U.S. LIGHT-WATER REACTOR SPENT FUEL INVENTORY—FISSILE DISTRIBUTION

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INTRODUCTION

Those conducting waste management studies to reduce the potential for a nuclear criticality accident in a future geological repository must examine the quantities and distribution of fissile isotopes that are present in discharged boiling-water reactor (BWR) and pressurized-water reactor (PWR) spent nuclear fuel (SNF) scheduled for disposition (Forsberg et al., 1995). The major fissile isotopes present in LWR fuels that impact criticality safety are the nuclides, ^{235}U, ^{239}Pu, and ^{241}Pu. The sum of the quantities of these three nuclides, expressed as a percentage of the total amount of all U and Pu isotopes present in a batch of discharged fuel, determines the final enrichment of the fuel batch under consideration. The final enrichment provides an approximate measure of the nuclear criticality potential. As the final enrichment increases, the mass, geometry, or administrative controls that must be in place to prevent nuclear criticality become more stringent. Below an enrichment of about 0.7%, however, criticality is no longer a concern because the infinite multiplication factor for any heterogeneous or homogeneous mixture of fuel and water, even under conditions of optimum moderation, is less than unity. The current study examines the distribution of the final enrichment of the LWR SNF which was discharged through December 31, 1993, and which currently resides in the fuel storage pools of the various utilities or in one of several AFR facilities.

ASSUMPTIONS

The information on which this study is based is the SNF data contained in Nuclear Fuel Data Form RW-859 (Department of Energy, December 31, 1993). Historical inventories of discharged LWR SNF recorded on this data tape have been updated through December 31, 1993. The total inventory of BWR fuel discharged from U.S. commercial reactors through December 31, 1993, amounts to 10,178.53 metric tons of initial heavy metal (MTIHM), while that for discharged PWR fuel amounts to 17,851.69 MTIHM. The data include the quantity (MTIHM) of fuel contained in each discharge batch, the initial enrichment of the batch, and the final burnup at discharge for each batch (expressed in MWd/MTIHM).

METHODOLOGY

The methodology used to determine the distribution of the final enrichment of the historical inventory of discharged LWR SNF began with the creation of a 3-D array whose members represent the quantities of discharged LWR fuel contained in the various discharged batches, categorized by (a) fuel type, (b) initial enrichment, and (c) burnup. The range of initial enrichment (0–5%) was divided into 50 equal increments of 0.1% each; the range of fuel burnup (0–60,000 MWd/MTIHM) was divided into 24 equal increments of 2,500 MWd/MTIHM each. Initial enrichment and burnup values at the midpoint of each increment were assigned to each of the array members to determine the final enrichment at discharge.

Next, the ORGENTRE (Oak Ridge Waste GENeration and TREatment) Code, a series of computer codes and data bases which characterize nuclear waste generation and treatment, was run to calculate the nuclide composition for BWR and PWR fuel corresponding to each combination of initial enrichment and final burnup increment midpoint values. The ORGENTRE code (Morrison, 1986) is based on the ORIGEN2 isotope generation and decay code (Croff, 1980), which is used worldwide for simulating the nuclear fuel cycle. The final fuel enrichment associated with each member of the 3-D array was obtained by summing the weights of the nuclides, ^{235}U, ^{239}Pu, and ^{241}Pu—calculated by ORGENTRE and corresponding to a 1-MTIHM fuel batch—and expressing this quantity as a percentage of the total mass of all U and Pu isotopes contained in a 1-MTIHM fuel batch at discharge.

Because the range of the libraries contained within ORGENTRE is limited to BWR fuel having an initial enrichment in the range of 1 to 4% and to PWR fuel having an initial enrichment in the range of 2.5 to 5.0%, it was not possible to determine the final fuel enrichment for discharged BWR and PWR fuel batches of which initial enrichments were <1.0% and 2.5%, respectively. Consequently, fuel batches corresponding to these low enrichments (3.32% of all BWR fuel discharged and 14.70% of all PWR fuel discharged) were not included in determining the distribution of the final enrichment of LWR SNF reported in this document.

CONCLUSIONS

Table 1 shows the distribution of the final enrichment of LWR SNF that has been discharged through December 31, 1993. Figure 1 shows the same distribution. The percentage of fuel, grouped according to final enrichment range, is as follows: 0.00–<1.00% enr., 0.10%; 1.00–<2.00% enr., 96.64%; 2.00–<3.00% enr., 2.97%; 3.00–<4.00% enr., 0.29%.

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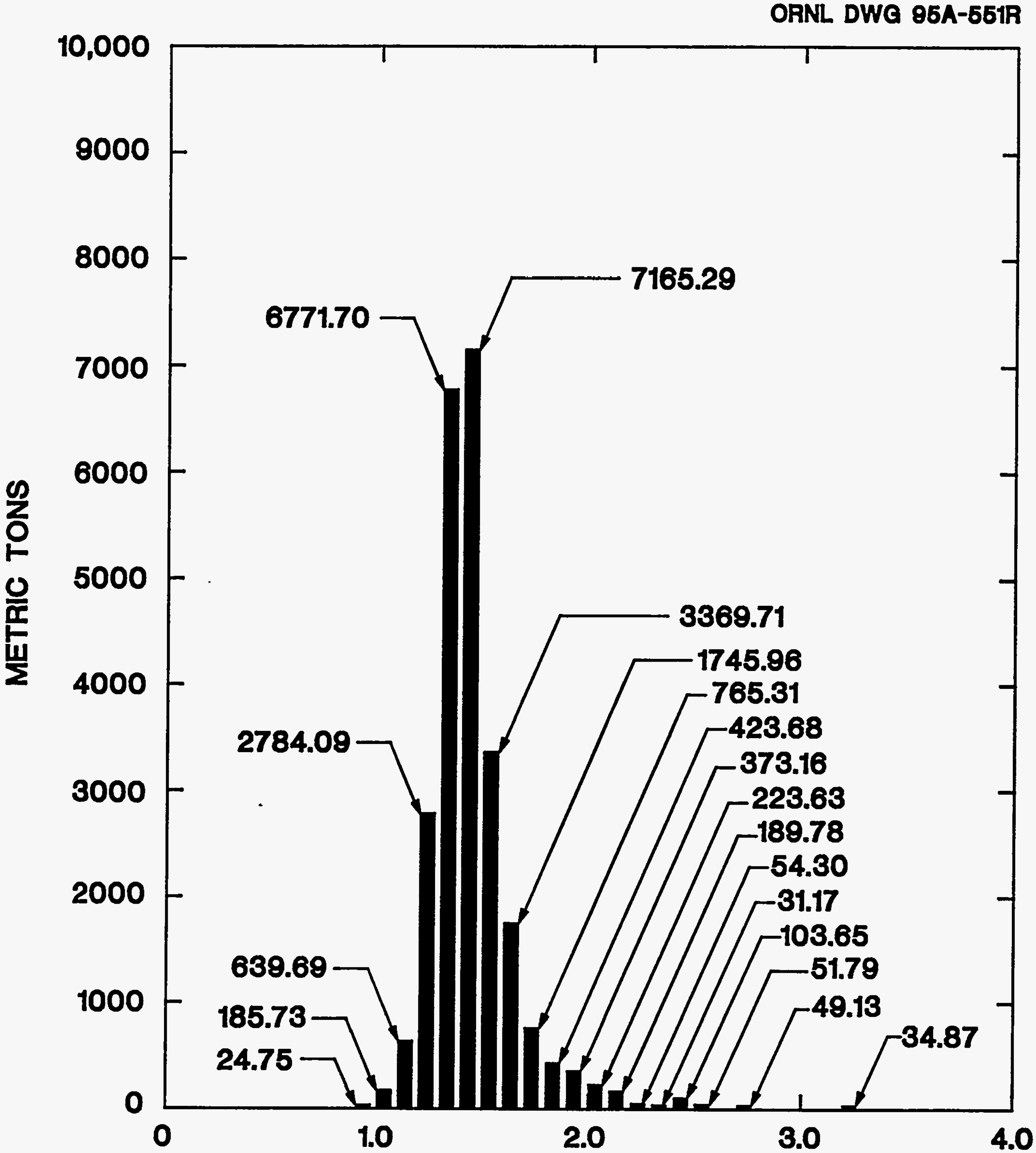
Table 1. LWR discharge fuel data[a]

Final enrichment (%)	MTIHM
0.00 – <0.10	0.00
0.10 – <0.20	0.00
0.20 – <0.30	0.00
0.30 – <0.40	0.00
0.40 – <0.50	0.00
0.50 – <0.60	0.00
0.60 – <0.70	0.00
0.70 – <0.80	0.00
0.80 – <0.90	0.18
0.90 – <1.00	24.75
1.00 – <1.10	185.73
1.10 – <1.20	639.69
1.20 – <1.30	2784.09
1.30 – <1.40	6771.70
1.40 – <1.50	7165.29
1.50 – <1.60	3369.71
1.60 – <1.70	1745.96
1.70 – <1.80	765.31
1.80 – <1.90	423.68
1.90 – <2.00	373.16
2.00 – <2.10	223.63
2.10 – <2.20	189.78
2.20 – <2.30	54.30
2.30 – <2.40	31.17

Final enrichment (%)	MTIHM
2.40 – <2.50	103.65
2.50 – <2.60	51.79
2.60 – <2.70	7.68
2.70 – <2.80	49.13
2.80 – <2.90	13.85
2.90 – <3.00	19.22
3.00 – <3.10	18.75
3.10 – <3.20	8.74
3.20 – <3.30	34.87
3.30 – <3.40	2.57
3.40 – <3.50	1.06
3.50 – <3.60	0.64
3.60 – <3.70	0.00
3.70 – <3.80	0.00
3.80 – <3.90	7.18
3.90 – <4.00	0.00

[a]Total BWR = 9,840.20 MTIHM, total PWR = 15,227.06 MTIHM, and total LWR = 25,067.26 MTIHM.



$$\text{FINAL ENRICHMENT} = \left[\frac{^{235}U + {}^{239}Pu + {}^{241}Pu}{U + Pu}\right] 100\%$$

LIGHT WATER REACTOR SPENT NUCLEAR FISSILE ENRICHMENT LEVELS