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FORWARDING CYCLE 2, FINAL PHYSIC TESTING SUMMARY OF SUBJECT FACILITY.

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FLORIDA POWER & LIGHT COMPANY

August 7, 1978
L-78-260

Office of Nuclear Reactor Regulation
Attention: Mr. R. W. Reid, Chief
Operating Reactors Branch #4
Division of Operating Reactors
U. S. Nuclear Regulatory Commission
Washington, D. C. 20555

Dear Mr. Reid:

Re: St. Lucie Unit 1
Docket No. 50-335
Cycle 2 Startup Physics
Testing Summary

The startup physics testing summary for St. Lucie Unit 1, Cycle 2 is attached for your information. It is a final report and is intended to satisfy both the draft report and final report commitments referenced in Section 11.0 (Physics Startup Tests) of the Staff's May 26, 1978 Safety Evaluation supporting Amendment 27 to Operating License DPR-67.

Very truly yours,

Robert E. Uhrig
Vice President

REU/MAS/cpc

Attachment

cc: Mr. James P. O'Reilly, Region II
Harold F. Reis, Esquire

7821900079

A001 S 3/3 ADD MIPC

FLORIDA POWER & LIGHT COMPANY

ST. LUCIE UNIT 1

CYCLE 2

STARTUP PHYSICS TESTING SUMMARY

AUTHOR: Clifford A. Pell DATE August 1, 1978
C. A. Pell
Reactor Engineering

REVIEWED: JC Potuchalski for DATE 8/2/78
J. R. Tomonto
Manager of Nuclear Analysis

APPROVED: R.K. Ryall DATE 8/2/78
R. K. Ryall
Reactor Engineering Supervisor - PSL

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

INTRODUCTION

The intent of this report is to satisfy the Nuclear Regulatory Commission's request for a summary of the St. Lucie Unit 1, Cycle 2 Startup Physics Testing results. The purpose of the Startup Physics Testing Program is to provide verification of selected design physics parameters before substantial increases in power are made. The major phases of this program are the core reload, approach to criticality, zero power physics testing, and power ascension testing.

CORE RELOAD:

The cycle 2 core contains five uniquely enriched fuel types as listed in Table 1 below.

TABLE 1

Fuel Type	No. of Assy's.	Enrichment (w/o)
A	9	1.93
B	80	2.33
C	68	2.82
D	40	3.03
D*	20	2.73

The cycle 2 loading pattern is given in Figure 1. The assembly serial number and full length control element assembly (CEA) present (if applicable) are given for each core location.

Following the fuel shuffle and prior to the approach to criticality, the CEA performance tests were executed. The objective of these tests was to measure travel time from the fully withdrawn position to the 90% inserted position as well as verify correct operation of the CEA position indication system. The average CEA drop time was found to be 2.25 seconds. The maximum and minimum drop times were 2.41 and 2.06 seconds respectively. All CEA drop times met the acceptance criteria of less than or equal to 3.0 seconds as required in Technical Specification 4.1.3.4. During this testing, CEDM coil holding times were measured and found to be significantly less (by greater than 0.1 second) than the 0.4 second assumed in the CEA withdrawal transient analysis.

DATE
5-4-78

FIGURE 1

Florida Power & Light Company
REACTOR FUEL LOCATION
St. Lucie Plant Unit No. 1

CYCLE 2

N

Y X W V T S R P N M L K J H G F E D C B A

21							D034	D047	D002	D028							
20					D005	D018	D123	B007 65	B006	B031 64	D108	D037	D046				
19				D043	D105 63	B065	C030 62	B078	D115 73	B018	C011 61	B028	D104 60	D017			
18			D013	C001 69	B001	C029 59	B062	B008 58	B044	B076 57	B020	C015 56	B032	C024 68	D009		
17		D033	D101 55	B061	B050	B071	C007 54	C106	C014	C201	C010 53	B063	B079	B077	D112 52	D021	
16		D038	B004	C019 51	B069	C109 50	B049	C111	B054	C107	B019	C113 49	B016	C012 48	B033	D015	
15		D106	C018 47	B074	C022 46	B037	C037 45	C206	A060 44	C208	C040 43	B021	C004 42	B066	C031 41	D117	
14																	D030
13	D004	B035 40	B068	B067 39	C205	C105	C210	A061 38	C039	A063 37	C207	C101	C112	B075 36	B073	B015 35	
12	D040																D024
11		B017 S-1	D116 72	B026	C009	B051	A055 34	C016	A019 33	C017	A066 32	B055	C008	B011	D113 71	B048 S-2	
10	D032																D025
9		B045 31	B042	B057 30	C102	C104	C204	A064 29	C035	A067 28	C211	C115	C203	B022 27	B014	B072 26	
8	D031																D027
7		D107	C026 25	B039	C005 24	B046	C033 23	C209	A058 22	C212	C027 21	B024	C021 20	B034	C032 19	D110	
6		D001	B038	C020 18	B012	C114 17	B043	C116	B025	C110	B030	C103 16	B002	C034 15	B070	D007	
5		D048	D124 14	B059	B023	B013	C023 13	C202	C013	C108	C006 12	B052	B009	B064	D103 11	D020	
4			D035	C002 67	B010	C038 10	B027	B029 9	B053	B047 8	B080	C036 7	B003	C003 66	D036		
3				D014	D102 6	B056	C025 5	B041	D111 70	B060	C028 4	B058	D109 3	D019			
2					D042	D006	D118	B040 2	B036	B005 1	D114	D003	D008				
1							D039	D026	D044	D029							

LEGEND

Assembly No.
CEA No.

APPROACH TO CRITICALITY:

The approach to criticality involved the dilution from a non-critical boron concentration of 1730 ppm to a critical boron concentration of 995 ppm. Inverse count rate ratio plots were maintained during the dilution process and are provided in Figure 2 and Figure 3. A plot of boron concentration versus dilution time is provided in Figure 4. The following table delineates the dilution rates and range of boron concentrations for which these are applicable.

TABLE 2

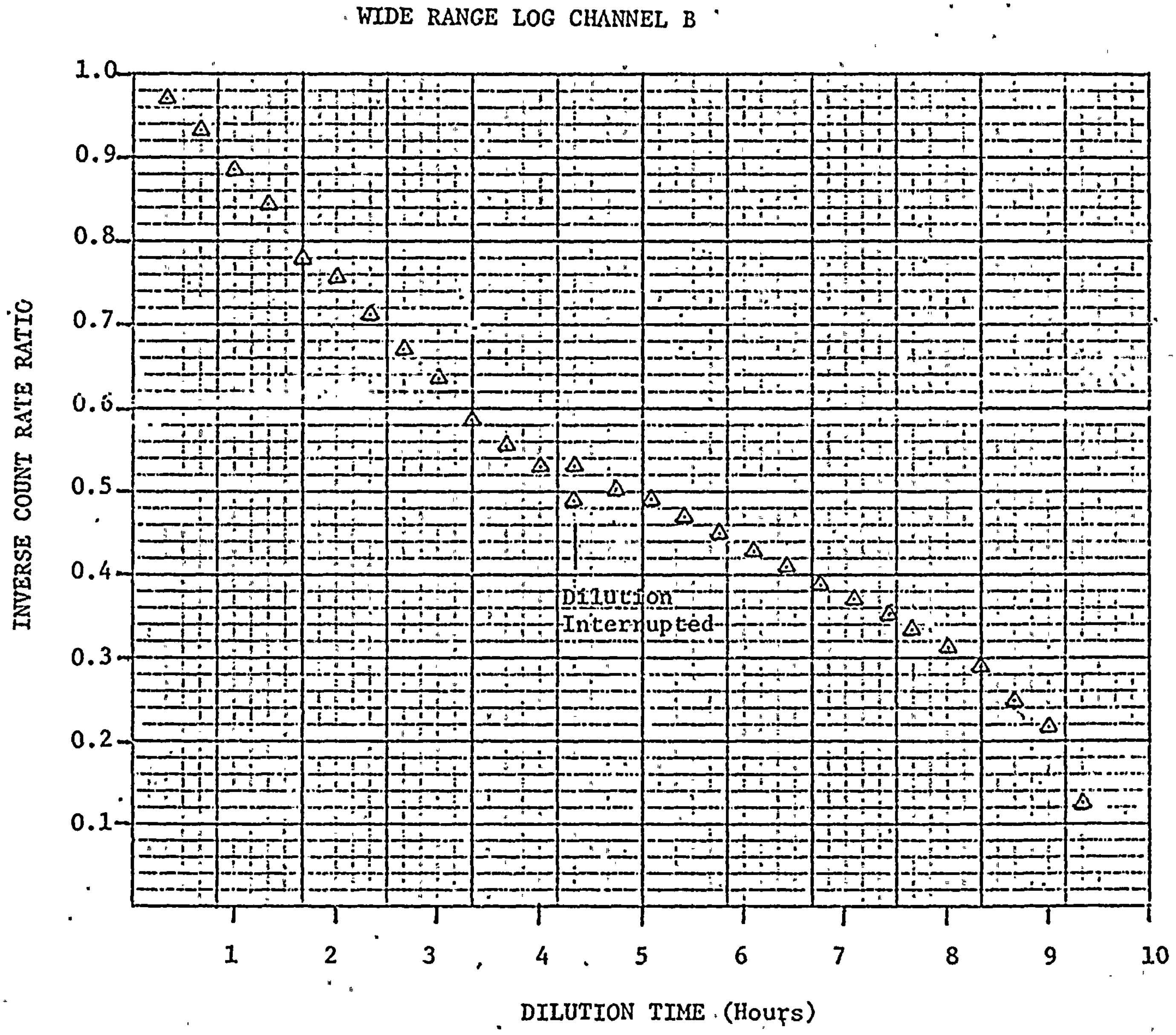
Dilution Rate	Initial Boron Concentration	Final Boron Concentration	Dilution Time
88 GPM	1730	1250	4 Hrs. 20 Min.
44 GPM	1250	995	5 Hrs. 25 Min.

Criticality was achieved on May 26, 1978, at 22:43 hours with CEA group 7 at 54 inches withdrawn and a critical boron concentration of 995 ppm.

ST. LUCIE UNIT 1
BOC, CYCLE 2

INVERSE COUNT RATE vs. DILUTION TIME

FIGURE 2

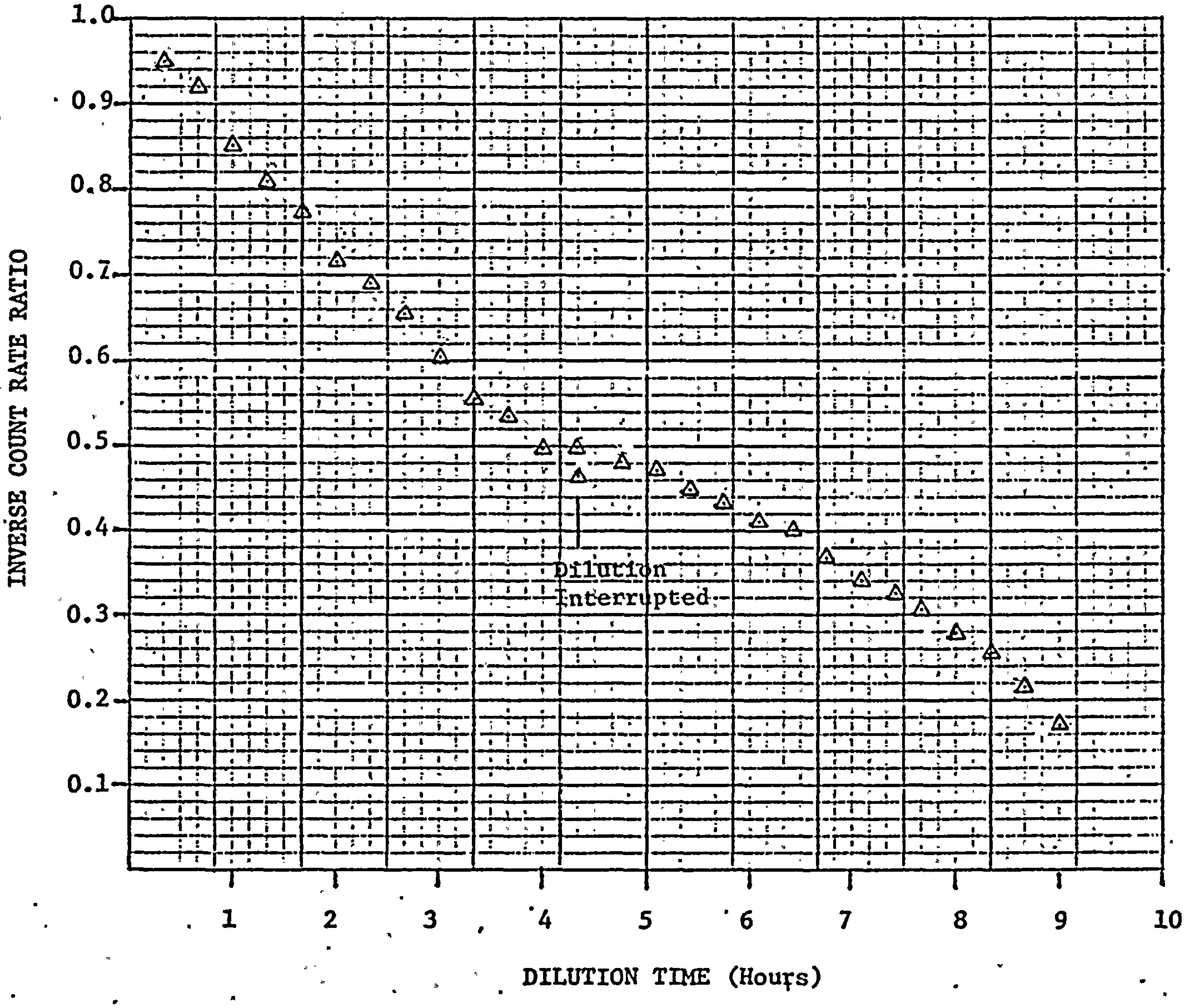


ST. LUCIE UNIT 1
BOC, CYCLE 2

INVERSE COUNT RATE vs. DILUTION TIME

FIGURE 3

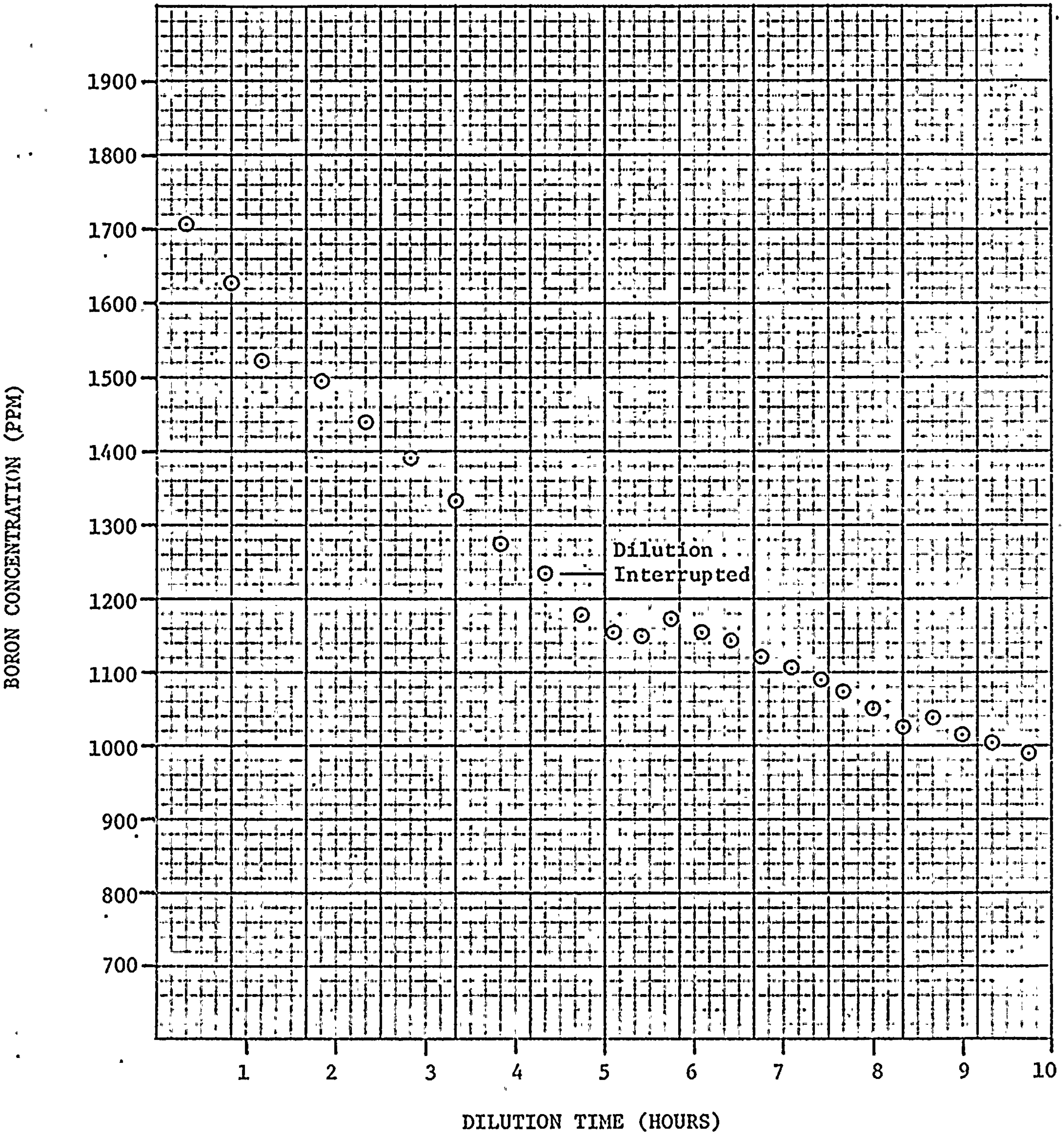
WIDE RANGE LOG CHANNEL D



ST. LUCIE UNIT 1
BOC, CYCLE 2

BORON CONCENTRATION VS. DILUTION TIME

FIGURE 4



ZERO POWER PHYSICS TESTING:

The major tests in this phase of the startup testing program consist of the following:

1. Reactivity Computer Checkout
2. CEA Latch Verification
3. Unrodded Critical Boron Concentration
4. Moderator Temperature Coefficient Measurement
5. Rod Worth Measurements

During the performance of the reactivity computer checkout, an appropriate range of flux was selected for use throughout the remainder of the zero power physics testing program. A comparison of measured reactivity insertion for a given period with the appropriate design reactivity value was also performed with good results.

Following the successful completion of the CEA latch verification for groups 7, 6, 5, 4, 3, 2, 1 and B a symmetry check test was performed on CEA group A. The acceptance criterion for this test states that the reactivity measured for each of group A's dual CEA's shall be within ± 2.5¢ of the average reactivity measured for all of the group of A duals. This criterion was satisfied.

The unrodded critical boron concentration was determined to be 1024 ppm. This was well within the acceptance criteria of ± 100 ppm of the predicted unrodded critical boron concentration of 1004 ppm.

The ARO, HZP moderator temperature coefficient was measured to be $+.41 * 10^{-4}\ \Delta k/k/^{o}F$. This met the Technical Specification requirement that the MTC shall be less positive than $0.5 * 10^{-4} \Delta k/k/^{o}F$.

A comparison of the measured and design CEA group reactivity worths is provided in Table 3. A plot of integral rod worth as a function of rod position for each CEA group is provided in Figure 5 through Figure 11. The following acceptance criteria for rod worth measurements were met:

1. The measured value of each group CEA worth is within $\pm 15\%$ or $0.1\% \Delta\rho$ of the design CEA worths, whichever is greater.

2. The total worth for all the CEA groups measured is within $\pm 10\%$ of the total design worth.

TABLE 3

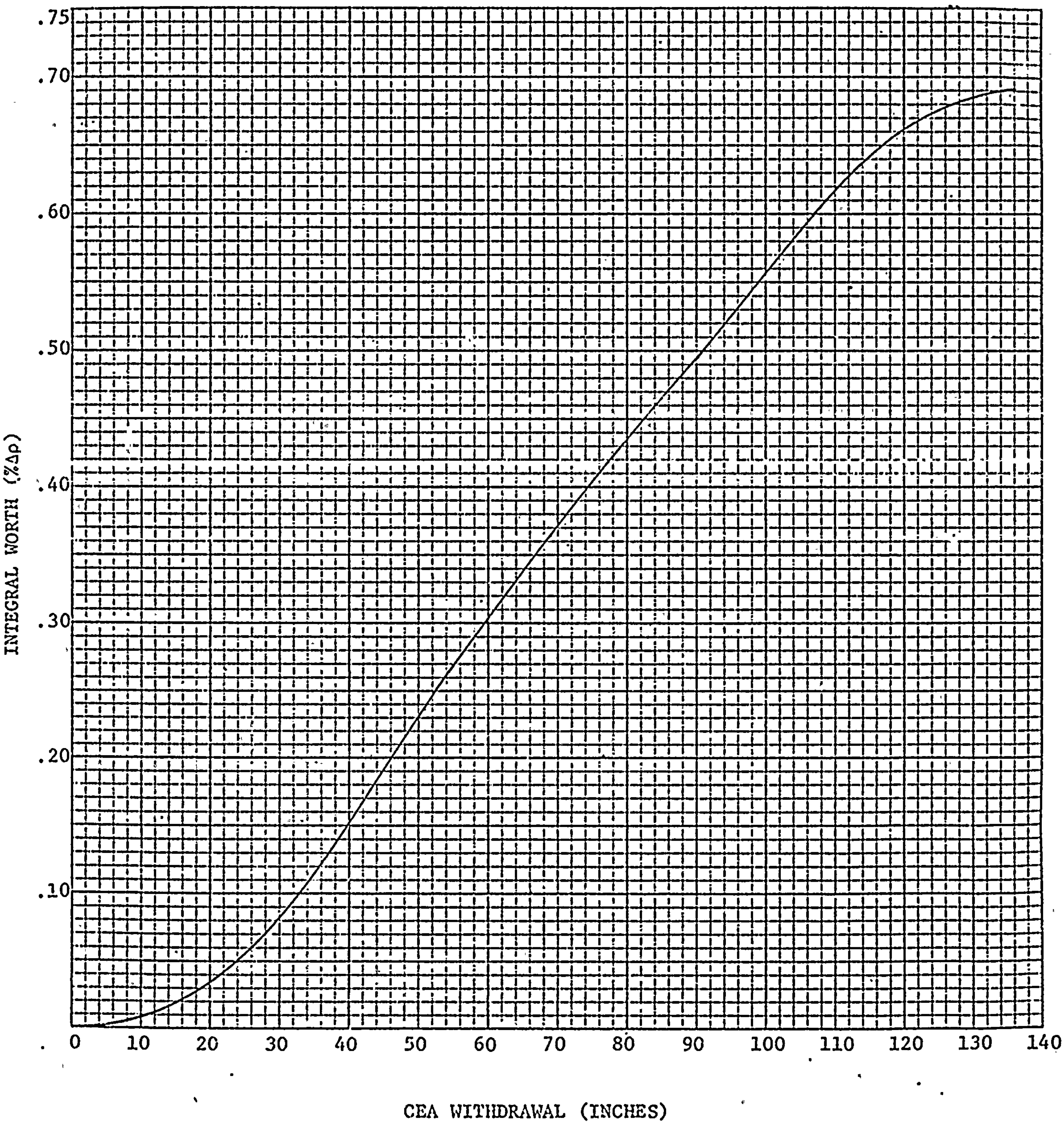
CEA WORTH SUMMARY

CEA GROUP	MEASURED WORTH	DESIGN WORTH	PERCENT DIFFERENCE
7	.691 %Δρ	.78 %Δρ	-11.40
6	.430	.46	- 6.52
5	.197	.19	3.68
4	1.153	1.28	- 9.92
3	.320	.35	- 8.57
2	1.184	1.22	- 2.95
1	.375	.37	1.35
TOTAL	4.35 %Δρ	4.65 %Δρ	- 6.45

ST. LUCIE UNIT 1
INTEGRAL CEA GROUP WORTH
BOC, HZP, CYCLE 2

CEA GROUP 7

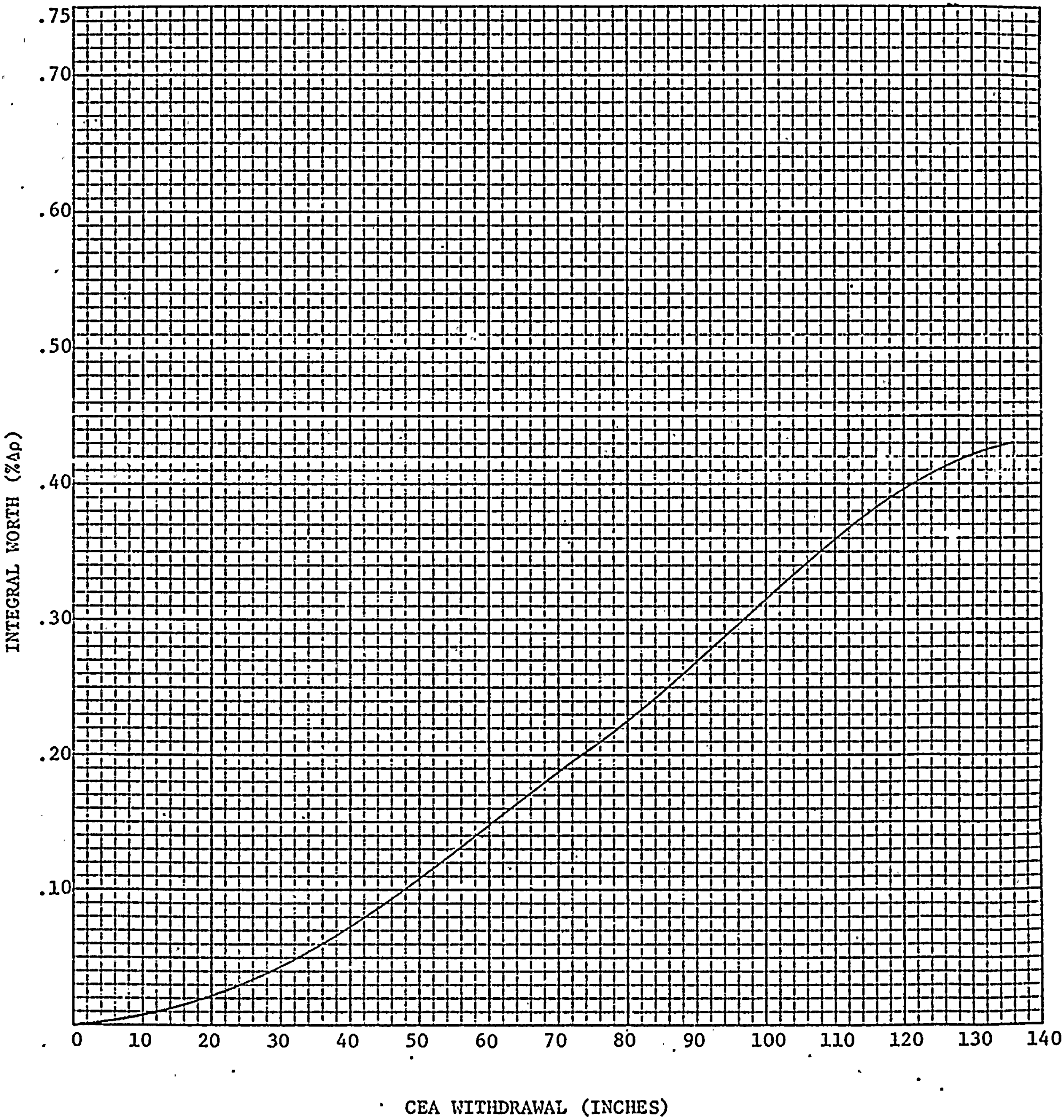
FIGURE 5



ST. LUCIE UNIT 1
INTEGRAL CEA GROUP WORTH
BOC, HZP, CYCLE 2

CEA GROUP 6

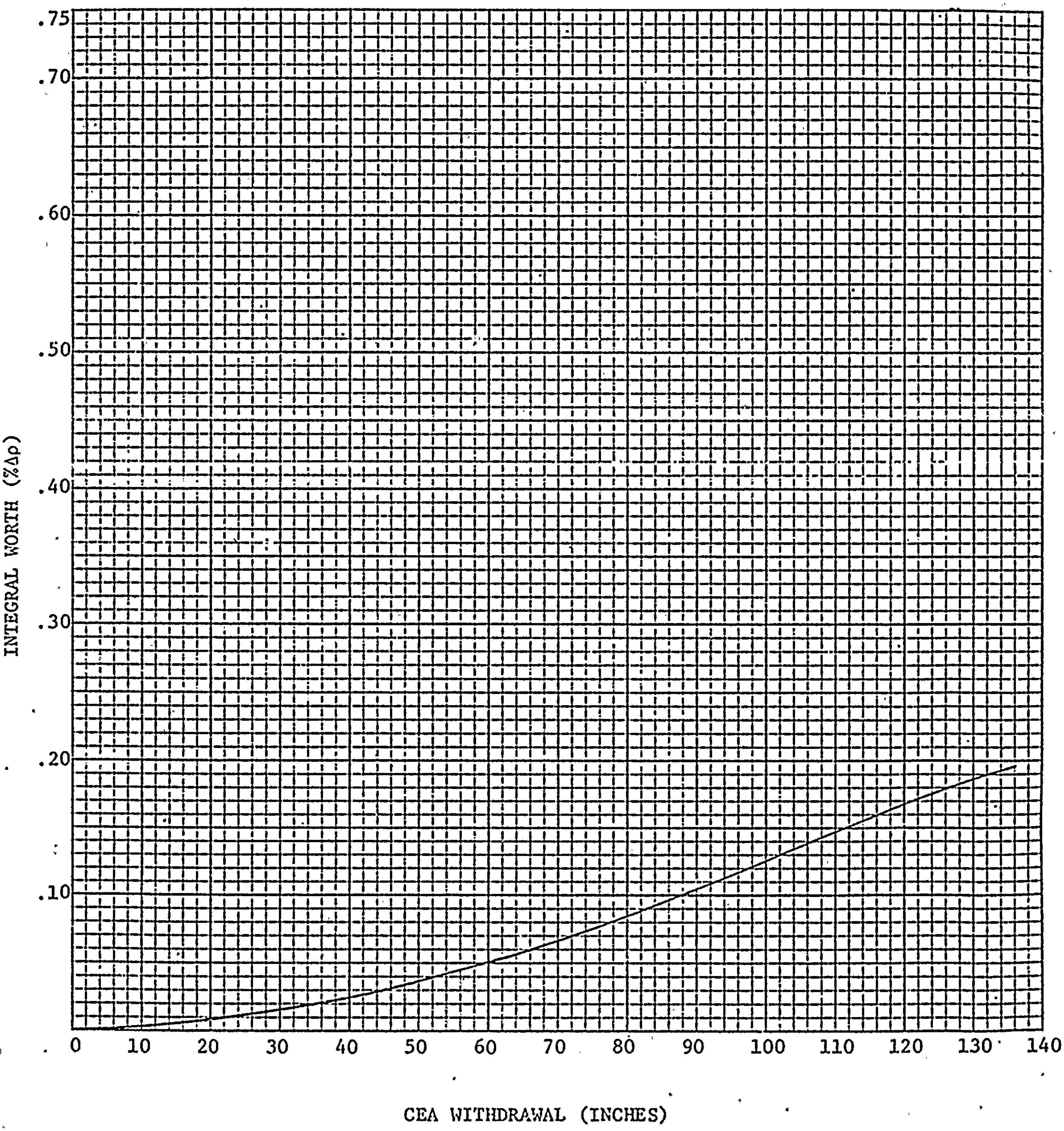
FIGURE 6



ST. LUCIE UNIT 1
INTEGRAL CEA GROUP WORTH
BOC, HZP, CYCLE 2

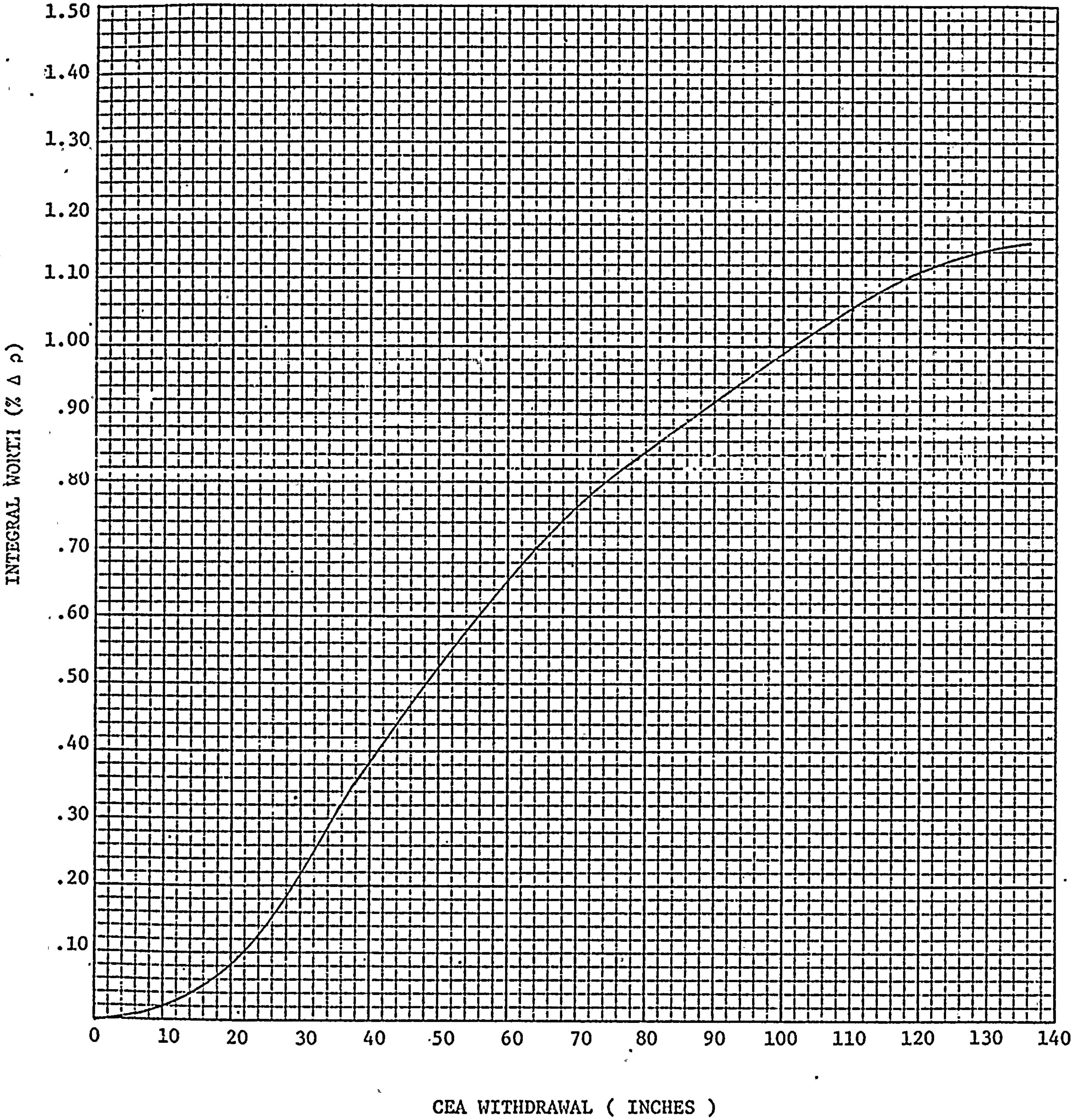
CEA GROUP 5

FIGURE 7



ST. LUCIE UNIT 1
INTEGRAL CEA GROUP WORTH
BOC, HZP, CYCLE 2
CEA GROUP 4

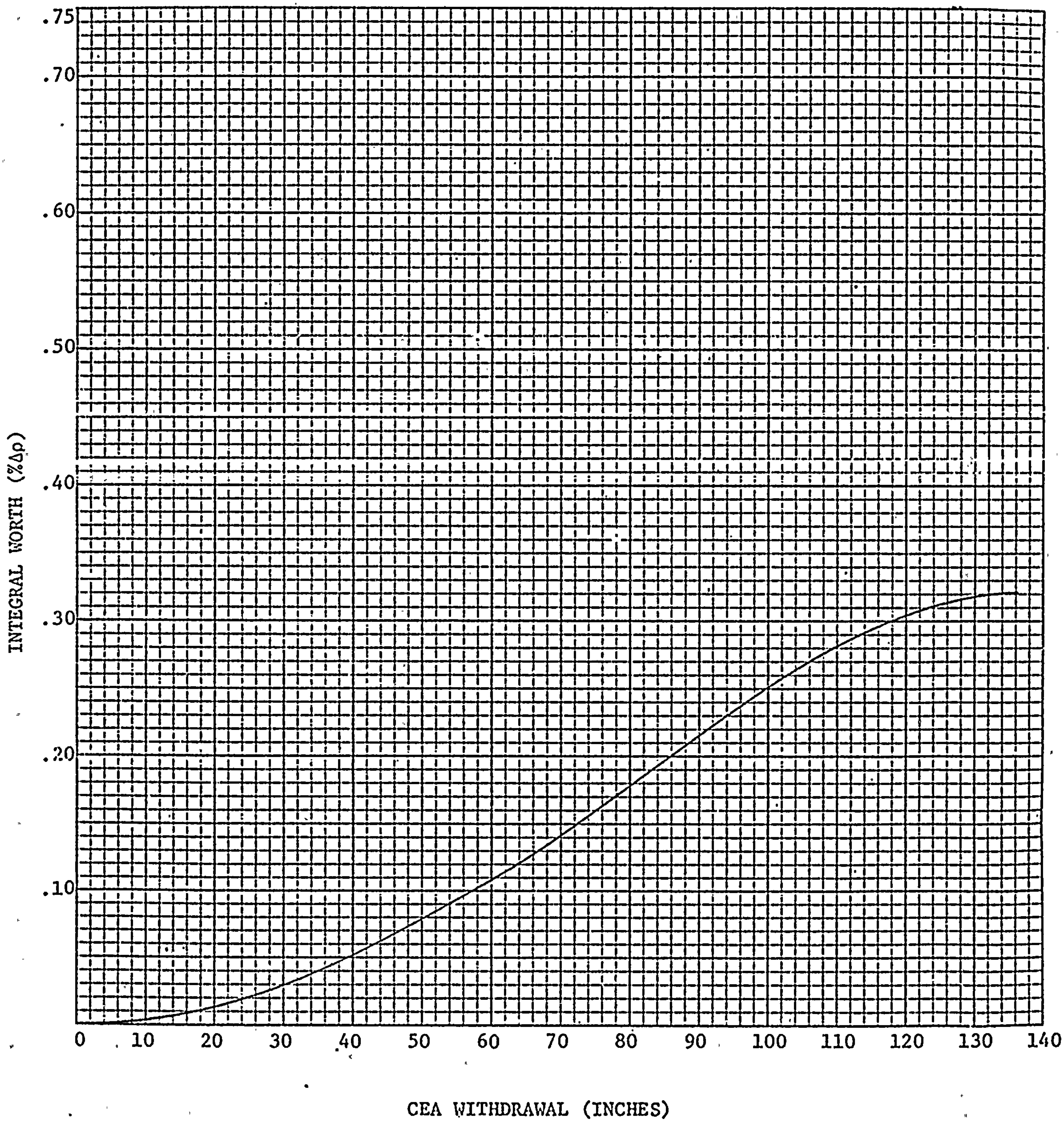
FIGURE 8



ST. LUCIE UNIT 1
INTEGRAL CEA GROUP WORTH
BOC, HZP, CYCLE 2

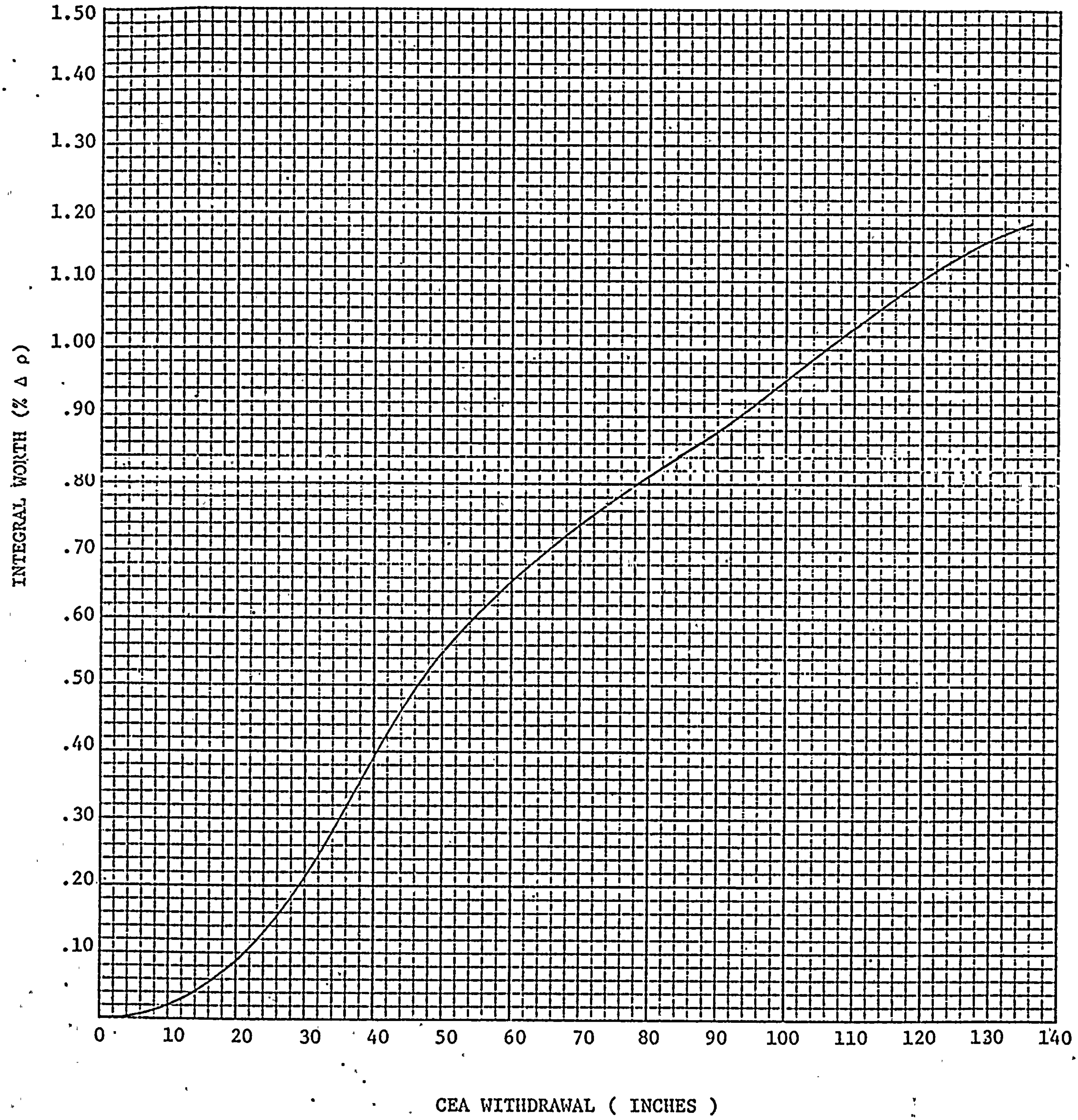
CEA GROUP 3

FIGURE 9



ST. LUCIE UNIT 1
INTEGRAL CEA GROUP WORTH
BOC, HZP, CYCLE 2
CEA GROUP 2

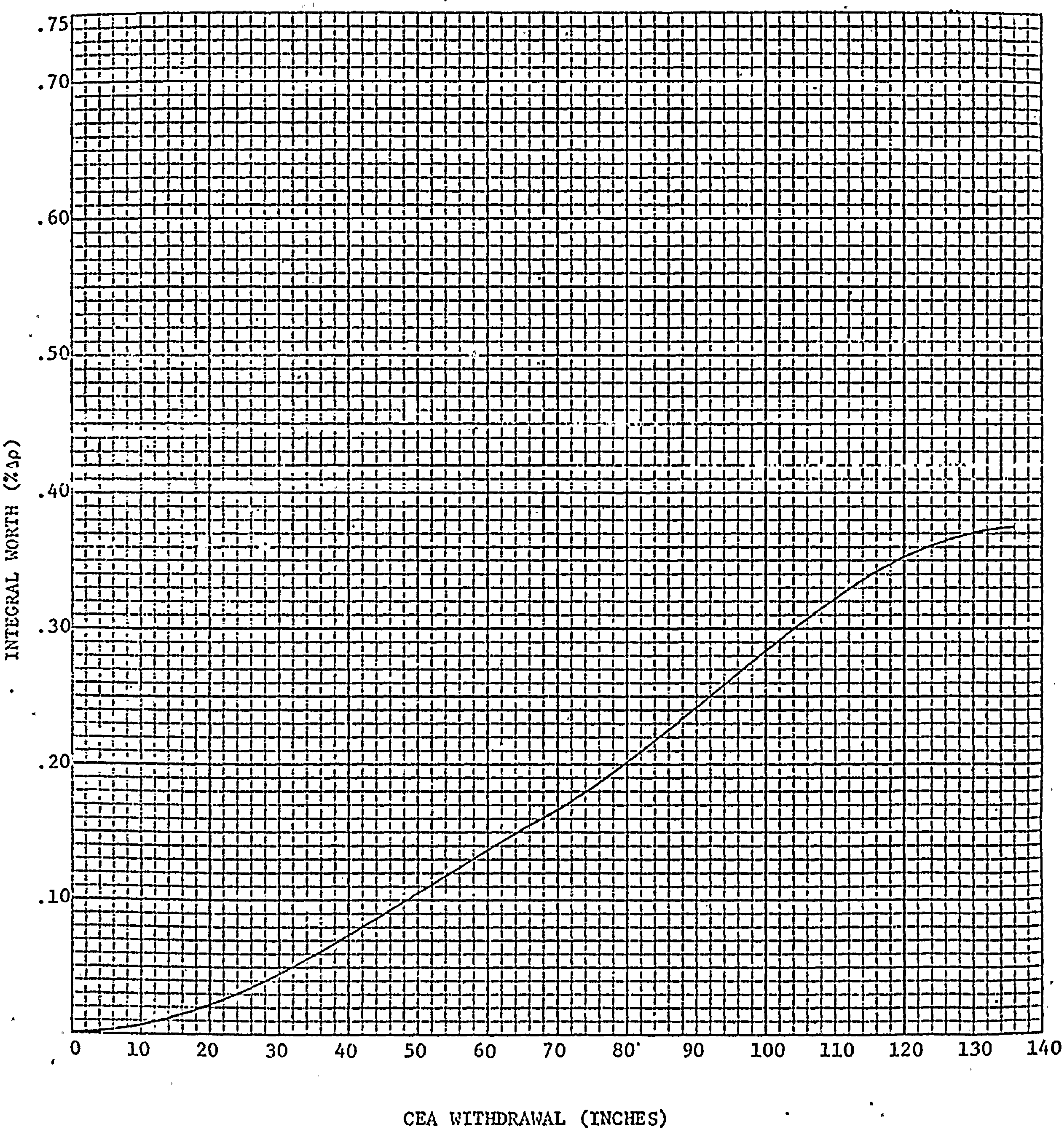
FIGURE 10



ST. LUCIE UNIT 1
INTEGRAL CEA GROUP WORTH
BOC, HZP, CYCLE 2

CEA GROUP 1

FIGURE 11



POWER ASCENSION:

Flux maps from the fixed incore detector system were used to verify that no unexpected abnormalities occurred in the Tq, LHR, $F_r T$, F^T_{xy}, Fq, and ASI_I values at the 30, 50, 80, and 100 percent power plateaus. All of the above values corresponded well with design predictions except the total planar radial peaking factor, F^T_{xy}. This peaking factor (F^T_{xy}) was measured to be slightly greater than the design value of 1.53 and required power to be limited to less than 99 percent power as delineated in Technical Specification 3.2.2. The F^T_{xy} was decreased by inserting group 7 to 124 inches at 100% power and accumulating burnup. On July 21, 1978, the reactor was brought to HFP with all CEA's out and F^T_{xy} was found to be reduced as expected. Calorimetric, nuclear power, and ΔT power calibrations were performed at the 20, 30, 50, 80, and 100 percent power plateaus. A summary of the results obtained during the 30, 50, and 100 percent power flux maps is provided in Figure 12, Figure 13, and Figure 14 respectively.

A verification of the shape annealing factors (SAF) calculated and input as a gain adjustment in the linear power range sub-channels was performed. During this test, a xenon oscillation was induced with the corresponding oscillation of the axial shape index (ASI) being monitored for each power range channel and by CECOR. The cycle 1 SAF values were found to still be valid and the gain adjustments for the linear power range sub-channels were left as they were.

The moderator temperature coefficient was measured shortly after entering the 100 percent power plateau. This test was performed in two phases, both with group 7 at 102 inches withdrawn. The first involves holding power constant, varying T-AVG and compensating for the resulting reactivity changes by CEA 7-1 movement. The second entails holding T-AVG constant, varying power and again compensating with CEA 7-1 movement. The measured value of $-.112 * 10^{-4} \Delta k/k/^{o}F$ satisfies the Technical Specification requirement that the MTC shall be less negative than $-2.2 * 10^{-4} \Delta k/k/^{o}F$ at rated thermal power, and less positive than $0.2 * 10^{-4} \Delta k/k/^{o}F$ whenever thermal power is greater than 70 percent. During this test, the isothermal temperature coefficient (ITC) was measured and found not to meet the vendor's acceptance criterion. During the subsequent investigation, CE determined that the calculation of the original design value did not properly reflect the conditions at which the measurement was made. Per CE's recommendation, an adjustment was made to the design value and the acceptance criterion was satisfied.

FIGURE 12

POWER DISTRIBUTION AT 30% POWER

Relative Power Densities

Measured →
Design →

						.635 .617	.786 .773	
				.785 .771	1.025 1.021	1.058 1.056	.865 .860	.868 .865
			.858 .856	1.240 1.254	1.042 1.056	1.158 1.162	.960 .970	1.226 1.230
		.862 .860	1.100 1.108	1.006 1.020	1.202 1.211	1.057 1.071	.989 .994	.984 .988
	.784 .774	1.246 1.259	1.014 1.023	.967 .999	1.007 1.019	1.230 1.214	1.167 1.142	1.209 1.178
	1.018 1.023	1.048 1.059	1.202 1.214	.999 1.021	1.106 1.113	1.019 1.014	1.069 1.045	.939 .922
.617 .622	1.035 1.059	1.149 1.170	1.052 1.071	1.216 1.217	1.005 1.012	1.083 1.062	1.018 .979	.775 .747
.769 .778	.850 .864	.953 .975	.979 .995	1.148 1.132	1.057 1.040	1.002 .972	.753 .729	.907 .880
	.859 .870	1.214 1.239	.971 .997	1.199 1.188	.956 .929	.772 .750	.910 .881	.700 .698

Measured

Snapshot ID	F234392
Date	6-1-78
Time	22:10
Power	29.25%
Rods	Group 7 at 115" withdrawn
T_q	.010
F^T_{xy}	1.589
F^T_r	1.490
F_q	1.782
ASI_I	.0346
Exposure	5.0 MWD/MTU

Design

Power	30%
Rods	ARO
Exposure	50 MWD/MTU

FIGURE 13

POWER DISTRIBUTION AT 50% POWER

Relative Power Densities

Measured →
Design →

						.632 .609	.784 .762	
				.775 .748	1.014 .991	1.051 1.033	.865 .856	.871 .863
			.850 .831	1.228 1.216	1.029 1.041	1.153 1.150	.963 .971	1.244 1.223
		.854 .834	1.105 1.084	1.002 1.009	1.195 1.203	1.058 1.075	.993 1.006	.989 1.000
	.774 .750	1.233 1.221	1.009 1.012	.964 1.002	1.005 1.029	1.232 1.235	1.173 1.161	1.216 1.198
	1.006 .993	1.036 1.044	1.194 1.205	.997 1.030	1.107 1.131	1.025 1.037	1.079 1.074	.951 .951
.614 .613	1.025 1.036	1.141 1.157	1.048 1.075	1.122 1.226	1.009 1.034	1.093 1.091	1.033 1.014	.786 .779
.767 .765	.849 .858	.955 .975	.980 1.004	1.152 1.149	1.066 1.069	1.016 1.007	.767 .763	.926 .920
	.861 .867	1.231 1.230	.976 1.008	1.205 1.204	.969 .956	.784 .782	.931 .921	.725 .734

Measured

Snapshot ID	F234445
Date	06-02-78
Time	11:00
Power	52.93%
Rods	Group 7 @ 116" withdrawn
T_q	.011
F_{xy}^T	1.569
F_r^T	1.472
F_q	1.740
ASI_I	-0.0341
Exposure	18 MWD/MTU

Design

Power	50%
Rods	ARO
Exposure	150 MWD/MTU

FIGURE 14

POWER DISTRIBUTION AT 100% POWER

Relative Power Densities

Measured →
Design →

						.626 .602	.782 .752	
				.735 .723	.977 .961	1.031 1.011	.863 .854	.877 .863
			.809 .806	1.175 1.176	.993 1.024	1.136 1.134	.969 .974	1.269 1.214
		.812 .809	1.070 1.055	.978 .999	1.174 1.190	1.052 1.078	1.008 1.018	1.026 1.013
	.733 .726	1.175 1.179	.981 1.002	.957 1.005	1.006 1.038	1.243 1.229	1.195 1.179	1.253 1.214
	.962 .961	.988 1.026	1.176 1.192	1.010 1.040	1.125 1.148	1.053 1.060	1.127 1.104	1.012 .984
.604 .605	.999 1.012	1.121 1.140	1.055 1.076	1.235 1.230	1.035 1.057	1.130 1.120	1.080 1.054	.828 .820
.758 .755	.843 .855	.956 .976	1.000 1.015	1.178 1.165	1.099 1.097	1.058 1.047	.806 .805	.977 .967
	.862 .867	1.253 1.219	1.018 1.019	1.241 1.215	1.009 .988	.821 .822	.985 .967	.774 .779

Measured

Snapshot ID	F236254
Date	06-02-78
Time	13:03
Power	97.74%
Rods	ARO
Tq_T	.007
Fxy	1.585
$F_r T$	1.485
Fq	1.667
ASI_I	-0.0206
Exposure	469 MWD/MTU

Design

Power	100%
Rods	ARO
Exposure	250 MWD/MTU

SUMMARY:

All Technical Specification requirements were met. No abnormalities remain unresolved.

REFERENCES:

1) Letter F-CE-6374, A.S. Jameson to A.L. Heil dated April 27, 2978.

2) Letter F-CE-6420, A.S. Jameson to A.L. Heil dated June 7, 1978.

3) Letter PRN-LI-79-143, A.D. Schmidt to R.E. Uhrig dated May 23, 1978.

4) Letter F-CE-6453, A.S. Jameson to R. K. Ryall dated July 26, 1978.