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ADDITIONAL MEASUREMENTS ON THE
ARMY PACKAGE POWER REACTOR
ZERO POWER EXPERIMENTS
ZPE-1 and ZPE-2

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by

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ADDITIONAL MEASUREMENTS ON THE ARMY PACKAGE POWER REACTOR ZERO POWER EXPERIMENTS: ZPE-1 and ZPE-2

Introduction

During the course of the ZPE-2 experimental program additional measurements were performed under the Alco Products Research and Development program. Included in this program were the evaluation of various absorber section compositions and reactivity studies designed to facilitate analytical techniques. The results of these measurements are presented in this memo.

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Chapter I Evaluation of Various Absorber Section Compositions

The worths of an APPR absorber section with reduced amounts of boron were measured relative to a standard boron absorber. In addition the APPR type absorber section containing europium oxide as the poison was evaluated relative to the standard boron absorber.

In all of the measurements control rods A and B were withdrawn 20.5 inches. Control rods 1, 2, 3 and 4 were operated as a bank. The absorber being measured was placed in rod C and was always fully inserted. The position of the four rod was determined with the different types of absorbers. The bank was calibrated at various positions to determine the change in absorber worth for the different absorbers.

In Table 1 the reactivity worths of various amounts of B-10 and europium in the absorber section are tabulated relative to a stainless absorber section containing no poison.

Table 1

Type of Absorber	Reactivity Worth-relative to the stainless steel-cents
Stainless Steel-no poison	0
8.46 gms B-10	191
33.84 gms B-10	255
56.40 gms B-10	276
488.32 gms Europium	254

Chapter II Worth of Individual APPR Control Rods

Several measurements were made during the ZPE-2 experiments which can be used to determine the approximate integral worth of various individual control rods in a core unperturbed by other rods. Since the shape of the differential worth curve of various rods is the same when unperturbed by other rods, it was necessary to obtain only one complete calibration. This calibration was performed on the center control rod in the 7 x 7 core poisoned with boron. ⁽¹⁾

Table 2

Integral Worth of Individual Control Rods in the 7 x 7 Core Array

Control Rod	Reactivity Worth - cents
C	575 $\pm$ 25
1	320 $\pm$ 50
A	430 $\pm$ 50

In Table 2 it would appear that the integral worth of the five rod bank is 1855 ± 200 cents and the seven rod bank is 2715 ± 300 cents. However, due to reinforcement of the control rods in the five rod bank the integral worth is 2800 cents or approximately 50% more. ⁽²⁾ In the seven rod bank the integral worth is 3300 cents or approximately 20% more. ⁽³⁾ Consequently, the insertion of control rods A and B introduces shadowing.

- (1) APAE 21 Extended Zero Power Experiments on the Army Package Power Reactor, ZPE-2, S.D. MacKay, H. W. Giesler, J.W. Noaks, November 1957
- (2) APAE 8 Army Package Power Reactor Zero Power Experiments, J. W. Noaks, W. R. Johnson, February 8, 1957
- (3) AP Memo 61 Results and Analysis of the APPR-1 Zero Power Experiments, Part I, H. W. Giesler, et al, November 7, 1956

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Calibrations of APPR control rods in the 5 x 5 core array (21 elements with 7 control rods) were made. Again the shape of the calibration curve was similar to that in the 7 x 7 core.

Table 3

Integral Worth of Individual Control Rods in the 5 x 5 Core Array

Control Rod	Reactivity Worth - cents
C	1000 $\pm$ 200
1	300 $\pm$ 50
A	600 $\pm$ 100

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Chapter III Substitution of Fixed Fuel Elements for Control Rod
Fuel Elements

The reactivity effect of replacing fixed fuel elements for control rod fuel elements and baskets in a core unperturbed by control rods was measured.

Table 4

Reactivity Coefficient of a Fixed Fuel Element in a Control Rod

Fuel Element Position in the 7 x 7 Core Array

Control Rod Position	Reactivity Coefficient Cents
C	67.3 $\pm$ 10.
1	37.0 $\pm$ 10.
A	49.7 $\pm$ 10.

The substitution of fixed fuel elements in all of the control rod positions results in an increase in reactivity of 315 $\pm$ 50 cents.

Table 5

Reactivity Coefficient of a Fixed Fuel Element in a Control Rod

Fuel Element Position in the 5 x 5 Core Array

Control Rod Position	Reactivity Coefficient Cents
C	115. $\pm$ 10.
1	34.3 $\pm$ 10.
A	70.1 $\pm$ 10.

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The substitution of fixed fuel elements in all of the control rod positions in the 5 x 5 core results in an increase in reactivity of 392 ± 50 cents.

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Chapter IV

Excess Reactivity in Various Core Arrays

The excess reactivity in a core containing a minimum number of fuel elements consistent with a symmetric geometry was measured. The core contained 16 fuel elements in a 4 x 4 array (15 fixed fuel elements and one control rod in an outside row of elements). The control rod was withdrawn 7.92 inches. Boron was added uniformly and the control rod was calibrated. This configuration with the rod fully withdrawn has 317 ± 15 cents excess reactivity. The substitution of a fixed fuel element for the control rod fuel element was estimated to be worth an additional 56 ± 10 cents. Therefore the total excess reactivity in a core containing 16 fixed fuel elements in a 4 x 4 array is 373 ± 25 cents.

The excess reactivity in the 5 x 5 core array with 21 elements of which 7 were control rod elements was estimated to be 700 ± 100 cents. Substitution of fixed elements for the seven control rods yielded an additional 392 ± 50 cents. Therefore the total excess reactivity a core containing 21 fixed fuel elements in a 5 x 5 array is 1092 ± 150 cents.

Previously the excess reactivity in the 7 x 7 core was determined as being 2280 ± 200 cents. ⁽²⁾ Substitution of fixed fuel elements yields an additional 315 ± 50 cents. The total excess reactivity in a core containing 45 fixed fuel elements in a 7 x 7 array is therefore 2595 ± 250 cents.

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Using a delayed neutron fraction of 0.0073 the reactivity values can be expressed as an experimental ΔK_{ex} . This ΔK_{ex} is then converted to K_{eff} by the expression $K_{eff} = e^{\Delta K_{ex}}$ (4)

- (4) APAE Memo 92 APPR-1 Control Rod Experiments and Calculations, F.B. Fairbanks, J.G. Gallagher, March 6, 1957

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The implied M^2 is 34.3 cm². The calculated K_{eff} for the 5 x 5 array and 7 x 7 array can now be found.

Table 8

Core Array	B^2 cm ⁻²	Calculated K_{eff}	Measured K_{eff}
4 x 4	0.01341	(1.0275)	1.0275 $\pm$.002
5 x 5	0.01118	1.084	1.083 $\pm$ 0.010
7 x 7	0.00707	1.207	1.208 $\pm$ 0.02

The excellent agreement is in some respect fortuitous in consideration of the assumptions made. However, since the implied M^2 was calculated from the 4 x 4 core array where K_{eff} was most exactly measured, it can also be assumed reasonably accurate.

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