RECEIVED
OFFICE OF
R. L. DOAN

JAN 24 1957

R. L. DOAN

RMF MEASUREMENTS ON MTR-IRRADIATED EUROPIUM OXIDE

J. W. Henscheid and E. Fast

January 18, 1957

DISTRIBUTION

R. L. Doan ←
J. R. Huffman
B. F. Boardman
D. R. deBoisblanc
G. H. Barnard (KAPL) 5
R. B. Johns (r) A. S. Richardson
E. Fast
E. E. Burdick
J. W. Henscheid
D. W. Knight
D. A. Millsap
Library - 10

PHILLIPS PETROLEUM CO.
ATOMIC ENERGY DIVISION
(UNDER CONTRACT NO. AT (10-1)-205)
IDAHO OPERATIONS OFFICE
U. S. ATOMIC ENERGY COMMISSION

DISCLAIMER

This report was prepared as an account of work sponsored by an agency of the United States Government. Neither the United States Government nor any agency Thereof, nor any of their employees, makes any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness, or usefulness of any information, apparatus, product, or process disclosed, or represents that its use would not infringe privately owned rights. Reference herein to any specific commercial product, process, or service by trade name, trademark, manufacturer, or otherwise does not necessarily constitute or imply its endorsement, recommendation, or favoring by the United States Government or any agency thereof. The views and opinions of authors expressed herein do not necessarily state or reflect those of the United States Government or any agency thereof.

DISCLAIMER

Portions of this document may be illegible in electronic image products. Images are produced from the best available original document.

RMF MEASUREMENTS ON MTR-IRRADIATED EUROPIUM OXIDE

By: J. W. Henscheid and E. Fast

INTRODUCTION

As part of the KAPL-28 MTR irradiation program on burnable poisons and control rod materials, several capsules containing europium oxide in stainless steel were included. Prior to their irradiation in the MTR, Ed Renzi and George H. Barnard of Knolls Atomic Power Laboratory, General Electric, requested that reactivity measurements be made in the RMF on two of these capsules, both before and after irradiation in the MTR as a means of determining the change in their effective poison cross section. The work on this problem, which was done during the period of September to November, 1956, is summarized in this report.

The RMF (Reactivity Measurement Facility) is a critical test reactor in the MTR canal, made up of an array of MTR-type fuel assemblies, light water moderated and reflected. Experiments are mounted in a central water hole, and their effect on the reactivity is measured from the change in position of a calibrated regulating rod when the reactor is in servo operation. The arrangement of the fuel, detectors, and control elements is shown schematically in Figure 1.

EXPERIMENTAL PROCEDURE

The two capsules used in this experiment, identical except for content, are 2-S aluminum cylindrical tubes approximately 4 inches long, 1.125 inches in diameter, with aluminum inserts and filled with one atmosphere of helium. Each capsule contains four europium oxide-stainless steel strips (samples). A third capsule, identical in Eu_2O_3

concentration with one of the capsules above, was also made available as a standard and was not subjected to irradiation in the MTR. A fourth capsule, referred to as a "dummy" capsule, contains aluminum strips in place of the Eu_2O_3 - SS strips. A cross-sectional diagram of these capsules is shown in Figure 2, and additional physical information is given in Table I.

The reactivity effect of each of the four capsules was measured in two locations in the experimental hole of the RMF lattice; one at the very center and the other near the west side of the experimental hole, centered at the horizontal center-plane of the active lattice. In the lattice diagram (Figure 1) these locations are denoted by circles C and W respectively.

With the RMF in servo controlled operation, the recorded displacement of the regulating rod, caused by insertion of a capsule, is used to measure the reactivity effect of the capsule. The calibration of the regulating rod is based on period measurements and the inhour equation.

After initial reactivity measurements in the RMF, capsules #33 and #34 were irradiated for several cycles in the MTR and remeasured in the RMF after each cycle along with the standard. The dummy capsule, belatedly received, was also measured following irradiation Cycles 76 and 77. By measuring the standard, a correlative check was obtained whereas the dummy provided a correction for the effect of the capsule material and the displaced water to obtain the net effect of the poison itself. The MTR irradiation history is summarized in Table II.

RESULTS

The raw reactivity data for the gross effects on the RMF of the four capsules are given in Table III. The individual readings are, in most cases, the average of several readings. In Table IV these data have been corrected for the effect of the capsule (by subtracting the value of the dummy) and normalized to the initial value of the standard. This provides a common base for comparison of all exposures which is necessary to obtain the fractional change in the effective poison cross section given in Table V. The results tabulated in Table V are presented graphically as a function of MTR exposure in Figure 3.

DISCUSSION

Interim data was previously submitted on these capsules in letters Fa-21-56A and Fa-25-56A. However, since this time a more detailed calibration of the RMF regulating rod has resulted in slight differences in the previously reported values of the capsules. The revised results only are given in this report.

The standard deviation recorded in Table V is based upon differences in repeat measurements made during an uninterrupted period of RMF operation. Differences in reactor sensitivity over a period of time, e.g., following Cycle 76, have been normalized on the basis of the standard sample to the first of these measurements. Although a number of probable factors could be mentioned, the exact cause of such variations in sensitivity of the RMF has not been established.

The sensitivity of the RMF for poisons is a function of position in the experimental hole, depending on the importance of a neutron in that

position and on the neutron energy spectrum. The sensitivity values previously obtained for essentially a thin sample of boron were $0.45 \times 10^{-4} \Delta k/k$ per cm^2 in the center and 1.1×10^{-4} in the west side location. The KAPL-28 samples were measured in both positions as a check on the results obtained for burnup after MTR irradiation.

From Figure 3 and Table V the fractional change in effective poison cross section appears to differ by a significant fraction in these two locations which is particularly evident in capsule #34. A semi-quantitative consideration of the nuclear constants and experimental conditions involved indicates that this result is reasonable. The two natural isotopes of europium (atomic masses 151 and 153) are present in approximately equal concentration. The respective thermal cross sections are 8600 and 400 barns which leads to a preferential burnup of Eu^{151} . This same isotope likewise has a greater resonance integral. Depletion in this isotope, therefore, leads to a greater fractional change in the RMF region having the greater resonance flux, which is the location nearest the fuel, i.e. the W position in Figure 1. This agrees qualitatively with results given in Table V and Figure 3.

Consideration should also be given to Eu^{152} the product of neutron capture in Eu^{151} . About 16 per cent goes into an isomer which decays with a 9.2 hr. half-life electron capture to the relatively low cross section gadolinium-152. The remaining 84 per cent has a 5000 barn cross section which is sufficiently large that the buildup of this isotope at these exposures would be small. Any effect of a change in resonance integral from this source should therefore be small.

ACKNOWLEDGEMENTS

Other members of the RMF group who aided in making the measurements were D. W. Knight, J. N. Nixon, D. A. Millsap and E. E. Burdick. The helpful cooperation of Project Engineer A. S. Richardson and of KAPL Representative George H. Barnard is also acknowledged.

TABLE I

PHYSICAL DATA ON SPECIMENS*

<u>Capsule No.</u>	<u>Sample Material</u>	<u>Σ_p (cm²/in/capsule)</u>
33	30 w/o Eu ₂ O ₃ - SS	25.92
34	5 w/o Eu ₂ O ₂ - SS	4.32
Standard	30 w/o Eu ₂ O ₃ - SS	25.92
Dummy	aluminum	-----
Poison sample dimensions	3" x 0.2" x 0.5" (4 per capsule)	
Capsule weight	170 grams	
Sample weight per capsule	14 grams	

* Information furnished by KAPL.

TABLE II

MTR IRRADIATION DATA

<u>Capsule No.</u>	<u>MTR Location</u>	<u>Cycle</u>	<u>MWD</u>	<u>Total Effective nvt x 10²⁰</u>
33	L-56 10" above CL	75	510	.406
	L-56 8" above CL	76	537	.545
	L-56 8" above CL	77	<u>473</u>	<u>.480</u>
	Total Exposure	-----	1520	1.43
34	L-47 7" above CL	75	510	1.25
	L-47 4" above CL	76	<u>537</u>	<u>1.81</u>
	Total Exposure	-----	1047	3.06

TABLE III

GROSS REACTIVITY VALUES OF KAPL-28 CAPSULES
IN RMF

<u>Capsule No.</u>	<u>Location in RMF</u>	<u>$\Delta k/k$ (Units of 10^{-4}) Before and After Irradiation Cycles</u>			
		<u>Pre-Irradiation</u>	<u>MTR Cycle 75</u>	<u>MTR Cycle 76</u>	<u>MTR Cycle 77</u>
Standard	C	-1.59	-1.58	-1.54	-1.585
#34	C	+0.04	+0.23	+0.58	-----
#33	C	-1.615	-1.595	-1.46	-1.445
Dummy	C	(+1.79)*	(+1.79)*	+1.74	+1.79
Standard	W	-4.29	-4.25	-4.11	-4.22
#34	W	-1.22	-0.85	-0.06	-----
#33	W	-4.34	-4.105	-4.13	-3.93
Dummy	W	(+2.16)*	(+2.14)*	+2.00	+2.13

* Since the dummy capsule was not available during the first two series of measurements, these assumed values are based upon the standard sample.

TABLE IV

NORMALIZED NET REACTIVITY VALUES FOR Eu_2O_3 SAMPLES

<u>Sample No.</u>	<u>Location in RMF</u>	<u>$\Delta k/k$ (Units $\times 10^{-4}$) Before and After Irradiation Cycles</u>			
		<u>Pre-Irradiation</u>	<u>MTR Cycle 75</u>	<u>MTR Cycle 76</u>	<u>MTR Cycle 77</u>
Standard	C	-3.38	-3.38	-3.38	-3.38
#34	C	-1.75	-1.58	-1.195	-----
#33	C	-3.40	-3.39	-3.30	-3.24
Standard	W	-6.45	-6.45	-6.45	-6.45
#34	W	-3.38	-3.03	-2.17	-----
#33	W	-6.50	-6.32	-6.47	-6.16

TABLE V

PERCENTAGE OF ORIGINAL POISON IN Eu_2O_3 AFTER MTR IRRADIATION

<u>Sample No.</u>	<u>Location in RMF</u>	<u>Percentage of Original Poison Effect After Irradiation</u>		
		<u>MTR Cycle 75</u>	<u>MTR Cycle 76</u>	<u>MTR Cycle 77</u>
#34	C	90.3 ± 1.07	68.2 ± 1.3	
#33	C	99.7 ± 0.56	97.1 ± 0.54	95.3 ± 0.53
#34	W	89.2 ± 1.0	64.2 ± 0.88	
#33	W	97.2 ± 0.54	97.2 ± 0.54	94.8 ± 0.53

FIG. 1
SCHEMATIC DIAGRAM OF RMF LATTICE

FIG. 2

CROSS SECTION OF HELIUM
FILLED POISON CAPSULE

RECEIVED
PHILLIPS PETROLEUM CO.
JAN 29 1957
NRTS
TECHNICAL LIBRARY