**METHOD OF CALCULATION OF HEAT GENERATION
RATES FOR DWPF GLASS (U)**

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METHOD OF CALCULATION OF HEAT GENERATION RATES FOR DWPF GLASS**INTRODUCTION AND SUMMARY**

The Waste Acceptance Preliminary Specifications (WAPS)¹ require estimates of the heat generation rate of DWPF waste glasses. Estimates of the heat generation rates of projected glass compositions are to be reported in the Waste Form Qualification Report. Similar estimates for actual production glasses are to be reported in the Production Records. In this report, a method of calculating the heat generation rate from the radionuclide inventory is provided. Application of the method to the DWPF Design-Basis glass indicates that the heat generation rate can be accurately estimated from the Sr-90, Y-90, Cs-137, Ba-137m, and Pu-238 contents alone.

SPECIFICATION AND STRATEGY

The WAPS specification for heat generation (Specification 3.7) requires that

"The producer shall document in the WQR the expected thermal output of canistered waste forms and the range of expected variation in thermal output for each waste type during the life of the production facility. The method to be used for demonstrating compliance shall be described by the producer in the WCP. Projections for compositions not available for reporting in the initial WQR shall be included in an addendum to the WQR.

The producer shall report in the Production Records the heat generation rate for each canistered waste form at time of production. The estimated error of the heat generation rates shall be provided in the WQR. The producer shall describe the plan for compliance in the WCP."¹

The DWPF will calculate the heat generation rate from the radionuclide inventory.² In this report, up-to-date factors for converting curies to watts are listed. Calculations of the heat generation rate of the DWPF Design-Basis glass as a function of time are provided to demonstrate the use of the method.

RADIONUCLIDES TO BE REPORTED

The recommended factors to convert curies to watts are listed in Table 1. These values are from the repository program's Integrated Data Base,³ and are more current than the values used in the DWPF Basic Data Report.⁴ All of the radionuclides whose content will be reported to the repository in the Production Records are included in Table 1. These radionuclides have a half-life > 10

TABLE 1
RECOMMENDED ACTIVITY TO HEAT GENERATION CONVERSION FACTORS

<u>Nuclide</u>	<u>Watts/Curie</u>
Co-60	1.54E-02*
Ni-59†	3.98E-05
Ni-63	1.01E-04
Se-79	3.13E-04
Sr-90	1.16E-03
Y-90	5.54E-03
Zr-93	2.90E-04
Nb-93m	1.77E-04
Tc-99	5.00E-04
Ru-106	5.95E-04
Rh-106	9.60E-03
Pd-107	5.50E-05
Sn-126	1.08E-03
Sb-125	3.37E-03
Cs-134	1.02E-02
Cs-135	3.30E-04
Cs-137	1.11E-03
Ba-137m	3.94E-03
Ce-144	6.58E-04
Pr-144	7.34E-03
Pm-147	3.70E-04
Sm-151	7.41E-04
Eu-154	9.08E-03
Eu-155	7.59E-04
Th-230	2.77E-02
Np-237	2.88E-02
U-234	2.83E-02
U-238	2.49E-02
Pu-238	3.26E-02
Pu-239	3.02E-02
Pu-240	3.06E-02
Pu-241	3.10E-05
Pu-242	2.90E-02
Am-241	3.28E-02
Am-243	3.15E-02
Cm-244	3.44E-02

*1.54E-02 = $1.54 \cdot 10^{-2}$.

†Radionuclides printed in **bold** are ones to be reported in the Production Records.

TABLE 2
RADIONUCLIDE CONTENT OF DESIGN-BASIS GLASS AS A FUNCTION OF TIME
 (Units are curies/canister, 0 years = time of production of glass)

<u>Nuclide</u>	<u>0 years</u>	<u>5 years</u>	<u>10 years</u>	<u>95 years</u>
Co-60	1.70E+02	8.79E+01	4.54E+01	6.16E-04
Ni-59+	2.39E-02	2.39E-02	2.39E-02	2.39E-02
Ni-63	2.97E+00	2.86E+00	2.76E+00	1.50E+00
Se-79	1.70E-01	1.70E-01	1.70E-01	1.69E-01
Sr-90	4.82E+04	4.26E+04	3.77E+04	4.63E+03
Y-90	4.77E+04	4.26E+04	3.77E+04	4.63E+03
Zr-93	1.12E+00	1.12E+00	1.12E+00	1.12E+00
Nb-93m	0.00E+00	2.39E-01	4.24E-01	1.05E+00
Tc-99	3.07E+00	3.07E+00	3.07E+00	3.07E+00
Ru-106	2.24E+03	7.26E+01	2.35E+00	0.00E+00
Rh-106	2.25E+03	7.26E+01	2.35E+00	0.00E+00
Pd-107	1.47E-02	1.47E-02	1.47E-02	1.47E-02
Sn-126	4.38E-01	4.38E-01	4.38E-01	4.38E-01
Sb-125	8.60E+02	2.42E+02	6.79E+01	0.00E+00
Cs-134	3.36E+02	6.26E+01	1.16E+01	0.00E+00
Cs-135	9.92E-02	9.92E-02	9.92E-02	9.92E-02
Cs-137	4.33E+04	3.86E+04	3.44E+04	4.85E+03
Ba-137m	4.14E+04	3.65E+04	3.25E+04	4.59E+03
Ce-144	9.84E+03	1.15E+02	1.34E+00	0.00E+00
Pr-144	9.85E+03	1.15E+02	1.34E+00	0.00E+00
Pm-147	2.41E+04	6.44E+03	1.72E+03	0.00E+00
Sm-151	2.39E+02	2.31E+02	2.22E+02	1.18E+02
Eu-154	6.20E+02	4.14E+02	2.77E+02	2.91E-01
Eu-155	4.91E+02	2.38E+02	1.16E+02	5.36E-04
Th-230	0.00E+00	2.01E-06	4.92E-06	1.64E-04
Np-237	8.86E-03	8.87E-03	8.90E-03	1.01E-02
U-234	3.42E-02	5.48E-02	7.45E-02	3.14E-01
U-238	1.05E-02	1.05E-02	1.05E-02	1.05E-02
Pu-238	1.48E+03	1.42E+03	1.37E+03	6.99E+02
Pu-239	1.29E+01	1.29E+01	1.29E+01	1.28E+01
Pu-240	8.67E+00	8.66E+00	8.66E+00	8.58E+00
Pu-241	1.66E+03	1.31E+03	1.04E+03	1.89E+01
Pu-242	1.22E-02	1.22E-02	1.22E-02	1.22E-02
Am-241	1.10E+01	2.27E+01	3.19E+01	5.90E+01
Am-243	5.79E-03	5.79E-03	5.79E-03	5.74E-03
Cm-244	1.07E+02	8.87E+01	7.33E+01	2.83E+00
TOTAL	2.35E+05	1.71E+05	1.47E+05	1.96E+04

TABLE 3
HEAT GENERATION BY DESIGN-BASIS GLASS AS A FUNCTION OF TIME
 (Units are watts/canister, 0 years = time of production of glass)

<u>Nuclide</u>	<u>0 years</u>	<u>5 years</u>	<u>10 years</u>	<u>95 years</u>
Co-60	2.62E+00	1.35E+00	6.99E-01	9.49E-06
Ni-59†	9.51E-07	9.51E-07	9.51E-07	9.51E-07
Ni-63	3.00E-04	2.89E-04	2.79E-04	1.52E-04
Se-79	5.32E-05	5.32E-05	5.32E-05	5.29E-05
Sr-90	5.59E+01	4.94E+01	4.37E+01	5.37E+00
Y-90	2.64E+02	2.36E+02	2.09E+02	2.57E+01
Zr-93	3.25E-04	3.25E-04	3.25E-04	3.25E-04
Nb-93m	0.00E+00	4.23E-05	7.50E-05	1.87E-04
Tc-99	1.54E-03	1.54E-03	1.54E-03	1.54E-03
Ru-106	1.33E+00	4.32E-02	1.40E-03	0.00E+00
Rh-106	2.16E+01	6.97E-01	2.26E-02	0.00E+00
Pd-107	8.09E-07	8.09E-07	8.09E-07	8.09E-07
Sn-126	4.73E-04	4.73E-04	4.73E-04	4.73E-04
Sb-125	2.90E+00	8.16E-01	2.29E-01	0.00E+00
Cs-134	3.43E+00	6.39E-01	1.18E-01	0.00E+00
Cs-135	3.27E-05	3.27E-05	3.27E-05	3.27E-05
Cs-137	4.81E+01	4.28E+01	3.81E+01	5.38E+00
Ba-137m	1.63E+02	1.44E+02	1.28E+02	1.81E+01
Ce-144	6.47E+00	7.57E-02	8.82E-04	0.00E+00
Pr-144	7.23E+01	8.44E-01	9.84E-03	0.00E+00
Pm-147	8.92E+00	2.38E+00	6.36E-01	0.00E+00
Sm-151	1.77E-01	1.71E-01	1.65E-01	8.74E-02
Eu-154	5.63E+00	3.76E+00	2.52E+00	2.64E-03
Eu-155	3.73E-01	1.81E-01	8.80E-02	4.07E-07
Th-230	5.57E-08	1.36E-07	2.41E-07	1.43E-05
Np-237	2.55E-04	2.55E-04	2.56E-04	2.91E-04
U-234	9.68E-04	1.55E-03	2.11E-03	8.88E-03
U-238	2.62E-04	2.62E-04	2.62E-04	2.62E-04
Pu-238	4.82E+01	4.63E+01	4.47E+01	2.28E+01
Pu-239	3.90E-01	3.90E-01	3.90E-01	3.87E-01
Pu-240	2.65E-01	2.65E-01	2.65E-01	2.63E-01
Pu-241	5.15E-02	4.06E-02	3.22E-02	5.86E-04
Pu-242	3.54E-04	3.54E-04	3.54E-04	3.54E-04
Am-241	3.61E-01	7.45E-01	1.05E+00	1.94E+00
Am-243	1.82E-04	1.82E-04	1.82E-04	1.81E-04
Cm-244	3.68E+00	3.05E+00	2.52E+00	9.74E-02
TOTAL	7.10E+02	5.34E+02	4.72E+02	8.01E+01

years, and constitute at least 0.01 % (on a curie basis) of the radionuclide inventory of the Design-Basis glass at the time of production, or at some later time up to 1100 years after production.⁵ Also included in the Table are shorter-lived radionuclides which are present in large enough quantities to contribute significantly to the heat generation rate at time of production, in watts.

CALCULATION METHOD AND SAMPLE APPLICATION

The calculation is an extremely simple, albeit tedious, one. The content of each radionuclide in curies is multiplied by the appropriate factor in Table 1, and the resulting values summed to give the heat generation rate of the glass of interest.

As examples of the application of the method, Table 2 contains the radionuclide content of the Design-Basis glass at various times after production. Application of the method described here results in the values in Table 3. These values are higher than those in the Basic Data Report by approximately 3 %. Use of the more current conversion factors in this report is recommended.

Based on the values in Table 3, the heat generation rate is dominated by just five species within 10 years after production. The contributions from Cs-137, Ba-137m, Sr-90, Y-90, and Pu-238 account for approximately 97 % of the heat generation rate from 5 years after production until approximately 100 years after production. Since the curie contents of these five species can be relatively easily determined, they provide a quick method of determining the heat generation rate of DWPF glass. Although exclusion of other species introduces a slight negative bias in the calculated values, the resulting inaccuracy is negligible.

REFERENCES

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3. Oak Ridge National Laboratory, **Integrated Data Base for 1991: U. S. Spent Fuel and Radioactive Waste Inventories, Projections, and Characteristics, Revision 7**, USDOE Report RW-0006, Washington, DC (1991).
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5. B. A. Hacker, "Radionuclides to be Reported for DWPF Waste Acceptance," DPST-86-789, November 19, 1986.

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