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NUCLEAR MEASUREMENTS FOR TYPE 3 REPLACEMENT CORES FOR SM-1, SM-1A AND PM-2A

CE-3

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ABSTRACT

This report contains the description and results of an experimental program to evaluate the effect of utilizing Type 3 (SM-2) replacement cores in existing Army field plants SM-1, SM-1A and PM-2A.

This program, conducted at the Alco Products Critical Facility, employed SM-2 mockup fuel elements similar in composition to Type 3 fuel elements to determine start-up characteristics of Type 3 cores in SM-1, SM-1A and PM-2A core configurations. Measurements include comprehensive power distribution, temperature coefficients, initial critical bank positions, control rod calibrations, critical rod configurations and material coefficients, all obtained under cold, clean, core conditions.

The 45 element SM-1 and SM-1A configurations with SM-2 mockup fuel elements contain 36.4 Kg U-235 and an estimated 67.9 gm B-10, while the 37 element PM-2A configuration with SM-2 mockup elements contains 30.0 Kg U-235 and an estimated 56 gm B-10. A summary of major experimental results is presented below:

NUCLEAR MEASUREMENTS UTILIZING
SM-2 MOCKUP FUEL ELEMENTS IN SM-1, SM-1A AND PM-2A
CORE CONFIGURATIONS UNDER CORE STARTUP CONDITIONS

Measurements	SM-1	SM-1A	PM-2A
Peak internal power generation in core*	4.19	4.30	3.67
Minimum power generation in core*	0.10	0.10	0.10
Maximum fuel cell/average power generation*	1.32	1.33	1.30
Minimum fuel cell/average power generation*	0.75	0.66	0.70
Critical seven rod bank position at 68°F, inches	8.04	8.12	8.56
Critical seven rod bank position at simulated 440°F and 1200 psi, inches	11.3	**	
Average U-235 worth in core, cents per gm U-235	0.14	**	0.15
Average B-10 worth in core, cents per gm B-10	23.8	**	30.2
Temperature coefficient at simulated 440°F, cents/°F	-3.9	**	
Reactivity loss due to operation at 440°F and 1200 psi, dollars	7.3	**	
Excess reactivity available at 440°F and 1200 psi, dollars	10.1	**	

* All core power measurements were performed under room conditions and are normalized to a core average of unity, where the core average was obtained without benefit of flux suppressors at the bottom of the stationary fuel elements.

** Assumed to be the same as the SM-1.

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SUMMARY

The use of Type 3 (SM-2) fuel elements in the SM-1, SM-1A, and PM-2A was evaluated by a series of critical experiments conducted in the exact core configuration of the field plants, under cold clean (startup) core conditions. SM-2 mockup fuel elements similar in composition to Type 3 elements were utilized throughout the experimental program. Results of these measurements are summarized below.

SM-1

The SM-1 configuration with SM-2 mockup elements contains 36. 4 Kg of U-235 and an estimated 67. 9 gm B-10. The initial seven rod bank critical position at 68°F was 8. 04 in. ; the five rod bank critical position with rods A and B fully withdrawn was 6. 94 in. The worth of a stainless steel skirt surrounding the core was -46 cents. The average measured material coefficients for U-235 and B-10 were 0. 141 and 23. 76 cents/gm respectively. Operation at 440°F and 1200 psi causes a loss of core reactivity of 7. 3 dollars, with approximately 10. 1 dollars excess reactivity remaining. The temperature coefficient at 440° was approximately -3. 9 cents/°F. The seven and five rod (A and B fully withdrawn) critical bank positions at operating conditions were 11. 31 and 10. 45 in. respectively. Power distribution measurements indicate that peak internal power generation of 4. 19 times the core average occurred in the center of the core while the minimum of 0. 10 of the core average occurred at the top edge of the core. Maximum cell average power generation in the active core was 1. 32 times core average; minimum was 0. 75 of core average. Various critical rod configurations were determined and tabulated.

SM-1A

The SM-1A configuration is almost identical to the SM-1; therefore, only a limited experimental program was carried out. The seven and five rod (rods A and B at 19 in.) critical bank position at 68°F was 8. 12 and 6. 90 in. respectively. The worth of the stainless steel skirt that surrounds the core was -40 cents. Peak internal power generation was 4. 30 times the core average and occurred in the center of the core. Minimum power of 0. 10 of the core average occurred at the edge of the core. Maximum and minimum average power generation per fuel cell in the active core were 1. 33 and 0. 66 times the core average respectively.

PM-2A

The PM-2A configuration with SM-2 mockup elements contains 30. 048 Kg U-235 and an estimated 56 gm of B-10. The initial five rod bank position at 68°F was 8.56 in. The worth of the stainless steel skirt was -51 cents. The measured average U-235 and B-10 reactivity coefficients in the core were 0.154 and 30.19 cents/gm respectively. Control rods 1 and 2 were calibrated against each other for their entire length with the three rod bank at 8.447 in. Critical rod configuration measurements indicated that at the beginning of life, criticality cannot be attained by full withdrawal of any single control rod. Results for other cases measured are tabulated and presented. Extensive power mappings of one quadrant of the symmetrical core were made. Peak internal power and minimum power occurring respectively at the center and edge of the core were 3.67 and 0.10 times the core average. Highest cell average power generation in the active core was 1.30 times core average; lowest was 0.70 of core average.

This work was conducted at the Alco Criticality Facility as a part of Item 3.1 of Task 3 of the Program Plan for Engineering Support and Development of Army Pressurized Water Reactor Power Plants, Contract No. AT(30-1)-2639, with the New York Operations Office of the USAEC.

INTRODUCTION

The AEC-Army Reactor Program has pioneered in the application of fully enriched, uranium-stainless steel dispersion, plate-type fuel elements for pressurized water reactors. This program has progressed to a state where one core (SM-1 Core I) has successfully met design life, two other field plant cores (SM-1 Core II and PM-2A Core I) are in successful operation, and a fourth core (SM-1A Core I) is ready for loading.

To meet the objectives of increased core life, lower fuel costs and more efficient, reliable cores, extensive advanced fuel element development work has been done. This advance in core technology is integrated into existing Army PWR's by a standard fuel element. The following table presents the essential features of three core types covered in the replacement core program. The characteristics of Type 5 cores, currently under development, are not shown.

The first core shown, labeled Type 1, is the original ORNL developed core used in the SM-1. The original control rods utilized iron B-10 alloy absorber sections; these were later replaced by Eu_2O_3 dispersed in stainless steel. SM-1 Cores I and II, SM-1A Core I and PM-2A Core I are of Type 1.

The Type 2 cores incorporate metallurgical improvements. The Geneva oxide has been replaced by commercially available spherical oxide which produces a better UO_2 - stainless steel dispersion, and the 304 stainless steel cladding has been replaced by low impurity 347 to obtain better cladding integrity. SM-1A Core II and PM-2A Core II are of Type 2.

The Type 3 core, based upon the SM-2 reference design, takes advantage of the extensive development work done in the SM-2 program. This is the first core using 40 mil plates instead of the original 30 mil plates. Zirconium diboride was selected as the burnable poison because of its chemical stability and because boron losses could be reduced to approximately -5 percent. Development of welded fuel assemblies allows more accurate dimensional control and eliminates the problem of braze metal corrosion.

The principal effort of the task described in this report was to evaluate the reactivity and power distribution effects resulting from the use of Type 3 cores in the existing SM-1, SM-1A and PM-2A plants. Application of these fuel elements with increased fuel and poison inventory required critical experiment measurements with the exact plant core configuration both to establish core performance and control with available rod configurations and to determine other important parameters

CORE TYPES IN REPLACEMENT CORE PROGRAM

Core Type	Type I	Type II	Type III
Cell size, in.	2.94 x 2.94	2.94 x 2.94	2.94 x 2.94
Active core height, in.	21.75	21.75	22
Fuel plate thickness, mil	30	30	40
Fuel type	Geneva UO_2	Spherical UO_2	Spherical UO_2
Burnable poison	B_4C	B_4C	ZrB_2
Loading in matrix, w/o UO_2	26	26	25
Loading in matrix, w/o B	0.08	0.09	0.17
Cladding, SS type	304	347	347
Assembly method	Braze	Braze	Weld
B-10 loading in 45 elements, gm	15.8	17.8	56.8
U-235 loading in 45 elements, Kg	22.5	22.5	36.3
Energy release (440^{o}F), MWYR	16.4	16.4	32.
Average burnup, a/o U-235	36.4	36.4	38.6

necessary for nuclear analysis and design. The experimental program, conducted at the Alco Products, Inc. Critical Facility, utilized SM-2 mockup fuel elements similar in composition to Type 3 elements at simulated core startup conditions.

Utimately, further development will lead to improved cores lasting for a plant's lifetime, thus realizing the full advantage of nulcear power.

1.0 SYSTEM DESCRIPTION

1.1 INTRODUCTION

A detailed description of the experimental assembly and its relationship to the Alco Criticality Facility is presented in APAE-36[1], APAE-36, Supplement I[2] and APAE-5[3]. This chapter describes the experimental technique and core assembly and defines the system nomenclature used.

1.2 EXPERIMENTAL ASSEMBLY

1.2.1 Core Support Assembly

The core support assembly consists of a three-tiered, stainless steel table located over the center of the reactor tank floor at the Critical Facility. Structural support, alignment and position of the assembly are assured by tie rods and spacers as shown in Fig. 1.1.

The core support can accommodate reactor cores with a total of 89 fuel elements and control rods; however, 38 stationary fuel elements and 7 control rod assemblies were utilized in the SM-1 and SM-1A tests and 32 stationary fuel element and 5 control rod assemblies were utilized in the PM-2A tests. The elements were arranged in a 7 x 7 lattice with one element missing from each corner in the SM-1 and SM-1A configurations and with three elements missing from each corner in the PM-2A configuration, as shown in Fig. 1.2, 1.3 and 1.4 respectively.

1.2.2 Control Rod Assembly

Reactor control is maintained by insertion and withdrawal of control rod assemblies which contain both nuclear fuel and box-type boron absorbers in a stainless steel basket (Fig. 1.5). The control rod assemblies are driven by overhead drives and drop by gravity on scram. Guide rods and dashpot plungers, acting as guides and decelerative devices respectively, are attached to the bottom of the control rod baskets.

1.2.3 Fuel Element Structure

The mockup stationary fuel elements contain 18 stainless steel UO_2 matrix fuel plates, each loaded with 46.3 gm U-235 not equipped with flux suppressors. Control rod fuel elements contained 16 similar fuel plates each loaded with 42.2 gm U-235 and equipped with 0.5 in. mockup flux suppressors at the top of the active meat. The individual fuel plates are composed of 26.5 w/o uranium oxide held in a 0.030 in. thick matrix of stainless steel and clad with 0.005 in. of stainless steel. It should be noted that the reference Type 3 core will contain flux suppressors in both stationary and control rod fuel elements.

Flexibility of number and distribution of fuel plates in both stationary and control rod fuel elements is provided by extruded polystyrene grooves which hold the fuel plates erect and maintain a center-to-center fuel plate spacing of 0.163 inches. Figures 1.6 and 1.7 show a stationary fuel element and control rod fuel element in the partially assembled state. The complete specifications for stationary fuel elements and control rod fuel and absorber sections are reported in APAE No. 54.[4]

1.2.4 Stainless Steel Skirt

The mockup skirt consists of a number of 0.050 in. thick stainless steel sheets surrounding the outer periphery of the core.

1.2.5 Neutron Source

A neutron source of encapsulated plutonium-beryllium with an emission rate of 8×10^6 neut/sec is used during reactor operation at the critical facility. The source is inserted into and withdrawn from the reactor by means of a friction drive acting through an attached 0.25 in. rod.

1.3 NOMENCLATURE AND EXPLANATIONS

1.3.1 Active Core

The active core is defined by the upper and lower average limits of the U-235 distribution in the stationary fuel elements and the cell boundaries of the outer row of stationary elements.

1.3.2 Control Rod Withdrawal

Control rod withdrawal refers to the withdrawal of the absorber section of the control rod from the active core and the consequent simultaneous insertion of fuel.

1.3.3 Control Rod Position

Control rod positions are reported as the distance withdrawn from the position of deepest insertion measured in inches. Deepest insertion represents the nominal alignment of the bottom of the active core with the top limit of the flux suppressor of the control rod fuel element. Bank position results from the average position of the individual rods comprising the bank.

1.3.4 Data Point, Experimental

All experimental data points are plotted as a point (circled, squared or other). Points derived from experimental data by cross plot or integration are represented by crosses.

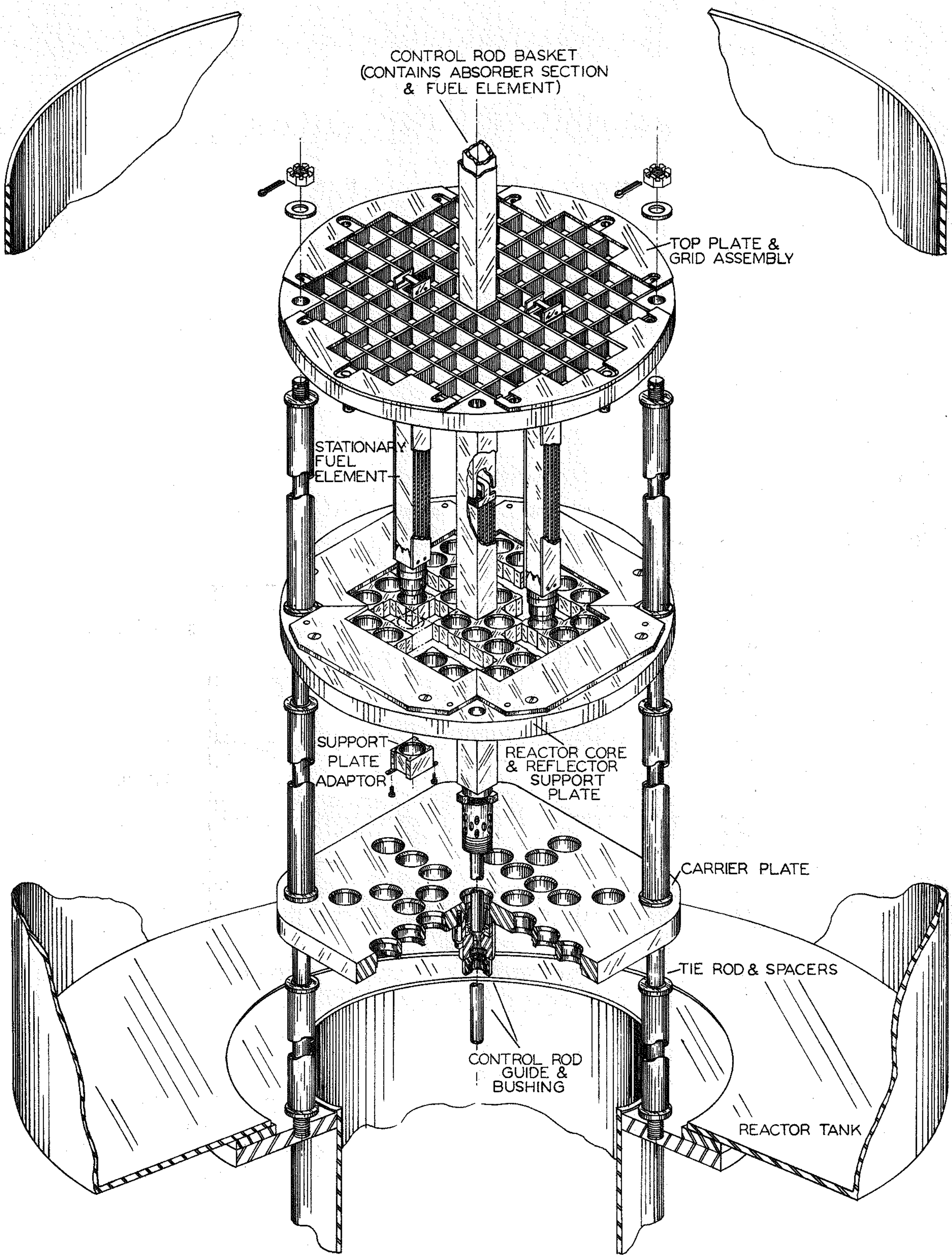

Figure 1.1. Core Support Structure

U-235 Loading: 36.4 Kg
Estimated B-10 Loading: 67.9 gm

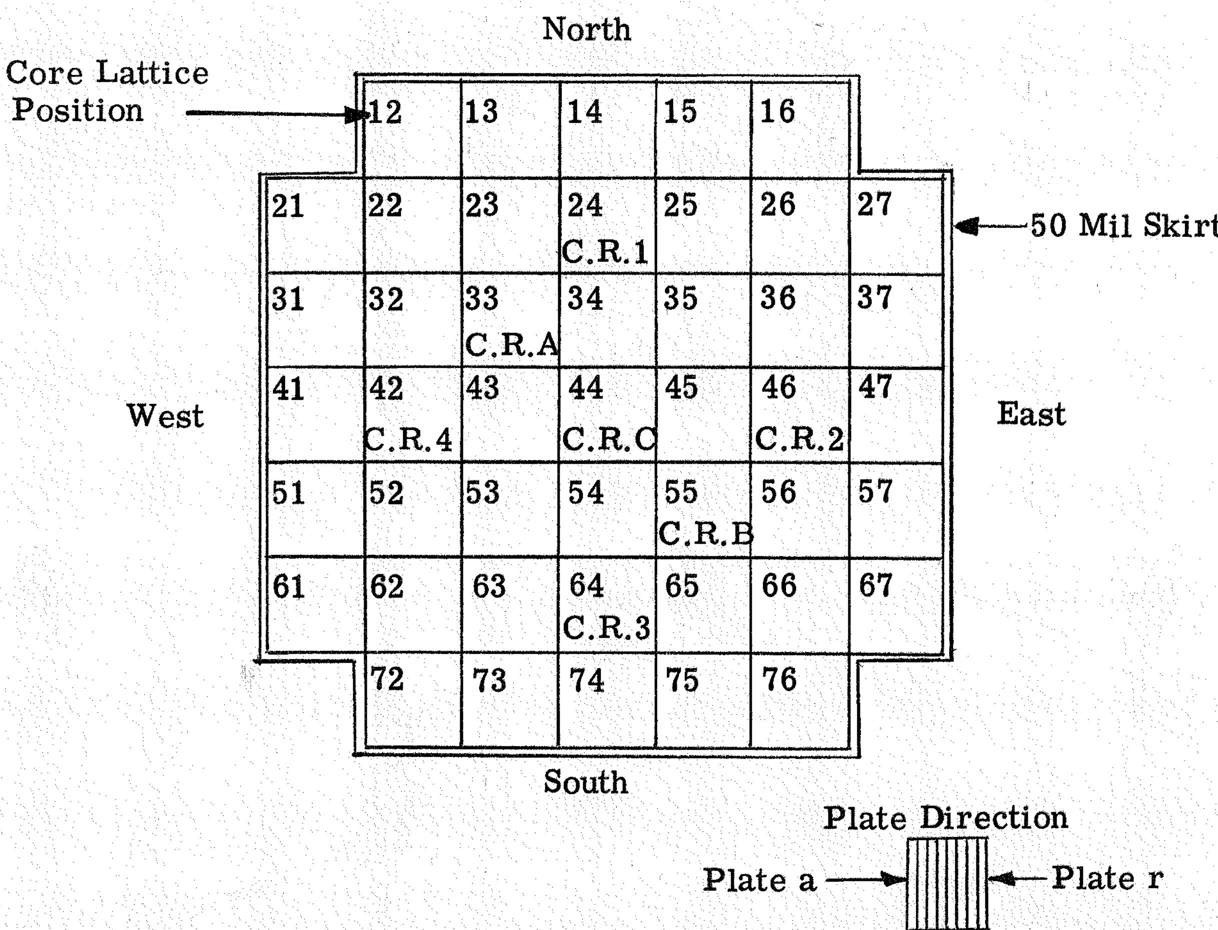

Fig. 1.2 - SM-1 Core Mockup Configuration

U-235 Loading: 36.4 Kg
Estimated B-10 Loading: 67.9 gm

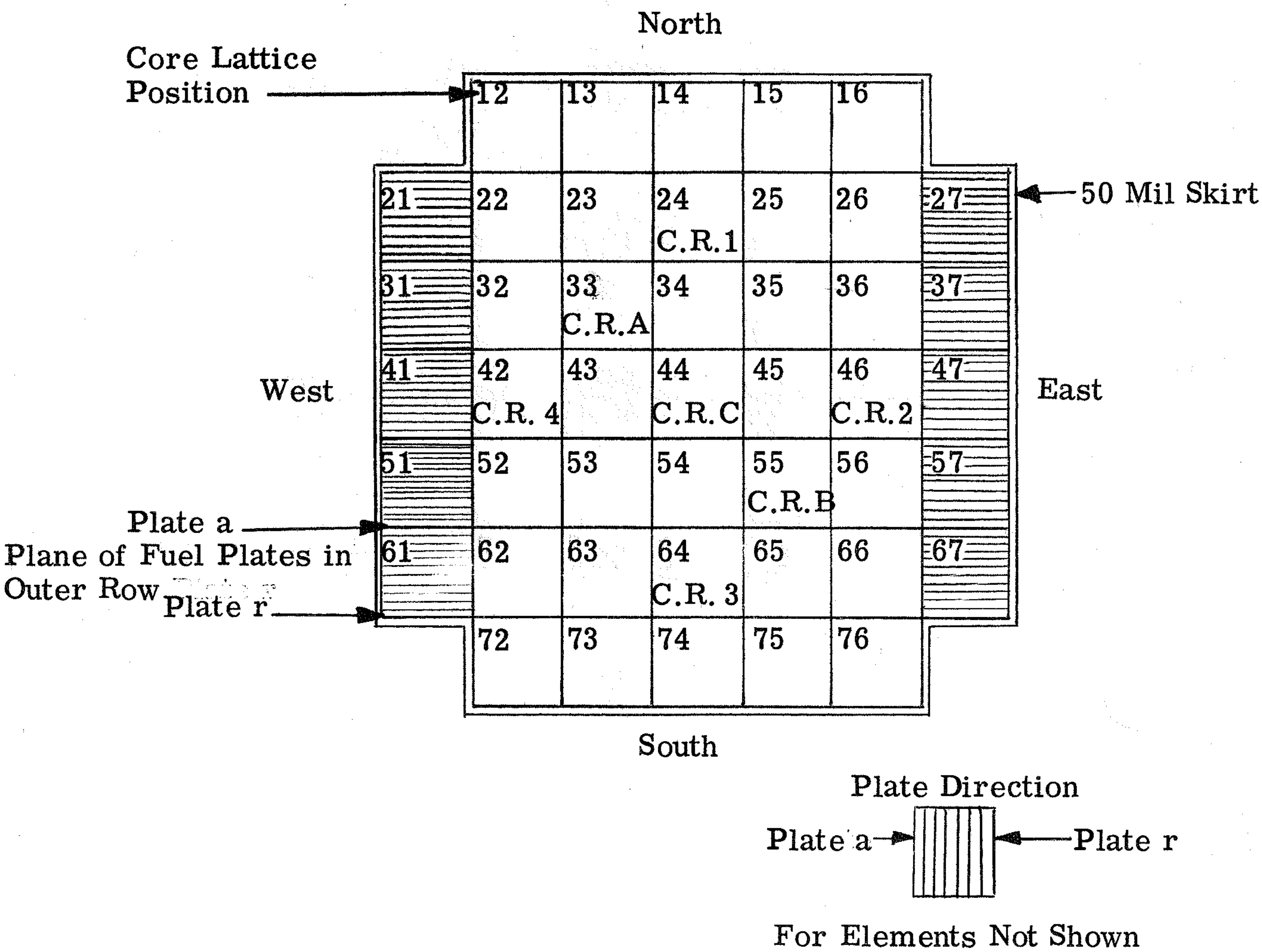

Fig. 1.3 - SM-1A Core Mockup Configuration

U-235 Loading: 30.048 Kg
Estimated B-10 Loading: 56 gm

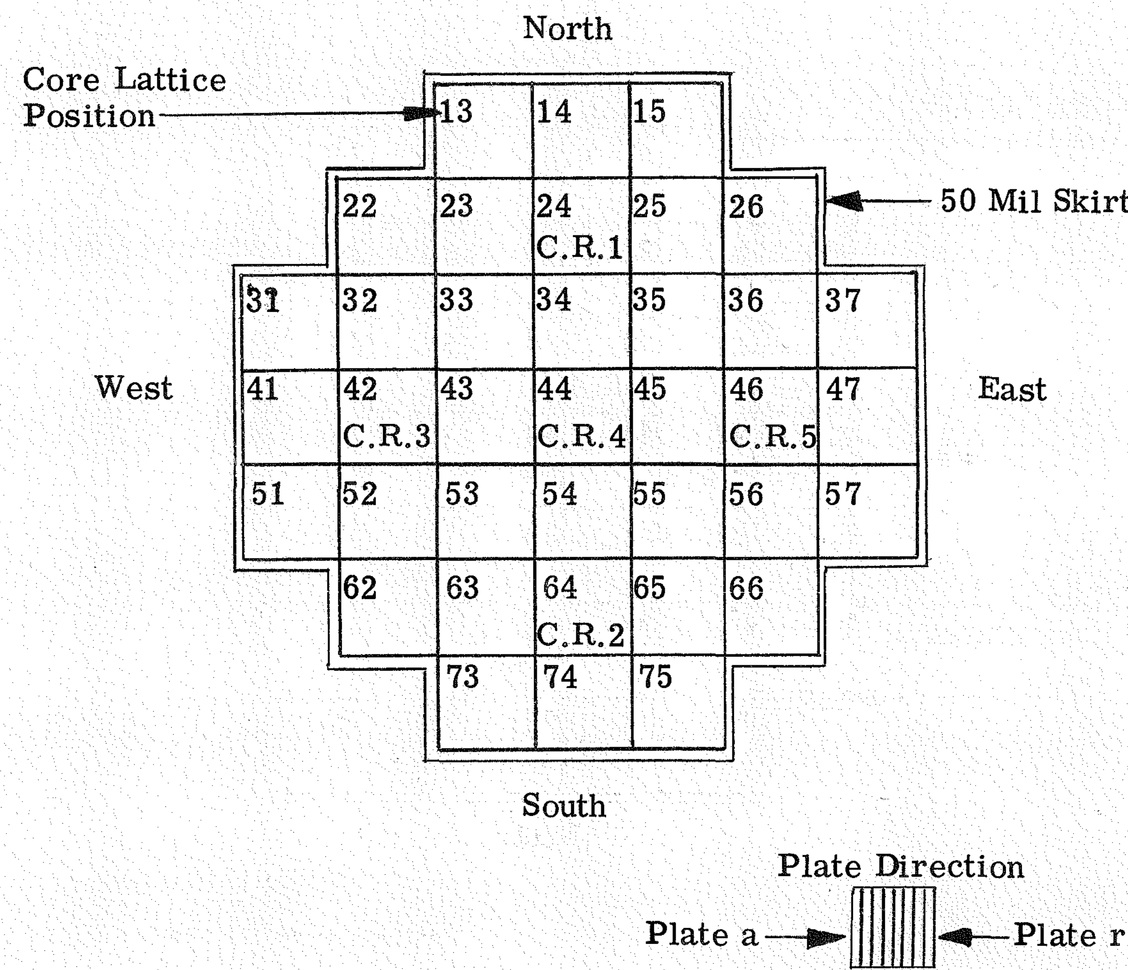

Fig. 1.4 - PM-2A Core Mockup Configuration

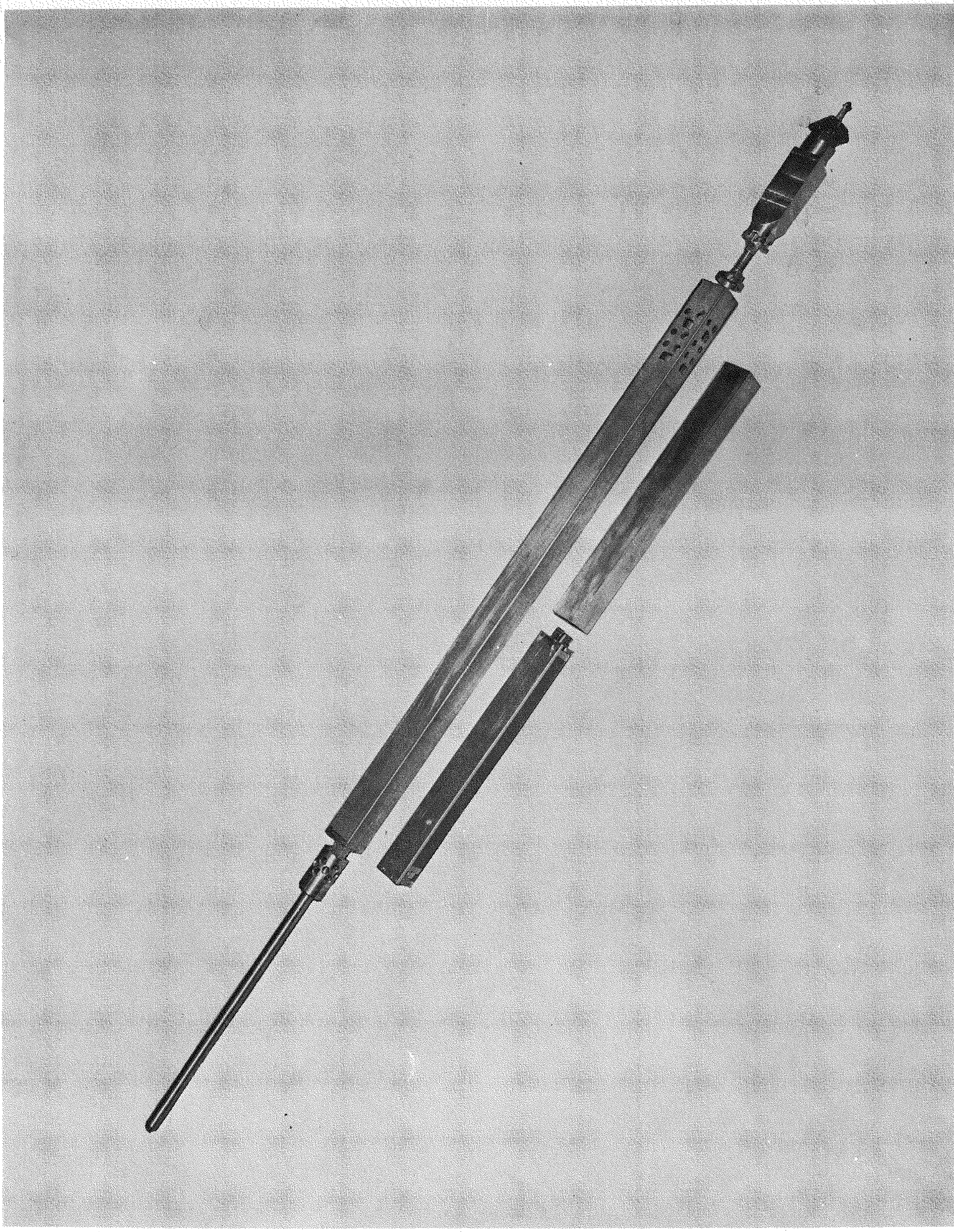

Figure 1. 5. Control Rod Assembly

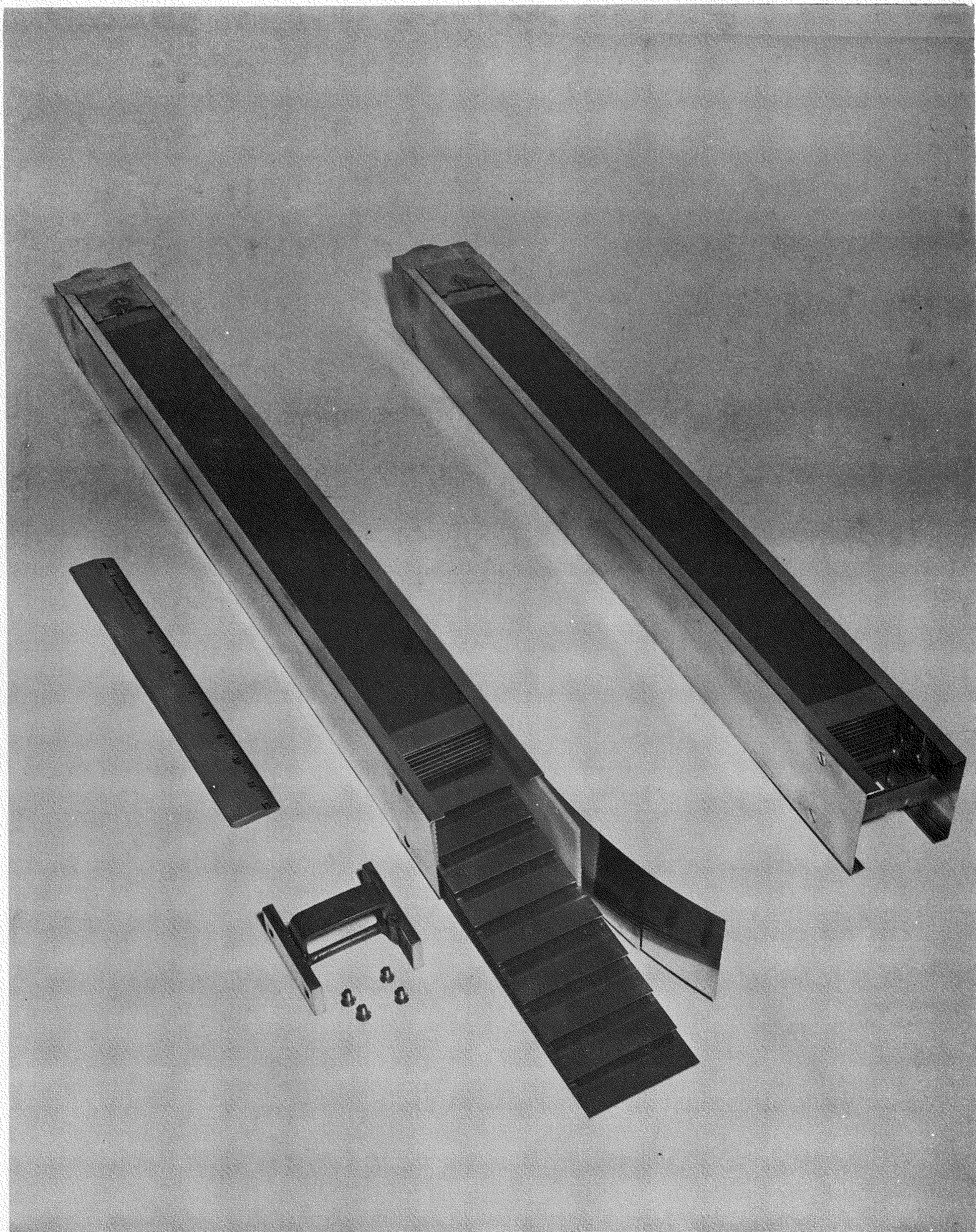

Figure 1. 6. Stationary Fuel Element

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Figure 1.7. Control Rod Fuel Element

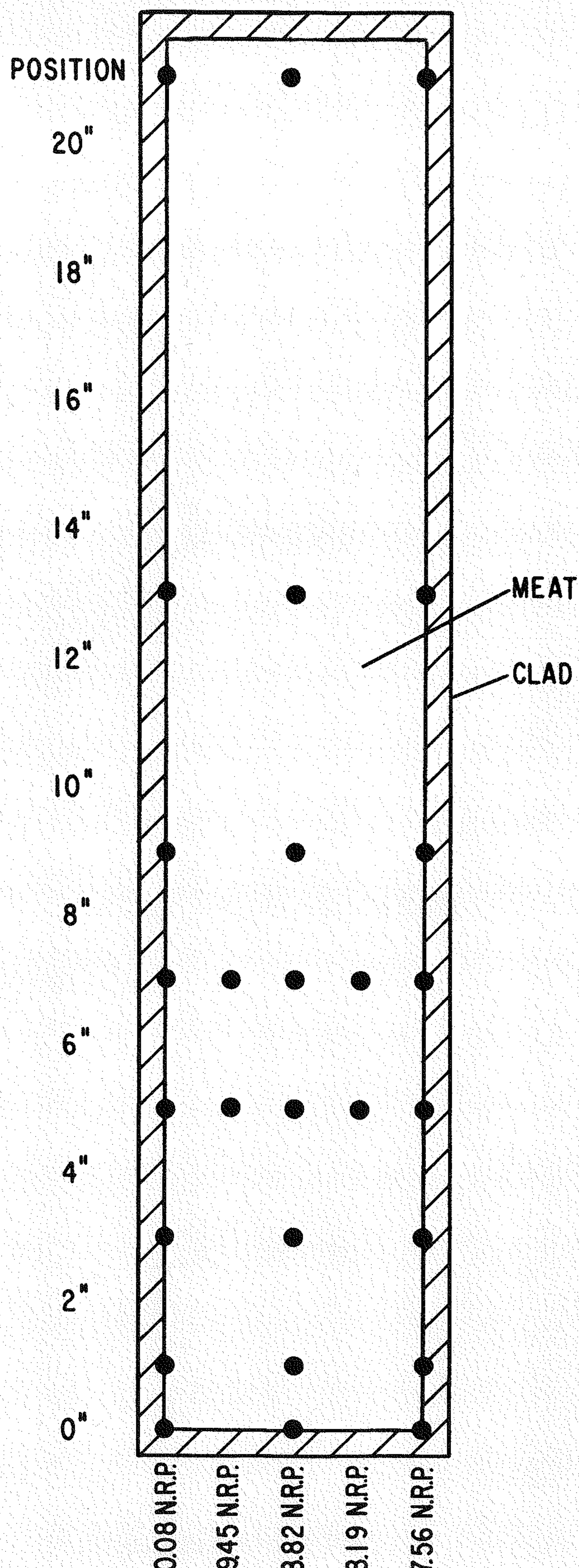


Figure 1.8. Typical Uranium Foil Locations on Fuel Plate Element 13 Used as Example

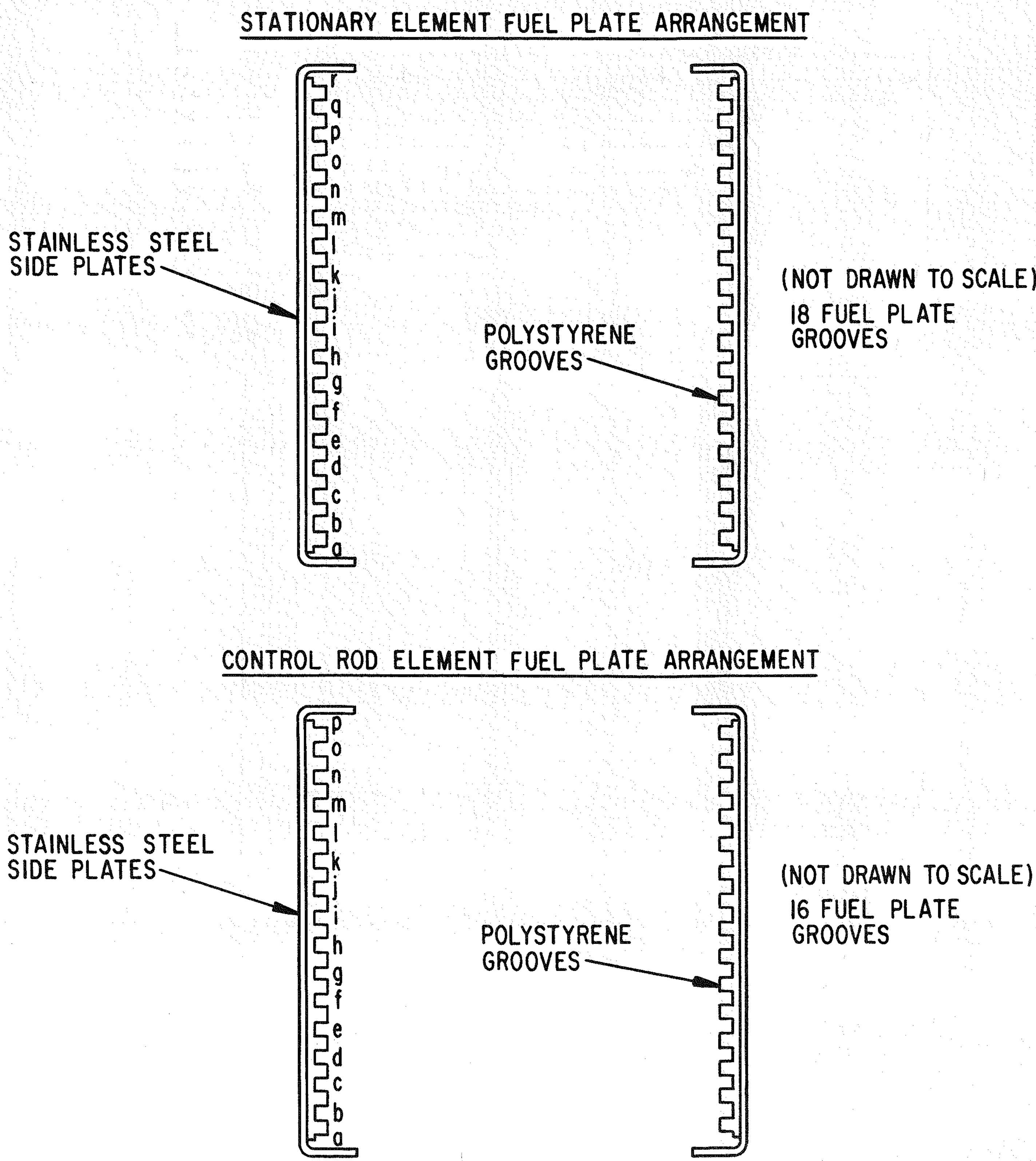


Figure 1.9. Fuel Plate Arrangement

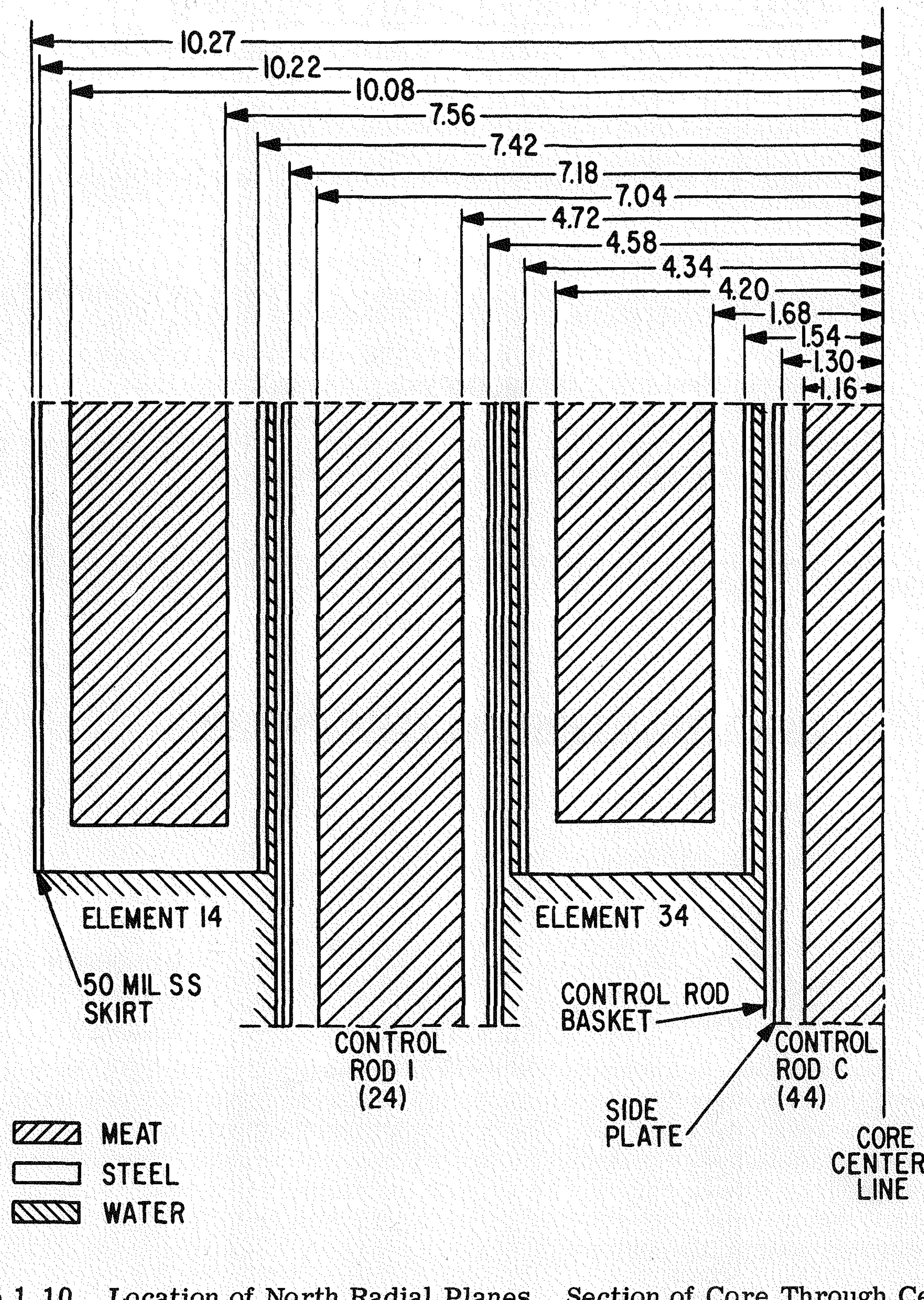


Figure 1.10. Location of North Radial Planes. Section of Core Through Center of Elements in Positions 14, 24, 34, 44

1.3.5 Temperature

Unless otherwise noted, all measurements were taken at 68°F.

1.3.6 Nomenclature Used in Reporting Power Distribution Measurements

1. Position: Location of foil measured from bottom of the active core in inches.

2. Axial Plane: Plane perpendicular to the core axis and measured from the bottom of the active core in inches.

3. North-South Central Radial Plane: Plane parallel to the north-south plane of the core and passing through the core centerline.

4. East-West Central Radial Plane: Plane parallel to the east-west plane of the core and passing through the core centerline.

5. Radial Plane: Plane parallel to the north-south or east-west plane of the core, distance measured from the central radial plane in inches.

   The following abbreviations are used:

   a. North Radial Plane: N. R. P.

   b. South Radial Plane: S. R. P.

   c. East Radial Plane: E. R. P.

   d. West Radial Plane: W. R. P.

1.4 EXPERIMENTAL METHODS AND PROCEDURES

1.4.1 Reactivity Measurements

All reactivity measurements were taken by measuring the difference in control rod position to achieve criticality between some reference condition and the condition under investigation. The reactivity worth of moving the single rod or bank was established by a series of control rod calibrations obtained by the period method at various control rod or bank locations. The total worth of a reactivity measurement was obtained from the difference in the critical position of a calibrated control rod or bank.

1.4.2 Material Coefficients Measurements

1.4.2.1 B-10 Worth

Small, incremental amounts of B-10 were added sequentially to each core lattice position and the resulting core reactivity change measured on a calibrated control rod or bank to obtain the B-10 worth. B-10 was added in the form of boron-impregnated Mylar tape (ref. Section 1.4.6) to a fuel element and placing it in different lattice positions in the core. The reactivity difference due to the added B-10 was measured on a calibrated rod or bank. This difference divided by the number of grams of B-10 added rendered the B-10 worth in cents/gm B-10.

1.4.2.2 U-235 Worth

U-235 worth measurements were obtained by changing the fuel loading in each fuel element in sequence and determining the core reactivity change from the difference in critical positions of calibrated control rods or bank. Fuel loadings were varied in the respective fuel elements either by replacing certain fuel plates of an element with fuel plates containing a higher fuel loading or with plates containing depleted uranium. In either case, the metal-to-water ratio and the boron loading was held constant. This element was inserted into various positions in the core and the core reactivity change due to the change in U-235 loading measured on a calibrated rod or bank. U-235 worth was then determined by dividing the change in reactivity by the change in U-235 loading to render the U-235 worth in cents/gm U-235.

1.4.3 Temperature Coefficient Measurements

Simulation of reactor operating temperature and pressure was accomplished by inserting aluminum strips between the fuel plates to simulate the decrease in moderator density. Temperatures between room and operating temperature were simulated and the resulting core reactivity changes obtained from the calibrated control rod bank. For these measurements, the control rod bank was calibrated at the simulated temperature to minimize uncertainties resulting from the dual dependency of control rod bank worth upon bank location and upon core temperature. The simulated core operating pressure was maintained constant during the temperature coefficient measurements. A plot of integral core reactivity change versus temperature was generated and the temperature coefficient of reactivity determined from the slope of this curve.

1.4.4 Control Rod Calibrations

All control rod calibrations were made by period method measurements. After a critical position was established, the rod or rods to be calibrated were raised above the critical position to put the reactor on about a 30 sec period. The period was related to the reactivity change divided by the change in rod position, which yields the differential rod worth at a point midway between the critical position and the period position.

1.4.5 Power Distribution Measurements

1.4.5.1 Introduction

Bare uranium-aluminum alloyed fission foils were attached directly to the fuel plates and activated in the core to obtain relative power distribution measurements. All foil data were corrected for radioactive decay and differences in foil masses. A reference foil was exposed at an identical core location during each activation experiment to provide a power normalization factor between runs. The reference foil for all power distribution measurements included in this report was located at the centerline of fuel plate i of element position 34 and at an axial elevation 6 in. above the bottom of the active core. By taking an adequate number of data points and utilizing core symmetry, the relative power distribution in the core was obtained. Each data point reported is normalized to a core average activation; thus, the core average becomes unity by definition.

1.4.5.2 Procedure

The fuel plates to be mapped were instrumented with 19 w/o fully enriched uranium-aluminum foils of approximately 12-15 mg weight, 0.005 in. thickness and 0.25 in. diameter. The number, location and symmetry of fuel plates to be mapped were chosen to obtain complete radial and axial power traverses in the core. All activation foils were placed on the west side of the fuel plates, opposite the boron-impregnated Mylar film which was on the east side of each fuel plate excepting the east and west boundary fuel elements in the SM-1A core mockup (ref. Fig. 1.3). In those fuel elements, the activation foils were placed on the south side of the fuel plates and the Mylar film was on the north side of the fuel plates. The foils were activated in the core for 30 min at power levels of approximately 10 watts. The foils were then removed and counted by two scintillation counters. Typical foil locations for a fuel plate are shown in Fig. 1.8. Fuel plate arrangement and location of radial planes are shown in Fig. 1.9 and 1.10 respectively. It should be noted that distances between fuel plates, fuel elements and other core components have been rounded off to two decimal places.

1.4.5.3 Data Processing

The data were processed as described in AP Note 246.[5] This method yields activity of the different foils relative to the reference foil, allowing corrections for weight, counter background and radioactive decay.

1.4.5.4 Core Average

A useful relationship for purposes of core design is the local power generation related to that of the core average. Since all power measurements were related to reference location in the core, the following procedure was utilized in obtaining a core average that is unity by definition.

First, the relative power averages for each fuel plate, each fuel element and the power generating core volume were obtained. Fuel plate averages relative to the reference foil were obtained from measurements across the face of the fuel plates at several axial positions. All averages were obtained from the average values of the fuel plates selected for power mapping. The core average power value was determined by summing all the fuel cell power averages and dividing by the power generating volume of the core. Each experimental data point was ratioed to the core average; thus, for purposes of data presentation, each data point equal to the core average becomes unity by definition. In determining the core average, the cell averages for the control rod fuel elements have been weighted to include only the portion of the fuel plates actually inserted in the active core. A typical calculation for obtaining the core average is presented in Appendix B of APAE-54, Supplement 1.[6]

1.4.6 Boron Loading

SM-2 mockup fuel elements were loaded with boron-impregnated tape cut into strips to fit over the uranium matrix of a fuel plate. The tapes are sections of adhesive-backed Mylar film loaded with boron carbide, of approximately 1 - 3 micron particle size, dispersed in ferrous oxide; they provide an ideal method of adding controlled amounts of B-10 to fuel plate surfaces. These boron strips were applied by means of a simple wringer-type tape dispenser.[4]

2.0 SM-1 MEASUREMENTS WITH SM-2 MOCKUP FUEL ELEMENTS

2.1 INTRODUCTION

The SM-1 is presently utilizing its second Type 1 core. To evaluate the effect of using Type 3 fuel elements [7] as a future replacement core in the SM-1, nuclear measurements were performed using SM-2(Type 3) mockup fuel elements in SM-1 configurations. The measurements included determination of critical bank positions, material coefficients and power distribution in the core as well as stuck rod measurements, temperature coefficients and simulation of operating conditions.

2.2 CORE CONFIGURATION AND INITIAL CRITICAL POSITION

The SM-1 core configuration is illustrated in Fig. 1.2. The total U-235 loading in the core was 36.4 Kg; the B-10 loading was estimated to be 67.9 gm.[6] The core was equipped with a 0.050 in. thick stainless steel skirt. The initial seven rod critical bank position measured at 68°F was 8.04 in. The five rod bank with rods A and B fully withdrawn was 6.94 in. at 68°F.

2.3 WORTH OF STAINLESS STEEL SKIRT

The worth of the 60 mil stainless steel skirt around the outer boundary of the core was measured on calibrated rod 3. The worth of the skirt was determined to be -46 cents. Based upon measurements performed on the SM-1 Core I,[8] the worth of a complete 50 mil thick skirt is estimated to be -47 cents, which is in close agreement with measurements presented here utilizing an SM-2 core mockup. This leads to the conclusion that changing the core composition to Type 3 does not significantly alter the reactivity worth of the stainless steel skirt.

2.4 CRITICAL ROD CONFIGURATION

Various combinations of control rods were withdrawn at startup to determine the minimum rod withdrawal to achieve criticality and to provide an indication of the criticality margin if one or more control rods should stick in operating position. Table 2.1 presents the critical control rod configurations and the rod worth of the critical rod or rods for various cases tested. Rods omitted in the table were fully inserted and the reactor was brought critical on the critical rod(s) indicated in each case.

TABLE 2.1
CRITICAL ROD CONFIGURATIONS

Case	Rod(s) Fully Withdrawn	Critical Rod(s)	Critical Position - in.	Worth Cents/in.
1	1, C	A	14.237	38.9 @ 14.437 in.
2	1, 4	A	13.475	39.9 @ 13.727 in.
3	2, 3	B	14.126	38.4 @ 14.402 in.
4	1, C, 4	A	5.426	50.4 @ 5.655 in.
5	1, C, 4	3	9.600	23.5 @ 9.949 in.
6	1, C, 4	2	9.779	26.4 @ 10.049 in.
7	1, C, 4	B	10.798	22.9 @ 11.255 in.
8	1, C, 3	2	11.331	33.4 @ 11.653 in.
9	2, C, 3	1	10.024	26.8 @ 10.365 in.
10	1, 2, 3	4	17.427	10.0 @ 18.214 in.
11	A, B, C	1	9.312	53.6 @ 9.507 in.
12	A, B, C	2	9.386	49.3 @ 9.592 in.
13	None	1, A, C	16.679	55.8 @ 16.835 in.

It is noted from the above results that criticality may be achieved by selectively withdrawing two rods fully and partially withdrawing a third; however, in most cases, three rods could be fully withdrawn and a fourth partially withdrawn before criticality was reached. In general, there is agreement between critical positions and control rod calibrations for similar control rod arrays. Small differences as illustrated by comparison of Cases 2 and 3, and 5 and 9 are attributed to a slight non-uniformity of poison distribution in the core. (Refer to Table 2.3, reference 6.)

2.5 MATERIAL COEFFICIENTS

2.5.1 Introduction

All core material coefficients were measured on a calibrated control rod at room temperature and pressure. Control rod 3 was chosen as the calibrated rod to allow measurements to be made in another section of the core, thereby minimizing core perturbations due to rod motion; also, preliminary investigation indicated that the calibration curve for rod 3 in the region above 10 in. withdrawal is smooth and essentially linear. A zero reference position was established by substituting a standard SM-1 Core I element into position 76 and placeing element 76 in position 22. This procedure leaves element No. 22 free for substitution measurements into other positions in the core. Using the above configuration, rod 3 was placed at 12.000 in. and a six rod bank (A, B, C, 1, 2, 4) critical position of 7.565 in. was determined. This six rod bank position was maintained throughout the test series. The calibration curve obtained for control rod 3 during the course of the material coefficient measurements and with the other rods at 7.565 in. is shown in Fig. 2.1.

2.5.2 B-10 Worth

B-10 reactivity coefficients were determined for each element position in the north half of the symmetrical core. Fuel element 22 was substituted successively for each fuel element in the north half of the core and the reactor brought critical on control rod 3 with the remaining bank (A, B, C, 1, 2, 4) located at 7.565 in. to establish a zero or reference critical position. Element 22 was then removed from the core and one strip of boron-impregnated Mylar tape was added to each of the fuel plates of element No. 22 for a total of 0.4716 gm B-10 added.[6] Then, element 22 was substituted successively for the second time into the stationary fuel element positions in the north half of the core and the reactor brought critical on control rod 3 as before. From the measured difference in control rod 3 critical positions, with and without the incremental addition of boron to each stationary position, and from the measured control rod 3 worth, the core reactivity change resulting from the addition of a known amount of boron was obtained. For the control rods, one strip of boron tape was added to each of the fuel plates of control rod 4 fuel element, giving an equivalent of 0.3857 gm B-10.[6] This element was then interchanged with other control rod fuel elements for the positions under consideration. These reactivity differences, ranging from 5 to 22 cents, were divided by the B-10 content of the additional tapes (0.0752 gm/cm^2) to obtain the B-10 worth in cents per gram for the various positions in the core. Results are presented in Table 2.2. Symmetry relationships may be used to obtain B-10 worths for the element positions not shown in the table.

Inspection of Table 2.2 reveals an assymetry of B-10 worth distribution where the average worth for the northeast quadrant is approximately 10 percent greater than that for the northwest quadrant. This effect is a result of the assymetric control rod distribution.

Differences in B-10 worths between Table 2.2 and those previously reported [4], [6] are attributed to the difference in the techniques of measurement employed in the respective tests and to differences in the bank positions. In the previous tests, [4] the entire boron loading was stripped from selected fuel plates and reactivity difference measurements taken to obtain the average B-10 worth of the entire boron loading at the selected position for measurement. Subsequent survey tests indicated a strong dependency of B-10 worth upon total B-10 loading, where the worth decreases with increased B-10 loading. In the present series, the test method was modified to render a measure of the core reactivity change that results from changing the B-10 loading an incremental amount near the design loading, thus allowing more accurate engineering estimates to be made of the core reactivity effects which may be expected from loading variations about the design point and minimizing self shielding effects. Comparison of Table 2.2 with the earlier data (ref. APAE-54[4] Tables 3.3 and 4.5) illustrates the effects of decreasing B-10 worth with increasing core poison and fuel loading.

TABLE 2.2
B-10 REACTIVITY COEFFICIENTS
UTILIZING SM-2 MOCKUP FUEL ELEMENTS IN AN SM-1 CORE CONFIGURATION

Element Position	B-10 Worth in Cents/gm
12	9.72
13	13.85
14	13.59
15	14.16
16	11.01
21	9.75
22	16.69
23	25.87
25	33.38
26	23.85
27	12.53
31	13.13
32	25.25
34	42.62
35	46.84
36	29.69
37	15.41
41	15.99
43	41.33
24 Control Rod 1	31.28
33 Control Rod A	33.76
42 Control Rod 4	31.66
44 Control Rod C	46.69
Average for stationary fuel elements	21.82
Core Average	23.76

2.5.3 U-235 Worth

For the U-235 reactivity coefficients, the basic 18 fuel plates of element 22 with 46.3 gm U-235 each were replaced with 18 heavily loaded plates containing 48.6 gm U-235 each. This provided a net difference of 41.40 gm U-235 in element 22 for the test series. The same reference core composition (ref. Section 2.5.1) used in the B-10 coefficient measurements was retained for the U-235 coefficient measurements. The change in reactivity resulting from placing the heavily loaded element 22 into other element positions was determined on the calibrated control rod 3, Fig. 2.1, with the six rod bank (A, B, C, 1, 2, 4) maintained at 7.565 in. The results of the measurements for the positions determined are given in Table 2.3.

TABLE 2.3
U-235 REACTIVITY COEFFICIENTS

Element Position	U-235 Worth, Cents/gm
14	0.081
34	0.210
41	0.090
43	0.298

To obtain an estimate of the average worth of U-235 in the core, the ratio of the U-235 coefficient to the B-10 coefficient for the four positions in Table 2.3 was multiplied by the average B-10 worth in the core. This method is justified, because the B-10 and the U-235 worth measurements were obtained under identical core test conditions and the U-235 worth measurements are representative of core radial distributions and fuel plate orientation. The average U-235 worth thus obtained was 0.129 cents/gm for stationary fuel elements and 0.141 cents/gm for the whole core.

2.6 SIMULATION OF OPERATING CONDITIONS AND TEMPERATURE CONTROL

2.6.1 Introduction

Since it is not possible to operate the ALCO Critical Facility at the operating conditions of the SM-1 reactor, 440°F and 1200 psi, it was necessary to simulate these effects to obtain an estimate of control rod bank worth under operating core conditions and to evaluate the core reactivity change associated with raising core temperature and pressure from room to simulated operating conditions. Operation at elevated temperature and pressure causes a loss in moderator density and a consequent loss in core reactivity. The relationship of moderator temperature vs. density is presented in Fig. 2.2. The reduced effective water density was simulated by inserting 2.266 x 0.0154 x 23.0 in. aluminum strips. Figure 2.3 shows the number of aluminum strips per fuel element required to simulate elevated temperatures at 1200 psi pressure.

2.6.2 Five and Seven Rod Bank Position and Calibration at Simulated Elevated Temperature and Pressure

Table 2.4 lists the equivalent core water temperature, the corresponding number of aluminum strips used and the effect on the critical bank position. Except for Case 1, the initial, cold, clean, critical bank position, which was obtained at room temperature and pressure, all other measurements were made at simulated 1200 psi pressure. At a simulated 440°F and 1200 psi in the core and in the water inside the control rod absorbers, the seven rod bank critical position was 11.306 in.; the five rod bank critical position (rods A and B fully withdrawn) was 10.447 in.

The five and seven critical bank positions as a function of simulated core temperature are presented in Fig. 2.4. Following each critical position, the rods were raised to calibrate the bank by the period method. The bank displacement was affected by the addition of aluminum strips until a simulated 440°F and 1200 psi was reached. Figure 2.5 illustrates the bank worth in cents per inch of the five and seven rod bank vs. bank position. The bank positions illustrated in Fig. 2.5 were obtained by changing the simulated core temperature until operating core conditions were obtained and the five and seven rod bank positions were 10.447 and 11.306 in. withdrawn respectively. Beyond those respective bank positions, the control rod bank location was varied by the removal of fuel and the insertion of boron while maintaining a constant metal to water ratio. As a consequence of the test methods employed, the rod calibration curves of Fig. 2.5 are slightly temperature dependent over the approximate range between 7 and 11 in. withdrawn and are slightly core composition dependent beyond 11 in. Comparison of these data with those previously collected (ref. 4, Fig. 3.1) indicates that while the control rod worth variation with core temperature and composition is a measurable effect, it is not a strongly dependent function.

2.6.3 Reactivity Change Due to Operation at 440°F and 1200 psi

Operation at elevated temperature and pressure causes a loss in core reactivity. Figure 2.6 presents the change in reactivity at simulated elevated water temperatures and 1200 psi pressure. These values were obtained by integrating segments of the seven rod bank calibration curve, Fig. 2.5. The loss in reactivity due to operation at 440°F and 1200 psi from that at room conditions is approximately 7.3 dollars. The excess reactivity available at operating conditions, approximately 10.1 dollars, is obtained by integrating the seven rod bank calibration curve, Fig. 2.6, from the operating position of 13.306 in. to the fully withdrawn position.

TABLE 2.4

CRITICAL BANK POSITIONS AT SIMULATED ELEVATED TEMPERATURE AND PRESSURE

Case	No. of Aluminum Strips per Element: Stationary	No. of Aluminum Strips per Element: Control Rod	Temperature °F: Stationary	Temperature °F: Control Rod	Average Simulated Core Temp. °F	Seven Rod Critical Bank Position Inches	Five Rod Bank Critical Position (Rods A & B Fully Withdrawn) Inches
1	0	0	Room Temperature and Pressure			8.040	6.940
2	3	3	154	155	154	8.309	7.254
3	6	6	200	202	200	8.587	7.566
4	14	14	298	304	299	9.383	8.450
5	19	19	348	353	349	9.960	9.070
6	30	29	440	438	440	11.379	10.572
7*	30	29	440	438	440	11.306	10.447

* 25 aluminum strips added to each absorber section to bring the equivalent water temperature in the absorber sections to 440°F.

2.6.4 Temperature Coefficients

The differential of the curve shown in Fig. 2.6 is the approximate temperature coefficient of reactivity at the temperature corresponding to that point. The results of the temperature coefficient vs. temperature are plotted in Fig. 2.7 along with that previously obtained for the SM-1 Core I.[10] The temperature coefficient at 440°F and 1200 psi was -3.9 cents per °F as compared to -3.6 cents per °F for the SM-1 Core I.

2.7 POWER DISTRIBUTION MEASUREMENTS

2.7.1 Introduction

The relative power distribution in the SM-1 core configuration with SM-2 elements was obtained by uranium foil activation measurements employing the experimental method and procedure described in Section 1.4.5 and the nomenclature reported in Section 1.3.6. Approximately 2000 data points were taken in one half of the symmetrical core, yielding the core average and a detailed description of local effects. All power distribution data were collected while operating with the seven rod bank withdrawn to 8.04 in. All measurements were made with stationary fuel elements that did not contain flux suppressors and with control rod fuel elements equipped with 0.5 in. mockup suppressors at the top of the active meat.

2.7.2 Core Average

The average power generation in the core was obtained using the procedure described in Section 1.4.5 and in APAE-54, Supplement 1.[6] Each data point reported in this chapter is normalized to the average power generation; thus, those data points equal to the core average become unity by definition.

2.7.3 Experimental Data and Discussion of Results

Figure 2.8 gives the complete normalized cell power averages in the core. Of the 45 core positions, 12 stationary fuel elements clustered about the center of the core exceed the core average. The cell averages for the control rod fuel elements are reported as less than the core average even though they have a higher than average power density over the region. They were weighted to include only the portion of the fuel plates actually in the active core, at a seven rod bank critical position of 8.04 in. Figure 2.8 illustrates the assymmetry introduced into the SM-1 core power distribution as a result of operating the core on the close packed seven rod bank and compares it to previous similar measurements obtained with the symmetrical open seven control rod array.[6] Based upon these measurements, obtained with the close packed seven rod bank and in the cold, clean core, the northeast core quadrant will operate at an average power level approximately 16 percent greater than the northwest quadrant.

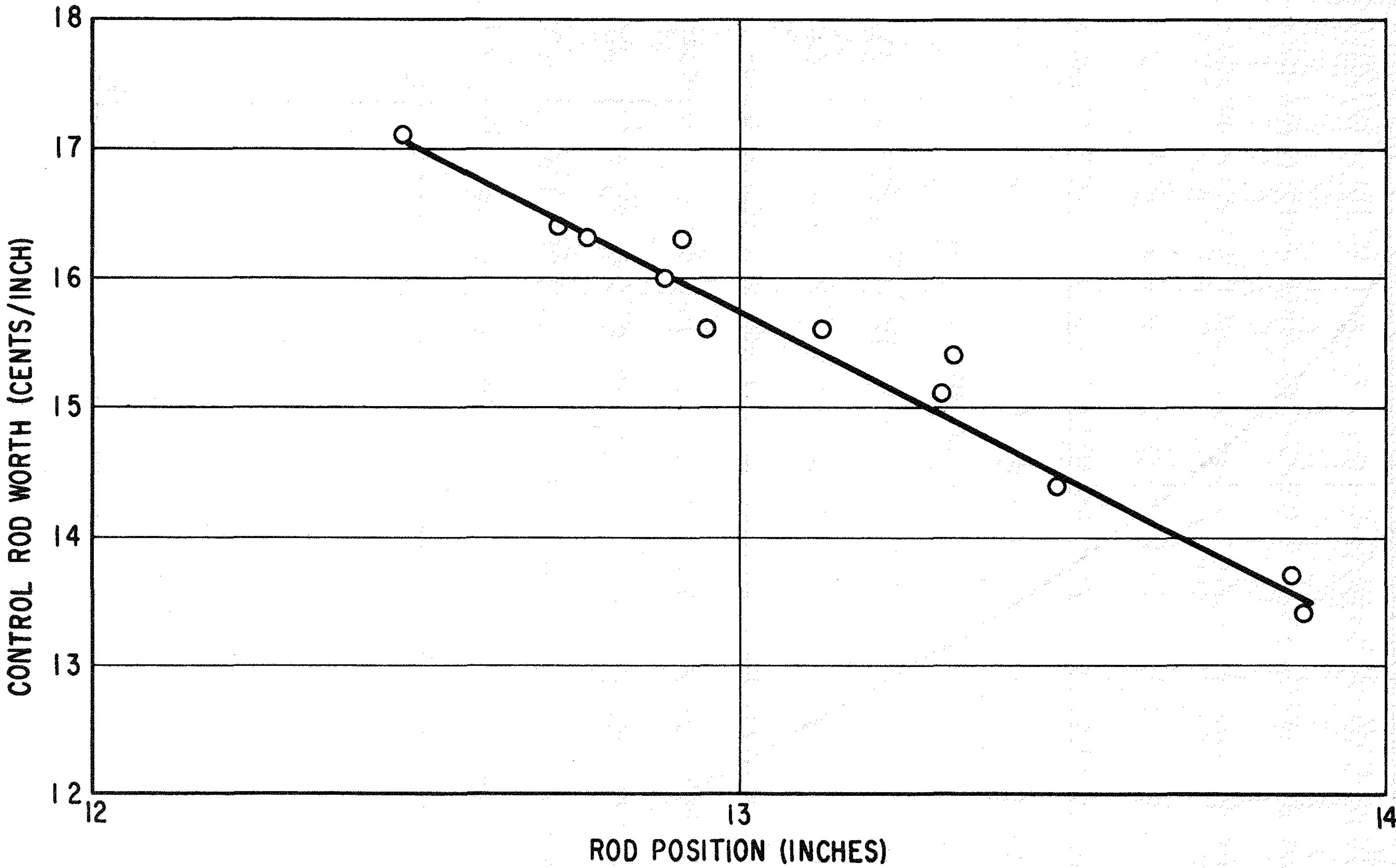


Figure 2.1. Control Rod 3 Worth Vs. Location with the Six Rod Bank Located at 7.565 Inches - SM-1 Configuration with SM-2 Elements

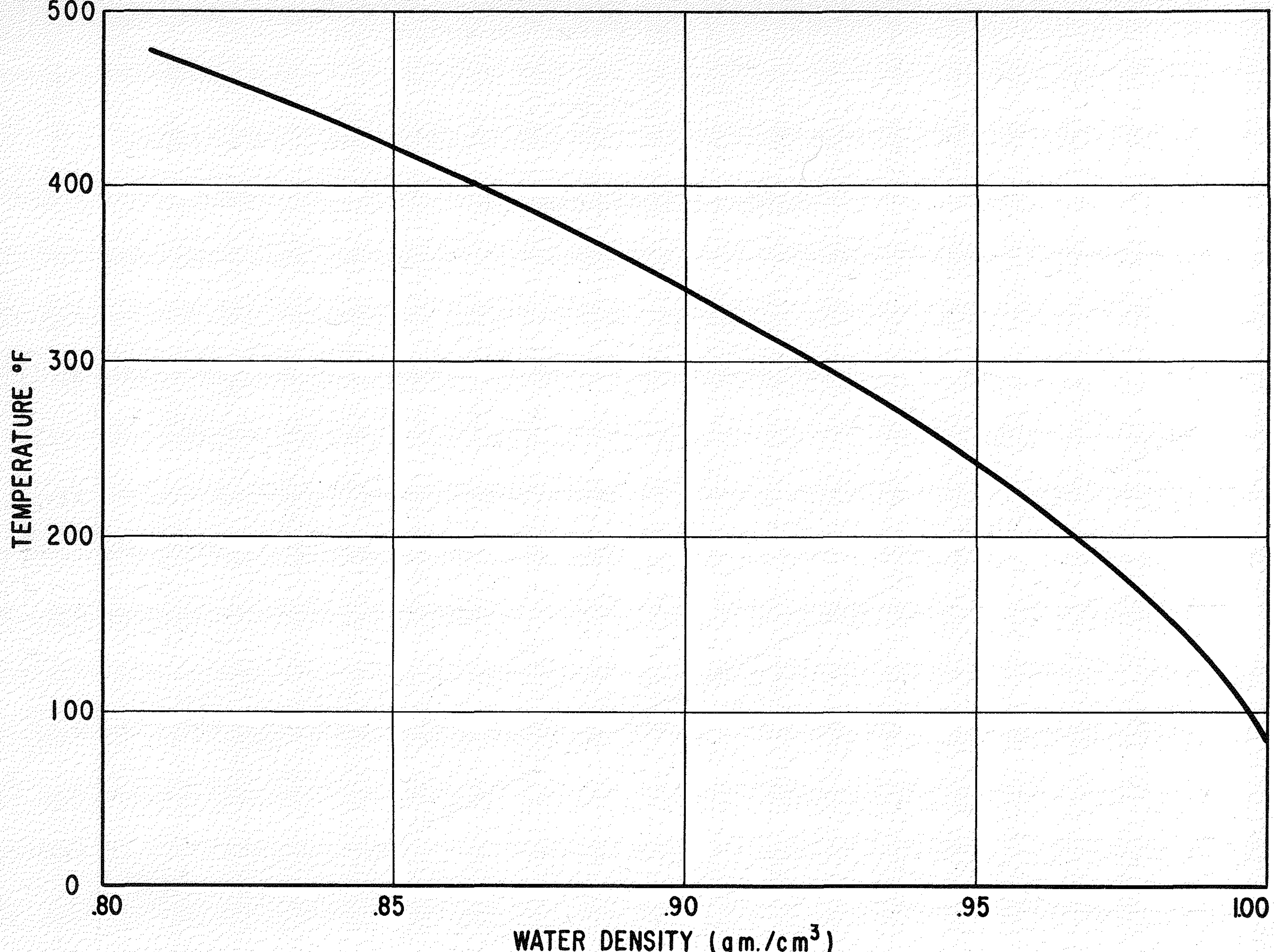


Figure 2. 2. Density of Water as a Function of Temperature at a Constant Pressure of 1200 PSI

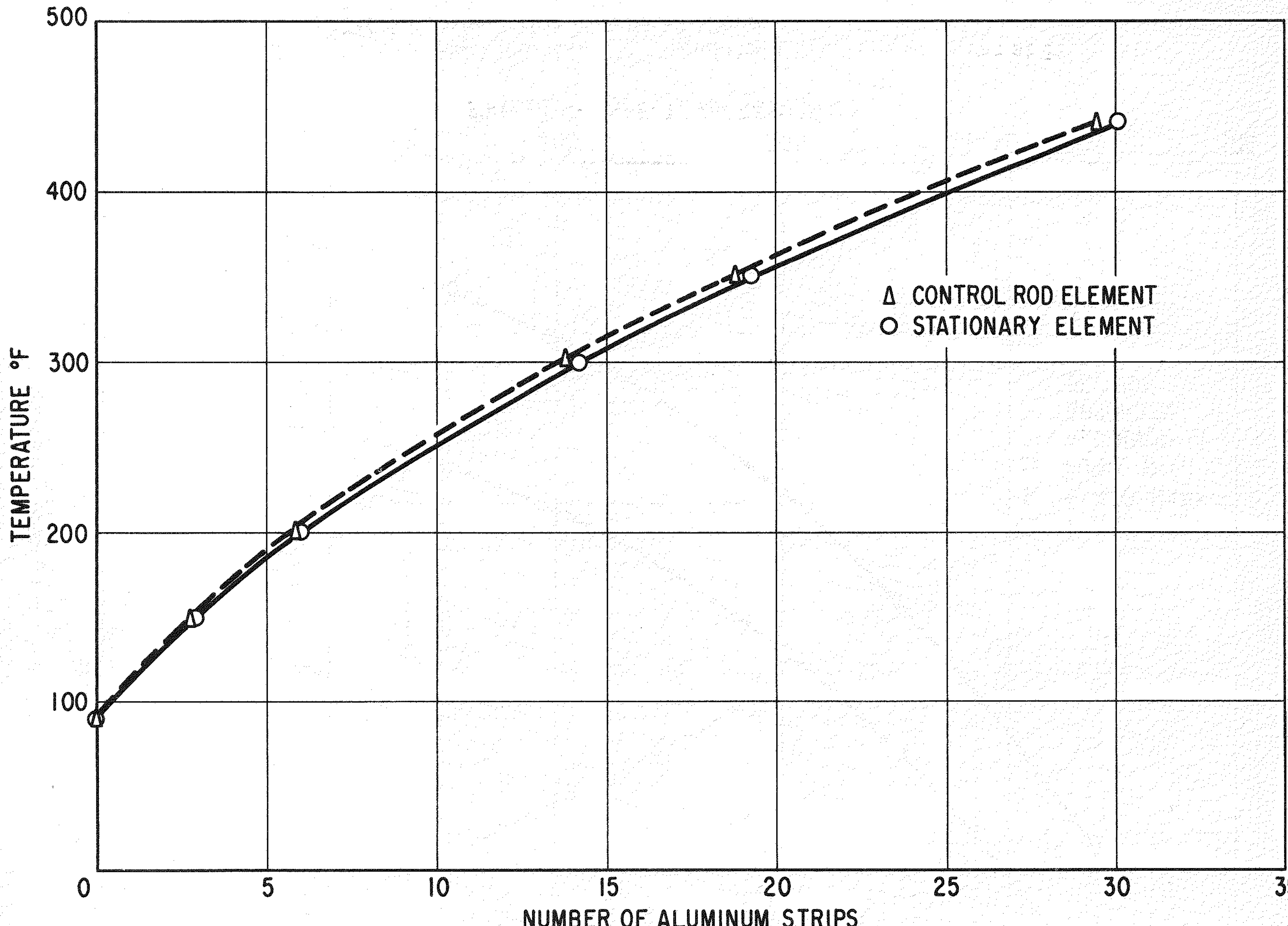


Figure 2.3. Number of Aluminum Strips per Fuel Element Required to Simulate Moderator Temperature at 1200 PSI - SM-1 Configuration with SM-2 Elements

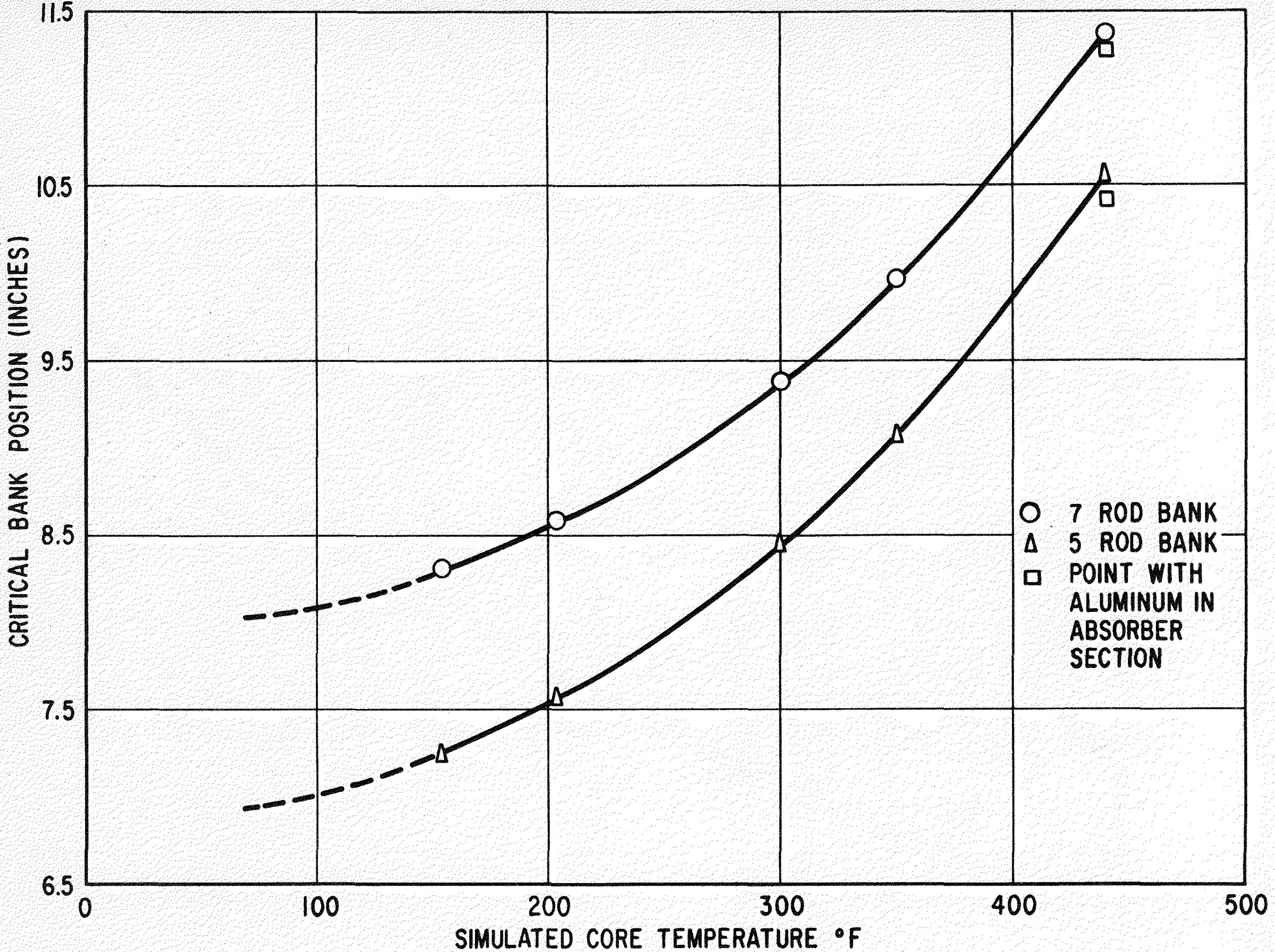


Figure 2. 4. Critical Bank Position Vs. Simulated Core Temperatures at 1200 PSI - SM-1 Configuration with SM-2 Elements

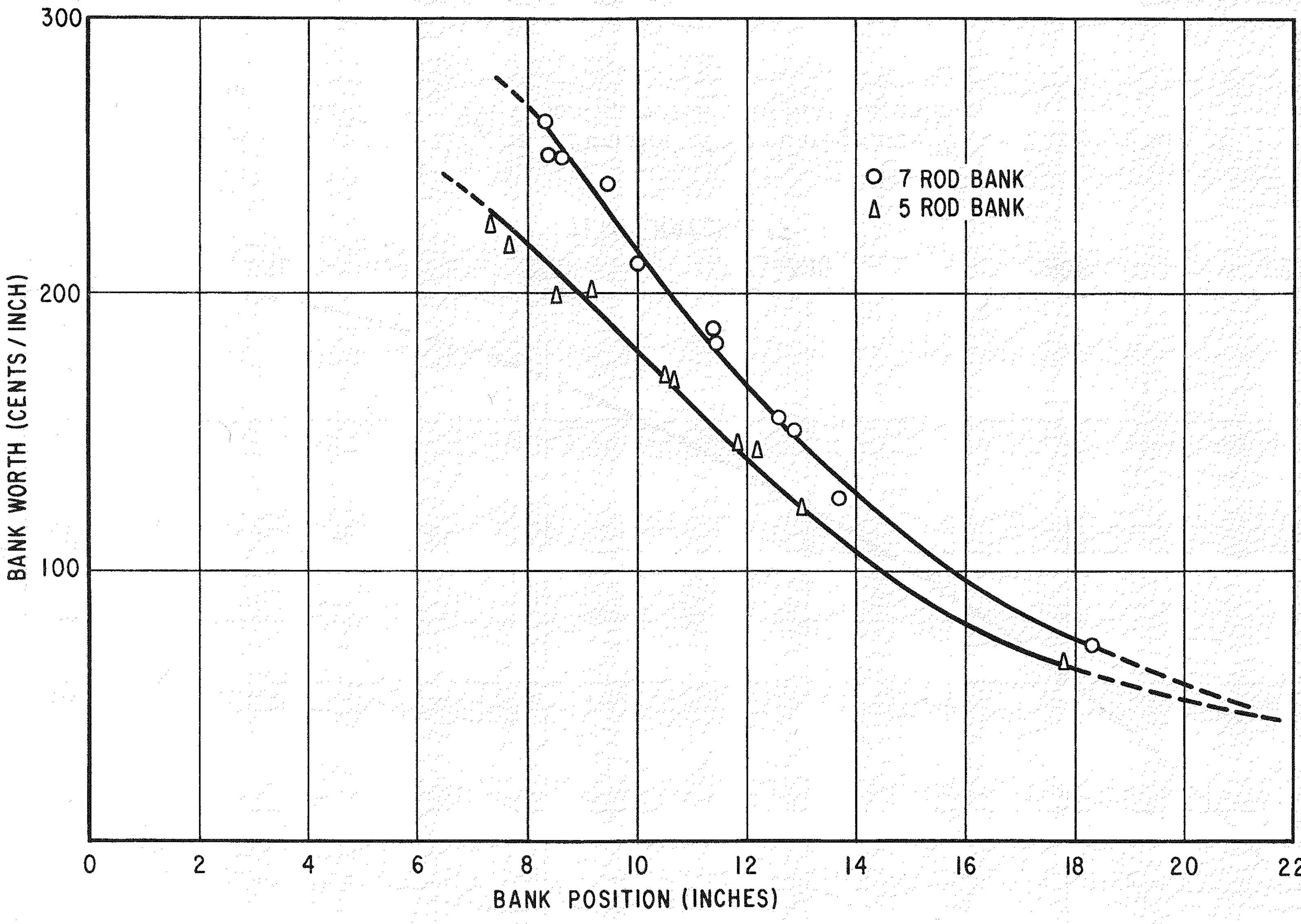


Figure 2. 5. 5 and 7 Control Rod Bank Worth Vs. Bank Locations - SM-1 Configuration with SM-2 Elements

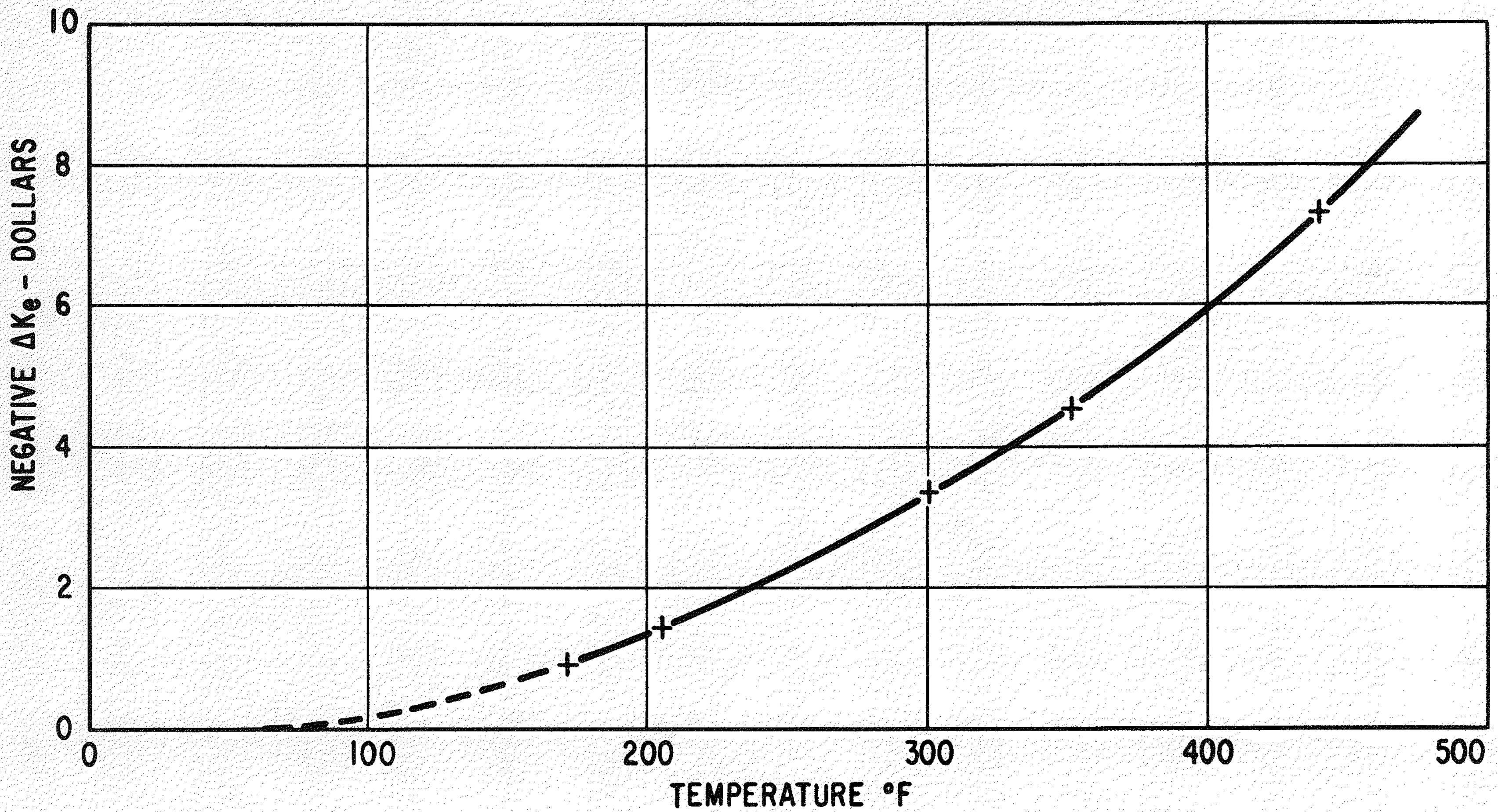


Figure 2. 6. Negative ΔK_e as a Function of Simulated Core Water Temperature at 1200 PSI - SM-1 Configuration with SM-2 Elements

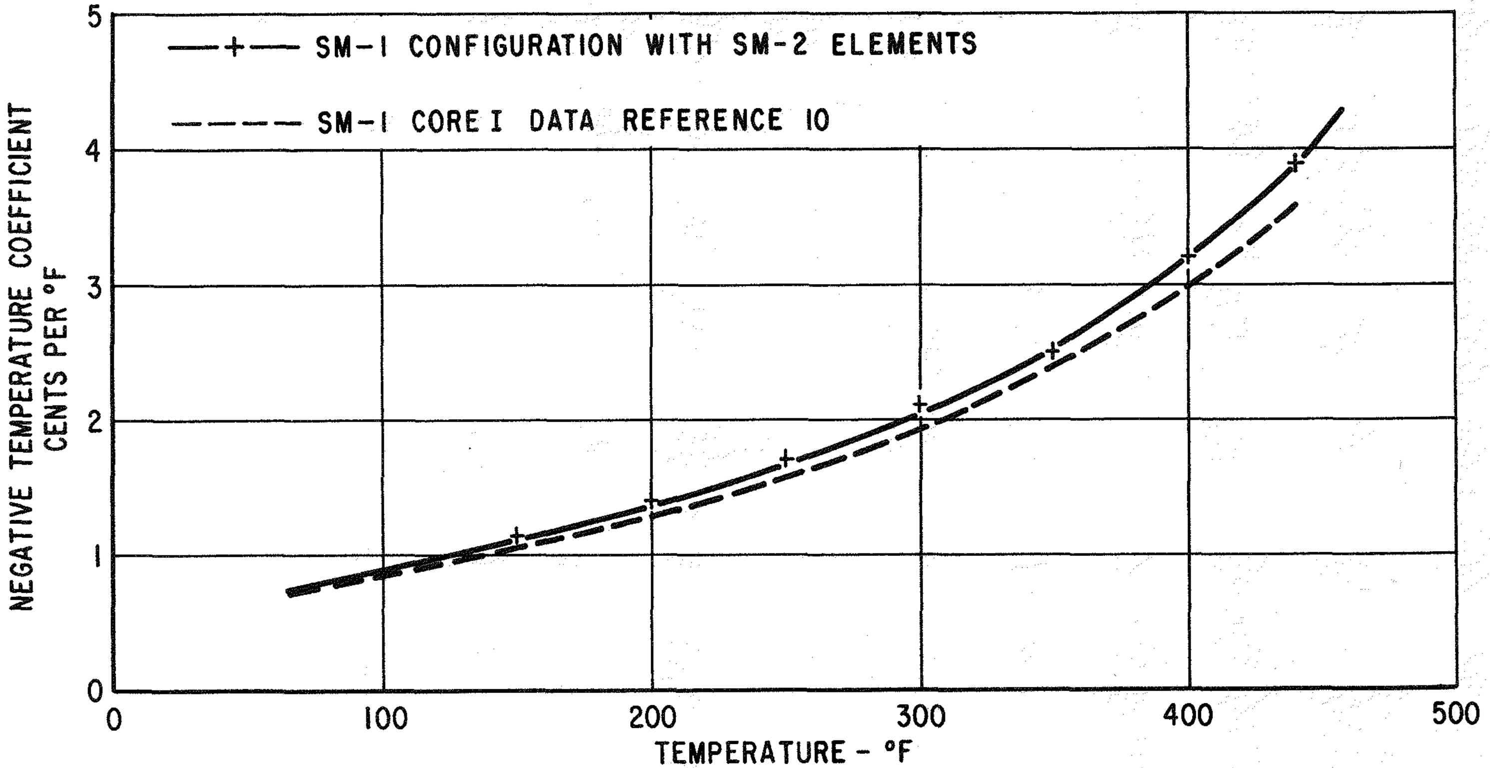


Figure 2. 7. Negative Temperature Coefficient Vs. Core Water Temperature at 1200 psi

Core Loading
36.4 Kg U-235
67.9 gm B-10

Critical Bank Position
8.04 in. - 7 Rod Bank
6.94 in. - 5 Rod Bank (Rods A&B Fully Withdrawn

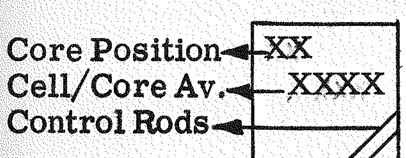
North

West / East

	12 .745	13 .801	14 .835	15 .895	16 .822	
21 .786	22 .880	23 .957	24 Rod 1 .517	25 1.103	26 1.016	27 8.37
31 .844	32 .936	33 Rod A .587	34 1.204	35 1.318	36 1.157	37 .853
41 .877	42 Rod 4 .510	43 1.195	44 Rod C .660	45 1.225	46 Rod 2 .500	47 .851
51 .853	52 1.157	53 1.318	54 1.204	55 Rod B .587	56 .936	57 .844
61 .837	62 1.016	63 1.103	64 Rod 3 .517	65 .957	66 .880	67 .786
	72 .822	73 .895	74 .835	75 .801	76 .745	

50 Mil Skirt

South



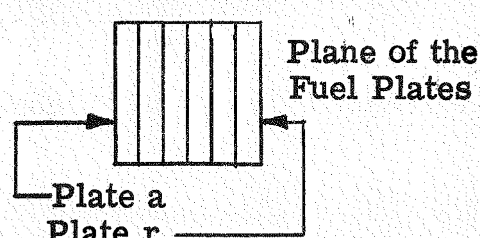


Fig. 2.8 - SM-1 Cell Power Averages Normalized to a Core Average of Unity; SM-2 Elements

This is principally an effect of higher control concentration in the northwest quadrant, where an effective 2.25 control rods are concentrated, compared to an effective concentration of 1.25 control rods in the northeast quadrant.

Tables 2.5 through 2.25 present the normalized power distribution along axial traverses of fuel plates a, j, and r of stationary elements in the north half of the core. Tables 2.26 through 2.30 present data along axial traverses of fuel plates a, i and p of control rods A, C, 1, 2 and 4. The data range from a normalized low of 0.10 of the core average occurring at several points near the top boundary of the core to an internal high of 4.19 times the core average in the center of the core. The overall maximum of 4.68 occurred as a spike at the bottom of the active core of element in position 45 due to the absence of flux suppressors.

The power traverses shown in Fig. 2.9 through 2.16 are typical of the axial power distribution along the specified fuel plates. Figure 2.9 through 2.15 show the power of the centerline traverses of fuel plate j normalized to the core average for stationary fuel elements in the north half of the core. Figure 2.16 shows similar traverses for fuel plate i of control rods A, C, 1 and 4. It may be concluded from the above that all stationary fuel elements exhibit a large power peak at the bottom of the active core due to absence of flux suppressors, and a smaller axial peak about 4 - 6 in. above the bottom of the active core. The power gradually diminishes as it approaches the top of the active core. For example, in element position 45, along centerline of fuel plate j, this power peaking is about 3.5 times the core average at the bottom of the active core and 2.09 times the core average at an axial position 5 in. above it, while it is only 0.14 of the core average at the top of the active core. The power generation in the control rod fuel elements increase from the bottom of the core to the bottom of the flux suppressors, at which point a sharp drop in power density occurs.

Figures 2.17 through 2.20 illustrate typical radial power traverses. Figures 2.17 and 2.18 show the power distribution along radial traverses 5 in. above the active core parallel to the fuel plates and through the center of elements in positions 14, 34, Rod 1 and Rod C and positions 15, 25, 35 and 45 respectively. Figures 2.19 and 2.20 show similar traverses but perpendicular to the fuel plates through center of elements in positions 41, 42, Rod 4, Rod C and 34, 35, 36 and 37 respectively. These results indicate the overall rise in power upon approaching the center of the core and the power minima along the centerline of a fuel element in relation to its outer edges. They also illustrate the power peaking that occurs in the region of the reflector.

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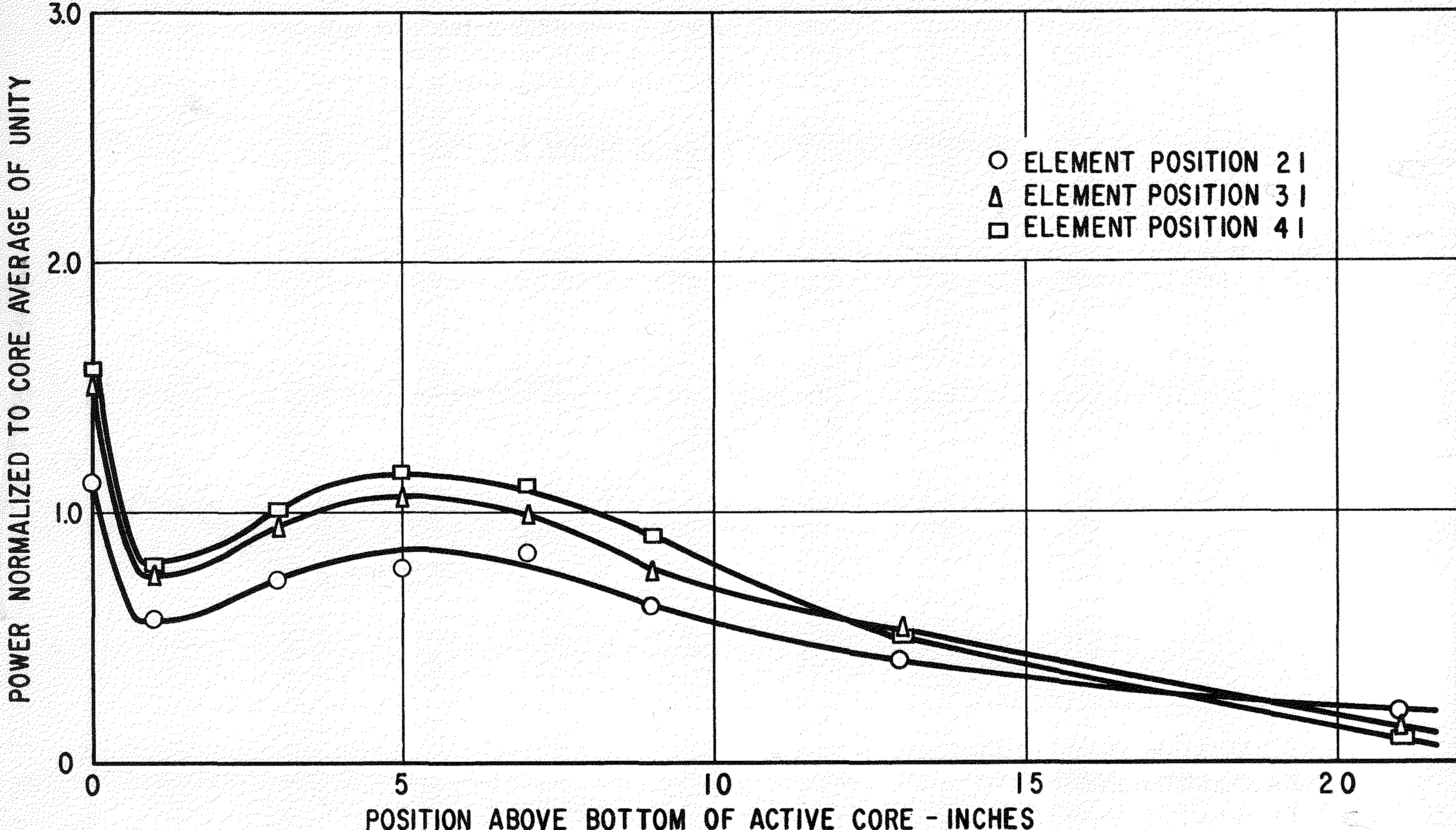

Figure 2.9. Relative Power Distribution Along Axial Traverse on Centerline of Fuel Plate "J" of Elements in Positions 21, 31, 41 - SM-1 Configuration with SM-2 Elements

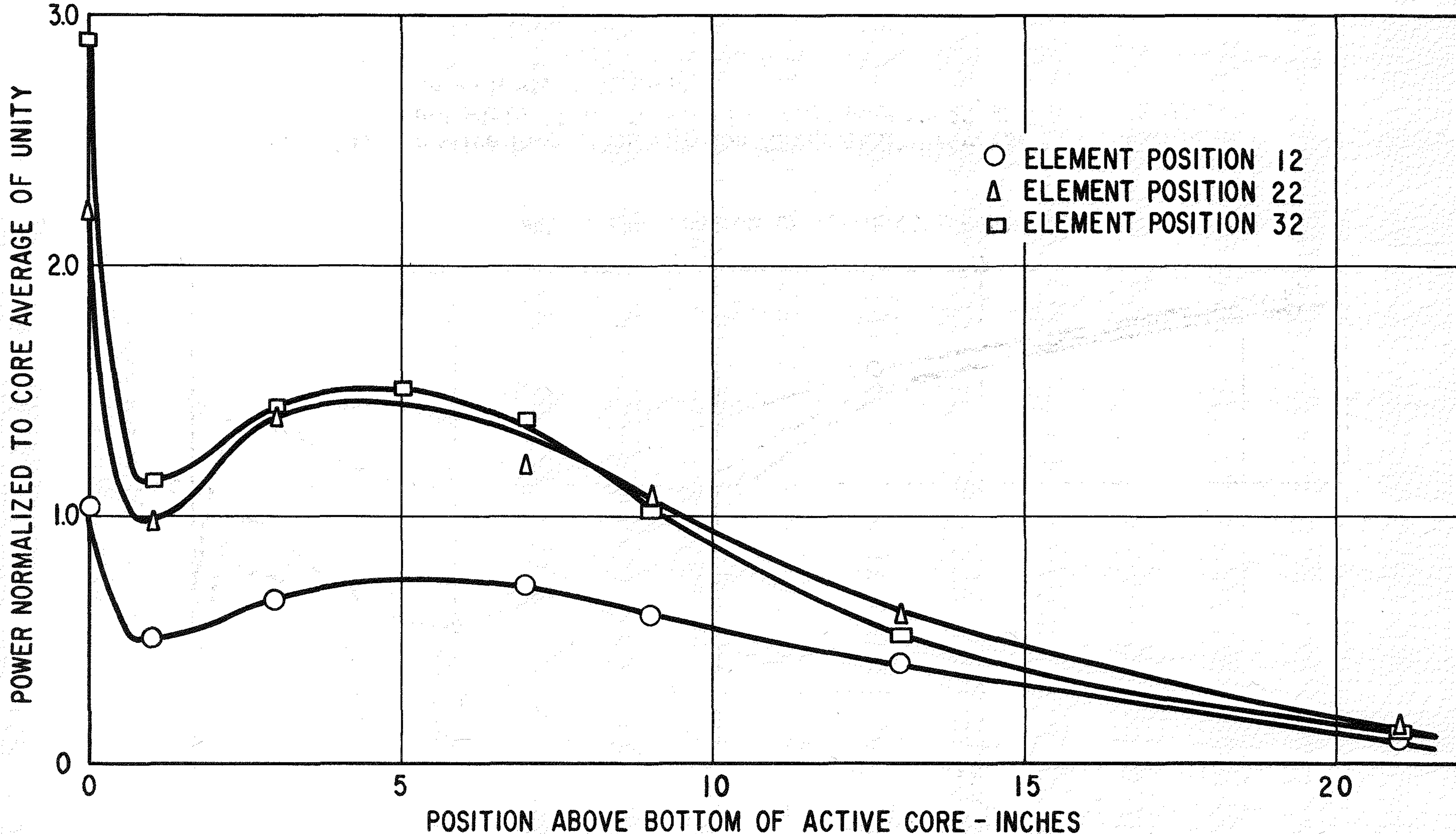

Figure 2.10. Relative Power Distribution Along Axial Traverse on Centerline of Fuel Plate "J" of Elements in Positions 12, 22, 32 - SM-1 Configuration with SM-2 Elements

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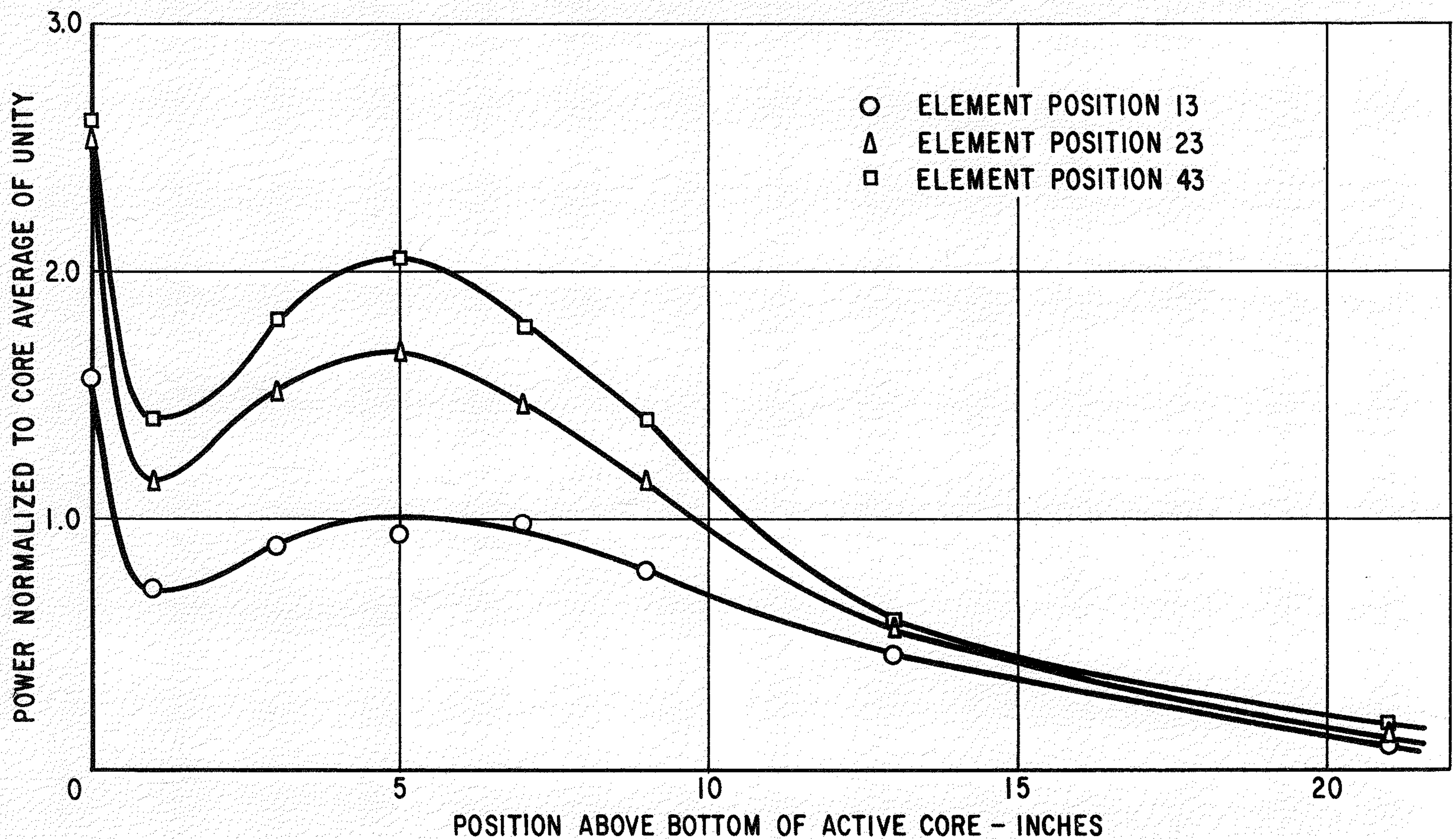

Figure 2.11. Relative Power Distribution Along Axial Traverse on Centerline of Fuel Plate "J" of Elements in Positions 13, 23, 43 - SM-1 Configuration with SM-2 Elements

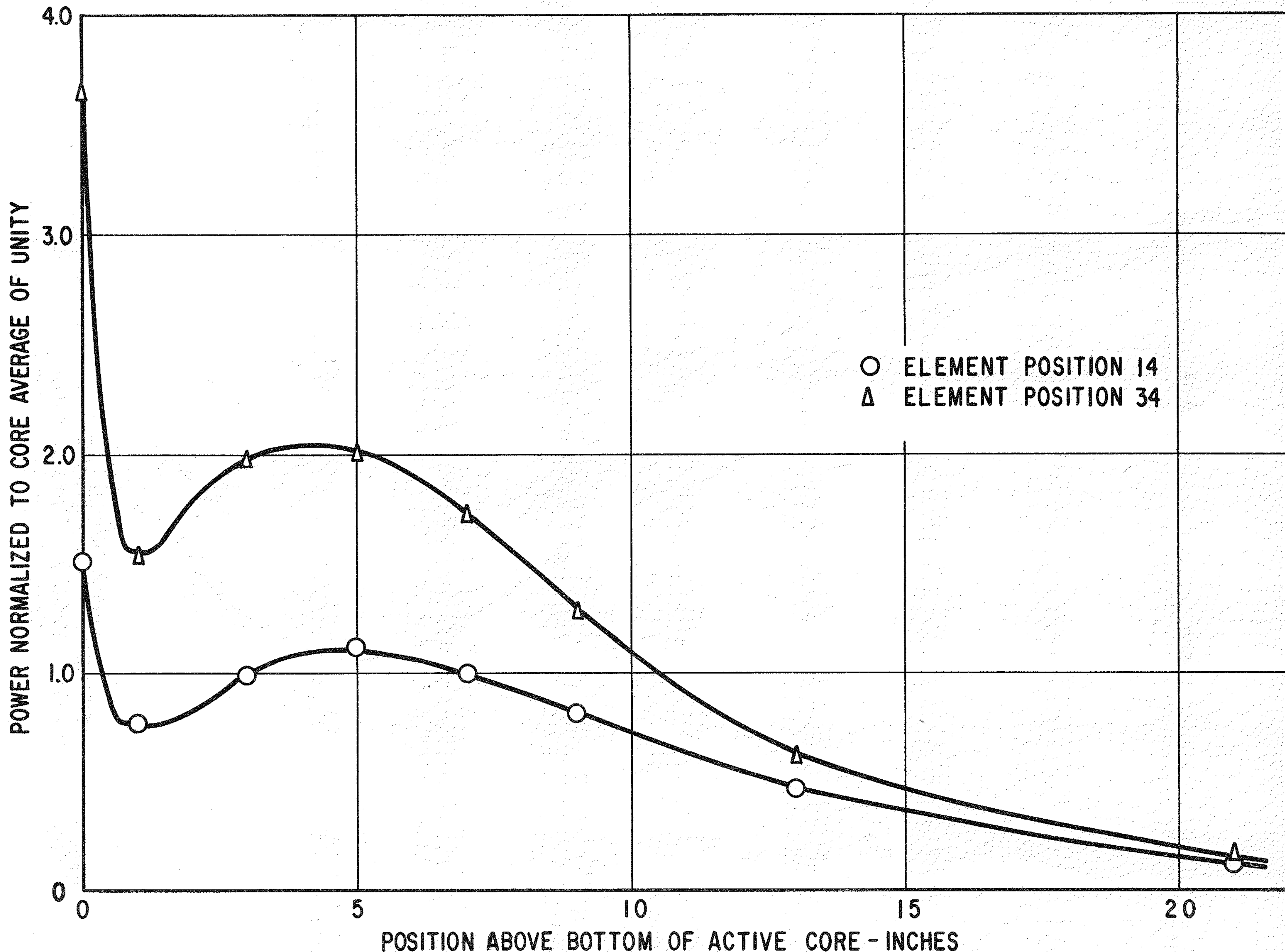

Figure 2.12. Relative Power Distribution Along Axial Traverse on Centerline of Fuel Plate "J" of Elements in Positions 14, 34 - SM-1 Configuration with SM-2 Elements

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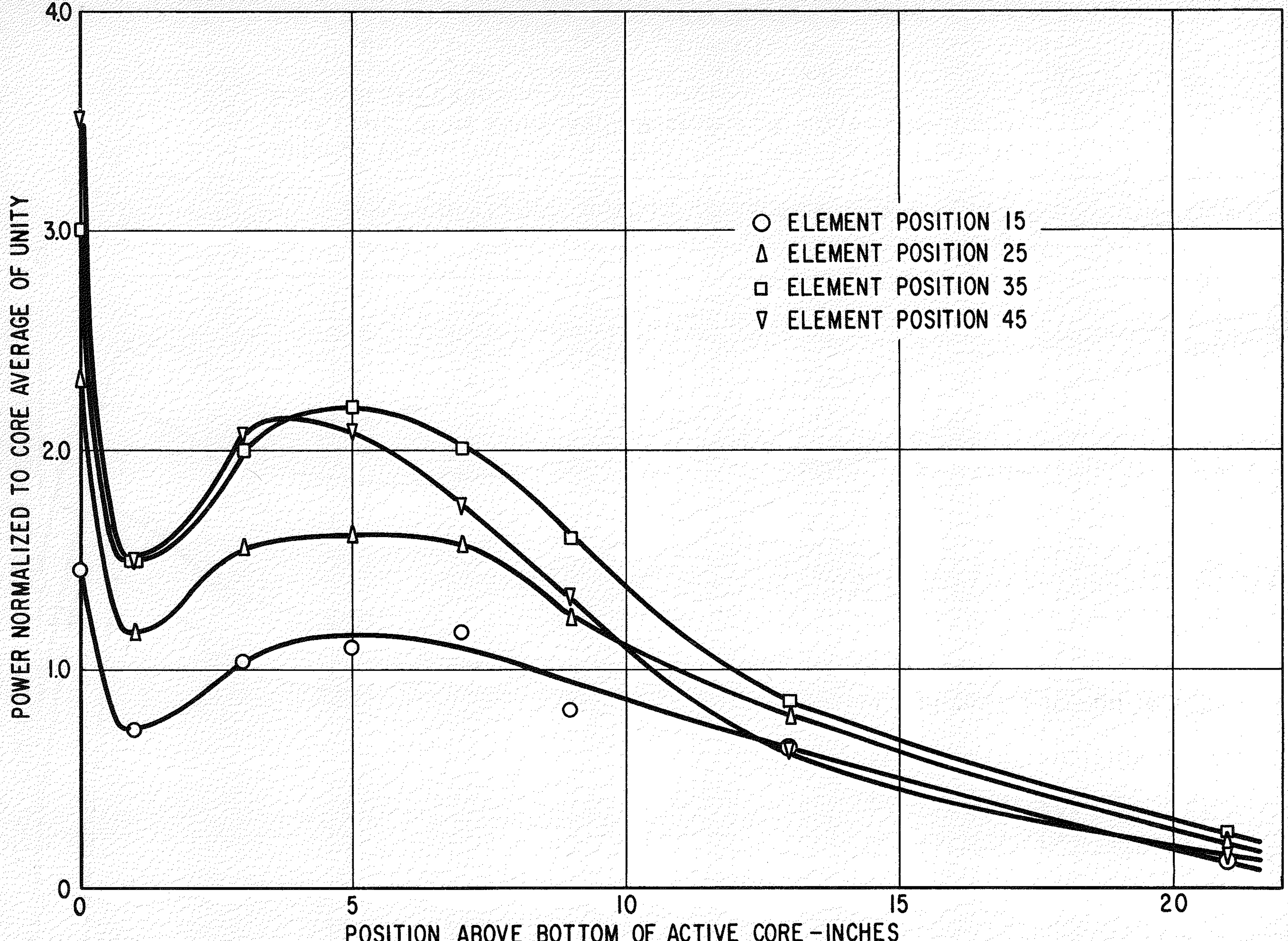

Figure 2.13. Relative Power Distribution Along Axial Transverse on Centerline of Fuel Plate "J" of Elements in Positions 15, 25, 35, 45 - SM-1 Configuration with SM-2 Elements

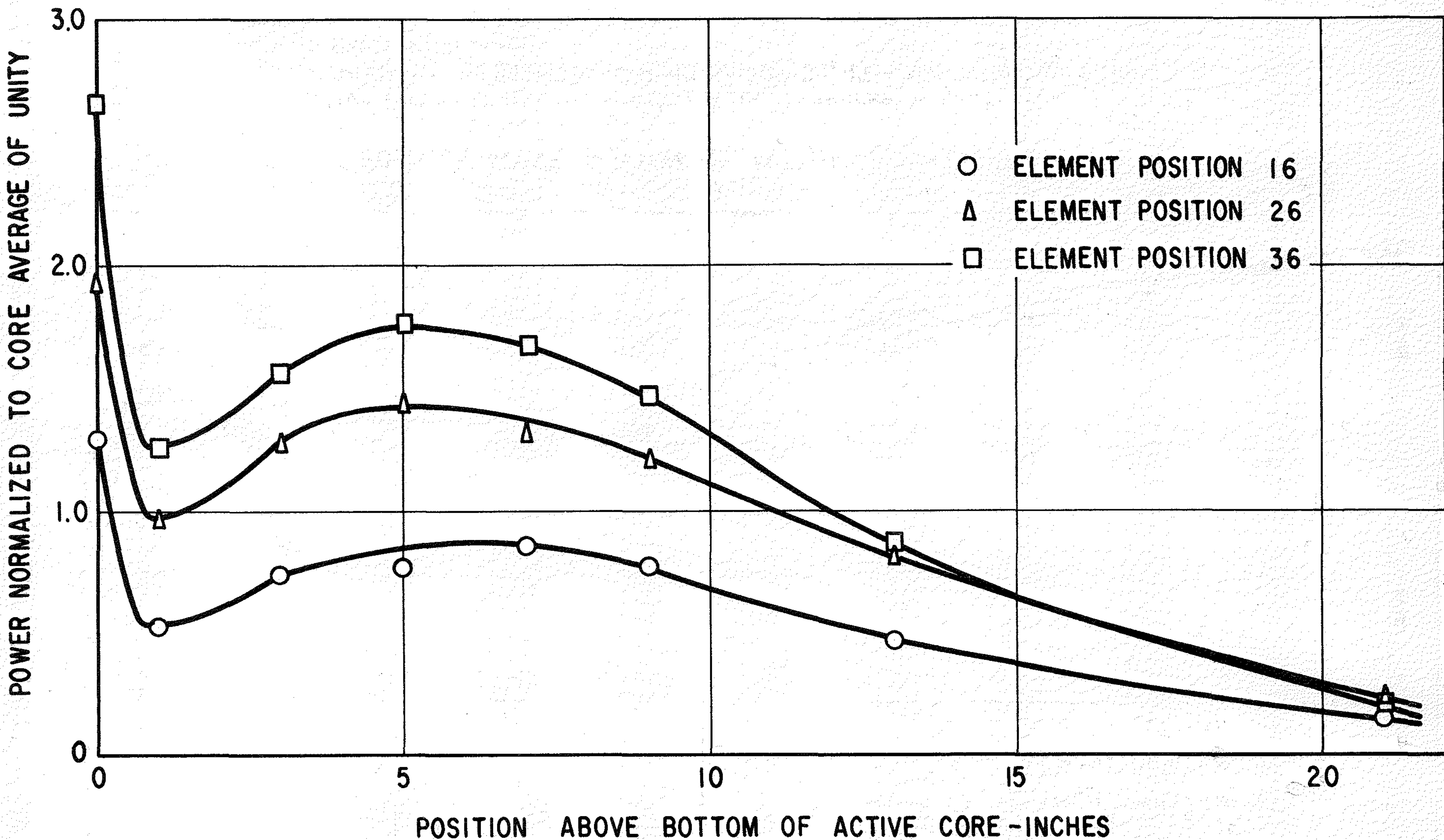

Figure 2.14. Relative Power Distribution Along Axial Traverse on Centerline of Fuel Plate "J" of Elements in Positions 16, 26, 36 - SM-1Configuration with SM-2 Elements

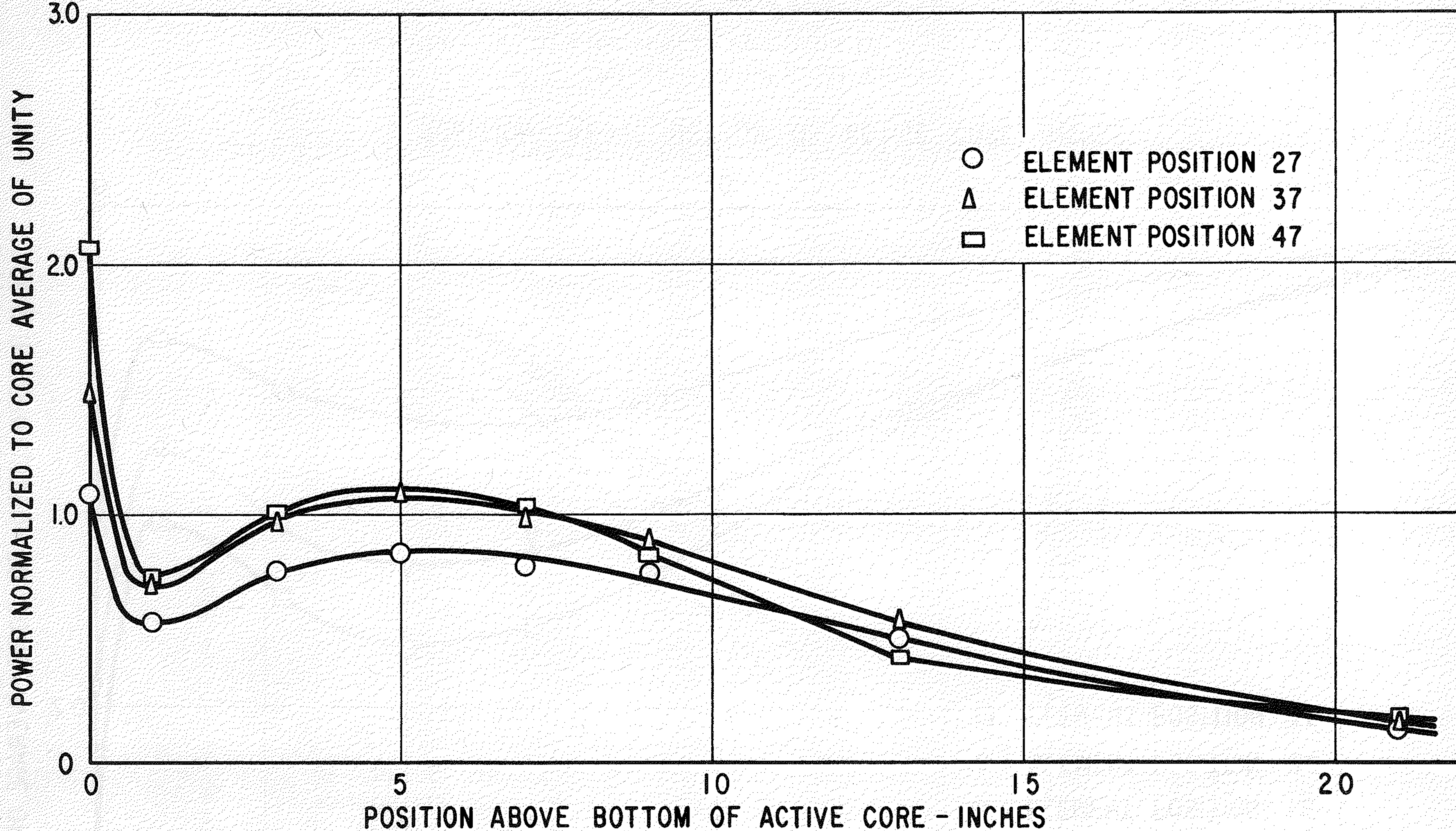

Figure 2.15. Relative Power Distribution Along Axial Traverse on Centerline of Fuel Plate "J" of Element in Positions 27, 37, 47 - SM-1 Configuration with SM-2 Elements

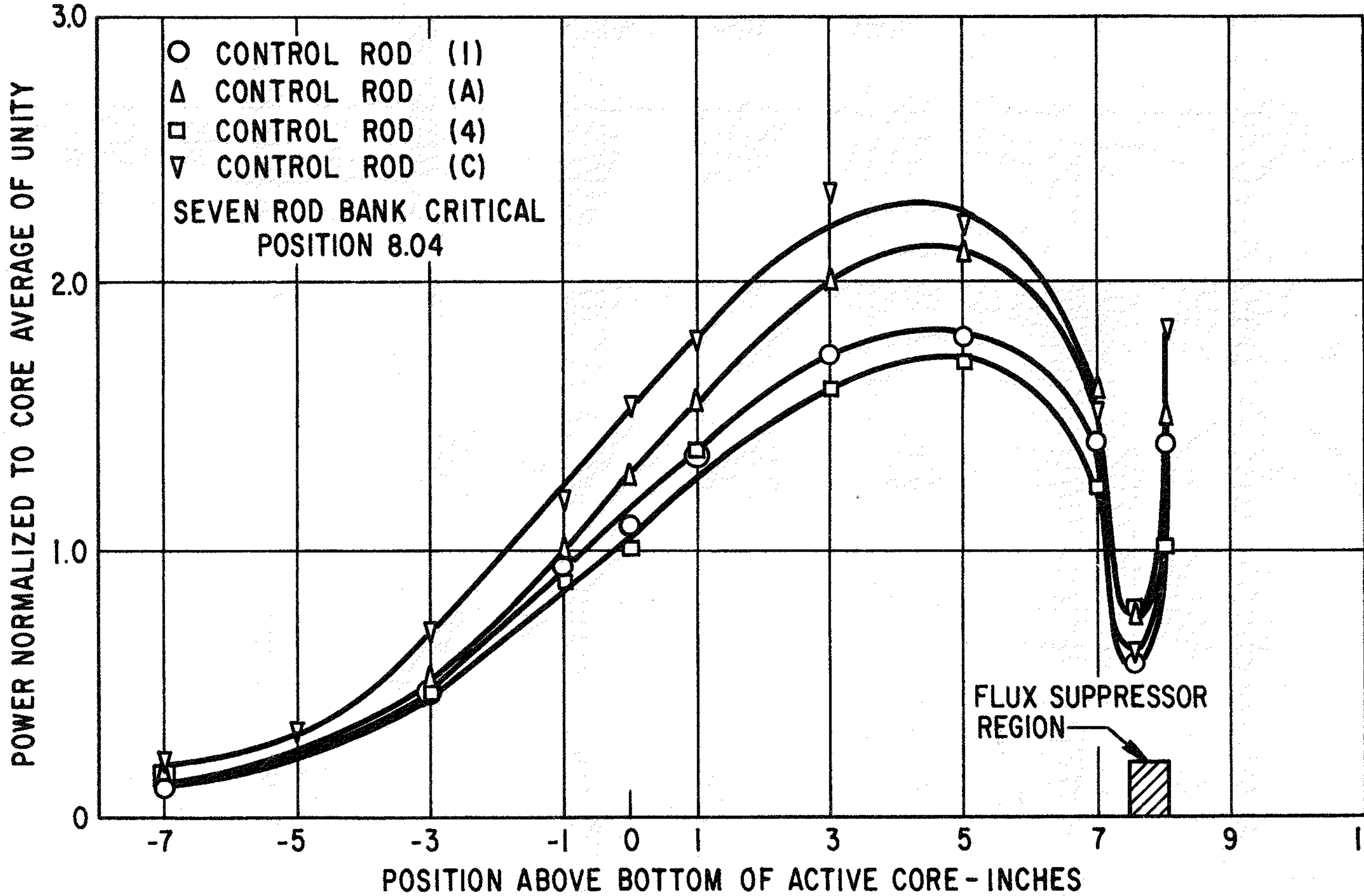

Figure 2.16. Relative Power Distribution Along Axial Traverse on Centerline of Fuel Plate "I" of Control Rods (1), (A), (4), (C) - SM-1 Configuration with SM-2 Elements

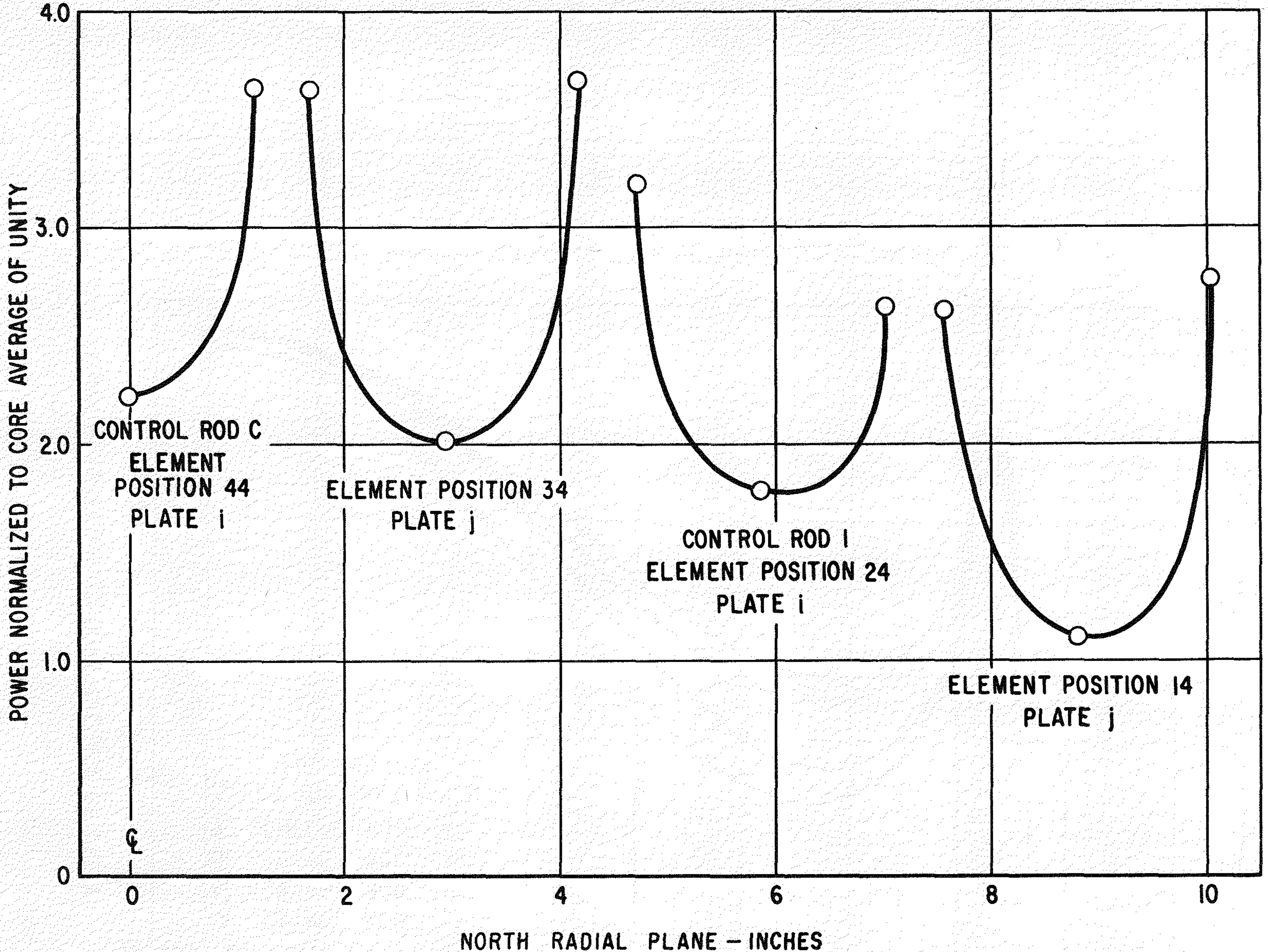

Figure 2.17. Relative Power Distribution Along Radial Traverse Parallel to Fuel Plates, 5" Above Bottom of Active Core Through Center of Elements in Positions 44, 34, 24, 14 - SM-1 Configuration with SM-2 Elements

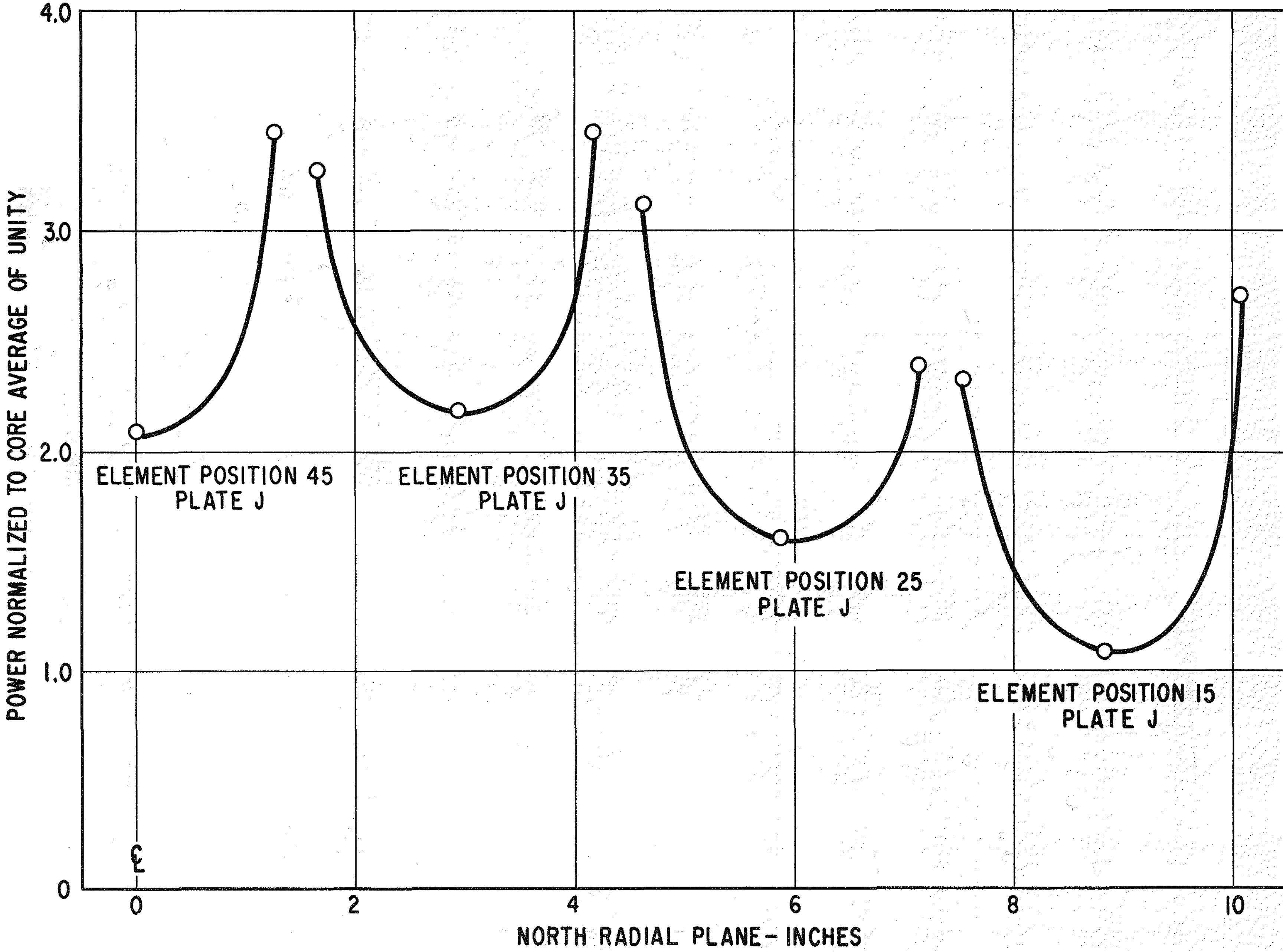

Figure 2.18. Relative Power Distribution Along Radial Traverse Parallel to Fuel Plates, 5" above Bottom of Active Core Through Center of Elements in Positions 45, 35, 25, 15 - SM-1 Configuration with SM-2 Elements

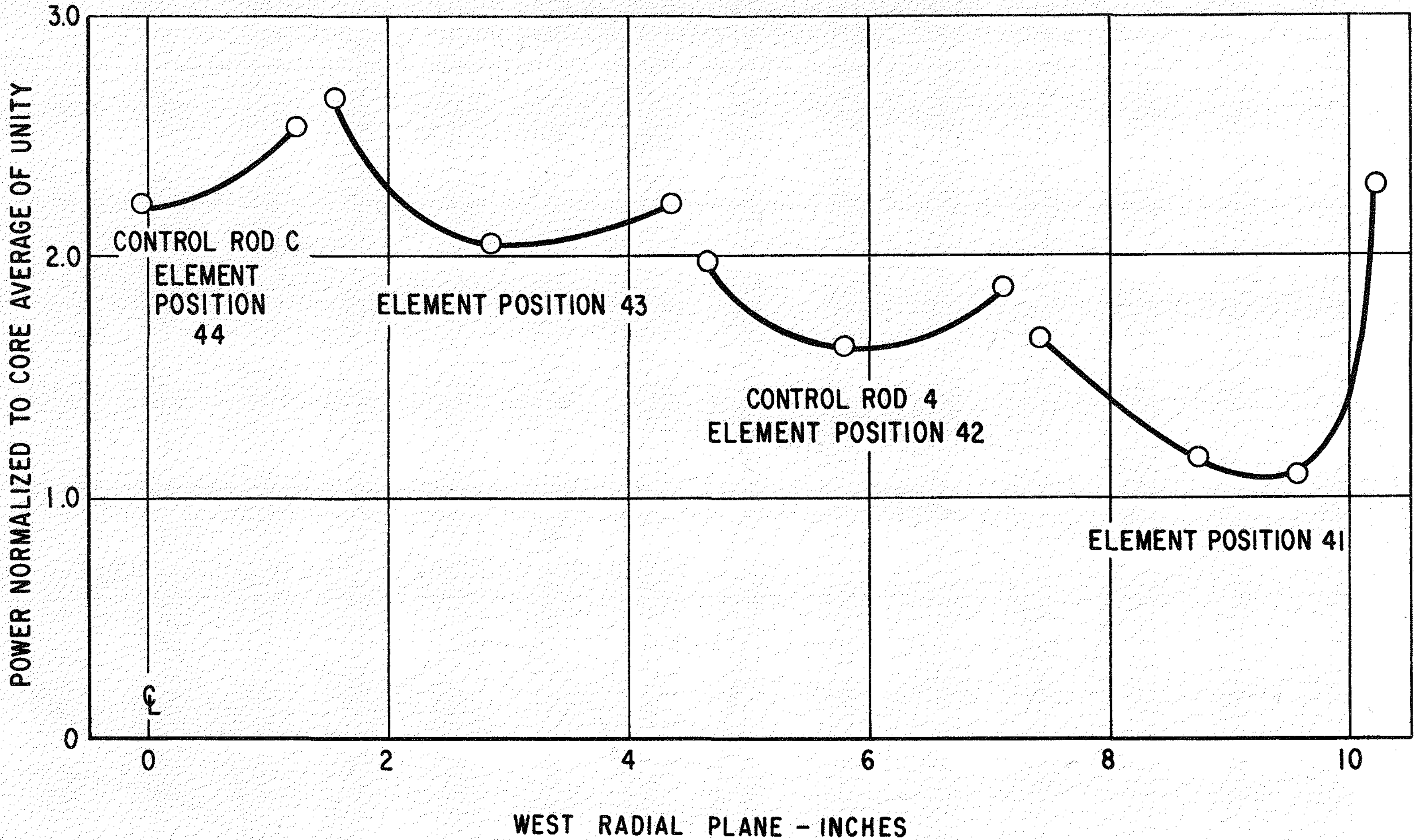

Figure 2. 19. Relative Power Distribution Along Radial Traverse Perpendicular to Fuel Plates 5" Above Bottom of Active Through Center of Elements in Positions 44, 43, 42, 41 - SM-1 Configuration with SM-2 Elements

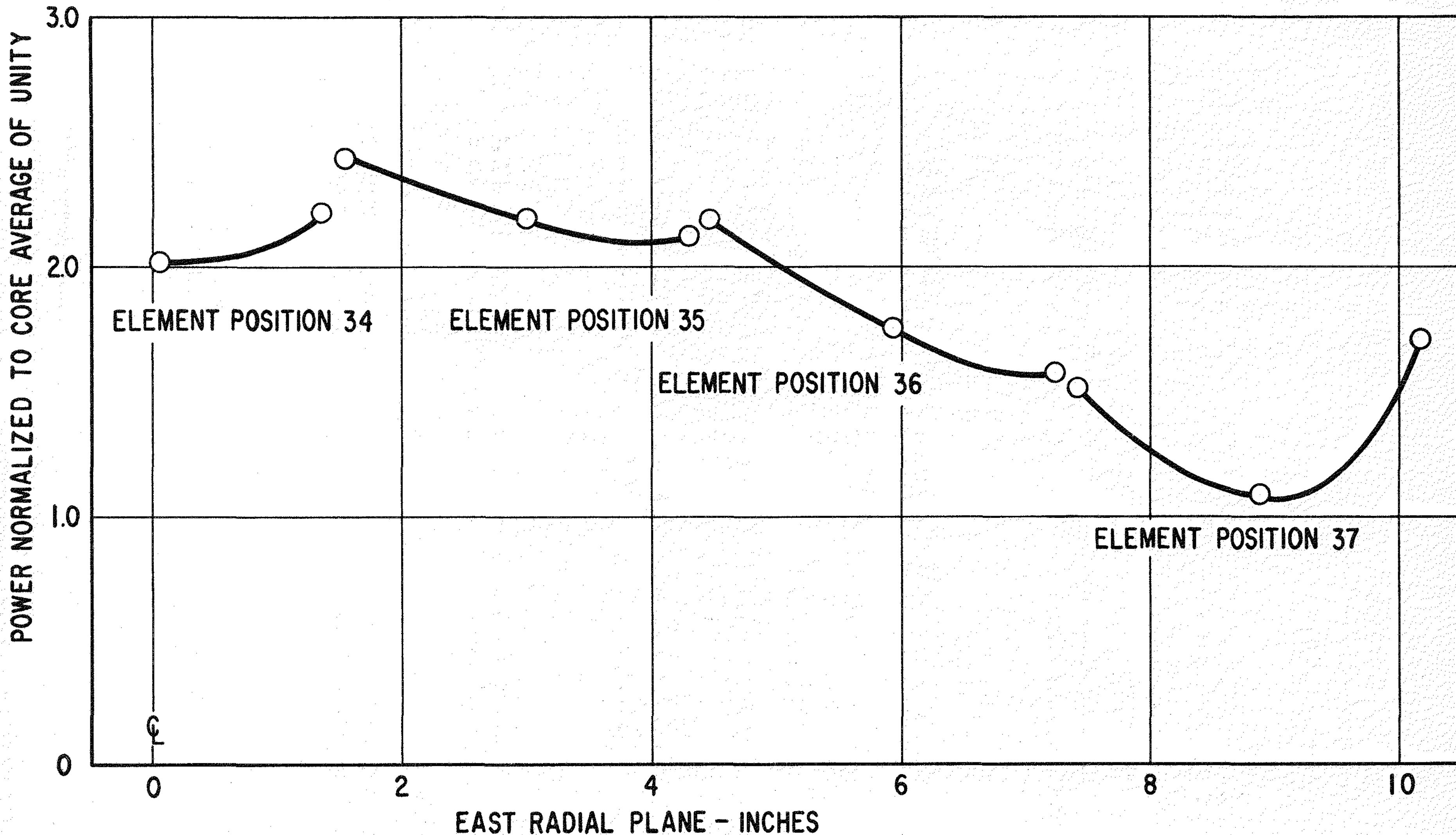

Figure 2.20. Relative Power Distribution Along Radial Traverse Perpendicular to Fuel Plates, 5" above Bottom of Active Core Through Center of Elements in Positions 34, 35, 36, 37 - SM-1 Configuration with SM-2 Elements

TABLE 2.5
RELATIVE POWER DISTRIBUTION ALONG AXIAL TRAVERSES FOR ELEMENT IN POSITION 12
SM-1 CORE CONFIGURATION WITH SM-2 ELEMENTS

	Plate a			Plate j			Plate r		
Position	10.08 NRP	8.82 NRP	7.56 NRP	10.08 NRP	8.82 NRP	7.56 NRP	10.08 NRP	8.82 NRP	7.56 NRP
0	1.73	1.60	1.89	1.51	1.03	1.80	1.61	1.18	2.34
1	1.69	1.19	1.47	1.21	0.50	1.11	1.51	0.66	1.61
3	2.24	1.84	1.85	1.53	0.66	1.41	2.01	0.89	1.80
5	2.51	1.77	2.05	1.77	0.56	1.61	2.19	0.91	2.09
7	2.56	1.77	2.09	1.87	0.72	1.63	2.07	0.91	1.83
9	2.29	1.55	1.77	1.63	0.59	1.38	1.89	0.77	1.63
13	1.41	1.01	1.13	1.06	0.40	0.79	1.23	0.47	0.91
21	0.34	0.22	0.28	0.24	0.10	0.22	0.30	0.10	0.25

TABLE 2.6
RELATIVE POWER DISTRIBUTION ALONG AXIAL TRAVERSES FOR ELEMENT IN POSITION 13
SM-1 CORE CONFIGURATION WITH SM-2 ELEMENTS

	Plate a			Plate j			Plate r		
Position	10.08 NRP	8.82 NRP	7.56 NRP	10.08 NRP	8.82 NRP	7.56 NRP	10.08 NRP	8.82 NRP	7.56 NRP
0	1.77	1.29	2.15	2.17	1.57	2.56	2.17	1.65	2.53
1	1.45	0.67	1.45	1.71	0.72	1.67	1.99	0.88	1.63
3	1.97	0.81	1.99	2.31	0.89	1.93	2.39	1.03	1.95
5	2.24	0.99	1.97	2.43	0.94	2.01	2.54	1.11	2.12
7	2.07	0.94	1.89	2.32	0.98	1.91	2.71	1.06	1.95
9	1.83	0.84	1.60	1.97	0.79	1.60	2.22	0.86	1.57
13	1.28	0.54	0.24	1.31	0.46	0.96	1.43	0.57	0.72
21	0.28	0.12	0.22	0.30	0.10	0.20	0.30	0.10	0.14

TABLE 2.7
RELATIVE POWER DISTRIBUTION ALONG AXIAL TRAVERSES FOR ELEMENT IN POSITION 14
SM-1 CORE CONFIGURATION WITH SM-2 ELEMENTS

	Plate a			Plate j			Plate r		
Position	10.08 NRP	8.82 NRP	7.56 NRP	10.08 NRP	8.82 NRP	7.56 NRP	10.08 NRP	8.82 NRP	7.56 NRP
0	2.46	1.61	2.46	2.31	1.51	2.31	2.19	1.35	2.53
1	1.95	0.88	1.87	1.99	0.77	1.85	1.91	0.84	2.01
3	2.43	1.08	2.19	2.53	0.98	2.43	2.56	1.11	2.21
5	2.81	1.21	2.24	2.76	1.11	2.61	2.88	1.09	2.48
7	2.66	1.18	2.02	2.66	0.99	2.32	2.68	1.11	1.95
9	2.39	0.88	1.63	2.15	0.81	1.99	2.34	0.99	1.97
13	1.47	0.54	0.66	1.38	0.46	0.54	1.47	0.56	0.86
21	0.32	0.12	0.18	0.34	0.12	0.14	0.37	0.86	0.20

TABLE 2.8
RELATIVE POWER DISTRIBUTION ALONG AXIAL TRAVERSES FOR ELEMENT IN POSITION 15
SM-1 CORE CONFIGURATION WITH SM-2 ELEMENTS

	Plate a			Plate j			Plate r		
Position	10.08 NRP	8.82 NRP	7.56 NRP	10.08 NRP	8.82 NRP	7.56 NRP	10.08 NRP	8.82 NRP	7.56 NRP
0	2.24	1.45	2.46	2.19	1.45	2.44	1.87	1.45	2.43
1	1.87	0.88	1.99	1.91	0.72	1.51	1.53	0.69	1.60
3	2.29	1.19	2.29	2.34	1.03	2.09	2.29	0.94	2.15
5	2.81	1.25	2.46	2.71	1.09	2.34	2.32	0.99	2.29
7	2.56	1.13	1.75	2.61	1.16	2.29	2.41	1.09	2.17
9	2.59	1.03	1.80	2.43	0.81	1.80	2.15	0.94	1.97
13	1.41	0.57	0.88	1.63	0.64	1.21	1.41	0.59	1.31
21	0.24	0.16	0.20	0.36	0.12	0.28	0.40	0.18	0.34

TABLE 2.9
RELATIVE POWER DISTRIBUTION ALONG AXIAL TRAVERSES FOR ELEMENT IN POSITION 16
SM-1 CORE CONFIGURATION WITH SM-2 ELEMENTS

Position	Plate a			Plate j			Plate r		
	10.08 NRP	8.82 NRP	7.56 NRP	10.08 NRP	8.82 NRP	7.56 NRP	10.08 NRP	8.82 NRP	7.56 NRP
0	1.87	1.33	2.02	1.67	1.28	1.97	1.87	1.41	2.09
1	1.57	0.74	1.47	1.28	0.52	1.19	1.79	1.06	1.50
3	2.07	0.98	1.95	1.75	0.74	1.60	2.43	1.43	2.02
5	2.24	1.08	2.07	1.97	0.77	1.65	2.51	1.53	2.29
7	2.43	1.08	2.05	2.05	0.86	1.95	2.73	1.63	2.34
9	1.95	1.09	1.63	1.97	0.77	1.57	2.46	1.43	1.95
13	1.41	0.67	1.16	1.40	0.47	1.11	1.87	1.08	1.43
21	0.36	0.15	0.34	0.36	0.14	0.30	0.44	0.25	0.40

TABLE 2.10
RELATIVE POWER DISTRIBUTION ALONG AXIAL TRAVERSES FOR ELEMENT IN POSITION 21
SM-1 CORE CONFIGURATION WITH SM-2 ELEMENTS

Position	Plate a			Plate j			Plate r		
	7.14 NRP	5.88 NRP	4.62 NRP	7.14 NRP	5.88 NRP	4.62 NRP	7.14 NRP	5.88 NRP	4.62 NRP
0	1.80	1.47	2.05	1.91	1.11	1.67	1.87	1.71	2.39
1	1.73	1.08	1.77	1.65	0.57	1.06	1.47	0.72	1.45
3	2.22	1.53	2.41	1.99	0.72	1.47	1.95	0.99	1.91
5	2.59	1.61	2.44	2.32	0.77	1.57	2.09	1.03	2.01
7	2.66	1.53	2.43	2.39	0.84	1.67	2.01	1.01	1.79
9	2.34	1.43	2.09	2.21	0.62	1.38	1.67	0.91	1.53
13	1.53	0.96	1.41	1.40	0.40	0.79	1.19	0.56	0.89
21	0.36	0.24	0.30	0.32	0.20	0.15	0.25	0.10	0.25

TABLE 2.11
RELATIVE POWER DISTRIBUTION ALONG AXIAL TRAVERSES FOR ELEMENT IN POSITION 22
SM-1 CORE CONFIGURATION WITH SM-2 ELEMENTS

	Plate a			Plate j			Plate r		
Position	7.14 NRP	5.88 NRP	4.62 NRP	7.14 NRP	5.88 NRP	4.62 NRP	7.14 NRP	5.88 NRP	4.62 NRP
0	1.85	1.51	2.39	2.24	2.22	2.93	2.37	2.61	3.12
1	1.33	0.79	1.40	1.41	0.99	1.87	1.50	1.08	1.19
3	1.80	1.16	1.95	1.69	1.40	2.37	1.89	1.47	2.44
5	1.80	1.25	2.17	1.87	1.19	2.43	2.07	1.63	2.74
7	1.89	1.16	2.07	1.83	1.21	2.34	1.97	1.45	2.43
9	1.57	1.03	1.63	1.43	1.06	1.99	1.61	1.21	1.89
13	1.09	0.62	1.06	0.96	0.62	1.06	0.89	0.59	0.88
21	0.24	0.18	0.24	0.24	0.15	0.25	0.20	0.15	0.20

TABLE 2.12
RELATIVE POWER DISTRIBUTION ALONG AXIAL TRAVERSES FOR ELEMENT IN POSITION 23
SM-1 CORE CONFIGURATION WITH SM-2 ELEMENTS

	Plate a			Plate j			Plate r		
Position	7.14 NRP	5.88 NRP	4.62 NRP	7.14 NRP	5.88 NRP	4.62 NRP	7.14 NRP	5.88 NRP	4.62 NRP
0	2.53	2.15	3.06	2.73	2.53	3.25	2.56	2.01	3.50
1	1.57	1.16	2.24	1.40	1.16	2.27	2.02	1.50	2.84
3	1.97	1.51	2.64	2.24	1.51	2.73	2.56	1.93	3.56
5	2.12	1.57	2.68	2.34	1.67	2.84	2.61	2.01	3.66
7	2.05	1.47	2.42	2.05	1.45	2.44	2.37	1.87	3.06
9	1.65	1.19	1.95	1.63	1.16	2.07	1.97	1.61	2.34
13	1.01	0.62	0.72	0.94	0.56	0.50	0.76	0.42	0.56
21	0.24	0.14	0.18	0.20	0.12	0.15	0.20	0.10	0.12

TABLE 2.13
RELATIVE POWER DISTRIBUTION ALONG AXIAL TRAVERSES FOR ELEMENT IN POSITION 25
SM-1 CORE CONFIGURATION WITH SM-2 ELEMENTS

Position	Plate a			Plate j			Plate r		
	7.14 NRP	5.88 NRP	4.62 NRP	7.14 NRP	5.88 NRP	4.62 NRP	7.14 NRP	5.88 NRP	4.62 NRP
0	2.56	1.99	3.08	2.63	2.32	3.58	2.21	1.93	3.16
1	1.95	1.47	2.54	1.73	1.16	2.27	1.61	1.06	2.21
3	2.51	1.95	3.15	2.21	1.55	2.81	2.07	1.53	2.93
5	2.76	2.05	3.48	2.39	1.61	3.12	2.41	1.73	3.25
7	2.29	1.75	2.86	2.29	1.57	2.96	2.22	1.71	2.98
9	2.41	1.93	2.39	1.87	1.25	2.43	1.91	1.45	2.49
13	0.88	0.42	0.86	1.19	0.79	1.35	1.21	0.81	1.50
21	0.18	0.08	0.24	0.28	0.20	0.34	0.34	0.24	0.36

TABLE 2.14
RELATIVE POWER DISTRIBUTION ALONG AXIAL TRAVERSES FOR ELEMENT IN POSITION 26
SM-1 CORE CONFIGURATION WITH SM-2 ELEMENTS

Position	Plate a			Plate j			Plate r		
	7.14 NRP	5.88 NRP	4.62 NRP	7.14 NRP	5.88 NRP	4.62 NRP	7.14 NRP	5.88 NRP	4.62 NRP
0	2.22	2.11	3.34	2.29	1.93	2.73	1.71	1.47	2.24
1	1.47	1.18	2.27	1.33	0.96	1.73	1.21	0.79	1.53
3	1.91	1.61	2.83	1.73	1.28	2.34	1.85	1.13	1.69
5	2.05	1.73	3.00	1.99	1.43	2.96	2.05	1.31	2.22
7	2.31	1.63	2.88	1.95	1.31	2.73	1.97	1.19	2.41
9	1.97	1.47	2.41	1.83	1.21	2.51	1.83	1.09	2.07
13	1.28	0.91	1.45	1.25	0.81	1.55	1.25	0.84	1.31
21	0.36	0.20	0.37	0.34	0.22	0.36	0.37	0.14	0.30

TABLE 2.15
RELATIVE POWER DISTRIBUTION ALONG AXIAL TRAVERSES FOR ELEMENT IN POSITION 27
SM-1 CORE CONFIGURATION WITH SM-2 ELEMENTS

	Plate a			Plate j			Plate r		
Position	7.14 NRP	5.88 NRP	4.62 NRP	7.14 NRP	5.88 NRP	4.62 NRP	7.14 NRP	5.88 NRP	4.62 NRP
0	1.89	1.41	2.09	2.01	1.06	1.63	1.69	3.18	2.01
1	1.65	0.81	1.50	1.47	0.56	1.08	1.63	1.41	1.60
3	1.99	1.08	1.97	2.15	0.77	1.40	2.41	1.25	1.93
5	2.34	1.23	2.27	2.49	0.84	1.61	2.84	1.35	2.21
7	2.32	1.21	1.95	2.44	0.79	1.57	2.81	1.40	2.39
9	2.19	1.19	1.77	2.22	0.76	1.40	2.66	1.31	2.27
13	1.53	0.74	1.19	1.57	0.50	1.11	1.83	0.96	1.60
21	0.40	0.20	0.32	0.40	0.14	0.28	0.47	0.24	0.36

TABLE 2.16
RELATIVE POWER DISTRIBUTION ALONG AXIAL TRAVERSES FOR ELEMENT IN POSITION 31
SM-1 CORE CONFIGURATION WITH SM-2 ELEMENTS

	Plate a			Plate j			Plate r		
Position	4.20 NRP	2.94 NRP	1.68 NRP	4.20 NRP	2.94 NRP	1.68 NRP	4.20 NRP	2.94 NRP	1.68 NRP
0	2.12	1.85	2.74	1.97	1.51	2.21	2.32	2.29	2.54
1	1.79	1.41	2.39	1.19	0.76	1.29	1.57	0.98	1.83
3	2.17	1.79	3.03	1.51	0.94	1.71	1.75	1.38	2.12
5	2.49	2.11	3.44	1.61	1.06	1.93	1.97	1.38	2.43
7	2.37	2.05	3.26	1.53	0.99	1.87	1.95	1.29	2.22
9	2.02	1.75	2.83	1.23	0.77	1.61	1.63	1.08	1.83
13	1.35	1.35	1.71	0.79	0.52	0.81	0.91	0.59	0.77
21	0.32	0.25	0.40	0.24	0.14	0.18	0.20	0.14	0.18

TABLE 2.17
RELATIVE POWER DISTRIBUTION ALONG AXIAL TRAVERSES FOR ELEMENT IN POSITION 32
SM-1 CORE CONFIGURATION WITH SM-2 ELEMENTS

	Plate a			Plate j			Plate r		
Position	4.20 NRP	2.94 NRP	1.68 NRP	4.20 NRP	2.94 NRP	1.68 NRP	4.20 NRP	2.94 NRP	1.68 NRP
0	2.43	2.34	2.54	3.45	2.90	2.83	2.95	2.95	3.45
1	1.43	1.06	1.83	2.05	1.13	1.91	2.12	1.61	2.81
3	1.93	1.38	2.29	2.43	1.43	2.64	2.86	2.01	3.38
5	2.11	1.50	2.27	2.66	1.51	2.64	3.03	2.15	3.58
7	1.97	1.33	2.15	2.32	1.38	2.32	2.61	1.63	2.63
9	1.57	1.03	1.73	1.85	1.03	1.80	2.10	1.65	2.29
13	0.94	0.59	0.69	0.98	0.52	0.50	0.76	0.40	0.47
21	0.24	0.15	0.15	0.28	0.14	0.14		0.10	0.10

TABLE 2.18
RELATIVE POWER DISTRIBUTION ALONG AXIAL TRAVERSES FOR ELEMENT IN POSITION 34
SM-1 CORE CONFIGURATION WITH SM-2 ELEMENTS

	Plate a			Plate j			Plate r		
Position	4.20 NRP	2.94 NRP	1.68 NRP	4.20 NRP	2.94 NRP	1.68 NRP	4.20 NRP	2.94 NRP	1.68 NRP
0	3.62	3.10	3.77	3.70	3.67	3.82	3.56	2.93	4.02
1	2.95	2.11	3.15	2.73	1.55	2.74	2.83	1.75	3.26
3	3.80	2.63	3.54	3.45	1.99	3.44	3.38	1.75	3.66
5	3.86	2.71	4.16	3.67	2.02	3.64	3.62	2.22	4.02
7	3.15	2.12	3.26	3.05	1.73	2.90	3.05	2.01	4.04
9	2.41	2.11	2.21	2.34	1.29	2.37	2.37	1.61	2.68
13	0.54	0.40	0.57	0.64	0.62	0.54	0.94	0.86	0.91
21	0.14	0.14	0.10	0.12	0.15	0.20	0.24	0.20	0.22

TABLE 2.19
RELATIVE POWER DISTRIBUTION ALONG AXIAL TRAVERSES FOR ELEMENT IN POSITION 35
SM-1 CORE CONFIGURATION WITH SM-2 ELEMENTS

	Plate a			Plate j			Plate r		
Position	4.20 NRP	2.94 NRP	1.68 NRP	4.20 NRP	2.94 NRP	1.68 NRP	4.20 NRP	2.94 NRP	1.68 NRP
0	3.97	3.52	4.24	3.96	3.00	4.29	3.50	2.71	3.87
1	2.84	1.89	3.06	2.51	1.50	2.64	2.31	1.53	2.61
3	3.56	2.37	3.28	3.25	1.99	3.20	2.86	1.93	3.03
5	3.96	2.44	3.99	3.45	2.19	3.28	3.12	2.12	3.34
7	3.34	2.21	3.52	3.20	2.01	2.96	1.89	1.89	2.96
9	2.66	1.77	2.37	2.68	1.61	2.21	2.61	1.61	2.34
13	1.13	0.86	1.06	1.60	0.84	1.25	1.53	0.91	1.09
21	0.24	0.15	0.22	0.36	0.25	0.32	0.37	0.20	0.30

TABLE 2.20
RELATIVE POWER DISTRIBUTION ALONG AXIAL TRAVERSES FOR ELEMENT IN POSITION 36
SM-1 CORE CONFIGURATION WITH SM-2 ELEMENTS

	Plate a			Plate j			Plate r		
Position	4.20 NRP	2.94 NRP	1.68 NRP	4.20 NRP	2.94 NRP	1.68 NRP	4.20 NRP	2.94 NRP	1.68 NRP
0	3.20	3.03	3.89	3.34	2.66	2.66	2.59	2.27	2.66
1	2.39	1.63	2.83	2.05	1.25	2.02	1.67	1.16	1.87
3	2.81	2.07	3.44	2.59	1.57	2.88	2.09	1.45	2.32
5	3.08	2.19	3.62	3.06	1.75	3.30	2.24	1.57	2.73
7	2.95	2.02	3.03	2.71	1.67	2.68	2.24	1.47	2.44
9	2.64	1.71	2.54	2.39	1.47	2.46	2.02	1.35	2.29
13	1.55	0.99	1.08	1.45	0.86	0.84	1.33	0.88	0.88
21	0.44	0.34	0.24	0.37	0.20	0.18	0.40	0.22	0.20

TABLE 2.21
RELATIVE POWER DISTRIBUTION ALONG AXIAL TRAVERSES FOR ELEMENT IN POSITION 37
SM-1 CORE CONFIGURATION WITH SM-2 ELEMENTS

	Plate a			Plate j			Plate r		
Position	4.20 NRP	2.94 NRP	1.68 NRP	4.20 NRP	2.94 NRP	1.68 NRP	4.20 NRP	2.94 NRP	1.68 NRP
0	2.27	1.93	2.41	1.79	1.47	2.02	2.11	2.61	2.24
1	1.43	1.06	1.73	1.09	0.72	1.29	1.71	1.21	1.87
3	1.75	1.28	2.17	1.50	0.99	1.67	2.05	1.67	2.46
5	2.02	1.51	2.34	1.57	1.08	1.83	2.46	1.71	2.76
7	2.01	1.43	2.21	1.55	0.99	1.71	2.56	1.67	2.71
9	1.79	1.23	1.79	1.35	0.91	1.45	2.22	1.60	2.37
13	1.16	0.74	0.86	0.99	0.56	0.91	1.53	1.08	1.55
21	0.30	0.18	0.24	0.28	0.15	0.22	0.36	0.25	0.47

TABLE 2.22
RELATIVE POWER DISTRIBUTION ALONG AXIAL TRAVERSES FOR ELEMENT IN POSITION 41
SM-1 CORE CONFIGURATION WITH SM-2 ELEMENTS

	Plate a		Plate e			Plate j		Plate r	
Position	1.26 NRP	0 NRP	1.26 NRP	0 NRP	1.26 SRP	1.26 NRP	0 NRP	1.26 NRP	0 NRP
0	2.46	2.07	2.02	1.61	2.02	2.39	1.57	2.19	1.33
1	2.22	1.67	1.40	0.67	1.25	1.45	0.79	1.75	1.03
3	2.88	2.05	1.71	0.99	1.51	1.80	1.01	2.15	1.33
5	3.18	2.29	1.83	1.09	1.80	1.97	1.16	2.51	1.65
7	3.00	2.21	1.71	0.96	1.71	1.93	1.11	2.11	1.35
9	2.63	2.01	1.41	0.89	1.45	1.57	0.91	1.80	1.45
13	1.60	1.21	0.89	0.50	0.91	0.81	0.50	0.66	0.37
21	0.34	0.30	0.22	0.10	0.25	0.24	0.10	0.20	0.10

TABLE 2.23
RELATIVE POWER DISTRIBUTION ALONG AXIAL TRAVERSES FOR ELEMENT IN POSITION 43
SM-1 CORE CONFIGURATION WITH SM-2 ELEMENTS

	Plate a		Plate j		Plate r	
Position	1.26 NRP	0 NRP	1.26 NRP	0 NRP	1.26 NPR	0 NRP
0	3.45	3.18	3.45	2.61	3.80	2.96
1	2.93	1.79	2.12	1.40	3.38	2.07
3	3.52	2.12	3.00	1.80	4.06	2.49
5	3.76	2.21	3.72	2.05	4.19	2.66
7	3.03	1.93	3.30	1.77	3.50	2.07
9	2.41	1.91	2.43	1.40	2.66	2.11
13	0.52	0.37	0.69	0.59	0.57	0.47
21	0.12	0.08	0.14	0.18	0.12	0.10

TABLE 2.24
RELATIVE POWER DISTRIBUTION ALONG AXIAL TRAVERSES FOR ELEMENT IN POSITION 45
SM-1 CORE CONFIGURATION WITH SM-2 ELEMENTS

	Plate a		Plate j		Plate r	
Position	1.26 NRP	0 NRP	1.26 NRP	0 NRP	1.26 NRP	0 NRP
0	4.18	3.12	4.68	3.52	3.50	2.88
1	3.30	2.24	2.93	1.50	2.56	1.77
3	3.82	2.74	3.25	2.05	3.08	2.15
5	3.97	2.88	3.45	2.09	3.14	2.31
7	3.40	2.51	3.18	1.73	3.10	1.93
9	2.64	2.27	2.39	1.33	2.43	1.93
13	0.94	0.42	1.21	0.62	0.89	0.46
21	0.22	0.10	0.30	0.14	0.22	0.12

TABLE 2.25
RELATIVE POWER DISTRIBUTION ALONG AXIAL TRAVERSES FOR ELEMENT IN POSITION 47
SM-1 CORE CONFIGURATION WITH SM-2 ELEMENTS

	Plate a		Plate j		Plate r	
Position	1.26 NRP	0 NRP	1.26 NRP	0 NRP	1.26 NRP	0 NRP
0	2.61	2.21	2.24	2.07	2.53	2.34
1	1.95	1.23	1.40	0.76	1.99	1.25
3	2.34	1.71	1.65	1.01	2.61	1.73
5	2.63	1.75	1.91	1.01	2.61	1.83
7	2.39	1.65	1.67	1.03	2.51	1.75
9	2.11	1.75	1.43	0.84	2.29	1.53
13	0.88	0.37	0.94	0.42	1.57	1.03
21	0.15	0.18	0.22	0.18	0.46	0.25

TABLE 2. 26
RELATIVE POWER DISTRIBUTION ALONG AXIAL TRAVERSES FOR ELEMENT IN POSITION 33 (CONTROL ROD A)
SM-1 CORE CONFIGURATION WITH SM-2 ELEMENTS

	Plate a			Plate i			Plate p		
Position	4. 10 NRP	2. 94 NRP	1. 78 NRP	4. 10 NRP	2. 94 NRP	1. 78 NRP	4. 10 NRP	2. 94 NRP	1. 78 NRP
-7	0. 74	0. 44	0. 76	0. 54	0. 15	0. 59	0. 74	0. 52	0. 77
-3	0. 99	0. 91	1. 13	1. 08	0. 52	1. 29	1. 23	0. 99	1. 41
-1	2. 93	1. 80	2. 98	2. 31	0. 99	2. 81	2. 86	1. 99	3. 28
0	3. 00	1. 83	2. 71	2. 34	1. 28	2. 66	2. 53	1. 89	3. 12
1	2. 32	1. 73	2. 56	2. 32	1. 55	2. 78	2. 73	2. 02	3. 15
3	2. 78	2. 15	3. 08	2. 90	2. 01	3. 64	3. 22	2. 46	3. 80
5	3. 06	2. 31	3. 34	3. 10	2. 12	3. 45	3. 67	2. 64	4. 06
7	2. 59	1. 80	2. 71	2. 39	1. 60	2. 76	2. 96	2. 05	3. 22
7. 54	1. 93	1. 25	1. 93	1. 41	0. 76	1. 65	1. 80	0. 84	2. 09
8. 04	2. 09	1. 85	2. 22	2. 05	1. 50	2. 01	1. 97	1. 57	2. 37

TABLE 2. 27
RELATIVE POWER DISTRIBUTION ALONG AXIAL TRAVERSES FOR ELEMENT IN POSITION 24 (CONTROL ROD 1)
SM-1 CORE CONFIGURATION WITH SM-2 ELEMENTS

	Plate a			Plate i			Plate p		
Position	7. 04 NRP	5. 88 NRP	4. 72 NRP	7. 04 NRP	5. 88 NRP	4. 72 NRP	7. 04 NRP	5. 88 NRP	4. 72 NRP
-7	0. 59	0. 44	0. 69	0. 37	0. 14	0. 57	0. 54	0. 30	0. 89
-3	0. 89	0. 86	1. 18	0. 79	0. 46	1. 08	0. 86	0. 66	1. 28
-1	2. 53	1. 77	3. 20	1. 85	0. 94	2. 90	2. 27	1. 65	3. 32
0	1. 95	1. 51	2. 59	1. 73	1. 09	2. 54	1. 99	1. 40	2. 98
1	2. 02	1. 61	2. 76	1. 99	1. 35	2. 54	2. 05	1. 63	2. 93
3	2. 46	1. 97	3. 28	2. 51	1. 73	3. 12	2. 54	2. 05	2. 44
5	2. 66	2. 09	3. 40	2. 64	1. 79	3. 20	2. 73	2. 09	3. 87
7	2. 17	1. 65	2. 66	2. 22	1. 40	2. 63	2. 19	1. 73	3. 08
7. 54	1. 53	1. 18	1. 99	1. 31	0. 57	1. 73	1. 41	0. 69	1. 75
8. 04	1. 75	1. 90	2. 43	1. 57	1. 40	1. 83	1. 69	0. 98	2. 31

TABLE 2.28
RELATIVE POWER DISTRIBUTION ALONG AXIAL TRAVERSES FOR ELEMENT IN POSITION 42 (CONTROL ROD 4)
SM-1 CORE CONFIGURATION WITH SM-2 ELEMENTS

	Plate a		Plate i		Plate p	
Position	1.16 NRP	0 NRP	1.16 NRP	0 NRP	1.16 NRP	0 NRP
-7	0.54	0.22	0.66	0.32	0.79	0.47
-3	1.06	0.54	0.89	0.62	1.23	0.91
-1	2.17	0.88	2.32	1.53	2.98	2.02
0	2.17	1.06	1.93	1.25	2.63	1.69
1	2.32	1.50	2.02	1.23	2.71	1.89
3	2.71	1.80	2.43	1.57	3.22	2.24
5	2.81	1.87	2.64	1.63	3.44	1.97
7	2.11	1.33	2.05	1.41	2.32	1.80
7.54	1.19	0.67	1.59	0.98	1.40	0.98
8.04	2.22	2.19	2.01	1.60	1.65	1.61

TABLE 2.29
RELATIVE POWER DISTRIBUTION ALONG AXIAL TRAVERSES FOR ELEMENT IN POSITION 46 (CONTROL ROD 2)
SM-1 CORE CONFIGURATION WITH SM-2 ELEMENTS

	Plate a		Plate i		Plate p	
Position	1.16 NRP	0 NRP	1.16 NRP	0 NRP	1.16 NRP	0 NRP
-7	0.89	0.57	0.44	0.15	0.57	0.30
-3	1.45	1.01	0.89	0.47	0.96	0.64
-1	3.52	2.19	2.11	0.88	2.27	1.28
0	2.81	1.80	2.01	1.01	1.97	1.23
1	2.71	1.91	2.12	1.38	1.97	1.45
3	3.16	2.49	2.74	1.60	2.41	1.75
5	3.34	2.54	2.90	1.71	2.61	1.79
7	2.83	1.91	2.53	1.23	2.15	1.35
7.54	2.22	1.28	1.63	0.76	1.53	0.72
8.04	2.71	1.60	1.55	1.02	1.69	1.41

TABLE 2.30
RELATIVE POWER DISTRIBUTION ALONG AXIAL TRAVERSES FOR ELEMENT IN POSITION 44 (CONTROL ROD C)
SM-1 CORE CONFIGURATION WITH SM-2 ELEMENTS

	Plate a			Plate i			Plate p		
Position	1.16 NRP	0 NRP	1.16 SRP	1.16 NRP	0 NRP	1.16 SRP	1.16 NRP	0 NRP	1.16 SRP
-12.96	0.15	0.10	0.18	0.12	0.06	0.12	0.14	0.10	0.14
-9	0.50	0.30	0.62	0.40	0.12	0.46	0.62	0.32	0.50
-7	0.88	0.56	1.08	0.77	0.22	0.77	1.03	0.52	0.89
-5	0.79	0.66	0.77	0.76	0.32	0.79	0.81	0.57	0.81
-3	1.51	1.21	1.60	1.45	0.69	1.45	1.55	1.06	1.63
-1	3.45	2.39	3.67	3.28	1.19	3.08	3.44	1.99	3.48
0	2.98	1.77	3.18	2.84	1.53	2.84	3.00	1.87	3.15
1	3.03	2.07	3.00	3.05	1.79	3.08	2.96	2.01	3.16
3	3.97	2.64	3.70	3.92	2.34	3.58	3.66	2.59	4.04
5	3.87	2.54	3.77	3.64	2.22	3.70	3.74	2.56	3.64
7	2.98	1.89	2.98	2.76	1.53	2.86	2.39	2.02	3.15
7.54	1.99	1.28	1.79	1.75	0.62	1.53	1.61	0.69	1.75
8.04	2.32	1.93	2.43	1.97	1.83	2.02	2.17	1.87	2.64

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3.0 SM-1A MEASUREMENTS WITH SM-2 MOCKUP FUEL ELEMENTS

3.1 INTRODUCTION

The SM-1A core configuration is identical to the SM-1 except that the outer row of elements on the east and west side of the core are rotated 90° to have their fuel plates oriented perpendicular to the reflector. Because of this similarity, only a limited experimental program was carried out to evaluate the effect of SM-2 elements in the SM-1A core configuration. This program included initial bank positions, worth of stainless steel skirt and power distribution measurements.

3.2 CORE CONFIGURATION AND INITIAL CRITICAL POSITION

The SM-1A configuration is shown in Fig. 1.3. With SM-2 mockup elements, the SM-1A U-235 loading of 36.4 Kg and estimated B-10 loading of 67.9 gm were identical to the SM-1. The SM-1A core is also equipped with a 0.050 in. stainless steel skirt. The seven rod critical bank position measured at 68°F was 8.12 in.; thus, the reactivity worth of rotating the outer row of fuel elements was approximately -20 cents. The five rod bank position at 68° with rods A and B at 19 in. was 6.90 in.

3.3 WORTH OF STAINLESS STEEL SKIRT

The worth of the stainless steel skirt around the outer boundary of the core was measured on the calibrated seven rod bank. The seven rod bank critical without skirt was 7.96 in. compared to 8.12 with skirt. The reactivity worth of the SM-1A skirt was -40 cents compared to an SM-1 skirt worth of -46 cents.

3.4 POWER DISTRIBUTION MEASUREMENTS

3.4.1 Introduction

Relative power distribution in the SM-1A core was obtained by the same method and procedure described in Section 2.7 for the SM-1. The two outer row of elements in one half of the symmetrical core were extensively mapped with uranium fission foils; the remainder innermost elements were assumed to be identical to the SM-1. This is justified by the close similarity of the two configurations, since only the fuel plate orientation of the two outer rows is different. Stationary fuel elements used in this experimental program did not contain flux suppressors; control rod fuel elements were equipped with 0.5 in. mockup suppressors at the top of the active meat.

3.4.2 Core Average

The core average for the SM-1A power distribution was obtained by utilizing raw SM-1 data for the nine central elements and data obtained from measurements in the SM-1A configuration for the remainder of the elements in the core. The core average was calculated in a similar manner to that described previously in Section 1.4.5.4. All data points reported in this chapter, including the portion used from the SM-1 measurements, were normalized to the SM-1A core average.

3.4.3 Experimental Data and Discussion of Results

Power distribution results obtained in the SM-1A configuration are similar to those obtained in the SM-1 configuration. Figure 3.1 gives the complete normalized cell power averages in the core. Fourteen central elements exceeded the core average of unity. The cell averages for the control rod fuel elements are reported as less than the core average even though they have a higher than average power density over the region, since they were weighted to include only the portion of the fuel plates actually inserted in the core, the seven rod bank critical position being 8.12 in.

In general the SM-1A core exhibits the same assymmetry of core power distribution due to the non-uniform control rod distribution previously described (ref. 2.7.3). Similar to the SM-1 mockup, the average power generation in the northeast quadrant of the SM-1A is approximately 16 percent greater than that of the northwest quadrant based upon close packed seven rod bank operation and cold clean power distribution measurements. The effects of reduced local power generation resulting from the 90^{o} rotation of the fuel elements along the east and west boundaries of the SM-1A core are apparent by comparative inspection of Fig. 2.9 and 3.1. When normalized to a common entity, at the core centerline, the average power reduction in fuel elements along the west boundary is approximately 11 percent. The strongest effects are shown in positions 21 and 41, where the reduction was 17.1 and 15.2 percent respectively. These are primarily leakage effects introduced by reorienting fuel plates along the core boundary; in the case of position 41, the plates were reoriented with respect to both the core boundary and the adjacent control rod. As a result of the increased leakage from position 41, the peak power generation along the western core boundary shifts from position 41 to 51, which is in general agreement with the results along the north core boundary where similar test conditions exist in both the SM-1 and SM-1A core mockups. The power distribution in boundary fuel elements tends to increase toward the northeast and southwest quadrants due to the asymmetry of the control rod array. (Ref. Section 2.7.3).

It should be noted that although the average power generation in the rotated fuel elements along the west boundary decreased, the power spike at the core - reflector interface is somewhat increased where the fuel plates are normal to the reflector as illustrated by comparison of Fig. 2.19 with 3.12 and 2.20 with 3.13.

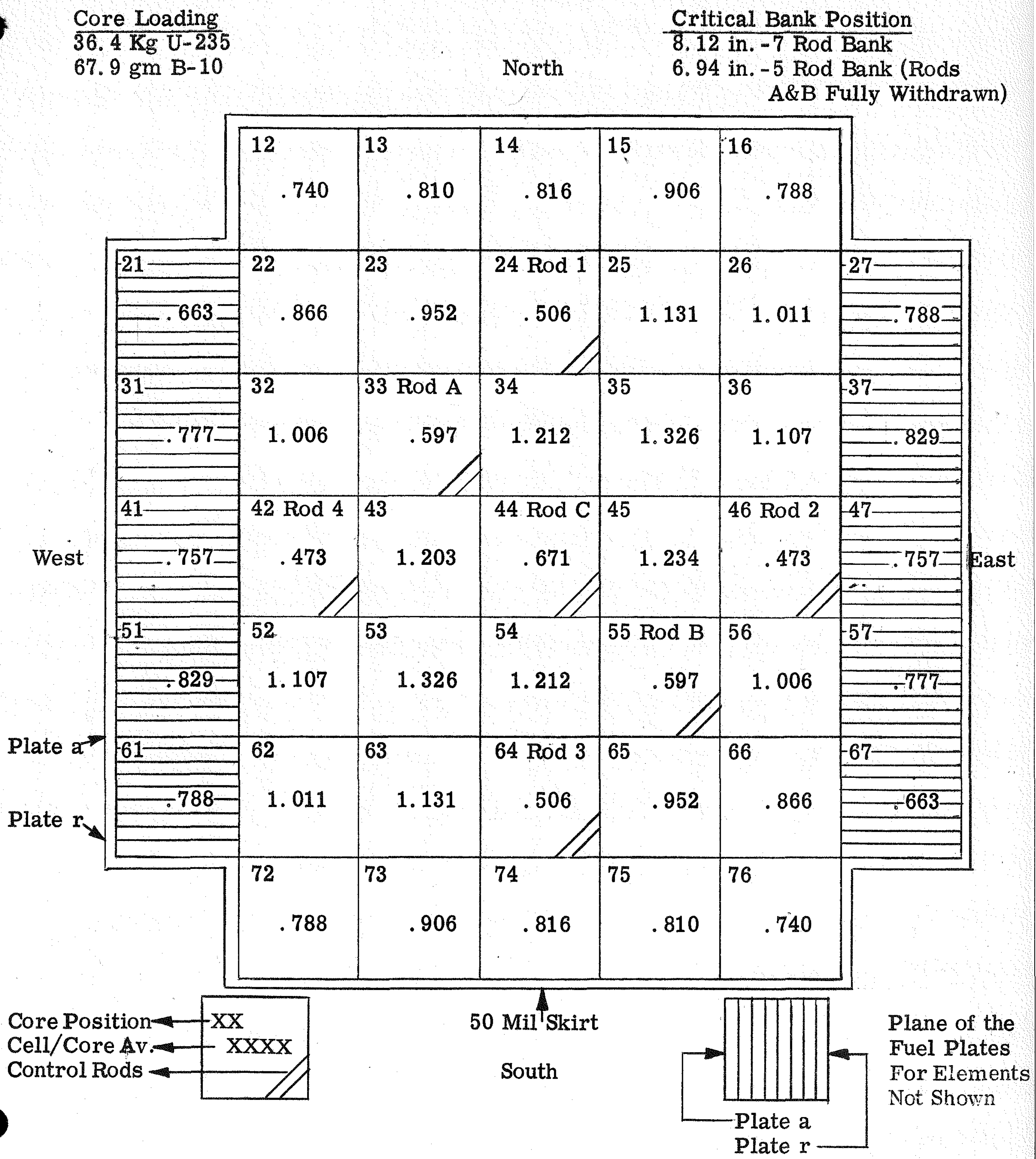

Fig. 3.1 - SM-1A Cell Power Averages Normalized to a Core Average of Unity; SM-2 Elements

Tables 3.1 through 3.20 present the normalized power distribution along axial traverses of fuel plates a, j, and r of stationary elements in the north half of the core. Tables 3.21 through 3.24 present data along axial traverses of fuel plates a, i, and p of control rods 1, 4, A and C. Minimum power generation of 0.10 of the core average occured along the edge of the core while the internal maximum of 4.30 times the core average in the center of the core. Peak power generation in the core of 4.79 times the core average occured as a spike at the bottom of the active core of in element position 45 due to the absence of flux suppressors.

Typical axial power traverses along a fuel plate are shown in Fig. 3.2 through 3.9. Figures 3.2 through 3.8 show the power distribution of the centerline traverses of fuel plate j normalized to the core average for stationary fuel elements in the normal half of the core. Figures 3.9 illustrates similar traverses for fuel plate i of control rods 1, 4, A, and C. These results indicate the usual power spikes occurring at the bottom of the active core due to absence of flux suppressors, the axial power peaking occurring 4 - 6 in. above the bottom of the active core and the gradual diminishing of power as the top of the active core is reached. As an example, in element position 36 along the centerline of fuel plate j, power peaks of 2.95 and 1.69 times the core average occur at the bottom of the active core and 5 in. above it respectively; minimum power of 0.18 of the core average occurred near the top of the active core. In the control rod fuel elements, the sharp reduction of power at the bottom of the flux suppressor following a gradual increase is evident from Fig. 3.9.

Several radial power traverses through the core are shown in Fig. 3.10 through 3.13. Figures 3.10 and 3.11 show the power distribution along radial traverses 5 in. a bove the bottom of the active core, parallel to the fuel plates and through the center of elements in position 14, 34, rod 1, rod C and 15, 25, 35, and 45 respectively. Similar traverses perpendicular to the fuel plates and through the center of elements in position 41, 42, rod 4, rod C and 34, 35, 36, 37 are shown in Fig. 3.12 and 3.13 respectively. These results indicate an overall increase in power as the center of the core is apprached and the power minima along the centerline of a fuel element in relation to its outer edges. Figures 3.12 and 3.13 also illustrate the local effect on the power distribution resulting from the rotation of elements in position 41 and 37 by 90° to maintain a fuel plate orientation normal to the reflector.

All of the above results confirm the close similarity of the SM-1 and SM-1A power distributions and validate the assumption that the power distribution of the innermost elements are essentially identical for the two cores.

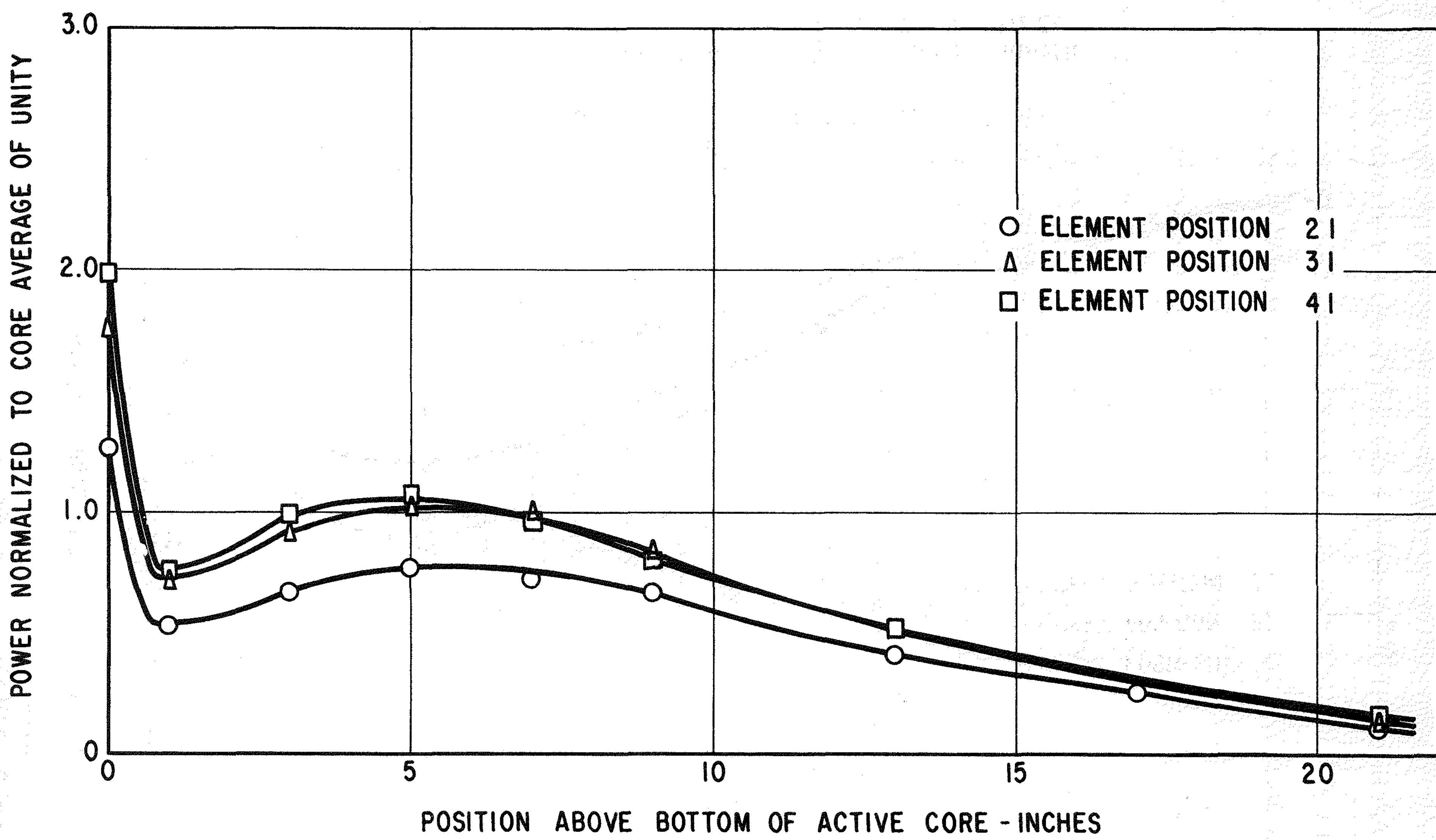

Figure 3.2. Relative Power Distribution Along Axial Traverse on Centerline of Fuel Plate "J" of Elements in Positions 21, 31, 41 - SM-1A Configuration with SM-2 Elements

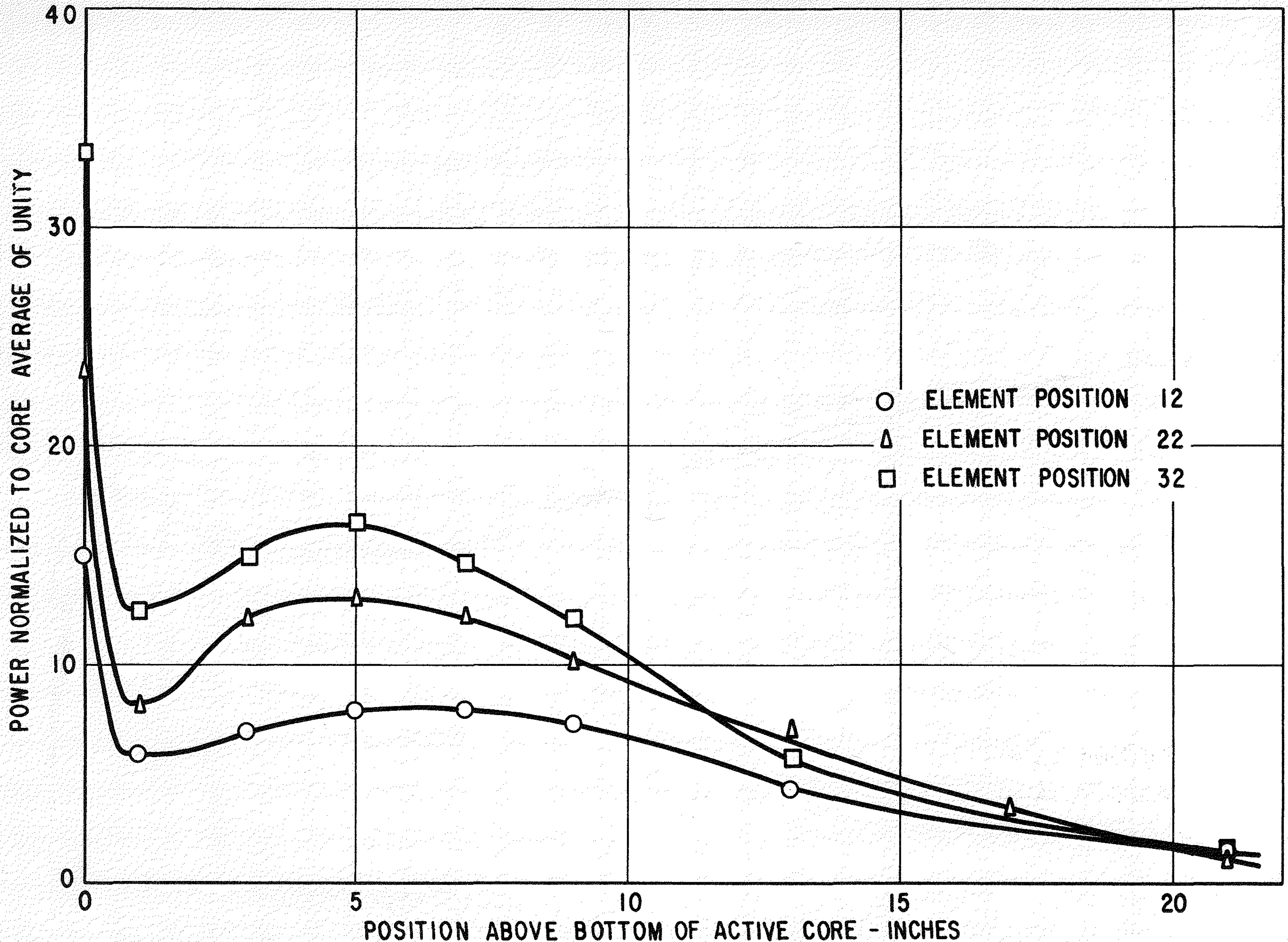

Figure 3.3. Relative Power Distribution Along Axial Traverse on Centerline of Fuel Plate "J" of Elements in Positions 12, 22, 32 - SM-1A Configuration with SM-2 Elements

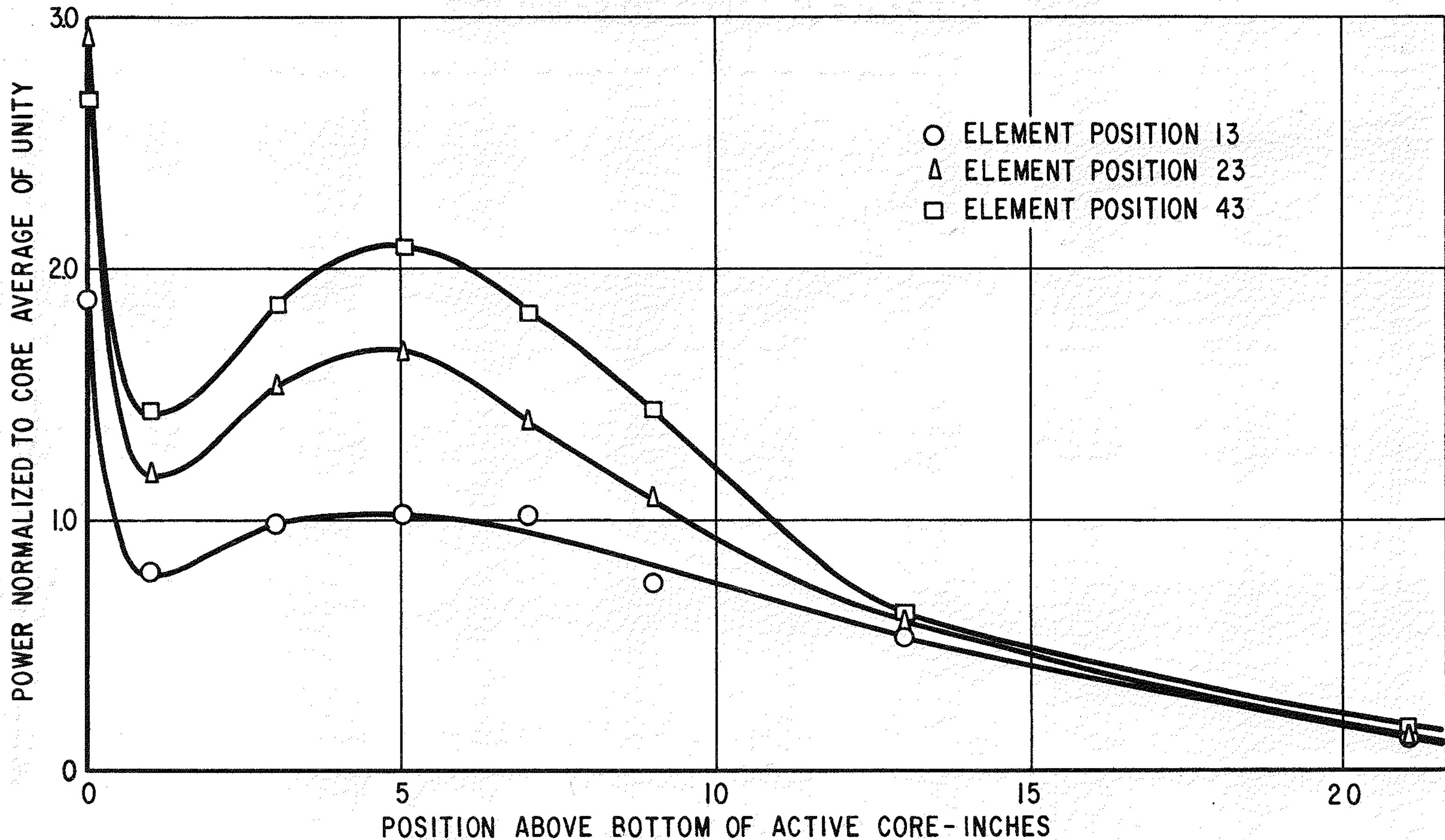

Figure 3.4. Relative Power Distribution Along Axial Traverse on Centerline of Fuel Plate "J" of Elements in Positions 13, 23, 43 - SM-1A Configuration with SM-2 Elements

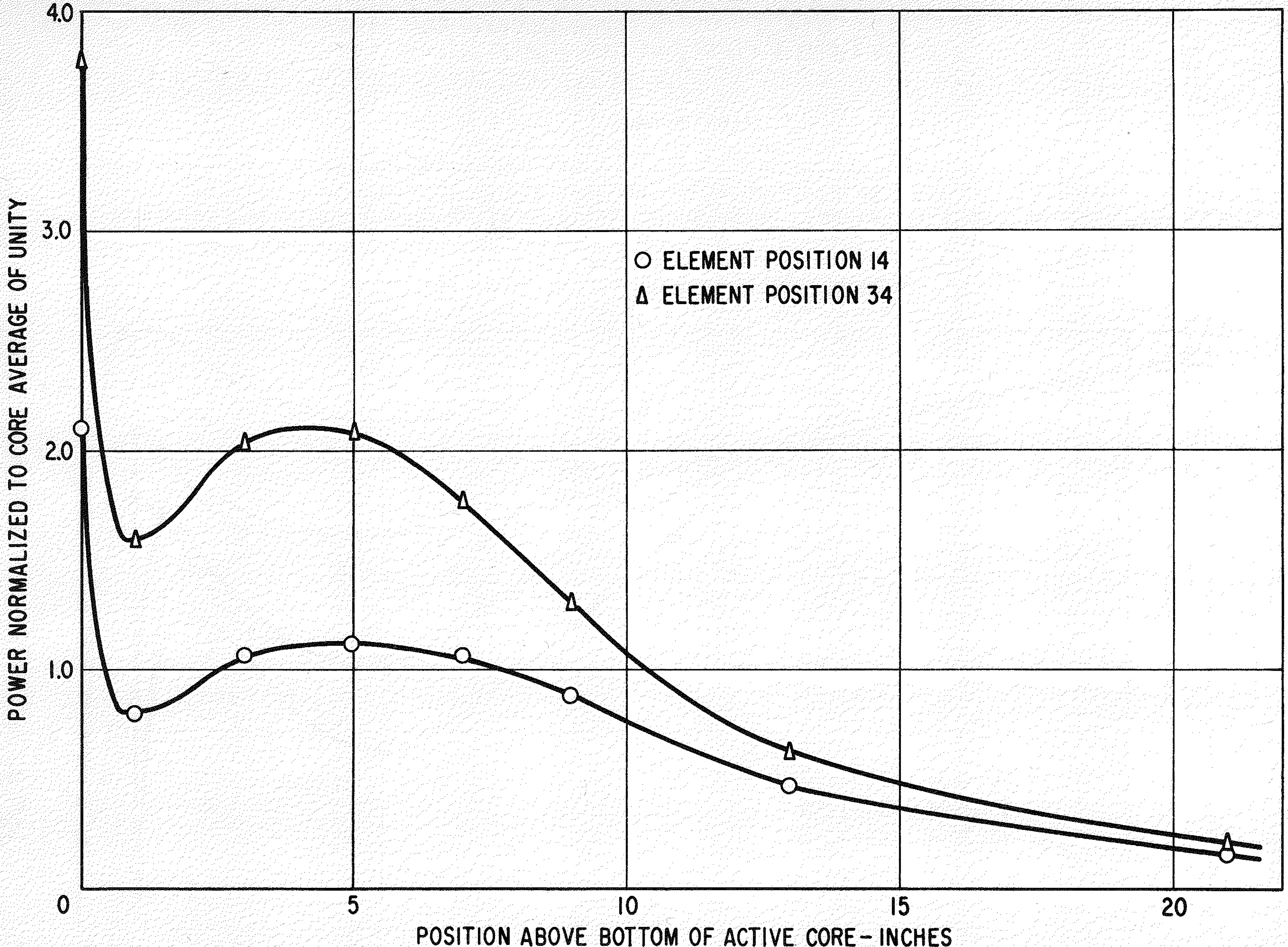

Figure 3.5. Relative Power Distribution Along Axial Traverse on Centerline of Fuel Plate "J" of Elements in Positions 14, 34 - SM-1A Configuration with SM-2 Elements

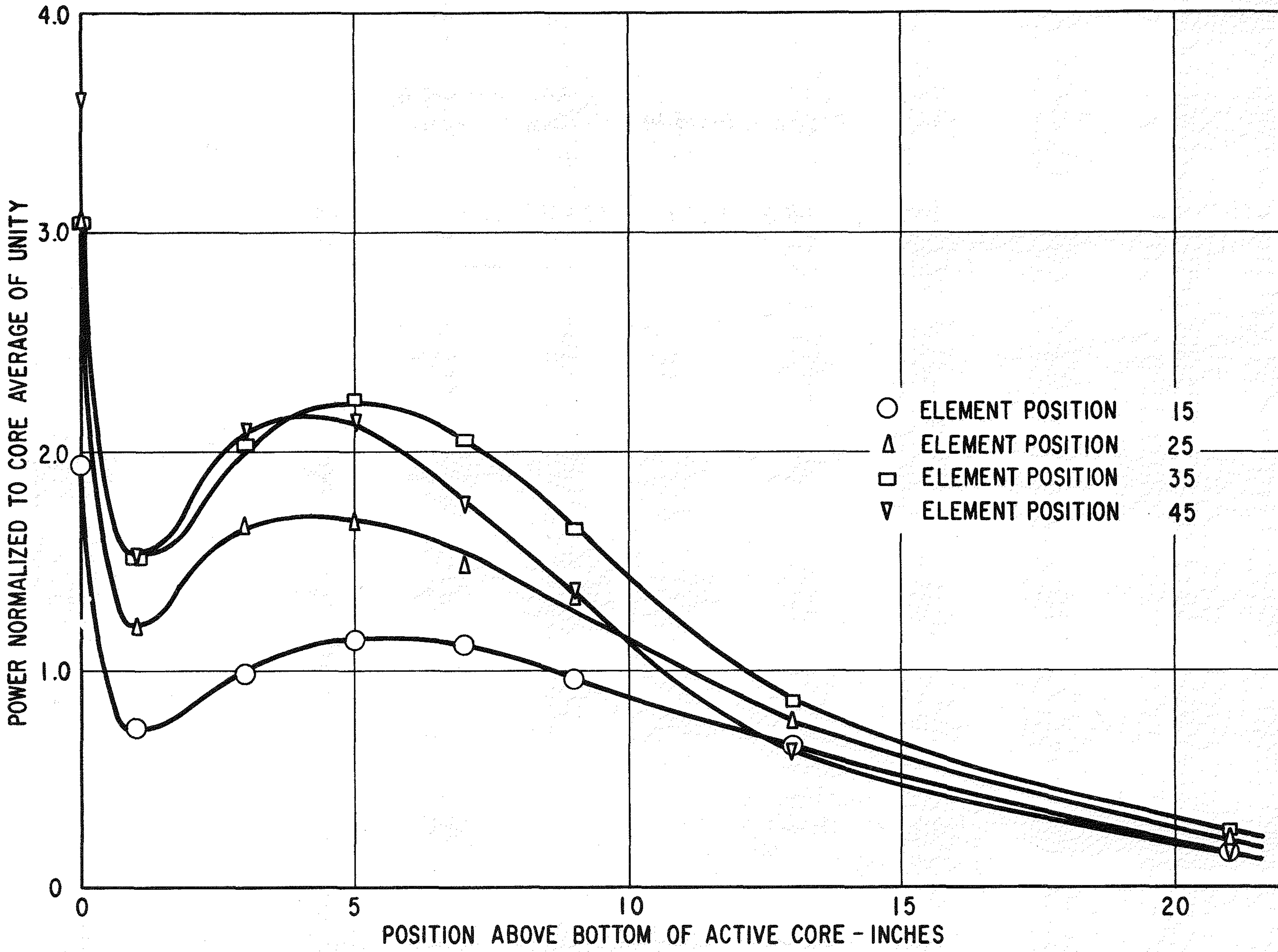

Figure 3.6. Relative Power Distribution Along Axial Traverse on Centerline of Fuel Plate "J" of Elements in Positions 15, 25, 35, 45 - SM-1A Configuration with SM-2 Elements

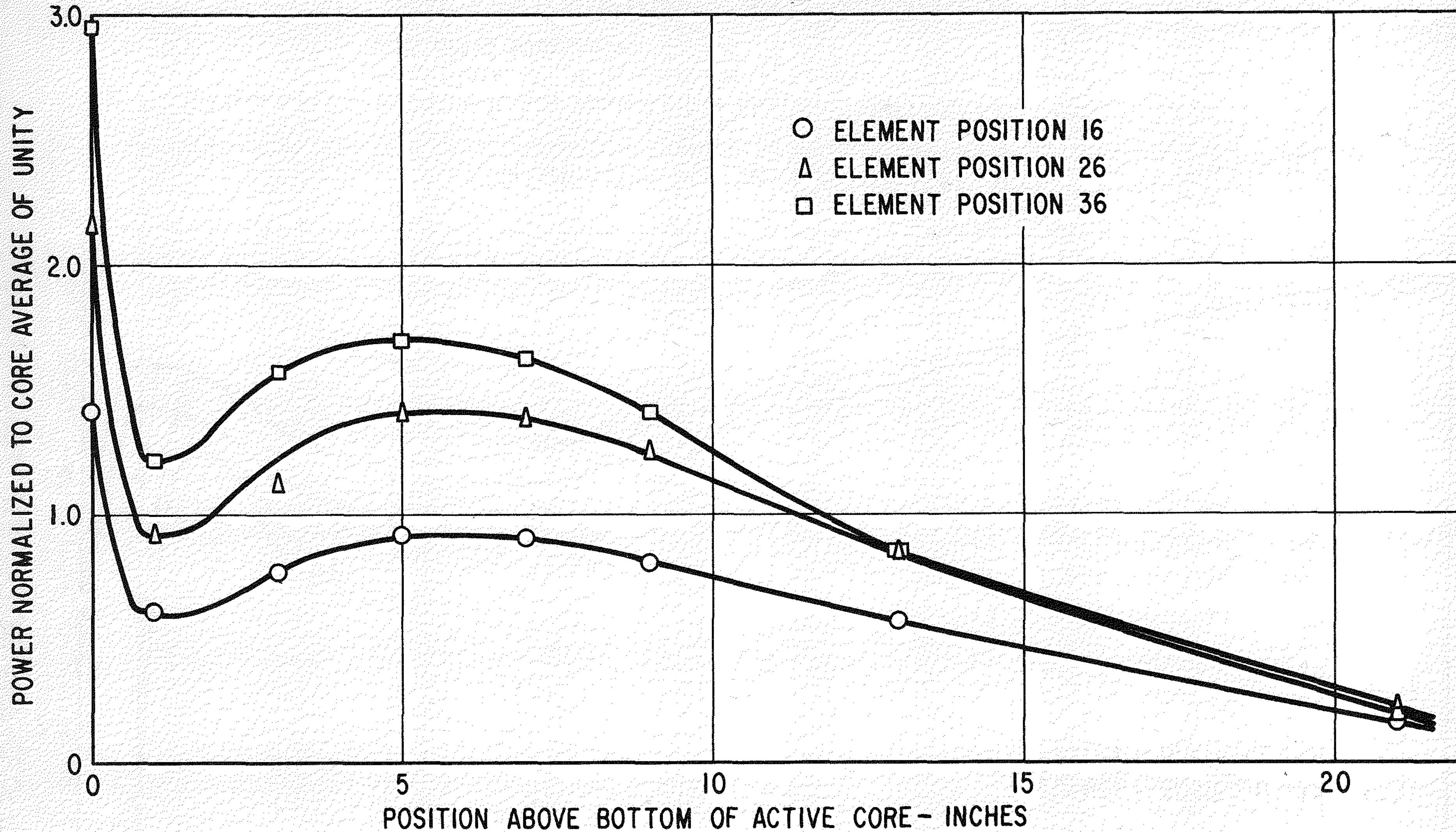

Figure 3.7. Relative Power Distribution Along Axial Traverse on Centerline of Fuel Plate "J" of Elements in Positions 16, 26, 36 - SM-1A Configuration with SM-2 Elements

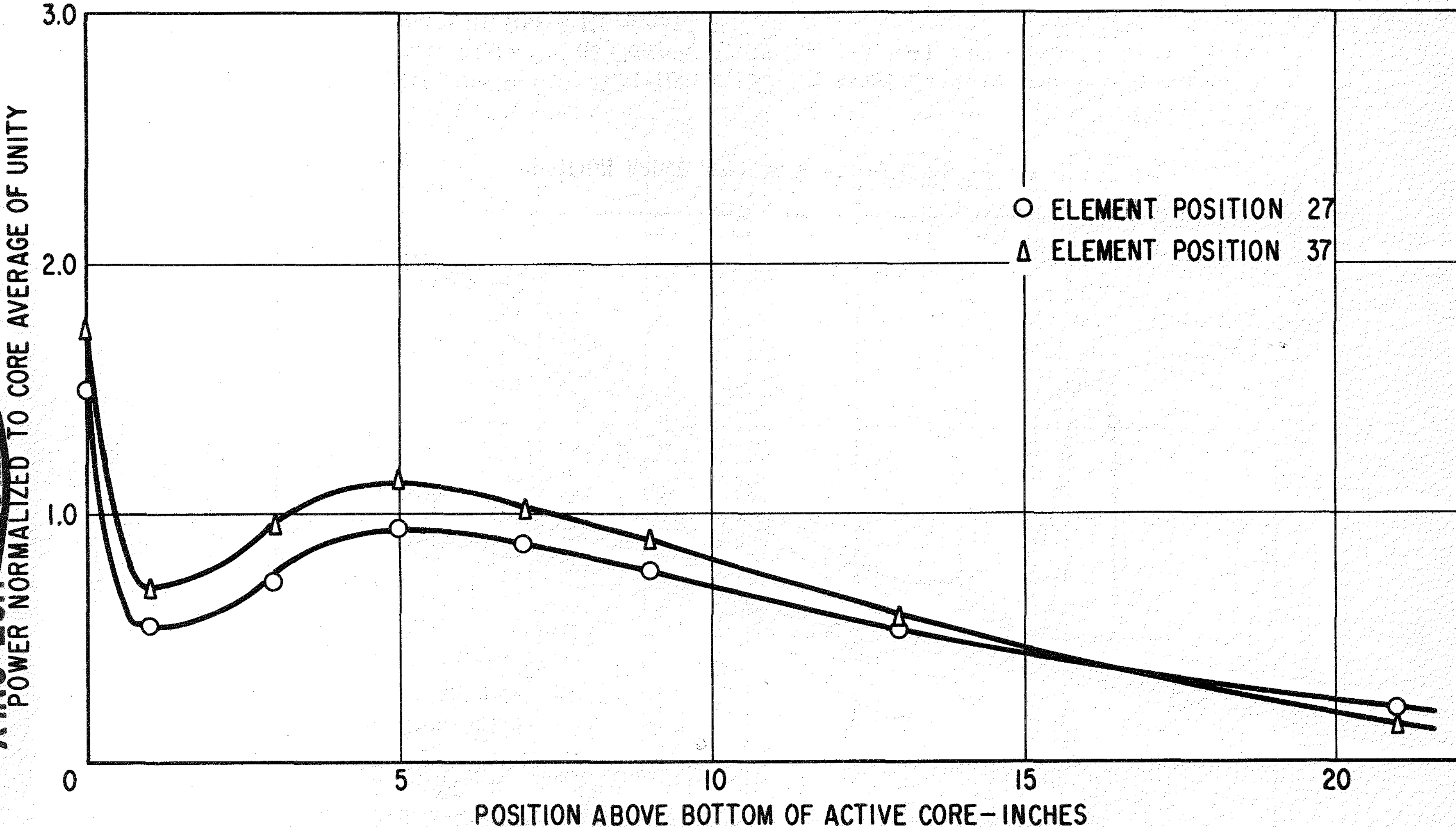

Figure 3. 8. Relative Power Distribution Along Axial Traverse on Centerline of Fuel Plate "J" of Elements in Positions 27, 37 - SM-1A Configuration with SM-2 Elements

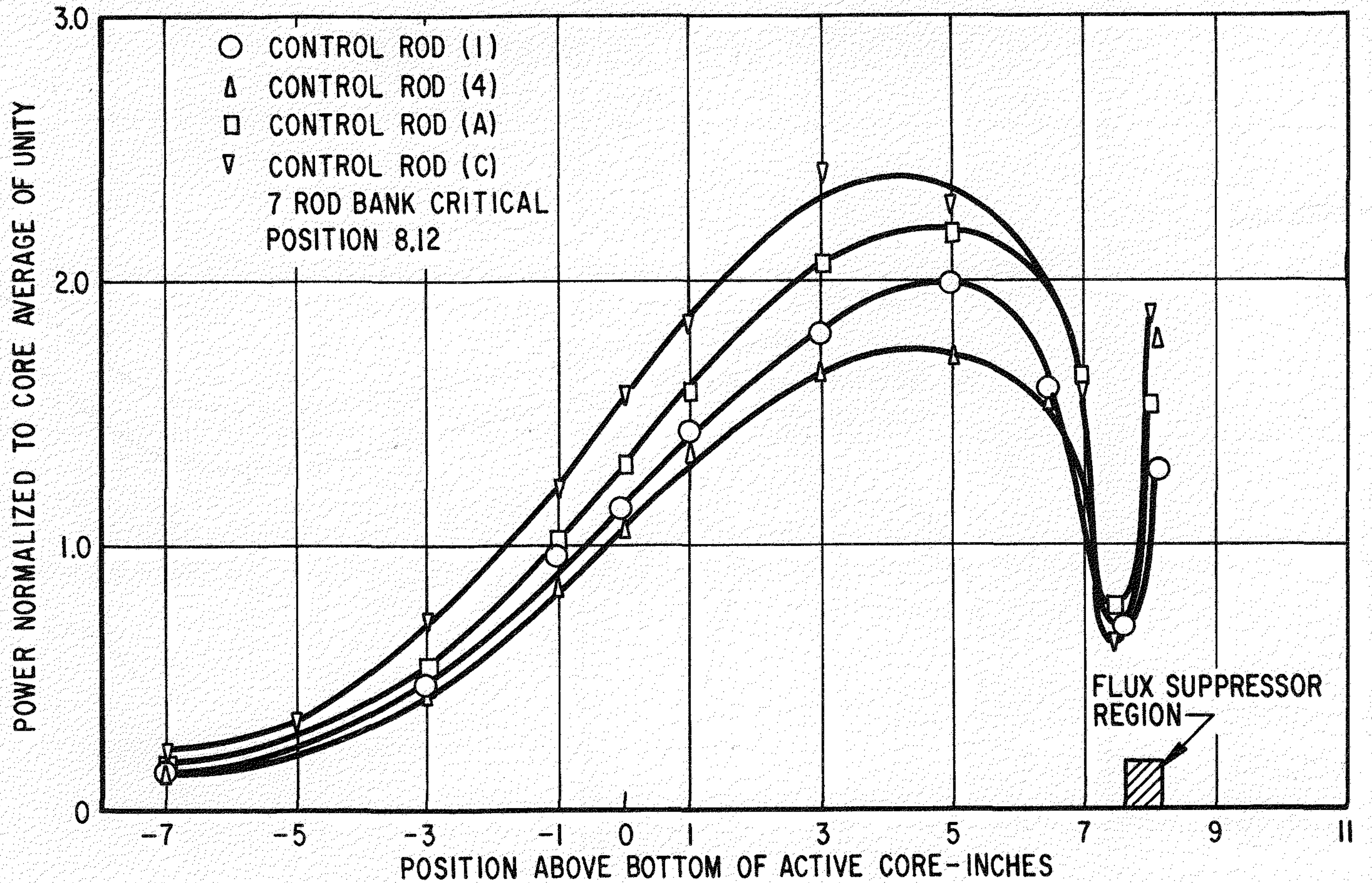

Figure 3.9. Relative Power Distribution Along Axial Traverse on Centerline of Fuel Plate "I" of Control Rods (1), (4), (A), (C) - SM-1A Configuration with SM-2 Elements

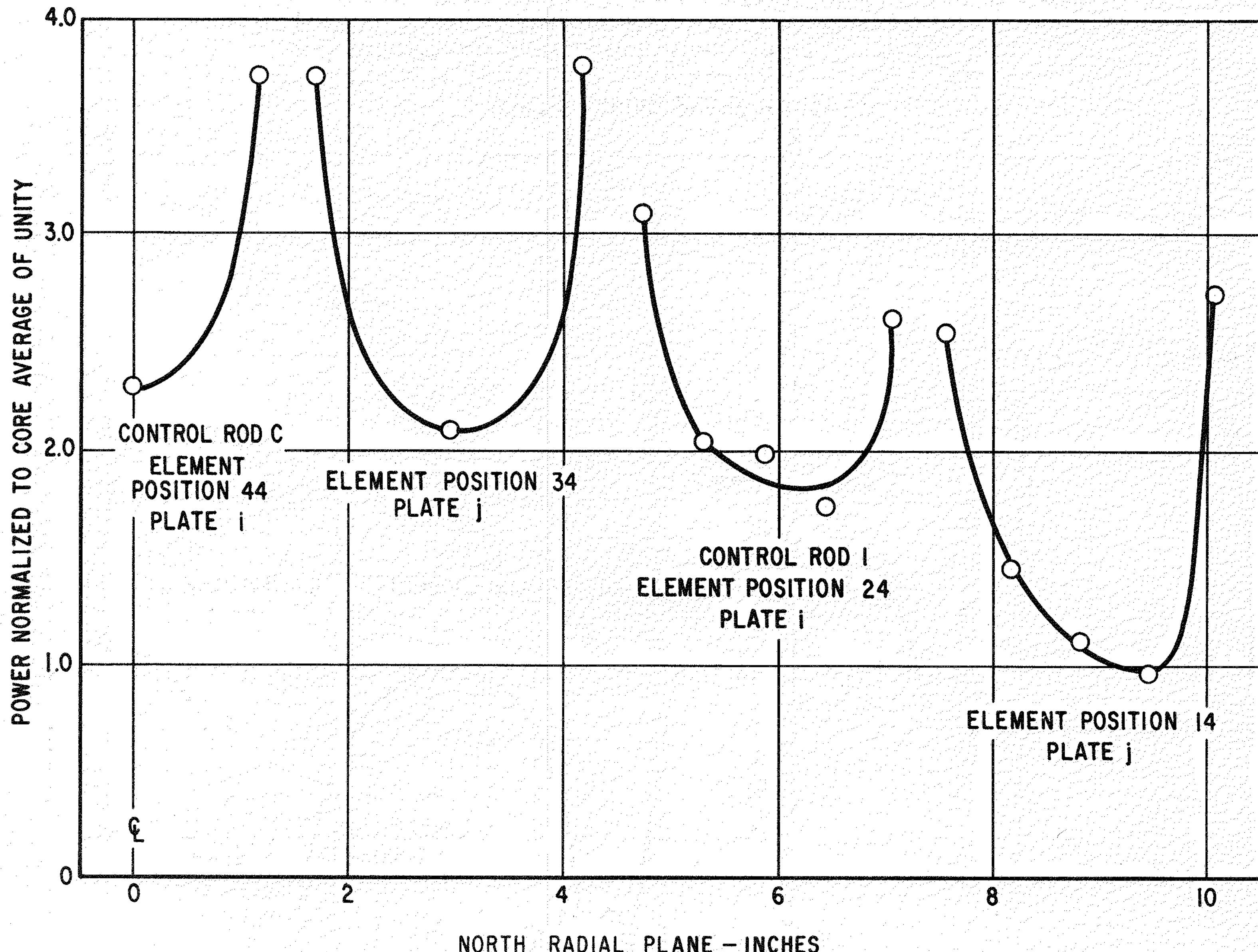

Figure 3.10. Relative Power Distribution Along Radial Traverse Parallel to Fuel Plates, 5" Above Bottom of Active Core Through Center of Elements in Positions 44, 34, 24, 14 - SM-1A Configuration with SM-2 Elements

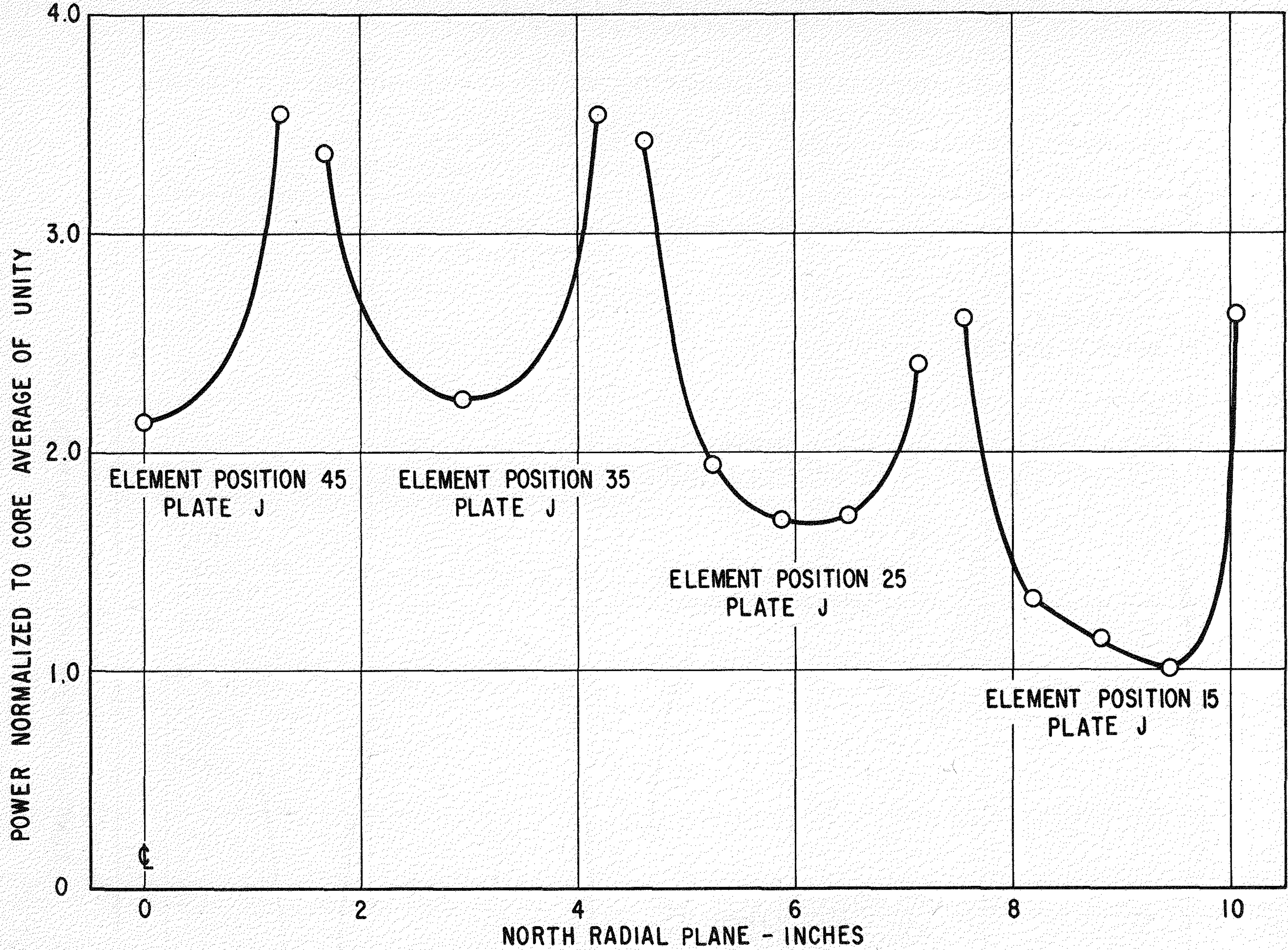

Figure 3.11. Relative Power Distribution Along Radial Traverse Parallel to Fuel Plates, 5" above Bottom of Active Core Through Center of Elements in Positions 45, 35, 25, 15 - SM-1A Configuration with SM-2 Elements

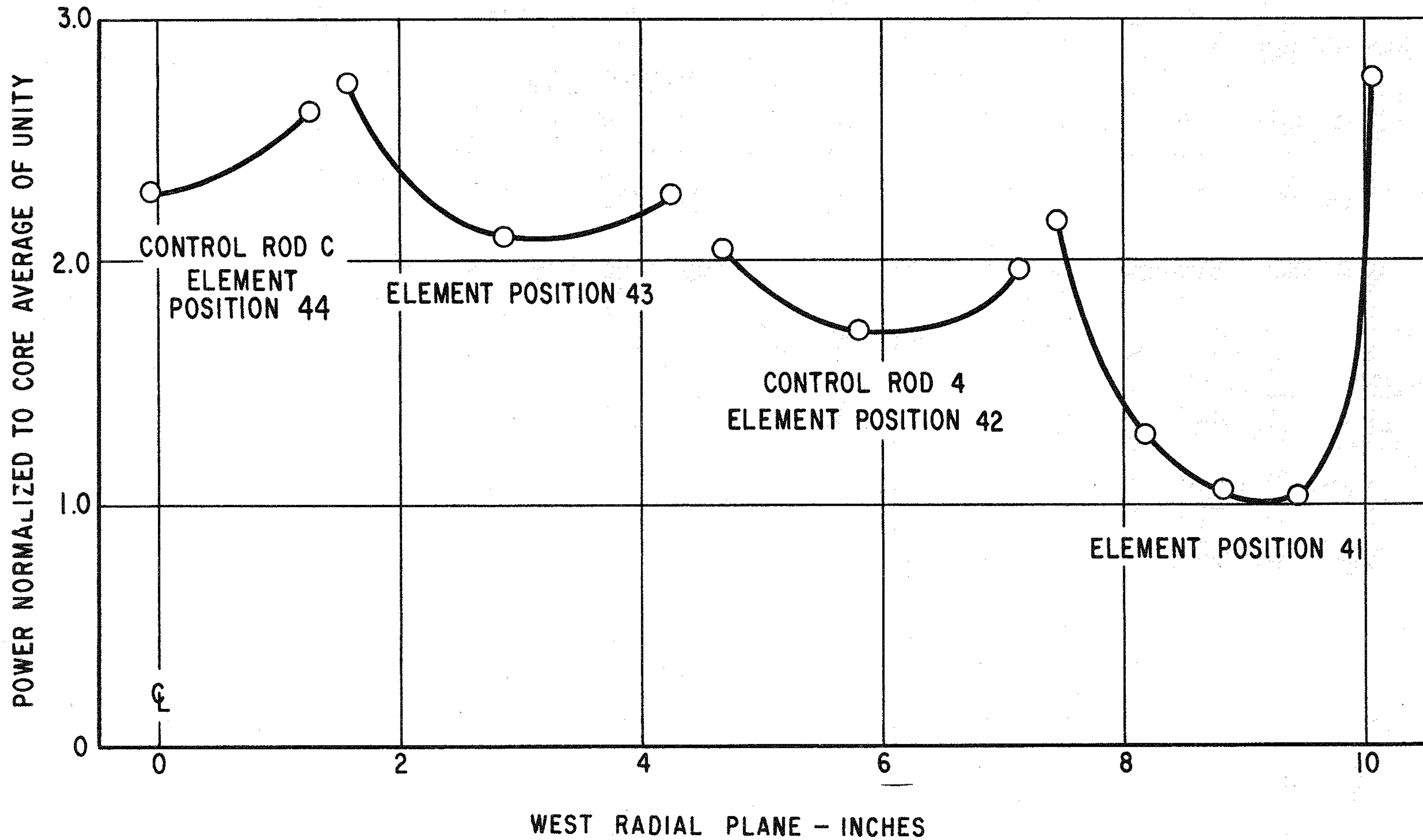

Figure 3.12. Relative Power Distribution Along Radial Traverse Perpendicular to Fuel Plates, 5" Above Bottom of Active Core Through Center of Elements in Positions 44, 43, 42 and Parallel with the Fuel Plates in Position 41 - SM-1A Configuration with SM-2 Elements

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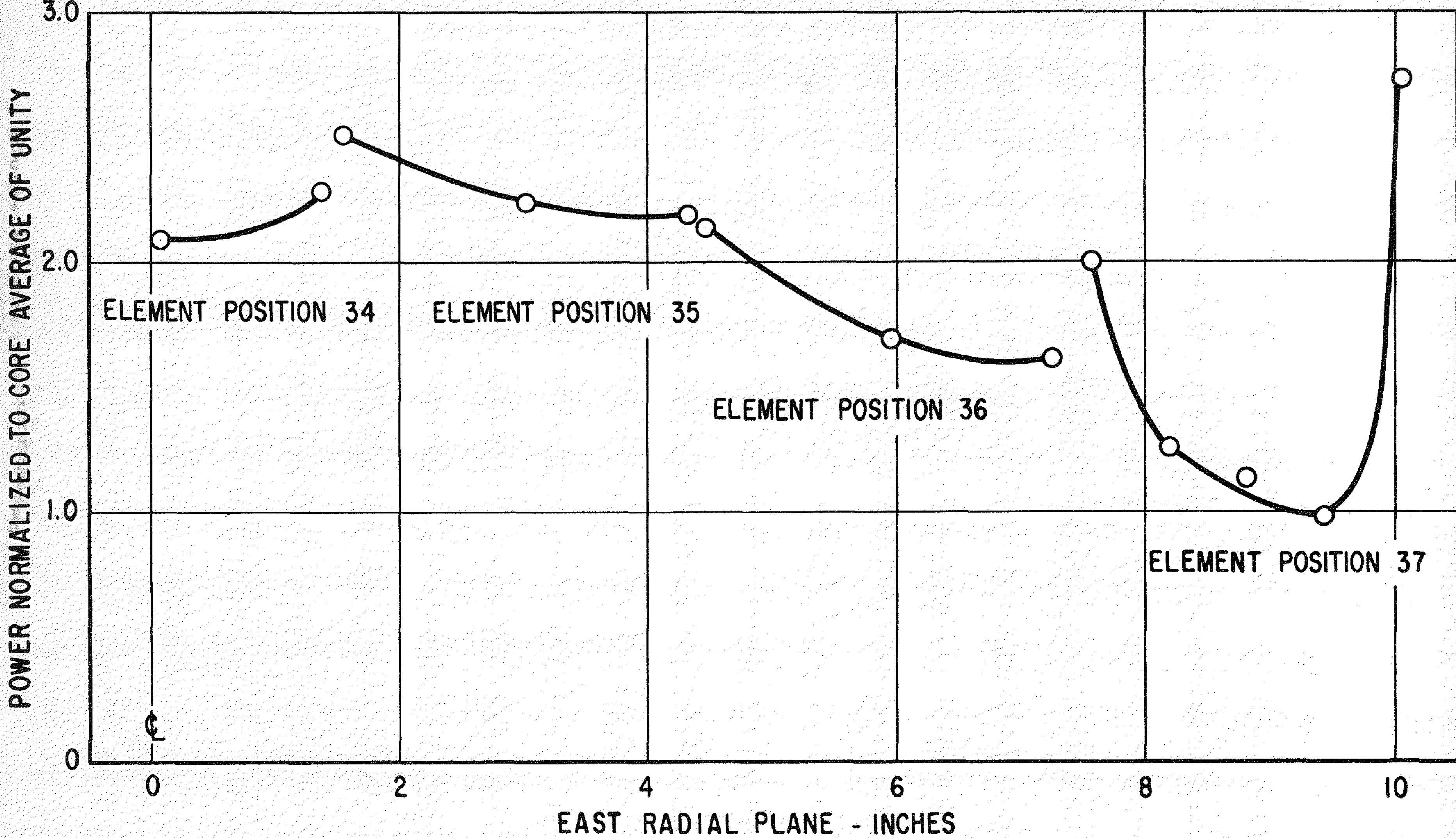

Figure 3.13. Relative Power Distribution Along Radial Traverse Perpendicular to Fuel Plates, 5" above Bottom of Active Core Through Center of Elements in Positions 34, 35, 36, and Parallel with the Fuel Plates in Position 37 - SM-1A Configuration with SM-2 Elements

TABLE 3.1
RELATIVE POWER DISTRIBUTION ALONG AXIAL TRAVERSES
FOR ELEMENT IN POSITION 12; SM-1A CORE CONFIGURATION
WITH SM-2 ELEMENTS

Position	10.08 NRP	9.45 NRP	Plate a 8.82 NRP	8.19 NRP	7.56 NRP
0	1.81		1.81		2.00
1	1.83		1.24		1.53
3	2.30	1.47	1.67	1.67	1.96
5	2.69	1.81	1.79	1.87	2.20
7	2.61		1.87		2.12
9	2.10		1.24		1.75
13	1.39		1.10		1.24
21	0.35		0.20		0.33

Position	10.08 NRP	9.45 NRP	Plate j 8.82 NRP	9.19 NRP	7.56 NRP
0	1.69		1.49		2.02
1	1.30		0.59		1.10
3	1.65	0.69	0.69	1.02	1.55
5	1.75	0.73	0.79	1.04	1.77
7	1.85		0.79		1.61
9	1.75		0.73		1.51
13	1.10		0.43		0.98
21	0.29		0.14		0.22

Position	10.08 NRP	9.45 NRP	Plate r 8.82 NRP	8.19 NRP	7.56 NRP
0	1.75		1.61		2.16
1	1.63		0.71		1.55
3	2.06	0.75	0.92	1.26	2.40
5	2.26	0.88	1.02	1.16	2.12
7	2.00		1.00		2.08
9	1.87		0.92		1.77
13	1.26		0.47		0.94
21	0.31		0.12		0.24

TABLE 3.2
RELATIVE POWER DISTRIBUTION ALONG AXIAL TRAVERSES FOR ELEMENT IN POSITION 13; SM-1A CORE CONFIGURATION WITH SM-2 ELEMENTS

Plate a

Position	10.08 NRP	9.45 NRP	8.82 NRP	8.19 NRP	7.56 NRP
0	1.85		1.61		2.99
1	1.55		0.81		1.59
3	2.06	1.08	1.08	1.16	2.08
5	2.24	0.92	1.12	1.32	2.20
7	2.16		1.10		2.22
9	2.14		0.88		1.77
13	1.20		0.55		1.28
21	0.31		0.20		0.22

Plate j

Position	10.08 NRP	9.45 NRP	8.82 NRP	8.19 NRP	7.56 NRP
0			1.87		3.14
1	1.75		0.79		1.67
3	2.36	0.92	0.98	1.28	2.10
5	2.59	1.12	1.02	1.18	2.30
7	2.49		1.02		2.02
9	2.36		0.75		1.77
13	1.41		0.53		1.08
21	0.31		0.14		0.29

Plate r

Position	10.08 NRP	9.45 NRP	8.82 NRP	8.19 NRP	7.56 NRP
0	2.46		1.96		2.69
1	2.02		1.04		1.67
3	2.38	0.98	1.22	1.39	2.06
5	2.83	1.18	1.22	1.59	2.63
7	2.26		1.04		2.08
9	2.26		0.92		1.87
13	1.41		0.61		0.94
21	0.45		0.10		0.18

TABLE 3.3
RELATIVE POWER DISTRIBUTION ALONG AXIAL TRAVERSES FOR ELEMENT IN POSITION 14; SM-1A CORE CONFIGURATION WITH SM-2 ELEMENTS

Position	10.08 NRP	9.45 NRP	Plate a 8.82 NRP	8.19 NRP	7.56 NRP
0	2.42		2.03		2.61
1	2.06		0.81		1.96
3	2.34	1.08	1.14	1.16	2.20
5	2.67	1.10	1.26	1.47	2.44
7	2.24		1.08		2.20
9	2.04		1.00		1.77
13	1.18		0.55		0.69
21	0.33		0.10		0.24

Position	10.08 NRP	9.45 NRP	Plate j 8.82 NRP	8.19 NRP	7.56 NRP
0	2.36		2.10		2.61
1	1.94		0.79		1.87
3	2.69	0.90	1.06	1.26	2.10
5	2.73	0.96	1.12	1.45	2.55
7	2.00		1.06		2.02
9	2.22		0.88		1.83
13	1.51		0.47		0.57
21	0.41		0.22		0.12

Position	10.08 NRP	9.45 NRP	Plate r 8.82 NRP	8.19 NRP	7.56 NRP
0	2.40		1.81		2.49
1	1.94		0.90		1.79
3	2.28	0.79	1.18	1.53	2.28
5	2.99	1.04	1.16	1.51	2.91
7	2.53		1.10		2.34
9	2.10		1.12		2.08
13	1.45		0.63		0.71
21	0.59		0.16		0.35

TABLE 3.4
RELATIVE POWER DISTRIBUTION ALONG AXIAL TRAVERSES
FOR ELEMENT IN POSITION 15; SM-1A CORE CONFIGURATION
WITH SM-2 ELEMENTS

			Plate a		
Position	10.08 NRP	9.45 NRP	8.82 NRP	8.19 NRP	7.56 NRP
0	2.55		2.26		2.83
1	2.00		0.92		1.83
3	2.67	1.16	1.22	1.45	2.38
5	2.93	1.24	1.22	1.55	2.65
7	2.93		1.26		2.49
9	2.14		1.04		2.02
13	1.65		0.67		0.90
21	0.43		0.18		0.22

			Plate j		
Position	10.08 NRP	9.45 NRP	8.82 NRP	8.19 NRP	7.56 NRP
0	2.28		1.94		3.08
1	1.83		0.73		1.73
3	2.32	0.92	0.98	1.18	2.26
5	2.63	1.00	1.14	1.32	2.61
7	2.59		1.12		2.53
9	2.32		0.96		2.24
13	1.67		0.65		1.30
21	0.37		0.16		0.35

			Plate r		
Position	10.08 NRP	9.45 NRP	8.82 NRP	8.19 NRP	7.56 NRP
0	2.00		1.79		2.85
1	1.85		0.71		1.65
3	2.22	0.96	0.96	1.36	2.08
5	2.44	1.02	1.08	1.36	2.44
7	2.57		1.14		2.53
9	2.30		1.08		2.40
13	1.69		0.67		1.20
21	0.49		0.22		0.41

TABLE 3.5
RELATIVE POWER DISTRIBUTION ALONG AXIAL TRAVERSES
FOR ELEMENT IN POSITION 16; SM-1A CORE CONFIGURATION
WITH SM-2 ELEMENTS

Plate a

Position	10.08 NRP	9.45 NRP	8.82 NRP	8.19 NRP	7.56 NRP
0	1.91		1.65		2.46
1	1.65		0.73		1.53
3	2.00	0.90	1.00	1.16	1.94
5	2.34	0.88	1.06	1.34	2.16
7	2.24		1.12		2.24
9	1.96		0.92		1.98
13	1.28		0.61		1.26
21	0.39		0.16		0.33

Plate j

Position	10.08 NRP	9.45 NRP	8.82 NRP	8.19 NRP	7.56 NRP
0	1.71		1.41		2.32
1	1.30		0.61		1.43
3	1.83	0.65	0.77	0.94	1.71
5	2.00	0.77	0.92	1.08	1.96
7	2.18		0.90		1.83
9	1.94		0.79		1.69
13	1.43		0.57		1.22
21	0.37		0.16		0.33

Plate r

Position	10.08 NRP	9.45 NRP	8.82 NRP	8.19 NRP	7.56 NRP
0	1.85		2.12		2.22
1	1.73		1.02		1.49
3	2.46	1.34	1.39	1.55	2.04
5	2.79	1.61	1.57	1.81	2.38
7	2.69		1.73		2.38
9	2.53		1.55		2.18
13	2.00		1.02		1.51
21	0.57		0.33		0.37

TABLE 3.6
RELATIVE POWER DISTRIBUTION ALONG AXIAL TRAVERSES
FOR ELEMENT IN POSITION 21; SM-1A CORE CONFIGURATION
WITH SM-2 ELEMENTS

Position	10.08 WRP	9.45 WRP	Plate a 8.82 WRP	8.19 WRP	7.56 WRP
0	1.79		1.53		2.34
1	1.51		0.65		1.49
3	1.71	0.77	0.84	1.10	1.77
5	2.26	0.90	0.90	1.10	1.87
7	1.98		0.92		1.77
9	1.87		0.73		1.65
13	1.18		0.49		0.88
17	0.69		0.22		0.45
21	0.26		0.10		0.18

Position	10.08 WRP	9.45 WRP	Plate j 8.82 WRP	8.19 WRP	7.56 WRP
0	1.69		1.26		1.83
1	1.22		0.53		1.10
3	1.77	0.61	0.67	0.77	1.36
5	1.75	0.71	0.77	0.90	1.47
7	2.02		0.73		1.49
9	1.67		0.67		1.30
13	1.08		0.41		0.79
17	0.55		0.26		0.39
21	0.31		0.10		0.20

Position	10.08 WRP	9.45 WRP	Plate r 8.82 WRP	8.19 WRP	7.56 WRP
0	1.65		1.69		2.10
1	1.67		0.94		1.39
3	2.02	1.10	1.39	1.43	1.81
5	2.59	1.39	1.49	1.53	1.96
7	2.42		1.47		2.00
9	2.16		1.22		1.79
13	1.49		0.86		1.18
17	0.84		0.47		0.57
21	0.41		0.18		0.24

TABLE 3.7
RELATIVE POWER DISTRIBUTION ALONG AXIAL TRAVERSES
FOR ELEMENT IN POSITION 22; SM-1A CORE CONFIGURATION
WITH SM-2 ELEMENT

Plate a

Position	7.14 NRP	6.51 NRP	5.88 NRP	5.25 NRP	4.62 NRP
0	1.89		1.73		2.51
1	1.24		0.98		1.61
3	1.63	1.22	1.26	1.34	2.00
5	1.83	1.34	1.34	1.45	2.20
7	1.81		1.28		1.98
9	1.67		1.08		1.65
13	0.88		0.69		0.98
17	0.59		0.41		0.51
21	0.22		0.20		0.29

Plate j

Position	7.14 NRP	6.51 NRP	5.88 NRP	5.25 NRP	4.62 NRP
0	2.36		2.34		3.48
1	1.45		0.81		2.06
3	1.67	1.16	1.22	1.36	2.42
5	1.85	1.28	1.30	1.53	2.55
7	1.89		1.22		2.18
9	1.63		1.02		1.96
13	0.96		0.71		1.04
17	0.51		0.35		0.51
21	0.26		0.12		0.24

Plate r

Position	7.14 NRP	6.51 NRP	5.88 NRP	5.25 NRP	4.62 NRP
0	2.34		2.59		3.38
1	1.57		1.22		2.26
3	1.98	1.36	1.61	1.81	2.75
5	2.24	1.55	1.65	1.73	2.79
7	2.02		1.49		2.53
9	1.73		1.24		2.02
13	0.98		0.67		0.88
17	0.49		0.35		0.47
21	0.31		0.18		0.18

TABLE 3.8
RELATIVE POWER DISTRIBUTION ALONG AXIAL TRAVERSES
FOR ELEMENT IN POSITION 23; SM-1A CORE CONFIGURATION
WITH SM-2 ELEMENT

Plate a

Position	7.14 NRP	6.51 NRP	5.88 NRP	5.25 NRP	4.62 NRP
0	2.63		2.42		3.65
1	1.65		1.22		2.32
3	2.08	1.59	1.61	1.75	2.79
5	2.22	1.63	1.65	1.83	2.83
7	2.10		1.53		2.53
9	1.69		1.18		2.02
13	0.98		0.67		0.77
21	0.26		0.16		0.14

Plate j

Position	7.14 NRP	6.51 NRP	5.88 NRP	5.25 NRP	4.62 NRP
0	2.91		2.91		3.40
1	1.71		1.18		2.63
3	2.16	1.45	1.53	1.73	3.01
5	2.36	1.57	1.67	1.85	3.04
7	2.20		1.39		2.77
9	1.65		1.08		2.26
13	0.96		0.59		0.59
21	0.24		0.14		0.10

Plate r

Position	7.14 NRP	6.51 NRP	5.88 NRP	5.25 NRP	4.62 NRP
0	2.75		2.63		3.73
1	1.98		1.45		2.67
3	2.51	1.79	1.85	2.16	3.61
5	2.55	2.00	1.98	2.20	3.63
7	2.59		1.81		3.14
9	2.02		1.65		2.53
13	0.73		0.39		0.57
21	0.20		0.10		0.12

TABLE 3.9
RELATIVE POWER DISTRIBUTION ALONG AXIAL TRAVERSES
FOR ELEMENT IN POSITION 25; SM-1A CORE CONFIGURATION
WITH SM-2 ELEMENT

Position	7.14 NRP	6.51 NRP	Plate a 5.88 NRP	5.25 NRP	4.62 NRP
0	2.69		2.57		3.71
1	2.04		1.57		2.77
3	2.59	2.00	2.12	2.36	3.56
5	2.77	2.24	2.14	2.42	3.77
7	2.63		1.98		3.36
9	2.24		1.22		2.81
13	0.94		0.55		0.88
21	0.26		0.14		0.18

Position	7.14 NRP	6.51 NRP	Plate j 5.88 NRP	5.25 NRP	4.62 NRP
0	3.12		3.06		4.07
1	1.77		1.20		2.34
3	2.38	1.67	1.67	1.87	3.04
5	2.40	1.71	1.69	1.94	3.42
7	2.42		1.49		3.18
9	2.08		1.36		2.67
13	1.26		0.77	1.59	
21	0.37		0.22		0.37

Position	7.14 NRP	6.51 NRP	Plate r 5.88 NRP	5.25 NRP	4.62 NRP
0	2.65		2.89		3.67
1	1.73		1.16		2.26
3	1.96	1.61	1.61	1.81	3.01
5	2.24	1.77	1.79	1.89	3.20
7	2.32		1.79		3.04
9	2.08		1.51		2.40
13	1.28		0.92		1.61
21	0.39		0.20		0.45

TABLE 3.10
RELATIVE POWER DISTRIBUTION ALONG AXIAL TRAVERSES
FOR ELEMENT IN POSITION 26; SM-1A CORE CONFIGURATION
WITH SM-2 ELEMENT

Position	7.14 NRP	6.51 NRP	Plate a 5.88 NRP	5.25 NRP	4.62 NRP
0	2.42		2.87		3.56
1	1.45		1.18		2.16
3	2.02	1.59	1.59	1.71	2.55
5	2.26	1.83	1.75	1.89	3.04
7	2.22		1.73		2.87
9	2.02		1.47		2.40
13	1.34		0.90		1.51
21	0.37		0.22		0.35

Position	7.14 NRP	6.51 NRP	Plate j 5.88 NRP	5.25 NRP	4.62 NRP
0	2.18		2.16		2.91
1	1.24		0.92		1.91
3	1.71	1.18	1.12	1.36	2.40
5	1.85	1.30	1.41	1.55	2.24
7	1.89		1.39		2.65
9	1.81		1.26		2.44
13	1.30		0.84		1.47
21	0.33		0.22		0.37

Position	7.14 NRP	6.51 NRP	Plate r 5.88 NRP	5.25 NRP	4.62 NRP
0	1.85		2.00		2.53
1	1.28		0.88		1.61
3	1.81	1.14	1.14	1.34	2.06
5	1.96	1.26	1.41	1.47	2.30
7	2.12		1.41		2.46
9	1.81		1.39		2.04
13	1.24		0.88		1.32
21	0.37		0.20		0.35

TABLE 3.11
RELATIVE POWER DISTRIBUTION ALONG AXIAL TRAVERSES
FOR ELEMENT IN POSITION 27; SM-1A CORE CONFIGURATION
WITH SM-2 ELEMENT

Position	7.56 ERP	8.19 ERP	Plate a 8.82 ERP	9.45 ERP	10.08 ERP
0	2.30		1.59		2.00
1	1.43		0.69		1.59
3	1.98	1.20	0.98	0.92	1.87
5	2.20	1.41	1.10	1.00	2.38
7	2.18		1.08		2.46
9	1.98		0.98		2.12
13	1.22		0.63		1.45
21	0.35		0.16		0.37

Position	7.56 ERP	8.19 ERP	Plate j 8.82 ERP	9.45 ERP	10.08 ERP
0	2.53		1.49		1.69
1	1.08		0.55		1.53
3	1.53	0.86	0.73	0.67	1.75
5	1.67	1.08	0.94	0.79	2.00
7	1.73		0.88		2.04
9	1.71		0.77		1.81
13	1.04		0.53		1.36
21	0.31		0.22		0.57

Position	7.56 ERP	8.19 ERP	Plate r 8.82 ERP	9.45 ERP	10.08 ERP
0	1.91		1.61		1.87
1	1.49		1.08		1.83
3	2.04	1.51	1.45	1.32	2.16
5	2.22	1.73	1.59	1.53	2.67
7	2.26		1.69		2.75
9	2.08		1.51		2.32
13	1.41		1.04		1.59
21	0.39		0.29		0.45

TABLE 3.12
RELATIVE POWER DISTRIBUTION ALONG AXIAL TRAVERSES FOR ELEMENT IN POSITION 31; SM-1A CORE CONFIGURATION WITH SM-2 ELEMENT

Plate a

Position	10.08 WRP	9.45 WRP	8.82 WRP	8.19 WRP	7.56 WRP
0	2.49		2.16		2.61
1	1.94		0.81		1.59
3	2.65	1.14	1.12	1.30	1.94
5	2.81	1.22	1.20	1.41	2.30
7	2.63		1.14		2.04
9	2.38		0.98		1.63
13	1.57		0.55		0.69
21	0.33		0.12		0.16

Plate j

Position	10.08 WRP	9.45 WRP	8.82 WRP	8.19 WRP	7.56 WRP
0	2.14		1.77		2.75
1	1.69		0.73		1.55
3	2.30	0.92	0.92	1.14	1.87
5	2.42	0.96	1.02	1.26	2.02
7	2.55		1.00		1.94
9	2.10		0.84		1.55
13	1.39		0.29		0.86
21	0.33		0.14		0.26

Plate r

Position	10.08 WRP	9.45 WRP	8.82 WRP	8.19 WRP	7.56 WRP
0	1.94		1.73		2.51
1	1.73		0.75		1.63
3	2.06	0.86	0.96	1.08	2.02
5	2.34	0.94	1.04	1.24	2.22
7	2.24		1.00		2.02
9	2.10		0.92		1.71
13	1.30		0.55		0.98
21	0.35		0.12		0.22

TABLE 3.13
RELATIVE POWER DISTRIBUTION ALONG AXIAL TRAVERSES
FOR ELEMENT IN POSITION 32; SM-1A CORE CONFIGURATION
WITH SM-2 ELEMENT

Position	4.20 NRP	3.57 NRP	Plate a 2.94 NRP	2.31 NRP	1.68 NRP
0	2.75		2.67		2.85
1	1.77		1.43		1.98
3	2.22	1.63	1.67	1.81	2.49
5	2.53	1.85	1.85	1.98	2.65
7	2.20		1.75		2.34
9	1.81		1.43		1.94
13	1.00		0.86		0.77
21	0.29		0.26		0.20

Position	4.20 NRP	3.57 NRP	Plate j 2.94 NRP	2.31 NRP	1.68 NRP
0	3.83		3.34		3.26
1	2.14		1.24		2.10
3	2.38	1.61	1.49	1.69	2.75
5	2.71	1.69	1.65	1.79	2.89
7	2.55		1.47		2.44
9	2.00		1.20		2.10
13	1.00		0.57		0.55
21	0.29		0.16		0.20

Position	4.20 NRP	3.57 NRP	Plate r 2.94 NRP	2.31 NRP	1.68 NRP
0	3.26		2.77		3.44
1	2.51		1.63		2.57
3	2.97	1.98	1.98	1.98	3.18
5	3.08	2.18	2.10	2.20	3.32
7	2.69		1.81		2.81
9	2.14		1.71		2.30
13	0.79		0.41		0.49
21	0.26		0.12		0.22

TABLE 3.14
RELATIVE POWER DISTRIBUTION ALONG AXIAL TRAVERSES FOR ELEMENT IN POSITION 34*
SM-1A CORE CONFIGURATION WITH SM-2 ELEMENT

	Plate a			Plate j			Plate r		
Position	4.20 NRP	2.94 NRP	1.68 NRP	4.20 NRP	2.94 NRP	1.68 NRP	4.20 NRP	2.94 NRP	1.68 NRP
0	3.71	3.18	3.87	3.79	3.77	3.91	3.65	2.99	4.11
1	3.01	2.16	3.22	2.79	1.59	2.81	2.89	1.79	3.34
3	3.89	2.69	3.63	3.54	2.04	3.52	3.46	1.79	3.75
5	3.95	2.77	4.26	3.77	2.08	3.73	3.71	2.28	4.11
7	3.22	2.18	3.34	3.12	1.77	2.97	3.12	2.06	4.14
9	2.46	2.16	2.26	2.40	1.32	2.42	2.42	1.65	2.75
13	0.55	0.41	0.59	0.65	0.63	0.55	0.96	0.88	0.93
21	0.14	0.14	0.10	0.12	0.16	0.20	0.24	0.20	0.22

* SM-1 data normalized to SM-1A core average.

TABLE 3.15
RELATIVE POWER DISTRIBUTION ALONG AXIAL TRAVERSES FOR ELEMENT IN POSITION 35*
SM-1A CORE CONFIGURATION WITH SM-2 ELEMENT

	Plate a			Plate j			Plate r		
Position	4.20 NRP	2.94 NRP	1.68 NRP	4.20 NRP	2.94 NRP	1.68 NRP	4.20 NRP	2.94 NRP	1.68 NRP
0	4.07	3.61	4.34	4.05	3.08	4.40	3.59	2.77	3.97
1	2.91	1.94	3.14	2.57	1.53	2.71	2.36	1.57	2.67
3	3.65	2.42	3.36	3.32	2.04	3.28	2.93	1.98	3.10
5	4.05	2.51	4.09	3.54	2.24	3.36	3.20	2.18	3.42
7	3.42	2.26	3.61	3.28	2.06	3.04	2.67	1.94	3.04
9	2.73	1.81	2.42	2.75	1.65	2.26	1.94	1.65	2.40
13	1.16	0.88	1.08	1.63	0.86	1.28	1.57	0.94	1.12
21	0.24	0.16	0.22	0.37	0.26	0.33	0.39	0.20	0.31

* SM-1 data normalized to SM-1A core average.

TABLE 3.16
RELATIVE POWER DISTRIBUTION ALONG AXIAL TRAVERSES
FOR ELEMENT IN POSITION 36; SM-1A CORE CONFIGURATION
WITH SM-2 ELEMENT

Plate a

Position	4.20 NRP	3.57 NRP	2.94 NRP	2.31 NRP	1.68 NRP
0	3.65		3.67		3.81
1	2.30		1.67		2.55
3	3.01	2.08	1.96	2.18	2.65
5	3.22	2.20	2.14	2.40	3.56
7	2.99		2.12		3.10
9	2.44		1.67		2.46
13	1.59		0.88		1.04
21	0.39		0.20		0.29

Plate j

Position	4.20 NRP	3.57 NRP	2.94 NRP	2.31 NRP	1.68 NRP
0	3.14		2.95		3.10
1	1.77		1.22		2.18
3	2.49	1.61	1.59	1.69	2.79
5	2.63	1.65	1.69	1.81	3.06
7	2.67		1.63		2.75
9	2.30		1.36		2.40
13	1.47		0.79		0.77
21	0.37		0.18		0.20

Plate r

Position	4.20 NRP	3.57 NRP	2.94 NRP	2.31 NRP	1.68 NRP
0	2.53		2.61		2.85
1	1.61		1.20		1.55
3	2.06	1.55	1.57	1.65	2.46
5	2.32	1.75	1.61	1.79	2.95
7	2.30		1.73		2.51
9	1.77		1.41		2.12
13	1.32		0.84		0.92
21	0.35		0.26		0.26

TABLE 3.17
RELATIVE POWER DISTRIBUTION ALONG AXIAL TRAVERSES FOR ELEMENT IN POSITION 37; SM-1A CORE CONFIGURATION WITH SM-2 ELEMENT

Position	7.56 ERP	8.19 ERP	Plate a 8.82 ERP	9.45 ERP	10.08 ERP
0	2.40		1.91		2.38
1	1.75		0.94		1.85
3	2.30	1.41	1.12	1.08	2.20
5	2.49	1.53	1.28	1.26	2.49
7	2.24		1.22		2.79
9	1.91		0.94		2.20
13	0.92		0.61		1.53
21	0.18		0.22		0.45

Position	7.56 ERP	8.19 ERP	Plate j 8.82 ERP	9.45 ERP	10.08 ERP
0	2.71		1.75		2.32
1	1.57		0.71		1.75
3	1.83	1.14	0.96	0.90	2.08
5	2.00	1.26	1.14	0.98	2.73
7	2.06		1.02		2.55
9	1.71		0.90		2.34
13	0.98		0.59		1.45
21	0.31		0.16		0.45

Position	7.56 ERP	8.19 ERP	Plate r 8.82 ERP	9.45 ERP	10.08 ERP
0	2.44		1.59		1.98
1	1.61		0.71		1.67
3	1.91	1.16	1.00	0.96	2.02
5	2.16	1.45	1.10	0.98	2.20
7	2.26		1.14		2.51
9	1.91		1.04		2.08
13	1.22		0.67		1.49
21	0.31		0.20		0.41

TABLE 3.18
RELATIVE POWER DISTRIBUTION ALONG AXIAL TRAVERSES
FOR ELEMENT IN POSITION 41; SM-1A CORE CONFIGURATION
WITH SM-2 ELEMENT

Position	10.08 WRP	9.45 WRP	Plate a 8.82 WRP	8.19 WRP	7.56 WRP
0	2.28		2.18		2.40
1	1.81		0.84		1.61
3	2.16	0.98	1.06	1.26	2.08
5	2.46	1.04	1.12	1.36	2.32
7	2.32		1.18		2.08
9	2.10		0.92		1.71
13	1.32		0.57		0.73
21	0.39		0.14		0.22

Position	10.08 WRP	9.45 WRP	Plate j 8.82 WRP	8.19 WRP	7.56 WRP
0	2.42		1.98		2.10
1	1.71		0.75		1.55
3	2.34	0.92	0.98	1.16	1.96
5	2.75	1.02	1.06	1.28	2.16
7	2.75		0.98		1.96
9	2.22		0.81		2.06
13	1.45		0.51		0.49
21	0.31		0.16		0.14

Position	10.08 WRP	9.45 WRP	Plate r 8.82 WRP	8.19 WRP	7.56 WRP
0	2.10		1.96		2.40
1	1.85		0.84		1.65
3	2.30	0.94	1.02	1.30	2.10
5	2.55	1.06	1.16	1.39	2.24
7	2.46		1.10		2.14
9	2.10		0.79		1.81
13	1.36		0.51		0.67
21	0.35		0.16		0.18

TABLE 3.19
RELATIVE POWER DISTRIBUTION ALONG AXIAL TRAVERSES FOR ELEMENT IN POSITION 43*
SM-1A CORE CONFIGURATION WITH SM-2 ELEMENT

	Plate a		Plate j		Plate r	
Position	1.26 NRP	0 NRP	1.26 NRP	0 NRP	1.26 NRP	0 NRP
0	3.54	3.26	3.54	2.67	3.89	3.04
1	2.99	1.83	2.18	1.43	3.46	2.12
3	3.61	2.18	3.08	1.85	4.16	2.55
5	3.85	2.26	3.81	2.10	4.30	2.73
7	3.10	1.98	3.38	1.81	3.59	2.12
9	2.46	1.96	2.49	1.43	2.73	2.16
13	0.53	0.39	0.71	0.61	0.59	0.49
21	0.12	0.08	0.14	0.18	0.12	0.10

* SM-1 data normalized to SM-1A core average.

TABLE 3.20
RELATIVE POWER DISTRIBUTION ALONG AXIAL TRAVERSES FOR ELEMENT IN POSITION 45*
SM-1A CORE CONFIGURATION WITH SM-2 ELEMENT

	Plate a		Plate j		Plate r	
Position	1.26 NRP	0 NRP	1.26 NRP	0 NRP	1.26 NRP	0 NRP
0	4.28	3.20	4.79	3.61	3.59	2.95
1	3.38	2.30	2.99	1.53	2.63	1.81
3	3.91	2.81	3.32	2.10	3.16	2.20
5	4.07	2.95	3.54	2.14	3.22	2.36
7	3.48	2.57	3.26	1.77	3.18	1.98
9	2.75	2.32	2.44	1.36	2.49	1.98
13	0.96	0.43	1.24	0.63	0.92	0.47
21	0.22	0.10	0.31	0.14	0.22	0.12

* SM-1 data normalized to SM-1A core average.

TABLE 3.21
RELATIVE POWER DISTRIBUTION ALONG AXIAL TRAVERSES
FOR ELEMENT IN POSITION 24 (CONTROL ROD 1) SM-1A
CORE CONFIGURATION WITH SM-2 ELEMENT

Position	7.04 NRP	6.46 NRP	Plate a 5.88 NRP	5.30 NRP	4.72 NRP
-13.88			0.10		
- 7			0.43		
- 3	0.92		0.86		1.22
- 1	2.38		1.79		3.24
0	2.04		1.71		2.89
1	2.00		1.63		2.73
3	2.59	2.02	2.46	2.36	3.34
5	2.75	2.12	2.24	2.32	3.46
6.5	2.53		1.98		2.93
7.62	1.69		1.36		1.91
8.12	2.02		2.20		2.34

Position	7.04 NRP	6.46 NRP	Plate i 5.88 NRP	5.30 NRP	4.72 NRP
-13.88			0.06		
- 7			0.14		
- 3	0.75		0.45		1.20
- 1	1.83		0.96		2.71
0	1.79		1.14		2.59
1	2.04		1.43		2.63
3	2.32	1.73	1.79	1.94	3.26
5	2.61	1.73	1.98	2.04	3.10
6.5	2.16		1.59		2.87
7.62	1.45		0.69		1.61
8.12	2.04		1.28		2.12

Position	7.04 NRP	6.46 NRP	Plate p 5.88 NRP	5.30 NRP	4.72 NRP
-13.88			0.06		
- 7			0.33		
- 3	0.84		0.69		1.30
- 1	2.04		1.49		3.12
0	1.94		1.57		2.85
1	1.81		1.51		2.89
3	2.30	1.81	1.94	2.30	3.06
5	2.69	2.06	2.08	2.44	3.67
6.5	2.34		1.96		3.24
7.62	1.53		0.77		1.85
8.12	2.20		2.06		2.40

TABLE 3.22
RELATIVE POWER DISTRIBUTION ALONG AXIAL TRAVERSES
FOR ELEMENT IN POSITION 42 (CONTROL ROD 4) SM-1A
CORE CONFIGURATION WITH SM-2 ELEMENT

Position	1.16 NRP	0.58 NRP	Plate a 0 NRP	0.58 SRP	1.16 SRP
-13.88			0.10		
- 7			0.29		
- 3	0.77		0.57		0.75
- 1	2.08		1.41		2.30
0	1.85		1.24		1.98
1	1.75		1.53		1.83
3	2.36	1.75	1.79	1.91	2.36
5	2.36	1.91	1.96	2.14	2.75
6.5	2.30		1.73		2.44
7.62	1.69		1.24		1.91
8.12	2.02		1.65		2.04

Position	1.16 NRP	0.58 NRP	Plate i 0 NRP	0.58 SRP	1.16 SRP
-13.88			0.08		
- 7			0.14		
- 3	1.00		0.43		0.90
- 1	2.06		0.84		2.18
0	2.00		1.06		2.00
1	2.10		1.36		2.18
3	2.57	1.67	1.65	1.81	2.79
5	2.57	1.83	1.71	1.85	2.97
6.5	2.30		1.55		2.61
7.62	1.47		0.69		1.61
8.12	1.91		1.77		2.32

Position	1.16 NRP	0.58 NRP	Plate p 0 NRP	0.58 SRP	1.16 SRP
-13.88			0.12		
- 7			0.37		
- 3	1.16		0.86		1.18
- 1	2.73		1.73		2.85
0	2.65		1.69		2.63
1	2.51		1.59		2.36
3	2.99	2.20	2.12	2.22	3.08
5	2.95	2.10	2.04	2.26	3.08
6.5	2.75		1.83		2.83
7.62	1.67		0.88		1.81
8.12	2.16		1.69		2.08

TABLE 3.23
RELATIVE POWER DISTRIBUTION ALONG AXIAL TRAVERSES FOR ELEMENT IN POSITION 33 (CONTROL ROD A)*
SM-1A CORE CONFIGURATION WITH SM-2 ELEMENT

	Plate a			Plate i			Plate p		
Position	4.10 NRP	2.94 NRP	1.78 NRP	4.10 NRP	2.94 NRP	1.78 NRP	4.10 NRP	2.94 NRP	1.78 NRP
-7	0.75	0.45	0.77	0.55	0.16	0.61	0.75	0.53	0.79
-3	1.02	0.94	1.16	1.10	0.53	1.32	1.26	1.02	1.45
-1	2.99	1.85	3.06	2.36	1.02	2.87	2.93	2.04	3.36
0	3.08	1.87	2.77	2.40	1.30	2.73	2.59	1.94	3.20
1	2.38	1.77	2.63	2.38	1.59	2.85	2.79	2.08	3.22
3	2.85	2.20	3.16	2.97	2.06	3.72	3.30	2.53	3.89
5	3.14	2.36	3.42	3.18	2.18	3.54	3.77	2.71	4.16
7	2.65	1.85	2.77	2.44	1.63	2.83	3.04	2.10	3.30
7.54	1.98	1.28	1.98	1.45	0.77	1.69	1.85	0.86	2.14
8.04	2.14	1.89	2.28	2.10	1.53	2.06	2.02	1.61	2.42

* SM-1 data normalized to SM-1A core average.

TABLE 3.24
RELATIVE POWER DISTRIBUTION ALONG AXIAL TRAVERSES FOR ELEMENT IN POSITION 44 (CONTROL ROD C)*
SM-1A CORE CONFIGURATION WITH SM-2 ELEMENT

	Plate a			Plate i			Plate p		
Position	1.16 NRP	0 NRP	1.16 SRP	1.16 NRP	0 NRP	1.16 SRP	1.16 NRP	0 NRP	1.16 SRP
-12.96	0.16	0.10	0.18	0.12	0.06	0.12	0.14	0.10	0.14
-9	0.51	0.31	0.63	0.41	0.12	0.47	0.63	0.33	0.51
-7	0.90	0.57	1.10	0.79	0.22	0.79	1.06	0.53	0.92
-5	0.81	0.67	0.79	0.77	0.33	0.81	0.84	0.59	0.84
-3	1.55	1.24	1.63	1.49	0.71	1.49	1.59	1.08	1.67
-1	3.54	2.44	3.77	3.36	1.22	3.16	3.52	2.04	3.56
0	3.06	1.81	3.26	2.91	1.57	2.91	3.08	1.91	3.22
1	3.10	2.12	3.08	3.12	1.83	3.16	3.04	2.06	3.24
3	4.07	2.71	3.79	4.01	2.40	3.67	3.75	2.65	4.14
5	3.97	2.61	3.87	3.73	2.28	3.79	3.83	2.63	3.73
7	3.06	1.94	3.06	2.83	1.57	2.93	2.44	2.08	3.22
7.54	2.04	1.30	1.83	1.79	0.63	1.57	1.65	0.71	1.79
8.04	2.38	1.98	2.49	2.02	1.87	2.08	2.22	1.91	2.71

* SM-1 data normalized to SM-1A core average.

4.0 PM-2A MEASUREMENTS WITH SM-2 MOCKUP FUEL ELEMENTS

4.1 INTRODUCTION

The PM-2A differs from the SM-1 and SM-1A in that it contains 32 stationary elements and 5 control rod assemblies. The core configuration is also different. Since Type 3 elements are scheduled for future core replacement for the PM-2A plant, nuclear measurements were performed utilizing SM-2 mockup elements in PM-2A startup core configuration. These included bank positions, rod calibrations, critical rod configurations, material coefficients and power distribution measurements.

4.2 CORE CONFIGURATION AND INITIAL CRITICAL POSITION

The PM-2A core configuration was previously illustrated in Fig. 1.4. The total U-235 content in the core was 30.048 Kg; the estimated B-10 loading was 56 gm. A 50 mil stainless steel skirt surrounded the core. The initial five rod bank critical position measured at 68°F was 8.56 in.

4.3 WORTH OF STAINLESS STEEL SKIRT

The worth of the 0.050 in. thick stainless steel skirt around the outer boundary of the core was measured on the calibrated five rod bank as - 51 cents.

4.4 CALIBRATION OF CONTROL RODS 1 and 2

Control rods 1 and 2 were calibrated against each other using the period method. For this purpose, rod 1 was fully withdrawn, rod 2 was fully inserted and the reactor was brought critical on the three rod bank 3, 4, 5 at a critical position of 8.447 in. which was maintained throughout the calibration measurements. Following this, control rod 2 was withdrawn, putting the reactor on about a 30 sec. period, and control rod 1 was inserted to bring the reactor critical again. This process was repeated for the full lengths of rods 1 and 2. The composite calibration curve derived from these measurements is presented in Fig. 4.1. There are no similar measurements available from PM-2A Core I data which would provide a comparison.

4.5 CRITICAL ROD CONFIGURATION

Various individual and combination control rod withdrawal measurements were performed to provide an estimate of the minimum rod withdrawal required to maintain criticality in the PM-2A reactor at beginning of core life. Table 4.1 presents the critical rod configurations and rod worth for cases tested. Rods omitted in table 4.1 were fully inserted and the reactor was brought critical on the critical rod(s) indicated in each case. In general, there is good internal agreement of the data in Table 4.1. Small differences, as illustrated by cases 4 and 8, are attributed to the slight non-uniformity of burnable poison loading previously mentioned (Ref. Section 2.4). It should be noted that an SM-2 core in a PM-2A core configuration will not maintain criticality on any single control rod. By contrast, the PM-2A Core I would maintain criticality in the cold, clean core condition by withdrawal of control rod No. 4 to 16.28 in. or rod No. 2 to 19.74 in. or rod No. 5 to 19.50 in.

4.6 MATERIAL COEFFICIENTS

4.6.1 Introduction

Material coefficients in the PM-2A core configuration were measured on calibrated control rod 2 at room temperature and pressure. Rod 2 was chosen because it is distant from the quadrant of the core where measurements are made. Also, preliminary investigation indicates that its calibration curve in the region of measurement is smooth and essentially linear. A zero reference position was established by substituting a standard SM-1 element into position 75 and placing element 75 into position 22. This procedure leaves element No. 22 free for substitution measurements into other positions in the core. Using the above configuration, the four rod bank (1, 3, 4, 5) was placed at 8.000 in. and the rod 2 critical position was 11.926 in. This four rod bank position was maintained throughout the test series. The calibration curve for rod 2 with the other rods at 8.000 in. is shown in Fig. 4.2.

4.6.2 B-10 Worth

B-10 reactivity coefficients were determined for each element position in one quadrant of the symmetrical core. One strip of boron-impregnated Mylar tape containing 0.0752 mg B-10/cm^2 [6] was added to each of the fuel plates of element No. 22 for a total of 0.4716 gm B-10 added. [6] Then element No. 22 was substituted into the other stationary positions in one quadrant of the core. For the control rods, one strip of boron tape containing 0.0752 mg B-10/cm^2 [6] was added to each of the fuel plates of the control rod 3 fuel element, the equivalent of 0.3857 gm B-10. [6] This element was then interchanged with other control

TABLE 4.1
CRITICAL ROD CONFIGURATIONS

Case	Rod (s) Fully Withdrawn	Critical Rod (s)	Critical Position - in.	Worth Cents/in.
1	4	1	17.145	
2	4	3	16.708	31.15 at 16.929 in.
3	1, 3	2	11.532	23.42 at 11.880 in.
4	1, 3	5	11.352	23.71 at 11.748 in.
5	3, 5	1	13.315	33.16 at 13.610 in.
6	3, 5	4	9.029	65.10 at 9.221 in.
7	3, 5	2	13.582	31.80 at 13.942 in.
8	1, 5	2	11.779	24.16 at 12.313 in.
9	1, 5	4	6.378	51.76 at 6.619 in.
10	1, 5	3	11.434	26.07 at 11.913 in.
11	1, 2	5	13.780	32.72 at 14.136 in.
12	1, 2	3	13.750	46.81 at 13.985 in.
13	1, 2	4	9.438	63.13 at 9.636 in.
14		1, 2, 4	13.002	97.57 at 13.107 in.
15		1, 4, 5	11.959	116.84 at 12.057 in.
16		3, 4, 5	12.790	109.34 at 12.897 in.
17		2, 4, 5	12.053	119.21 at 12.154 in.
18		1, 2, 5	16.593	52.20 at 16.797 in.
19		2, 3, 5	16.557	53.25 at 16.753 in.
20		1, 3, 4, 5	9.919	12.50* at 1.008 in.

* Control rod 2 worth.

rod fuel elements in the positions under consideration. For each element position, the worth of the added B-10 was measured on calibrated rod 2 with the four rod bank at 8.000 in. B-10 worth in cents per gm was obtained by dividing the measured core reactivity change due to the additional tapes by their B-10 content. The results for the various positions in the core are presented in Table 4.2. Symmetry relationships may be used to obtain B-10 worths for element positions not shown in the table.

4.6.3 U-235 Worth

For the U-235 reactivity coefficients in stationary elements, six basic fuel plates (b, d, g, k, m, q) of element No. 22 were replaced by depleted plates. This provided a net difference of 277.8 gm U-235 in element No. 22 for the test series. For the control rods, five basic plates (b, e, i, l, o) with 211.2 gm U-235 of control rod 4 fuel element were replaced by depleted plates. In all cases, the metal of water ratio and B-10 loadings were preserved. The same reference configuation used in the B-10 coefficients measurements was retained for the U-235 coefficients measurements. Changes in reactivity resulting from placing the elements with depleted plates into the core positions in the quadrant under consideration were determined on the calibrated control rod 2, Fig. 4.2, with the four rod bank 1, 3, 4, 5 maintained at 8.000 in. Reactivity differences thus obtained divided by U-235 loading differences yield the U-235 coefficients in cents per gm. The results of the measurements are presented in Table 4.3. Coefficients for element positions not shown in table 4.3 may be obtained from core symmetry.

4.7 POWER DISTRIBUTION MEASUREMENTS

4.7.1 Introduction

Power distribution measurements were made in the PM-2A configuration with SM-2 mockup elements by uranium foil activation in one quadrant of the symmetrical core. Using the procedure described in Section 1.4.5, approximately 1000 data points were collected, permitting calculation of the core average and determination of location and magnitude of local power peaking. Stationary fuel elements without flux suppressors and control rod fuel elements equipped with 0.5 in. mockup suppressors at the top of the active meat were utilized throughout the experimental program.

4.7.2 Core Average

The PM-2A core average was calculated from data obtained using the method described in Section 1.4.5.4. All power distribution data were then normalized to this core average, which then becomes unity by definition.

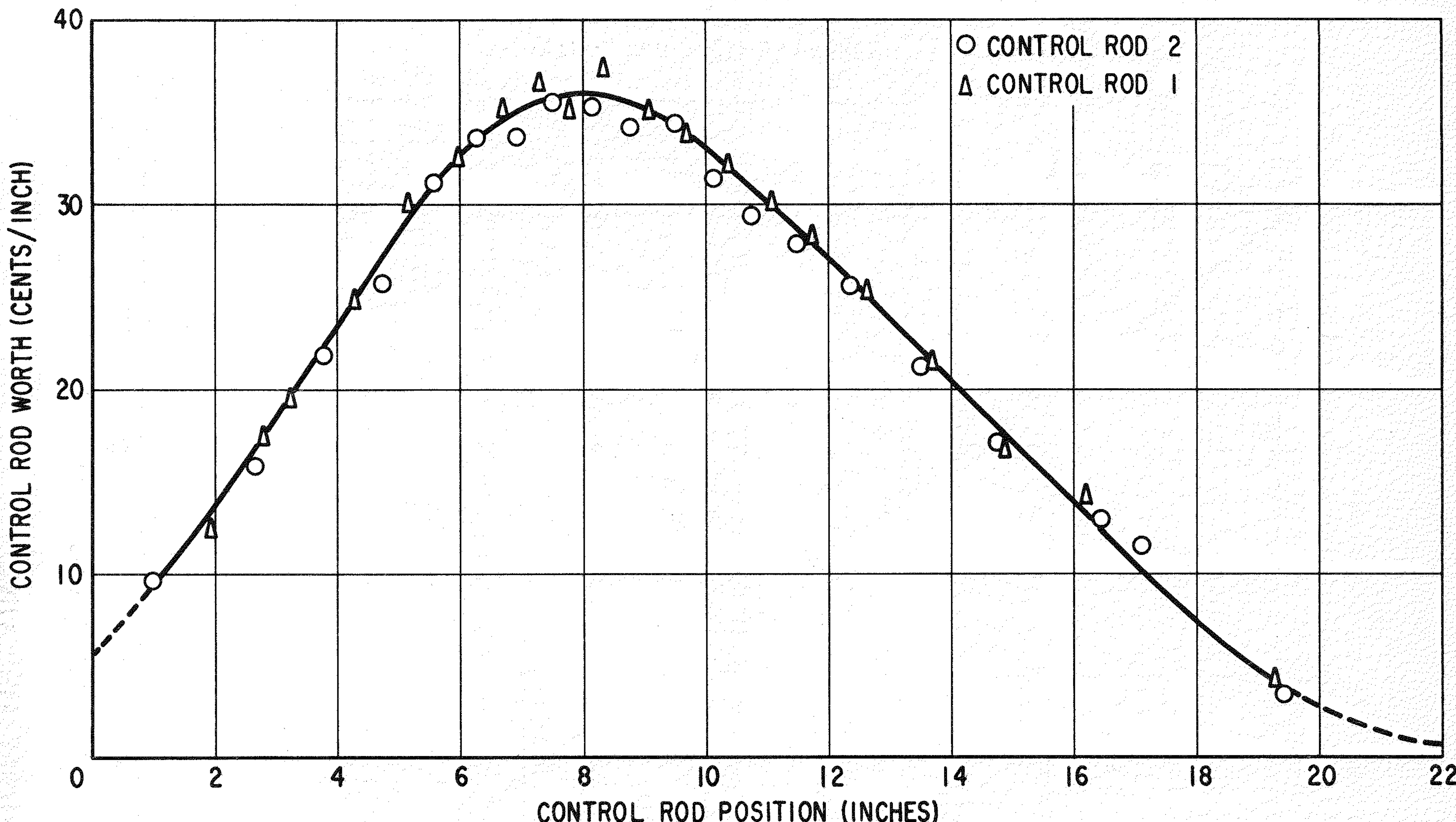

Figure 4.1. Composite Calibration Curve for Rods 1 and 2; Three Rod Bank at 8.447 Inches - PM-2A Configuration with SM-2 Elements

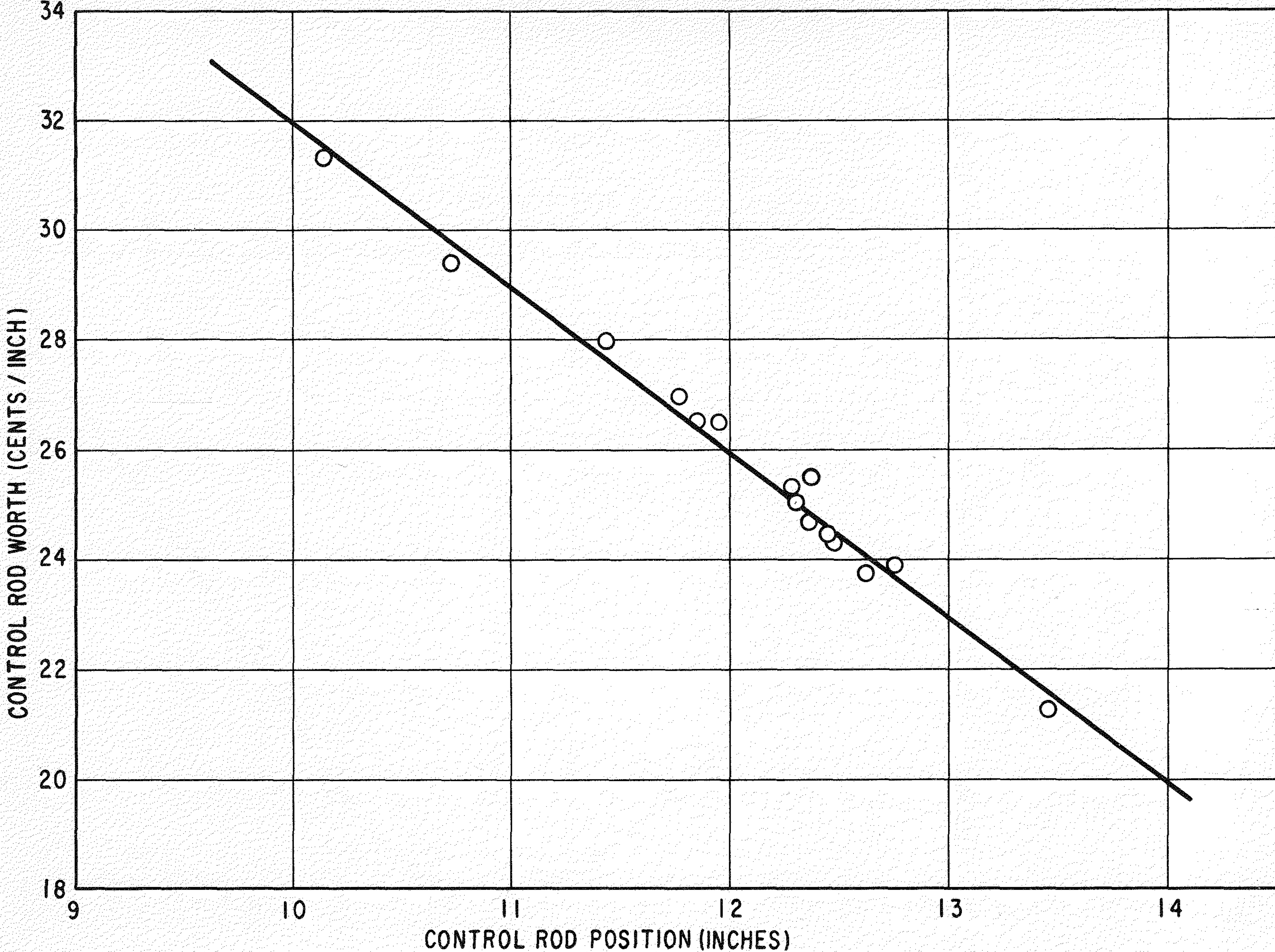

Figure 4.2. Control Rod 2 Calibration Four Rod Bank at 8.00 Inches - PM-2A Configuration with SM-2 Elements

Core Loading
30.5 Kg U-235
56 gm B-10

Critical Bank Position
8.56 in. 5 Rod Bank

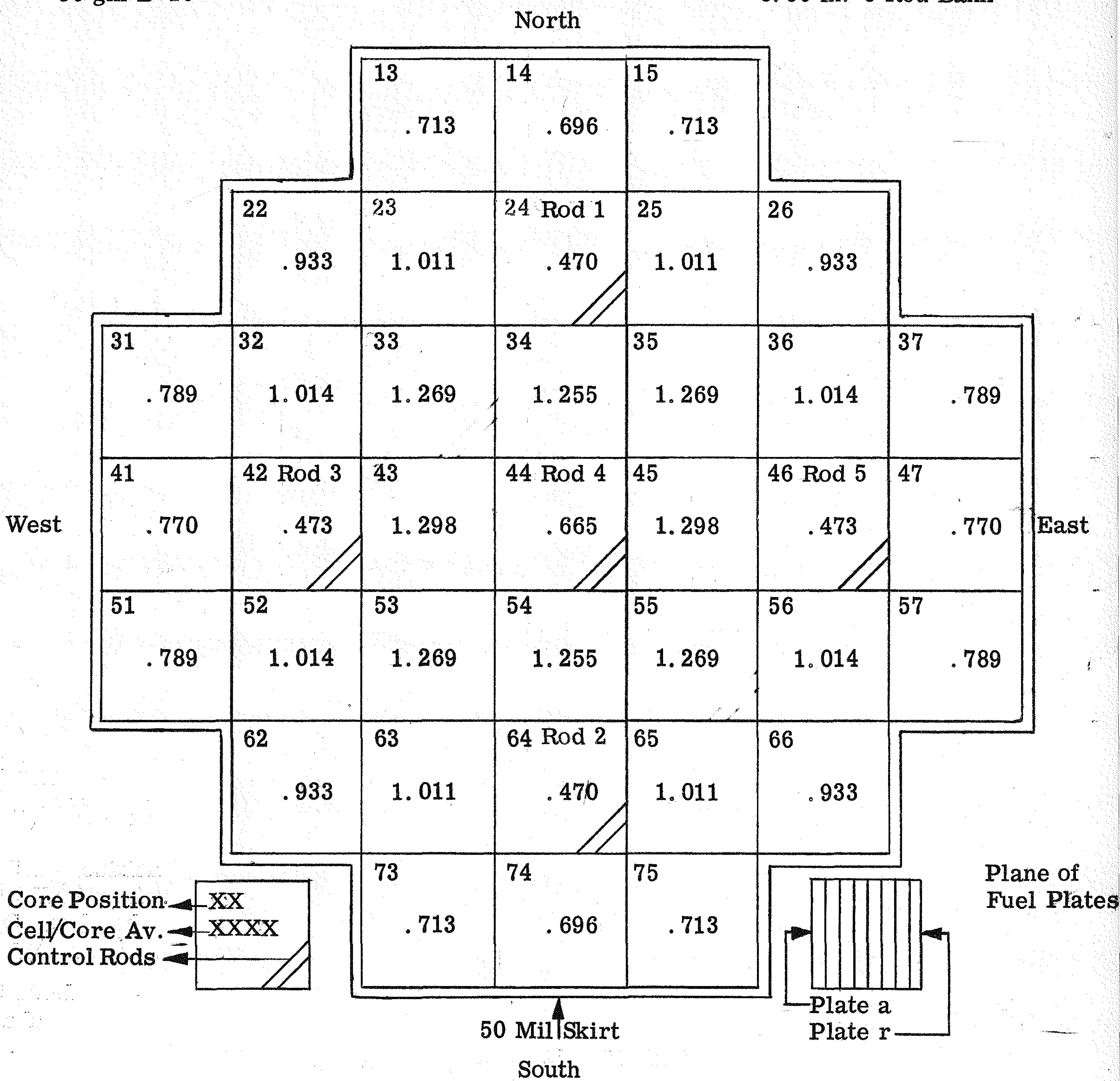

Fig. 4.3 - PM-2A Cell Power Averages Normalized to a Core Average of Unity; SM-2 Elements

TABLE 4.2
B-10 REACTIVITY COEFFICIENTS

Element Position	B-10 Worth, cents/gm
13	11.87
14	12.30
22	20.61
23	29.92
31	12.55
32	31.68
33	51.38
34	54.11
41	13.78
43	62.49
24 Control Rod 1	31.76
42 Control Rod 3	33.47
44 Control Rod 4	69.30
Average for stationary fuel elements	28.67
Core Average	30.19

TABLE 4.3
U-235 REACTIVITY COEFFICIENTS

Element Position	U-235 Worth, cents/gm
13	0.057
14	0.068
22	0.098
23	0.153
31	0.065
32	0.154
33	0.255
34	0.287
41	0.076
43	0.333
24 Control Rod 1	0.167
42 Control Rod 3	0.176
44 Control Rod 4	0.350
Average for stationary fuel elements	0.146
Core Average	0.154

4.7.3 Experimental Data and Discussion of Results

The complete, normalized, cell power averages are presented in Fig. 4.3. Sixteen elements located in the center of the core exceed the core average; the highest, 1.298 times core average, is for elements in positions 43 and 45. Elements in positions 14 and 74 had the lowest cell power averages among stationary elements in the core, 0.696 of the core average. The cell averages for the control rod fuel elements are reported as less than the core average even though they have a higher than average power density over the region actually inserted into the active core. Power generation for the control rod fuel elements was calculated on the basis of the fraction of the fuel plates actually inserted in the core, the five rod bank critical position being 8.56 in.

Tables 4.4 through 4.16 present the normalized power distribution along axial traverses of stationary fuel elements in 13, 14, 22, 23, 31, 32, 33, 34, 41, 43 and for control rod fuel elements 1, 3 and 4 in positions 24, 42 and 44 respectively. Fuel plates a, j and r were selected for these measurements for the stationary fuel elements, plates a, i, and p for the control rod fuel elements. The data range from a normalized low of 0.10 of core average at the edge of the core to an internal high of 3.67 times core average in the element in position 33 at the center of the core. Peak power generation of 4.08 times core average occured, as a spike at the bottom of the active core of element in position 33 due to the absence of flux suppressors.

The power traverses shown in Fig. 4.4 through 4.7 are typical of the power distribution axially along a fuel plate. Fig. 4.4 and 4.5 show the power of the centerline traverses of plate j normalized to the core average for stationary elements in positions 31, 41, and 22, 32, respectively. Fig. 4.6 and 4.7 show similar traverses for stationary elements in positions 13, 23, 33, 43, and 14, 34, respectively. The above data indicate that all stationary fuel elements exhibit a large power spike at the bottom of the active core (due to absence of flux suppressors) and a smaller axial peak 4 - 6 in. above it. The power gradually decreases as the top of the active core is approached. For example, in element in position 33 along centerline of fuel plate j, this power peaking is about 3.44 times core average at the bottom of the active core and 1.85 times core average at an axial position 5 in. above it, while it is only 0.23 of the core average at the top of the active core. Measurements near the critical position indicate a small increase in power in that region for stationary elements adjacent to control rods.

Fig. 4.8 shows the normalized power of the centerline traverses of fuel plate i of control rods 1, 3, and 4. There is a small uniform increase in the power until the bottom of the flux suppressors is reached, at which point a sharp drop in power occurs.

TABLE 4.4
RELATIVE POWER DISTRIBUTION ALONG AXIAL TRAVERSES
FOR ELEMENT IN POSITION 13; PM-2A CORE CONFIGURATION
WITH SM-2 ELEMENTS

Plate a

Position	10.08 NRP	9.45 NRP	8.82 NRP	8.19 NRP	7.56 NRP
0	1.94		1.87		2.35
1	1.79		1.28		1.75
3	2.37	1.67	1.83	1.94	2.31
5	2.74	1.90	1.98	2.18	2.51
8.6	2.62		1.90		2.37
9.1	2.41		1.87		2.22
13	1.79		1.24		1.50
21	0.39		0.29		0.35

Plate j

Position	10.08 NRP	9.45 NRP	8.82 NRP	8.19 NRP	7.56 NRP
0	1.75		1.40		2.25
1	1.30		0.52		1.26
3	1.79	0.68	0.72	0.89	1.71
5	2.02	0.74	0.84	0.97	1.85
8.6	1.87		0.76		1.67
9.1	1.75		0.72		1.57
13	1.17		0.43		0.95
21	0.27		0.10		0.25

Plate r

Position	10.08 NRP	9.45 NRP	8.82 NRP	8.19 NRP	7.56 NRP
0	1.77		1.40		2.04
1	1.50		0.64		1.40
3	1.96	0.76	0.87	1.05	1.92
5	2.27	0.89	0.95	1.24	2.10
8.6	2.18		0.87		1.83
9.1	1.92		0.76		1.73
13	1.19		0.45		0.84
21	0.31		0.12		0.21

TABLE 4.5
RELATIVE POWER DISTRIBUTION ALONG AXIAL TRAVERSES FOR ELEMENT IN POSITION 14; PM-2A CORE CONFIGURATION WITH SM-2 ELEMENTS

Position	10.08 NRP	9.45 NRP	Plate a 8.82 NRP	8.19 NRP	7.56 NRP
0	1.79		0.97		1.92
1	1.52		0.68		1.48
3	1.94	0.84	0.89	1.11	2.04
5	2.20	0.91	0.99	1.19	2.16
8.6	1.92		0.89		1.96
9.1	1.75		0.82		1.77
13	1.17		0.45		0.80
21	0.31		0.10		0.25

Position	10.08 NRP	9.45 NRP	Plate j 8.82 NRP	8.19 NRP	7.56 NRP
0	2.00		1.22		1.69
1	1.50		0.62		1.52
3	1.90	0.74	0.99	1.03	2.06
5	2.18	0.87	0.97	1.17	2.27
8.6	2.12		0.80		1.73
9.1	1.83		0.76		1.73
13	1.15		0.47		0.54
21	0.29		0.12		0.16

Position	10.08 NRP	9.45 NRP	Plate r 8.82 NRP	8.19 NRP	7.56 NRP
0	1.83		1.30		1.92
1	1.40		0.64		1.44
3	1.90	0.82	0.89	1.13	1.87
5	2.16	0.87	0.95	1.17	2.18
8.6	2.02		0.84		1.61
9.1	1.98		0.87		1.55
13	1.34		0.45		0.70
21	0.31		0.12		0.19

TABLE 4.6
RELATIVE POWER DISTRIBUTION ALONG AXIAL TRAVERSES
FOR ELEMENT IN POSITION 22; PM-2A CORE CONFIGURATION
WITH SM-2 ELEMENTS

			Plate a		
Position	7.14 NRP	6.51 NRP	5.88 NRP	5.25 NRP	4.62 NRP
0	2.49		1.94		2.27
1	2.18		1.46		1.77
3	2.90	1.81	1.98	2.06	2.20
5	3.36	2.14	2.27	2.51	2.58
8.6	3.32		2.06		2.35
9.1	3.15		2.00		2.31
13	2.12		1.38		1.44
21	0.54		0.33		0.35

			Plate j		
Position	7.14 NRP	6.51 NRP	5.88 NRP	5.25 NRP	4.62 NRP
0	2.39		1.75		2.43
1	1.83		0.68		1.38
3	2.43	0.91	0.91	1.07	1.77
5	2.68	1.07	1.05	1.24	2.04
8.6	2.47		1.01		1.90
9.1	2.33		0.89		1.79
13	1.61		0.61		1.19
21	0.39		0.14		0.31

			Plate r		
Position	7.14 NRP	6.51 NRP	5.88 NRP	5.25 NRP	4.62 NRP
0	2.22		2.14		2.72
1	1.55		0.95		1.73
3	2.29	1.11	1.15	1.42	2.33
5	2.51	1.38	1.40	1.61	2.45
8.6	2.35		1.28		2.37
9.1	2.20		1.24		2.08
13	1.42		0.76		1.34
21	0.41		0.19		0.33

TABLE 4.7
RELATIVE POWER DISTRIBUTION ALONG AXIAL TRAVERSES
FOR ELEMENT IN POSITION 23; PM-2A CORE CONFIGURATION
WITH SM-2 ELEMENTS

Position	7.14 NRP	6.51 NRP	Plate a 5.88 NRP	5.25 NRP	4.62 NRP
0	1.92		1.75		2.82
1	1.42		1.05		1.85
3	1.85	1.32	1.40	1.46	2.43
5	2.02	1.34	1.38	1.69	2.72
8.6	1.87		1.11		2.39
9.1	1.77		1.34		2.20
13	1.28		0.76		1.36
21	0.31		0.21		0.35

Position	7.14 NRP	6.51 NRP	Plate j 5.88 NRP	5.25 NRP	4.62 NRP
0	2.35		2.00		2.99
1	1.42		1.01		2.02
3	1.75	1.22	1.28	1.61	2.70
5	1.96	1.38	1.52	1.73	3.07
8.6	1.81		1.15		2.58
9.1	1.61		1.26		2.45
13	1.09		0.72		1.38
21	0.27		0.19		0.33

Position	7.14 NRP	6.51 NRP	Plate r 5.88 NRP	5.25 NRP	4.62 NRP
0	2.22		2.06		3.03
1	1.75		1.24		2.33
3	2.14	1.83	1.67	2.04	2.88
5	2.49	1.87	1.90	2.10	3.38
8.6	1.92		1.48		2.49
9.1	2.00		1.69		2.51
13	1.15		0.68		1.11
21	0.23		0.14		0.31

TABLE 4.8
RELATIVE POWER DISTRIBUTION ALONG AXIAL TRAVERSES
FOR ELEMENT IN POSITION 31; PM-2A CORE CONFIGURATION
WITH SM-2 ELEMENTS

			Plate a		
Position	4.20 NRP	3.57 NRP	2.94 NRP	2.31 NRP	1.68 NRP
0	1.83		1.46		2.04
1	1.73		0.99		1.71
3	2.31	1.38	1.44	1.52	2.35
5	2.78	1.52	1.61	1.65	2.66
8.6	2.45		1.48		2.33
9.1	2.29		1.38		2.22
13	1.61		0.97		1.42
21	0.41		0.23		0.31

			Plate j		
Position	4.20 NRP	3.57 NRP	2.94 NRP	2.31 NRP	1.68 NRP
0	2.16		1.59		2.08
1	1.81		0.60		1.11
3	2.20	0.78	0.76	0.89	1.48
5	2.70	0.89	0.89	0.91	1.65
8.6	2.45		0.78		1.44
9.1	2.33		0.72		1.26
13	1.59		0.43		0.78
21	0.41		0.23		0.19

			Plate r		
Position	4.20 NRP	3.57 NRP	2.94 NRP	2.31 NRP	1.68 NRP
0	2.18		1.85		2.06
1	1.57		0.89		1.42
3	2.12	0.97	1.09	1.22	1.81
5	2.45	1.15	1.19	1.34	2.08
8.6	2.16		1.09		1.75
9.1	2.06		1.03		1.73
13	1.34		0.64		0.78
21	0.33		0.16		0.19

TABLE 4.9
RELATIVE POWER DISTRIBUTION ALONG AXIAL TRAVERSES
FOR ELEMENT IN POSITION 32; PM-2A CORE CONFIGURATION
WITH SM-2 ELEMENTS

			Plate a		
Position	4.20 NRP	3.57 NRP	2.94 NRP	2.31 NRP	1.68 NRP
0	1.92		1.44		1.94
1	1.65		0.91		1.55
3	1.98	1.15	1.15	1.32	1.98
5	2.18	1.24	1.30	1.46	2.25
8.6	2.06		1.13		1.85
9.1	1.83		1.11		1.73
13	1.17		0.64		0.76
21	0.27		0.16		0.21

			Plate j		
Position	4.20 NRP	3.57 NRP	2.94 NRP	2.31 NRP	1.68 NRP
0	2.39		1.81		2.37
1	1.63		1.01		2.12
3	2.00	1.34	1.42	1.48	2.49
5	2.06	1.50	1.50	1.63	2.86
8.6	1.85		1.30		2.25
9.1	2.14		1.28		2.29
13	1.22		0.72		0.72
21	0.31		0.14		0.14

			Plate r		
Position	4.20 NRP	3.57 NRP	2.94 NRP	2.31 NRP	1.68 NRP
0	2.84		2.43		3.09
1	1.85		1.19		2.06
3	2.41	1.63	1.57	1.87	2.82
5	2.66	1.83	1.81	2.08	3.17
8.6	2.43		1.57		2.43
9.1	2.20		1.44		2.49
13	1.44		0.89		1.05
21	0.37		0.21		0.25

TABLE 4.10
RELATIVE POWER DISTRIBUTION ALONG AXIAL TRAVERSES
FOR ELEMENT IN POSITION 33; PM-2A CORE CONFIGURATION
WITH SM-2 ELEMENTS

Plate a

Position	4.20 NRP	3.57 NRP	2.94 NRP	2.31 NRP	1.68 NRP
0	2.76		2.90		3.19
1	1.87		1.28		2.27
3	2.27	1.63	1.67	1.77	2.84
5	2.64	1.96	1.90	2.08	3.30
8.6	2.14		1.63		2.41
9.1	2.14		1.52		2.39
13	1.30		0.82		1.05
21	0.31		0.21		0.27

Plate j

Position	4.20 NRP	3.57 NRP	2.94 NRP	2.31 NRP	1.68 NRP
0	3.44		3.44		4.08
1	2.27		1.32		2.37
3	2.70	1.67	1.65	1.79	3.11
5	3.05	1.94	1.85	2.14	3.36
8.6	2.45		1.57		2.93
9.1	2.41		1.55		2.95
13	1.34		0.89		1.46
21	0.39		0.23		0.39

Plate r

Position	4.20 NRP	3.57 NRP	2.94 NRP	2.31 NRP	1.68 NRP
0	3.15		3.07		3.83
1	2.31		1.42		2.51
3	2.80	1.92	1.92	2.04	3.30
5	3.17	2.08	2.37	2.33	3.67
8.6	2.66		1.75		2.82
9.1	2.47		1.81		2.60
13	1.13		0.87		1.26
21	0.29		0.21		0.31

TABLE 4.11
RELATIVE POWER DISTRIBUTION ALONG AXIAL TRAVERSES
FOR ELEMENT IN POSITION 34; PM-2A CORE CONFIGURATION
WITH SM-2 ELEMENTS

			Plate a		
Position	4.20 NRP	3.57 NRP	2.94 NRP	2.31 NRP	1.68 NRP
0	2.97		2.95		3.19
1	2.22		1.55		2.33
3	2.86	1.92	1.83	2.22	3.28
5	3.17	2.06	2.12	2.55	3.50
8.6	2.41		1.79		2.80
9.1	2.47		1.94		2.60
13	0.97		0.89		1.13
21	0.25		0.19		0.62

			Plate j		
Position	4.20 NRP	3.57 NRP	2.94 NRP	2.31 NRP	1.68 NRP
0	2.93		2.82		3.15
1	2.26		1.40		2.47
3	2.90	1.83	1.73	1.98	3.30
5	3.15	2.06	1.92	2.25	3.61
8.6	2.41		1.71		2.80
9.1	2.41		1.63		2.53
13	0.64		0.82		0.87
21	0.23		0.19		0.21

			Plate r		
Position	4.20 NRP	3.57 NRP	2.94 NRP	2.31 NRP	1.68 NRP
0	3.36		3.01		3.67
1	2.37		1.44		2.43
3	3.11	1.87	1.90	2.02	3.32
5	3.48	2.20	2.18	2.18	3.56
8.6	2.62		1.77		2.78
9.1	2.66		1.57		2.70
13	1.13		0.91		1.09
21	0.25		0.21		0.25

TABLE 4.12
RELATIVE POWER DISTRIBUTION ALONG AXIAL TRAVERSES
FOR ELEMENT IN POSITION 41; PM-2A CORE CONFIGURATION
WITH SM-2 ELEMENTS

Plate a

Position	1.26 NRP	0.63 NRP	0 NRP	0.63 SRP	1.26 SRP
0	2.00		1.71		2.02
1	1.46		1.28		1.55
3	2.06	1.61	1.59	1.65	2.06
5	2.20	1.92	1.81	1.79	2.22
8.6	2.06		1.69		2.25
9.1	1.90		1.52		1.90
13	1.32		1.05		1.36
21	0.31		0.33		0.31

Plate j

Position	1.26 NRP	0.63 NRP	0 NRP	0.63 SRP	1.26 SRP
0	1.90		1.77		2.04
1	1.05		0.76		1.26
3	1.34	0.91	0.93	0.91	1.44
5	1.61	1.13	0.91	0.99	1.57
8.6	1.38		0.82		1.52
9.1	1.24		0.76		1.36
13	0.80		0.43		0.78
21	0.21		0.12		0.41

Plate r

Position	1.26 NRP	0.63 NRP	0 NRP	0.63 SRP	1.26 SRP
0	1.94		1.44		1.96
1	1.42		0.93		1.61
3	1.96	1.34	1.26	1.34	1.94
5	2.08	1.42	1.36	1.42	2.04
8.6	1.71		1.03		1.71
9.1	1.79		1.34		1.73
13	0.64		0.58		0.72
21	0.41		0.33		0.19

TABLE 4.13
RELATIVE POWER DISTRIBUTION ALONG AXIAL TRAVERSES FOR ELEMENT IN POSITION 43; PM-2A CORE CONFIGURATION WITH SM-2 ELEMENTS

Plate a

Position	1.26 NRP	0.63 NRP	0 NRP	0.63 SRP	1.26 SRP
0	2.74		2.18		3.09
1	2.16		1.59		2.25
3	2.97	2.16	2.06	2.27	2.97
5	3.09	2.39	2.22	2.39	3.23
8.6	2.60		1.79		2.72
9.1	2.53		2.37		2.64
13	1.03		0.58		1.01
21	0.45		0.12		0.54

Plate j

Position	1.26 NRP	0.63 NRP	0 NRP	0.63 SRP	1.26 SRP
0	3.15		2.78		3.98
1	2.53		1.40		2.20
3	3.09	1.92	1.85	1.87	3.05
5	3.23	2.00	1.96	2.39	3.11
8.6	2.70		1.67		2.72
9.1	2.58		1.83		2.41
13	1.48		0.82		1.40
21	0.37		0.49		0.31

Plate r

Position	1.26 NRP	0.63 NRP	0 NRP	0.63 SRP	1.26 SRP
0	3.61		2.55		3.46
1	2.62		1.63		2.53
3	3.63	2.37	2.35	2.37	3.42
5	3.65	2.55	2.51	2.49	3.48
8.6	2.86		1.75		2.80
9.1	2.93		2.04		2.68
13	1.13		0.62		1.11
21	0.41		0.14		0.21

TABLE 4.14
RELATIVE POWER DISTRIBUTION ALONG AXIAL TRAVERSES
FOR ELEMENT IN POSITION 24 (CONTROL ROD 1) PM-2A
CORE CONFIGURATION WITH SM-2 ELEMENTS

Position	7.04 NRP	6.46 NRP	Plate a 5.88 NRP	5.30 NRP	4.72 NRP
-13.44			0.04		
- 7			0.23		
- 3			0.56		
- 1			1.46		
0	1.55		1.28		2.43
1	1.61		1.38		2.39
3	2.08	1.85	1.59	2.02	3.05
5	2.31	2.00	2.06	2.25	3.34
8.06	1.75		1.22		2.22
8.56	2.04		1.75		2.45

Position	7.04 NRP	6.46 NRP	Plate i 5.88 NRP	5.30 NRP	4.72 NRP
-13.44			0.00		
- 7			0.06		
- 3			0.33		
- 1			0.68		
0	1.34		0.91		2.06
1	1.50		1.09		2.33
3	2.04	1.46	1.42	1.65	2.74
5	2.25	1.50	1.59	1.77	2.97
8.06	1.22		0.76		1.40
8.56	1.83		1.96		2.25

TABLE 4.15
RELATIVE POWER DISTRIBUTION ALONG AXIAL TRAVERSES FOR ELEMENT IN POSITION 42 (CONTROL ROD 3)
PM-2A CORE CONFIGURATION WITH SM-2 ELEMENTS

	Plate a			Plate i			Plate p		
Position	1.16 NRP	0.58 NRP	0 NRP	1.16 NRP	0.58 NRP	0 NRP	1.16 NRP	0.58 NRP	0 NRP
-13.44			0.02			0.00			0.02
-7			0.21			0.10			0.27
-3			0.45			0.37			0.89
-1			1.11			0.72			1.38
0	1.59		1.05	1.73		0.91	2.14		1.34
1	1.59		1.07	1.83		1.07	2.02		1.48
3	2.06	1.38	1.44	2.49	1.52	1.46	2.93	1.87	1.94
5	2.35	1.63	1.57	2.80	1.71	1.65	3.17	2.22	2.12
8.06	1.48		1.01	1.28		0.89	1.22		0.70
8.56	1.75		1.46	2.64		2.20	2.53		1.83

TABLE 4.16
RELATIVE POWER DISTRIBUTION ALONG AXIAL TRAVERSES FOR ELEMENT IN POSITION 44 (CONTROL ROD 4)
PM-2A CORE CONFIGURATION WITH SM-2 ELEMENTS

	Plate a			Plate i		
Position	1.16 NRP	0.58 NRP	0 NRP	1.16 NRP	0.58 NRP	0 NRP
-13.44			0.08			0.02
-7			0.37			0.14
-3			0.82			0.45
-1			2.02			0.91
0	2.82		1.98	2.33		1.30
1	2.70		1.90	2.55		1.50
3	3.28	2.39	2.39	3.09	2.22	1.98
5	3.67	2.66	2.51	3.42	2.33	2.25
8.06	2.33		1.42	1.77		0.89
8.56	2.86		2.70	2.18		2.55

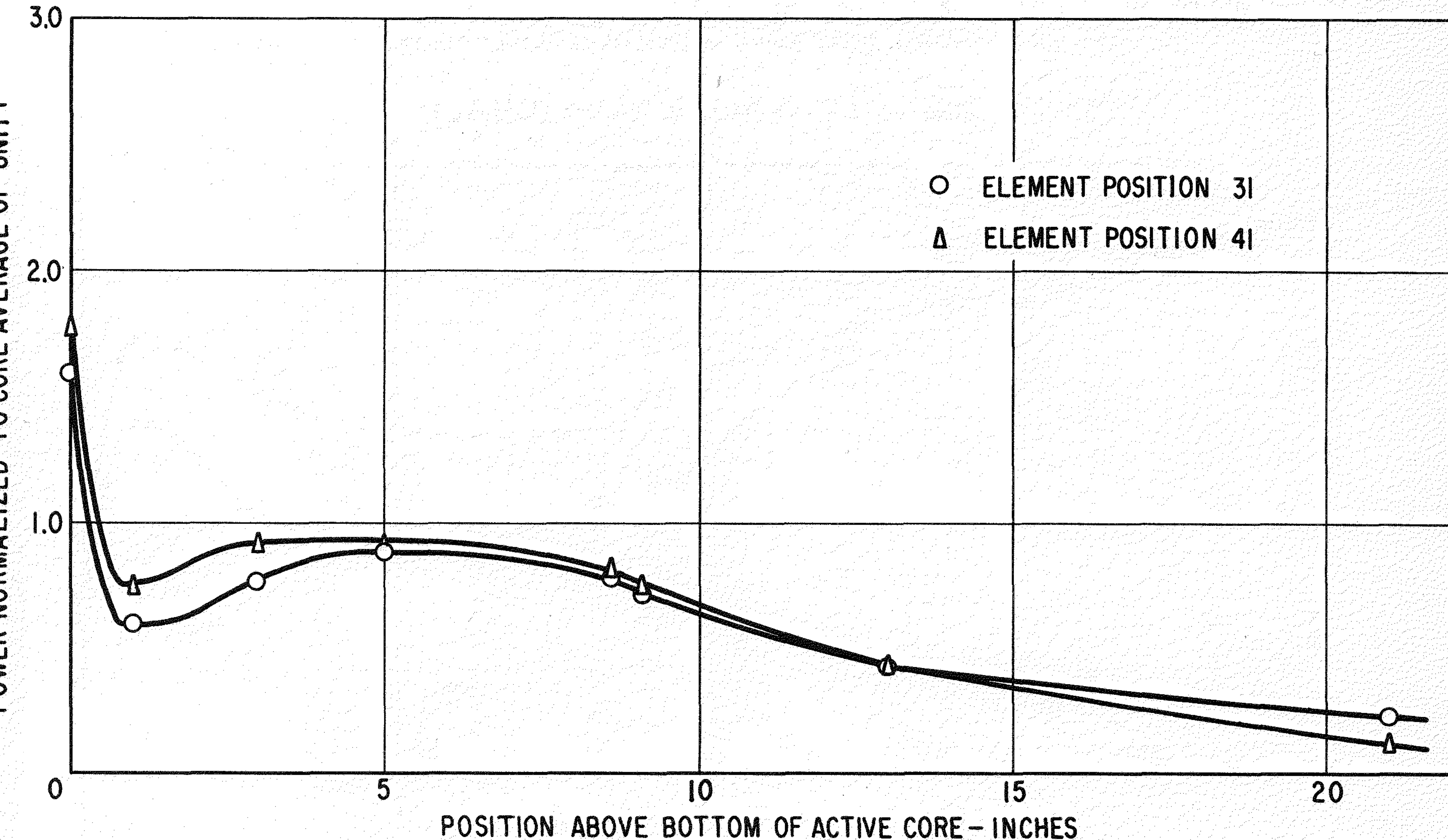

Figure 4. 4. Relative Power Distribution Along Axial Traverse on Centerline of Fuel Plate "J" of Elements in Positions 31, 41 - PM-2A Configuration with SM-2 Elements

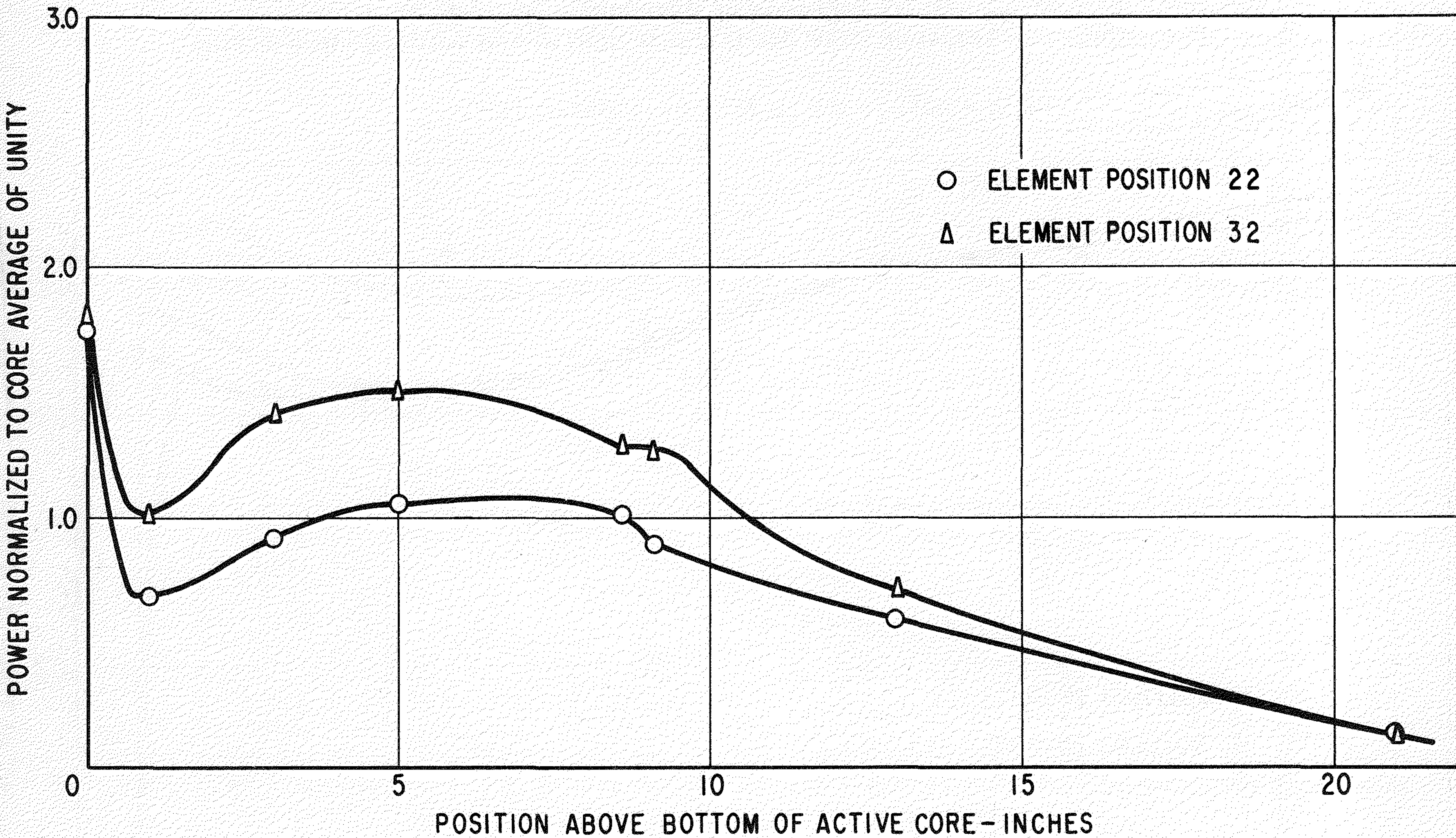

Figure 4.5. Relative Power Distribution Along Axial Traverse on Centerline of Fuel Plate "J" of Elements in Positions 22, 32 - PM-2A Configuration with SM-2 Elements

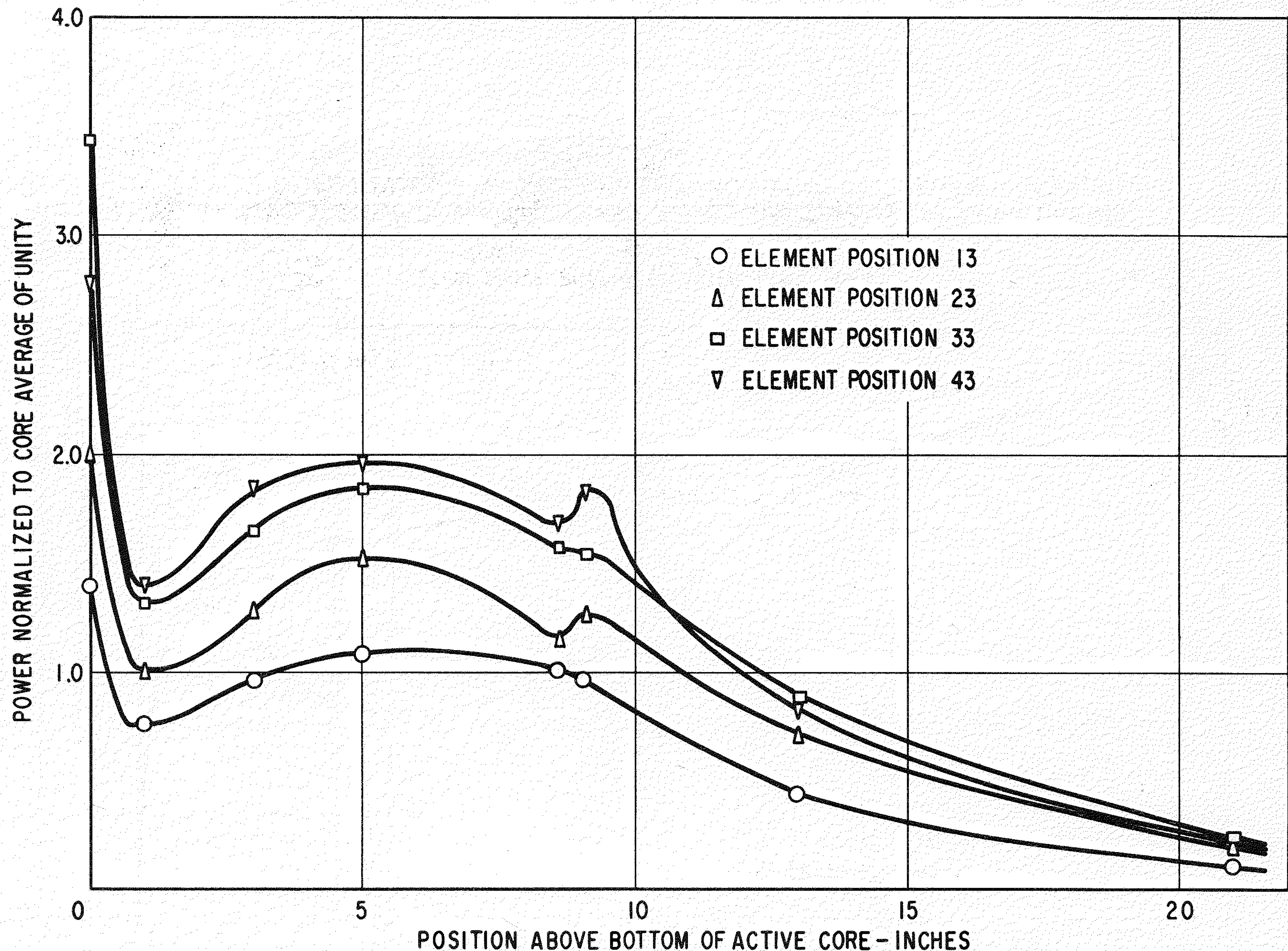

Figure 4. 6. Relative Power Distribution Along Axial Traverse on Centerline of Fuel Plate "J" of Elements in Positions 13, 23, 33, 43 - PM-2A Configuration with SM-2 Elements

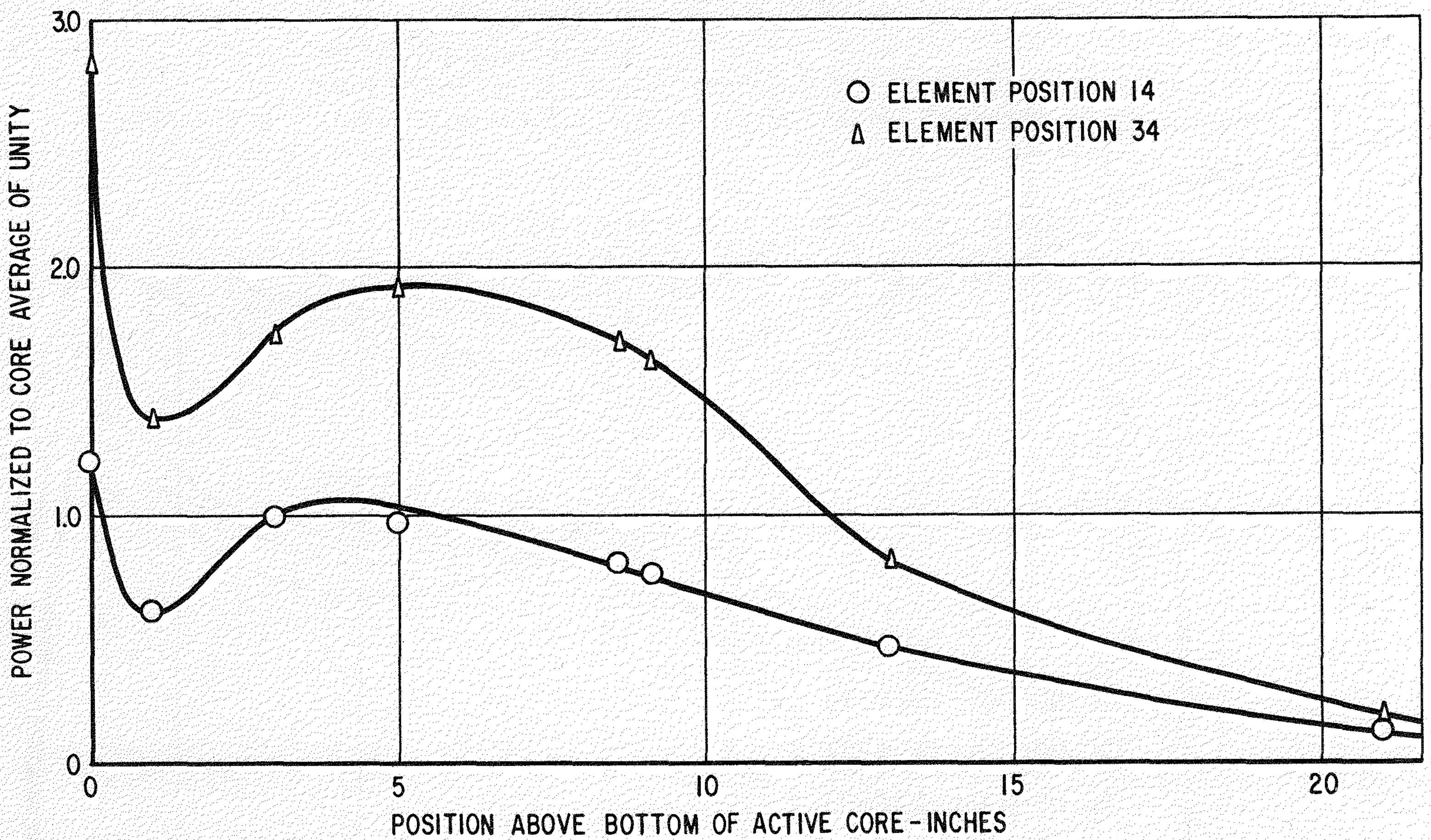

Figure 4. 7. Relative Power Distribution Along Axial Traverse on Centerline of Fuel Plate "J" of Elements in Positions 14, 34 - PM-2A Configuration with SM-2 Elements

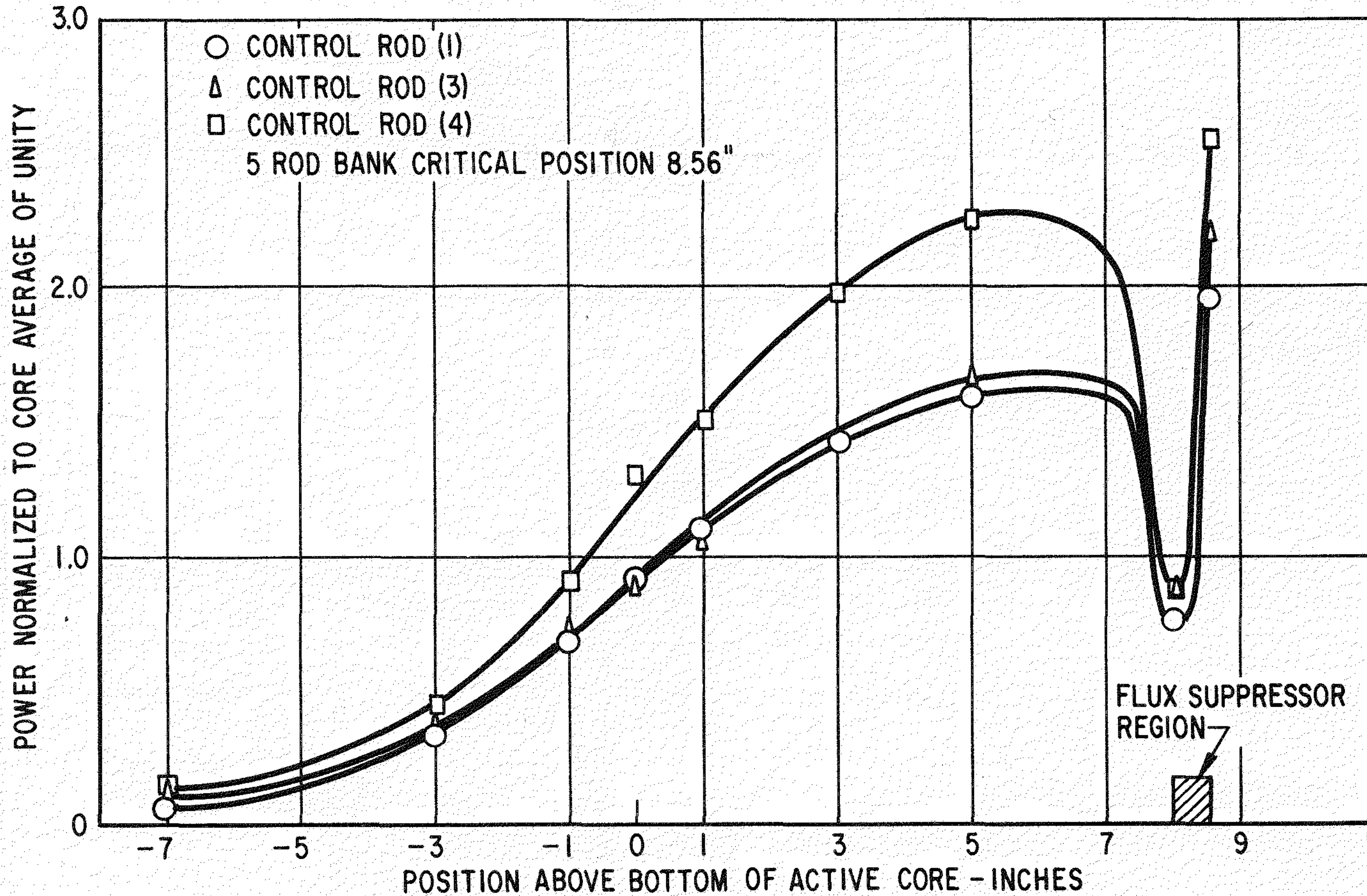

Figure 4. 8. Relative Power Distribution Along Axial Traverse on Centerline of Fuel Plate "I" of Control Rods (1), (3), (4) - PM-2A Configuration with SM-2 Elements

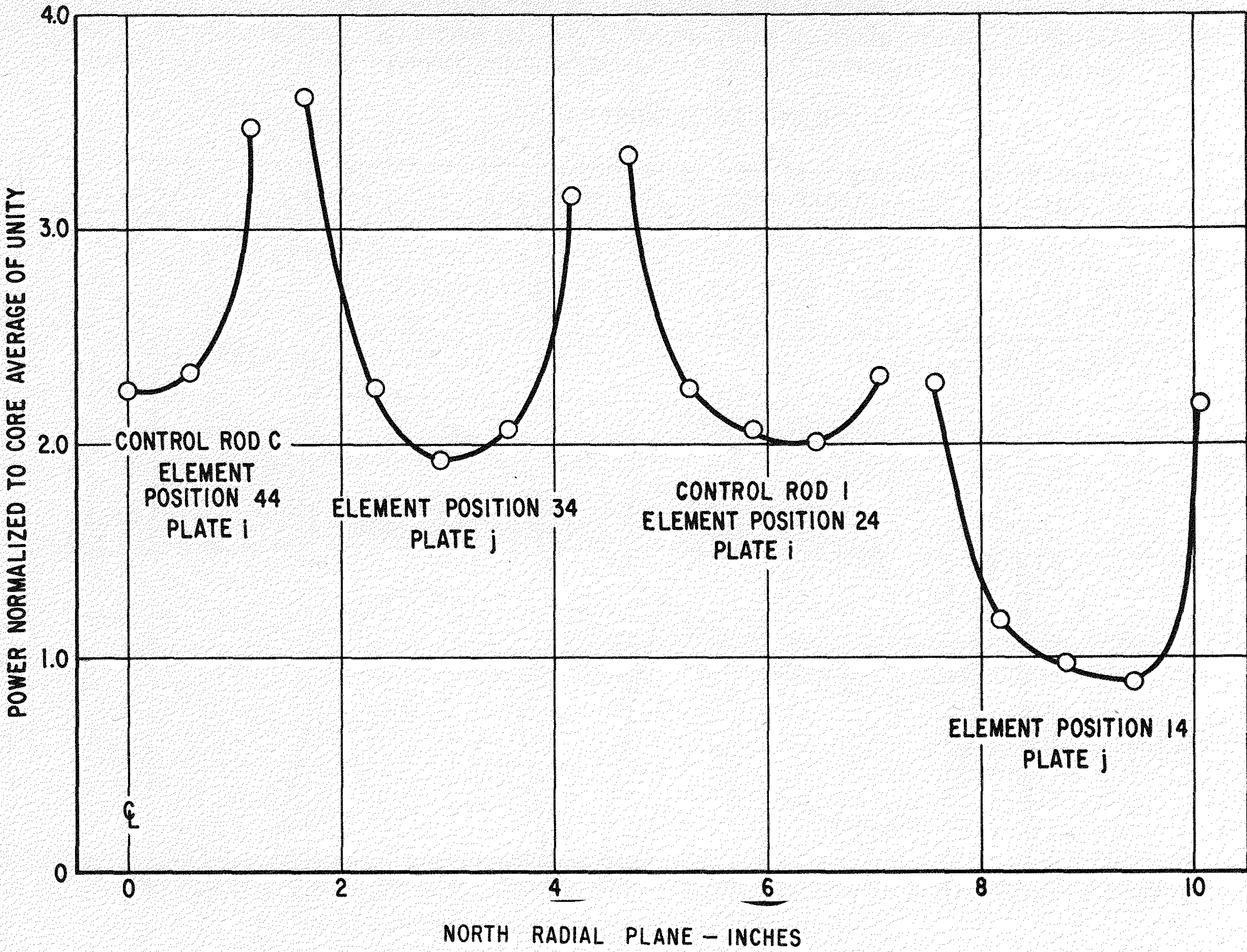

Figure 4.9. Relative Power Distribution Along Radial Traverse Parallel to Fuel Plates, 5" Above Bottom of Active Core Through Center of Elements in Positions 44, 34, 24, 14 - PM-2A Configuration with SM-2 Elements

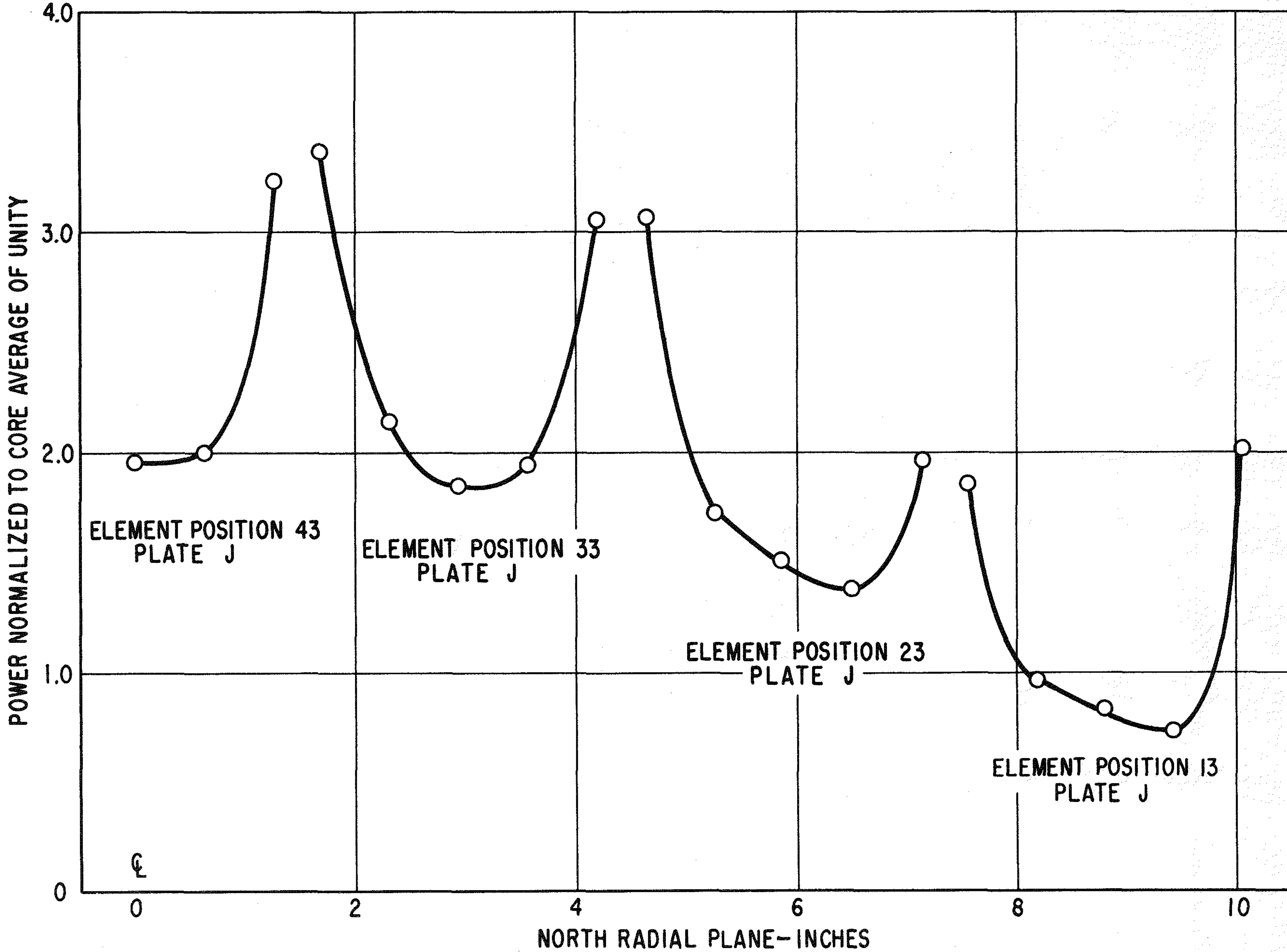

Figure 4.10. Relative Power Distribution Along Radial Traverse Parallel to Fuel Plates, 5" above Bottom of Active Core Through Center of Elements in Positions 43, 33, 23, 13 - PM-2A Configuration with SM-2 Elements

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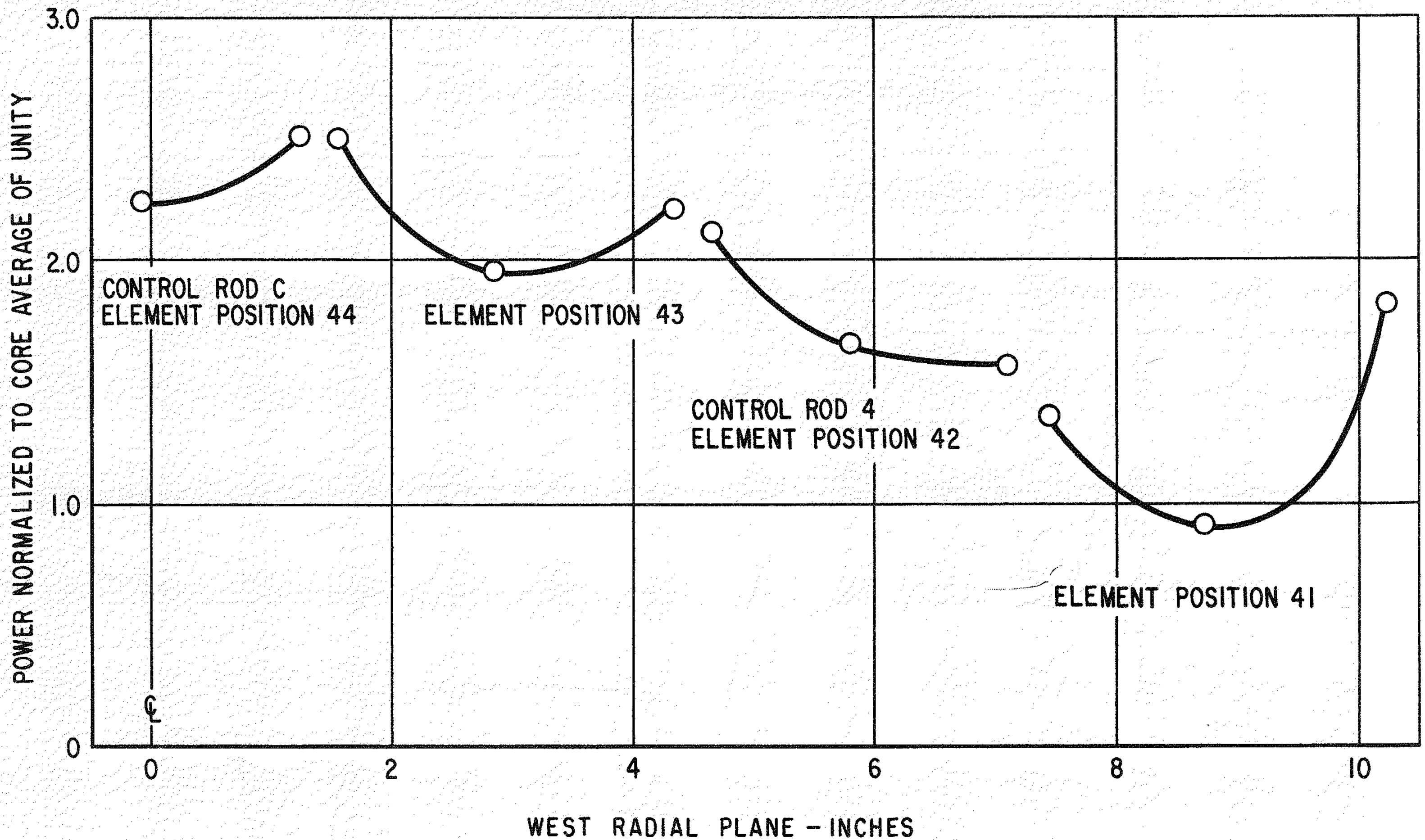

Figure 4. 11. Relative Power Distribution Along Radial Traverse Perpendicular to Fuel Plates 5" Above Bottom of Active Core Through Center of Elements in Positions 44, 43, 42, 41 - PM-2A Configuration with SM-2 Elements

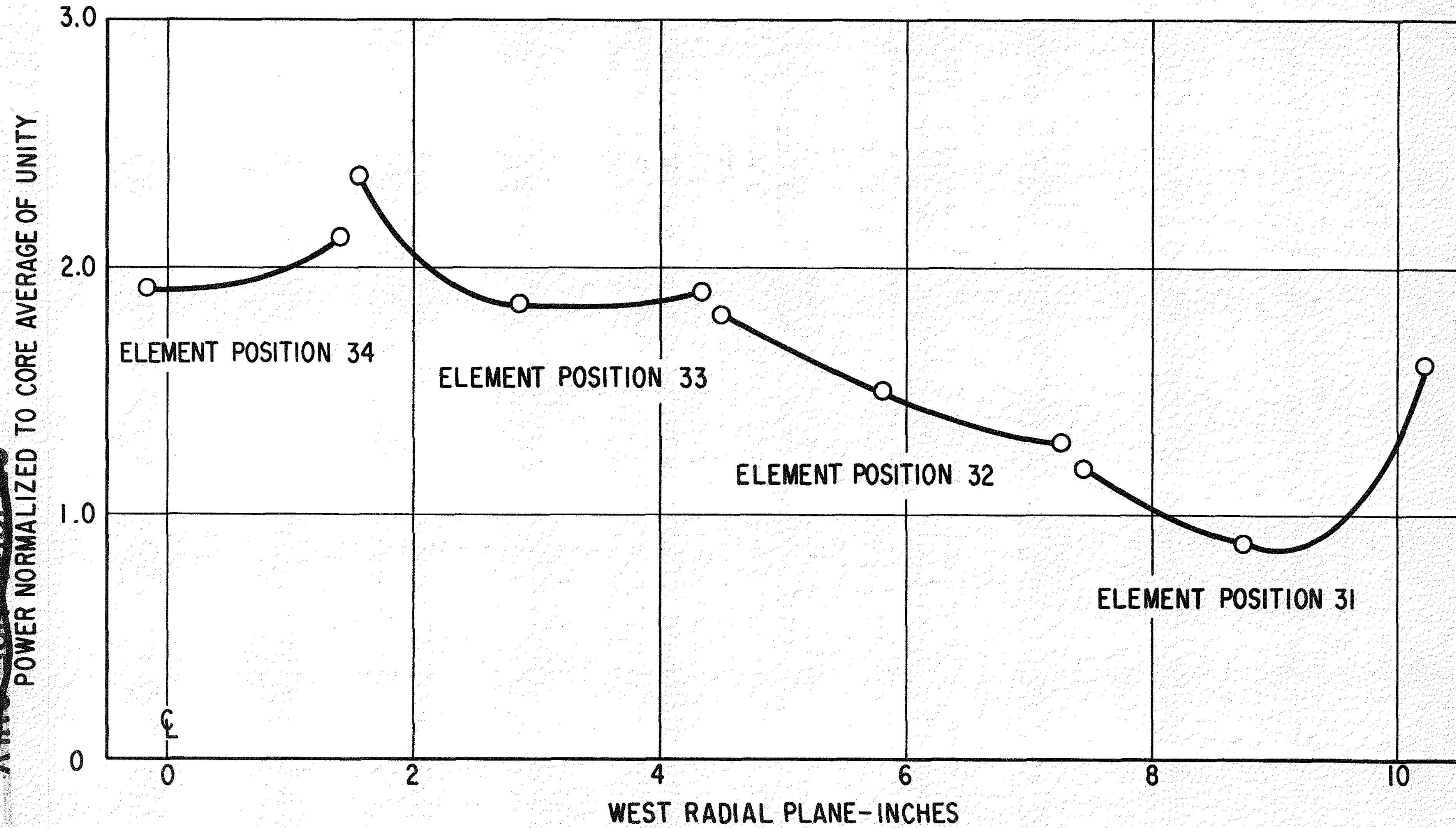

Figure 4. 12. Relative Power Distribution Along Radial Traverse Perpendicular to Fuel Plates, 5" above Bottom of Active Core Through Center of Elements in Positions 34, 33, 32, 31 - PM-2A Configuration with SM-2 Elements

Fig. 4.9 and 4.10 are plots of the radial power distribution parallel to the fuel plates at an axial elevation 5 in. above the bottom of the active core through centerof elements in position 14, 34, rod 1, rod 4, and 13, 23, 33, 43 respectively. Fig. 3.10 and 3.11 show similar radial distribution traverses perpendicular to the fuel plates through center of fuel elements in position 41, 43, rod 3, rod 4, and elements in position 31, 32, 33, 34, respectively. These plots show the normal rise in power as the center of the core is approached, power peaking in the reflector region and the power minima along the centerline of a fuel element in relation to its outer edges.

4.8 DISCUSSION OF PM-2A CORE REACTIVITY UTILIZING SM-2 ELEMENTS

Based upon measurements of the integral bank worth, and the cold to hot core reactivity change performed at the PM-2A Core I [9] and upon equilibrium and peak xenon reactivity measurements performed at the SM-1 [10] under similar plant load conditions, the PM-2A configuration with SM-2 fuel elements containing the above B-10 loading would not over-ride equilibrium xenon concentration at rated power. The estimated integral bank worth for the PM-2A five rod bank between 8.56 in. and the fully withdrawn position is about + $12.70, while the negative reactivity effects of cold to hot change and equilibrium xenon are approximately - $11.50 and - $3.10 respectively. This condition will require some modification of the B-10 loading for SM-2 type fuel elements in a PM-2A core configuration to permit full power operation. Since it was decided for preliminary investigation to utilize existing mockups in all measurements, subsequent changes in the core composition will affect the critical bank position, the boron and fuel worths and to some extent, the power distribution measurements reported here.

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