YANKEE-ROWE

CORE XIII STARTUP REPORT

NOVEMBER 1977

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INTRODUCTION

This report conveys a summary of the results obtained during the startup testing of Core XIII. It is divided into ten sections which parallel the sections specified in the Core XIII Performance Analysis Startup Program (Proposed Change to the Technical Specification 145, Supplement 4). All testing results included in this report were obtained under the guidance of operating procedures OP-1701 (Rev. 1), "Core XIII BOL Zero Power Physics Test" and OP-1702 (Rev. 3), "Core XIII Zero to Full Power Physics Test Procedure".

Many of the results obtained during Core XIII startup testing were done with the use of a reactivity computer. The computer is a Westinghouse model NBSU 8094 analog computer. Programming is unique for each set delayed neutron fractions. Verification of proper programming is completed by feeding the computer an exponential signal and measuring the reactivity response of the computer. The computer is properly programmed if it yields correct values of reactivity for a given startup rate. When the computer is connected to the excore detector both the computer and the delayed neutron fractions used in programming it are checked, this time using a real neutron response to reactivity input from control rod withdrawal.

The delayed neutron fractions which were used during the physics testing are tabulated below.

GROUP	FRACTION BETA BAR	EFFECTIVE FRACTION	LAMBDA (SEC)-1
1	.00018770	.00018588	.01252
2	.00133860	.00132866	.03055
3	.00122062	.00121025	.11512
4	.00249749	.00247441	.30932
5	.00085575	.00084951	1.16220
6	.00030523	.00030300	3.04024

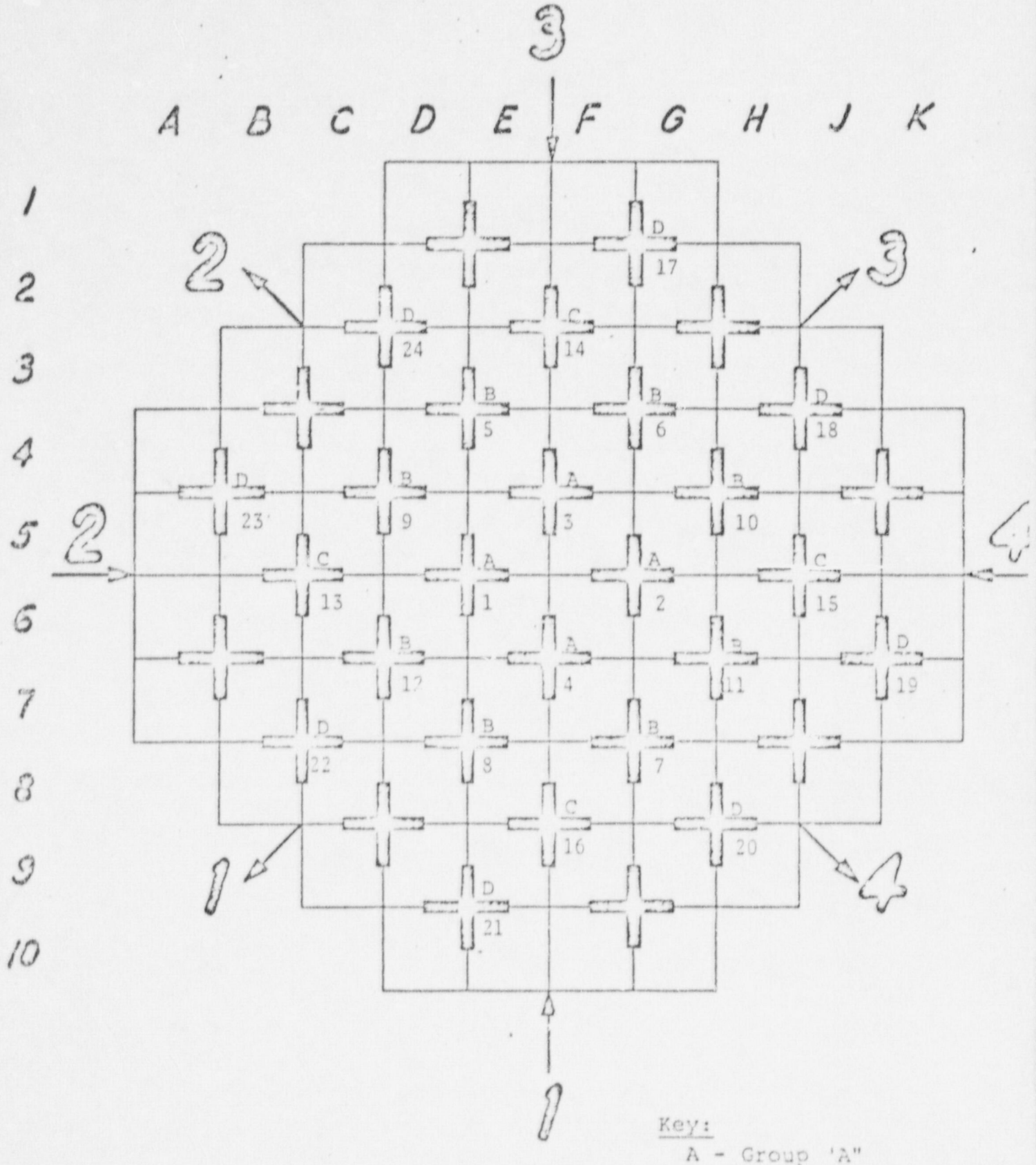
Beta Effective = .006352
Beta Bar = .006405
I Bar = .9916
Prompt Neutron Lifetime = 18.60 microseconds

Core XIII is loaded with 36 new Exxon fuel assemblies. The fuel is 4% enriched in U-235 with Zircaloy cladding. The new assemblies are loaded around the perimeter with 40 once burnt assemblies in the interior. A figure depicting the fuel arrangement follows.

Yankee-Rowe has 24 cruciform shaped control rods arranged as shown in the following figure.

Following refueling and prior to vessel reassembly each as loaded fuel assembly was verified to be properly positioned. This was done with an underwater television on July 7, 1977. An attempt was made to video tape the verification but the recorder failed.

YANKEE ROWE CONTROL ROD GROUPS

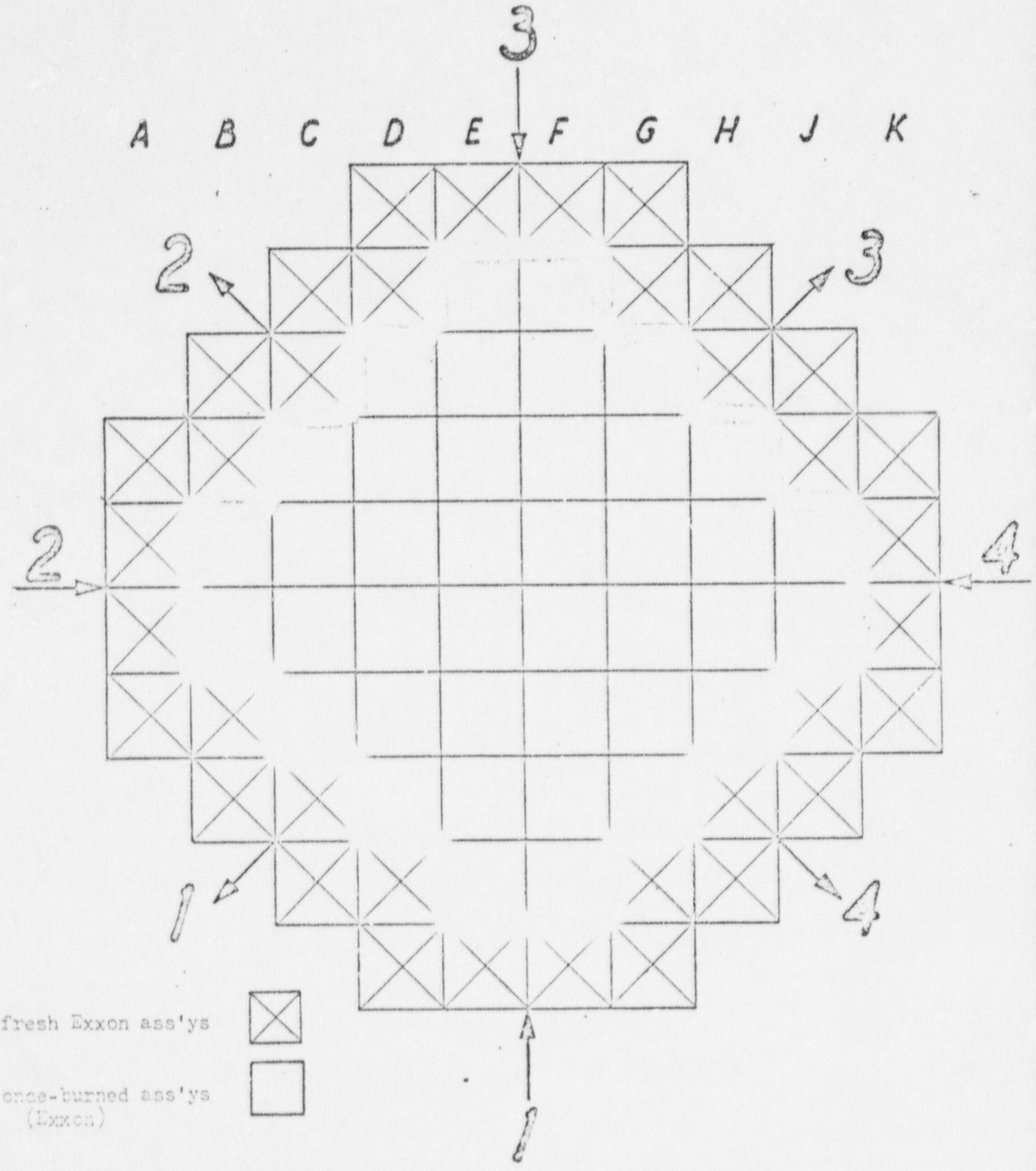


Key:

A - Group "A"
B - Group "B"
C - Group "C"
D - Group "D"

REACTOR CORE FUEL LOCATIONS

CORE XIII



1. Prior to the initial criticality the operability of each of the four control rod groups was demonstrated. This was done by exercising each group in turn from fully inserted to fully withdrawn and return to fully inserted. The control rod position lights were used to verify proper rod movement. Each control rod and control rod group responded correctly. In addition each control rod was individually withdrawn nine inches to verify proper identification. As before, the rod position lights were used to verify rod movement.

2. The control rod insertion time was measured for each control rod, prior to the initial criticality of Core XIII. Determination of the drop time involved measuring the time from the opening of the stationary gripper power supply circuit to the insertion of the rods below the six inch indicating coil light. A Visicorder (recording oscillograph) was used for this measurement.

   All control rods inserted well within the required 2.5 seconds. Below is a table of the drop times from cycle XIII as well as cycle XII for comparison.

Control Rod	Drop Time (Sec) XIII	XII	Control Rod	Drop Time (Sec) XIII	XII
1	1.42	1.77	13	1.50	1.74
2	1.56	1.73	14	1.54	1.52
3	1.69	1.61	15	1.47	1.50
4	1.70	1.74	16	1.70	1.53
5	1.52	1.54	17	1.51	1.62
6	1.46	1.56	18	1.64	1.56
7	1.50	1.58	19	1.60	1.59
8	1.50	1.58	20	1.79	1.61
9	1.53	1.56	21	1.54	1.84
10	1.52	1.56	22	1.52	1.68
11	1.49	1.48	23	1.54	1.86
12	1.74	1.54	24	1.56	1.60

3. Equilibrium, just critical, main coolant boron concentrations were measured four times during startup testing. The measured results, predicted results and approximate control rod confirguration are tabulated below.

Control Rod Configuration	Just Critical Boron Conc. Measured	Predicted
All rods withdrawn	1990 ppm	1762 ppm
Group C inserted	1805	1520
Groups C and A inserted	1608	1333
Groups C, A and B inserted	1286	949

The measured values do not meet the acceptance criteria of plus or minus ten percent of predicted. The exact reason for the discrepancy is under investigation. To verify the validity of the measured data two hand calculations were performed.

Method number one was to start with the critical boron concentration (1405 ppm) as calculated under hot, full power, all rods out conditions. This normally accurate value is based on boron letdown curves from the previous two cores. This value however, must be adjusted to simulate measured conditions. This is done by removing the xenon and doppler contributions to get zero power, no xenon conditions. When these adjustments are done, the resulting adjusted just critical, all rods out boron is 1962 ppm which is in good agreement with the measured value of 1990 ppm.

Method number two involved the use of cycle XII excess reactivity compared to cycle XIII excess. The difference in calculated excess is equal to 1.65% reactivity. The measured value for the just critical all rods out boron for cycle XII was 2258 ppm. As the calculated difference was 1.65% reactivity (equivalent to 249 ppm) between cycle XII and XIII, method two would predict 2009 ppm. This is also in good agreement with the measured value, 1990 ppm.

Based on these two methods the measured value was taken to be correct and the predicted number to be in error. Examination of chemistry analysis methods and boron 10 content in the boron used support this conclusion.

Such an error in the predicted beginning of cycle, all rods out just critical boron has no effect on the accident analysis or safe operation of the plant. Therefore cycle XIII startup was not affected.

4. The differential and integral worths of control rod groups C, A and B were measured. This was done by introducing a constant dilution, balancing the dilution with control rod group insertion and measuring the worth of each step with a reactivity computer. The integral worths were obtained by summing the worth of all the steps. In each case, prior to beginning the measurement, the boron concentration was determined to be in equilibrium. Also, while the measurements were going on, the temperature was held as close to constant as possible.

   The table below summarizes the results:

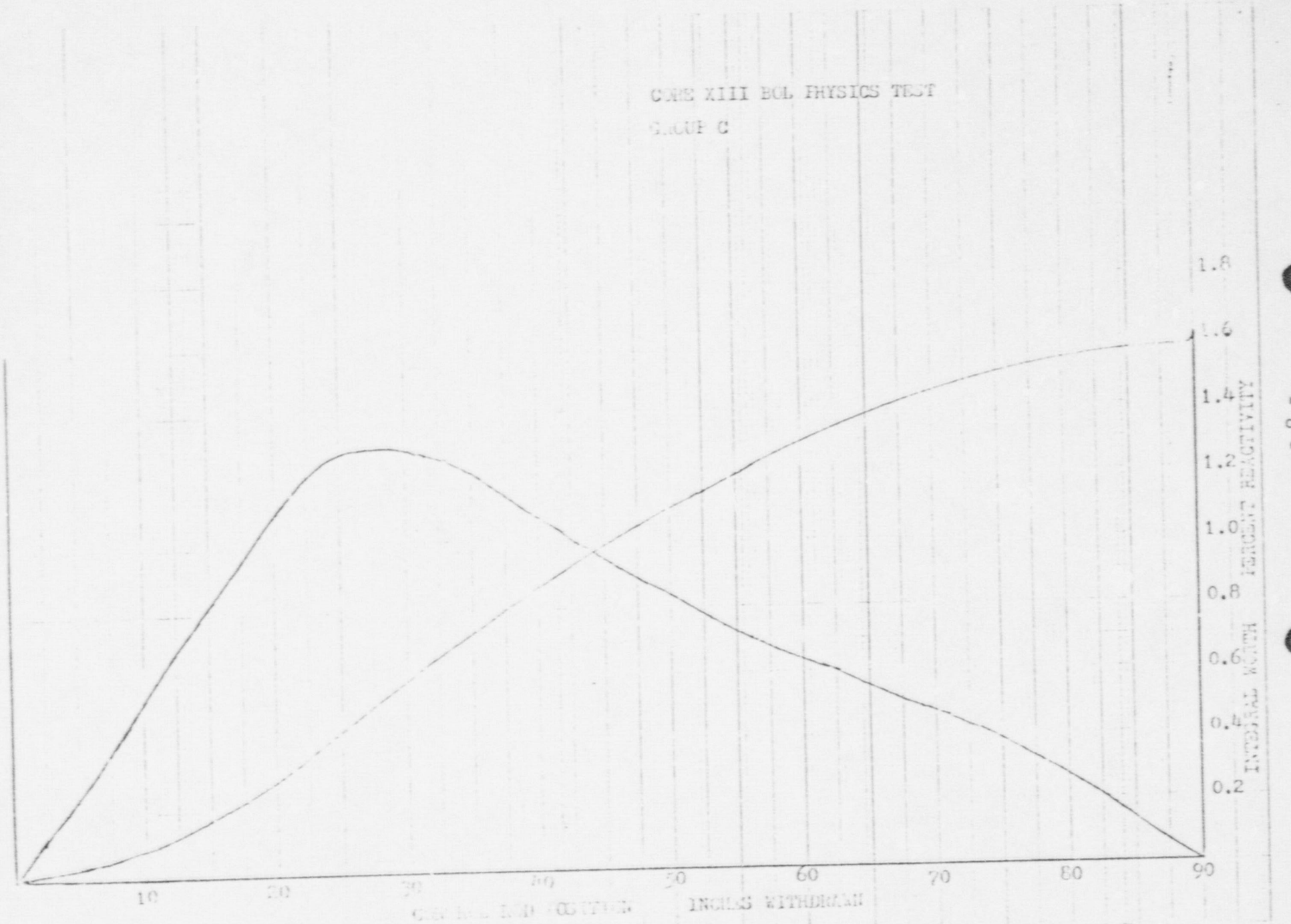
	Measured % $\Delta\rho$	Predicted % $\Delta\rho$
Group C (4 rods)	1.57	1.60
Group A (4 rods)	1.25	1.23
Group B (8 rods)	2.50	2.55

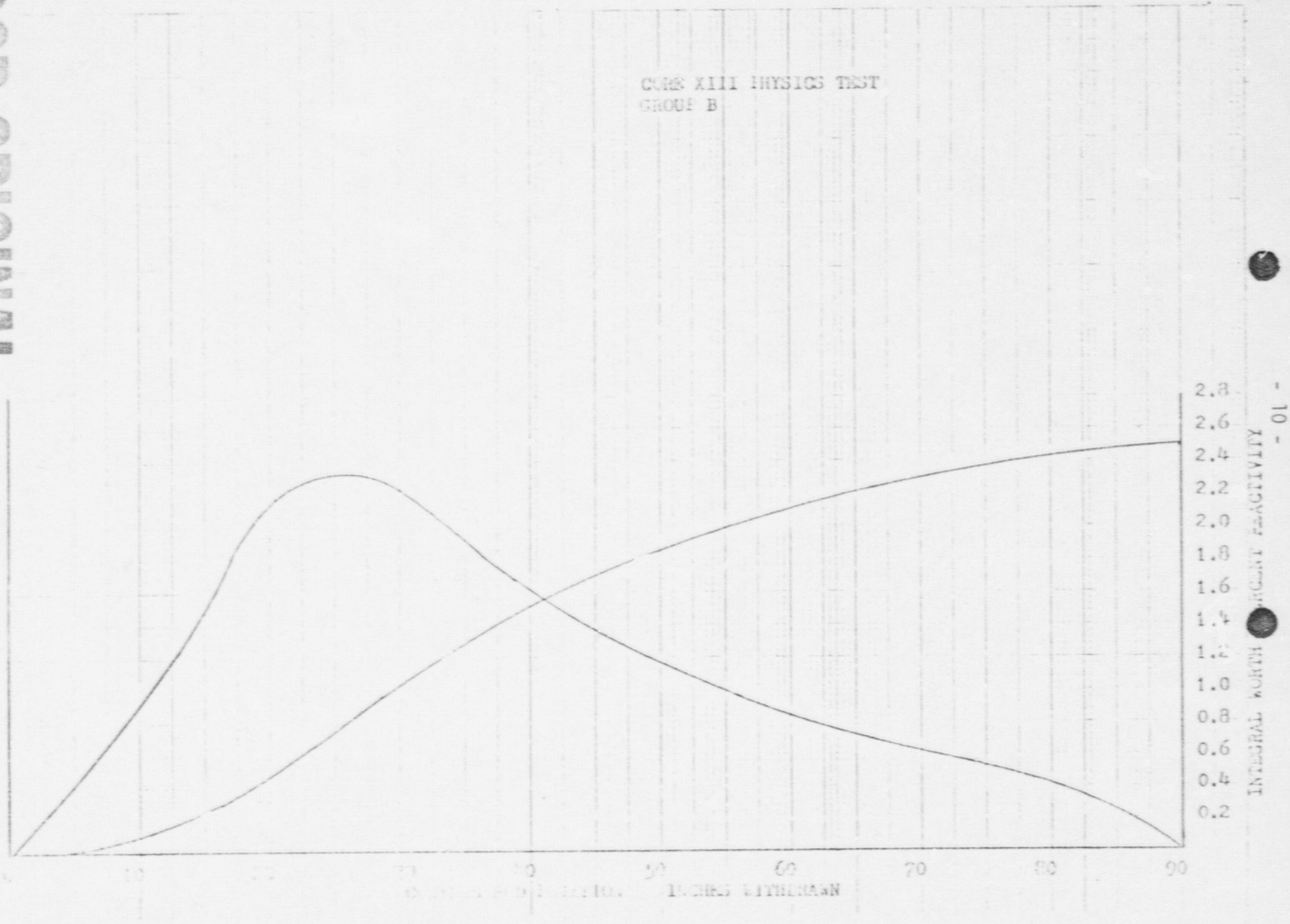
   The acceptance criteria imposed on control rod group worth was that the measured value must agree within the predicted plus or minus 7 1/2%. All measurements successfully verified the calculated number.

   Graphs of the differential and integral rod worths of groups C, A and B occupy the following three pages.

CORE XIII BOL PHYSICS TEST

GROUP C





5. The worth of an ejected control rod for cycle XIII was measured for two conditions. The ejected rod worth was measured with group C inserted and all other rods fully withdrawn. This condition mocks the "full power" case.

   The "zero power" case ejected rod was measured with groups C and A inserted and all other rods fully withdrawn.

   In both the full power and zero power cases the measurement was conducted with more rods inserted than would be allowed by the rod restriction curve. The ejected rod worths, as assumed in the accident analysis, were calculated based on the control rod restriction curve limitation. Hence the measurements do not directly measure the accident analysis input, but verify the methods which produce that input.

   Ejected rod worths were obtained by balancing a small boron dilution with insertion of the rod. The reactivity computer was used to measure the value of the ejected rods.

   The results of the ejected rod worth measurements are tabulated below.

	Worth % Δρ	
	Measured	Predicted
Rod 16, Group C inserted ("full power" case)	0.60	0.62
Rod 16 Groups C and A inserted ("zero power" case)	0.82	0.81

   Acceptance Criteria: predicted ± 15%

6. Cycle XIII dropped control rod worth was measured for the calculated most worthy rod. The measurement was performed from the all rods out condition by establishing a small steady dilution, balancing the reactivity addition with insertion of the dropped rod, and measuring the worth of the rod with the reactivity computer. Below is the result:

	Worth % Δρ	
	Measured	Predicted
Rod 4, most worthy dropped rod	0.33	0.32

   Acceptance Criteria: predicted ± 15%

7. Moderator temperature coefficient was measured as part of the start up program. The measurement was performed by first attaining a stable, just critical reactor condition at equilibrium boron concentration. Then the main coolant system temperature was varied by operating a secondary side steam dump and the reactivity change was measured with the reactivity computer.

   Measurements of moderator temperature coefficient were made at four different boron concentrations. Insertion of control rods allowed the boron to be reduced over the range from 2000 to 1287 ppm. Corrections were made in the predicted values to account for rod insertion.

   The results are tabulated below and graphically represented on the following page. Acceptance Criteria: predicted ± 0.5E-4 ΔK/K/°F.

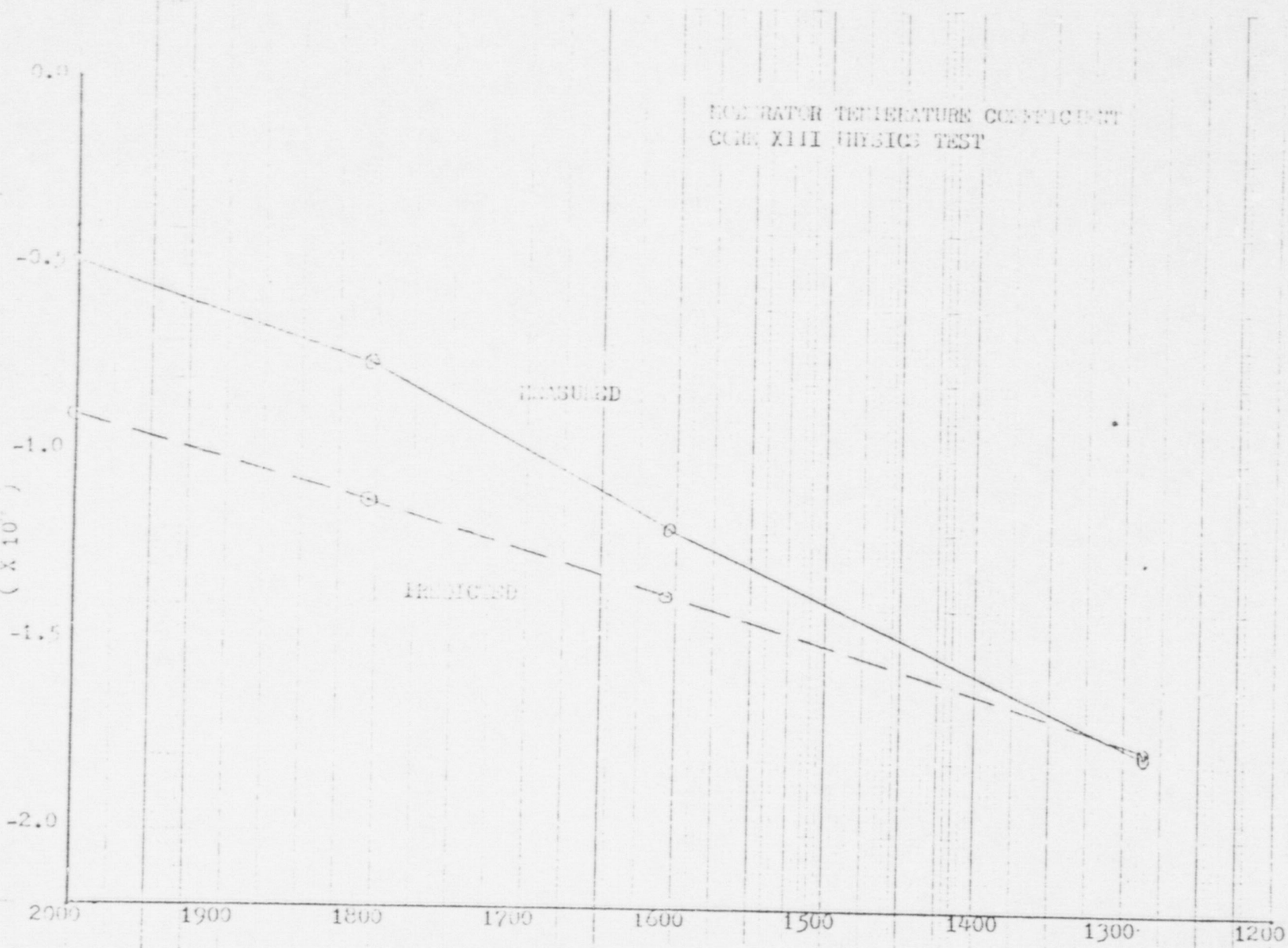
Boron Concentration	Moderator Temperature Coefficient Measured	Predicted
2000	-0.49E-4ΔK/K/°F	-0.90E-4 ΔK/K/°F
1805	-0.75E-4	-1.12E-4
1606	-1.19E-4	-1.37E-4
1287	-1.78E-4	-1.74E-4

   The measured data recorded above is the result of averaging the data from a minimum of five changes in temperature (heatup or cooldown). Each change in temperature was a minimum of two degrees. All measurements were in the range of 518 to 528°F main coolant temperature.

8. The combined xenon and power (doppler) defects were measured from zero power to equilibrium 499 MWt (~83%). This was accomplished by recording all pertinent data at zero and 499 MWt. Changes in main coolant temperature and pressure, control rod position, boron, and burnup were accounted for in calculating the combined defect.

	Measured	Predicted
Power + zenon defect	3.38% ΔK/K	3.4% ΔK/K

   Acceptance Criteria: None



9. At approximately 7 percent power a set of flux traces were taken to verify core symmetry. At this power level, the flux levels are so low the amplitude produced on the strip chart is less than 1.5 inches. This small amplitude leads to inaccuracy in the measurements and analysis. Initially, a visual check of the traces was made by comparing symmetric locations. From the visual inspection, symmetric locations appeared symmetric. An analysis was later done with INCORE and the comparison of measured and theoretical signals can be seen on the map which follows.

At 348 MWt (58%) another set of flux traces was taken with the moveable fission chambers. This set was analyzed with the INCORE program, using theoretical information from the PDQ program. During this set of traces, only one pen was operable on the recorders. The analysis showed a small but noticeable tilt. However, since only one pen was used, no cross calibration of detectors was possible. To verify what had been analyzed a second set of traces were taken with both pens operable. The conditions present during this second set of traces were:

Burnup	75 MWD/MTU
Power	448 MWt (74.7%)
Boron	1513 ppm
Tinlet	496°F
Group C	87 in.
Group A, B, D.	87 in.

The comparison of measured and theoretical signals can be seen in the figure which follows. The quadrant tilt seen in this analysis is less than 2%. This tilt is taken into account in the hot channel factors Thus, the measured linear heat generation rate takes the tilt into account.

Below is a summary of the results of the INCORE run prior to exceeding 75% power.

Parameter	Measured	Limit
LHGR	8.415 kw/ft	9.438 kw/ft
F_Q	2.454	2.76
$F^N_{\Delta H}$	1.609	1.80

This measured LHGR takes into account all the factors required by the Technical Specifications.

COMPARISON OF MEASURED AND THEORETICAL SIGNALS

INCORE RUN YR-13-001

60.0 MWT. GROUP C AT 75.0 INCHES

0. MWD/MTU

MEASURED SIGNAL
THEORETICAL SIGNAL
PERCENT DIFFERENCE

			.703 .724 -2.892							
				.988 1.052 -6.079						
					1.063 1.124 -5.472					
		1.024 1.124 -8.904		1.108 1.054 5.103						
.737 .727 1.362			1.040 1.058 -1.740				.978 1.049 -6.757			
						1.131 1.058 6.855				
	1.095 1.102 -.598				1.114 1.054 5.722		1.122 1.124 -.165			
			1.165 1.124 3.669			1.195 1.119 6.822				
		.752 .731 2.875		1.054 1.052 .234						
					.731 .724 .916					

AVERAGED ABSOLUTE DIFFERENCE
BETWEEN MEASURED AND THEORETICAL 3.892 PERCENT

COMPARISON OF MEASURED AND THEORETICAL SIGNALS

INCORE RUN YR-13-003

448.0 MWT. GROUP C AT 87.0 INCHES

75. MWD/MTU

MEASURED SIGNAL
THEORETICAL SIGNAL
PERCENT DIFFERENCE

		.700 .727 -3.688						
			.998 1.049 -4.892					
				1.090 1.121 -2.775				
	1.119 1.121 -.128		1.082 1.050 2.289					
.742 .730 1.688		1.099 1.062 3.504				1.028 1.050 -2.068		
					1.090 1.062 2.605			
	1.115 1.098 1.531			1.091 1.058 3.174		1.092 1.121 -2.574		
		1.127 1.121 .577			1.095 1.116 -1.886			
	.727 .731 2.202		1.046 1.049 -.316					
				.738 .727 1.571				

AVERAGED ABSOLUTE DIFFERENCE
BETWEEN MEASURED AND THEORETICAL 2.203 PERCENT

10. Doppler coefficient was measured by recording the change for pertinent reactivity parameters between two equilibrium steady state power levels. Changes in main coolant boron concentrations, temperature and pressure are accounted for as are rod positions, fuel burnup and Xenon.

Twice doppler coefficient was measured, once between 60 and 70% and again between 70 and 83%.

Δpower	Measured	Predicted
60 - 70%	-1.75E-5 Δρ/°F	-1.48E-5 Δρ/°F
70 - 83%	-1.47E-5 Δρ/°F	-1.46E-5 Δρ/°F

Acceptance criteria: predicted ± 25%

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