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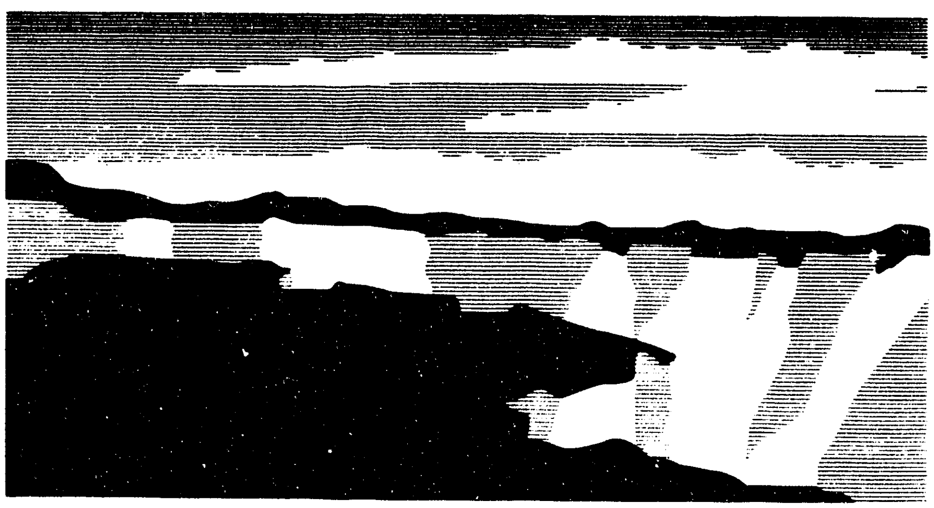

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ATW Neutronics: A Comparison of One-, Two-, and Three-Dimensional Calculations

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Introduction

The Los Alamos Accelerator Transmutation of Nuclear Waste (ATW) concept consists of four principal systems: accelerator, neutron spallation target, blanket (moderating region surrounding the target), and chemical separator. The device is designed to transmute actinides and fission products carried in heavy water (D_2O) slurries or aqueous solutions. The design goals of the device are to transmute the actinide and fission product waste from at least two 1000 MW_e LWRs, and to produce enough electricity to power the accelerator with some excess to sell to local power utilities. This means our goal is to transmute 80 kg of technetium and iodine, and 600 kg of actinide (neptunium, americium, and plutonium) per year. Calculational and design details may be found in Ref. 1.

This device is the latest in a series of ATW systems[2,3,4] that have been studied by Los Alamos National Laboratory. Each device has been the object of many radiation physics calculations in order to arrive at some local optimum in terms of transmutation rates and achievable power production. Our basic calculational tool is the one-dimensional (1D) transport code ONEDANT.[5]

It is important to know, however, how close our results are to those obtainable from a real device. This requires that two- (2D) and three-dimensional (3D) calculations be made in order to obtain a calculational benchmark. For the two- and three-dimensional calculations we use the codes TWODANT[6] and MCNP,[7] respectively. This paper presents the results of one set of comparisons for the ATW device discussed above. These results provide a basis to ascertain the accuracy of the

1D calculations and to provide a means to establish the calculational requirements for future devices.

Calculational Model

Our current base case design is an aqueous system that uses D_2O for the target coolant, moderator, actinide slurry carrier fluid, and fission product solution. The proton target is D_2O cooled tungsten, which is surrounded by a lead-D_2O region. Next is an inner region of D_2O and technetium, which is followed by the actinide slurry. The last region contains technetium and D_2O. These regions are contained in a low-pressure aluminum moderator tank. The tank is 3.58 meters long with a radius of 1.5 meters. Figure 1 is a model of the blanket.

The equilibrium composition of the actinide waste depends on the relative capture and fission reactions in the actinide isotopes. We determined the neutron flux-spectra in a unit actinide cell, which was used to calculate one-group cross sections using ONEDANT. Using a simple point depletion code, we iterated until the transport and depletion calculations converged. This resulting actinide composition was used in the blanket calculations.

The 3D MCNP calculations used explicit models of Figure 1 with piping included. The 1D ONEDANT calculations are of homogenized cylindrical regions corresponding to a slice in the blanket. The regions are: (1) tungsten and D_2O, (2) lead and D_2O, (3) zircaloy, (4) technetium, zircaloy, and D_2O, (5) actinides and D_2O, (6) D_2O, and (7) technetium, zircaloy, and D_2O. The 2D TWODANT cases were also modeled with homogenous regions, however it included the structure, reflector, and voids at the top and bottom of the blanket.

Results and Conclusions

Only eigenvalue calculations were made with TWODANT, and using a buckling with a ONEDANT eigenvalue calculation, the eigenvalues obtained were less than 0.2 percent different. A comparison of a ONEDANT calculation with MCNP is given in Table 1. With the exception of the leakage, which is small, the differences in reaction rates between the two codes are generally less that 2%. We find that the 1D calculations are clearly adequate for survey calculations.

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Table 1. Reference Blanket Neutron Balance

Codes	ONEDANT	MCNP
k_{eff}	0.95	0.942±0.12%
Sources		
Accelerator	1.00	1.00
Fission Neutrons	11.628	11.81
Total Sources[a]	12.628	12.81
Absorptions		
Target		
Tungsten Region	0.447	
Lead-D_2O Region	0.057	
Al Wall	0.022	
Inner Tc		
Tc	0.308	0.309±1.0
Zirc+D_2O	0.013	
Lattice		
Slurry	10.214	
Tubes	0.401	
Moderator	-0.001	
D_2O Reflector	0.024	
Outer Tc		
Tc	0.729	0.746±1.2
Zr+D_2O	0.058	
Total Abs.	12.271	12.141
Leakage		
Radial	0.050	0.108±2.1%
Axial	0.308	0.394±1.6%
Total Leakage	0.358	0.502±1.4%
Total Losses	12.629	
Total Fissions	3.798	3.852±1.4%
Average Slurry Flux	2.3e15	2.26e15±2.4%

[a]Excluding n,2n

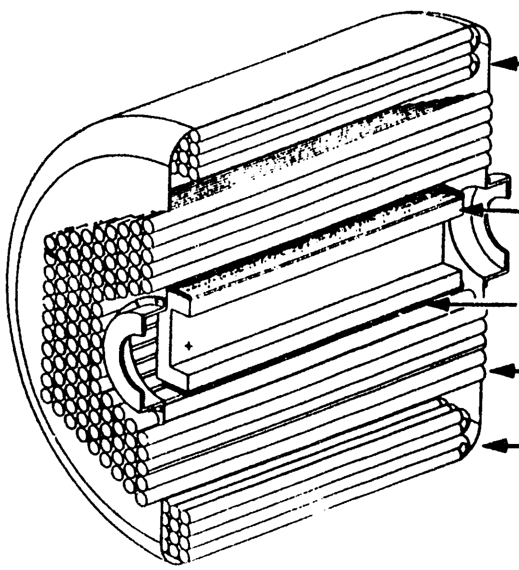

Fig. 1.
ATW blanket design.

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