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APAE MEMO No. 206

15

SM-1
RESEARCH AND DEVELOPMENT PROGRAM
INTERIM REPORT NO. 2
ON
CORE MEASUREMENTS
TASK NO. VII

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APAE Memo No. 206

SM-1
RESEARCH AND DEVELOPMENT PROGRAM

INTERIM REPORT NO. 2
ON
CORE MEASUREMENTS

TASK NO. VII

ARMY PACKAGE POWER REACTOR
CONTRACT AT(30-3)-326

Issued June 30, 1959

S.D. MacKay - Project Engineer

By: S.D. MacKay
D.C. Tubbs

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ABSTRACT

Physics experiments were performed on the SM-1 core under Research and Development Task No. VII. Measurements were made on five rod bank positions and rod calibrations. The reactivity effects of core modifications were investigated. Modifications to the core included replacement of the boron absorbers in rods 1, 2, 3, 4 and C with europium absorbers; replacement of a control rod fuel element with one containing an integral europium flux suppressor; and replacement of a stationary fuel element. Additional experiments were designed to determine the reactivity of the SM-1 with 4 and 8 stationary elements removed; the neutron flux in the biological shield and in the region of an integral europium flux suppressor; and the gamma flux above the core and from irradiated control rod components.

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1.0 INTRODUCTION

This report is the second interim report on SM-1 core measurements, covering the period from November, 1958 to June 30, 1959. The experimental work was performed under Task VII of the SM-1 Research and Development program. The experiments will provide a basis for evaluating the nuclear performance of the SM-1 Core. The first interim report[1](issued March 1, 1959) on core measurements to November 1958, included a description of the SM-1 and the experimental techniques developed for core measurements. A final report on core measurements during the entire lifetime of core I will be issued in early 1960.

2.0 EXPERIMENTAL WORK PERFORMED

From November, 1958 to June 30, 1959 (from 9.1 MWYR to approximately 11 MWYR of energy release) no shut-downs were scheduled for core measurements. However, the SM-1 was shut down on March 6, 1959, and the pressure vessel head was removed to allow physical examination of the core and fuel elements. Some core data were obtained while the pressure vessel was open. Work performed under stipulated Task VII experiments included plotting of five rod bank positions; rod calibrations; and source multiplication. Experimental work was also performed to determine the effect of modifications on the core, such as the replacement of a stationary fuel element; the replacement of a control rod fuel element with one containing an integral europium flux suppressor; and the replacement of boron absorbers in control rods 1, 2, 3, 4, and C, with europium absorbers. Other experiments were designed to determine the reactivity of the SM-1 core with 4 and 8 fuel elements removed; the neutron flux in the region of the integral europium flux suppressor and in the biological shield; and the gamma flux above the core and from irradiated control rod components.

2.1 Five Rod Bank Position

The critical five rod bank positions for several conditions were obtained. The critical bank position at 70°F, no xenon, 10.5 MWYR burn-up was 7.20 inches. The critical bank position at 440°F, equilibrium xenon, 10.7 MWYR burn-up, was 12.86 inches. These positions are shown in Fig. 2.1.1, where the five rod bank position is plotted as a function of energy release. The critical five rod bank position with the boron absorbers in control rods 1, 2, 3, 4, and C, replaced by europium absorbers at 70°F, no xenon, 10.5 MWYR, was 7.09 inches.

The hot, equilibrium xenon bank position at 10.7 MWYR burn-up is approximately 0.3 inches below the fitted extrapolation of bank position plotted as a function of energy release as shown in Fig. 2.1.2. A displacement of -0.2 inches in the hot, equilibrium xenon bank position was expected as a result of the core modifications (see Section 2.4.2 C). Since the latest point falls 0.3 inches below the extrapolated curve, this indicates that the fitted extrapolation may under estimate core life.

The energy release plotted as a function of calendar time is shown in Fig. 2.1.3. Assuming a load factor of 62% shown in Fig. 2.1.3, and 15 MWYR energy release, the end of core life will occur in January, 1960.

2.2 Rod Calibrations

Rod calibrations were performed at approximately 70°F with no xenon present. Rod A was calibrated by the period method[1], and the five rod bank was calibrated from the integral rod A worth.

Three calibrations of rod A at a burn-up of 10.5 MWYR with rod B at 19 inches are shown in Fig. 2.2.1. Two of the calibrations were performed as a function of the position of the five

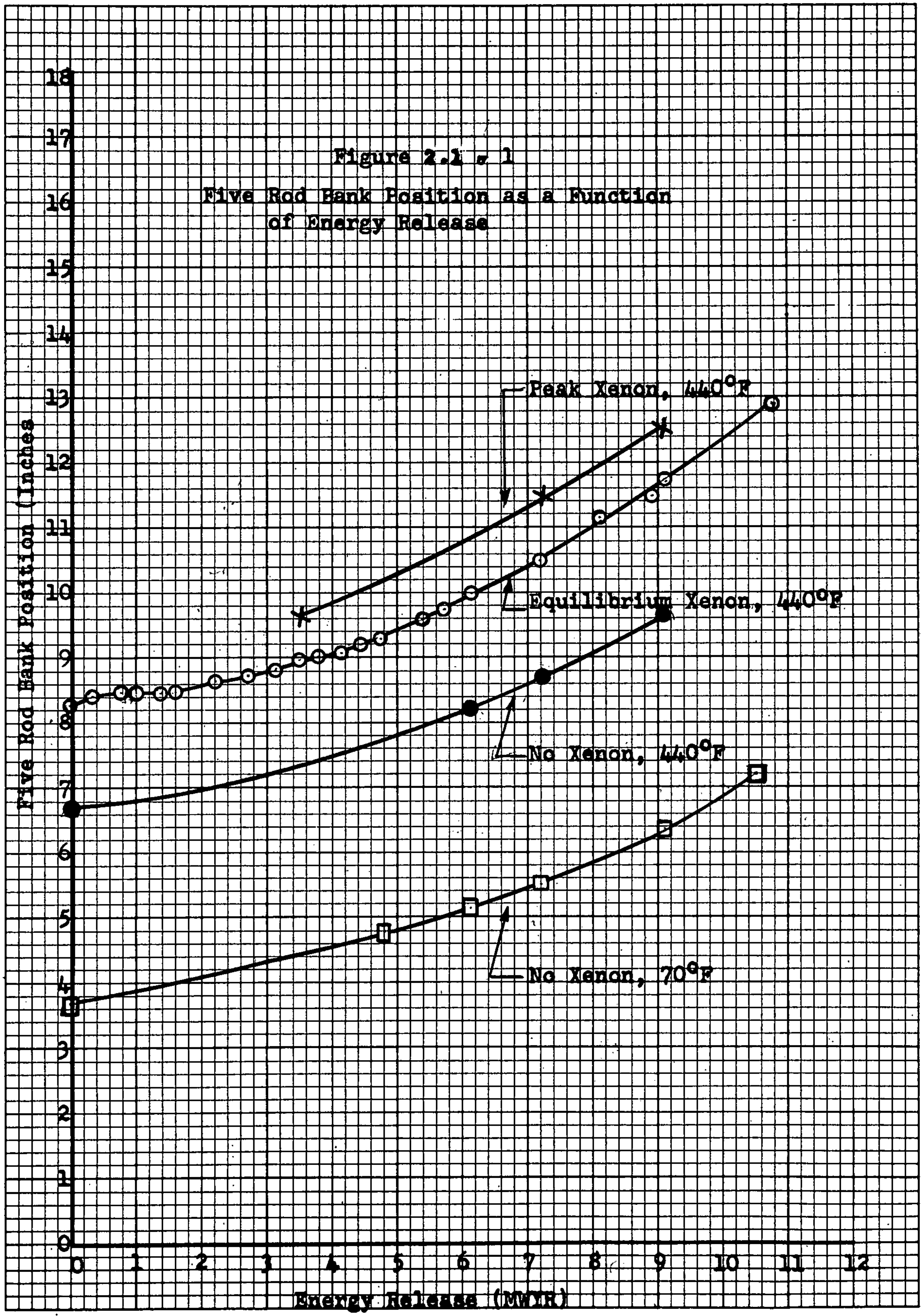


Figure 2.1 - 1

Five Rod Bank Position as a Function of Energy Release

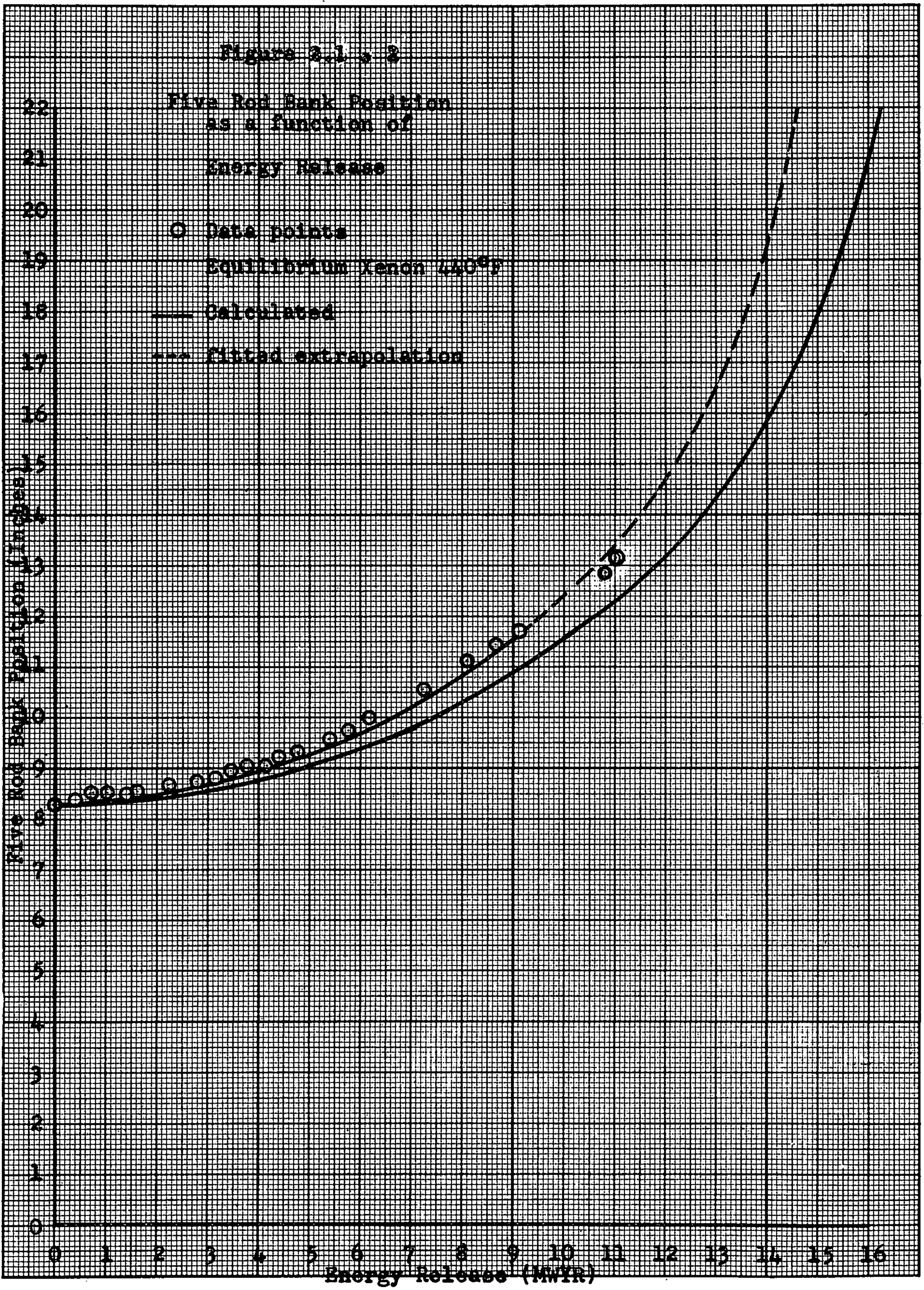


Figure 2.1.a.2

Five Rod Bank Position
as a function of
Energy Release

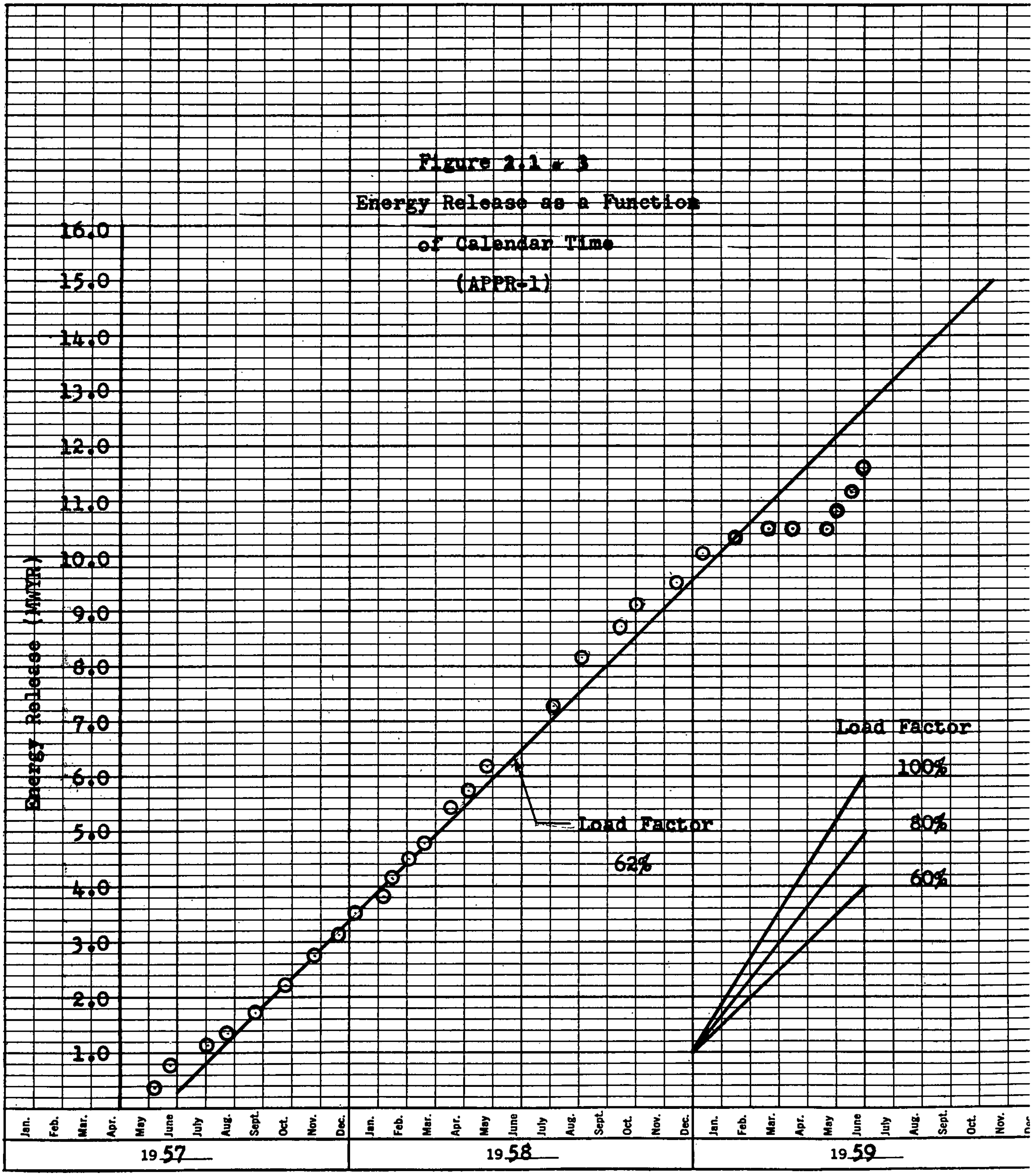


Figure 2.1 - 3

Energy Release as a Function of Calendar Time

(APPR-1)

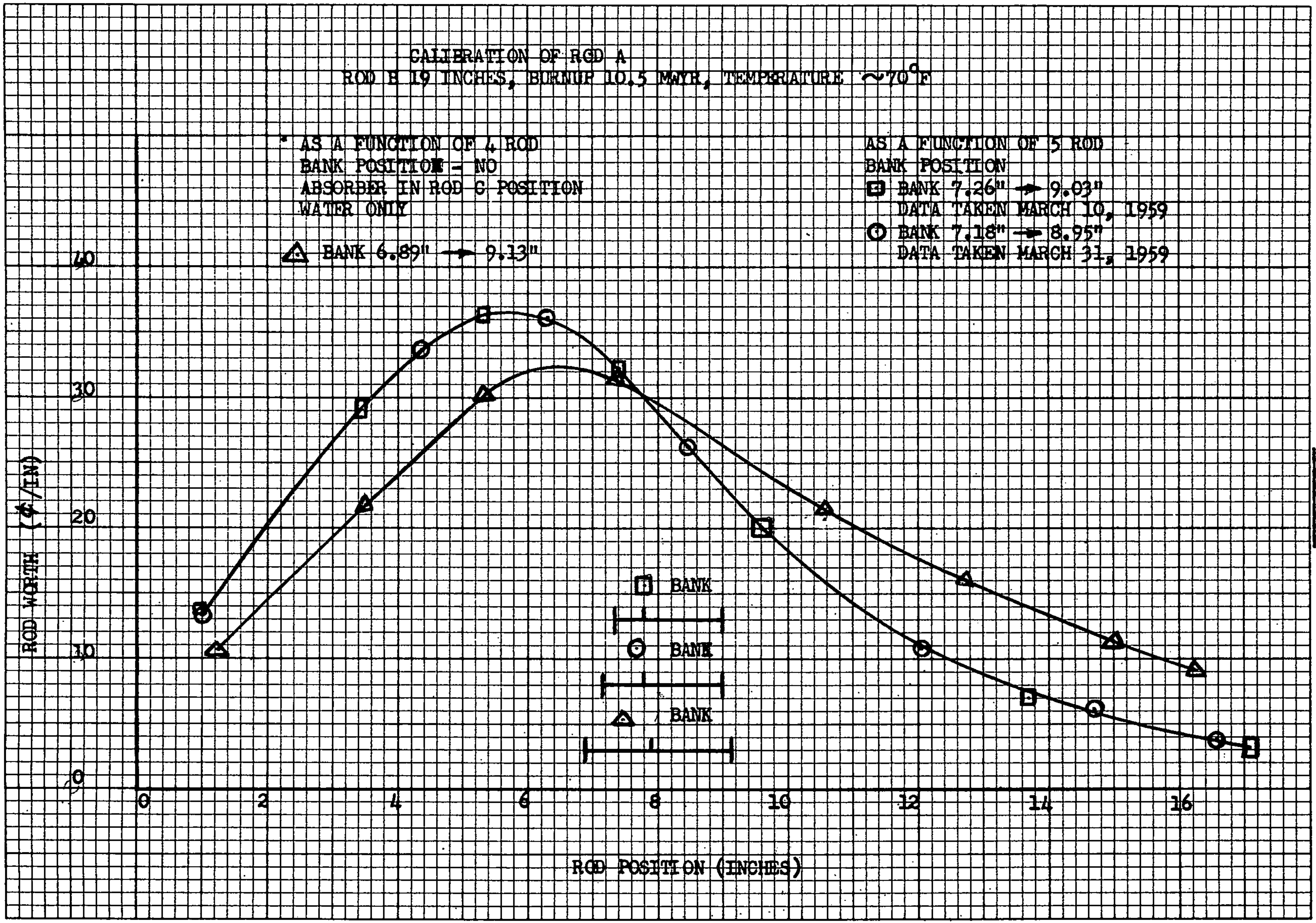

CALIBRATION OF ROD A
ROD B 19 INCHES, BURNUP 10.5 MWYR, TEMPERATURE ~70°F
AS A FUNCTION OF 4 ROD BANK POSITION - NO ABSORBER IN ROD C POSITION WATER ONLY
△ BANK 6.89" → 9.13"
AS A FUNCTION OF 5 ROD BANK POSITION
□ BANK 7.26" → 9.03" DATA TAKEN MARCH 10, 1959
⊙ BANK 7.18" → 8.95" DATA TAKEN MARCH 31, 1959
□ BANK
⊙ BANK
△ BANK
ROD WORTH (¢/IN)
0
10
20
30
40
0
2
4
6
8
10
12
14
16
ROD POSITION (INCHES)

FIGURE 2.2.1

rod bank. The third calibration was performed as a function of the four rod bank position with the absorber and fuel sections removed from rod C position, leaving water in that position. The two curves in the figure have approximately the same integral worth (321 ± 6 cents). The figure shows that the removal of fuel and absorber from rod C increases the worth of rod A in the absorber region of the core (above the bank), but decreases the worth in the all-fuel region (below the bank).

The calibrations of rod A as a function of the five rod bank position for the normal SM-1 core and the 41 and 37 element cores are shown in Fig. 2.2.2. The calibrations were performed at a burn-up of 10.5 MWYR, with rod B at 19 inches. The bank motion and the position at which rod A is even with the bank is shown for each core configuration. The original boron absorbers in rods 1, 2, 3, 4, and C, were replaced by new europium absorbers before these calibrations were performed.

The integral worth of rod A in various cores was obtained by integrating the differential worth curves shown in Fig. 2.2.2. The integral worth is given for each case in Table 2.2-1. The five rod bank position at the terminal points of the integration are also given in the table. The differential bank worth was calculated by dividing the integral worth of rod A by the corresponding motion in the five rod bank as given in Table 2.2-1.

The reactivity worths of several boron-10 absorbers fully inserted in the rod C position are shown in Fig. 2.2.3. The worth of a stainless steel absorber was taken as 0 cents, and other absorbers were evaluated relative to the steel absorber.

The reactivity worth is plotted as a function of weight of B-10 in the absorber. Figure 2.2.3 shows data from a europium absorber, plotted so that the number of europium atoms equal the number of boron atoms.

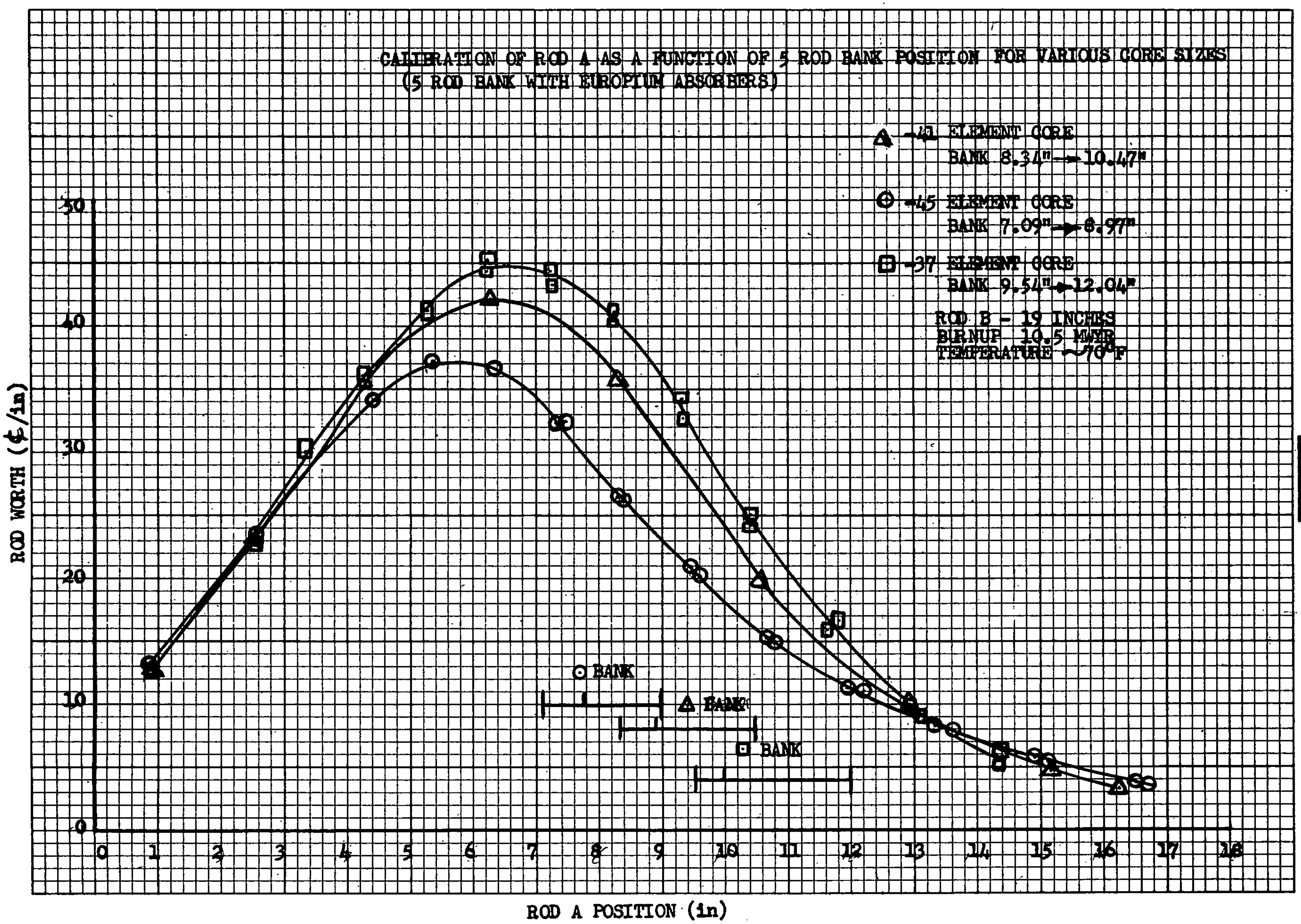

CALIBRATION OF ROD A AS A FUNCTION OF 5 ROD BANK POSITION FOR VARIOUS CORE SIZES
(5 ROD BANK WITH EUROPIUM ABSORBERS)

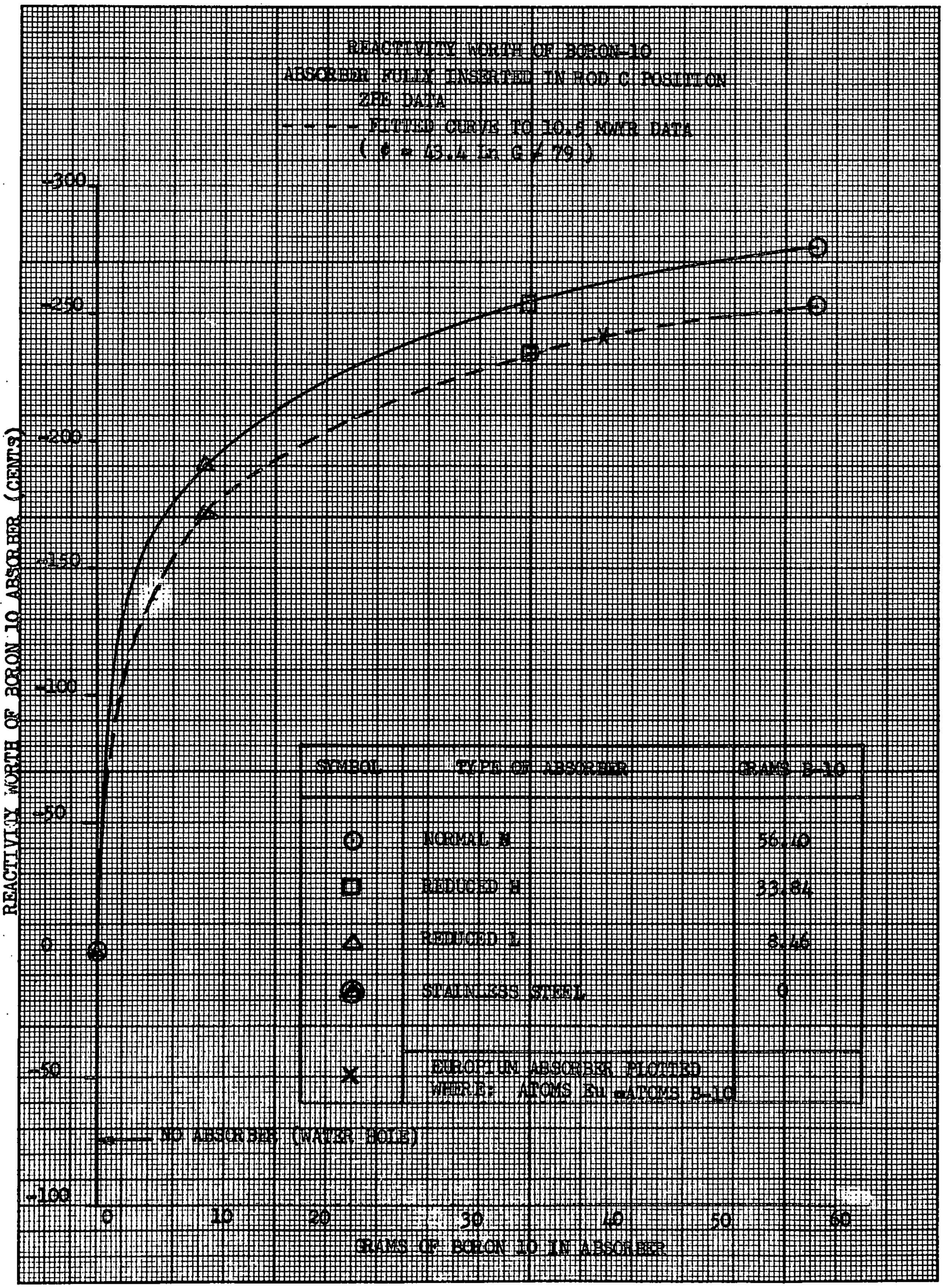
FIGURE 2.2.2

Table 2.2 -1

Five Rod Bank Calibration

Number of Elements in the Core	Rod A Position (inches	Integrated Rod A Worth (cents)	Five Rod Bank Position (inches)	Average Bank Position (inches)	Average Bank Worth (cents/inch)
45	0.00		8.97	8.03	175.8
		330.5			
	18.00		7.09		
41	1.00		10.47	9.41	167.6
		356.9			
	16.00		8.34		
37	0.00		12.04	10.79	158.4
		395.9			
	18.00		9.54		

FIGURE 2.2.3


REACTIVITY WORTH OF BORON-10
ABSORBER FULLY INSERTED IN ROD C POSITION
ZPE DATA
– – – – FITTED CURVE TO 10.5 MWYR DATA
(¢ = 43.4 ln G + 79)
-300
-250
-200
-150
-100
-50
0
-50
-100
0
10
20
30
40
50
60
REACTIVITY WORTH OF BORON 10 ABSORBER (CENTS)
GRAMS OF BORON 10 IN ABSORBER
NO ABSORBER (WATER HOLE)
SYMBOL
TYPE OF ABSORBER
GRAMS B-10
⊙ NORMAL M 56.40
⊡ REDUCED M 33.84
△ REDUCED L 8.46
◉ STAINLESS STEEL 0
✕ EUROPIUM ABSORBER PLOTTED WHERE: ATOMS Eu = ATOMS B-10

2.3 Source Multiplication

Data was recorded from two BF_3 neutron counters for various times after shut-down from full power. Relative count rate plotted as a function of counter high voltage is shown for the two counters in Figures 2.3.1 and 2.3.2. The counter performance is unsatisfactory for short times after shut-down, but the performance improves with increasing time after shut-down. The high gamma flux shortly after shut-down apparently is responsible for the poor performance; however, activations in the counter walls could also contribute to the loss of plateau. The gamma dose rate for various times after shut-down as given in Figures 2.3.1 and 2.3.2 was obtained from shielding measurements[3].

2.4 Core Modifications

On May 8, 1959, the following modifications were completed on the SM-1 core:

1. The boron absorbers in control rods 1, 2, 3, 4, and C, were replaced by europium absorbers numbered 1, 5, 4, 6, and 8, respectively.
2. The fuel element in control rod 4 was replaced by a new control rod fuel element containing an integral europium flux suppressor.
3. The stationary fuel element from position 56 was rotated 180° and used to replace the element removed from position 57.
4. A spare, unused core I stationary fuel element was placed in position 56.

The position numbers in the core are shown in Fig. 2.4.1. The hazards associated with the modifications were evaluated and are reported in APAE Memo 194[4]. The effects on core measurements are described below.

FIGURE 2.3.1

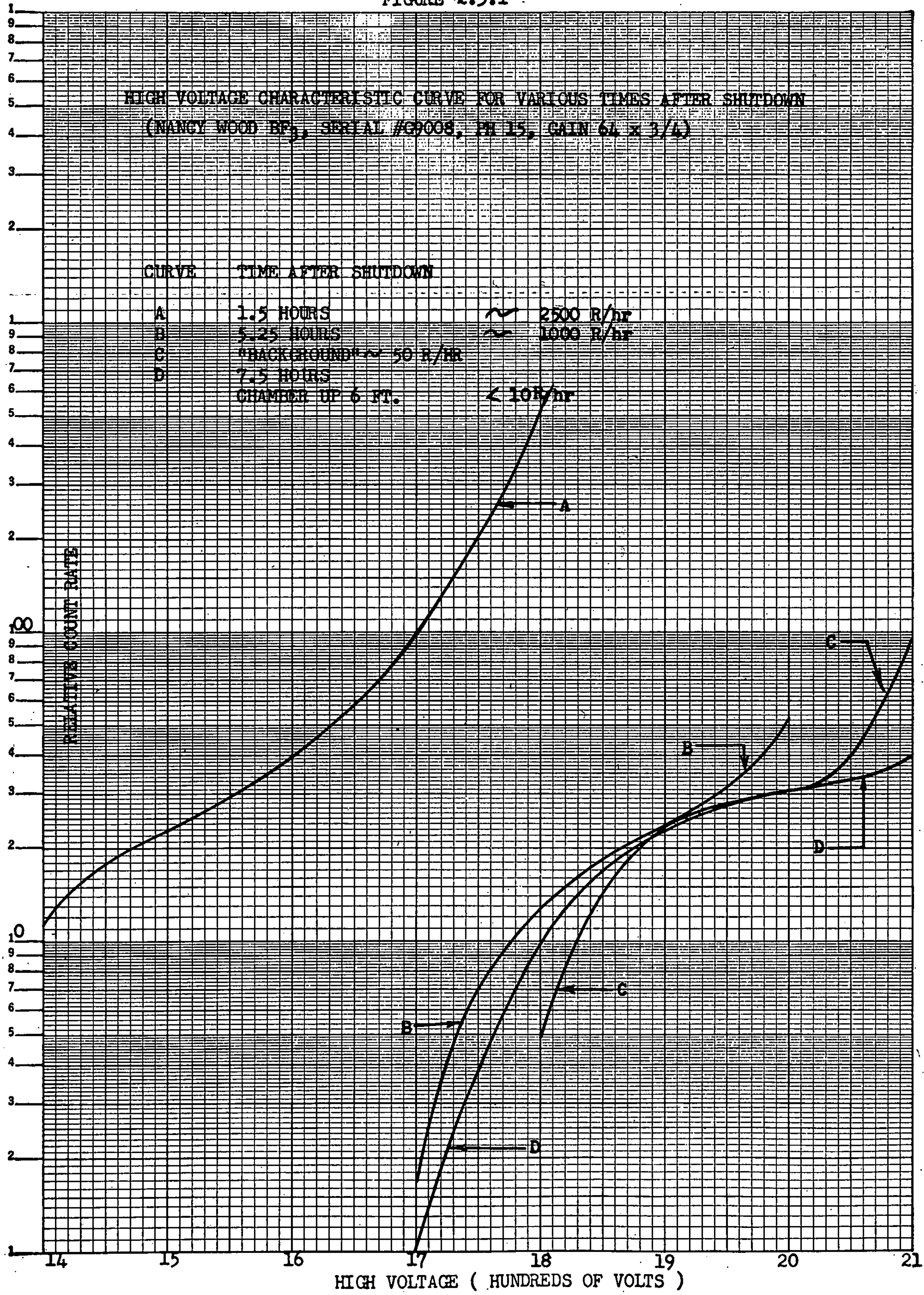

HIGH VOLTAGE CHARACTERISTIC CURVE FOR VARIOUS TIMES AFTER SHUTDOWN
(NANCY WOOD BF$_3$, SERIAL #G9008, PH 15, GAIN 64 x 3/4)
CURVE TIME AFTER SHUTDOWN
A 1.5 HOURS ~ 2500 R/hr
B 5.25 HOURS ~ 1000 R/hr
C "BACKGROUND" ~ 50 R/HR
D 7.5 HOURS
CHAMBER UP 6 FT. < 10R/hr
A
B
C
D
RELATIVE COUNT RATE
100
10
1
9
8
7
6
5
4
3
2
14
15
16
17
18
19
20
21
HIGH VOLTAGE (HUNDREDS OF VOLTS)

FIGURE 2.3.2

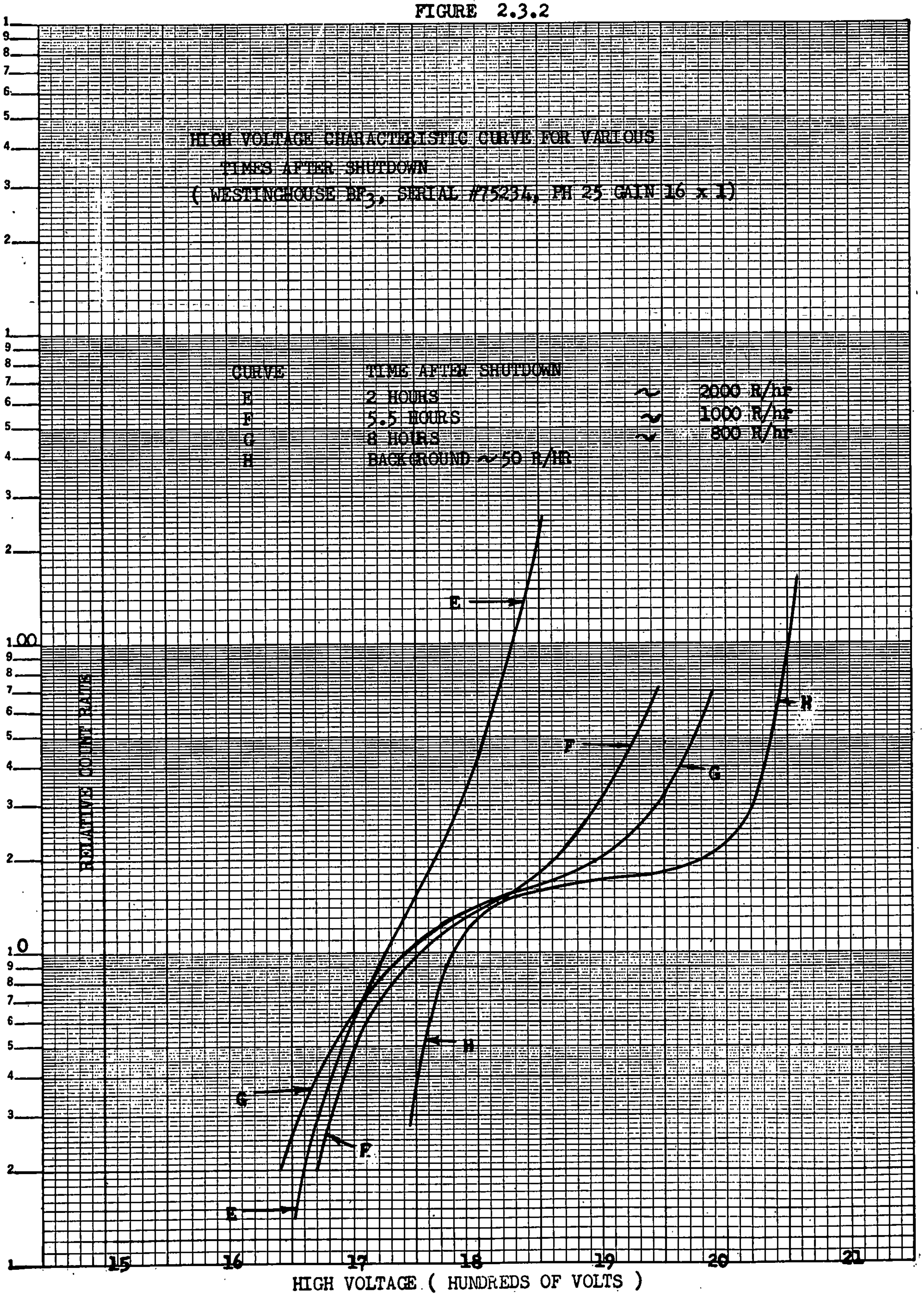
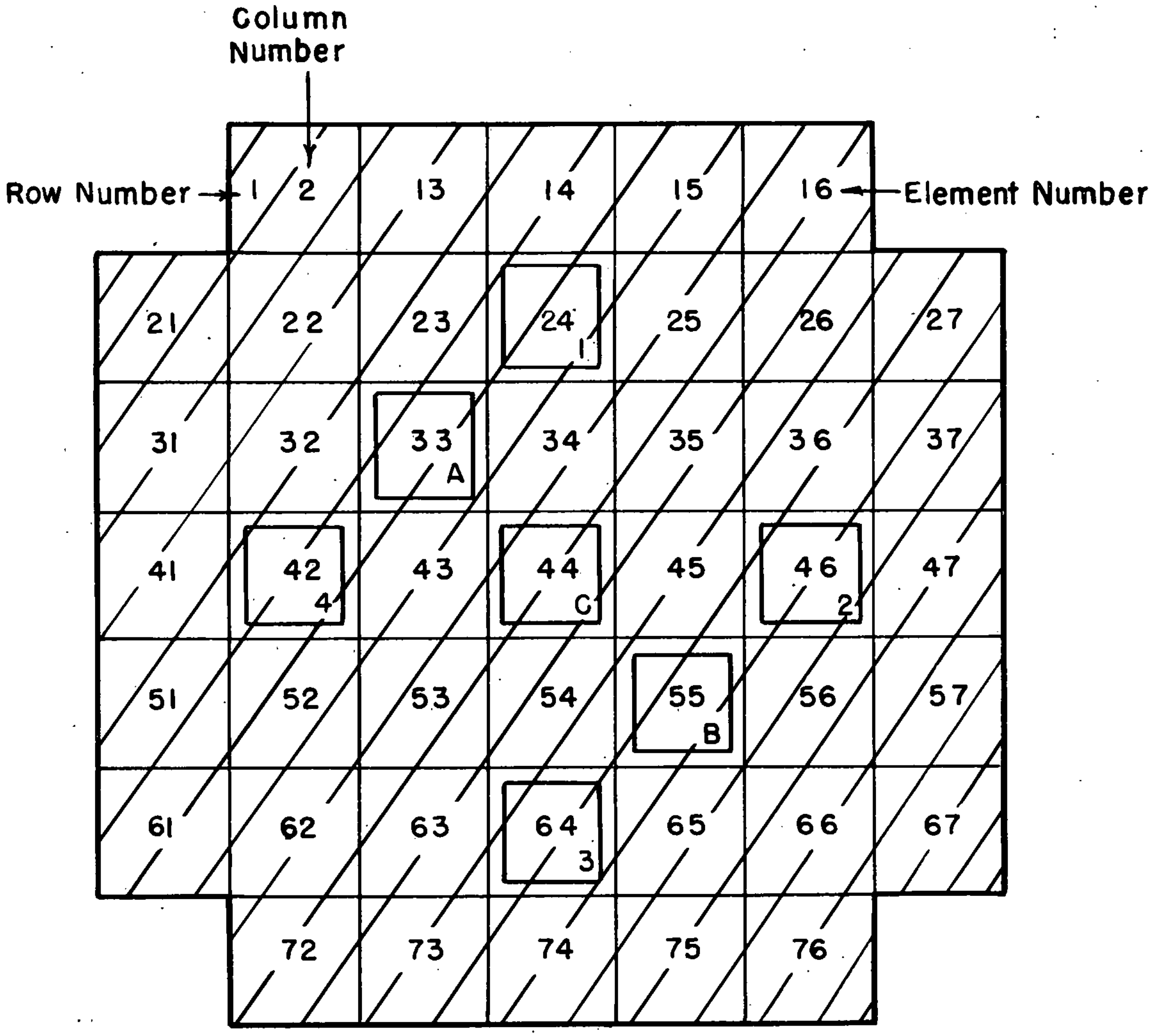

HIGH VOLTAGE CHARACTERISTIC CURVE FOR VARIOUS
TIMES AFTER SHUTDOWN
(WESTINGHOUSE BF$_3$, SERIAL #75234, PH 25 GAIN 16 x 1)
CURVE
TIME AFTER SHUTDOWN
E
2 HOURS
~ 2000 R/hr
F
5.5 HOURS
~ 1000 R/hr
G
8 HOURS
~ 800 R/hr
H
BACKGROUND ~ 50 R/HR
E
F
G
H
G
F
E
H
RELATIVE COUNT RATE
1.00
1.0
15
16
17
18
19
20
21
HIGH VOLTAGE (HUNDREDS OF VOLTS)

FIG. 2.4.1

CORE ARRAY



2.4.1 Temperature and Pressure Coefficient

Since the temperature and pressure coefficients are primarily functions of the water volume fraction, small changes in fuel and absorber loading will have a negligible effect on this experiment.

2.4.2 Bank Positions

A. Replacement of Boron Absorbers with Europium Absorbers

The cold, no xenon 5 rod bank position was 7.20 inches with original boron absorbers, and 7.09 inches with new europium absorbers. The reactivity associated with the replacement was evaluated by several methods and is 20¢ ± 5¢. This should cause a displacement of approximately -0.1 inches in the operating bank position at approximately 12.8 inches (10.5 MWYR). The correction can be made in the plot of bank position as a function of energy release, and the correction will diminish to zero at the end of core life.

A new boron absorber was used as a reference for comparison with europium absorber worth as given in Table 2.4-1. The measurement was performed by fully inserting the absorber, new boron or europium, in rod C position and determining the critical four rod bank position. Differences in the four rod bank position were converted to reactivity changes using a measured worth of 143 cents per inch for the four rod bank from 8.7 to 9.1 inches.

B. Replacement of Fuel Elements

The net reactivity effect of moving and rotating the fuel element from position 56 to position 57 and the replacement of fuel elements in rod 4 and position 56 was estimated as 0.084% ρ, or 11.5 cents. This would cause a displacement of -0.1 inches in the operating bank position at 10.5 MWYR. The increase in core life due to the addition of these fuel elements is estimated at 0.2 to 0.5 MWYR.

TABLE 2.4-1

COMPARISON OF BORON AND EUROPIUM ABSORBERS

ABSORBER		FOUR ROD BANK POSITION (INCHES)	CHANGE IN BANK POSITION (INCHES)	DIFFERENCE IN WORTH* (CENTS)
Boron #16 (New (reference)		9.039	0	0
Europium - S.S.	#1	8.944	-0.095	+13.6
	#4	8.944	-0.095	+13.6
	#5	8.942	-0.097	+13.9
	#6	8.942	-0.097	+13.9
	#8	8.947	-0.092	+13.2
	#3	8.768	-0.271	+38.8
	#7	8.772	-0.267	+38.2
Boron (Used 10.5 MWYR)				+ 1.9

* Positive sign indicates less poisonous rod.

C. Net Effect on Bank Positions

The net effect of absorber replacement and fuel element changes on the operating bank position will be to displace the bank approximately -0.2 inches at 10.5 MWYR.

2.4.3 Rod Calibrations

The effect of core modifications on rod calibrations will be negligible.

2.4.4 Start-up Count Rate

The core modifications will have negligible effect on start-up count rate.

2.4.5 Stuck Rod Conditions

The change in safety margin as a result of core modification was evaluated and is reported in APAE Memo No. 194[4].

2.5 Reactivity of Smaller Cores

Experiments were performed to determine the loss of reactivity associated with the removal of fuel elements from core positions 12, 21, 16, 27, 67, 76, 61, and 72. In the first experiment, only the fuel elements in positions 16, 27, 61, and 72 were removed and the reactivity effect measured. It was assumed that the measured effect could be mulitplied by two to obtain an estimate of the effect of removing 8 fuel elements. Because the measured reactivity loss was large and adversely affected the estimate of the PM-2A lifetime, it was decided to perform a second experiment in which 8 elements were removed from the SM-1 core.

The general procedure for both experiments was to calibrate rod A as a function of the five rod bank position in the normal SM-1 core, and then in the core with elements removed. The integral worth of rod A was used to calibrate the five rod bank (see section 2.2). Five rod bank calibrations are shown in Fig.

2.5.1. The reactivity change associated with fuel element changes is subject to different interpretations because of the change in rod worth with core size and bank position.

Table 2.5-1 gives the results of $\Delta\rho$ computed on the basis of rod calibrations in the various cores. To estimate the reactivity remaining in the 45 and 37 element cores, the differential bank worth curves were extrapolated linearly to zero at 22 inches, as shown in Figure 2.5.2. The differential curves in Figure 2.5.2 were integrated to yield Figure 2.5.3. The straight line extrapolation of Fig. 2.5.2 yields an integral worth from 7.09 inches to 22 inches, which agrees within 0.1%. With the integral worth taken from the differential worth curve in APAE Memo 178[1].

The critical five rod bank positions in the 45 and 37 element cores were 7.09 inches and 9.54 inches, respectively. Reading from Figure 2.5.3 at these positions,

$$\int_{9.54}^{22.0} 37 \text{ element core} = \$10.95$$

$$\rho = 1 - e^{-10.95} = .0768$$

$$\int_{7.09}^{22.0} 45 \text{ element core} = \$13.90$$

$$\rho = 1 - e^{-13.90} = .0964$$

$$\Delta\rho = \int_{7.09}^{22.0} 45 \text{ element core} - \int_{9.54}^{22.0} 37 \text{ element core} = 1.96\%$$

The integral bank worth method of determining the reactivity difference between the two cores has the advantage of correctly treating the change in bank worth with core size. However, it is subject to a large uncertainty due to the extrapolation employed. This method yields a value of $\Delta\rho_{45 \rightarrow 37} = -1.96\%$.

FIGURE 2.5.1

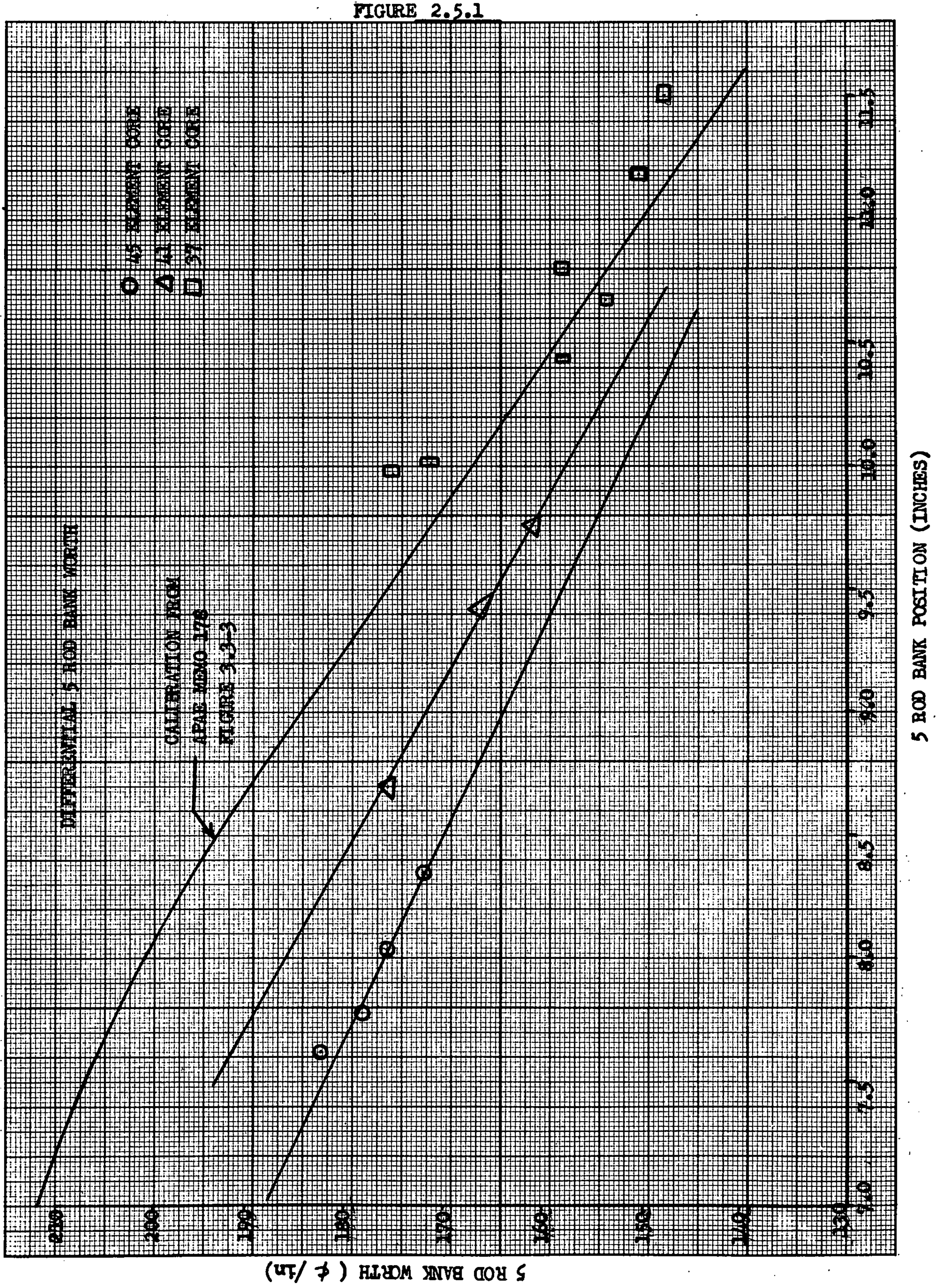

DIFFERENTIAL 5 ROD BANK WORTH
○ 45 ELEMENT CORE
△ 41 ELEMENT CORE
□ 37 ELEMENT CORE
CALIBRATION FROM
APAE MEMO 178
FIGURE 3.3-3
5 ROD BANK WORTH (¢/in)
210
200
190
180
170
160
150
140
130
5 ROD BANK POSITION (INCHES)
7.0
7.5
8.0
8.5
9.0
9.5
10.0
10.5
11.0
11.5

TABLE 2.5-1

Reactivity Change Associated with Fuel Element Changes

Change in Number of Elements	Reactivity Loss (based on larger core Bank calibration)	Reactivity Gain (based on smaller core bank calibration)
45 to 41	1.43%	
45 to 37	3.09%	
41 to 45		1.51%
37 to 45		3.51%

FIGURE 2.5.2

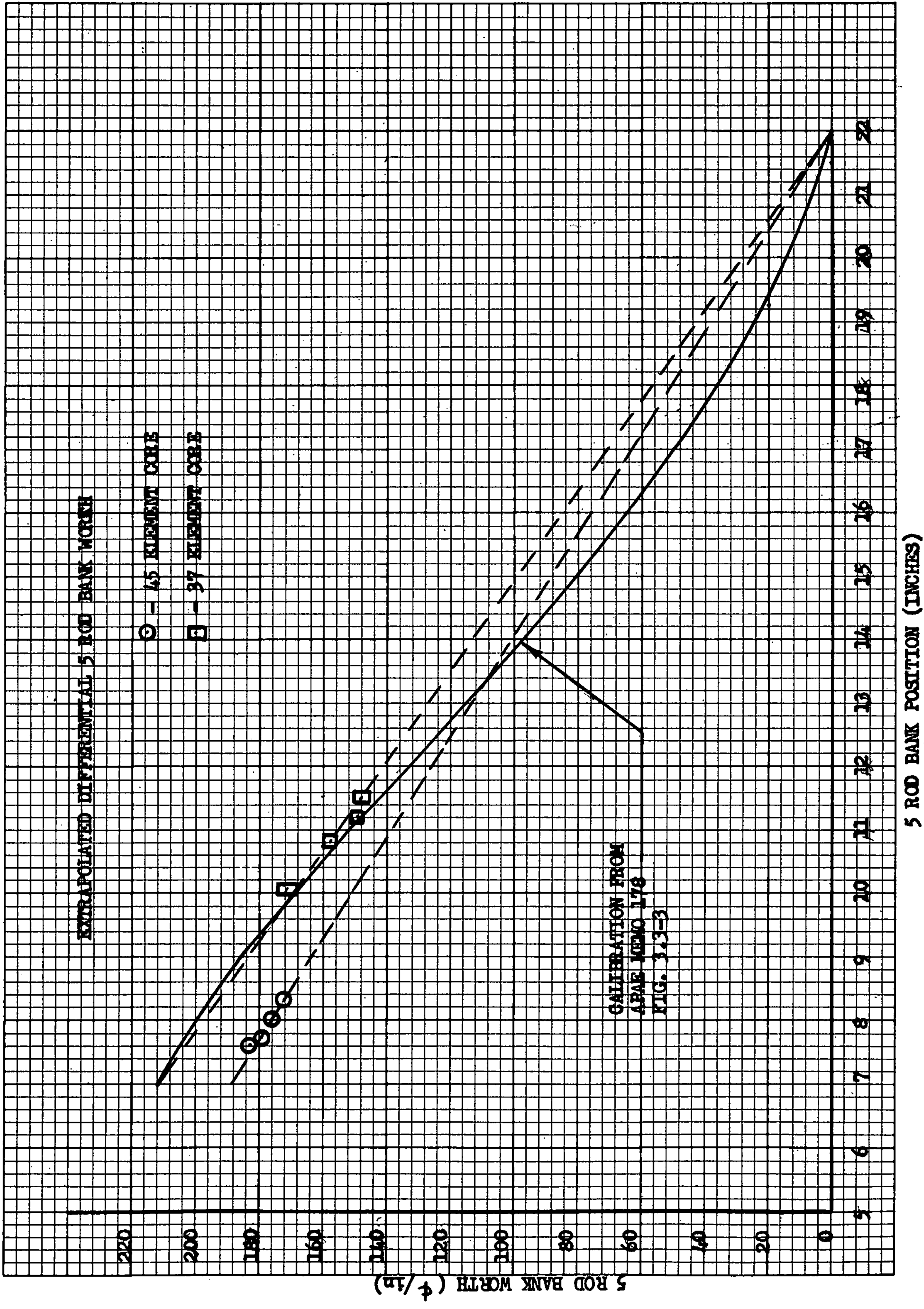
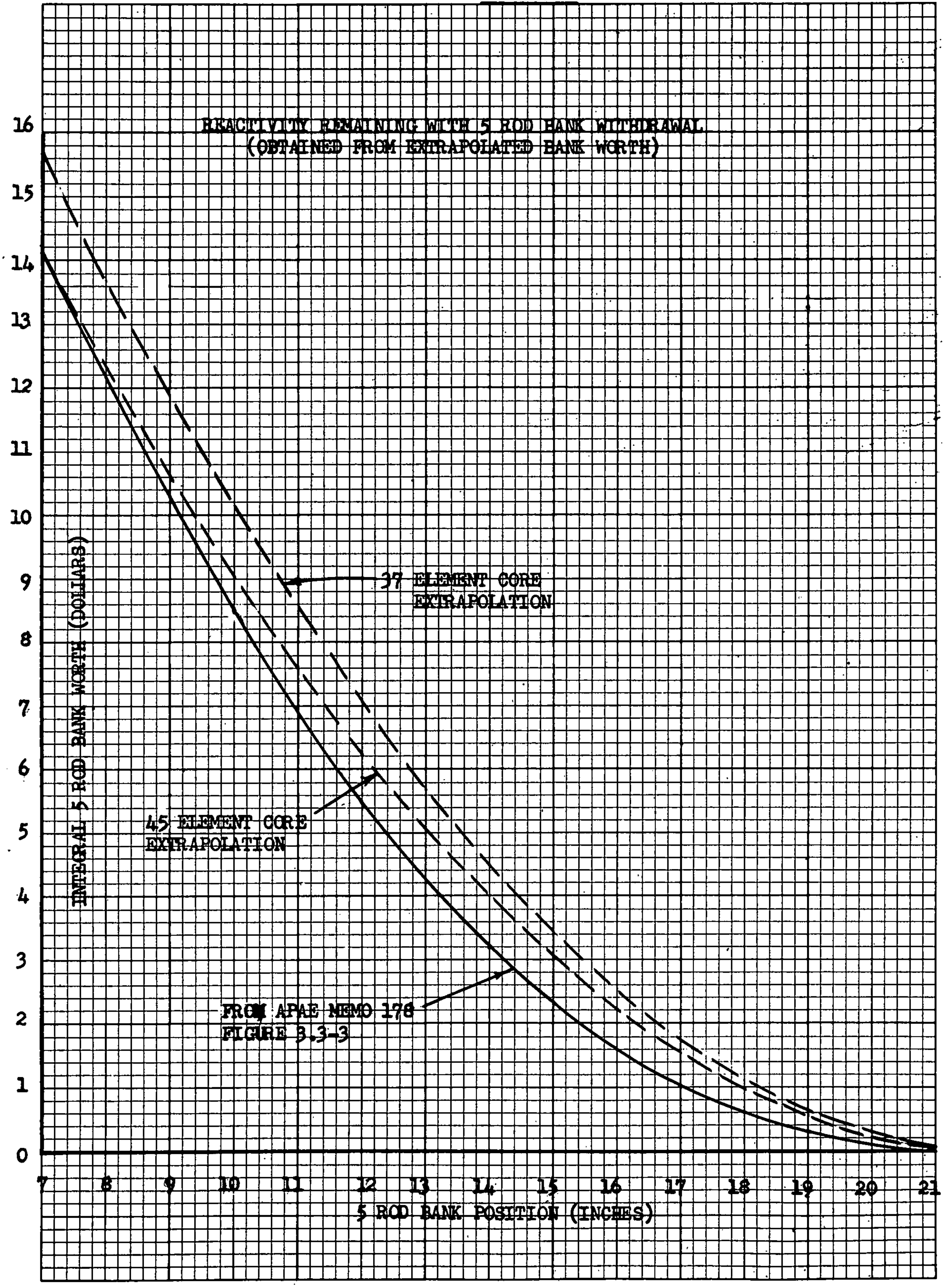

EXTRAPOLATED DIFFERENTIAL 5 ROD BANK WORTH
⊙ – 45 ELEMENT CORE
□ – 37 ELEMENT CORE
CALIBRATION FROM
APAE MEMO 178
FIG. 3.3-3
5 ROD BANK POSITION (INCHES)
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
22
5 ROD BANK WORTH (¢/in)
0
20
40
60
80
100
120
140
160
180
200
220

FIGURE 2.5.3


REACTIVITY REMAINING WITH 5 ROD BANK WITHDRAWAL
(OBTAINED FROM EXTRAPOLATED BANK WORTH)
37 ELEMENT CORE
EXTRAPOLATION
45 ELEMENT CORE
EXTRAPOLATION
FROM APAE MEMO 178
FIGURE 3.3-3
INTEGRAL 5 ROD BANK WORTH (DOLLARS)
16
15
14
13
12
11
10
9
8
7
6
5
4
3
2
1
0
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
5 ROD BANK POSITION (INCHES)

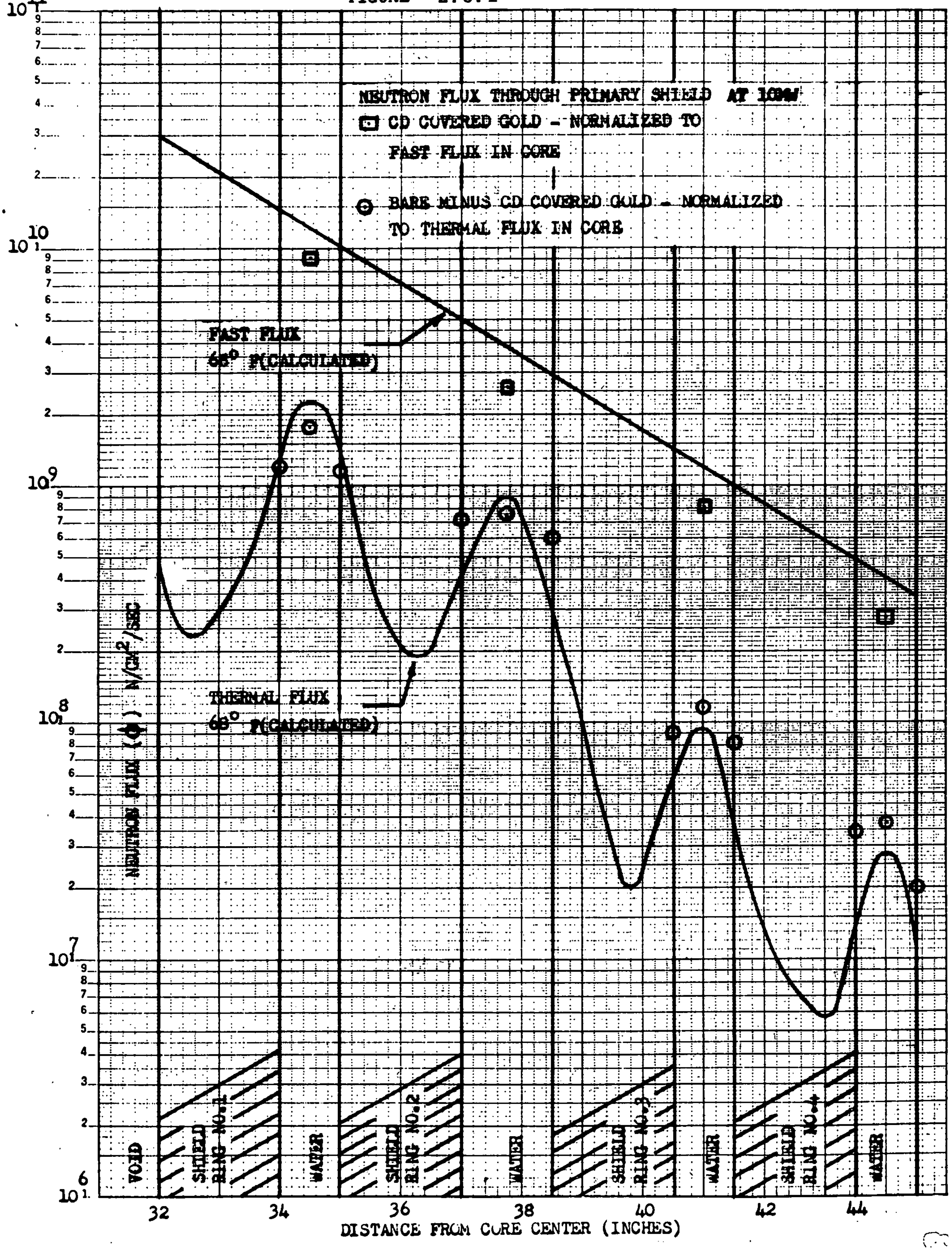
2.6 Neutron Flux Measurements

The relative neutron flux in the core, in the region of an integral europium flux suppressor in a fuel element, and in the shield rings, was measured by the activation of gold foils.

2.6.1 Shielding

For the measurement of the relative neutron flux attenuation between the core and the shield rings, foils were placed in fuel element positions 35 and 62 in the core and in the water gaps between shield rings 1, 2, 3, 4, and 5. The foils were activated for 10 hours with the reactor operating at a power level of 10 kw. The reactor was then shutdown and the foils removed. The activity of the foils was determined and decay corrected to the time of shutdown. Corrections were made using the relative axial flux plot[1] for the displacement of the foils in the core from the relative peak flux. The activity of cadmium covered gold foils activated in the core was normalized to the calculated[3] peak fast neutron flux in the core. The bare gold activity minus the cadmium covered gold foil activity for foils activated in the core was normalized to the calculated[3] peak thermal neutron flux in the core. The normalization factors determined in the core for the fast and thermal fluxes were applied to the measurements between the shield rings. The comparison between the core-normalized relative gold foil activities and the calculated fast and thermal neutron fluxes in shield rings is shown in Figure 2.6.1. The figure shows the design shield ring spacing; however, the actual spacing may vary ± 0.5 inches from the design. The variation in spacing from the design is the reason for the apparent inconsistant peaking of the thermal flux in water gaps.

FIGURE 2.6.1


NEUTRON FLUX THROUGH PRIMARY SHIELD AT 10MW
CD COVERED GOLD - NORMALIZED TO FAST FLUX IN CORE
BARE MINUS CD COVERED GOLD - NORMALIZED TO THERMAL FLUX IN CORE
FAST FLUX 68° F(CALCULATED)
THERMAL FLUX 68° F(CALCULATED)
NEUTRON FLUX (Φ) N/CM² /SEC
10^{11}
10^{10}
10^{9}
10^{8}
10^{7}
10^{6}
VOID
SHIELD RING NO.1
WATER
SHIELD RING NO.2
WATER
SHIELD RING NO.3
WATER
SHIELD RING NO.4
WATER
32
34
36
38
40
42
44
DISTANCE FROM CORE CENTER (INCHES)

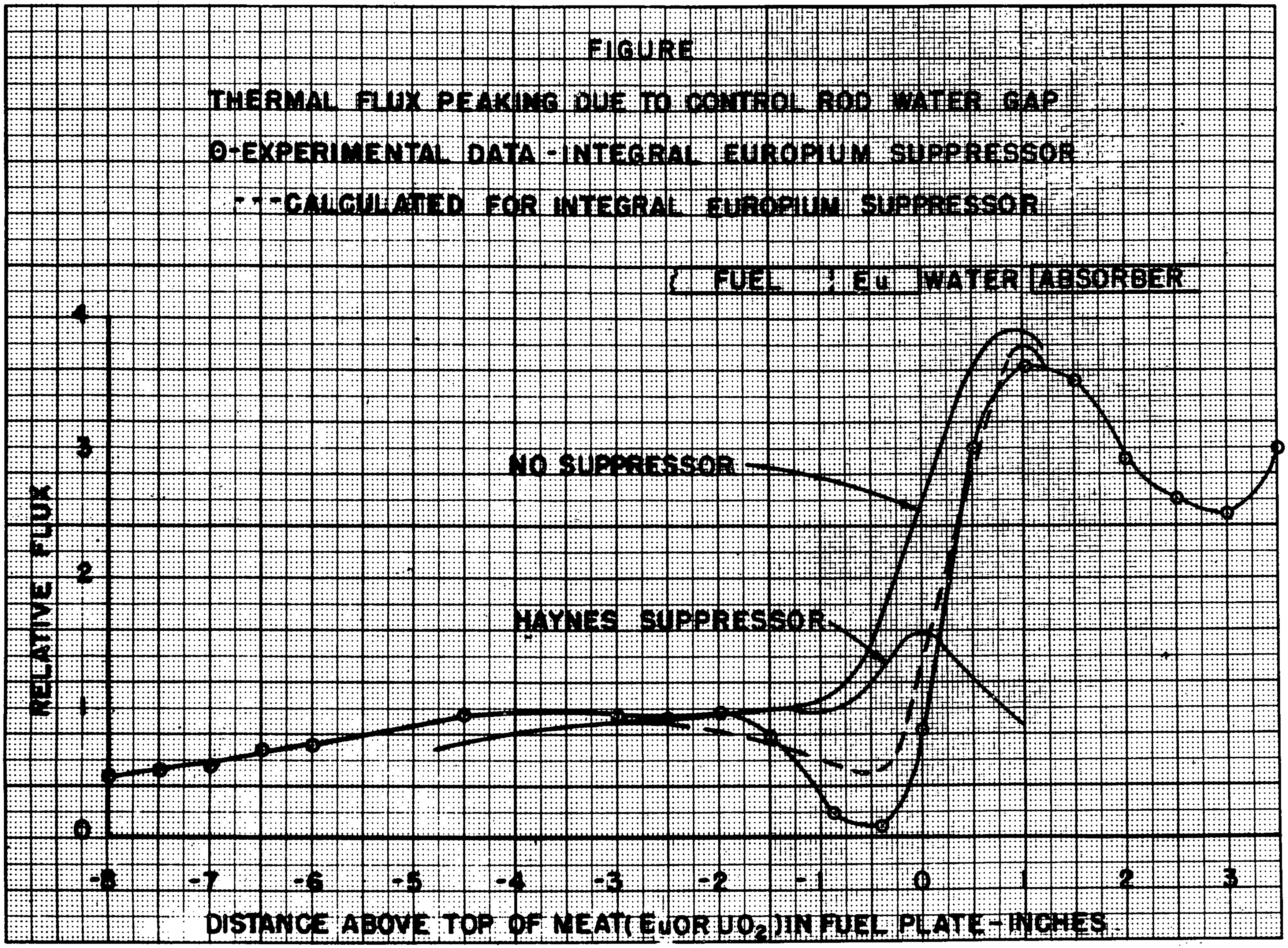
2.6.2 Europium Flux Suppressors

A new control rod fuel element containing integral europium flux suppressors was placed in control rod four. Gold foils were activated in the suppressor region to measure the effectiveness of the suppressor in reducing the thermal flux in the tip of the fuel element section of the control rod. Bare and cadmium covered gold foils were activated for 10 minutes with the reactor operating at a power level of approximately 80 watts. The reactor was shut down and the foils removed. The relative activity was determined and corrected to the time of shut-down. The activity of the bare gold foils minus the activity of the cadmium covered gold foils was normalized to a measurement of relative thermal flux with no suppressor[4] between 2 and 3 inches below the top of the active fuel. Figure 2.6.2 shows a comparison of the relative thermal flux measured by gold foil activation for an integral europium suppressor; no suppressor; Haynes suppressor[4]; and the calculated thermal flux for an integral europium suppressor[4].

2.7 Gamma Dose Rate Measurements

2.7.1 Above-Core

The shut-down gamma flux was measured on March 31, 1959 at points above the core. The air-walled ionization chamber used to make the measurements is described in APAE No. 35[3]. To take measurements under water, the chamber was enclosed in a section of 3-inch diameter iron pipe, approximately 10 inches long. The pipe was gasketed and capped with aluminum on the lower end, and attached by a welded connection on the top to a 1-inch diameter iron pipe 17 feet long. The upper pipe provided waterproof protection for the electrical connections to the chamber and was marked to determine the position of the chamber. Measurements were taken at several positions above the core, and the dose rate



FIGURE

THERMAL FLUX PEAKING DUE TO CONTROL ROD WATER GAP

O-EXPERIMENTAL DATA - INTEGRAL EUROPIUM SUPPRESSOR

- - -CALCULATED FOR INTEGRAL EUROPIUM SUPPRESSOR

Figure 2.6.2

was calculated by the equation:

$$D = FAI \frac{P_o}{P} \frac{T}{T_o} \qquad (3)$$

where D = dose rate R/hr

F = chamber sensitivity = $R/hr/\mu\mu A$ at S.T.P. = 0.2452

A = attenuation through pipe wall = 2.72

P_o = standard pressure = 760 mm of Hg

P = pressure in chamber during measurement (assumed to be 760 mm of Hg)

T_o = standard temperature = 492° R

T = temperature in chamber during measurement (530°R)

I = chamber current ($\mu\mu$ amperes)

The shut-down gamma dose rate plotted as a function of position above the core centerline is shown in Fig. 2.7.1. The results shown in Fig. 2.7.1 are difficult to interpret with respect to generated fission products because of intermittent reactor operation. The reactor was on line 183 hours in February and 69 hours in March.

2.7.2 Control Rod Components

The gamma dose rate from components of safety rod A was measured with a Jordon probe. Measurements were made with the instrument approximately one inch from the surface of the water and one inch from the holding tool, with the component underwater, or one inch from the component when removed from the water.

1) Fuel Element Section

The gamma dose rate with the fuel element section underwater is plotted in Figure 2.7.2. The distance is measured from the surface of the water to the bottom of the element pin. The dose rate is greater than 50 R/hr with the fuel element section less than 2.3 feet underwater.

FIGURE 2.7.1

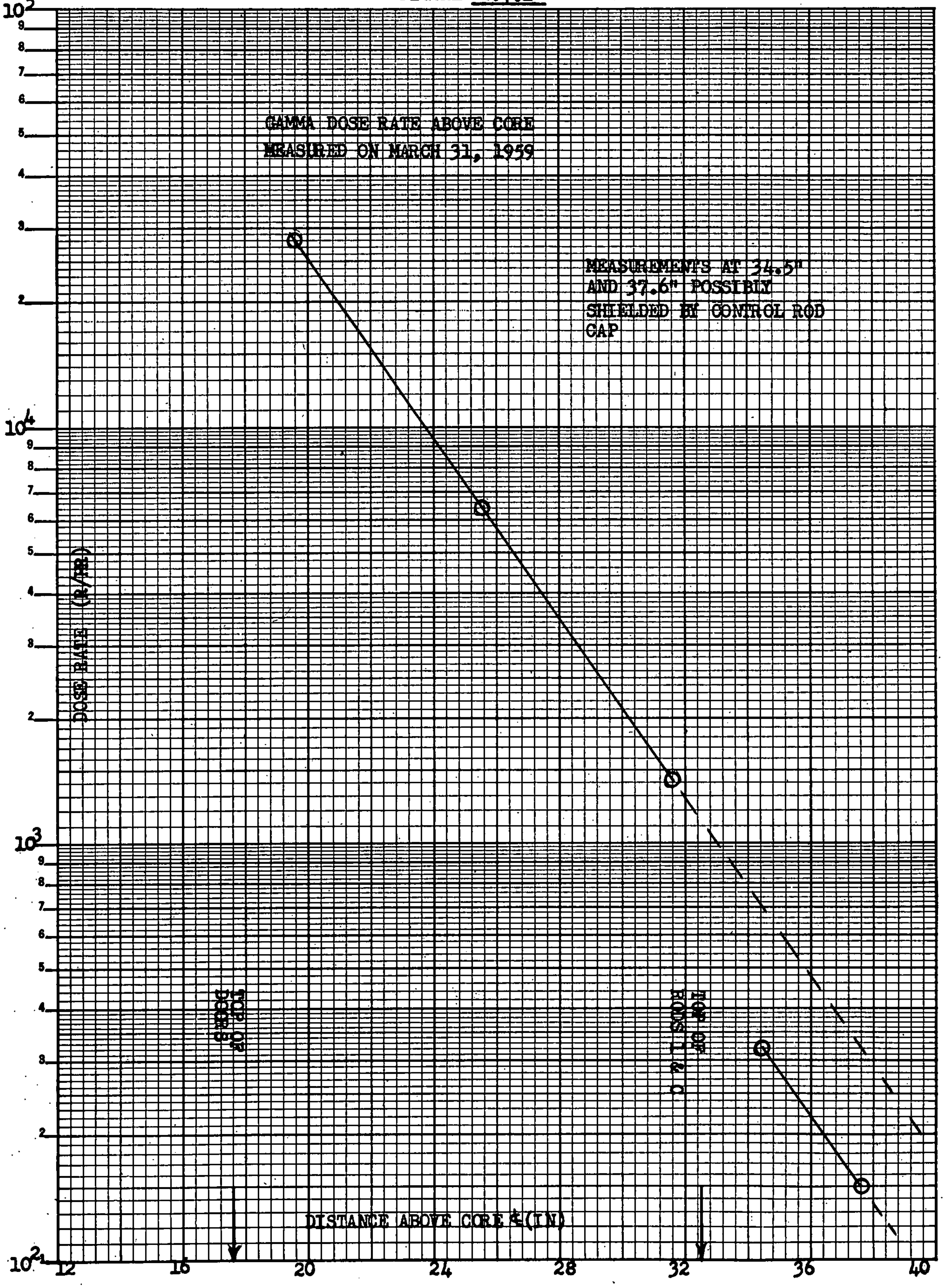
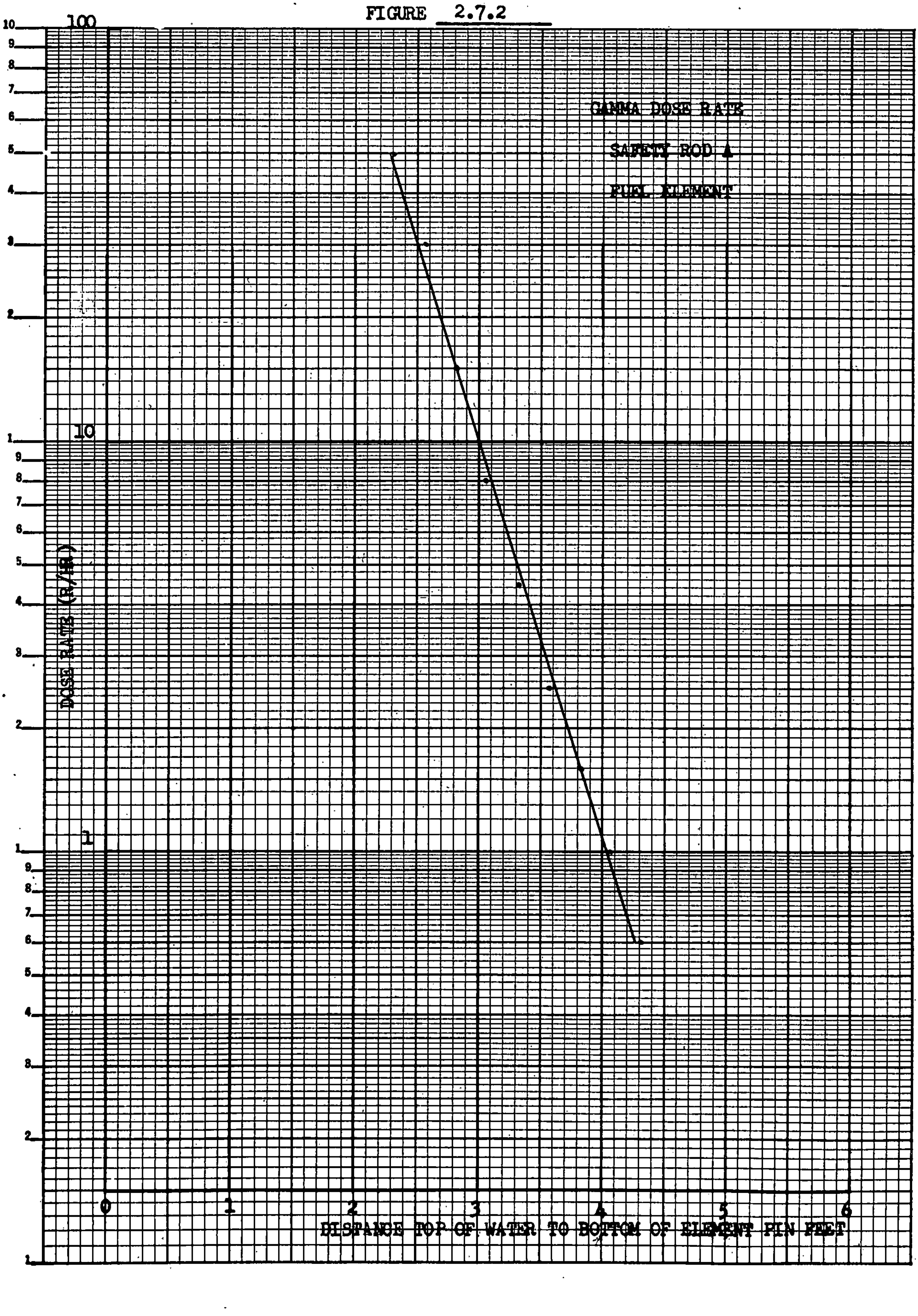

GAMMA DOSE RATE ABOVE CORE
MEASURED ON MARCH 31, 1959
MEASUREMENTS AT 34.5"
AND 37.6" POSSIBLY
SHIELDED BY CONTROL ROD
CAP
DOSE RATE (R/HR)
TOP OF CORE
TOP OF RODS 1 & 2
DISTANCE ABOVE CORE ℄ (IN)
10^5
9
8
7
6
5
4
3
2
10^4
9
8
7
6
5
4
3
2
10^3
9
8
7
6
5
4
3
2
10^2
12
16
20
24
28
32
36
40

FIGURE 2.7.2


GAMMA DOSE RATE
SAFETY ROD A
FUEL ELEMENT
DOSE RATE (R/HR)
100
10
1
0
1
2
3
4
5
6
DISTANCE TOP OF WATER TO BOTTOM OF ELEMENT FIN FEET

2) Boron Absorber Section

The gamma dose rate was measured with the boron absorber section underwater and also with it fully exposed. The results of the measurements are tabulated in Table 2.7-1. The measurements with the absorber fully exposed give a dose rate greater than 50 R/hr when the detector is placed more than 9.5 inches below the top.

3) Rod Cap

The gamma dose rate was measured with the rod cap underwater and when fully exposed. The results are tabulated in Table 2.7-2. Measurements with the cap fully exposed gave a maximum dose rate of 2.7 R/hr. However, it should be noted that rod A is withdrawn during operation at power, and the top of the cap is then approximately 51 inches above the center of the core.

TABLE 2.7-1

Gamma Dose Rate from Safety Rod A Boron Absorber Element

Measurement Position	Dose Rate R/hr
6.5 inches from top of water to bottom of element pin	0.06
3.5 inches from top of water to bottom of element pin	0.6
0.5 inches from top of water to bottom of element pin (.125 inches of element exposed)	1.3
4.0 inches from top of element completely exposed	15
9.5 inches from top of element completely exposed	50
All of element more than 9.5 inches from top of element completely exposed.	greater than 50

TABLE 2.7-2

GAMMA DOSE RATE FROM SAFETY ROD A CAP

Measurements Are From the Surface of the Water to the End of the Tool Installed On the Cap.

MEASUREMENT POSITION	Dose Rate (R/hr)
.10 feet under water	0.5
.40 feet above water	1.4
.65 feet above water	1.5
.89 feet above water	2.4
1.15 feet above water	2.7
Cap clear of water, measured 0.5 inches from spring	2.4

3.0 CONCLUSIONS

The experimental measurements included in this report indicate that:

1. The unsatisfactory performance of BF_3 neutron counters for short times after shut-down is apparently caused by high gamma flux.
2. Modifications made to the core will not seriously hinder the interpretation of measurements made under Task VII
3. Measurements of the neutron flux verify the calculated[4] attenuation of neutrons to the biological shield and show that an integral europium suppressor effectively reduces the thermal flux peak at the tip of a control rod fuel element.
4. The total energy release will be approximately 15 MWYR.

REFERENCES

1) MacKay, S.D., et. al., "SM-1 (APPR-1) Research and Development Program, Interim Report on Core Measurements - Task No. VII", APAE Memo No. 178, Issued March 1, 1959

2) Byrne, B.J., et. al., "Nuclear Effects due to Replacement of Fuel Elements in SM-1", AP Note No. 143, Issued April 1959

3) Rosen, S.S., et. al., "APPR-1 Research and Development Program, Shielding Experiments and Analyses - Task No. VI", APAE No. 35, Issued October 15, 1958

4) Fried, B.E., MacKay, S.D., "Evaluation of Hazards Associated with SM-1 Core I Modification", APAE Memo No. 194, Issued May 8, 1959

5) Williamson, T.G., et. al., "Reactor Analysis APPR-1 Core II", APAE No. 32, Issued July 15, 1958

APAE Memo No. 206

SM-2

RESEARCH AND DEVELOPMENT PROGRAM

INTERIM REPORT NO. 2

ON

CORE MEASUREMENTS

TASK No. VII

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