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April 1980

TRAC-P1A INDEPENDENT ASSESSMENT SUMMARY REPORT

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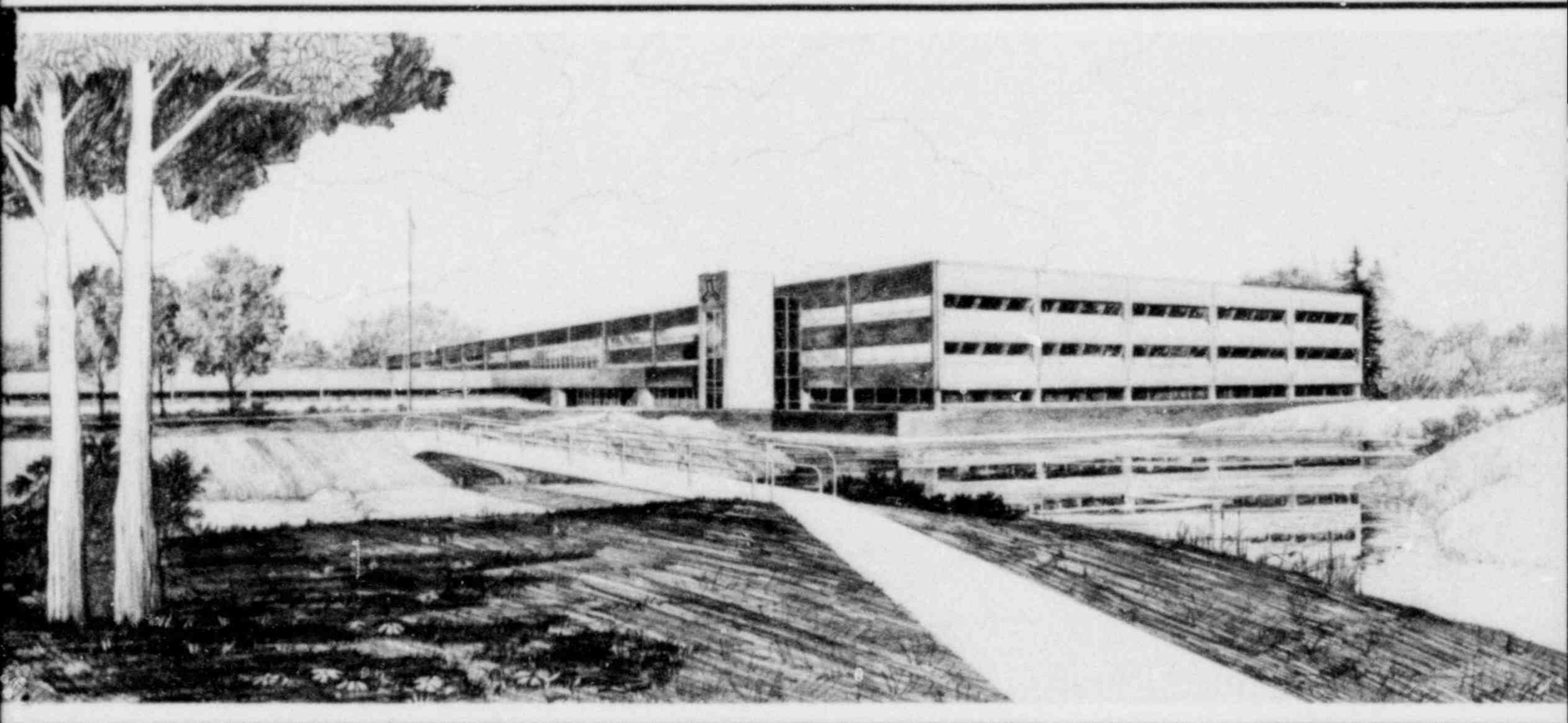
U.S. Department of Energy
Idaho Operations Office • Idaho National Engineering Laboratory



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ABSTRACT

As part of the overall Nuclear Regulatory Commission assessment program of TRAC-P1A two comparisons between TRAC-P1A calculations and experimental data were performed.

The comparisons performed were for a nuclear experiment (L2-3) in the LOFT facility and an experiment (S-04-6) in the Semiscale Mod-1 electrically heated facility.

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SUMMARY

TRAC-P1A calculated results were compared to selected results from LOFT Test L2-3 and Semiscale Mod-1 Test S-04-6. These comparisons were performed as part of the overall assessment of TRAC-P1A at the Idaho National Engineering Laboratory for the Nuclear Regulatory Commission.

LOFT Test L2-3 was a 200% cold leg break in a one thousand three hundred rod nuclear facility. A forty rod electrically heated core was installed in Semiscale Mod-1 Test S-04-6. Test S-04-6 represented a 200% cold leg break.

The results of the comparisons indicated that a higher system pressure was calculated than was measured early in the transient primarily due to the calculation of a lower mass flow at the broken loop cold leg than was measured during the same time period. A better comparison between measured and calculated transient pressure drop was obtained during single phase than during two phase flow. The core thermal response for the Semiscale Mod-1 electrically heated core was calculated more accurately than for the LOFT nuclear core. The major reason for the more accurate calculation of the thermal response for the Semiscale Mod-1 core was that the general core hydraulics were calculated more accurately for Test S-04-6 than for Test L2-3.

1. INTRODUCTION

As part of the overall Nuclear Regulatory Commission (NRC) assessment program of TRAC-P1A, two comparisons between TRAC-P1A calculations and experimental data were performed at the Idaho National Engineering Laboratory. The comparison performed were for LOFT Test L2-3 and Semiscale Mod-1 Test S-04-6. The results of the comparisons are summarized in this document. A detailed discussion of the calculations and comparisons are contained in References 1 and 2, respectively. A summary of the results is presented to assist the NRC in issuing a Research Information Letter (RIL) on the independent assessment of TRAC-P1A.

The assessment of TRAC-P1A includes both qualitative and quantitative assessment. For qualitative assessment, selected code calculations are compared to experimental results to determine if the calculated results are physically reasonable. For quantitative assessment selected key "indicators" are identified. The comparisons of key "indicators" from selected facilities, will be used to identify the affect of scale on the capabilities of TRAC-P1A. Both qualitative and quantitative assessment parameters from LOFT Test L2-3 and Semiscale Mod-1 Test S-04-6 are presented herein.

A brief description of each test is contained in Section 2. The noding of the facilities used in each calculation is discussed in Section 3. Section 4 presents the results of the comparisons. The conclusions from the comparisons of the calculations are presented in Section 5.

2. TEST DESCRIPTION

The description of the general system configuration and initial test conditions for the two comparisons performed at the INEL are discussed in the following section. The details of the experimental conditions of LOFT Test L2-3 and Semiscale Mod-1 Test S-04-6 are discussed in References 3 and 4, respectively.

2.1 LOFT Test L2-3

Experiment L2-3 simulated a 200% double-ended offset shear in the pump discharge of the cold leg. The LOCE was performed at a total reactor power of 36.7 MW(t). The core inlet and outlet temperatures were 560.7 K and 592.9 K respectively, providing a core ΔT of 32.2 K. The core mass flow rate was 199.8 kg/s, the sytem pressure was 15.06 MPa and the maximum linear heat generation rate was 39.4 kW/m.

Blowdown was initiated by opening two quick opening blowdown valves, which open in approximately 20 ms. Reactor scram, high pressure injection, low pressure injection and accumulator flow were initiated when predetermined system setpoints were reached.

The measured initial conditions for Test L2-3 and the conditions for the initiation of the transient calculation with TRAC-P1A are shown in Table 1. A comparison of these conditions indicates that the proper boundary conditions were established for the initiation of the TRAC-P1A calculations.

2.2 Semiscale Mod-1 Test S-04-6

Semiscale Mod-1 LOCE S-04-6 was the sixth experiment in the baseline emergency core cooling (ECC) test series which was designed to study the integral response of the Semiscale Mod-1 system with an electrically heated core. Test S-04-6 simulated a 200% double-ended offset shear in the cold

TABLE 1

INITIAL CONDITIONS FOR TEST L2-3

	Test L2-3	TRAC-P1A
Mass Flow Rate (kg/s)	199 ± 6.3	200.3
Pressure (MPa)	15.06 ± 0.03	15.04
Cold Leg Temperature (K)	560.7 ± 1.8	560.0
Hot Leg Temperature (K)	592.9 ± 1.8	592.7
Reactor Power (MW)	36.0 ± 3.0	36.0
Maximum Linear Heat Generation Rate (kW/m)	39.0 ± 3.0	40.0
Pressurizer Pressure (MPa)	15.06 ± 0.03	15.07
Pressurizer Pressure Level (m)	1.19 ± 0.01	1.20
Broken Loop Temperature (K)		
Hot Leg		
Near Vessel	565.5 ± 1.8	565.5[a]
Near Break	556.6 ± 1.8	556.0[a]
Cold Leg		
Near Vessel	554.3 ± 1.8	554.3[a]
Near Break	550.3 ± 1.8	550.0[a]

a. Measured temperatures were used in transient calculation.

leg with ECC injection into the intact and broken loop cold legs. Four of the forty electrically heated rods were unpowered during Test S-04-6. The core inlet and outlet temperatures were 560.1 K and 598.6 K resulting in a core ΔT of 38.5 The core inlet mass flow rate was 6.9 kg/s. The system pressure was 15.5 MPa and the maximum linear heat generation rate was 37.8 kW/m. Blowdown was initiated by rupturing a disc in each of the broken loops.

The measured initial conditions for Test S-04-6 and the conditions at the initiation of the transient calculation with TRAC-P1A are shown in Table 2.

TABLE 2. INITIAL CONDITIONS FOR TEST S-04-6

	Test S-04-6	TRAC-P1A
Mass flow rate (Kg/s)	6.9 ± 0.4	6.8
Pressure (MPa)	15.5 ± 0.2	15.5
Cold leg temperature (K)	560.1 ± 2	554.7
Hot leg temperature (K)	593.0 ± 2	598.6
Reactor power (MW)	1.44	1.44
Maximum linear heat	37.8	37.8
Generation Rate (kW/m)		
Pressurizer pressure (MPa)	15.5 ± 0.2	15.5
Pressurizer level (m)	0.69 ± 0.03	0.69
Broken loop temperature		
Hot leg		
Near-vessel	589.7 ± 2	589.4
Near break	588.3 ∓ 2	587.4
Cold leg		
Near vessel	554.7 ± 2	556.3
Near break	554.7 ∓ 2	554.7

3. TRAC-P1A SYSTEM MODEL

The system models that were used in each calculation are discussed in the following section. Noding diagrams for each facility are also provided.

3.1 LOFT Facility

The LOFT facility was modeled with 280 cells in the vessel and 164 cells in the loops for a total of 444 cells. The component noding for the system is shown in Figure 1. Figure 2 shows the noding for the vessel. The vessel was divided into fourteen axial levels, four azimuthal segments, and five radial rings. The outermost ring modeled the downcomer. Levels five through ten contained the core. The lower plenum was noded in four levels with a relatively small level at the bottom of the downcomer. The steam generator was modeled with 12 cells on the primary side and 9 cells on the secondary side. The broken legs were modeled as a tee connected to a valve. The reflood assist valves and associated piping were modeled as the secondary side of each tee. The broken hot leg was modeled with a total of 41 cells in the primary and secondary side of the tee. The broken cold leg was modeled in a similar manner with a total of 28 cells. A cell length of 4.7 cm was used at both break planes.

3.2 Semiscale Mod-1

The Semiscale Mod-1 facility was modeled with 72 cells in the vessel and 140 cells in the loops and components for a total of 212 cells. The noding for the facility is shown in Figure 3. the vessel model contained 18 axial levels, two azimuthal segments and two radial rings as shown in Figure 4. Levels five through fourteen contained the heated core. The lower plenum was modeled with two levels. The steam generator was noded by 8 cells on the primary side and 6 cells on the secondary side. The broken loop hot leg was modeled with a total of 33 cells and the broken loop cold leg was modeled with 20 cells. A minimum cell length of 0.156 cm was used at each break plane.

4. RESULTS

The results presented for each calculation consist of comparisons between experimental results and TRAC-P1A calculations and selected additional results from the calculation. The additional calculated results are included to aid in the interpretation and evaluation of the capabilities of TRAC-P1A and will be used in the quantitative assessment. A more detailed analysis of the comparisons between TRAC-P1A calculations and results from Test L2-3 and S-04-6 are contained in References 1 and 2, respectively.

The calculations of Test L2-3 were terminated at 40 s after rupture because many of the significant phenomena occurred before 40 s in the L2-3 experiment and the calculation was running slowly. The calculation for Test S-04-6 was terminated at 60 s after rupture because refill was occurring quite slowly and the calculation was running slowly. The continuation of the calculations would provide limited additional details for code assessment.

4.1 LOFT Test L2-3

An indication of the capability of TRAC-P1A to calculate the general system response for Test L2-3 was obtained from a comparison between the calculated and measured upper plenum pressure. Figure 5 is a comparison of calculated and measured upper plenum pressure. Both the experiment and the calculated results depressurize to about 10 MPa at the initiation of rupture. At 1 s after rupture TRAC-P1A calculated a small system repressurization. The non-equilibrium model used in TRAC-P1A calculated an approximately 20 K superheating of the core liquid. The rapid void which occurred after the calculations of the superheated liquid may have caused the repressurization shown in the calculations but was not measured in the experiment. The calculated pressure was higher than the measured pressure from about 1 to 8 s after rupture, however, after 8 s good agreement was obtained between calculated and measured results. The difference between the calculated and measured results from 1 to 8 s after rupture was partly a result of calculating too low a mass flow rate in the broken loop cold leg during the early period of the calculation.

The mass flow rate in the broken loop cold leg and hot leg are shown in Figures 6 and 7, respectively. The calculated mass flow rate in the broken loop cold leg was less than the measured mass flow for the first 2.5 s and the calculated mass flow was larger than the measured for the remainder of the calculation as shown in Figure 6. At 3 s after rupture the measured and calculated mass flows decreased sharply indicating hot core fluid had reached the break plane in the broken loop cold leg resulting in saturated choked flow. The calculated broken cold leg mass flow rate after 20 s contained several large spikes that were not measured in the experiment. These spikes in the mass flow rate were due to large quantities of ECC fluid bypassing the core. The calculated mass flow rate in the broken loop hot leg was generally less than the measured mass flow as shown in Figure 7.

An indication of the capability of TRAC-P1A to calculate flow in complex geometries was obtained by comparing the calculated and measured pressure drop across the pump simulator. This comparison is shown in Figure 8. The calculated pressure drop was significantly higher than the measured pressure drop during the initial period of the test. Later in the transient when the flow was mostly steam reasonable agreement was obtained between the calculated and measured pressure drop.

Comparisons between calculated and measured pressure drops in the intact loop are shown in Figures 9 and 10. The calculated and measured steam generator pressure drop are shown in Figure 9. The measured pressure drop was higher than the calculated pressure drop for the initial 8 s of the transient. After 8 s the comparisons were in reasonable agreement. The calculated and measured pressure drop across the two LOFT pumps are compared in Figure 10. The measured pressure drop across the pumps was higher than the calculated pressure drop for the entire calculation. These comparisons indicate that early in the transient when the flow was changing from single phase liquid to mostly steam a lower pressure drop was generally calculated than was measured.

An indication of the capability of TRAC-P1A to calculate the general core thermal response is shown in Figure 11. The calculated rod cladding temperatures for each axial level and each radial ring are shown. For the core locations which contained cladding thermocouples, the measured responses are also shown. At core locations which contained more than one measurement, the extremes in the measured response are shown. Figure 11 shows that the heat up and rewets measured in the inner radial rings in the experiments were not calculated. An increase in the rod cladding temperature was calculated in ring 3, whereas, a cladding temperature increase was not measured in ring 3. A good comparison was obtained between the measured and calculated rod cladding temperature in the outer ring four which contained the low power rods.

An additional evaluation of the calculated results was obtained by examining selected calculated parameters. Figure 12 contains the calculated void fracion in each cell of the downcomer. These results show that the downcomer was calculated to generally void of water from about 12 to 30 s after rupture. At about 30 s ECC fluid was calculated below the intact loop inlet nozzle. The calculated lower plenum mass fraction is shown in Figure 13 which illustrates the voiding in the lower plenum until about 32 s when the lower plenum was filled by the ECC fluid. Some oscillations in the downcomer mass were calculated from about 3 s to 40 s after rupture. The calculated core inlet flow is shown in Figure 14. the core inlet mass flow was negative until 22.7 s after rupture. The core inlet mass flow oscillated near zero for most of the remainder of the calculation. The results of the core inlet mass flow rate indicate that the positive core inlet flow that rewet the core from the bottom at about 6 s after rupture in this test was not calculated.

A comparison of important events some of which are key indicators for quantitative assessment for Test L2-3 are summarized in Table 3. A significant difference between the calculated and measured events was the initiation of the HPIS flow. The calculated initiation was somewhat later than measured since the 2 s delay in the initiation of HPIS flow used during the experiment was not included in the calculation.

4.2 Semiscale Test S-04-6

The calculated and measured upper plenum pressure for Test S-04-6 are compared in Figure 15. In general the comparisons are similar to the results discussed for LOFT Test L2-3 in Section 4.1. The calculated and measured pressure decrease to about 10 MPa at the initiation of the test. A slight repressurization was calculated at about 1 s after rupture similar to the calculation for Test L2-3. The calculated system pressure was higher than the measured pressure until about 5 s after rupture. From about 5 s to 25 s after rupture the measured pressure was higher than the calculated pressure, whereas, from about 25 s to 50 s after rupture reasonably good agreement was obtained between the calculated and measured upper plenum pressure. An increase in the upper plenum pressure was calculated at about 53 s after rupture. This increase in pressure was a result of rapid steam generation in the core pressurizing the system.

The calculated and measured mass flow in the broken loop cold leg are compared in Figure 16. The calculated mass flow was lower than the measured mass flow until about 3 s after rupture. From 3 s to 9 s after rupture, the measured mass flow was less than the calculated mass flow. After about 9 s, oscillations in both the calculated and measured mass flow occurred. The oscillations were larger in the measured mass flow than in the calculated mass flow.

The calculated and measured pressure drops across the intact loop steam generator and pump are compared in Figures 17 and 18, respectively. From about 4 s to 7 s after rupture the measured pressure drop was higher than the calculated pressure drop across the steam generator and pump.

TABLE 3. COMPARISON OF CALCULATED AND MEASURED EVENTS FOR TEST L2-3

Event	TRAC-P1A (s)	L2-3 (s)
HPIS Initiation	14	8.7[a]
Accumulator Discharge Initiated	15.8	17
First indication of non-negative core inlet flow	22.7	b
Upper plenum pressure decreased to 1 MPa	28.4	28.4
Minimum lower plenum mass increased by 10%	33	b

a. LOFT experienced approximately a 2 second delay on initiation that was not included in the model.
b. Measurement not available.

From 7 s to 60 s after rupture good agreement occurred between the measured and calculated pressure drop across the pump. From about 3 s to 60 s after rupture the measured pressure drop was higher than the calculated pressure drop across the steam generator, as shown in Figure 18.

An indication of the capability of TRAC-P1A to calculate the general core thermal response for Test S-04-6 is shown in Figure 19. The calculated rod cladding temperature for each axial level and each radial ring are shown. Each axial level corresponds to a power step in the Semiscale Mod-1 electrically heated rods. For comparison with measurements, the thermocouples which had the lowest and highest temperature response at each core location are also shown on Figure 19. The calculated rod cladding temperature response was within the range of the measured temperature response except for axial power levels 6, 7, 8, and 9 which were above the core hot spot. At these locations higher temperatures were measured than were calculated. A delayed CHF was measured at these locations, whereas, the calculated results did not have a delayed CHF. The difference in the time of CHF accounts for some of the difference in comparisons of the rod thermal response.

To assist in the evaluation of the capabilities of TRAC-P1A, the calculated void fraction for each cell in the downcomer are shown in Figure 20. These results show that except for levels 16 and 17 the entire downcomer was void of liquid at about 15 s after rupture. After the initiation of accumulator injection at 14 s after rupture, a filling of the upper volumes of the downcomer below the intact loop cold vessel inlet, cell 3, were calculated. A comparison of the void fraction in cell 3 with cell 4 indicated an asymmetric distribution of liquid in the downcomer with more liquid on the intact loop than on the broken loop side, as would be expected.

The calculated lower plenum mass fraction is shown in Figure 21. The refill of the lower plenum was initiated at about 25 s after rupture. The lower plenum was nearly refilled at 55 s after rupture when a voiding of the lower plenum occurred as a result of oscillations in the core inlet flow. The large increase in the calculated core inlet flow at 55 s after rupture was a result of the accumulator emptying. When the accumulator was emptying an increase in the volumetric flow from the accumulator resulted. The increase in the volumetric flow forced liquid and steam down the downcomer and into the core. The oscillations in the core inlet flow resulted from steam generation in the core. The calculated and measured core inlet flow are shown in Figure 22. Reasonable agreement was obtained between measured and calculated results, expect for the large oscillations in the calculated flow rate at about 55 s after rupture.

A comparison of important events for Test S-04-6 are summarized in Table 4. The first indication of non-negative core inlet flow was calculated about 2 s earlier than was measured.

TABLE 4. COMPARISON OF CALCULATED AND MEASURED EVENTS FOR TEST S-04-6

Event	TRAC-P1A (s)	L2-3 (s)
HPIS Initiation	0[a]	0[a]
Accumulator Discharge Initiated	15.8	17
First indication of non-negative core inlet flow	0.95	3
Upper plenum pressure decreased to 1 MPa	26	28
Minimum lower plenum mass increased by 10%	27	b

a. HPIS flow was initiated at the time of rupture.
b. Measurement not available.

5. CONCLUSIONS

Comparisons between experimental results and TRAC-P1A calculations for facilities of a different scale were performed. An evaluation of the results of the comparisons has led to the following conclusions on the capabilities of TRAC-P1A.

The refill and reflood phases of a 200% cold leg LOCA calculation run slowly.

Calculations were terminated before the core was calculated to have quenched for LOFT Test L2-3 or Semiscale Mod-1 Test S-04-6. The calculations were terminated because of the excessive running time of the computer calculation.

The calculated system pressure was higher than the measured pressure during the initial five to eight s of the blowdown.

The calculated mass flow rate at the break during subcooled blowdown was lower than the measured mass flow rate. The calculation of a lower break mass flow rate contributed to the calculations of a higher system pressure than was measured.

The differences between the calculated and measured pressure drop were dependent on the fluid conditions.

The pressure drop across the complex geometry of the pump simulator was calculated to be larger than the measured pressure drop early in the transient when the flow was two phase. Reasonably good agreement between measured and calculated results occurred when the flow was mostly steam.

The ability to calculate the core thermal response was dependent on the facility.

The core thermal response in the Semiscale Mod-1 was generally satisfactorily calculated during blowdown and refill. Higher rod cladding temperatures were calculated for the LOFT facility than were measured. The differences between the measured and calculated temperatures in LOFT was primarily a result of a measured rewet of the entire LOFT core that was not calculated.

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2. P. N. Demie, "An Analysis of Semiscale MOD-1 LOCE S-04-6 Using the TRAC-P1A Computer Program," (to be issued).

3. P. G. Passinos, et. al., Experiment Data Report for LOFT Power Ascension Experiment L2-3, NUREG-CR-0792; TREE-1326, July 1979.

4. H. S. Crapo et. al., Experimental Data Report for Semiscale MOD-1 Tests S-04-5 and S-04-6 (Baseline ECC tests), TREE-NUREG-1045, January 1977.

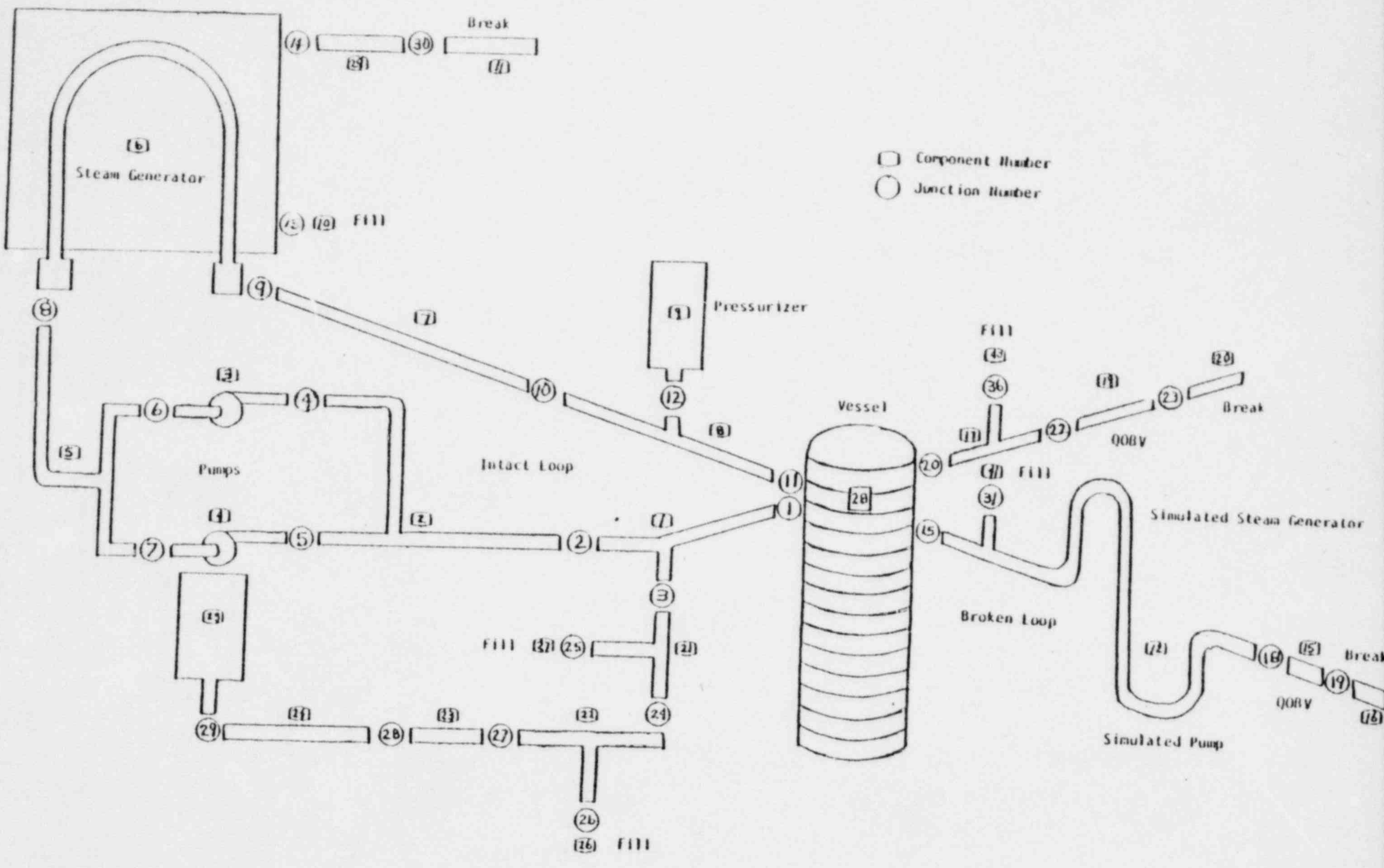

Figure 1. TRAC-P1A noding of LOFT facility for Test L2-3.

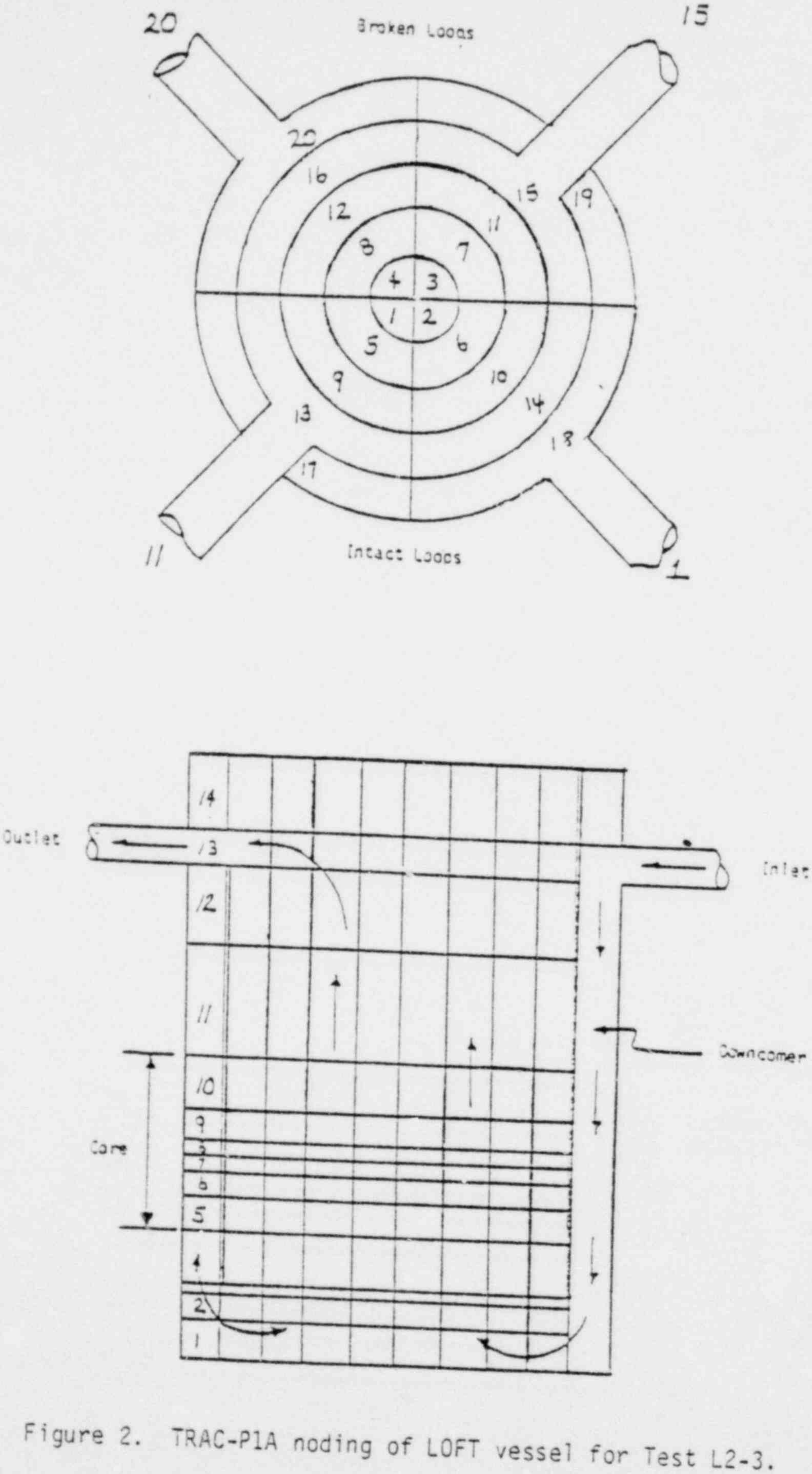

Figure 2. TRAC-P1A noding of LOFT vessel for Test L2-3.

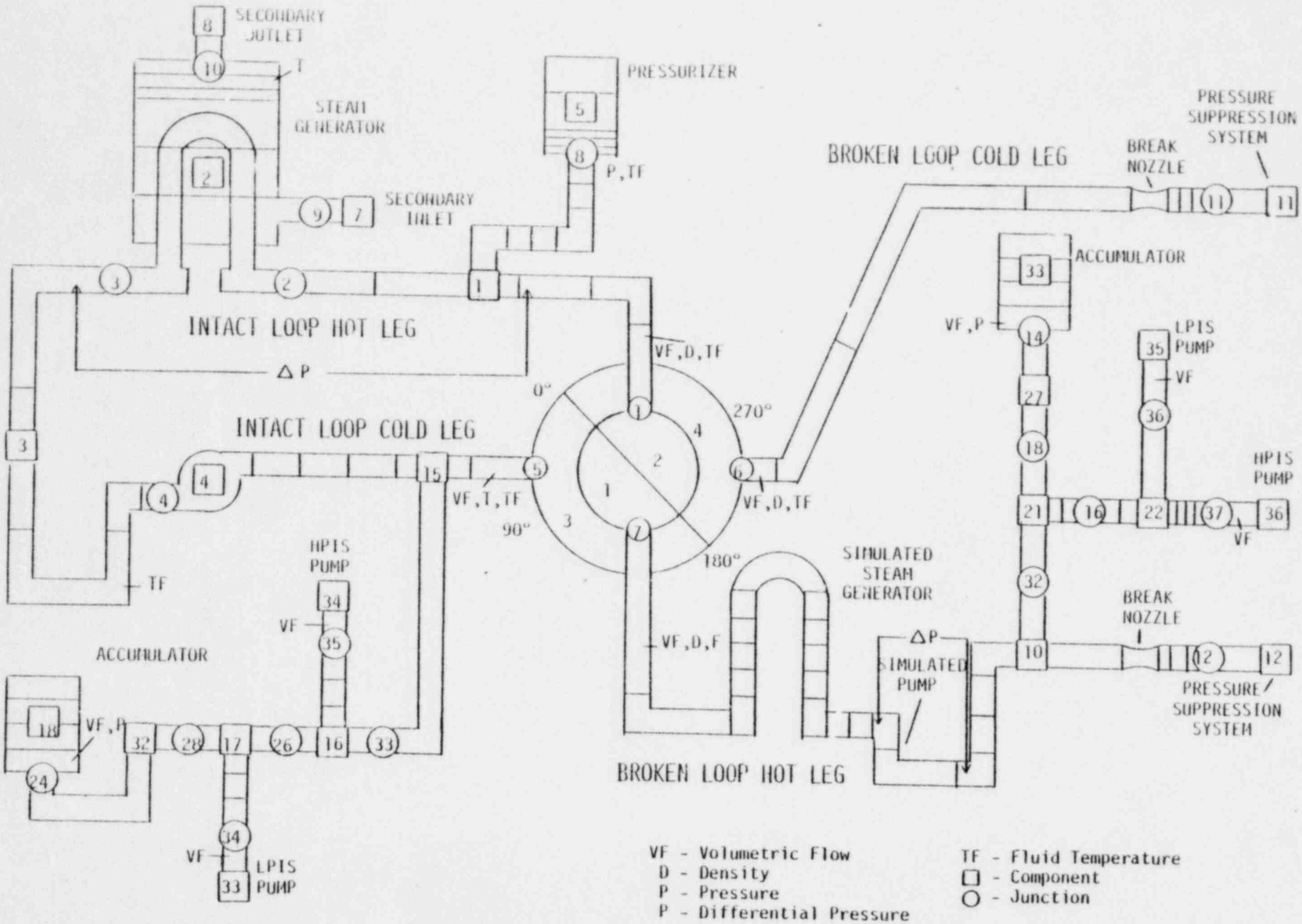

Figure 3. TRAC-P1A noding of Semiscale Mod-1 facility for Test S-04-6.

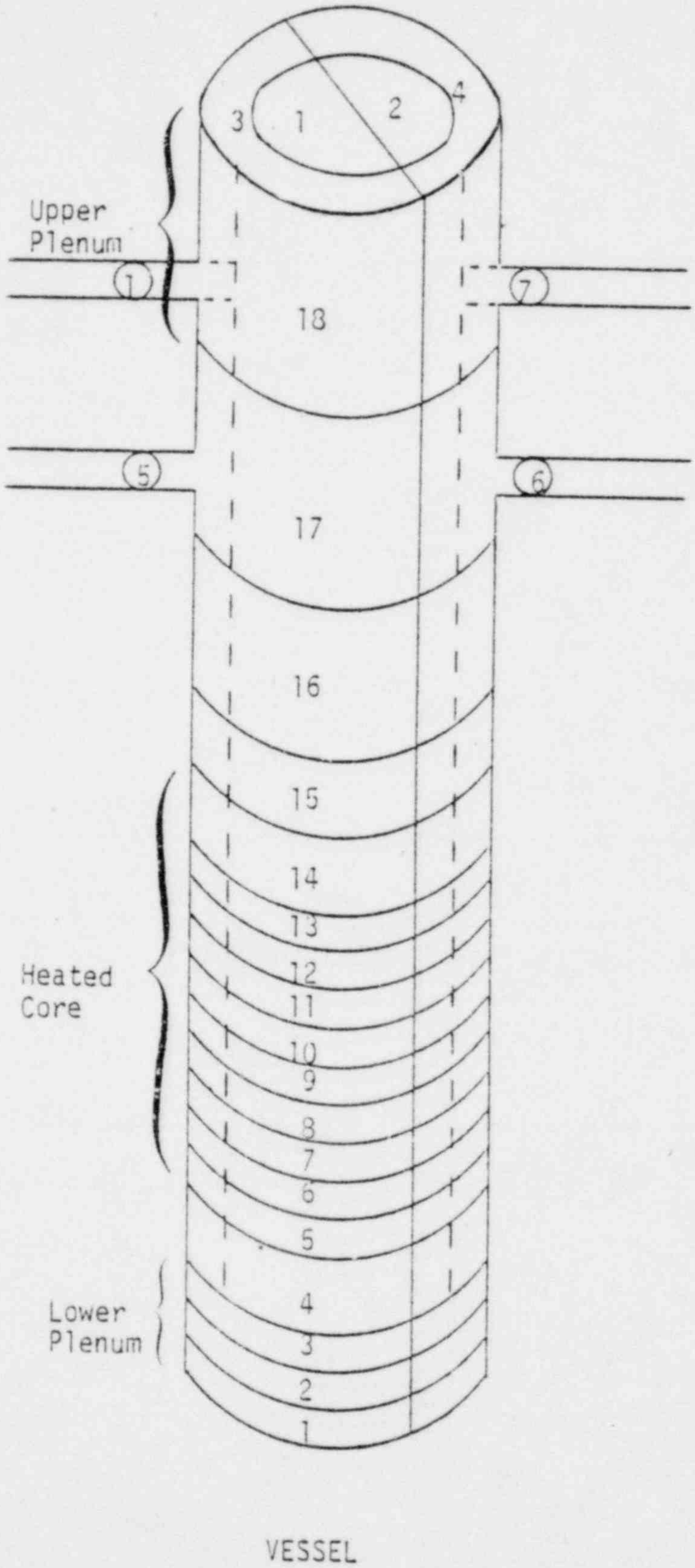

Figure 4. TRAC-P1A noding of Semiscale Mod-1 vessel for Test S-04-6.

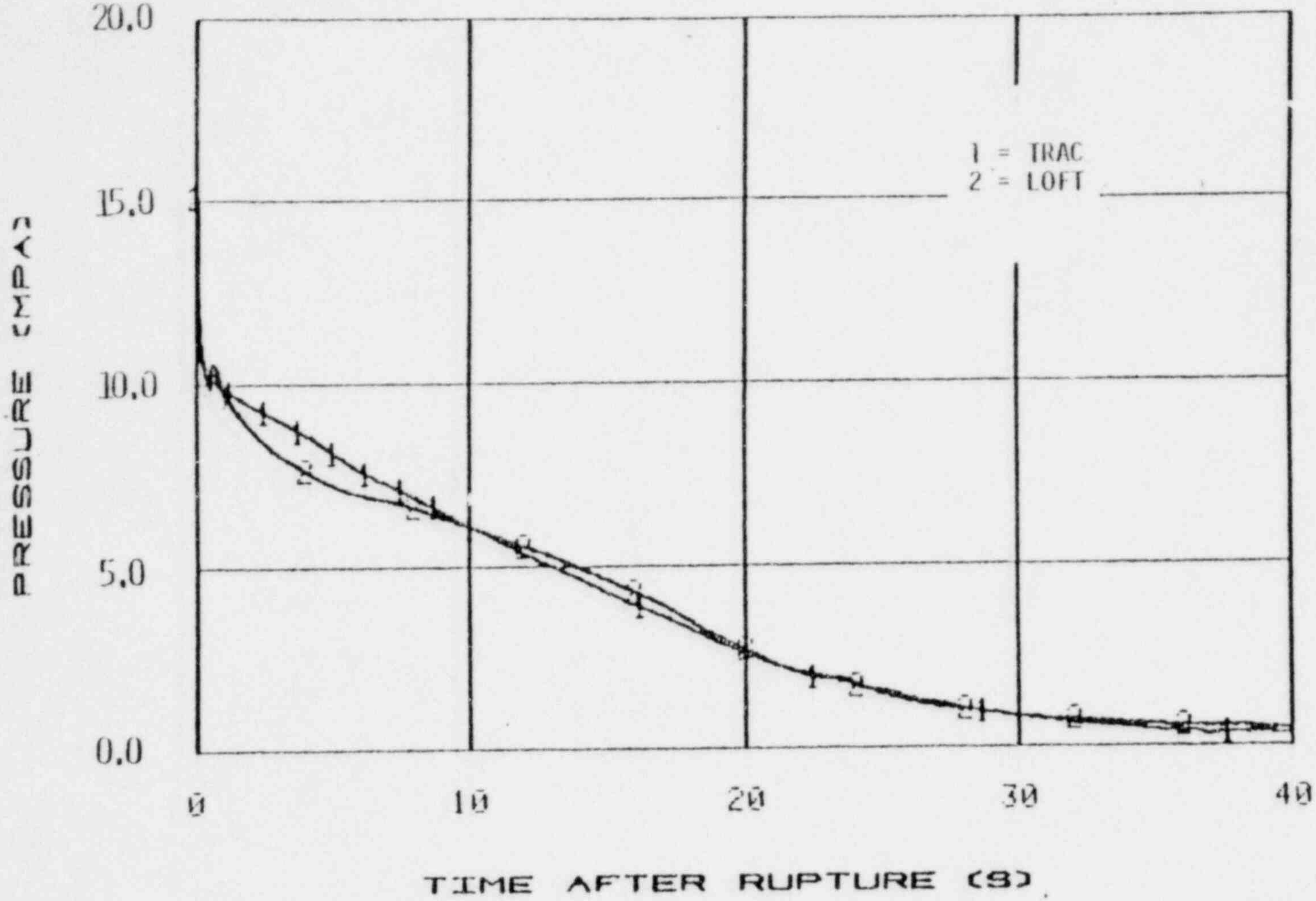

Figure 5. Comparison of measured and calculated upper plenum pressure for LOFT Test L2-3.

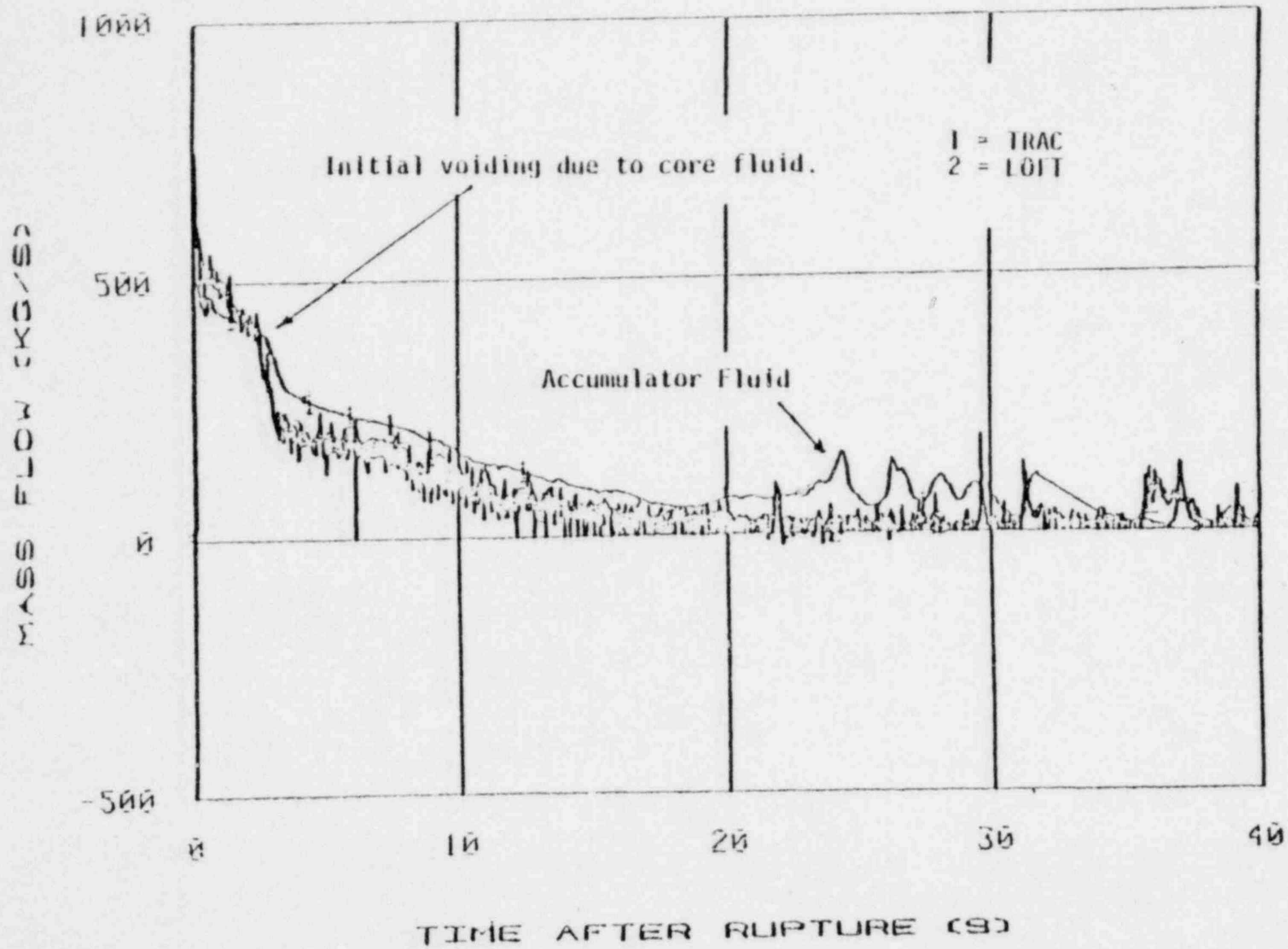

Figure 6. Comparison of measured and calculated broken loop cold leg mass flow rate for Test L2-3.

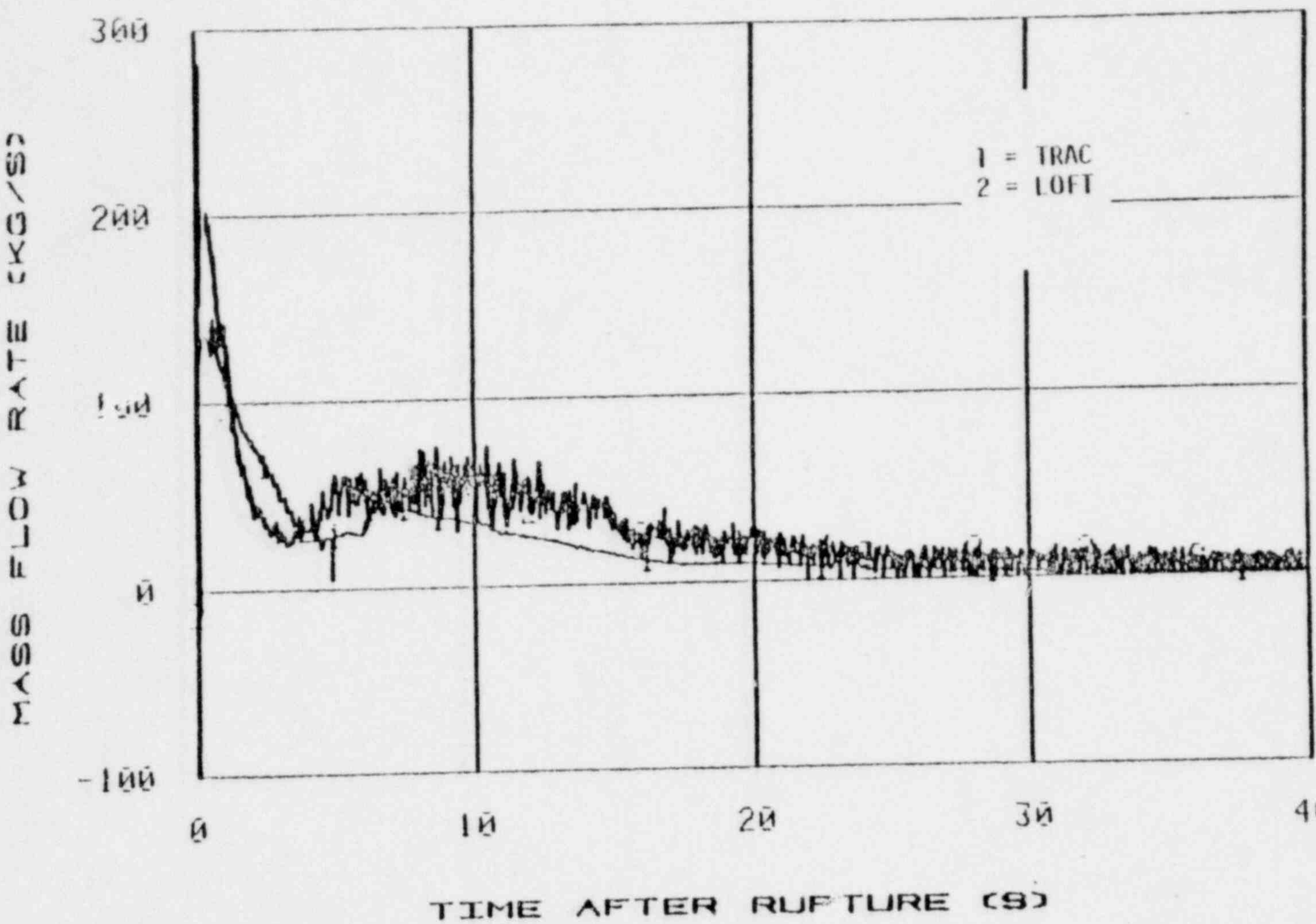

Figure 7. Comparison of measured and calculated broken loop hot leg mass flow rate for Test L2-3.

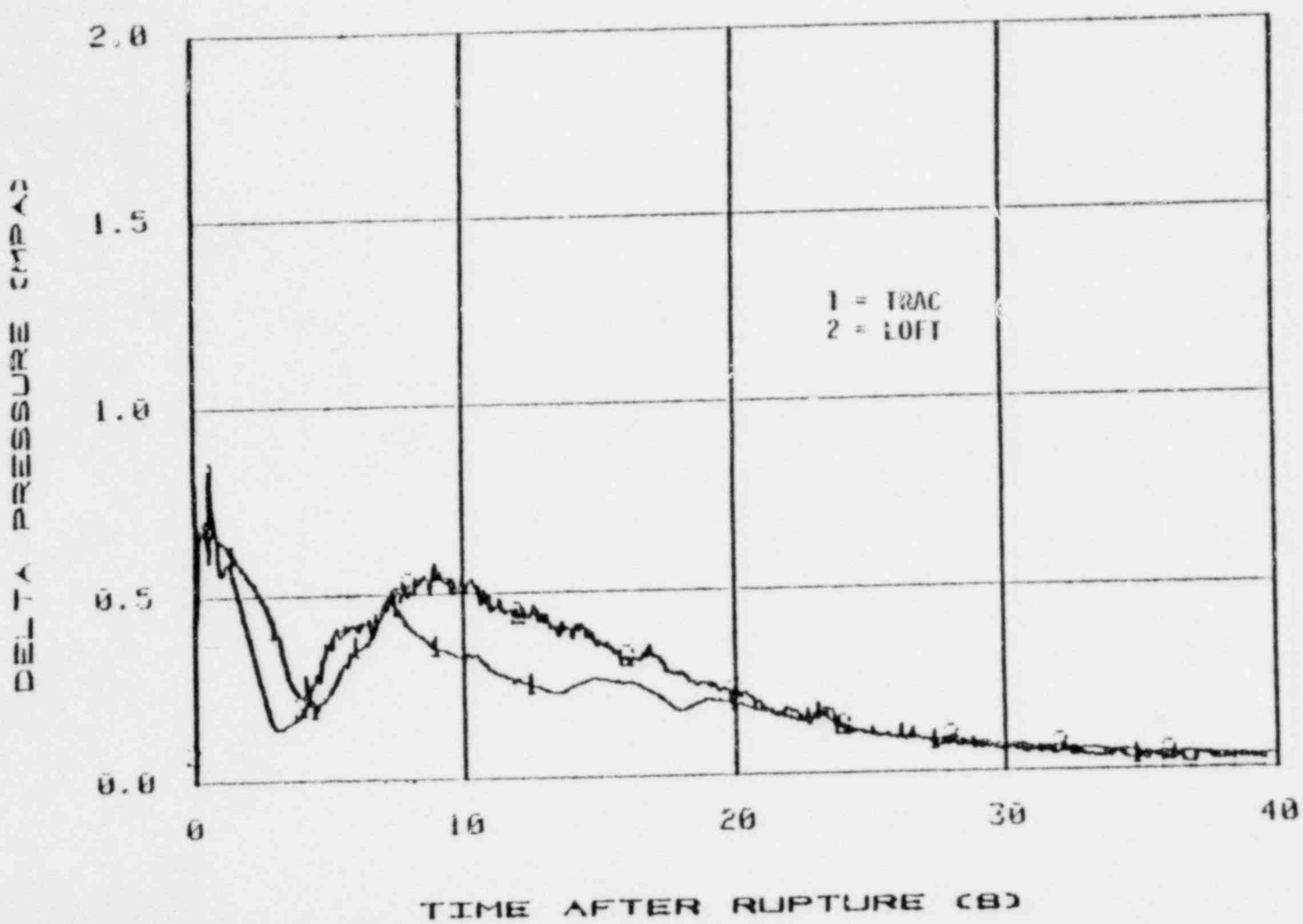

Figure 8. Comparison of measured and calculated pump simulator pressure drop for Test L2-3.

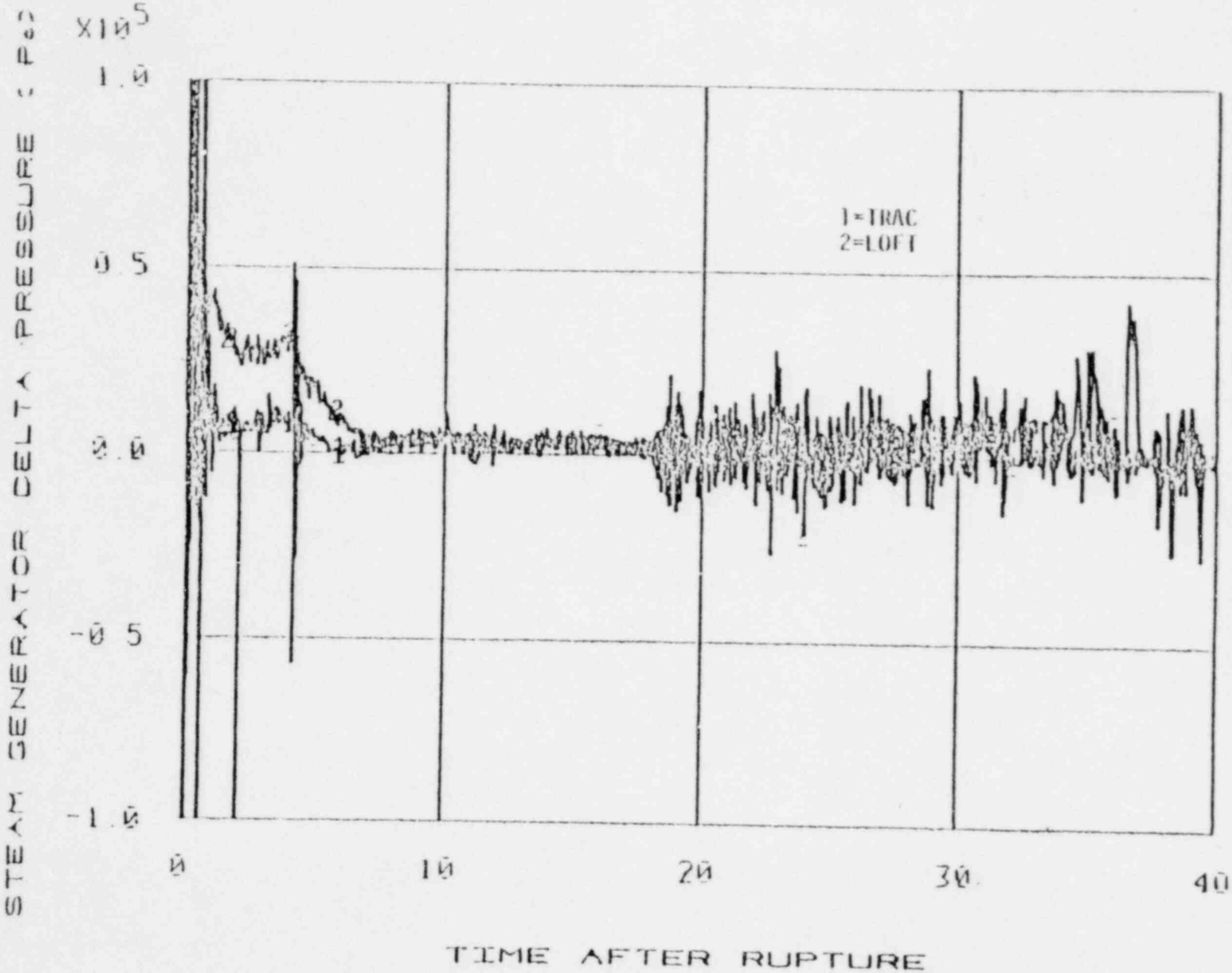

Figure 9. Comparison of measured and calculated steam generator pressure drop for Test L2-3.

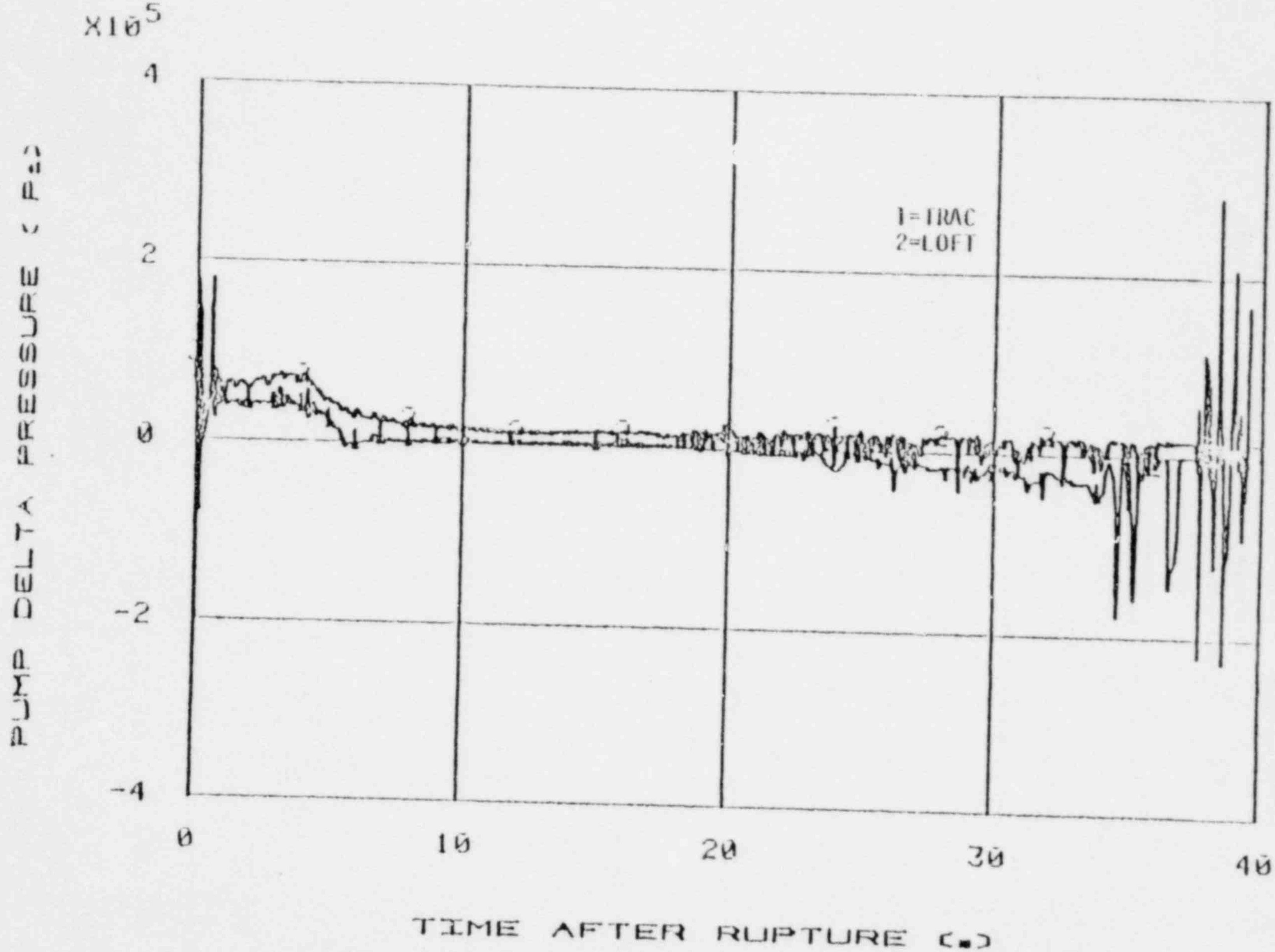

Figure 10. Comparison of measured and calculated pump pressure drop for Test L2-3.

CLAD TEMPERATURES IN Δ θ

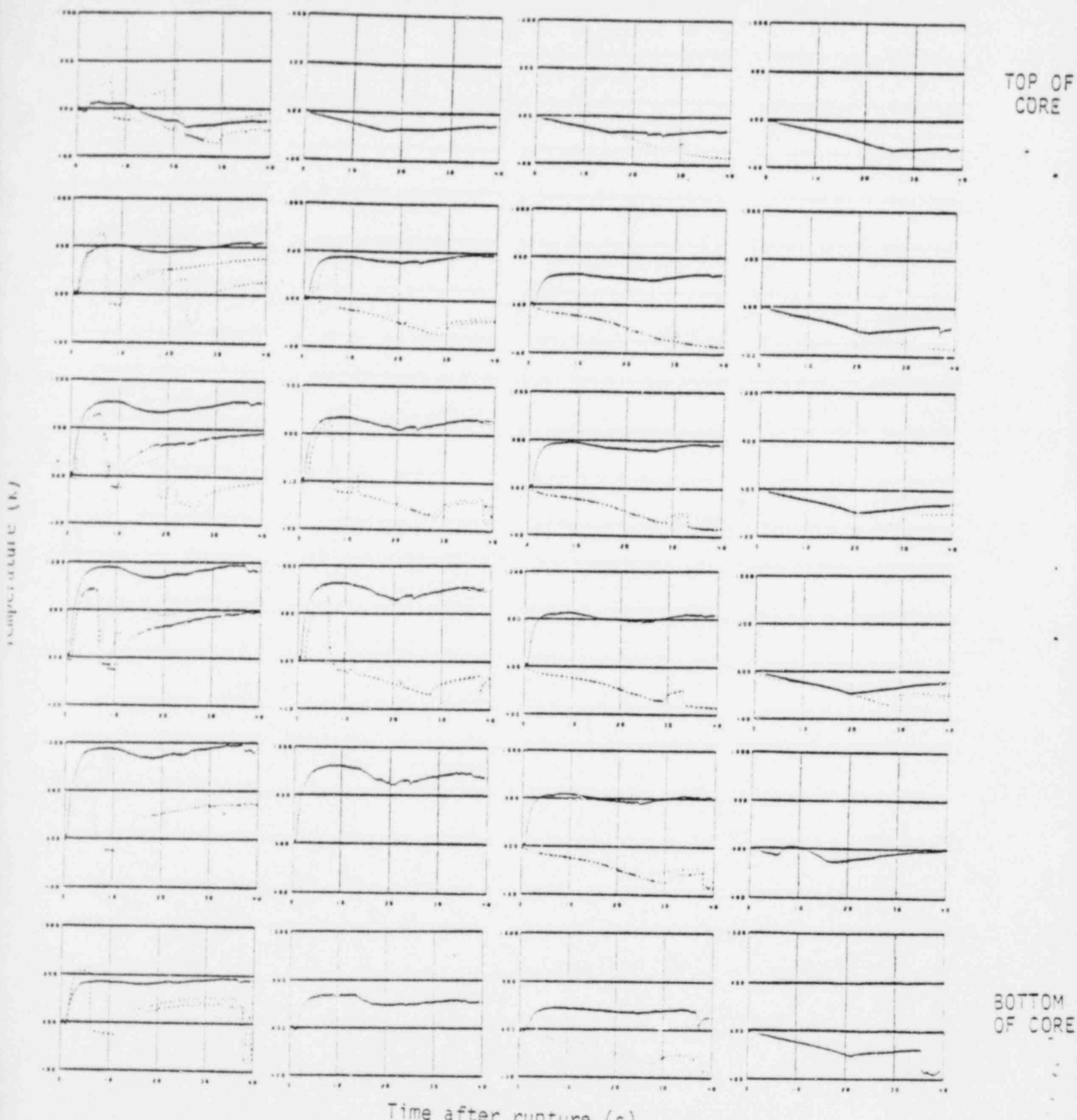

Figure 11. Comparison of measured and calculated rod cladding temperature response for Test L2-3.

VOID FRACTION IN CELLS OF UNWRAPPED DOWNCOMER

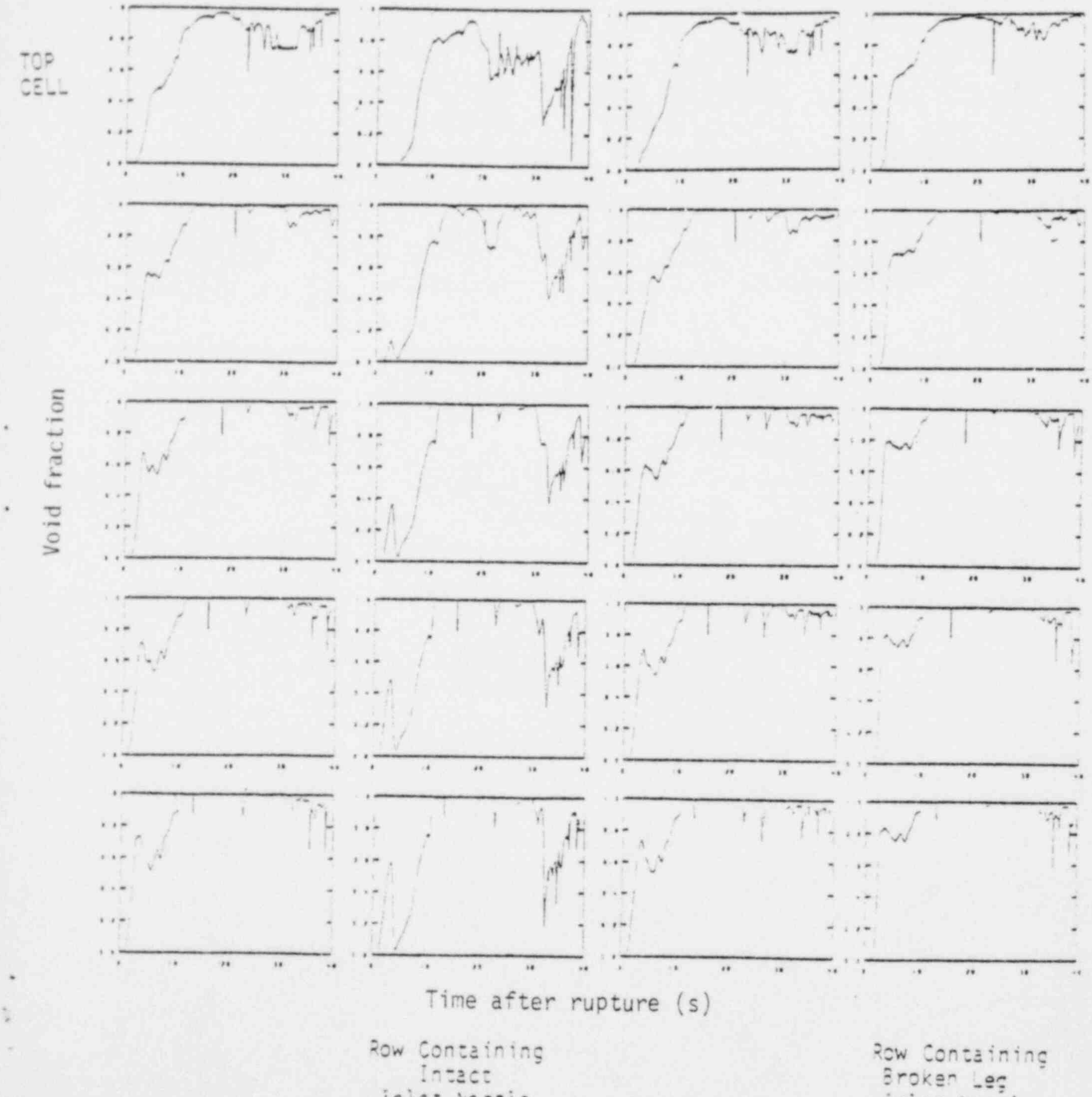

Figure 12. Calculated void fractions in the downcomer for Test L2-3. (Sheet 1 of 2)

POOR ORIGINAL

VOID FRACTIONS IN CELLS OF UNWRAPPED DOWNCOMER (Cont.)

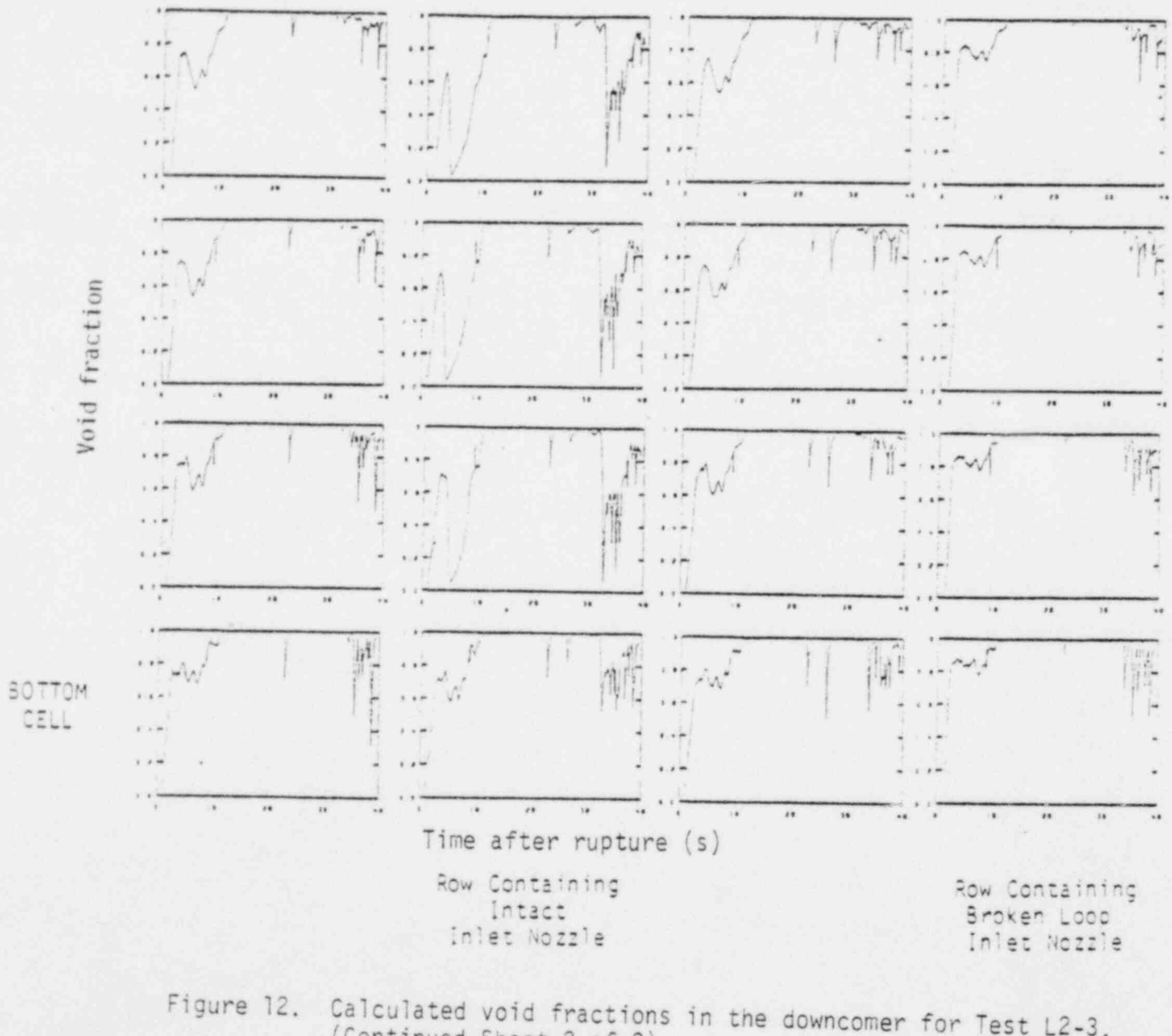

Figure 12. Calculated void fractions in the downcomer for Test L2-3. (Continued Sheet 2 of 2)

POOR ORIGINAL

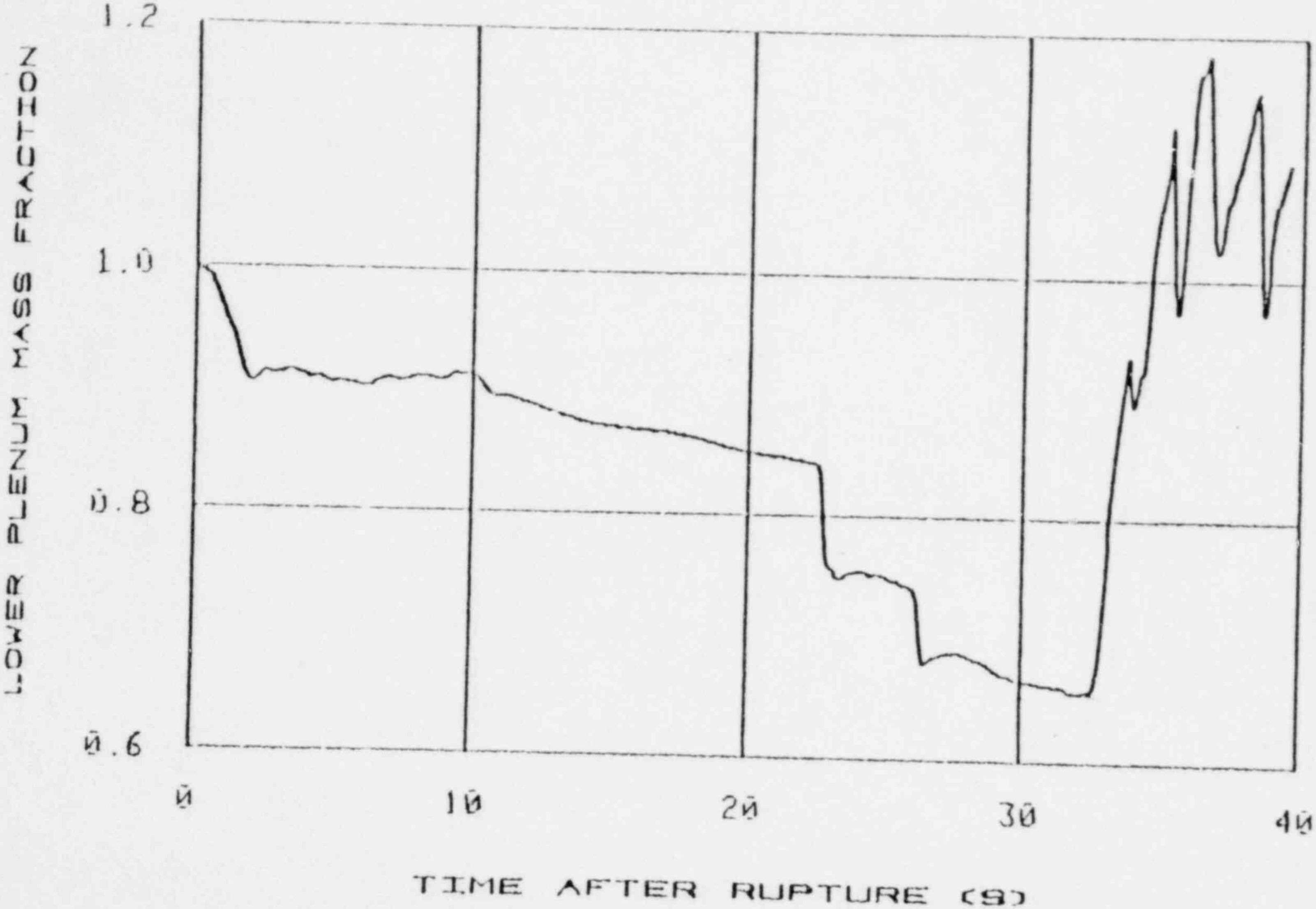

Figure 13. Calculated lower plenum mass fraction for Test L2-3.

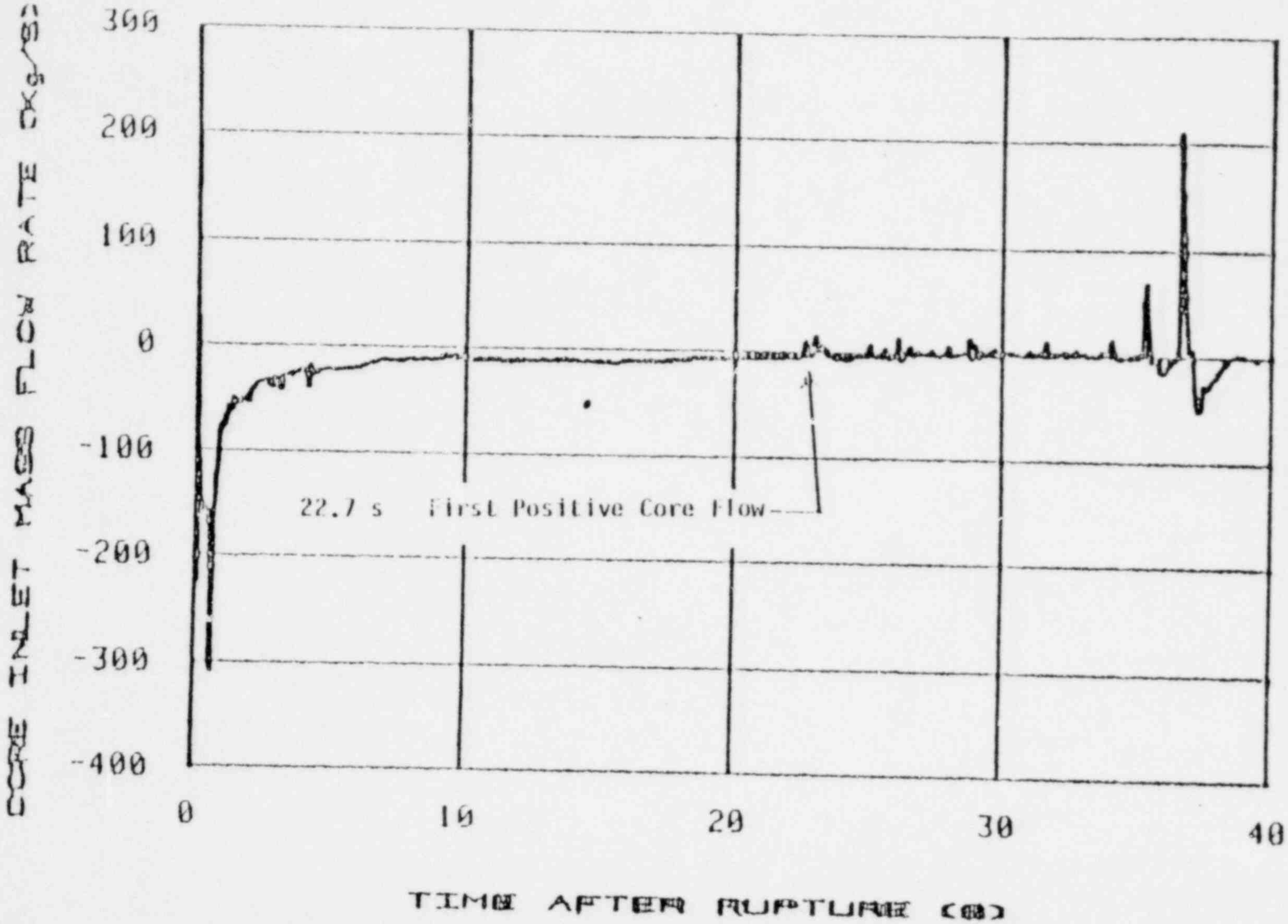

Figure 14. Calculated core inlet mass flow rate for Test L2-3.

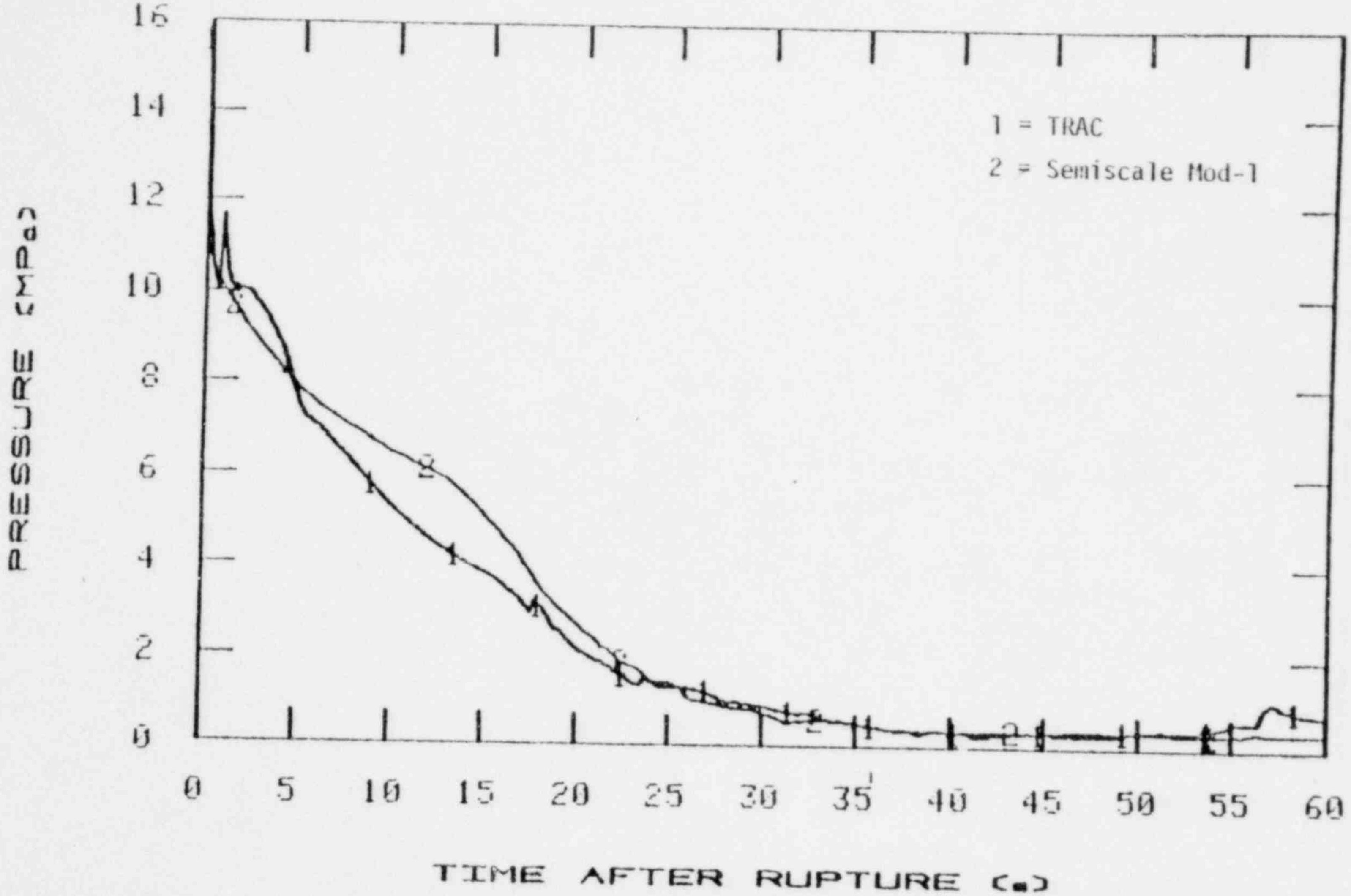

Figure 15. Comparison of measured and calculated upper plenum pressure for Semiscale Mod-1 Test S-04-6.

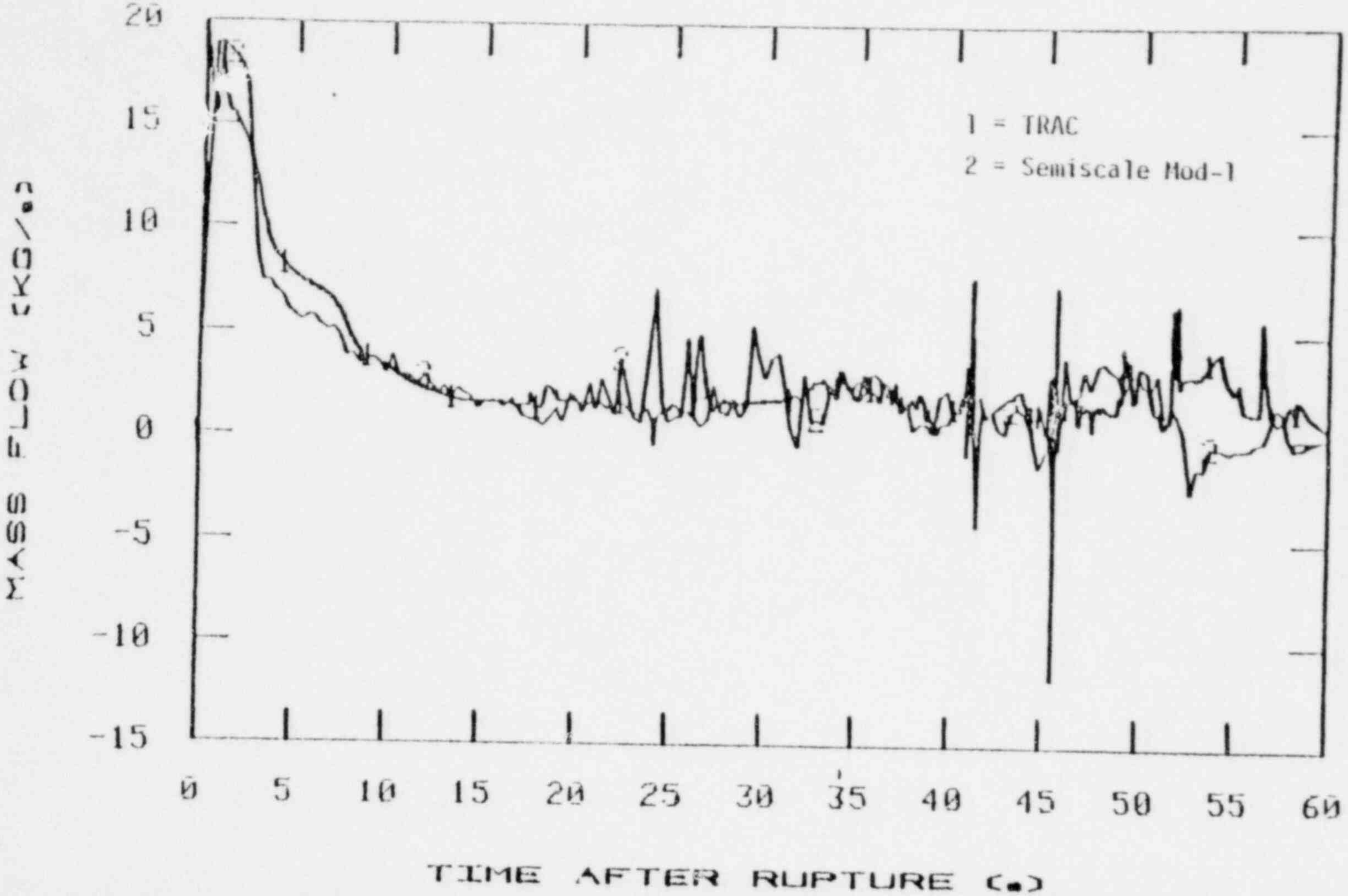

Figure 16. Comparison of measured and calculated mass flow in the broken loop cold leg for Test S-04-6.

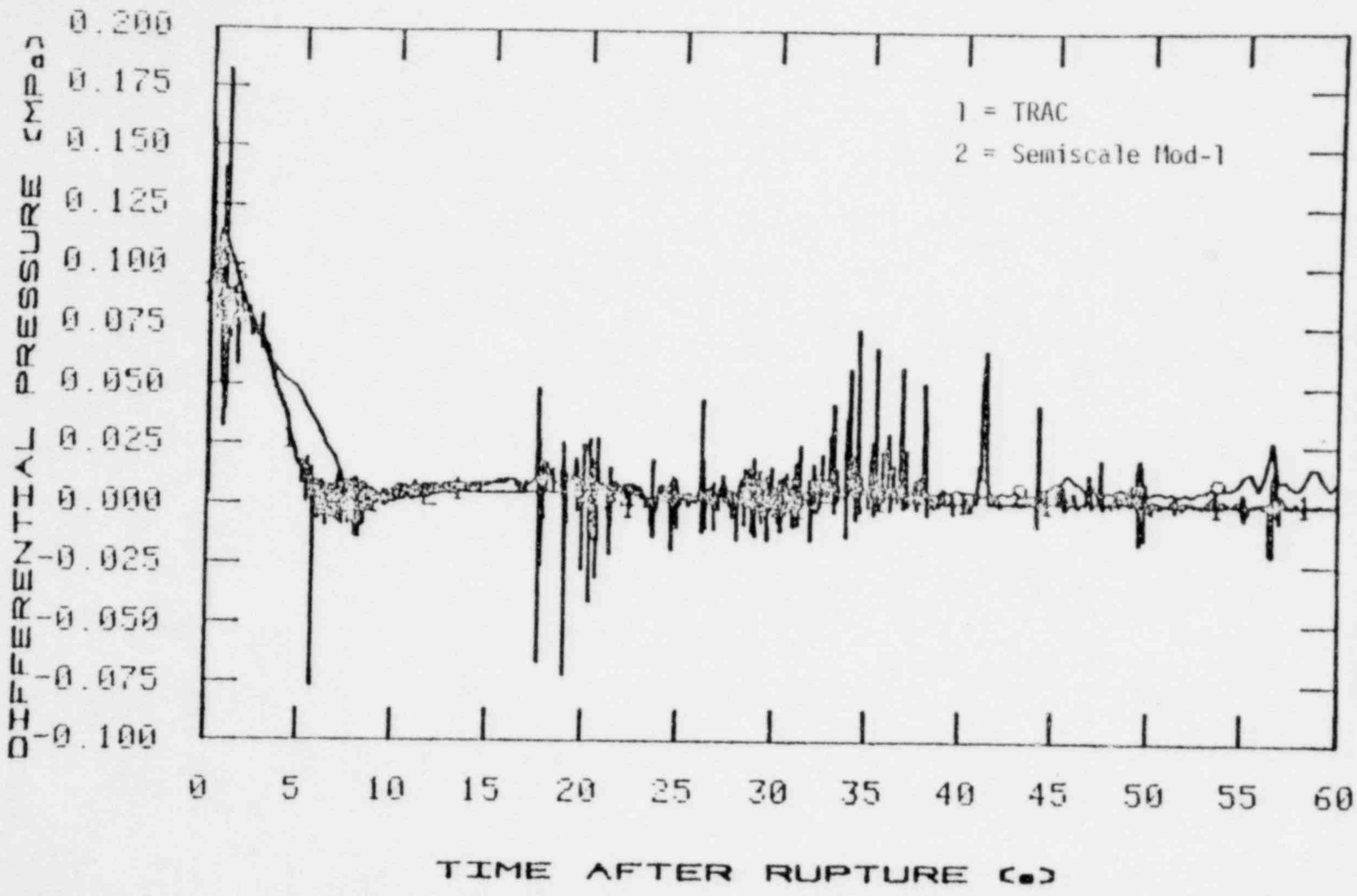

Figure 17. Comparison of measured and calculated pressure drop across the steam generator in the intact loop for Test S-04-6.

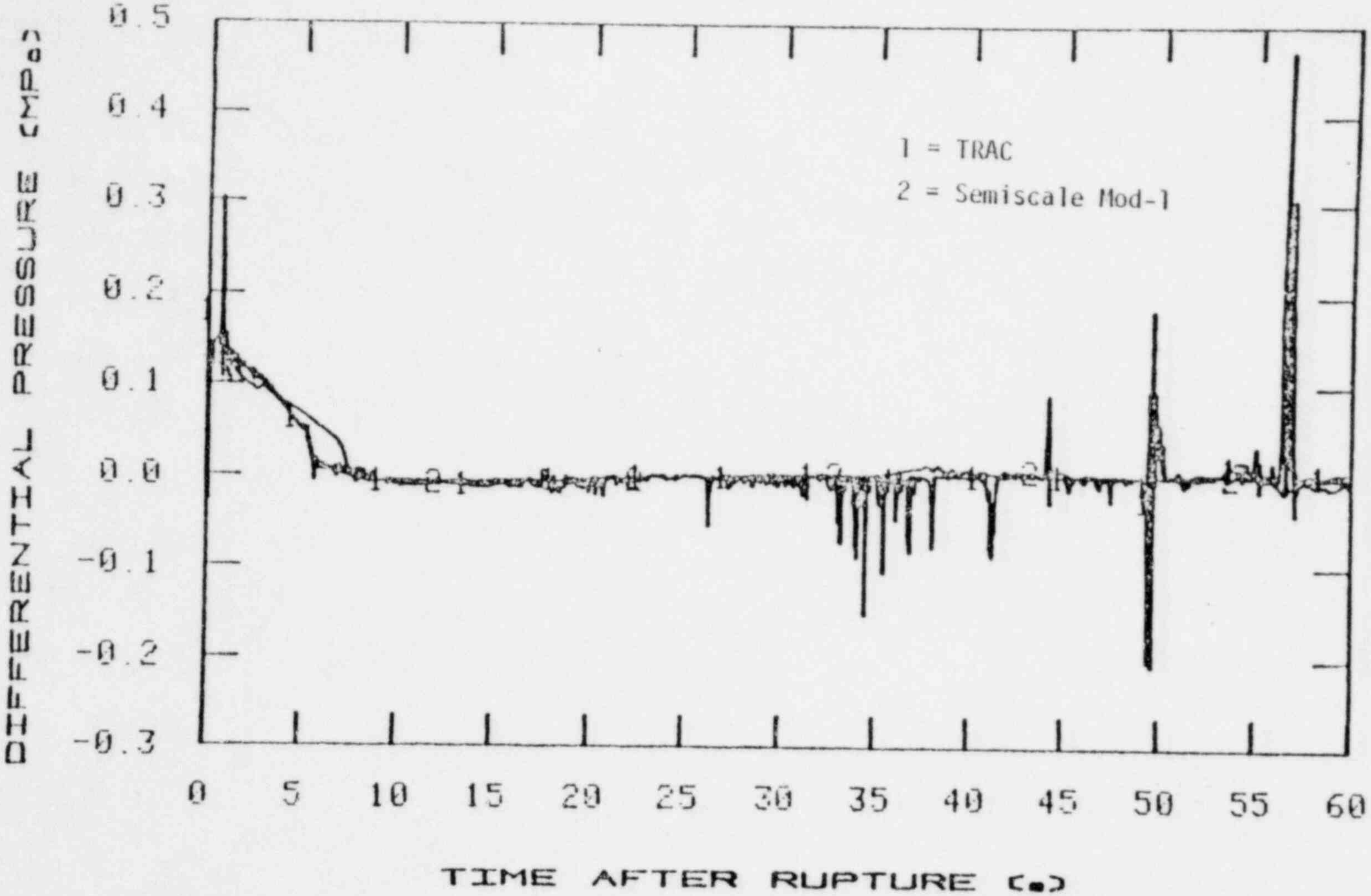

Figure 18. Comparison of measured and calculated differential pressure drop across the pump in the intact loop for Test S-04-6.

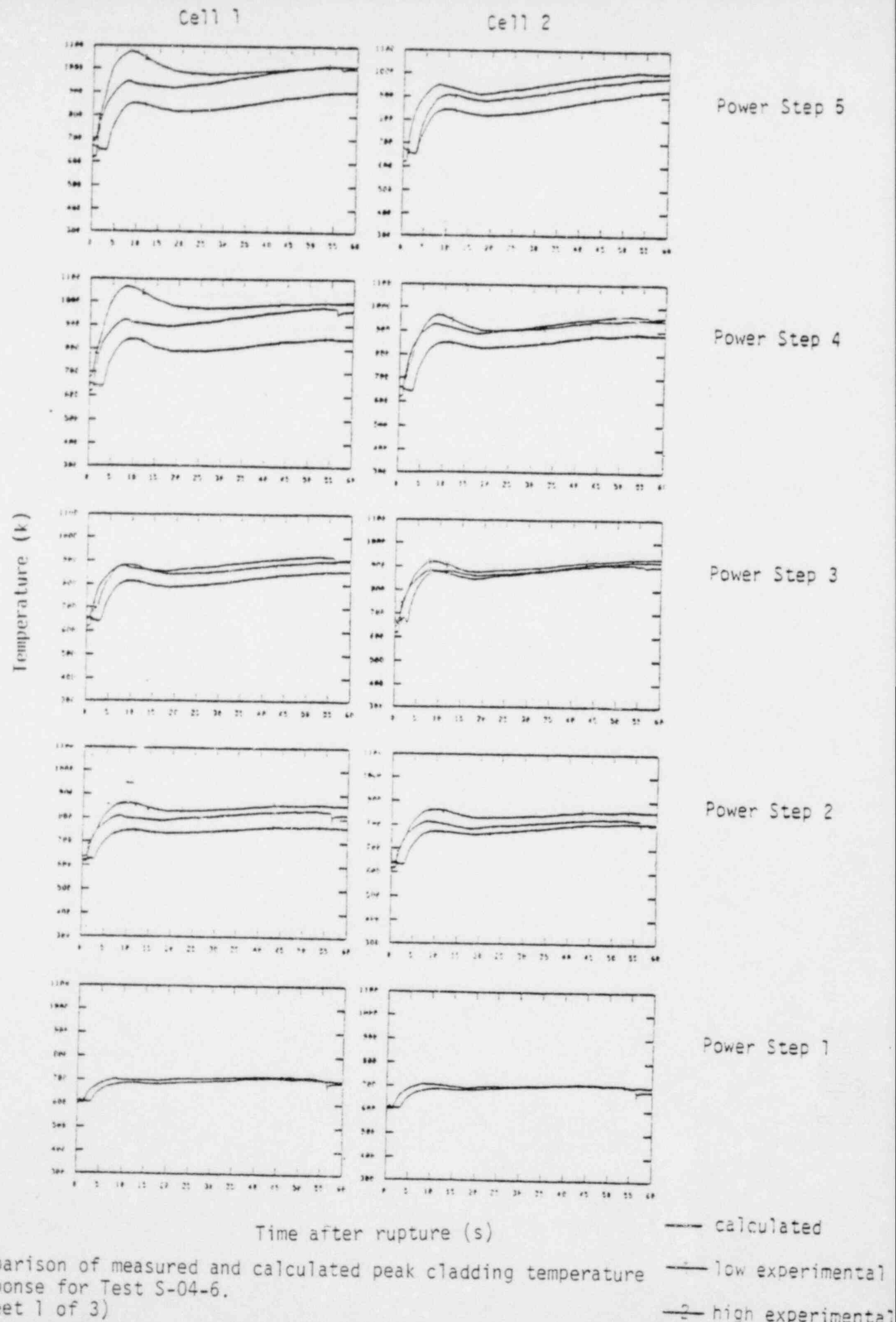

Figure 19. Comparison of measured and calculated peak cladding temperature response for Test S-04-6.
(Sheet 1 of 3)

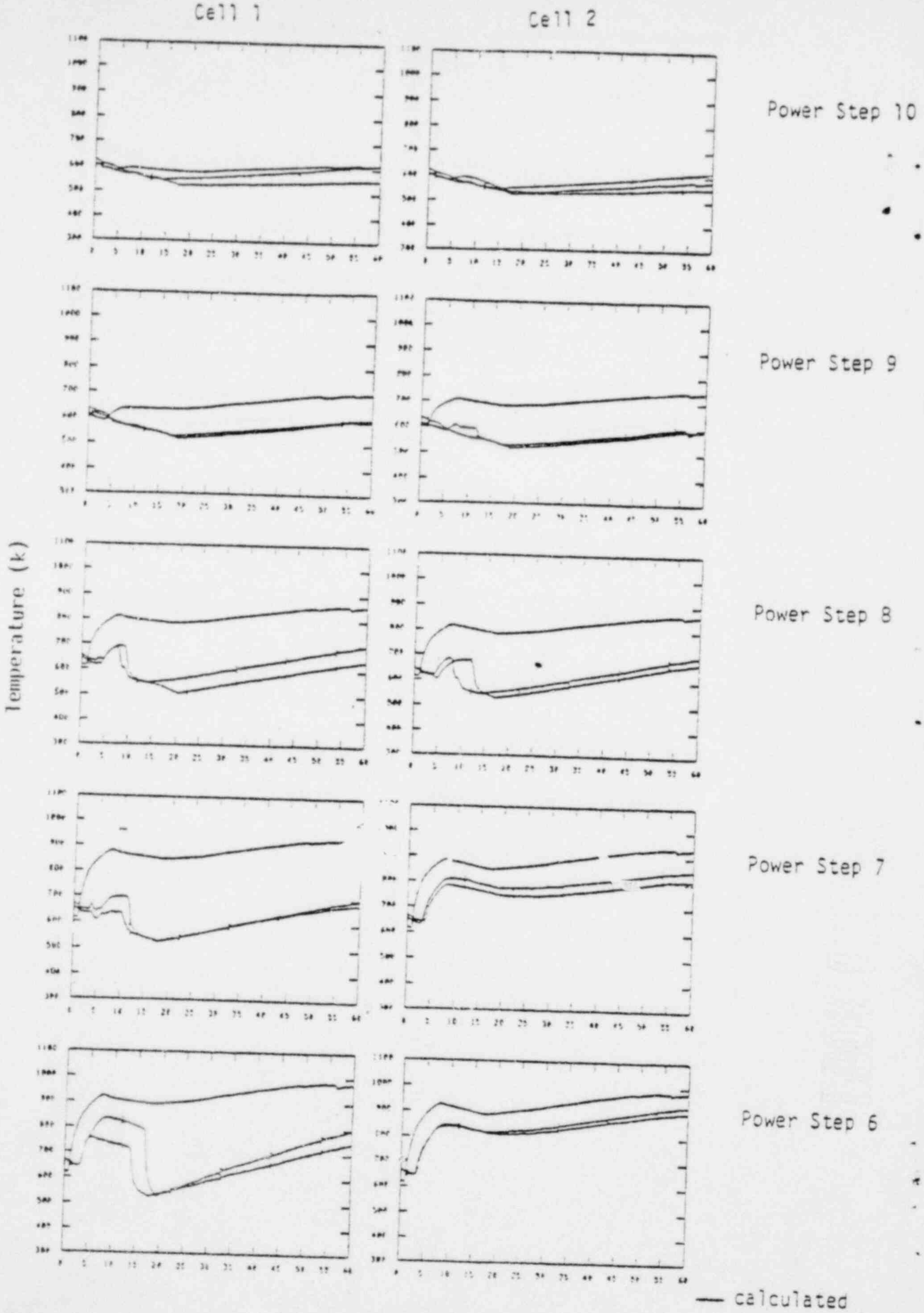

Figure 19. Comparison of measured and calculated peak cladding temperature response for Test S-04-6.
(Continued Sheet 2 of 3)

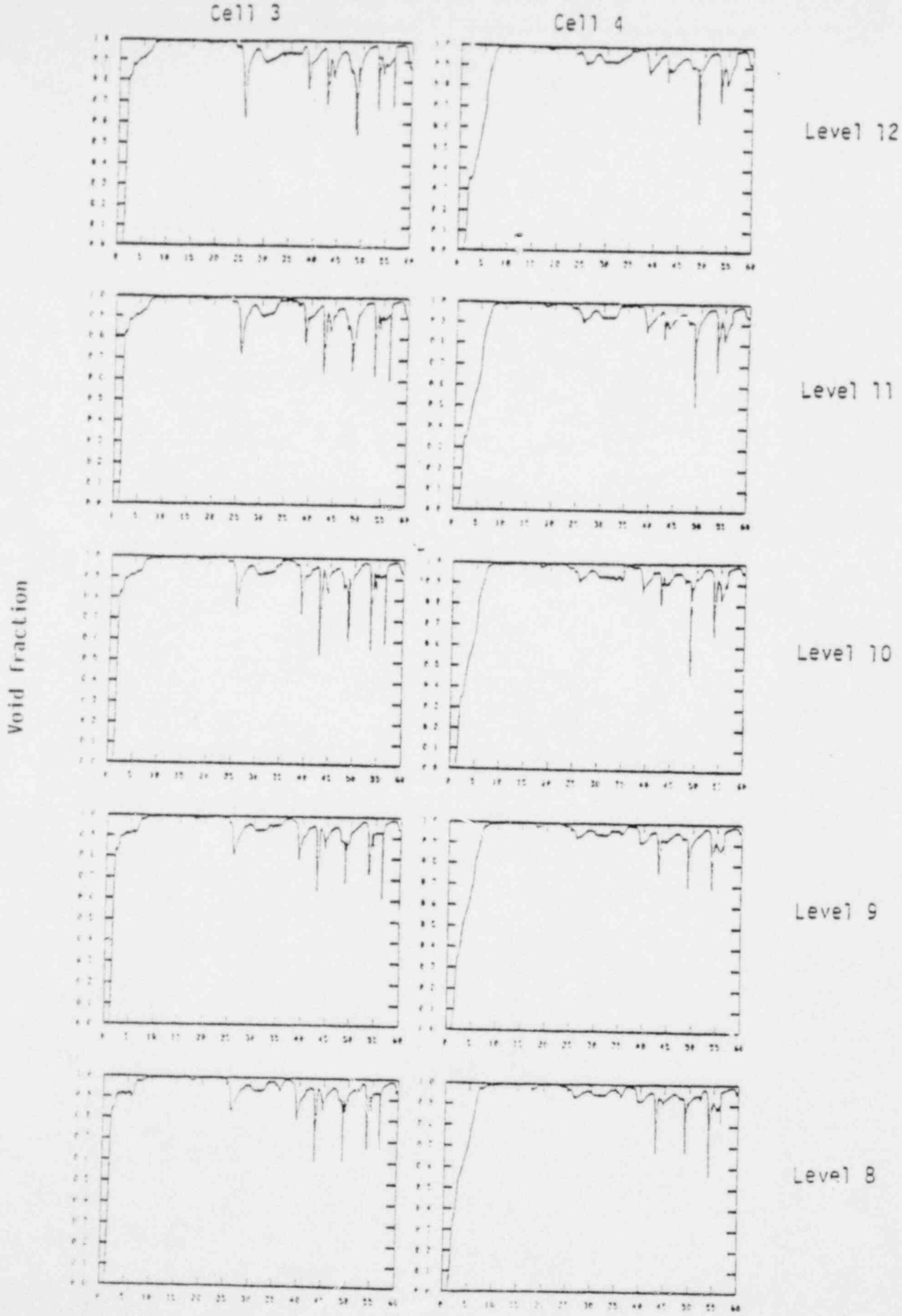

Figure 20. Calculated void fraction in the downcomer for Test S-04-6. (Sheet 1 of 2)

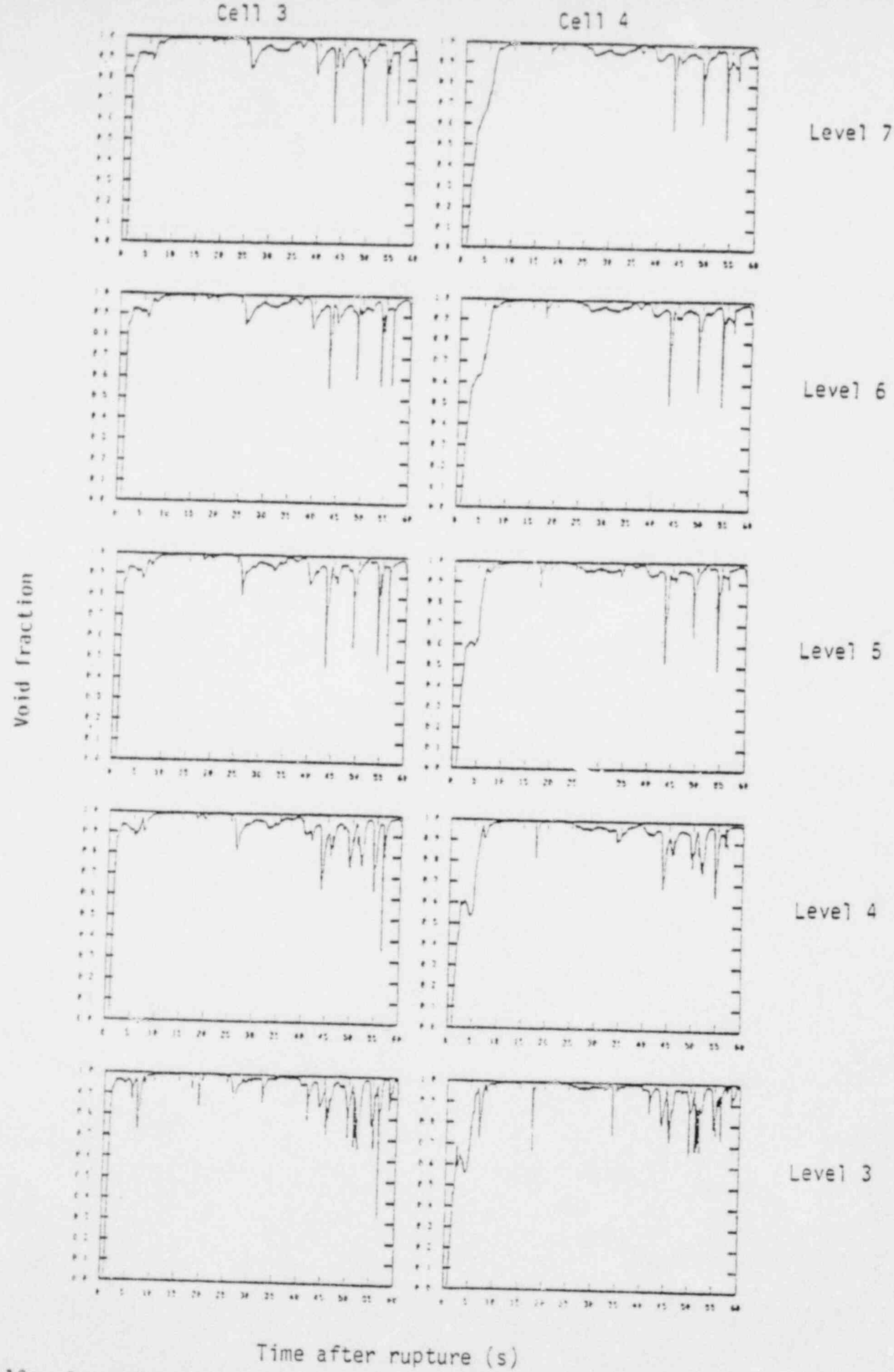

Figure 19. Comparison of measured and calculated peak cladding temperature response for Test S-04-6. (Continued Sheet 3 of 3)

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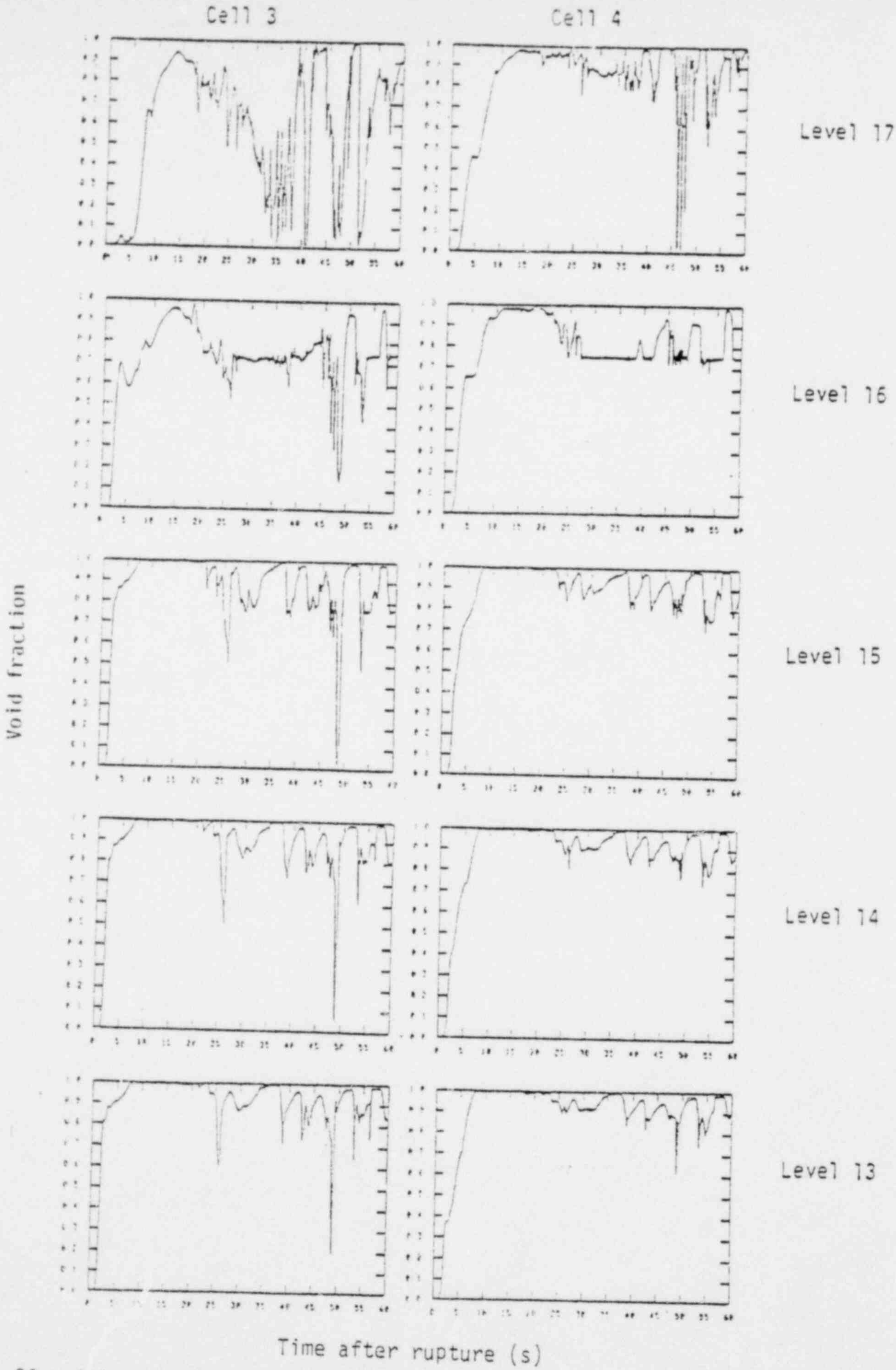

Figure 20. Calculated void fraction in the downcomer for Test S-04-6. (Continued Sheet 2 of 2)

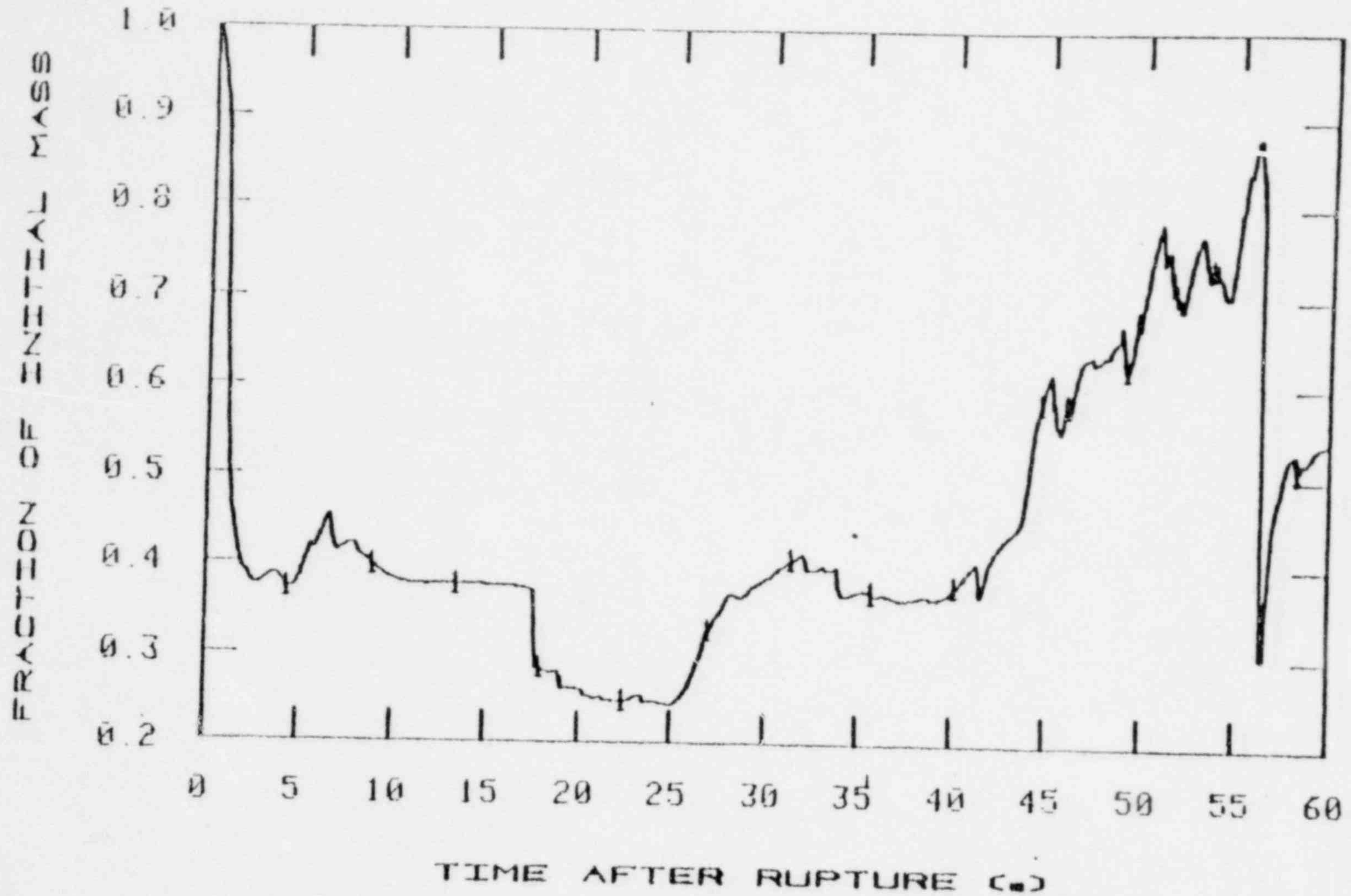

Figure 21. Calculated lower plenum mass fraction for Test S-04-6.

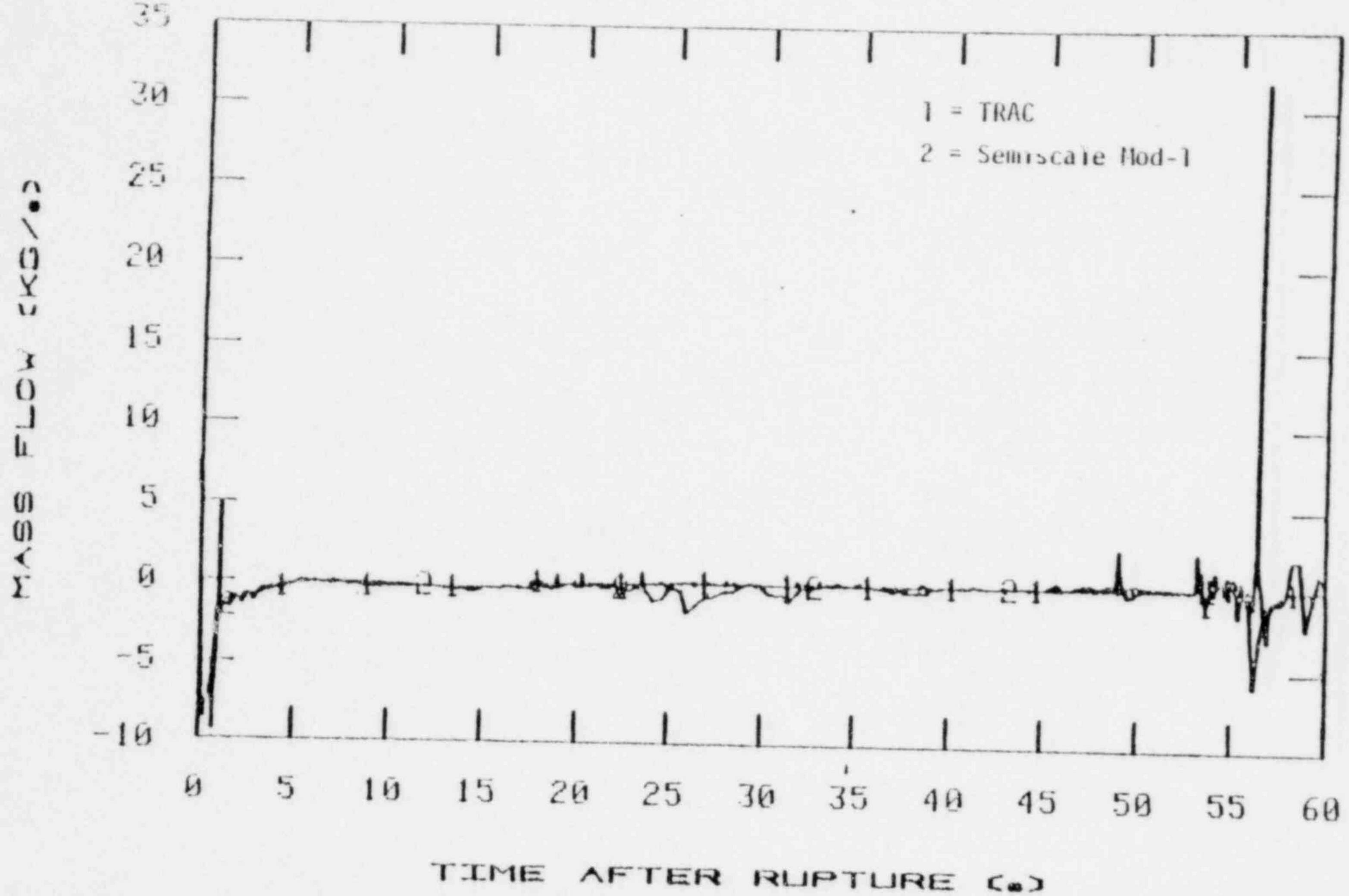

Figure 22. Comparison of measured and calculated core inlet mass flow for Test S-04-6.