SB-2.

FIG. 24

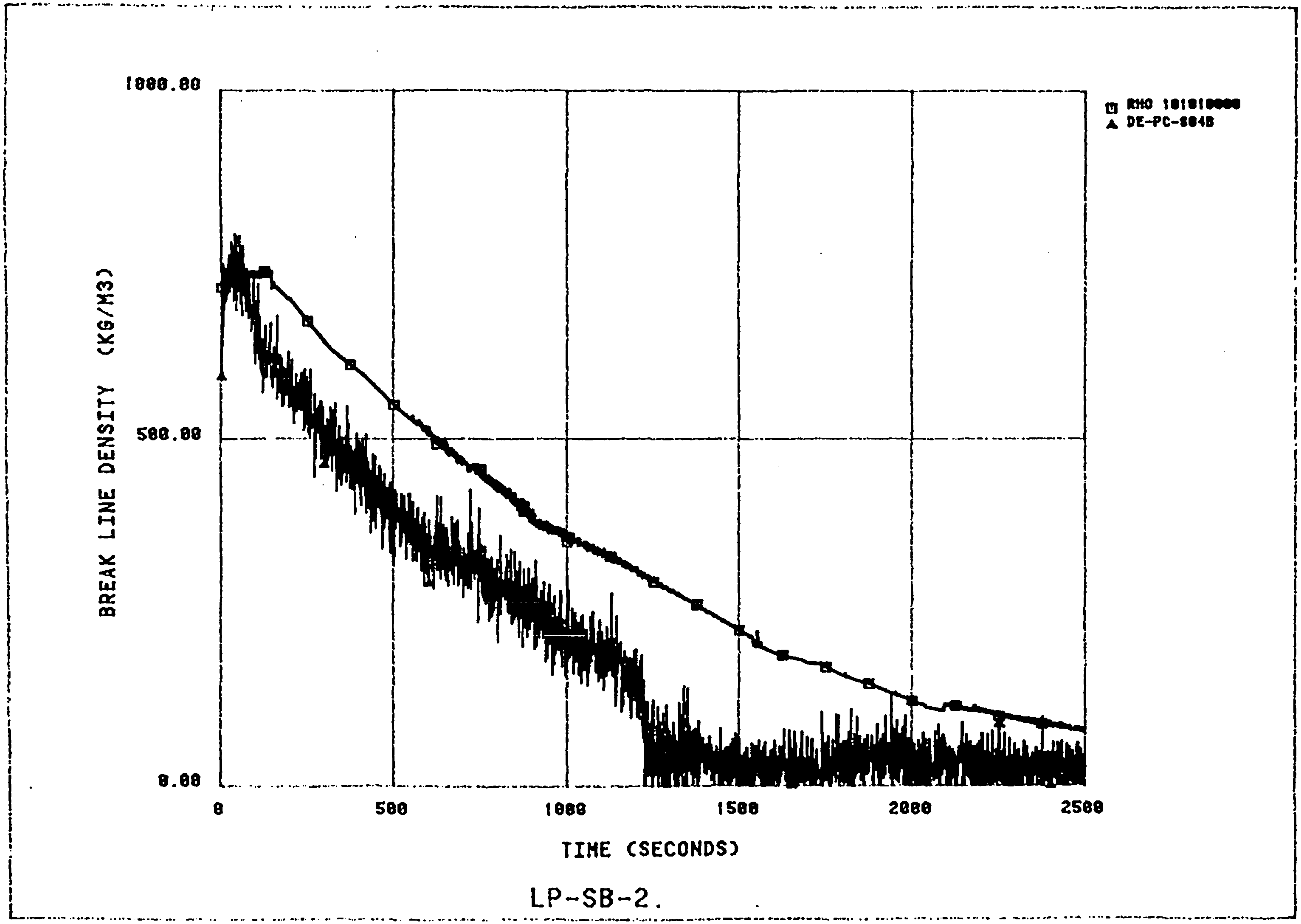

1000.00
500.00
0.00
0
500
1000
1500
2000
2500
BREAK LINE DENSITY (KG/M3)
TIME (SECONDS)
RHO 101010000
DE-PC-004B
LP-SB-2.

FIG. 25

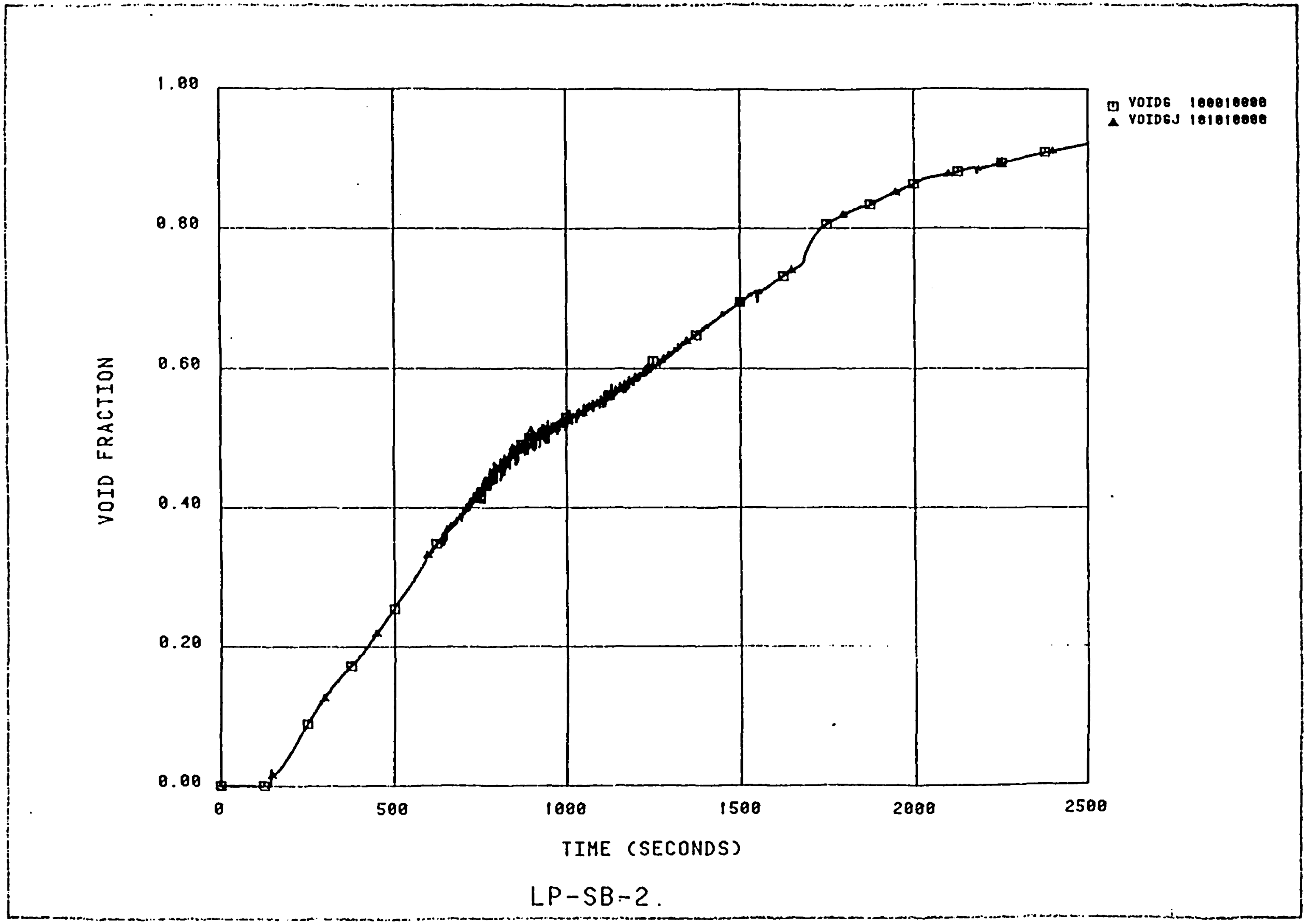
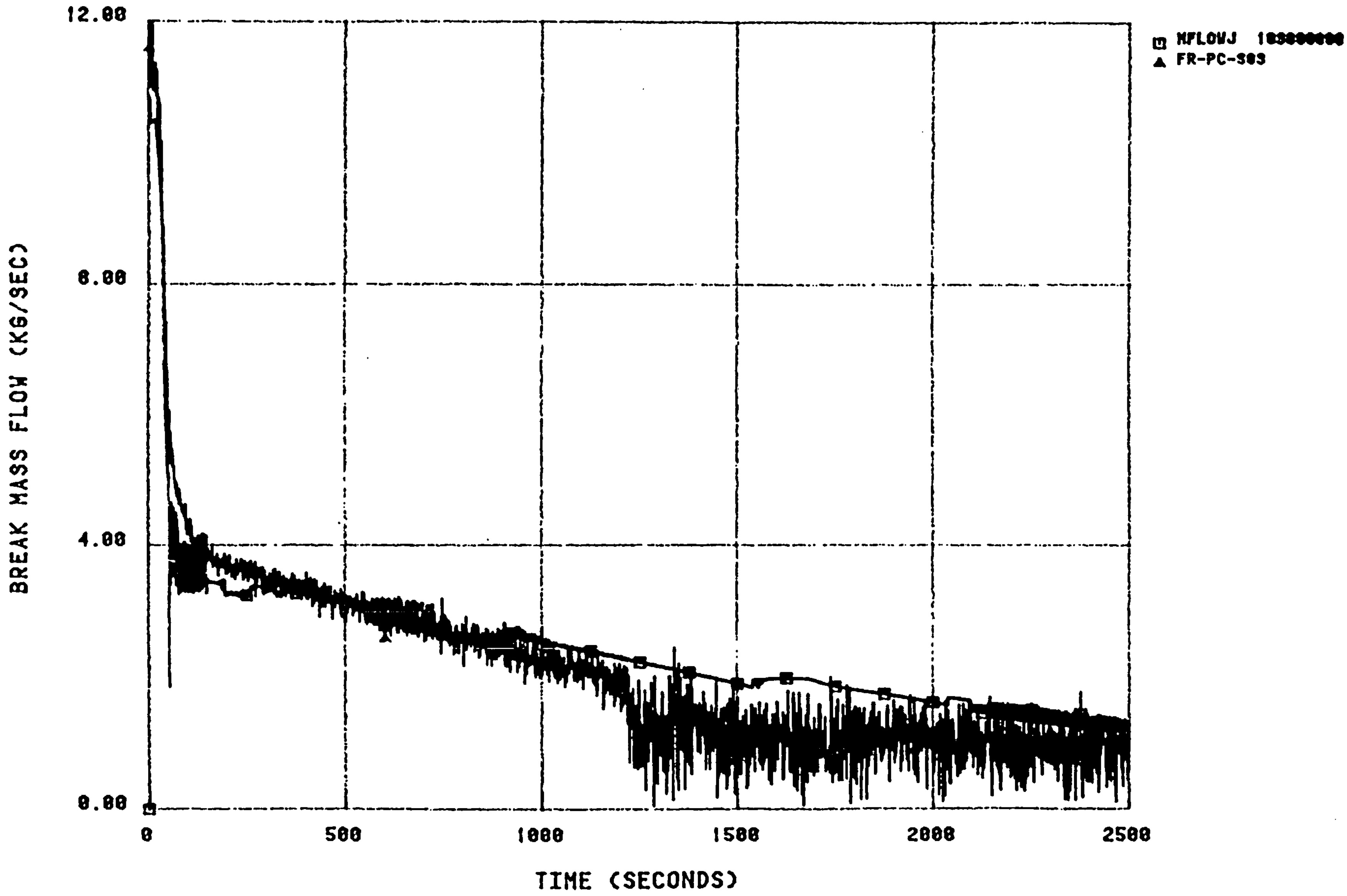
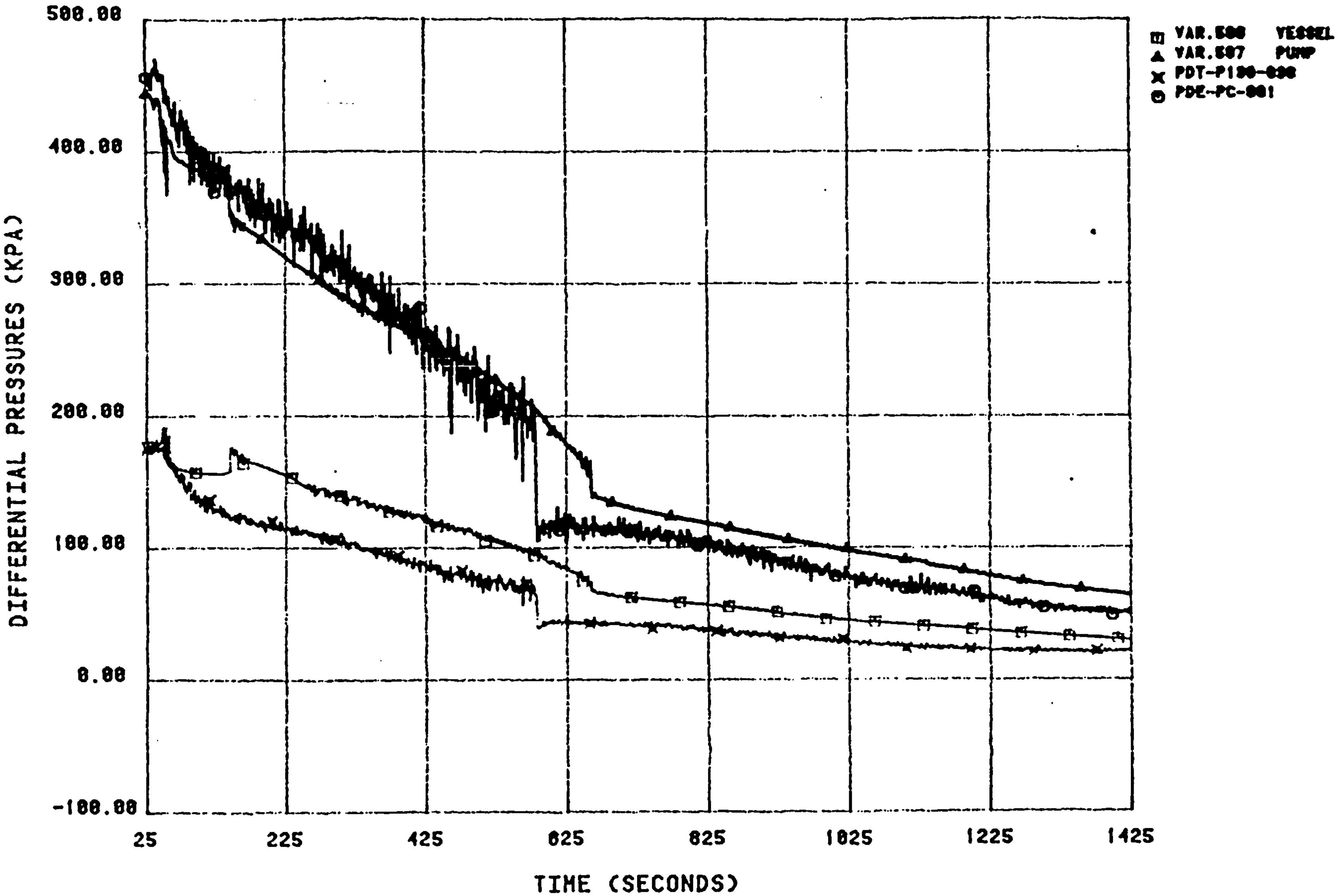

1.00
0.80
0.60
0.40
0.20
0.00
VOID FRACTION
0
500
1000
1500
2000
2500
TIME (SECONDS)
VOIDG 100010000
VOIDGJ 101010000
LP-SB-2.

FIG. 26


12.00
8.00
4.00
0.00
BREAK MASS FLOW (KG/SEC)
0
500
1000
1500
2000
2500
TIME (SECONDS)
MFLOWJ
FR-PC-303

LP-SB-2.

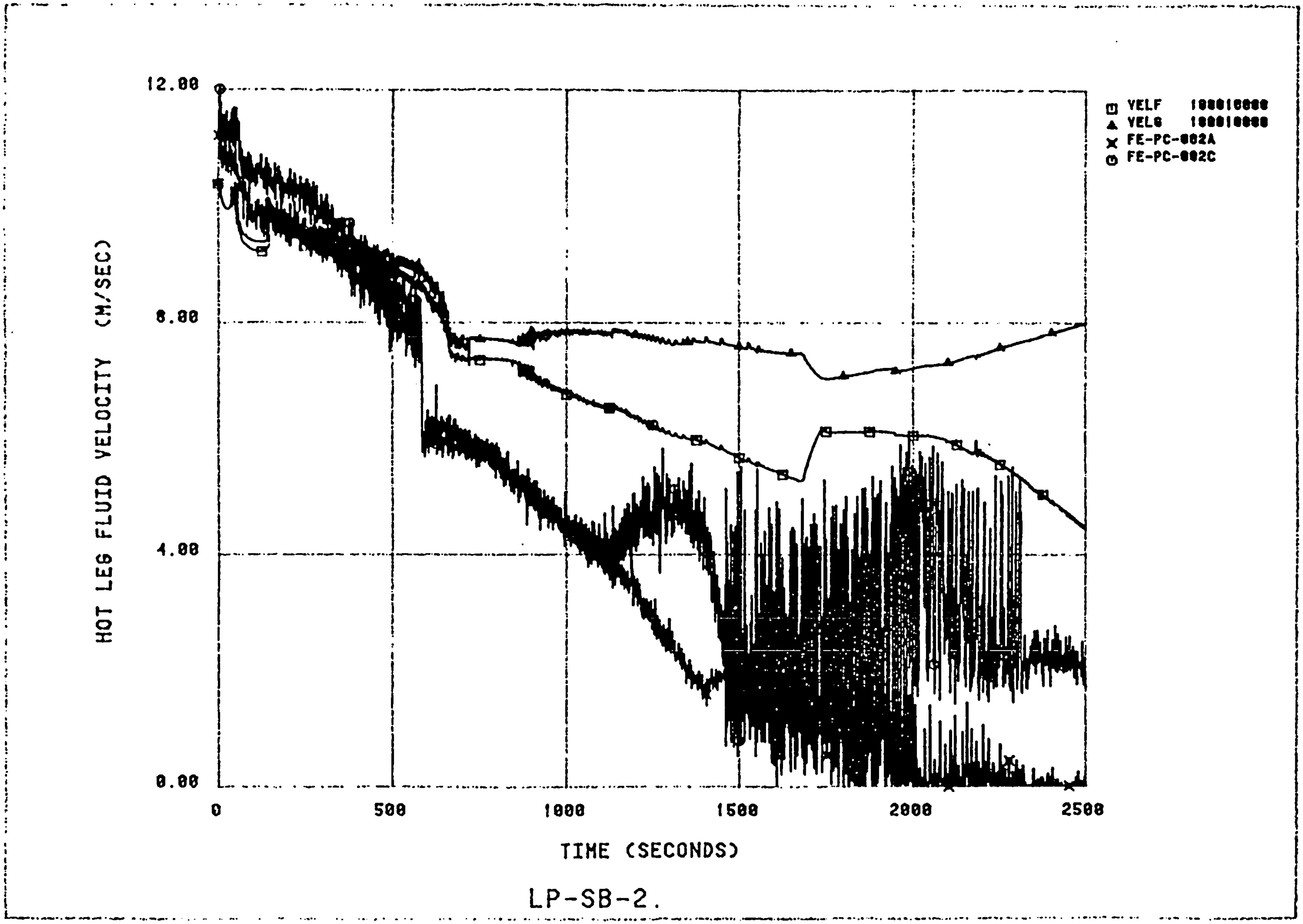
FIG. 27


500.00
400.00
300.00
200.00
100.00
0.00
-100.00
DIFFERENTIAL PRESSURES (KPA)
25
225
425
625
825
1025
1225
1425
TIME (SECONDS)
VESSEL
PUMP

LP-SB-2.

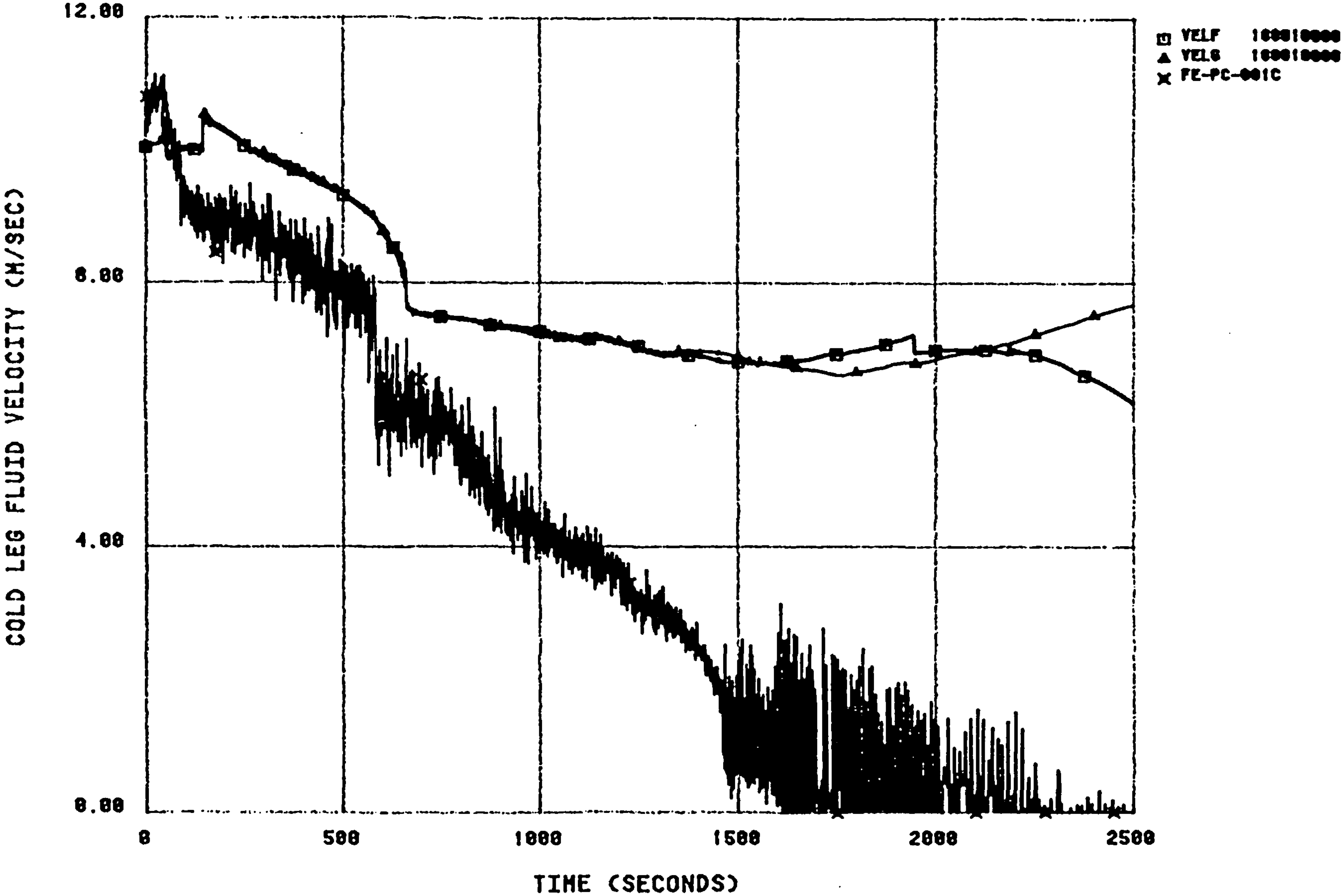
FIG. 28

Ø4



12.00
8.00
4.00
0.00
0
500
1000
1500
2000
2500
HOT LEG FLUID VELOCITY (M/SEC)
TIME (SECONDS)
VELF 100010000
VELG 100010000
FE-PC-002A
FE-PC-002C
LP-SB-2.

FIG. 29


12.00
8.00
4.00
0.00
COLD LEG FLUID VELOCITY (M/SEC)
0
500
1000
1500
2000
2500
TIME (SECONDS)
VELF 100010000
VELG 100010000
FE-PC-001C

LP-SB-2.

FIG. 30

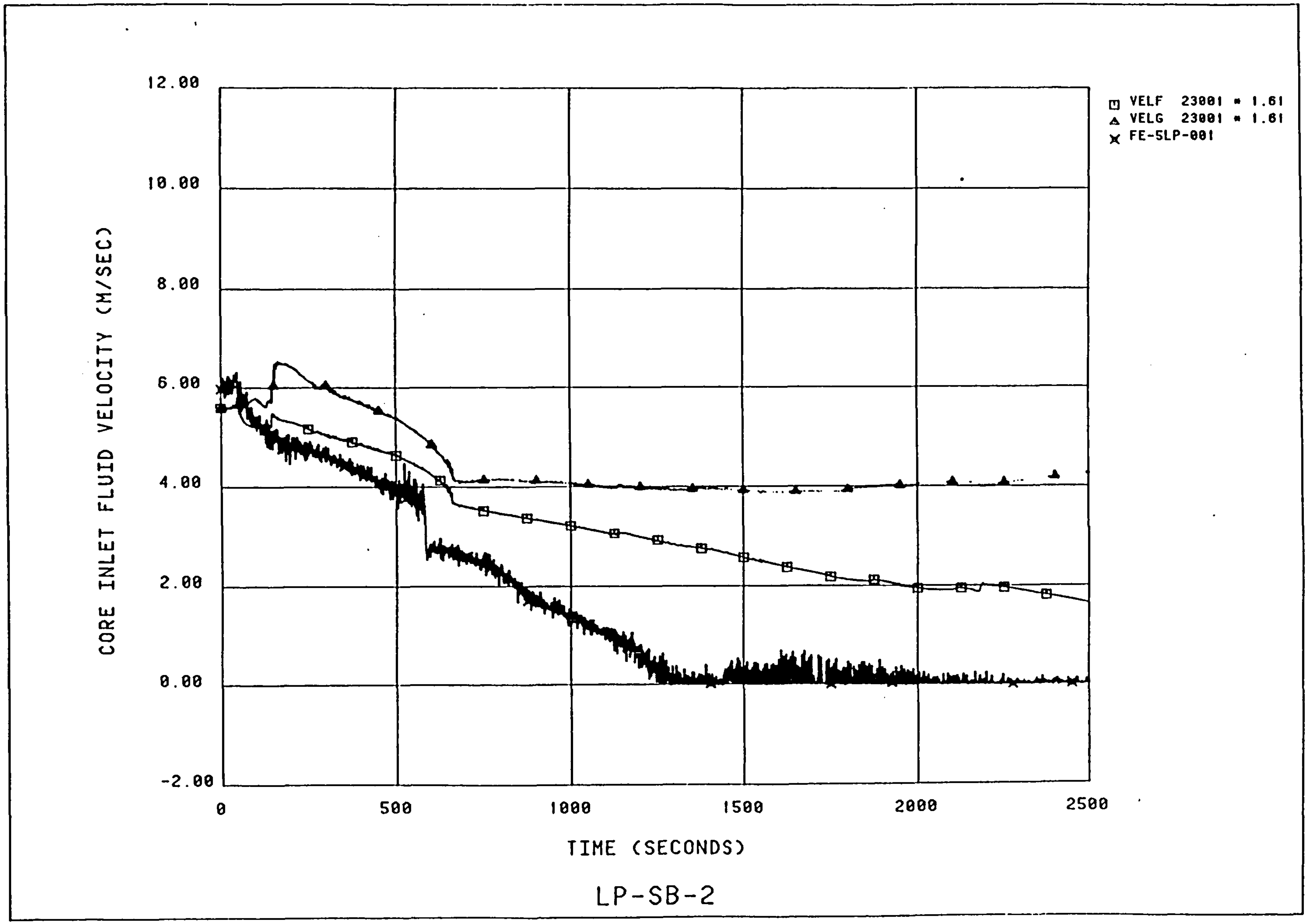

12.00
10.00
8.00
6.00
4.00
2.00
0.00
-2.00
CORE INLET FLUID VELOCITY (M/SEC)
0
500
1000
1500
2000
2500
TIME (SECONDS)
VELF 23001 * 1.61
VELG 23001 * 1.61
FE-5LP-001
LP-SB-2

FIG. 31

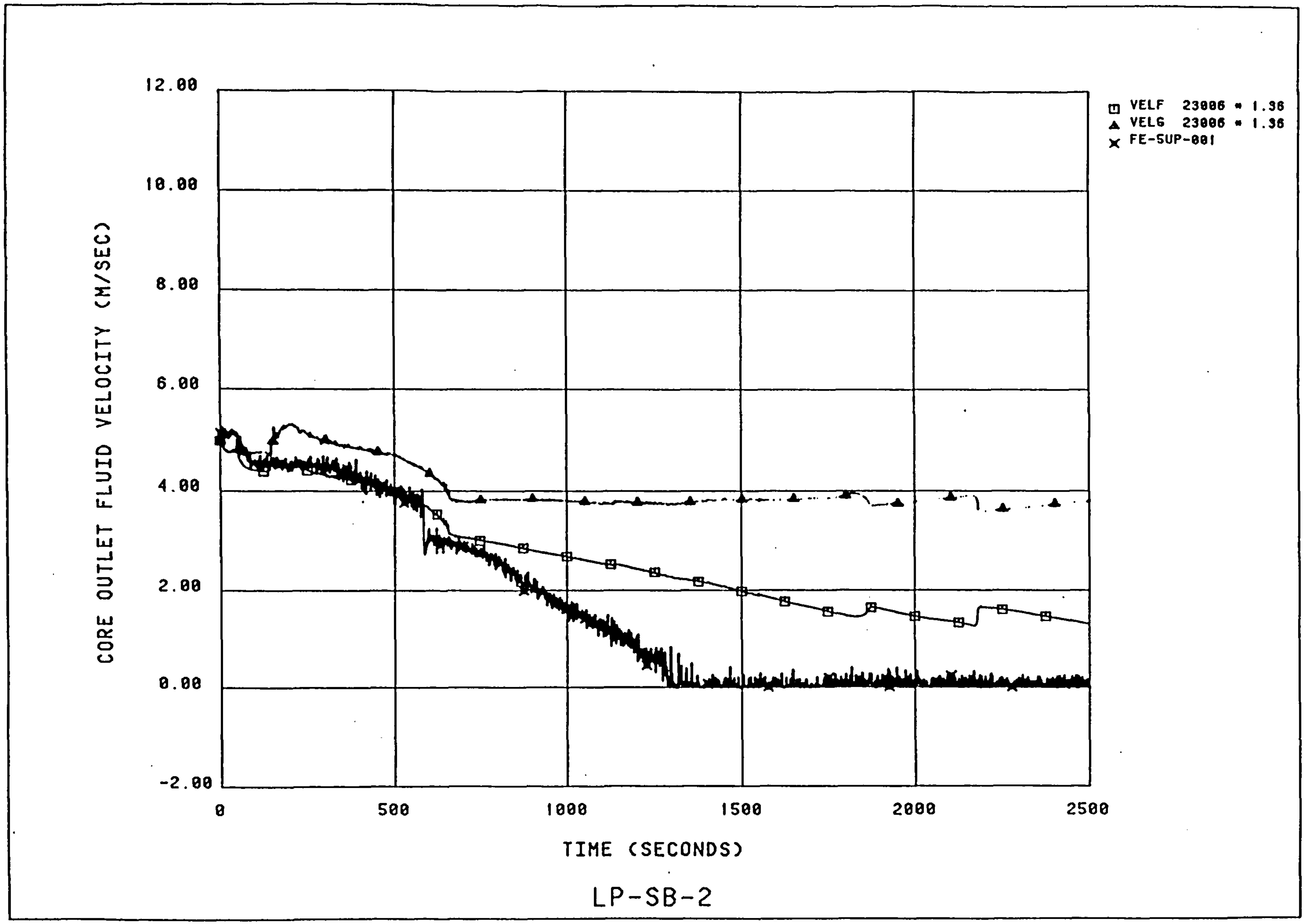

12.00
10.00
8.00
6.00
4.00
2.00
0.00
-2.00
CORE OUTLET FLUID VELOCITY (M/SEC)
0
500
1000
1500
2000
2500
TIME (SECONDS)
VELF 23006 * 1.36
VELG 23006 * 1.36
FE-SUP-001
LP-SB-2

FIG. 32

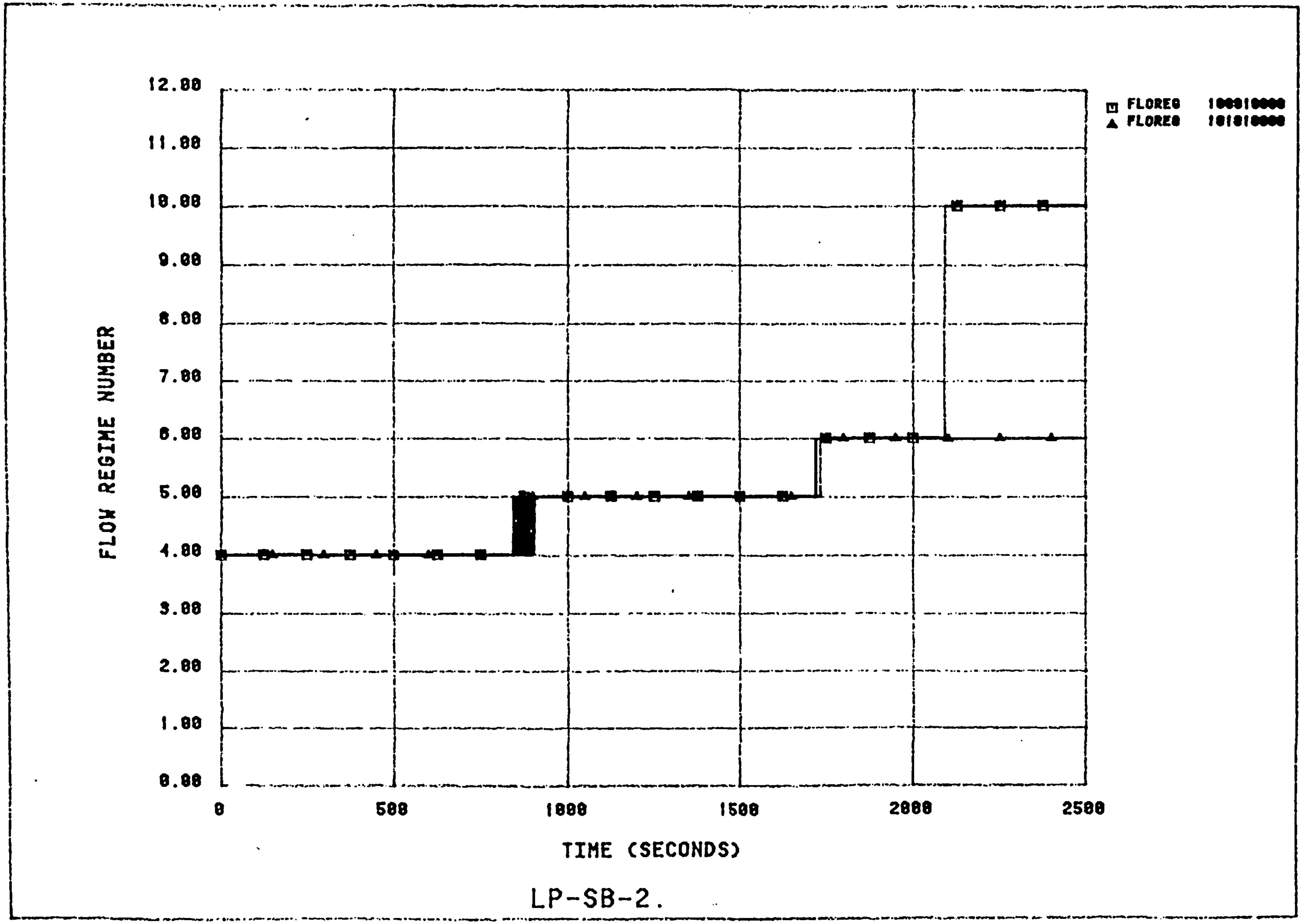

12.00
11.00
10.00
9.00
8.00
7.00
6.00
5.00
4.00
3.00
2.00
1.00
0.00
FLOW REGIME NUMBER
0
500
1000
1500
2000
2500
TIME (SECONDS)
FLOREG 100010000
FLOREG 101010000
LP-SB-2.

FIG. 33

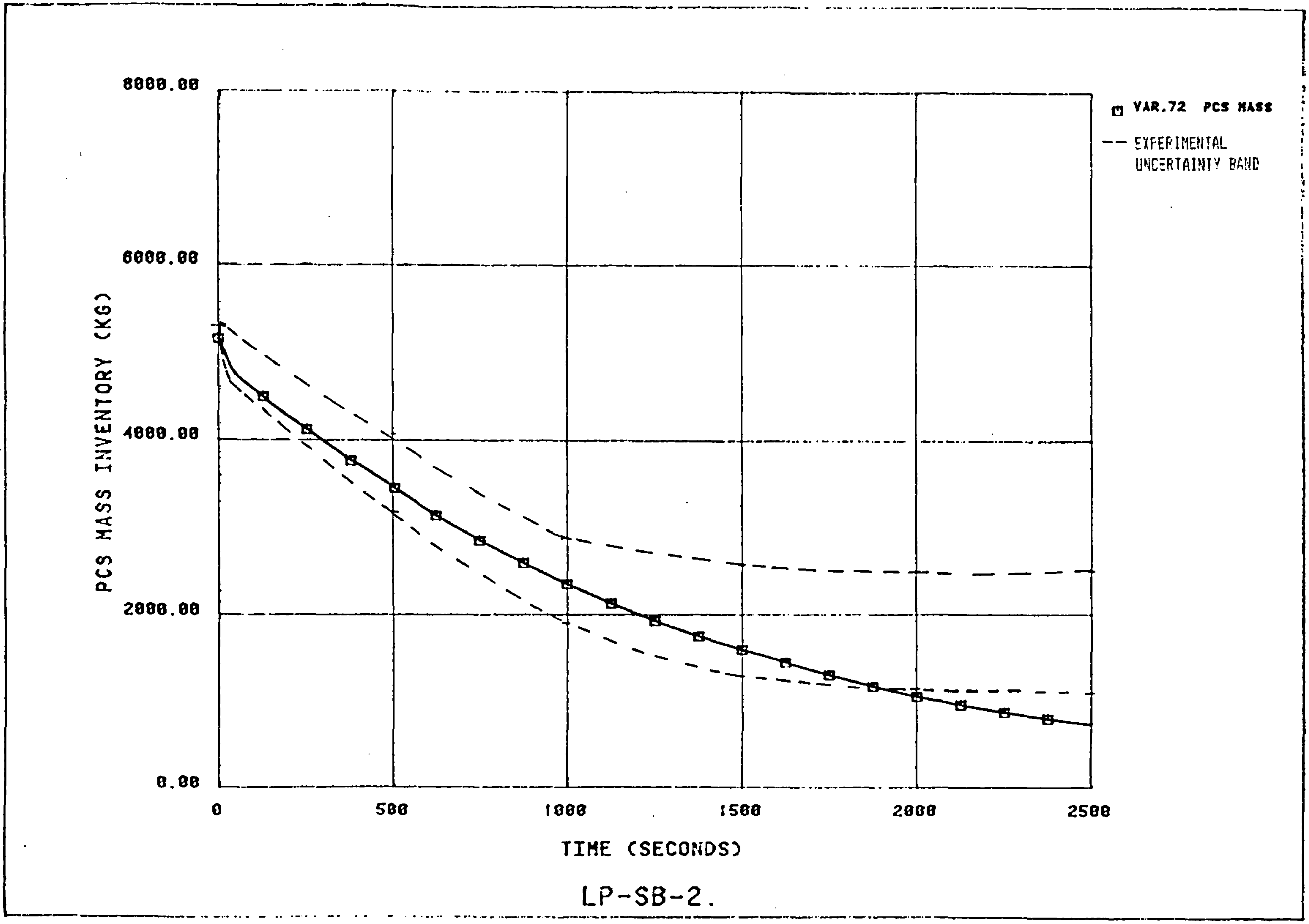

8000.00
6000.00
4000.00
2000.00
0.00
PCS MASS INVENTORY (KG)
0
500
1000
1500
2000
2500
TIME (SECONDS)
VAR.72 PCS MASS
EXPERIMENTAL UNCERTAINTY BAND
LP-SB-2.

FIG. 34

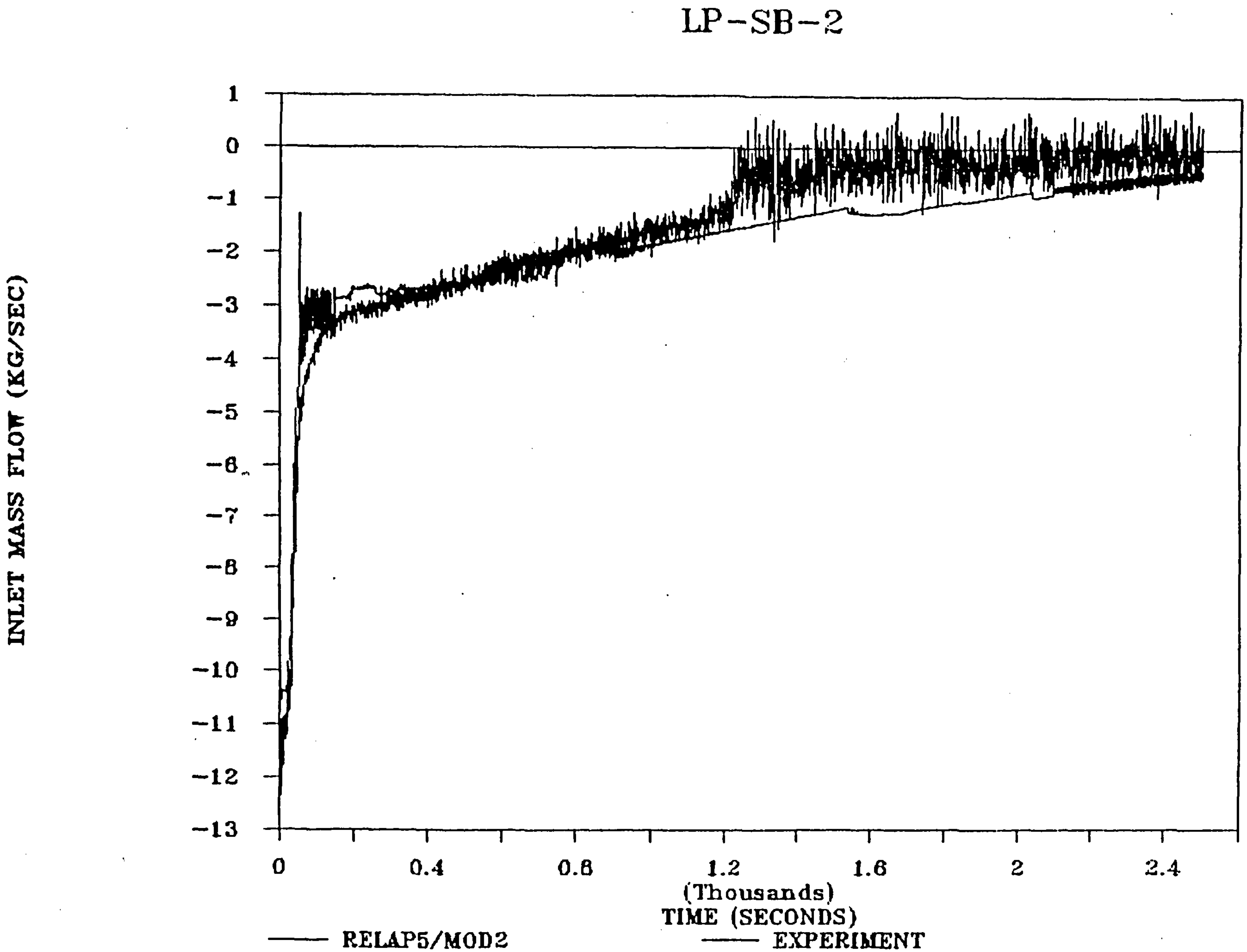
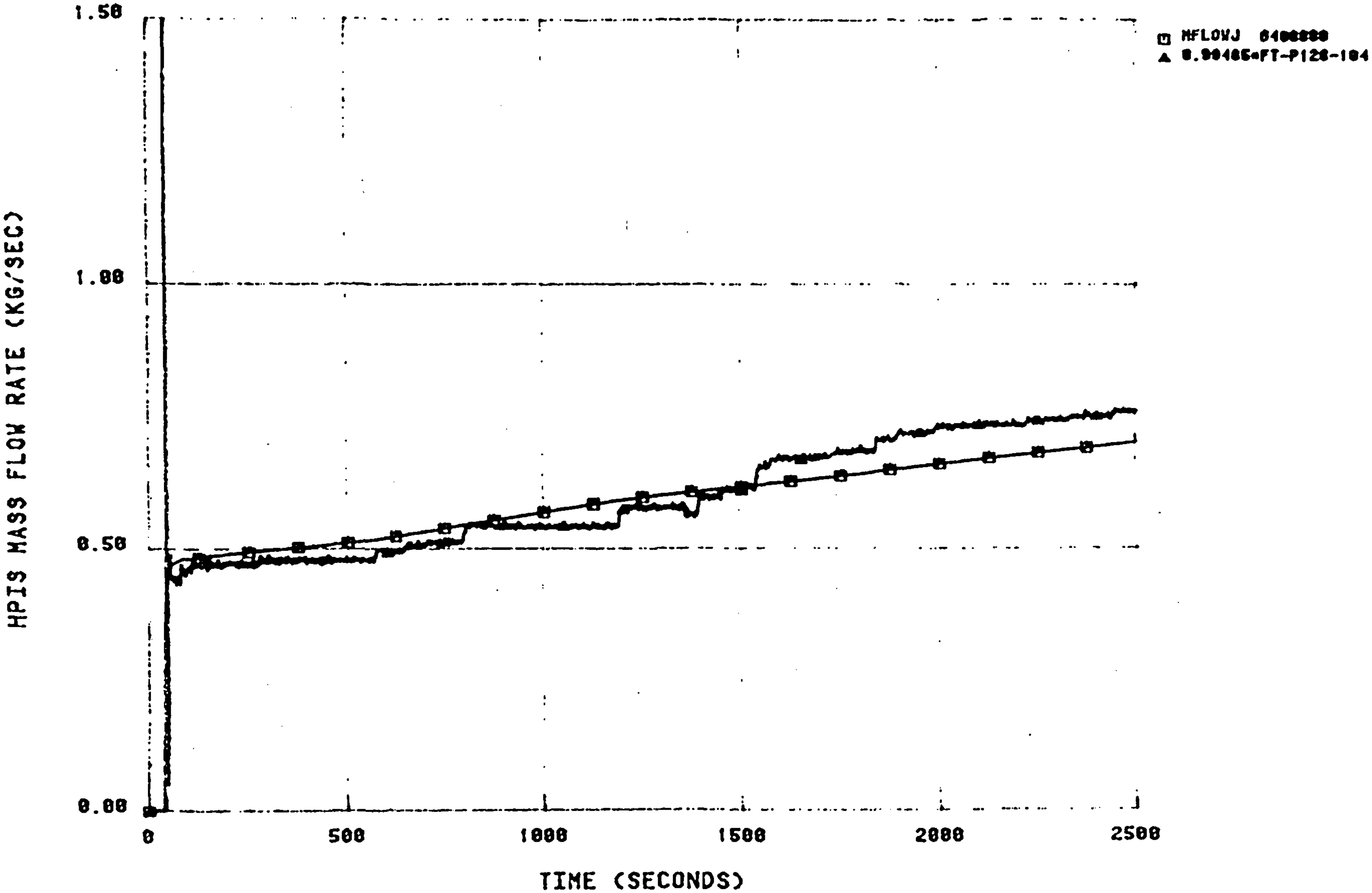

LP-SB-2
INLET MASS FLOW (KG/SEC)
1
0
-1
-2
-3
-4
-5
-6
-7
-8
-9
-10
-11
-12
-13
0
0.4
0.8
1.2
1.6
2
2.4
(Thousands)
TIME (SECONDS)
RELAP5/MOD2
EXPERIMENT

FIG. 35


MFLOWJ 0400000
0.90486*FT-P120-104
HPIS MASS FLOW RATE (KG/SEC)
1.50
1.00
0.50
0.00
0
500
1000
1500
2000
2500
TIME (SECONDS)

LP-SB-2.

FIG. 36

NRC FORM 335 (2-89) NRCM 1102, 3201, 3202

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(See instructions on the reverse)

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Washington, DC 20555

10. SUPPLEMENTARY NOTES

11. ABSTRACT (200 words or less)

This document presents the analysis of the OECD LOFT LP-SB-2 Experiment performed by the Consejo de Seguridad Nuclear of Spain working group making use of RELAP5/MOD2 in the frame of the Spanish LOFT Project. LB-SB-2 experiment studies the effect of a delayed pump trip in a small break LOCA scenario with a 3-inch equivalent diameter break in the hot leg of a commercial PWR.

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