LAC-TR-070

LACBWR FUEL CYCLE 6

STARTUP TEST PROGRAM RESULTS

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TABLE OF CONTENTS

Page

759091

FIGURES

Figures		Page

1.0 INTRODUCTION

On May 25, 1979, the NRC issued Amendment No. 16 to Provisional Operating License No. DPR-45 (Reference 1) authorizing operation of the LACBWR for Fuel Cycle 6. The LACBWR core configuration for Cycle 6, shown in Figure 1, consists of 26 fresh Type III (Exxon) fuel assemblies, 2 fresh Type I (Allis-Chalmers) assemblies, 32 previously irradiated Type III assemblies, and 12 previously irradiated Type II (Allis-Chalmers) assemblies.

On May 25, 1979, at 2140 hours, the LACBWR was taken critical for the beginning of Fuel Cycle 6. A summary report of the plant startup and power escalation testing outlined in References 1 and 2 is presented below.

2.0 TEST PROGRAM AND RESULTS

2.1 VERIFICATION THAT THE LACBWR CORE CONFIGURATION FOR CYCLE 6 AGREES WITH THE DESIGN CONFIGURATION

As each fuel assembly was loaded into the LACBWR core, it was identified by the serial number on the lower end fitting by a Fuel Accountability Delegate and its position in the core documented. After all of the previously irradiated fuel assemblies had been positioned in the core according to the design configuration, the core was examined visually by the Fuel Accountability Representative to verify that an irradiated fuel assembly of the proper type was in each location designated for a previously exposed fuel assembly, and that locations designated for fresh fuel were still empty. The visibility during the examination was excellent and there was no problem in identifying the Type II and Type III assemblies by the difference in upper end fittings. After this examination was satisfactorily completed, the fresh fuel assemblies were loaded into the core according to the design configuration with a Fuel Accountability Delegate identifying each assembly by serial number and documenting each move.

When the refueling was completed, a new high resolution TV camera was used to read the serial number on the handle of each fuel assembly in place in the core. The numbers were easily distinguished with the new TV equipment and the as loaded core configuration for fuel Cycle 6 was verified to be in agreement with the design configuration.

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2.2 CONTROL ROD DRIVE FUNCTIONAL AND SCRAM TESTS AND CHECK FOR CRITICALITY WITH ONE ROD OUT

Before the reactor was taken critical, all of the control rod drives were functionally checked. Each control rod was exercised over its full range of travel while carefully observing the count rate on the source range nuclear instrumentation channels. Only very small changes in the count rate due to subcritical multiplication of source neutrons was observed during individual control rod withdrawals indicating that the reactor was significantly subcritical with any single control rod fully withdrawn.

Each of the control rods was scram tested with an average scram time of 1.98 seconds and minimum and maximum scram times of 1.82 and 2.13 seconds respectively observed. The Technical Specification limit for control rod scram time is 3.0 seconds. Both scram solenoids were observed to operate as each rod was scramed.

All control rod position indicators were functionally checked. All interlocks and scram functions associated with the control rods, such as high reactor power trips, short reactor period trip, high reactor pressure trip, reactor coolant flow rate abnormal trip, reactor coolant flow rate low trip, reactor water level high trip, reactor water level steam isolation valves not fully open trips, turbine stop valve not fully open trip, low oil level or low gas pressure in any control rod drive accumulator trips, low voltage trips, the interlock to prevent increasing recirculation pump speed while withdrawing a control rod and interlocks controlling reactor start permits and control rod withdrawal permits were functionally tested and/or calibrated as required by Technical Specifications before reactor startup.

2.3 VERIFICATION OF PREDICTION OF CRITICAL ROD PATTERN

On May 25, 1979, the LACBWR was taken critical to begin Fuel Cycle 6. Criticality was achieved at 2140 hours with all 29 control rods withdrawn as a bank to 12.819 dial inches. The reactor temperature was 95°F and the recirculation flow rate was 7.1×10^6 lb/hr. The predicted 29 control rod bank critical position for these conditions was 12.590 dial inches. The deviation between actual and predicted critical position was, therefore, 0.229 dial inches or 0.334% $\Delta k/k$. This value is well within the LACBWR Technical Specification requirement that the reactivity worth of the difference between the observed and predicted critical rod pattern not exceed 2% $\Delta k/k$ following core reloading and/or core rearrangement.

.4 SHUTDOWN MARGIN VERIFICATION WITH MOST REACTIVE ROD WITHDRAWN

As reported in Reference 3, the stuck rod shutdown margin at the beginning of Fuel Cycle 6 has been calculated for each rod (excluding symmetric duplicates) using the TRILUX model.

The least shutdown margin determined from this model was 1.4% $\Delta k/k$ with control rod No. 14 out of the core and the other 28 control rods fully inserted. The LACBWR Technical Specification requirement for shutdown margin with the most reactive control rod stuck out of the core is 0.5% $\Delta k/k$. In order to experimentally confirm that the required shutdown margin is available, the following experiment was performed:

(1) Control Rod No. 14 was withdrawn from the critical reactor while criticality was maintained by inserting the remaining twenty-eight control rods as a bank. Stable critical conditions were obtained with Rod No. 14 fully withdrawn and the remaining twenty-eight control rods banked at 12.679 dial inches.

(2) The twenty-eight rod bank was inserted 0.221 inches so that the reactor was subcritical by 0.358% $\Delta k/k$ as determined from the known worth of the 28-rod bank, and the steady state subcritical count rate of each of the startup channels was obtained.

(3) The twenty-eight rod bank was inserted in several increments, and the steady state count rate of each startup channel was obtained after each incremental insertion.

Theoretically, the k_{eff} of the system and therefore the shutdown margin after each control rod insertion (x) in Step (3) above may be determined from the following equation:

$$(k_{eff})_x = 1 - \left[1 - (k_{eff})_1\right] \frac{(CR)_1}{(CR)_x}$$

WHERE: $(k_{eff})_1$ and the count rate $(CR)_1$ are determined in Step (2) above and $(CR)_x$ is the steady state subcritical count rate observed after control rod insertion (x).

After each incremental insertion of the twenty-eight rod bank, the count rate in the startup channels decreased indicating a continuous insertion of negative reactivity as the rods were inserted. With the twenty-eight rods fully inserted and rod 14 fully withdrawn, the above procedure yielded values of 1.27% and 1.96% $\Delta k/k$ shutdown margin from startup channels 1 and 2 respectively. The average of these two values, 1.62% $\Delta k/k$, agrees quite favorably with the calculated value, 1.4% $\Delta k/k$, determined from the TRILUX model.

2.5 VERIFICATION THAT THE TEMPERATURE COEFFICIENT OF REACTIVITY IS NEGATIVE AT ALL TEMPERATURES FROM AMBIENT TO OPERATING TEMPERATURE

The moderator temperature coefficient of reactivity in the LACBWR was shown to be negative at all temperatures from ambient to operating temperature as required by the LACBWR Technical Specifications by determining that continuous withdrawal of the 29 control rod bank is required to maintain criticality as the reactor is heated from ambient to operating temperature. During the heatup of the system, the position of the 29 rod bank for criticality at essentially zero power was determined approximately every 50°F and the results are plotted in Figure 2.

2.6 INITIAL POWER ESCALATION FOR FUEL CYCLE 6

Upon completion of the system heatup on the 27th of May, reactor power was escalated and an attempt was made to put the turbine-generator on line. However, problems with the turbine oil and governor system delayed power escalation for approximately two days. Instrument problems causing reactor shutdowns on May 30, June 1, and June 18 also delayed the power escalation. Figure 3 shows the power history for the LACBWR during the initial startup and power escalation for Fuel Cycle 6. In order to limit stresses in the fuel rod cladding, the initial power escalation was limited to 10% of rated power per day between 30% and 50% of rated power, 5% of rated power per day between 50% and 70% of rated power and 3% of rated power per day above 70% of rated power.

2.7 COMPARISON OF CALCULATED POWER SHAPE WITH INCORE MONITOR DATA

On June 25, 1979, approximately 4 days after reaching a steady state operating power of 92% of rated power, data was obtained from the traversing incore flux monitoring system for comparison with values calculated by the TRILUX model. The locations of the nine incore flux monitors are shown in Figure 1. Data was obtained from only 8 of these monitors since the channel 1 detector is not operational at the present time.

These incore monitors measure the neutron reaction rate in a ^{10}B or ^{235}U lined detector as it is moved vertically in the center of a Zirconium post along the common junction line of four fuel shroud cans and the accuracy of the data is dependent on amplifier and recorder calibration and on the ability to know the detector position in the core.

On the other hand, the calculation with the TRILUX model determines the nodal power distribution in each of the fuel assemblies surrounding the monitor. In order to compare the two, it is necessary to convert one to the other by means of a calculation. The procedure selected was to convert the calculated power distribution in the fuel assemblies to predicted reaction rates in the detectors in the Zirconium posts and compare results with the incore monitor data. This reaction rate is a function of neutron spectrum and neutron density and, therefore, is a function of fission rate in the surrounding fuel, isotopic composition of the fuel, voids in the moderator, type of shroud can, presence of control rods, etc.

A computer code called BF_3, written specifically for LACBWR, is used to calculate this reaction rate at the center of the Zirconium posts from TRILUX output. Since the LACBWR incore monitors cannot be intercalibrated, they can only be used to determine axial relative flux shapes and the comparison of the amplitude of one monitor output to another has no valid basis. Therefore, it was decided that both the incore monitor data and the calculated data would be normalized to an average value of one for each channel to facilitate their comparison.

The comparison of the normalized incore monitor data and the normalized results calculated by the TRILUX and BF_3 model are shown in Figures 4 and 4a. As can be seen in these figures, the agreement between the calculated and the measured axial flux shape is quite good.

3.0 CONCLUSIONS

The startup testing of the LACBWR was completed on June 25, 1979, and the reactor was operating at a nominal steady state power level of 92% of rated power. All operating parameters were conservatively within Technical Specification limits and consistent with design predictions. All reactor systems were operating satisfactorily.

REFERENCES

1. NRC Letter, Ziemann to Linder, dated May 25, 1979.

2. DPC Letter, LAC-6274, Linder to Director of NRR, dated May 9, 1979.

3. DPC Letter, LAC-6130, Linder to Director of NRR, dated February 26, 1979.

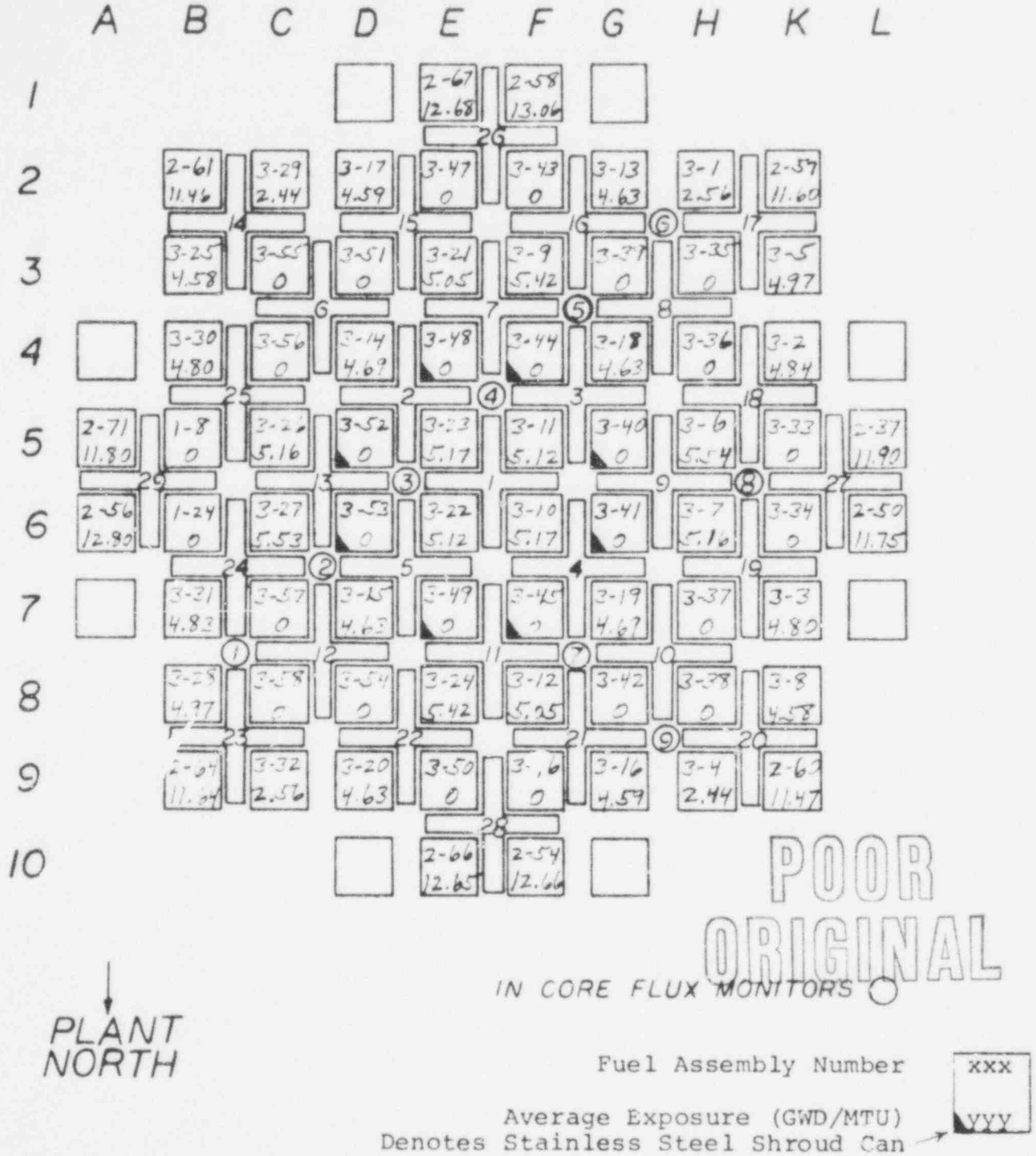


FIGURE 1 - LACBWR Reload Configuration For Cycle 6. The BOC Core Average Exposure is 4,203 MWD/MTU (Trial Reload H).

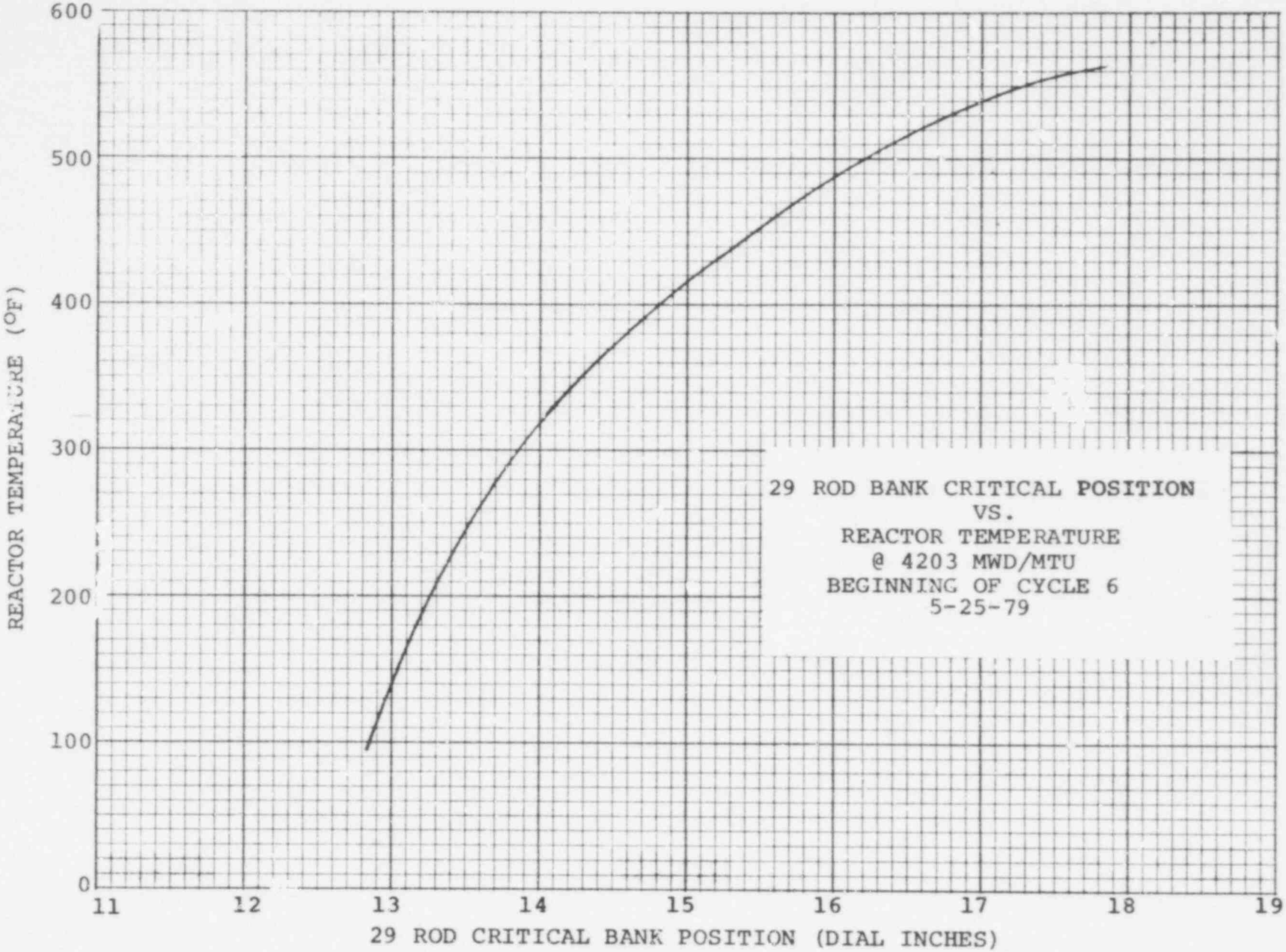
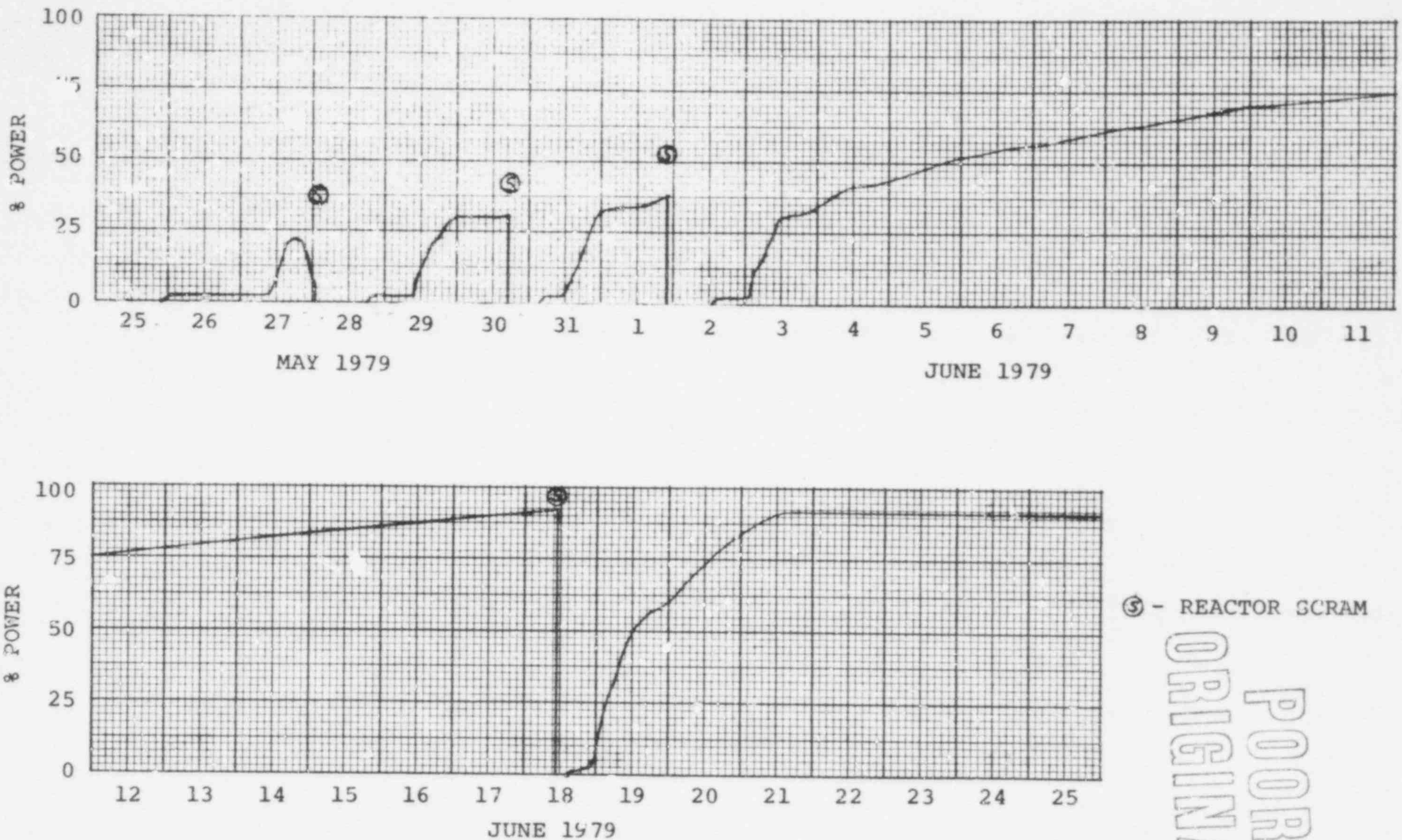

600
500
400
300
200
100
0
REACTOR TEMPERATURE (^{o}F)
11
12
13
14
15
16
17
18
19
29 ROD CRITICAL BANK POSITION (DIAL INCHES)
29 ROD BANK CRITICAL POSITION
VS.
REACTOR TEMPERATURE
@ 4203 MWD/MTU
BEGINNING OF CYCLE 6
5-25-79

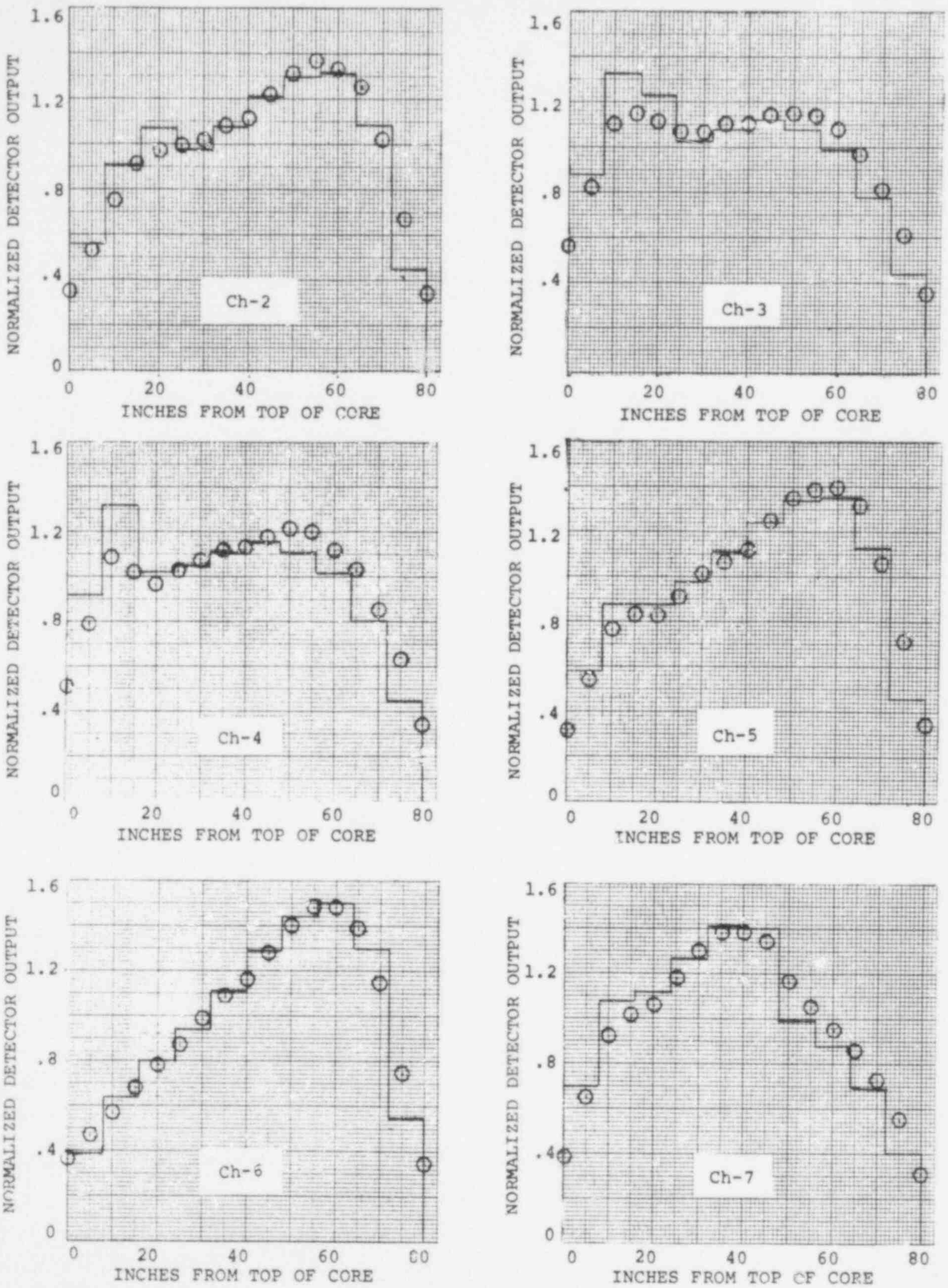
FIGURE 2



Ⓢ - REACTOR SCRAM

LACBWR POWER HISTORY DURING INITIAL STARTUP AND POWER ESCALATION FOR FUEL CYCLE 6

FIGURE 3



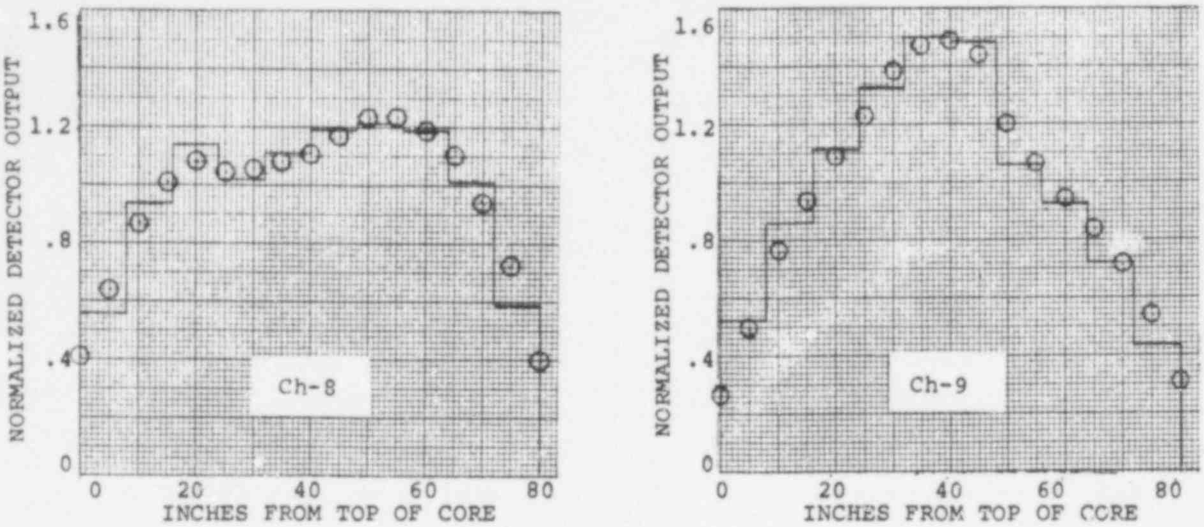
REACTOR OPERATING CONDITIONS: Power = 91.83%, Equilibrium Xenon, Recirc. Flow = 10.6 x 10^6 lb/hr., Subcooling = 17.98 Btu/lb., Control Rods: 1 @ 16"
6, 10 @ 50.25"
7, 11 @ 16.0"
8, 12 @ 75.25"
9, 13 @ 25.12"

— Normalized TRILUX Data
o Normalized Incore Monitor Data

DATA TAKEN: 25 June 1979

EXPERIMENTAL AND CALCULATED RELATIVE AXIAL INCORE MONITOR SIGNAL

FIGURE 4



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REACTOR OPERATING CONDITIONS: Power = 91.83%, Equilibrium Xenon, Recirc. Flow = 10.6×10^6 lb/hr., Subcooling = 17.98 Btu/lb., Control Rods: 1 @ 16"
6, 10 @ 50.25"
7, 11 @ 16.0"
8, 12 @ 75.25"
9, 13 @ 25.12"

— Normalized TRILUX Data
o Normalized Incore Monitor Data

DATA TAKEN: 25 June 1979

EXPERIMENTAL AND CALCULATED RELATIVE AXIAL INCORE MONITOR SIGNAL

FIGURE 4a