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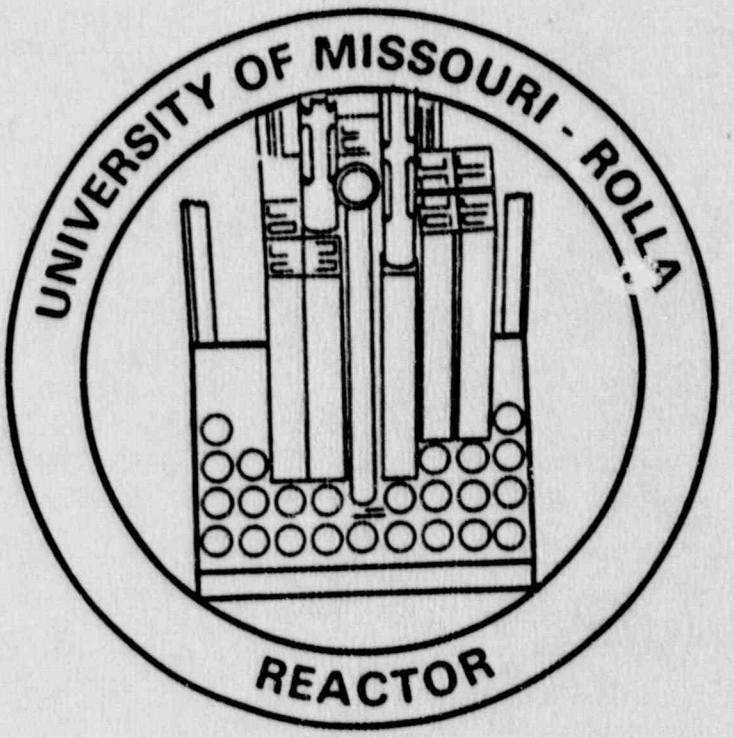
UMRR/88-1

REACTIVITY WORTH OF THE FLOODED ISOTOPE PRODUCTION ELEMENT IN A CORE OF THE UMR REACTOR



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Rolla, Fall 1988

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INTRODUCTION

At the UMR Reactor (UMRR) preparations are underway for a fuel conversion. The high enriched uranium (HEU) fuel will be replaced with a low enriched uranium (LEU) fuel of the similar geometry. One important part of this work is a theoretical analysis of the new reactor core. Detailed investigations into the reactor physics behavior play an important part of this analysis [1].

A set of computer programs has been provided by the Argonne National Laboratory for the theoretical analysis. More details on this program package and the analytical investigations are given in [2]. It is important to verify the methods and procedures used in this analysis since no comparable experience is available at this time. Therefore the techniques suggested for the conversion analysis were first applied to the present HEU core. In doing so, the calculational results for a number of important core parameters could have been compared with the experimental data.

In this report, it will be reported on reactivity measurements performed for the isotope production (IP) element inserted in two different positions of the HEU core 67 W. The method will be briefly discussed, results analyzed, and conclusions drawn. A comparison with the theoretical results will be made in this report.

MEASUREMENT METHOD

The method used to measure a reactivity worth of the IP element is based on the neutron multiplication in a subcritical reactor. The subcritical multiplication factor M is defined as

$$M = \frac{n_r}{n_o} = \frac{1 - k^{r+1}}{1 - k} \qquad (1)$$

where n_0 = number of neutrons produced by the source

n_r = number of neutrons produced in the reactor after r generations

k = effective multiplication factor (< 1.0)

For a sufficiently long time, eq. (1) simplifies to

$$N = \frac{C_r}{C_0} = \frac{1}{1-k} \qquad (2)$$

where n_r and n_0 were replaced with C_r and C_0 respectively, which are counts measured with a neutron counting equipment during a certain time interval. They are, of course, proportional to n_r and n_0 respectively.

Using eq. (2) for two subsequent changes in the effective multiplication factor k_1 and k_2 the count rate C_0 can be eliminated.

$$\frac{C_2}{C_1} = \frac{1 - k_1}{1 - k_2} \qquad (3)$$

Therefore, when k_1 is known and the count rates C_1 and C_2 are measured the new effective multiplication factor k_2 can be calculated. Obviously, the accuracy with which C_1 and C_2 were measured and k_2 determined is very important in this method. The error (or the uncertainty) in the value of k_1 propagates according to the formula

$$\Delta k_2 = \frac{C_1}{C_2} \Delta k_1 \qquad (4)$$

where Δk_1 = uncertainty in k_1

Δk_2 = error in the calculated value of k_2 (assuming C_1 and C_2 error-free)

The reactivity change between two subcritical states k_1 and k_2 can be expressed using the following formula

$$\rho = \frac{1}{k_1} - \frac{1}{k_2} \qquad (5)$$

An example is shown in Figure 1. The reactivity worth ρ of the UMkk void device is shown as calculated using eqs. (3) and (5). The core multiplication factor k_1 was selected as the dependent variable ranging between 0.9897 and 0.9996. The ratio of C_1/C_2 measured in this subcritical experiment was 1.6. It can be seen, from this example, that an error of about 0.2% in k_1 leads to a rather large relative error in ρ. Depending on the value of k_1 the error varies between 20 and 80%. This is rather surprising, but it can be shown that the absolute reactivity error Δ is approximately equal to

$$\Delta \doteq \frac{C_1}{C_2} - 1 \; \Delta k_1 \qquad (6)$$

Therefore, depending on the ratio C_1/C_2, an error of 0.2% in k_1 will give rise to an absolute error of a wide varying magnitude in the measured reactivity.

It seems that a conclusion can be drawn that the subcritical method is not very suitable for measurement of small reactivities. On the other hand, for larger reactivities, say 1% and more, this method can give good results.

SUBCRITICAL EXPERIMENTS

The method of subcritical multiplication has been used to measure a reactivity of the Isotope Production (IP) element in the position D-5 and C-7 of the HEU core configuration 67W. In both positions the IP element was filled either with air or water and respective reactivities measured. Table I shows the procedure and the measured data.

Table I. IP Element in D-5

Step	Reactor	Avg. Count Rate [cpm]	k [-]	[%]
1	RR @ 24" all SS @ 19" no IP	277.9	0.857987	-16.55
2	RR @ 24" all SS @ 19" IP w/air	405.6	0.902705	-10.78
3	RR @ 24" all SS @ 19" IP w/water	402.7	0.902005	-10.86

From Table I. one can see that the reactivity worth of the air-filled element in the position D-5 is about 5.8%.

Flooding with water will decrease its worth by about 0.1%. Incidentally, this value is of the same order of magnitude as the measurement error. For the reactivity one-sigma deviation was calculated to be 0.07%.

Measurement data and results for the position C-7 are shown in Table II.

Table II. IP Element in C-7

Step	Reactor	Avg. Count Rate [cpm]	k [-]	[%]
1	RR @ 24" all SS @ 18" no IP	6246.	0.993267	-0.678
2	RR @ 24" all SS @ 18" IP w/air	12399.1	0.996608	-0.340
3	RR @ 24" all SS @ 18" IP w/water	25708.7	0.998364	-0.164

The reactivity worth of the IP element in the periphery position C-7 is about 0.34%. Flooding of this element will increase its worth by about 0.18%

According to the analysis advanced in the previous Section the relative measurement error can be large since small reactivity values are measured. It was, therefore, of interest to compare results of this work with the results obtained by the criticality methods and by the computer code 2DB-UM [2]. Table III shows this comparison. The

Table III. Reactivity Measured in C-7 by Subcritical and Critical Experiment, and Calculated (%)

	Method		
	Subcriticality	Criticality	Calculation
IP Element w/air	0.338	0.425	0.421
w/water	0.514	0.425	0.479
Void only	-0.176	-0.160	-0.058

results of all three methods are consistent in that a void reactivity at the UMRR periphery is always negative.

The error of determining the reactivity worth of the IP element is quite large, varying between 20 and 60% depending upon what value is accepted as the true one. The worth of void is, however, remarkably close, at least for both experimental methods. One should note, that while a large error can be attached to the reactivity of both the air-filled and water-filled IP element due to an incorrect value of k_∞ used in the subcritical calculation, this becomes rather inconsequential when both reactivities are compared between themselves. Therefore, the reactivity worth of the "void only" measured by this method is expected to agree quite well with the one measured by the criticality method. This is, of course, confirmed in

the above Table.

CONCLUSIONS

The method of subcritical multiplication can be used to measure the reactivity of an unknown object placed at or into the reactor provided that its magnitude is larger than 1%. For objects whose reactivity worth is less than 1% this method can be used too, but the accuracy will suffer, if the value of k_0 is not known well. The method seems to be very well suitable (even for small reactivities) if only a comparison between two different samples (or states of a sample) is sought. Then the value of k_0 does not seem to be relevant because only the difference in reactivity of the two samples is the variable of interest.

It was shown in this work that flooding of the isotope production element positioned in the HEU core center will have only negligible reactivity effect. At the core periphery, flooding will give rise to a small positive reactivity change of about 0.2%. A similar behavior is expected for the proposed LEU core.

REFERENCES

[1] Straka M. and Covington L., "Study of Neutron Physics: Conversion of the University of Missouri-Rolla Reactor to Low Enriched Fuel", Trans. Am. Nucl. Soc., Vol. 55, November 1987.

[2] Covington L., "Neutronics Study of the Conversion of the University of Missouri-Rolla Reactor to Low Enriched Uranium Fuel", MS Thesis, University of Missouri-Rolla, 1989.

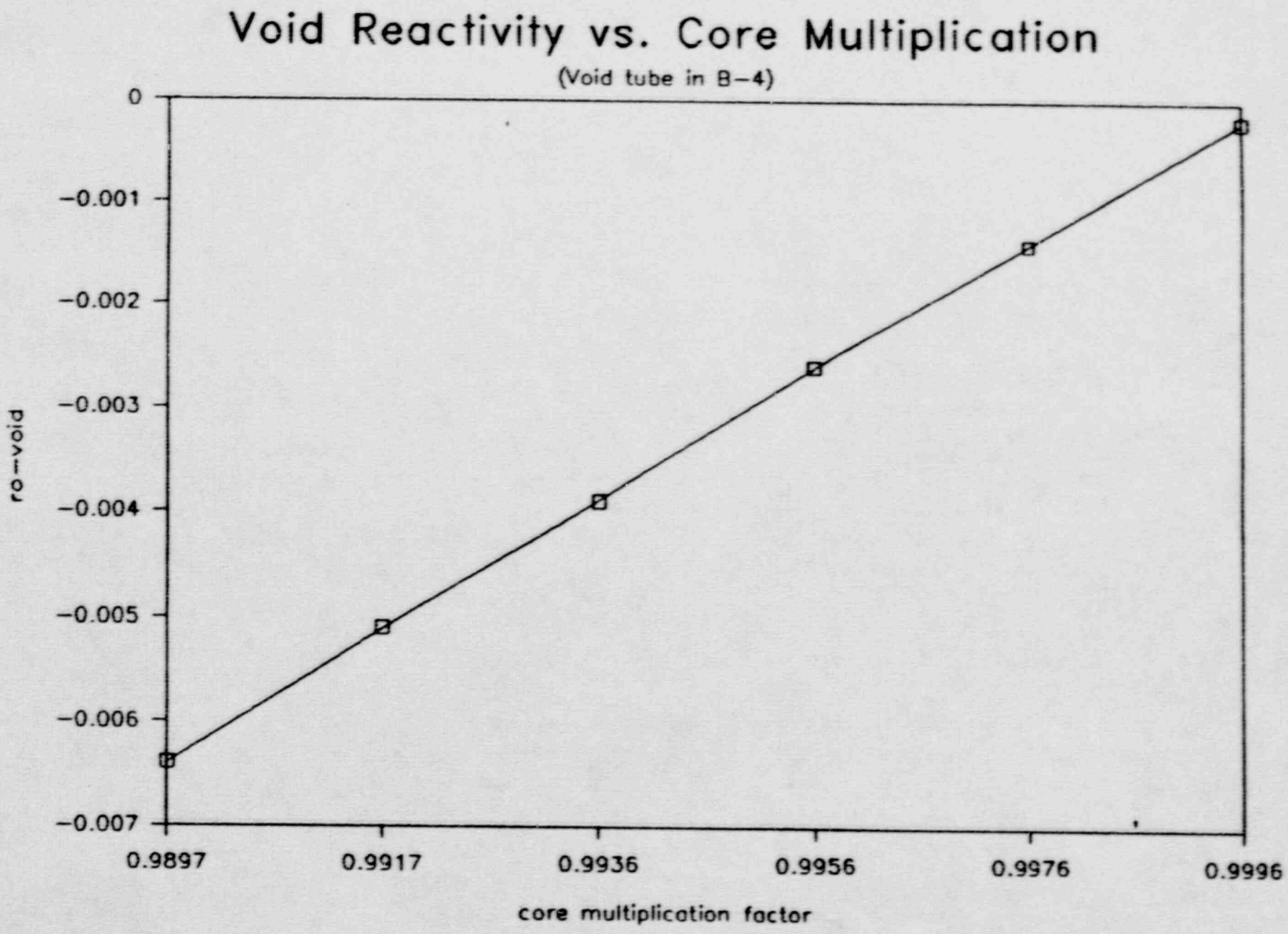
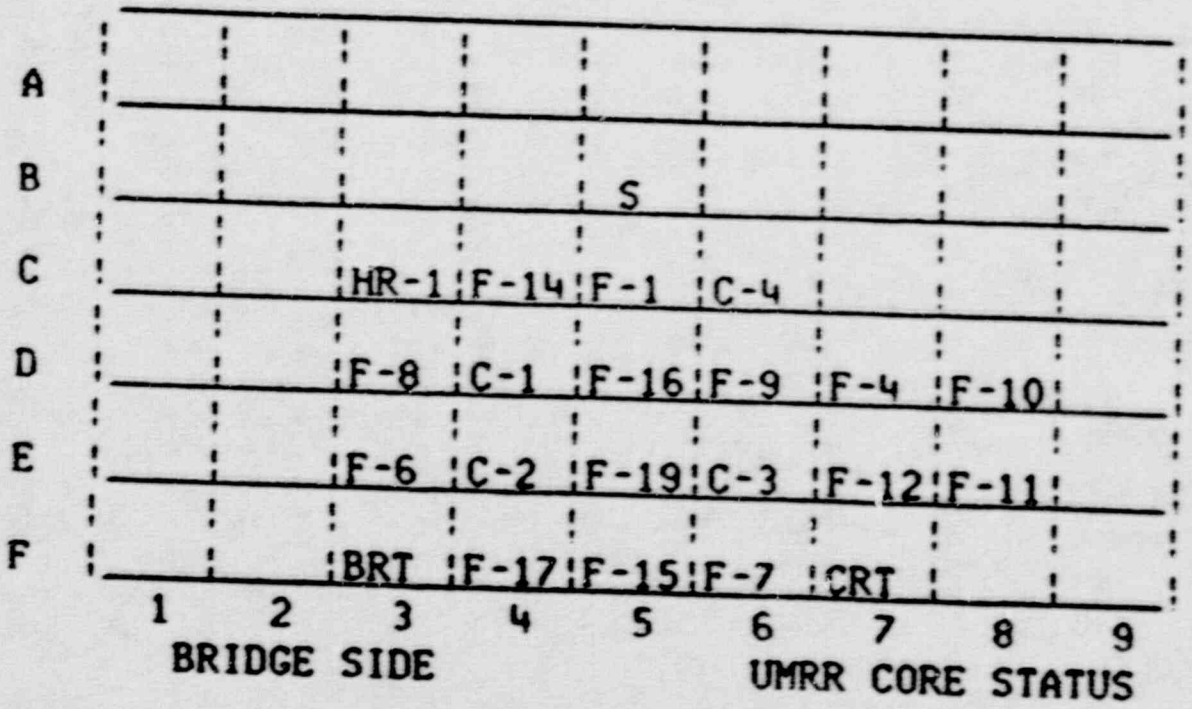

Void Reactivity vs. Core Multiplication
(Void tube in B-4)
0
-0.001
-0.002
-0.003
-0.004
-0.005
-0.006
-0.007
ro-void
0.9897
0.9917
0.9936
0.9956
0.9976
0.9996
core multiplication factor

Figure 1.



KEY TO PREFIXES

F - Standard Elements
C - Control Elements
HF - Half Front Element
HR - Half Rear Element
S - Source Holder

Other BRT - Bare Rabbit Tube
CRT - Cadmium Rabbit Tube

Figure 2. UMRR Core 67