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AN EXPERIMENTAL INVESTIGATION OF SOME SOURCES OF ERROR IN THE MEASUREMENT OF ABSOLUTE FISSION RATIOS IN FAST REACTORS

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ABSTRACT

This report describes measurements in AFSR of the changes in some fission ratios which result from the proximity of relatively small quantities of steel and polyethylene. The results show that some of the measurements with the Kirn absolute fission chambers in ZPR III are probably in error by several percent.

I. INTRODUCTION

The relative fission rates of different fissile materials are widely used to deduce neutron spectra in reactors. This method is valid only if the detectors do not perturb the spectra significantly. The degree of perturbation depends upon the magnitudes of the cross sections of the materials used in the detectors, and since cross sections are generally small at high energies, no great efforts have been made to minimize the size of fission chambers used in fast reactors. The objective of the experiments reported here was to estimate the perturbation caused by the use of the Kirn absolute fission chambers in ZPR-III assemblies.

The measurements, which were made in the blanket of the Argonne Fast Source Reactor (AFSR), show that the reaction rates of some threshold fissionable elements are altered appreciably by the proximity of relatively small quantities of steel and polyethylene; hence, it is probable that some of the data obtained with the Kirn chambers are in error.

II. MECHANISMS FOR ALTERATION OF THE NEUTRON SPECTRUM

In a Kirn absolute fission chamber,(1) the fissile material is electroplated onto platinum or stainless steel discs. A disc is then mounted in a chamber made principally of stainless steel and having a copper pumping tube, a Kovar vacuum seal, and a BNC-type connector. The connector does not have an insulator which contains hydrogen. The chambers are normally used with RG71U cable. In a ZPR-III measurement, two such chambers are placed face-to-face at the center of the reactor.

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The measurements, which were made in the blanket of the Argonne Fast Source Reactor (AFSR), show that the reaction rates of some threshold fissionable elements are altered appreciably by the proximity of relatively small quantities of steel and polyethylene; hence, it is probable that some of the data obtained with the Kirn chambers are in error.

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The average wall thickness of such a chamber is about 0.3 cm, and, as two chambers are placed together, on the average a neutron has to pass through about 0.6 cm of constructional material.

Consideration of the various possible processes leads to the conclusion that the only mechanisms which could affect the spectrum are (a) inelastic scattering in the steel and other materials, and (b) elastic scattering in the hydrogen present in the cable. The former process is significant because of the considerable amount of steel present, and the latter because of the excellent moderating properties of hydrogen.

No attempt has been made to evaluate the magnitude of the changes resulting from scattering by hydrogen, as this is believed to be a very complex problem, but inelastic scattering in the walls was considered in an elementary calculation.

In this calculation, the chamber walls were assumed to be of iron and 0.6 cm thick since, on the average, a neutron passes through two wall thicknesses. Using the Yiftah, Okrent, and Moldauer (YOM) set of cross sections and a mean path length of 1.2 cm, i.e., twice the wall thickness, the probability of scattering in each neutron group was obtained. Then, the change in the neutron spectrum of a typical ZPR-III assembly which resulted from this scattering was calculated. The spectra before and after scattering were then used to derive changes in fission ratios.

The calculated changes in the U^{238}/U^{235}, U^{234}/U^{235}, and Pu^{239}/U^{235} ratios were, respectively, about $-6\frac{1}{2}\%$, $-2\frac{1}{2}\%$ and -0.3%. In each case the ratio decreased because of scattering.

Although the method of calculation was crude, it was believed to give the correct order of magnitude of the effect.

III. EXPERIMENTAL METHOD

The experimental arrangement is shown in Figures 1 and 2.

In each experiment, a pair of ZPR-III "traverse" fission chambers was used at the center of the grazing hole of AFSR. These chambers are made principally of brass, have an OD of about 1 cm, an active length of about 3 cm, and contain about 5 mg of fissile material. They were located in a thin-walled, close-fitting aluminum tube centered in the grazing hole by aluminum plugs at the outside of the shield and by a steel spacing ring at the midpoint of its length. Amphenol Subminax connectors and cables were used.

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The calculated changes in the U^{235}/U^{238}, U^{234}/U^{235}, and Pu^{239}/U^{235} ratios were, respectively, about -6½%, -2½%, and -0.3%. In each case the ratio decreased because of scattering.

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III. EXPERIMENTAL METHOD

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In each experiment, a pair of ZPR-III "traverse" fission chambers was used at the center of the grazing hole of AFSR. These chambers are made principally of brass, have an OD of about 1 cm, an active length of about 8 cm, and contain about 5 mg of fissile material. They were located in a thin-walled, close-fitting aluminum tube centered in the grazing hole by aluminum plugs at the outside of the shield and by a steel spacing ring at the midpoint of its length. Amphenol Subminax connectors and cables were used.

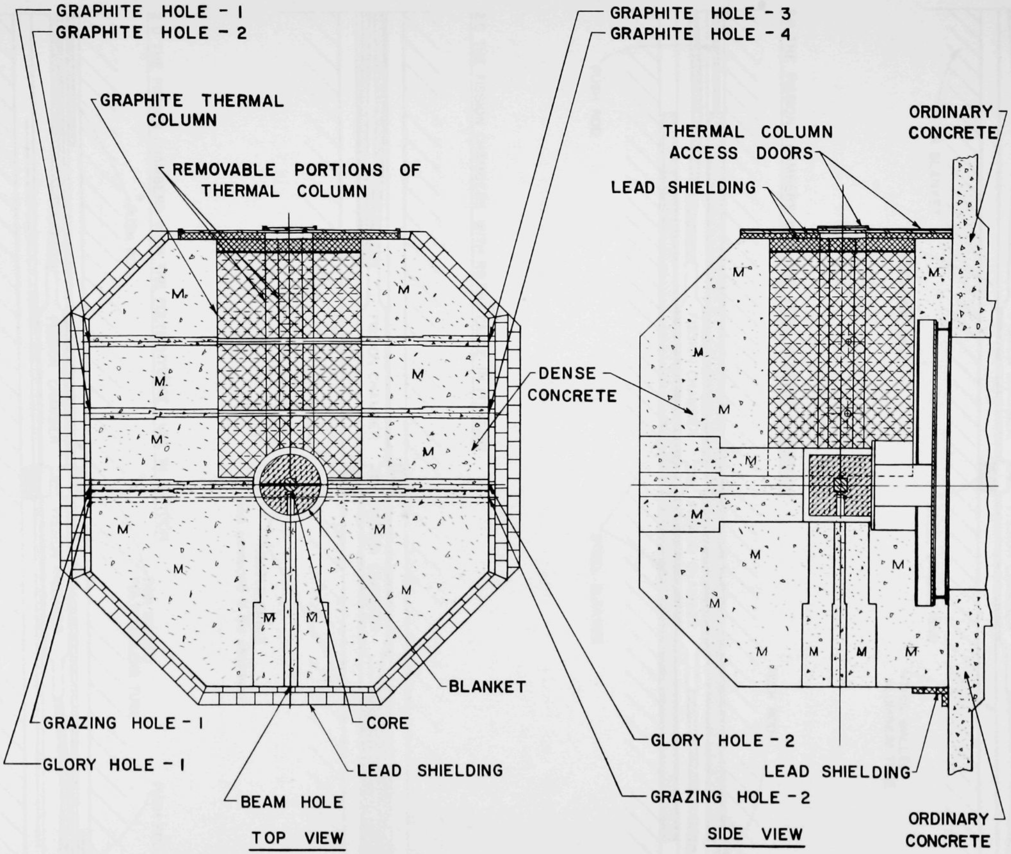

Fig. 1. Experimental Facilities - AFSR

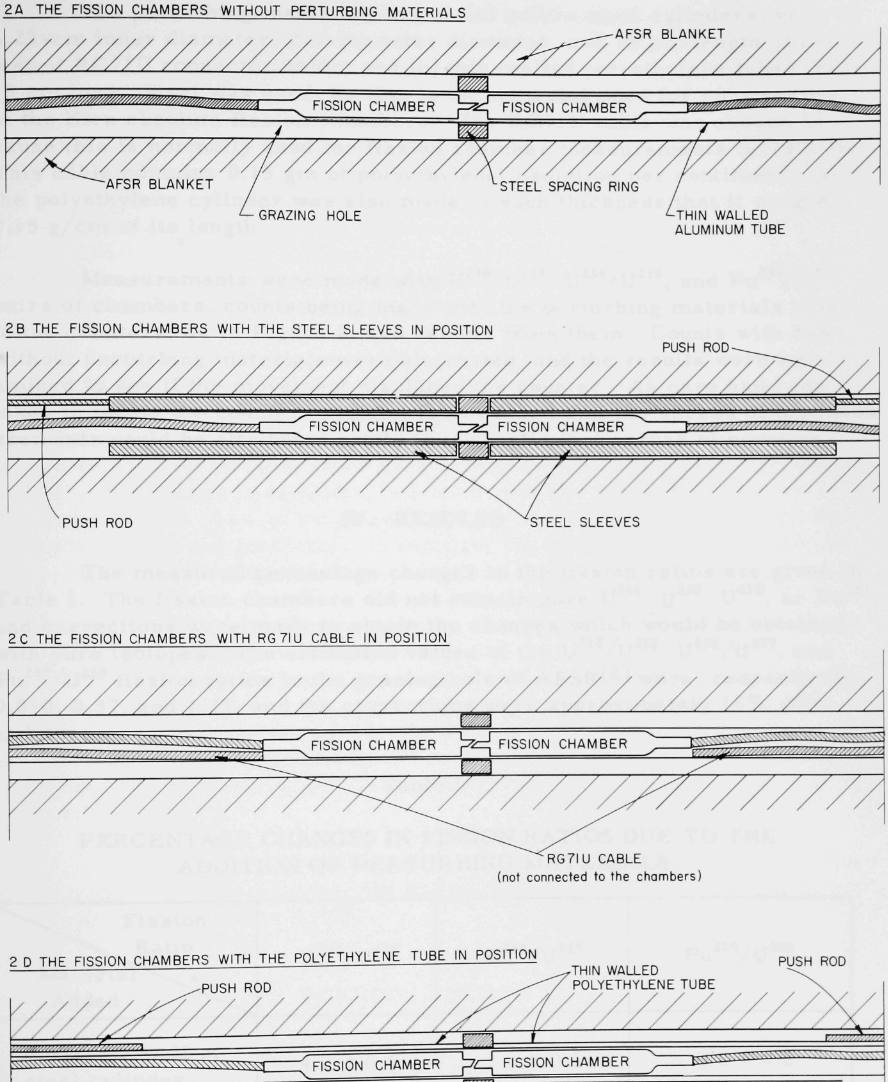

Fig. 2. Arrangement of the Fission Chambers and Perturbing Materials

The perturbing materials were: (a) hollow steel cylinders, each of 1.23-cm inner diameter, 2.5-cm outer diameter, and 15 cm length; (b) several feet of RG71U connector cable; and (c) thin-walled polyethylene tubes, each 15 cm long. Steel was used, as this is the material used for construction of the Kirn absolute fission chambers. The RG71U cable was chosen because this is normally used for fission chamber measurements in ZPR III. This cable contains 0.15 gm of polyethylene insulation per centimeter, and the polyethylene cylinder was also made of such thickness that it weighed 0.15 g/cm of its length.

Measurements were made with U^{238}/U^{235}, U^{234}/U^{235}, and Pu^{239}/U^{235} pairs of chambers, counts being made with the perturbing materials close to the counters, as in Figure 2, and remote from them. Counts with and without perturbing materials were alternated, and the results were examined to see if the movement displaced the counter. As care had been taken to locate the counters rigidly, it was found that the spread of the measurements could be attributed solely to the statistical errors of counting.

IV. RESULTS

The measured percentage changes in the fission ratios are given in Table I. The fission chambers did not contain pure U^{234}, U^{235}, U^{238}, or Pu^{239}, and corrections were made to obtain the changes which would be obtained with pure isotopes. The estimated values of the U^{238}/U^{235}, U^{234}/U^{235}, and Pu^{239}/U^{235} fission ratios in the grazing hole of AFSR(2) were, respectively, 0.050, 0.37, and 1.27, and the corrections were approximately 15%, 25%, and zero.

Table I

PERCENTAGE CHANGES IN FISSION RATIOS DUE TO THE ADDITION OF PERTURBING MATERIALS

Fission Ratio / Material Added	U^{238}/U^{235}	U^{234}/U^{235}	Pu^{239}/U^{235}
0.635-cm wall of steel cylinder	-4.2 ± 0.5	-2.6 ± 0.5	0.0 ± 0.2
RG71U cable	-1.0 ± 0.6	-0.6 ± 0.5	Not measured
Polyethylene cylinder	-3.1 ± 0.8	-4.8 ± 0.6	-0.6 ± 0.2

The errors quoted are one standard deviation.

The perturbing materials were: (a) hollow steel cylinders, each of 1.27-cm inner diameter, 2.[illegible]-cm outer diameter, and 15 cm length; (b) several feet of RG71U connector cable; and (c) thin-walled polyethylene tubes, each 15 cm long. Steel was used as this is the material used for construction of the Kirn* absolute fission chambers. The RG71U cable was chosen because this is normally used for fission chamber measurements in ZPR III. This cable contains 0.15 gm of polyethylene insulation per centimeter, and the polyethylene cylinder was also made of such thickness that it weighed 0.[illegible] g/cm of its length.

Measurements were made with U^{238}/U^{235}, U^{234}/U^{235}, and Pu^{239}/U^{235} pairs of chambers, counts being made with the perturbing materials close to the counters, as in Figure 2, and removed from them. Counts with and without perturbing materials were alternated, and the counters were examined to see if the movement displaced the counters. Care had been taken to locate the counters rigidly, so that the spread of the measurements could be attributed solely to the statistical errors of counting.

IV. RESULTS

The measured percentage changes in the fission ratios are given in Table I. The fission chambers did not contain pure U^{235}, U^{234}, U^{238}, or Pu^{239} and corrections were made to obtain the changes which would be obtained with pure isotopes. The estimated values of the U^{238}/U^{235}, U^{234}/U^{235}, and Pu^{239}/U^{235} fission ratios in the grazing hole of APSR[2] were, respectively, 0.050, 0.37, and 1.27, and the corrections were approximately 13%, 25%, and zero.

Table I

PERCENTAGE CHANGES IN FISSION RATIOS DUE TO THE ADDITION OF PERTURBING MATERIALS

Material Added \ Fission Ratio	U^{238}/U^{235}	U^{234}/U^{235}	Pu^{239}/U^{235}
0.[illegible]-cm wall of steel cylinder	+4.2 ± 0.5	-2.6 ± 0.5	0.0 ± 0.2
RG71U cable	-1.0 ± 0.6	-0.1 ± 0.5	Not measured
Polyethylene cylinder	-3.1 ± 0.8	-4.8 ± 0.6	-0.6 ± 0.2

The errors quoted are one standard deviation.

All changes are negative for the addition of perturbing material, and this indicated that the addition of these materials degrades the neutron spectrum.

V. DISCUSSION AND CONCLUSIONS

The magnitudes of the effects measured using steel sleeves are in reasonable agreement with the elementary calculations reported in Section 2; hence it appears that inelastic scattering in the steel walls is the mechanism involved. It is therefore probable that a similar effect will occur in any fast reactor spectrum.

The effects obtained by adding cable and polyethylene are not easy to interpret. The fluxes at the positions where the cables were added were lower than those at the fissile material, whereas the polyethylene cylinders were wrapped around the chambers so that it is reasonable that any effects should be smaller in the former case. However, it is clear that the magnitude of the change is exceedingly sensitive to the position of the polyethylene, and the present measurements are not sufficient to evaluate the effect in a different geometry. In addition, the changes may well be dependent upon the reactor composition.

Although there are uncertainties of interpretation, it can be safely concluded that, unless chambers intended to give absolute fission ratios are designed with sufficiently thin walls, and unless moderating materials are excluded from the vicinity of the chambers, the errors of the measurements may be of the order of 5%. As these conditions were not satisfied in measurements with the Kirn chambers in ZPR III, it is probable that the measured data with threshold fissile materials are in error by several percent.

At present, it is probably necessary for the individual experimenter to evaluate these effects under the actual conditions of his experiments by such methods as used in AFSR.

ACKNOWLEDGMENTS

The authors are indebted to Glenn Brunson for his encouragement to make these measurements, to Dale Puckett for the construction of the experimental equipment, and to Robert Huber, Walter Windmiller, and Larry Hill for the operation of the AFSR reactor.

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