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Prepared for the U.S. Department of Energy
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Quality Assurance Review of ISOTOPE and ORIGEN Decay Masses for PWR Fuel (51 GWd/MTU)

JA Gastelum

March 2011

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1.0 Introduction

ISOTOPE and ORIGEN are two tools that compute the mass of radionuclides as they decay over time. In an effort to provide decay heat figures for selected used nuclear fuels, the UFD campaign identified ISOTOPE as the preferred tool to compute radionuclide masses. ISOTOPE was selected over ORIGEN because of its relative ease to integrate with current tools used to calculate waste stream volumes associated with selected fuels and fuel cycles.

This memorandum documents the comparison of decay mass calculations for PWR fuel with burnup of 51 GWd/MTU in ISOTOPE with analogous calculations in ORIGEN. Two comparisons were made: a “horizontal cut” comparing the masses of selected radionuclides over time; and a “vertical cut” comparing the masses of radionuclides common to both tools at selected years.

2.0 Selected Radionuclide Comparison

This section compares masses, over time, computed using ISOTOPE and ORIGEN for selected radionuclides. Table 2-1 lists the radionuclides selected for comparison, the principle decay mode, and the sum of the absolute difference in mass over the range of 1.00E-01 to 2.00E+06 years after discharge. Pu-241, Cs-137, Sr-90, and He-4 were included for comparison per the direction of the project manager. Bi-209, Np-237, and U-238 were included because they were responsible for the three largest sums of absolute difference in mass between ISOTOPE and ORIGEN.

Figures 2-1 through 2-7 plot the mass over time from ISOTOPE and ORIGEN for the selected radionuclides. Masses were plotted for years common to both data sets over the range of 1.00E-01 to 2.00E+06 years after discharge.

Visual inspection of the figures indicates that for years less than 7.00E+03, the masses are nearly identical. For Np-237 the difference only first exceeds one gram in year 2.00E+06, the last year in which results are computed in ORIGEN. For Bi-209 the difference only first exceeds one gram in year 2.00E+05. For U-238, the first larger than one gram difference in mass occurs substantially earlier, in year 7.00E+03. However, even in year 2.00E+06, the difference in calculated mass for U-238 was only 885 grams. This represents less than one tenth of a percent difference in calculated mass between ISOTOPE and ORIGEN.

Table 2-1 Selected Radionuclides

Radionuclide	Decay Type	Sum of Absolute Difference in Mass (g)
Pu-241	Beta	5.64
Cs-137	Beta	7.17
Sr-90	Beta	0.99
He-4	Stable	108.41
Bi-209	Stable	466.26
Np-237	Alpha	489.55
U-238	Alpha	3,360.36

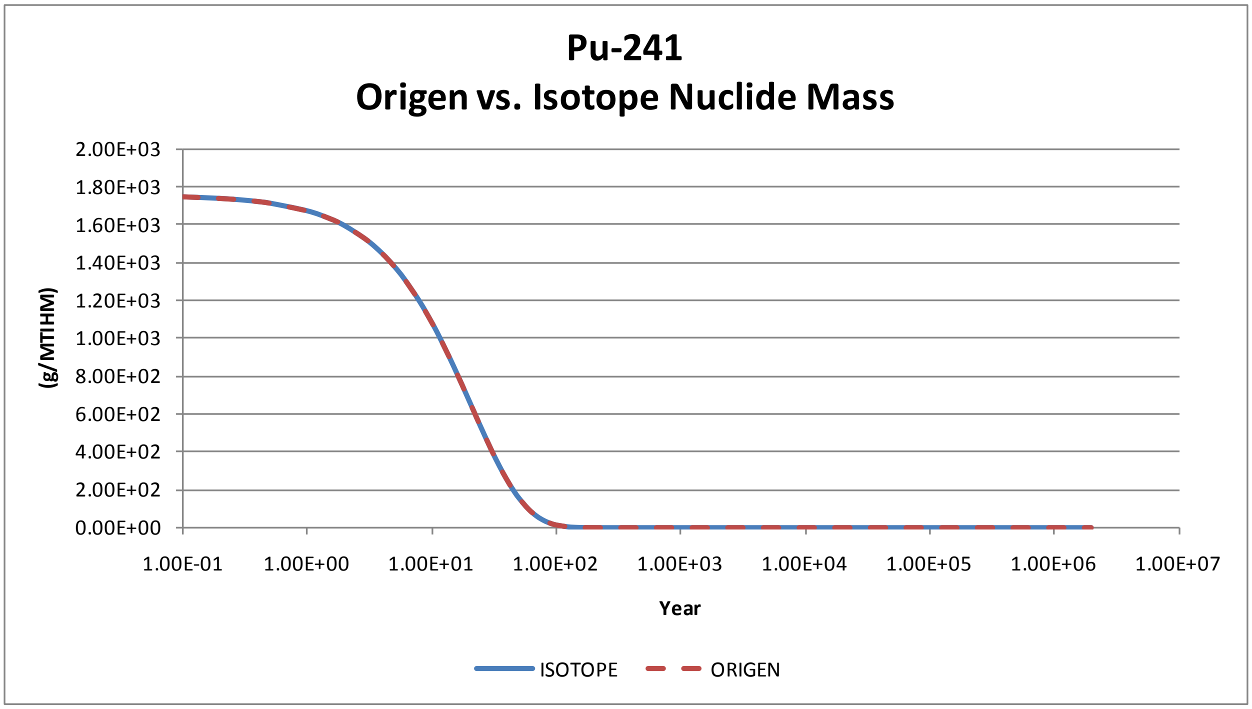

Figure 2-1 Pu-241

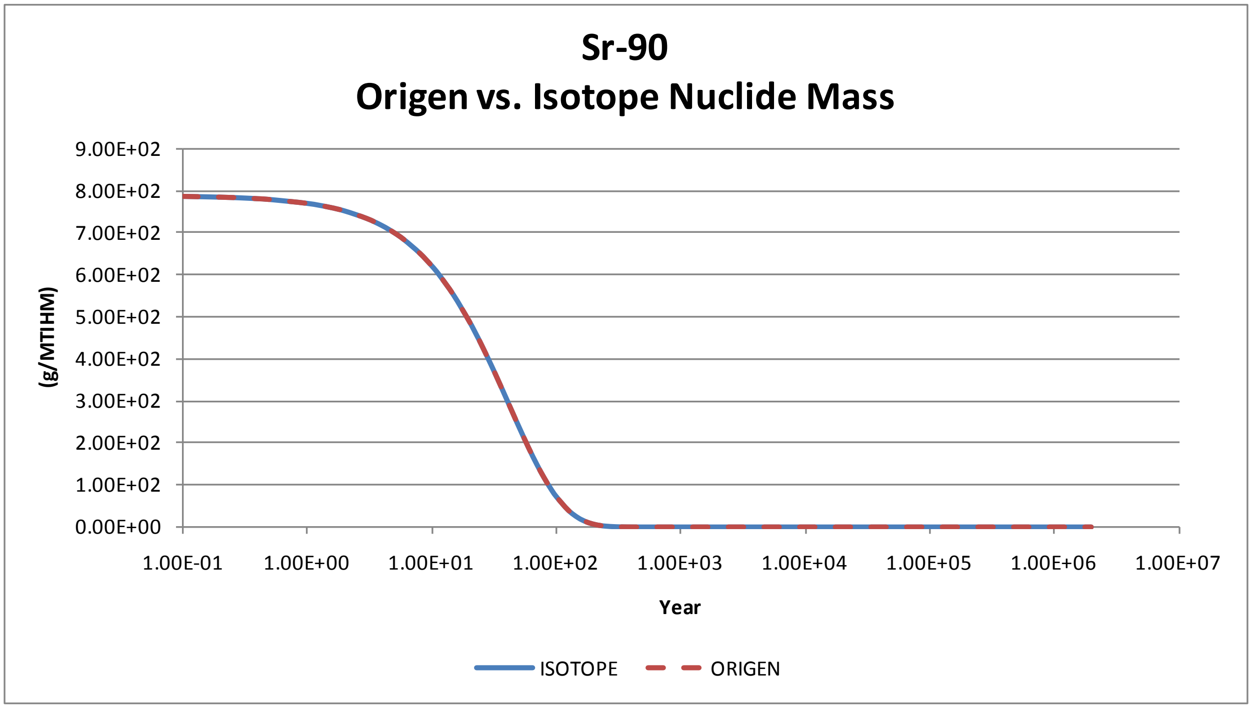

Figure 2-2 Sr-90

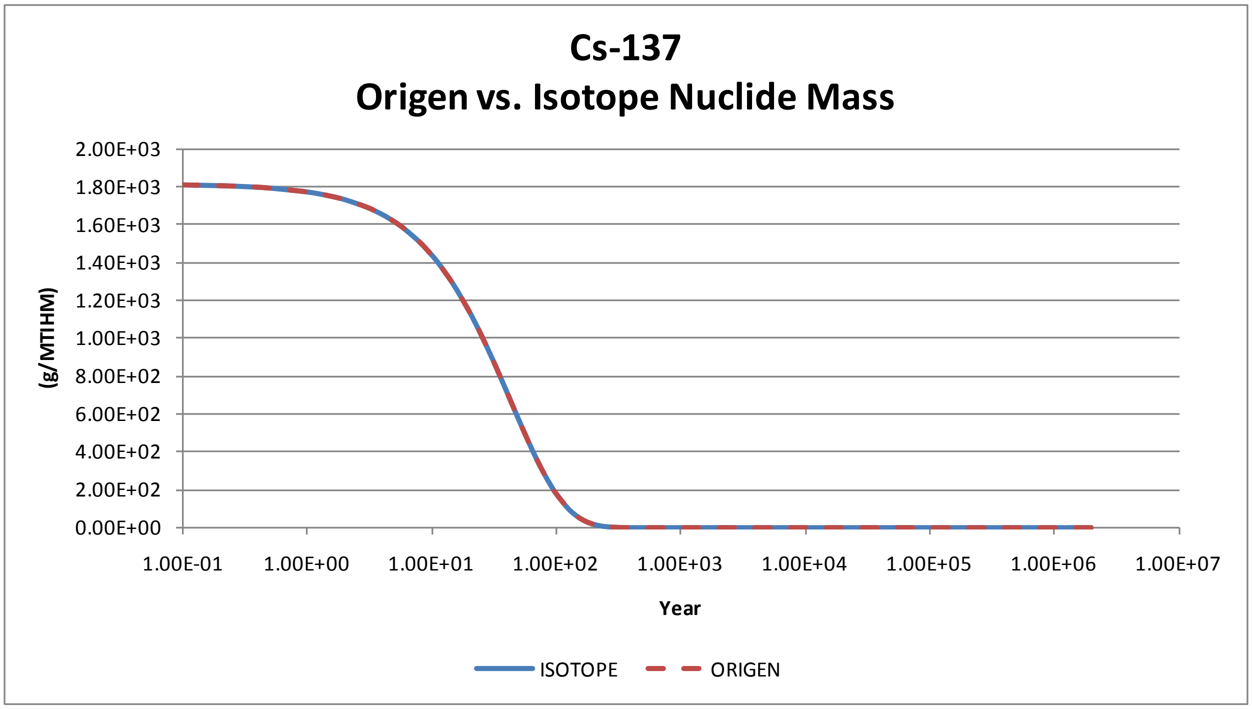

Figure 2-3 Cs-137

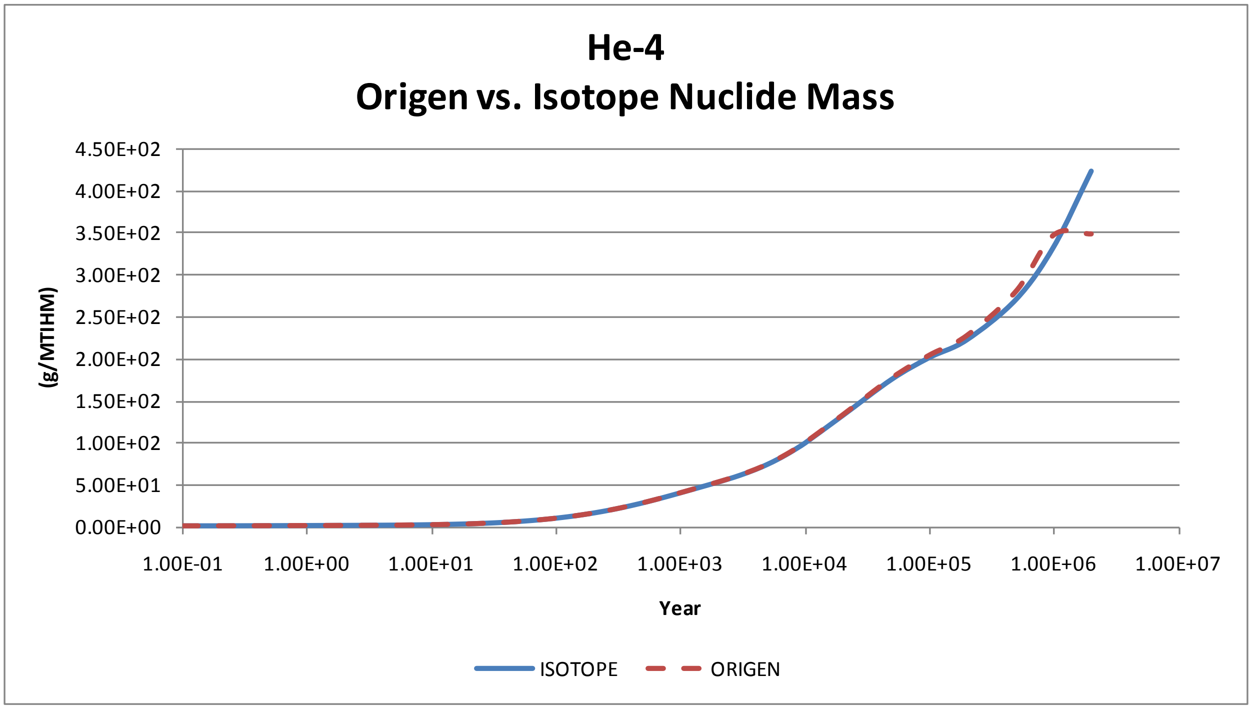

Figure 2-4 He-4

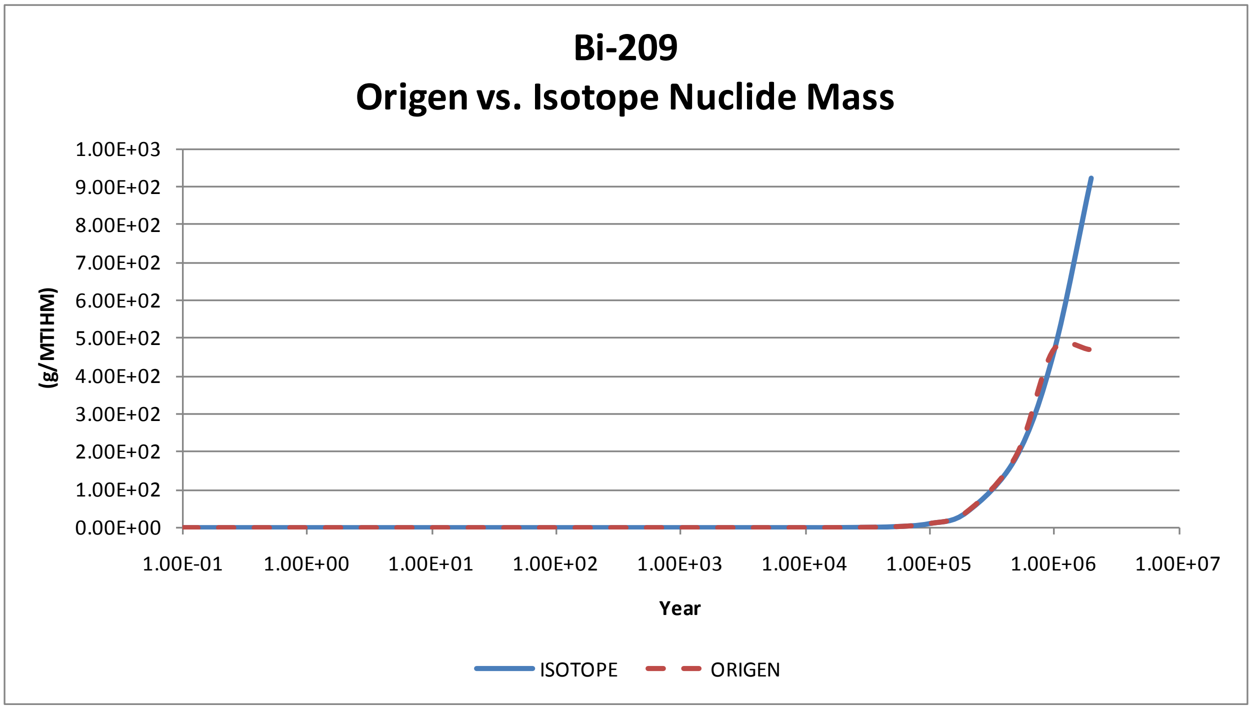

Figure 2-5 Bi-209

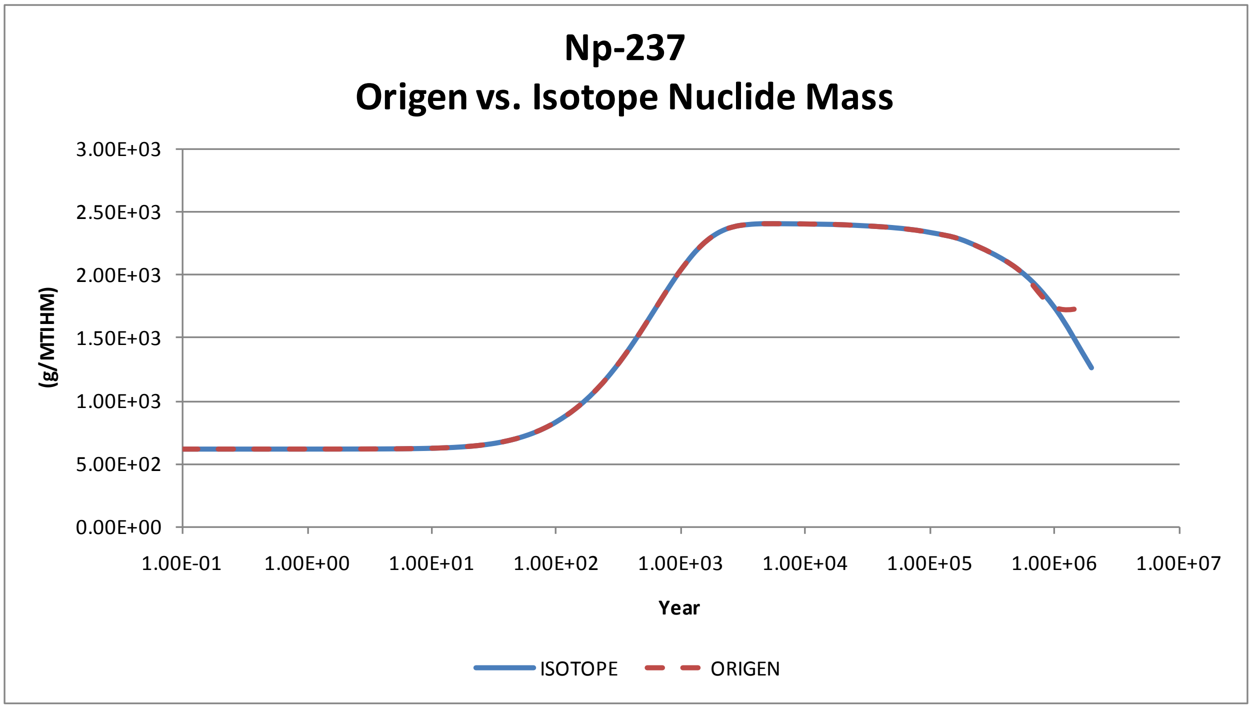

Figure 2-6 Np-237

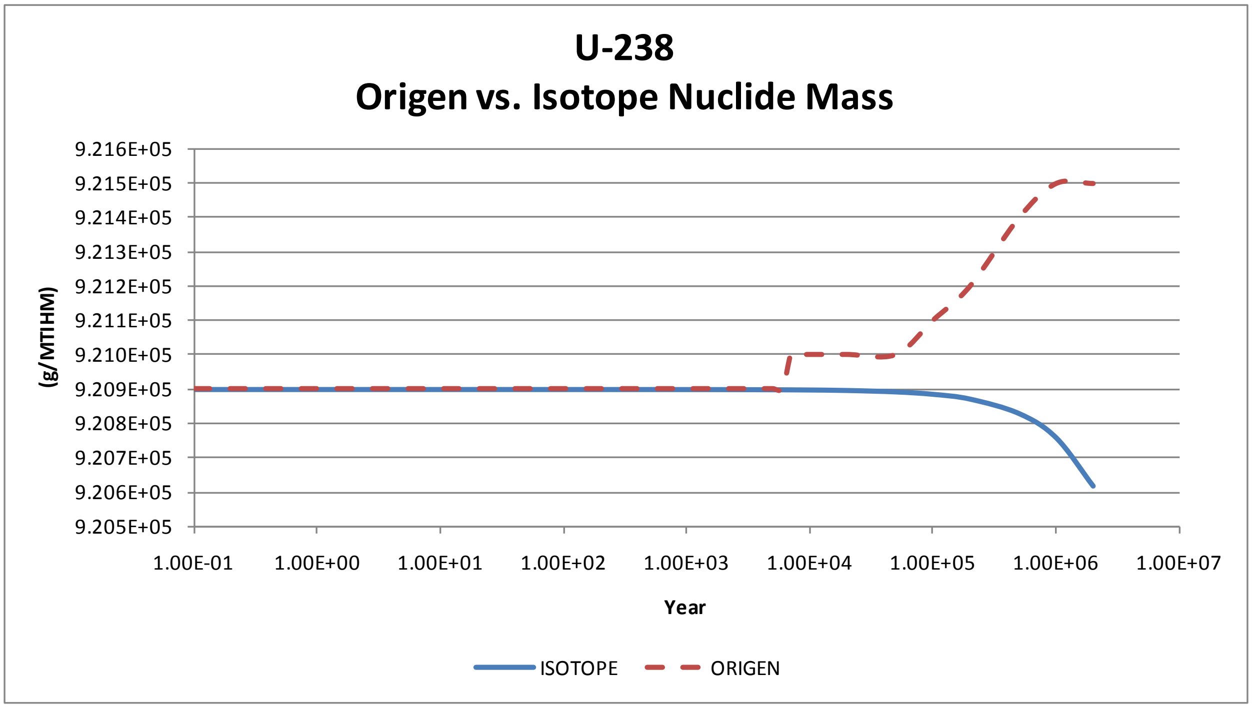

Figure 2-7 U-238

3.0 Selected Year Comparison

This section compares the difference in decay mass for each of the 1,005 radionuclides common to both ISOTOPE and ORIGEN for nine common years spanning the decay calculations. The sum of the absolute difference in decay mass, over all common radionuclides, is presented in column two of Table 3-1. This figure is represented as a percent of the total ORIGEN mass in column three. Table 3-1 also displays the radionuclide with the largest difference in mass for each time period in column four, and the magnitude of the difference in column five.

Results indicate that while the sum of differences generally increases with time, even at year 1.00E+06 the sum of differences is less than a tenth of a percent of the total ORIGEN mass for all radionuclides.

Table 3-1 Results of Selected Year Comparison

Year	Sum of Difference in Decay Mass	Percent of Total ORIGEN Mass	Radionuclide with Max Difference	Max Difference
0.00E+00	0.00	0.00000%		
1.00E-01	7.01	0.00070%	Pr141	0.82
1.00E+00	7.33	0.00073%	Pr141	0.93
1.00E+01	7.40	0.00074%	Pr141	0.91
1.00E+02	6.95	0.00070%	Pr141	0.91
1.00E+03	6.41	0.00064%	Pr141	0.91
1.00E+04	107.88	0.01080%	U238	101.42
1.00E+05	226.61	0.02267%	U238	214.15
1.00E+06	773.44	0.07735%	U238	742.12

4.0 Conclusion

This analysis indicates that decay mass calculations for PWR fuel with burnup of 51 GWd/MTU using ISOTOPE yield essentially the same results as those calculated using ORIGEN for the first thousand years after discharge from the reactor. While the results for the two methodologies begin to diverge after this time for some radionuclides, the difference in mass across all radionuclides is still less than a tenth of a percent of the ORIGEN mass even at one million years.