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MONTE CARLO CRITICALITY CALCULATIONS OF HYDROGEN MODERATED URANIUM SYSTEMS
USING THE PROBABILITY TABLE METHOD AND MULTIGROUP CROSS SECTION REPRESENTATIONS

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April, 1977

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Ernest F. Plechaty

April, 1977

Abstract

Monte Carlo criticality calculations using the Probability Table Method and Multigroup cross section representation show the importance of the Resonance structure of the uranium isotopes in well-moderated systems.

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Introduction

Criticality calculations have been done using three Monte Carlo neutron transport codes. The neutron cross section data used in calculations were derived from the ENDL¹ Library. The purpose of the calculations is to show the importance of the resonance structure in Uranium to criticality calculations. The three Monte Carlo codes used in the calculation were TART², TARTMK, and ALICE-K.

The TART and TARTMK codes are the same except for the number of energy groups used to represent the cross sections. TART uses 175 energy groups, while TARTMK uses 2020 energy groups. In TARTMK there are 1936 energy groups below 10.0 keV. TART has 102 groups below 10.0 keV.

The ALICE-K code uses the probability table method³⁻⁷ with the TART 175 energy group structure. The effects of resonance self shielding for an isotope is handled by having two probabilities and two cross section sets for the total, elastic, capture, and fission reactions for each energy group. The probabilities are used to select the cross section set to be used for a neutron in a given energy group.

Calculation of Fast Critical Assemblies

The TART and ALICE-K codes have been used to calculate 41 experimental critical assemblies. These assemblies have median fission energies in excess of .5 MeV. Forty of the assemblies calculated by both ALICE-K and TART had Keff in the range of .987-1.014. One assembly calculated with TART had a Keff of 1.018 while ALICE-K calculated 1.004. For this assembly the tamping material (nickel has resonance structure from 10.0 keV to 3 MeV.

Calculation of Well Moderated Critical Assemblies

TART, TARTMK and ALICE-K were used to calculate K_{eff} for four experimentally determined critical assemblies⁸⁻⁹ in which the moderator was H_2O . There are three spherical, and one cubic assembly with different ratios of hydrogen to Uranium. The physical descriptions of the assemblies are given in Table I.

TABLE I
Physical Description of Critical Assemblies

Spherical Radius cm.	Density g/cm ³	H/U ²³⁵	Relative Atom Densities				
			U ²³⁵	U ²³⁸	H	O	C
16.636	8.027	3.0	8.8135	20.306	26.441	13.220	o
17.602	4.177	10.0	4.5861	10.567	45.861	22.931	o
17.131	1.759	30.0	1.9318	4.4498	57.954	28.977	o
cube							
Length of Side							
cm							
29.814	4.8127	16.3	2.900	6.638	47.27	19.076	23.635

The calculated results for the four critical systems and the three codes are given in Tables II thru IV.

TABLE II
Calculated K_{eff}
H/U²³⁵ ratio

Code	H/U ²³⁵ ratio			
	3/1	10/1	30/1	16.3/1
TART	.901±.003	.859±.003	.866±.003	.843±.003
TARTMK	.950±.003	.978±.003	.993±.003	.965±.003
ALICE-K	.957±.003	.989±.003	.996±.003	.976±.003

TABLE III

Calculated Median Fission Energy in Electron Volts

Code	H/U ²³⁵ ratio			
	3/1	10/1	30/1	16.3/1
TART	12600.	113.2	.364	21.5
TARTMK	7700.	56.6	.244	10.2
ALICE-K	7250.	54.3	.244	8.04

TABLE IV

Calculated Removal Life Time in Microseconds

Code	H/U ²³⁵ ratio			
	3/1	10/1	30/1	16.3/1
TART	.0945±.0010	.342±.003	1.230±.008	.665±.005
TARTMK	.1143±.0013	.468±.004	1.509±.008	.856±.005
ALICE-K	.1162±.0014	.473±.004	1.507±.008	.873±.006

Table II shows that ALICE-K always calculates a value of K_{eff} that is closer to the experimental value of $K = 1.0$. The 3/1 H to U²³⁵ assembly deviates the greatest from the experimental value. The calculate median fission energy (7.25 keV) is in the energy range (3.0 to 18 keV.) where the (n, γ) cross section for U²³⁵ has never been measured. The TART code underestimated K_{eff} because it does not treat resonance structure. Likewise, the TARTMK code with approximately 1900 energy groups in the resonance region is inferior to the probability table method of ALICE-K for calculating K_{eff} of these systems.

Conclusions

1. When the median fission energy of a system is in the resonance region of either the fuel or tamping material, the probability table method of ALICE-K gives results that are in better agreement with experiment than the multigroup method of either TART or TARIMK.

2. When the median fission energy is outside the resonance region of both the fuel and tamping material ALICE-K and TART agree.

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