Reg Guide 3.XXX
Task FP 34-4

UNION CARBIDE

UNION CARBIDE CORPORATION

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Mr. D. E. Solberg
Office of Nuclear Regulatory Research
7915 Eastern Avenue
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Dear Don:

This letter is in response to your request for an assessment of the accuracy with which the ORIGEN-S module in the SCALE system can be used to predict heat generation rates in spent fuel elements. It is my understanding that ORIGEN has been reputed to overpredict the heat load at a 1000-day cooling period by 100%.

At the outset it should be noted that such a poor comparison is possible. The original standard in this area was developed in the early 1960's with a very limited amount of data. It seriously underpredicts the heat loads for cooling periods in this range. The new draft standard is considered to be much better. However, comparison of ORIGEN results and the new draft standard can also be poor, depending on the data libraries used with the ORIGEN analysis. Agreement between ORIGEN results based on ENDF/B-IV data and the new draft standard has been observed to be very good. We have incorporated the ENDF/B-IV fission-product yield and decay and energy release data in the libraries used with ORIGEN-S. We also use ENDF/B-IV data in updating neutron cross sections for certain of the nuclides on a problem dependent basis.

Comparison between ORIGEN-S and experiment has been limited to the relatively short cooling times (≤ 12000S) for which experimental information is available. Approximately three-quarters of the total delayed energy from fission is emitted during this time period. With the exception of the first few seconds, agreement over this range is within a few percent.

Our primary interest in applying ORIGEN in the SCALE system has been the determination of radiation source terms for spent fuel shielding analyses. Although the heat generation rate is closely related to the radiation source, the importance of a particular radionuclide in terms of a shielded radiation source can vary widely from its significance for the heat load. Most of our previous effort in improving cross section data has been oriented towards obtaining more accurate concentrations of the neutron and high energy photon emitting nuclides. As part of the present review, we have determined which nuclides are important contributors to the heat generation rate and which data pertinent to these nuclides could be improved. A listing of these nuclides is given in the attached table.

As you will observe from the table, over 90% of the total thermal power is due to the eight fission products having significant emission rates for intermediate cooling times. These fission products come from three principal processes: direct fission yield, beta decay along chains of nuclides with equal mass numbers or isotopic transition through radiative capture. Often beta decay and radiative capture in nuclide precursors are competing processes in determining specific concentrations. Among the data pertinent to these determinations, the fission product yields and the half-lives for beta decay are generally better known than the radiative capture cross sections.

The concentrations for three of the fission products: Rh-106, Cs-134 and Eu-154, depend primarily on the rate of radiative capture in lower mass number isotopes. We have investigated the effect of replacing the capture cross section for CS-133 with ENDF/B-IV data processed for this problem. The heat generation rates from a previous ORIGEN-S calculation using the old capture cross section for CS-133 are shown in parentheses. Use of the improved cross section reduced the heat generation rate by approximately twelve percent. Better cross sections for Rh-105 and Eu-153 could lead to a further reduction of less than fifteen percent. Therefore, we feel that given the present data, ORIGEN-S can be used to predict heat generation rates to within a twenty-five to thirty percent accuracy. Given further improvements in the data, the analytical model could be used to calculate much more accurate values.

We hope that this assessment is sufficiently detailed to be useful in your deliberations. However, given a more specific description of the comparison that has led to this concern, we will be glad to investigate the matter further.

Sincerely yours,

R. M. Westfall

R. M. Westfall
Computer Sciences Division

RMW:bn

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Spent Fuel Thermal Power Calculated[a] with ORIGEN-S

Nuclides	Time After Fuel Discharge: 730 days (2 yr) Watts[b]	730 days (2 yr) Percent[c]	1825 days (5 yr) Watts	1825 days (5 yr) Percent	Source[d]
Light Elements (244)	311	5.3	248	12.3	Activation
Actinides (104)	90	1.6	60	3.0	Transmutation
Fission Products					
Y-90	415	7.1	386	19.1	(Sr-190, β^- out)
Rh-106	1430	24.7	182	9	(Rh-105, $\sigma_{n,\gamma}$ = 85,100)
Cs-134	941	16.2	343	17	(Cs-133, $\sigma_{n,\gamma}$ = 112b)
(Cs-134 Previous)	(1710)	(26)	(623)	(27)	(Cs-133, $\sigma_{n,\gamma}$ = 226b)
Cs-137	108	1.9	101	5	Direct Yield
Ba-137m	388	6.7	362	17.9	(Cs-137, β^- out)
Ce-144	146	2.5	10	0.5	Direct Yield
Pr-144	1680	29	117	5.8	(Ce-144, β^- out)
Eu-154	115	2	91	4.5	(Eu-153, $\sigma_{n,\gamma}$ = 764b)
Other (~800)	177	3	120	5.9	
Total (Fission Products)	5400 (6170)	93.1	1712 (1990)	84.7	
Total Thermal Power	5801 (6571)	100	2020 (2300)	100	

[a]Burnup 33 GWD/MTU, No Down Time, 3.3 wt % U-235 PWR.
[b]Watts/Metric Ton Heavy Metal Charged to the Reactor.
[c]Percent of Total Thermal Power.
[d]Note, ORIGEN cross sections are normalized relative to the thermal flux.