PDR 9/
86-11264600 00
76

DRAFT

ENGINEERING SUMMARY REPORT

of a Complete Loss

of Feedwater Transient Analyses

for Davis-Besse, Unit 1

THIS DOCUMENT IS PRESENTED AS PRELIMINARY AND FOR INFORMATION ONLY. THIS DOCUMENT DOES NOT SERVE AS A LICENSING / PROCEDURE BASE DOCUMENT FOR DAVIS-BESSE.

Babcock & Wilcox Company
582-7151-14-00
June 22, 1981

86-1126460 00

Analysis of a Complete Loss of Feedwater Transient for the Davis-Besse Unit

1. Introduction

During a complete loss of feedwater accident and heat removal via the steam generator, the primary system repressurizes rapidly to the PORV setpoint. The primary system relies on the high pressure injection (HPI) system to ensure core coverage throughout the transient. For the raised loop Davis-Besse plant which is equipped with low shut-off head HPI pumps, the operator action is required in order to depressurize the system.

Analyses have been performed in order to define when and what operator actions are necessary to mitigate the accident. The following is a compilation of all ECCS analyses for a complete loss of feedwater transient performed to date with applicability to DB-1:

(a) Using conservative licensing assumptions, the maximum time available for operator action to prevent core uncovery was determined.

(b) Using a "realistic" decay heat curve, an analysis of operator action at 30 minutes to open the PORV and manually initiate two makeup pumps was examined.

(c) Using a "realistic" decay heat curve, opening of the PORV, manual initiation of one makeup pump, and actuation of the startup feedwater pump via operator action at 30 minutes was examined.

(d) Using a "realistic" decay heat curve, manual initiation of two makeup pumps and startup feedwater pump via the operator action at 30 minutes without taking credit for PORV was examined.

Using the results of these analyses, other operator actions which would control the transient are also identified.

2. Summary and Conclusions

Analyses have been performed for a complete loss of feedwater transient on Davis-Besse 1. Due to the low shutoff head on the HPI pumps at Davis-Besse 1, operator action is required to prevent core uncovery. Using normal conservative licensing assumptions and no operator action, core uncovery started at approximately 37 minutes and was completely uncovered by 41 minutes. Thus, operator action should be taken by 30 minutes to ensure that core uncovery does not occur.

Using a "realistic" decay heat curve, three analyses were performed examining the effect of various operator actions. In the first case, opening of the PORV and manual initiation of two makeup pumps by the operator at 30 minutes was assumed and extends the core uncovery time from 37 minutes to greater than one hour. However, further operator action would be required to prevent core uncovery.

Operator action at 30 minutes to open the PORV, manually initiate one makeup pump and actuate the startup feedwater pump was analyzed for the second case and is shown to prevent core uncovery.

In the third case, operator action was assumed to manually initiate two makeup pumps and the startup feedwater pump at 30 minutes while the PORV remained closed. Similar to the second case, the operator action was sufficient to prevent core uncovery.

A review of the analyses was performed to determine other combinations of acceptable operator actions. Table 2.1 shows alternate operator actions that were evaluated and found to be acceptable for controlling the event.

Table 2.1 Alternate Operator Actions for TECO, Loss of All Feedwater and Offsite Power Transient

Operator action required at 30 minutes	1.2 ANS decay heat	1.0 ANS decay heat (realistic cases)			
Number of makeup pumps actuated at 30 minutes	2	2	1	2	1
PORV opened at 30 minutes	Yes	No	No	Yes	Yes
Electric startup feedwater pump actuated at 30 minutes	Yes	Yes	Yes	Yes	Yes
Success of action to mitigate accident	50%*	Yes	50%*	Yes	Yes

*Chance of success.

3. Results of Analysis

3.1 Method

The analyses in this report were performed using the Davis-Besse CRAFT model utilized in the analysis presented in Section 6.2.5 of "Evaluation of Transient Behavior and Small Reactor Coolant System Breaks in the 177-Fuel assembly Plant," May 7, 1979, Reference 1. The analysis method is that described in Chapter 5 of BAW-10104, Revision 3, "B&W ECCS Evaluation Model," Reference 2. The model and input assumptions are basically identical to that used for the 177 FA lowered-loop plant small break analysis submitted in the letter report of July 18, 1978 from J. H. Taylor (B&W) to S. A. Varga (NRC), Reference 3. The CRAFT2 noding model used in this analysis is shown in Figure 1. The following assumptions are made for conditions and system responses during the accident:

1. The reactor is operating at 102 percent of the steady-state power level of 2772 MW_t.
2. No offsite power is available.

3. The safety rods begin entering the core after 0.5 seconds delay from the time the reactor trip signal is reached.
4. The RC pumps trip and coast down coincident with reactor trip.
5. The pressurizer code safeties (2) were modeled to be opened to 70 percent of full capacity at a set pressure of 2435 psig, and to be fully opened at 103 percent of the set pressure.
6. When operator action was assumed to manually open the PORV valve, the flow characteristics were based on full design capacity plus 10 percent.
7. The discharge from the code safety valves and the PORV valve used the Bernoulli equation for the subcooled portion of the transient, while the Moody correlation was used in the two-phase and steam portion. The area of the valves were chosen such that the Moody calculated steam flow at the valve rated pressure were coincident with the design capacity of the valve.
8. When operator action was assumed to manually initiate the makeup pump(s), the makeup pump flow characteristics, based on the control valve being wide open, were modeled.
9. For the "realistic" decay heat curve cases, the decay heat curve is based on 1.0 time the 1971 ANS 5.1 Standard for infinite reactor operation.
10. The auxiliary feedwater (FW) system is assumed not to be available during the transient.

Additional assumptions for each specific case are given in the content of the analysis.

A total of four analyses were performed, all of which assumed a complete loss of feedwater. Except for the first case which utilized conservative licensing assumptions, the other three used a "realistic" 1.0 ANS decay heat. Table 3.1 shows the matrix of "realistic" analyses.

1. Mass rate of liquid boiled by core decay heat

$$W_{core} = \frac{Q_{DH}}{h_{fg(PS)}}$$

2. Steam volume generated by core decay heat

$$V_c = W_{core} * \nu_{fg(PS)}$$

3. Makeup water volume injected into the RCS

$$V_\mu = 2W_\mu * \nu_{f(PS)}$$

4. Mass of steam condensed by the makeup injection

$$W_{\mu cond} = \frac{2W_\mu (h_{f(PS)} - h_{in})}{h_{fg(PS)}}$$

5. Volume of steam condensed by the makeup water

$$V_{\mu cond} = W_{\mu cond} * \nu_{fg(PS)}$$

6. Mass of steam condensed in primary system due to feedwater injection

$$W_{SGcond} = \frac{W_{fw}[h_{g(SS)} - h_{in}]}{h_{fg(PS)}}$$

7. Volume of steam condensed in primary system due to feedwater injection

$$V_{FWcond} = W_{SGcond} * \nu_{fg(PS)}$$

8. Volume balance

$$V_{net} = V_c + V_\mu - V_{\mu cond} - V_{FWcond}$$

if $V_{net} \geq 0$ system pressure is controlled at pressurizer code safety valve pressure

if $V_{net} < 0$ system will depressurize and safety valves will close

9. Mass lost via pressurizer safety valves

If $V_{net} > 0$, then

$$W_{SV} = \frac{V_{net}}{v_{f(PS)}}$$

If $V_{net} \leq 0$, then

$$W_{SV} = 0.$$

10. Liquid Mass Balance

$$W_{net} = 2W_{\mu} + W_{\mu cond} + W_{SGcond} - W_{core} - W_{SV}$$

if $W_{net} < 0$ liquid mass in primary system is decreasing

$W_{net} = 0$ system liquid mass is constant

$W_{net} > 0$ liquid mass in primary system is increasing.

System pressure is determined by the volume balance. If we had a closed system and V_{net} was greater than zero, primary system pressure would increase. However, the code safety valves on the pressurizer will open and discharge sufficient volume of fluid to maintain the system pressure constant.
is less than zero, the primary system will depressurize and the pressurizer code safety valves will close and the system will refill.
The volume balance calculation, given in Equation 8 above was utilized to determine the time the RCS starts to depressurize due to condensation effects of the makeup water and the startup feedwater injected to the SG. A mass balance was performed, using Equation 10, to determine the amount of fluid inventory lost, following the operator action at 30 minutes, and to determine whether the core remains covered during the transient.

Table 3.1 Matrix of Realistic Analyses performed for a Complete Loss of Feedwater Transient for TECO

Specific assumptions and operator actions	Case 1	Case 2	Case 3
1.0 ANS decay heat (realistic)	X	X	X
PORV opened at 30 minutes	X	X	
Electric startup feedwater pump actuated at 30 minutes		X	X
Number of Makeup pumps actuated at 30 minutes	2	1	2

The realistic cases analyzed used combinations of makeup pump and electric startup feedwater pump flows for accident mitigation. Tables 3.2, 3.3 and 3.4 show the flow provided by one and two makeup pumps and electric feedwater pump, respectively.

Table 3.2 Flow Rate versus Back Pressure for one Makeup Pump

Flow, GPM	Back Pressure, Psia
350	15
300	1015
250	1515
205	1915
170	2115
135	2315
110	2415
80	2515
40	2615
0	2800

Table 3.3 Flow Rate versus Back Pressure for two Makeup Pumps

Flow, GPM	Back Pressure, Psia
500	15
430	1015
380	1515
310	1915
270	2115
220	2315
190	2415
165	2515
130	2615
0	2800

Table 3.4 Flow Rate versus Secondary Pressure for Startup Feedwater Pump

Flow, LBM/SEC	Pressure, Psia
20.79	0.
20.79	925.
17.325	1001.29
13.86	1049.97
12.82	1065.55
10.395	1086.14
6.93	1111.12
3.465	1127.49
0.0	1141.30

The "realistic" cases one and two were analyzed using computer calculations for the entire transient. However, hand calculations were utilized for the last realistic case after 30 minutes to determine if the operator actions to actuate two makeup pumps and startup feedwater pump were sufficient to keep the core covered throughout the transient. The system response prior to the operator action at 30 minutes was the same as that of the other realistic cases. The following equations show the methods utilized for the hand calculations. A list of nomenclatures utilized is given in Section 4.

3.2 Results

Table 3.5 provides a summary of the computer runs. Results of individual cases are in the following sections

Table 3.5 Summary of Computer Runs for Complete Loss of Feedwater Transient

Code	Version/Date	Run Name	Date of Run	Description
CRAFT2	8.4/6-26-78	DB501R3	5/16/79	1.2 ANS, PORV opened at 40 minutes
CRAFT2	8.4/6-26-78	DB502S5	5/17/79	1.0 ANS, PORV opened and 2 makeup pumps
CRAFT2	8.4/6-26-78	DB50452	5/25/79	1.0 ANS, PORV opened, 1 makeup pump, startup feedwater pump

3.2.1 Loss of All Feedwater - 1.2 ANS

Complete loss of all feedwater -- PORV manually opened simultaneously actuating LPI-HPI piggy-back at 40 minutes -- 1.2 x ANS 5.1 decay heat.

Figures 2 through 17 show the transient system response for this accident. The following table presents key results of the analysis:

Sequence of events	Time, s
Loss of main feedwater, loss of offsite power (RC pumps coastdown)	0.0
Reactor trips on high pressure, turbine trip	8.0
SG secondary side inventory boiled-off	250.0
Two pressurizer code safety valves open, pressurizer goes solid	750.0
Natural circulation essentially lost	1550.0
Pressurizer goes two-phase	1600.0
Maximum repressurization reached	1800.0
Pressurizer level begins to drop	2150.0
Core starts to uncover	2200.0
PORV manually opened, LPI-HPI piggy-back actuated	2400.0
Core completely uncovers	2500.0

Figure 2 shows the core pressure transient for this accident. With the simultaneous loss of main feedwater and loss of offsite power, RCS pressure rapidly rises to the high pressure trip setpoint (2300 psia) thus causing the RCS to scram. The reduction in core power causes the RCS pressure to decrease. With the loss of heat removal to the steam generators at 250 seconds, due to failure of auxiliary feedwater to come on, the RCS repressurizes to the pressurizer code safety setpoint. The two pressurizer safety valves open discharging RCS liquid inventory. At 1600 seconds into the transient, the pressurizer liquid volume begins to drop and a two-phase steam-water mixture exits the safety valves. The mass flow rate out of the safety valves drops and the RCS pressure increases. This causes the safety valves to go full open. At 1900 seconds, the liquid volume in the hot legs, as shown in Figure 7, drops below the surge line, thus high quality steam enters the pressurizer. This results in an increase of steam volume being relieved through the safety valves thus decreasing the RCS pressure to just above the

code safety set pressure. Just prior to core uncovery, as is shown in Figure 4, the pressurizer mixture level begins to drop. At 2200 seconds the core starts to uncover and is completely uncovered at 2500 seconds, as shown in Figure 3. The core remains uncovered throughout the remainder of the transient, thus the cladding temperature would rise above that allowed by 10 CFR 50.46.

At 2400 seconds the PORV valve was manually opened to attempt to lower the RCS pressure and thus actuate the HPI system. The RCS pressure did not depressurize because the discharge rate out of the PORV was too small to relieve sufficient steam being generated by the core. Thus, additional operator actions are required for this transient.

3.2.2 Realistic Analyses

3.2.2.1 Complete Loss of All Feedwater — PORV Manually Opened and 2 Makeup Pumps Actuated at 30 Minutes — 1.0 x ANS 5.1 Decay Heat

Figures 18 through 34 show the transient system response for this accident. The following table presents key results of the analysis:

Sequence of events	Time, s
Loss of main feedwater, loss of offsite power (RC pumps coastdown)	0.0
Reactor trips on high pressure, turbine trip	8.0
SG secondary side inventory boiled-off	275.0
Two pressurizer code safety valves open, pressurizer goes solid	1000.0
PORV manually opened, 2 makeup pumps inject water also into RCS	1800.0
Natural circulation essesntially lost	2000.0
Pressurizer goes two-phase	2250.0
Maximum repressurization reached	2000.0
Pressurizer level begins to drop (est.)	3800.0
Core starts to uncover (est.)	3900.0

The scenario is similiar to Case 1 except that the decay heat is based on a realistic value of 1.0 x ANS 5.1 decay power.

Figure 18 shows the core pressure transient for this accident. With the simultaneous loss of main feedwater and loss of offsite power, RCS pressure rapidly rises to the high pressure trip setpoint (2300 psia) thus causing the RCS to scram. The reduction in core power causes the RCS pressure to decrease. With the loss of heat removal to the steam generators, the RCS repressurizes to the pressurizer code safety setpoint. The two pressurizer safety valves open discharging the RCS liquid inventory.

At 1800 seconds the operator is assumed to manually open the PORV and concurrently actuate 2 makeup pumps. The RCS pressure did not depressurize because the discharge rate out of the PORV and the condensation effect of the makeup water was less than the steam generation rate of the core. Figure 19 shows the inner vessel mixture level. Just prior to loss of natural circulation, the inner vessel mixture level decreases to the hot leg nozzle elevation and holds constant to 3500 seconds. At this point in time the core mixture level starts to drop again. Hand calculations indicate that the core will start to uncover at approximately 3900 seconds. As shown in Figure 20, the pressurizer mixture level remains full but, similiarly to Case 1, the pressurizer level will begin to drop just prior to core uncovery. Figures 21 and 22 show pressurizer code safety flowrate and exit quality, respectively. Figures 23 and 24 show pressurizer PORV flowrate and exit quality, respectively. At 3100 seconds into the transient, a steam bubble forms at the top of the pressurizer and the two-phase mixture discharging from the 2 code safety valves and PORV change to steam.

As shown, opening of the PORV and actuation of 2 makeup pumps to 30 minutes

is insufficient to mitigate the transient. However, core uncovery time is extended from 2200 seconds to 3900 seconds. Since all available makeup has been utilized in this analysis, it is shown that a depressurization mechanism must be found.

3.2.2.2 Complete Loss of All Feedwater - PORV Manually Opened and One Makeup Pump and Startup Feedwater Pump Actuation at 30 Minutes -- 1.0 x ANS 5.1 Decay Heat

Figures 35 through 51 show the transient system response for this accident. The following table presents key results of the analysis:

Sequence of events	Time, s
Loss of main feedwater, loss of offsite (RC pumps coastdown)	0.0
Reactor trips on high pressure, turbine trips	8.0
SG secondary side inventory boiled-off	275.0
Two pressurizer code safety valves open, pressurizer goes solid	1000.0
PORV manually opened, one makeup pump injects water in RCS, electric startup feedwater pump actuated	1800.0
Maximum repressurization reached	1800.0
Natural circulation essentially lost	2100.0
Long term cooling established (based on one makeup pump)	5000.0 (est.)
Minimum core level	16.7 ft (est.)

The first 30 minutes of this case is the same as the realistic analysis described in Section 3.2.2.1. At 30 minutes into the transient operator action is taken, the PORV valve is manually opened, one makeup pump is actuated and starts to inject water in the RCS and the startup feedwater pump is actuated and injects water into the secondary side of the steam

generator. Figure 35 shows the core pressure transient for this accident. The RCS pressure depressurizes because of the cumulative effect of the following mechanisms: The PORV relieves steam generated by the core, the water from the makeup pumps condenses steam in the RCS, and the secondary side of the steam generator removes energy, thus condensing steam and contracting liquid inventory in the RCS. The code safety valves close as the RCS pressure falls below the valve set pressure of 2435 psig.

As the RCS depressurizes, the liquid volume contracts in the loops forming a steam bubble at the top of the hot leg thereby stopping natural circulation. The loss of natural circulation interrupts the steam generator cooling and results in a temporary build up of steam in loops and a rise in system pressure. A local contraction of liquid in the bottom half of the steam generator tubes due to heat removal to the SG, causes intermittent recurrences of natural circulation. That is, slugs of hotter liquid in the hot legs rise over the candy cane and into the upper portion of the steam generator. The slugs of hotter liquid mixes with the cooler liquid in the primary side of the steam generator, the RCS pressure decreases, the liquid volume contracts, natural circulation stops, and the oscillatory cycle repeats. At 3100 seconds the liquid volume in the hot legs has depleted sufficiently to prevent hot leg water from flowing into the steam generator, and the intermittent natural circulation ceases. As shown in Figure 36, the inner vessel mixture height levels off at approximately the hot leg centerline. The pressurizer mixture height, as shown in Figure 37, remains full throughout the transient. Figures 39 and 40 show the flow rate through the PORV and exit quality from the pressurizer, respectively. The low quality two-phase leak rate out of the PORV slowly decreases with system pressure. Hand calculations show that the core will remain covered throughout the transient and long term cooling would occur

at approximately 5000 seconds. If the LPI-HPI system was piggy-backed to the LPI prior to one hour, long term cooling would occur at approximately 4100 seconds. Since no core uncovery occurs, the criteria of 10 CFR 50.46 is satisfied and cladding temperatures will remain with a few degrees of saturation.

3.2.2.3 Complete Loss of All Feedwater - PORV Remained Closed - Two Makeup Pumps and Startup Feedwater Pump Actuated at 30 Minutes 1.0 ANS Decay Heat

As stated previously, the computer analysis presented in other realistic case are valid for the first 30 minutes of the transient. At 30 minutes, there is 251480 lbm of liquid available in the system, excluding the pressurizer, above the top of the core. Assuming operator action at 30 minutes to actuate the two makeup pumps and the startup feedwater pump, the following are the results of the equations in Section 3.1 at 1800 seconds.

$$W_{core} = 127 \text{ lb/s}$$
$$V_c = 13.54 \text{ ft}^3\text{/s}$$
$$W_\mu = 24.7 \text{ lb/s}$$
$$V_\mu = .39 \text{ ft}^3\text{/s}$$
$$W_{\mu cond} = 44.48 \text{ lb/s}$$
$$V_{\mu cond} = 4.73 \text{ ft}^3\text{/s}$$
$$W_{SGcond} = 76.2 \text{ lb/s}$$
$$V_{FWcond} = 8.1 \text{ ft}^3\text{/s}$$
$$V_{net} = +1.1 \text{ ft}^3\text{/s}$$
$$W_{SV} = 216.47 \text{ lb/s}$$
$$W_{net} = -198.09 \text{ lb/s}$$

Thus, we can see at 1800 seconds, the primary system pressure will remain at The safety valve pressure and system inventory is decreasing.

A similar calculation was performed at 2400 seconds. The results of that calculation shows that V_{net} = 0 and the primary system will depressurize thereafter due to reduced core heat. A mass balance performed at that time shows that W_{net} = +28.4 lb/s and the primary system is refilling.

A conservative assessment of the system inventory was made for this case. Using the liquid loss rate calculated at 1800 seconds and holding it constant between 1800 and 2400 seconds, 118854 lbm of liquid is calculated to be lost from the system. Substracting this from the liquid inventory above the top of the core at 1800 seconds, there will still be at least 132626 lbm above the top of the core prior to system refill. Since the core will not uncover, the cladding temperature will remain within a few degrees of the saturated fluid temperature and no cladding ruptures nor metal-water reaction will occur. Thus the criteria of 10 CFR 50.46 is satisfied.

3.2.3 Other Acceptable Operator Actions

For all cases in which normal auxiliary feedwater is supplied within 30 minutes of the loss of main feedwater event, the transient can be safely terminated without core damage. Actuation of auxiliary feedwater will cause the RCS to rapidly depressurize, immediately closing the core safety valves. This will stop the loss of RCS inventory. The pressure will continue to decrease to the ESFAS setpoint and actuate the high pressure injection system resulting in a refill of the RCS.

Extensive hand calculations were made to determine other combinations of acceptable operator actions. The calculations determined the time when the RCS will depressurize due to condensation effects from the makeup water, steam generator feedwater effects, and RCS inventory released through the PORV. When the RCS begins to depressurize a mass balance calculation was made to assure

that the core remained covered until long term cooling was established.

Table 3.6 shows alternate operator actions examined with the assumption of 1.2 ANS decay heat, there is only one case that has a 50 percent chance of success. This case requires actuation of two makeup pumps, opening of the PORV, and actuation of the startup feedwater pump at 30 minutes. All other cases with 1.2 ANS decay heat will uncover the core and be unacceptable. For use of 1.0 ANS decay heat (realistic cases) there are three combinations which will successfully mitigate the accident, a combination which has a 50 percent change, and three cases that will uncover the core. All the successful cases require actuation of the startup feedwater pump and at least one makeup pump.

Table 3.6 Summary of Alternate Operator Actions for TECO, BURP & SLURP Analysis. Loss of All Feedwater and Offsite Power

Operator action required at 30 minutes	1.2 ANS decay heat						1.0 ANS decay heat (realistic cases)						
Number of makeup pumps actuated at 30 minutes	2	1	2	1	1	2	2	1	2	1	1	2	2
PORV opened at 30 minutes	No	No	Yes	Yes	Yes	Yes	No	No	Yes	Yes	Yes	Yes	No
Electric startup feedwater pump actuated at 30 minutes	Yes	Yes	Yes	Yes	No	No	Yes	Yes	Yes	Yes	No	No	No
Success of action to mitigate accident	No	No	50%*	No	No	No	Yes	50%*	Yes	Yes	No	No**	No

*Chance of success.

**Refer to Section 3.2.2.

4. Nomenclature

W_{core} = Rate of liquid boiled by core decay heat, lbm/s

Q_{DH} = Core decay heat, Btu/s

V_c = Volume of steam created by core decay heat, ft.^{3}/lbm

W_μ = Flow for one makeup pump, lbm/s

V_μ = Volume of fluid injected from makeup pumps, ft.^{3}/s

$W_{\mu cond}$ = Rate of steam condensed due to condensation caused by the makeup water, lbm/s

$V_{\mu cond}$ = Volume of steam condensed by the makeup water, ft.^{3}/lbm

h_{in} = Enthalpy of injected fluid, Btu/lbm

W_{FW} = Startup feedwater pump flow, lb/s

W_{SGcond} = Mass rate of steam condensed in primary system by startup feedwater pump flow, lb/s

V_{FWcond} = Volume of steam condensed in primary system by startup feedwater pump flow, ft.^{3}/s

W_{SV} = Rate of liquid loss through safety valves, lbm/s

Subscripts PS = Property evaluated at primary system pressure

SS = Property evaluated at secondary side of SG pressure

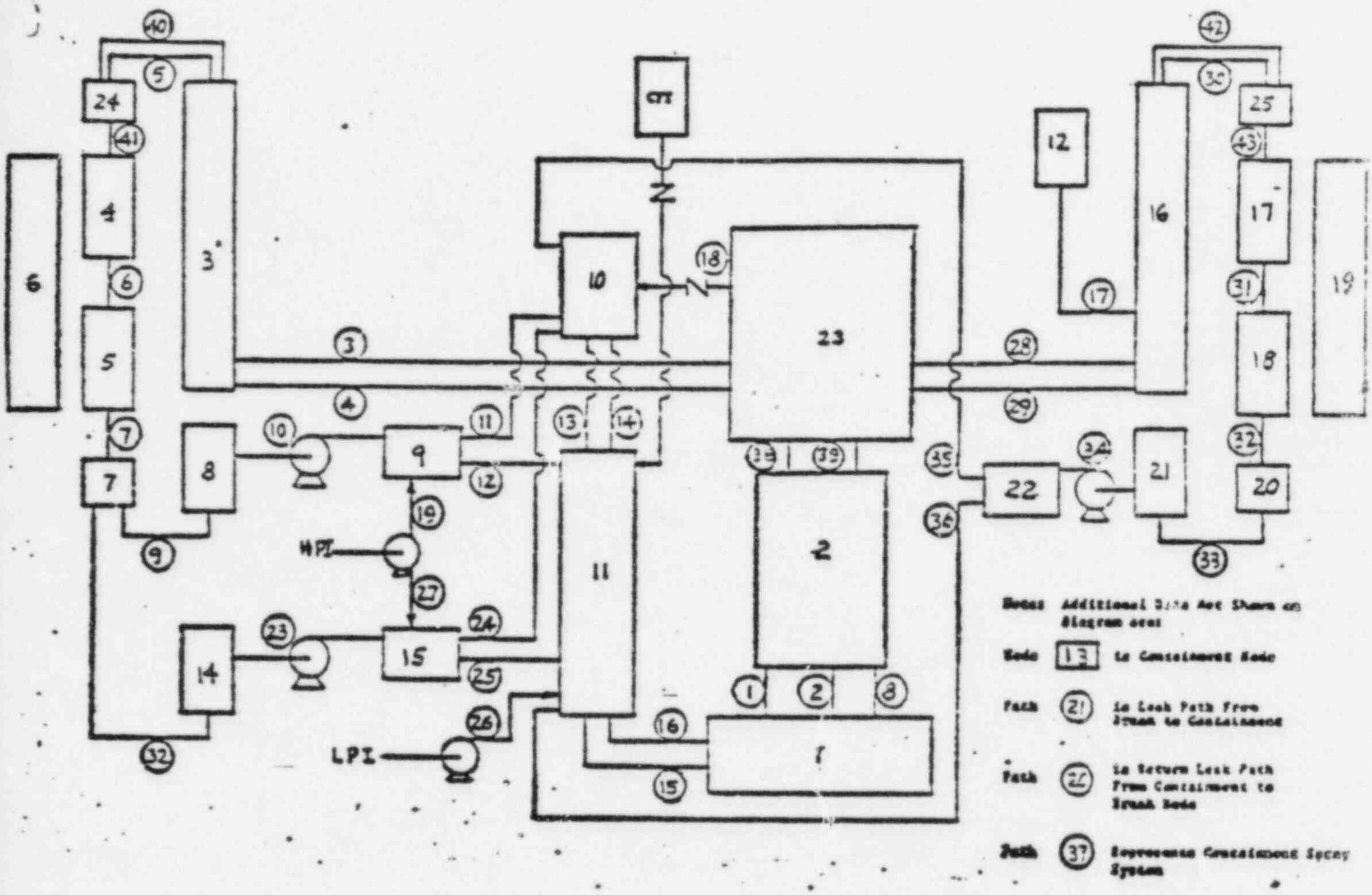
5. References

1. "Evaluation of Transient Behavior and Small Reactor Coolant System Breaks in the 177-Fuel Assembly Plant," Babcock & Wilcox, May 7, 1979.

2. BAW-10104, Rev. 3, "B&W ECCS Evaluation Model," August 1977.

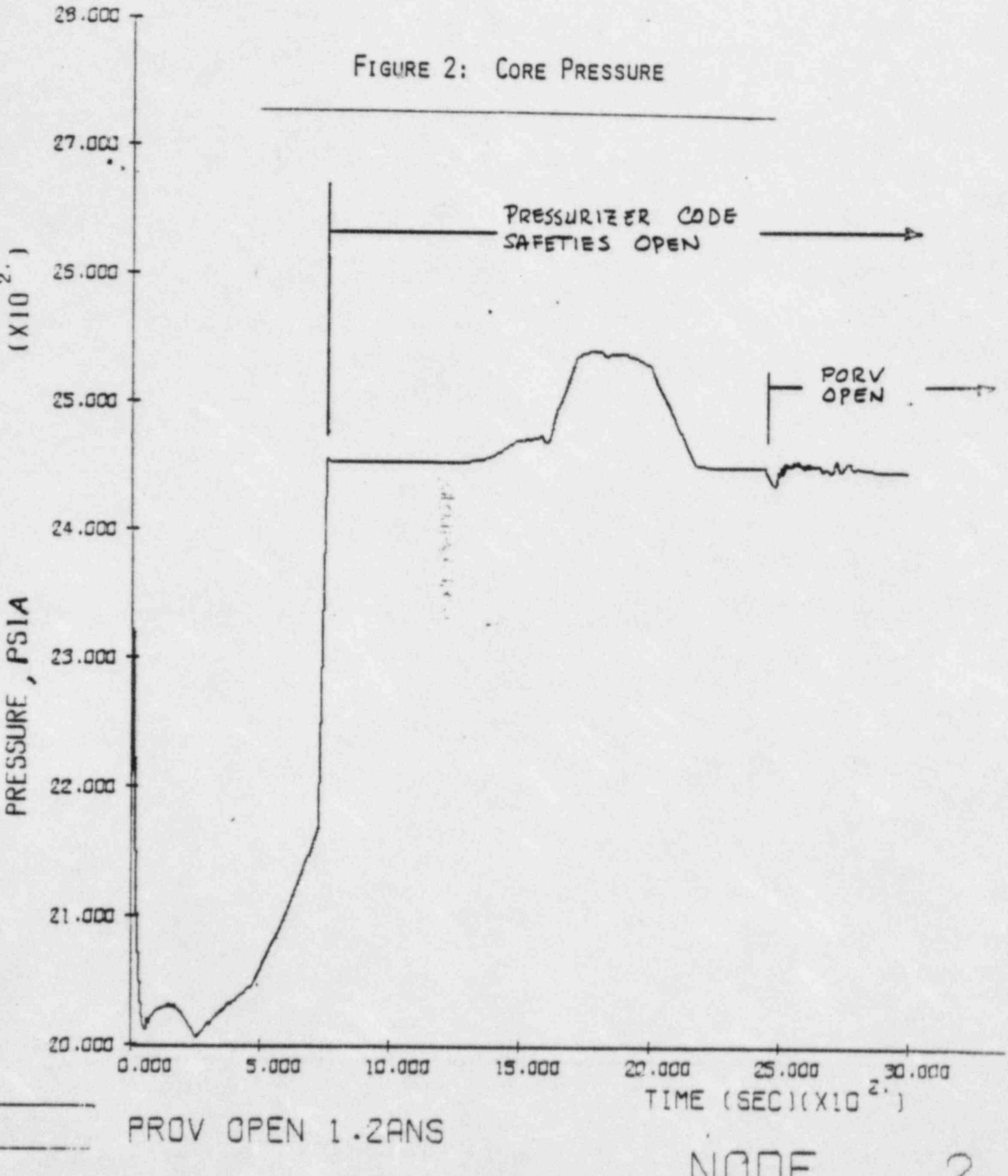
3. Letter from J. H. Taylor to S. A. Varga, July 18, 1978, concerning 177FA Plants Small Break Analysis.

FIGURE 1 : CRAFT2 MODEL NODING DIAGRAM

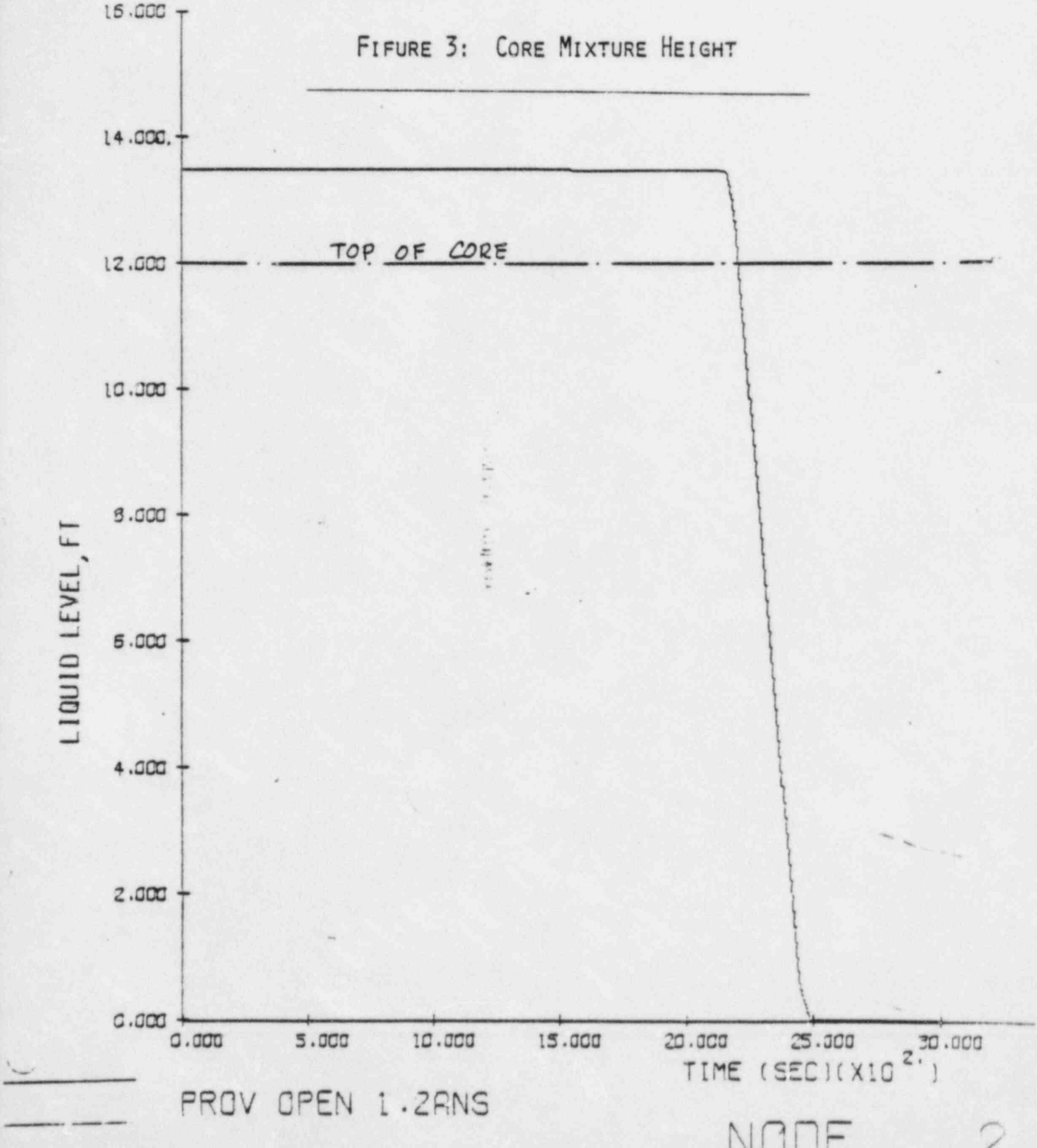


Node No.	Identification	Path No.	Identification
11	Downcomer	1,2	Core
1	Lower Plenum	3,4,28,29	Hot Leg Piping
2	Core & Upper Plenum	5,30,41,43	Hot Leg, Upper
3,16	Hot Leg Piping	6,31	SG Tubes
4,17	SG & Upper Head	7,32	SG Lower Head
5,18	Steam Generator Tubes	8	Core Bypass
6,19	Secondary, SG	9,22,33	Cold Leg Piping
7,20	SG Lower Head	10,23,34	Pumps
8,14,21	Cold Leg Piping	11,12,24,25,35,36	Cold Leg Piping
9,15,22	Cold Leg Piping	15,16	Downcomer
10	Upper Downcomer	26	LPI
12	Pressurizer	13,14	Upper Downcomer
13	Containment	17	Pressurizer
23	Upper Plenum	18	Vent Valve
24,25	SG Upper Head	19,27	HPI
		37	Containment Sprays
		38,39	Core to Upper Plenum
		40,42	SG Upper Head
		20,21	Leak & Return Path

86-1126460 00



86-1126460 00



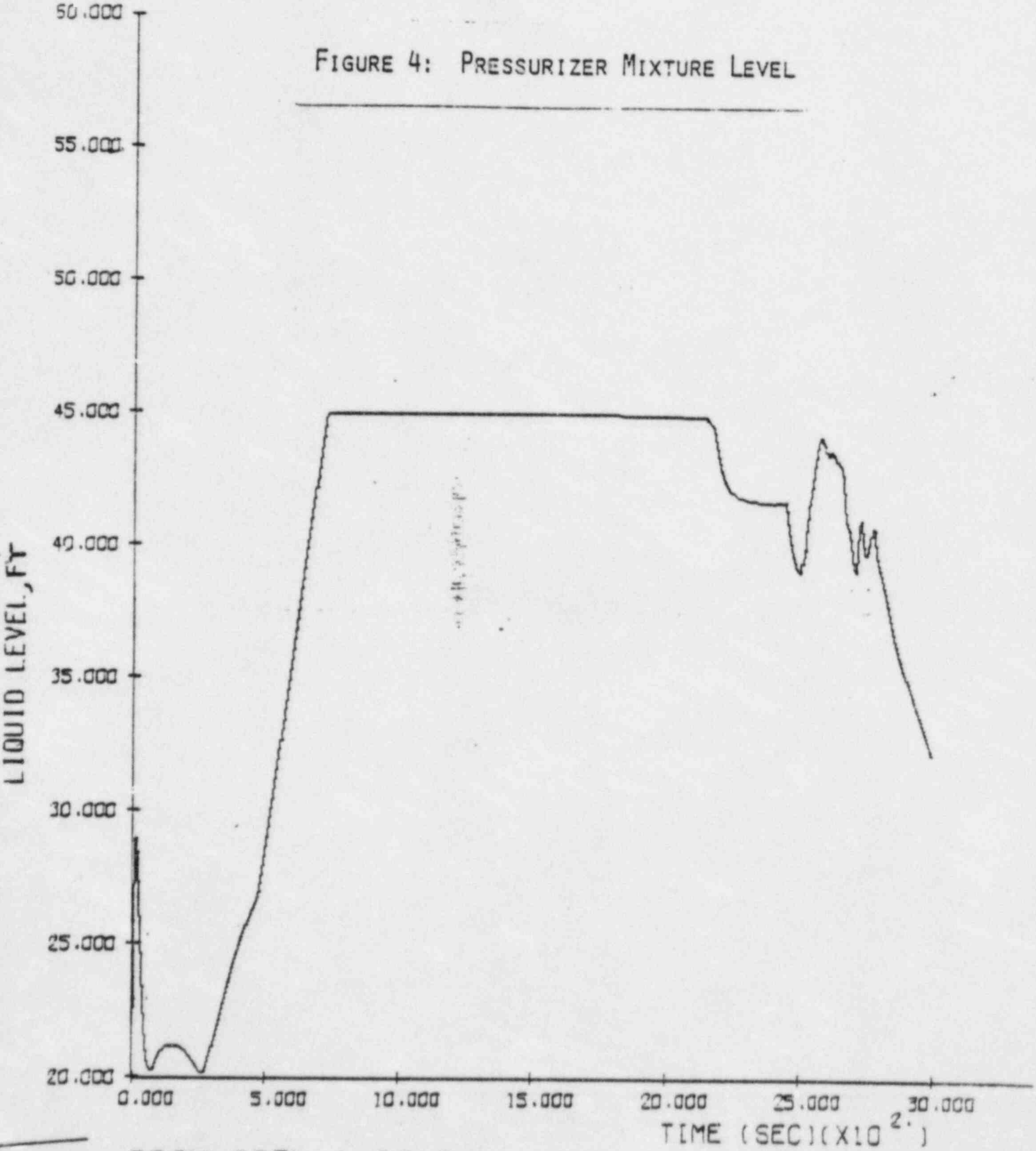


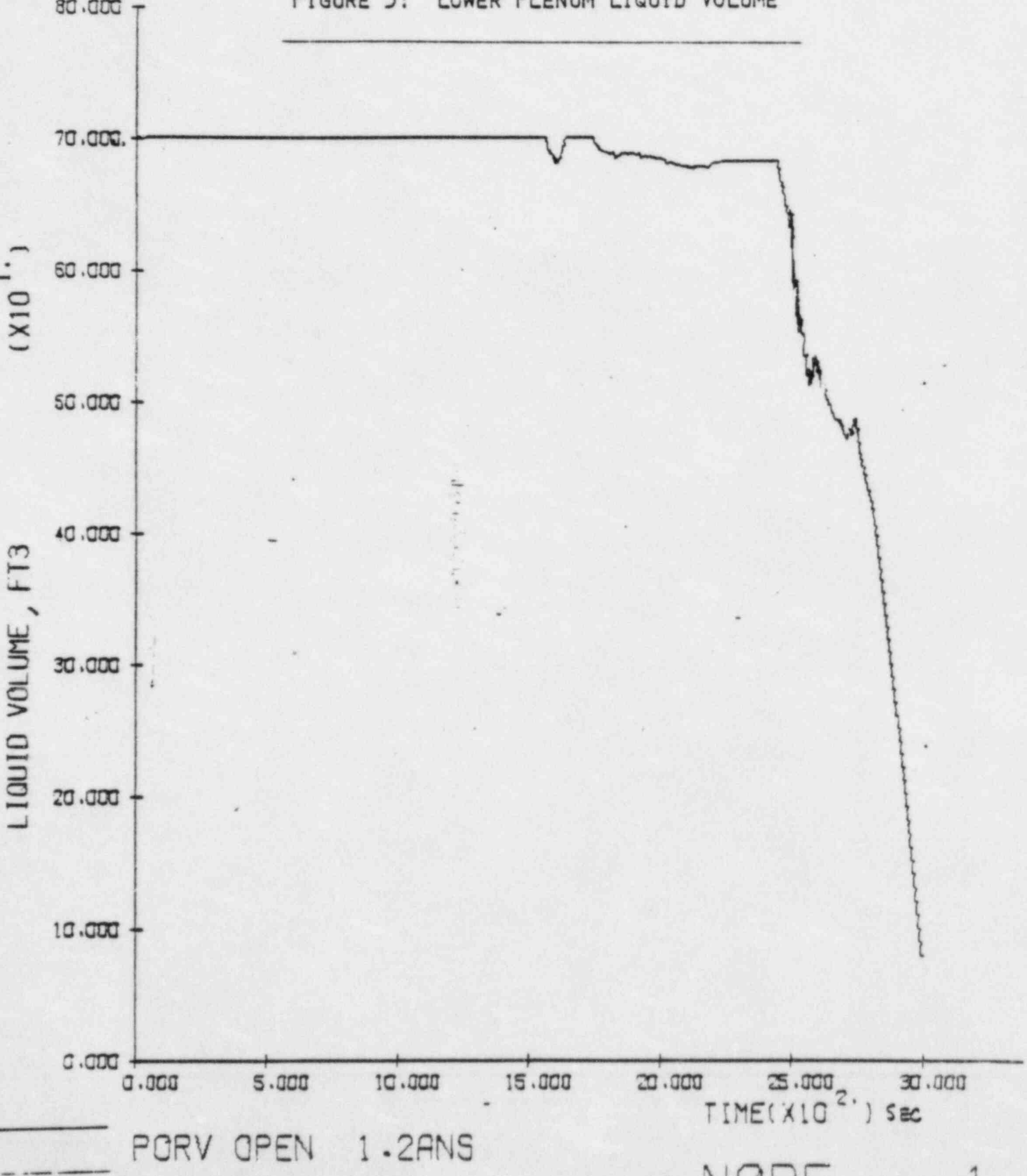
FIGURE 4: PRESSURIZER MIXTURE LEVEL

PROV OPEN 1.2ANS

NODE 12

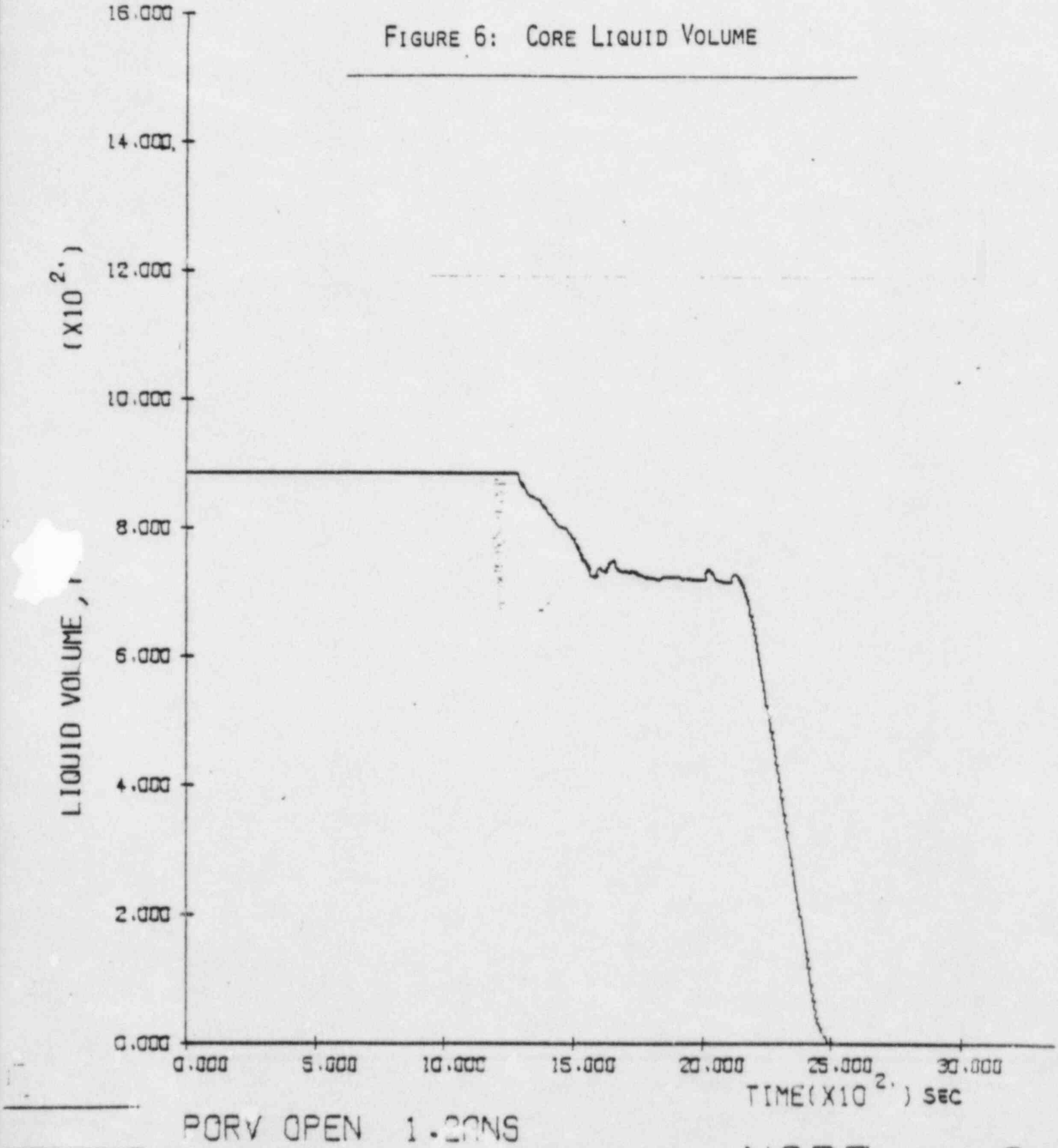
86-1126460 00

FIGURE 5: LOWER PLENUM LIQUID VOLUME



NODE 1

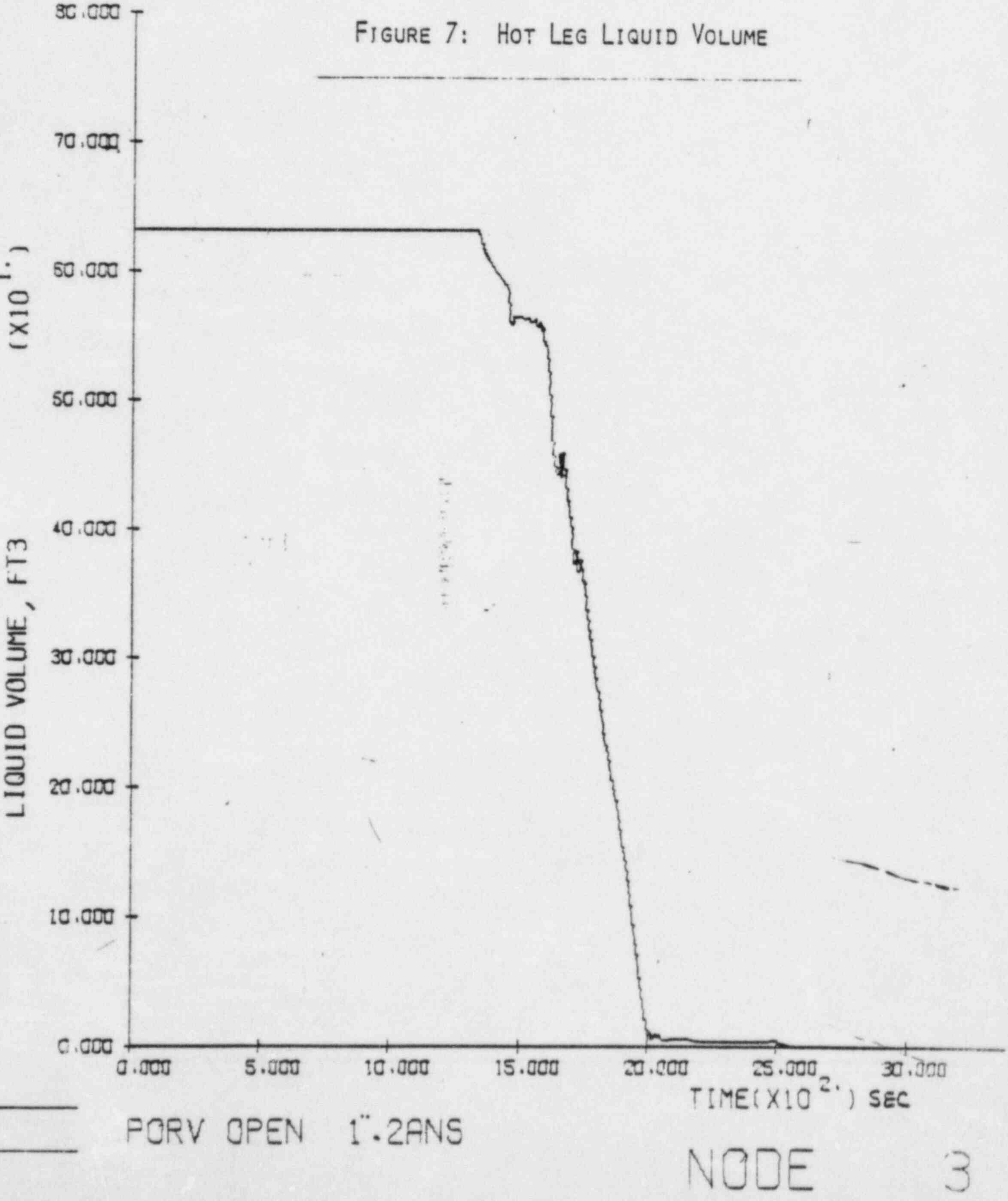
86-1126460 00



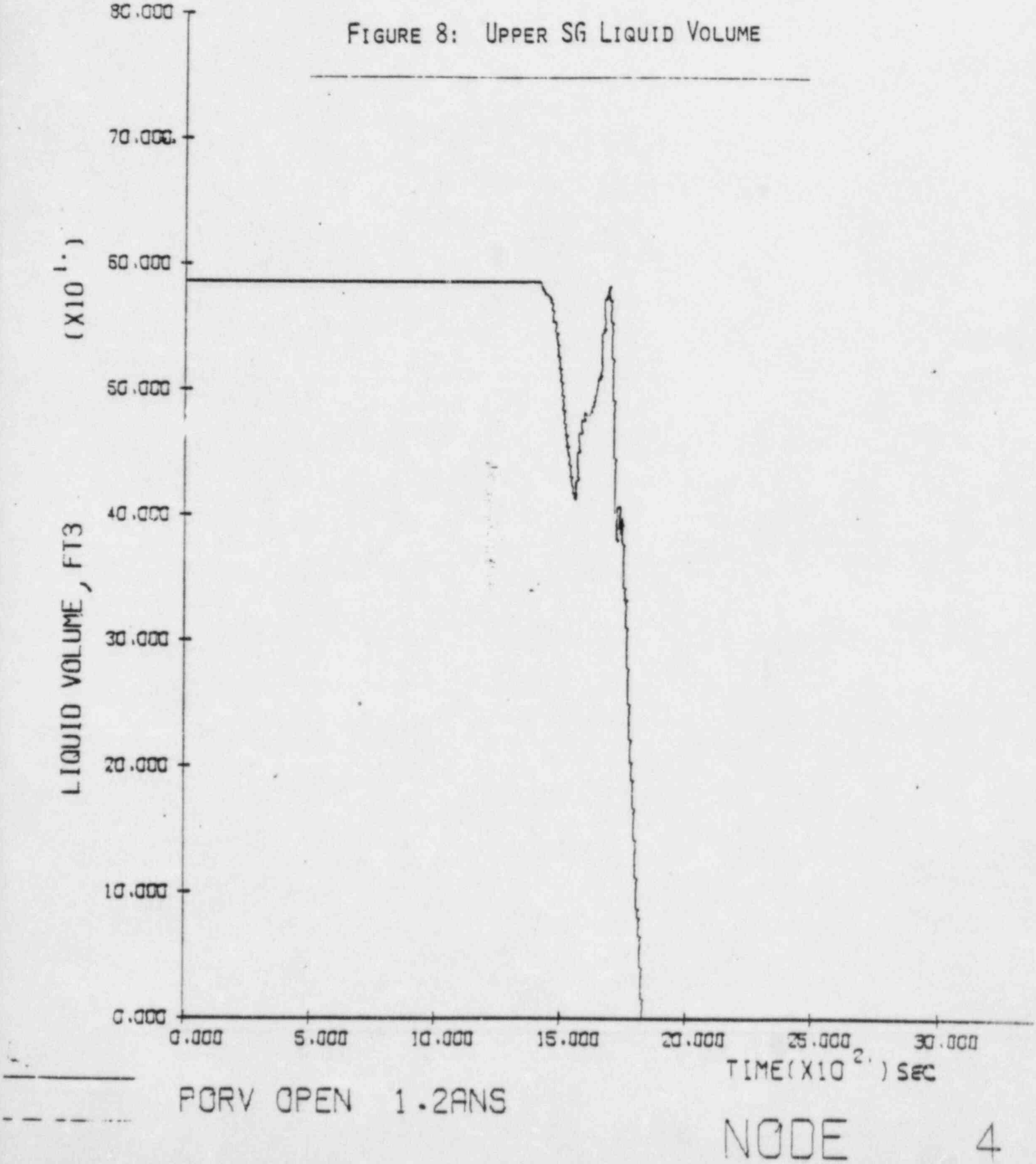
NODE 2

86-1126460 00

FIGURE 7: HOT LEG LIQUID VOLUME

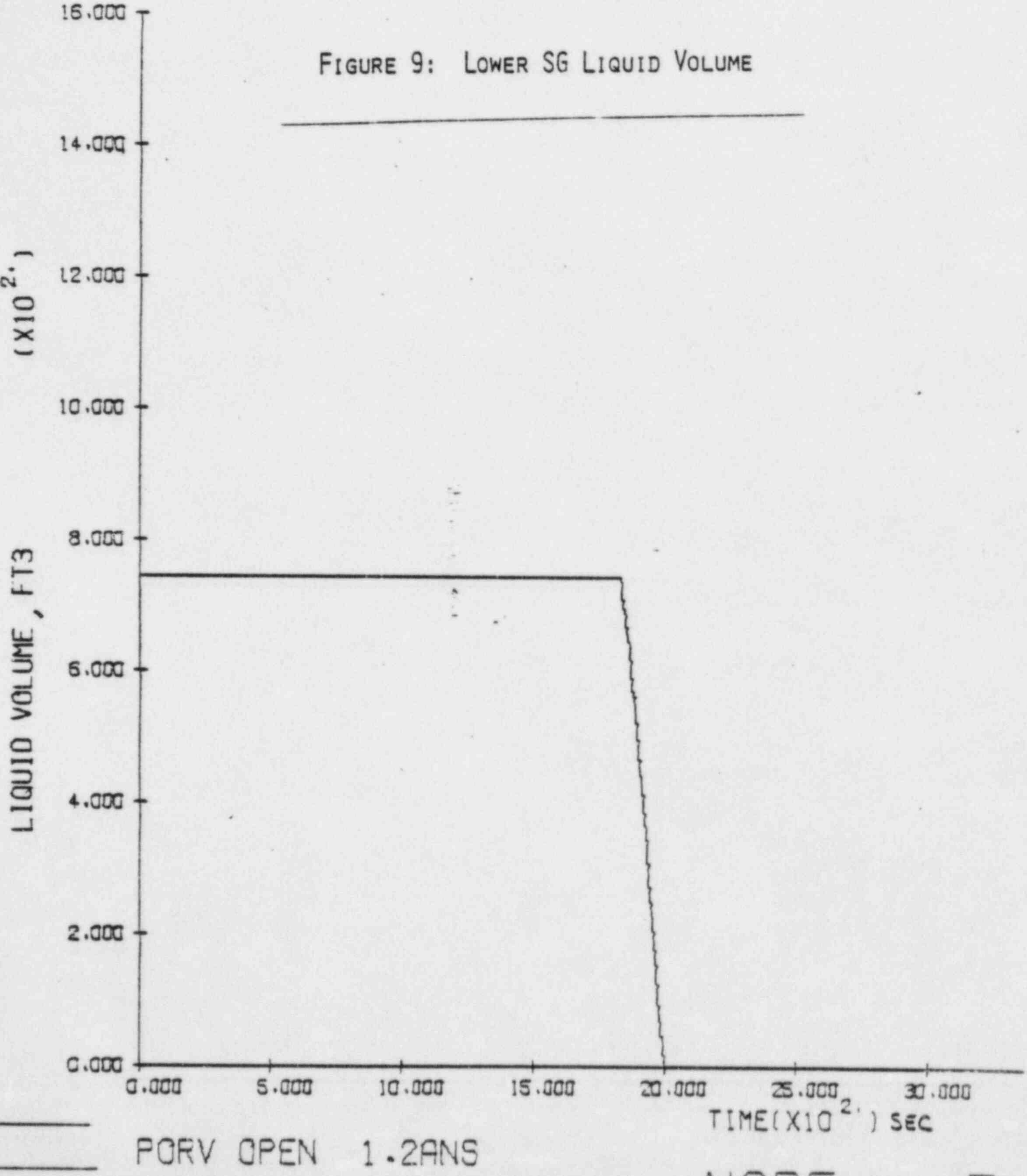


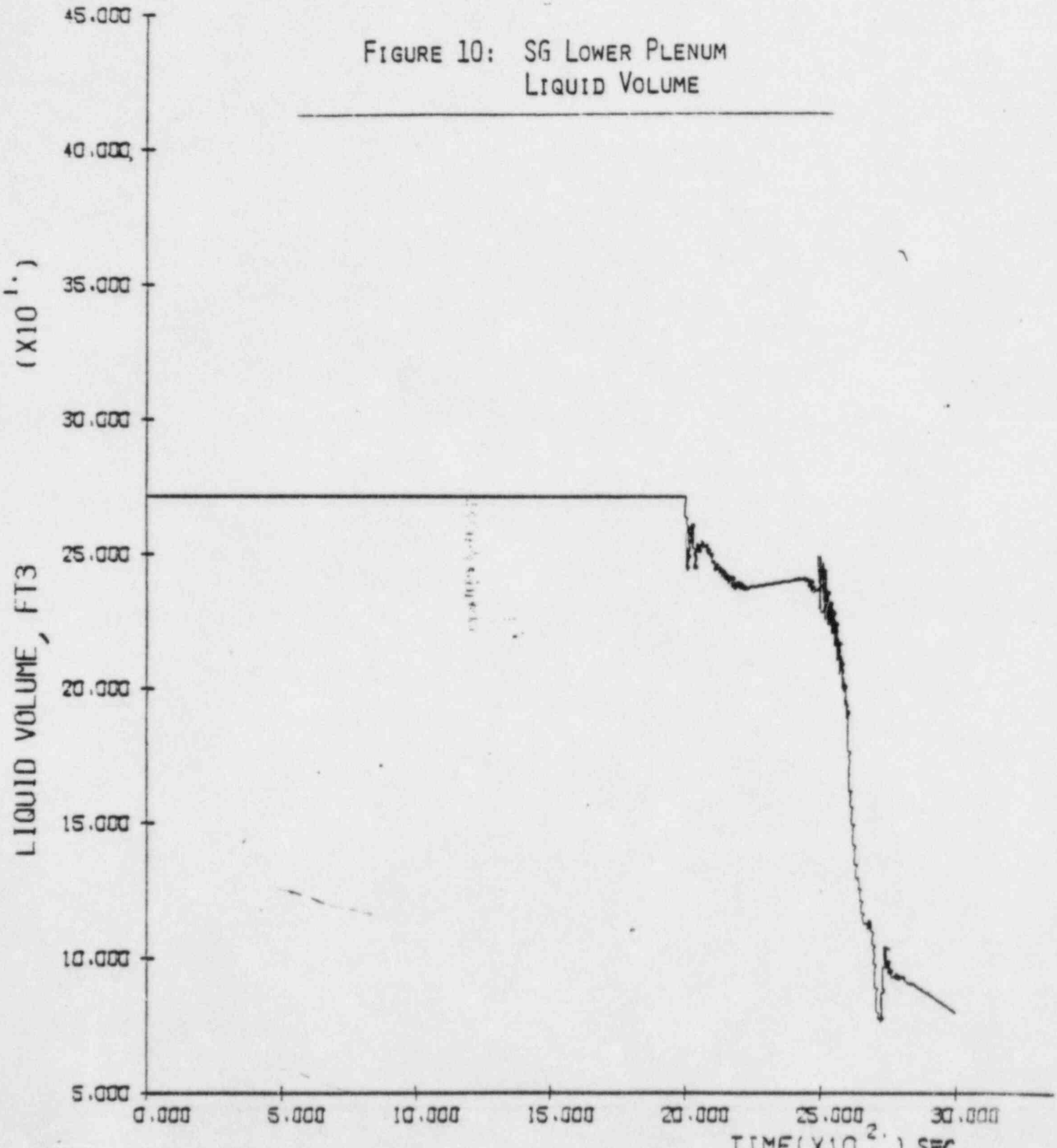
86-1126460 00



86-1126460 00

FIGURE 9: LOWER SG LIQUID VOLUME





PORV OPEN 1.2ANS

NODE 7

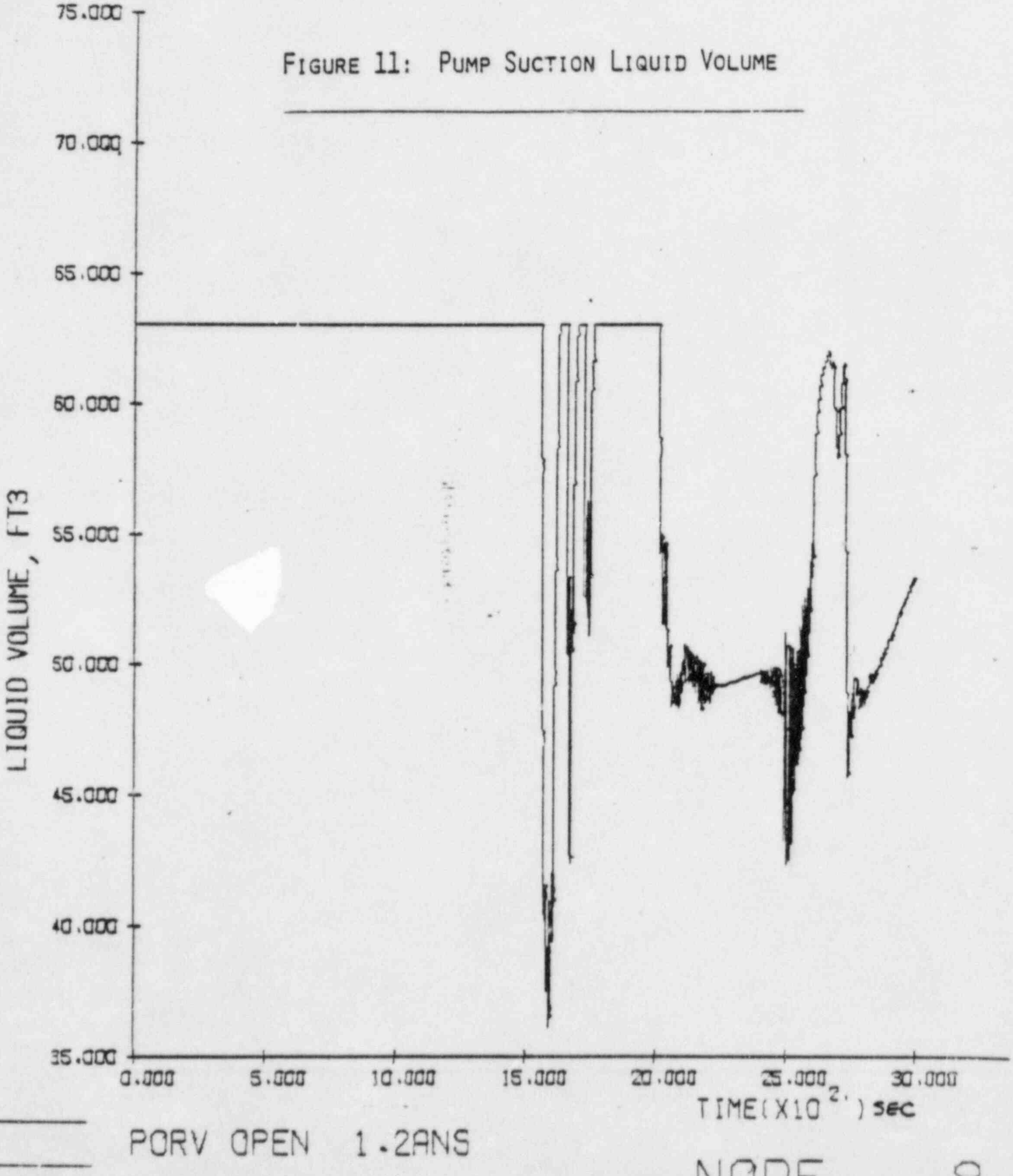
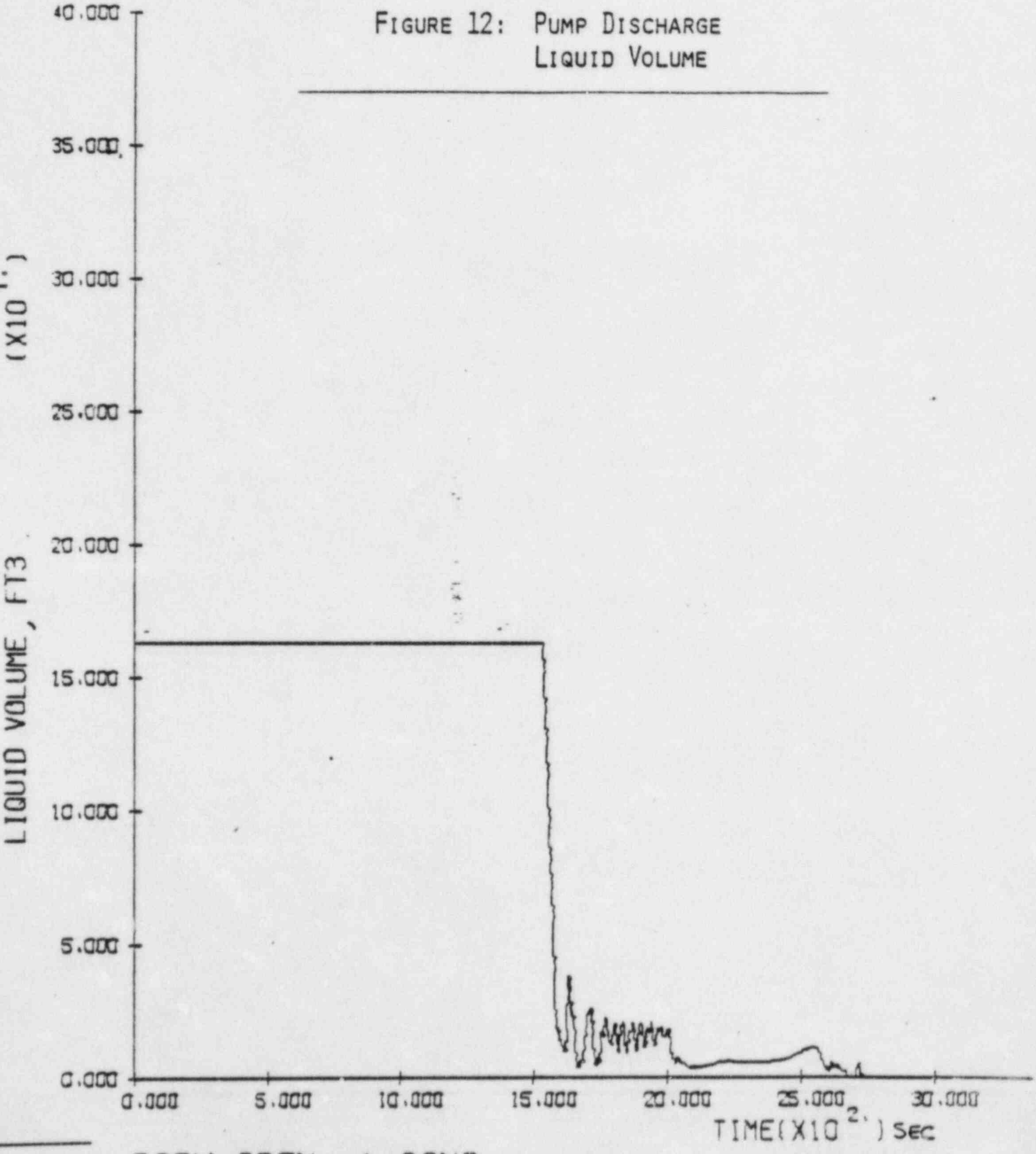


FIGURE 11: PUMP SUCTION LIQUID VOLUME
75.000
70.000
65.000
60.000
55.000
50.000
45.000
40.000
35.000
LIQUID VOLUME, FT3
0.000
5.000
10.000
15.000
20.000
25.000
30.000
TIME(X10^{2}) sec
PORV OPEN 1.2ANS
NODE 8

FIGURE 12: PUMP DISCHARGE LIQUID VOLUME



PORV OPEN 1.2ANS

NODE 9

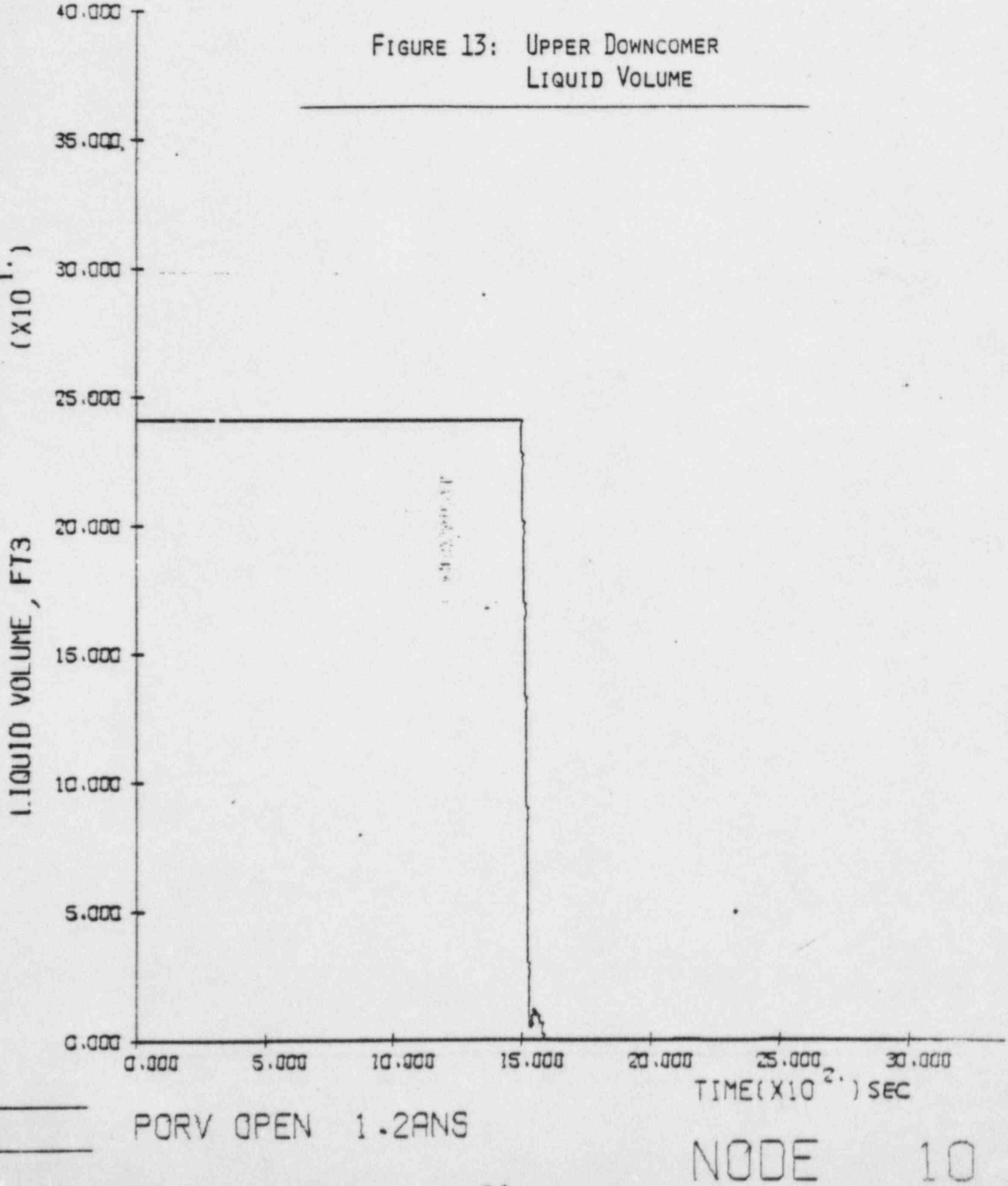
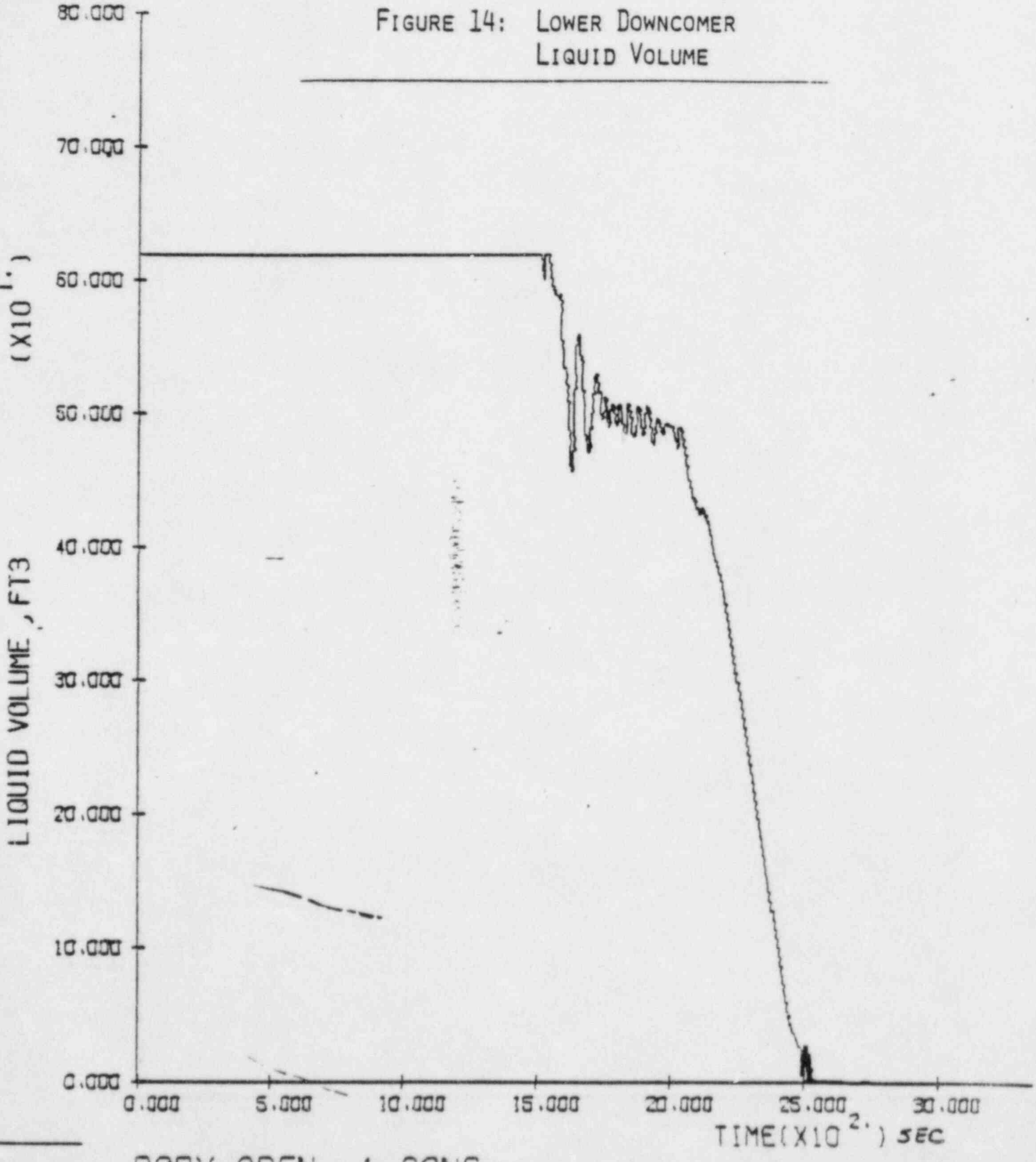


FIGURE 13: UPPER DOWNCOMER LIQUID VOLUME
LIQUID VOLUME, FT3 (X10 1.)
40.000
35.000
30.000
25.000
20.000
15.000
10.000
5.000
0.000
0.000
5.000
10.000
15.000
20.000
25.000
30.000
TIME(X10 2.) SEC
PORV OPEN 1.2ANS
NODE 10



PORV OPEN 1.2ANS

NODE 11

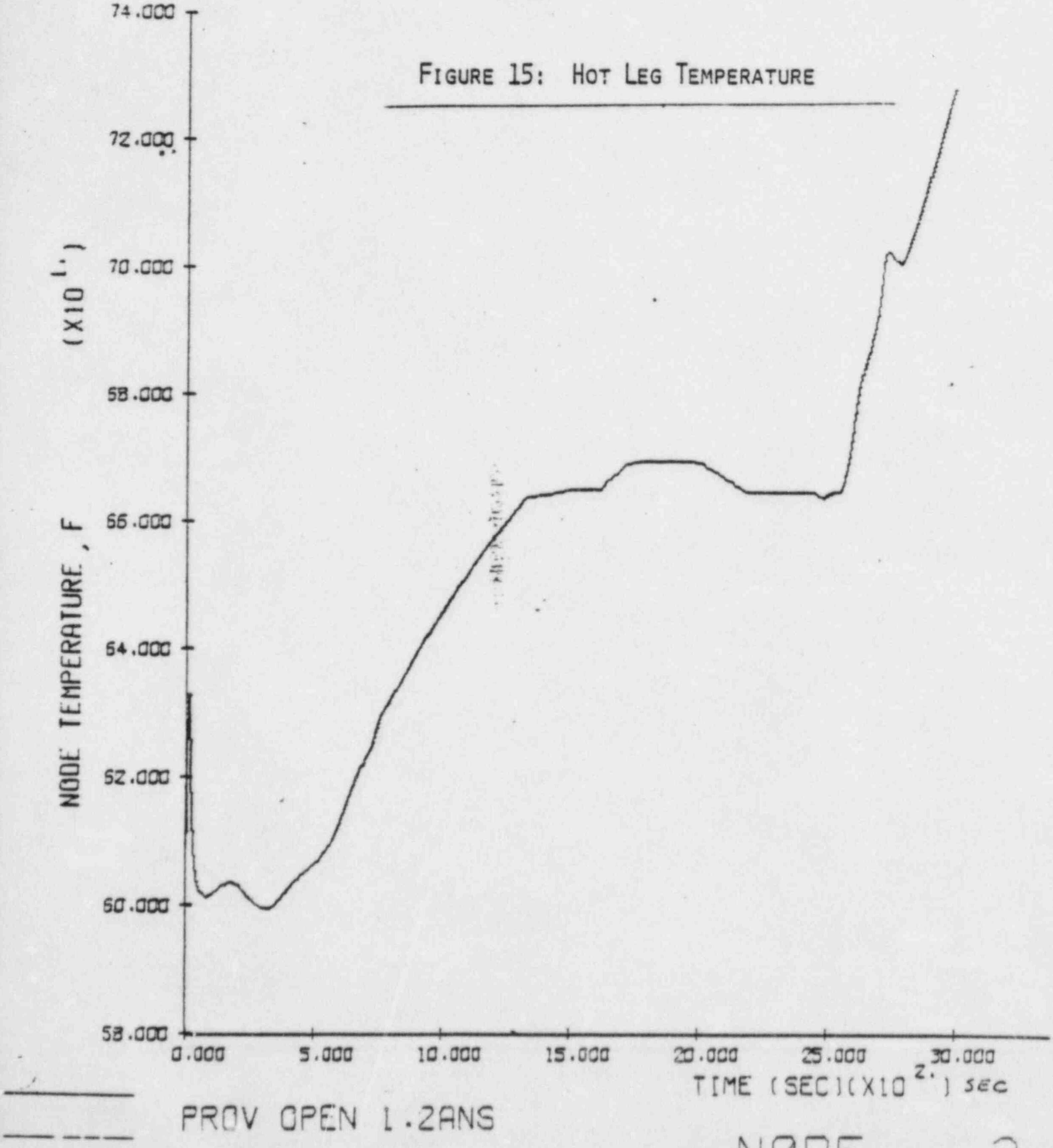
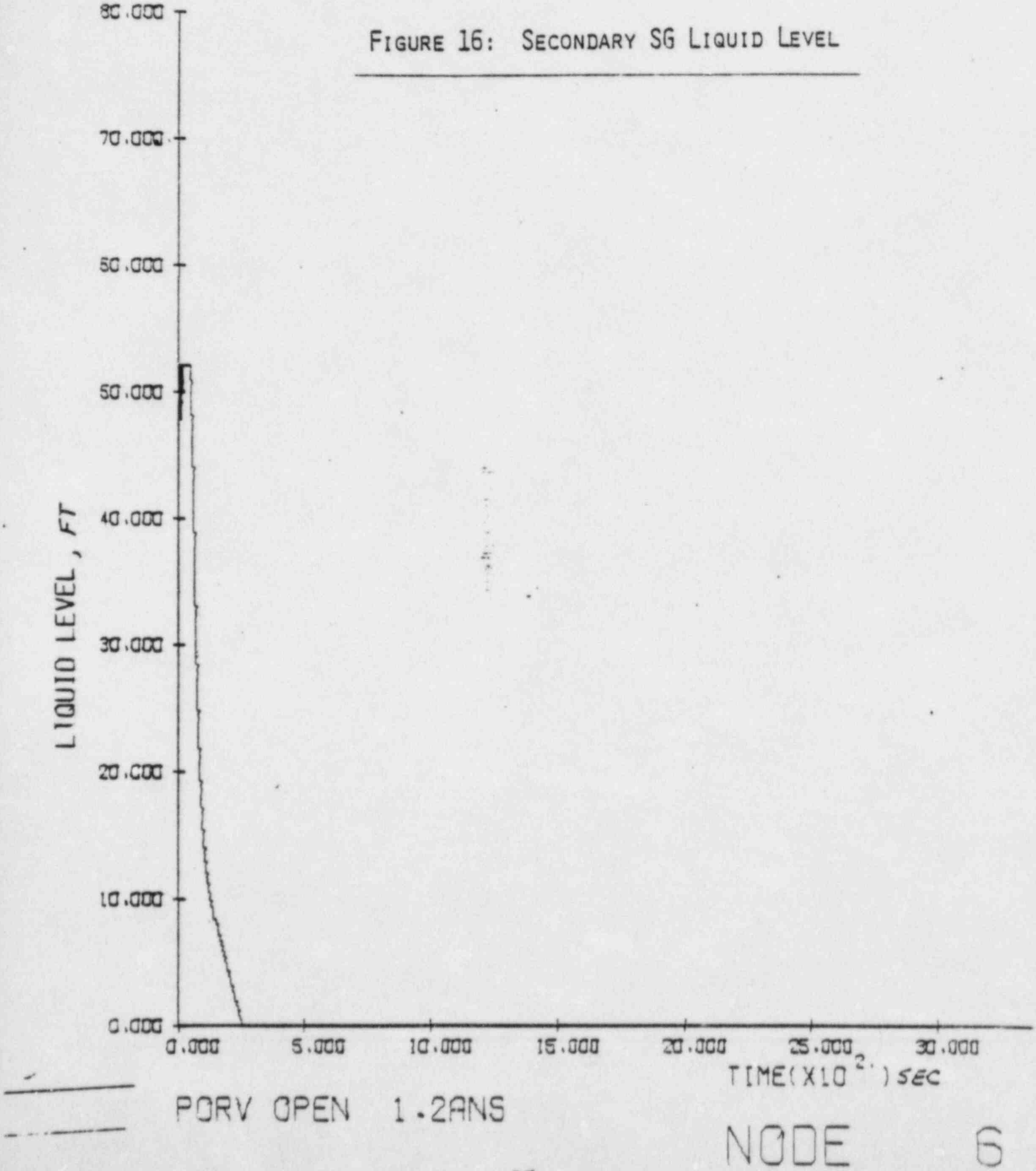


FIGURE 15: HOT LEG TEMPERATURE
74.000
72.000
70.000
58.000
66.000
64.000
52.000
60.000
58.000
NODE TEMPERATURE , F
(X10 1.)
0.000
5.000
10.000
15.000
20.000
25.000
30.000
TIME (SEC)(X10 2.) sec
PROV OPEN 1.2ANS
NODE 3

FIGURE 16: SECONDARY SG LIQUID LEVEL



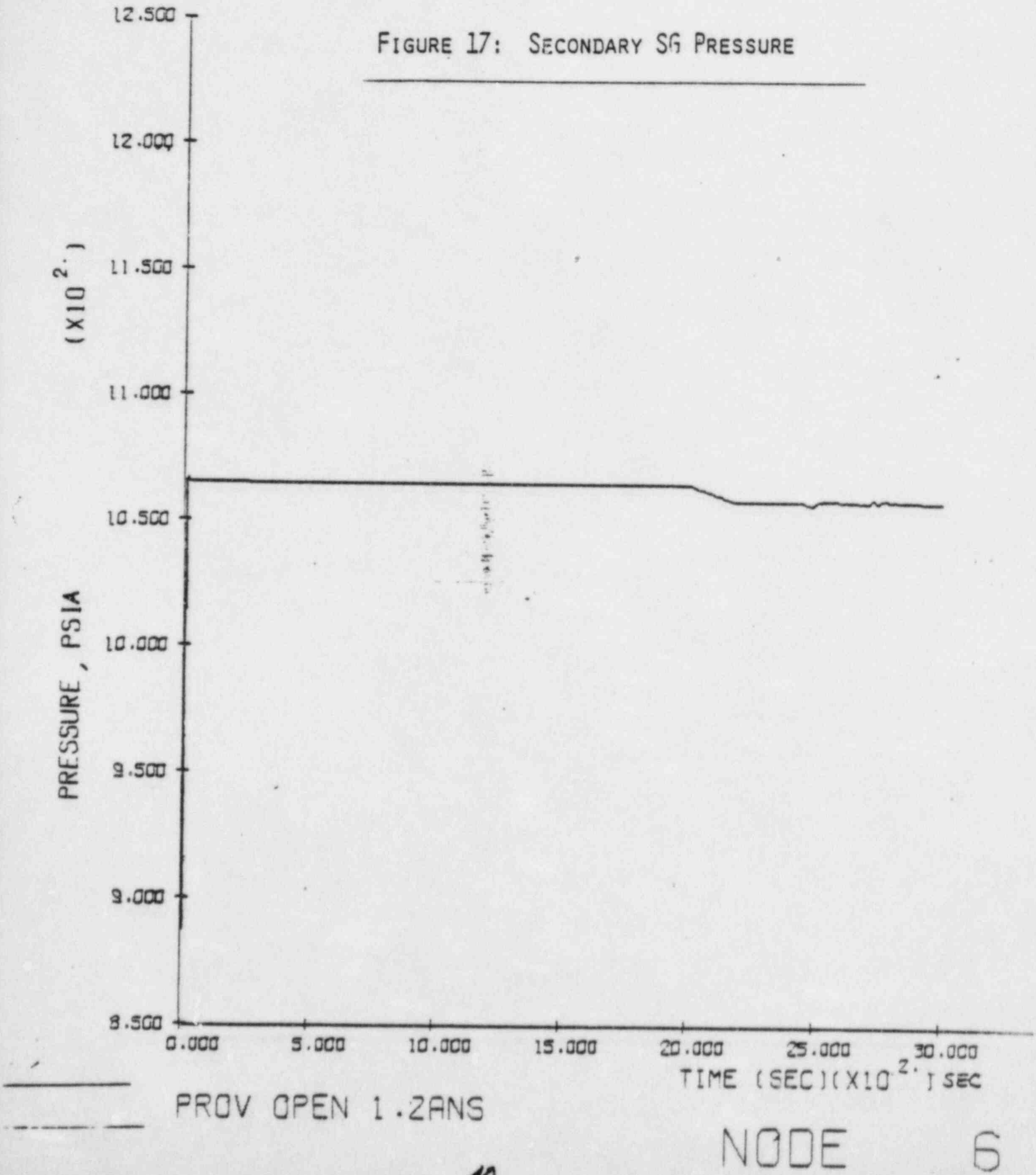
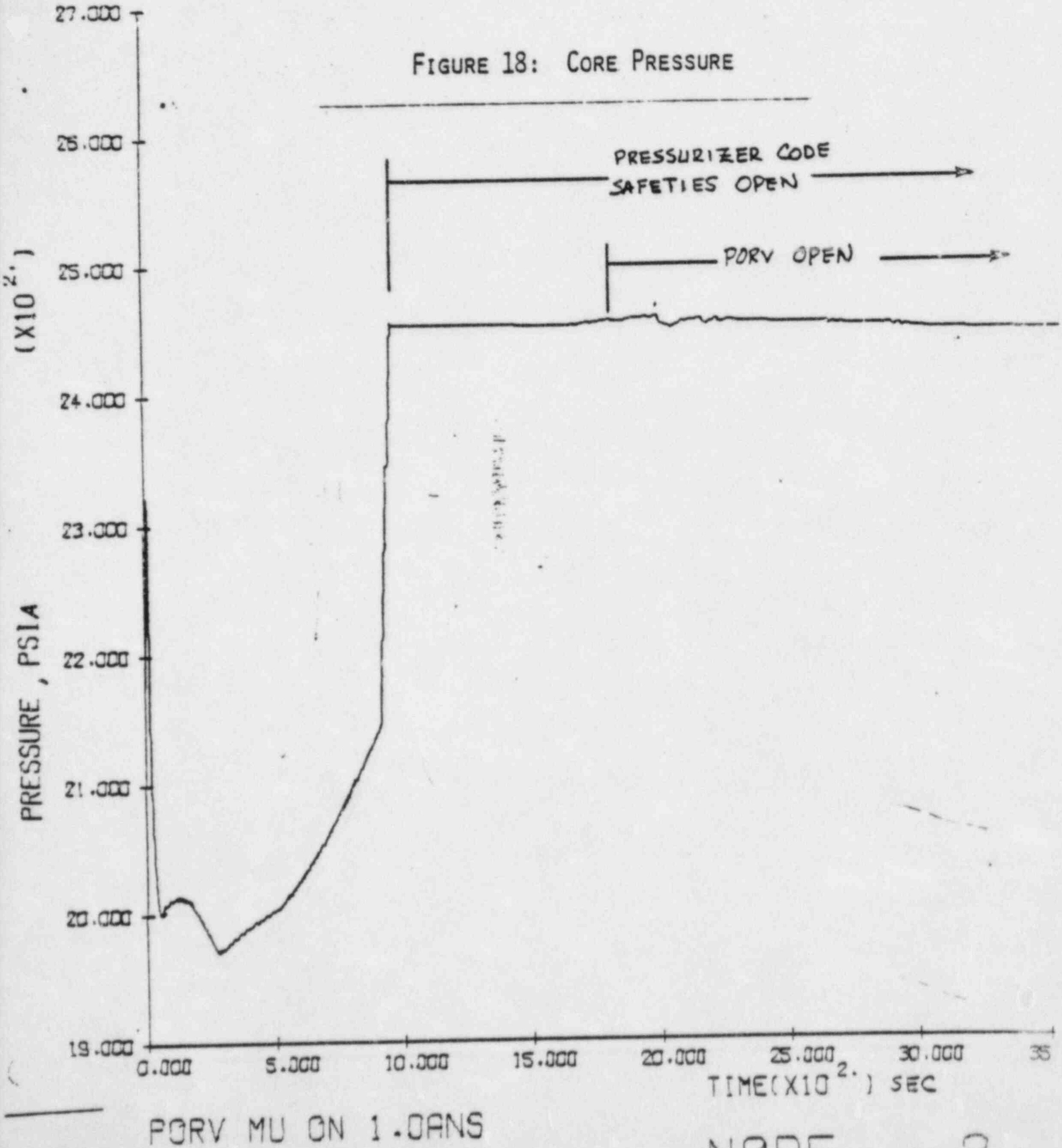


FIGURE 17: SECONDARY SG PRESSURE
12.500
12.000
11.500
11.000
10.500
10.000
9.500
9.000
8.500
PRESSURE, PSIA
(X10^2)
0.000
5.000
10.000
15.000
20.000
25.000
30.000
TIME (SEC)(X10^2) SEC
PROV OPEN 1.2ANS
NODE 6

86-1126460 00

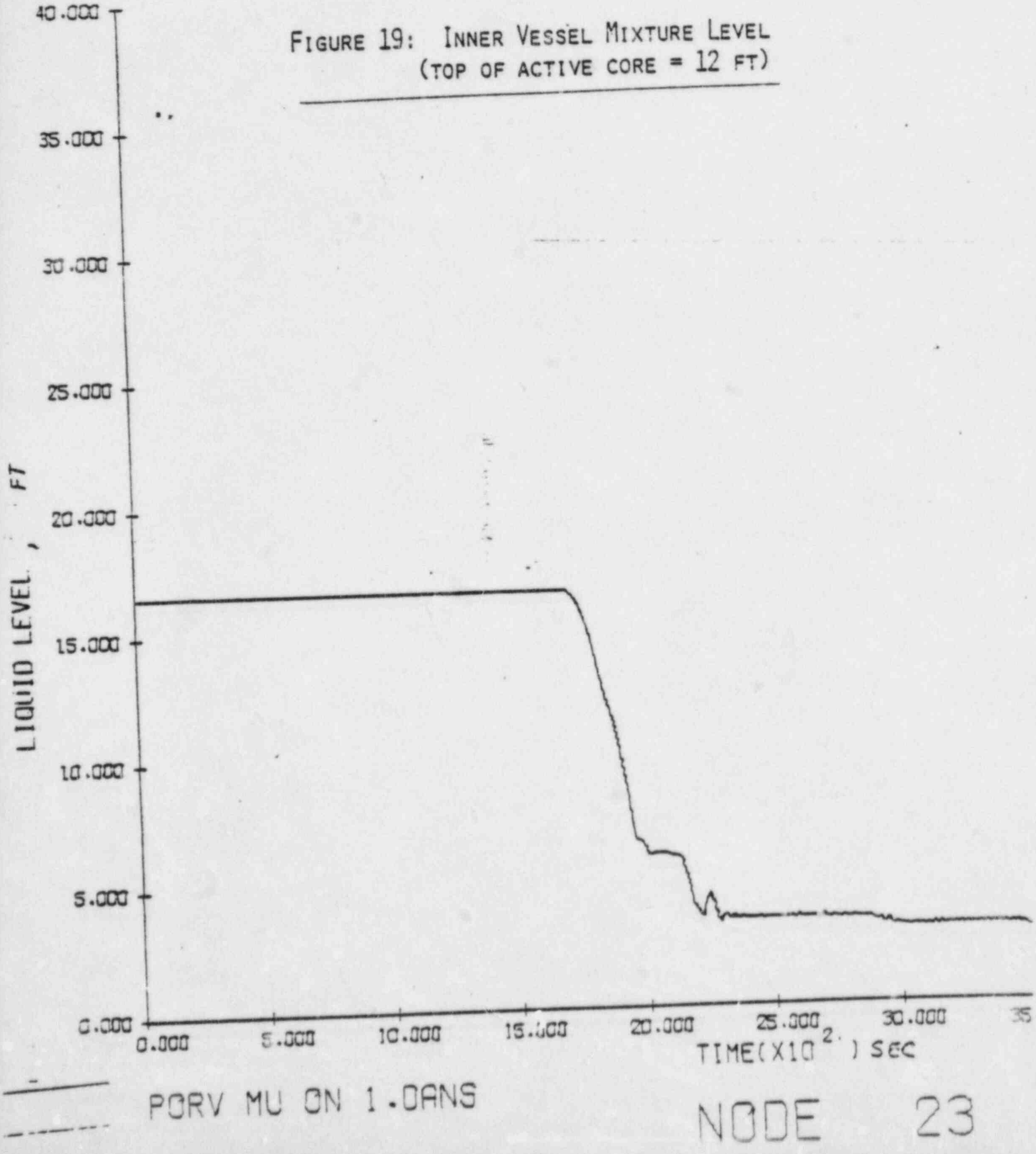
FIGURE 18: CORE PRESSURE



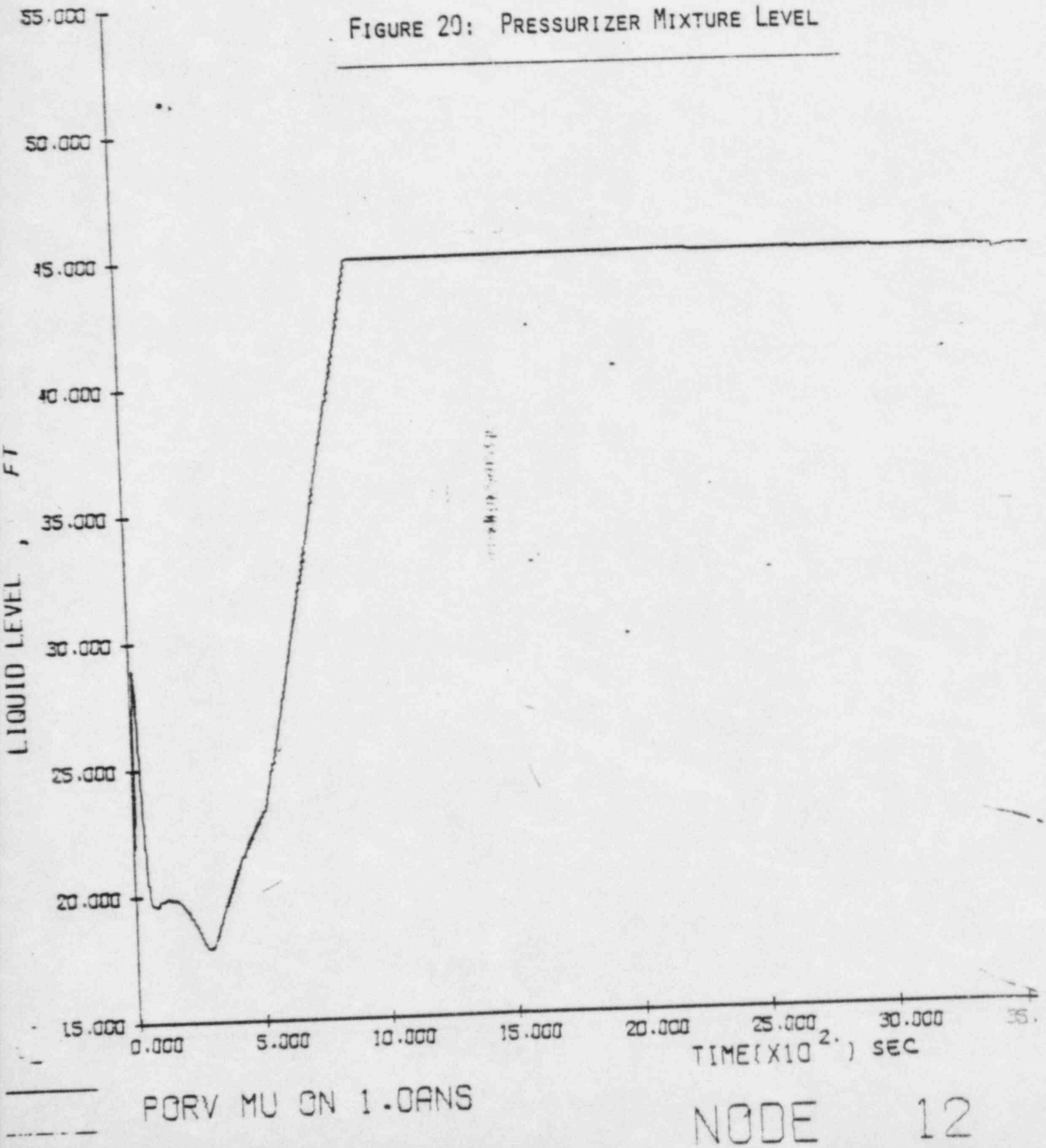
NODE 2

86-1126460 00

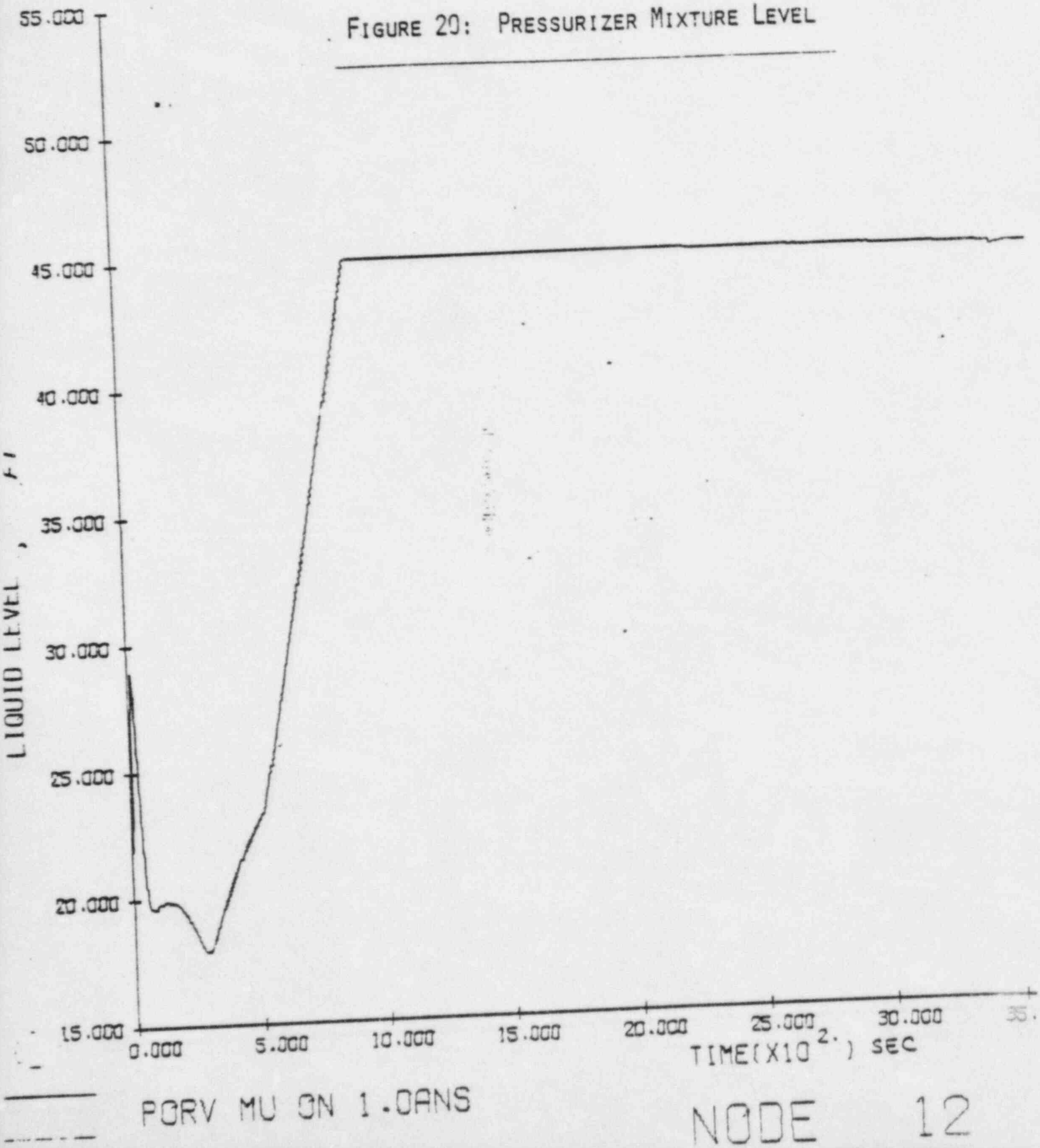
FIGURE 19: INNER VESSEL MIXTURE LEVEL
(TOP OF ACTIVE CORE = 12 FT)



86-1126460 00

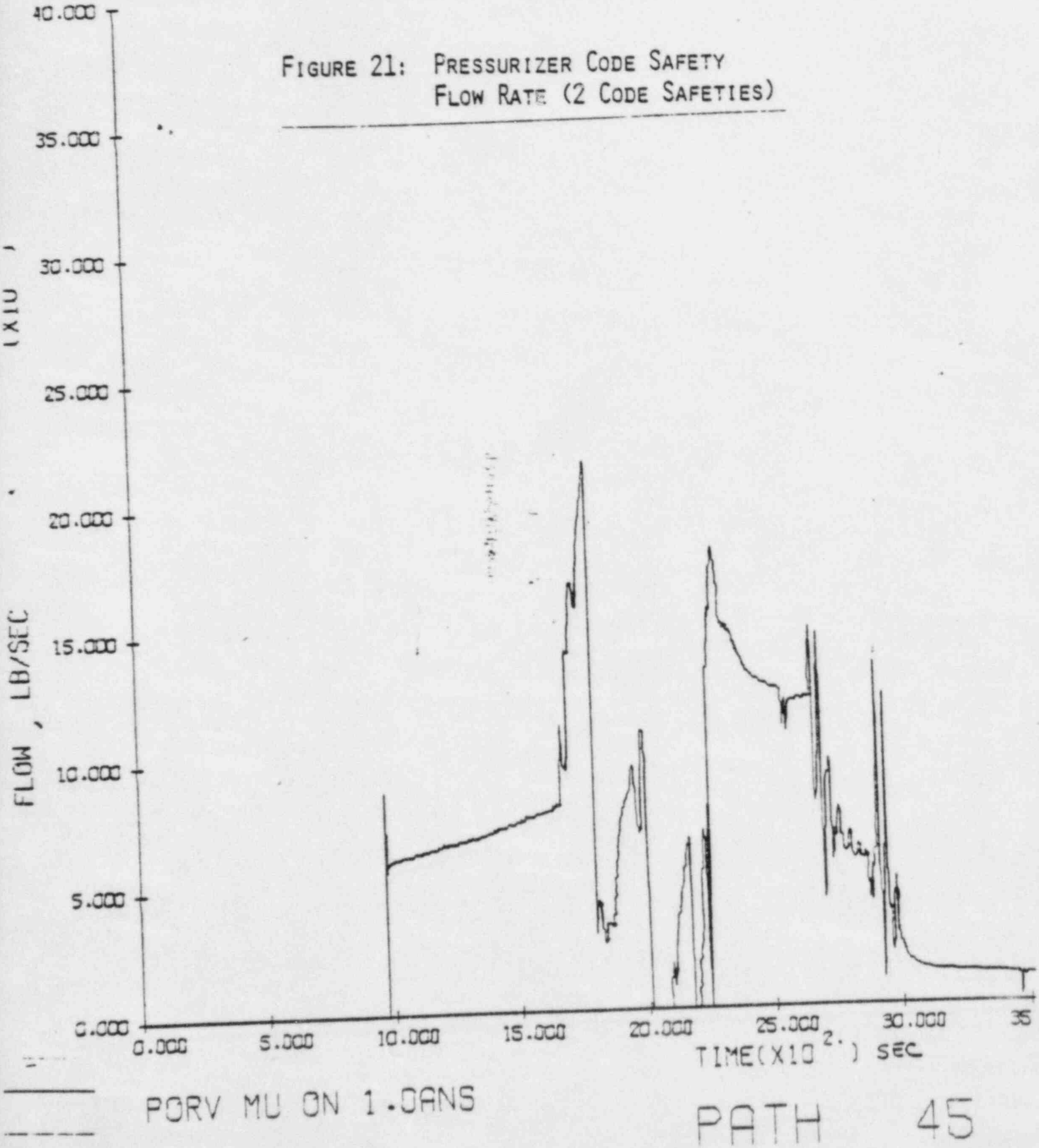


86-1126460 00

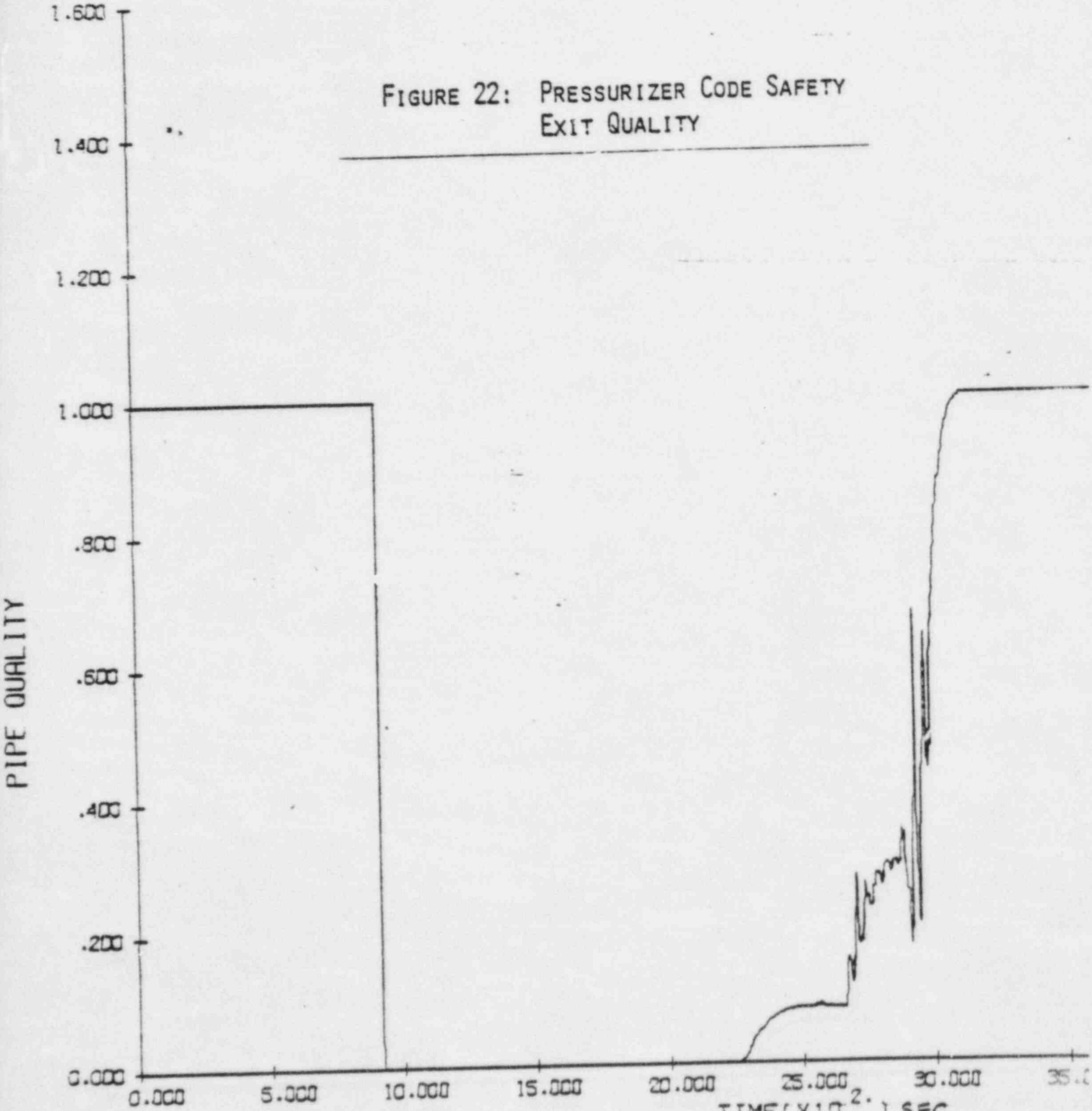


86-1126460 00

FIGURE 21: PRESSURIZER CODE SAFETY FLOW RATE (2 CODE SAFETIES)



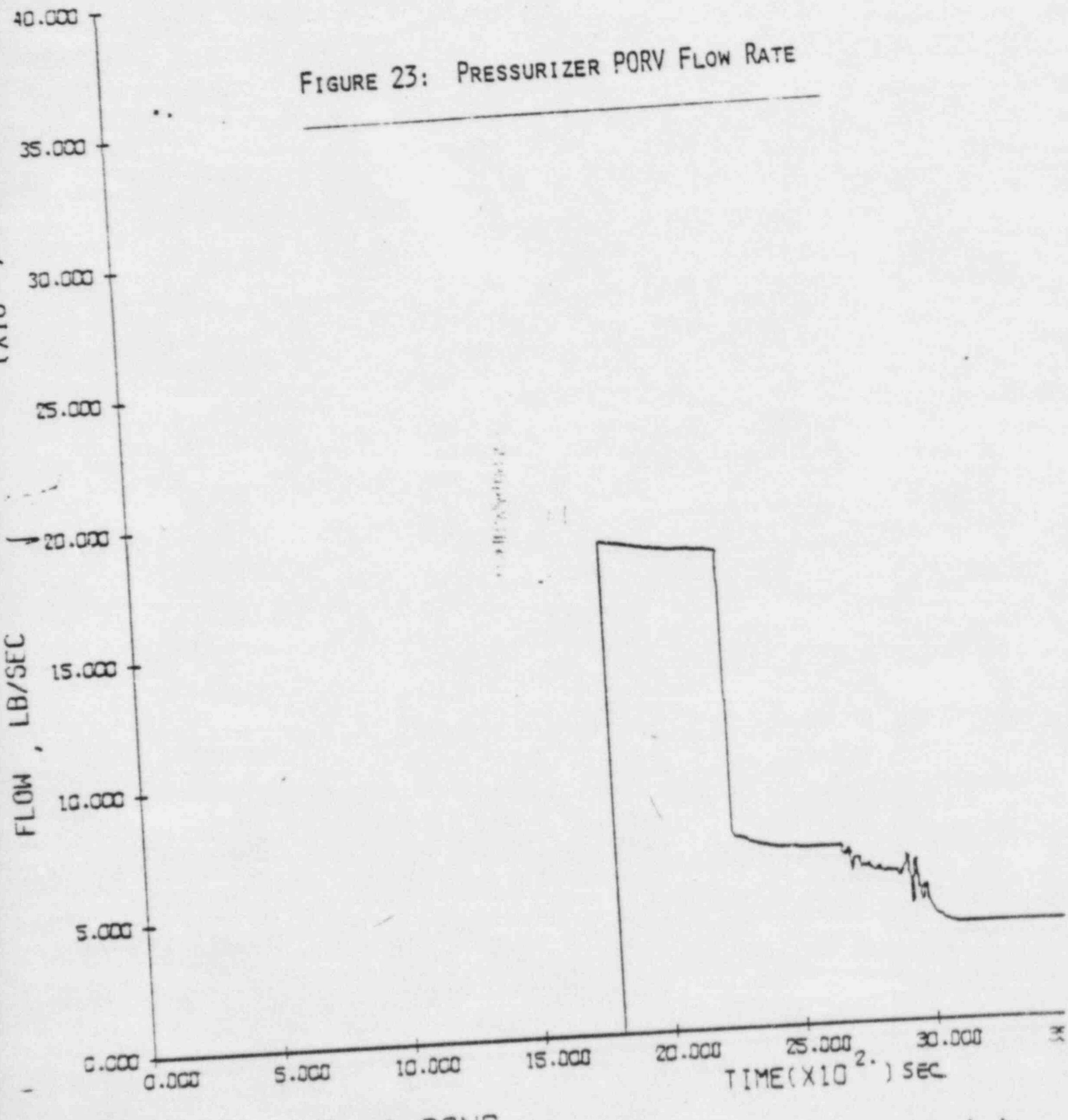
86-1126460 00



PORV MU ON 1.0ANS

PATH 45

86-1126460 00



PATH 44

86-1126460 00

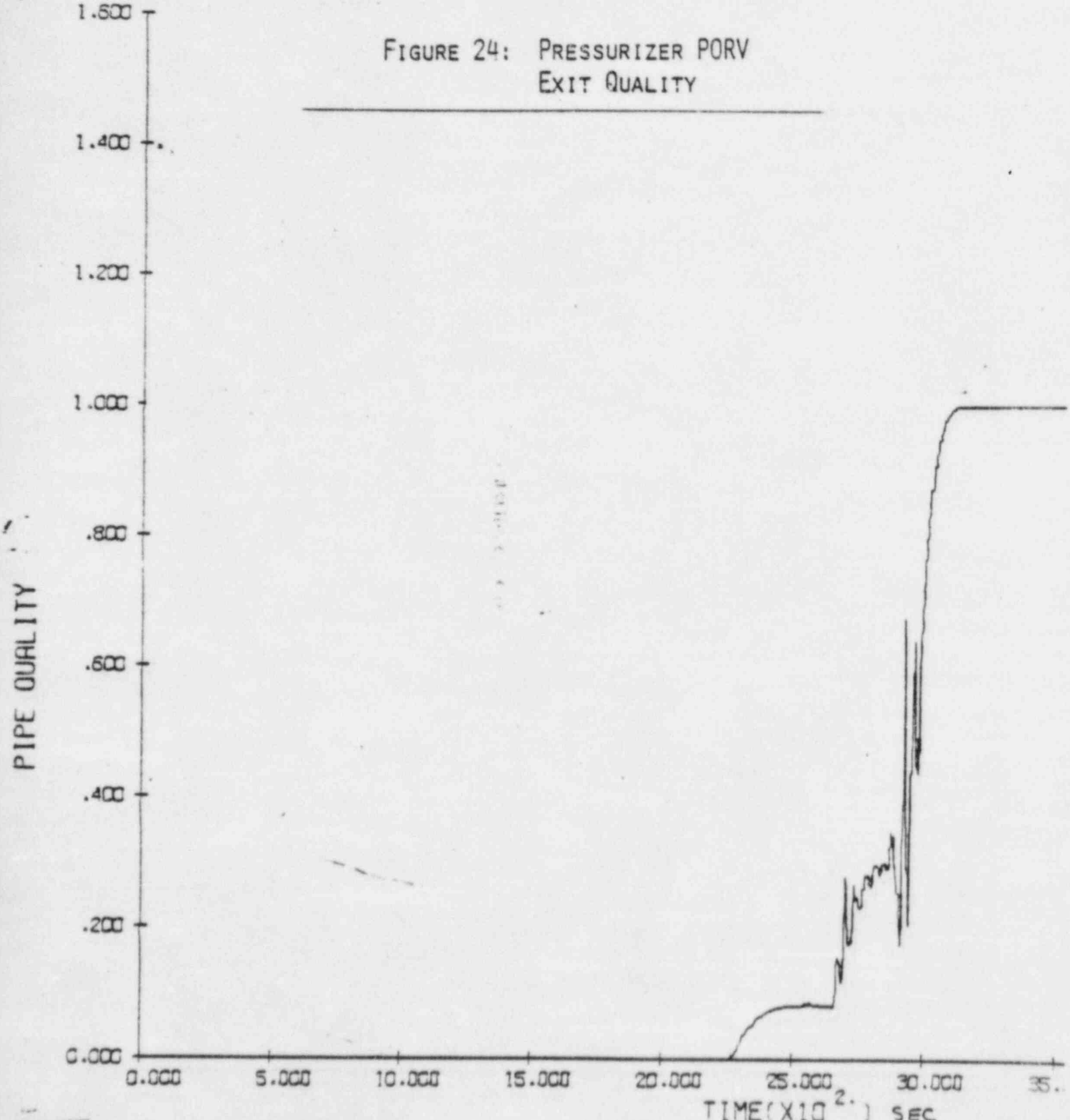


FIGURE 24: PRESSURIZER PORV EXIT QUALITY

PORV MU ON 1.0ANS

PATH 44

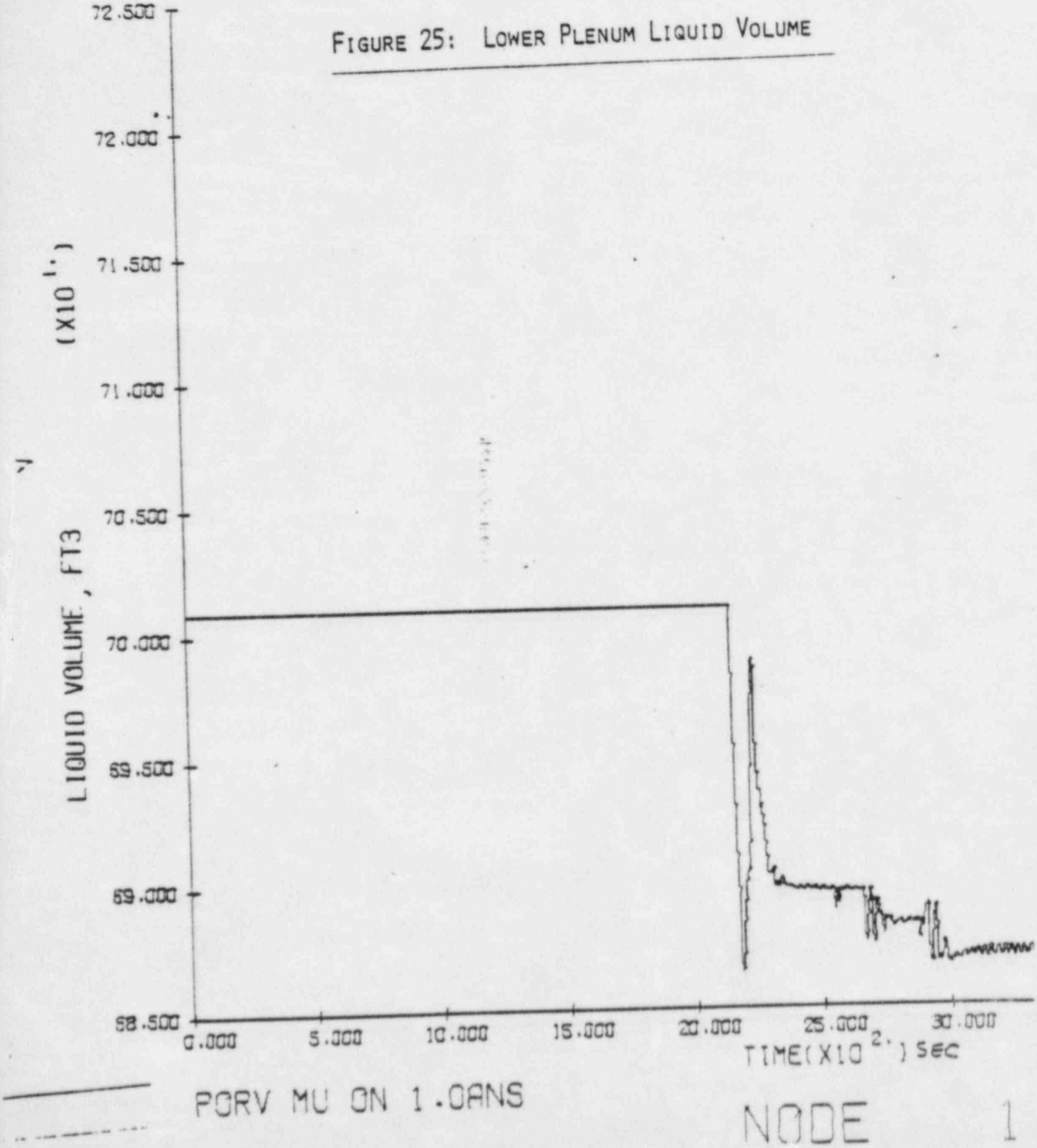
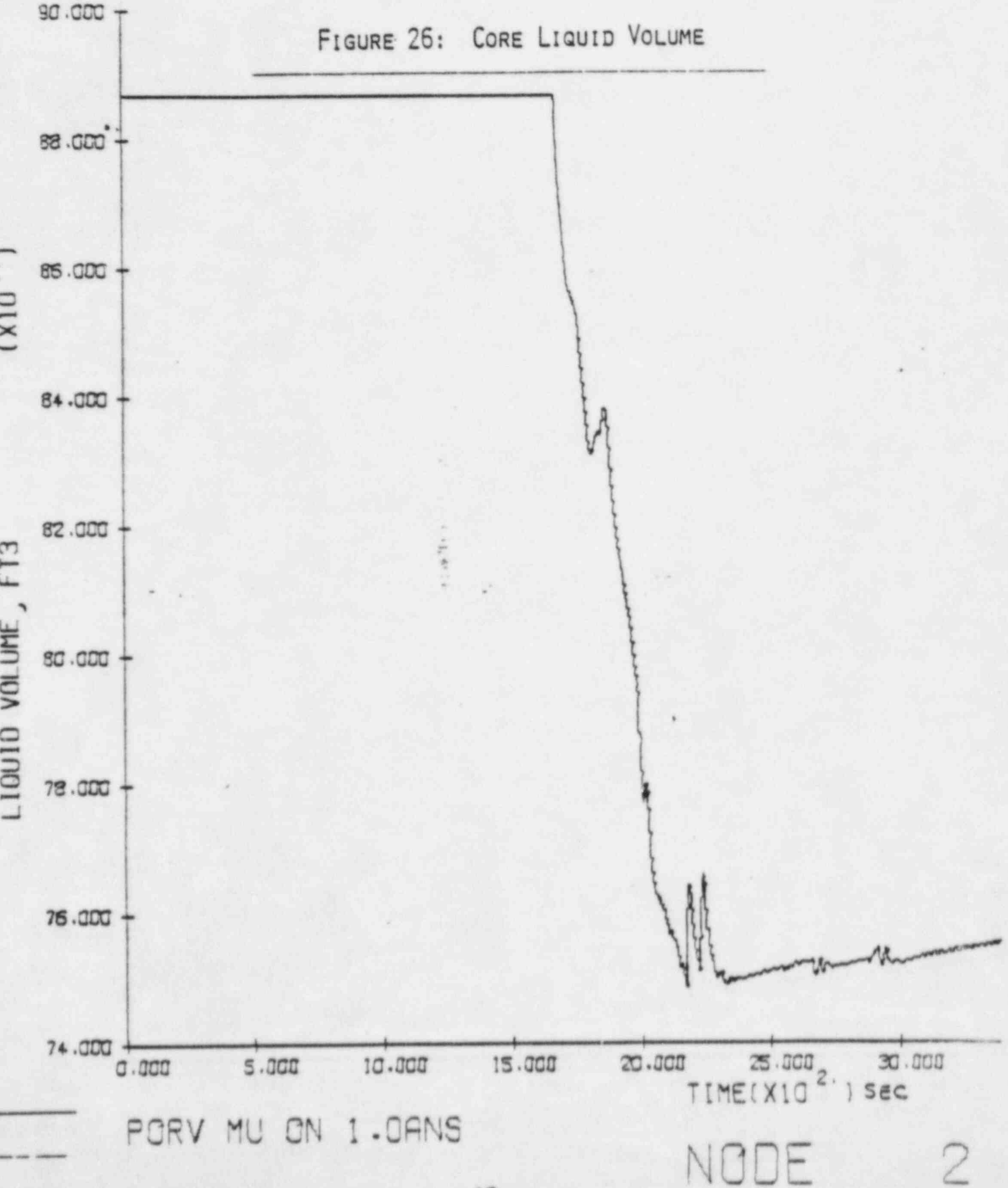


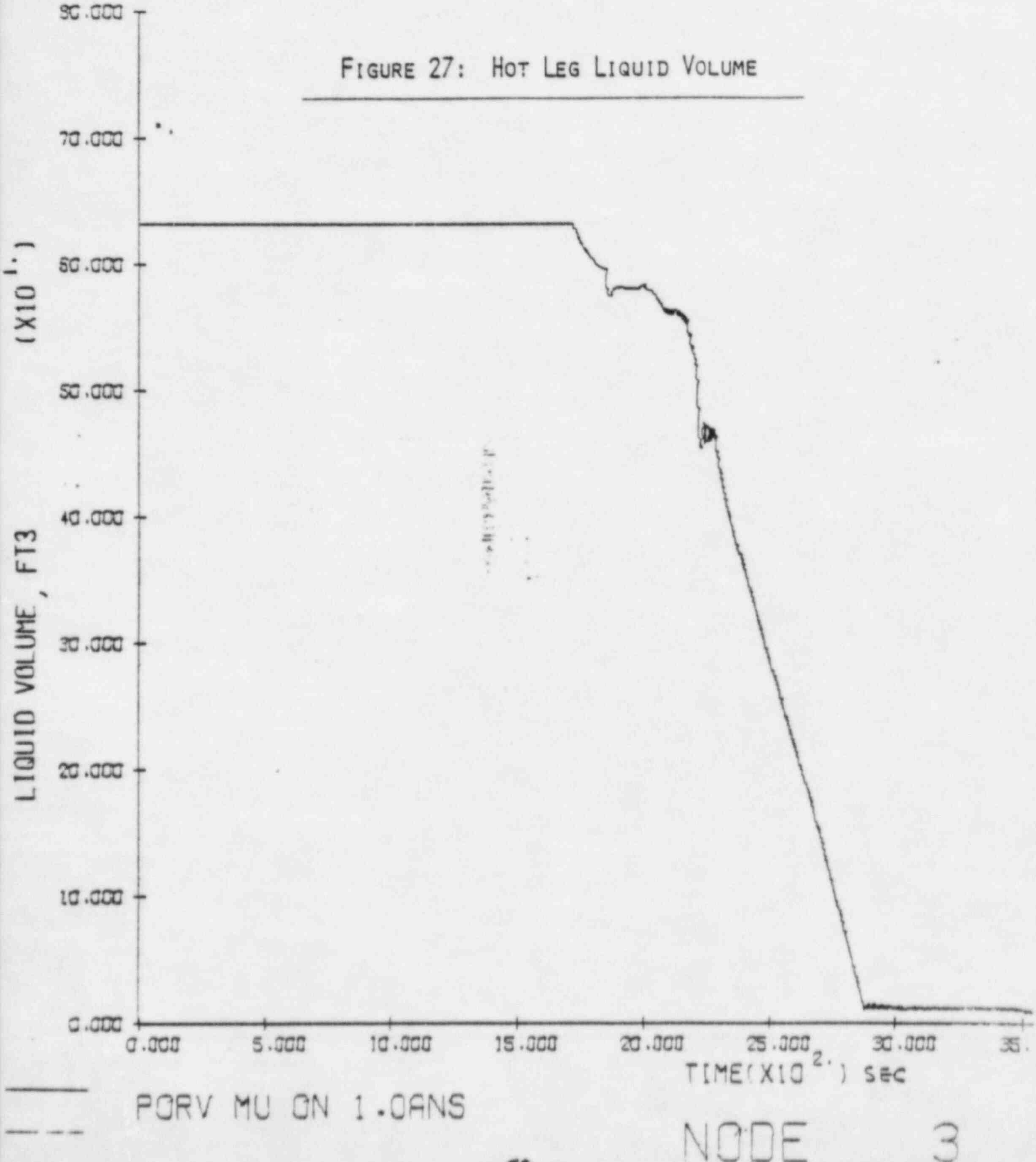
FIGURE 25: LOWER PLENUM LIQUID VOLUME
LIQUID VOLUME , FT3 (X10 1)
72.500
72.000
71.500
71.000
70.500
70.000
69.500
69.000
68.500
0.000
5.000
10.000
15.000
20.000
25.000
30.000
TIME(X10 2) SEC
PORV MU ON 1.0ANS
NODE 1

FIGURE 26: CORE LIQUID VOLUME

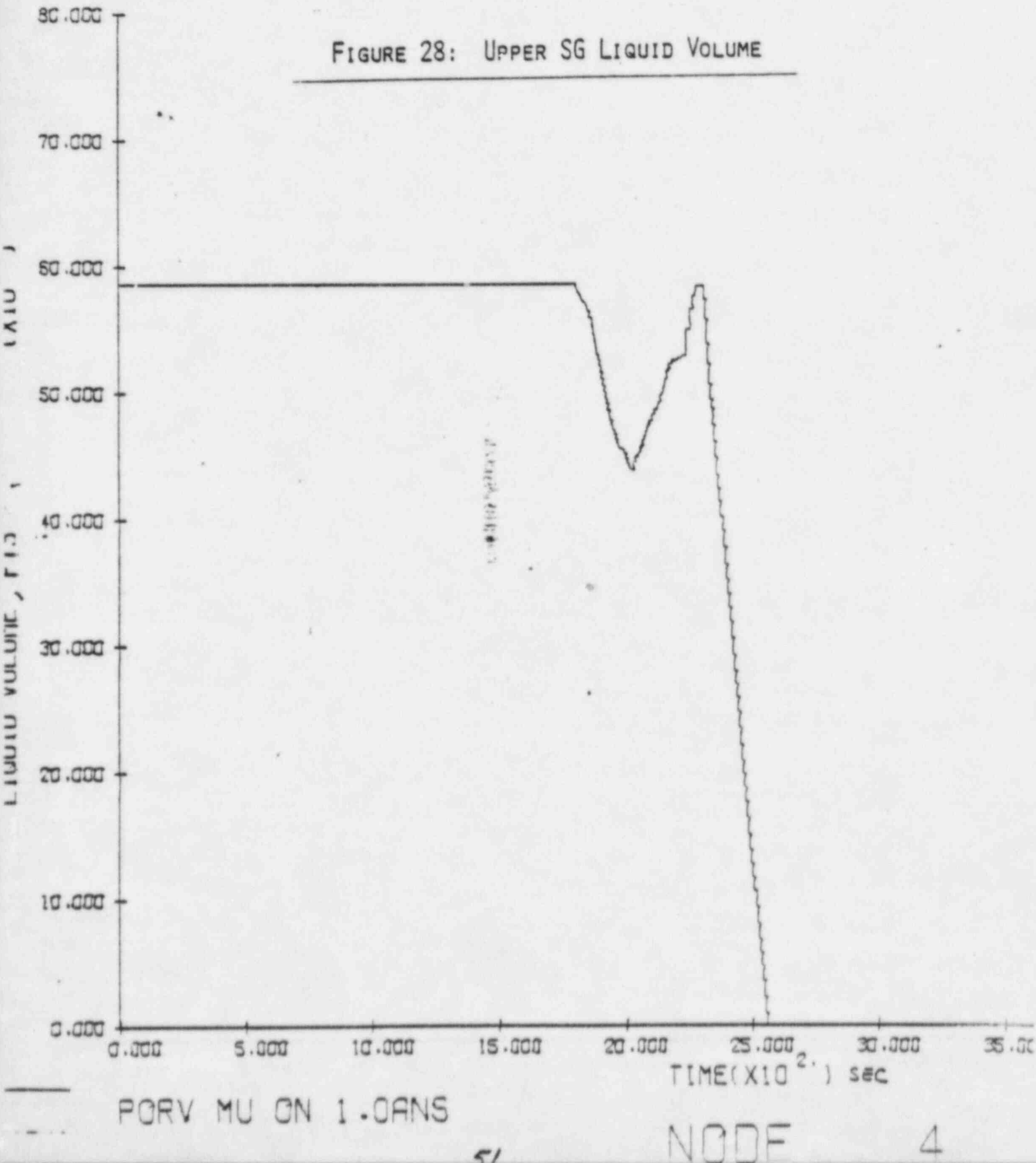


86-1126460 00

FIGURE 27: HOT LEG LIQUID VOLUME



86-1126460 00



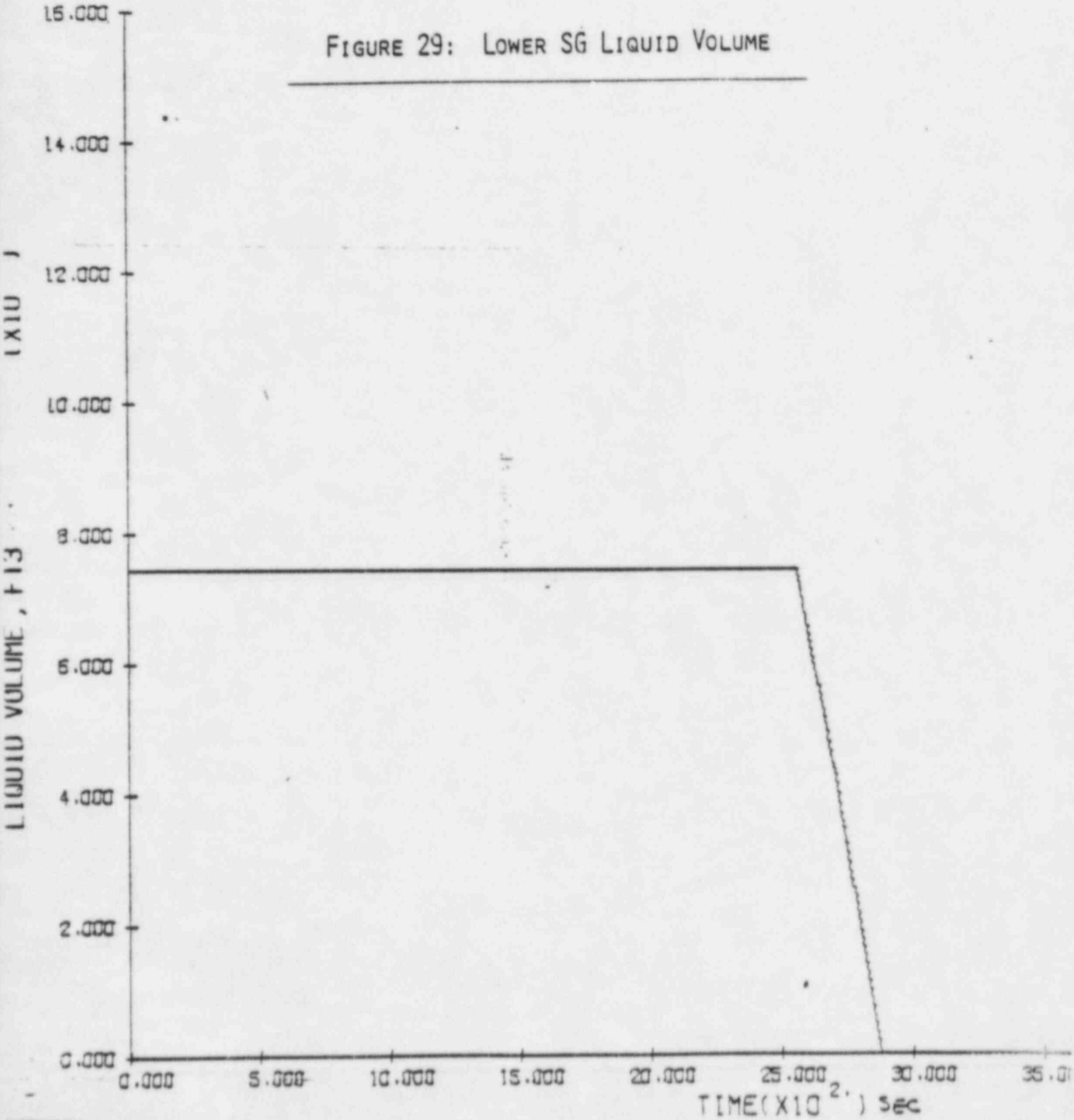
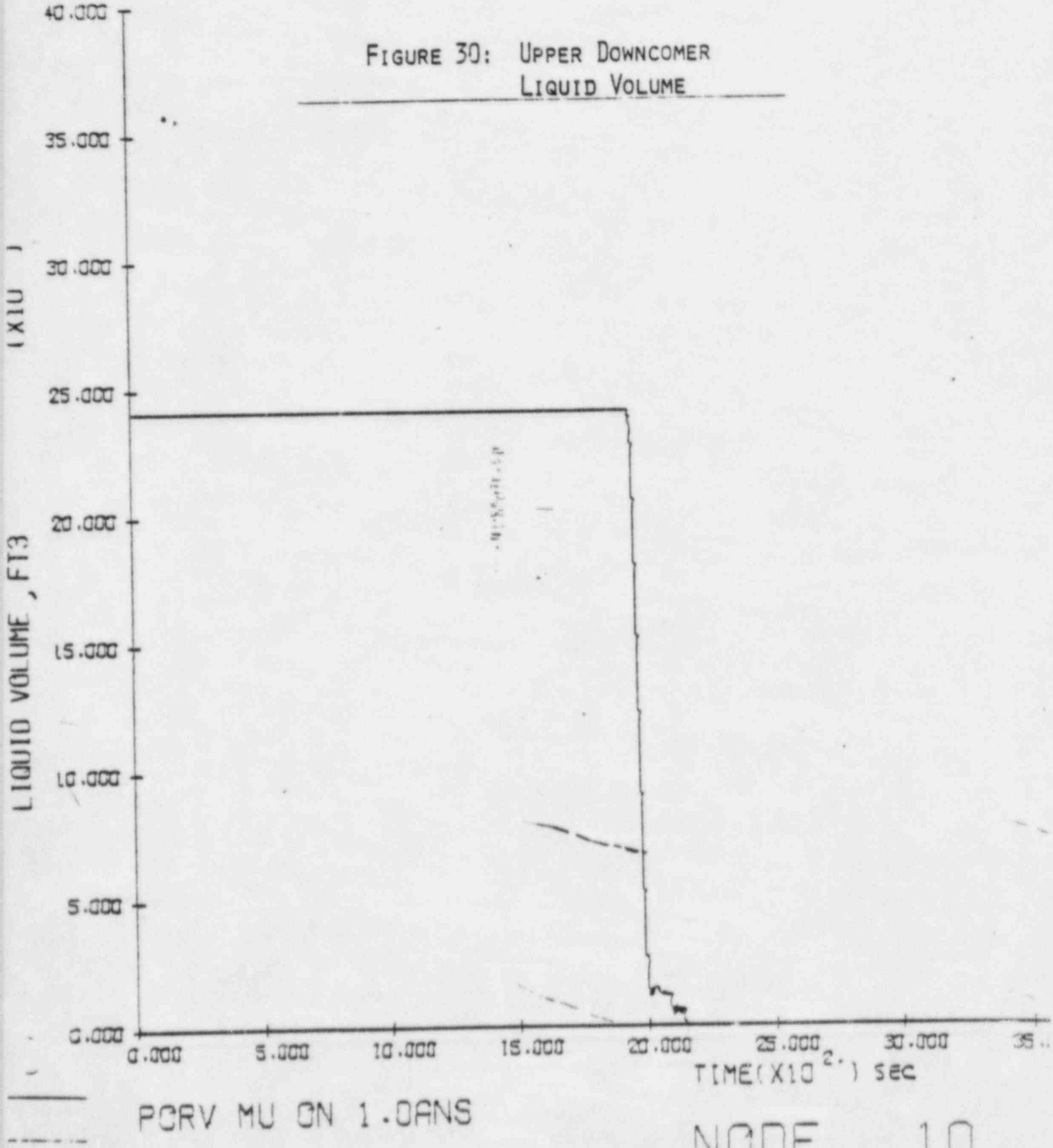


Figure 29: Lower SG Liquid Volume

PORV MU ON 1.0ANS

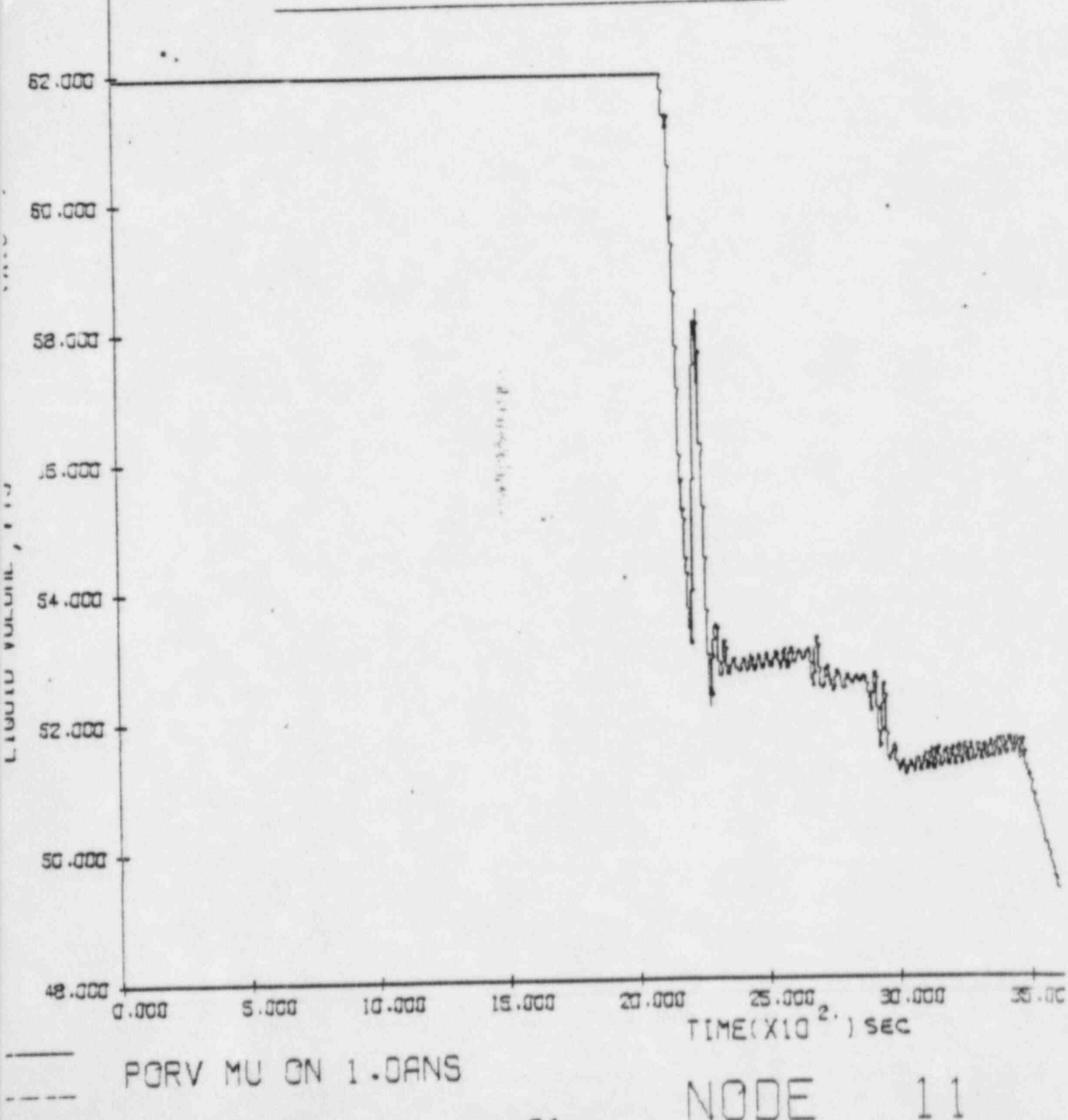
NODE 5

86-1126460 00



86-1126460 00

FIGURE 31: LOWER DOWNCOMER LIQUID VOLUME



86-1126460 00

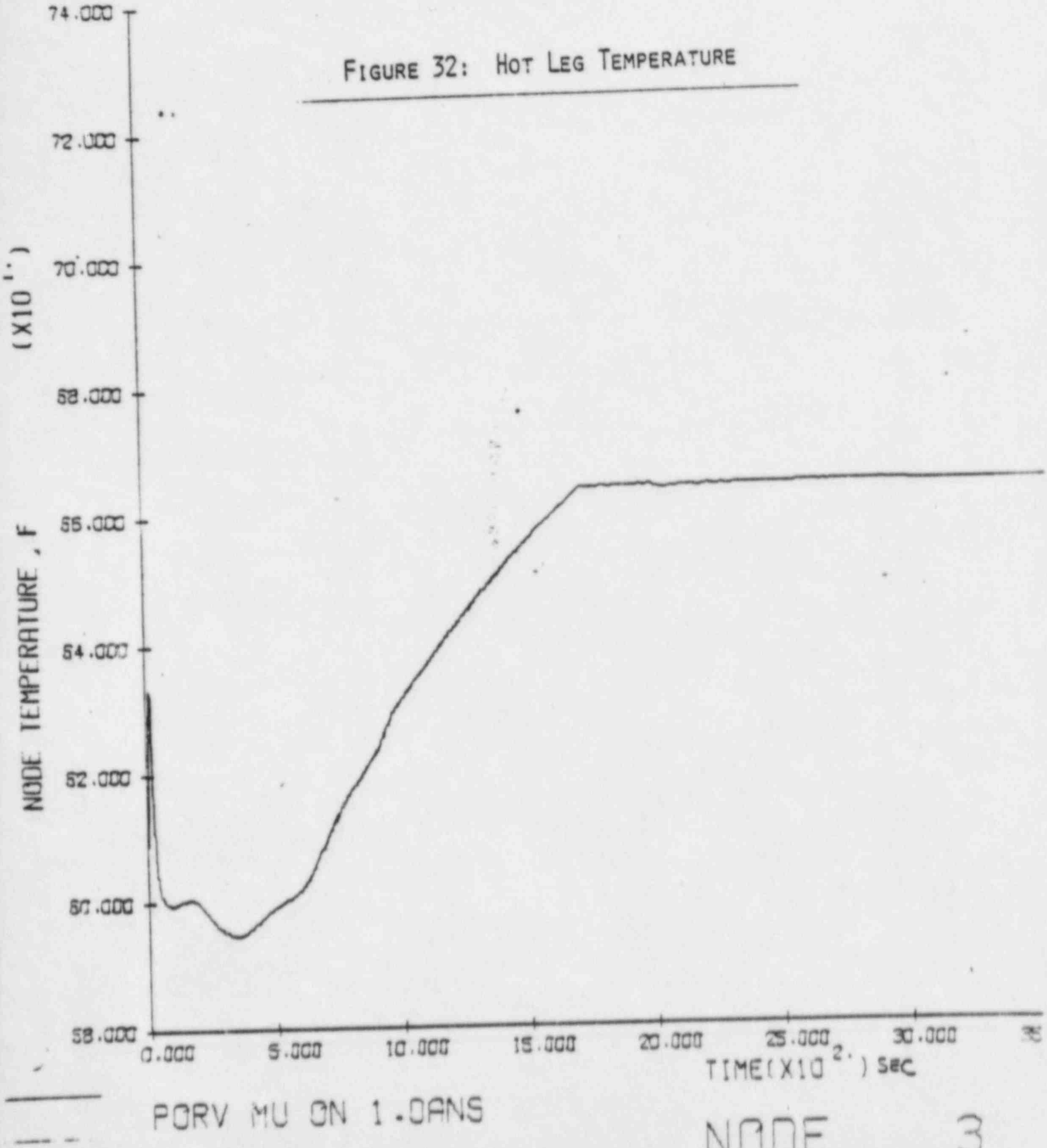
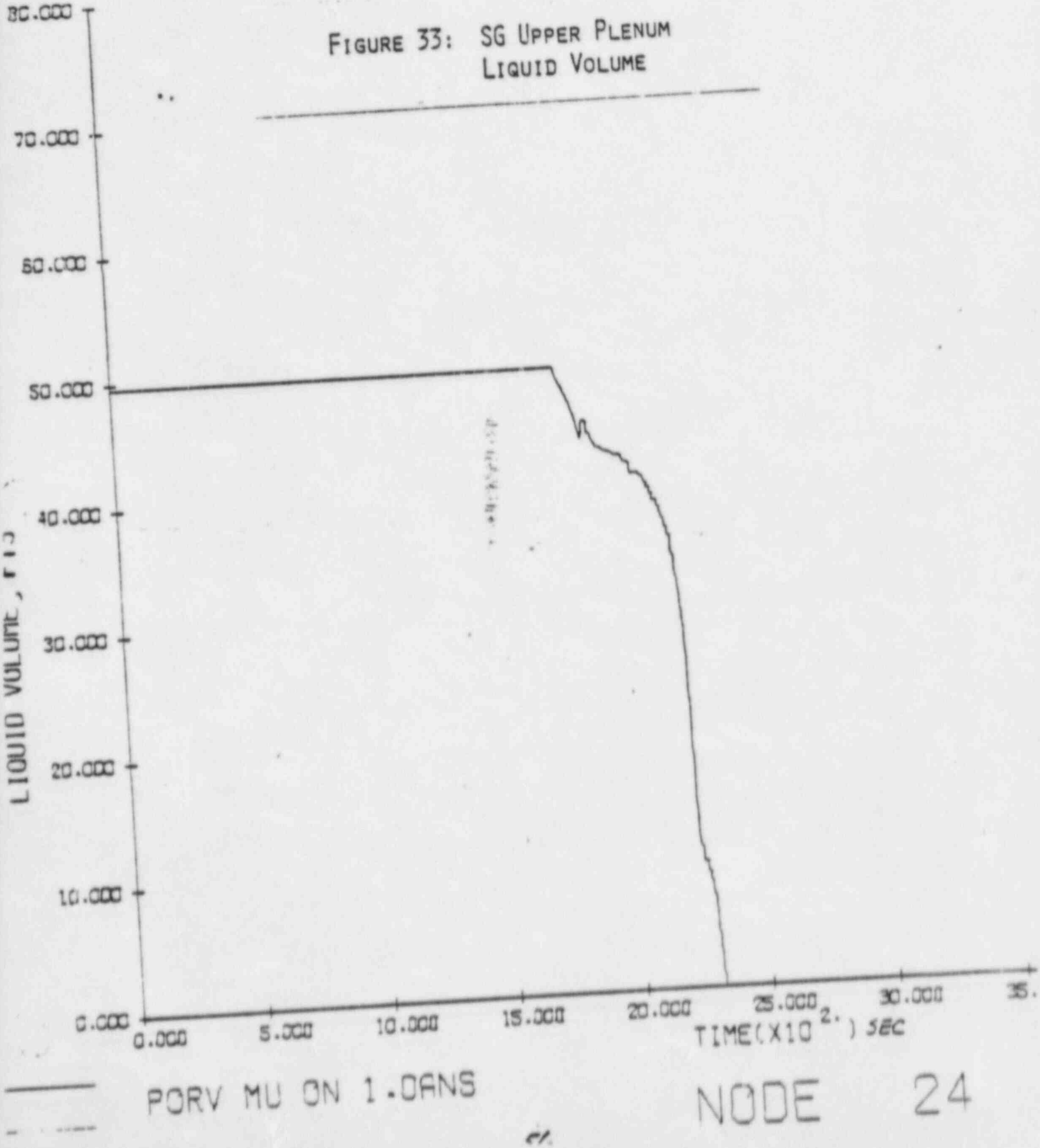


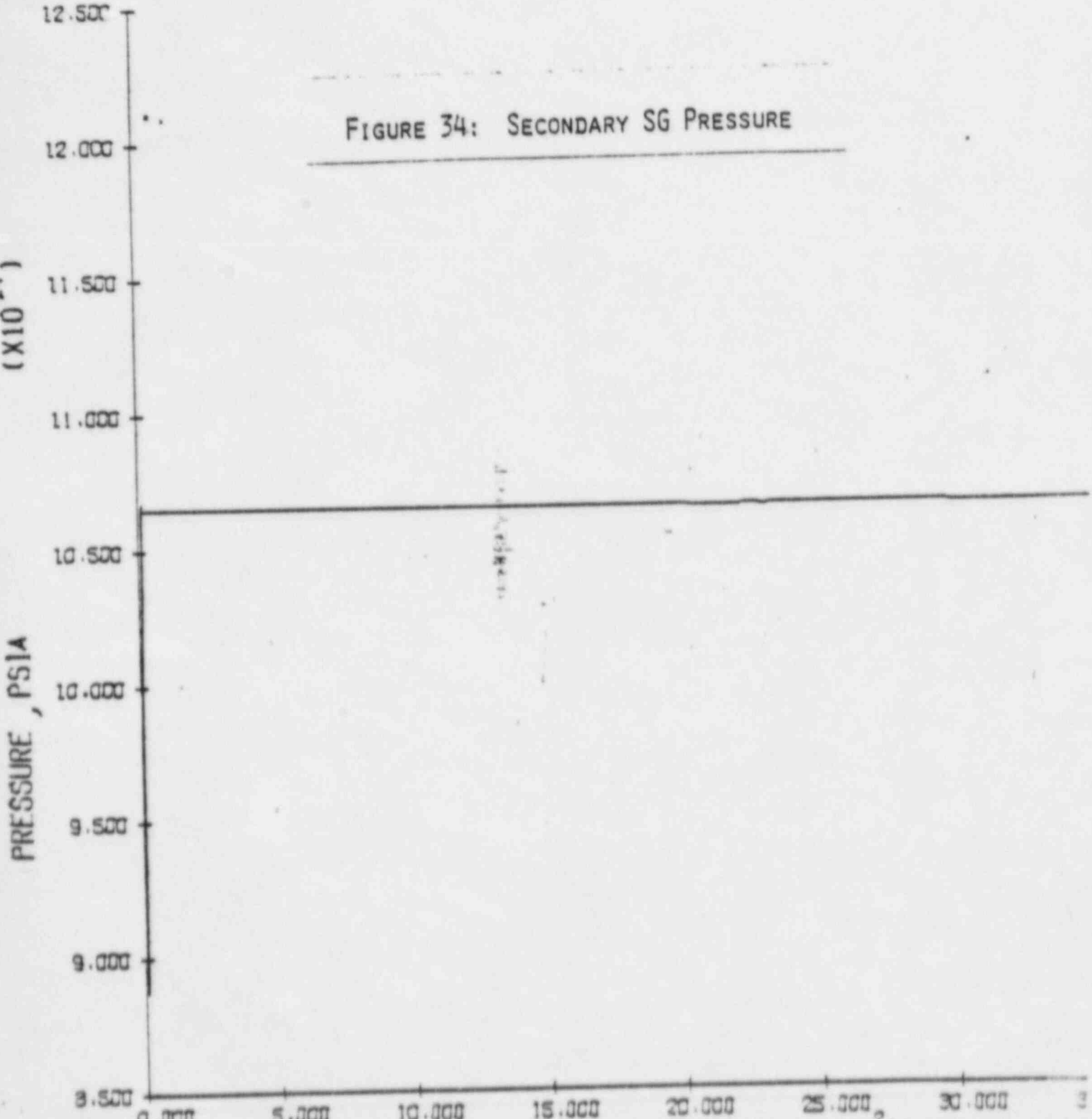
Figure 32: Hot Leg Temperature

86-1126460 00



86-1126460 00

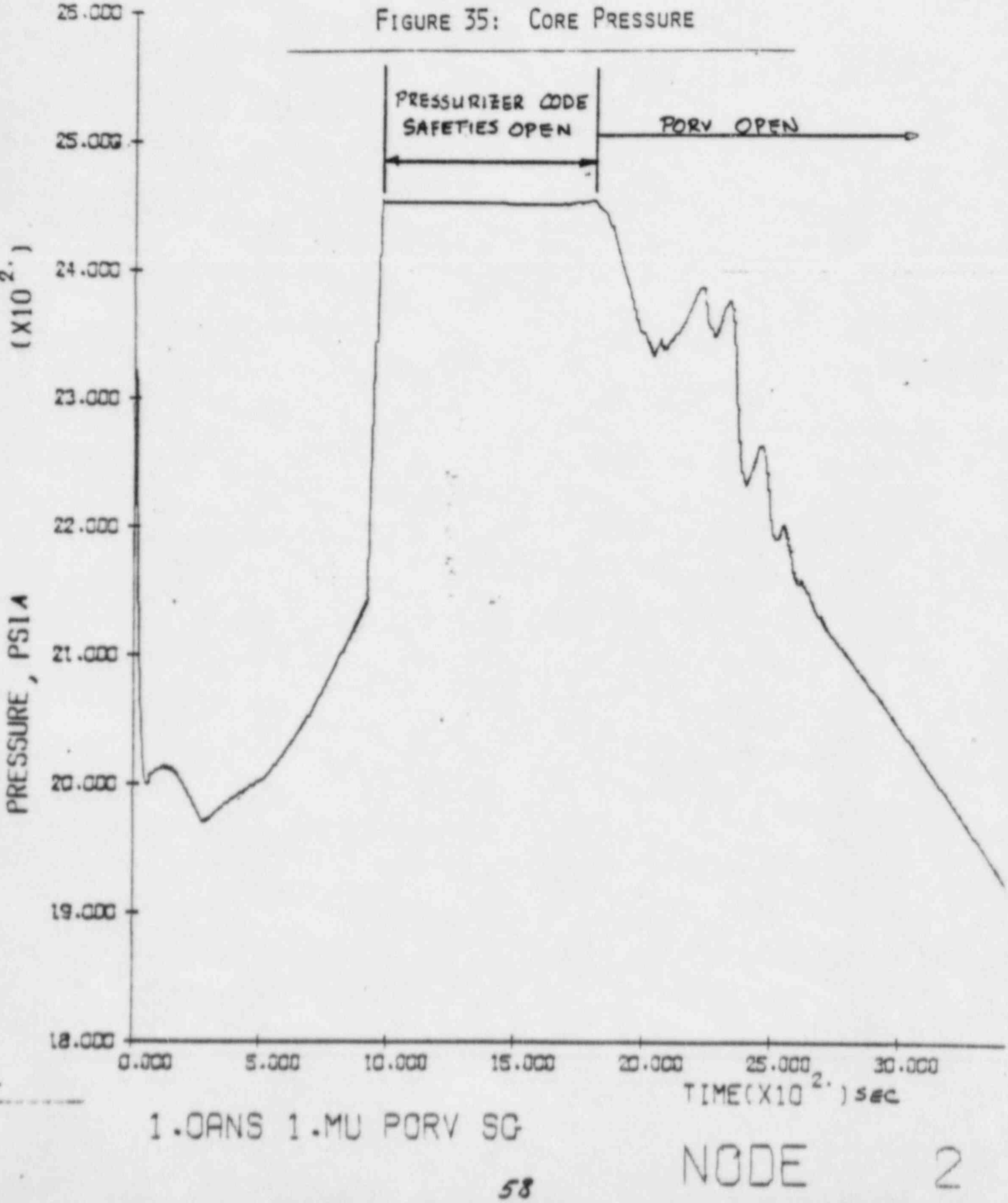
FIGURE 34: SECONDARY SG PRESSURE



PORV MU ON 1.0ANS

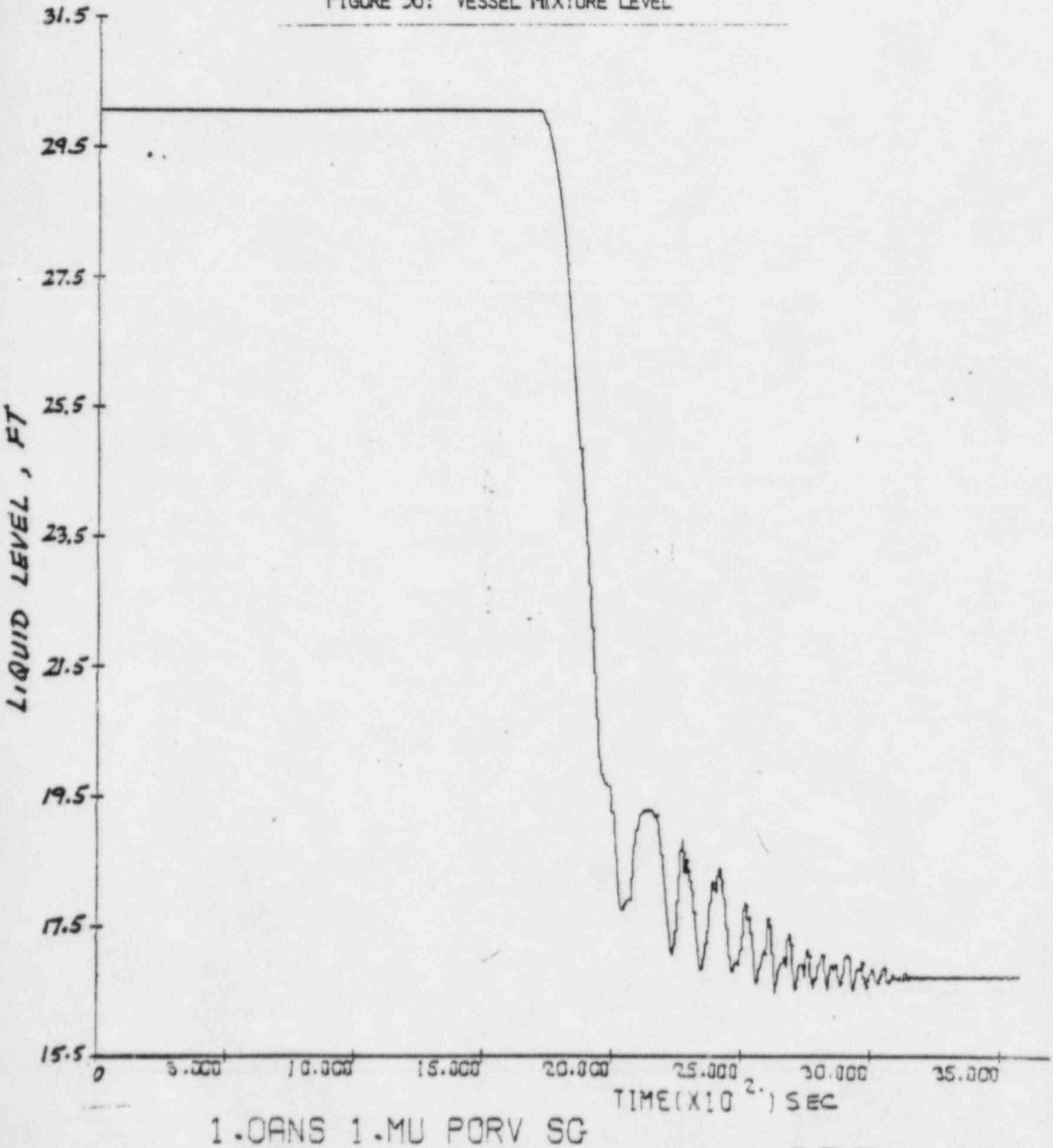
NODE 6

86-1126460 00



86-1126460 00

FIGURE 36: VESSEL MIXTURE LEVEL



NODE 23

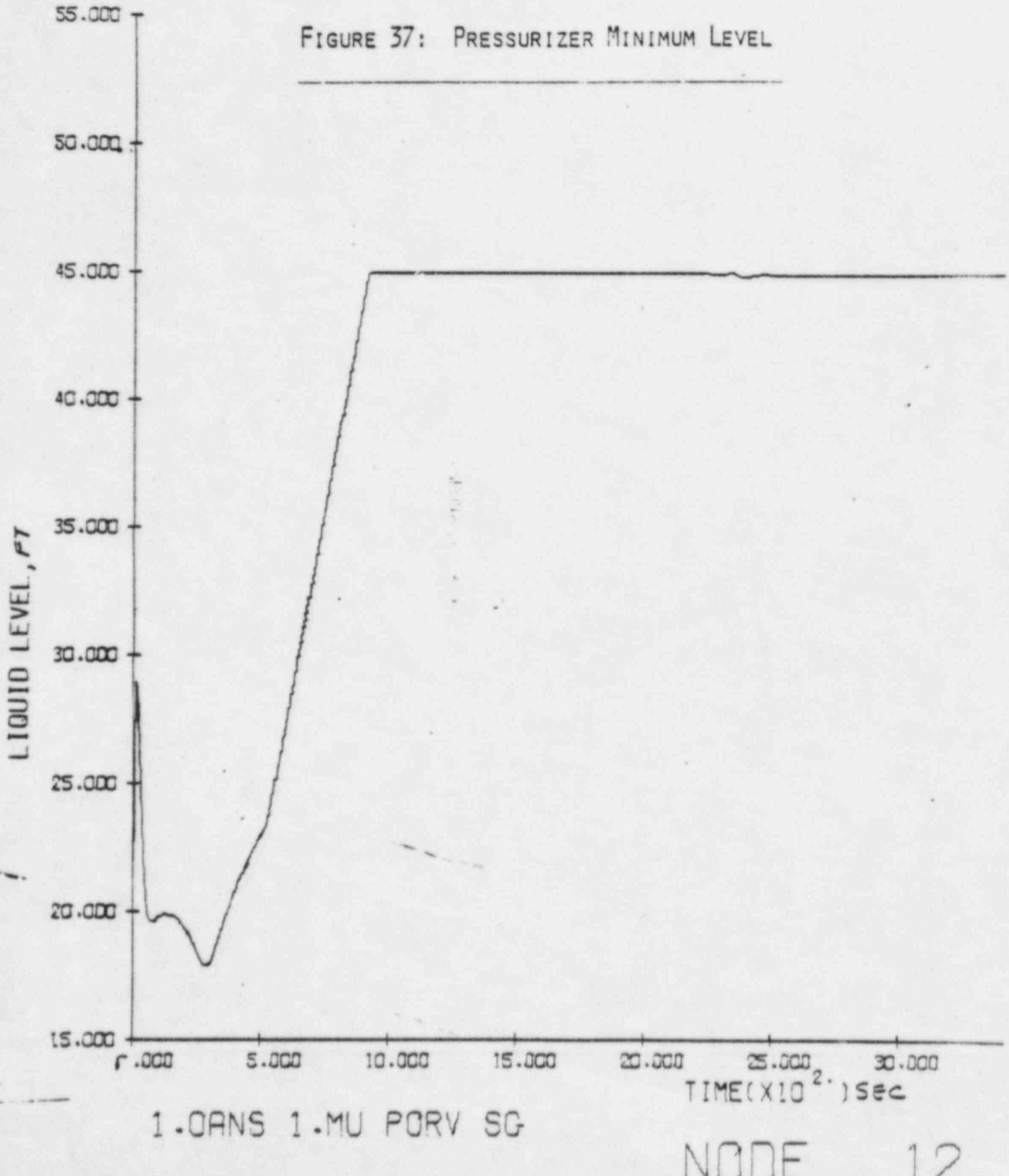
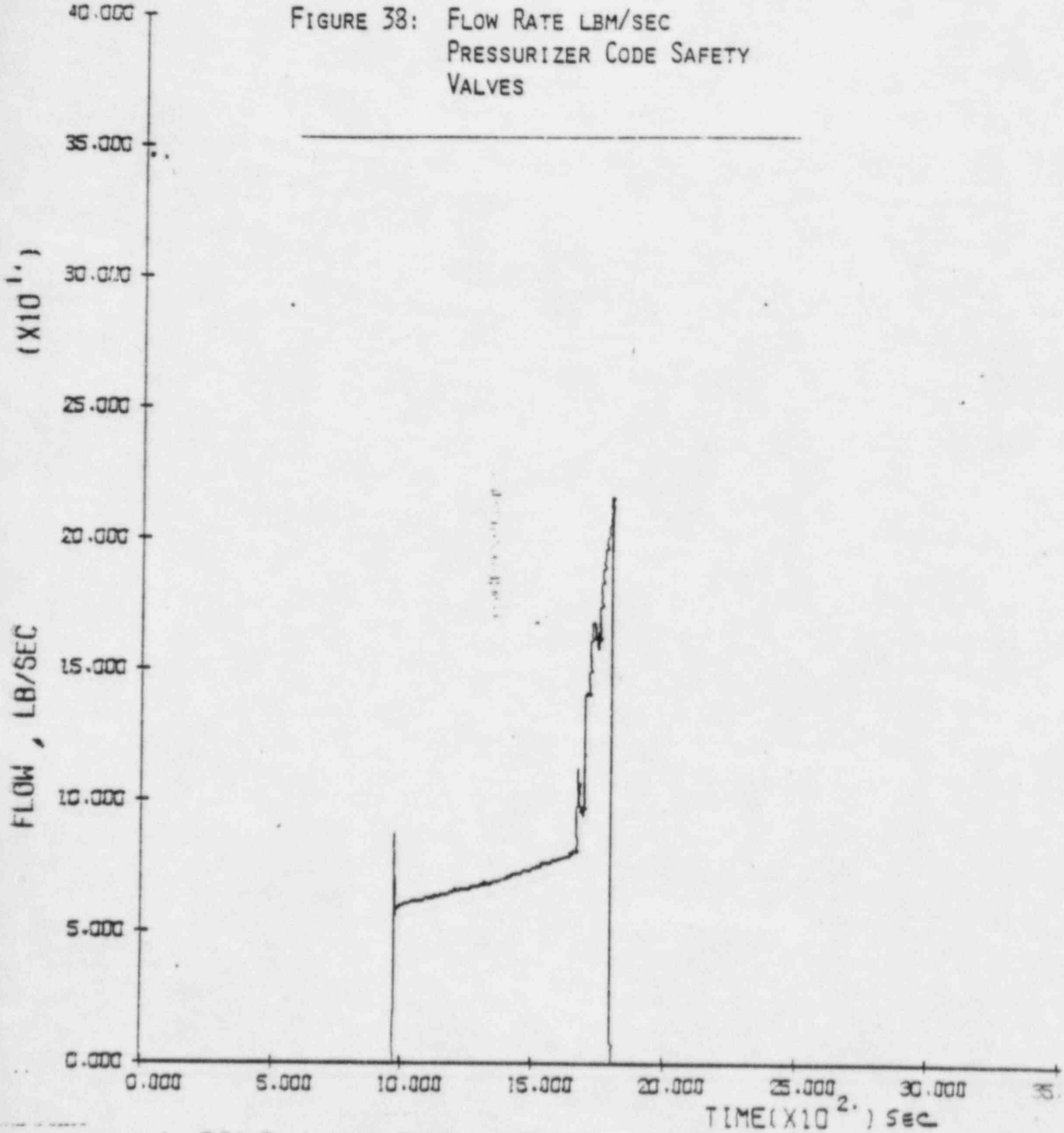


FIGURE 37: PRESSURIZER MINIMUM LEVEL
55.000
50.000
45.000
40.000
35.000
30.000
25.000
20.000
15.000
LIQUID LEVEL, FT
0.000
5.000
10.000
15.000
20.000
25.000
30.000
TIME(X10 2.)Sec
1.0ANS 1.MU PORV SG
NODE 12

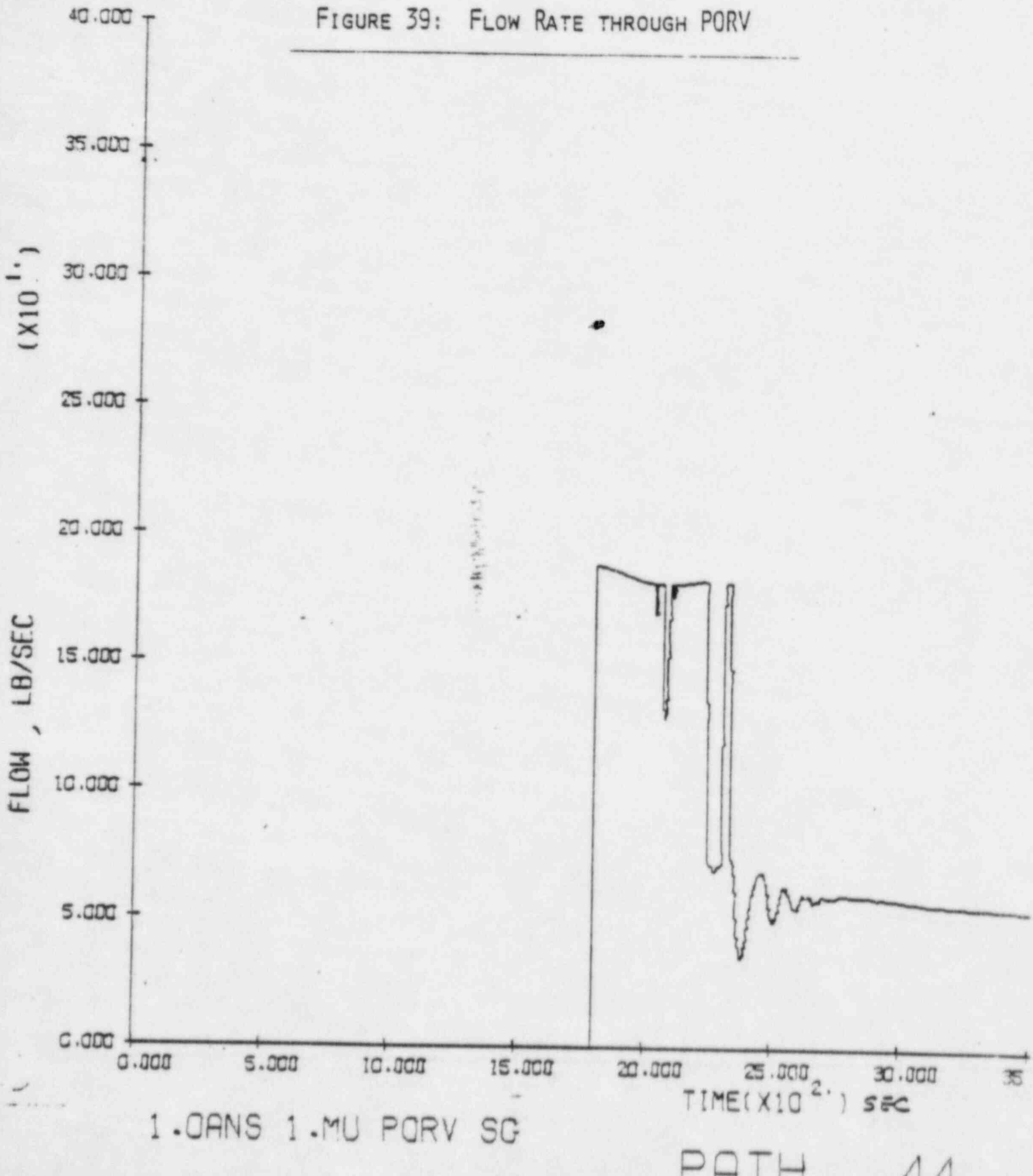
86-1126460 00

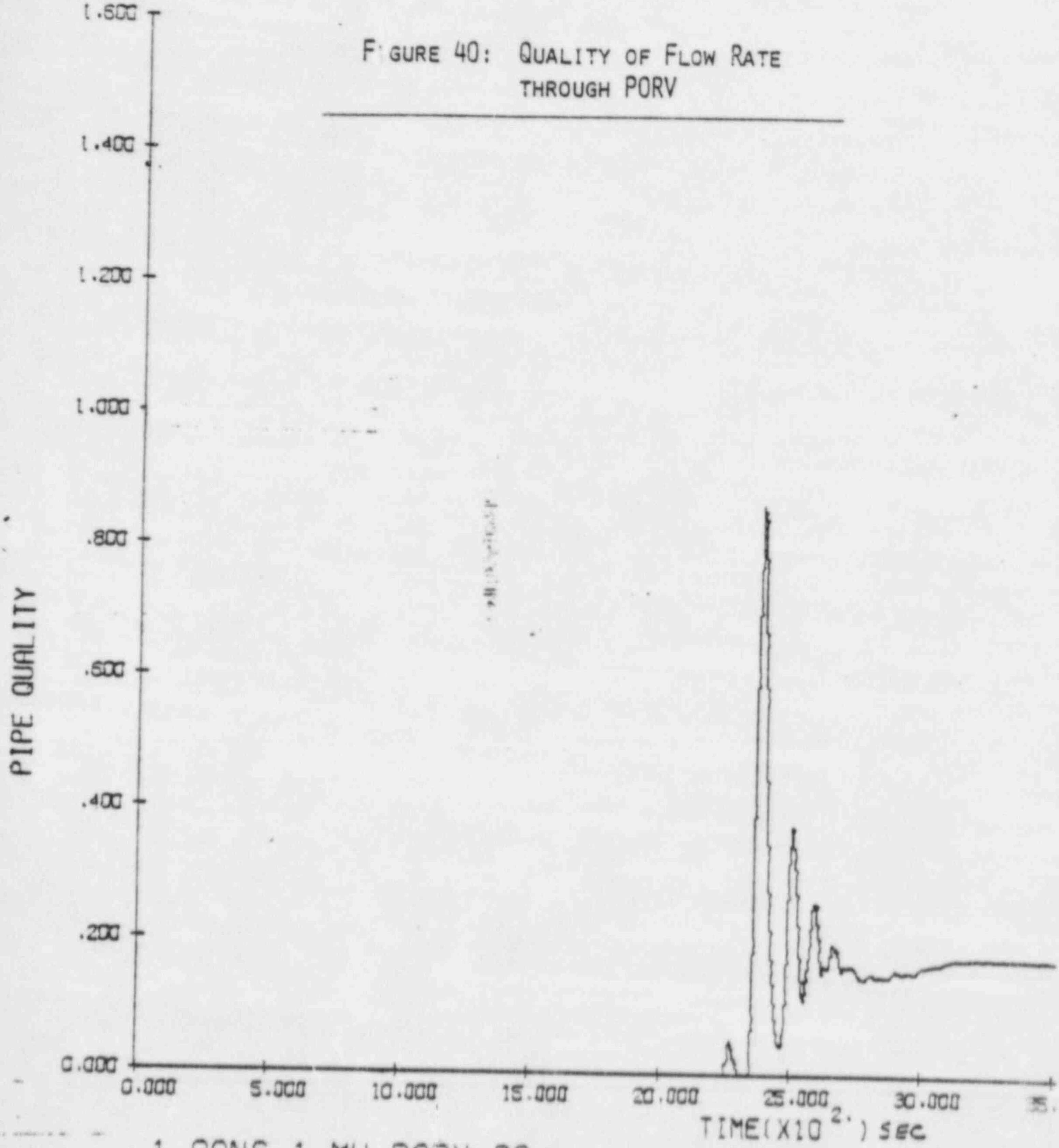


1.0ANS 1.MU PORV SG

PATH 45

86-1126460 00

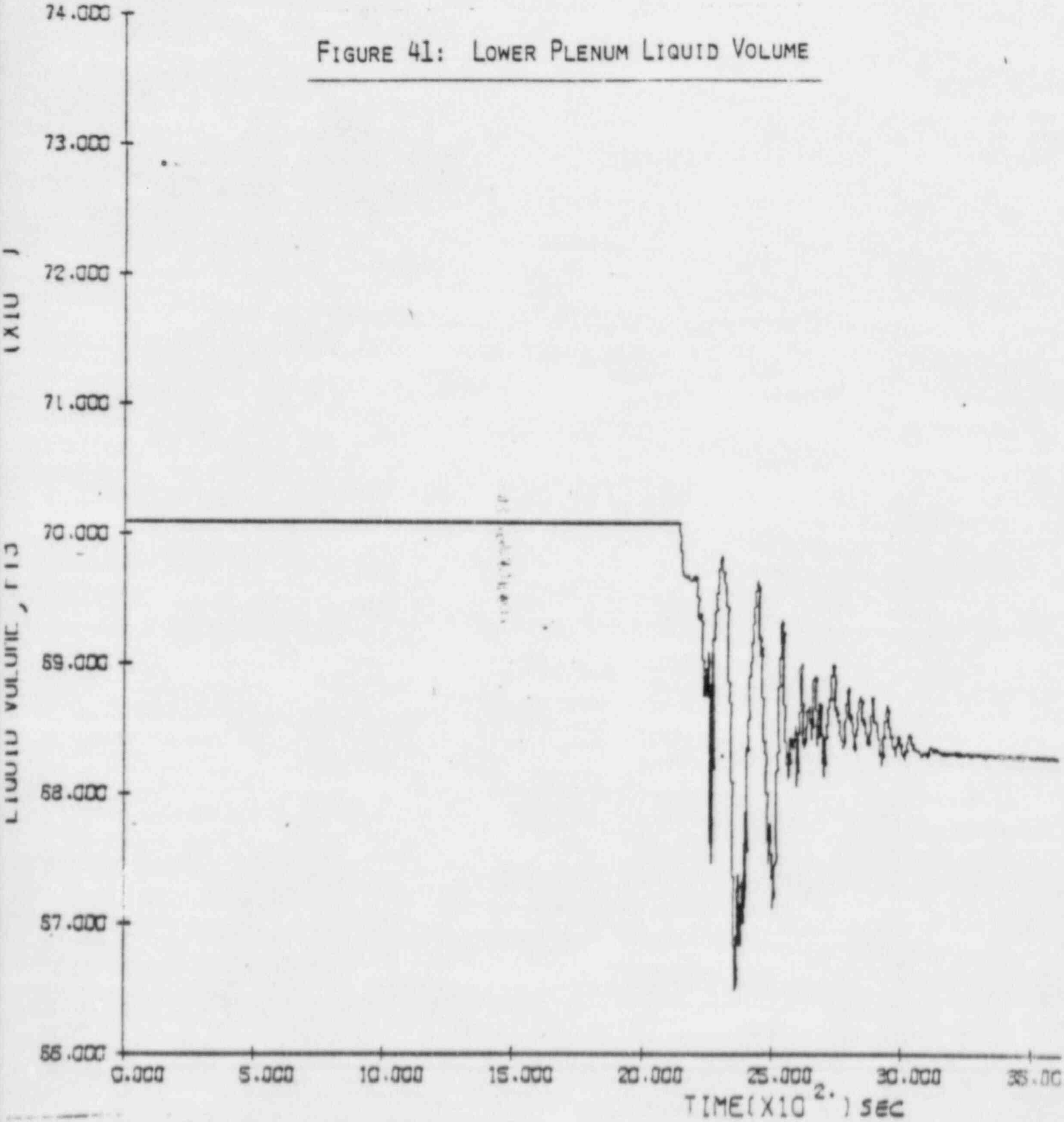




1.0ANS 1.MU PORV SG

PATH 44

86-1126460 00



1.OANS 1.MU PORV SG

NODE 1

86-1126460 00

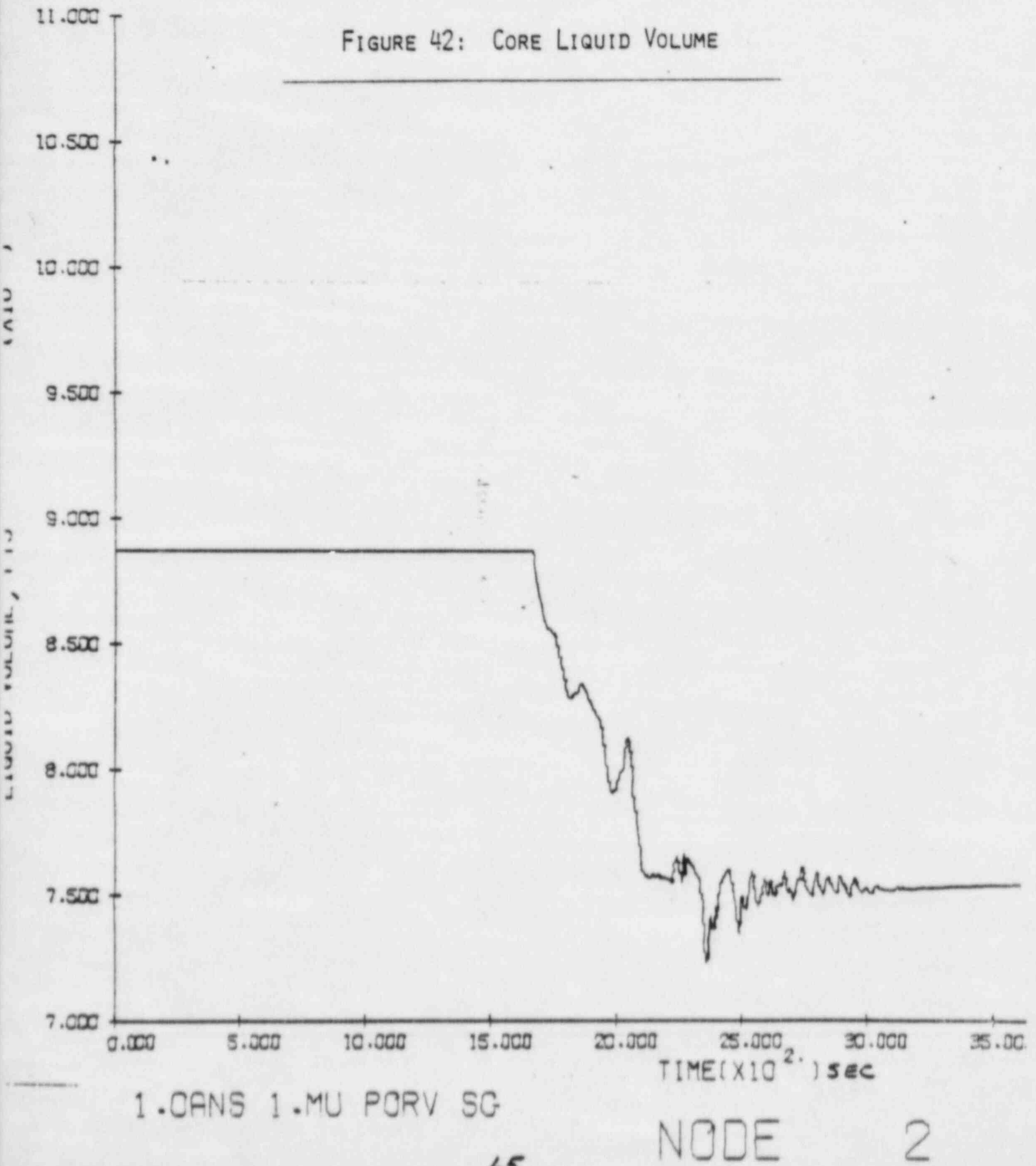
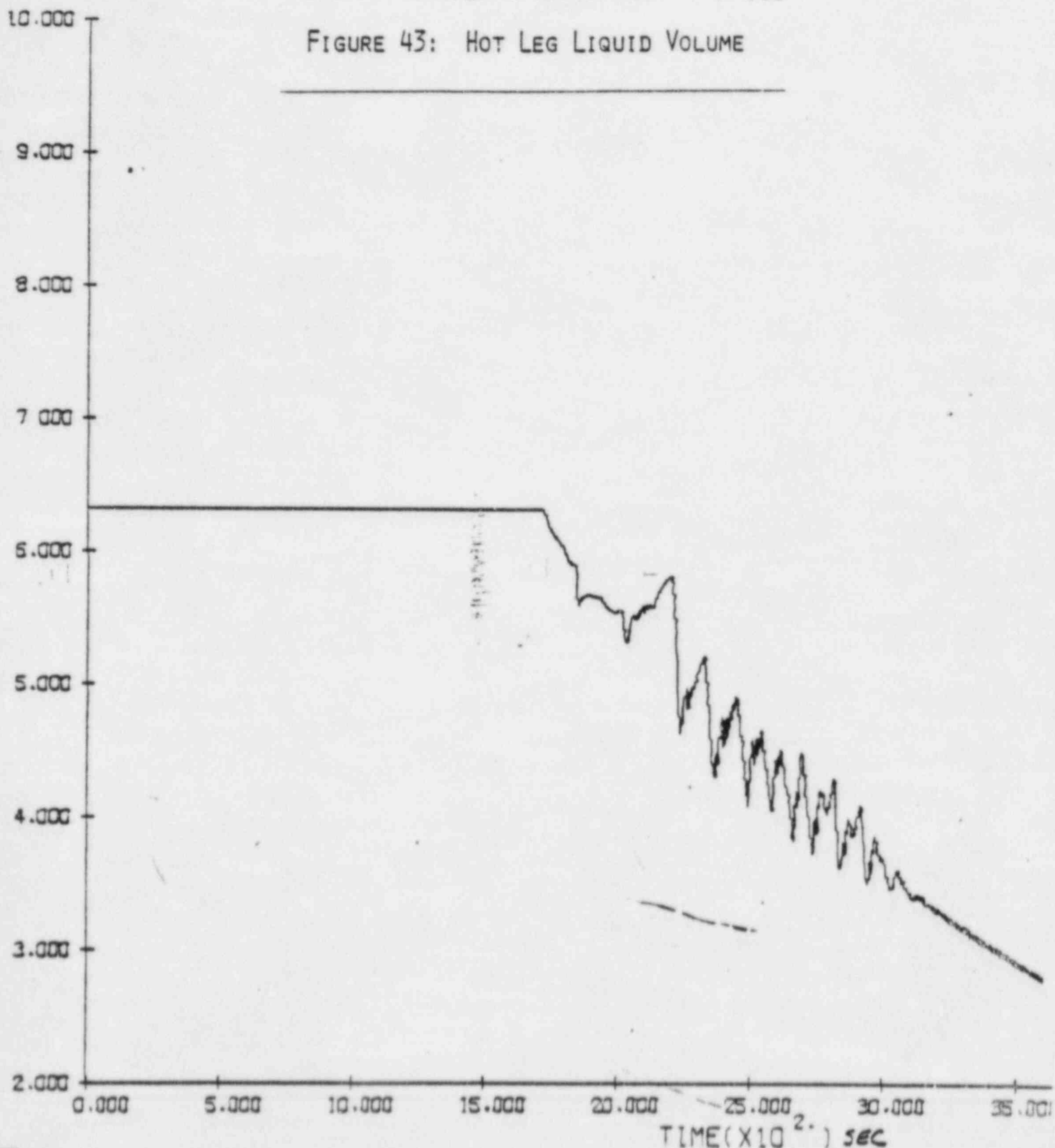


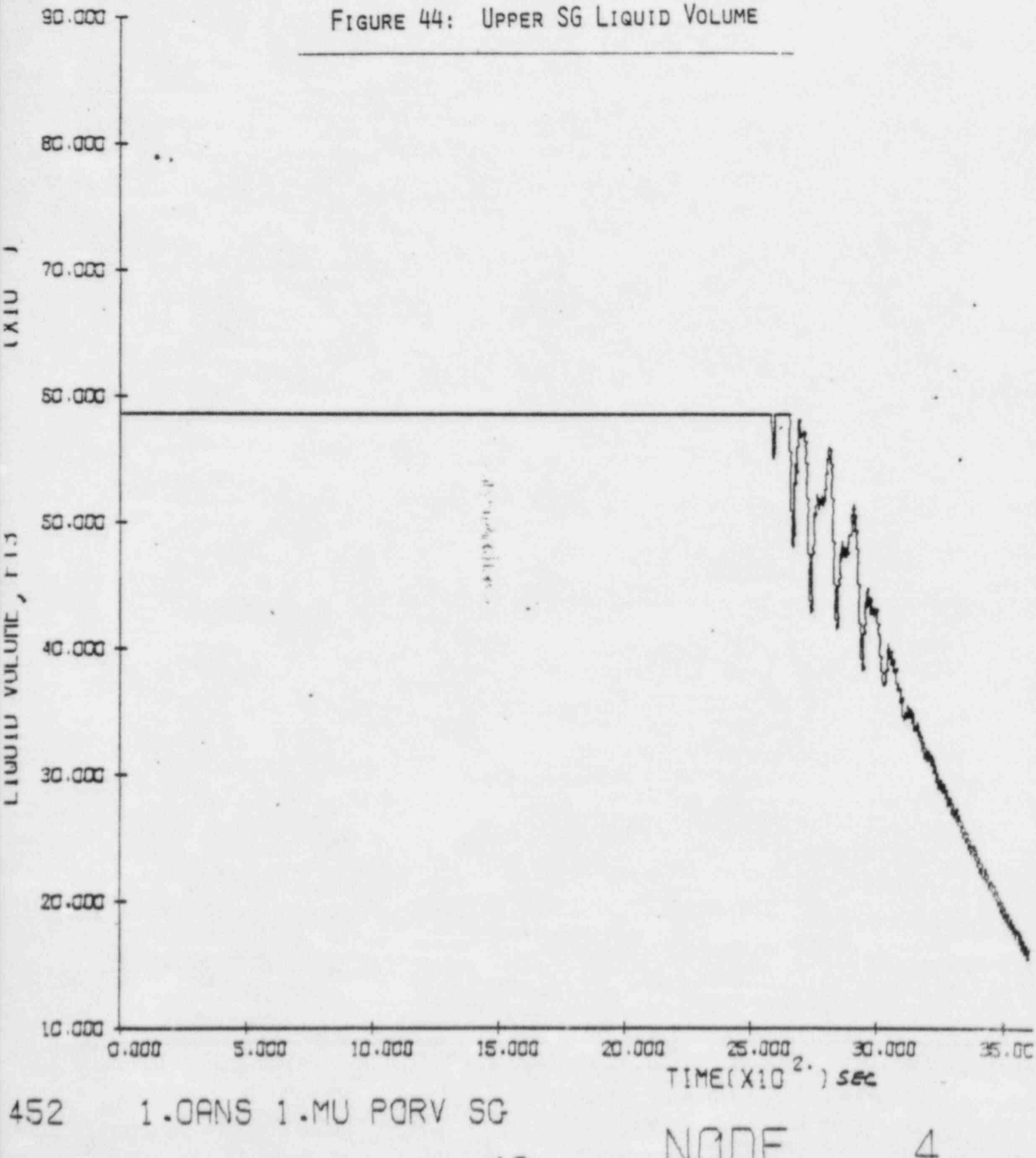
FIGURE 43: HOT LEG LIQUID VOLUME



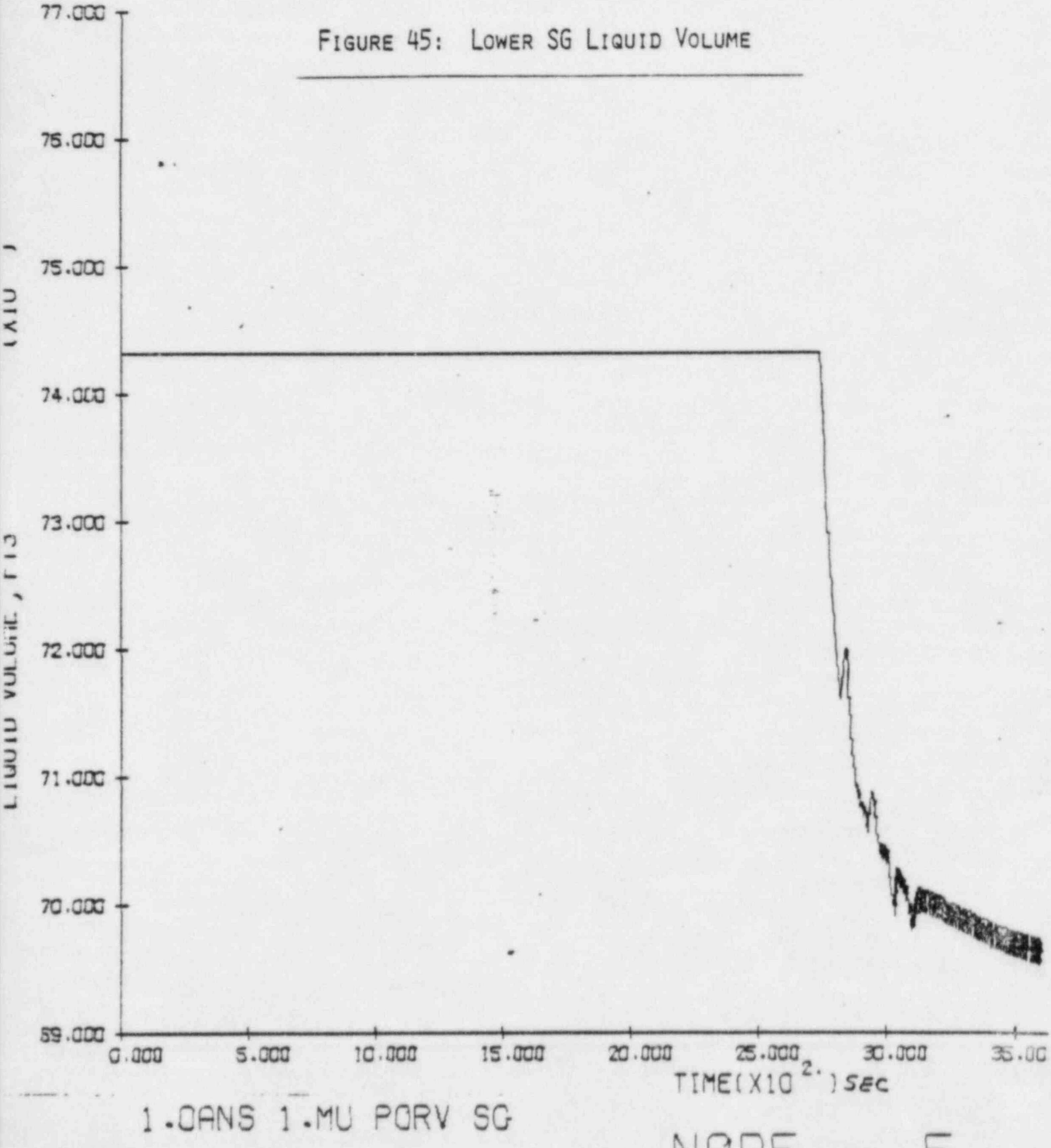
1.0ANS 1.MU PORV SG

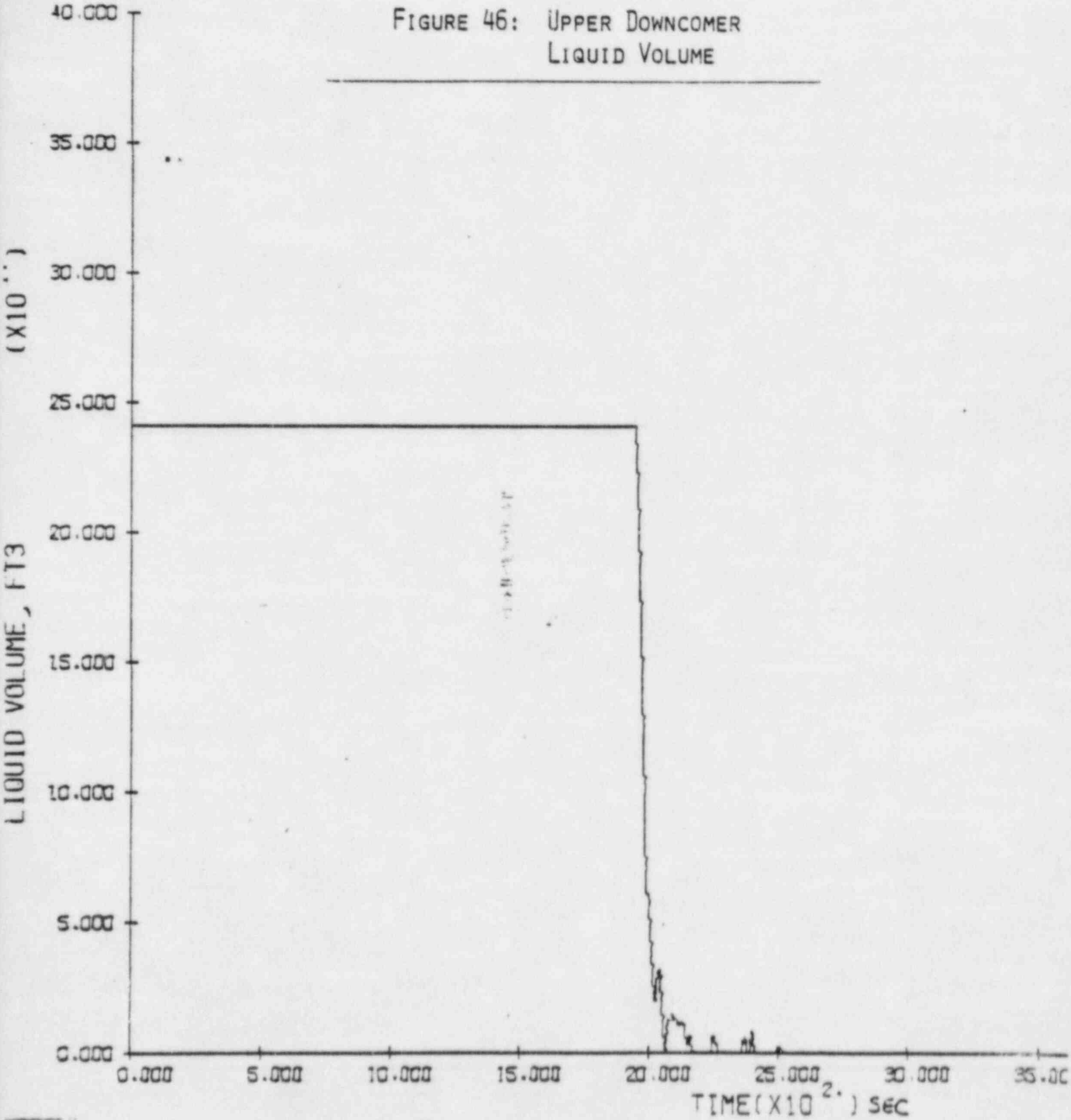
NODE 3

FIGURE 44: UPPER SG LIQUID VOLUME



86-1126460 00

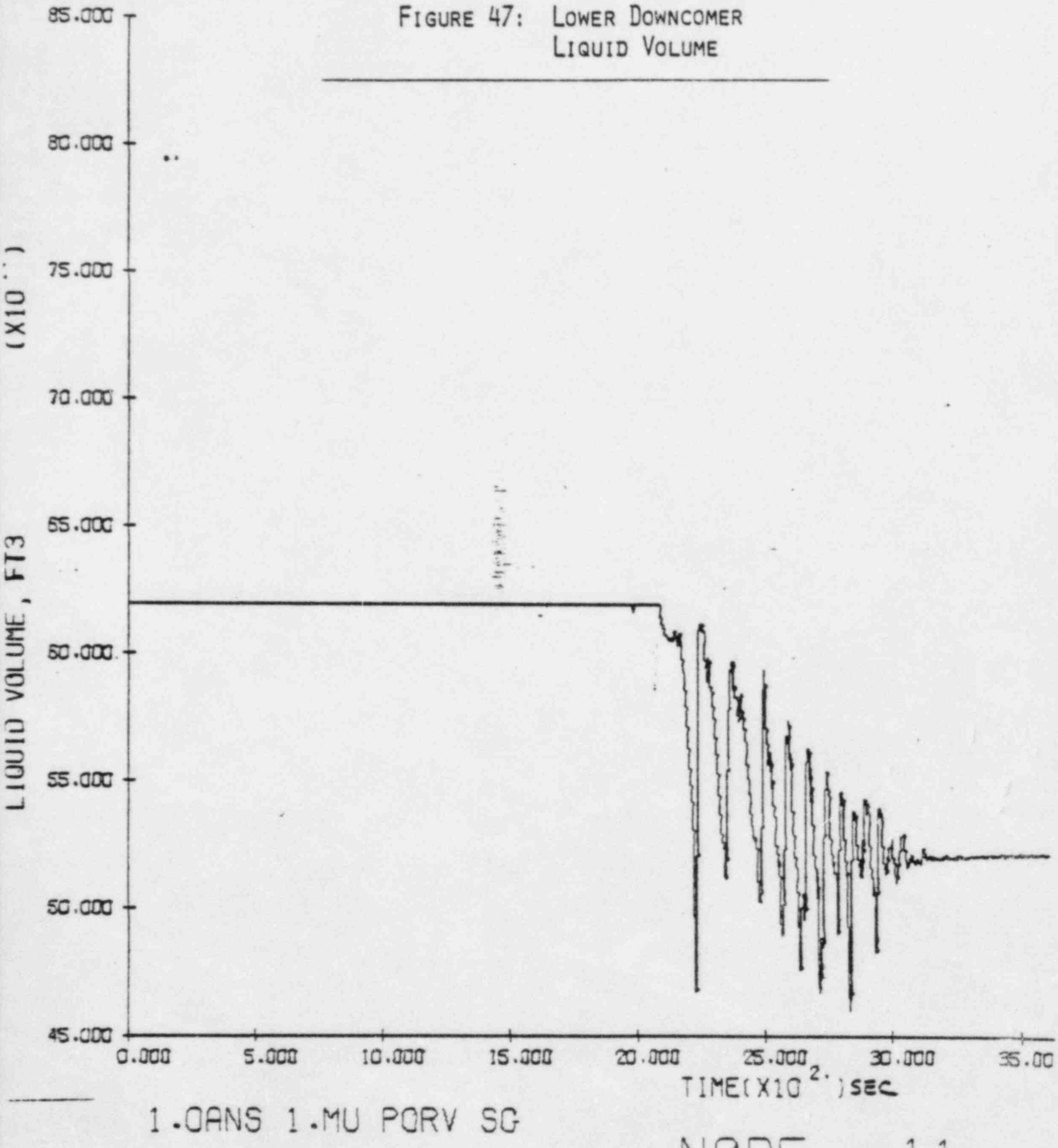




1.0ANS 1.MU PORV SG

NODE 10

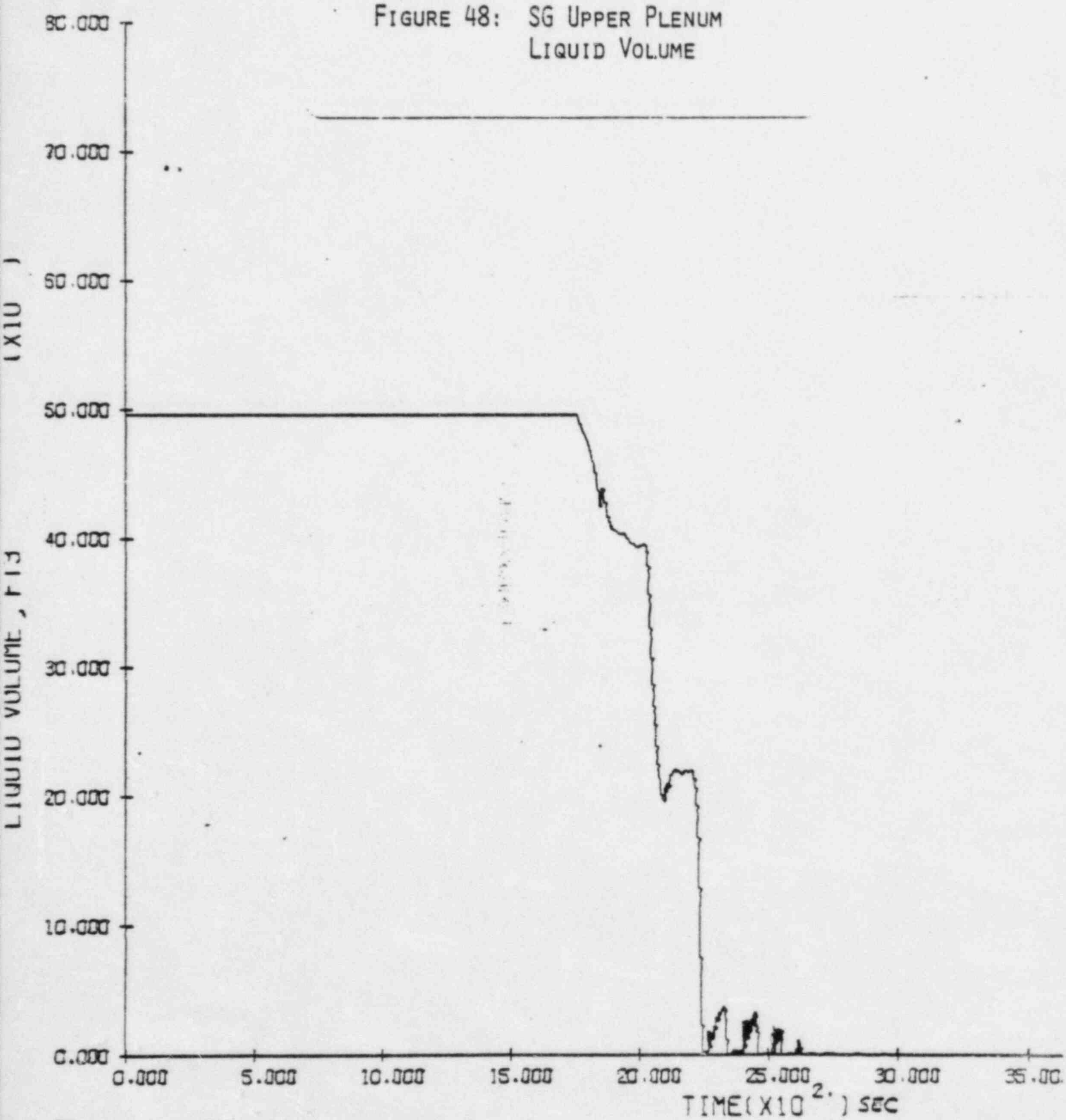
86-1126460 00



70

86-1126460 00

FIGURE 48: SG UPPER PLENUM LIQUID VOLUME

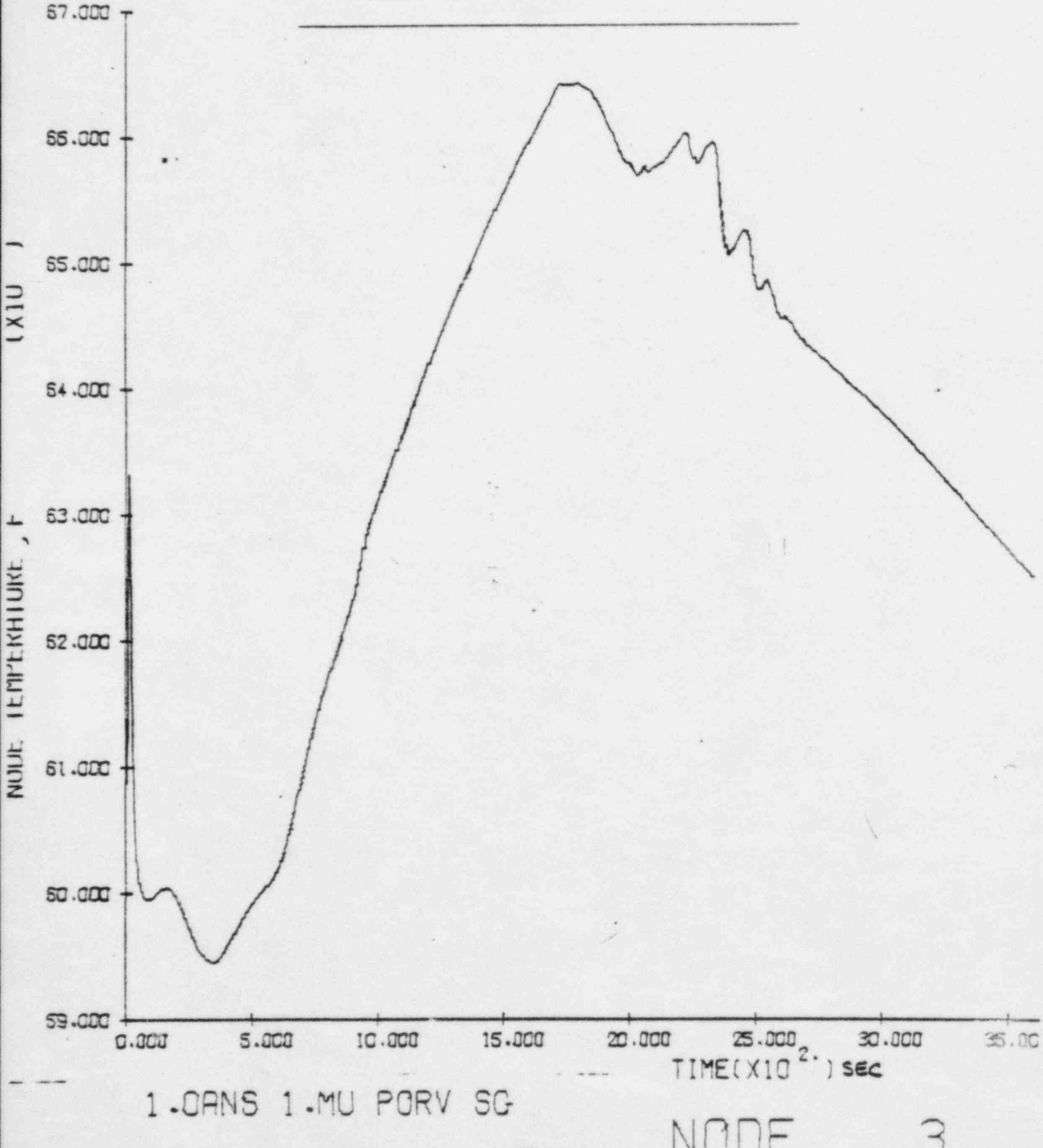


1.0ANS 1.MU PORV SG

NODE 24

86-1126460 00

FIGURE 49: HOT LEG TEMPERATURE



86-1126460 00

FIGURE 50: SECONDARY SG LIQUID VOLUME

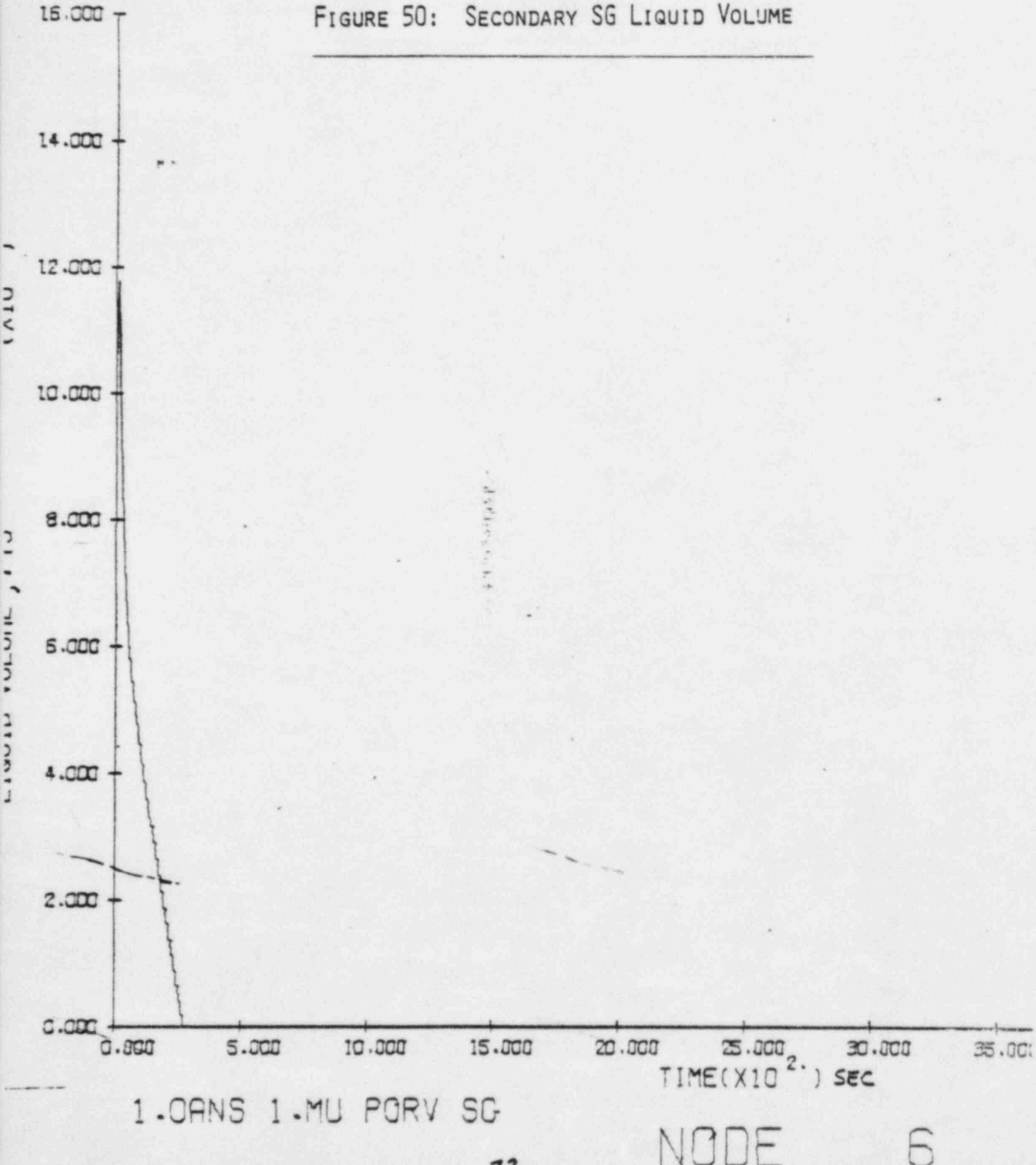


FIGURE 51: SECONDARY SG PRESSURE