RECORDS ADMINISTRATION
ACGE

Acc# 739149

DP-MS-81-130

VALIDATION OF ANS-5.1 AS THE DECAY HEAT STANDARD AT THE SAVANNAH RIVER PLANT

by

Courtney E. Apperson, Jr.

E. I. du Pont de Nemours & Co.
Savannah River Laboratory
Aiken, South Carolina 29808

SRL
RECORD COPY

A paper for presentation at the
1982 Annual Meeting of the American Nuclear Society
June 6-11, 1982
Los Angeles, California

This paper was prepared in connection with work done under Contract No. DE-AC09-76SR00001 with the U.S. Department of Energy. By acceptance of this paper, the publisher and/or recipient acknowledges the U.S. Government's right to retain a nonexclusive, royalty-free license in and to any copyright covering this paper, along with the right to reproduce and to authorize others to reproduce all or part of the copyrighted paper.

DP-MS-81-130

VALIDATION OF ANS-5.1 AS THE DECAY HEAT STANDARD AT THE SAVANNAH RIVER PLANT*

by

Courtney E. Apperson, Jr.

E. I. du Pont de Nemours & Co.
Savannah River Laboratory
Aiken, South Carolina 29808

INTRODUCTION

The Savannah River Laboratory (SRL) is upgrading the methods used to predict the post shutdown decay heat of the Savannah River reactors by implementing procedures based on the ANS "Decay Heat Power in Light Water Reactors"[1] standard. This approach takes advantage of the large volume of research used in developing the standard and establishes compatibility with the nuclear industry.

The Savannah River reactors are thermal reactors which are cooled and moderated by D_2O and are operated primarily for the production of plutonium-239 and tritium. The reactor charges are composed of a regular array of mixed lattices of fuel and target assemblies as shown in Figures 1 and 2. The assemblies are approximately 4 inches in diameter and are on a 7-inch pitch. The fuel assemblies contain a uranium-aluminum alloy highly enriched in uranium-235 arranged in two or three concentric rings

---

* The information contained in this article was developed during the course of work under Contract No. DE-AC09-76SR00001 with the U.S. Department of Energy.

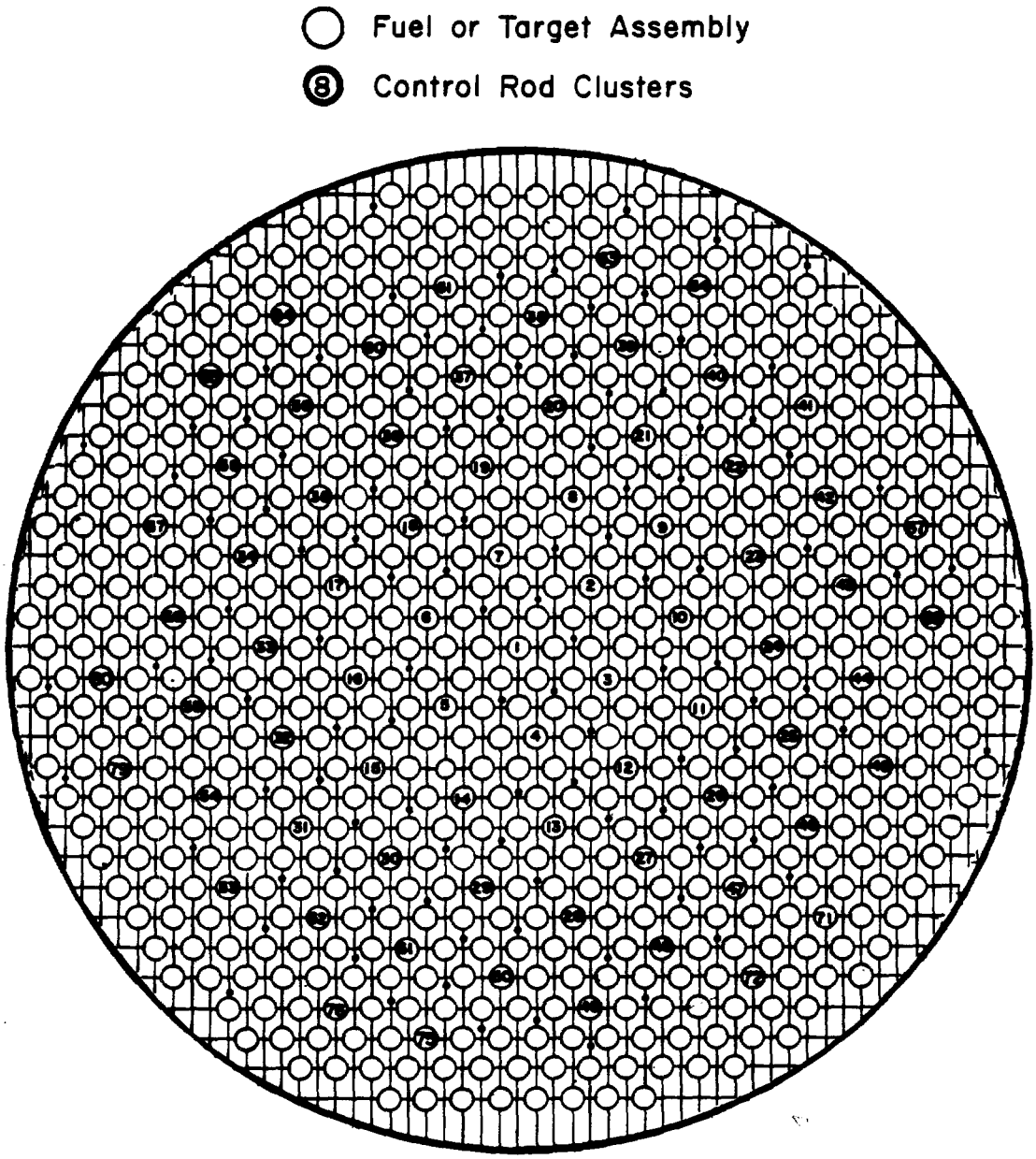

FIGURE 1. Cross Section of a Typical Savannah River Reactor Core

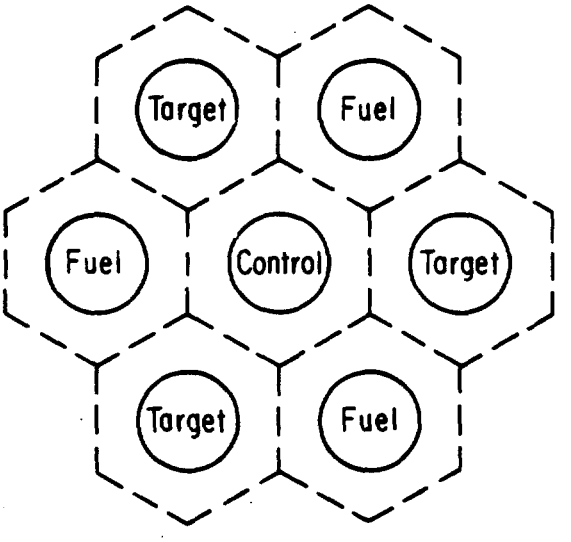

FIGURE 2. Mixed Lattice Pattern

(Figure 3a). The target assemblies for the production of plutonium-239 consist of tubular slugs of aluminum-clad depleted uranium metal (Figure 3b). The control assembly is composed of a cluster of seven rods of a lithium-aluminum alloy within an aluminum housing (Figure 3c).

Since these reactors are sufficiently different from the reactor described in the standard, a light water reactor of the type currently operating in the USA, the first step in the program was to validate the standard for use with the Savannah River reactors. Then, it was necessary to apply the standard to the operations at Savannah River.

For these production reactors, which operate on relatively short cycles, it is important to minimize the time after shutdown when the assemblies can be discharged. An accurate calculation of the energy deposited in the assemblies in a reactor is essential since the post shutdown power level in the assemblies establishes the duration of the delay before the initiation of discharge operations. To obtain an accurate value of the energy actually deposited in the assemblies it is necessary to modify the ANS standard to account for photon energy redistribution.

QUALIFICATION OF STANDARD

To qualify the decay heat standard for use, a series of comparisons were made between detailed decay heat calculations performed using the SHIELD code system[2] and results obtained from the standard. The SHIELD system is a recently developed SRL computational tool for the calculation of isotopic inventory,

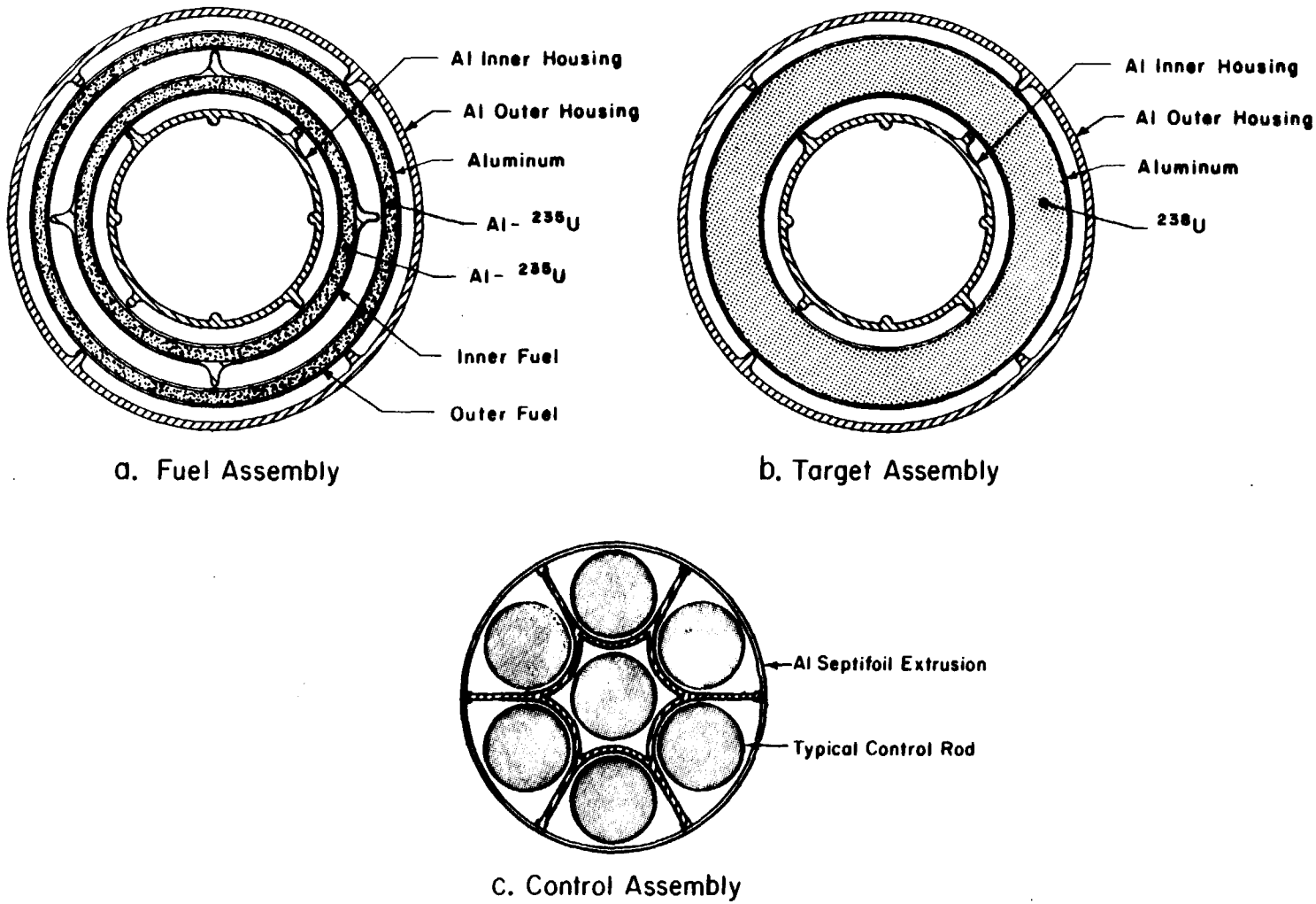

FIGURE 3. Typical Savannah River Reactor Assemblies

radiation sources, and decay heat power, and for shielding assessment in any part of the nuclear fuel cycle. SHIELD was used to calculate assembly inventories as a function of exposure for a typical mixed lattice of fuel and target assemblies. The calculated inventories were then used as the source for estimating the time-dependent post shutdown decay heat power source in each assembly. SHIELD utilized the ENDF/B-IV data set. The operating history information required by the decay heat standard was extracted from the exposure calculation. The results from the SHIELD calculation and the standard for both the fuel and target assemblies are given in Figure 4. The percent difference between the two methods is summarized in Table 1 for decay times typical for SRP operation. The maximum observed difference is 2.2 percent.

This good agreement was expected for the fuel assembly since the standard has been demonstrated to be quite accurate for uranium-235 decay heat predictions. Although the target assembly provided a more stringent test of the standard, since at the time of shutdown fission is occurring in uranium-235, uranium-238, and plutonium-239, there was even better agreement. Based on these results, the standard was judged to be acceptable for the Savannah River reactors.

INCORPORATION OF PHOTON REDISTRIBUTION

The second phase of this work was to determine how to best incorporate the redistribution of photon energy into the standard results. SHIELD calculated fission product concentrations and

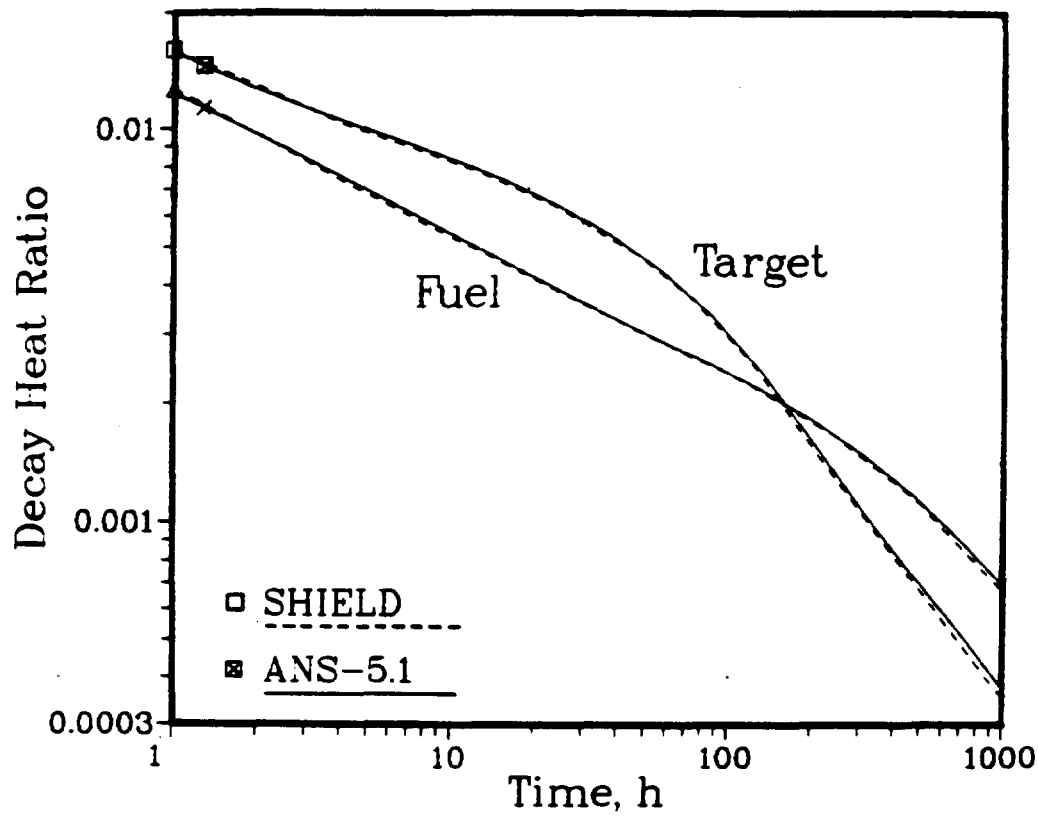

FIGURE 4. Comparison of ANS-5.1 and SHIELD without Photon Redistribution

TABLE 1

Post Shutdown Decay Heat Ratio, $\frac{P(t)}{P_0}$

Time, h	Fuel			Target		
	Analytic*	ANS-5.1	% Diff.	Analytic*	ANS-5.1	% Diff.
1	.01255	.01230	-2.0	.01590	.01586	-0.2
4	.00742	.00756	1.9	.01034	.01054	1.9
8	.00578	.00591	2.2	.00874	.00890	1.8
12	.00502	.00510	1.6	.00788	.00800	1.5
24	.00391	.00394	0.8	.00638	.00644	0.9
48	.00307	.00309	0.6	.00477	.00482	1.0
72	.00268	.00270	0.7	.00380	.00384	1.0
120	.00225	.00226	0.4	.00260	.00264	1.5

* As calculated by SHIELD system.

their associated photon sources were used as input for a mixed lattice transport theory photon redistribution calculation. Assuming all of the beta decay energy is deposited in the assemblies and using the computed time-dependent photon redistribution, the decay heat energy deposited in the fuel and target assemblies was evaluated. To account for photon redistribution in the standard, the energy generated in an assembly as computed by the standard was modified by multiplying by an energy redistribution factor. This value, which can be obtained from the detailed redistribution calculation, is a function of time after shutdown. For ease of application, however, it was desirable to use a constant value over a time range of interest. The value of the redistribution factor was determined by reviewing the time behavior of the beta-particle energy fraction (Figure 5) and the gamma-ray absorbed energy factor (Figure 6) and combining them according to Equation 1.

$$G(t) = \beta(t) + (1 - \beta(t))\, GF(t) \qquad (1)$$

where

$G(t)$ is the energy redistribution factor,

$\beta(t)$ is the beta-particle energy fraction, and

$GF(t)$ is the gamma-ray absorbed energy factor.

The appropriate constant is obtained by selecting the energy redistribution factor which is most representative of the time range of greatest interest for SRP operations, Table 2. For the example given here the constant values of G were 0.72 for the fuel

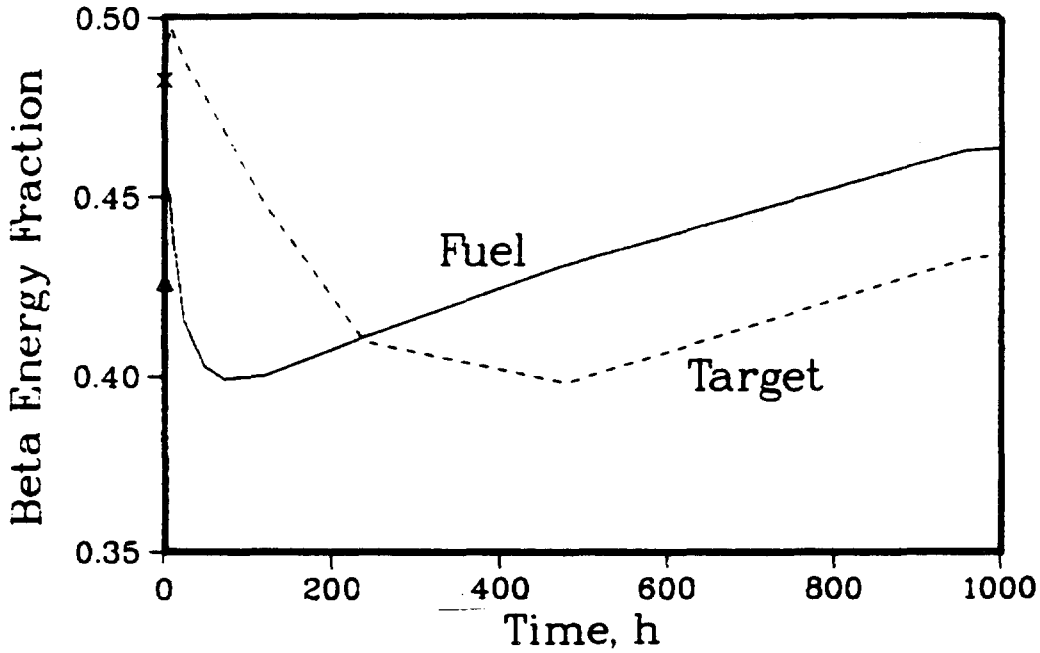

FIGURE 5. Beta Energy Fraction

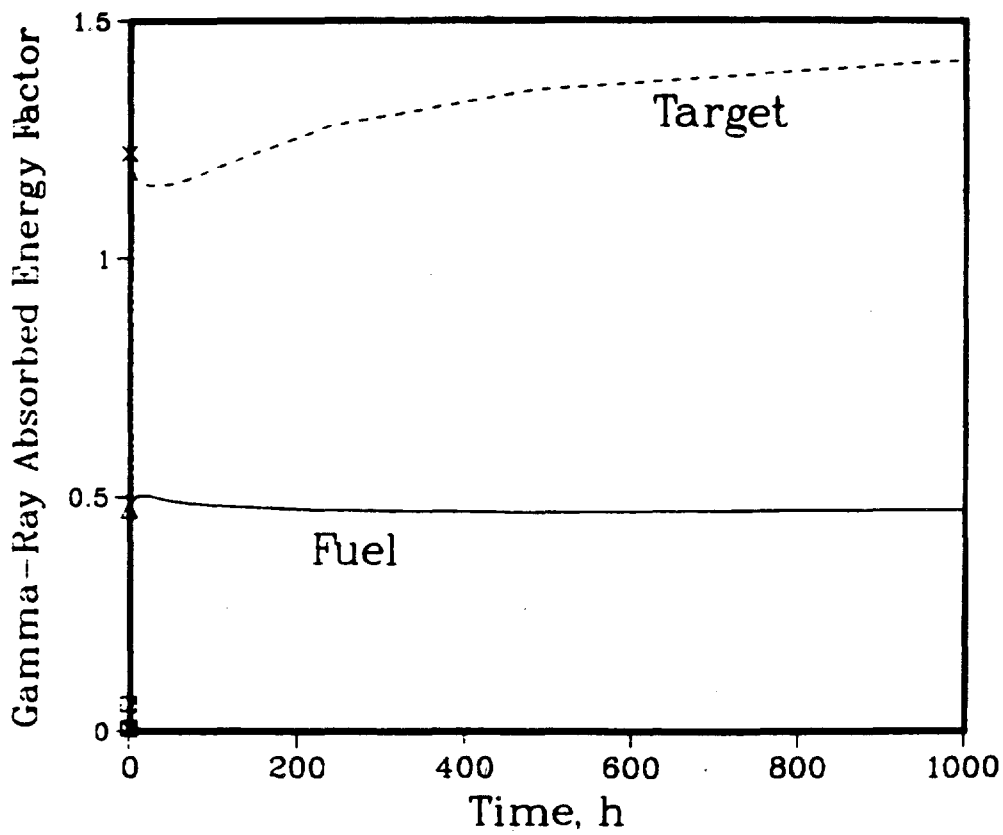

FIGURE 6. Gamma-Ray Absorbed Energy Factor

TABLE 2

Energy Redistribution Factor

Time, h	Fuel β	Fuel GF	Fuel G	Target β	Target GF	Target G
1	.426	.475	.699	.483	1.218	1.113
4	.453	.489	.720	.493	1.182	1.092
8	.450	.501	.726	.498	1.166	1.083
12	.438	.505	.722	.495	1.160	1.081
24	.416	.505	.711	.488	1.152	1.078
48	.403	.496	.699	.479	1.154	1.080
72	.400	.490	.694	.468	1.166	1.088
120	.401	.484	.691	.448	1.199	1.110

assembly and 1.07 for the target assembly. The fuel assemblies are a net exporter of energy as is indicated by a G value less than 1. The targets which are energy importers have a G value greater than 1. As illustrated by Figure 7, this approximation gives good agreement for the assemblies in a lattice configuration. The percent difference between the two methods is summarized in Table 3 for decay times of interest. Over the time range of interest, 8 to 48 hr, the fuel assembly differs by 3.2 percent or less and the target assembly differs by 0.6 percent or less. For SRP applications this is considered acceptable.

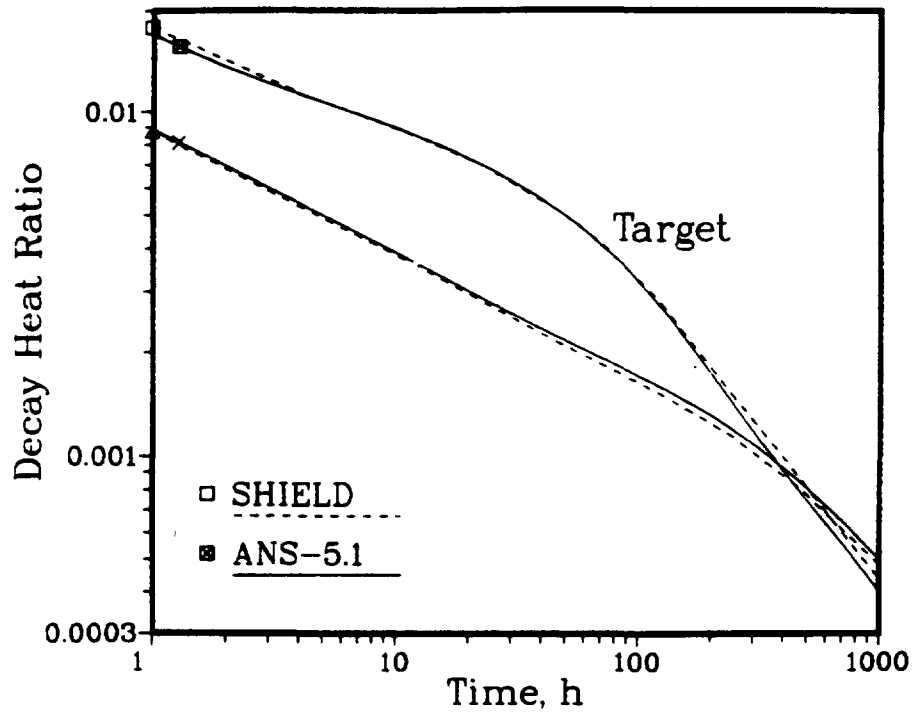

FIGURE 7. Comparison of ANS-5.1 and SHIELD with Photon Redistribution

TABLE 3

Post Shutdown Decay Heat Ratio, $\frac{P(t)}{P_0}$, with Photon Redistribution

Time, h	Fuel			Target		
	Analytic*	ANS-5.1	% Diff.	Analytic*	ANS-5.1	% Diff.
1	.00878	.00886	0.9	.01769	.01697	-4.2
4	.00535	.00544	1.7	.01130	.01128	-0.2
8	.00420	.00426	1.4	.00947	.00953	0.6
12	.00362	.00367	1.4	.00852	.00856	0.5
24	.00278	.00284	2.1	.00688	.00689	0.1
48	.00215	.00222	3.2	.00515	.00516	0.2
72	.00186	.00194	4.2	.00413	.00411	-0.5
120	.00156	.00163	4.4	.00289	.00283	-2.1

* As calculated by SHIELD system.

CONCLUSION

The principal conclusions to be drawn from this work are that the ANS decay heat standard can be applied to D_2O moderated thermal reactors of the type at Savannah River and by accounting for photon redistribution the standard can be applied to several operating scenarios of the Savannah River reactors. The ANS decay heat standard with modifications to account for photon redistribution is being implemented at Savannah River for use in routine operational analysis.

REFERENCES

1. American Nuclear Society Standards Committee Working Group ANS-5.1. "American National Standard for Decay Heat Power in Light Water Reactors." ANSI/ANS-5.1-1979 (August 1979).
2. D. R. Finch, J. R. Chandler, and J. P. Church. "The SHIELD System." Presented at the American Nuclear Society Meeting, San Francisco, CA, November 11-16, 1979 (CONF-791103-74).