LETTERS TO THE EDITOR

Reactivity Coefficients of Rare Earth Oxides

TABLE I

A COMPARISON OF SIMILAR SAMPLES MEASURED IN THE DRESDEN AND NMSR CRITICAL ASSEMBLIES

Material	Nominal thickness of sample in cm	Reactivity-measured relative to same thickness of cadmium	
		NMSR[a]	Dresden
Cd	0.24	1.000	1.000
Sm_2O_3	0.24	1.074	1.042
Gd_2O_3	0.24	1.047	1.052
Dy_2O_3	0.24	1.015	1.024
Er_2O_3	0.24	0.728	0.870
Cd	0.48	1.000	1.000
Sm_2O_3	0.48	1.156	1.072
Gd_2O_3	0.48	1.139	1.087
Dy_2O_3	0.48	1.137	1.101
Er_2O_3	0.48	0.932	0.964
Gd_2O_3-Dy_2O_3	0.48	1.172	1.083
Gd_2O_3-Er_2O_3	0.48	1.124	1.041

[a] Reactivity Measurements are Accurate to ±0.01

Reactivity coefficients of several of the rare earth oxides were reported in a recent issue of *Nuclear Science and Engineering* (*1*) from measurements made in the Dresden Critical Assembly. Because of the difference in reactor types, we wish to report similar measurements made at The Babcock & Wilcox Company's Critical Experiment Laboratory, in the critical assembly for the NS Savannah nuclear merchant ship. The comparative data are presented in tables below.

The measurements were made by remotely removing the samples from the center of the critical reactor and calculating the reactivity change from the resulting reactor period. The accuracy of the average measurement is better than 0.1%, where most of the error results from period timing.

A comparison of similar samples measured in the Dresden and NMSR reactors show, in general, similar results; however, there are some differences which may be attributable to the difference in neutron spectra of the two reactors.

Table I is a comparison of measurements in the two reactors. The column labeled "Dresden" in Table I uses information from Tables III and IV of reference 5.

TABLE II

REACTIVITY OF SAMPLES OF VARIOUS CONTROL ROD MATERIALS

Run No.	Material	Sample number	Length (cm)	Width (cm)	Thickness (cm)	Weight (g)	Surface density g/cm²	Thermal "blackness" ΣaT	Reactivity[a] (cents)
1	Sm_2O_3 single	S-3	7.69	7.65	0.226	58.05	0.988	34.1	−13.45
	Sm_2O_3 single	S-4	7.69	7.69	0.226	58.20			
2	Gd_2O_3 single	G-2	7.71	7.67	0.239	59.60	1.013	127.8	−13.17
	Gd_2O_3 single	G-5	7.69	7.67	0.239	59.40			
3	Dy_2O_3 single	D-2	7.68	7.65	0.221	56.35	0.958	3.4	−12.84
	Dy_2O_3 single	D-4	7.69	7.65	0.221	56.33			
4	Er_2O_3 single	E-5	7.68	7.65	0.229	67.15	1.142	0.612	−9.90
	Er_2O_3 single	E-2	7.69	7.65	0.229	66.85			
5	Sm_2O_3 double	S-3/S-4	7.69	7.67	0.452	116.25	1.975	68.2	−15.00
6	Gd_2O_3 double	G-5/G-2	7.70	7.67	0.478	119.00	2.022	255.2	−14.82
7	Dy_2O_3 double	D-2/D-4	7.69	7.65	0.442	112.68	1.915	6.68	−14.80
8	Er_2O_3 double	E-5/E-2	7.69	7.65	0.458	134.00	2.277	1.22	−12.57
9	Dy_2O_3-Gd_2O_3 Combined	D-2/G-2	7.69	7.66	0.460	115.75	1.967	131.2	−15.18
10	Er_2O_3-Gd_2O_3 Combined	E-5/G-2	7.69	7.66	0.468	126.55	2.150	128.4	−14.66
11	Boral	BA-1	7.63	7.62	0.216	10.79[d]	0.185[d]	7.77[d]	−14.08
12	Boron S.S.[b]	BS-1	7.60	7.62	0.241	1.602[d]	0.0277[d]	1.16[d]	−10.26
13	Cadmium	C-1	7.77	7.80	0.610	227.15	5.27	93.14	−13.58
14	Ag-In-Cd[c]	AIC-1	7.70	7.62	0.576	340.95	5.82	17.28	−16.31
15	Sample holder (empty)								+2.45

[a] Reactivity measurements are accurate to ±0.1 cent.
[b] Analysis—1.5 w/o B, 98.5 w/o 304 S.S.
[c] Analysis—15 w/o Cd, 5 w/o In, 80 w/o Ag.
[d] Considering elemental boron only.

TABLE III

CHARACTERISTICS OF THE NMSR CRITICAL ASSEMBLY

Fuel material	UO_2 fuel rods (swaged)
Fuel density	9.45 g/cm³
Fuel enrichment	4.0% (by weight)
Diameter of oxide	0.444 in.
Cladding material	304 stainless steel
Outside diameter of cladding	0.500 in.
Thickness of cladding	0.028 in.
Fuel length	66.7 in.
Moderator	Light water
Fuel pitch (square)	0.663 in.

A comparison of similar samples measured in the two reactors shows good agreement for the $\frac{1}{4}$-cm thick samples, but for thicker samples, the Maritime reactor shows larger reactivity changes. Since most of the samples are thermally black (see Table II for values of Σ_a times thickness), the larger reactivity effect in the NMSR reactor is most probably due to a larger fraction of epithermal absorptions. This would imply a harder spectrum for the NMSR reactor.

Table II shows reactivity data measured with samples other than rare earths in comparison with the rare earth samples. Reactivity of these samples is expressed in cents as obtained directly from the reactor periods.

Table III lists some of the characteristics of the NMSR Critical Assembly.

REFERENCE

1. H. F. JOHNSTON, J. L. RUSSELL, JR., AND W. L. SILVERNAIL, Relative control rod worth of some rare earth oxides. *Nuclear Sci. and Eng.* **6**, 93 (1959).

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Comparison of Measurements with a Monte Carlo Calculated Spatial Distribution of Resonance Neutron Capture in a Uranium Rod

A recent article in this Journal (*1*) presented a comparison of measured and Monte Carlo calculated spatial distributions of resonance neutron capture across a gold rod. This letter reports a similar comparison for the case of U^{238} resonance neutron capture in a 0.387-in. diameter uranium metal rod in a hexagonal light-water moderated lattice with rod center-to-center spacing of 0.567 in.

A Monte Carlo digital program (*2*) was used to calculate the histories of 30,000 neutrons from 10 kev to 3 ev. The initial source was chosen by assuming a spatially flat, isotropic, $1/E$ flux in the cell at energies above 10 kev. Doppler broadened resonance cross sections of 27 resolved resonances were used over the energy range from 3 ev to 531 ev. Scattering was taken to be isotropic in the center-of-mass system, and interference between resonance and potential scattering was accounted for. Above 531 ev, the resonances were treated statistically, using a Porter-Thomas distribution of reduced neutron widths. The resonances were assumed to be evenly spaced with a separation of 16 ev and to have a constant $\Gamma\gamma$ of 0.024 ev. The cross-sectional area of the uranium rod was divided in the calculations into two main regions with outer radii of 0.1835 in. and 0.1935 in., respectively. Each of these two regions was subdivided into 10 equal area rings. The following calculational results were obtained:

TABLE I

NEUTRON CAPTURES[a]

ΔE (ev)	Outer region	Inner region
3.0–8.44	0.02272	0.06023
8.44–15.6	0.00055	0.00485
15.6–28.9	0.01062	0.03179
28.9–51.6	0.00840	0.03002
51.6–73.7	0.00317	0.01160
73.7–85.6	0.00109	0.00439
85.6–96.5	0.00013	0.00111
96.5–110.0	0.00247	0.00888
110.0–131.5	0.00184	0.00511
131.5–156.0	0.00037	0.00195
156.0–178.5	0.00057	0.00260
178.5–201.0	0.00111	0.00500
201.0–381.5	0.00337	0.01348
381.5–539.0	0.00141	0.00760
539.0–2000	0.00561	0.02937
2000–10000	0.00316	0.02293
Total/region	0.06659	0.24091
Inner region		0.24091
Outer region		0.06659
Total capture		0.30750

[a] Normalized to one neutron entering at 10 kev.

1. Fraction of neutrons started at 10 kev which are captured in the uranium rod above 3 ev.
2. Fraction of total capture in each of the twenty rings across the uranium rod.
3. Fraction of total capture in each of 16 energy intervals for each of the two main regions.

From the Monte Carlo calculations, a resonance escape probability (P) of 0.693 was obtained, which gave an effective resonance integral of 10.65 barns. To obtain the complete resonance integral above 0.5 ev, 1.3 barns (*3*, *4*) is added to account for p wave capture up to 30 kev and s wave capture from 10 to 30 kev. Also, 0.8 barns is added for all capture above 30 kev. There is 0.7 barn of $1/v$ capture between 0.5 ev and 3 ev; most of the remaining 0.5 barn of $1/v$ capture is accounted for by the Monte Carlo calculation. Therefore, 0.8 barns is added to account for $1/v$ capture.