BENCHMARK ANALYSIS FOR

ASYMMETRIC LOOP EVENTS

(177 FA PLANTS)

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1.0 INTRODUCTION

Asymmetric loop events are defined for this study as those feedwater (main or auxiliary) transients that result from sequenced feedwater addition to each of two once through steam generators (OTSG). These events are not normally considered in SAR analyses as they are bounded in consequences by malfunctions that affect both OTSG's. This report is a confirmation of the ability of B&W computer codes to model asymmetric loop events by a benchmark to operating plant data.

The transient to be benchmarked is described in Section 2.0. 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. This study is a preliminary benchmark and further refinements in the simulation could be made to more closely predict the transient response. However, this analysis does show that the data trends can be predicted by analysis. Where the magnitude of a variable differs significantly from plant data, an explanation is included of possible model changes which would tend to align the analysis with plant data.

A reduced noding model of TRAP2, a two-loop code, was used in the benchmark. A detailed model and code description, the analysis assumptions used, and the benchmark results are presented in Section 3.

2.0 SITE EVENT DESCRIPTION

The event described below occurred at Florida Power Corporation's Crystal River-3 Unit, which is a 2452 MWt, 177 FA B&W reactor with a lowered loop configuration and two OTSG's. It occurred during start-up testing with approximately 31 EFPD burnup on the core. The specific test being conducted was the Loss of Offsite Power Test.

For the Loss of Offsite Power Test, certain plant loads are placed on one operating diesel (3B) to protect equipment, and then, from 15% power, the reactor and startup transformer were tripped and all four RC pumps coasted down. The startup time of the other diesel generator (3A) is recorded. Vital loads are then changed over to the diesel (3A) previously tested, and startup time of the other diesel (3B) is tested. One emergency diesel generator was left operating to power a makeup pump, cooling water pumps, an instrument air compressor, and some pressurizer heaters. In one minute, the emergency feedwater pump was operating and supplying feedwater to both steam generators. Operators tried to use both steam-driven and motor-driven emergency feedwater pumps to evenly and simultaneously supply water to both steam generators. One steam generator received too little feedwater and boiled dry until the filling operation of the other steam generator was completed. This resulted in unmatched loop A and B hot and cold leg temperatures.

The data available from the site includes the sequence of events (Table 2-1) and the system parameters in Figures 3-2 through 3-7. This information is very limited in terms of the input required for setting up a computer code simulation; however, it does provide a rigorous method to demonstrate the ability of the code simulation to reasonably benchmark the test output.

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Table 2-1

Site Sequence of Events

Time, Minutes	Event
0	Lost power, all feedwater to both generators stopped
1	Steam-driven emergency feedwater (EFW) pump up to to speed and feeding both steam generators
2	Started electric-driven emergency feedwater pump. "A" steam generator is being preferentially fed, but both are getting water.
3	Stopped steam-driven EFW pump. "A" steam generator is being filled (startup level indication), "B" steam generator startup and operating range level indicators are both apparently at the bottom of their range.
4	"B" loop startup feedwater flow indication is at the bottom of its range (as verified by subsequent calibration checks).
9 1/2	Restarted steam driven EFW pump, started feeding "B" steam generator again.
10	Opened a parallel valve (EFV-162) in the feedwater train to "A" steam generator by mistake.
12 1/2	Shut EFV-162 and opened a parallel valve (EFV-161) in the feedwater train to "B" steam generator.
14	"B" steam generator filling, on its way to recovery.

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3.0 TRAP2 BENCHMARK

3.1 Model and Code Description

The TRAP2 (BAW-10128) code was developed to permit analysis of transient response of the once-through steam generator and associated reactor coolant system to upset and faulted conditions in the secondary system. The code requires a user input control volume-flow path network model of both the primary and secondary systems. TRAP2 utilizes appropriate pressure and property search subroutines and applies the method and logic for solution of the conservation equations for mass, energy, and momentum, in a manner similar to the CRAFT2 LOCA code.

In the reduced noding model used, each steam generator is represented by 3 primary, secondary, and tube metal control volumes of equivalent corresponding primary to secondary height. The tube height of each node is determined by fitting to the specific secondary side steam generator conditions. For example, in this case, the first node, 30% of the tube height, is two-phase, the second node, also 30%, is superheat with the aspirator at the top of this node, and the last node is all superheat above the aspirator. Input to the steam generator models is based on a detailed steady-state analysis to establish initial control volume pressures, temperatures, enthalpies, flows, and primary and secondary side heat transfer coefficients. Control volumes are also used to describe segments of the reactor core. Connecting these volumes are flow paths in which the core heat transfer is evaluated, describing the thermal-hydraulic characteristics of the core. Associated with each reactor core flow path is a corresponding section of the fuel pins, from which heat is transferred into the core water from the energy generated by fuel fissions (point kinetics model) and fission product decay.

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3.1.2 Model for Benchmark

Figure 3-1 shows the noding scheme used for this analysis and Table 3-1 gives a detailed description of the nodes and paths. In addition to the tube region nodes noted earlier, each steam generator model contains downcomer, lower plenum, and heat riser nodes. In addition to each independent secondary loop, the primary system has been divided into semi-independent loops. The reactor vessel is modeled with downcomer, lower plenum, core, and upper plenum regions. These core and reactor vessel nodes are further divided in half, with paths connecting the upper and lower plenum nodes to allow for mixing and pressure equalization. The remaining nodes describe primary and secondary piping, the turbine, and pressurizer.

The asymmetric transient chosen was the Crystal River-3 natural circulation on Loss of Offsite Power (LOOP) test, where one steam generator was preferentially fed by Emergency Feedwater (EFW). The transient is further described in Section 2.0.

3.2 Analysis Assumptions

Since a minimal amount of information was available on Crystal River-3 and the time to set the model up was limited, most of the required input for the analysis was based on a generic 177 FA plant. The system geometry and BOL kinetic conditions were based on TMI-2 benchmark. The initial conditions of state for both the primary and secondary systems were extrapolated to 15% FP from higher power information available for the OTSG steady state operation. The similarity of the plants allow for this approach, without any significant loss of accuracy in modeling a particular plant. Operating data, when available, was used instead of conservative Safety Analysis values, such that the transient model would more closely match the actual data. Other assumptions were as follows:

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1) Upon LOOP, the reactor main feed pumps and turbine were tripped, and the main coolant pumps coasted down. Aside from Emergency Feedwater (EFW) flow, no other actions were taken.
2) EFW flow was modeled from the flow versus time information from site data. A nominal value of 58 Btu/lbm (90°F) was assumed for the EFW enthalpy (see Figures 3-6 and 3-7).
3) The decay heat model was based on the site information (Figure 3-5) and was employed 120 seconds into the transient.
4) A pressurizer heater model was not employed since feedback effects from repressurization were not considered in TRAP2.

3.3 Results

Twenty minutes of the CR-3 transient were analyzed on TRAP2 and the responses of the important system parameters can be found in Figures 3-2 through 3-7. The TRAP2 values are superimposed on the site information (connected data points) to facilitate comparison.

The TRAP2 simulation of the CR-3 transient is representative of the site data; the general trends are reproduced and the asymmetry is exhibited. Figures 3-2 and 3-3 show the increasing ΔT for both loops, with loop 'A' removing considerably more heat. While TRAP2 shows an immediate increase in heat transfer (increase in the loop ΔT), the site data lags about 2 minutes behind. This might be explained by the use of shielded RDT's for temperature measurement during this test. The loop 'B' temperature profiles fairly closely match the site data, noting that the initial temperatures predicted by TRAP2 are lower than the site data. TRAP2 predicts the expected average temperature of 579°F at 15% full power compared with the 583°F for the site data. Apparently, the reference

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points of the temperature recorders used for this test contained some inaccuracy. The site data for this transient was based on the information from a post trip review; the data being taken from the plant computer. The information of this type may be inaccurate in both parameter magnitude and the first point real time, but the trends should be relatively accurate.

In general, the TRAP2 data correlates very well with the site information. The loop 'A' cold leg temperatures, Figure 3-2, as predicted by TRAP2, do not decrease at as fast a rate as the site data after three minutes. This is primarily due to TRAP2's limitation in modeling EFW flow to the top of the steam generator. Instead, EFW was injected into the downcomer and allowed to flow upward through the tube region. Because of the injection location, even the increasing EFW flow after two minutes does not quench the steam in the upper region of the generator. This reduces the depressurization in steam generator 'A' (Figure 3-4) after four minutes, and causes the lower rate of heat removal in loop 'A' (shown in Figure 3-2 by TRAP2's higher cold leg temperatures after four minutes). Aside from these explainable differences, the agreement with the site information is relatively good for these parameters.

The TRAP2 RC pressure and pressurizer level, shown in Figure 3-2, compares less favorably with the site information during the transient. However, the primary system depressurization, after the first minute, exhibits the same slope as the site data. The rapid decrease of the TRAP2 predicted pressures and pressurizer level in the first minute is due to the use of a coarsely noded steam generator model, a pressurizer model with limited capabilities, and the lack of pressurizer heaters.

The TRAP2 data shows an increase in the depressurization after 10 minutes while the site data shows a decrease. The TRAP2 trend in pressure seems to be more reasonable since the total EFW flow to both generators is

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greater after 10 minutes than at any previous time. Unlike any of the other site data, the RC pressure and pressurizer level data were apparently extrapolated and did not result from actual data points.

Figure 3-4 shows the close correlation betwee: the TRAP2 predicted and the actual site data for the steam generator levels. For the actual level measurement, there is no indication below 10 inches, which accounts for the 'B' generator's steady level indications of approximately 10 inches from 2 to 12 minutes. During this time, TRAP2 shows the steam generator level to be boiling off until EFW begins to flow to steam generator 'B' again, where the level rises again. The zero level indication of the site data at 13 minutes means either than only zero level in the generator can be indicated when the generator dries out, or, when the EFW flow was resumed to the generator, the surge of cold water caused a fluctuation in the level measurement.

The steam generator pressure shown in Figure 3-4 also indicate that TRAP2 was able to predict the general trends. The higher pressures in loop 'A', as noted earlier, result from limitations in modeling EFW flow to the generators. The loop 'B' pressures predicted by TRAP2 drop off when EFW flow resumes after 12 minutes, but remain above the site values until that time. The slow drop in loop 'B' pressures from 3 to 7 minutes indicates that there was some EFW flow to the generator, although the site information does not indicate this (see Figure 3-7). The larger decrease in pressure from 7 to 10 minutes indicates additional release of steam from the generator, not indicated on any of the other data plots or in the site report describing the transient.

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Figure 3-5 compares the power transient from TRAP2 with the site data. At 2 minutes into the transient, the site data curve was used as input into TRAP2. Figures 3-6 and 3-7 show the EFW flow versus time for 'A' and 'B' generators, respectively. There figures taken from the TRAP2 output and the values are based on the site data for this transient.

The TRAP2 simulation of the CR-3 transient is a reasonable preliminary evaluation since the important trends are described and a good natural circulation state is established. Considering the lack of specific information on 15% power cases and the time constraints placed on the analysis, the TRAP2 simulation indicates that refinements could be made such that the site data could be more accurately reproduced. Specifically, the pressurizer model can be improved to help prevent the rapid initial system depressurization, a finer noding can be used in the steam generators to improve heat transfer transitions, the EFW model can be improved to allow quenching of all steam generator tubes from the top, and a pressurizer heater model can be implemented to also reduce the initial rapid primary depressurization.

4.0 SUMMARY AND CONCLUSIONS

The asymmetric loop effect has been studied using an operating plant event for benchmark purposes. The TRAP2 code was used in this benchmark and the site data trends were reasonably reproduced by the code. Several areas of code modeling refinements were noted that are expected to bring the analytical results even closer to the site data, but were precluded in this study. However, the results clearly indicate a code capability to model asymmetric loop (natural circulation) events which could be useful in confirming anticipated operating trends, leading to operating guidelines.

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MINITRAP NODING & FLOW PATH SCHEME

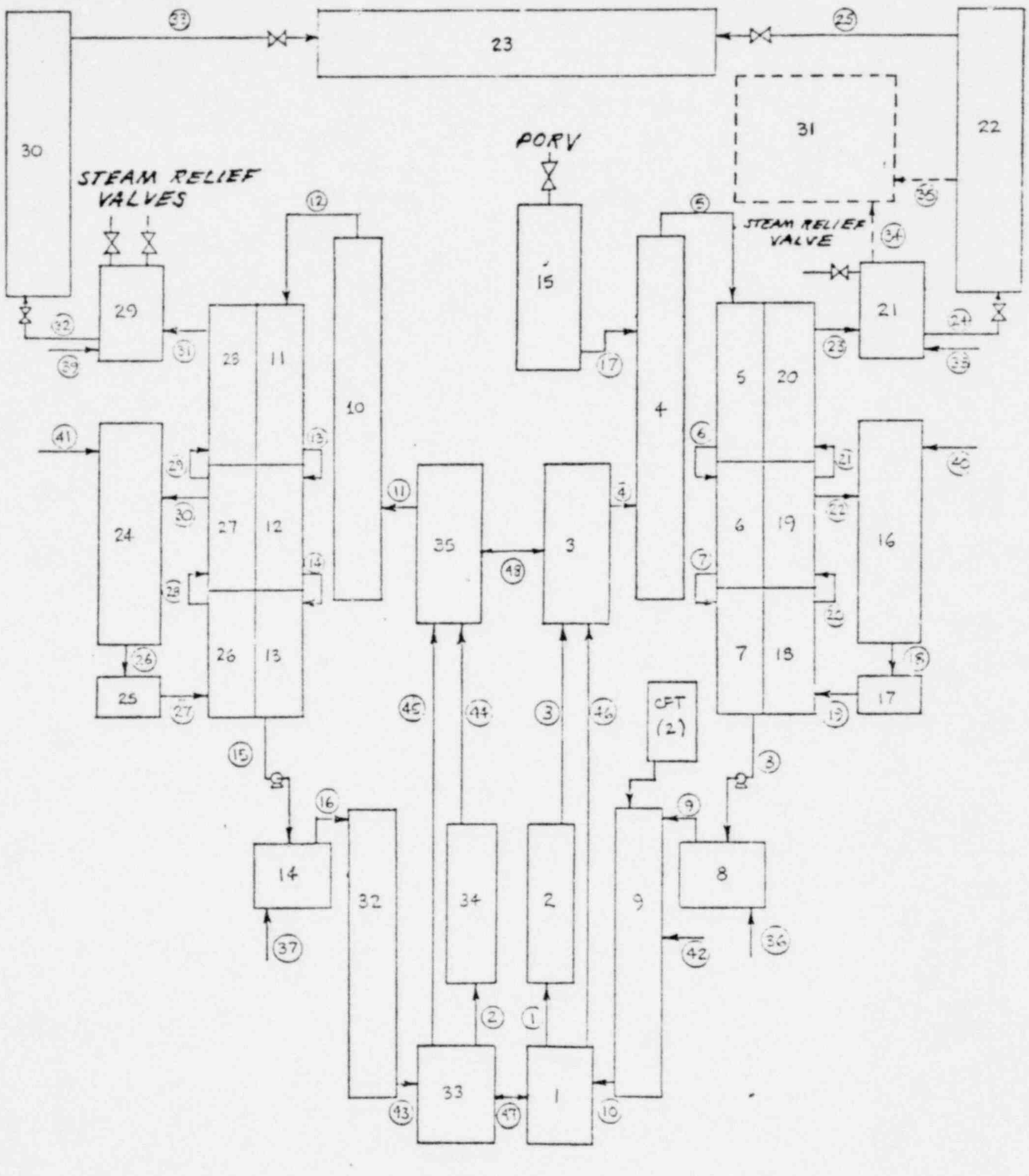

FIGURE 3-1

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TABLE 3-1

TRAP2 NODE DESCRIPTION

NODE NUMBER	DESCRIPTION
1, 33	REACTOR VESSEL, LOWER PLENUM
2, 34	REACTOR VESSEL, CORE
3, 35	REACTOR VESSEL, UPPER PLENUM
4, 10	HOT LEG PIPING
5-7, 11-13	PRIMARY, STEAM GENERATOR
8, 14	COLD LEG PIPING
9, 32	REACTOR VESSEL DOWNCOMER
15	PRESSURIZER
16, 24	STEAM GENERATOR DOWNCOMER
17, 25	STEAM GENERATOR LOWER PLENUM
18-20, 26-28	SECONDARY, STEAM GENERATOR
21, 29	STEAM RISERS
22, 30	MAIN STEAM PIPING
23	TURBINE
31	CONTAINMENT

TRAP2 PATH DESCRIPTION

PATH NUMBER	DESCRIPTION
1, 2	CORE
45, 46	CORE BYPASS
3, 4, 5, 11, 12, 44	HOT LEG PIPING
6, 7, 13, 14	PRIMARY, STEAM GENERATOR
8, 15	RC PUMPS
9, 16	COLD LEG PIPING
10, 43	DOWNCOMER, REACTOR VESSEL
17	PRESSURIZER SURGE LINE
18, 19, 26, 27	STEAM GENERATOR DOWNCOMER
20, 21, 28, 29	SECONDARY, STEAM GENERATOR
22, 30	ASPIRATOR
23, 31	STEAM RISER
24, 32	STEAM PIPING
25, 33	TURBINE PIPING
34, 35	BREAK (OR LEAK) PATH
36, 37	HPI
38, 39	AFW
40, 41	MAIN FEED PUMPS
42	LPI
47, 48	REACTOR VESSEL PLENUMS

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Figure 3-2 RC System Parameters During Loss of Offsite Power Test With Natural Circulation at Crystal River 3

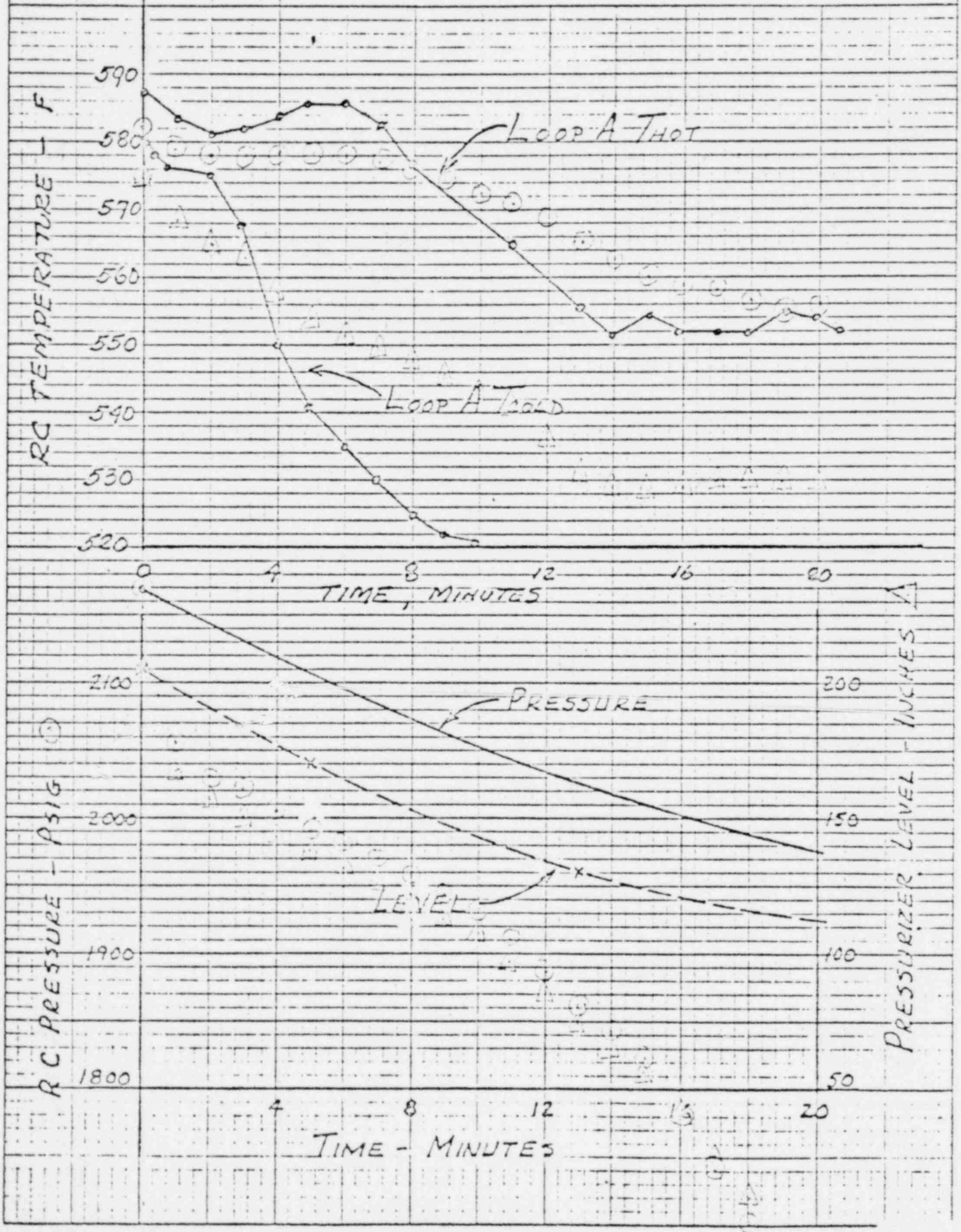

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Figure 3-3 RC System Temperatures and Saturation Temperature During Loss of Offiste Power Test With Natural Circulation at Crystal River 3

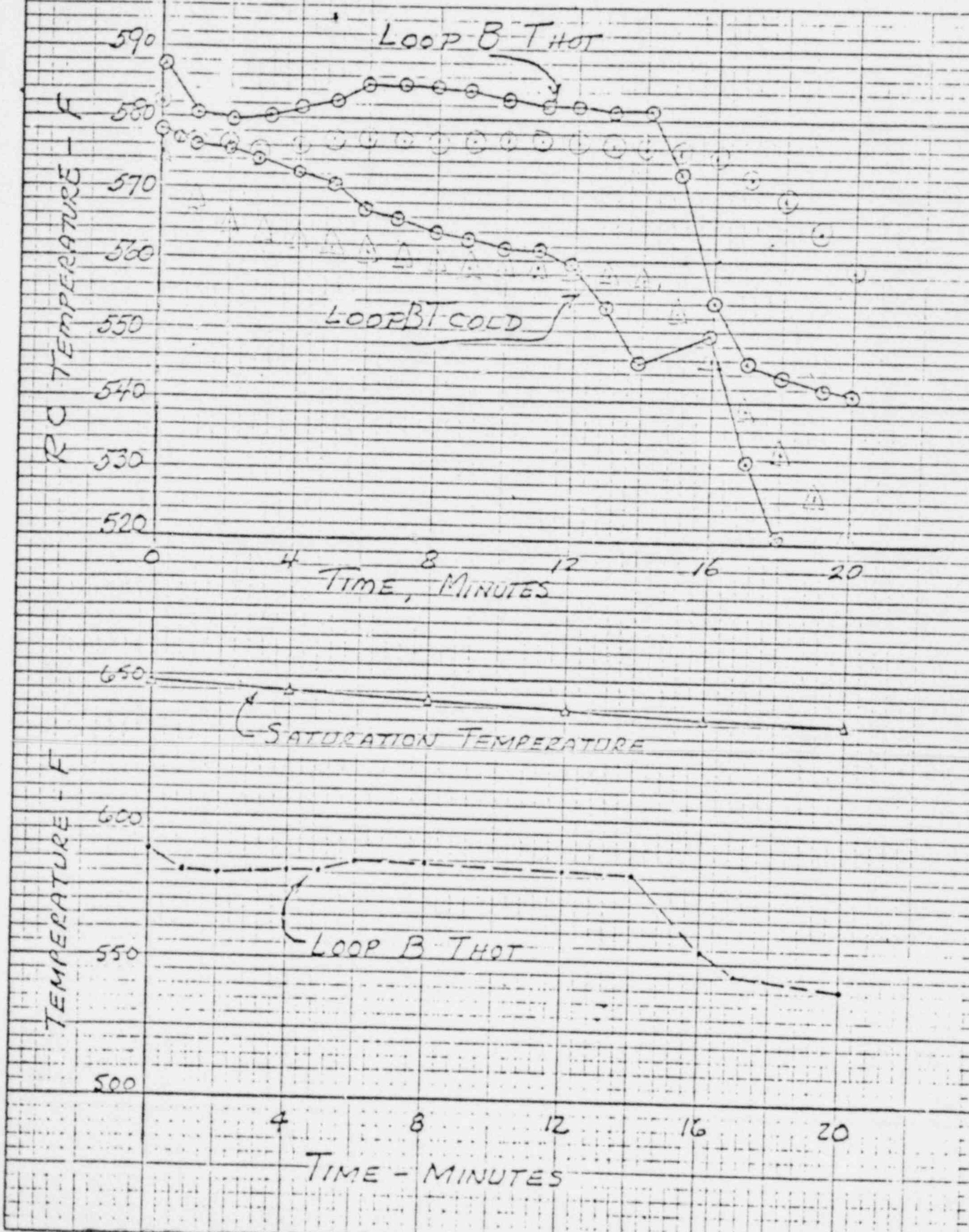


Figure 3-4 Steam Generator Conditions During Loss of Offsite Power Test With Natural Circulation at Crystal River 3

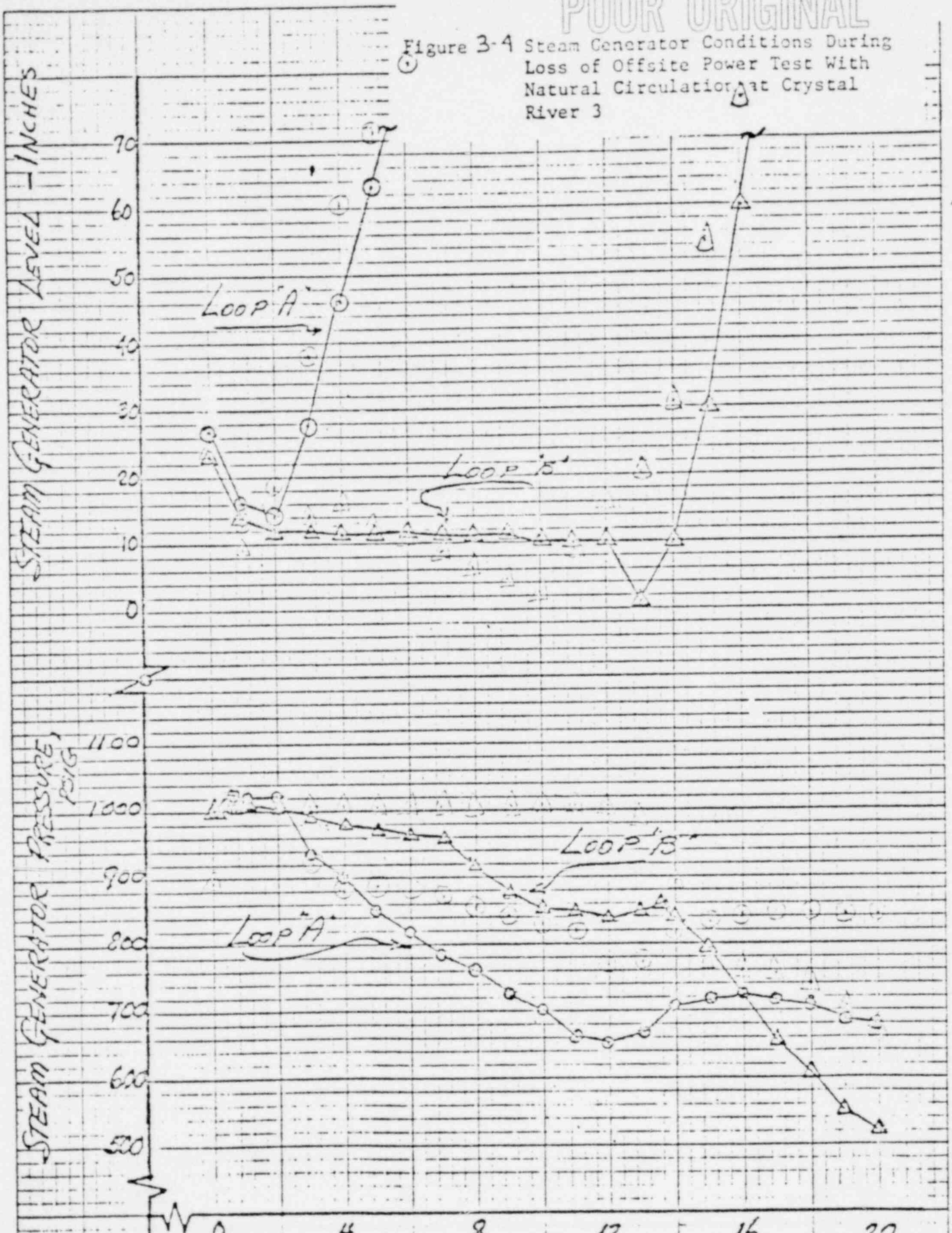
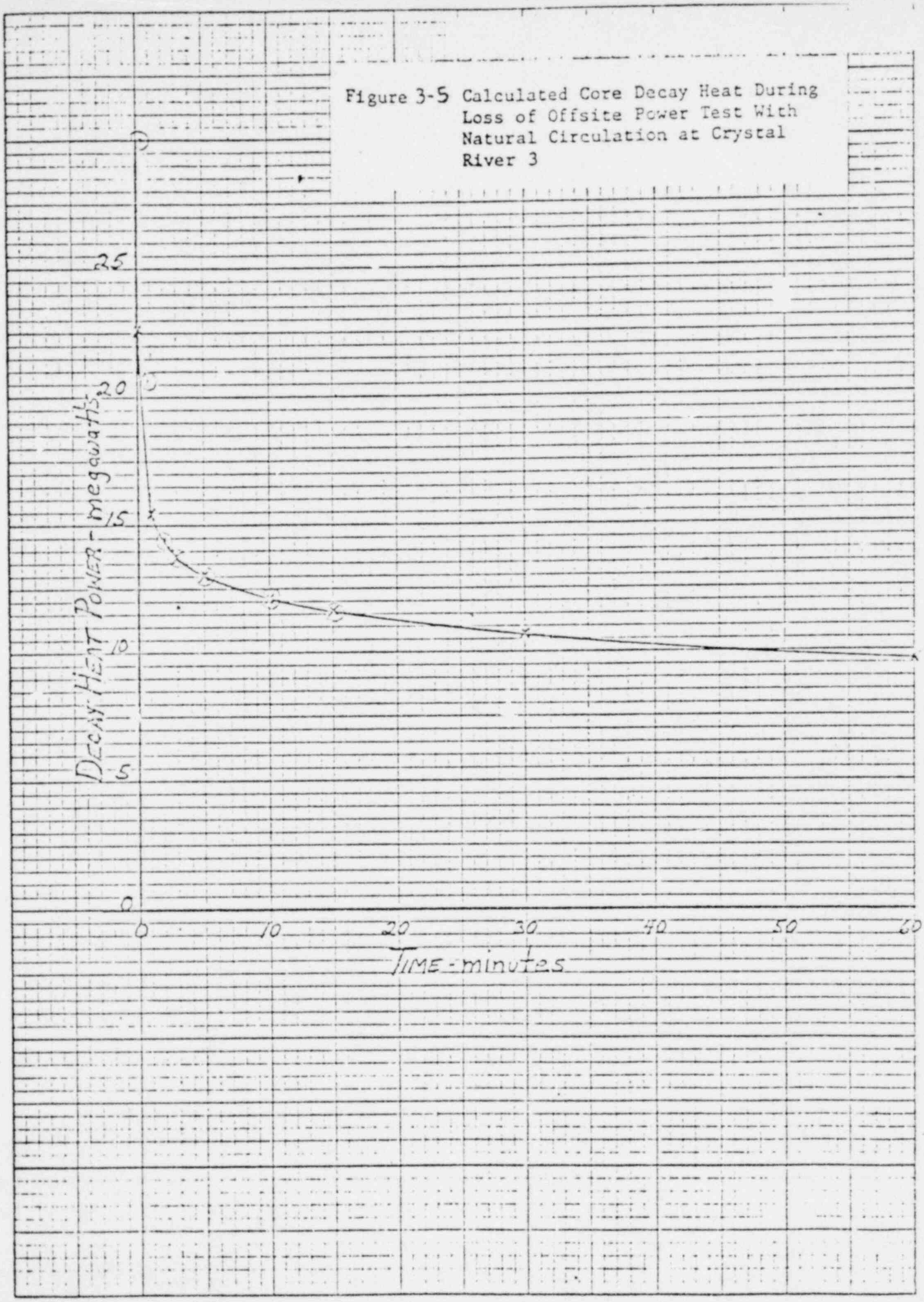


Figure 3-5 Calculated Core Decay Heat During Loss of Offsite Power Test With Natural Circulation at Crystal River 3



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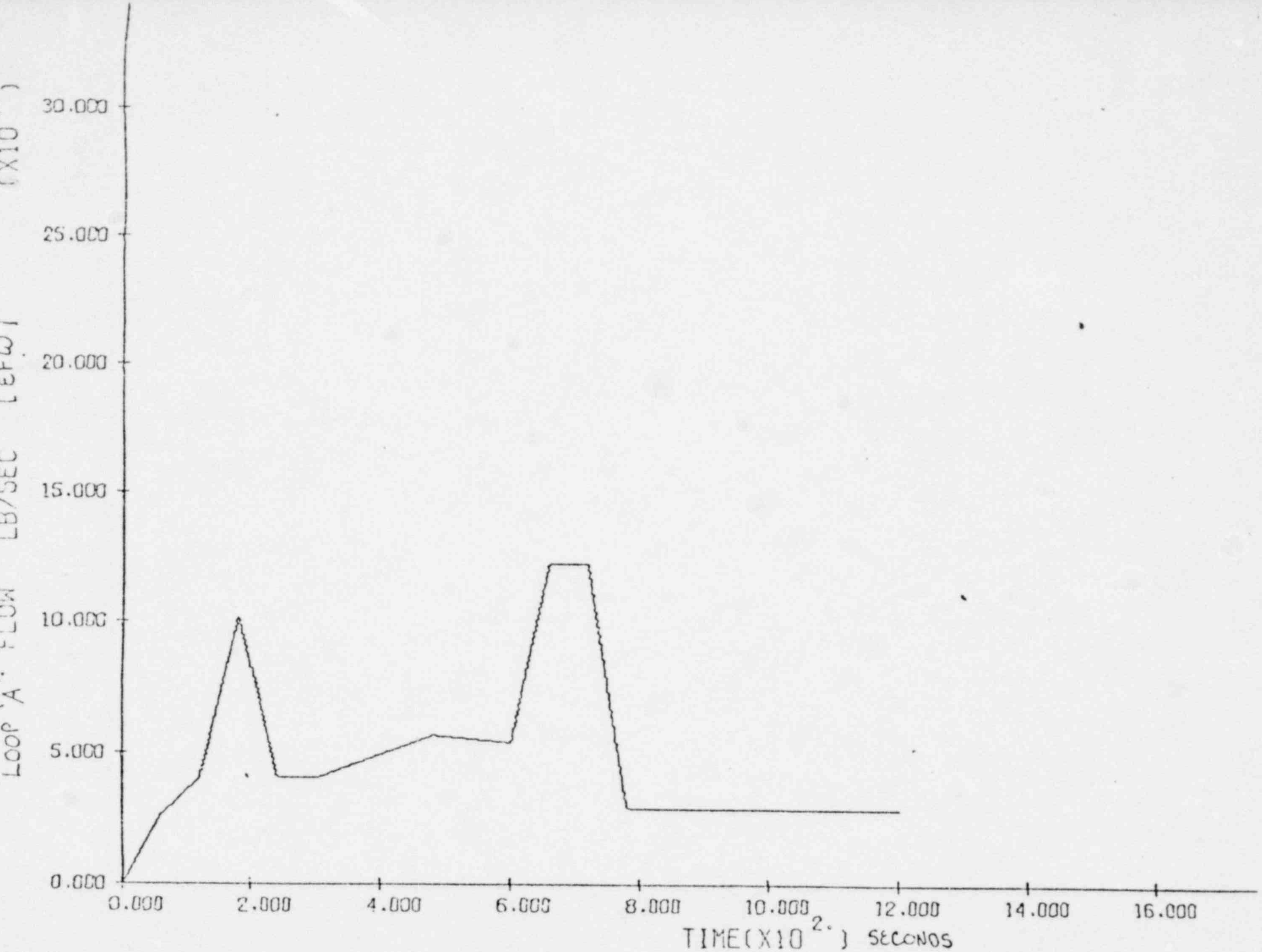

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FIGURE 3-6

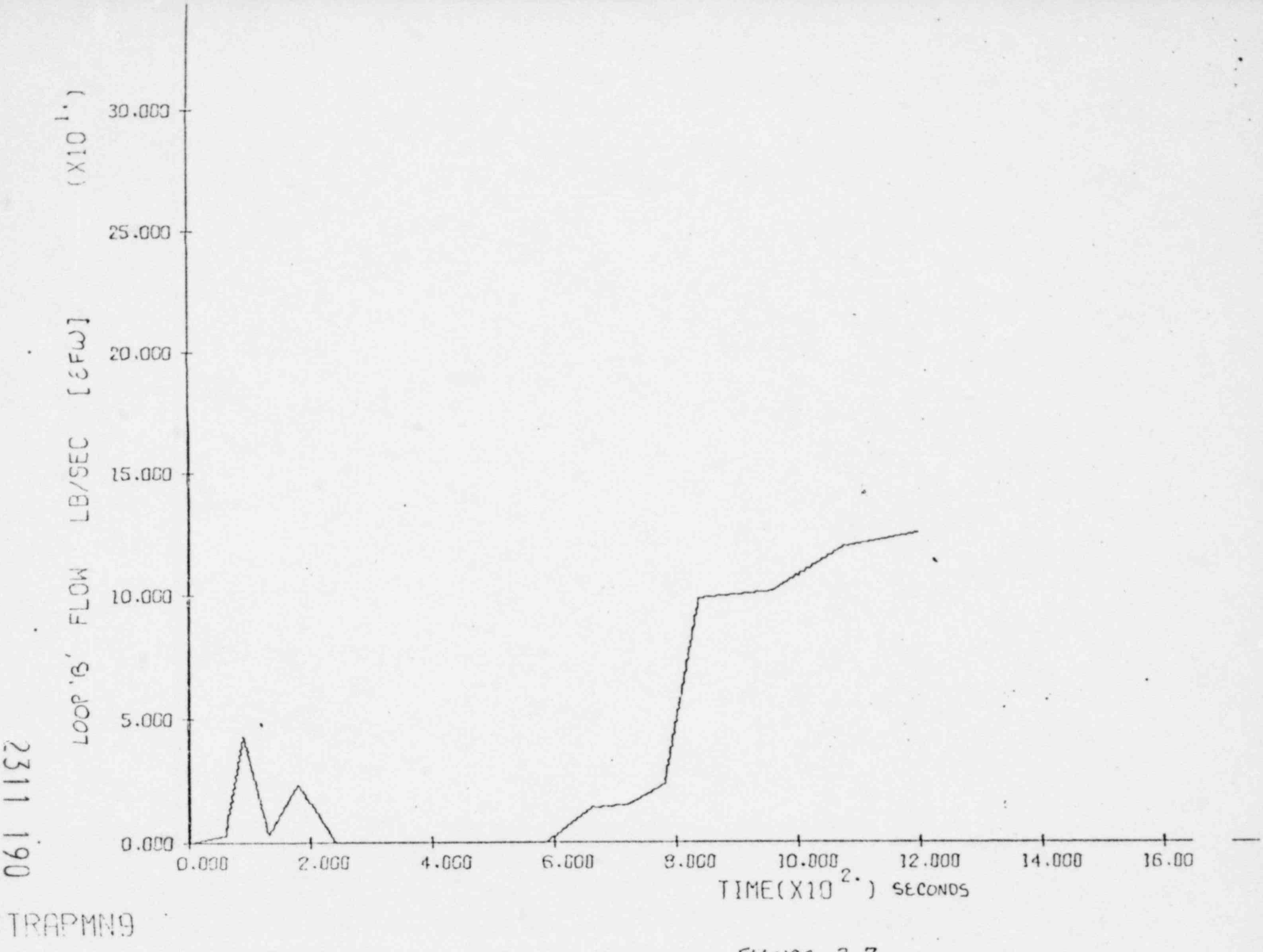

FIGURE 3-7

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