Attachment to MFN 193-95

Pre-Test Analysis of the GIRAFFE System Interaction Tests: GS1-GS4

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1. Introduction

Pre-test analyses were performed using the TRACG code, to simulate the conditions of four tests to be conducted at the GIRAFFE facility (Ref. 1) by TOSHIBA Corporation at Kawasaki, Japan and predict the results of these tests. A schematic of the test facility is given in Figure 1. The model used in the TRACG simulations was originally developed by TOSHIBA and was extensively modified at GENE to represent the conditions of the System Interaction tests (SI tests). This set of calculations is part of a validation effort for the TRACG code for application with the SBWR.

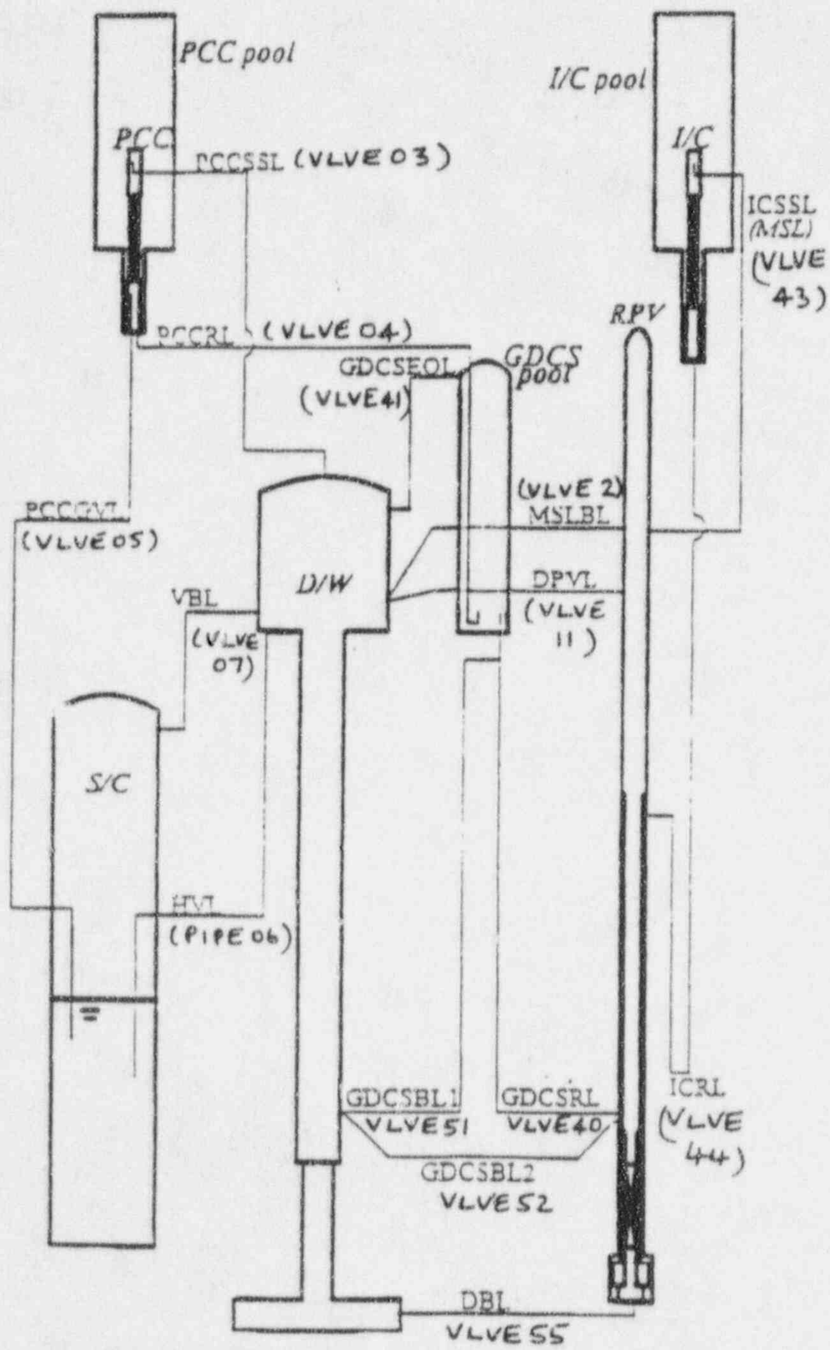
As described in the TAPD (Ref. 2), the test objective of the series of four SI Tests is to provide a data base to confirm the adequacy of TRACG to predict the SBWR ECCS performance during the late blowdown/early GDCS phase of a LOCA, with specific focus on potential systems interaction effects.

A series of four tests are planned and will have initial conditions approximately 10 minutes post-LOCA. The duration of the tests will be approximately 2 hours. The containment related parameters will be based on the corresponding SBWR TRACG LOCA case at the time the RPV pressure is 1.034 MPa. The basis for the tests is described in the TAPD (Ref 2,Table A.3-23). A brief description of each test is given below:

1. Test GS1, the base case, is a GDCS line break with one DPV failure and no PCC or IC operation. This set of test conditions resulted in the lowest predicted chimney level.

2. Test GS2 is the same as GS1 except that the PCC and IC are operational during the test. Test results can be compared with GS1 for potential systems interactions associated with the IC and PCC.

FIGURE 1



- **PCCSSL**
  PCC Steam Supply Line
  D/W top - PCC Steam Box
- **PCCRL**
  PCC Drain Water Return Line
  PCC Water Box - GDCS pool
  with U-tube
- **PCCGVL**
  PCC Gas Vent Line
  PCC Water Box - S/C
- **GDCSRL**
  GDCS Drain Return Line
  GDCS pool - RPV
- **GDCSEQL**
  GDCS - D/W Pressure
  Equalizing Line
  GDCS pool - D/W
- **MSLBL**
  Main Steam Line Break Line
  RPV - D/W
- **DPVL**
  DePressurization Valve Line
  RPV - D/W
- **HVL**
  LOCA(Main) Vent Line
  (Horizontal Vent Line
  D/W - S/C
- **VBL**
  Vacuum Breaker Line
  S/C - D/W
- **ICSSL**
  I/C Steam Supply Line
  RPV - I/C Steam Box (MSL)
- **ICRL**
  I/C Drain Water Return Line
  I/C Water Box - GDCS pool
  with U-tube
- **GDCSBL1**
  GDCSL Break Line
  GDCS pool - D/W
- **GDCSBL2**
  GDCSL Break Line
  RPV - D/W
- **DBL**
  Bottom Drain Break Line
  RPV bottom - D/W

3. Test GS3 is a bottom drain line break with a single DPV failure. Here again the IC and PCC will be operational. This test would represent the case with the fastest water level recovery.

4. Test GS4 is a GDCS break with a failure occurring in a GDCS valve in one of the other two GDCS lines. The IC and PCC will be operational in this case as well. This test is expected to give the slowest rate of recovery of the chimney swollen level.

2. TRACG Model

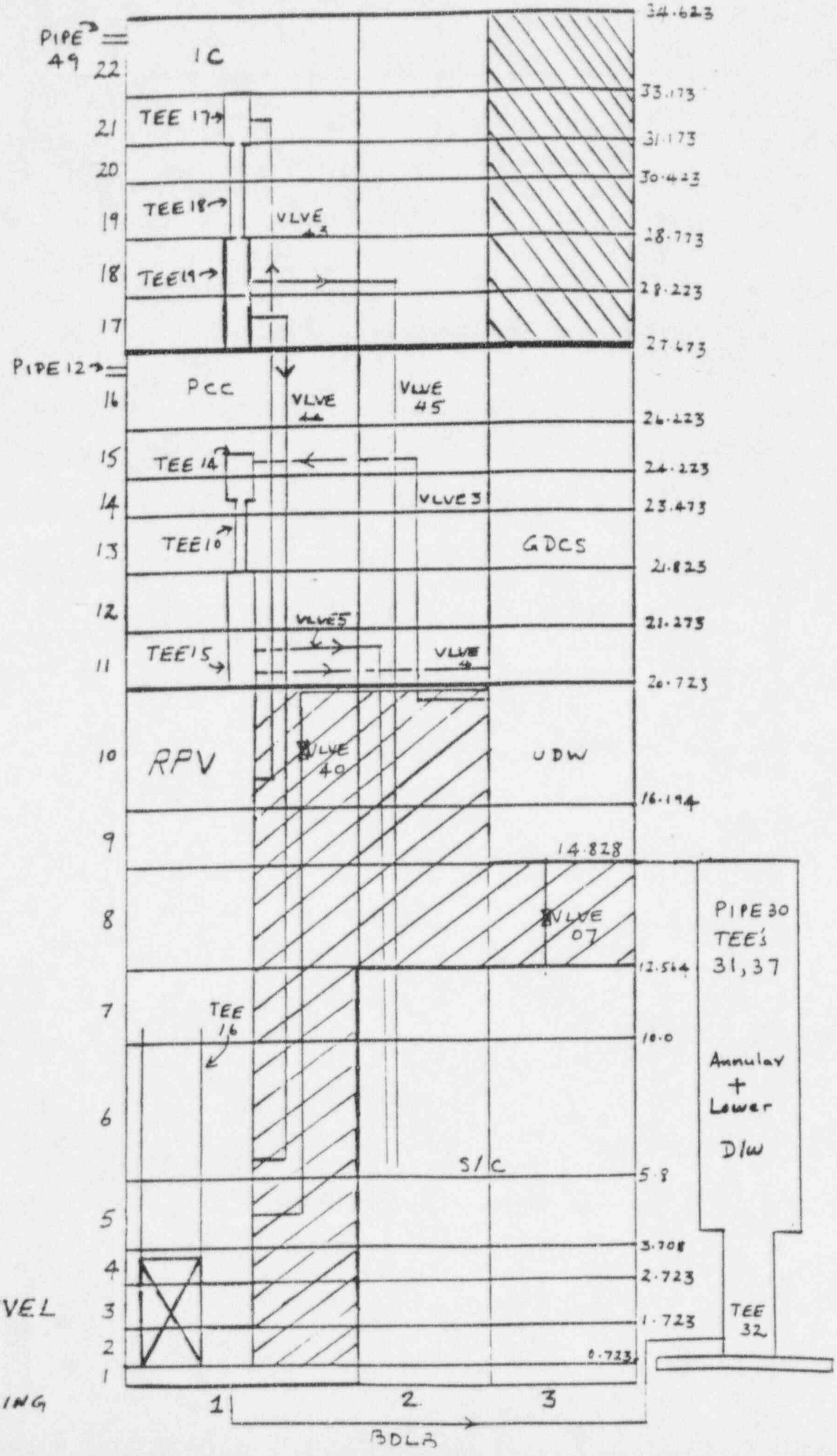
The TRACG model consists principally of a three dimensional component, known as the VSSL (vessel) component. Various parts of this component contain the models for the Reactor Pressure Vessel (RPV), the Suppression Chamber(SC), the Upper Dry Well (UDW), the GDCS pool, the PCC pool and the IC pool. The remainder of the components including the Annular and Lower Dry Well are modeled using one dimensional components. A schematic of the nodalization of the VSSL component is presented in Figure 2.
A list of 1-D components, consisting of VLVEs(valves), PIPEs and TEEs is given in Table 1. The differences between the SBWR nodalization and the GIRAFFE nodalization are presented in the next section.

2.1 3-D Vessel Component

The VSSL has 22 levels (axial divisions), 3 rings (radial divisions) and one azimuthal sector. This essentially represents three isolated 3-D regions: levels 1-10, levels 11-16 and levels 17-22. The true physical differences in the elevation of these three regions are determined by the heights of the 1-D components that connect them. Within the first 3-D region, ring 1 represents the RPV. The SC is represented by levels 1 through 7 in rings 2 and 3. The UDW is represented by levels 9 and 10 in ring 3. In the second 3-D region, levels 11 through 16 in ring 3 represent the GDCS pool. The PCC pool occupies rings 1 and 2 and levels 11 through 16. The IC pool occupies the third 3-D region and consisting of levels 17 through 22. The remainder of the space in the VSSL component is not used. Heat transfer to the ambient is possible in TRACG only from the outermost ring and thus the SC, UDW and GDCS pool all have heat losses to the ambient modeled with double-sided heat slabs. In the RPV, the walls are represented by lumped heat slabs.

2.2 RPV Internals

The RPV portion of the vessel contains three 1-D components to represent the channel, guide tube and bypass regions (GTBP) and the chimney. TRACG allows for a special 1-D component (actually a TEE component) to represent a fuel bundle and the present model represents the heater rod assembly by CHAN08. There are five cells in the channel component. The GIRAFFE RPV internals are shown schematically in Figure 3. The GTBP is modeled using TEE34. As depicted in Fig. 3, the heater rod region is surrounded



PIPE 49
IC
22
34.623
33.173
TEE 17
21
31.173
20
30.423
TEE 18
19
VLVE
28.773
TEE 19
18
28.223
17
27.673
PIPE 12
PCC
16
VLVE
VLVE 45
26.223
15
TEE 14
24.223
14
VLVE 3
23.473
TEE 10
13
GDCS
21.823
12
21.273
VLVE 5
TEE 15
11
VLVE 4
20.723
10
RPV
VLVE 40
UDW
16.194
9
14.828
8
VLVE 07
PIPE 30
TEE's
31, 37
12.564
7
TEE 16
10.0
Annular
+
Lower
D/W
6
S/C
5.8
5
3.708
4
2.723
LEVEL
3
1.723
TEE 32
2
0.723
1
RING
1
2
3
BDLA

FIGURE 2.

by the GTBP. In the TRACG model, the leak path into the GTBP from the channel is represented by the side junction of CHAN08 and TEE34. In addition CHAN08 exchanges thermal energy with TEE34, thus representing the GIRAFFE geometry very closely. The top of CHAN08 connects to TEE16, the chimney and the top of TEE34 connects to the side branch of TEE16 (see Fig. 3). The chimney and the GTBP have five cells each. Both TEE34 and TEE16 exchange heat with the fluid in the RPV (3-D) component. The bottom of CHAN08 and the top of TEE16 are connected to the 3-D RPV component. The heated length in the channel component is 2.44 m long and extends from 0.76m from the RPV bottom to 3.2m.

2.3 RPV Piping

VLVE40 represents the drain line from the bottom of the GDCS pool to the RPV (see Figs. 1 and 2) and enters the RPV at 1m above the top of active fuel (TAF). VLVE52 represents the vessel end of the broken GDCS line for the GS1, GS2 and GS4 cases. VLVE55 represents the bottom drain line break in GS3 and extends from the RPV bottom to the LDW. VLVE43 and VLVE44 are also connected to the RPV and represent the Isolation Condenser(IC) steam supply line and the drain lines respectively. VLVE11 represents the Automatic Depressurization System(ADS) opening. All the 1-D components of importance are shown in one or more of Figures 1, 2 and 3.

2.4 Dry Well, Suppression Chamber and GDCS Piping

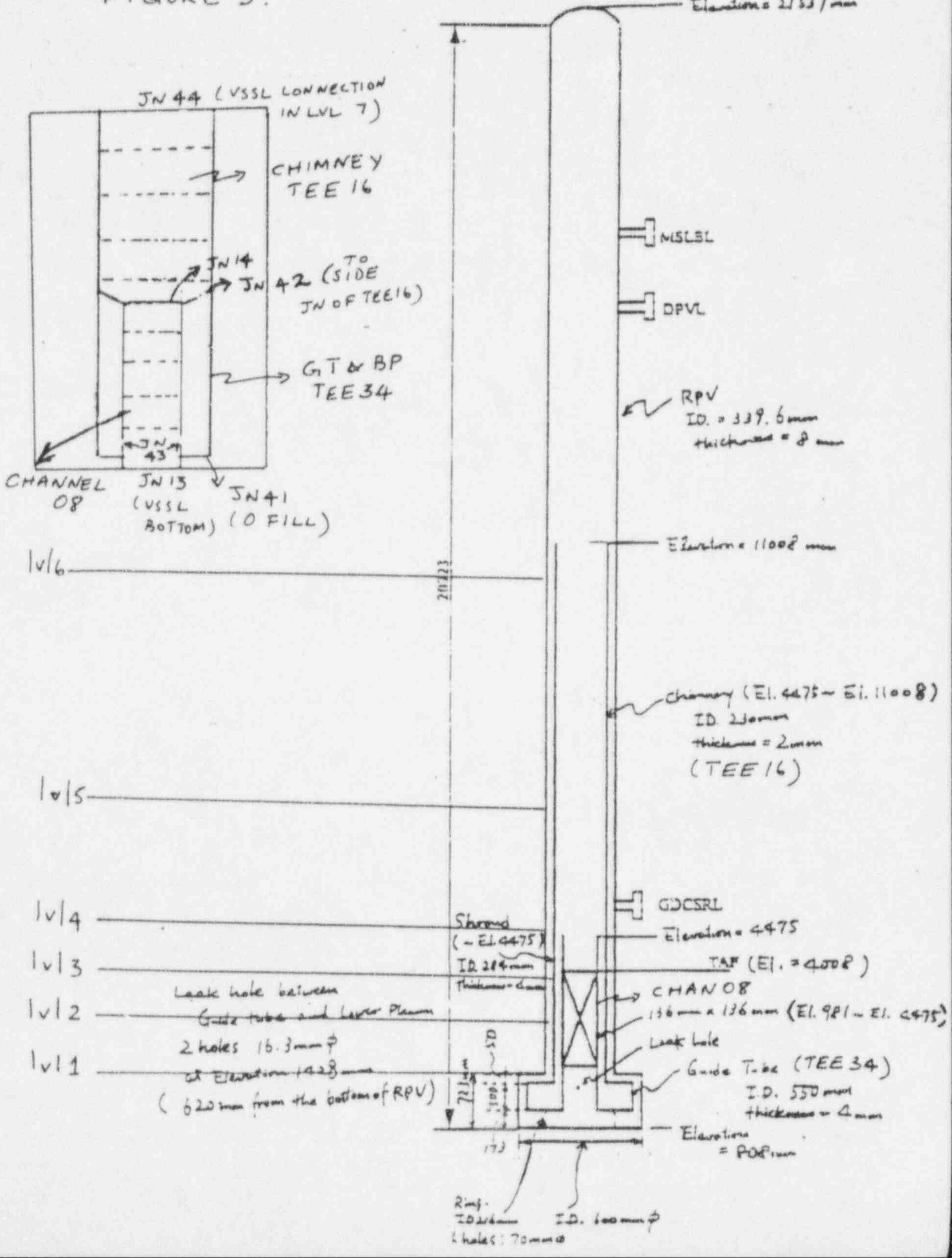
The LOCA vent line is represented by PIPE06 and has a submergence of 1.6m below the SC water level. The drywell end of this line is located at the bottom of the UDW. There will be flow through this line only when the DW pressure exceeds the SC pressure by more than the hydrostatic head corresponding to the vent submergence in the pool. The Vacuum Breaker line (VBL) between the SC and the DW is VLVE07 and opens or closes based on set points-the valve opens when the wetwell pressure is 3240 Pa higher than the DW and it closes when the pressure difference is less than 2060 Pa.

PIPE30, TEE31, TEE37 and TEE32 represent the Annular DW and the LDW with the top of PIPE30 connected to the bottom of the UDW. The GDCS break line,VLVE51, is connected to annular DW as is the other end of VLVE52. In test GS3, the BDLB line, VLVE55, is connected to the LDW. The Passive Containment Cooling System (PCCS) steam supply line is connected to the top of the UDW and is represented as VLVE03. There is also an pressure equalization line(VLVE41) between the GDCS and the DW.

The vent lines from the IC and PCC are connected to the SC. The PCC vent line, VLVE05, has a submergence of 0.85m. The IC vent line, VLVE45, is physically represented in the model, but is not used in the tests. The PCC drain line,VLVE04, connects to the GDCS pool.

2.5 IC and PCC systems

FIGURE 3.



JN 44 (VSSL CONNECTION IN LVL 7)
CHIMNEY TEE 16
JN 14
JN 42 (TO SIDE JN OF TEE16)
GT & BP TEE 34
JN 43
CHANNEL 08
JN 13 (VSSL BOTTOM)
JN 41 (0 FILL)
Elevation = 21539 mm
MSLSL
DPVL
RPV
I.D. = 339.6 mm
thickness = 8 mm
Elevation = 11008 mm
lvl 6
20723
Chimney (El. 4475 ~ El. 11008)
thickness = 2 mm
(TEE 16)
lvl 5
GDCSRL
lvl 4
Shroud
(~ El. 4475)
Elevation = 4475
lvl 3
TAF (El. = 4008)
Leak hole between Guide tube and Lower Plenum
lvl 2
CHAN 08
136 mm x 136 mm (El. 981 ~ El. 4475)
2 holes 16.3 mm ϕ
Leak hole
lvl 1
at Elevation 1428 mm
Guide Tube (TEE 34)
I.D. 550 mm
thickness = 4 mm
(620 mm from the bottom of RPV)
Elevation
I.D. 600 mm ϕ

The two systems occupy different pools and are made up of three 1-D components each. Each system consists of a steam box, a heat exchanger and a water box for the condensate. The GIRAFFE facility consists of three heat exchange tubes, each of length 1.8m in the PCC and 2.4m in the IC. All three tubes are operational in the PCC whereas only one tube is operational in the IC. All these features are modeled in TRACG using TEES- TEE14, TEE10 and TEE15 in the PCC and TEE17, TEE18 and TEE19 in the IC. The PCC and IC heat exchangers transfer heat to their respective pools.

Table 1.
List of 1-D Components

Component Number	Description
2	VLVE - Main Steam Line Break (not used)
3	VLVE - PCC Steam Supply from UDW
4	VLVE - PCC Drain to GDCS
5	VLVE - PCC Vent Line to SC
6	PIPE - Main LOCA Vent SC to DW
7	VLVE - Vacuum Breaker SC to DW
8	CHAN - Fuel Bundle with Heater Rods
9	BREK - Pressure Boundary to ambient-PCC pool vent
10	TEE - PCC Heat Exchanger
11	VLVE - ADS line RPV to DW
12	PIPE - PCC Pool Vent
13	VLVE - Pretest Valve for PCC (not used)
14	TEE - PCC Steam Box
15	TEE - PCC Water Box
16	TEE - Chimney
17	TEE - IC Steam Box
18	TEE - IC Heat Exchanger
19	TEE - IC Water Box
21	BREK - to VLVE13
30	PIPE - Annular DW
31	TEE - Annular DW
32	TEE - Lower DW
33	FILL - to bottom of TEE32
34	TEE - Guide Tube and Bypass
35	FILL - bottom of TEE34
36	FILL - Jn 3 of TEE10
37	TEE - Annular DW
40	VLVE - GDCS Line GDCS to RPV
41	VLVE - Equalization Line DW to GDCS
43	VLVE - IC Steam Supply
44	VLVE - IC Drain Line
45	VLVE - IC Vent Line
46	VLVE - Pretest valve for IC (not used)
47	BREK - VLVE46
48	FILL - to Jn 3 of TEE18
49	PIPE - IC pool Vent

Table 1. (continued)

50	BREK - Pressure Boundary to ambient for PIPE49
51	VLVE - GDCS Break Flow to DW
52	VLVE - GDCS Break from RPV to DW
54	TEE - GDCS Drain Line (hooks up GDCS pool and VLVE40 and VLVE51)
55	VLVE - Bottom Drain Line Break to DW (only in GS3)

2.6 Heat Losses in the System

The walls of the RPV are represented by lumped heat slabs. Heat losses to the ambient in the RPV are not modeled as the TRACG model does not allow heat transfer to the outside from inner rings in the VSSL component (the RPV is bounded radially by ring 1 of the VSSL component). Heat losses to the ambient are modeled for the GDCS pool, the DW and the SC. This is accomplished by the use of a double sided heat slab model in TRACG. The outside film resistance and insulation are combined into an effective heat transfer coefficient which is specified together with the ambient temperature. The heat losses in the SI Tests were not measured directly but were inferred from the Helium tests (Ref. 3). By simple extrapolation it was determined that these losses were not sufficiently different for the two test series. Thus, the net heat loss parameters (heat transfer coefficient or heat transfer area) from each component was adjusted to be the same as in the Helium tests.

2.7 Decay Heat

The decay heat curve for each test was determined by scaling down the SBWR values by a factor of 1:400.

Unlike in the previous tests, the heat losses were not compensated for by increasing the heater power. This would perturb the conditions of the test by introducing additional heat into the lower RPV, thus affecting the minimum level in the chimney. Tables 2 through 5 contain the appropriate initial power at the start of each test. The power in the heater rods is adjusted to produce the decay heat and an average of 8 kW over the first 200 secs representing stored energy in the channel, cladding and heater rods.

2.8 Initial Conditions

The initial amount of water in the RPV for each test was determined by scaling down the total mass of fluid contained in the SBWR RPV by a factor of 1:400 and adding 0.7 m as margin, as specified in the test specifications. All flows into and out of the RPV were also scaled down by a factor of 400. The initial mass of water in the drywell and flow rates were scaled by 1:400. The various temperatures and pressures for the four tests are given in Tables 2 through 5. The initial RPV pressure for all four tests is 1034 kPa and the GDCS pool water is in a subcooled state.

Microheaters were used to compensate for the heat losses in the DW, SC and GDCS pools. However, this was not sufficient to account for the heat losses in the DW (including LOCA vent) and the GDCS pool. There were no microheaters for the RPV. The net loss of heat for the RPV, DW and GDCS pool were approximately 8 kW, 12 kW and 7 kW respectively. The SC heat losses were fully compensated for.

TABLE 2

GS1 CONDITIONS - GDL BREAK, DPV FAILURE, IC/PCCS OFF

Parameter	Value	Tolerance
RPV Pressure (kPa)	1034	±12 kPa
RPV Initial Water Level*(m)	-0.35	±5%
Initial Heater Power (kW)	134	±1 kW
Drywell Pressure (kPa)	271	±4 kPa
Drywell Air Pressure (kPa)	45	±4 kPa
Drywell Steam Pressure (kPa)	226	±4 kPa
Drywell Initial Water Level (m)	0.05	+20%-0%
Wetwell Pressure (kPa)	255	±4 kPa
Wetwell Air Pressure (kPa)	234	±4 kPa
GDCS Gas Space Pressure (kPa)	271	±4 kPa
GDCS Gas Space Air Pressure (kPa)	259	±4 kPa
Suppression Pool Temperature (K)	334	±2 K
Isolation Condenser Pool Temperature (K)	NA	NA
Isolation Condenser Pool Level* (m)	NA	NA
PCCS Pool Temperature (K)	NA	NA
GDCS Pool Temperature (K)	322	±2 K
GDCS Pool Level* (m)	16.3	±0.075 m
Suppression Pool Level* (m)	3.15	±0.075 m
PCC Pool Level* (m)	NA	NA

*Referenced to TAF

TABLE 3

GS2 CONDITIONS - GDL BREAK, DPV FAILURE, IC/PCCS ON

Parameter	Value	Tolerance
RPV Pressure (kPa)	1034	±12 kPa
RPV Initial Water Level* (m)	+0.11	±5%
Initial Heater Power (kW)	134	±1 kW
Drywell Pressure (kPa)	279	±4 kPa
Drywell Air Pressure (kPa)	37	±4 kPa
Drywell Steam Pressure (kPa)	242	±4 kPa
Drywell Initial Water Level (m)	0.05	+20%-0%
Wetwell Pressure (kPa)	263	±4 kPa
Wetwell Air Pressure (kPa)	245	±4 kPa
GDCS Gas Space Pressure (kPa)	279	±4 kPa
GDCS Gas Space Air Pressure (kPa)	267	±4 kPa
Suppression Pool Temperature (K)	331	±2 K
Isolation Condenser Pool Temperature (K)	373	±2 K
Isolation Condenser Pool Level* (m)	23.2	±0.075 m
PCCS Pool Temperature (K)	373	±2 K
GDCS Pool Temperature (K)	322	±2 K
GDCS Pool Level* (m)	16.3	±0.075 m
Suppression Pool Level* (m)	3.15	±0.075 m
PCC Pool Level* (m)	23.2	±0.075 m

*Referenced to TAF

TABLE 4

GS3 CONDITIONS - BDL BREAK, DPV FAILURE, IC/PCCS ON

Parameter	Value	Tolerance
RPV Pressure (kPa)	1034	±12 kPa
RPV Initial Water Level* (m)	+1.86	±5%
Initial Heater Power (kW)	113	±1 kW
Drywell Pressure (kPa)	310	±4 kPa
Drywell Air Pressure (kPa)	8	±4 kPa
Drywell Steam Pressure (kPa)	302	±4 kPa
Drywell Initial Water Level (m)	0.05	+20%--0%
Wetwell Pressure (kPa)	294	±4 kPa
Wetwell Air Pressure (kPa)	278	±4 kPa
GDCS Gas Space Pressure (kPa)	310	±4 kPa
GDCS Gas Space Air Pressure (kPa)	298	±4 kPa
Suppression Pool Temperature (K)	328	±2 K
Isolation Condenser Pool Temperature (K)	373	±2 K
Isolation Condenser Pool Level* (m)	23.2	±0.075 m
PCCS Pool Temperature (K)	373	±2 K
GDCS Pool Temperature (K)	323	±2 K
GDCS Pool Level* (m)	16.3	±0.075 m
Suppression Pool Level* (m)	3.15	±0.075 m
PCC Pool Level* (m)	23.2	±0.075 m

*Referenced to TAF

TABLE 5

GS4 CONDITIONS - GDL BREAK, GDCS VALVE FAILURE, IC/PCCS ON

Parameter	Value	Tolerance
RPV Pressure (kPa)	1034	±12 kPa
RPV Initial Water Level* (m)	+0.14	±5%
Initial Heater Power (kW)	134	±1 kW
Drywell Pressure (kPa)	274	±4 kPa
Drywell Air Pressure (kPa)	40	±4 kPa
Drywell Steam Pressure (kPa)	234	±4 kPa
Drywell Initial Water Level (m)	0.05	+20%-0%
Wetwell Pressure (kPa)	258	±4 kPa
Wetwell Air Pressure (kPa)	240	±4 kPa
GDCS Gas Space Pressure (kPa)	274	±4 kPa
GDCS Gas Space Air Pressure (kPa)	260	±4 kPa
Suppression Pool Temperature (K)	331	±2 K
Isolation Condenser Pool Temperature (K)	373	±2 K
Isolation Condenser Pool Level* (m)	23.2	±0.075 m
PCCS Pool Temperature (K)	373	±2 K
GDCS Pool Temperature (K)	326	±2 K
GDCS Pool Level* (m)	16.3	±0.075 m
Suppression Pool Level* (m)	3.15	±0.075 m
PCC Pool Level* (m)	23.2	±0.075 m

*Referenced to TAF

3.0 COMPARISON TO THE SBWR NODALIZATION

Ideally, the nodalization for the GIRAFFE model should be similar to the existing SBWR nodalization. However, there will be differences related to the differences in physical configurations. The nodalization is similar in the upper DW, WW, and PCC which are considered crucial to the purpose of the GIRAFFE SI tests. A brief one on one comparison is best shown in tabular form.

Component	GIRAFFE	SBWR
RPV	VSSL - 10 levels 1 ring	VSSL - 16 levels 4 rings
GDCS pool	VSSL - 6 levels 1 ring	VSSL - 2 levels 3 rings
PCC pool	VSSL - 6 levels 2 rings	VSSL - 6 levels 2 rings
IC pool	VSSL - 6 levels 2 rings	VSSL - 6 levels 2 rings
WW	VSSL - 7 levels 2 rings	VSSL - 3 levels 3 rings
DW		
Upper	VSSL - 2 levels 1 ring	VSSL - 3 levels 1 rings
Annulus	1 - D, 9 cells in 3 components	VSSL - 4 levels 1 rings
Lower	1 - D, 4 cells	VSSL - 1 level 4 rings
PCC tubes	1 - D, 8 cells	1 - D, 8 cells
IC tubes	1 - D, 8 cells	1 - D, 8 cells
Channel	1 - D, 5 cells	1 - D, 21 cells
Chimney	1 - D, 5 cells	VSSL - 4 levels 3 rings

The GIRAFFE RPV has one ring compared to four rings in the SBWR. It is felt that the one ring design is sufficient to model the RPV flow since TEE34 models the guide tube and bypass regions along with two leak holes between it and the channel. Three additional levels were added at the bottom to the RPV model (compared to the GIRAFFE He test model) as minimum levels could reach those regions during the course of some of the SI tests and thus a finer level scheme was required to capture some of these effects. As a result of this, the SC also added three levels at the bottom making it a 7 -level 2 - ring model. The annular DW had to be broken up into three 1-D components to accommodate various breaks that needed to be modeled.

4. Discussion of the Test Simulation Results

4.1 Test Results

Results for the four tests are plotted in Figures 4-41. The set for test consists of the RPV, DW and SC pressures, the downcomer and chimney levels, the GDCS flow and the integrated mass from the vacuum breaker. In addition, the pressures and levels are shown in more detail in plots for the first ten minutes of the experiment. In GS2-4, the PCC and IC inlet flows are also shown.

4.2 Test GS1

As described in Section 1, this test was run with no IC or PCC in operation. It starts at a RPV pressure of 1034 kPa, at which time the ADS valves (except the 1 failed DPV) are opened to start the blowdown phase of the experiment. The water level in the chimney swells to about 5 m above the top of active fuel (TAF). In about three minutes, the pressure has fallen to about 300 kPa . The dry well, meanwhile pressurizes initially as a result of the blowdown but as the RPV-DW pressures equalize and the ADS flow stops (about 200 secs), the pressure drops as a result of the cold water that is continuing to pour in from the broken GDCS line. The driving head for the GDCS exceeds the RPV pressure at about 100 secs and the GDCS flow starts, quenching the voids in the RPV and collapsing the two phase level in the chimney to about 1.0 m above TAF. The level then recovers and continues to climb as a result of the GDCS flow. It reaches the top of the chimney at about 1600 secs and does not drop below this for the remainder of the test. At about 500 secs, the level reaches the broken GDCS line in the RPV (1 m above TAF) and flow starts from this line into the DW. As the water level in the RPV rises beyond the inlet point of the GDCS, the flow from the GDCS starts to drop as a result of the decreasing driving head.

The GDCS break flow to the DW is turned off in the test after about a third of the water volume in the GDCS pool is exhausted to simulate the fact that in the SBWR each of the three GDCS lines originates from a separate pool. This happens at about 3100 sec, after which the DW pressure slowly increases. The RPV water level reaches a maximum at about 2600 secs (see the downcomer level plot) and remains there till the GDCS flow stops at about 5900 secs. The level then starts to drop at this point and continues to do so till the end of the test.

During the period from about 200 sec -500 sec, the vacuum breaker opens a few times as the DW-RPV pressure drops below that of the WW. The breaker also opens and closes over a period of 600 secs starting at about 600 secs and to much lesser extent between 1700 and 2700 secs.

The test was designed to simulate a worst condition in the RPV where the water level drops to its lowest point. The TRACG simulation indicates that even in the absence of the PCC and IC, there is no threat of core uncovery during the GDCS phase of a blowdown where these minimum levels are expected to occur.

4.3 Test GS2

This test is very similar to GS1 except that the IC/PCC systems are active. The behavior of the RPV and containment is similar to GS1. In these tests, however, there is return flow from the IC back to the RPV up to about 1300 secs. The swollen chimney level reaches about 6m above TAF and the minimum level, which occurs at about 200 secs, is about 2.0 m above TAF (about 1.0 m in excess of GS1). This difference between GS1 and GS2 can be attributed to the flow back to the RPV from the IC. The level then recovers and reaches the top of the chimney at 1500 secs (about 100 secs before GS1). The RPV-DW pressure profile and the interaction with the WW is similar to GS1. The downcomer level also behaves like it does in GS1. The GDCS flow continues up to 6200 secs, longer than in GS1 because of the flow back from the PCC into the GDCS pool.

The flow into the IC ends at about 1500 sec. The PCC flow is very small, except for the first 200 secs, till about 4700 sec when it begins to pick up as the PCC inlet flow is once again established.

Overall, the effects of the IC and to a smaller extent, the PCC, are observed in this test. The lowest chimney swollen level is higher and the level recovers to the top of the chimney about a 100 secs earlier than in GS1.

4.4 Test GS3

This test has the lowest depressurization rate of all the tests and the fastest level recovery. The minimum level is at 3.8 m above TAF and the level recovers to the top of the chimney at around 900 secs. The GDCS flow starts at about 120 secs and the flow rate drops more rapidly than in the other tests due to the more rapidly diminishing driving head. The downcomer level reaches the ADS flow opening and the level lingers around this point for the rest of the test. The IC and PCC behavior is similar to the previous test.

The GDCS flow continues to the end of the test since there was no break in any of the GDCS lines in this test. Around 2500 secs there is two phase flow out of the DPV line into the DW. By about 4500 secs, as the RPV level fluctuates about the DPV opening, there is periodic venting of steam into the DW increasing the GDCS flow. The flow periodically rises and falls. Eventually, as the GDCS pool level starts to approach that of the RPV, this effect becomes more pronounced, with GDCS flow dropping close to zero periodically.

Test GS3 shows, as expected, the fastest chimney level recovery of all the tests.

4.5 Test GS4

This test is very similar to GS2 except that the failure is a GDCS nozzle instead of a DPV valve. Since this test has the lowest amount of GDCS flow, the chimney level recovery is the slowest. The minimum water level is about 2.0 m above TAF and it occurs at about 200 secs. The time of level recovery to the top of the chimney is about 2000 secs. The RPV-DW pressure is slightly higher than in GS2. The IC and PCC behavior is very similar to GS2.

As expected, this test shows the slowest level recovery.

4.6 Conclusions

The four tests show results as expected and indicate that the even in the absence of the IC and PCC the core will not uncover during these worst case breaks. The IC and PCC show the interaction of these systems with the vessel and containment have the effect of increasing the minimum chimney levels attained during these transients during the GDCS phase.

5. References

1) K.M. Vierow, "GIRAFFE Passive Heat Removal Testing Program", NEDC-32215P, Revision 0, Class 3, June 1993.

2) SBWR Test and Analysis Program Description, NEDC-32391P, Revision C, Class 3, August 1995.

3) Shakedown Test Series, May 1995. TOSHIBA, TOGE110-T18

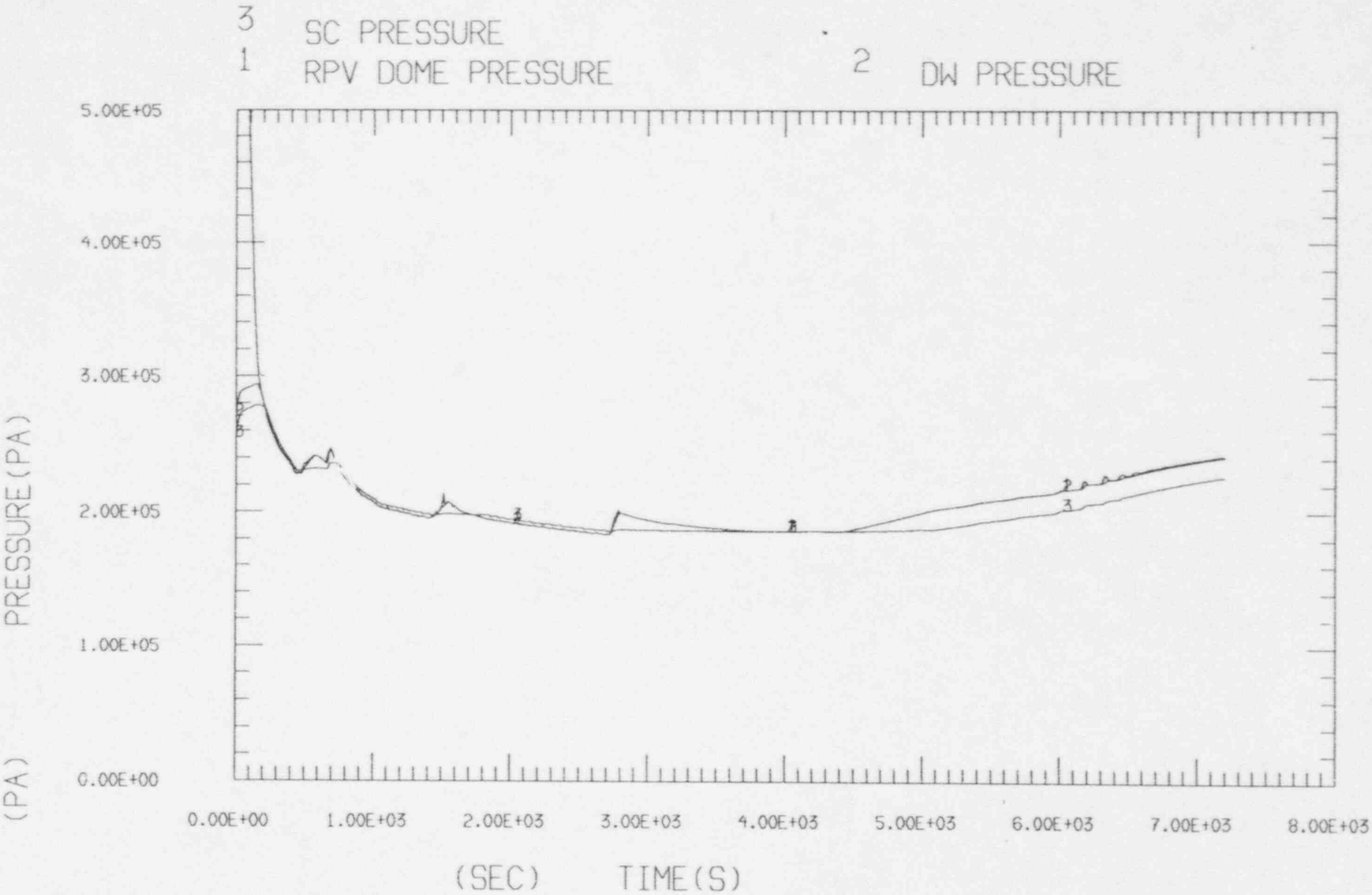


FIG 4 GIRAFFE_GS1

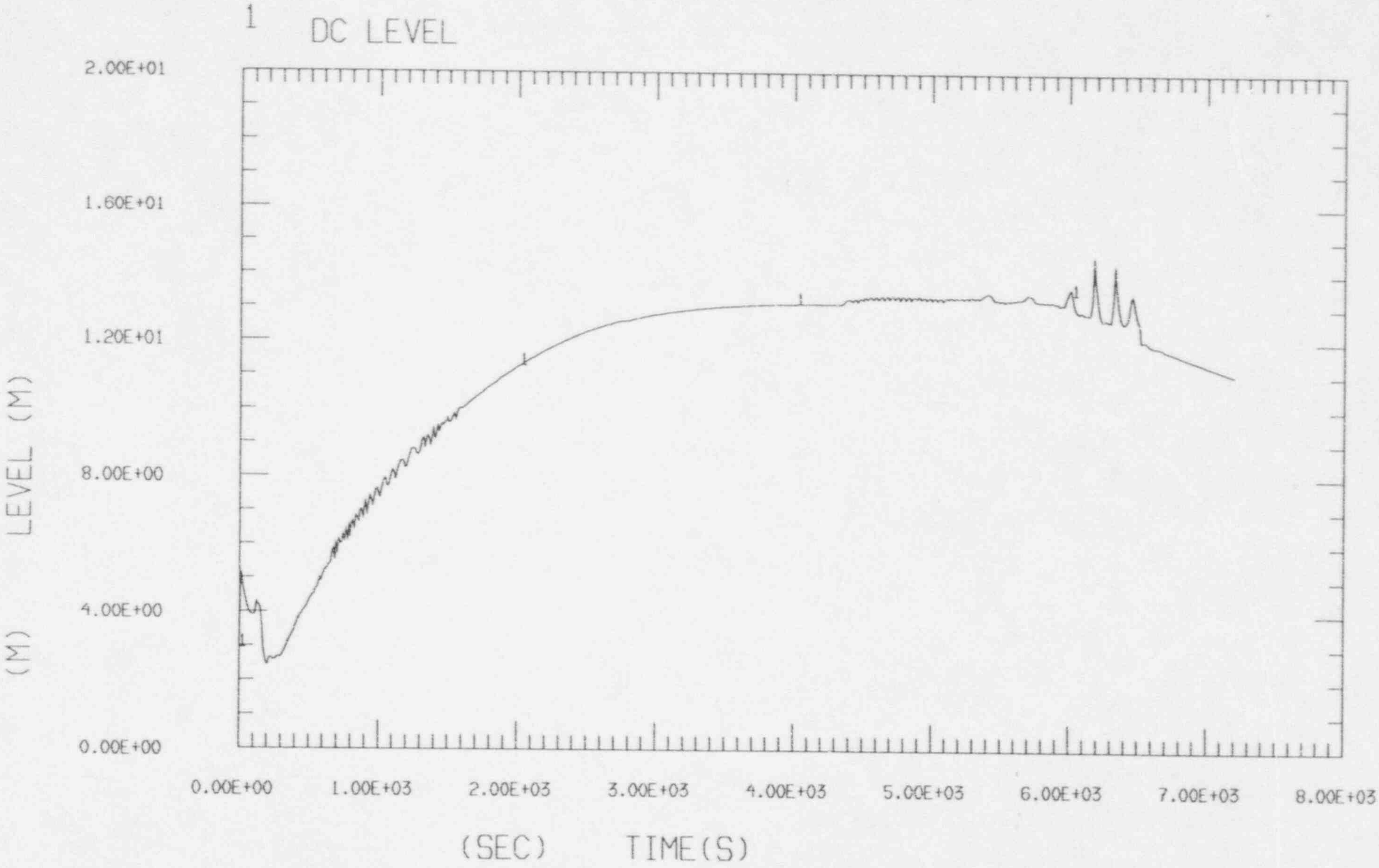


FIG 5 GIRAFFE_GS1

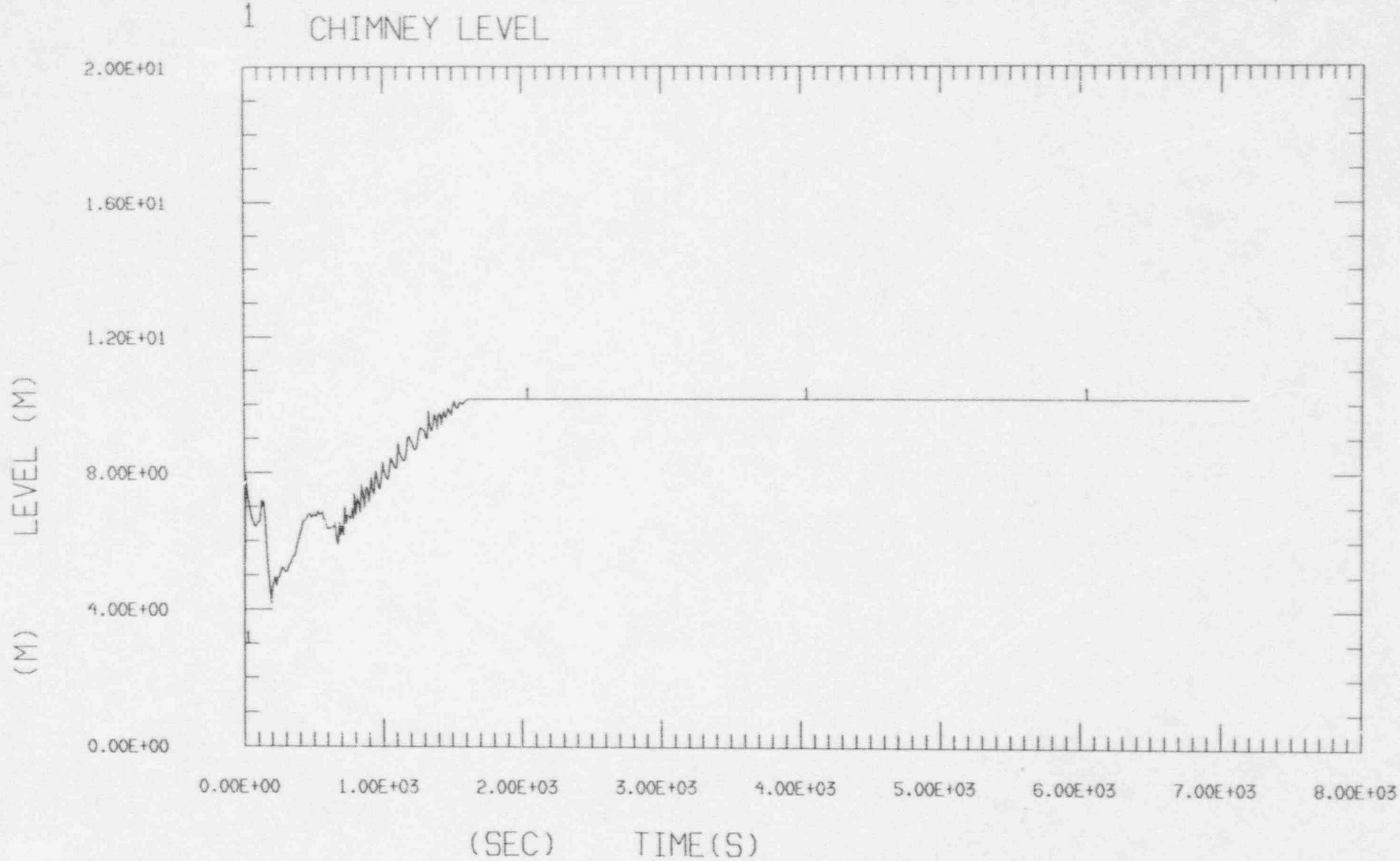


FIG 6 GIRAFFE_GS1

1

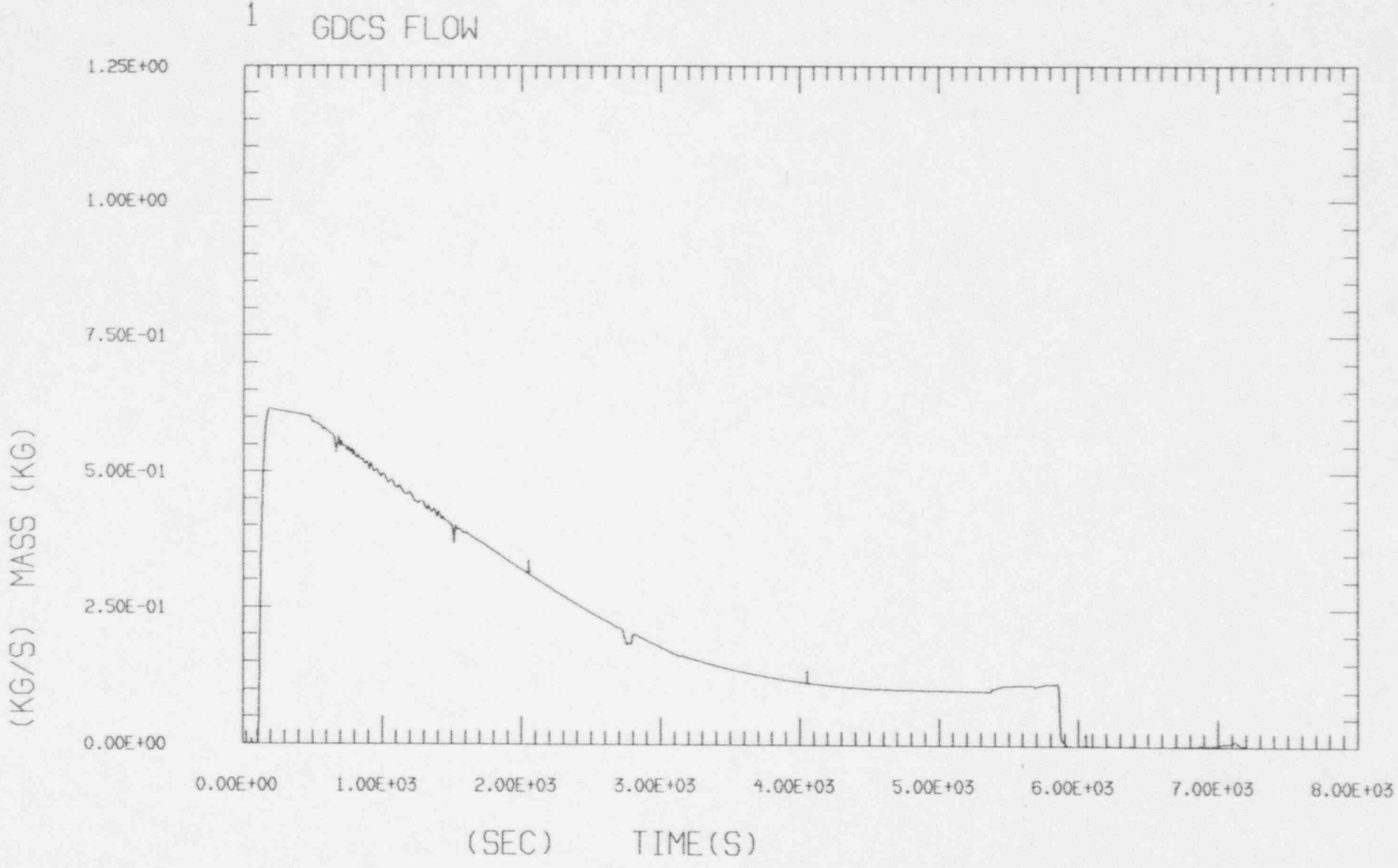


FIG 7 GIRAFFE_GS1

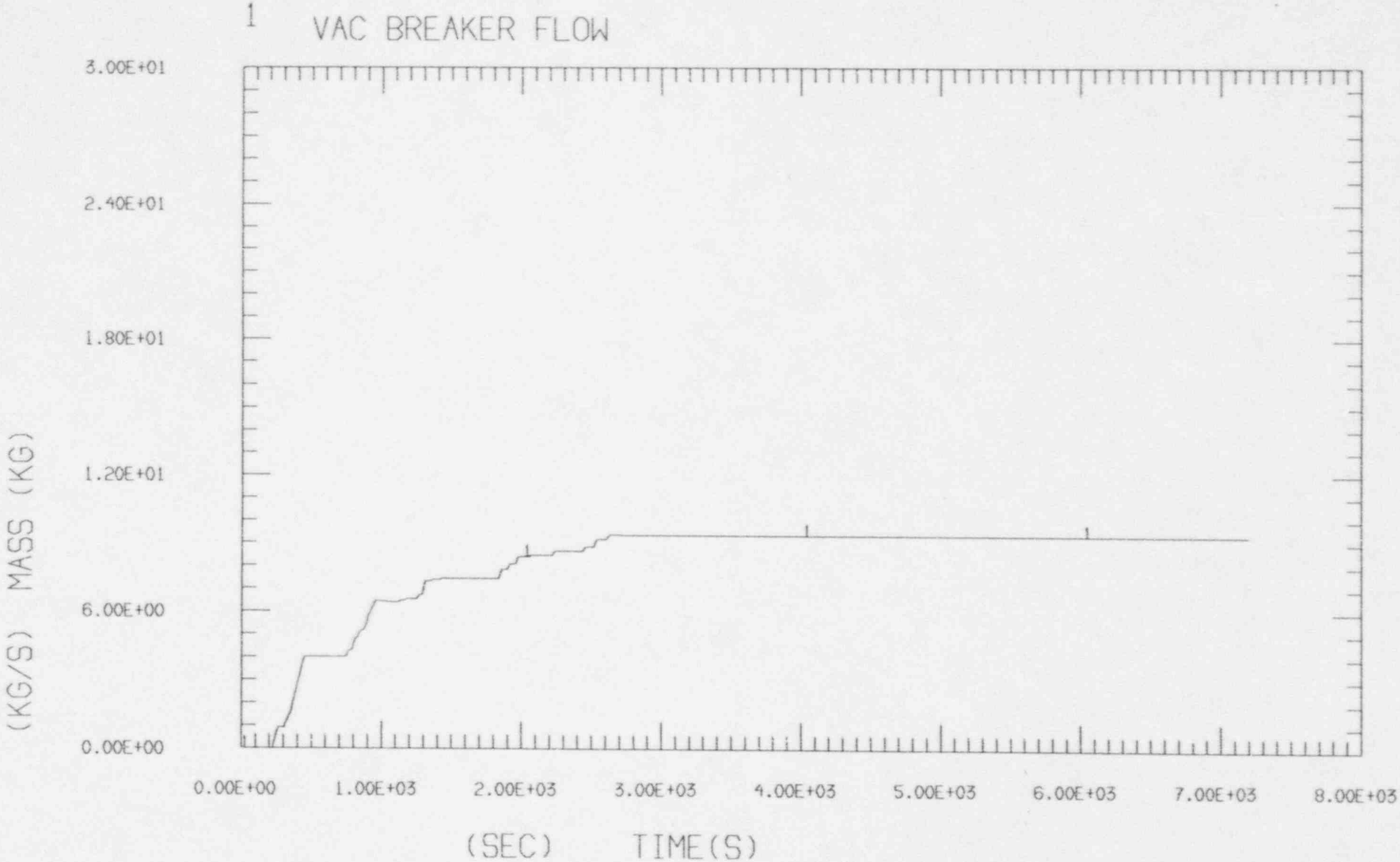


FIG 8 GIRAFFE_GS1

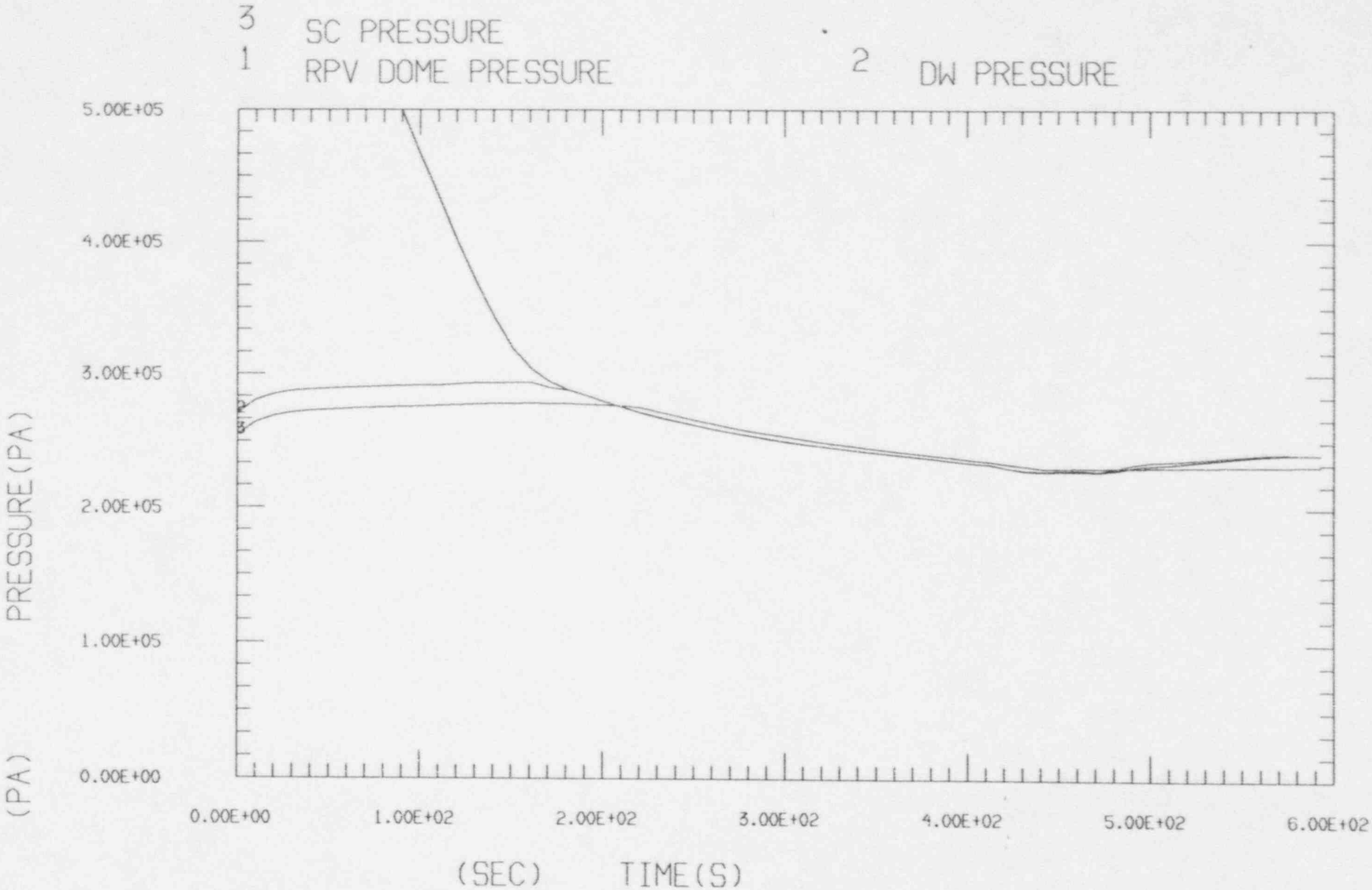


FIG 9 GIRAFFE_GS1

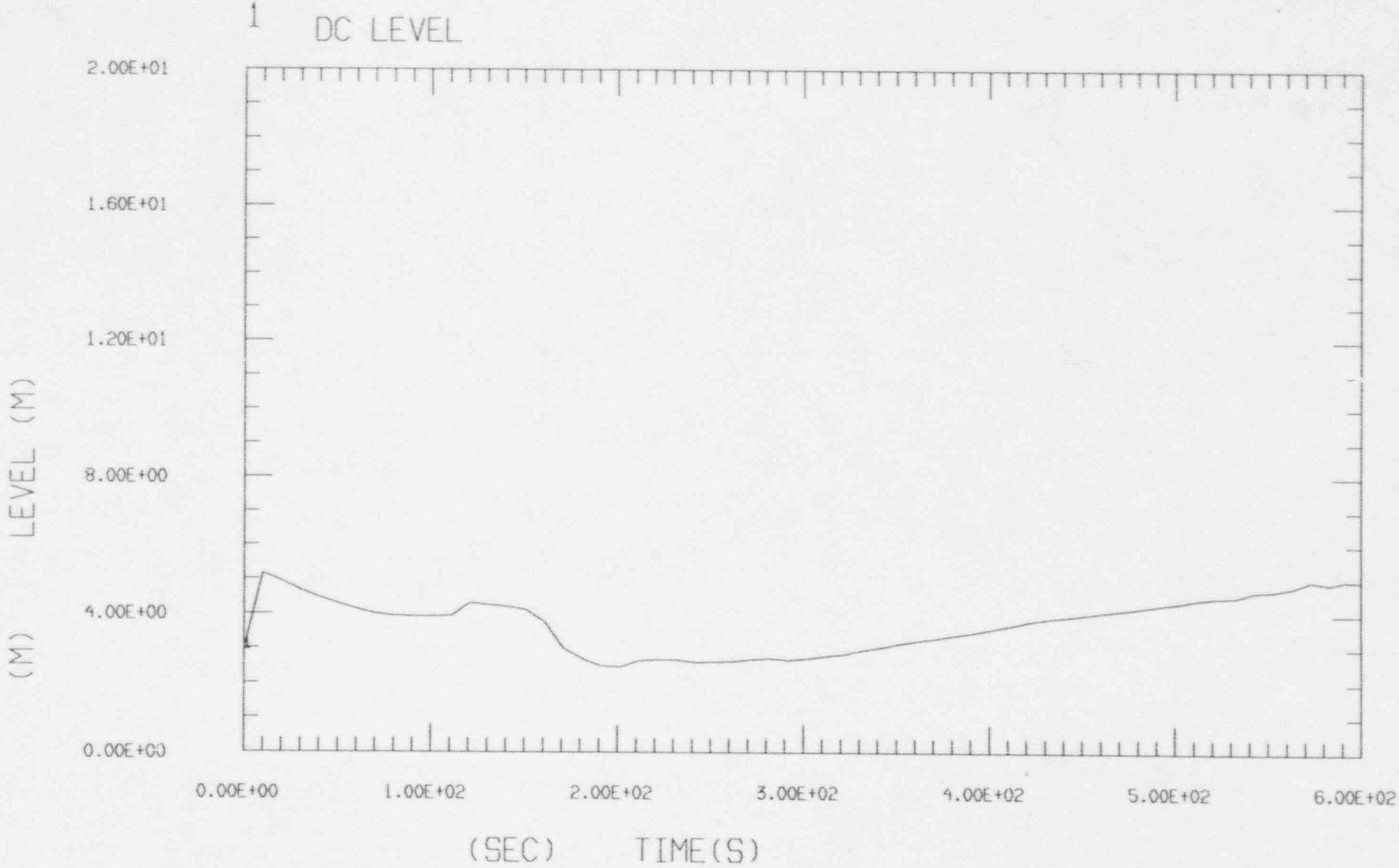


FIG 10 GIRAFFE_GS1

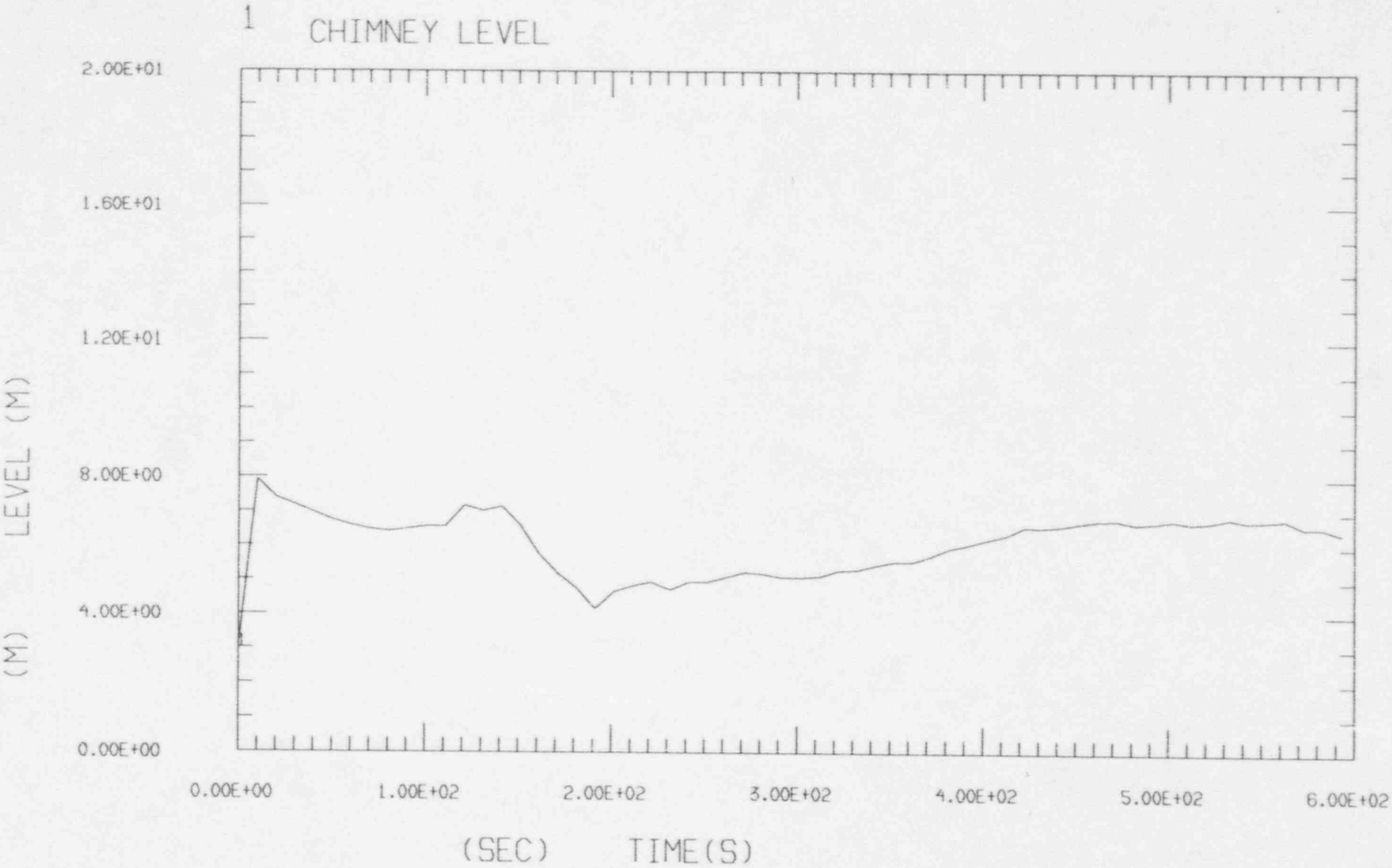


FIG 11 GIRAFFE_GS1

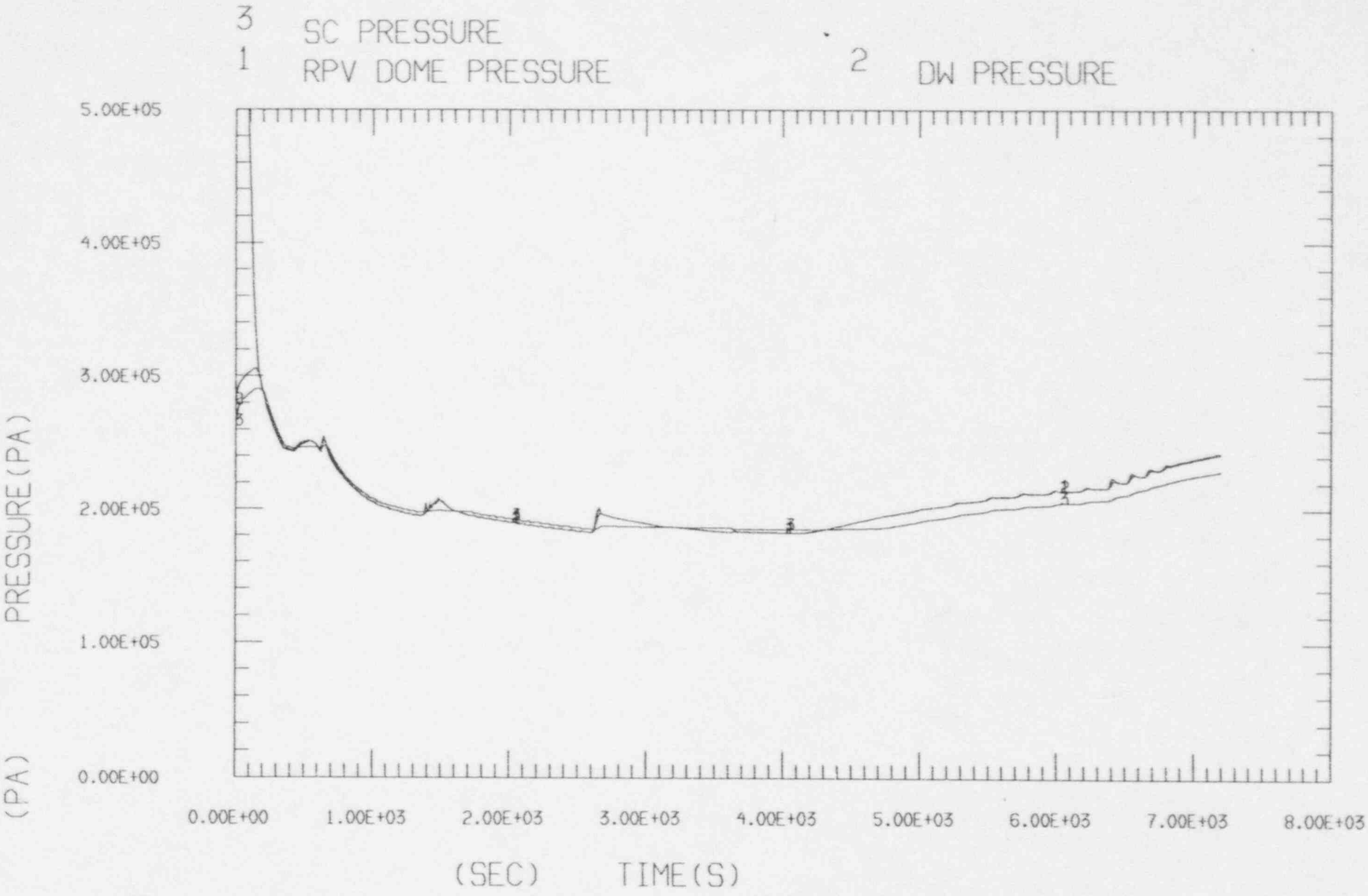


FIG 12 GIRAFFE_GS2

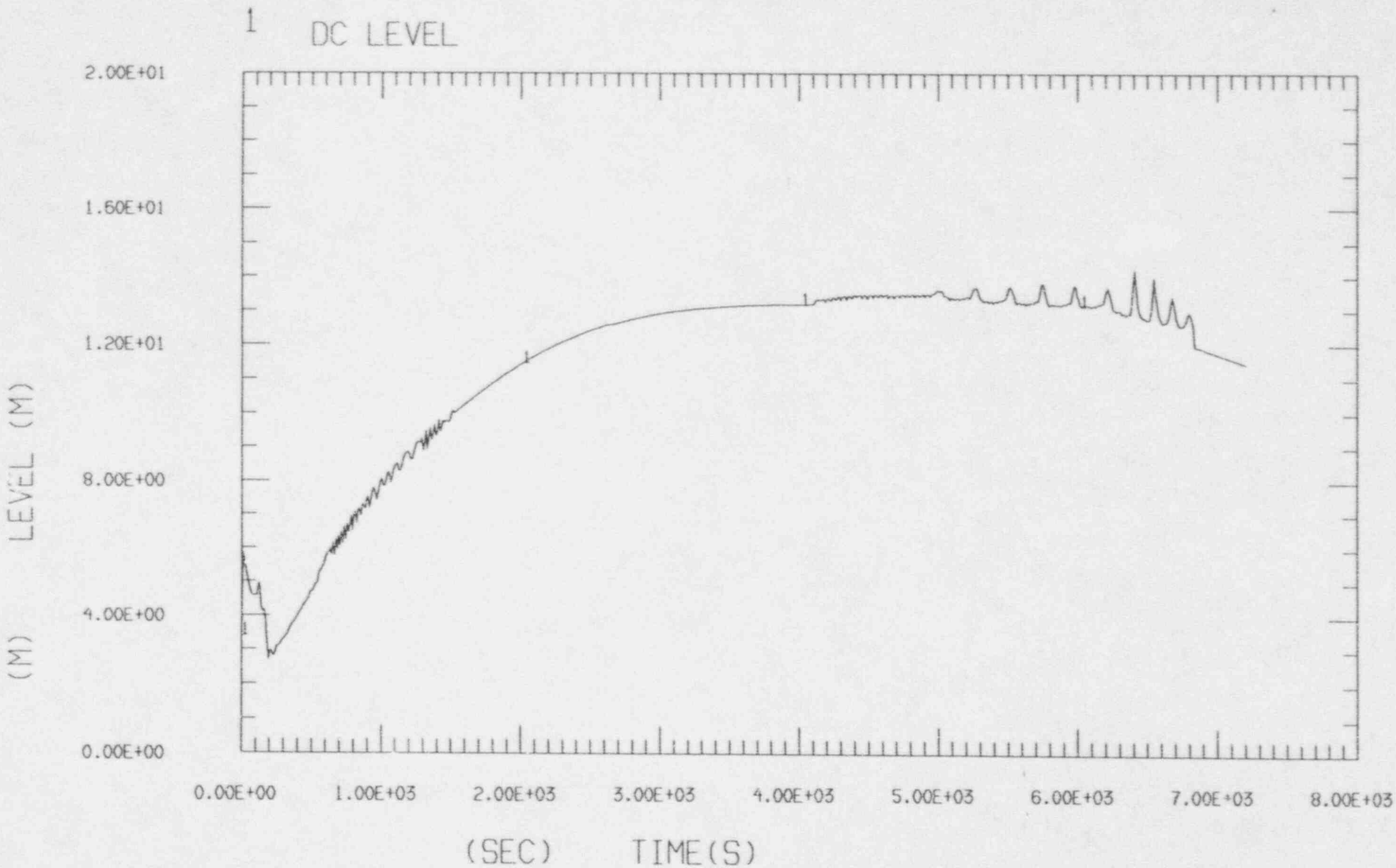


FIG 13 GIRAFFE_GS2

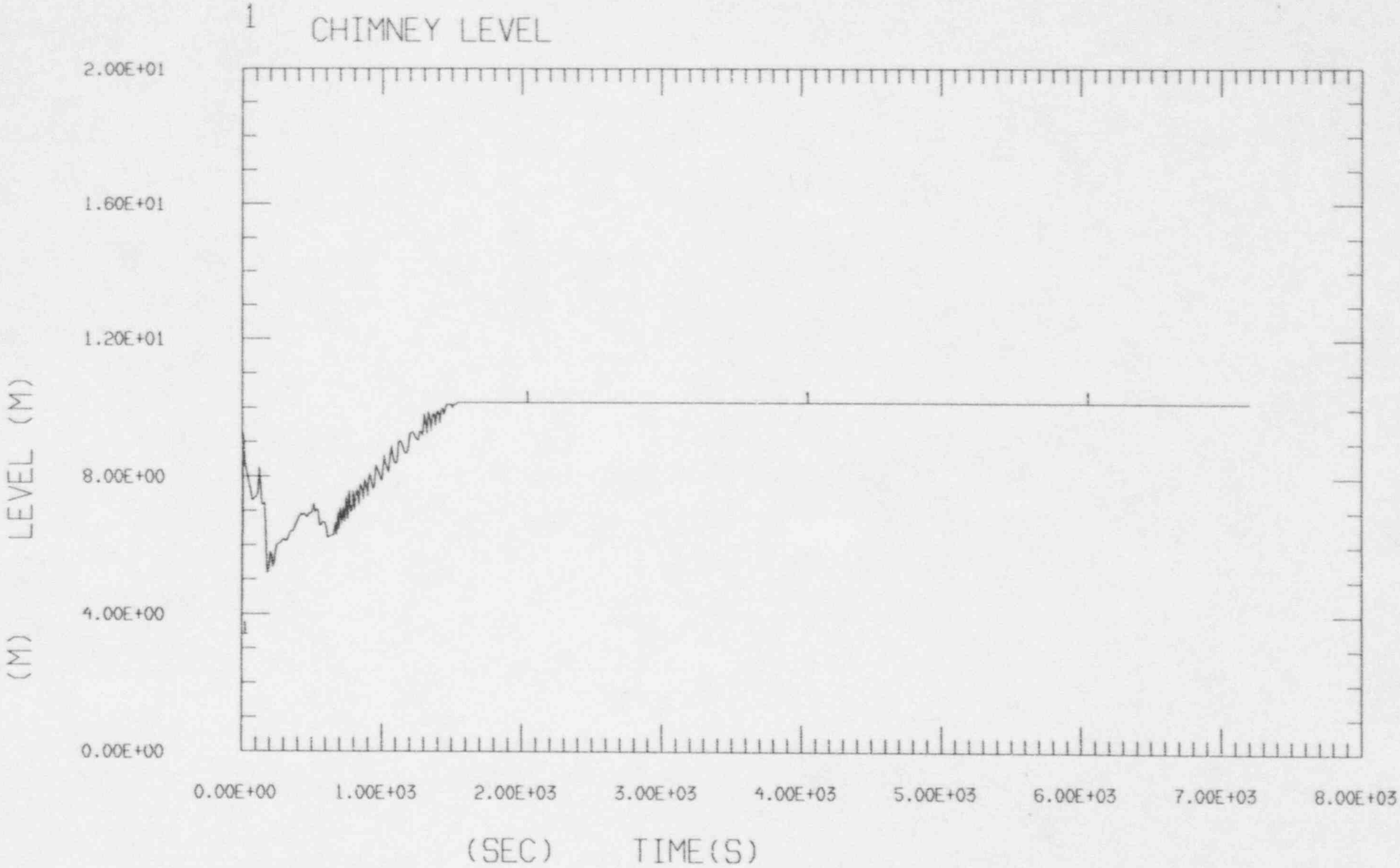


FIG 14 GIRAFFE_GS2

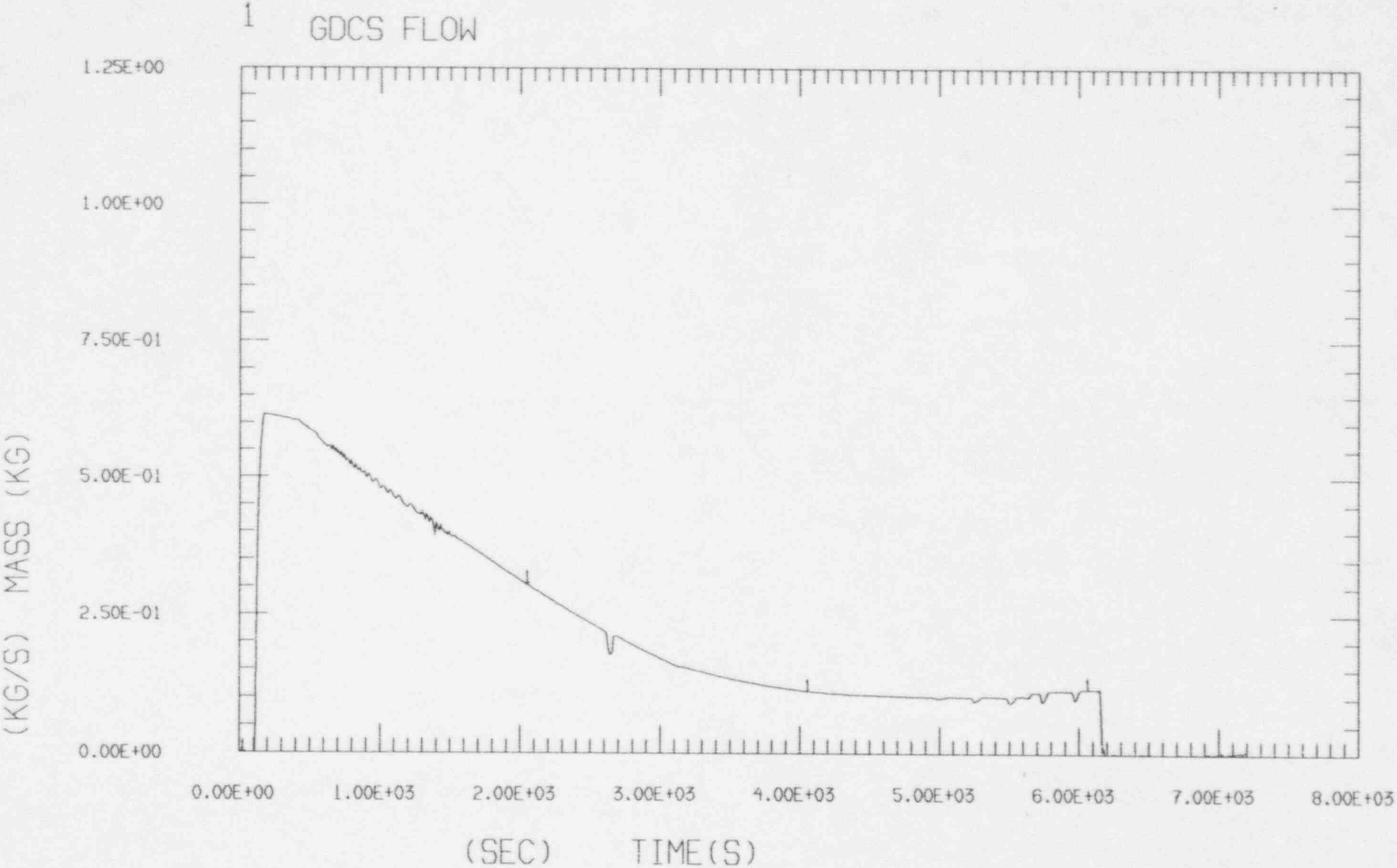


FIG 15 GIRAFFE_GS2

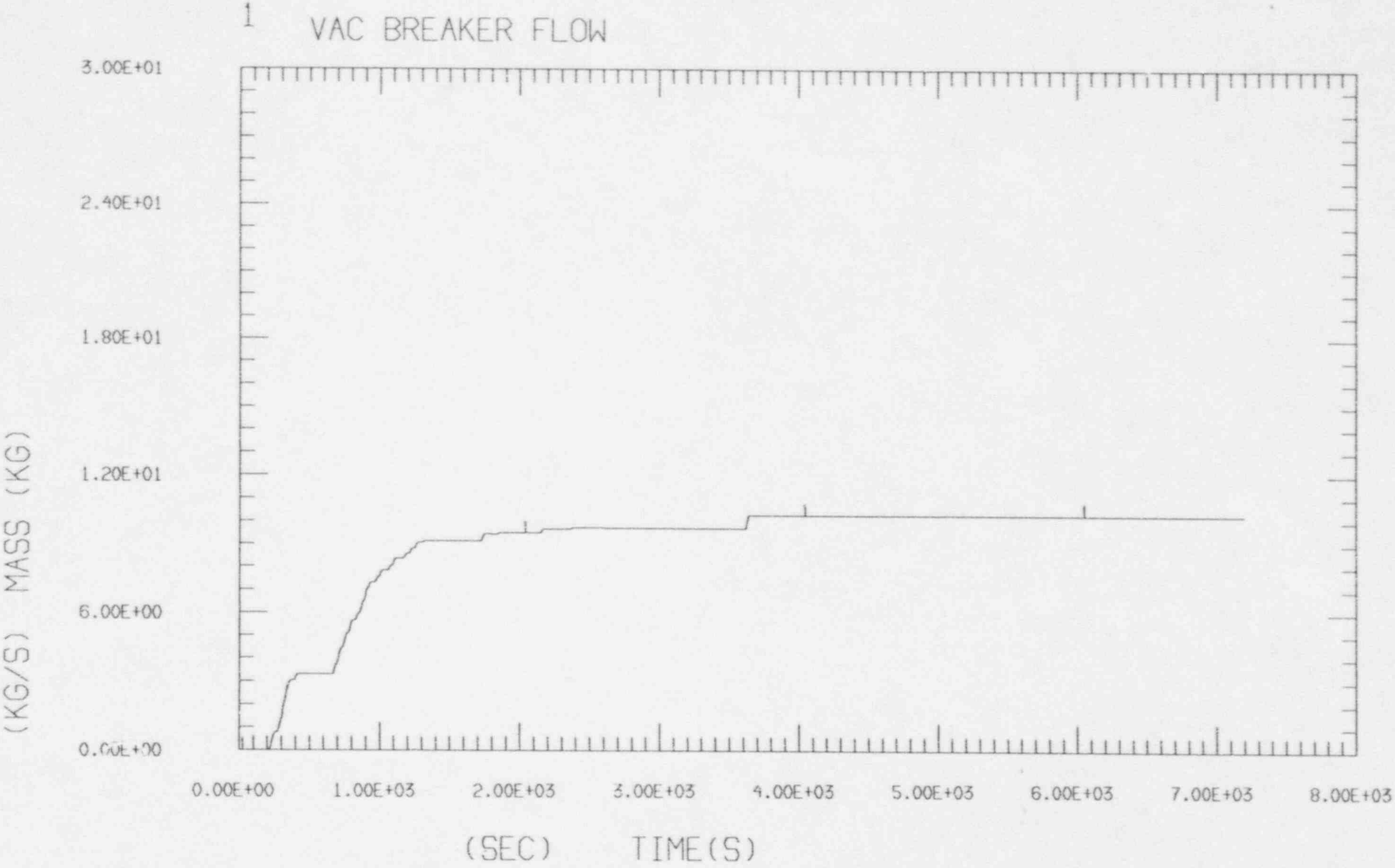


FIG 16 GIRAFFE_GS2

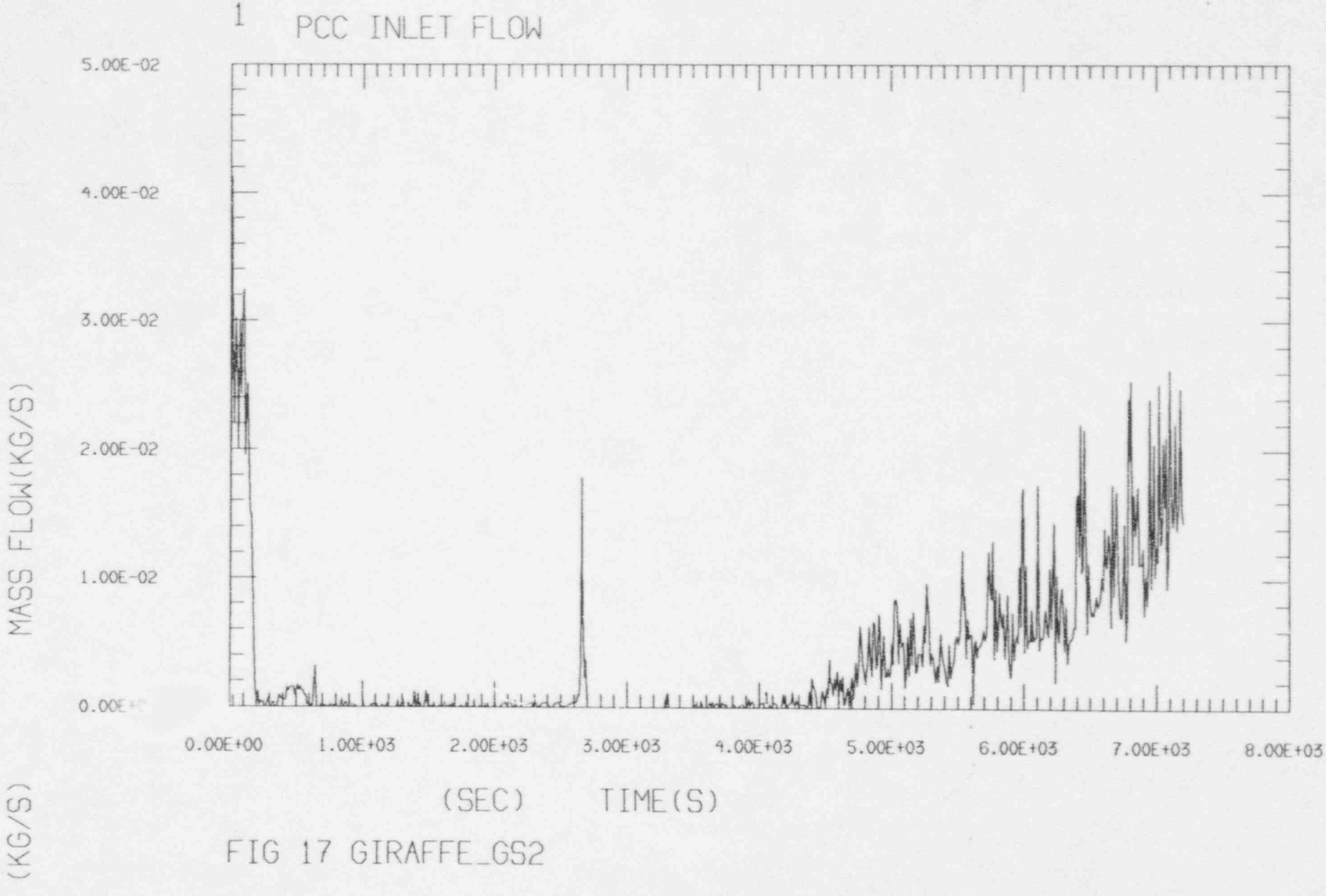


FIG 17 GIRAFFE_GS2

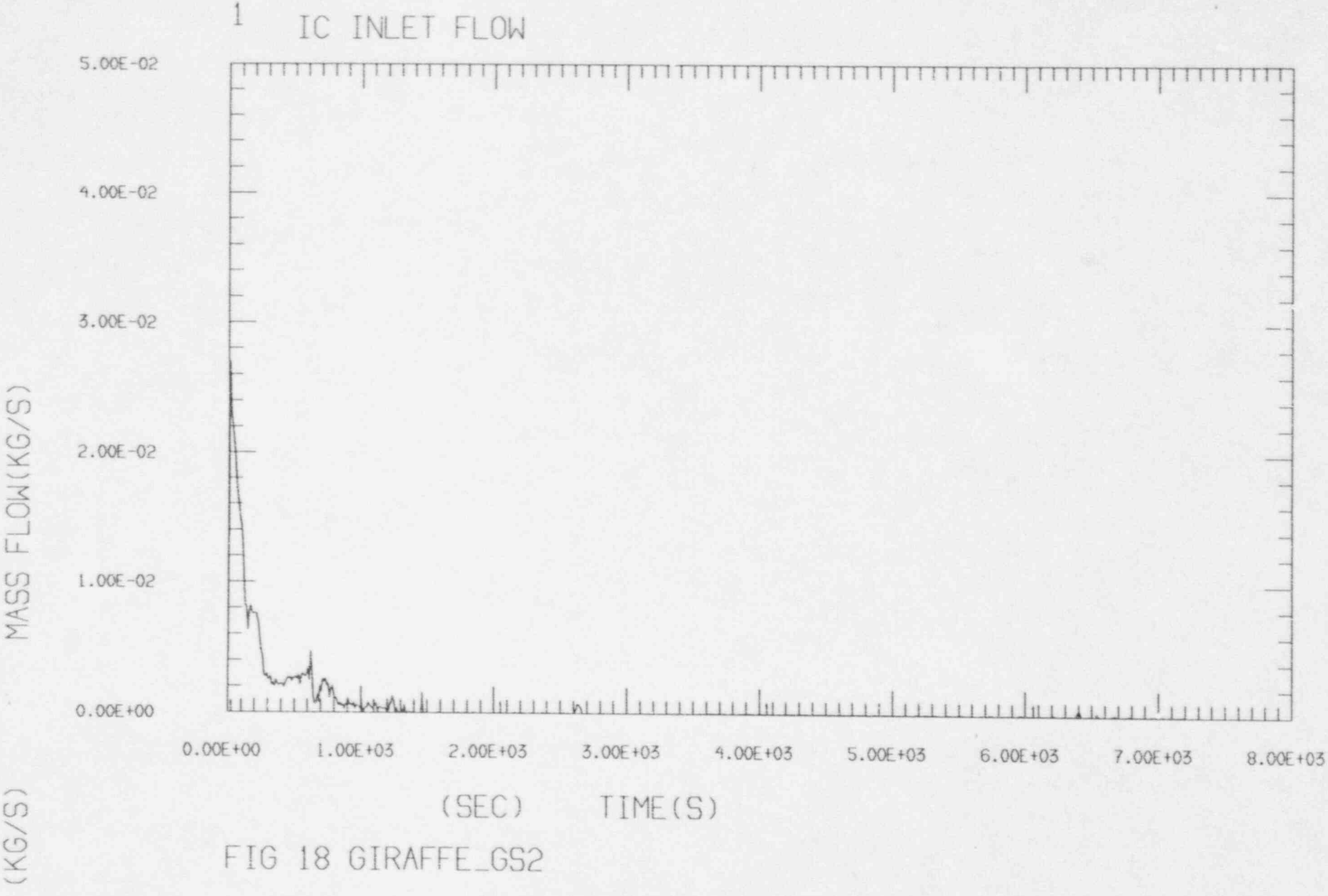


FIG 18 GIRAFFE_GS2

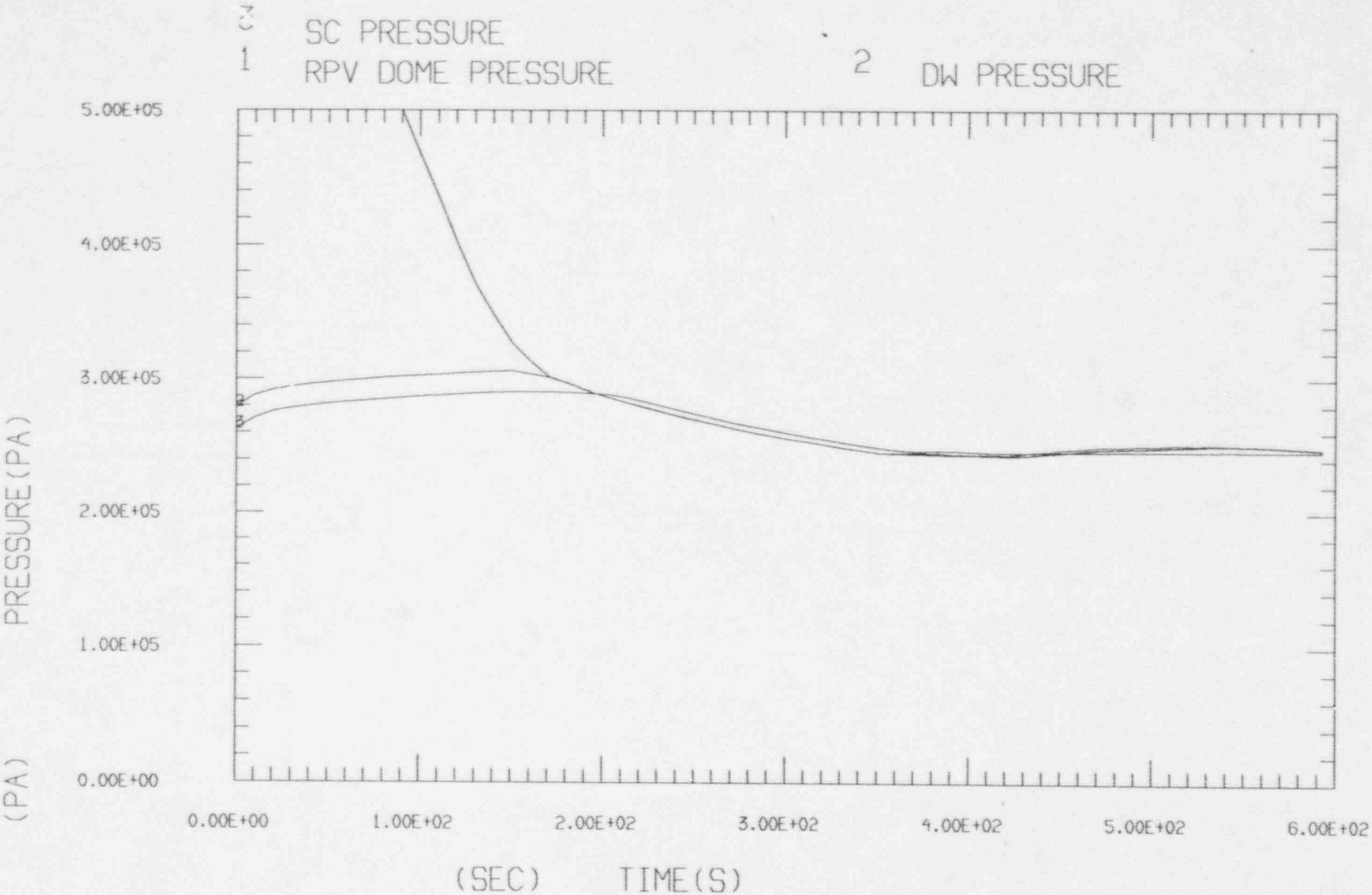


FIG 19 GIRAFFE_GS2

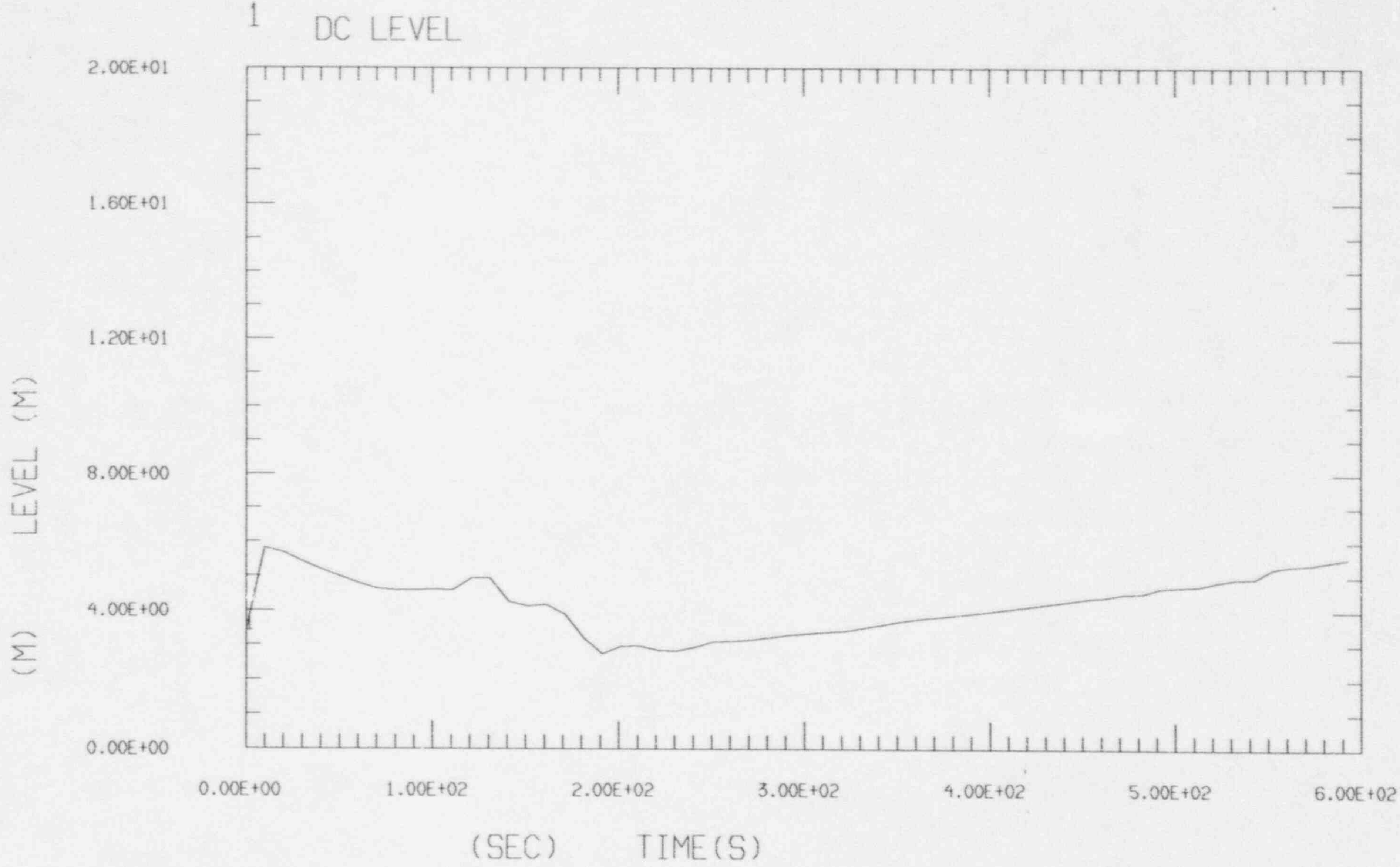


FIG 20 GIRAFFE_GS2

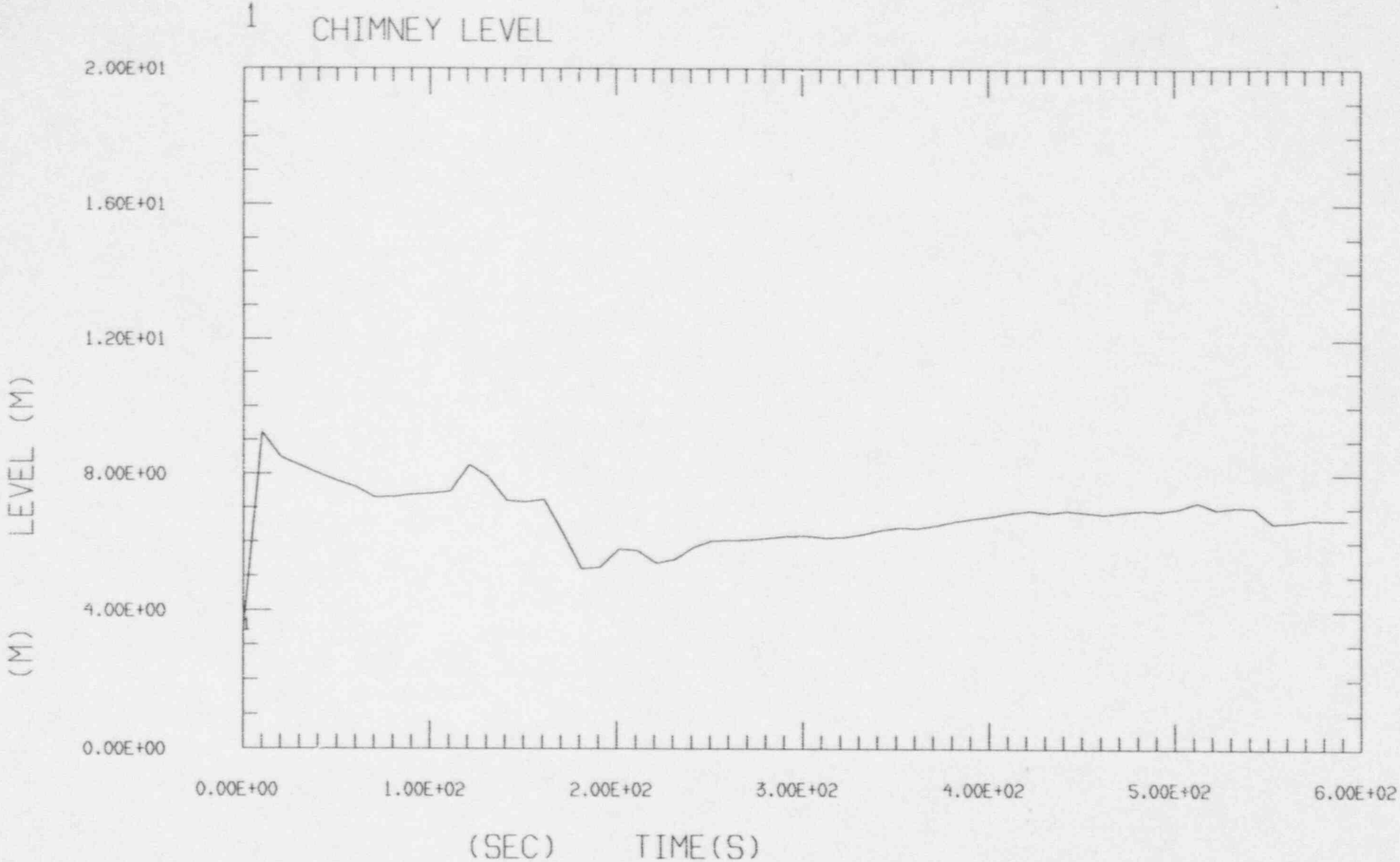


FIG 21 GIRAFFE_GS2

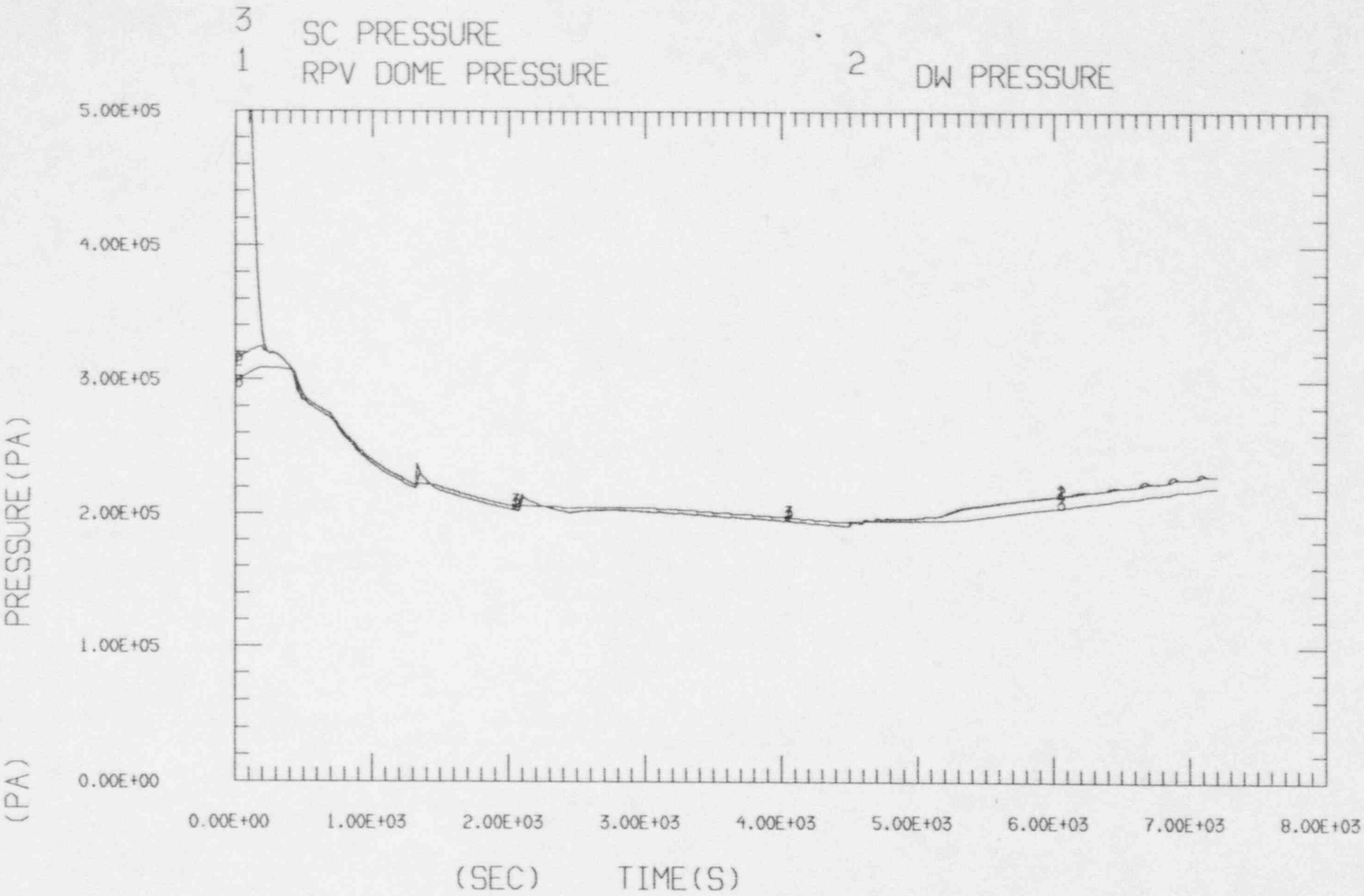


FIG 22 GIRAFFE_GS3

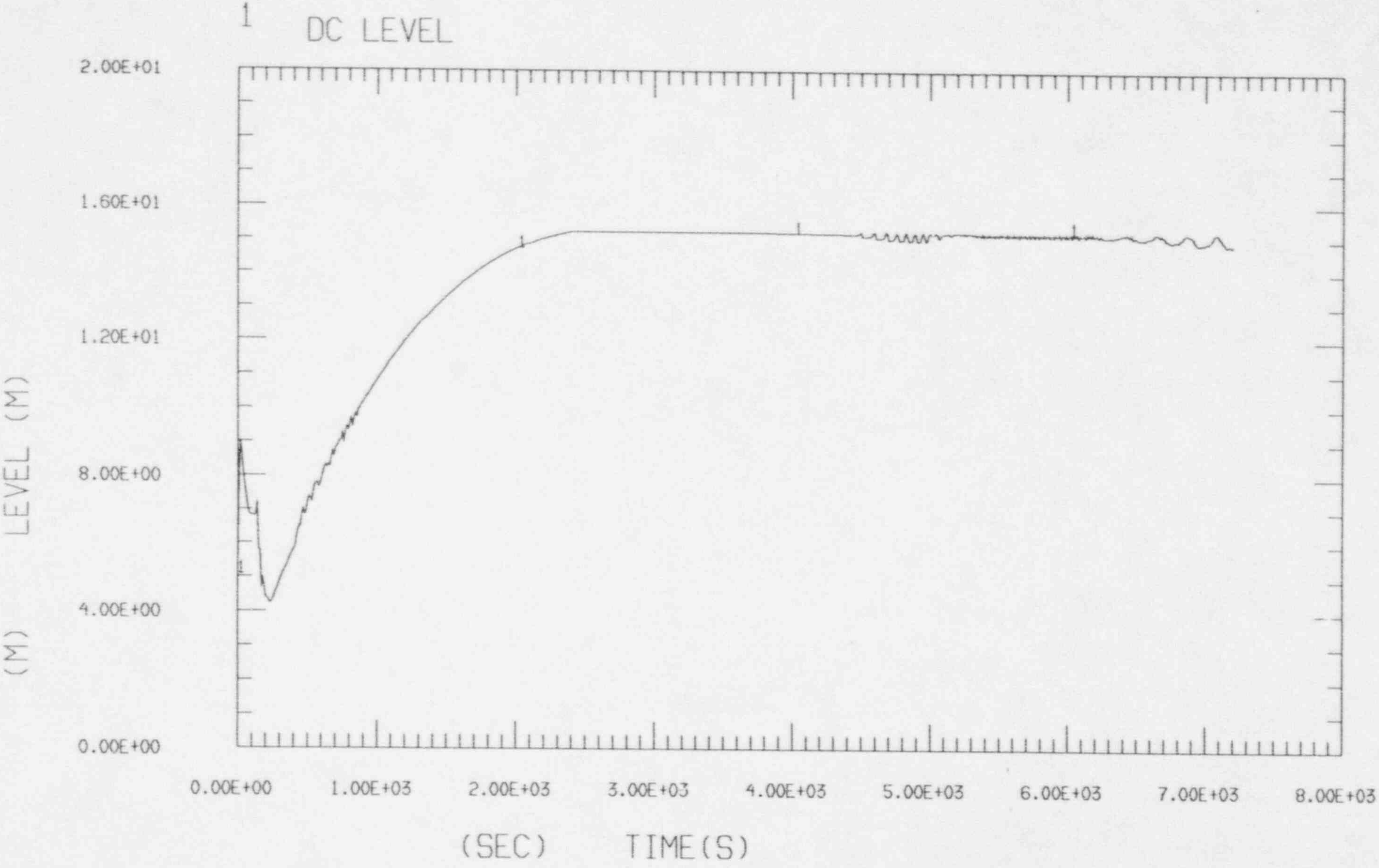


FIG 23 GIRAFFE_GS3

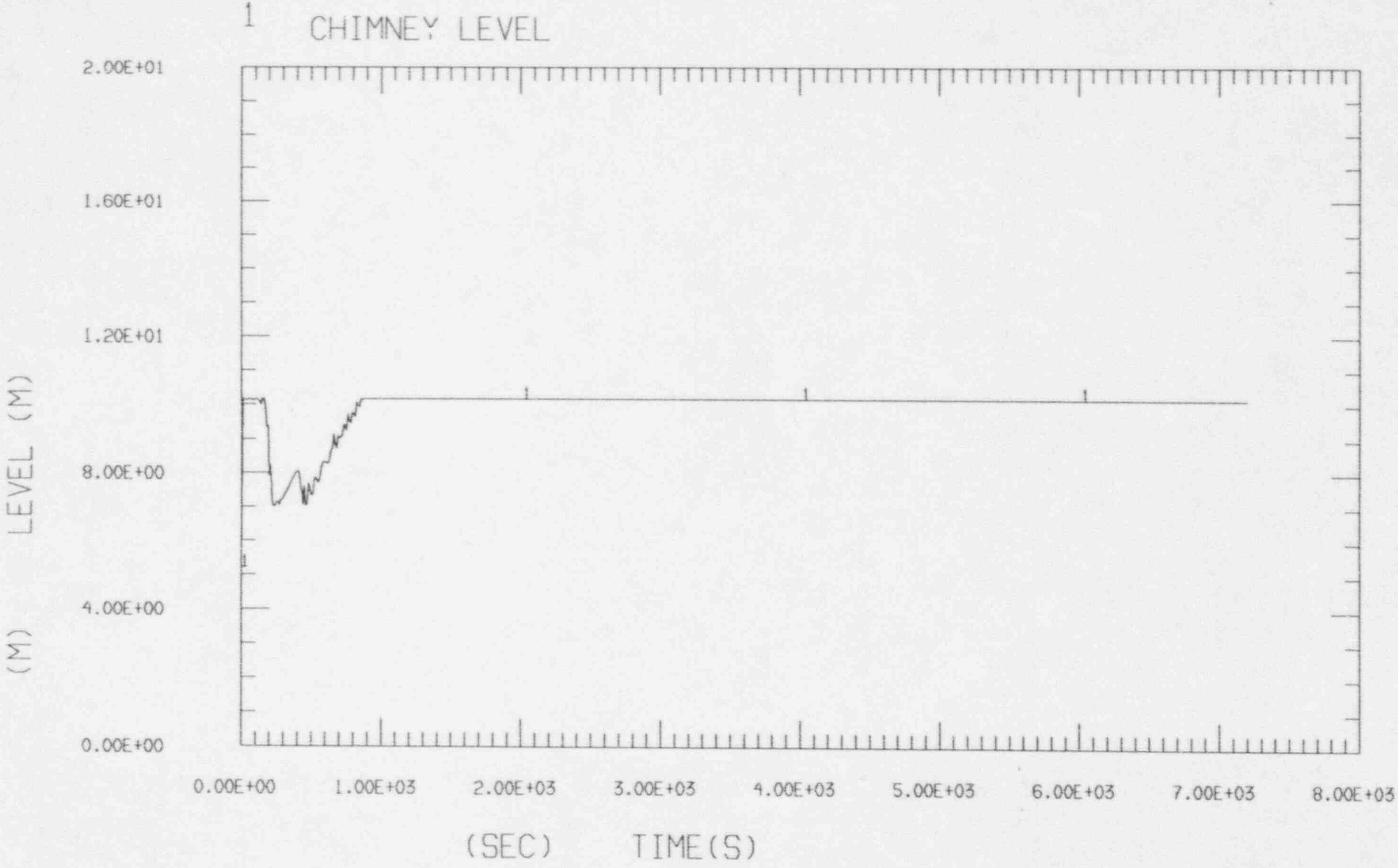


FIG 24 GIRAFFE_GS3

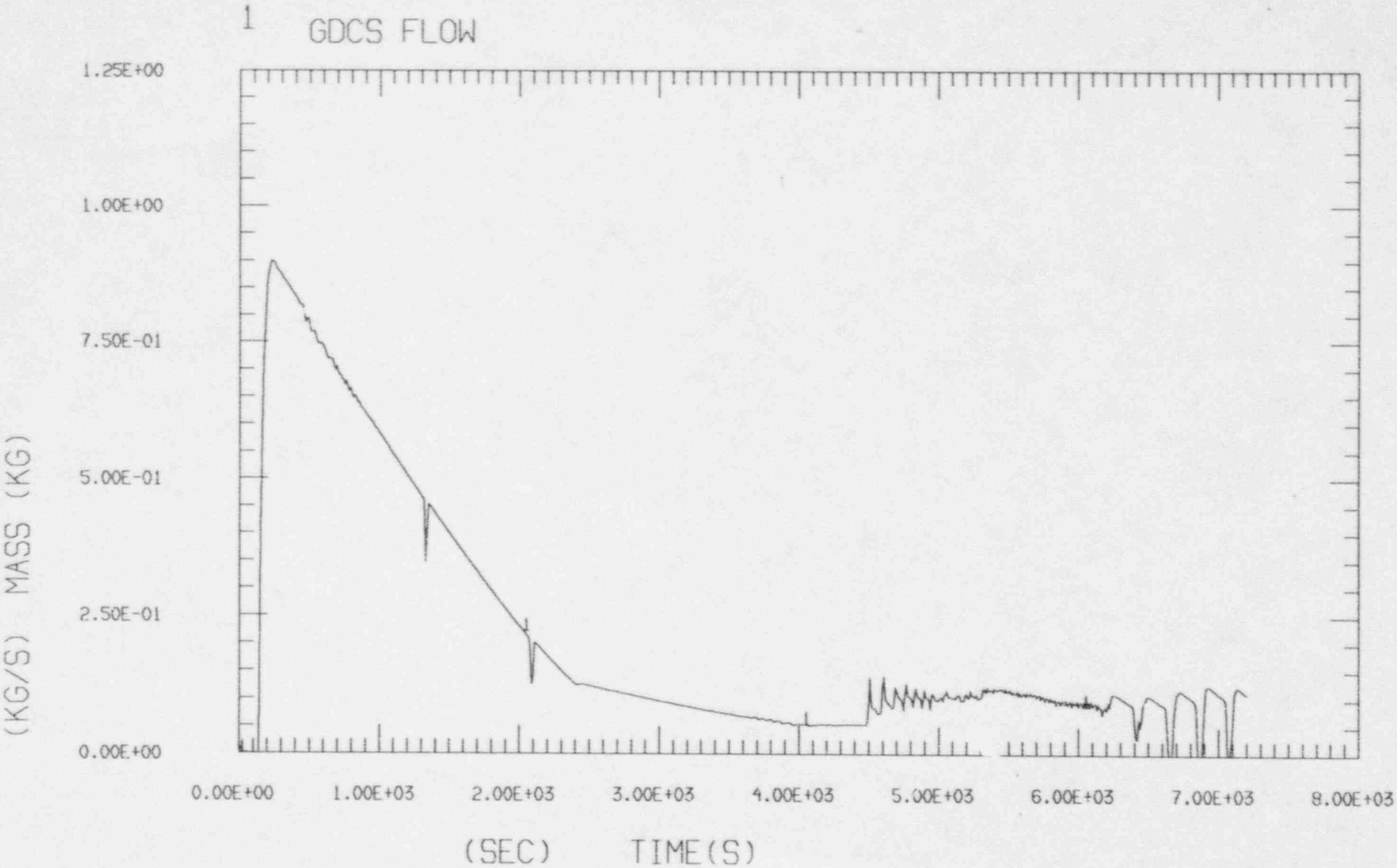


FIG 25 GIRAFFE_GS3

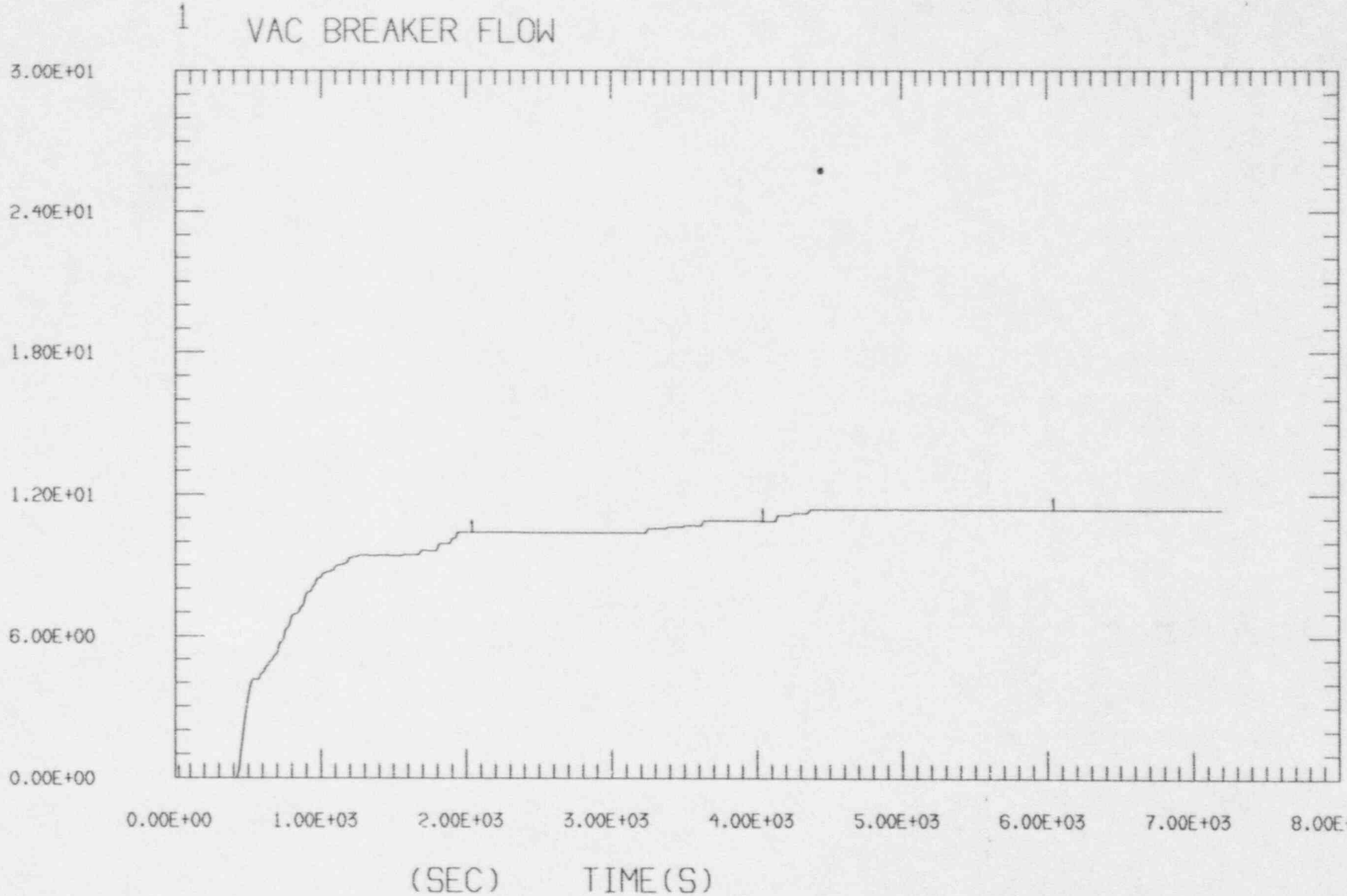


FIG 26 GIRAFFE_GS3

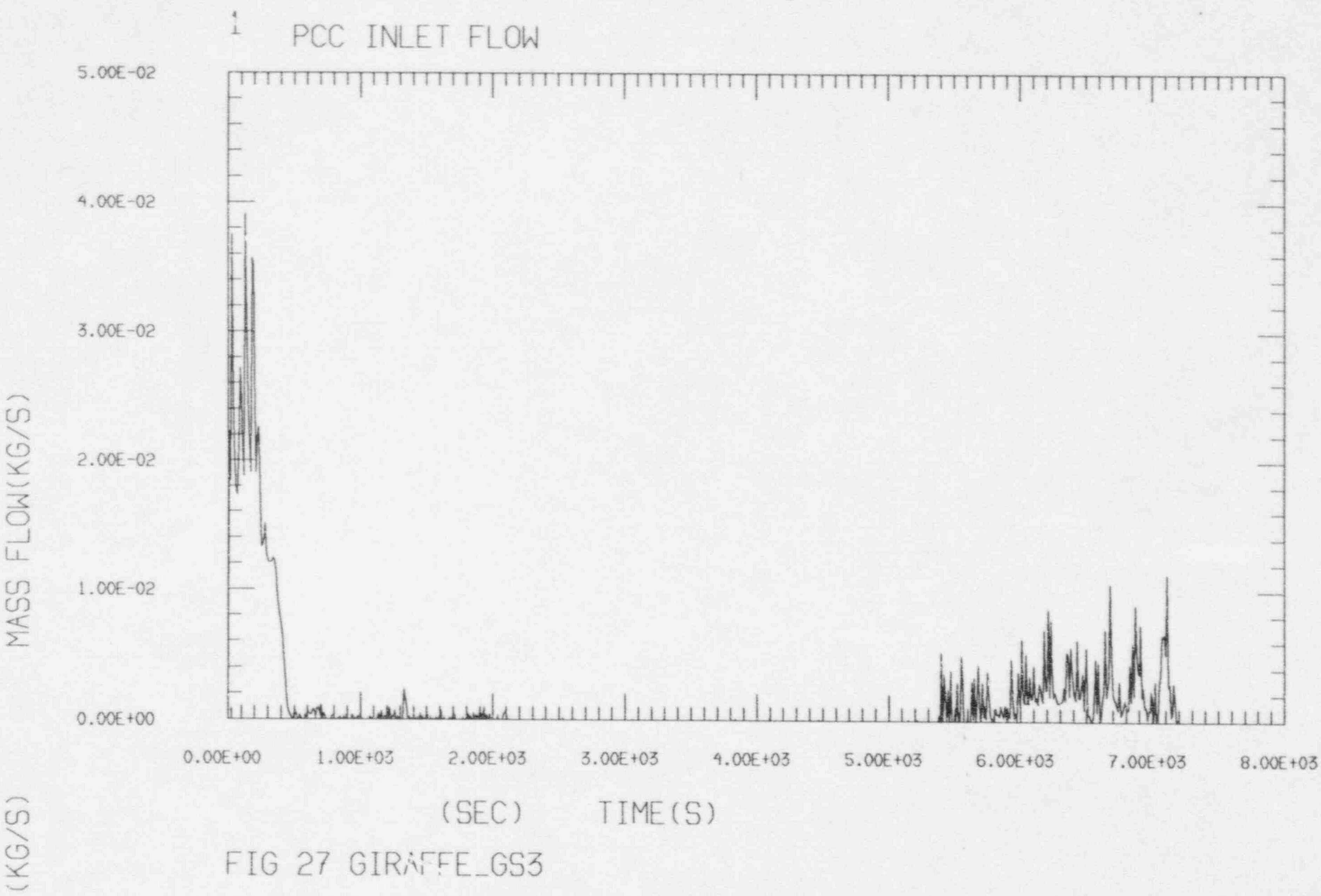


FIG 27 GIRAFFE_GS3

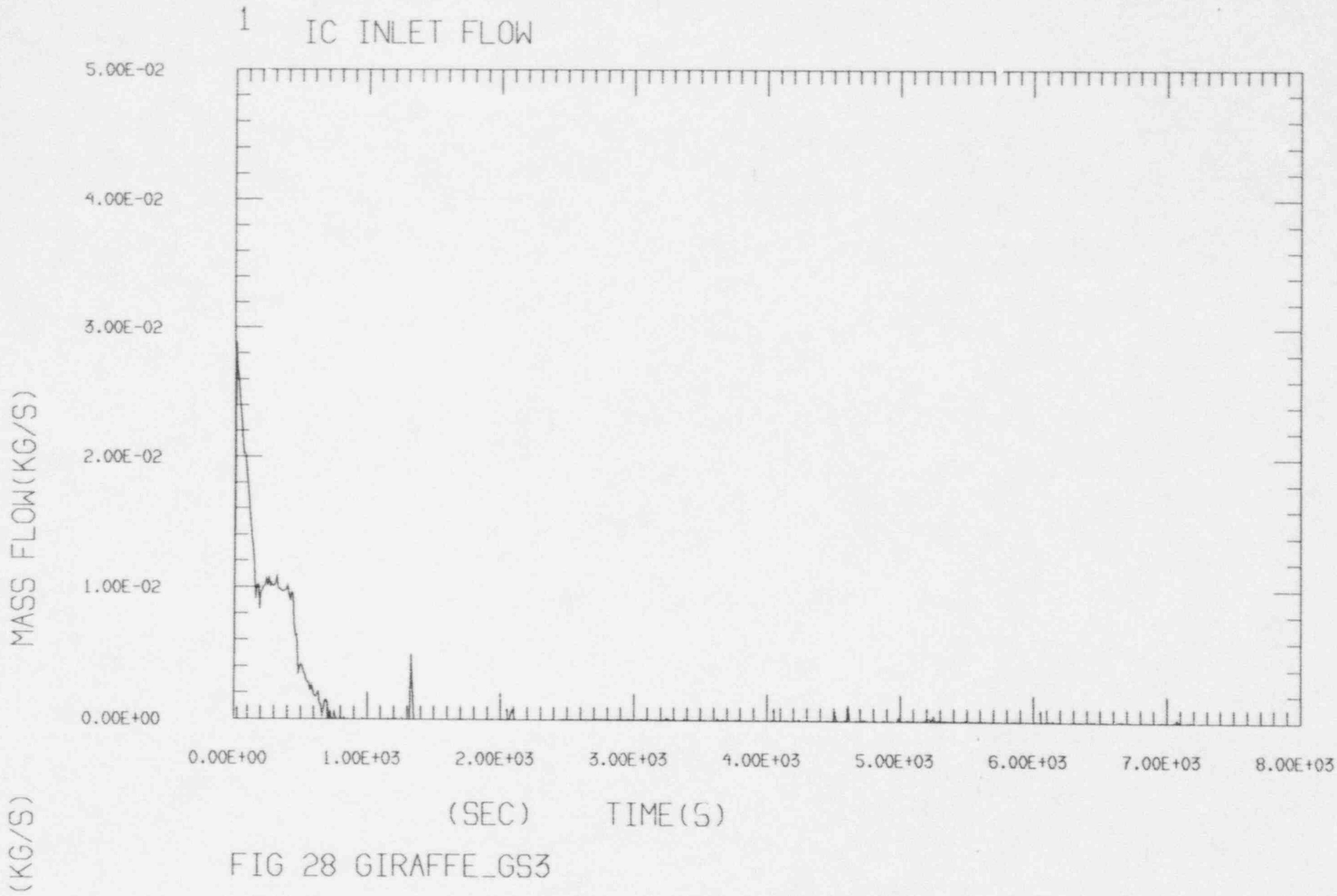


FIG 28 GIRAFFE_GS3

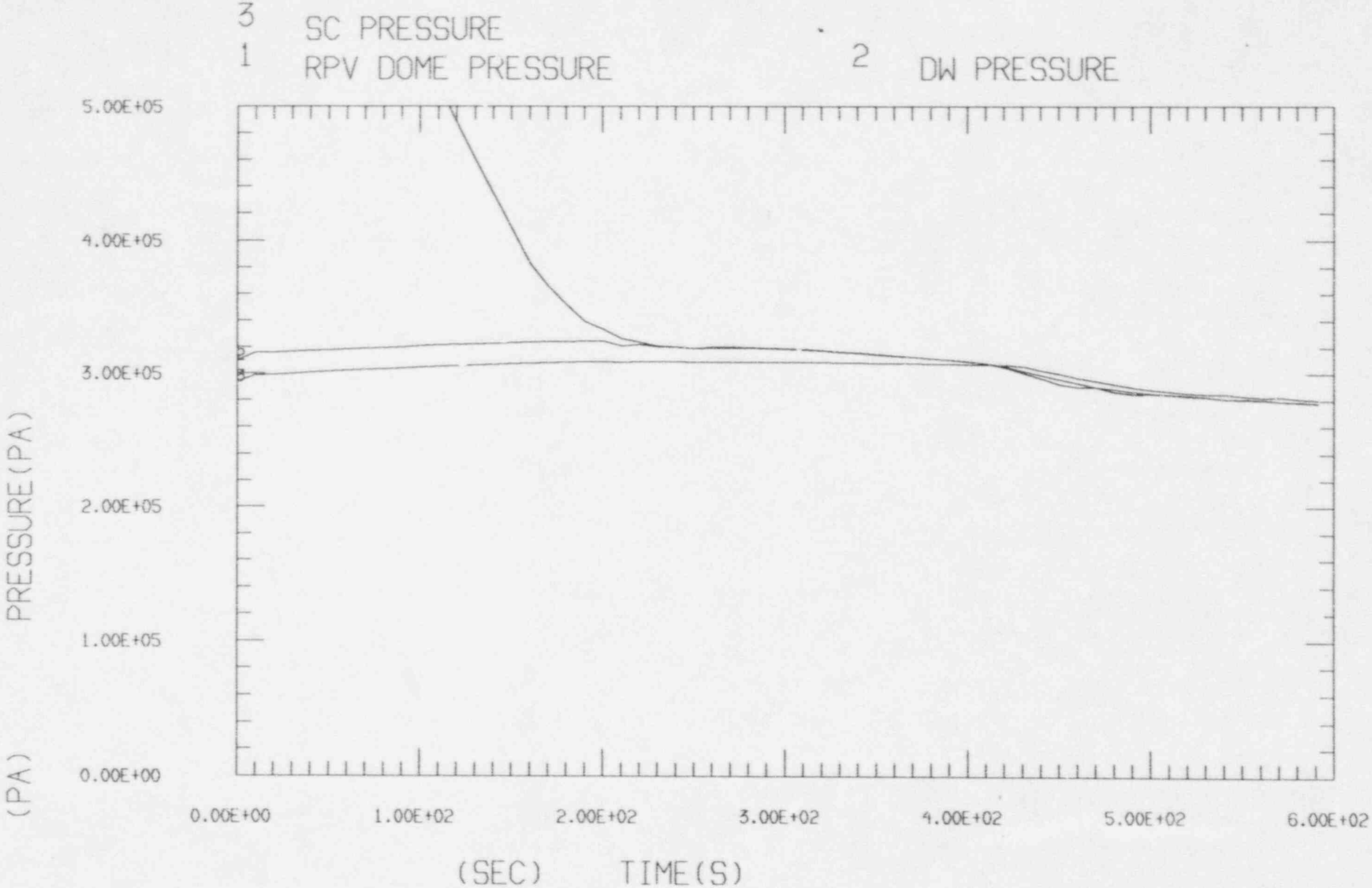


FIG 29 GIRAFFE_GS3

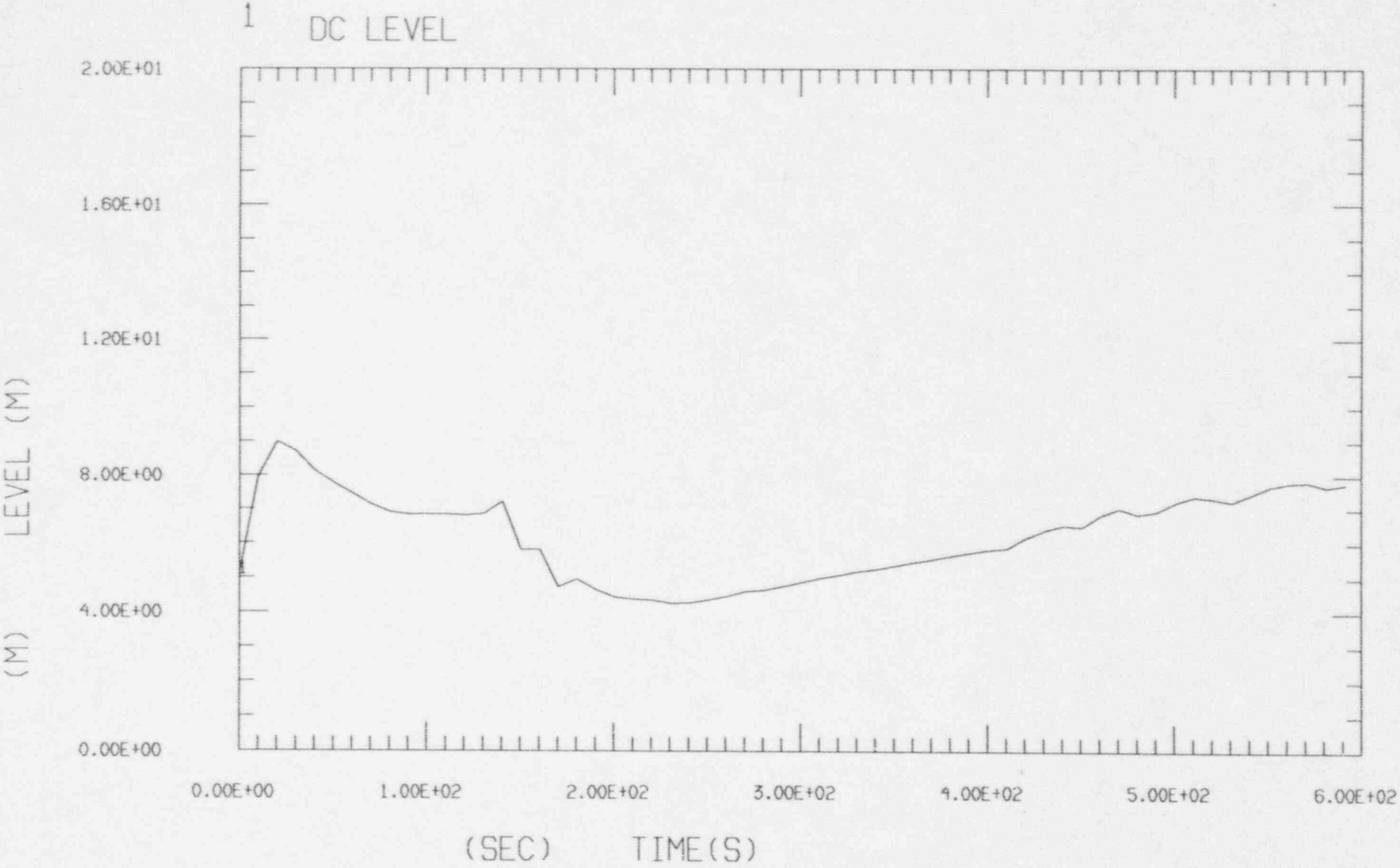


FIG 30 GIRAFFE_GS3

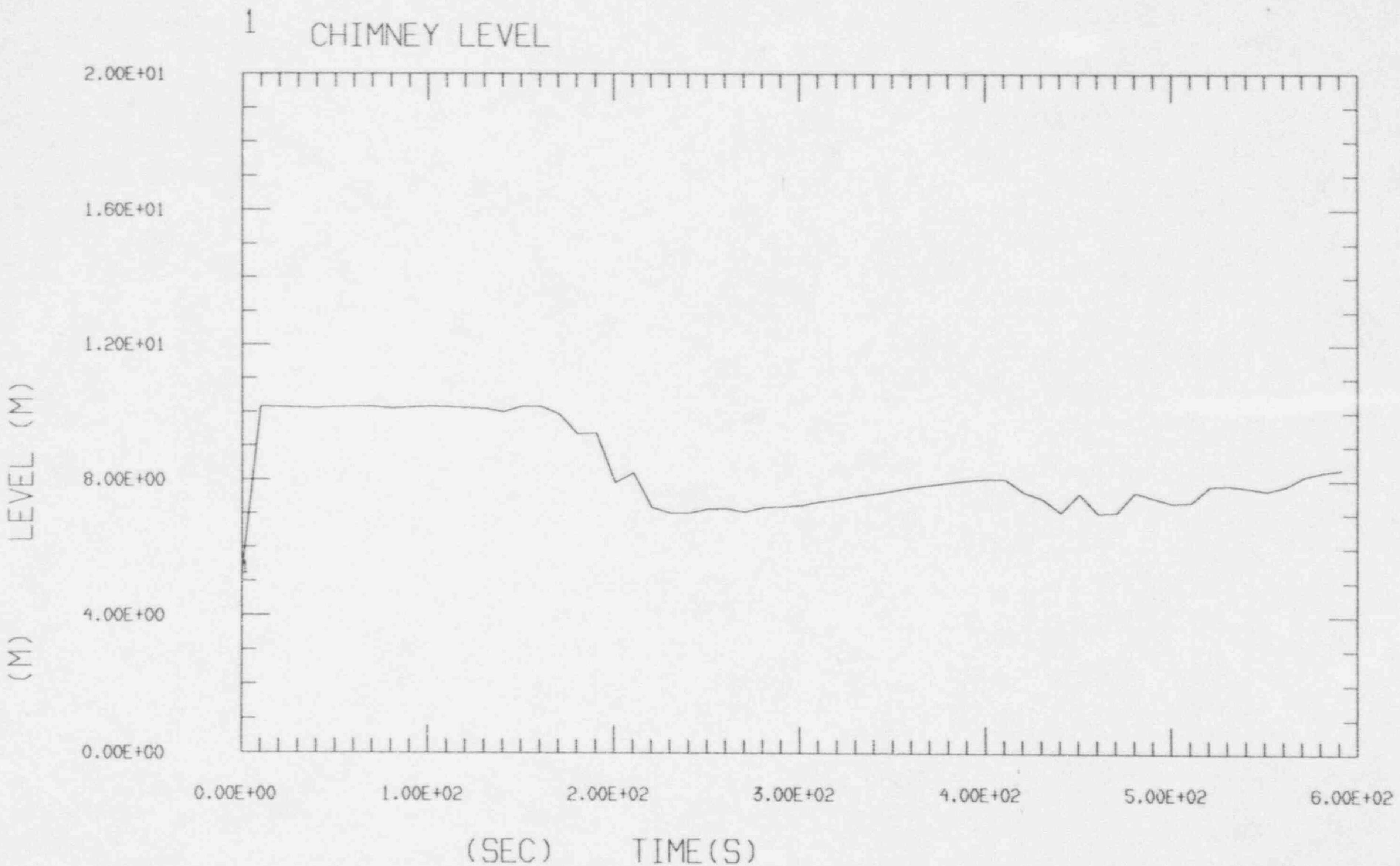


FIG 31 GIRAFFE_GS3

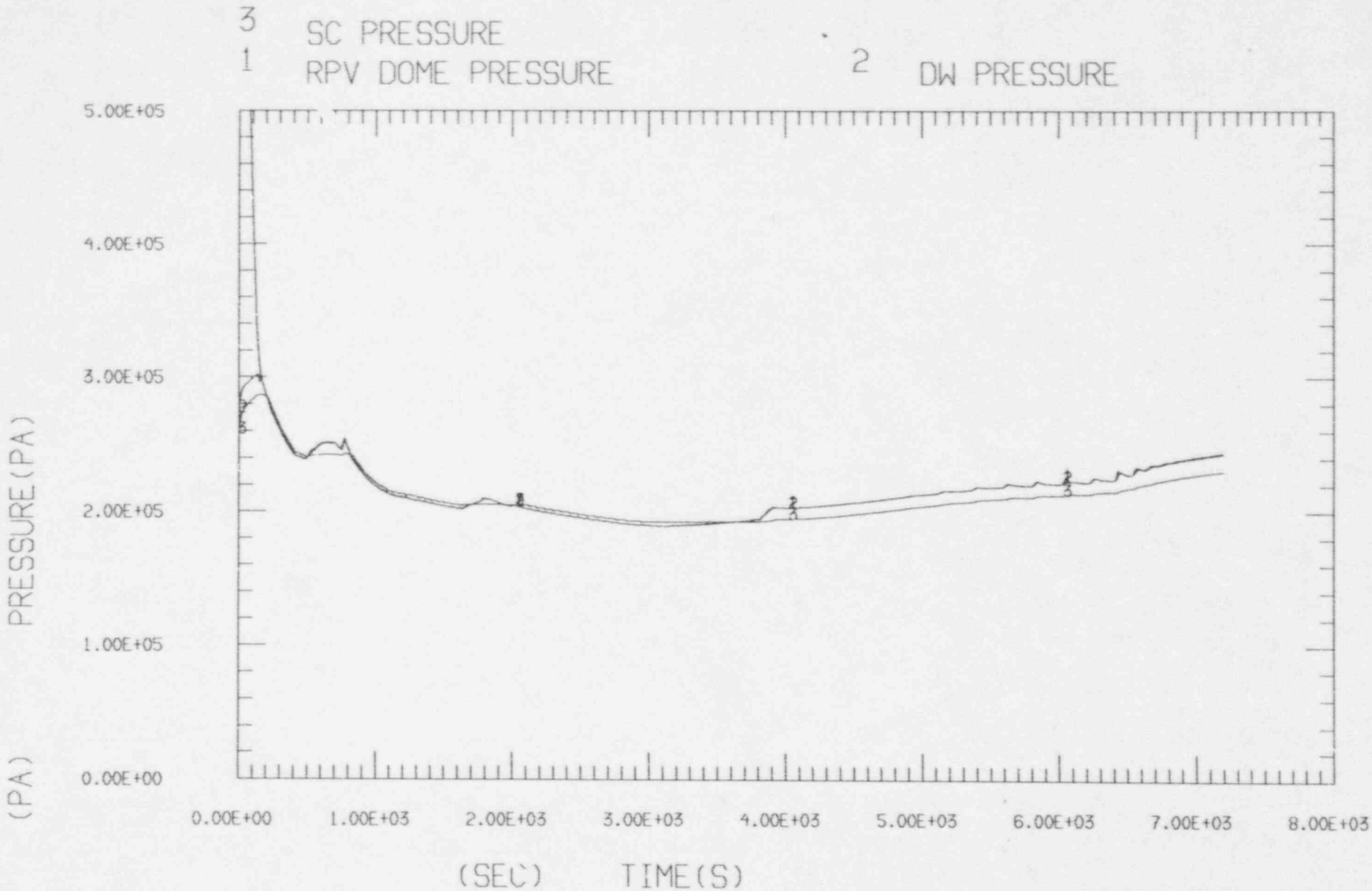


FIG 32 GIRAFFE_GS4

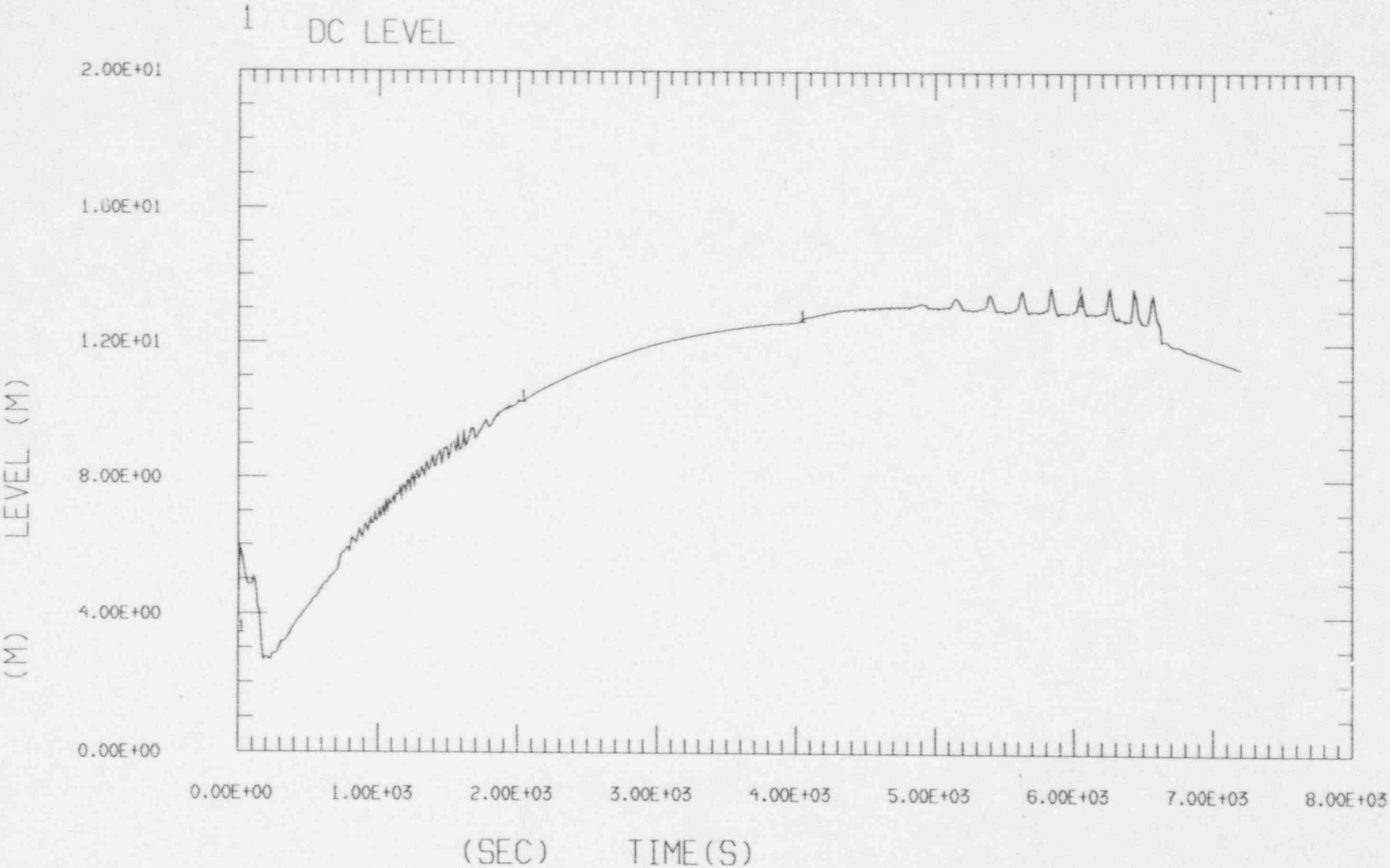


FIG 33 GIRAFFE_GS4

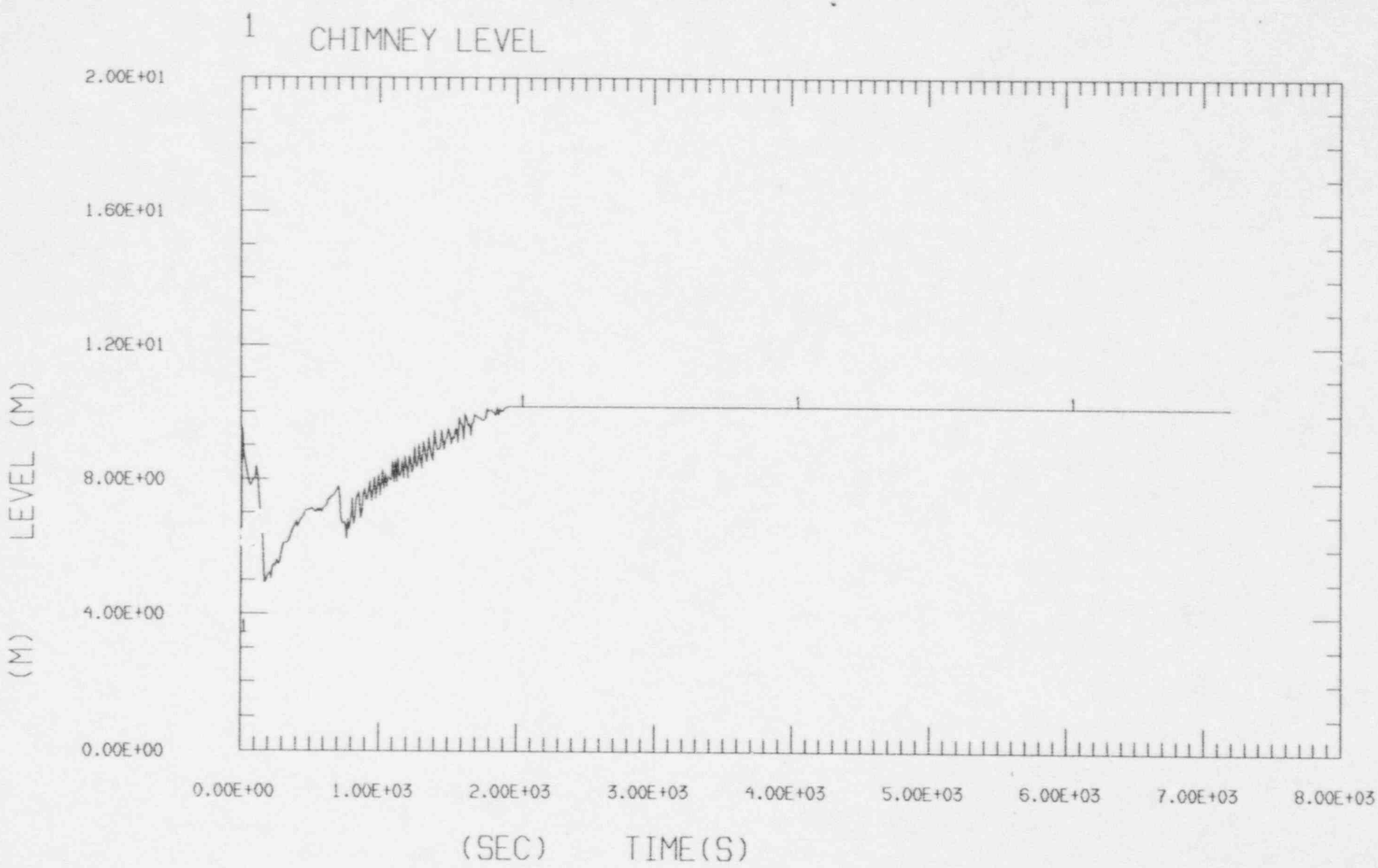


FIG 34 GIRAFFE_GS4

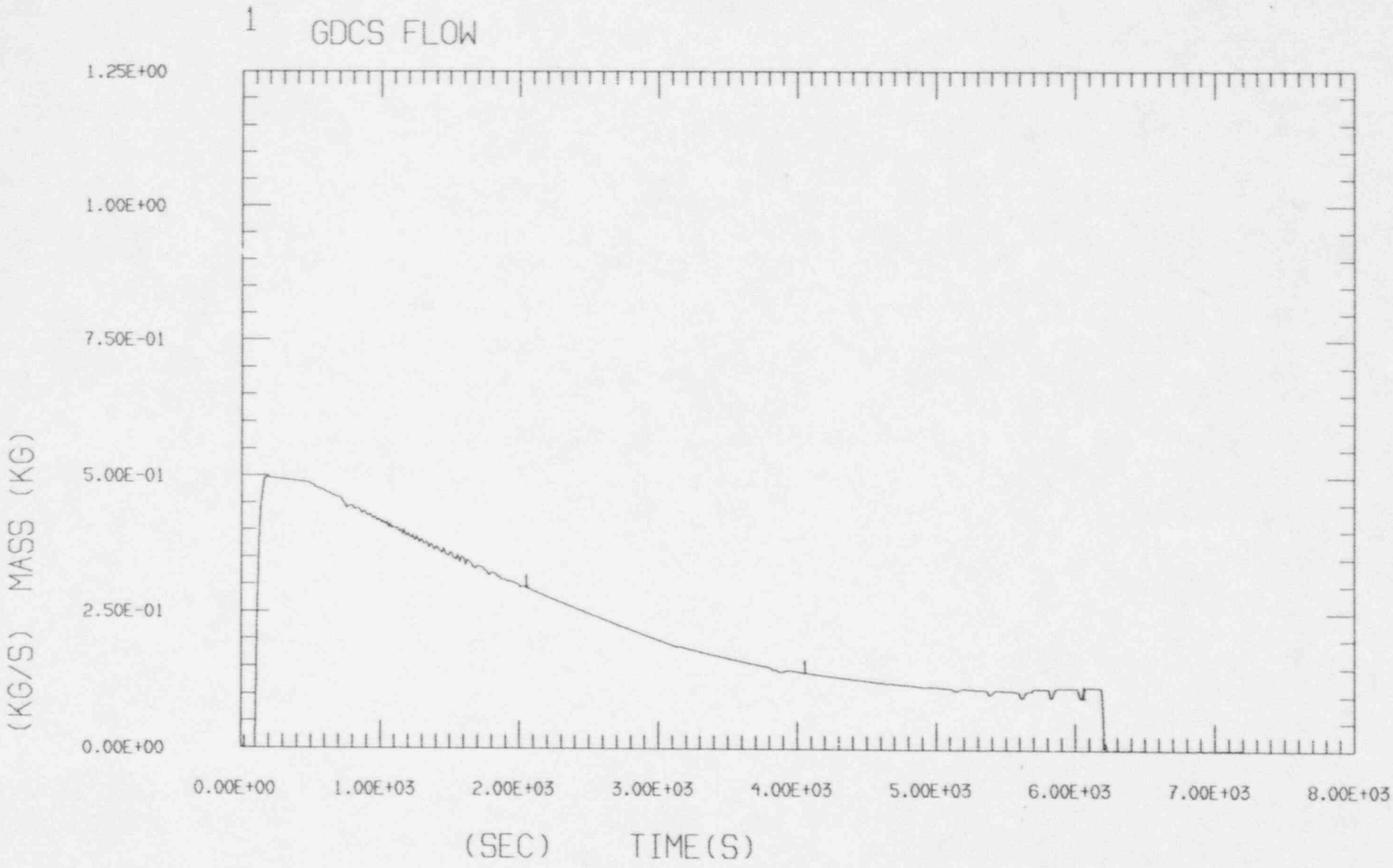


FIG 35 GIRAFFE_GS4

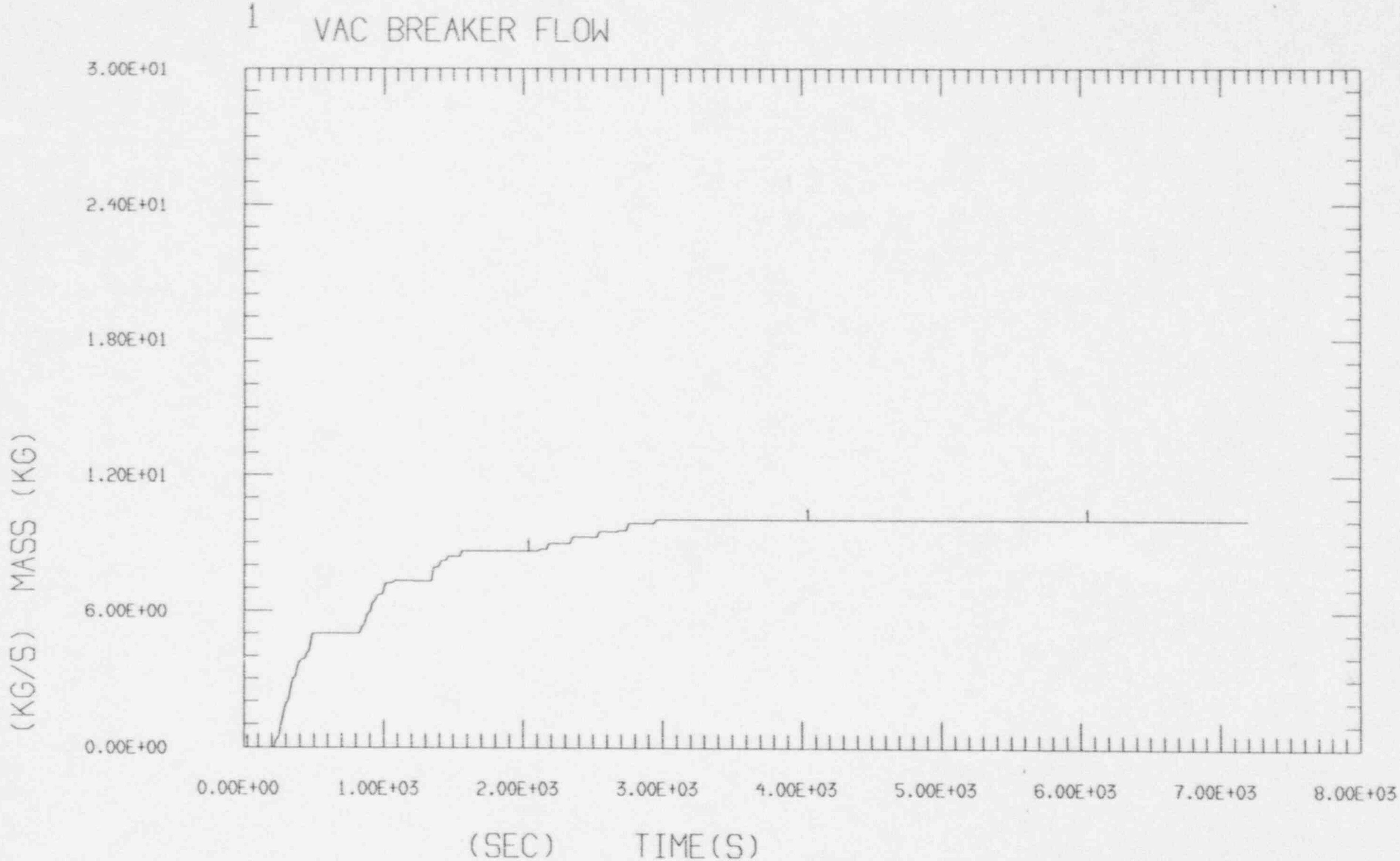


FIG 36 GIRAFFE_GS4

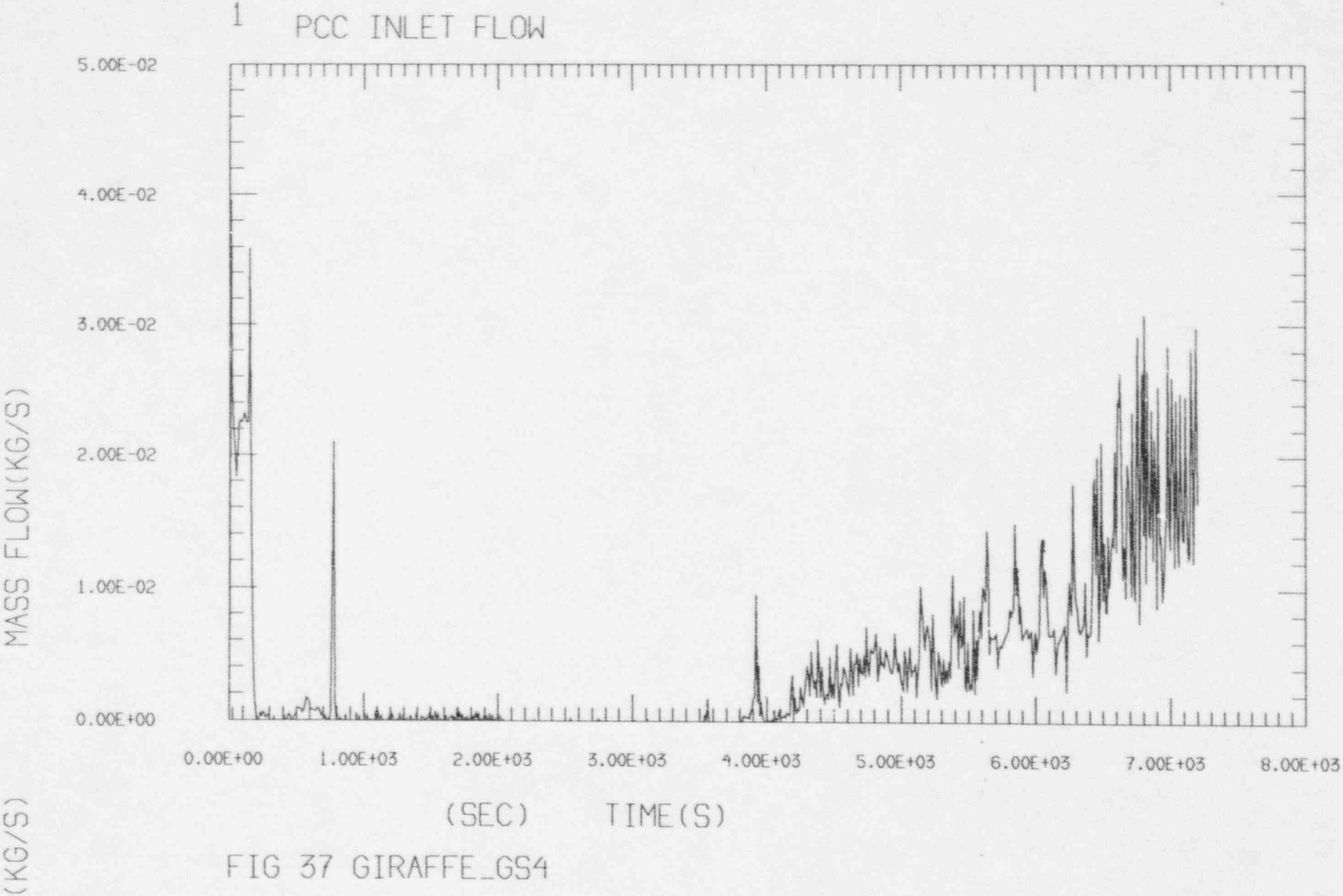


FIG 37 GIRAFFE_GS4

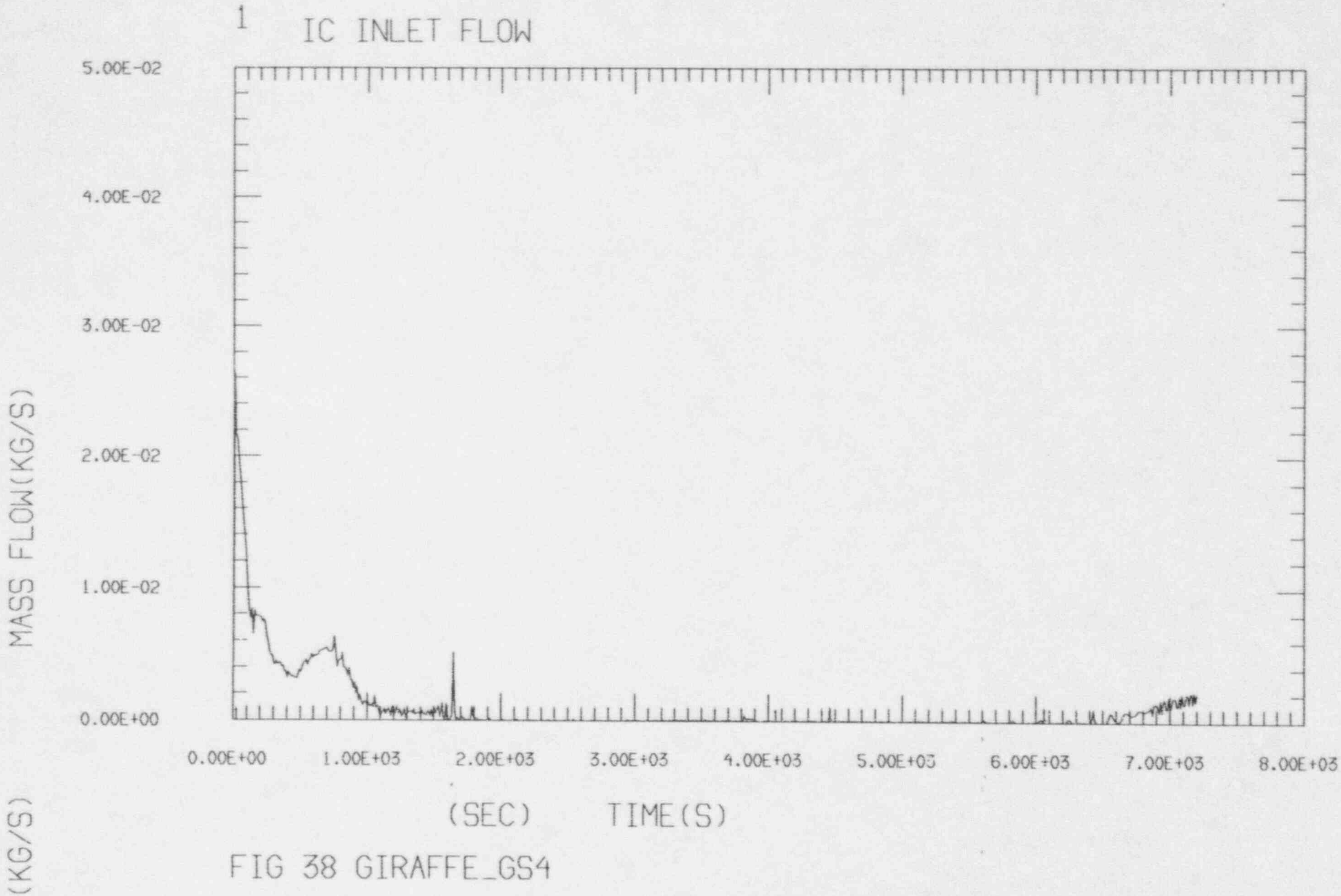
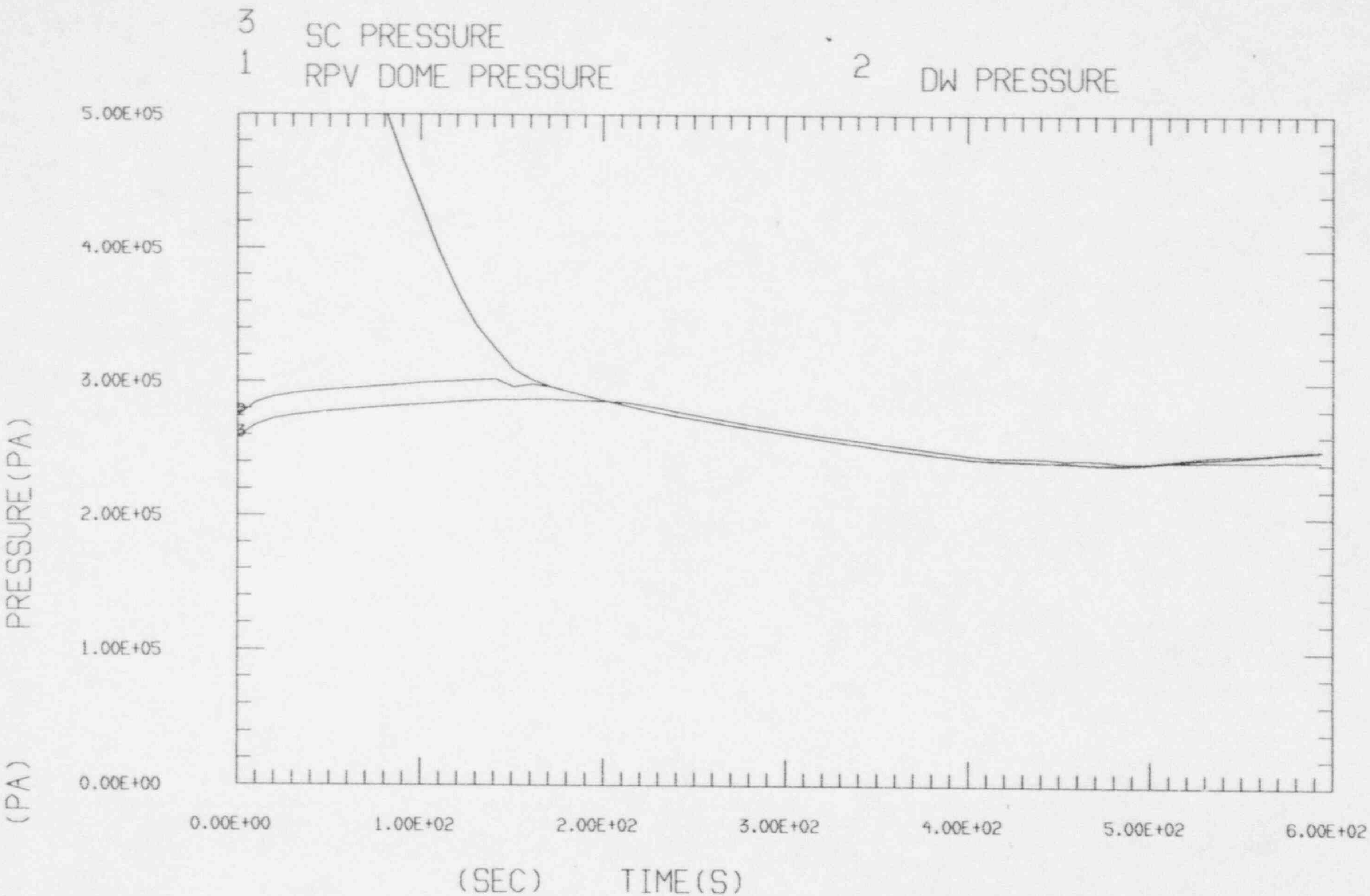


FIG 38 GIRAFFE_GS4



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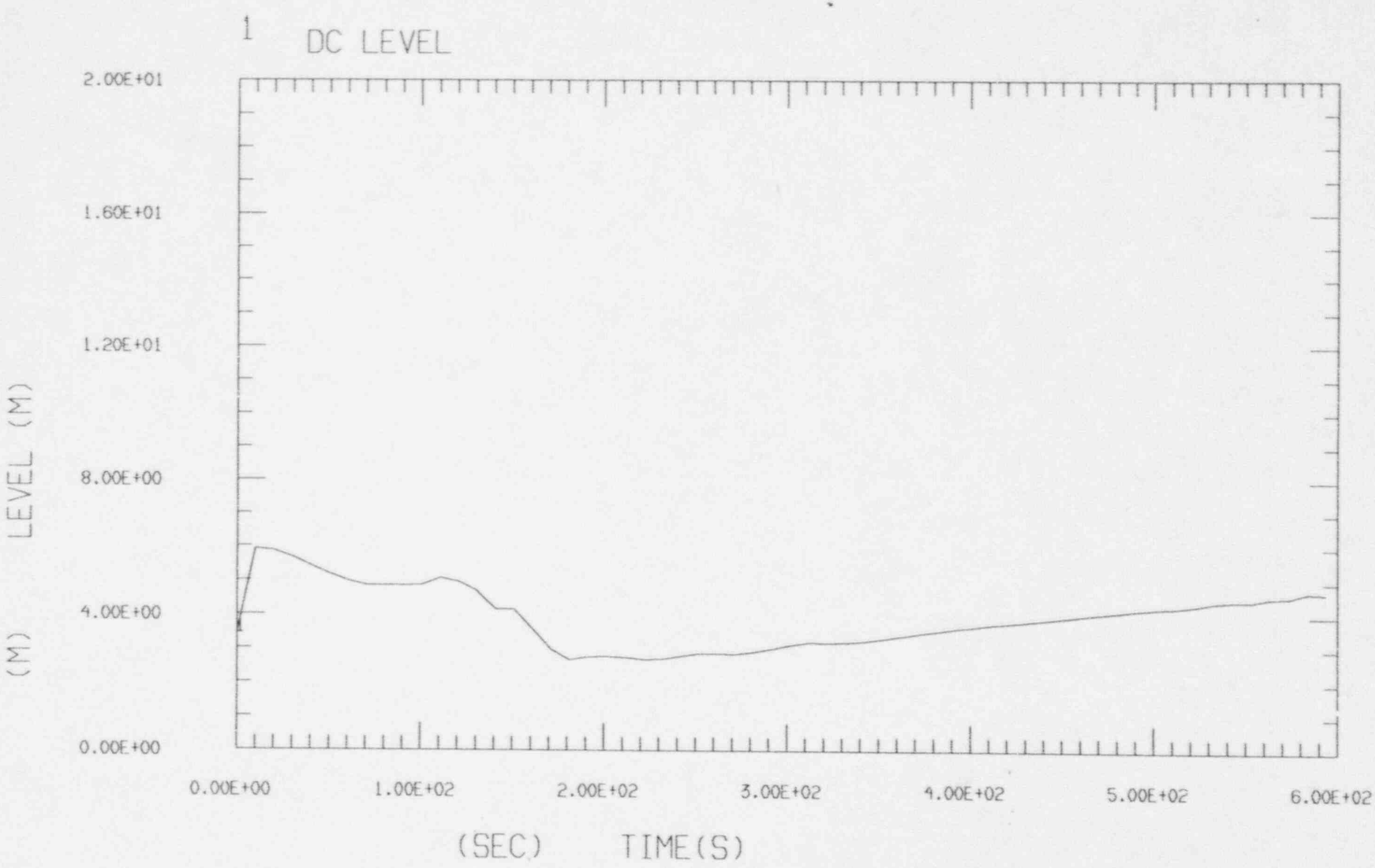

FIG 40 GIRAFFE_GS4

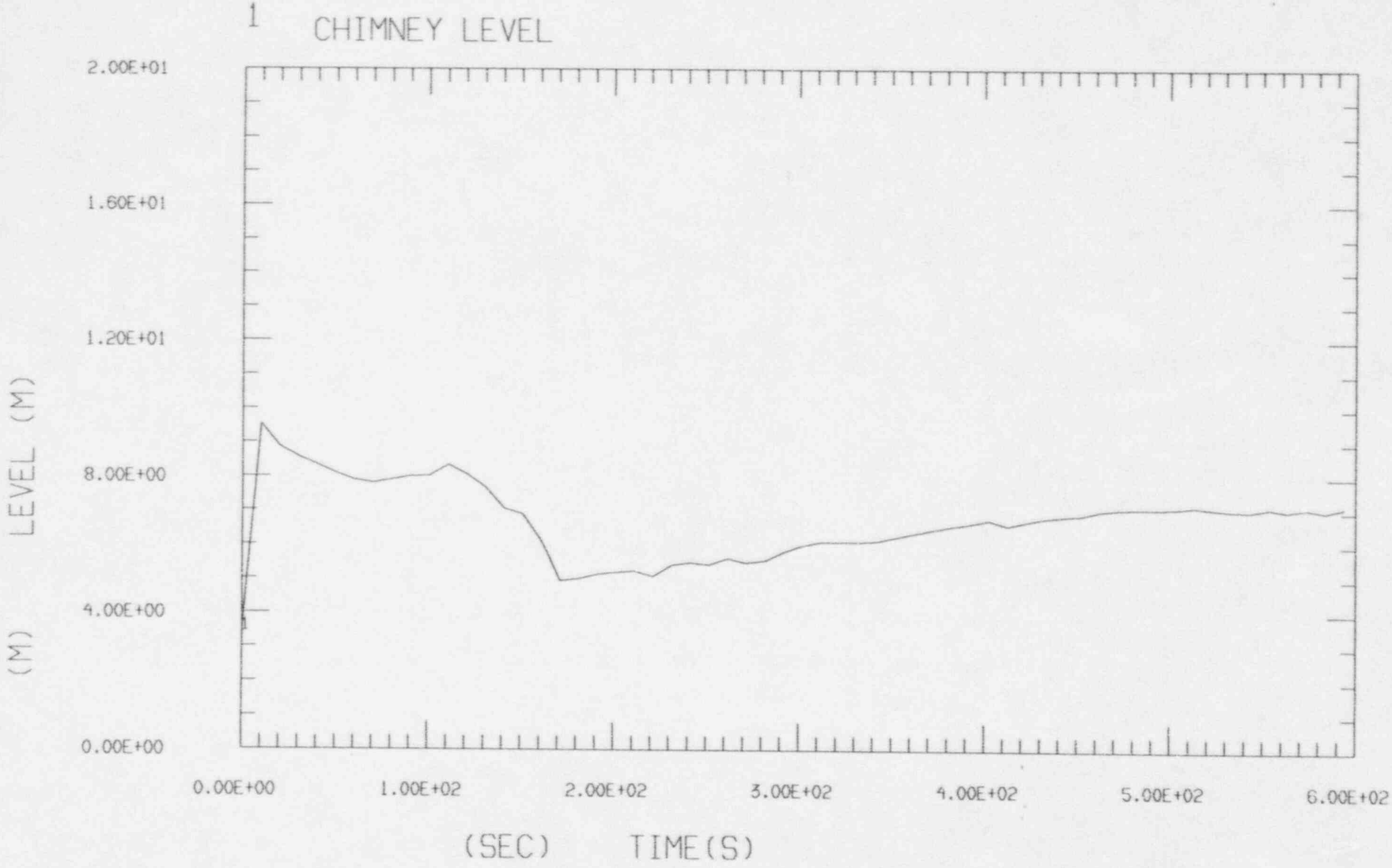

FIG 41 GIRAFFE_GS4