ARKANSAS POWER & LIGHT COMPANY
POST OFFICE BOX 551 LITTLE ROCK, ARKANSAS 72203 (501) 371-4000

February 11, 1980

1-020-05

Director of Nuclear Reactor Regulation
ATTN: Mr. Robert W. Reid, Chief
Division of Operating Reactors
Branch #4
U. S. Nuclear Regulatory Commission
Washington, D. C. 20555

Subject: Arkansas Nuclear One-Unit 1
Docket No. 50-313
License No. DPR-51
Outstanding Items Related to
B&W Small Break Analysis
(File: 1510.1)

Gentlemen:

Pursuant to our October 31, 1979, letter Arkansas Power & Light Company herein provides information requested in Dr. D. F. Ross' letter of August 21, 1979. Attached is our response to Question 1A which asked for a benchmark analysis of sequential auxiliary (emergency) feedwater flow to the steam generators following loss of main feedwater using a 3 mode CRAFT 2 OTSG representation.

Very truly yours,

David C. Trimble

David C. Trimble
Manager, Licensing

DCT:DGM:tw

Attachment

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I. INTRODUCTION

This report presents an analysis of sequential auxiliary feedwater (AFW) flow to the once through steam generators for a loss of main feedwater transient. The CRAFT2 code[1] and the small break model described in reference 2 have been used in the study. The calculated results have been compared to a loss of offsite power startup test data obtained from the Florida Power Corporation's Crystal River 3 Unit in which an imbalance in the auxiliary feedwater flows between the two operating loops resulted in an imbalance in the primary loop response. This transient tests several features of the computer simulation, including conditions of asymmetric loop temperatures, an almost dry generator to feed auxiliary feedwater into, loss of RC pumps, and establishment of natural circulation. In many cases the absolute validity of the boundary conditions and test data were questionable, and estimates had to be used. However, this analysis does show that the data trends can be predicted by a 3 node CRAFT2 SG representation.

II. SITE EVENT DESCRIPTION

The Crystal River 3 Unit is a 2452 MWt, 177-FA B&W reactor with a lowered-loop configuration. On April 23, 1977, a loss of offsite power test was performed. This test was initiated from approximately 15% full power operation. The secondary liquid levels were approximately 2 feet and was sufficient to remove the power and provide essentially steady-state operation prior to test initiation. The test was initiated by tripping the reactor, the reactor coolant pump, and feedwater pump power sources. The core power then dropped to the decay heat level and, as the primary coolant pumps coasted down, the primary flow decayed to natural circulation level. One diesel generator was started to provide power for the pressurizer heaters, one makeup pump, and other necessary services of secondary importance to this analysis.

The main feedwater flow coasted down resulting in both steam generators eventually drying out until the auxiliary feedwater flow became sufficient to start filling the A loop steam generator secondary at about two minutes into the transient.

The B loop steam generator remained dryed out until twelve to fourteen minutes into the transient when the A loop reached normal operating level and the feedwater flow was diverted to the B loop. The imbalance in the feedwater flows, and hence levels, resulted in a corresponding imbalance in the primary system response including the decay heat removal, the hot and cold leg temperatures and flows between the two loops. The transient results were used to evaluate the ability of the 3 node CRAFT2 steam generator model used in small break evaluations to calculate the effect of the feedwater transient.

III. METHODS

A. CRAFT Input Model

The input model developed for this calculation was based on the small break model used for licensing.[2] The schematic of the flow path nodalization is shown in Figure 1. The initial system conditions were defined based on the available measured data which were required to represent this test. The model was set up to provide a steady-state calculation until two seconds into the transient when the reactor, reactor coolant pumps, and main feedwater pumps were tripped initiating the transient calculation.

B. Initial Conditions

The initial mass flow was assumed to be identical to the full power operation value. The measured hot and cold leg temperatures were then used to determine a consistent core power to provide the initial steady-state operating conditions. This resulted in an initial power of 19% of full power operation versus the 15% power defined in the summary test report. Hand calculations, using the 15% core power and the measured hot and cold temperatures, resulted in a mass flow considerably below that required to balance the pump power. The actual mass flow is believed to have been only 1 or 2% less than full power flow. The pressure distribution around the system was revised, because of the new hot and cold leg temperatures, to maintain the loss coefficients defined by the referenced model. The liquid levels in the pressurizer and steam generator secondary were changed to reflect the measured data.

C. Boundary Conditions

The makeup pump flow was modeled by defining the pressure flow characteristic curve for normal operation with the recirculation line open. The makeup pump was actuated when the pressurizer level dropped to 30" below the initial liquid level value. The makeup pump flow was equally distributed between the two cold leg pump discharge modes as shown in Figure 1. The feedwater flows were defined by the test data and are given in Figure 2. An auxiliary feedwater enthalpy of 58 BTu/lbm, which is the nominal enthalpy of the system, was used.

The safety relief valves were set to 1030 psia to model the effect of the turbine bypass valves, which are fully open at 1030 psia. The safety relief flow is the only allowance made in the model for steam flow.

The heat transfer to the secondary was assumed to be to the mixture in the lower portion of the steam generator and the fraction which may have been deposited in the steam region was assumed to be negligible. A preliminary short-term transient evaluation demonstrated the need to define the heat transfer multiplier based on the steam generator secondary levels. Consequently, the final model contained a heat transfer multiplier as a function of time based on the measured secondary levels.

IV. RESULTS

This section presents a comparison of the CRAFT2 analysis to the data taken for the first 20 minutes of the CR-3 loss of offsite power test. As will be shown, some of the data utilized in the evaluation is questionable and greatly influence the transient response. However, even with the uncertainties in the measured data, the CRAFT2 code is shown to adequately calculate the RCS behavior.

A. Secondary Response

Figure 3 shows the secondary side SG levels during the test. The test data shows that, following the loss of main feedwater, the initial level in both steam generators decreases. At approximately 1 minute into the transient, the auxiliary feedwater system initiates, as shown in Figure 2, and preferentially feeds the A loop steam generator. Thus, the liquid level in SG A increases. 't 12 minutes, the liquid level in SG A stabilizes because it has reached its control point. At that time, the feedwater flow is diverted to SG B and its level increases.

The CRAFT2 code calculated results shows reasonable agreement with the SG A level during the first 12 minutes. After this time, however, the CRAFT2 calculation continues to increase the SG level while the data shows a level stabilization after this time. This difference is probably due to an overestimation of the auxiliary feedwater flow to SG A after this time. The auxiliary feedwater flow, as indicated in Figure 2, is very stable and at a relatively high flowrate after 12 minutes. Examining other data, such as the A loop hot and cold leg temperatures, does not support a high auxiliary feedwater flowrate. In light of the ability of the CRAFT 2 code to reasonably predict the SG response up to 12 minutes and the inferences obtained from other data, the flowrate given in Figure 2 after 12 minutes is believed to be in error.

The SG B liquid level response is generally overpredicted by the CRAFT calculation. This again is believed to be caused by an overestimation of the auxiliary feedwater flowrate to SG B, especially between 3 and 9 minutes. Figure 2 shows the auxiliary feedwater flow to be very low over this time period and very stable. This may be due to an initial instrumentation offset and no feedwater may have been delivered to the steam generator in this period. Once a sustained auxiliary feedwater flow is established to the SG, the CRAFT calculated level increases are in reasonable agreement with the data.

Figure 4 shows the SG secondary side pressure response during the transient. CRAFT2 predicts the pressure response for the A loop SG reasonably. Between 4 and 6 minutes, the calculated SG pressure increases above the data. Over this time period, it is believed that the measured auxiliary feedwater flows are low. This conclusion is consistent with the level comparison shown in Figure 3. For the remainder of the transient, the prediction is higher than the measured SG pressure.

The secondary side pressure for SG B was generally underestimated throughout the transient. This is caused by condensation of the steam within the SG due to the excess auxiliary feedwater flow utilized in the calculation.

B. Primary System Response

Figure 5 shows the A loop temperature response during the test. The hot leg temperature compares well with the transient data until 13 minutes. After this time, the CRAFT2 calculation continues to show a decrease in the hot leg temperature due to the continued feeding of the A loop SG. The data shows a flattening of the hot leg temperature due to the control of the SG level. This supports the belief that the auxiliary feedwater flows after 12 minutes is lower than the values indicated by Figure 2.

The calculated A loop cold leg temperature response is consistent with the data trend, but generally overpredicts the data after 4 minutes. This is caused by the overprediction of the SG A secondary pressure discussed previously.

The B loop temperature response is shown in Figure 6. Due to the overprediction in the B loop SG level and underprediction in the SG pressure, the hot leg temperatures are underpredicted.

Figures 7 and 8 show the pressurizer level and system pressure comparison. Hand calculations which were performed indicate that these parameters are not consistent. Examining these figures, it is seen that the calculated pressurizer level response is in good agreement out to approximately 12 minutes. After 12 minutes, the continued overcooling of the A loop, due to the overestimation of feedwater flow, results in an underestimation of the pressurizer level.

The pressure response shown in Figure 8 shows that the CRAFT2 calculation underpredicts the data. However, as mentioned previously, this is not unexpected as the system pressure and pressurizer level are not consistent.

V. CONCLUSION

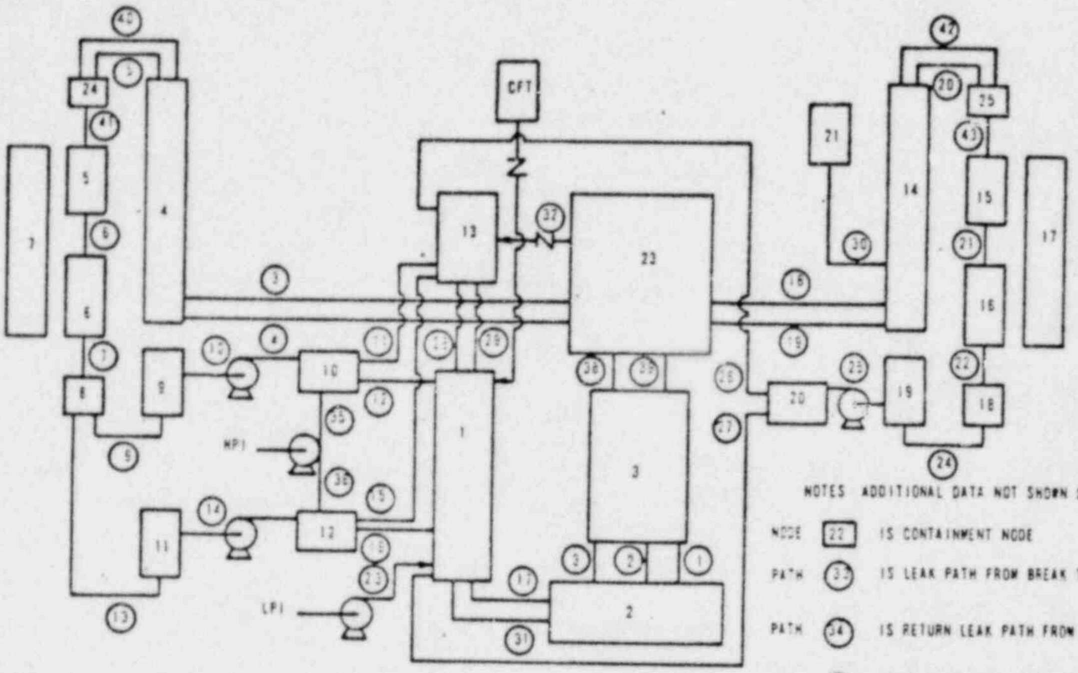
A sequential auxiliary feedwater flow transient has been benchmarked in this analysis using the CRAFT2 code with the 3 node SG model used in small break evaluations. The site data trends were reasonably reproduced by the code. In many cases the validity of test boundary conditions were questionable and estimates of the test data were used. However, the results provide assurance that the CRAFT2 code is capable of reasonably predicting the primary system behavior indicated by the test if the boundary conditions were well defined. Thus, this study has demonstrated that, in spite of the simplicity of the CRAFT2 steam generator model, the CRAFT2 code can estimate, with reasonable accuracy, a transient highly dependent on the steam generator. Thus, the ability of the small break model to calculate the effect of steam generator heat removal during a small break transient is reasonably assured.

REFERENCES

1 R.A. Hedrick, J.J. Cudlin, and R.C. Foltz, "CRAFT2 Fortran Program for Digital Simulation of a Multinode Reactor Plant During Loss-of-Coolant," BAW-10092, Rev. 2, Babcock & Wilcox, April 1975.

2 Letter J.H. Taylor (B&W) to S.A. Varga (NRC), July 18, 1978.

FIGURE 1 CRAFT2 NODING DIAGRAM FOR SMALL BREAKS



NOTES ADDITIONAL DATA NOT SHOWN ON DIAGRAM AREAS

NODE 22 IS CONTAINMENT NODE

PATH 33 IS LEAK PATH FROM BREAK TO CONTAINMENT

PATH 34 IS RETURN LEAK PATH FROM CONTAINMENT TO BREAK NODE

PATH 37 REPRESENTS CONTAINMENT SPRAY SYSTEM

NODE NO.	IDENTIFICATION
1	DOWNCOMER
2	LOWER PLENUM
3	CORE
4.14	HOT LEG PIPING
5.15	SG & UPPER HEAD
6.16	STEAM GENERATOR TUBES
7,17	SECONDARY SG
8,18	SG LOWER HEAD
9,11,19	COLD LEG PIPING
10.12.20	COLD LEG PIPING
13	UPPER DOWNCOMER
21	PRESSURIZER
22	CONTAINMENT
23	UPPER PLENUM
24.25	SG UPPER HEAD

PATH NO.	IDENTIFICATION
1,2	CORE
3,4,18,19	HOT LEG PIPING
5,20,40,42	HOT LEG, UPPER
6,21	SG TUBES
7,22	SG LOWER HEAD
8	CORE BYPASS
9,13,24	COLD LEG PIPING
10,14,25	PUMPS
11,12,15,16,26,27	COLD LEG PIPING
17,31	DOWNCOMER
23	LPI
28,29	UPPER DOWNCOMER
30	PRESSURIZER
32	VENT VALVE
33,34	LEAK & RETURN PATH
35,36	HPI
37	CONTAINMENT SPRAYS
41,43	SG UPPER HEAD

FIGURE 2. STARTUP FEEDWATER FLOW

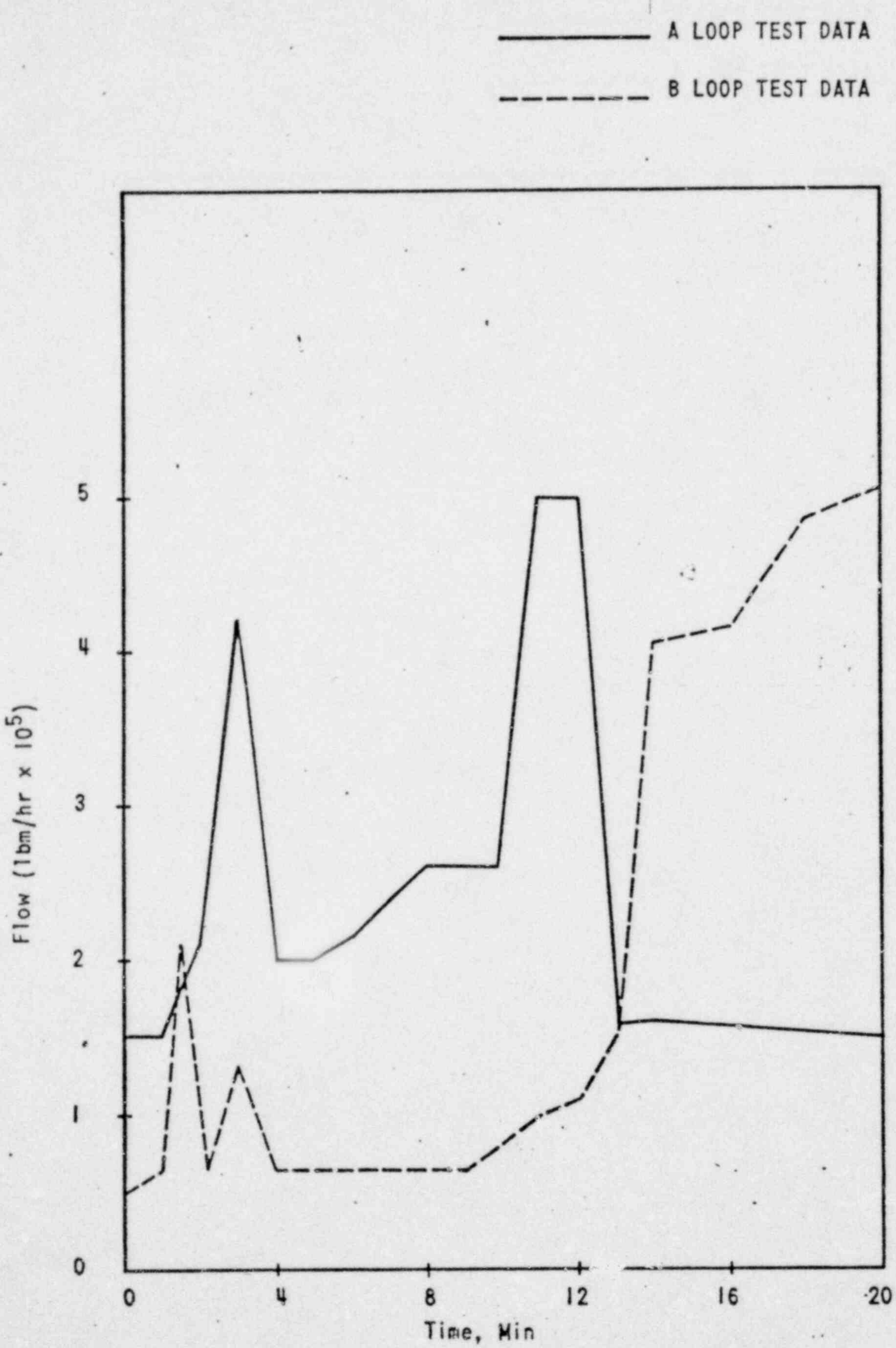


FIGURE 3 STEAM GENERATOR LIQUID LEVEL (TEMPERATURE ADJUSTED)

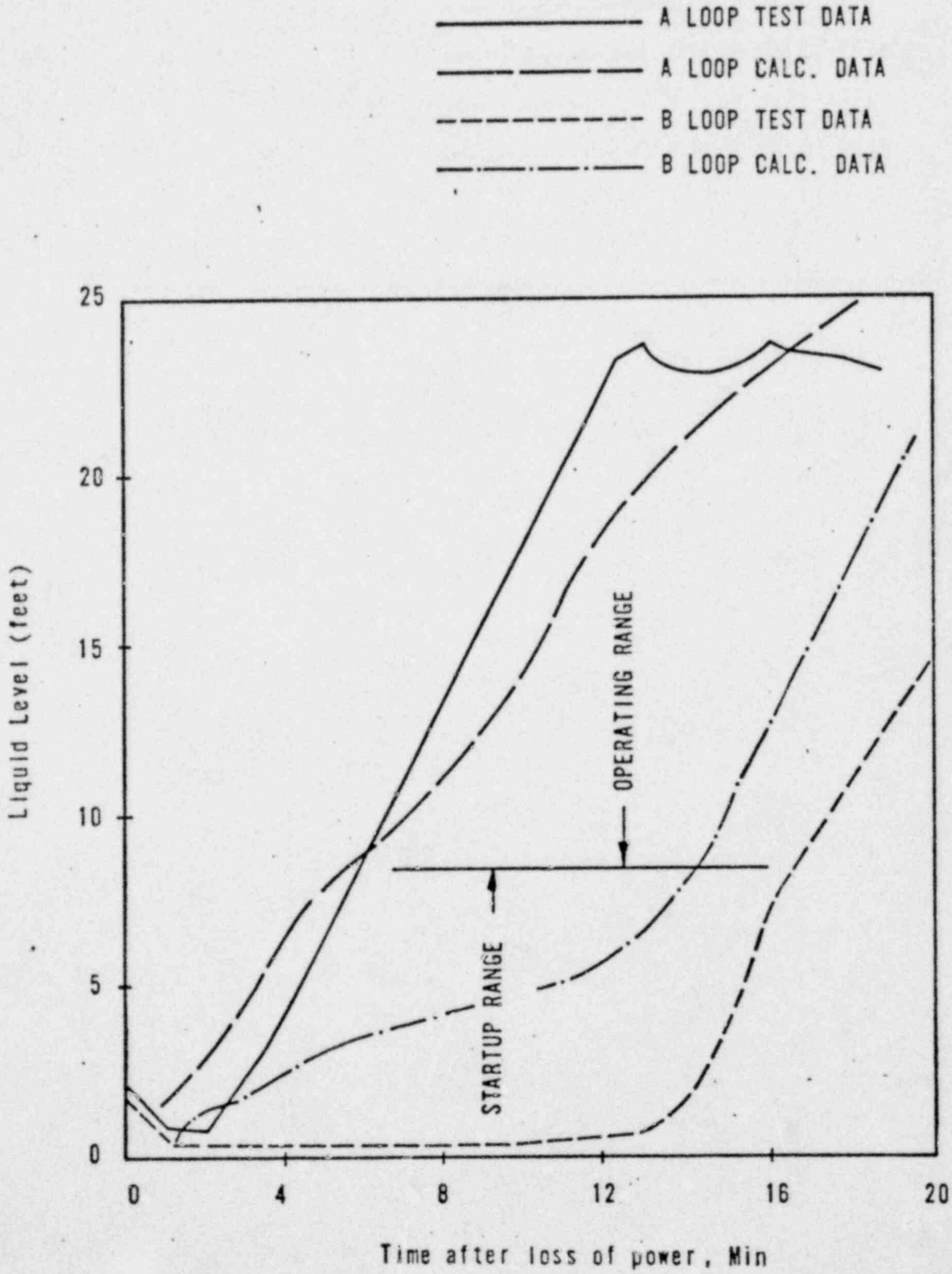


FIGURE 4 S.G. SECONDARY SIDE PRESSURE

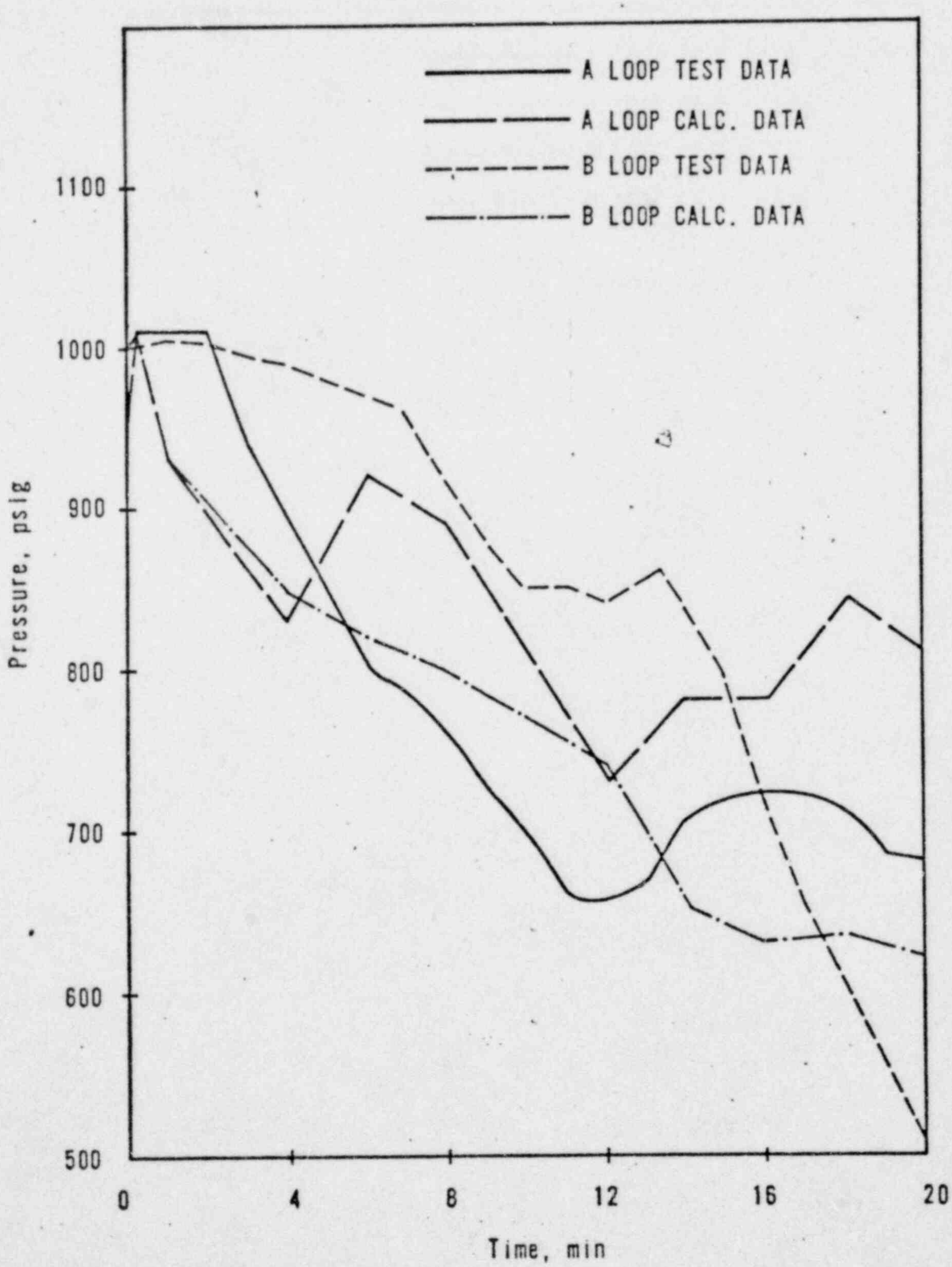


FIGURE 5 PRIMARY A LOOP TEMPERATURE

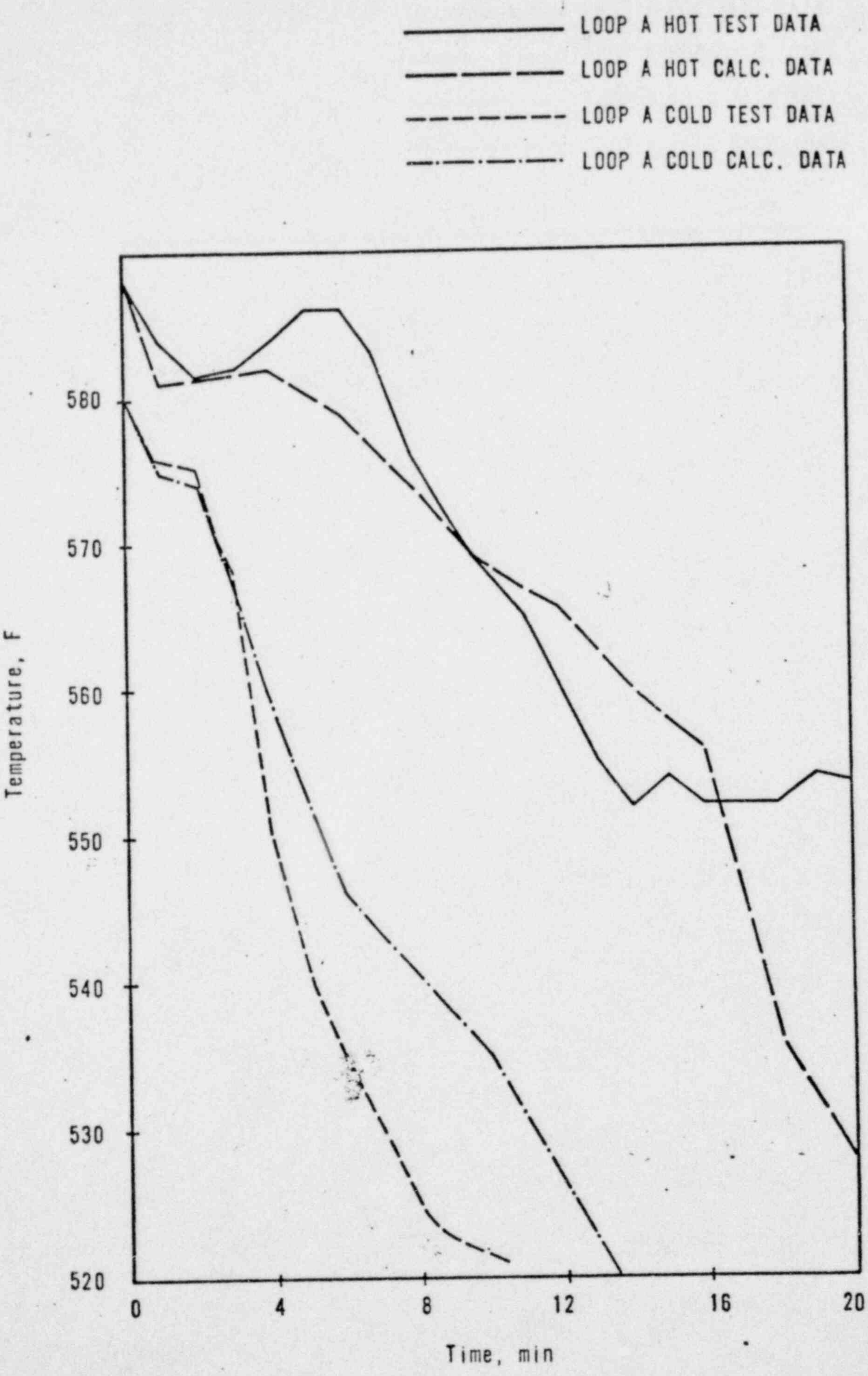


FIGURE 6. PRIMARY B LOOP TEMPERATURE

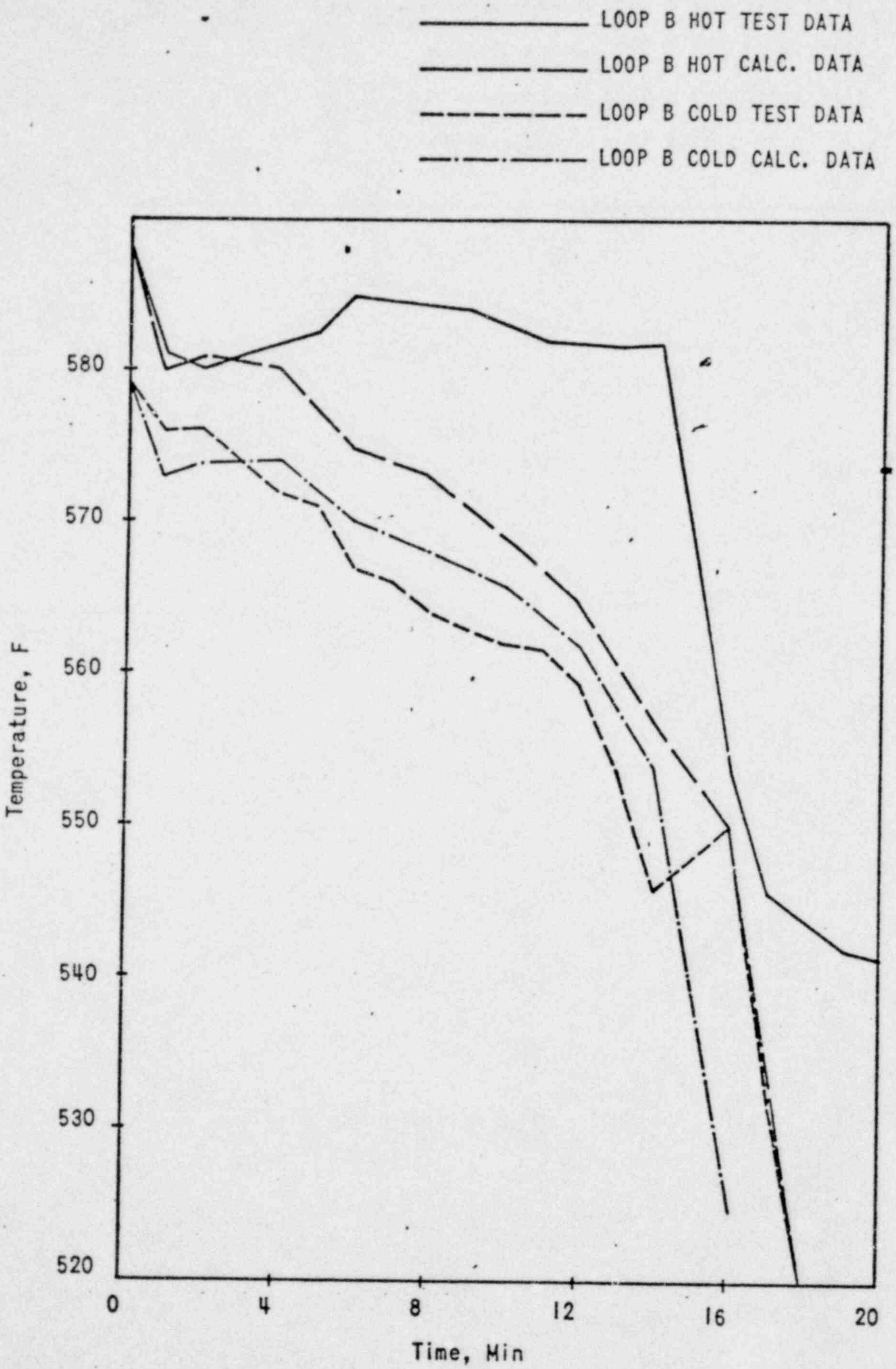


FIGURE 7. PRESSURIZER LEVEL

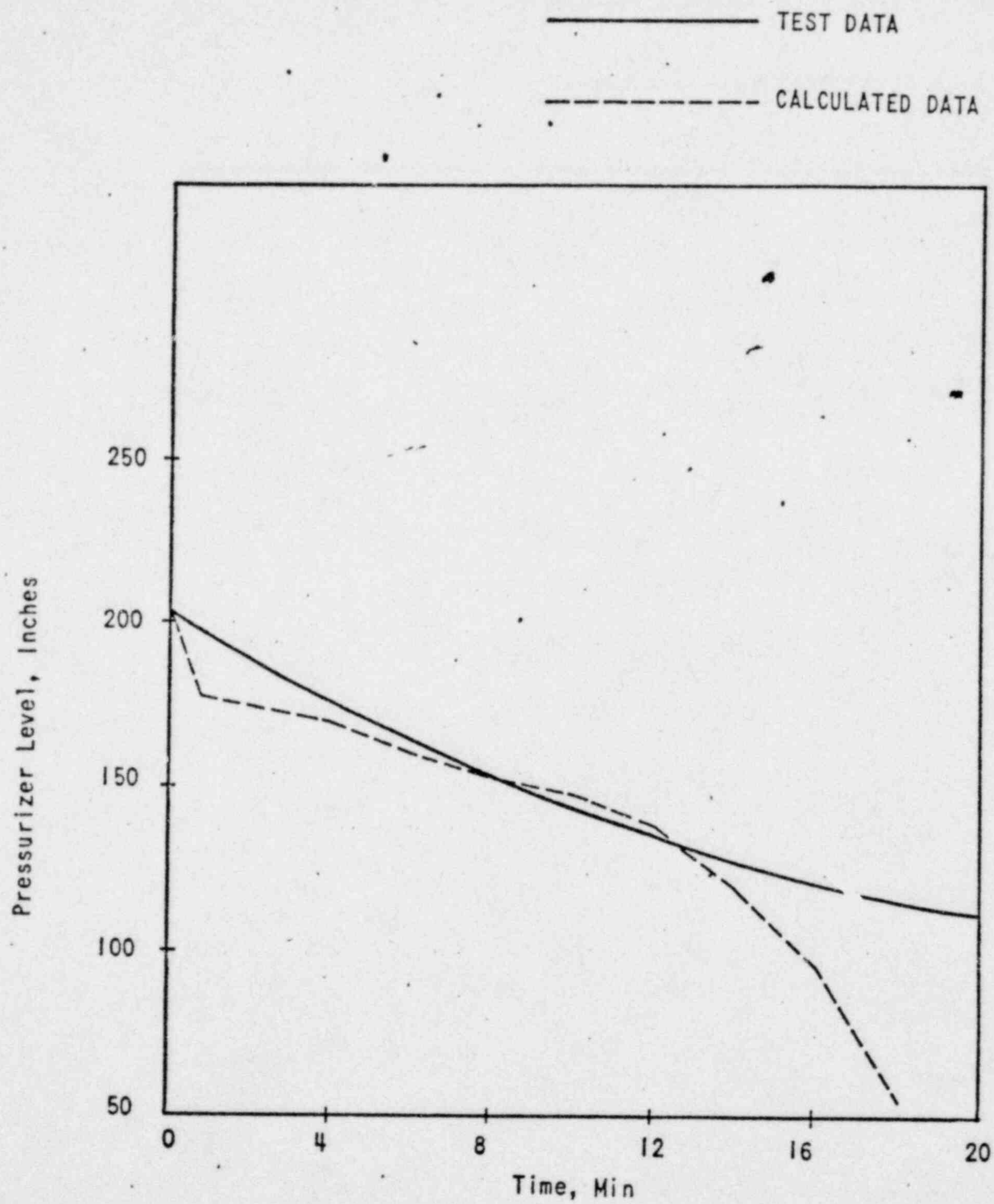


FIGURE 8. REACTOR VESSEL PRESSURE