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TITLE

FINAL REPORT - PT IP-416
MEASUREMENT OF THE HORIZONTAL ROD STRENGTH AT H REACTOR

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January 24, 1962

FINAL REPORT - PT IP-416
MEASUREMENT OF THE HORIZONTAL ROD STRENGTH AT H REACTOR

I. INTRODUCTION

The object of this test was to obtain data concerning the reactivity of the horizontal rods in the E-N fuel loading at H Reactor./1,2/ An accurate calibration of the control rods could then be used to provide a more accurate measurement of the other reactivity variables associated with the E-N loading.

/1/ HW-66300 PT1, and PT2, "Production Test IP-350-C, E-N Demonstration Load at H Reactor," R.D. Carter, 3-22-61, and 4-4-61

/2/ HW-70740, "Recommended E-N Charge Modification (Second Cycle) PT IP-350-C E-N Demonstration Load," R. D. Carter, 8-15-61

[redacted]

A comprehensive rod calibration test was performed at H Pile in 1957.[3] Results of the present test, needed because of the "blacker" E-N fuel in the pile, have been normalized to the 1957 test results and extrapolated to a full-system calibration. Two short tests were carried out for this purpose: 1) a scram transient test, and 2) a modified rising period calibration test.

II. SUMMARY

Horizontal control system evaluations performed in the E-N loading yielded results which indicate that the control rods at H Reactor are less effective in an E-N fuel loading than in a basically natural uranium loading.

Results from two scram transient tests indicate that the combined reactivity effect of the graphite and metal coefficients are approximately 20 per cent less in an E-N loading than with a natural uranium lattice.

III. DISCUSSION

A. Modified Rising Period Calibration Test

1. Description

The rising period calibration consisted of a partial recalibration of two select rod configurations; one rod group was a duplicate of a configuration calibrated in 1957, and the other followed the present insertion order and equilibrium configuration. In practice, rods were inserted to successive positions, and a pile rising period was obtained at each position. Periodically, a rod configuration previously measured was repeated; this repetition provided base points so that the pile reactivity as a function of time could be determined. Any given rod configuration was evaluated by subtracting the value of the rising period measured with the rods in that configuration from the pile reactivity derived by the summation of the reactivity increases at the tie points.

2. Instrumentation

Previously during rod calibration testing it has been customary to set up, in the control room, special amplifiers, scalers, and printers, attached to proportional chambers under the pile. A special timer would provide start and stop signals for both scalers. Raw data consisted of counts received per 15 second intervals which were then plotted, "by hand," on semi-log paper; the pile period was determined from the slope of the line which was the best "by eye" fit to the last four or five points.

This current test did not utilize any additional equipment. The subcritical monitors counted the pile neutron data and plotted the results. One person determined the period from the subcritical monitor chart data using the best "by eye" measurement of the time required for the neutron

[3] HW-52283, "Horizontal Rod Calibrations H Pile (Final Report PT IP-10-C)," C. L. Miller, 9-24-57

current to increase by a factor of 2.718. The data received was excellent; the two subcritical monitors agreed within one or two seconds on each period and permitted constant observation of the reactivity changes taking place during the test. The variable chamber positions enabled the periods to be taken from the best available count rate range throughout the entire transient.

3. Test Procedure

At the time of the test number 14 rod (a half-rod), could not be withdrawn beyond the 230" out position. Since the half-rods are included in both of the insertion orders used in the test, test data was not hampered except during the initial stages when individual rods or rod pairs were being calibrated. Forty different rod configurations in all were tested through a range of 0 to 780 c-mk. This range covers approximately forty-five per cent of the complete horizontal control system.

The reactivity transient and strength of the rod configurations used during the test are illustrated in Figure 1 just as they were measured during the test.

4. Results and Data from the Modified Rising Period Test

The best explanation of the test results can be given by the graphs illustrated in the following Figures. Each graph shows the comparison of control rod strengths measured in this test to the values obtained in the 1957 calibration. Not all of the difference shown can be attributed to the E-N fuel because the effect of the control rods has also been reduced, since the 1957 test measurement, by the conversion to I&E fuel elements, and an increase in flat zone size.

Considering the effects mentioned above plus the calibration uncertainty range ($\sim$20 per cent on basis of startup tests based on both pile size and period measurements) the measured differences in this test are in reasonable agreement with the 10 per cent difference predicted by D. I. Monnie./4/

a. Measurement of Specific Rod Pairs

The first set of graphs (i.e. Figures 2 and 3) illustrates the reactivity effect of various rod pairs measured during the test. The rapid xenon decay transient in the E-N fuel in comparison to the natural uranium loading prevented the measurement of all rod groups. However the data was adequate to derive nominal rod strengths for all fifteen control rods.

b. Results from the Measurement of Rod Groups

Two specific insertion orders were calibrated during this test. The first planned insertion order was a duplicate of a sequence followed during the 1957 calibration. A comparison of these two measurements is shown in Figure 4.

The second insertion order measured the reactivity effect of the rod withdrawal order presently in use at H Reactor. This data was very significant in deriving the proper metal and graphite temperature coefficients from the scram transient tests.

/4/ HW-69566, "Physics of E-N Load Compared to Natural Uranium Load at H Reactor," D. I. Monnie, 5-11-61

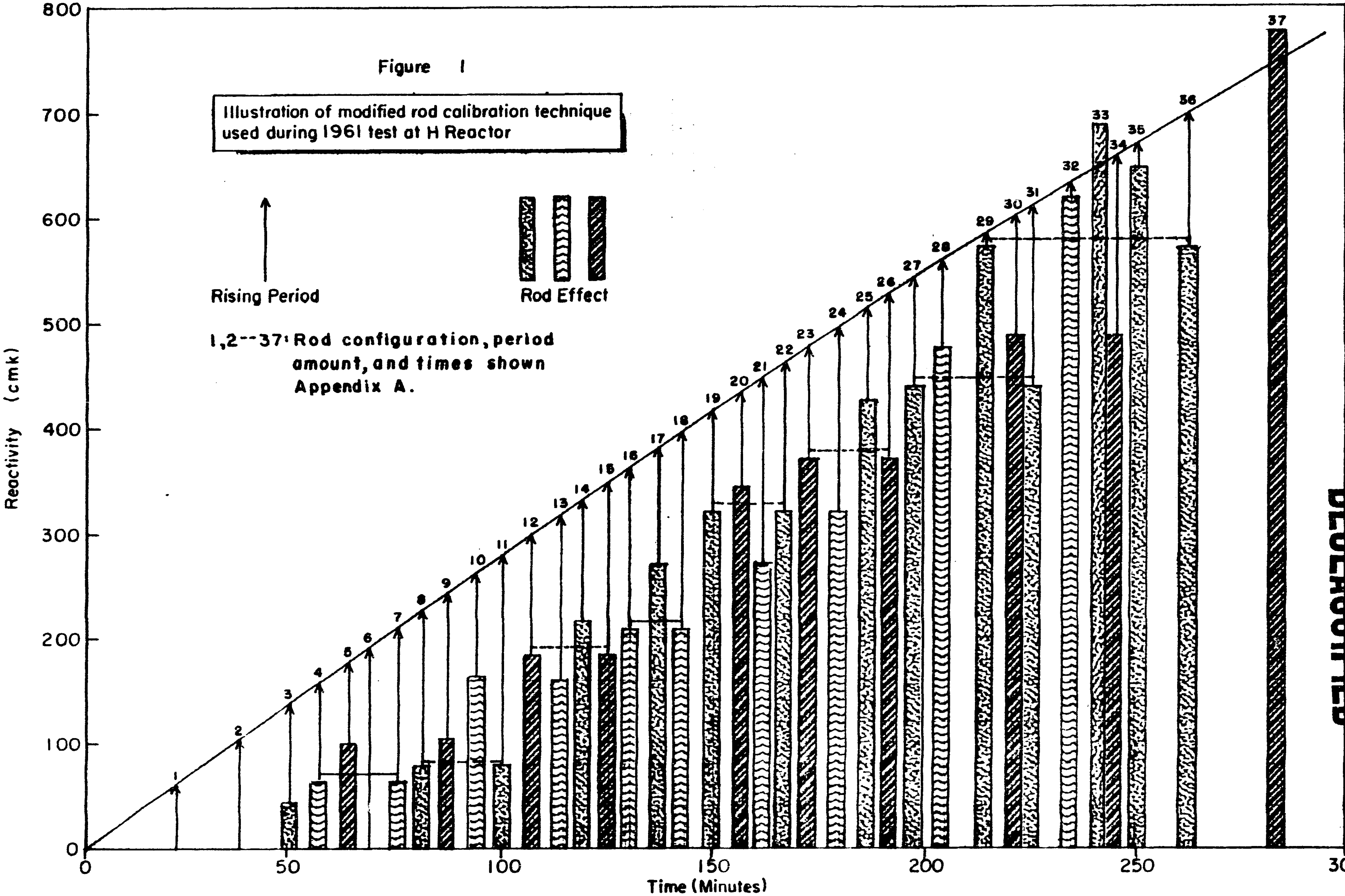
Figure 1
Illustration of modified rod calibration technique used during 1961 test at H Reactor
Rising Period
Rod Effect
1,2--37: Rod configuration, period amount, and times shown Appendix A.
Reactivity (cmk)
Time (Minutes)
0
100
200
300
400
500
600
700
800
0
50
100
150
200
250
300
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
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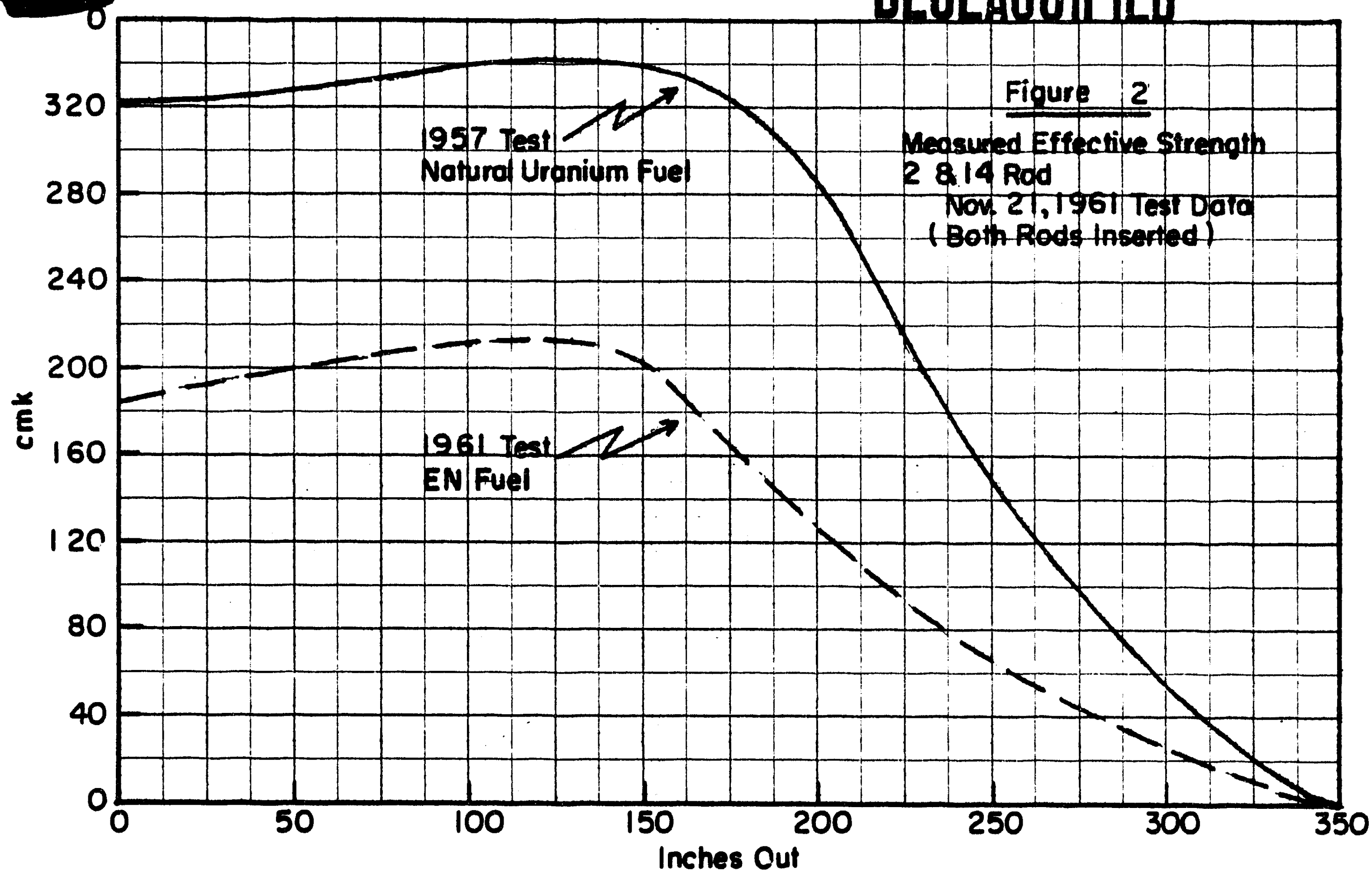
Figure 2
Measured Effective Strength
2 & 14 Rod
Nov. 21, 1961 Test Data
(Both Rods Inserted)
1957 Test
Natural Uranium Fuel
1961 Test
EN Fuel
cmk
Inches Out
0
40
80
120
160
200
240
280
320
0
50
100
150
200
250
300
350

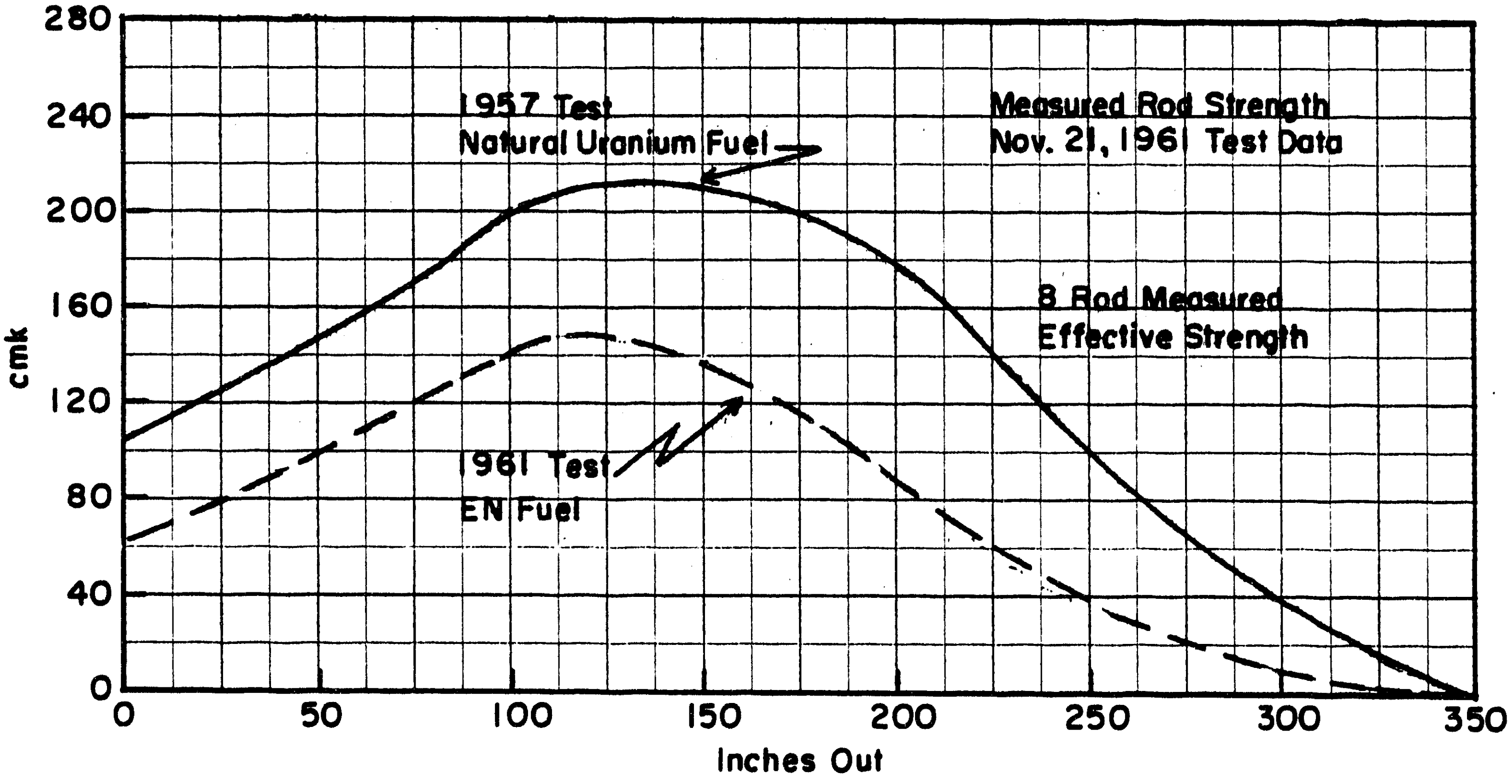
Measured Rod Strength
Nov. 21, 1961 Test Data
8 Rod Measured
Effective Strength
1957 Test
Natural Uranium Fuel
1961 Test
EN Fuel
cmk
Inches Out
0
40
80
120
160
200
240
280
0
50
100
150
200
250
300
350

Figure 3

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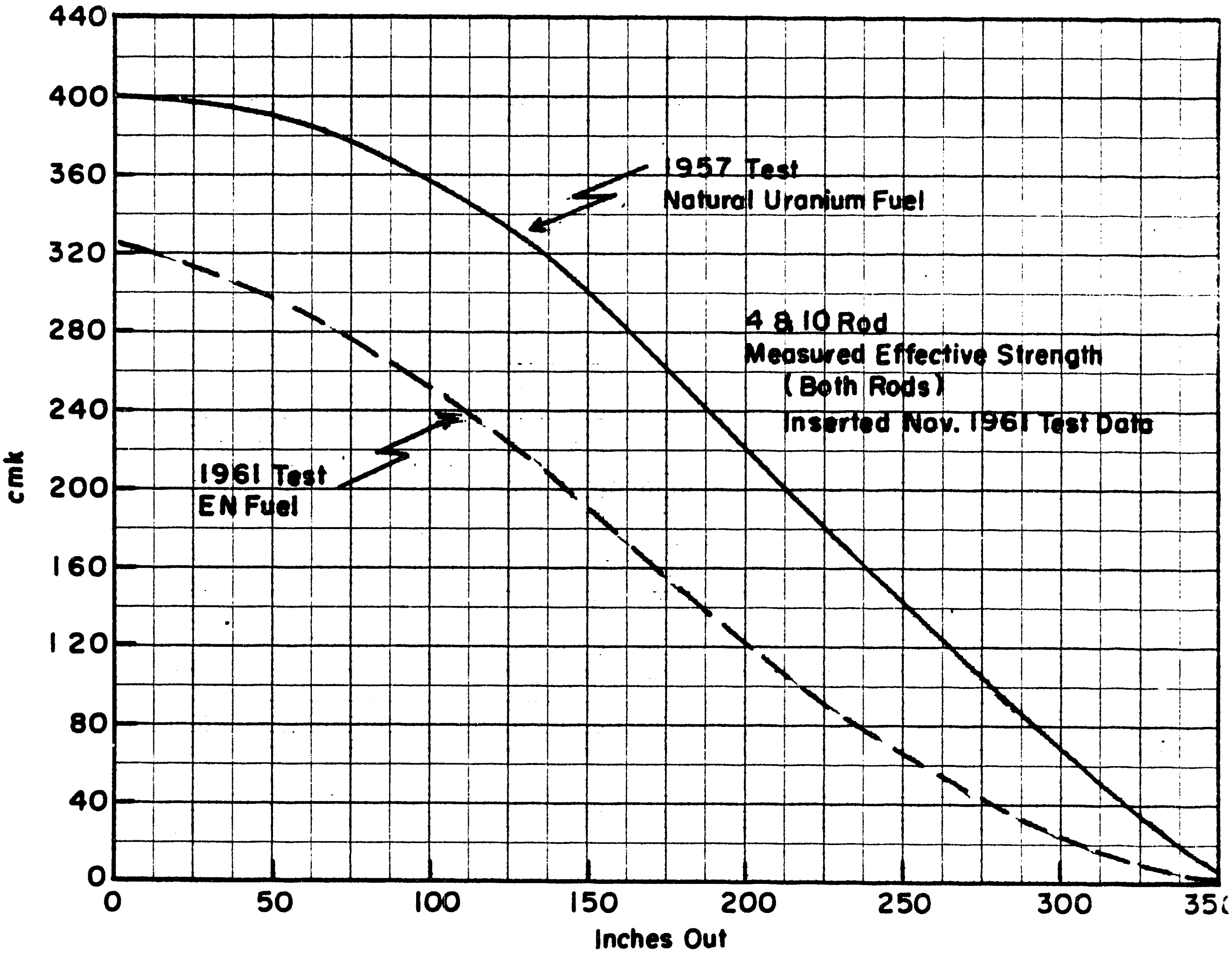

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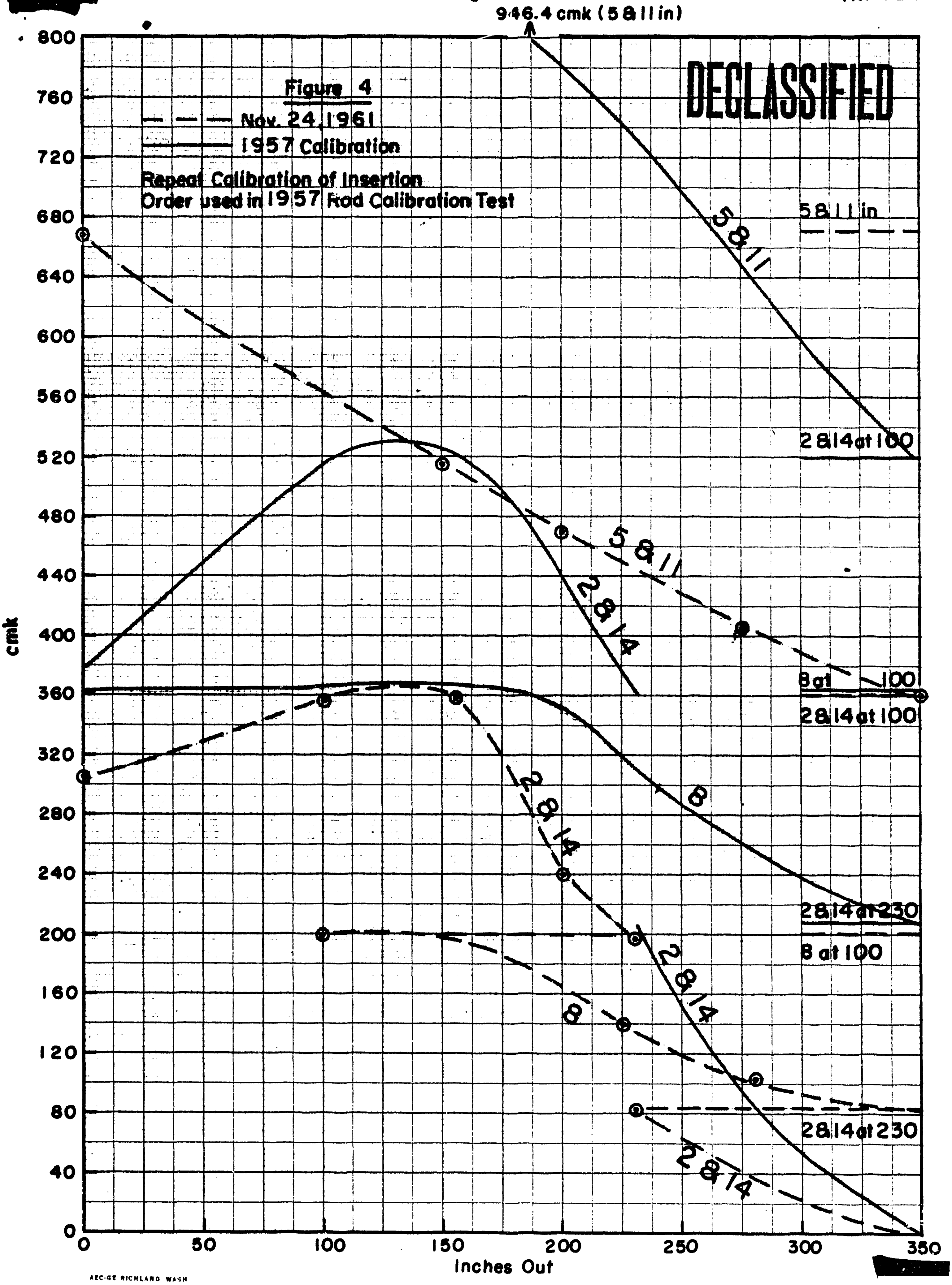
946.4 cmk (5&11 in)
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Figure 4
Nov. 24, 1961
1957 Calibration
Repeat Calibration of Insertion
Order used in 1957 Rod Calibration Test
cmk
800
760
720
680
640
600
560
520
480
440
400
360
320
280
240
200
160
120
80
40
0
50
100
150
200
250
300
350
Inches Out
5&11
5&11 in
2&14 at 100
5&11
2&14
8 at 100
2&14 at 100
2&14
8
2&14 at 230
8 at 100
2&14
8
2&14 at 230
2&14

The limited time allowed for the test prevented the measurement of rod groups with an effective strength much stronger than 800 c-mk. However, the equilibrium control configuration was measured through use of falling periods. The measured values of the current rod insertion order and equilibrium control configuration are illustrated in Figures 5 and 6 respectively.

c. Nominal Rod Stregnths

In order to accurately determine the effect of other reactivity variables in the E-N fuel loading it is necessary to derive nominal rod strengths and a nominal to effective ratio. More data (i.e., larger test time), is required to accurately determine the nominal rod effects of all fifteen control rods; however, the data available was sufficient to establish a reliable estimate. These parameters are shown in Figures 7, 8, 9 and 10.

B. Scram Transient Test

1. Description

Two scram transient tests were performed to measure the reactivity transient immediately following a reactor scram. By maintaining a constant galvanometer reading at a low power level (i.e., 1-10 MW), immediately following a shutdown, the "critical" transient was followed through the normal range of "excess held in the control rods."

2. Procedure

The first scram test was performed on 8-15-61 when the E to N fuel ratio was 19.37" E to 1" N. The second test was performed on 1-4-62 when the fuel ratio was 17.75" E to 1" N.

3. Analysis Procedure

The reactivity transient following a reactor shutdown from equilibrium operation is a function of the metal temperature effect, which occurs instantaneously at shutdown, graphite temperature effect, and fission product or xenon and iodine decay transient. The reactivity transient measured by the control rods is graphed as a function of time. By subtracting the change in the transient due to the xenon buildup, the graphite temperature transient can be derived. Extrapolating the graphite effect to zero time (i.e., half-down), it is possible to calculate the metal and graphite reactivity effects at the time of shutdown. By measuring the length of time required for the graphite effect to change by a factor of 2.718, the falling period (τ), is obtained. The results of this type of analysis are illustrated in Figures 11 and 12.

The values measured in the scram transient tests are in good agreement with the theoretical analysis by D. I. Monnie[4] which predicted the metal temperature coefficient to be about 90 per cent of the natural uranium metal coefficient.

/4/ HW-69566, Ibid

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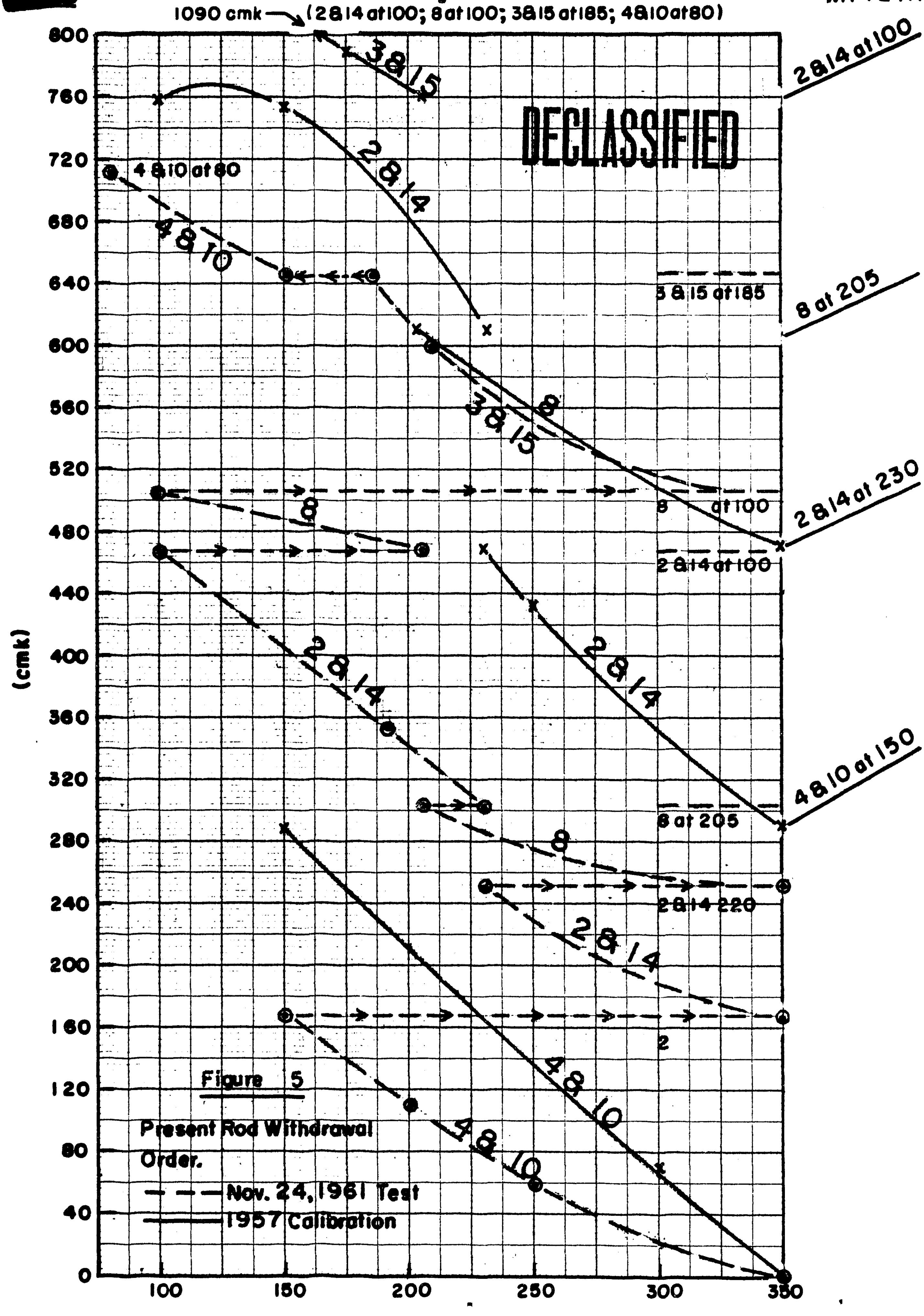

Figure 5

Present Rod Withdrawal Order.

Figure 6

Calibration of Equilibrium Rod Configuration. H Reactor-1961 Test

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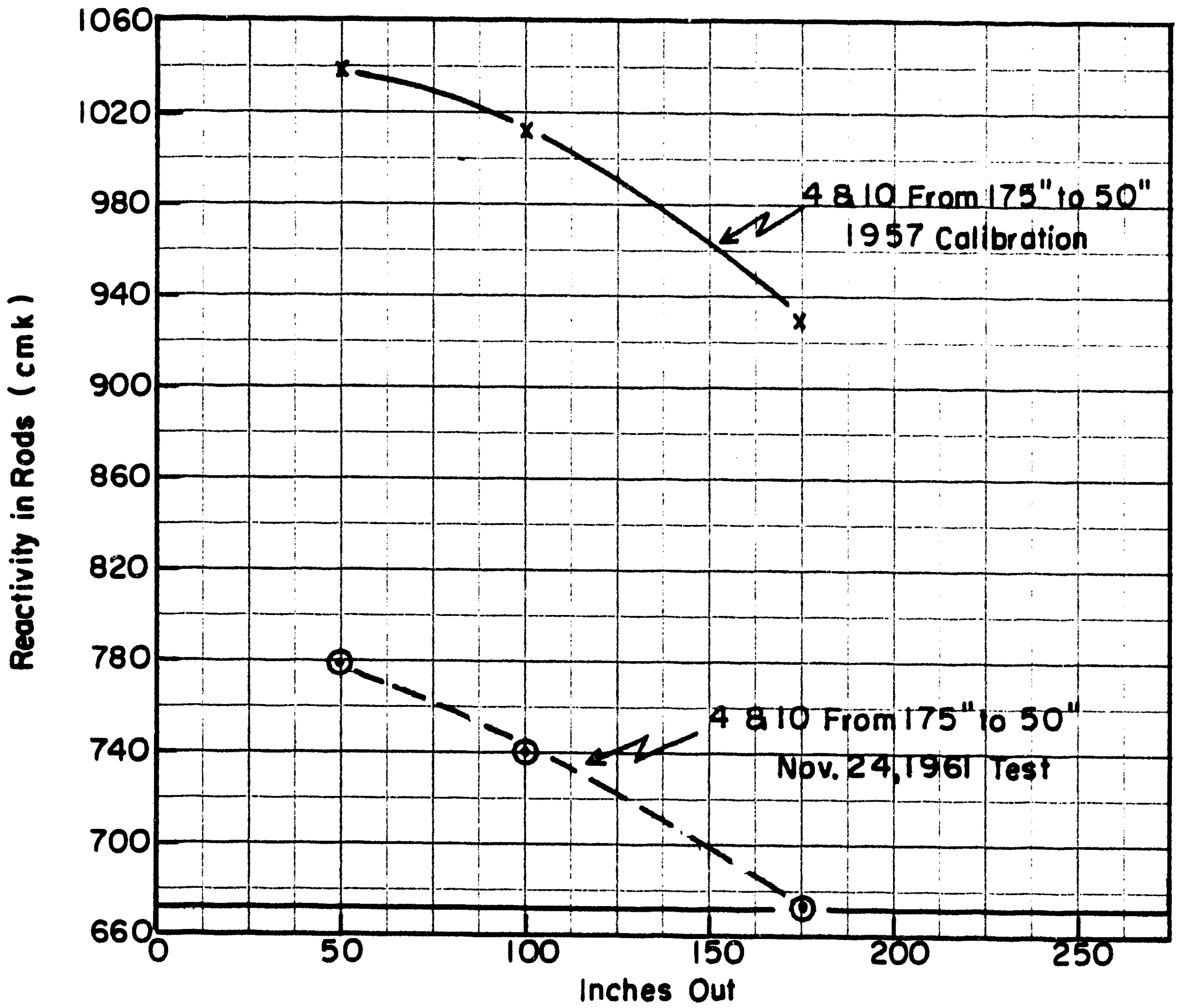

8 at 50 – 2 & 14 at 50 – 3 & 15 at 250 – 6 & 12 at 250 – 9 at 250

[redacted]

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Figure 7

Nominal Rod Strengths
H Reactor

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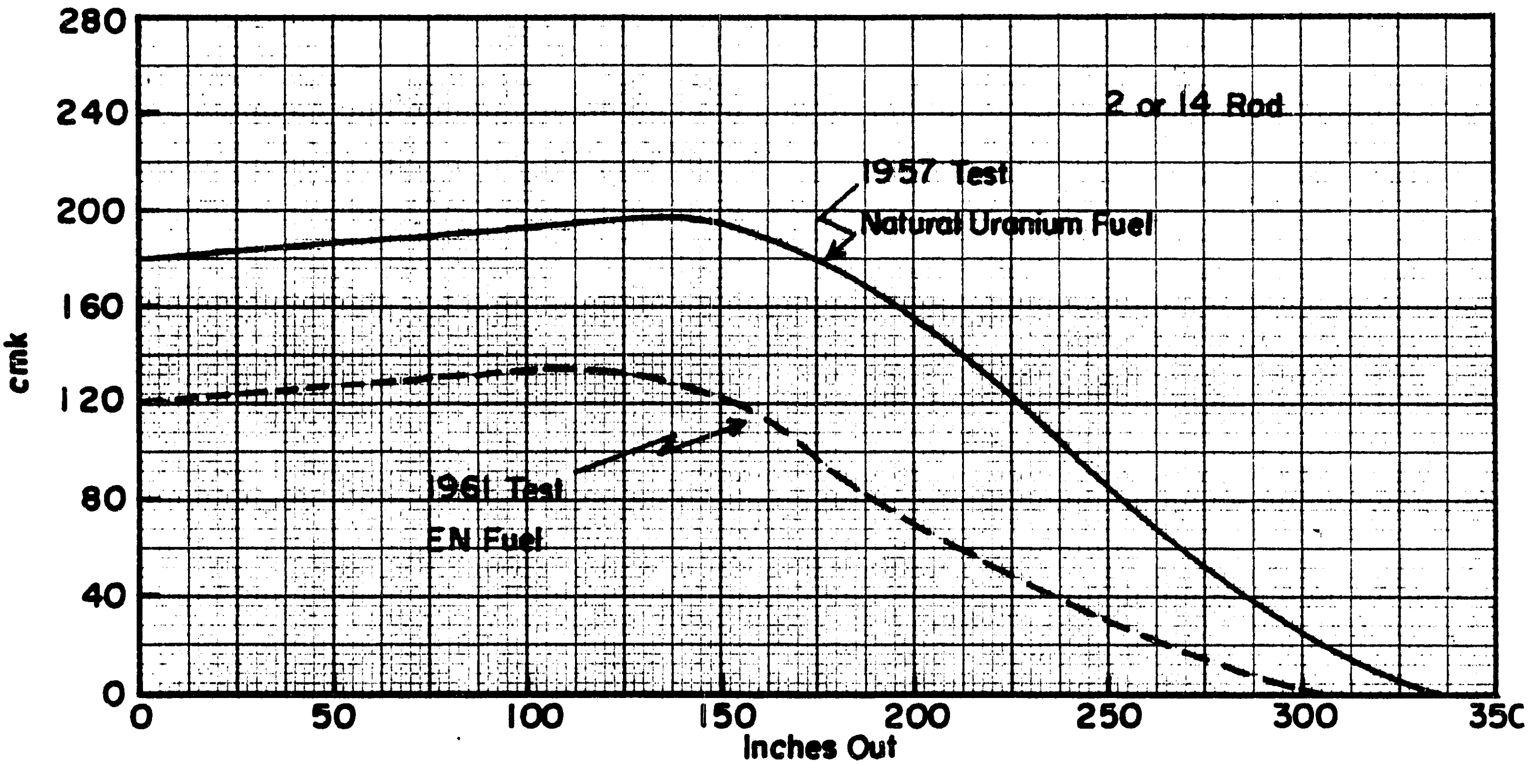

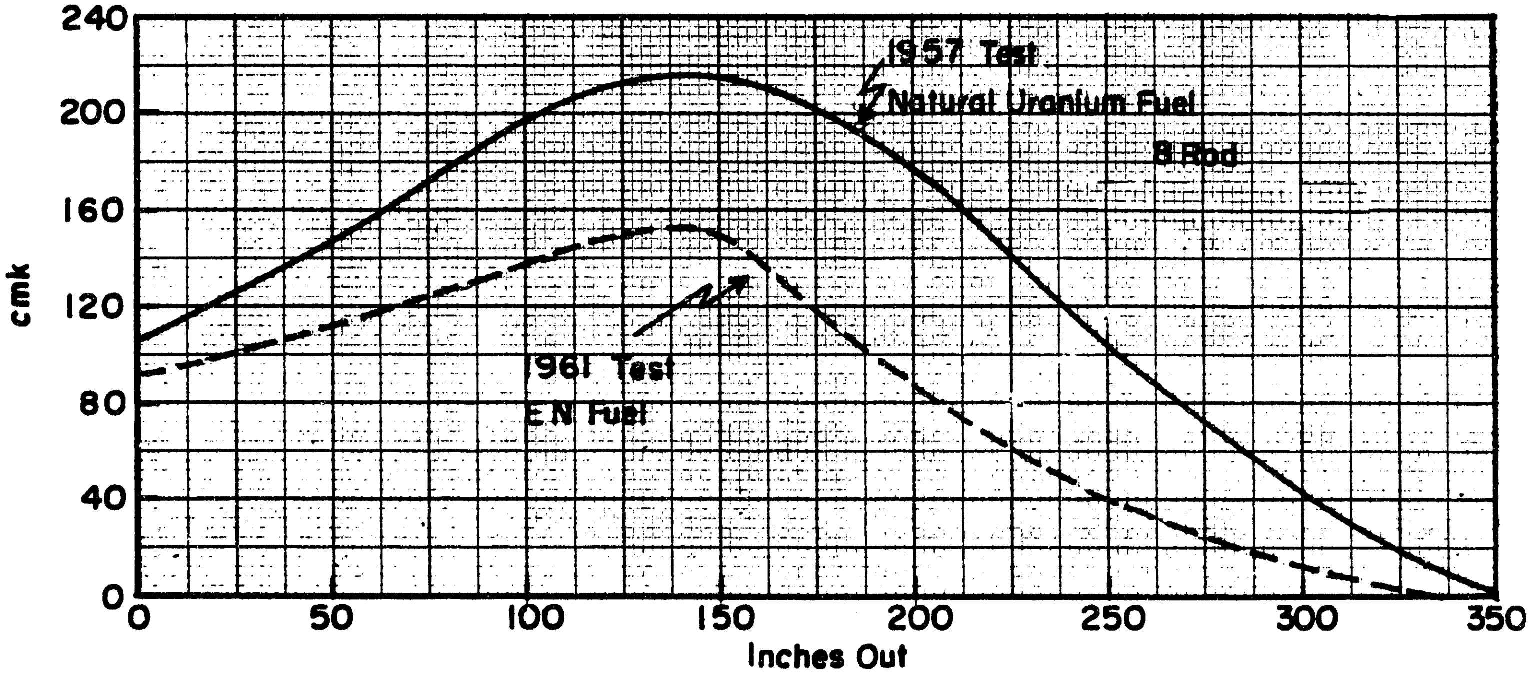

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Figure 8

Nominal Rod Strengths
H Reactor

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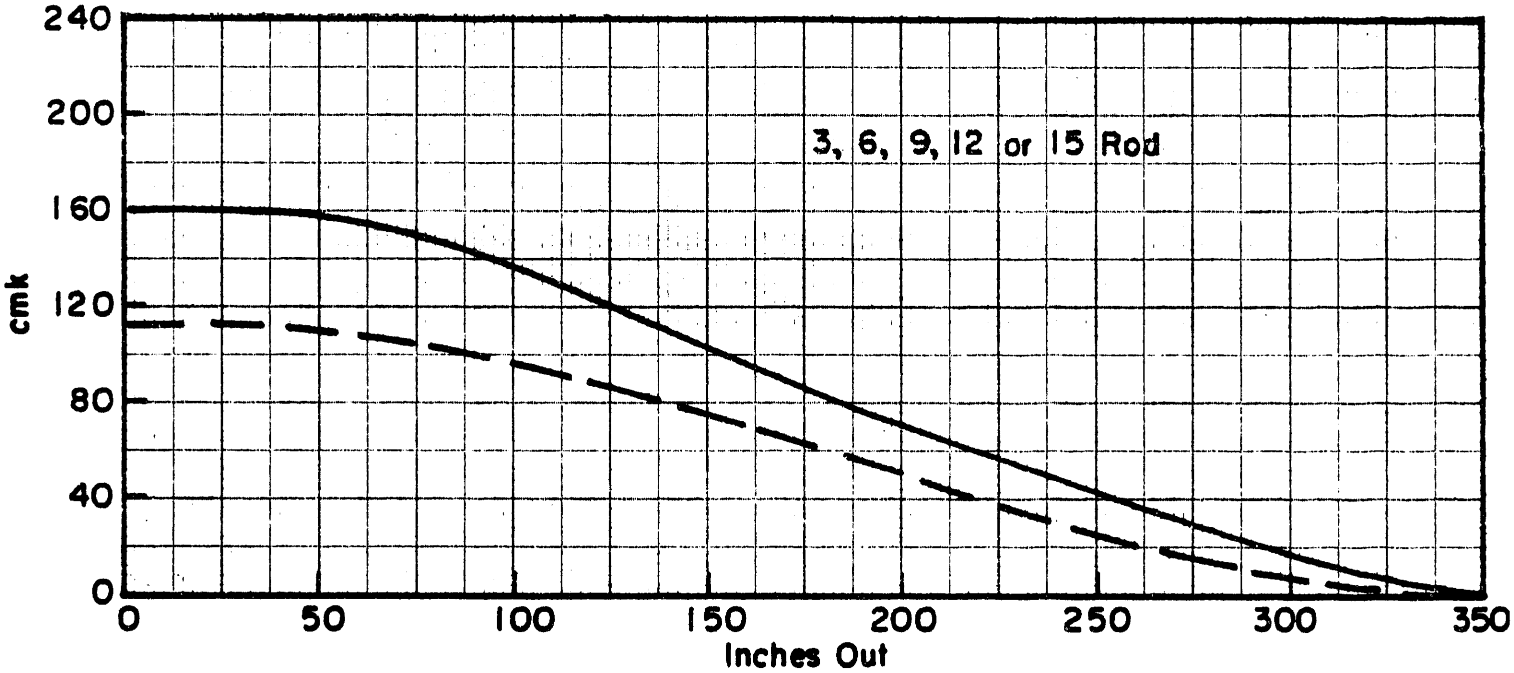

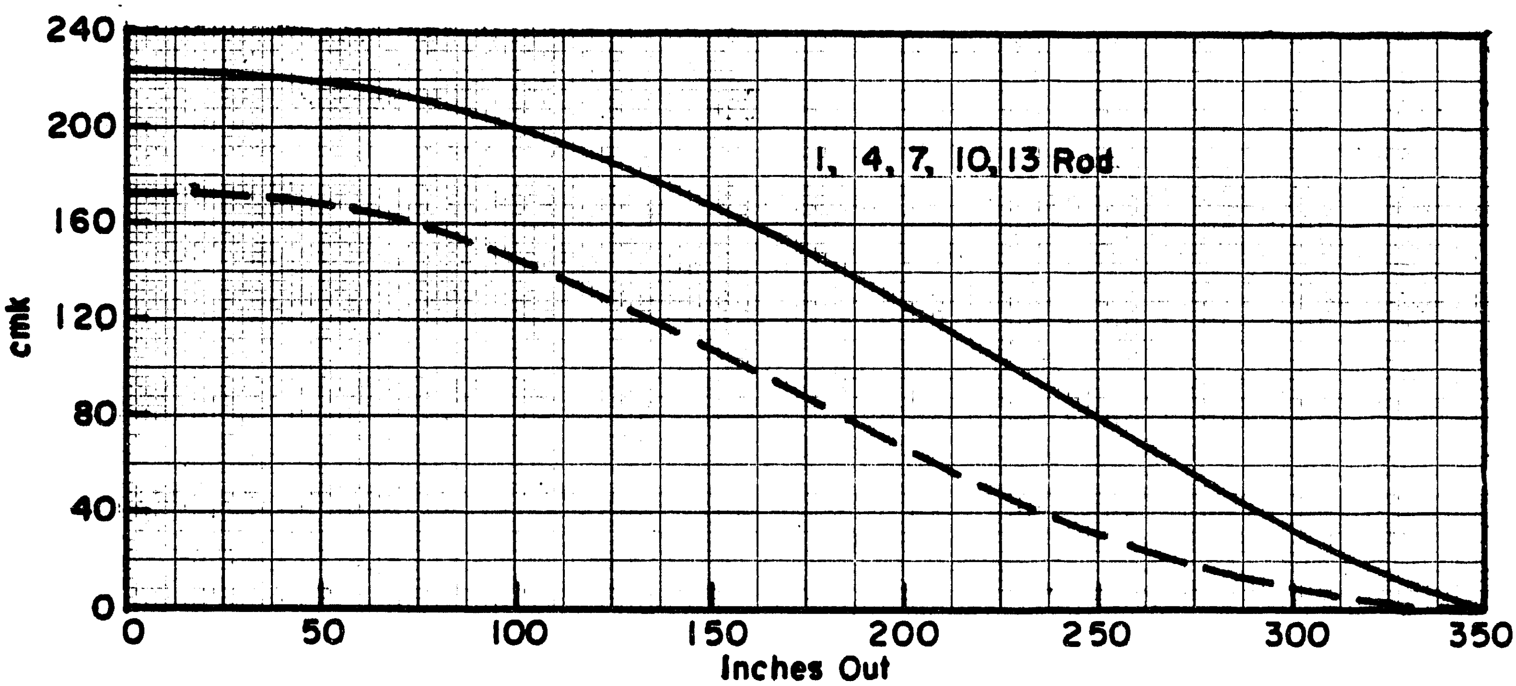

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Figure 9

Nominal Rod Strengths
H Reactor

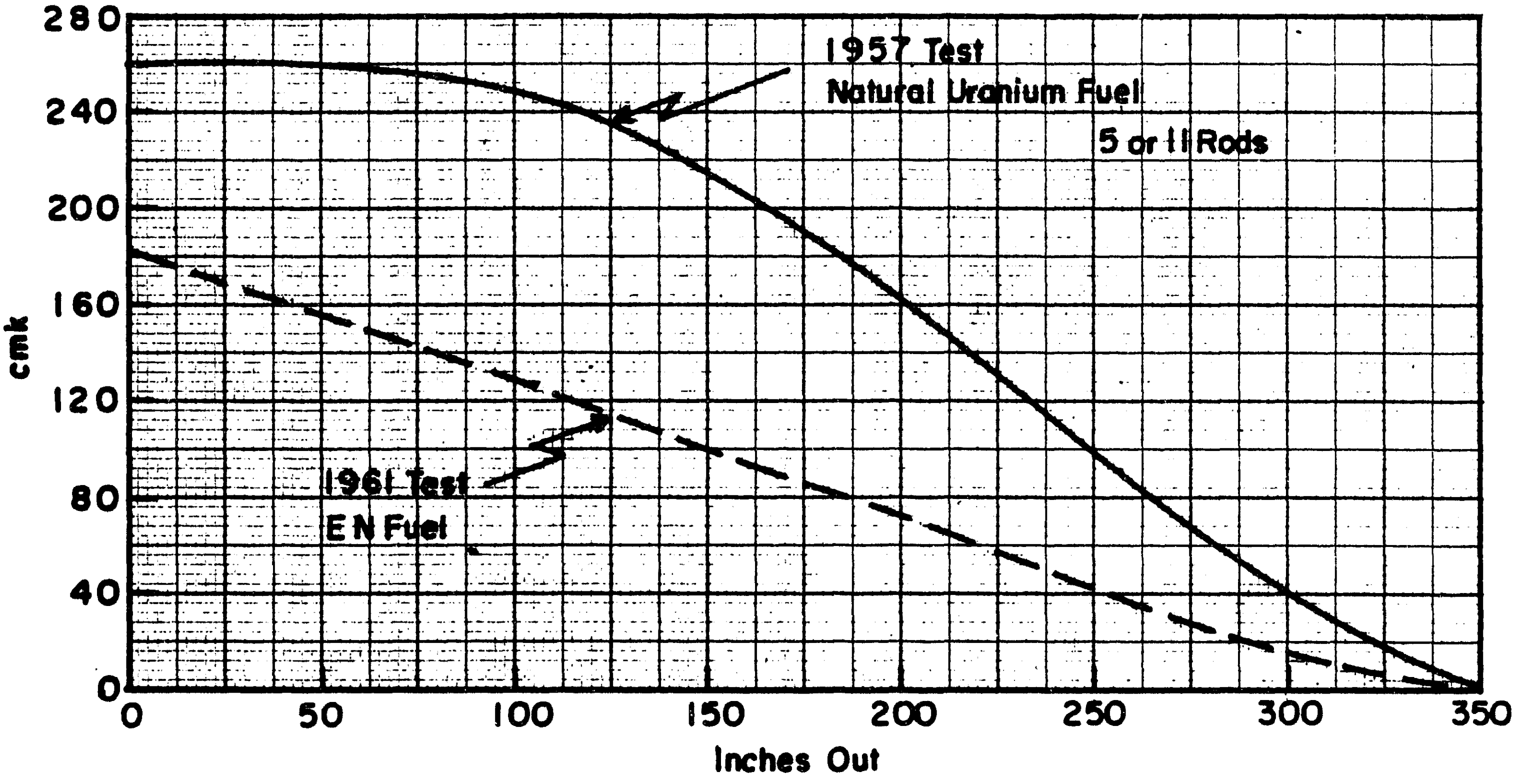

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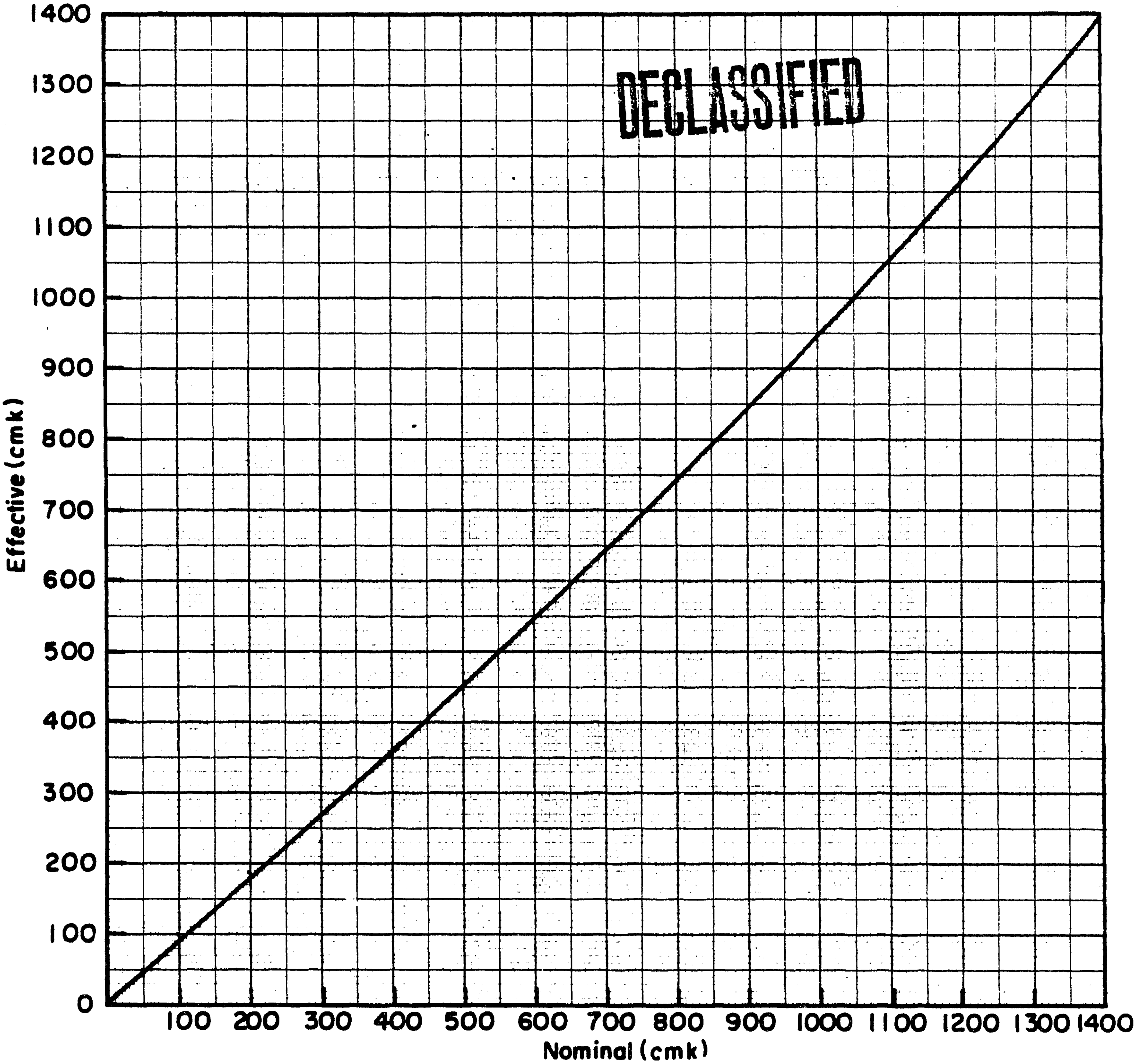
Figure 10

Nominal to Effective Ratio to be used with Estimated Nominal Rod Strengths During E N Fuel Loading.

Based on 1961 Test Results
H Reactor



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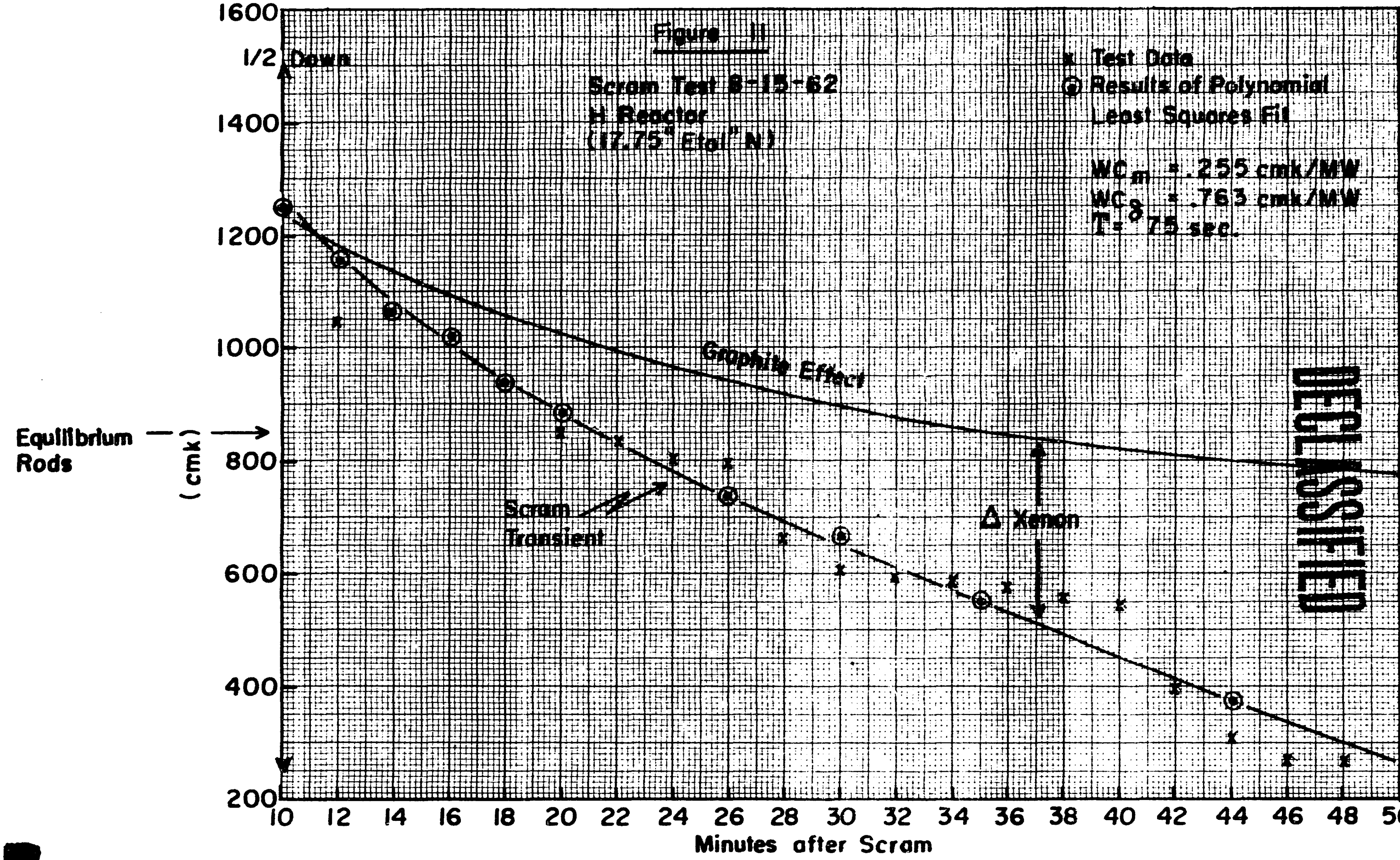
Figure 11
Scram Test 8-15-62
H Reactor
(17.75" Etol" N)
x Test Data
⊙ Results of Polynomial
Least Squares Fit
WC_m = .255 cmk/MW
WC_g = .763 cmk/MW
T = 75 sec.
1/2 Down
Equilibrium Rods
(cmk)
Graphite Effect
Scram Transient
Δ Xenon
Minutes after Scram
1600
1400
1200
1000
800
600
400
200
10 12 14 16 18 20 22 24 26 28 30 32 34 36 38 40 42 44 46 48 50

[redacted]

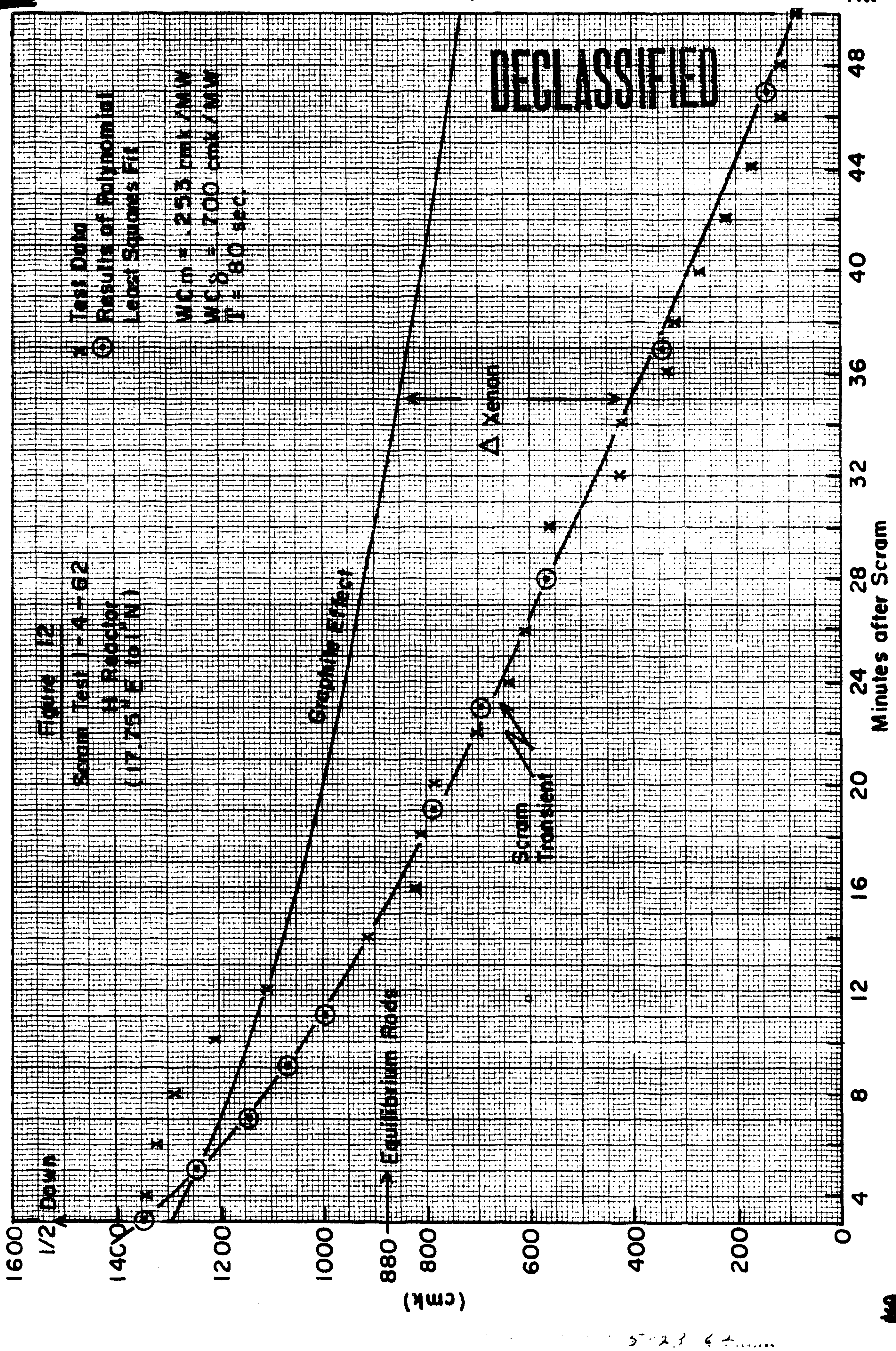

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Table 1

Metal Temperature Coefficient

Test Date	C_m (Measured)	C_m (Predicted)	C_m (Natural Uranium)
8-15-61	-.255 c-mk/MW	-0.253	-.300
1-4-62	-.253 c-mk/MW	-0.279	-.300

The following table lists the measured values of the graphite temperature coefficient. These values are not compared to the theoretical numbers as the latter were previously estimated only on the conservative side in order to assure reactor operating safety during the initial stages of operation with E-N fuel.

Table 2

	Graphite Temperature Coefficient	
Exposure MWD/Ton	Measured (E-N)	(Natural U)
~ 600	+0.731 c-mk/MW	+0.90 c-mk/MW

C. Confirmation of Test Results

1. Hot Startup Predictions

A hot startup was attempted after the reactor scrammed on June 6, 1961. Figure 13 illustrates the accuracy of predicting the reactivity transient during a hot startup using E-N fuel loading parameters based on the 1961 test results.

2. Cold Startup Predictions

In an attempt to prove the accuracy of the test data and the conclusions drawn from it, cold startup predictions were calculated for five random outages which occurred at H Reactor during the E-N fuel loading. Table 3 lists the accuracy of critical predictions based on the 1961 test data.

Table 3

Shutdown Date	Prediction Error Based on 1961 Test
8-3-61	+ 30 c-mk
8-15-61	-250 c-mk
8-30-61	-100 c-mk
12-21-61	- 69 c-mk
12-28-61	-184 c-mk

[redacted]

FIGURE 13

HOT STARTUP PREDICTION
(JUNE 7, 1961)
H REACTOR

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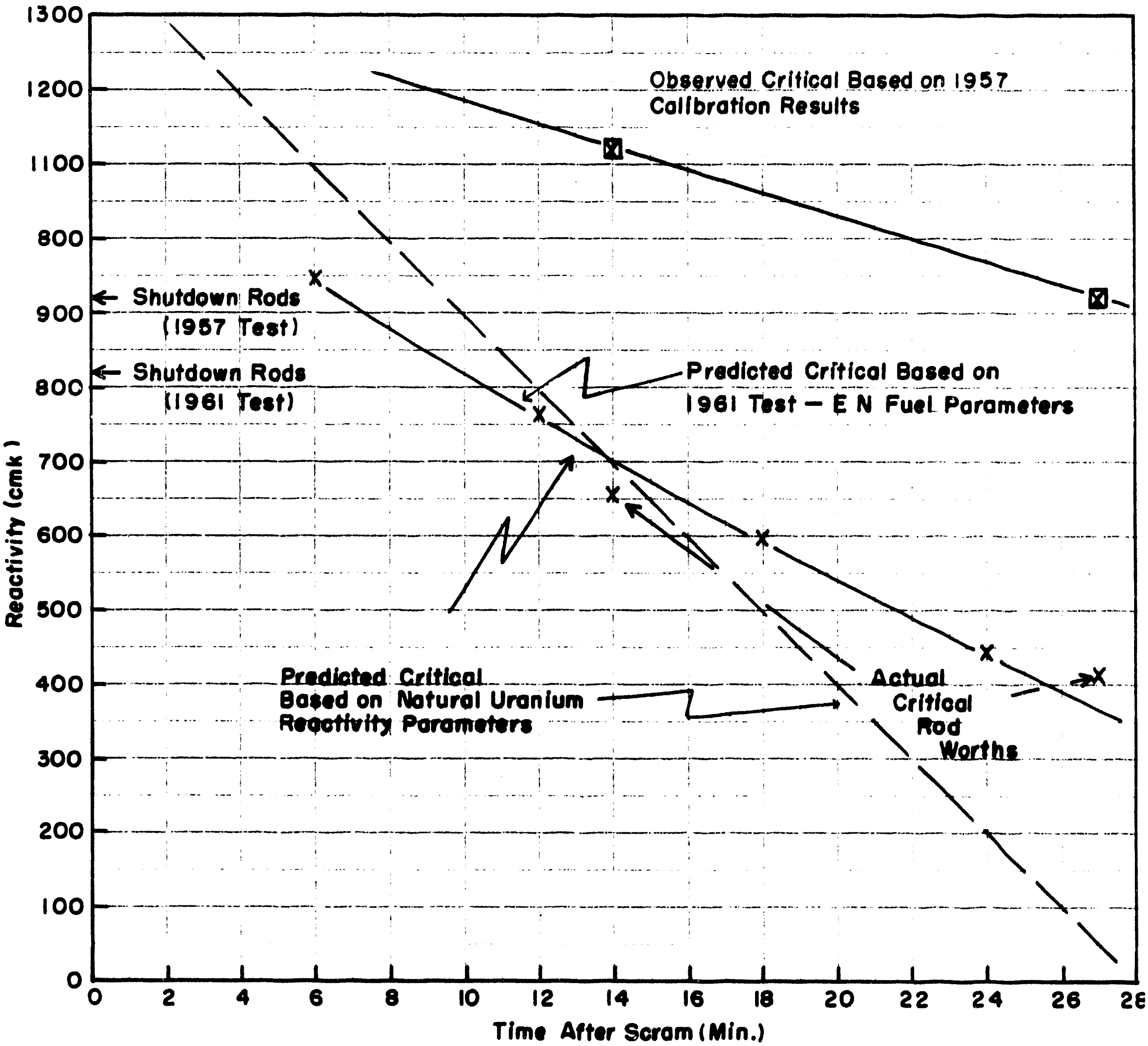

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IV. ACKNOWLEDGEMENT

The author wishes to express appreciation for the assistance and cooperation of the personnel at the H Reactor Operation in performing the many difficult steps required for the success of this test. The members of Operational Physics who assisted in obtaining the test data, especially during the Thanksgiving holiday season, also deserve an expression of thanks.

A. D. Vaughn
Pile Physics Unit
Operational Physics Sub-Section
Research and Engineering Section
IRRADIATION PROCESSING DEPARTMENT

AD Vaughn:gs

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Appendex A

Test Data

Period No.	Time	Rod Configuration		Period (c-mk)
1	0854	14 Rod at 230"	- - - - - - - - - - - -	61.3
2	0909	14 Rod at 230"	- - - - - - - - - - - -	103.7
3	0921	2 & 14 at 230"	- - - - - - - - - - - -	93.8
4	0928	2 & 14 at 230"	8 at 275" - - - - -	89.6
5	0935	2 & 14 at 230"	3 & 15 at 250" - - -	78.3
6	0941	14 at 230"	- - - - - - - - - - - -	190.7
7	0947	2 & 14 at 230"	8 at 275" - - - - -	141.8
8	0953	2 & 14 at 210"	- - - - - - - - - - - -	156.9
9	0959	2 & 14 at 230"	8 at 225" - - - - -	144.6
10	1006	2 & 14 at 230"	8 at 100" - - - - -	105.0
11	1012	2 & 14 at 210"	- - - - - - - - - - - -	208.4
12	1019	2 & 14 at 130"	- - - - - - - - - - - -	121.4
13	1025	2 & 14 at 230"	4 & 10 at 200" - - -	164.0
14	1031	2 & 14 at 230"	4 & 10 at 150" - - -	123.4
15	1037	2 & 14 at 130"	- - - - - - - - - - - -	176.2
16	1042	2 & 14 at 200"	8 at 100" - - - - -	164.0
17	1049	2 & 14 In	8 at 100" - - - - -	121.4
18	1055	2 & 14 at 200"	8 at 100" - - - - -	200.0
10	1102	2 & 14 at 100"	8 at 100" - - - - -	105.0
20	1109	2 & 14 at 230"	4 & 10 at 0" - - - -	103.7
21	1114	2 & 14 at 230" 4 & 10 at 155"	8 at 255" - - - - - - - - - - - -	190.7
22	1119	2 & 14 at 100"	8 at 100" - - - -	150.5
23	1125	2 & 14 at 100" 5 & 11 at 275"	8 at 100" - - - - - - - - - - - -	121.4
24	1132	2 & 14 at 190" 4 & 10 at 155"	8 at 205" - - - - - - - - - - - -	190.7
25	1139	2 & 14 at 100" 4 & 10 at 155"	8 at 205" - - - - - - - - - - - -	92.8
26	1144	2 & 14 at 100" 5 & 11 at 275"	8 at 100" - - - - - - - - - - - -	167.9
27	1150	2 & 14 at 100" 5 & 11 at 200"	8 at 100" - - - - - - - - - - - -	116.0
28	1157	2 & 14 at 100" 4 & 10 at 155"	8 at 100" - - - - - - - - - - - -	95.0
29	1207	2 & 14 at 100" 3 & 15 at 210"	8 at 100" 4 & 10 at 155" - - -	25.0
30	1214	2 & 14 at 100" 5 & 11 at 150"	8 at 100" - - - - - - - - - - - -	125.4
31	1218	2 & 14 at 100" 5 & 11 at 200"	8 at 100" - - - - - - - - - - - -	472.2
32	1227	2 & 14 at 100" 3 & 15 at 185"	8 at 100" 4 & 10 at 155" - - -	27.0
33	1234	2 & 14 at 100" 3 & 15 at 185"	8 at 100" 4 & 10 at 80"	-23.0

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Appendex A
(Continued)

Period No.	Time	Rod Configuration		Period (c-mk)
34	1238	2 & 14 at 100"	8 at 100"	
		5 & 11 at 150"		185.6
35	1243	2 & 14 at 100"	8 at 100"	
		5 & 11 In		43.0
36	1255	2 & 14 at 100"	8 at 100"	
		3 & 15 at 210"	4 & 10 at 155"	139.2

Equilibrium Configuration=(2 & 14 at 50"; 8 at 50"; 9 at 250")
(3 & 15 at 250"; 6 & 12 at 250")

Period No.	Time	Rod Configuration	Period (c-mk)
37	1304	Equilibrium Config. plus 4&10 at 100"	20
	1307	" " " 4&10 at 150"	75
	1310	" " " 4&10 at 175"	104
	1316	" " " 4 & 10 at 50"	-31

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