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Jersey Central Power & Light Company

MADISON AVENUE AT PUNCH BOWL ROAD • MORRISTOWN, N. J. 07960 • 201-539-6111
MEMBER OF THE
General Public Utilities Corporation
GPU ELECTRIC POWER COMPANIES
SYSTEM

February 1, 1974

Mr. Donald J. Skovholt
Assistant Director for Operating Reactors
Directorate of Licensing
Office of Regulation
U.S. Atomic Energy Commission
Washington, DC 20545

REFERENCE 1: Letter with attached report dated October 8, 1973. J.A. Hinds to D.J. Skovholt.
REFERENCE 2: "Reactor Control Blade Evaluation" MNPS-1 Special Report, July 23, 1973.
REFERENCE 3: Letter from D.A. Ross to D.J. Skovholt dated October 16, 1973. Re: Shutdown Margin Tests

Dear Mr. Skovholt:

SUBJECT: OYSTER CREEK NUCLEAR GENERATING STATION
DOCKET NO. 50-219
INVERTED POISON TUBES

Your letter dated September 28, 1973 indicated that insufficient data exists to conclude that poison redistribution cannot occur in control rods that may have inverted poison tubes. In this regard, you requested that we provide the information you require by responding to the seven questions listed in your letter.

Our response to these concerns are provided as Attachment I to this letter.

General Electric Company has provided generic responses to some of these questions and has recommended a generic approach to be followed with respect to others. These responses are contained in References 1 and 2 above and will be utilized, whenever possible, in responding to your concerns.

Very truly yours,

B/646

Ivan R. Finfrock, Jr.
Vice President

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Attachment

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QUESTION

1. Submit analyses of possible length and location of poison voids which could be caused by boron carbide redistribution.

RESPONSE (Reference 2, Section III)

A. Size of Poison Segments

During the loading of the individual absorber rods, it has been noted that a variation in density occurs over the rod length. This is evidenced by a decrease in segment length as the tube is loaded with successive equal charges of B_4C. An examination of production absorber rod lots shows the bottom segment to be 17.3 inches long with a 2σ variation of 2.2. The next to the bottom segment is 16.8 with 2σ variation of 3 inches. The next to the top segments average 14.0 inches with 2σ variation of 2.0, while the segment below averages 14.4 with 2σ equal to 2.4.

This density variation occurs because of powder segregation during the loading process. Larger particles separate as the mix falls in the tube, giving a coarser powder in the bottom of the lower segments and finer powder in the upper portions. This segregation has been noted in tube X-rays and found when tubes are cut open for examination.

Absorber rods that are inverted at assembly will be installed in the reactor in the same position in which they were loaded, i.e., the shorter, denser segments at the top, and the longer segments at the bottom. The density at the upper end of such tubes will be $\sim$ 10% greater than the average, or approximately 77% of theoretical density.

B. Maximum Theoretical Compaction

Specification for the B_4C powder requires an average particle density of not less than 2.38 g/cm^3 (95% of the theoretical density). The powder is vibrated to achieve an average value of 70% ± 5% of theoretical density during loading. This is verified by weighing of the loaded tubes, with the process limits based on 2.504 g/cm^3 - rather than the 2.38 minimum that could be supplied. This, in effect, shifts the average compaction achieved toward a higher percentage.

Published data on theoretical densities achievable by vibration, together with General Electric's experience with fuel powder compaction, indicate an 85% theoretical density to be the maximum achievable in the absorber rod. This will result in a very small additional compaction in the upper segments of rods already at 77% or more.

C. Cold Vibration Tests

A testing program was instituted on absorber rods to measure the effect of vibration on the B_4C in rods held in the inverted position. Eighty-two (82) absorber rods, representing four production lots processed over a one-month period, were vibrated for periods ranging from 80 minutes to 8 hours. The vibrating fixture used in normal rod loading was used. Compaction, as measured by movement of the separator balls during the test, appeared greater in the bottom (as loaded, tested, and incorrectly installed in deviating assemblies) segments. Longer vibrating time produced greater ball movement. No rod tested evidenced free movement of all balls in the column. The average movement of the top ball in the rod (a measure of compaction of the second B_4C segment) was 0.060 in. after 80 minutes vibration, 0.126 after 250 minutes, and 0.148 after 8 hours. The ball movement in the bottom segments, with their lower density, averaged 0.615 inches after 80 minutes, 0.870 after 4 hours and 1.288 after 8 hours. It must be noted that most balls wedge in the tube, so the amount of compaction is not necessarily reflected in ball movement. There were a few tubes that showed increasing ball movement over three or four of the lower segments, indicating the possibility of the space generated by compaction of the powder being "accumulated" toward the upper end of the control rod.

D. Operating Reactor Data

There has been very little data available after actual reactor service. Test absorber rods have been exposed in the Dresden I reactor by being placed in fuel instrument tubes. These rods were swaged tubes, similar to the actual Dresden I control rod absorber tubes. Neutron radiography techniques allowed examination of these tubes and no settling of the B_4C had taken place. An examination of tubes from a Dresden I control rod was made in 1967. Again, no compaction was visible in the absorber tubes.

E. Test Rod DN-181

A spare production control rod from the Dresden II production run has been under test in General Electric's San Jose facility for the past 5 or 6 years. It has experienced about 16,000 operations, with a minimum of 5000 scram cycles. The rod has "seen" more heat-up cycles than predicted during a reactor lifetime. This rod was X-rayed to examine the absorber tubes. The B_4C had settled from 1-1/2 inch to a maximum of 2-1/2 inches, the top (dimpled end) 16 inch-segment of the absorber rods.. Many, but not all of the top separator balls were settled to the locating dimples. All absorber rods were oriented correctly.

F. Maximum Gap Size

Based on the above data, an estimate can be made of the maximum settling that could occur in inverted absorber rods during reactor use. The assumption is made (which cannot be demonstrated by tests) that all separator balls will move down until restrained by the next lower dimple.

The average amount that the top ball could move is 14.4 inches, the length of the second segment. The initial density in the top segment is between 77% and 81%. Assuming an average 79%, and maximum possible compaction to 85%, the compaction of the top segment would be approximately 1.0 inches. The total gap would thus be 14.4 ball movement and 1.0 inches compaction or 15.4 inches. This production average value is applicable to the physics calculations because of the large number of individual absorber rods in each blade.

QUESTION

2. Analyze the effect of boron carbide redistribution on normal operation, transients and accidents.

RESPONSE

A. Pressurization Transients
(Reference 1, page 3-2, Section b.)

In reference (1), pressurization transients were evaluated with conservative assumption of 50% of the blades compacted to ∿16 inches. The analysis showed that 10 psi would be low from the margin between the peak pressure and setting of the first safety valve. With only 5% of the absorber tubes affected, the effect on the pressure margin should be negligible.

As a check, further scram calculations were made with effective control fraction from 1.0 to 0.7 in increments of 0.1. The results of these calculations are shown in Figure 1. From various pressure responses to scram reactivity curves it has been estimated that a degradation in scram reactivity from the 1.0 to 0.7 curve would result in peak pressure increase of three to seven psi, depending on the plant. This implies that a 0.8 effective control fraction would result in a peak pressure increase of two to five psi and 0.9 effective control fraction would result in peak pressure increase form one to two psi.

The effective control fraction in terms of defective absorber tubes (B_4C compacted ∿16") then needs to be defined. This is shown in Figure 2. The curve was developed from bundle eigenvalues or more importantly loss in control strength for various numbers and positions of defective tubes. The experimental data given in "Results of KWU Critical Experiments and Proposed Control Blade Acceptance Criteria for Inverted Tubes" was used.

5% of defective absorber tubes results in a loss in blade strength of about 4%, or the effective control fraction of the first 16" of the blade is about 0.96. On the basis of the discussion in the second paragraph, above, this would result in peak pressure increase of about one psi.

B. Accidents
(Reference 1, page 3-3, Section c.)
(Reference 2, Section IV.)

The effect of the potential settling of B_4C on accidents was evaluated. Settling of B_4C in some of the control blades only has a significance in the analysis of the Rod Drop Accident.

Rod drop accident margin will be affected to a lesser or greater degree depending on the distribution of inverted sheaths and/or absorber tubes throughout the core. Should the defective sheath or tubes be uniformly distributed the increase in the maximum rod worth is estimated to be less than 0.002 ΔK. If, however, four inverted sheaths should exist in one control blade with a maximum B_4C settling of approximately 16", the maximum rod worth is increased by an estimated 0.002 ΔK in the nearest blade. If many blades had settled B_4C, the reactivity effect is no longer localized and the effect on the strongesc blade is negligible.

C. Shutdown Margin

Shutdown margin demonstrations have shown that SDM requirements of the Technical Specifications have been satisfied. Also during these checks, no evidence of localized grouping of defective rods were observed. These demonstrations were performed for the Oyster Creek reactor core on September 27 and 28, 1973 and reported to the AEC on October 16, 1973 (Reference 3).

It was shown in Reference 2 that even if as much as 19 inches of B_4C were gone in 50% of the blades, nearly the design SDM can be retained with the strongest rod withdrawn. With only 5% of the absorber tubes inverted and with B_4C settled the maximum theoretical amount, the 0.014 ΔK margin can be maintained throughout the remainder of the cycle. This margin is expected to increase with exposure. Thus it may be concluded that even with the maximum theoretical settling of B_4C with 5% of the absorber tubes inverted, the 0.0075 $\Delta K/K$ shutdown margin, which the commission requested be demonstrated in a September 7, 1973 letter, can be met with substantial extra margin.

QUESTION

3. Submit proposed changes to the Technical Specifications which will assure that all safety margins stated or implied in your FSAR are maintained.

RESPONSE

Changes to Technical Specifications to preserve safety margins for the current cycle or after reloads will not be required. As discussed in the response to question 2, the current cycle Technical Specification requirements on shutdown margin will be met, pressure margin increase during transients is negligible and rod drop accident margin change is small.

After reload, additional shutdown margin tests will verify that safety margins are maintained.

QUESTION

4. Surveillance requirements to maintain adequate shutdown reactivity margins and monitor changes in poison distribution.

RESPONSE

As indicated in the response to question 3, shutdown margin tests have been conducted for the current cycle and additional shutdown margin tests will be conducted after reload to verify that safety margins are maintained.

QUESTION

5. Submit your plans and schedules for changeout of control rods.

RESPONSE

In view of the results of the evaluations made with respect to B_4C redistribution effects on normal plant operation, transients and accidents; in addition to the results of previous shutdown margin demonstration tests and proposed SDM demonstrations for future cycles, it has been demonstrated that premature changeout of control rods is not indicated at this time for the Oyster Creek Nuclear Generating Station.

QUESTION

6. Submit the expected curve of reactivity vs. burnup for the remainder of the current operating cycle.

RESPONSE

Figures 1 and 2 (attached) represent two calculational solutions of the requested curve at full power and full flow conditions. Control rod density vs. exposure provides the best measure of the core reactivity variation during the cycle. Figure 1 presents the results of control rod pattern solutions for the cycle. Note that the curve up to 2750 MWD/MT represents an original calculation. The rod patterns used for these predictions indicated more use of power shaping rods (hence higher rod density for the same rod worth) than was actually experienced. The use of power shaping rods was minimized in operation to minimize flux peaking off the control rods, hence, the MAPLHGR. The curve covering the period from 2750 MWD/MT to the end of cycle 3 represents a revised calculation based on adjusting the previous calculation for the reduced number of shaping rods and a slight correction for calculational bias found in the simulator eigenvalue prediction. A one percent variation in core reactivity is taken to be equivalent to 276 notches in all conditions.

Figure 2 represents the results of a Haling type solution for cycle 3. Again, the first portion of the curve is the original result and the second portion (from 2750 MWD/MT on) represents a revised calculation. One would expect that Figure 1 represents a more realistic prediction since all effects possible (with the model used) are included in the calculation.

Figures 1 and 2 also present a comparison of the actual to predicted control rod described for cycle 3. The plotted control rod densities are corrected for power, flow, and subcooling variations from those at full power and full flow.

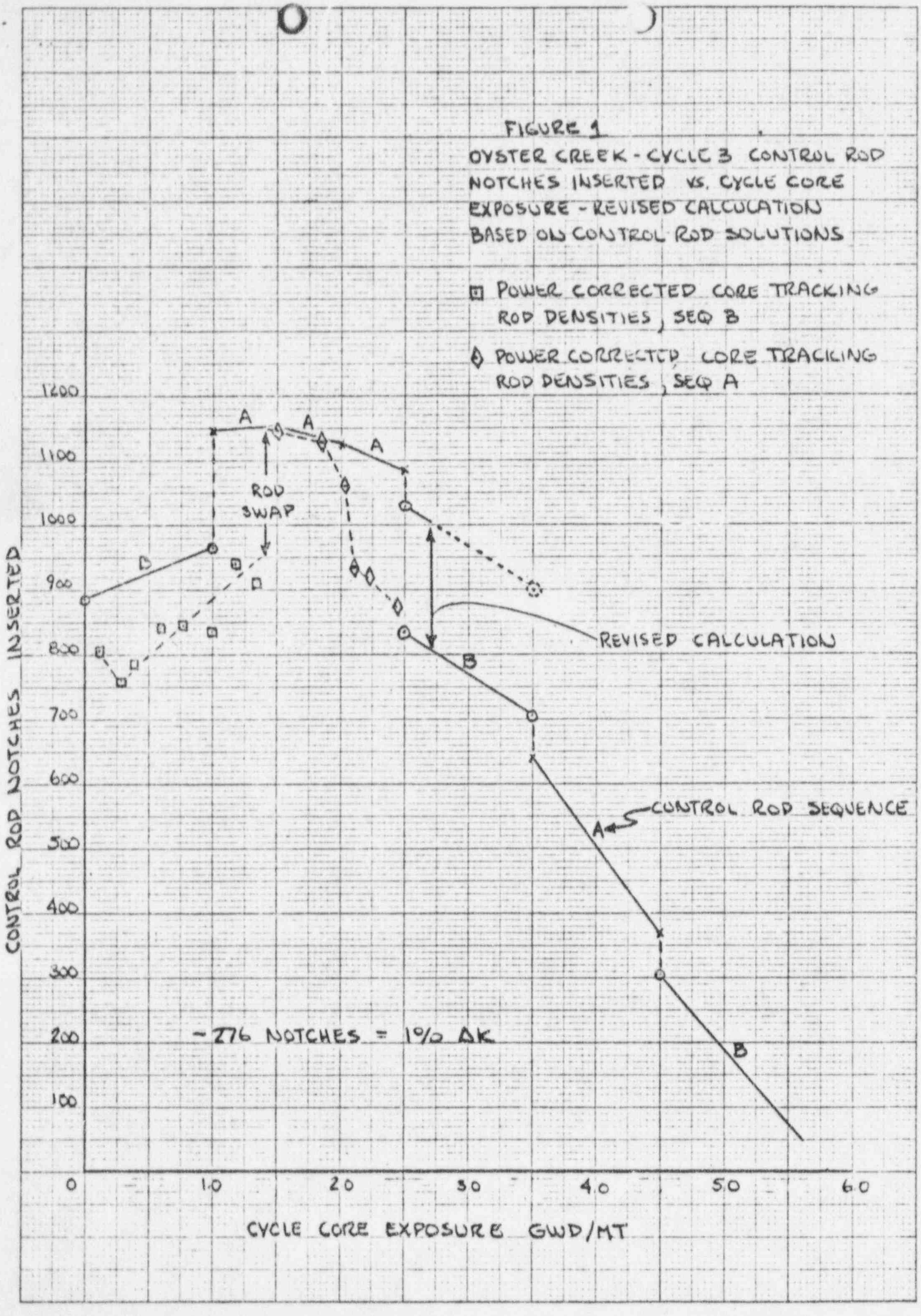

FIGURE 1
OYSTER CREEK - CYCLE 3 CONTROL ROD NOTCHES INSERTED VS. CYCLE CORE EXPOSURE - REVISED CALCULATION BASED ON CONTROL ROD SOLUTIONS

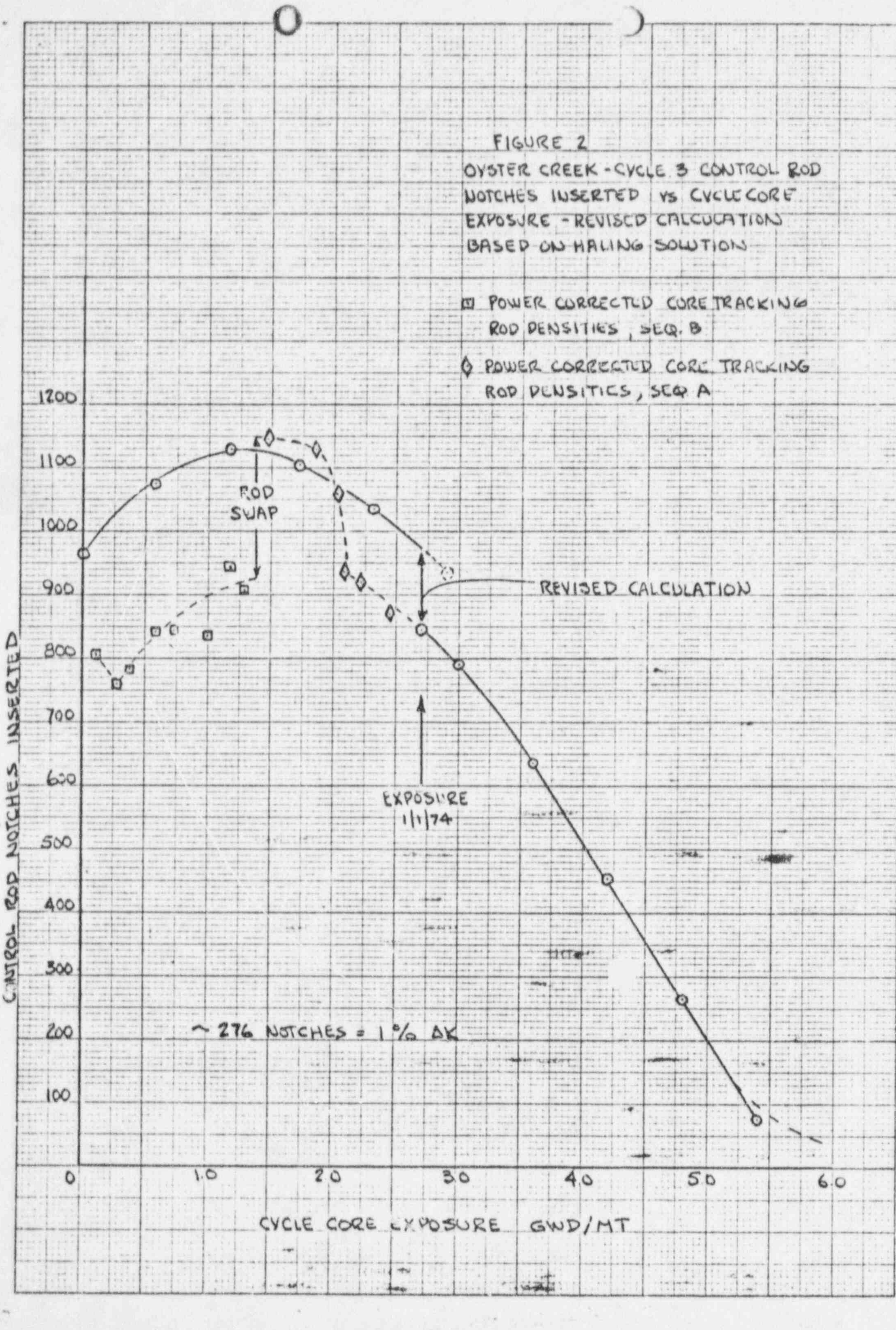
FIGURE 2
OYSTER CREEK - CYCLE 3 CONTROL ROD NOTCHES INSERTED VS CYCLE CORE EXPOSURE - REVISED CALCULATION BASED ON HALING SOLUTION
POWER CORRECTED CORE TRACKING ROD DENSITIES, SEQ. B
POWER CORRECTED CORE TRACKING ROD DENSITIES, SEQ A
ROD SWAP
REVISED CALCULATION
EXPOSURE 1/1/74
~ 276 NOTCHES = 1% ΔK
CONTROL ROD NOTCHES INSERTED
CYCLE CORE EXPOSURE GWD/MT
1200
1100
1000
900
800
700
600
500
400
300
200
100
0
1.0
2.0
3.0
4.0
5.0
6.0

QUESTION

7. Provide a comparison of predicted vs. measured criticality measurements for the 3 fuel cycles at Oyster Creek, as well as a summary of the results of the control rod inventory checks required by Technical Specification 4.2.F including any corrections made to the predictions based upon previous data.

RESPONSE

Tables 1 and 2 list results of comparisons made in measured and calculated hot operating criticals. Similar data for cycle 1 is not readily available.

Figures 3, 4 and 5 present comparisons of measured and predicted control inventory for various cycle exposures for cycles 1A, 1B and 2 respectively. In all these figures the raw (base) data has been corrected for the number of notches inserted in power shaping rods.

Table 1

CYCLE 2 - HOT OPERATING CRITICAL COMPARISONS

Core Exposure (MWD/MT)		Calculated K_{eff}
(7/5)	207 B	1.0001
(7/27)	590 B	1.0001
(3/31)	1064 A	1.0004
(9/8)	1200 A	1.0020
(9/21)	1430 A	1.0035
(10/10)	1760 A	1.0041
(10/19)	1917 A	1.0051

Mean = 1.0022

1σ = .0021

$M + 1\sigma$ = 1.0043

Table 2

CYCLE 3 - HOT OPERATING CRITICAL COMPARISONS

	Core Exposure (MWD/MT)	Calculated K_{eff}
(6/27/73)	332 B (1801)	1.0017
(7/18)	632 B (1876)	1.0047
(8/2)	813 B (1889)	1.0051
(8/17)	1040 B (1898)	1.0030
(10/22)	1600 A (1612)	0.9961
(11/15)	1966 A (1705)	0.9982
(12/13)	2395 A (1823)	1.0009
(12/26)	2612 A (1803)	1.0013

Mean $= 1.002388$

$1\sigma = .004063$

Mean $+ 1\sigma = 1.00645$

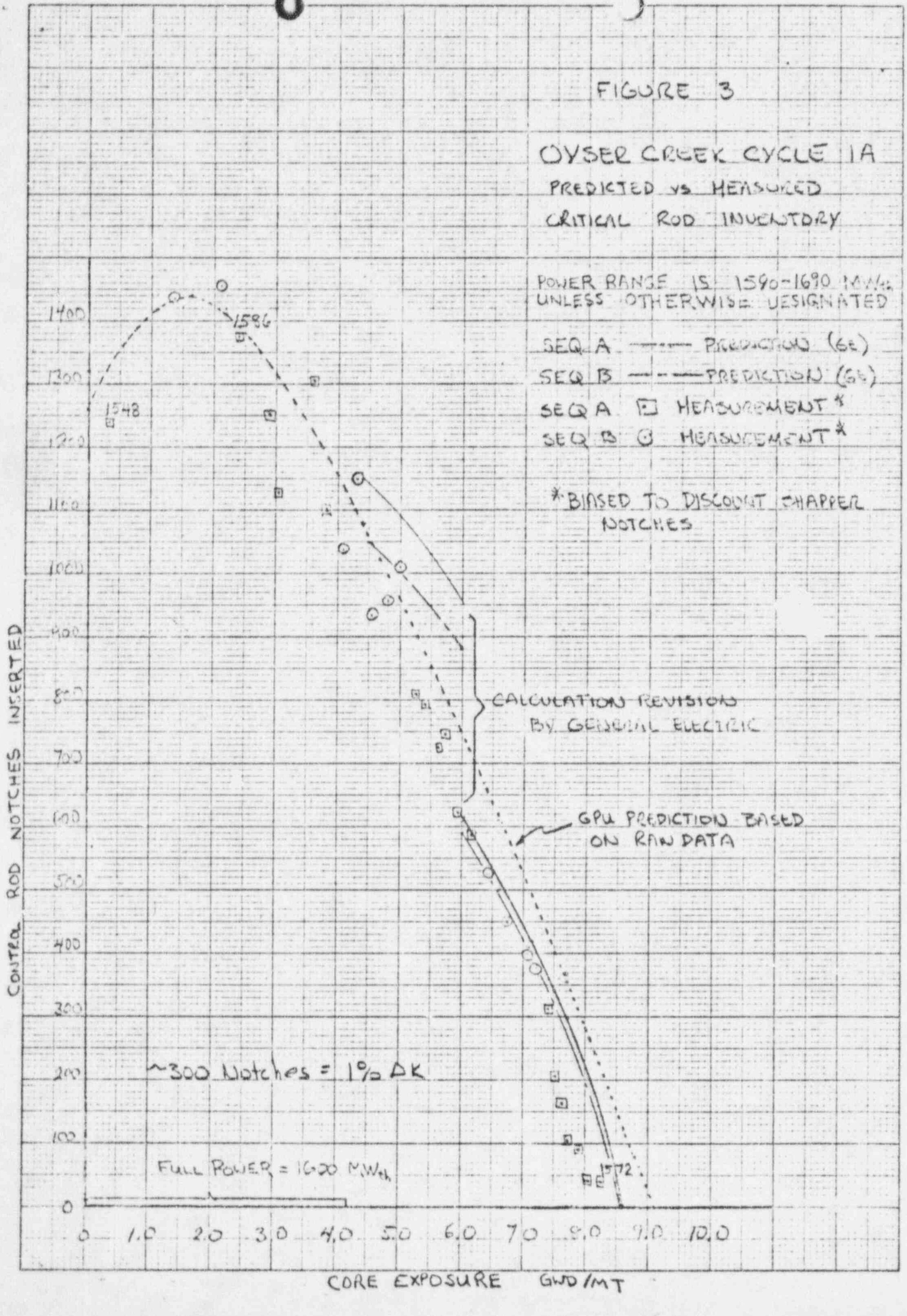
FIGURE 3
OYSER CREEK CYCLE 1A
PREDICTED vs MEASURED
CRITICAL ROD INVENTORY
POWER RANGE IS 1590-1690 MWth
UNLESS OTHERWISE DESIGNATED
SEQ A —·— PREDICTION (GE)
SEQ B —— PREDICTION (GE)
SEQ A ⊡ MEASUREMENT*
SEQ B ⊙ MEASUREMENT*
*BIASED TO DISCOUNT CHAPPER NOTCHES
CALCULATION REVISION BY GENERAL ELECTRIC
GPU PREDICTION BASED ON RAW DATA
~300 Notches = 1% ΔK
FULL POWER = 1620 MWth
1586
1548
1572
CONTROL ROD NOTCHES INSERTED
CORE EXPOSURE GWD/MT
0
100
200
300
400
500
600
700
800
900
1000
1100
1200
1300
1400
0
1.0
2.0
3.0
4.0
5.0
6.0
7.0
8.0
9.0
10.0

FIGURE 4

OYSTER CREEK
CYCLE 1B
CONTROL ROD NOTCHES VS
CYCLE CORE EXPOSURE
DATA PLOTTED IS CORRECTED
FOR SHAPPER ROD NOTCHES

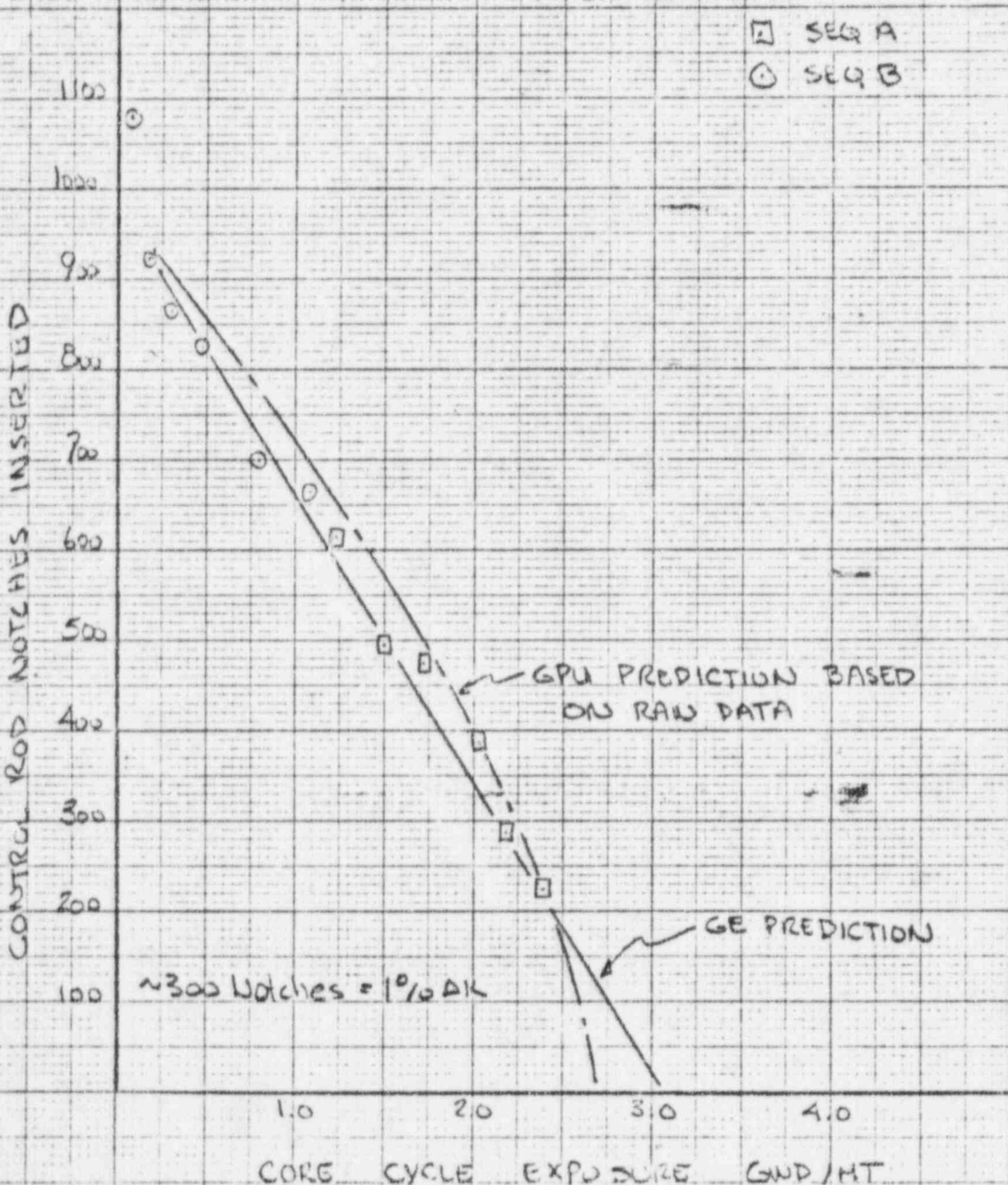

FIGURE 5

OYSTER CREEK CYCLE 2
PREDICTED VS MEASURED
CRITICAL ROD INVENTORY

SEQ A □
SEQ B ⊙

RANGE OF POWER 1314-1700 MWT