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International Agreement Report

RELAP5/MOD2 Calculation of OECD-LOFT Test LP-SB-03

Prepared by
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Office of Nuclear Regulatory Research
U.S. Nuclear Regulatory Commission
Washington, DC 20555

January 1990

Prepared as part of
The Agreement on Research Participation and Technical Exchange
under the International Thermal-Hydraulic Code Assessment
and Application Program (ICAP)

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Abstract: This report compares the results of the RELAP5/MOD2 analysis with experimental measurements.

A simulation of test LP-SB-03 was previously carried out at GDCD using the RELAP5/MOD1 code. RELAP5/MOD2 was developed from RELAP5/MOD1 and contains more sophisticated hydraulic models and constitutive relationships. Comparison of the RELAP5/MOD2 and MOD1 calculations show that RELAP5/MOD2 performs better than RELAP5/MOD1 in a number of key areas; notably mass errors are much reduced, there is improved numerical stability, and improved separator modelling and modelling of accumulator injection.

CONTENTS

Microfiche of computer output has been filed under Safety Technology Section in Microfiche Archive at Barnwood.

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Summary:

In order to confirm the ability of RELAP5/MOD2 to describe a small break LOCA sequence in a PWR type geometry, analysis of test LP-SB-03 of the OECD LOFT experimental program has been carried out. Test LP-SB-03 simulated a 0.4% cold leg break in a PWR, with failure of high head safety injection; cooldown was achieved by feed and bleed of the secondary side, some time after core uncovery.

This report compares the results of the RELAP5/MOD2 analysis with experimental measurements.

A simulation of test LP-SB-03 was previously carried out at GDCD using the RELAP5/MOD1 code. RELAP5/MOD2 was developed from RELAP5/MOD1 and contains more sophisticated hydraulic models and constitutive relationships. Comparison of the RELAP5/MOD2 and MOD1 calculations show that RELAP5/MOD2 performs better than RELAP5/MOD1 in a number of key areas; notably mass errors are much reduced, there is improved numerical stability, and improved separator modelling and modelling of accumulator injection.

Overall agreement with experiment obtained using RELAP5/MOD2 is excellent, with all key phenomena correctly predicted, in the correct sequence with accurate timing. The CPU to real time ratio was approximately 3.5:1 on the Harwell Cray-1 computer.

Results of this calculation have been submitted to the OECD LOFT program review group as the United Kingdom contribution to the comparison report for test LP-SB-03.

1. INTRODUCTION

Loss-of-coolant accident (LOCA) analyses for the Sizewell 'B' Pre-Operational Safety Report (POSR) are expected to be carried out mainly using proprietary Westinghouse computer codes. In order to assess the POSR calculations, and develop a CEGB capability for LOCA analysis for operating PWRs, GDCD is carrying out independent calculations of limiting LOCA sequences using computer codes accessible to CEGB. The assessment is being carried out at the request of PMT.

The RELAP5/MOD2 code [4] is presently being used by GDCD for calculating small-break LOCA (SBLOCA) sequences for Sizewell 'B' [5]. RELAP5/MOD2 uses a six-equation two fluid model to describe two-phase flow in the reactor primary and secondary systems. It supersedes the RELAP5/MOD1 code, which employed a five-equation two-phase flow model (one phase constrained to thermal equilibrium) and used less sophisticated models for flow regime transitions and interphase interaction terms.

To gain experience with using RELAP5/MOD2, the code was used to simulate SBLOCA test LP-SB-03 carried out in the LOFT experimental reactor [2, 3] under the OECD LOFT programme. An analysis of this experiment was previously carried out by GDCD using RELAP5/MOD1 [1].

LOFT test LP-SB-03 simulated a 0.4% cold leg break in a PWR with no high-head injection. As noted in [1] the experiment provides a severe test of a reactor analysis code since a wide-range of complex phenomena which occur in a reactor SBLOCA must be simulated, including:

(1) Steam generator heat transfer in forced circulation, natural circulation and reflux condensation mode;

(2) Core heat transfer for uncovered core conditions;

(3) Single and two-phase critical discharge flow;

(4) Two-phase pump head degradation;

(5) Accumulator injection.

The present report discusses the RELAP5/MOD2 analysis of test LP-SB-03, in detail. The results of the present calculation have been submitted to the OECD LOFT program review group as the United Kingdom contribution to the comparison report for test LP-SB-03.

GDCD is in the process of performing analyses of hot-leg break tests LP-SB-01 and LP-SB-02 carried out in the same series, and these will be reported subsequently.

2. INPUT DATA AND MODEL

The input data were based on the INEL deck used for the pre-test prediction, and for the RELAP5/MOD1 calculation reported previously [1]. The modified noding scheme employed (figure 26) included a number of changes to ensure compatibility with RELAP5/MOD2. These changes were:-

(1) Changes to both the inlet and outlet plenum models. In [1] the inlet plenum (upper downcomer) was divided laterally and vertically into four volumes. For the present calculation it was remodelled as an annular downcomer in three levels, with the cold legs connected to the central volume. The outlet plenum was changed from two vertically stacked cylindrical volumes to three to comply with the format of the inlet plenum. This nodalisation was adopted to comply with EG&G recommendations for use of RELAP5/MOD2 with the cross flow junction option [4].

(2) The connection between the cold leg and the break discharge line was modelled as a tee using a centrally located cross flow junction.

(3) In accordance with EG&G guidelines, junctions at the reactor pressure vessel (RPV) nozzles, the break line connection to the cold leg, and the pressuriser surge line connection to the hot leg were all treated as cross-flow junctions. In these junctions the momentum flux terms are deleted from the momentum conservation equations used to calculate junction flow.

(4) Junction Options: The MOD2 version of RELAP5 has a new option by which the junction inlet void fraction can be corrected to allow for flow stratification in the upstream volume. Separate models for a centrally located junction, upward oriented junction, downward oriented junction are available. In accordance with EG&G guidelines, this option with the centrally located junction model was invoked for all connections between horizontal pipes.

(5) Volume Options: The new boron transport model and facility to include fluids other than water were not employed. Other changes were needed in specifying initial conditions consistent with the 6 equation formulation.

The calculation was performed on the Harwell Cray-1 computer using RELAP5/MOD2/CYCLE 36.01 incorporating corrections to Cray conversion errors implemented by UKAEA Winfrith. An error that was identified but not corrected was that the code failed to utilise the horizontal stratification model at the junction between the break line and the cold leg. (see (4) above). It was discovered that code cycle 36.01 did not employ this model in a cross-flow junction due to a coding error. This error has subsequently been corrected and the horizontal stratification model is working correctly in cycle 36.02. The impact of this error on the present calculation is thought to be small and is discussed in section 4.2 (b).

3. STEADY STATE AND NULL TRANSIENT

RELAP5 does not solve steady state equations hence the code must be run in transient mode until stable conditions are achieved. This process is accelerated in RELAP5/MOD2 by use of a 'steady state' option in which the thermal inertia of heat structures are set to artificially low values. The steady state option also checks for convergence of a steady state.

Key parameters were controlled using RELAP5 control variables to provide the necessary feed back, to achieve the required steady state. Parameters controlled in this analysis were Pressuriser Pressure, Primary Mass Flow Rate, Secondary Pressure and SG downcomer water level. Calculation of steady state conditions is discussed below and illustrated in Figures 1-8. The experimental values at the start of the transient have been added to the graphs, where available, together with error bars.

Pressuriser pressure was set by attaching a fictitious RELAP5 time dependent volume to the steam space of the pressuriser. The dummy volume was assumed filled with saturated steam at the desired pressure (15.26 MPa). Pressuriser level was not adjusted as the final value fell within the experimental uncertainty range. Primary pressure in the steady state run is shown in figure 1; pressuriser level and surge line flow in figure 5.

Primary loop flow was adjusted by using a proportional/integral controller (based on loop flow error) to control pump speed. Active loop mass flow in the steady state run is shown in figure 2; inactive loop mass flow is shown in figure 3.

Secondary side pressure (and hence primary side temperature) was controlled by a proportional/integral control system (based on SG Dome pressure error) operating on the main steam control valve. Hot and cold leg temperatures in the steady state run are shown in figure 4.

Steam Generator downcomer collapsed liquid level was controlled by adjusting feed flow. Feed flow was set equal to steam flow plus a term proportional to the SG level error. The SG level was set higher than the measured value, as at lower levels, steam entrainment was found to occur in the SG separator component leading to an erroneous prediction of voiding in the downcomer. Various steam generator parameters in the steady state run are shown in figures 6-8.

It is seen that there is no evidence of the oscillations in the steam generator recirculation flow that appeared in the calculation of reference [1].

RELAP5/MOD2 calculated that a stable steady state was achieved at 78.9s. In order to check the stability of the converged steady state a null transient was run in which the steady state controls were removed and break flow and pump seal injection flow were set to zero. Apart from an anticipated decay in pressure due to pressuriser heat losses (the pressuriser heaters played an insignificant role in this test, and were omitted from the model) the calculated plant state was stable. Conditions after 15.7s of null transient were judged acceptably close to initial experimental conditions and the transient was initiated from this point.

Table 1 shows a comparison with the initial conditions measured in the experiment and those used in the calculation. Also shown are the initial conditions used for the RELAP5/MOD1 calculation reference [1]. The only significant discrepancy is the water level in the SG downcomer which, as noted above, was made artificially high in the RELAP5/MOD2 calculation in order to avoid steam being entrained into the lower SG downcomer.

4. TRANSIENT

4.1 DESCRIPTION OF EXPERIMENTAL TRANSIENT

In the experimental data report [3] the LP-SB-03 transient is divided into four distinct stages where different phenomena occur. These are as follows:-

(a) Rapid mass depletion phase. This is the period between break opening and pump trip at 1600s. During this phase the flow is a well mixed two phase flow and mass loss is relatively rapid. The break does not remove sufficient enthalpy to overcome decay heat and some enthalpy is consequently rejected via fluid discharge from the SG Main Steam Control Value (MSCV).

(b) Boildown phase. This period occurs after pump trip at 1600s (when primary system mass is reduced to about 50%) when the remaining liquid falls to the lowest points in the circuit, the RPV and loop seals. The break flow transitions to a high quality steam flow, leading to a lower rate of removal of mass; however the rate of removal of enthalpy is now sufficient to give primary depressurisation. Heat transfer from the primary to the secondary continues to be in the forward direction because of steam leakage from the SG MSCV. The core drys out and the break is isolated during this phase. Forward SG heat transfer is also lost.

(c) Cooldown by secondary feed and bleed. This phase began when the operator reintroduced SG feed and opened a SG relief valve at t= 5415s. This action was initiated after clad temperature had reached 977K in the reactor core. Forward heat transfer is restored in the SG and the primary pressure falls rapidly.

(d) Accumulator and LPIS injection. This phase occurs after t= 5800s, after primary pressure falls below the accumulator set point. Accumulator and Low Pressure Injection System (LPIS) flow rewets the core and refills the primary system.

4.2 RELAP5/MOD2 RESULTS

Results of the transients calculations are compared with data in figures 9-25. In these plots, time zero refers to the time of opening of the break valve. Table 2 shows the timing of key events in the test and in the calculation.

(a) Primary-Secondary Pressure. Primary and secondary side pressures are plotted in figures 12 and 13. Agreement with measurement is seen to be very good.

In the period before pump trip, calculated to occur at t= 1660s the break nozzle discharges a low quality two phase mixture, resulting in a relatively low enthalpy discharge rate. Consequently, the pressure tends to rise, causing periodic cycling of the main steam control valve (MSCV) on the Steam Generator. The cycling of the valve is correctly predicted by the code, though RELAP5 predicted 2 cycles instead of the 4 measured. (Note that in the test the MSCV failed to completely reseat leading to an estimated leakage of 0.13 kg/s [3]. This leakage rate was simulated in the RELAP5/MOD2 analysis by using an appropriate minimum valve flow area.)

After pump trip at t= 1660s the break discharges high quality steam, leading to a steady depressurisation of the primary and secondary systems which is well represented by RELAP5/MOD2. At about 4500s primary pressure is calculated to fall below secondary pressure (figure 11) owing to reduced heat input from the core which began to uncover at 4300s. This is in good agreement with the measurement (figures 12 and 13). There is experimental evidence that reflux condensation continued even after primary pressure fell below secondary pressure [1]. However RELAP5/MOD2 failed to predict this behaviour. The pressure levels out after break isolation, and then falls rapidly after initiation of secondary side bleed and feed. (t= 5415s in experiment, t= 5308s in RELAP5 simulation). Bleed and feed was initiated manually by the operator after peak clad temperatures exceeded 977K. The depressurisation during the bleed and feed phase is seen to be well represented by RELAP5. Accumulator injection occurs at 5501s when the set point of 2.84 MPa is reached. The reduction in depressurisation rate is due to steam formation as the core is rewetted.

(b) Break mass flow rate and primary inventory. The measured and calculated break flows, and the measured and calculated primary inventory are shown in figures 9 and 10. Agreement is seen to be extremely good.

The sharp drop in calculated break mass flow rate at t=1660 is associated with pump trip, which results in break-down of forced circulation and emptying of the cold leg pipework. The transition from two-phase conditions to high quality steam conditions in the cold leg causes the discharge flow to drop sharply. The magnitude of the flow rate reduction is seen to be well predicted by RELAP5/MOD2. In section 2 it was indicated that a code error prevented the horizontal stratification model from being used in a cross flow junction. This caused the break line junction to the cold leg to use average upstream conditions even when the cold leg was stratified. However, this error was considered insignificant as the cold leg drained rapidly after pump trip hence the potential mass flow error was small. The calculated primary inventory agrees well with measurement up to 6100s after which the ECCS injection is overpredicted, as shown in figure 25.

(c) Fluid Densities in Primary Pipework. Measured and predicted fluid densities in the cold leg and hot leg pipework and in the break discharge pipe are shown in figures 14 to 16. Agreement between measured and calculated values is seen to be good. After pump trip the hot leg density shows a sudden fall, followed by a recovery. This behaviour is believed due to the fact that when forced circulation ceases, the fluid in the hot leg drains back into the pressure vessel; water held up in the steam generator then drains downwards causing a partial refilling of the hot leg and loop seal downside. This behaviour is seen to be reproduced remarkably well by the RELAP5 calculation (see figures 16 and 17).

(d) Clad Temperatures. Fuel cladding temperatures at the elevations corresponding to the centres of the six RELAP5 core nodes are shown in figures 18 to 23. The timing of core uncovery is seen to be captured quite well by the RELAP5 calculation, with the rate of progress of the dryout front very well predicted. There is a tendency for RELAP5 to over-predict heat up of fuel in the lower part of the core and to underpredict the heat-up at the top of the core. This tendency was also seen in the RELAP5/MOD1 calculation reported in [1]. It was suggested in [1] that the effect was caused by the return of condensed water from the SG. In the calculation the water falls on the top core node and enhances cooling there. It is believed that in the experiment the water ran down the core periphery and was boiled off at the dryout front, contributing to heat transfer throughout the dry part of the core. A multiple channel core model would probably be required to correctly represent core heat transfer under these conditions.

Following feed and bleed initiation RELAP5 correctly predicts the rewetting of the second core slab (figure 19) but over predicts the cooling of the core particularly at the top (for similar reasons to those described above for the high heatup rate). The code then correctly predicts a second dryout of second core slab followed by rewetting of the whole core, from below, after accumulator injection.

(e) Accumulator Injection and Core Rewetting. Accumulator injection commenced at t= 5558s in the experiment and at t= 5501s in the RELAP5 simulation. Injection was initiated when the primary system pressure fell to the set-point pressure of 2.84 MPa.

The measured and calculated accumulator flows are shown in figure 24. The calculated accumulator flow is highly oscillatory, although the oscillations did not lead to termination of the calculation, as occurred in the analysis of [1]. The calculated mean injection flow-rate is considerably higher than the measured value in the later part of the transient. This appears to be due to an over-prediction of the rate of steam condensation in the injected water, which leads to a calculated primary system depressurisation rate which is higher than that observed. Accumulator level is shown in figure 25.

4.3 COMPUTING TIME

The total problem time simulated was 7000s. The maximum and minimum time-step sizes were 0.1 and 10^{-7}s respectively. The rate of CPU time to problem time was 3.5 on the Harwell Cray-1 computer.

5. DISCUSSION

In this section the RELAP5/MOD2 calculation is compared with the RELAP5/MOD1 analysis discussed in [1]. There were seven areas identified in [1] where RELAP5/MOD1 did not perform well. Here each area is examined in turn to determine whether or not the new code RELAP5/MOD2 produces improved results.

(a) Steam Generator Separator

In the RELAP5/MOD1 calculation in reference [1] a mass/energy conservation error occurred in the SG separator/lower separator region. To alleviate this problem the junction between the lower separator and the separator bypass was disconnected. This course of action was not found to be necessary in the MOD2 calculation. It was found, however, that in order to maintain the desired separator level it was necessary to increase the downcomer level arbitrarily, from the measured value of 3.16m, to 3.7m. Discussion with the code developers suggests that the desired result could also have been achieved by adjusting loss coefficients and friction factors.

(b) Mass Errors

At the end of the transient the mass error was approximately 12 kg which is 0.87% of the minimum inventory. This is a negligible error and is a major improvement over the MOD1 calculation where mass errors reached 100 kg.

(c) Steam Generator Level Oscillations

As in the MOD1 calculation, oscillations were observed in the SG level throughout the transient. In the MOD2 calculation, the oscillations are present but are of much reduced amplitude.

(d) Accumulator Injection

As in the RELAP5/MOD1 calculation the accumulator injection flow-rate was calculated to be more oscillatory than measured. Eventually the oscillations caused a water property error which led to the termination of the calculation. The RELAP5/MOD2 calculation did not terminate in the accumulator injection phase.

(e) Water Distribution and Inventory

RELAP5/MOD2 predicted fluid densities well; the problem identified with the RELAP5/MOD1 code in which water was predicted to rise faster than steam in the core outlet region, was not seen in the new calculation. The calculated primary inventory was in excellent agreement with the experiment, and showed a marked improvement on the MOD1 calculation. (see figure 9).

(f) Steam Generator Heat Transfer

As found with the MOD1 analysis, RELAP5/MOD2 calculated low SG heat transfer in steady state, and once again failed to predict the complex effects thought to be present after core dry out i.e. continued reflux condensation when primary pressure is below secondary pressure. It is possible that inclusion of a small node at the bottom of the SG riser would enable the code to model this behaviour. The code did however go on to predict restoration of reflux cooling and the feed and bleed phase, reasonably well.

(g) Core Heat Transfer

As with the RELAP5/MOD1 calculation, RELAP5/MOD2 under-predicted core heat transfer after dryout and predicted a more rapid quench than measured. In section 4.2(d) it is argued that a multi-channel core representation would be required to permit the code to adequately model these effects.

6. CONCLUSIONS

This report describes a RELAP5/MOD2 calculation of LOFT test LP-SB-03, which simulated a 0.4% cold leg loss of coolant accident (LOCA) in a PWR.

RELAP5/MOD2 calculated all the thermal-hydraulic phenomena exhibited in the test, in the correct order and with reasonable timing. No discrepancies were seen in this analysis which are expected to be of significance for reactor small break LOCA calculations.

RELAP5/MOD2 performed better than the RELAP5/MOD1 code which was previously used by GDCD for analysis of this test. In particular RELAP5/MOD2 was found to be more stable and robust, with an improved numerical solution scheme removing the mass error problems encountered in the earlier code version.

The present calculation was submitted to the OECD LOFT program review group as the United Kingdom contribution to the code comparison report for test LP-SB-03. It will also form part of a validation report to underwrite use of RELAP5/MOD2 by GDCD for analysing Sizewell 'B' small break LOCA sequences.

REFERENCES

1.	GD/PE-N/482	Post test analysis of OECD LOFT experiment LP-SB-03 using RELAP5/MOD1. Volume 1 Analysis, Volume 2 Figures. C Harwood	Feb. 1985
2.	OECD LOFT-T-3603	Best estimate prediction for OECD LOFT project small cold leg break experiment LP-SB-03 W H Grush, M Tanaka, P Marsili	Feb. 1984
3.	OECD LOFT-T-3604	Quick Look report on OECD LOFT experiment LP-SB-03 M Tanaka et al.	Mar. 1984
4.	NUREG/CR-4312 EGG-2396	RELAP5/MOD2 Code Manual Vols. 1 and 2 V H Ransom et al.	Apr. 1984
5.		RELAP5/MOD2 input data deck for Sizewell 'B' C Harwood	

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Table 1

Comparison of RELAP Steady State for MOD1 and MOD2 with measured Data

Variable	Units	Measured	MOD 2	MOD 1
Primary				
Pressuriser pressure	MPa	15.26 ± .11	15.30	15.26
Power	MW	50.3 ± 1.2	50.0	50.0
Intact loop mass flow	Kg/s	482.6 ± 2.6	482.6	482.6
Pressuriser level	m	1.115 ± .06	1.0893	1.097
Cold leg temperature	°K	556.4 ± 1	557.81	557.6
Hot leg temperature	°K	576.4 ± 1	577.06	576.9
Secondary				
Pressure	MPa	5.58 ± .06	5.47	5.43
Level	m	3.16 ± .02	3.704	3.114
Steam Flow	Kg/s	26.67 ± .77	26.19	26.32

Table 2

Timing of key events

Event	Measured time (s)	MOD2 time (s)	MOD1 [1] time (s)
Break opened	0	0	0
Scram	9.21 ± .01	11.525	10.6
Primary coolant pump trip	1600 ± 2	1660	1565
Start of core heatup	3800 ± 50	4385	3800
Break isolated	4742 ± 2	5085	4627
SG feed and bleed initiated	5415 ± 5	5308	4878
Accumulator injection	5558 ± 3	5501	5099
Core quenched	5800 ± 50	5650	5200
LPIS	6785 ± 2	6285	-

LIST OF FIGURES

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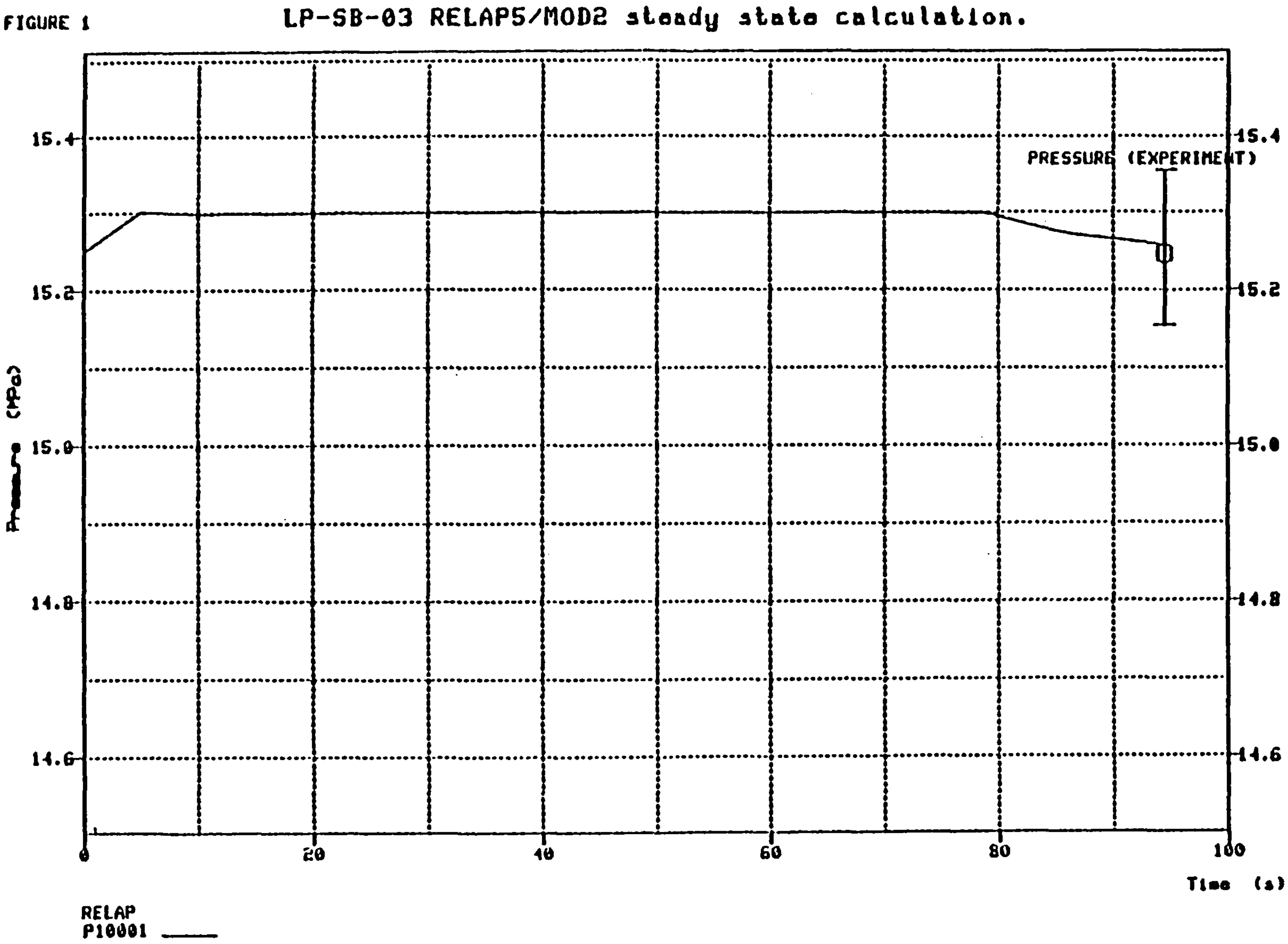
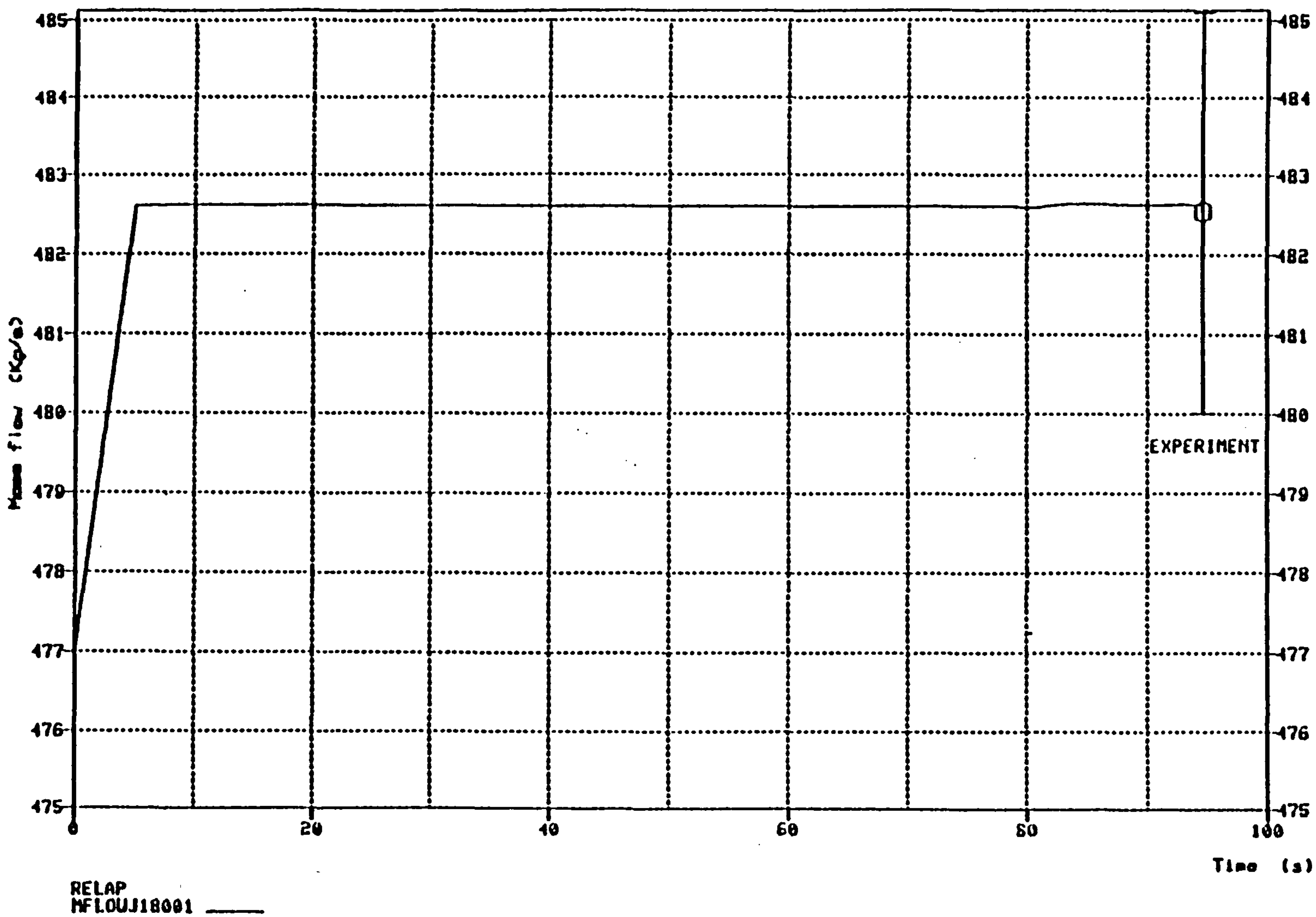
FIGURE 1



Primary pressure.

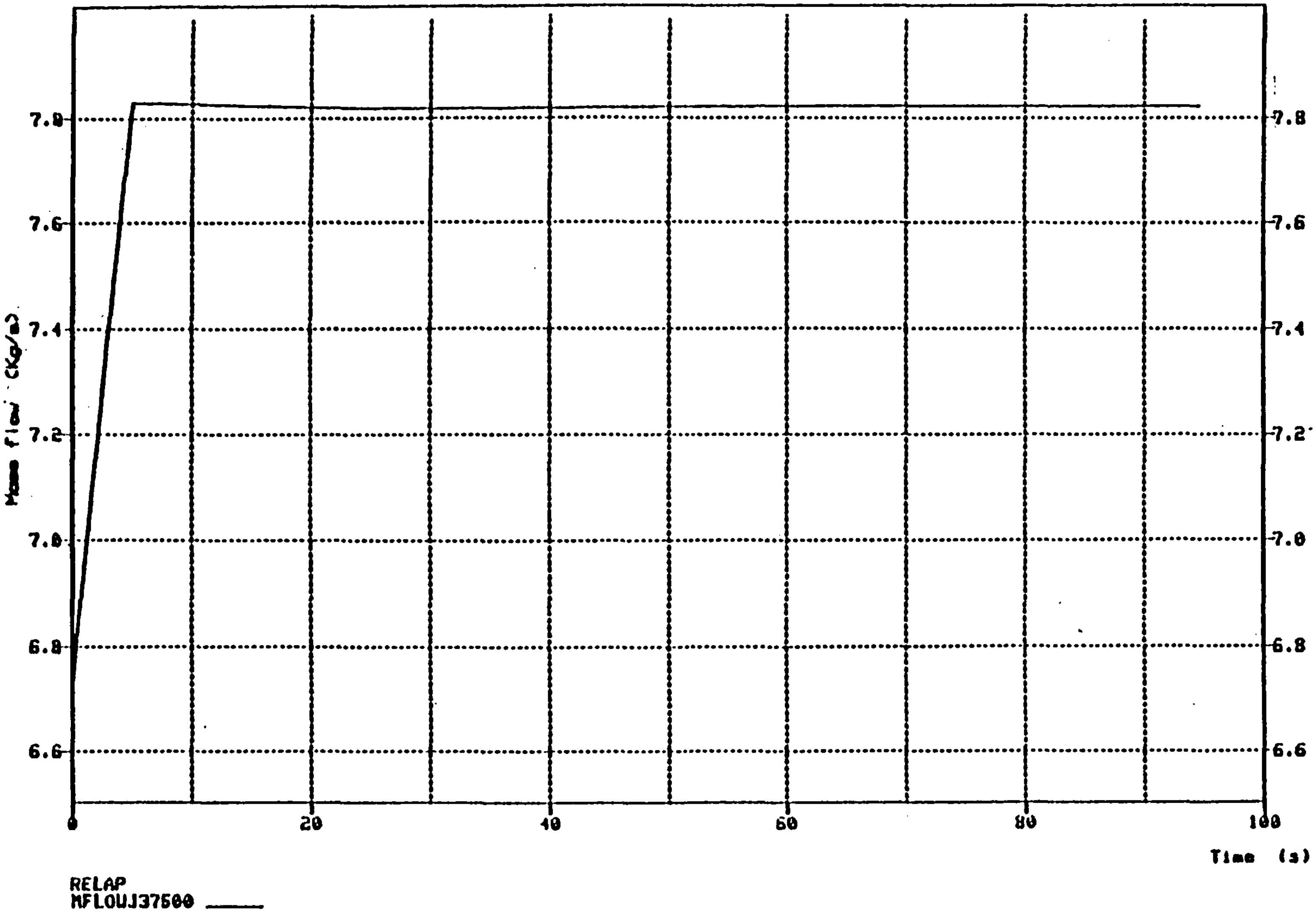
FIGURE 8

LP-SB-03 RELAP5/MOD2 steady state calculation.



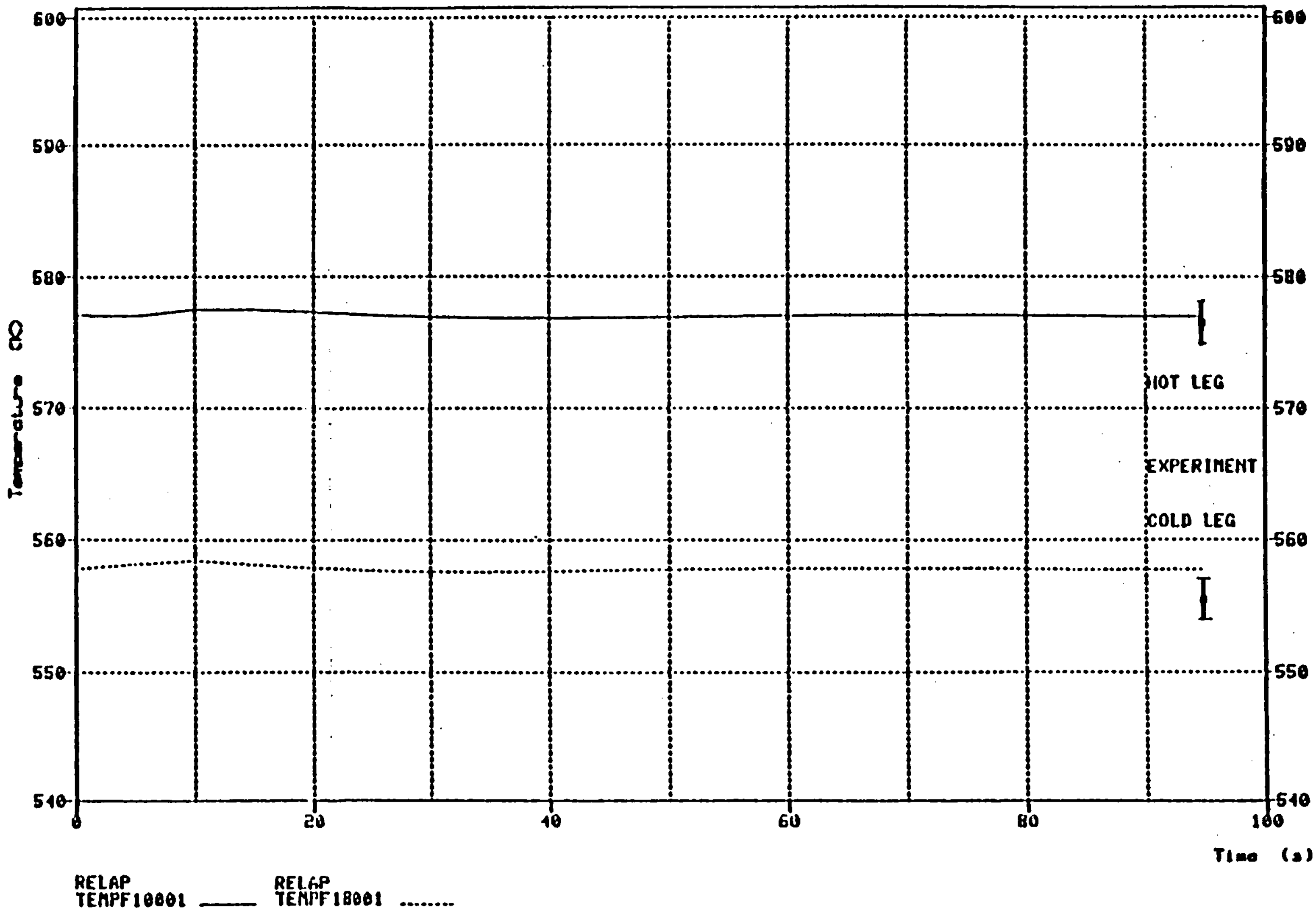
Active loop mass flow.

FIGURE 3 LP-SB-03 RELAP5/MOD2 steady state calculation.



Inactive loop mass flow.

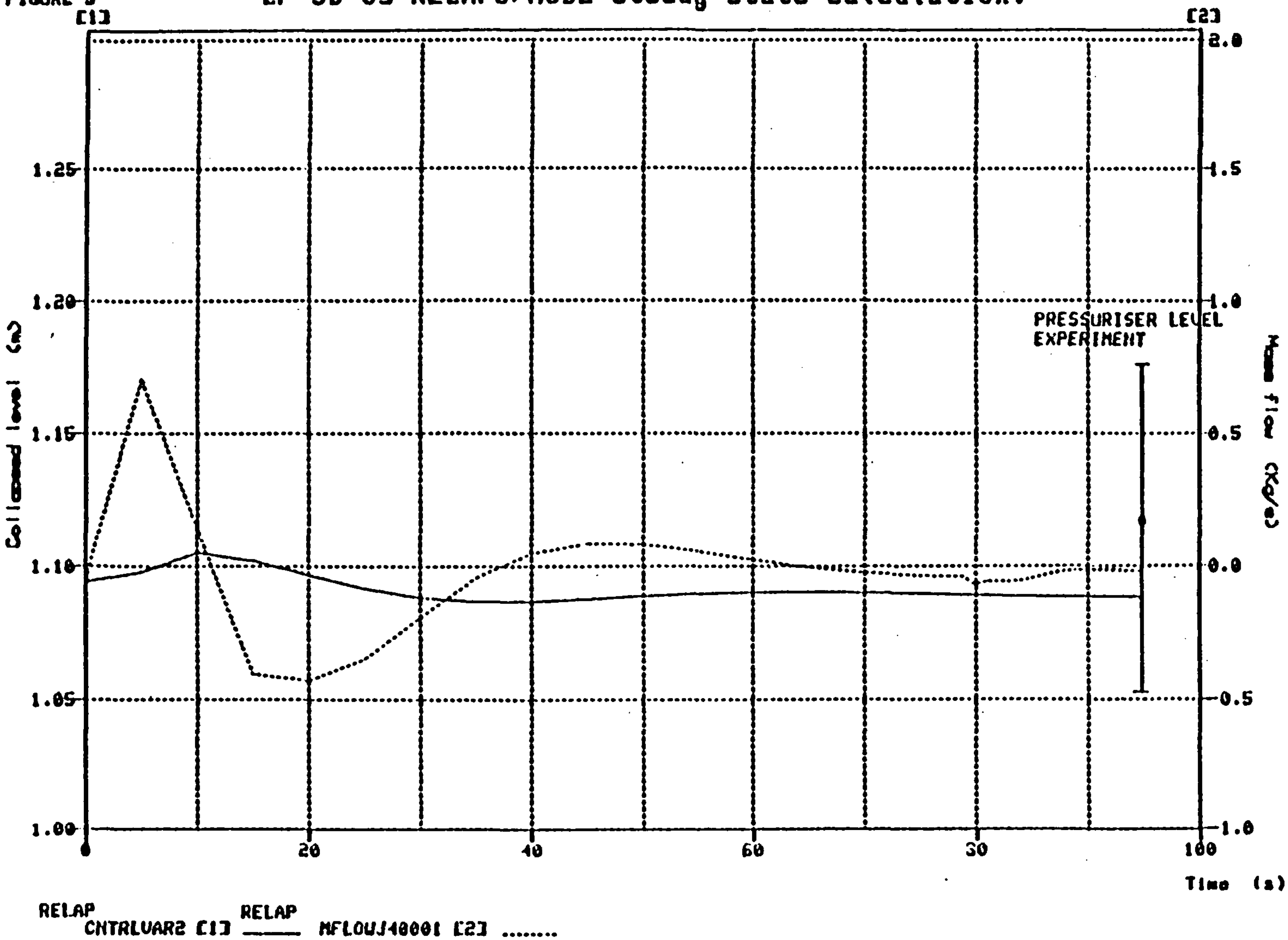
FIGURE 4 LP-SB-03 RELAP5/MOD2 steady state calculation.



Hot and cold leg coolant temperatures.

FIGURE 5

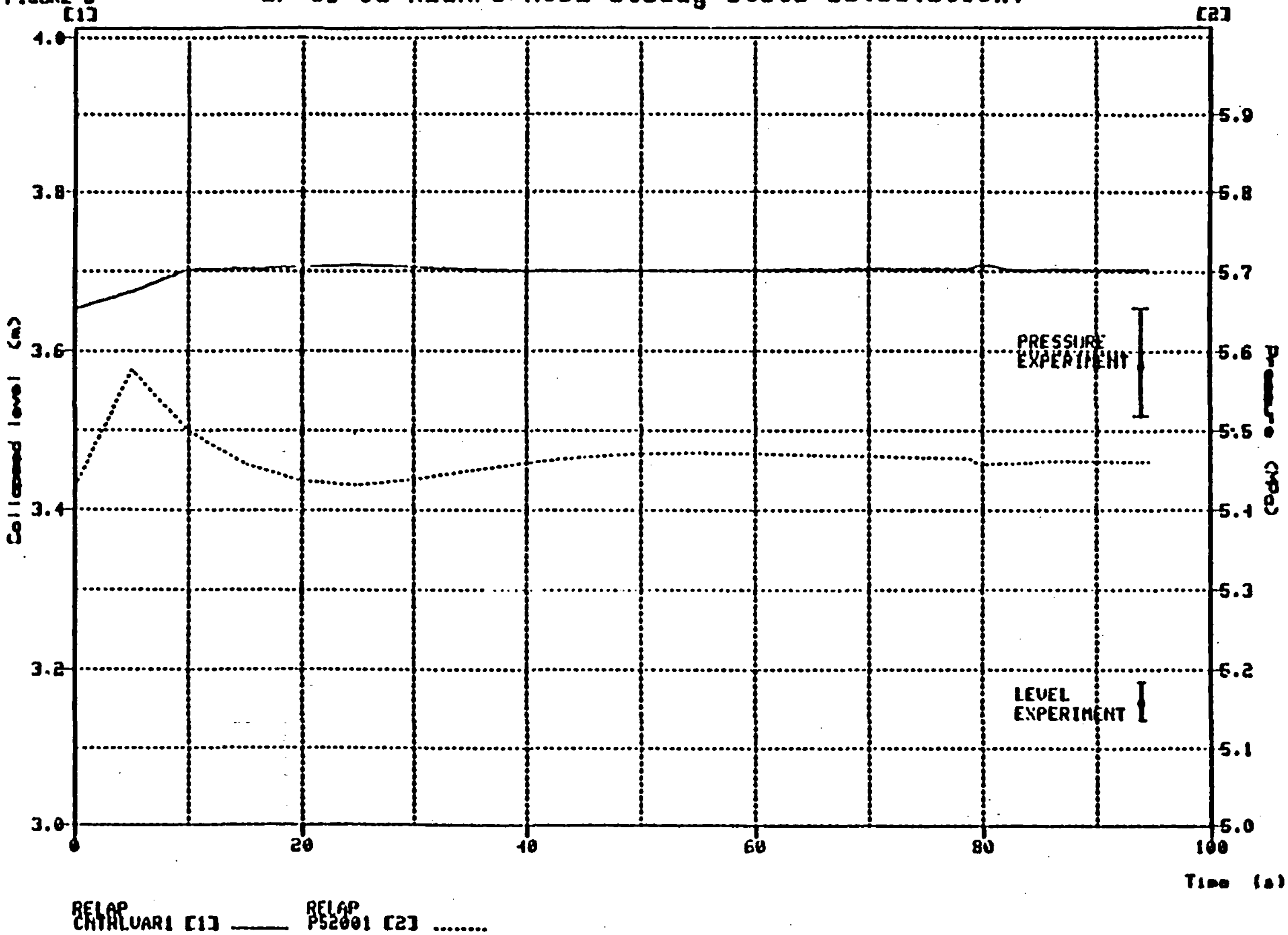
LP-SB-03 RELAP5/MOD2 steady state calculation.



Pressuriser level and surge line flow.

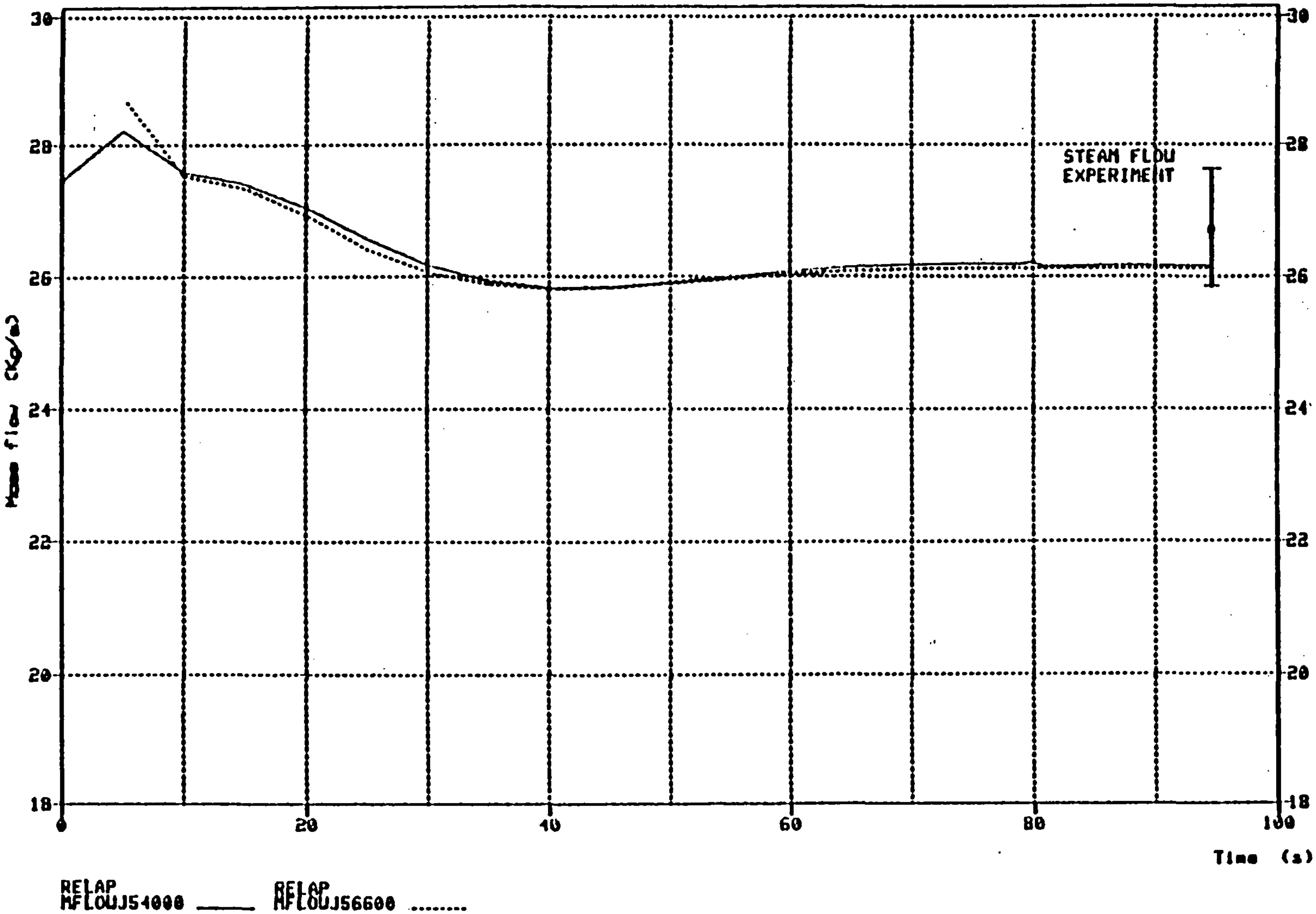
FIGURE 6

LP-SB-03 RELAP5/MOD2 steady state calculation.

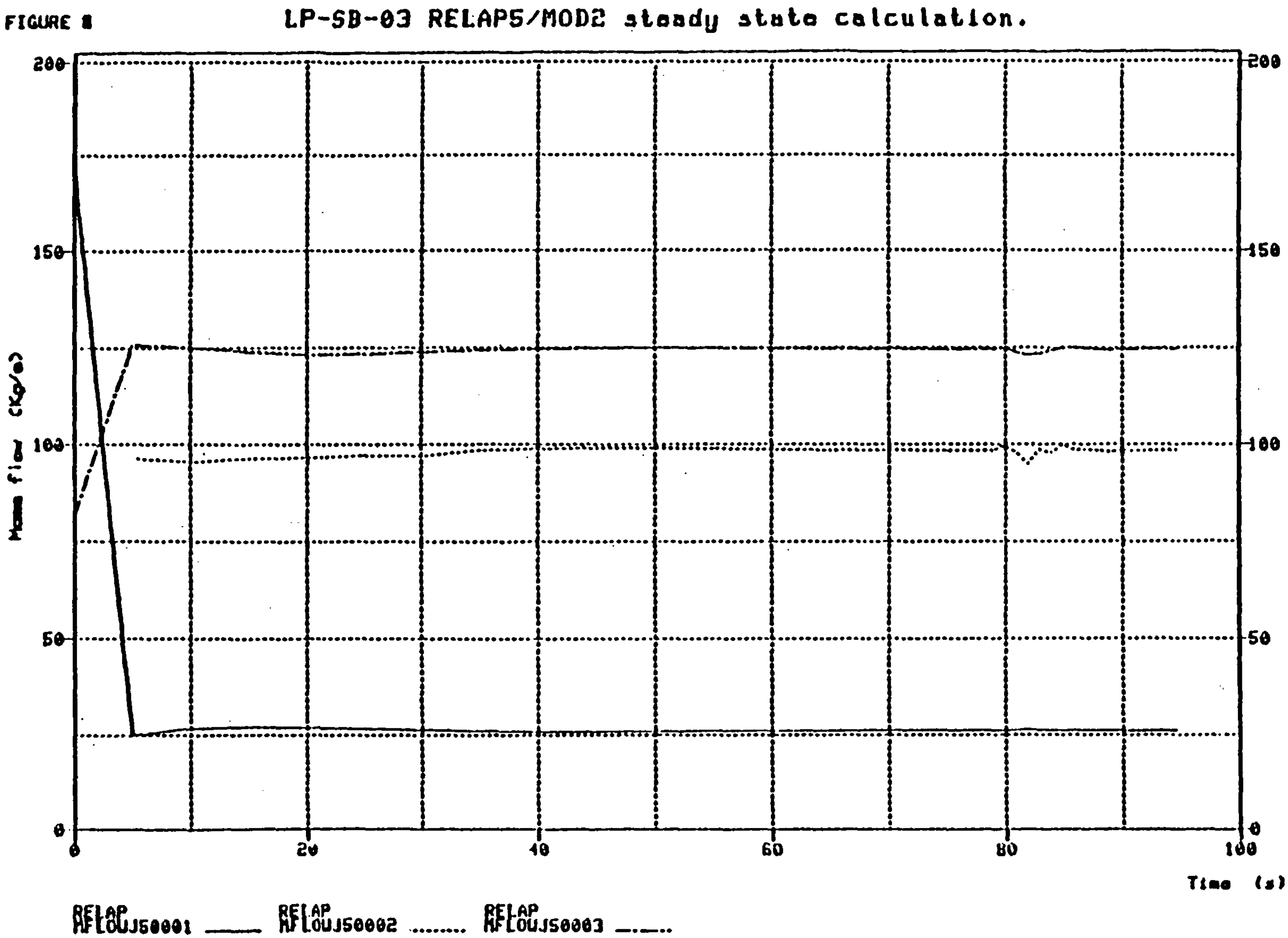


Steam generator level and pressure.

FIGURE 7 LP-SB-03 RELAP5/MOD2 steady state calculation.



Steam generator steam and feed flow.



SG separator steam, liquid return, and mixture inlet flows.

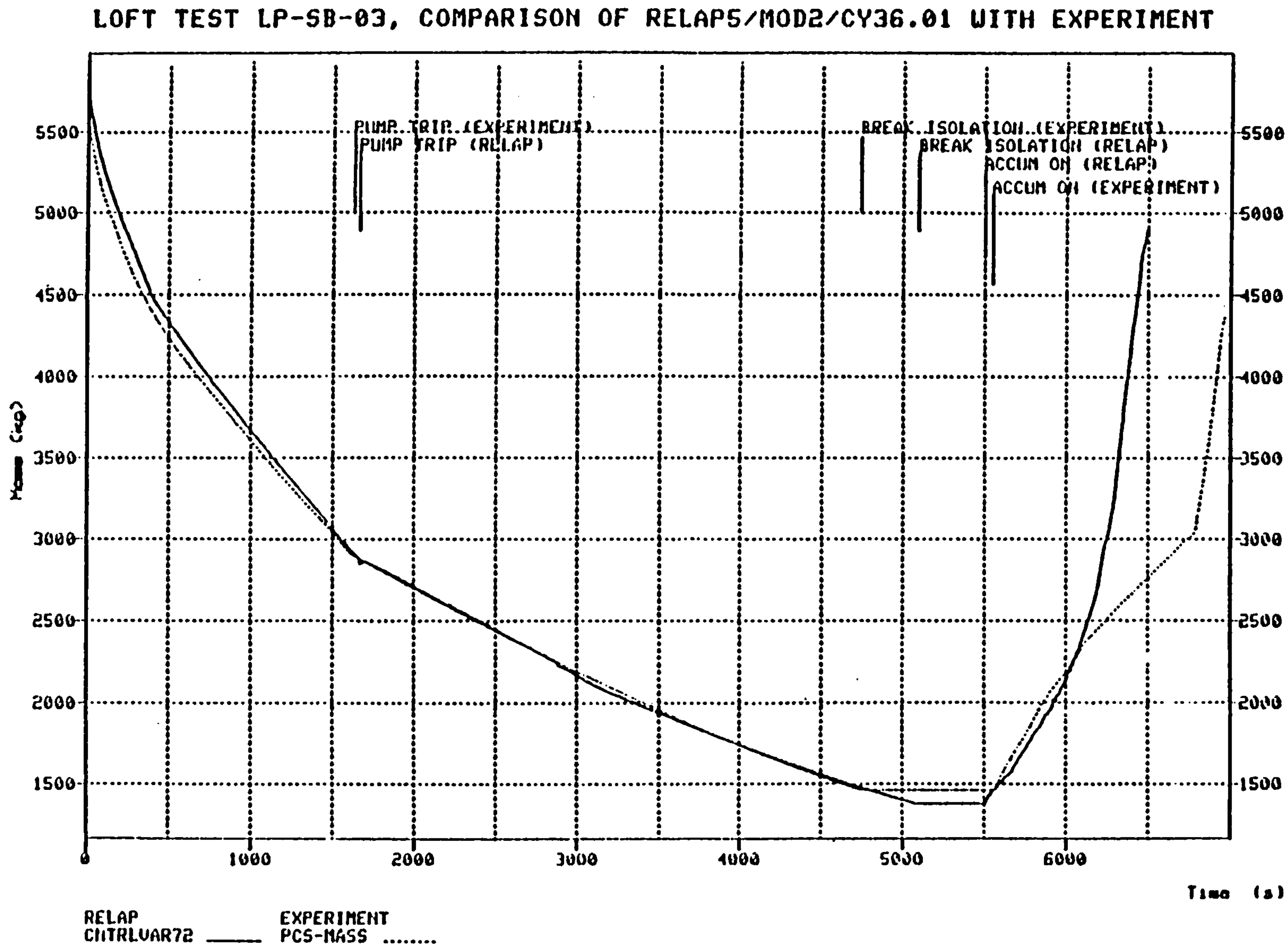
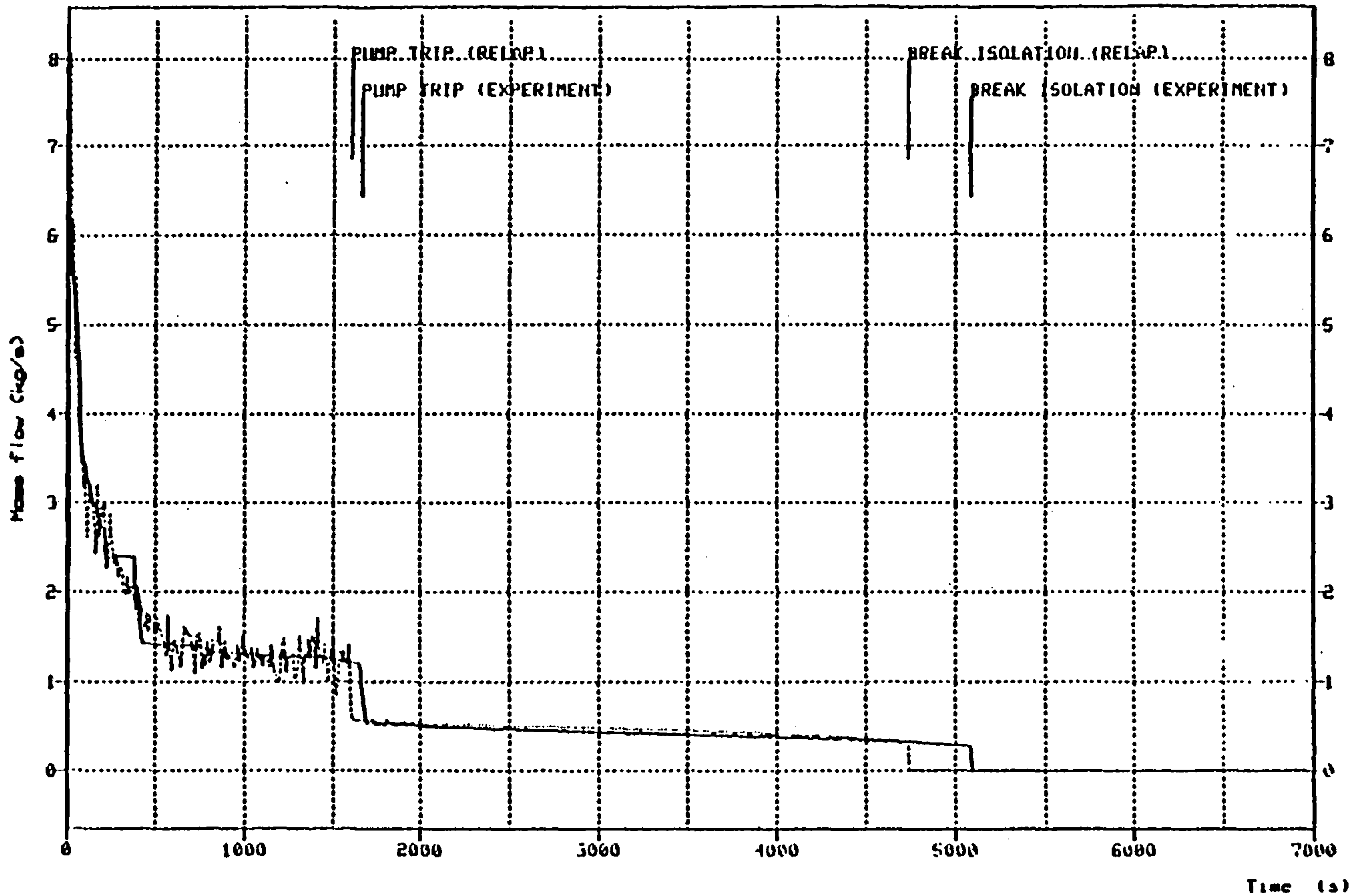


FIGURE 9 Primary system coolant inventory.

LOFT TEST LP-SB-03, COMPARISON OF RELAP5/MOD2/CY36.01 WITH EXPERIMENT.

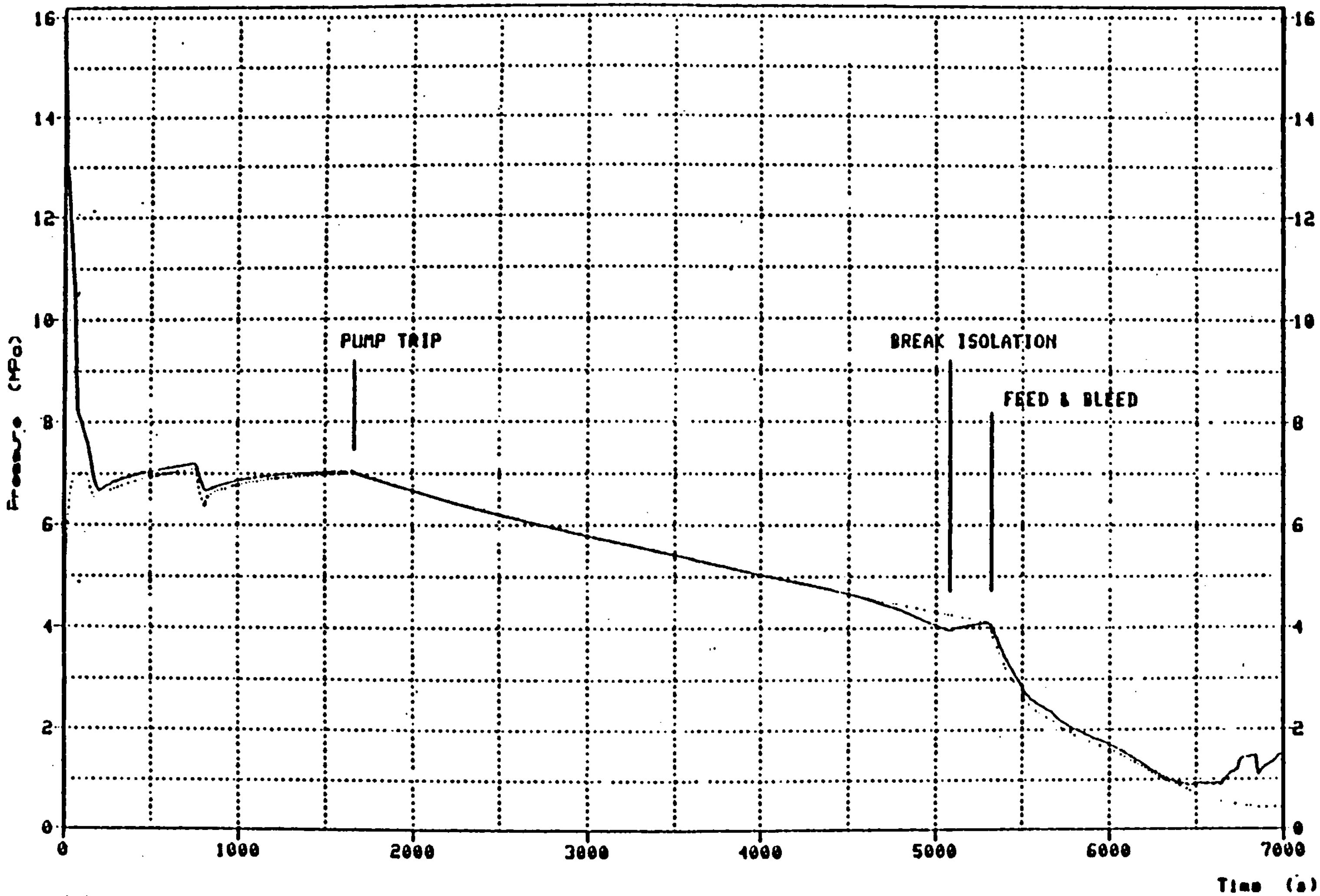


RELAP MFLOWJ18300 ——— EXPERIMENT FR-PC-BRK ....

FIGURE 10 Break flow.

VISION REFERENCE FILE LP-SB-3:LOFT11

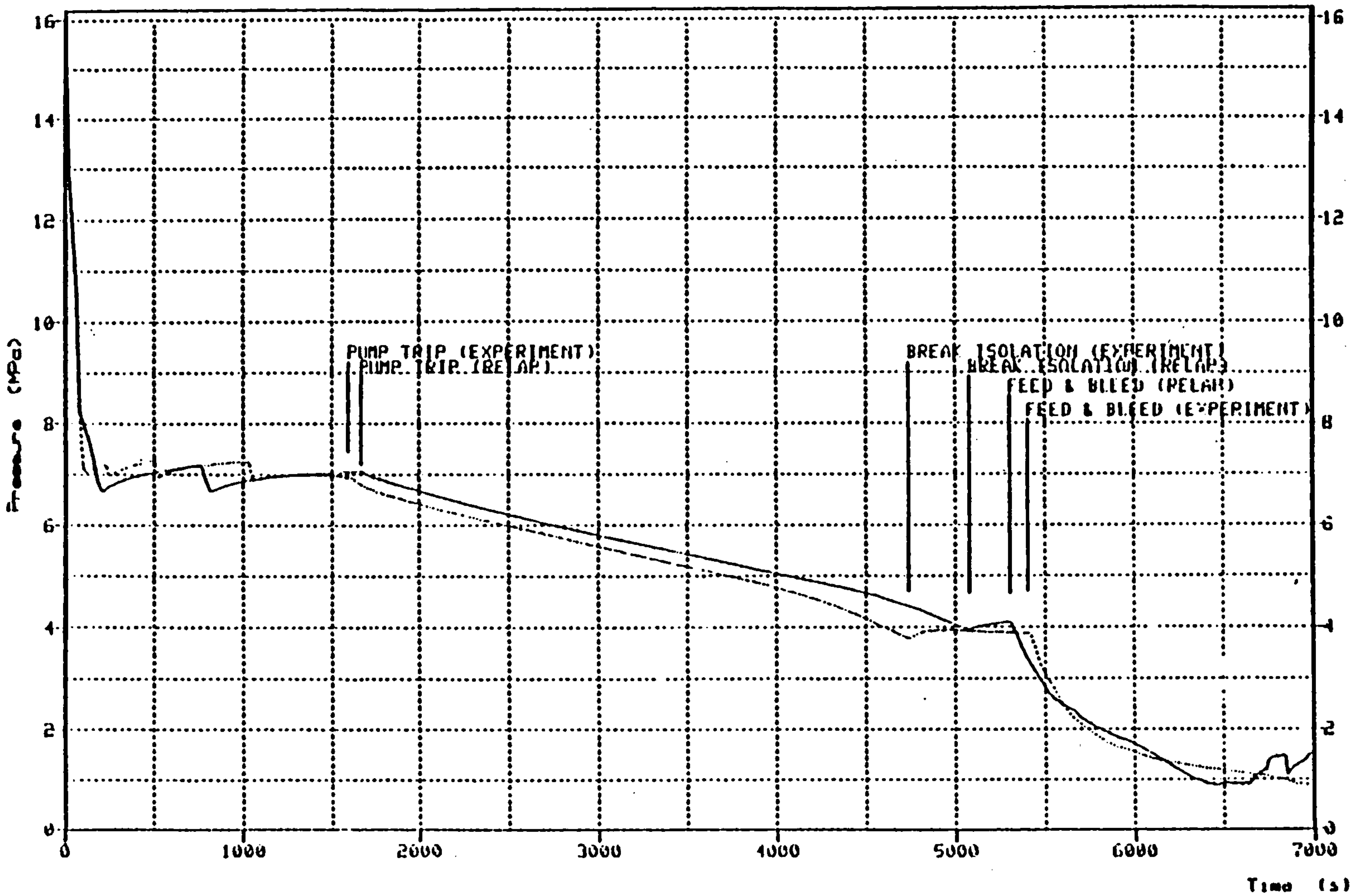
LOFT TEST LP-SB-03, RELAP5/MOD2/CY36.01 RESULTS.



RELAP P10001 ——— RELAP P52001 ....

FIGURE 11 Primary and secondary pressure.

LOFT TEST LP-SB-03, COMPARISON OF RELAP5/MOD2/CY36.01 WITH EXPERIMENT.



RELAP P10001 ———— EXPERIMENT PE-PC-002 ....

FIGURE 12 Primary pressure.

LOFT TEST LP-SB-03, COMPARISON OF RELAP5/MOD2/CY36.01 WITH EXPERIMENT.

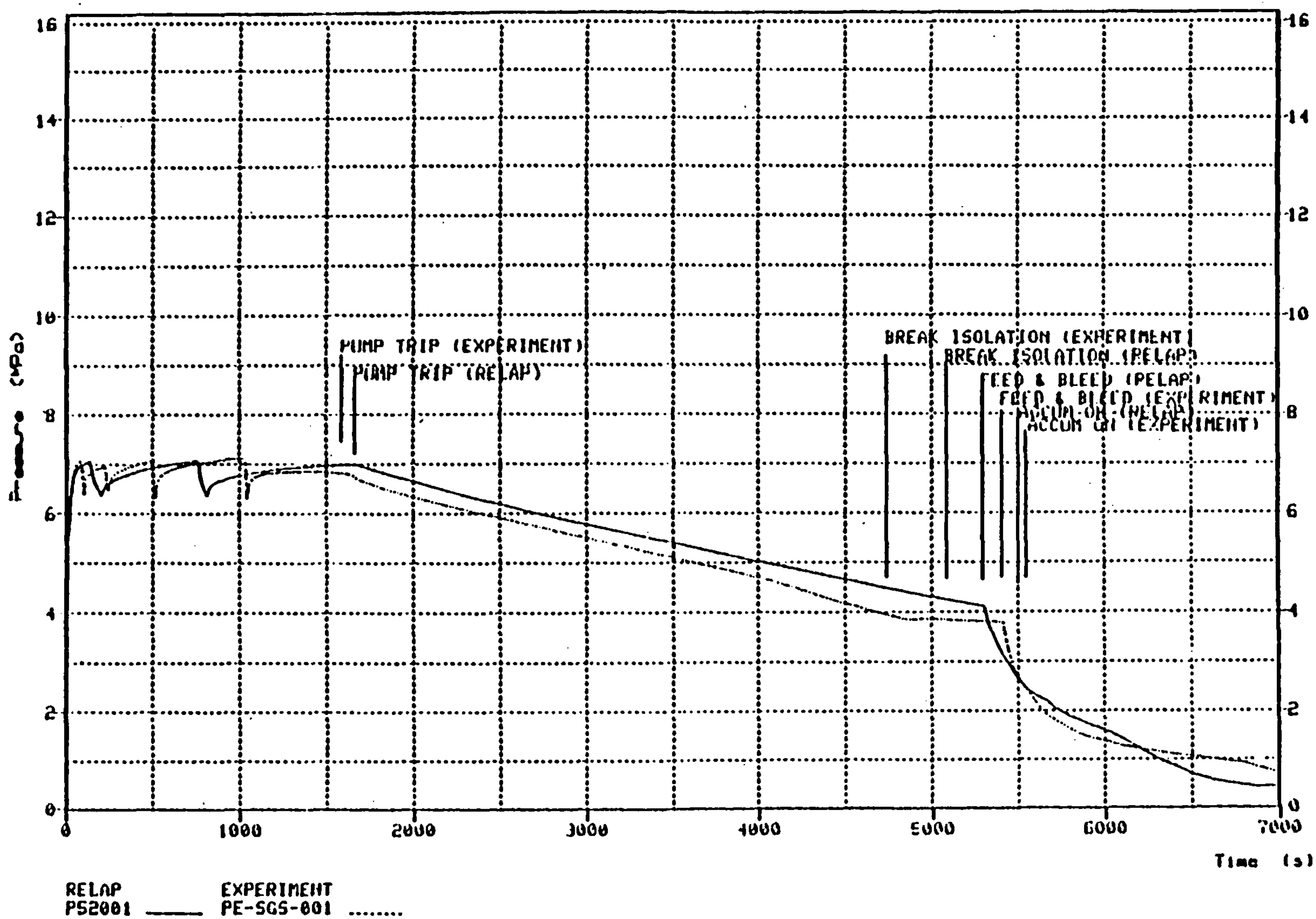


FIGURE 13 Secondary pressure.

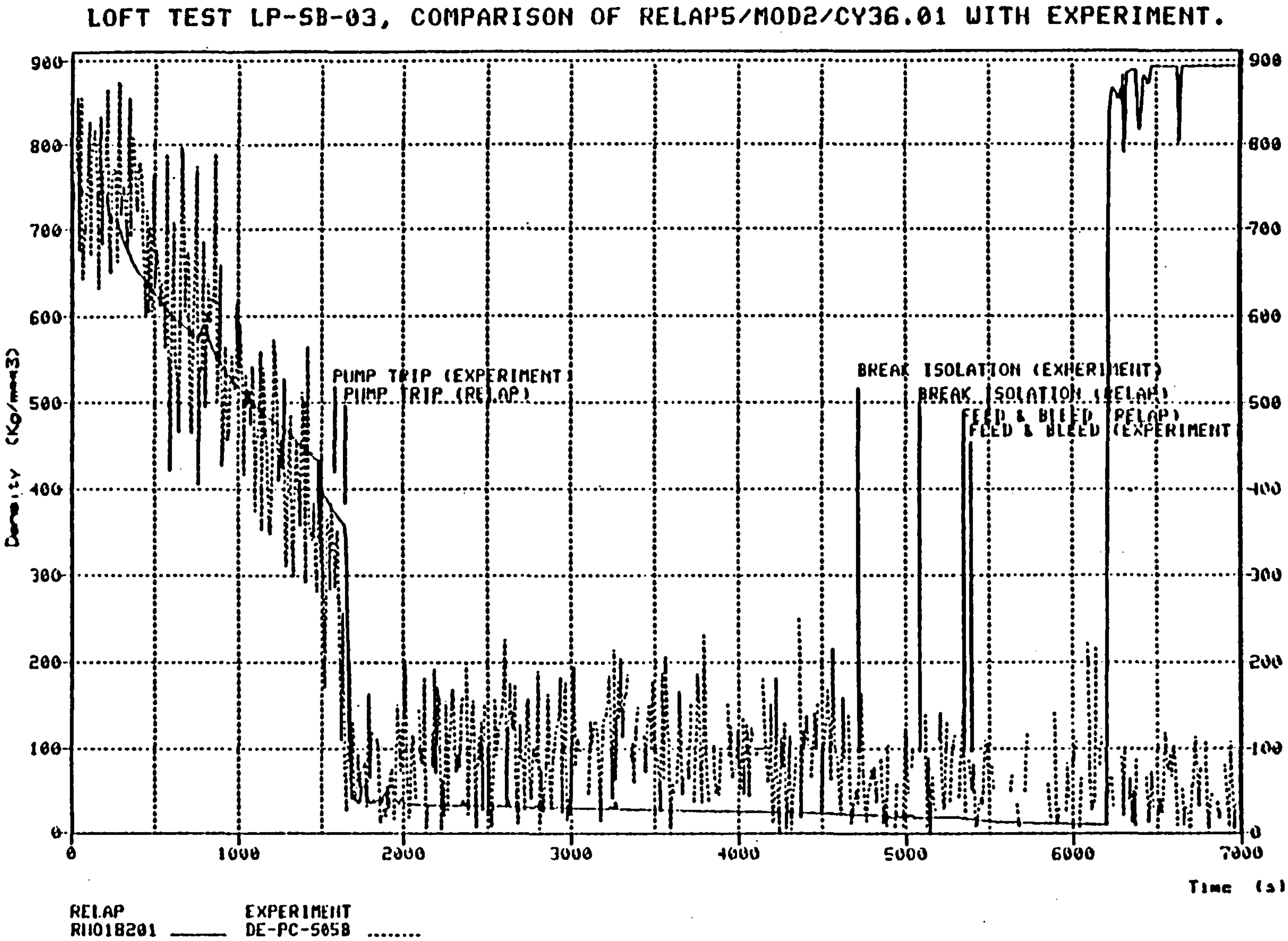


FIGURE 14 Break line density.

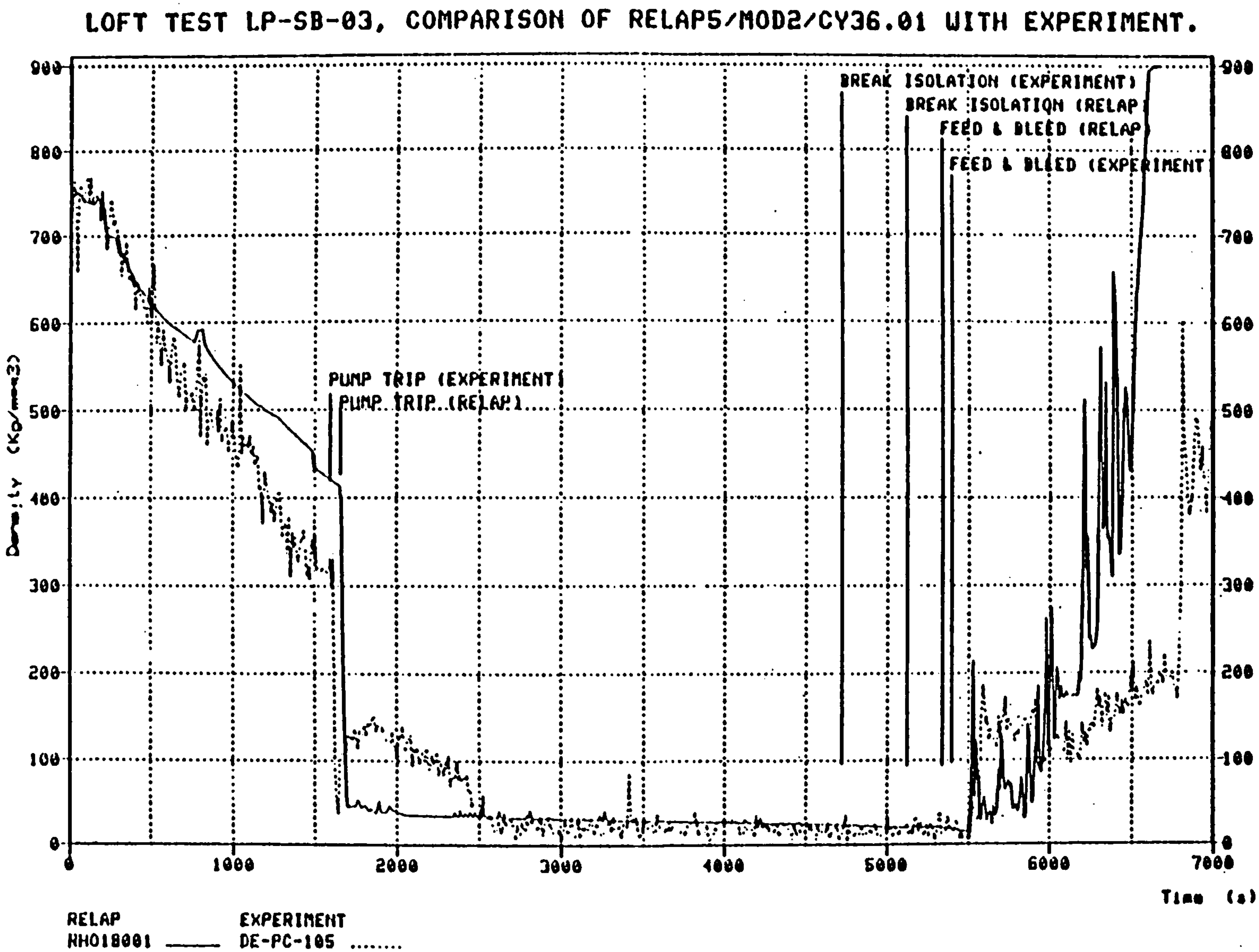
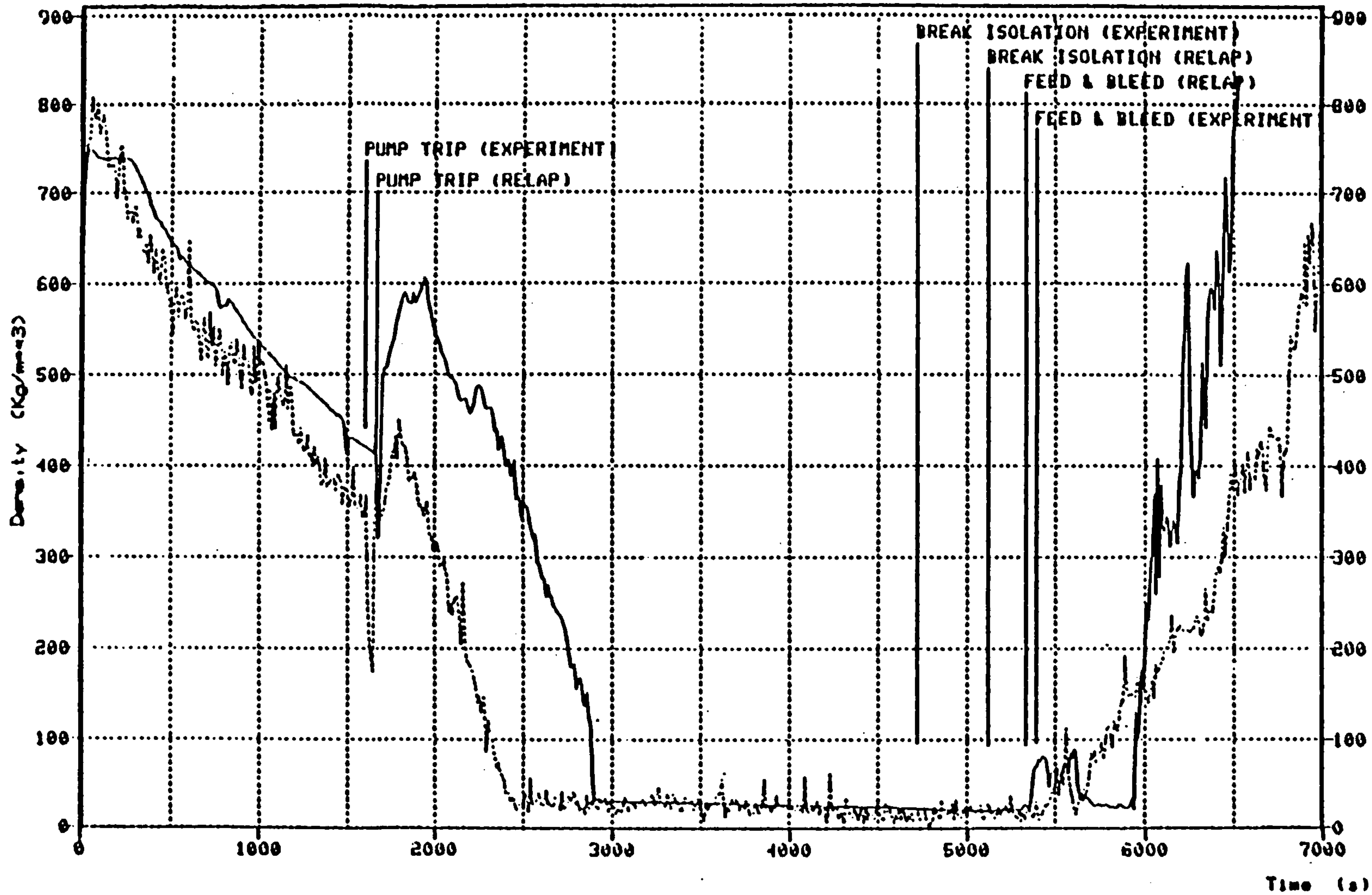


FIGURE 15 Cold leg density.

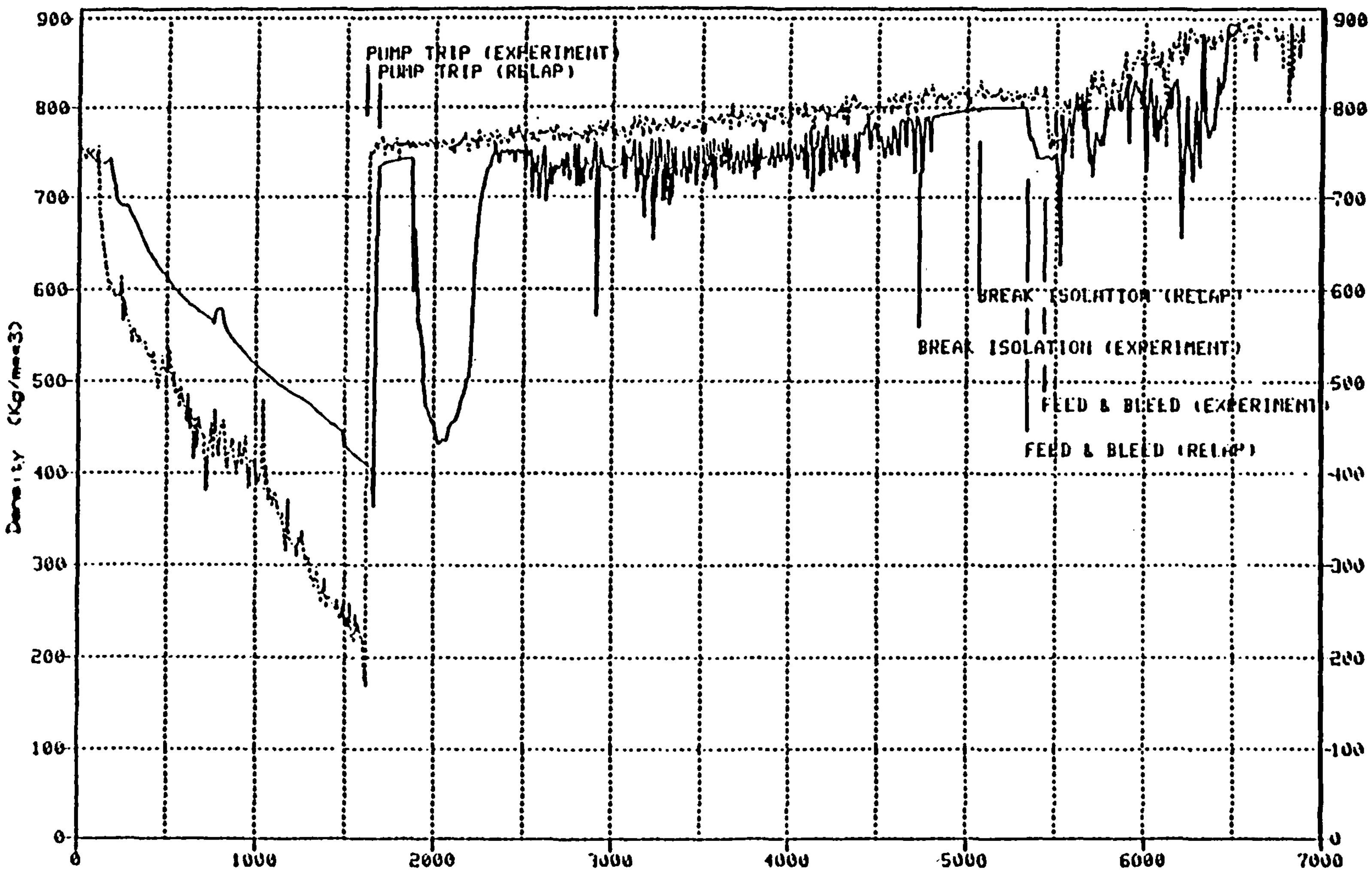
LOFT TEST LP-SB-03, COMPARISON OF RELAP5/MOD2/CY36.01 WITH EXPERIMENT.



RELAP RH010001 ———— EXPERIMENT DE-PC-205 ....

FIGURE 16 Hot leg density.

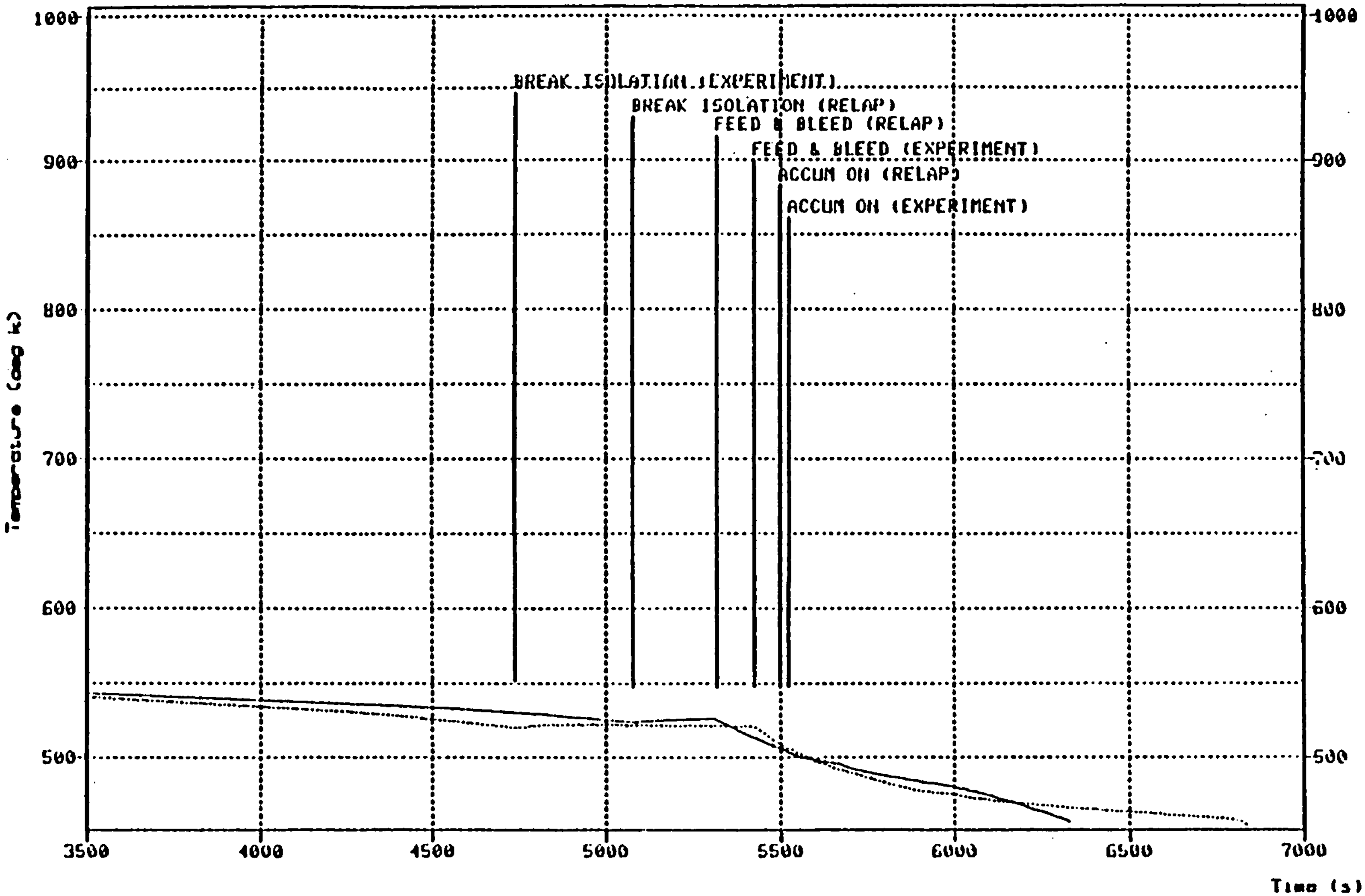
LOFT TEST LP-SB-03, COMPARISON OF RELAP5/MOD2/CY36.01 WITH EXPERIMENT.



RELAP RH011B02 ——— EXPERIMENT DE-PC-003B ....

FIGURE 17 Loop seal downside density.

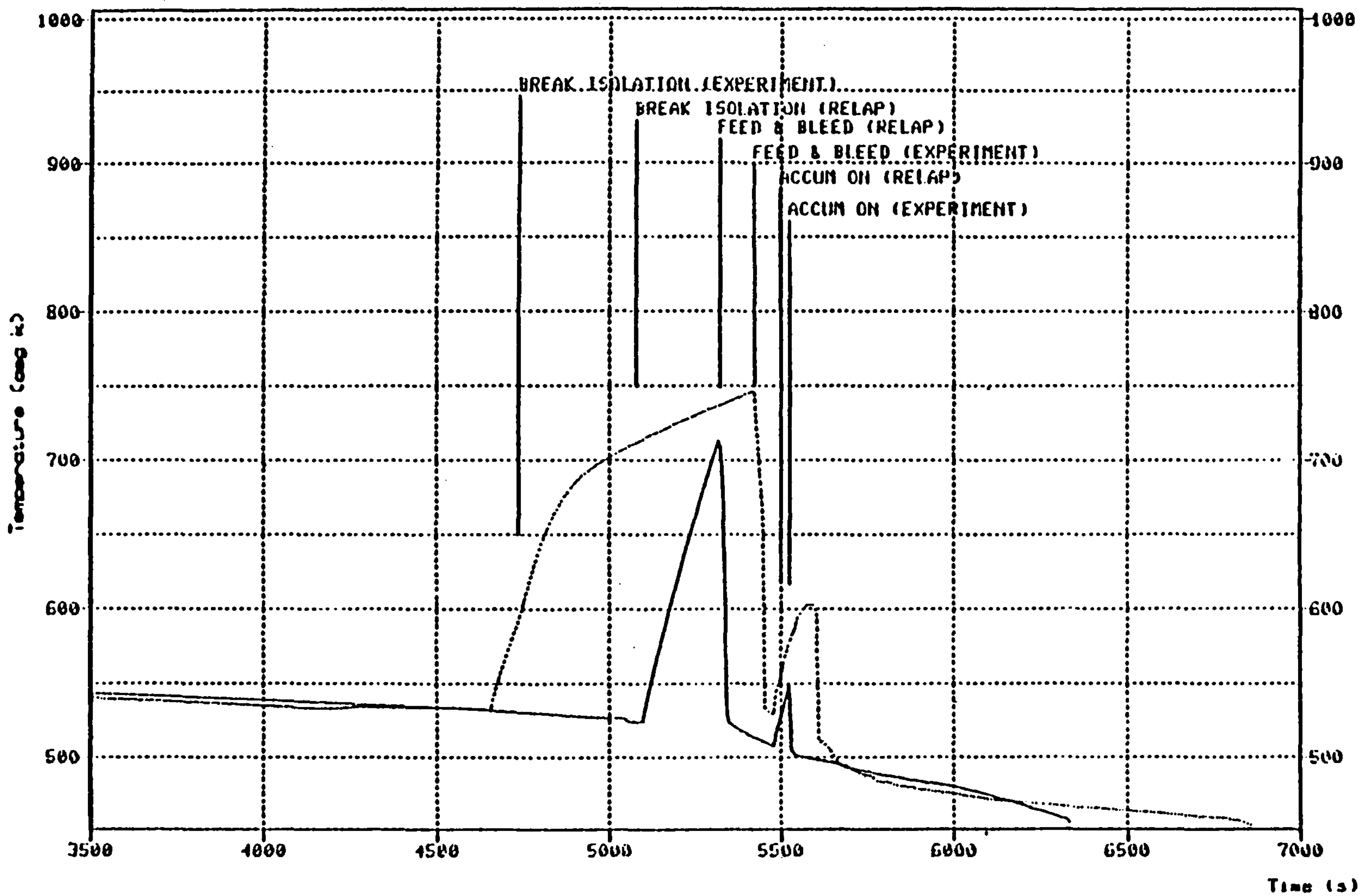
LOFT TEST LP-SB-03, COMPARISON OF RELAP5/MOD2/CY36.01 WITH EXPERIMENT.



RELAP TEMP23000110 ______ EXPERIMENT TE-5106-005 ....

FIGURE 18 Clad temperature, 0.14m level.

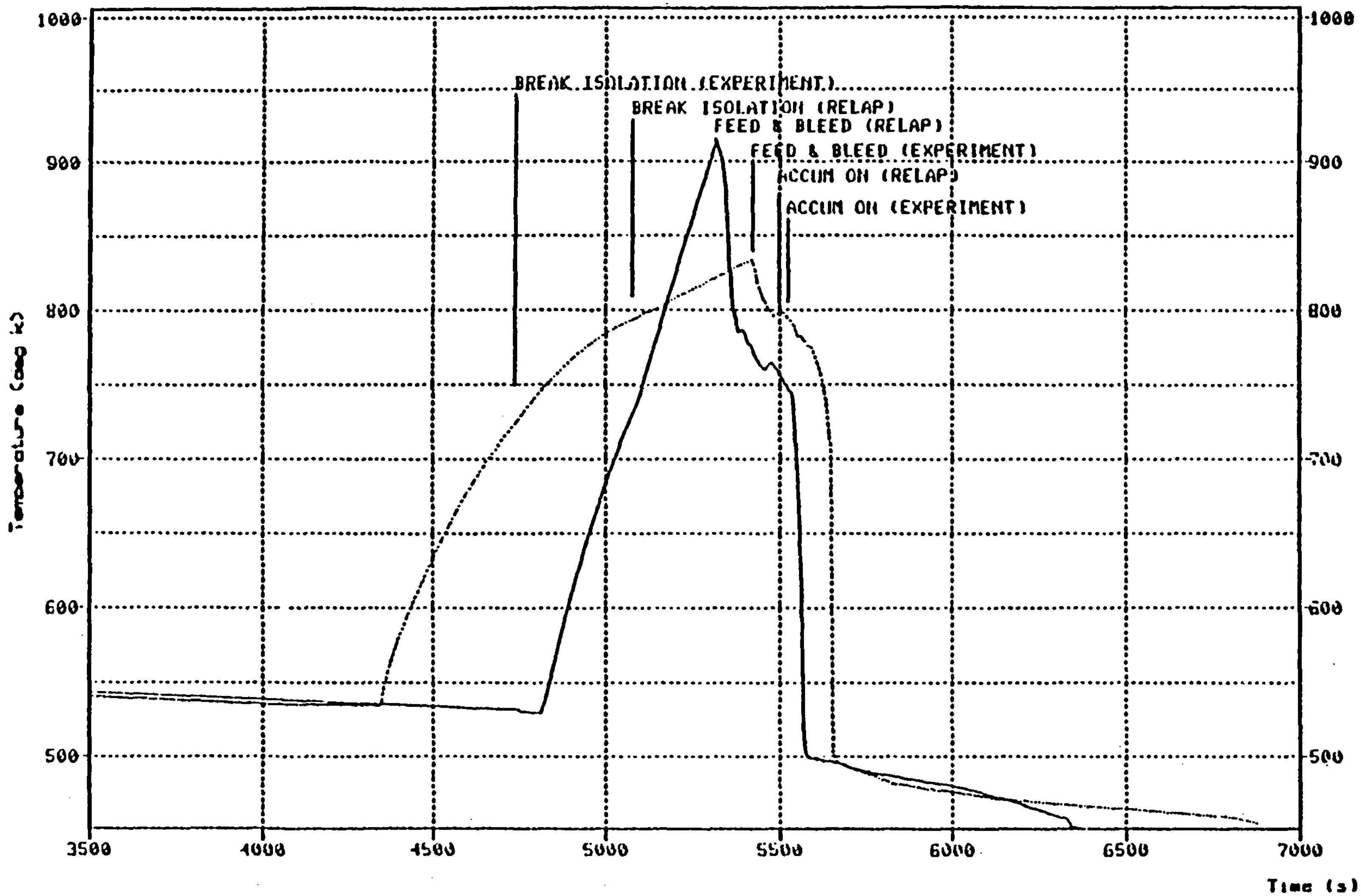
LOFT TEST LP-SB-03, COMPARISON OF RELAP5/MOD2/CY36.01 WITH EXPERIMENT.



RELAP TEMP23000210 ______ EXPERIMENT TE-4H13-015 ....

FIGURE 19 Clad temperature, 0.42m level.

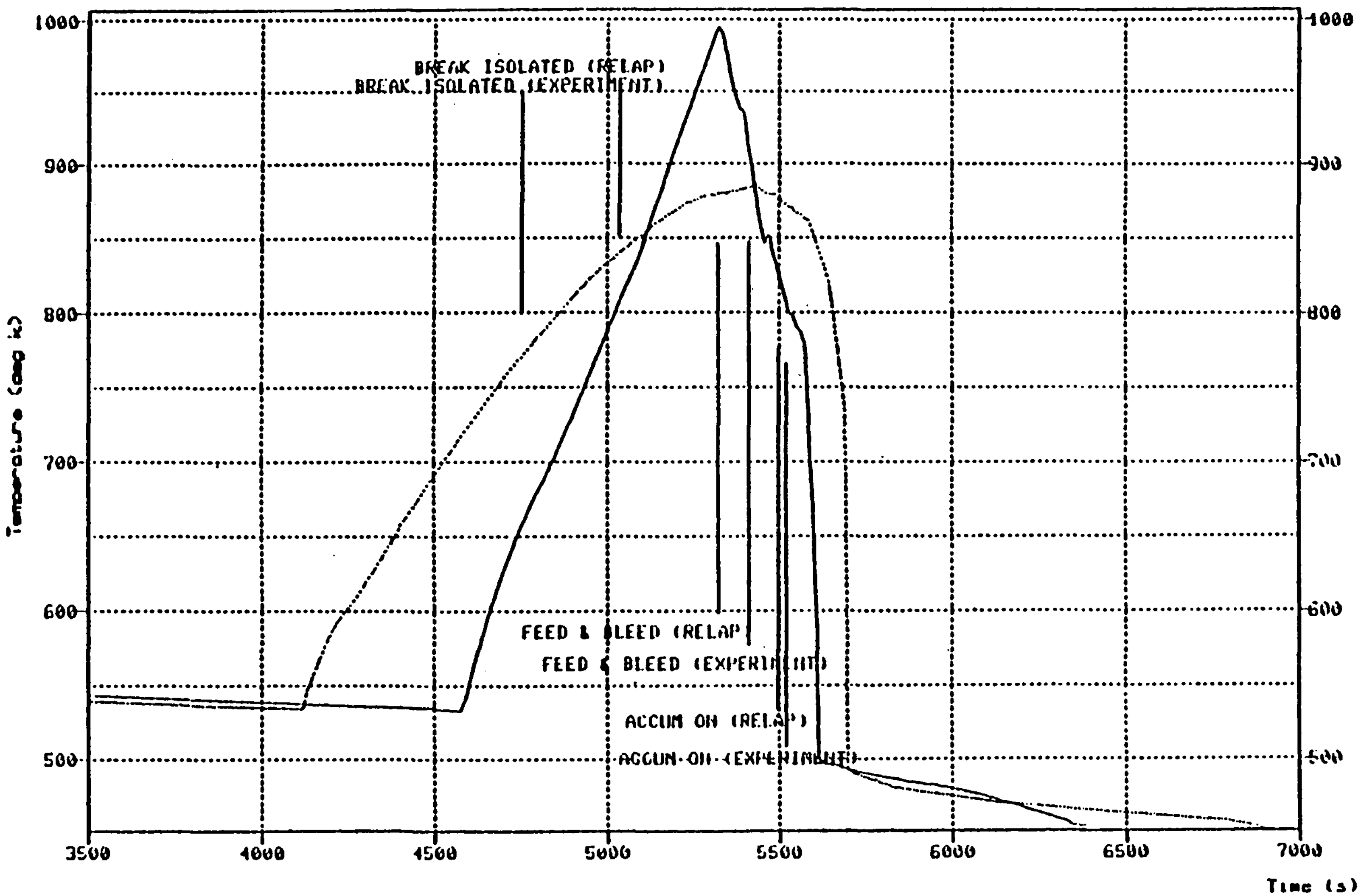
LOFT TEST LP-SB-03, COMPARISON OF RELAP5/MOD2/CY36.01 WITH EXPERIMENT.



RELAP TEMP23000310 ______ EXPERIMENT TE-4H14-028 ....

FIGURE 20 Clad temperature, 0.70m level.

LOFT TEST LP-SB-03, COMPARISON OF RELAP5/MOD2/CY36.01 WITH EXPERIMENT.

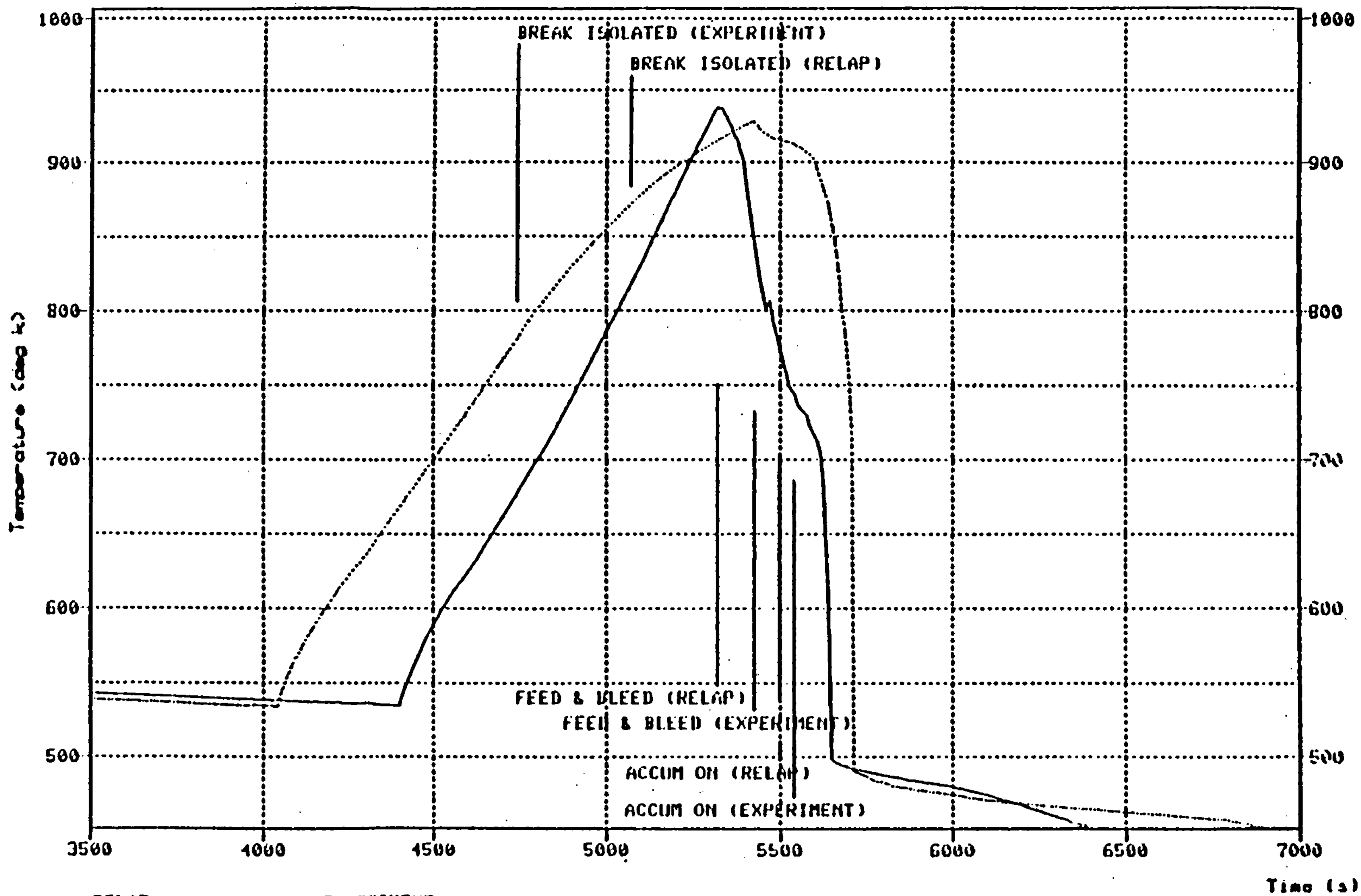


RELAP
TEMP23000410 ______

EXPERIMENT
TE-4114-039 ....

FIGURE 21 Clad temperature, 0.98m level.

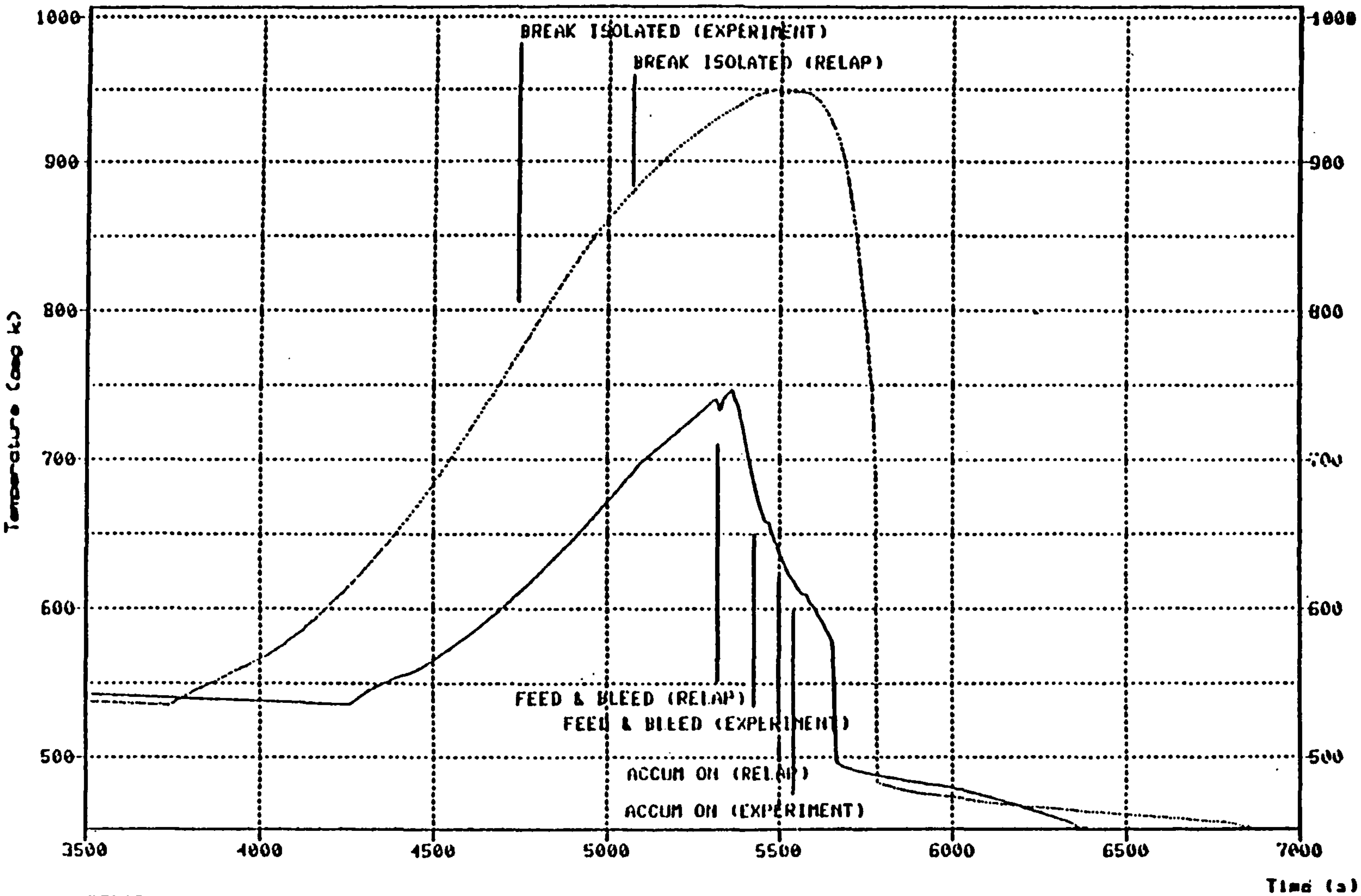
LOFT TEST LP-SB-03, COMPARISON OF RELAP5/MOD2/CY36.01 WITH EXPERIMENT.



RELAP TEMP23000510 ______ EXPERIMENT TE-2H13-049 ....

FIGURE 22 Clad temperature, 1.26m level.

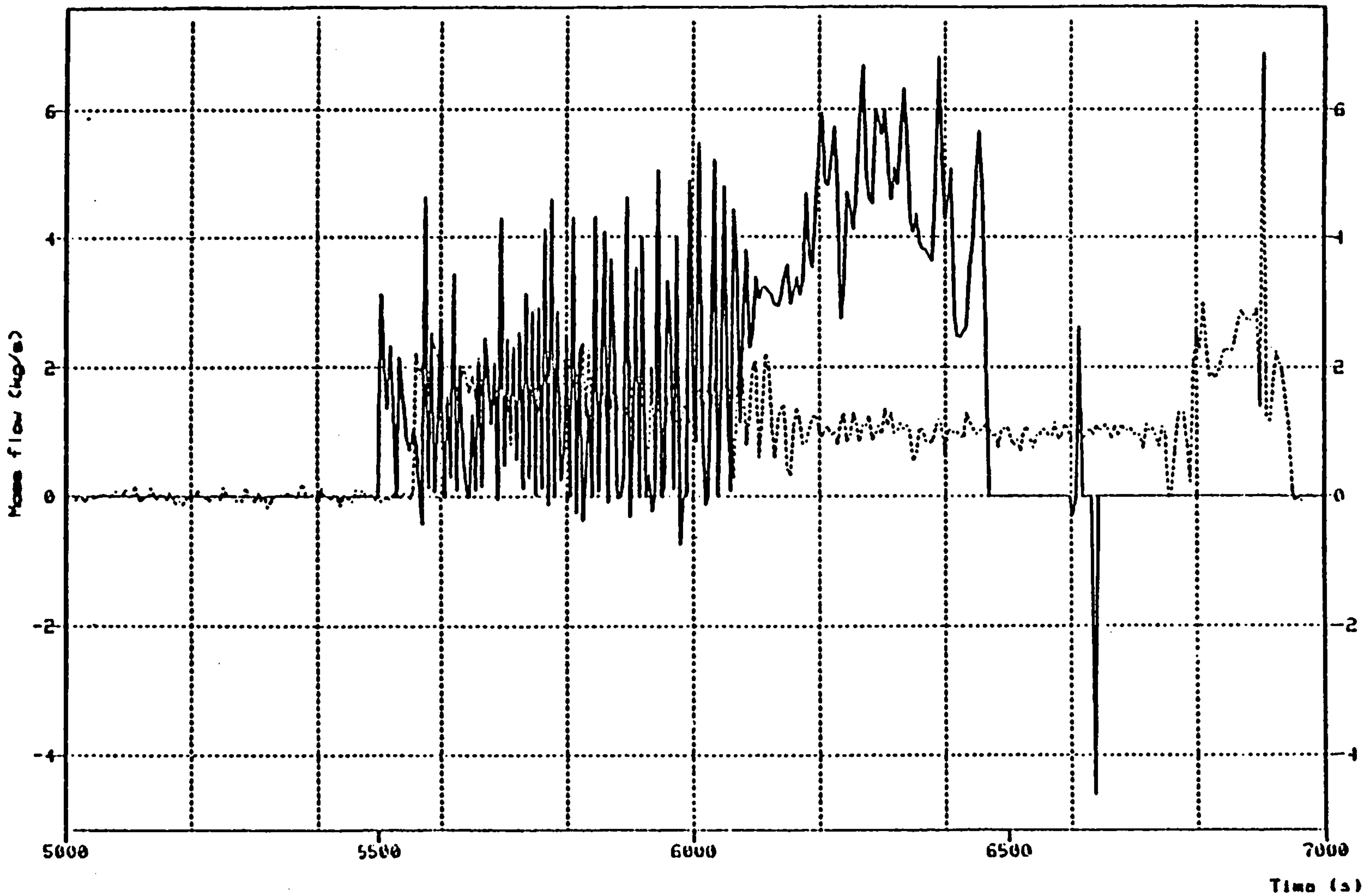
LOFT TEST LP-SB-03, COMPARISON OF RELAP5/MOD2/CY36.01 WITH EXPERIMENT.



RELAP TEMP23000610 ______ EXPERIMENT TE-5G06-062 ....

FIGURE 23 Clad temperature, 1.59m level.

LOFT TEST LP-SB-03, COMPARISON OF RELAP5/MOD2/CY36.01 WITH EXPERIMENT.



RELAP
MFLOWJ61000 ______

EXPERIMENT
FR-ECC-01A ....

FIGURE 24 Accumulator flow.

LOFT TEST LP-SB-03, COMPARISON OF RELAP5/MOD2/CY36.01 WITH EXPERIMENT.

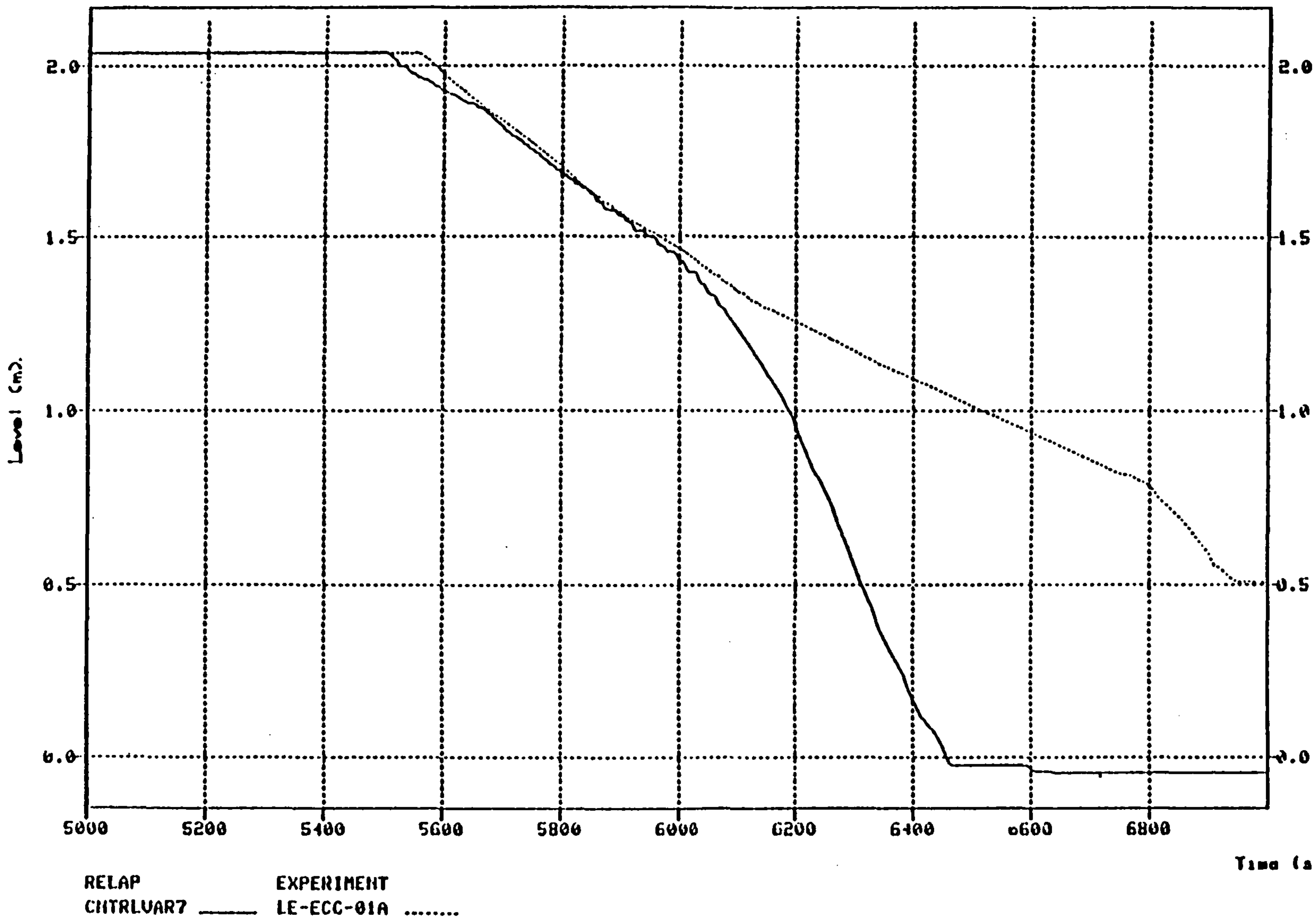


FIGURE 25 Accumulator level.

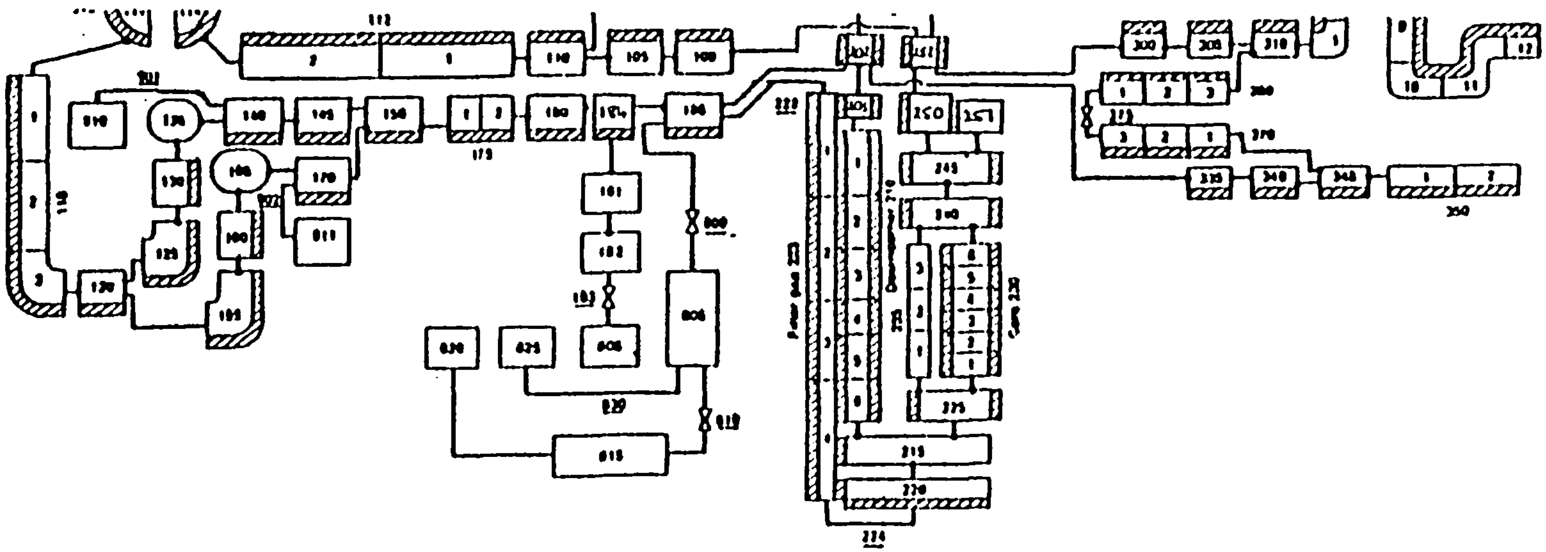


Figure 26 LOFT RELAP5 nodalization for Experiment LP-SB-3.

Modified from OECD LOFT-T-3603

NRC FORM 335 (2-84) NRCM 1102, 3201, 3202

U.S. NUCLEAR REGULATORY COMMISSION

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This report compares the results of the RELAP5/MOD2 analysis with experimental measurements.

A simulation of test LP-SB-03 was previously carried out at GDCD using the RELAP5/MOD1 code. RELAP5/MOD2 was developed from RELAP5/MOD1 and contains more sophisticated hydraulic models and constitutive relationships. Comparison of the RELAP5/MOD2 and MOD1 calculations show that RELAP5/MOD2 performs better than RELAP5/MOD1 in a number of key areas; notably mass errors are much reduced, there is improved numerical stability, and improved separator modelling and modelling of accumulator injection.

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