Calculation Cover Sheet

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1. PURPOSE

The purpose of this calculation is to obtain an estimate of a Westinghouse 17x17 mixed oxide (MOX) spent nuclear fuel (SNF) Vantage 5 assembly.

2. METHOD

An estimate of the MOX fuel assembly weight was derived from the weight of a Westinghouse commercial 17x17 UO₂ assembly adjusted for differences between the commercial and the MOX assembly fuel pin specifications.

3. ASSUMPTIONS

Assumptions made regarding the assembly weights are identified as follows.

- 3.1** It is assumed that the “total assembly weight” is exclusive of the non-fuel material that may be present in an assembly such as control rod systems, etc. The basis for this assumption is that both the total assembly weight and non-fuel weight are given for various assemblies. This assumption is used in Sections 5.2 and 5.3.
- 3.2** It is assumed that the non-fuel components are similar with adjustment for hybrid (B₄C-Ag-In-Cd) control rods used in the MOX core design. The basis for this assumption is that the assemblies are identical except for the fuel component. This assumption was used in the calculations involving non-fuel components (Section 5.3).
- 3.3** It is assumed that the fuel rod characteristics are the same with respect to non-fuel components. The basis for this assumption is that the fuel rods are identical except for the fuel material. This assumption was used in the calculations involving non-fuel components (Sections 5.2 and 5.3).

4. USE OF COMPUTER SOFTWARE

No computer software was involved in the weight estimates.

5. CALCULATION

5.1 Calculation Data

The disposition of weapons grade plutonium through processing in MOX fuel has been investigated through development of conceptual designs described in References 1 and 2. These studies include fuel element design characteristics important for the neutron economy but provide minimal information on mechanical characteristics, such as assembly weight, that are

necessary for engineering analyses. Thus an estimate of the MOX fuel assembly weight was derived from the weight of a commercial 17x17 UO₂ assembly adjusted for differences between the commercial and the MOX assembly fuel specifications. The MOX assembly design utilizes a Westinghouse Vantage 5 assembly with MOX fuel in place of commercial UO₂ (Ref. 2, p. 1-1). Thus, the MOX assembly dimensions are the same as for the commercial Vantage 5 assembly (Ref. 2, p. 2-9). The heavy metal content of the commercial fuel is given on a per assembly basis whereas the value for the MOX core is given for the whole core as 81.6 MT (Ref. 2, p. 2-9).

The calculations performed to estimate the weight of the Westinghouse 17x17 MOX SNF fuel assembly are based on the data for the commercial Westinghouse 17x17 assembly provided in Table 5-1 below.

Table 5-1. Mechanical Parameters of a Westinghouse Commercial 17x17 Vantage 5 Fuel Assembly				
Parameter	Value	English Units	Value	Metric Units
No. of Assemblies/Core	193 ^d			
No. of Fuel Rods/Assembly	264 ^a			
Cladding Material	Zirc-4 ^a			
Cladding Density			6.56 ^f	g/cm ³
Cladding Outer Diameter (OD)	0.36 ^a	inches	0.9144	cm
Cladding Thickness	0.0225 ^a	inches	0.05715	cm
Fuel Pellet OD	0.3088 ^a	inches	0.784352	cm
Cladding Length	152.3 ^a	inches	386.842	cm
Fuel Length	144 ^a	inches	365.76	cm
Heavy Metal Mass/Assembly	932.81	lbs	423.12 ^c	kg
Assembly Weight	1365 ^b	lbs	619.16	kg
Non-fuel Material/Assembly	180 ^{c, h}	lbs	81.65	kg
Mass Fraction of HM in Fuel	0.8815 ^g			

(a) Specifications for the commercial assembly are from the Westinghouse Vantage 5 design (Ref. 3, p. 2A-30).

(b) Ref. 4. Maximum weights have been estimated to be as much as 25 lbs greater (Ref. 5, p. 15).

(c) Ref. 5, p. 15.

(d) Ref. 6, p. 7.

(e) Ref. 6, p. 37.

(f) Ref. 7, p. 21.

(g) Ref. 7, p. 1-18.

(h) Ref. 1, p. 2.1-64. Weight of control rod assemblies for the MOX core design is given as 60 lbs lighter than Ag-In-Cd control rod assemblies.

5.2 Calculations for the UO₂ Assembly

$$\begin{aligned}\text{Assembly weight} &= (1365 \text{ lb/assembly}) * (\text{kg}/2.2046 \text{ lb}) \\ &= 619.16 \text{ kg/assembly}\end{aligned}$$

$$\begin{aligned}\text{Total heavy metal (HM) mass} &= (423.12 \text{ kg HM/assembly}) * (193 \text{ assemblies/core}) * \\ &\quad (1 \text{ MTHM}/1000 \text{ kg HM}) \\ &= 81.66 \text{ MTHM/core}\end{aligned}$$

$$\begin{aligned}\text{Cladding inside} \\ \text{diameter (ID)} &= 0.9144 \text{ cm} - 2 * 0.05715 \text{ cm} \\ &= 0.8001 \text{ cm}\end{aligned}$$

$$\begin{aligned}\text{Fuel clad volume} &= (\pi) * [(0.9144^2 \text{ cm}^2 - 0.8001^2 \text{ cm}^2) / 4] * (386.842 \text{ cm}) \\ &= 59.539 \text{ cm}^3/\text{fuel rod}\end{aligned}$$

$$\begin{aligned}\text{Fuel clad weight} &= (264 \text{ fuel rods/assembly}) * (59.539 \text{ cm}^3/\text{fuel rod}) * \\ &\quad (6.56 \text{ g/cm}^3) * (\text{kg}/1000\text{g}) \\ &= 103.11 \text{ kg/assembly}\end{aligned}$$

$$\begin{aligned}\text{Fuel pellet weight} &= (423.12 \text{ kg HM/assembly}) / (0.8815 \text{ kg HM}/1 \text{ kg Fuel}) \\ &= 480.00 \text{ kg/assembly}\end{aligned}$$

5.3 Calculations for the MOX Assembly

$$\begin{aligned}\text{Cladding ID} &= 0.9144 \text{ cm} - 2 * 0.05715 \text{ cm} \\ &= 0.8001 \text{ cm}\end{aligned}$$

$$\begin{aligned}\text{Fuel clad volume} &= (\pi) * [(0.9144^2 \text{ cm}^2 - 0.8001^2 \text{ cm}^2) / 4] * (386.842 \text{ cm}) \\ &= 59.539 \text{ cm}^3/\text{fuel rod}\end{aligned}$$

$$\begin{aligned}\text{Fuel clad weight} &= (264 \text{ fuel rods/assembly}) * (59.539 \text{ cm}^3/\text{fuel rod}) * \\ &\quad (6.56 \text{ g/cm}^3) * (\text{kg}/1000\text{g}) \\ &= 103.11 \text{ kg/assembly}\end{aligned}$$

$$\begin{aligned}\text{Heavy metal/fuel rod} &= (81.6 \text{ MT of Heavy Metal/core}) * (1000 \text{ kg HM}/1 \text{ MT of HM}) / \\ &\quad [(264 \text{ fuel rods/assembly}) * (193 \text{ assemblies/core})] \\ &= 1.60 \text{ kg/fuel rod}\end{aligned}$$

$$\begin{aligned}\text{Fuel pellet weight} &= (264 \text{ fuel rods/assembly}) * (1.6015 \text{ kg HM/fuel rod}) / \\ &\quad (0.8815 \text{ kg HM}/1 \text{ kg fuel}) \\ &= 479.63 \text{ kg/assembly}\end{aligned}$$

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$$\begin{aligned}\text{Assembly weight} &= (1365 \text{ lb/assembly}) * (\text{kg}/2.2046 \text{ lb}) - [(103.1120 \text{ kg clad /} \\ &\quad \text{UO}_2 \text{ assembly}) + (480 \text{ kg fuel/UO}_2 \text{ assembly})] + \\ &\quad [(103.1120 \text{ kg clad/MOX assembly}) + (479.6346 \text{ kg fuel/} \\ &\quad \text{MOX assembly})] \\ &= 618.79 \text{ kg/assembly}\end{aligned}$$

$$\begin{aligned}\text{Assembly weight} &= (618.7945 \text{ kg/assembly}) * (2.2046 \text{ lb/kg}) \\ &= 1364.19 \text{ lb/assembly}\end{aligned}$$

$$\begin{aligned}\text{Non-fuel component weight} &= 180 \text{ lbs} - 60 \text{ lbs} \\ &= 120 \text{ lbs}\end{aligned}$$

6. RESULTS

The MOX assembly weight is estimated to be 618.8 kg (1364.2 lbs) compared to 619.2 kg (1365 lbs) for the commercial Vantage 5 assembly. The slightly lower assembly weight for the MOX Vantage 5 assembly relative to the commercial Vantage 5 assembly is due to the lower heavy metal loading for the MOX assembly (0.4228 MT [derived from Table 5-1] versus 0.4231 MT [Ref. 4, p. 37] for the commercial assembly). These results were derived from industry and government sources that are considered qualified, and thus the results are considered qualified. Consequently, these results are suitable for input for design, construction, and procurement purposes. The mechanical parameters for a Westinghouse Vantage 5 fuel assembly with MOX fuel are listed in Table 6-1.

Table 6-1. Mechanical Parameters of a Westinghouse 17x17 MOX Vantage 5 Fuel Assembly				
Parameter	Value	English Units	Value	Metric Units
No. of Assemblies/Core	193			
No. of Fuel Rods/Assembly	264			
Cladding Material	Zirc-4			
Cladding Density			6.56	g/cm ³
Cladding Outer Diameter (OD)	0.36	inches	0.9144	cm
Cladding Thickness	0.0225	inches	0.05715	cm
Fuel Pellet OD	0.3088	inches	0.784352	cm
Cladding Length	152.3	inches	386.842	cm
Fuel Length	144	inches	365.76	cm
Assembly Weight	1364.2	lbs	618.8	kg
Non-fuel Material/Assembly	120	lbs	54.4	kg

7. REFERENCES

1. Westinghouse Electric Corporation, *Plutonium Disposition in Existing Pressurized Water Reactors*, DOE/SF/19683-6, June 1, 1994.
2. Westinghouse Electric Corporation, *Plutonium Disposition Study; Implementation of Weapons Grade MOX Fuel in Existing Pressurized Water Reactors*, DOE/SF/19683-7, August 30, 1996.
3. *Characteristics of Potential Repository Wastes*, DOE/RW-0184-R1, Volume 1, July, 1992.
4. *LWR Fuel Assemblies PC Database*, Media ID: VA-M04-20004.015.C008, CSCI: A00000000-02268-1200-20004 V1.1 (9/13/93).
5. *Qualification of Spent Fuel Assembly Characteristics for Use as a Design Basis*, Document Identification (DI) #: E00000000-01717-0200-00002 REV 02, Civilian Radioactive Waste Management System (CRWMS) Management & Operating Contractor (M&O).
6. *Summary Report of Commercial Reactor Criticality Data for McGuire Unit 1*, DI#: B00000000-01717-5705-00063, REV 01, CRWMS M&O.
7. *Material Compositions and Number Densities for Neutronics Calculations*, DI#: BBA000000-01717-0200-00002 REV 00, CRWMS M&O.

8. ATTACHMENTS

There are no attachments to this document.