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# Evaluation of Load Rejection to House Load Test at 100% Power for YGN 4

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## Abstract

The Load Rejection to House Load test at 100% power was successfully performed during the YGN 4 PAT period. In this test, all plant control systems automatically controlled the plant from 100% power to house load operation mode. The LTC code, which was used in the performance analysis during the design process of YGN 3&4, predictions of the test agreed with the measured data demonstrating the validity of the code as well as the completeness of the plant design.

## 1. Introduction

The Load Rejection to House Load test at 100% power, which was successfully performed on September 20, 1995, is one of the major tests which characterize the capability of Yonggwang Nuclear Power Plant unit 4 (YGN 4). During this event, both 345kV switchyard breakers, ESY-7771 and ESY-7700, were opened to generate a full load rejection. Unless the Nuclear Steam Supply System (NSSS) and Turbine/ Generator (T/G) control systems actuate properly, the reactor will be tripped due to a high pressurizer pressure. In order to prevent reactor trip and to continue power operation during the loss of main feedwater pump(LOMFP) or a large load rejection event, the YGN 4 is designed with the Reactor Power Cutback System (RPCS) which is an unique design for YGN 4 compared to other PWR plants in Korea[1]. The RPCS is designed to actuate during the LOMFP event or a large load rejection in order to rapidly reduce the reactor power by dropping the pre-selected control element assemblies into the core so that the plant can be operated at a reduced power level[2,3]. Along with the RPCS, other control systems such as the Steam Bypass Control System (SBCS), the Feedwater Control System(FWCS), Reactor Regulating System (RRS), and the Pressurizer Pressure and Level Control Systems (PPCS and PLCS) are designed to automatically stabilize the plant conditions at a new steady state.

This paper presents the results of the load rejection to house load test at 100% power performed during the YGN 4 PAT period by evaluating the performances of the NSSS and T/G control systems as compared to the design capabilities. Also, the measured data are compared against the results predicted by the LTC (Long Term Cooling) code [4], which is the plant performance analysis computer code, in order to verify the plant design as well as to validate the computer code.

## 2.Test Descriptions

### 2.1 Objectives and Acceptance Criteria

The main objectives of the load rejection test at 100% power[5] are as follows:

(1) To demonstrate that the NSSS can accommodate the load rejection at 100% power without initiating a Reactor Protection System (RPS) signal or an Engineered Safety Features Actuation System (ESFAS) signal as well as without opening any primary or secondary safety valves and tripping the turbine.

(2) To assess the performances of the NSSS control systems (SBCS, FWCS, RRS, PPCS, PLCD, RPCS) and Turbine Control System(TCS) following full load rejection to house load from 100% power.

The major acceptance criteria for the test[5] are;

(1) The RPS does not initiate a reactor trip.

(2) The ESFAS is not actuated.

(3) The primary and/or secondary safety valves do not open.

(4) The need to open the Atmospheric Dump Valves does not arise.

(5) The RPCS drops the selected CEA Groups into the core.

(6) The 100% power load rejection is accommodated without tripping the turbine and with the turbine generator supplying the house loads.

### 2.2 Initial Conditions

The test initial conditions are defined as the 100% power steady state conditions [5], and the measured major plant parameters at the time of test initiation are presented in Table 1 as compared to the nominal design values at 100% power. As shown in this table, all major initial conditions were within the acceptable range for performing the test, and all the NSSS and T/G control systems were in automatic mode of operation.

### 2.3 Expected Plant Performance

Upon opening of the 345kV switchyard breaker ESY-7700, the turbine power decreases immediately to house loads in response to the TCS control action. The decrease in turbine power causes a dramatic decrease in the steam flowrate to the turbine, and, hence, a sharp increase in the steam generator pressure. In response to the decrease in the steam flowrate and the increases in the steam generator pressure and the pressurizer pressure, the SBCS generates the steam bypass demand and the reactor power cutback demand signals, simultaneously. The SBCS Quick Open signal opens all Turbine Bypass Valves(TBV) 1001 through 1008, and the reactor power cutback signal drops the pre-selected CEA groups into the core resulting in a rapid reactor power decrease.

Also, the pressurizer pressure increases due to the reduction in the primary to secondary heat removal, and the PPCS actuates the main spray. Initially, the SG water level decreases mainly due to the shrink caused by SG pressure increase and, then, recovers to the normal water level as the SG pressure stabilizes and the FWCS controls the feedwater flow.

The immediate actuations of the control systems described above are followed by slower control system actions such as the modulation steam bypass demand by SBCS to control the steam pressure and the CEA insertion demand by the RRS to match the reactor power to the turbine power. As the reactor power decreases, the SBCS starts to close turbine bypass valves. Based on the decrease in the RCS average temperature(Tavg), the PLCS controls the letdown flow to match the pressurizer water level to the programmed level, and the PPCS controls the pressurizer pressure to its nominal pressure of 2250 psia by controlling the pressurizer heaters or spray.

## 3.Test Results and Comparison to Expected Results

The test data and the LTC code predictions for the major plant parameters are plotted in Figures 1 through 8. As shown in Figure 1, the turbine runback to house loads(about 45MWe) was successful by the appropriate TCS control action right after the 345 kV switchyard breaker ESY-7700 was opened from the initial load of 1040MWe.

As shown in Figures 2 and 3, the RPCS dropped the selected CEA group, control bank #5 for this test, on a large load rejection signal, and the RRS further inserted control bank #4 to match the reactor power to the turbine power. The maximum Tavg-Tref deviation was about 27°F (Figure 3) which exceeds the RRS high rate CEA insertion setpoint of 3.53 °F. As the RRS starts to insert CEA bank #4 into the core, the reactor power decreases to 55% within 100 seconds after the initiation of the testes (Figure 2). Since the AMI setpoint is set at 55% power, the SBCS generates AMI signal to block the automatic CEA insertion demand signal, and the reactor power stops decreasing further (See Figure 2). A slight decrease in the reactor power below the AMI setpoint of 55% is mainly due to the reactivity feedback caused by Xenon build-up. As compared in Figures 2 and 3, the LTC code predictions reasonably follow the trends of measured data. Since the LTC code uses a point kinetics core model, the Xenon effect can not be calculated as shown in Figure 2.

As shown in Figure 4, the steam generator water level decreases sharply right after the initiation of the test mainly caused by the rapid increase in the steam generator pressure (Figure 5). After this initial level shrink, the steam generator level is restored as the steam generator pressure is maintained by SBCS (Figure 5). The FWCS responded to the steam generator level transient and controls the main feedwater flowrate to the steam generator (Figure 6). As presented in Figures 4, 5, and 6, the LTC code predicted similar trends to the test data. However, the steam generator water level trend obtained with the LTC code is slightly different from the measured data mainly due to the response time difference which need to be investigated further.

Based on the decrease in the Tavg, the PLCS controlled the pressurizer water level to the programmed level by controlling letdown flow (Figure 7), and the PPCS restored the pressurizer pressure to its nominal pressure of 2250 psia (Figure 8). In general, reasonable agreement was observed between the code predictions and the measured data.

## 4. Conclusions

The Load Rejection test at 100% Power for YGN 4 unit was performed successfully, and the test acceptance criteria described in Section 2 were virtually met. The trends of all major plant parameters were as expected by the design of the plant. Also, all NSSS and T/G control systems responded automatically to prevent reactor trip. The LTC computer code used in the performance analysis during the design process of YGN 3&4 predicted the test results successfully. However, further tuning on the input data as well as code modeling are deemed to be necessary for better predictions.

## References


(1) KEPCO, YGN 3&4 FSAR, Chapter 7.

(3) J. J. Sohn, et al., "Evaluation of Load Rejection to House Load Test at 80% Power for YGN 3," *Proc. of the KNS Spring Meeting,* Ulsan, Korea, May (1995)

(2) H. T. Seo, et al., "Evaluation of the Loss of a Main Feedwater Pump Test at 100% power for YGN 3, "*Proc. of the KNS Spring Meeting,* Ulsan, Korea, May (1995)

(4) ABB-CE, "LTC User's Manual," December 1986.

(5) KEPCO, "Test Procedure for PAT Load Rejection (with RPCS)," 3S-I-000-26, Rev.0, 11/23/94.


**TABLE 1: Initial Conditions of Major Plant Parameters**

| Parameters | Values | Nominal Design Values |
|---|---|---|
| Neutron Flux Power | 100 % | 100 % |
| Turbine /Generator Power | 1040 MWe | 2825 MWt |
| Pressurizer Pressure | 2250.0 psia | 2250 psia |
| Pressurizer Level | 52.0 % | 52.6 % |
| RCS Average Temperature | 591.0 °F | 592.85 °F |
| RCS Reference Temperature | 592.88 °F | 592.85 °F |
| Steam Generator Pressure | 1075 psia | 1088 psia |
| Steam Generator Level | 44 % of NR | 44 % of NR |

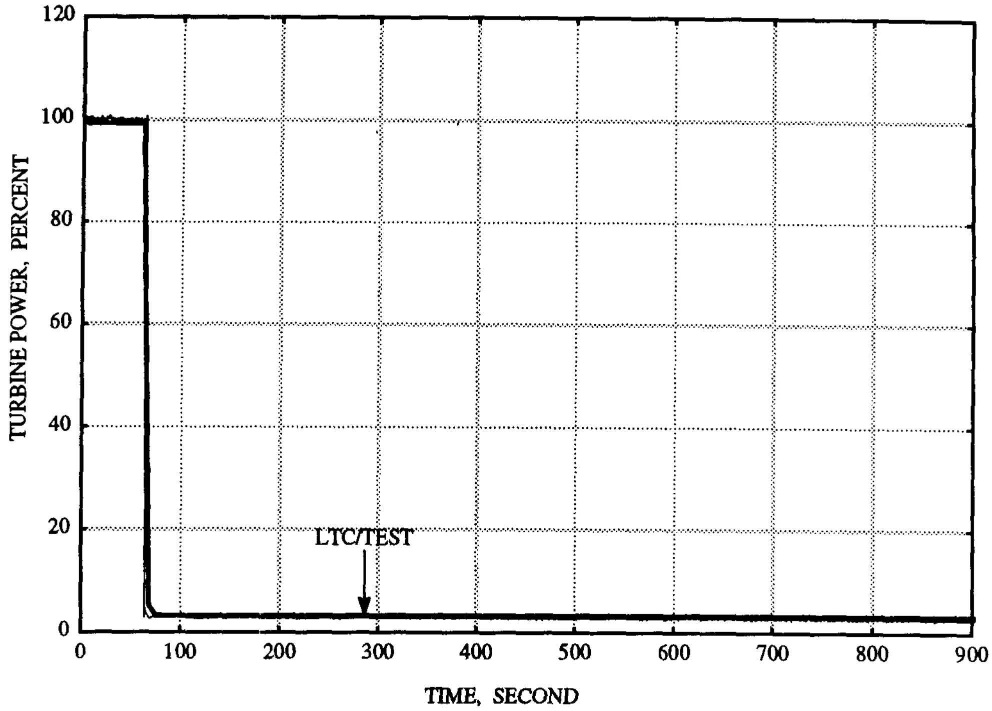

Figure 1. Turbine power vs. Time during Load Rejection Test at 100% Power

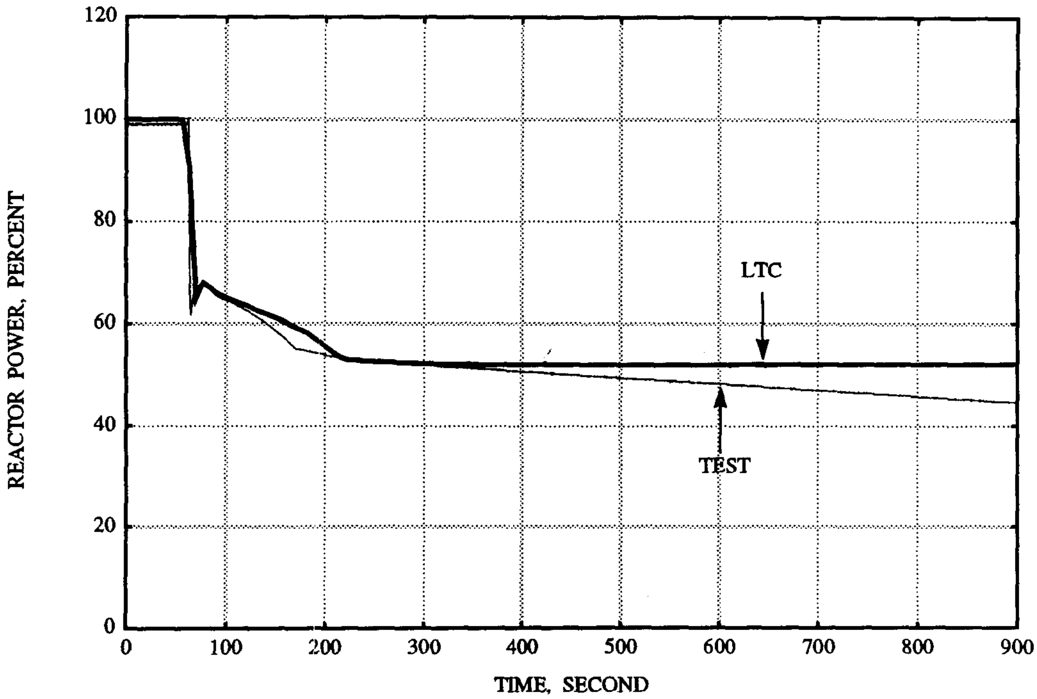

Figure 2. Reactor power vs. Time during Load Rejection Test at 100% Power

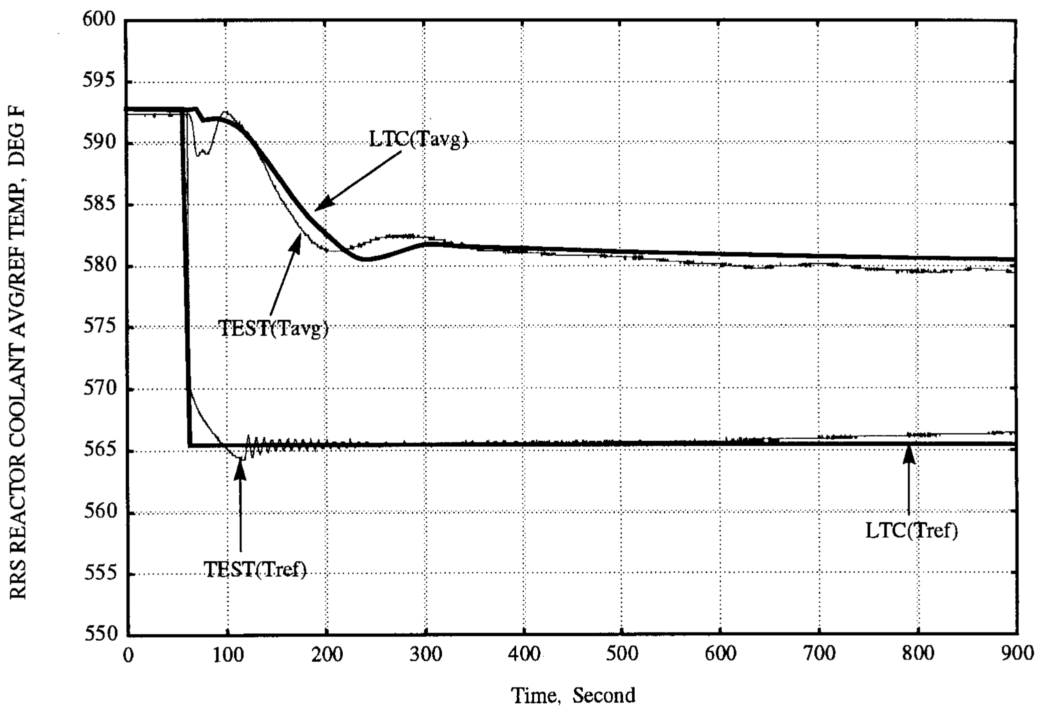


Figure 3. Tavg/Tref vs. Time during Load Rejection Test at 100% Power

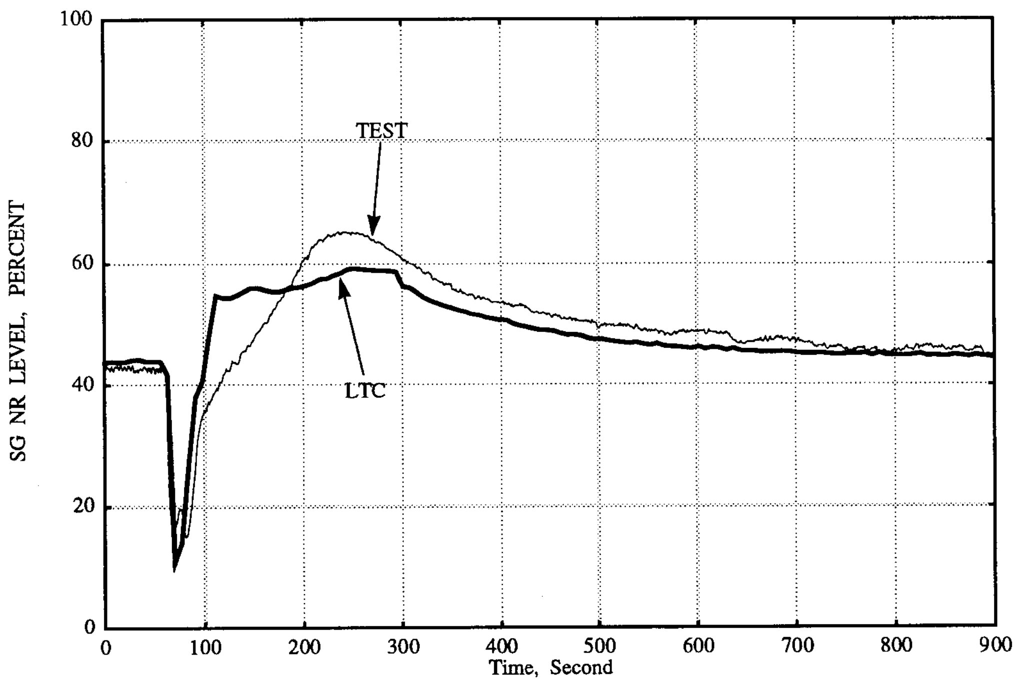


Figure 4. Steam Generator Water Level vs. Time during Load Rejection Test at 100% Power

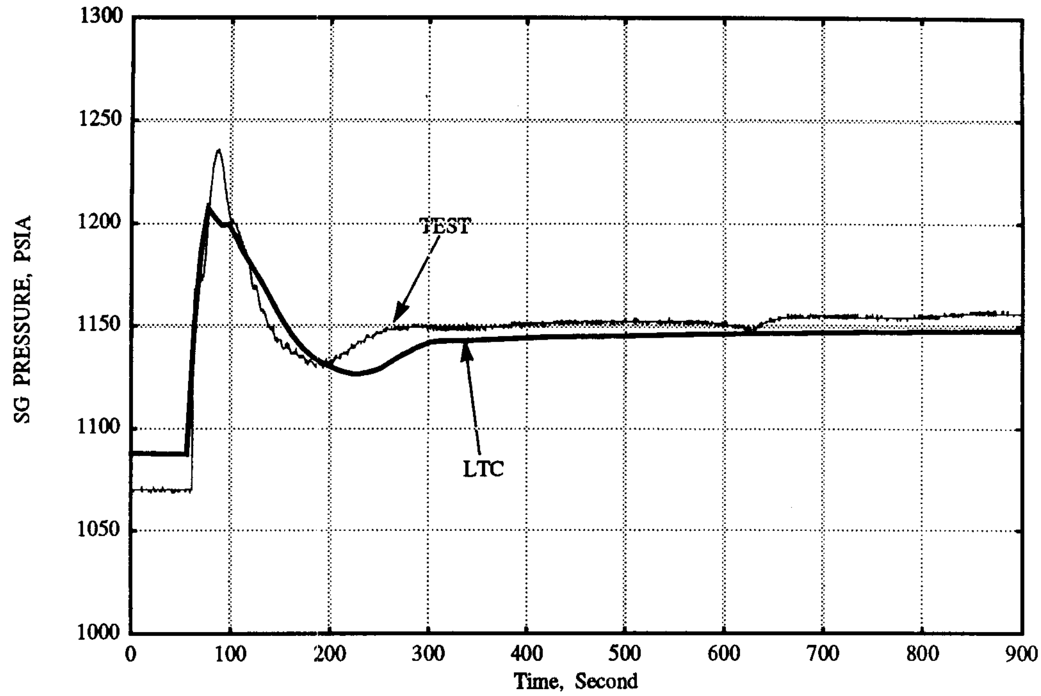


Figure 5. S/G pressure vs. Time during Load Rejection Test at 100% Power

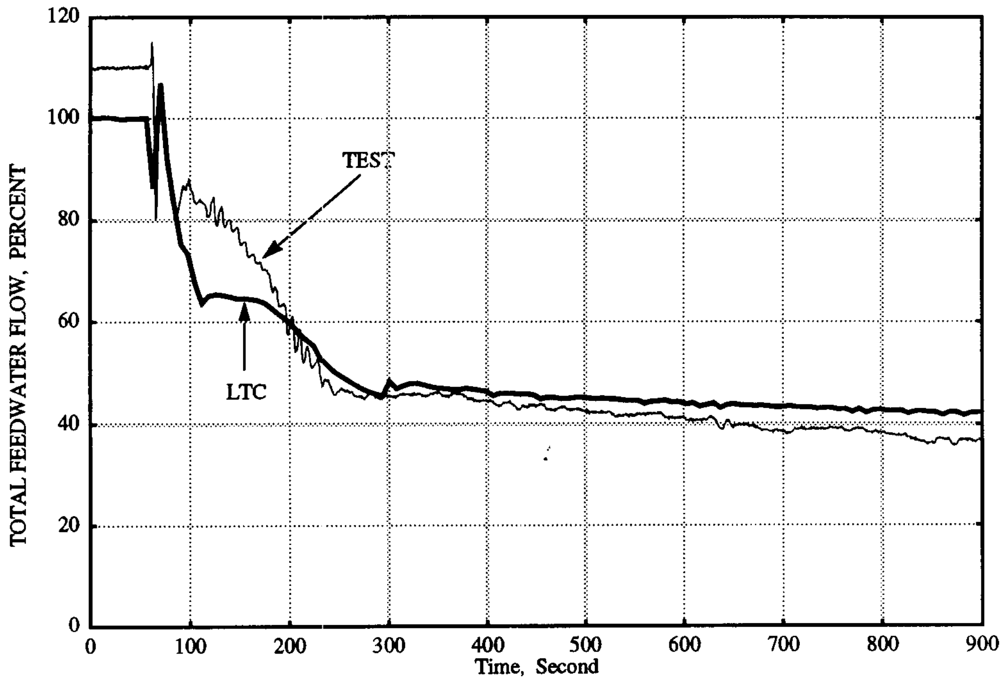


Figure 6. Feedwater Flow vs. Time during Load Rejection Test at 100% Power

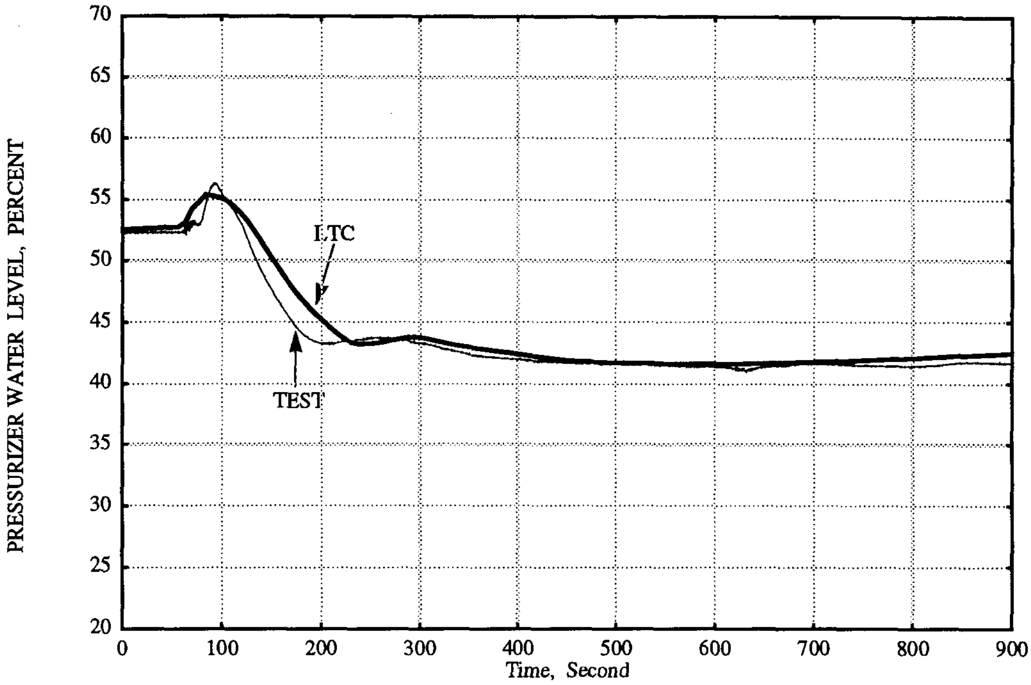


Figure 7. Pressurizer Water Level vs. Time during Load Rejection Test at 100% Power

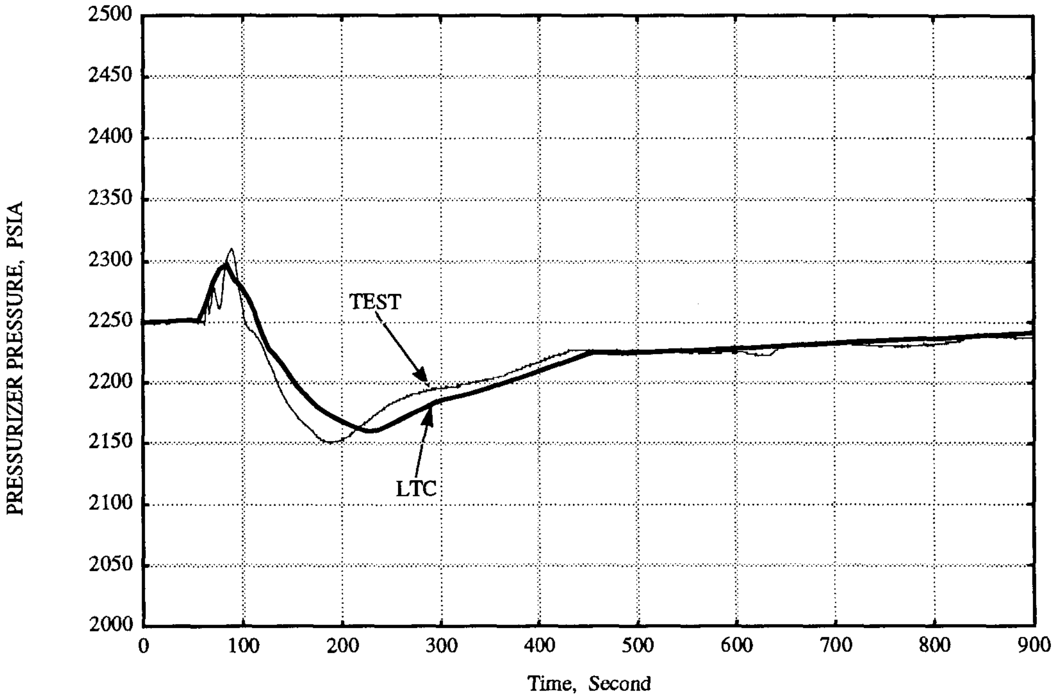


Figure 8. Pressurizer Pressure vs. Time during Load Rejection Test at 100% Power