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TIME RESPONSE TESTING OF RTDs FROM ST. LUCIE NUCLEAR POWER PLANT

by

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1. INTRODUCTION

The purpose of this report is to present the results of time constant measurements made at Technology for Energy Corporation's (TEC) laboratory in Knoxville, Tennessee. These measurements were funded by Florida Power and Light Company as a part of their sensor time response measurement program. Resistance thermometers (RTDs) furnished by Florida Power and Light Company from their St. Lucie site were tested using both plunge and LCSR* techniques.

The purpose of these tests was to verify that LCSR tests and plunge tests gave the same time constant for these RTDs. Industry standards for measuring RTD time constants are to plunge the sensor in a 170°F bath with a fluid velocity of three feet/second. Since reactor conditions are considerably different (500-600°F, 40 ft/sec) from industry standards, most of the tests performed here were done in a 540°F bath of lead. The velocity of the lead was set at one foot/second in order to obtain convective heat transfer coefficient similar to that obtained at reactor conditions.

Eight sensors were tested. They are identified in Table 1.1. All were tested in well 60 in lead, four were tested in well 66 in lead and in well 60 in water. Three were tested without the well (bare) in the water. In the balance of this report, we describe the experimental setup and test procedures and present the results of this testing program.

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*Details of the LCSR testing method are described in TEC Report R-8007.

TABLE 1.1

Sensor	Type	Purchase Date	Time in Reactor
57147	104VC	October 1971	33 months
57151	104VC	October 1971	33 months
57161	104VC	October 1971	33 months
57165	104VC	October 1971	33 months
57170	104VC	October 1971	not used
A8994	104VC	January 1976	not used
B5630	104-1696-1	April 1979	not used
B5642	104-1696-1	April 1979	not used

2. DATA ACQUISITION INSTRUMENTATION AND MEASUREMENTS

2.1 Test Equipment

All testing was performed using TEC's RTD Test Stand. This stand consists of an insulated tub in which the fluid to be used in a test may be rotated at a given constant speed. The temperature of the fluid is controlled by a proportional solid-state furnace controller, utilizing a thermocouple for rapid response to any slight temperature change in the fluid.

A sliding, vertical carriage is used to hold the RTD at a fixed radius perpendicular to the rotating fluid bath. During plunge testing, an electrically actuated pneumatic cylinder serves to propel the carriage and mounted RTD approximately 3.75 inches. This immerses approximately 3 inches of the RTD or RTD and well into the fluid. Transit time for the assembly is approximately 0.1 seconds, from point of electrical actuation to fluid contact.

Two different fluids were utilized in this test sequence. Water was used as a base for comparison of tests performed at TEC and earlier tests performed by the RTD manufacturer. The water bath was heated to a temperature of approximately 174 degrees F and rotated at the speed required to yield a 3.0 feet per second fluid velocity at the RTD surface.

The lead-tin alloy bath was heated to approximately 540 degrees F and rotated at the speed required to obtain a one foot/second fluid velocity at the RTD surface. The heat transfer coefficient at this condition is 12,000 B/hr-ft^2-°F which is the same as that in a 40 ft/sec stream of 540°F water.

2.2 Signal Conditioning and Control

Special instrumentation designed, fabricated, and tested by TEC was used in this measurement. A block diagram of the test instrumentation is presented in Fig. 2.1.

The rack mounted modular instrumentation system consisted of a TEC Model 1131 Constant Current Source, Model 1121 Control Module, and Model 1101 LCSR Bridge. In addition, three separate modular power sources were utilized to: (1) provide a floating excitation voltage for the bridge (relative to the signal conditioning circuitry), (2) power the control and switching logic, and (3) provide the normal instrumentation power for signal conditioning.

The RTD under test was interfaced with the Model 1101 LCSR bridge via a special 3-wire test cable.* During an LCSR test, a small standby current is furnished the RTD from the Model 1131 constant current source. Upon initiation of the LCSR step (controlled from the model 1121 Control Unit), a controlled step in RTD current is made and the output from the Model 1101 LCSR Bridge is sampled by the computing system and saved on floppy disk.

During these tests, automatic control of the LCSR steps was provided by the computing system.

During plunge testing, the bridge was balanced with the RTD above the fluid bath. Computer sampling was initiated when the RTD and carriage began to move toward the fluid bath and continued during a time period specified by the operator. Gains were determined by a single test performed during setup for each RTD.

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*The RTD was connected to the bridge in a two wire configuration.

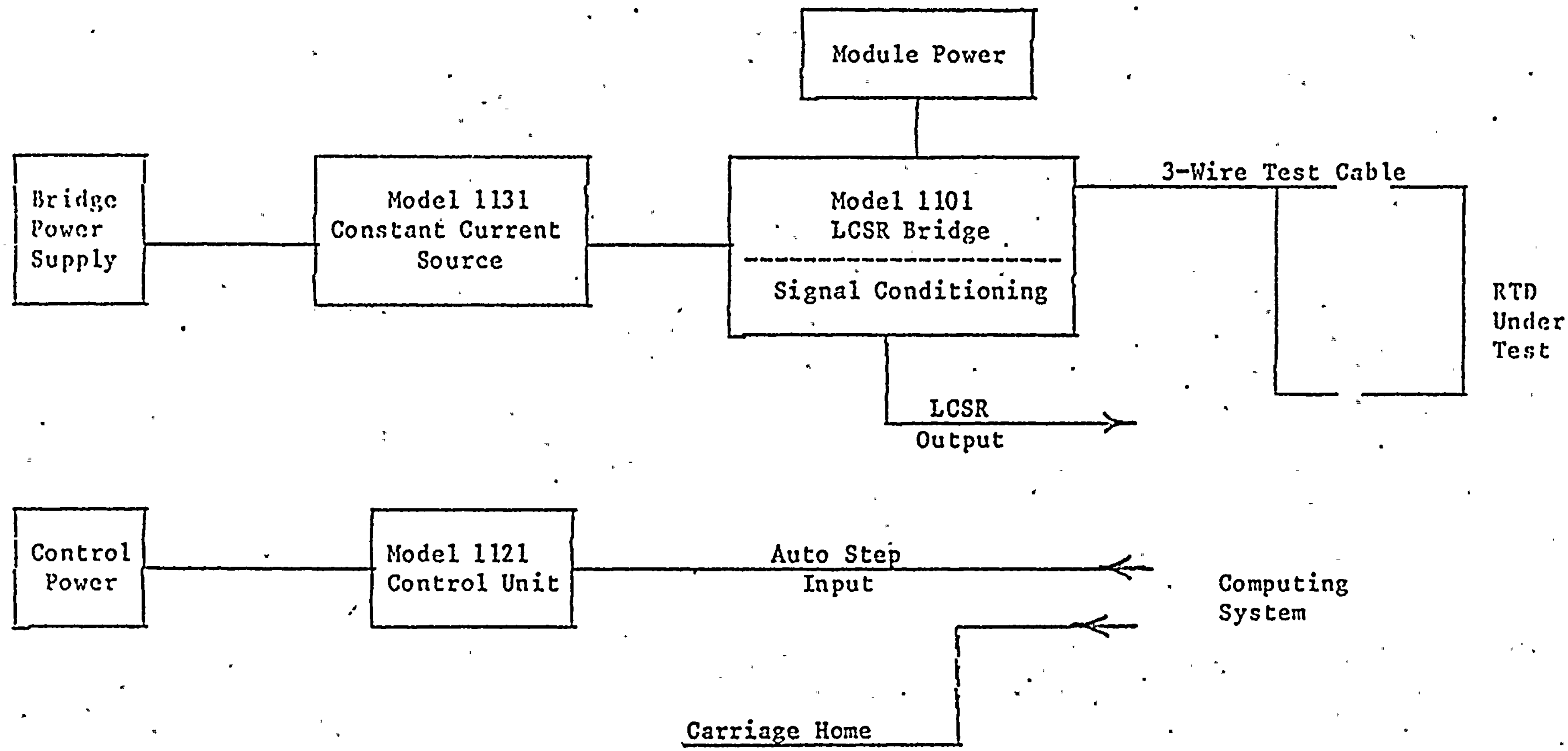

Figure 2.1 LCSR Measurement Instrumentation.

During LCSR testing, the bridge was balanced with the RTD in the fluid bath. Several sets of tests were initiated by the computing system on a timed basis. Sufficient time was introduced between tests to allow the RTD under test to return to equilibrium.

2.3 Test Procedures

Eight RTDs and two wells were tested. All eight RTDs were tested in well 60 in molten lead-tin alloy. Four representative RTDs were tested in well 66 in molten lead-tin alloy. The same four RTDs were tested in well 60 in water. Three bare RTDs were tested in water.

In all cases, the test procedure to be followed was similar. The RTD and well or the bare RTD was mounted securely in the TEC test equipment. Measurement of the resistance of the connection to the LCSR bridge was made to verify correct connection of the device.

When the RTD reached thermal equilibrium, the instrumentation was electrically balanced. A preliminary plunge test was performed to allow possible modification of instrumentation gain to achieve maximum allowable signal magnitude. The RTD was removed from the fluid and allowed to return to a balanced condition. A plunge test was then performed and the digitized results were saved on floppy disk. The bridge was balanced in the new environment and five LCSR measurements performed. Results of each test were saved on floppy disk, after computer digitization, for later off-line reduction. The RTD was removed from the fluid and allowed to regain thermal equilibrium. The six-test cycle was then repeated. Once the 12 test cycle was completed, the next RTD was mounted and the test cycle repeated.

3. RESULTS

3.1 Results

The results of the tests described in Chapter 2 are presented in Tables 3.1, 3.2, and 3.3. The plunge time constant error of 3% was determined in earlier tests of repeatability of plunge tests. The LCSR errors result from uncertainties in both geometry and eigenvalues. The geometric uncertainties are platinum radius (±0.010") and sheath radius (±0.010"). The uncertainty in first eigenvalue is ±5% and ±10% in the second eigenvalue.

The agreement of the plunge and LCSR tests was quite acceptable with an average difference of 0.3 seconds or 5% of the measured time constant.

Table 3.4 presents a comparison of plunge time constants of sensors in two wells and in both lead and water. Three observations can be made from these results. First, the time constant of a bare sensor has little effect on its time constant in a well. Bare sensor B5642 was 1.2 seconds slower than bare sensor A8994 yet their time constants in both wells in lead was virtually identical. Second, the time constant was not dependent on the well. Sensor 57161 was faster in well 60 than in well 66 while the other three were faster in well 66. Finally, surface transfer and bulk temperature had little direct effect on the time constant since there is no consistant difference in the 540°F-lead results and the 170°F-water results.

TABLE 3.1

PLUNGE AND LCSR TIME CONSTANTS IN 540°F LEAD

Well	Sensor	Plunge τ	LCSR τ
60	57147	5.9±0.2	6.0±0.4
60	57151	6.0±0.2	6.0±0.4
60	57161	5.0±0.2	4.8±0.3
60	57165	6.9±0.2	6.5±0.4
60	57170	5.4±0.2	5.2±0.2
60	A8994	6.7±0.2	7.0±0.4
60	B5630	5.6±0.2	5.8±0.4
60	B5642	6.8±0.2	6.9±0.4
66	57161	5.4±0.2	6.0±0.2
66	57165	5.9±0.2	5.3±0.5
66	A8994	6.2±0.2	7.0±0.5
66	B5642	5.9±0.2	5.7±0.3

TABLE 3.2

PLUNGE AND LCSR TIME CONSTANTS IN 170°F WATER

Well	Sensor	Plunge τ	LCSR τ
60	57161	5.9±0.2	5.6±0.3
60	57165	5.9±0.2	6.0±0.3
60	A8994	6.8±0.5	6.7±0.3
60	B5642	8.3±0.7	7.2±0.6

TABLE 3.3

PLUNGE TIME CONSTANTS OF BARE SENSORS

Sensor	Time Constant
A8994	2.3±0.1
B5630	2.2±0.1
B5642	3.4±0.1

TABLE 3.4

COMPARISON OF PLUNGE TIME CONSTANTS

Sensor	Lead-Well 66	Lead-Well 60	Water Well 60
57161	5.4	5.0	5.9
57165	5.9	6.9	5.9
A8994	6.2	6.7	6.8
B5642	5.9	6.8	8.2

The conclusion to be drawn from these results is that the contact resistance between sensor and well is an extremely important parameter that can contribute up to 50% of the time constant. This resistance is a function of mechanical tolerances, differential thermal expansion and mounting procedures. A sensor removed from a well and then reinserted may experience a change in time constant of up to a second or two. Thus, a sensor and well may be tested in the laboratory and its time constant obtained; then its time constant can be significantly modified after disassembly, welding into the piping and reassembly. This change cannot be interpreted as a degradation in the sensor since this will be the normal occurrence.

The last observation to be made from the results of these tests is that there is no consistant difference in the time constant of the sensors (57147-57165) that were removed from the reactor and the sensors (57170, A8994, B5630 and B5642) which had never been used. There is no evidence that any degradation occurred during 33 months operation.

4. CONCLUSIONS

The following conclusions can be drawn from the results of these tests:

1. No measureable degradation in time constant could be attributed to three years of operation in the St. Lucie reactor.
2. No difference in time constants obtained from plunge tests and time constants obtained from LCSR tests and TEC's continuous model transformation were observed.
3. Contact resistance between sensor and well was the determining factor in these measurements. Thus, laboratory tests are of little use in predicting in-situ time constants.