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MASTER

MEASUREMENT OF THE TEMPERATURE

DEPENDENCE OF k_{∞} FOR A

$^{233}\text{UO}_2 - \text{ThO}_2$ HTGR LATTICE

by

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ABSTRACT

The second in a series of experiments using the High Temperature Lattice Test Reactor has been completed and provides information on the temperature dependence of k_{∞} for a $^{233}\text{UO}_2 - ^{232}\text{ThO}_2 - \text{C}$ fuel mixture. The infinite medium multiplication factor, was found to decrease by $.0322 \pm .0015$ from 20°C to 1000°C . This result provides direct information necessary in the design of the control system and in the safety analysis for advanced High-Temperature Gas-Cooled reactors.

TEMPERATURE DEPENDENCE OF k_{∞} FOR A ThO_2 - $^{233}\text{UO}_2$ HTGR LATTICE

The temperature dependence of the infinite medium neutron multiplication factor, k_{∞} , for a ThO_2 - $^{233}\text{UO}_2$ Lattice has been measured in the High Temperature Lattice Test Reactor (HTLTR). These measurements were carried out as part of a program to measure nuclear parameters in lattices typical of high-temperature gas-cooled reactors (HTGR).

The ThO_2 - $^{233}\text{UO}_2$ Lattice was constructed of graphite blocks 24-inches long containing fuel channels on a 0.75-inch square pitch. Each fuel channel was 0.470-inches in diameter and was loaded with a mixture of ThO_2 powder, graphite powder, and ThO_2 - $^{233}\text{UO}_2$ microspheres coated with pyrocarbon. Each fuel channel was sealed with a 1/2-inch end cap on each end. The average carbon-to-thorium atom ratio is about 205 and the carbon to ^{233}U ratio is 11,000.

Room temperature measurements of k_{∞} in the Physical Constants Test Reactor (PCTR) have been described previously.⁽¹⁾ As in the PCTR experiment, the measurements in the HTLTR were made using the unpoisoned technique.⁽²⁾ In this technique the reactivity worth of a small sample of the lattice (central cell) at the center of the reactor is normalized to the worth of a bare reactor (copper) and k_{∞} is evaluated using the two energy group equation:⁽³⁾

$$k_{\infty} = 1 - \left[\frac{\Delta \rho^{\text{cell}}}{\Delta \rho^{\text{Cu}}} \right] \frac{(\Sigma \phi V)_2^{\text{Cu}}}{(\Sigma \phi V)_2^{\text{cell}}} \left[1 + \frac{(\phi_1^+ \Sigma_1 \phi_1)^{\text{Cu}}}{(\phi_2^+ \Sigma_2 \phi_2)^{\text{Cu}}} \right] \\ - \frac{(1+\tau B^2)(1+L^2 B^2)(1-p)L^2 B^2}{1+(1-p)L^2 B^2} + \frac{\tau B^2(1+L^2 B^2) [\tau B^2 - \eta_1 f_1 (1-p)]}{1 + \tau B^2 - \eta_1 f_1 (1-p)}$$

The k_{∞} defined in this expression is for fluxes in the fundamental mode (a bare critical system), and a small correction is necessary if the flux ratio at the reactor center differs from the fundamental mode value. The two correction terms dependent on the buckling are calculated using a buckling consistent with the experimental value of $k_{\infty}-1$. The PCTR absorption measurements were used and corrections for changes in central cell neutron absorption relative to the absorption in the normalizing copper absorber were calculated as a function of temperature.

The values of k_{∞} derived from the measured reactivity data at each temperature are presented in Table I, together with the experimental error. Presented also are calculated values of k_{∞} using the computer codes GRANIT,⁽⁴⁾ a modification of THERMOS⁽⁵⁾ which includes particle size effects in the fuel, for the thermal region and EGGNIT⁽⁶⁾ for the epithermal region. Several improvements in these codes since the earlier report⁽¹⁾ have resulted in slightly modified values of k_{∞} .

TABLE I

TEMPERATURE °C	MEASURED k_{∞}	CALCULATED k_{∞}
20	1.0587±.0014	1.0507
150	1.0471±.0017	1.0370
300	1.0367±.0014	1.0256
500	1.0297±.0011	1.0156
750	1.0245±.0011	1.0081
1000	1.0237±.0012	1.0034

A comparison of the calculated and experimental results indicates that the calculated k_{∞} is consistently smaller than the experimental value, about 0.008 at room temperature. This difference is larger than the experimental error, but may be due largely to uncertainties in the exact fuel loading (mainly in the ^{233}U particles) which would affect the theoretical value. However, fuel loading uncertainties have little effect on the temperature variation of k_{∞} . The measured change in k_{∞} from 20°C to 1000°C is 0.035 ± 0.002 compared to the calculated change of 0.047. The source of this significant discrepancy has not yet been identified.

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