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A COMPARISON OF EXPERIMENTAL DATA FROM ENERGY-DEPENDENT
RESONANCE SELF-SHIELDING FACTORS FOR ^{235}U AND ^{239}Pu WITH
CALCULATIONS FROM TART

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INTRODUCTION

TART, a Monte Carlo neutron transport code, has become the principal code used in neutron vulnerability calculations. Therefore, it is important to determine the accuracy of its cross section library. To do so, we carefully mocked up and calculated with TART the self-shielding experiments as performed by J. B. Czirr and R. L. Bramblett.¹ The experiments were performed at LLL to measure the energy dependence of resonance self-shielding using the 33-MeV linear accelerator. One experiment investigated ^{235}U ; the other, ^{239}Pu .

The experimental techniques used are described in detail in Ref. 1. Briefly, the bremsstrahlung-produced neutron spectrum was modified to nearly $1/E$ energy dependence. Increasing thicknesses of either Oy or Pu disks were inserted in the beam. The fission rate in the detector was then measured as a function of shielding thickness and incident neutron energy. The geometry of the experiments is shown in Fig. 1. The results of the experiments are shown in Tables 1 and 2.

TART CALCULATIONS

The parameters for each experiment were mocked up in a 2-D geometry (Fig. 2). The TART neutron spectra and energy groups were identical to those used by Czirr: $dN/dE \propto E^{-1}$ and a 2.15-to-1 ratio between the lower and upper energy group boundaries. The computed relative fissions in the detector zone as a function of shielding thickness and incident neutron energy are summarized in Tables 3 and 4. The comparisons are graphically shown in Figs. 3 through 22.

CONCLUSIONS

TART is not able to compute fission density vs depth correctly for incident neutron energies at which the cross sections have resonances. We attribute this to the relatively large width of the TART energy groups, compared to the width of resonances, over which the cross sections are averaged.

¹J. B. Czirr and R. L. Bramblett, Nucl. Sci. Eng. **35**, 350 (1969); Nucl. Sci. Eng. **28**, 62 (1967).

The calculations were done with the standard TART cross section library in use at LLL during March and April 1972. A detailed listing of these cross sections is available from E. F. Plechaty, LLL.

Table 1. Relative shielded fission rate vs absorber thickness for ^{235}U .^a

Energy group G	Energy range (eV)	x^2 (g/cm ² U)									
		0.141	0.260	0.504	0.794	1.968	3.852	9.473	19.04	5.575 ^b	
0	0.464 -	1.00	0.983	0.937	0.880	0.848	0.662	0.462	0.152	0.028	0.453
1	1.00 -	2.15	0.942	0.949	0.895	0.821	0.661	0.453	0.199	0.072	0.480
2	2.15 -	4.64	0.975	1.000	0.903	0.876	0.788	0.585	0.316	0.147	0.557
3	4.64 -	10.0	0.867	0.800	0.646	0.525	0.345	0.192	0.073	0.027	0.194
4	10.0 -	21.5	0.878	0.790	0.655	0.551	0.364	0.249	0.095	0.038	0.245
5	21.5 -	46.4	0.937	0.874	0.755	0.704	0.466	0.280	0.100	0.030	0.295
6	46.4 -	100	0.976	0.924	0.842	0.758	0.589	0.375	0.118	0.039	0.368
7	100 -	215	0.983	0.945	0.898	0.826	0.666	0.528	0.233	0.090	0.492
8	215 -	464	0.988	0.956	0.930	0.926	0.779	0.621	0.336	0.155	0.607
9	464 -	1000	1.011	0.988	0.945	0.942	0.786	0.676	0.433	0.231	0.707
10	1000 -	2150	0.995	0.941	0.973	0.921	0.847	0.779	0.541	0.299	0.745
% ^{235}U		93.22	93.22	93.17	93.17	93.13	93.13	93.22	93.22	59.7	
% ^{238}U		5.35	5.35	5.69	5.69	5.58	5.58	5.42	5.42	39.5	

^aFrom Ref. 1.

^b2.205 g/cm² of ^{238}U plus 3.328 g/cm² of ^{235}U were used to obtain these data.

Table 2. Relative group-averaged fission rate vs absorber thickness for ^{239}Pu .^{a,b}

Energy group G	x^2 (g/cm ² Pu)								Energy limits	
	0.0600	0.1217	0.2170	0.4117	0.7818	1.626	3.130			
1	—	—	—	—	—	—	—	1.0 -	2.15	eV
2	0.989	0.933	—	0.902	0.932	0.880	0.813	2.15 -	4.64	eV
3	0.884	0.695	0.683	0.562	0.416	0.290	0.192	4.64 -	10.0	eV
4	0.850	0.746	0.694	0.507	0.378	0.242	0.143	10.0 -	21.5	eV
5	0.851	0.756	0.728	0.567	0.441	0.318	0.215	21.5 -	46.4	eV
6	0.863	0.810	0.710	0.687	0.577	0.443	0.334	46.4 -	100	eV
7	0.909	0.884	0.770	0.773	0.730	0.631	0.524	100 -	215	eV
8	0.947	0.811	0.865	0.783	0.783	0.678	0.558	215 -	464	eV
9	—	0.864	0.861	0.949	0.962	0.736	0.637	464 -	1000	eV
10-12	0.886	0.918	0.936	0.911	0.938	0.870	0.847	1.0 -	10	keV
% ^{239}Pu	93.7	93.6	93.7	93.7	93.7	93.7	93.9			

^aFrom Ref. 1.

^bIn both cases, the incident neutron spectrum (neutrons per unit energy) was proportional to E^{-1} . The column headings refer to the areal density of the ^{239}Pu shielding the detector foil.

Table 3. Computer fission density vs depth in ^{239}Pu .

Depth into Pu (g/cm ²)	Energy groups (eV)								
	2.15-4.64	4.64-10.0	10.0-21.5	21.5-64.4	46.4-100.0	100-215	215-464	464-100	1kV-10kV
0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
0.06	0.998	0.95	0.95	0.947	0.97	0.99	0.995	0.999	0.997
0.1217	0.993	0.91	0.89	0.898	0.94	0.987	0.989	0.99945	0.994
0.217	0.986	0.85	0.82	0.8285	0.90	0.977	0.98	0.989	0.99
0.4117	0.97	0.73	0.68	0.703	0.82	0.957	0.963	0.975	0.98
0.7818	0.947	0.55	0.49	0.5357	0.7	0.92	0.93	0.9488	0.962
1.626	0.89	0.31	0.25	0.357	0.5	0.8454	0.86	0.89	0.919
3.13	0.8	0.14	0.089	0.162	0.3	0.72	0.75	0.798	0.85

Table 4. Computed fission density vs depth in ^{235}U .

Depth into Oy (g/cm ²)	Energy groups (eV)										
	464-1.0	1.0-2.15	2.25-4.64	4.64-10.0	10.0-21.5	21.5-46.4	46.4-100.0	100.0-215.0	215-464	464-1000	1000-2150
0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
0.141	0.96	0.976	0.98	0.92	0.89	0.96	0.98	0.983	0.988	0.989	0.99
0.260	0.94	0.957	0.967	0.87	0.81	0.93	0.96	0.97	0.977	0.98	0.986
0.504	0.88	0.917	0.94	0.76	0.67	0.86	0.92	0.94	0.955	0.96	0.97
0.794	0.82	0.873	0.91	0.66	0.54	0.79	0.88	0.91	0.93	0.94	0.958
1.968	0.62	0.715	0.78	0.39	0.27	0.57	0.74	0.79	0.83	0.86	0.9
3.852	0.204	0.53	0.625	0.2	0.13	0.37	0.55	0.63	0.7	0.746	0.81
9.473	0.073	0.23	0.325	0.06	0.046	0.12	0.25	0.33	0.42	0.49	0.596
19.04	0.018	0.066	0.113	0.014	0.012	0.03	0.06	0.109	0.17	0.237	0.355

Fig. 1. Geometry of a ^{239}Pu experiment (not to scale) from Ref. 1.

Fig. 2. Calculational geometry for a self-shielding experiment (not to scale).

Fig. 3. Comparison of calculated and measured fission densities in or alloy for an energy group with 0.464-1.0 eV.

Fig. 4. Comparison of calculated and measured fission densities in oralloy for an energy group with 1.0-2.15 eV.

Fig. 5. Comparison of calculated and measured fission densities in or alloy for an energy group with 2.15-4.64 eV.

Fig. 6. Comparison of calculated and measured fission densities in oralloy for an energy group with 4.64-10.0 eV.

Fig. 7. Comparison of calculated and measured fission densities in oralloy for an energy group with 10.0-21.5 eV.

Fig. 8. Comparison of calculated and measured fission densities in oralloy for an energy group with 21.5-46.4 eV.

Fig. 9. Comparison of calculated and measured fission densities in or alloy for an energy group with 46.4-100 eV.

Fig. 10. Comparison of calculated and measured fission densities in oralloy for an energy group with 100-215 eV.

Fig. 11. Comparison of calculated and measured fission densities in or alloy for an energy group with 215-464 eV.

Fig. 12. Comparison of calculated and measured fission densities in oralloy for an energy group with 464-1000 eV.

Fig. 13. Comparison of calculated and measured fission densities in or alloy for an energy group with 1000-2150 eV.

Fig. 14. Comparison of calculated and measured fission densities in plutonium for an energy group with 2.15-4.64 eV.

Fig. 15. Comparison of calculated and measured fission densities in plutonium for an energy group with 4.64-10.0 eV.

Fig. 16. Comparison of calculated and measured fission densities in plutonium for an energy group with 10.0-21.5 eV.

Fig. 17. Comparison of calculated and measured fission densities in plutonium for an energy group with 21.5-46.4 eV.

Fig. 18. Comparison of calculated and measured fission densities in plutonium for an energy group with 46.4-100 eV.

Fig. 19. Comparison of calculated and measured fission densities in plutonium for an energy group with 100-215 eV.

Fig. 20. Comparison of calculated and measured fission densities in plutonium for an energy group with 215-464 eV.

Fig. 21. Comparison of calculated and measured fission densities in plutonium for an energy group with 464-1000 eV.

Fig. 22. Comparison of calculated and measured fission densities in plutonium for an energy group with 1-10 keV.

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