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RELAP5 PRETEST ANALYSIS OF TEST S-PL-3

R. A. Shaw

Idaho National Engineering Laboratory
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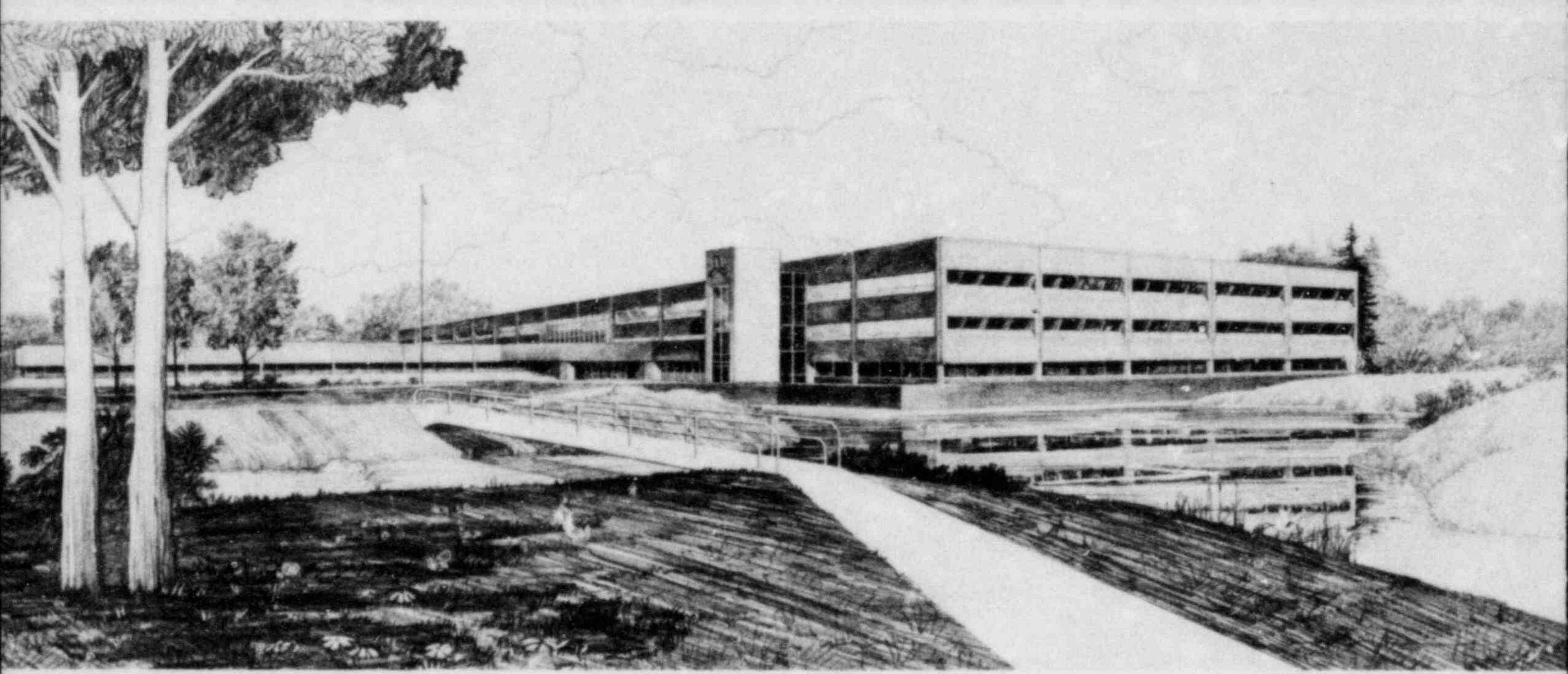

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R. A. Shaw

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EG&G Idaho, Inc.
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INTERIM REPORT

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1. INTRODUCTION

Test S-PL-3 will be performed on the Semiscale Mod-2B system and will simulate a station blackout with auxiliary feedwater failure.[1] This test will be similar to Test S-PL-2 except that the initial conditions will represent the technical specification limits for 100% power operation. These initial conditions (see Table 1) were expected to change the initial response of the system from that observed in Test S-PL-2 and were chosen to increase the severity of the transient by shortening the time available for the operator to initiate recovery procedures.

The objectives of the subject calculations are to aid the experiment planners and operators conducting the test and to provide an unbiased basis for the assessment of the RELAP5/MOD1 computer code's capability to predict the thermal-hydraulic responses of a loss-of-offsite power (LOP) transient.

The pretest analysis in this report addresses two separate areas of concern: the accident signature and recovery capability. One calculation commences from steady state and proceeds until the primary coolant system (PCS) reaches the specified relief valve setpoint. The results of this run will provide insight into the accident signature. The second calculation was started with near dry steam generators, continues as the PCS saturates at the power operated relief valve (PORV) setpoint where recovery procedures are initiated, and finally ending after the heater rods are quenched and the system recovered. The results for both calculations are presented individually and their interdependence is discussed.

Section 2 provides a brief experiment description. The RELAP5 modeling and calculational techniques are given in Section 3. The results of the calculations are presented in Section 4 and conclusions are given in Section 5.

TABLE 1. SPECIFIED AND CALCULATED INITIAL CONDITIONS FOR TEST S-PL-3

	Specified	Calculated
1. Primary Coolant System		
Intact/Broken Loop Flow Rate Ratio	3:1	2.9:1
Primary Flow Rate-Cold Leg		
Intact loop	7.3 kg/s	7.5 kg/s
Broken loop	2.4 kg/s	2.6 kg/s
Pressurizer Pressure	14.8 ± .2 MPa	14.7 MPa
Pressurizer Fluid Level (Measured cold from zero elevation reference)	216 ± 5 cm	211.6 cm
Pressurizer Relief Valve Setpoint		
Simulated Code Safety	15.9 ± .2 MPa	15.9 MPa
Total Core Power	2.18 ± .05 MW	2.199 MW
Cold Leg Fluid Temperature	567 ± 2 K	561.5 K
Hot Leg Fluid Temperature	605 ± 2 K	598.5 K
2. Secondary Coolant System		
S. G. Steam Dome Pressure	As required	5.66 MPa
S. G. Secondary Side Mass		
Intact loop	62.2 ± 1 kg	56.8 kg
Broken loop	20.8 ± 1 kg	24.5 kg
S. G. Relief Valve Setpoint	7.22 ± .2 MPa	7.22 MPa

2. EXPERIMENT DESCRIPTION

Steady-state initial conditions will be established by varying pressure and feedwater/steam mass flow rates in the steam generators. Transient initiation will occur with the simulated loss of offsite AC power. At this time both main steam valves close. Two seconds later the intact loop (IL) and broken loop (BL) pumps begin controlled coastdown and feedwater to both steam generators is stopped. SCRAM is scheduled to occur five seconds into the transient. The system will continue in this mode until both steam generators dry out and the PCS pressure reaches the PORV setpoint. The exact time that recovery should begin will be one of the conclusions of this report. Actual recovery will be achieved by reducing the PCS temperature at a rate of 56 K/hr by cycling the PORV until the primary pressue is within the specified feed and bleed operating band.[2] By this time the high pressure injection system (HPIS) will be enabled and the recovery procedures will be initiated. The test will continue until the heater rods have been quenched and the system recovered.

3. RELAP5 MODEL DESCRIPTION

The RELAP5 model used for the pretest prediction of Test S-PL-3 is basically similar to those used for Semiscale models in prior S-PL series tests. The model consists of 160 hydrodynamic volumes and 197 heat structures. It was assumed that the external guard heaters used in the Semiscale facility exactly offset environmental losses from the PCS, thus the external boundary of all primary piping and vessels was modeled as an abiabatic boundary. Use of the external boundary in this assumption allows the thermal energy stored in the metal of the primary piping and vessels to be considered in the calculation. Core power was input to the model by table and was at all times augmented by an amount equal to the calculated energy losses from the secondary side to the environment. The experiment operating procedure will include this practice. The nodalization diagram for this model is shown in Figure 1.

Cycle 19 of the RELAP5/MOD1 computer code[3] was used for the calculations. This code is retained under the INEL configuration control number F01047. An update to include the Biasi critical heat flux correlation and another to provide an improved interfacial drag correlation were utilized in the calculations. The use of these updates provided a better characterization of the primary-to-secondary heat transfer under the very low initial steam generator mass inventories specified for this experiment.

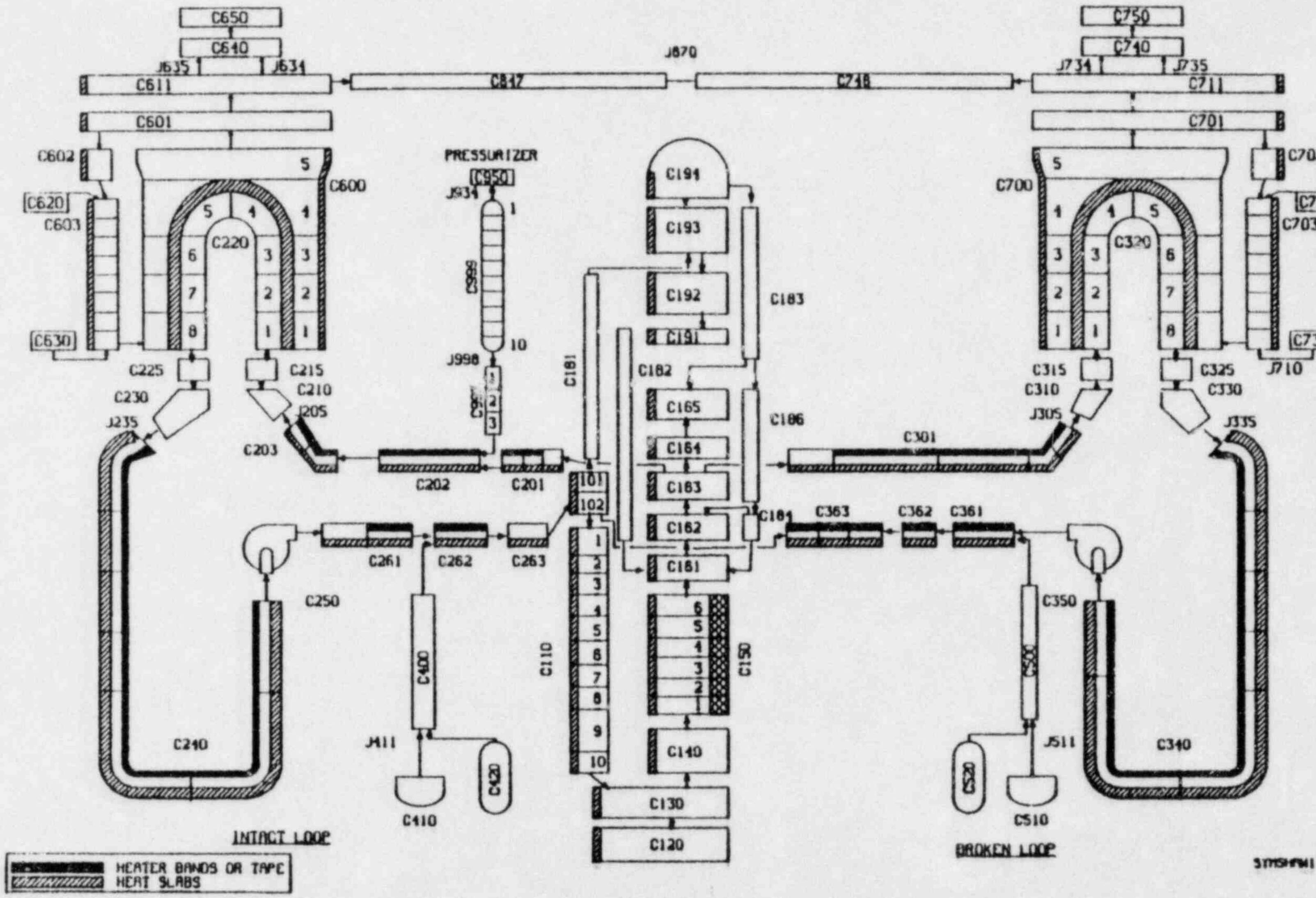

Figure 1. RELAP5 Semiscale/Mod2B nodalization diagram for the S-PL-3 precest predictions.

4. ANALYSIS RESULTS

4.1 Accident Signature

Pressurizer pressure is shown in Figure 2. At initiation of the transient (t = 0s) the main steam valves closed and two seconds later the IL and BL pump coastdown began (see Table 2). These occurrances resulted in a rapid pressurization of the PCS due to heatup and expansion of the coolant. This expansion is seen in the pressurizer level plot (Figure 3). SCRAM occurred at 5 s which resulted in shrinkage, hence depressurization of the PCS. By 40 s the IL and BL pumps had coasted to a stop and decay heat levels were sufficient to begin repressurization of the PCS. It can be seen in the long term pressurizer pressure plot, Figure 4, that the repressurization continued until the pressurizer pressure reached the relief valve setpoint (2070 s). It was at this time that the first calculation was concluded. Note that the pressurizer relief valve setpoint (15.9 MPa) was not reached in the initial period of the transient nor did the pressurizer empty at any time (Figures 2 and 3). The hot and cold leg temperatures are shown on Figures 5 and 6, respectively. Each hot leg temperature was within one degree of the other and began to rise rapidly when the heat transfer capability of the intact loop steam generator (ILSG) diminished at about 2000 s. The degradation of primary-to-secondary heat transfer in the ILSG was due to mass inventory depletion in that steam generator. This loss of heat transfer can also be seen in the IL cold leg temperature response plot where, at about 2000 s, the IL cold leg temperature began to increase.

The steam generator secondary pressures are presented in Figure 7. Both steam generators pressurized rapidly to the relief valve setpoint (7.2 MPa) following the closure of the steam valve at test initiation. The steam generators remained at this pressure throughout the remainder of the calculation. Feedwater was not discontinued until 2 s after initiation of the transient. This is shown in the mass inventory curves for the steam generators (Figure 8) as the increase in mass before 2 s. The mass in the ILSG was steadily lost through the relief valve and through the steam dome connection into the broken loop steam generator (BLSG) until at

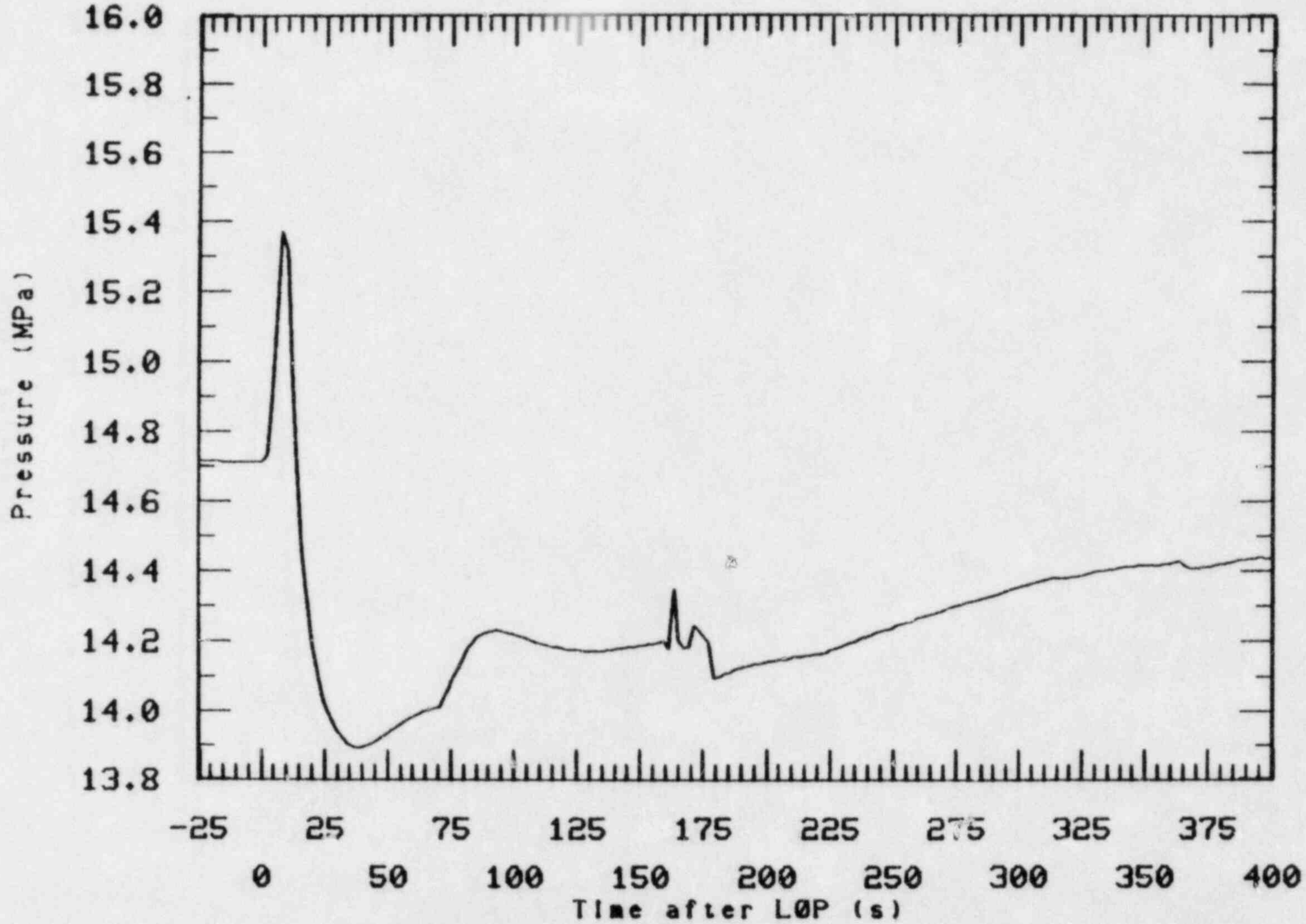

Figure 2. Pressurizer pressure for the S-PL-3 pretest predictions (short term).

TABLE 2. CALCULATED SEQUENCE OF EVENTS FOR TEST S-PL-3

Event	Time(s)
Loss of offsite AC power	0.0
Main steam line valves close	0.0
IL and BL pump coastdown initiated	2.0
Feedwater to IL and BL steam generator tripped off	2.0
SCRAM	5.0
IL and BL pumps coasted to stop	42.0
Steam generator relief valves initially open	305.0
Pressurizer relief valve initially opens	2170.0
ILSG boils dry	2000.0
PCS saturates (estimated)	4800.0
Recovery procedure begins (estimated)	4800.0
Heater rod heatup (estimated)	6650.0
HPIS initiated (estimated)	6650.0
Maximum heater rod temperature reached (estimated)	7300.0

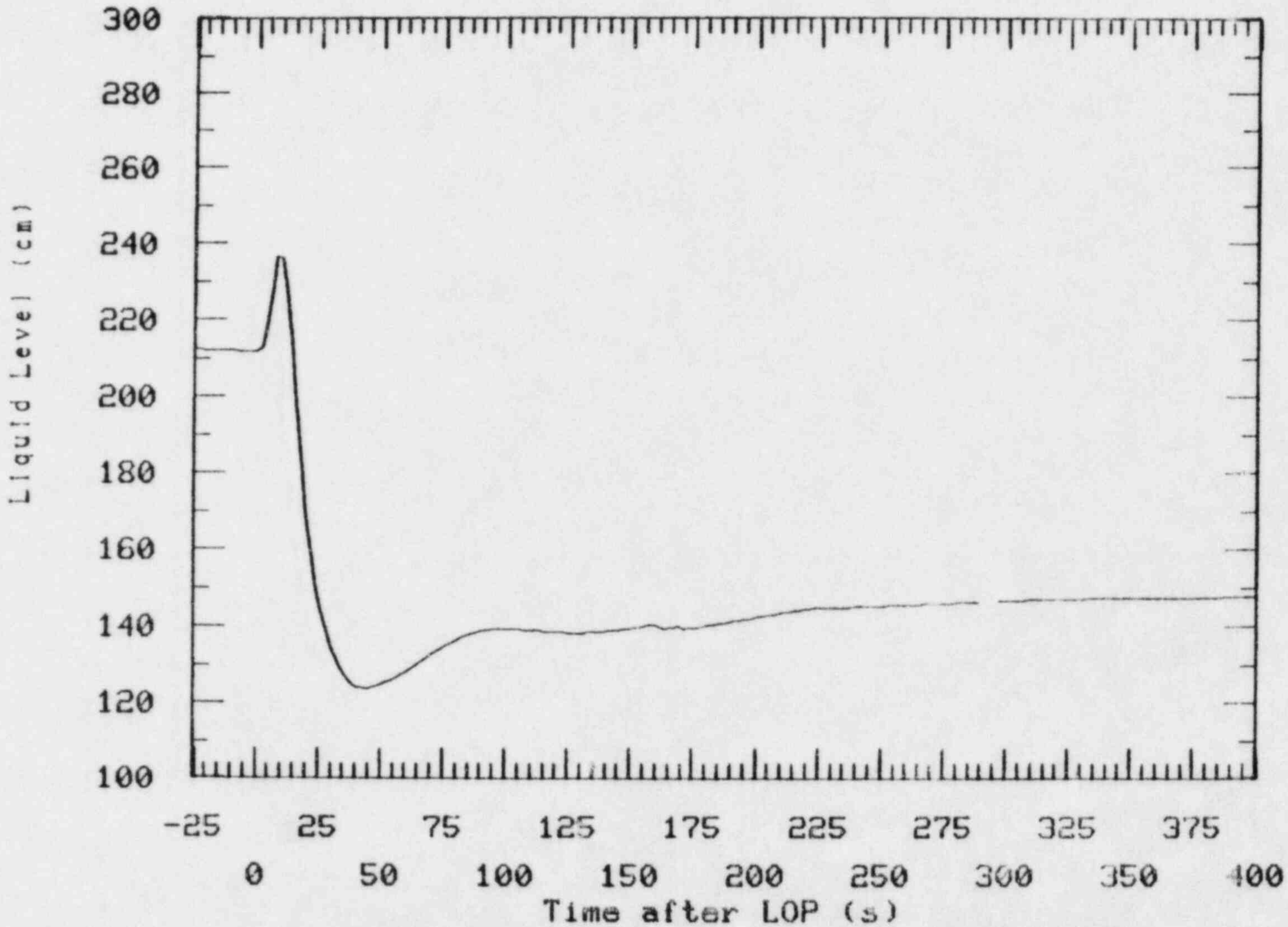

Figure 3. Pressurizer level for the S-PL-3 pretest predictions.

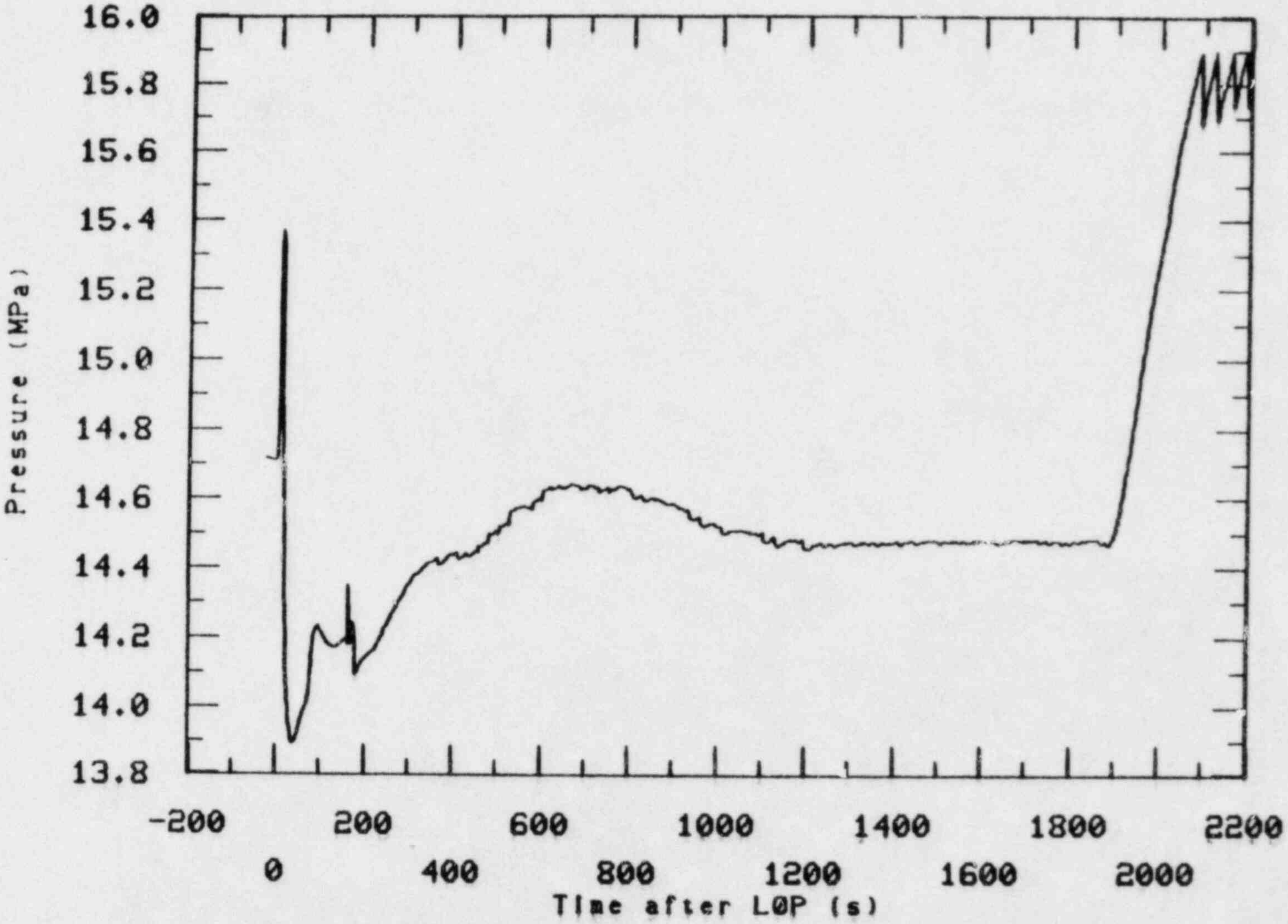

Figure 4. Pressurizer pressure for the S-PL-3 pretest predictions (long term).

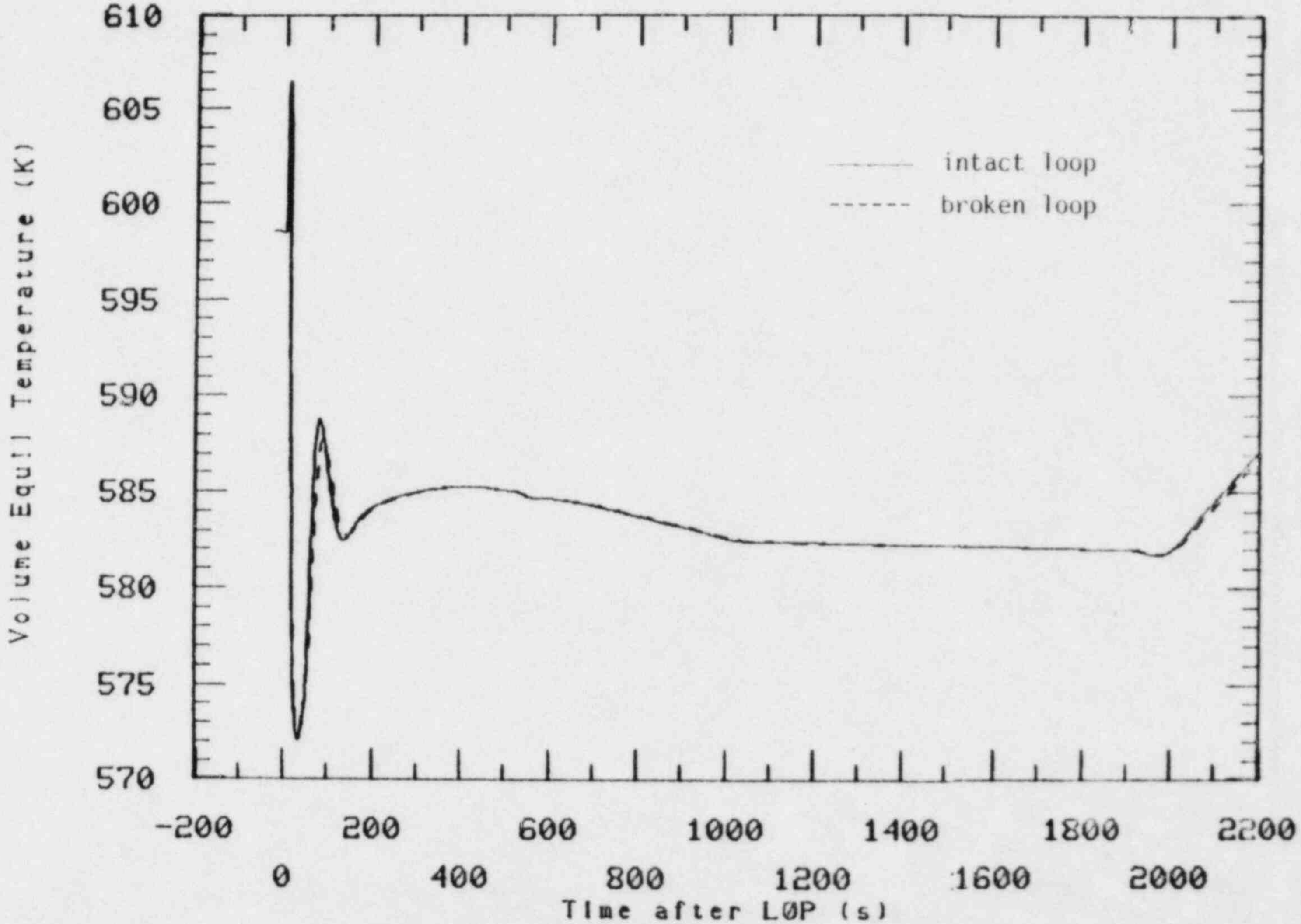

Figure 5. Hot leg temperatures for the S-PL-3 pretest predictions.

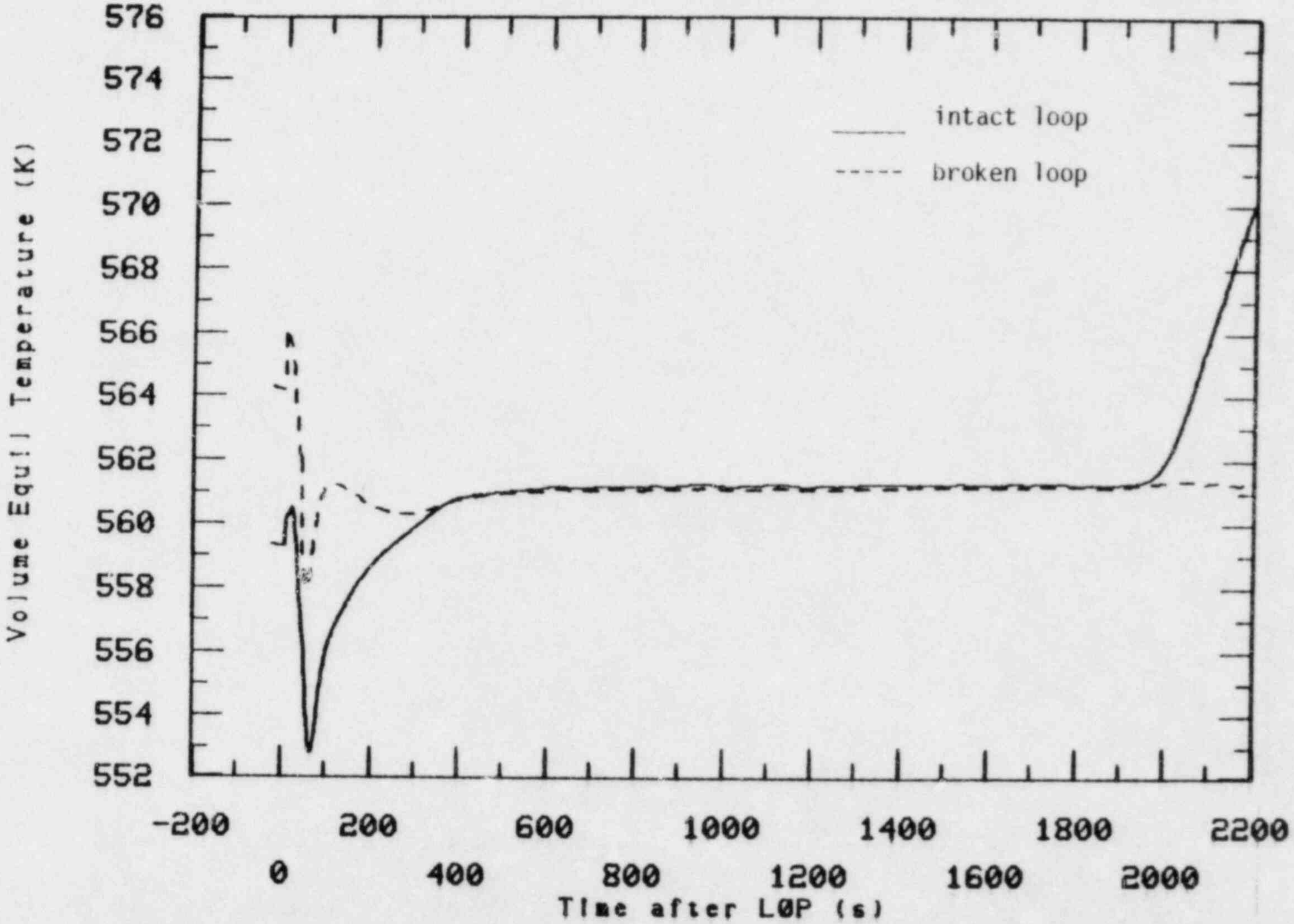

Figure 6. Cold leg temperatures for the S-PL-3 pretest predictions.

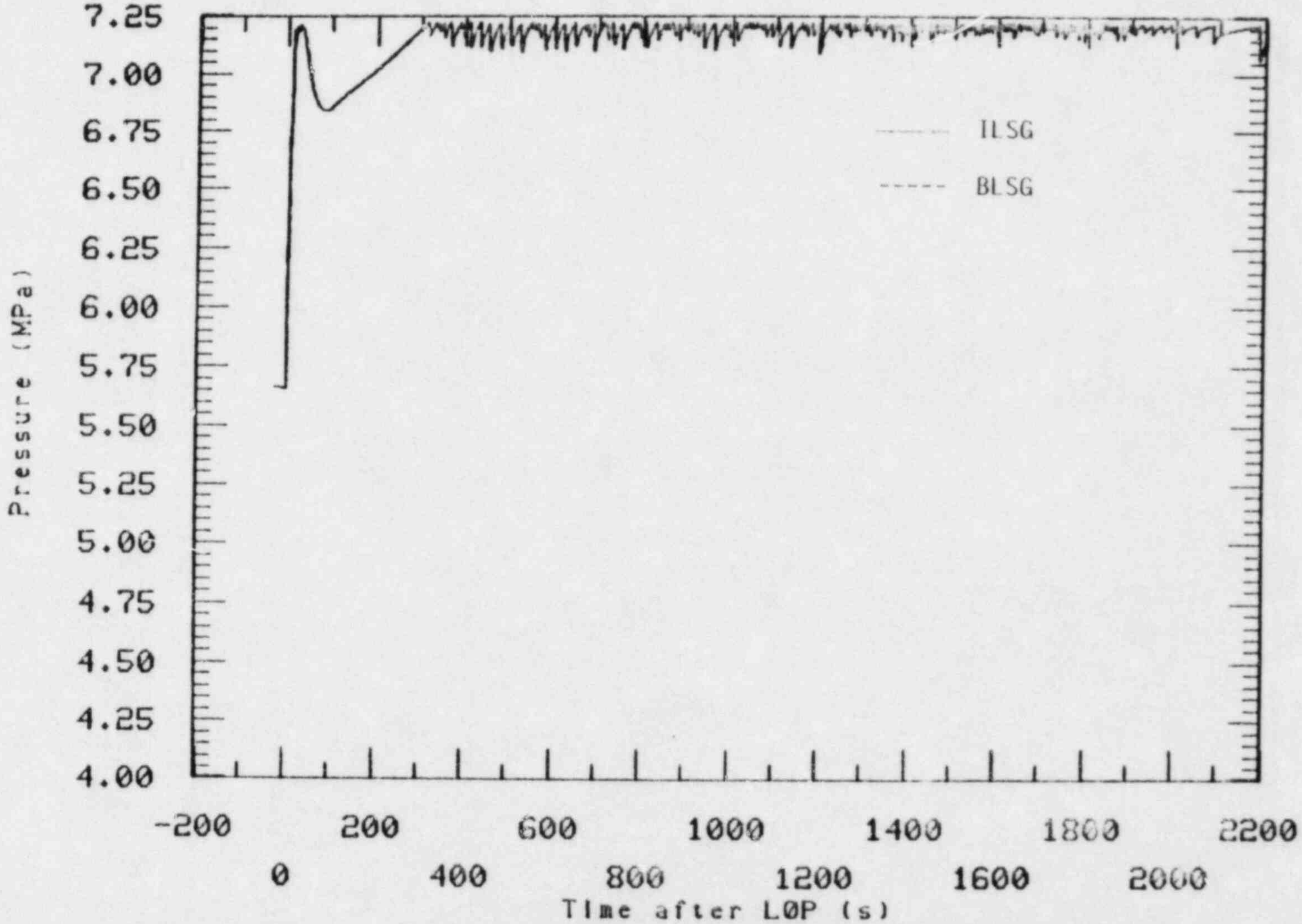

Figure 7. Steam generator secondary pressures for the S-PL-3 pretest predictions.

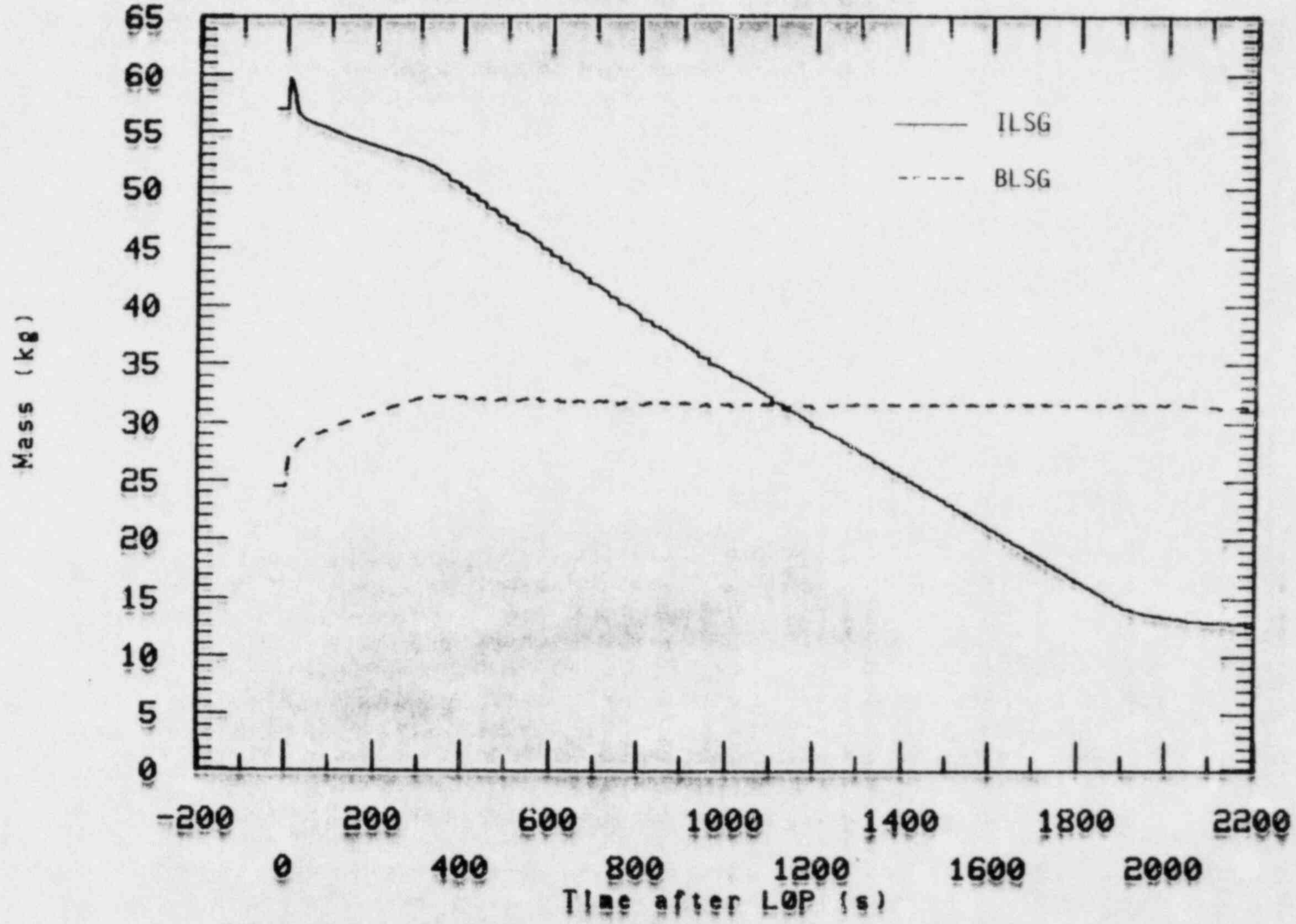

Figure 8. Steam generator secondary mass inventories for the S-PL-3 pretest predictions.

approximately 2000 s the ILSG was effectively dry. The calculation was not continued until the BLSG dried out, however the BLSG relief valve was also dumping mass to the atmosphere. The rate was about the same as it received mass from the ILSG so until approximately 2200 s the BLSG mass inventory was relatively constant. At 2200 s the BLSG mass also began to be depleted as the ILSG mass inventory was too low to supply mass to the BLSG.

4.2 System Recovery

The calculation for prediction of the system recovery was initiated from system conditions that would be expected at that stage of a LOP transient, i.e., nearly dry steam generators, PCS pressure at relief valve setpoint, PCS temperature at saturation point, complete PCS mass inventory, and core power at decay level. All parameters of interest were overlaid with the heater rod temperatures since it is the critical parameter at this stage of the transient. The recovery procedure consisted of cycling the PORV to reduce the PCS temperature at a rate of 56 K/hr as specified by the Zion Emergency Operating Procedure No. 7 Rev. 0. This reduction in temperature was begun in the calculation when the upper plenum reached saturation (see Figure 9). The PCS depressurization is shown in Figure 10. Note that heater rod heatup begins before the PCS depressurized to the feed and bleed operating band. Core collapsed liquid level is shown in Figure 11. The heater rod temperature began escalating when the core liquid level had fallen to approximately 200 cm above the bottom of the heated length. By integrating the PORV mass flow rate, it was found that the PCS mass inventory had been depleted by 97 kg at the time of rod heatup. (The Semiscale facility, with the pressurizer about one half liquid filled, operates with approximately 150 kg PCS mass inventory.) When heater rod heatup started, the PORV was opened to reduce the PCS pressure to the lower limit of the feed and bleed operating band thus activating the HPIS. Figure 12 shows the HPIS injection rates and its effect on the heater rod temperature. Within about 500 s after HPIS initiation the heater rod temperatures had begun to decline. The calculation was continued until the rod temperatures had returned to their pre-excursion levels.

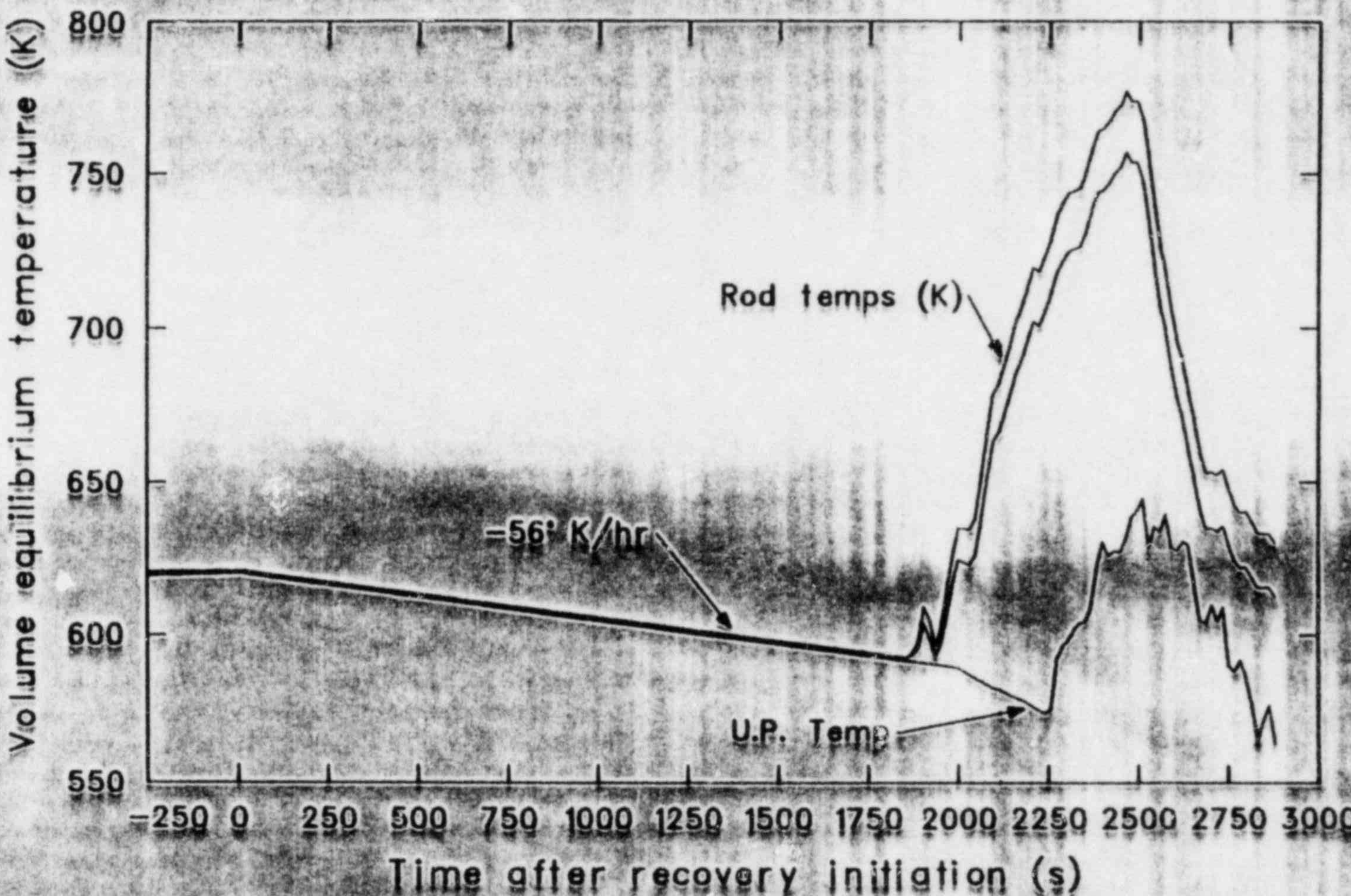

Figure 9. Upper plenum and heater rod temperatures during the S-PL-3 recovery pretest prediction.

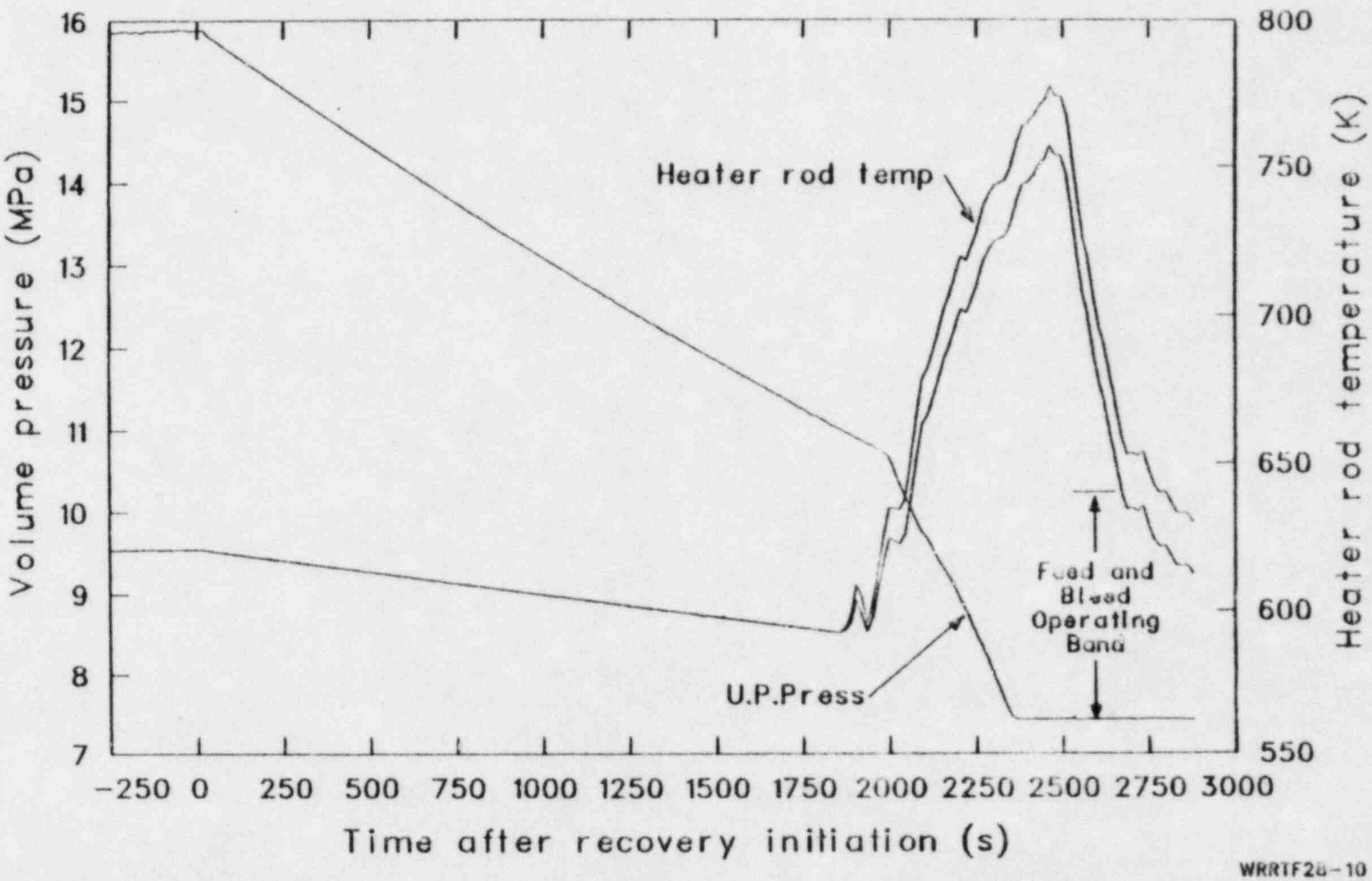

Figure 10. Upper plenum pressure and heater rod temperatures during the S-PL-3 recovery pretest predictions.

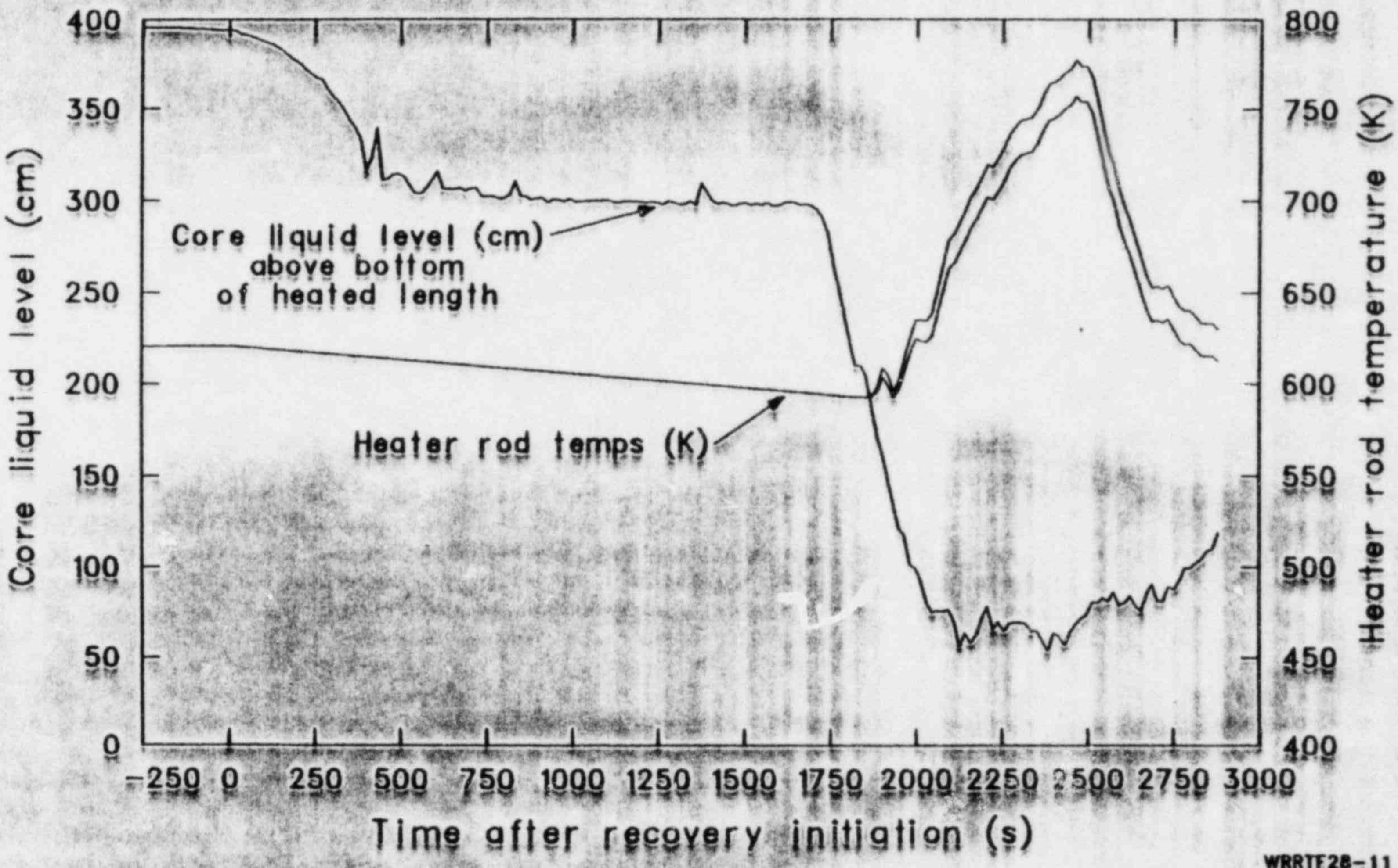

Figure 11. Core liquid level and heater rod temperatures during the S-PL-3 recovery pretest predictions.

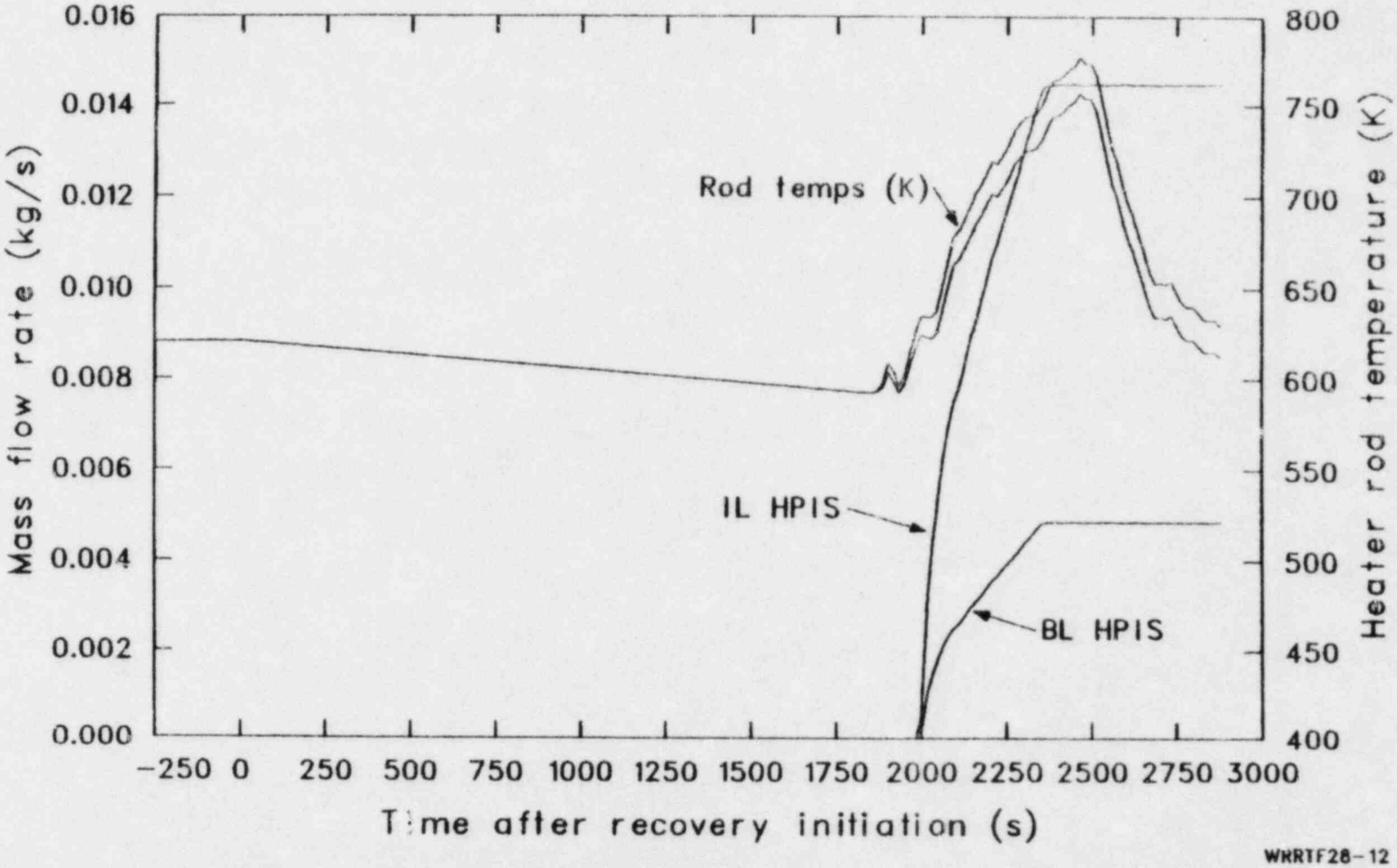

Figure 12. HPIS flow and heater rod temperatures during the S-PL-3 recovery pretest predictions.

5. CONCLUSIONS

The pretest prediction analysis for Test S-PL-3 indicates that the accident signature and system response through the time that the PCS pressurizes to the relief valve setpoint will not significantly differ from that predicted and observed for Test S-PL-2. Therefore, no unanticipated Semiscale facility plant protective actions should be required to complete this portion of the experiment.

The calculated system response during recovery indicates that recovery procedures initiated as late as when the upper plenum reaches saturation will result in a heater rod temperature excursion which will closely approach the Semiscale facility heater rod high temperature trip (820 K) setpoint. It is therefore recommended that recovery procedures be initiated as soon as possible after the PCS pressure reaches the relief valve setpoint and the objectives for the initial portion of the test have been accomplished. The analysis also indicates that the feed and bleed recovery technique will successfully quench the heater rods and recover the system.

6. REFERENCES

1. J. L. Chapman and J. R. Wolf, Experiment Operating Specification for Semiscale Mod-2B Power Loss Experiment Series, EGG-SEMI-6061, October 1982.

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3. V. H. Ransom, et. al., RELAP5/MOD1 Code Manual, Volumes 1 and 2, NUREG/CR-1826, EGG-2070, March 1982.