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235-F DEACTIVATION AND DECOMMISSIONING: INVENTORY AND SCENARIOS

Summary

Facility inventory has a significant influence on the fate and transport modeling of 235-F. This memorandum details the proposed source inventory for 235-F for verification from 235-F Risk Reduction (see Tables 7 and 9) and specifies two scenarios that will be investigated using GoldSim and PORFLOW as follows:

- Grout the entire first floor (including the area directly below PuFF cells)
- Grout the entire first and second floors (including the area directly below PuFF cells).

235-F Inventory

The Actinide Billet Line (ABL), Old Metallurgical Laboratory (OML), Plutonium Experimental Facility (PEF), and PuFF transfer and exhaust system Pu-238 and Np-237 assay results are obtained from Harris (2007). The inventories from these references (assayed in 2006) are given in Table 1. "Rest of Building" values are lower than those given in the report entitled *Basis for Interim Operation for Building 235-F: Deactivation* (SRNS 2017). SRNS (2017) utilized the Harris (2007) calculations but included a 75% increase in the measured value (plus 1 σ uncertainty) to ensure the semi-quantitative Consolidated Hazards Analysis (CHA) results were conservative.

Table 1. Actinide Billet Line and Rest of Building Pu-238 and Np-237 Assay Results

Inventory Division	Location	Pu-238 (g)	Effective Uncertainty (%)	Np-237 (g)	Effective Uncertainty (%)
Actinide Billet Line (ABL)	Gloveboxes (ABL)	-	-	34.84	58.4
	ABL GB HEPA (ABL)	-	-	24	25
	ABL Room 107 (ABL)	-	-	41.4	35
	ABL Exhaust 2nd (ABL)	-	-	15	35
	235-F HEPA (ABL)	-	-	0.73	50.7
	Subtotal	-	-	116.0	40.1
Rest of Building (RoB)	PuFF Transfer	0.16	61.4	-	-
	PuFF Exhaust System	6.35	50.5	-	-
	PuFF Ar/He	3.69	30.1	-	-
	GB Floor Area (PEF)	2.95	35.3	-	-
	GB HEPA Filter (PEF)	3.06	34	-	-
	Exhaust Piping (PEF)	0.2	30	-	-
	Miscellaneous Equipment (PEF)	0.11	30.3	-	-
	235-F HEPA Filters (PEF)	0.21	42	-	-
	Old Met Lab	13.47	34.2	0.11	38.5
	Subtotal	30.2	37.4	0.11	38.5

Because PuFF Cells 1-5 were shown to contain the majority of the inventory in 235-F, several enhanced characterization studies of the holdup have been performed. In 2017, the floors, walls, HEPA filters, furnaces, and coolers in Cells 1-5 were assayed (Brand et al. 2017 and Aucott et al. 2017). In 2018, four of the PuFF wing cabinets were also assayed (Aucott et al. 2018). Results of these recent assays are given in Table 2. The total Pu-238 PuFF Cells 1-5 inventory of 366.2 grams is 260.3 grams less than the inventory used in the 2012 study (or 60% of the 2012 Pu-238 inventory).

In late 2015, the West Cell Line (PuFF Cells 6-9) of 235-F was assayed for Pu as summarized in Table 3. Total inventory was 0.9 +/- 0.058 grams Pu (or 0.9 grams +/- 6.4 %), which is approximately one gram less than the 2006 assay inventory (Brand et al. 2016).

Table 2. Pu-238 Assay Results in Building 235-F PuFF Cells 1-5 (2017 Basis)

Location		Assay Mass (g)	Uncertainty (%) ^{1,5}
Cell 1	Cold Press GB ²	30.3	12
	Cold Press Entry Hood ²	0.3	28
	Maintenance GB ²	19.8	22
	Floor ³	91.5	12
	Walls ³	41.5	22
	HEPA ³	2.1	10
	South/North Furnace & Cooler ³	60.1	21
	Die Pass-Through ³	3.3	22
	GB Entry ³	7.7	22
Total		256.6	16.9
Cell 2	Floor ³	34.9	12
	Walls ³	16.3	22
	HEPA ³	0.7	10
	North/South Cooler ³	16.9	23
Total		68.8	17.1
Cell 3	PuFF Furnace GB ²	1.9	11
	Floors/Walls/HEPA ⁴	3	16
Total		4.9	14.1
Cell 4	Hot Press Access GB ²	14.2	14
	Hot Press ²	2.2	10
	Floors/Walls/HEPA ⁴	10.4	10 (7)
Total		26.8	12.1
Cell 5	Floors/walls/HEPA ⁴	9.1	10 (6)
Total		9.1	10.0
PuFF Cells 1-5 Total Pu238 Inventory		366.2	16.4

¹Uncertainty represents one standard deviation

²Aucott et al. 2018

³Aucott et al. 2017

⁴Brand et al. 2017

⁵Minimum uncertainty of 10% (uncertainty value from measurement document is given in parentheses)

Table 3. Pu-238 Assay Results in Building 235-F PuFF Cells 6-9 (2015 Basis)

Cell	2015 Assay Mass (g)	Uncertainty (%) ¹
6	0.75	10 (6.3)
7	0.15	10 (7)
8	1.23E-04	12
9	2.09E-05	24.6
PuFF Cells 6-9 Total Pu-238 Inventory	0.90	10

¹Uncertainty represents one standard deviation with a minimum value of 10% (uncertainty value from measurement document is given in parenthesis)

Table 4. 235-F Holdup Summary

	Pu-238 (g)			Np-237 (g)		
	Base	+1 σ	+2 σ	Base	+1 σ	+2 σ
PUFF Process Cells 1-5	366.20	426.22	486.23	-	-	-
PUFF Process Cells 6-9	0.90	0.99	1.08	-	-	-
Actinide Billet Line	-	-	-	115.97	162.43	208.88
Rest of Building 235-F	30.20	41.49	52.77	0.11	0.15	0.19
Entire Building 235-F	397.30	468.69	540.08	116.08	162.58	209.08

A summary of the PuFF Cells inventory is given in Table 4. The comparison of the GoldSim and PORFLOW models will utilize the “base” case inventory which is the measured value (no uncertainty included). It is recommended that subsequent uncertainty quantification and sensitivity analysis be conducted to include measurement uncertainty. The 235-F operations associated with PuO₂ and NpO₂ feed powders were primarily conducted between 1979 and 1983; therefore, 1981 was chosen as the year that the feed powders (and their associated impurities) entered 235-F. The total inventory from Table 4 was increased to account for radioactive decay since 1981. This was done to allow for daughter ingrowth between the time when Pu-238 entered the facility in 1981 (assumption) and when the cells were assayed (PuFF 1-5 in 2017; PuFF 6-9 in 2015; ABL and RoB in 2007). The full inventory (including Pu-238 daughters) was calculated using the typical isotopic fractions of PuO₂ and NpO₂ feed powders listed in Table 5 (WSRC 2003; Taylor and Phifer 2012).

Table 5. Typical Isotopic Fractions of PuO₂ and NpO₂ Feed Powders

PuO ₂ Feed		NpO ₂ Feed	
Isotope	Typical Isotopic Fraction (g/g metal)	Isotope	Typical Isotopic Fraction (g/g metal)
Pu-238	0.835	Np-237	0.99
Pu-239	0.138	Pu-238	0.01
Pu-240	0.02	Pa-233	3.24E-08
Pu-241	4.1E-03	U-233	1.0E-10
Pu-242	1.6E-03	Th-229	4.0E-17
Np-237	5.0E-04		
Th-232	5.0E-04		
Am-241	3.0E-04		

The 1981 inventory summary, which is considered the “base” case because it does not take into consideration uncertainty in the assay results, is shown in Table 6.

Table 6. 235-F Base 1981 Inventory

Inventory Division	PuFF Cells 1-5 (g)	PuFF Cells 6-9 (g)	Actinide Billet Line (g)	Rest of Building 235-F (g)	Entire Building 235-F (g)
Pu238 ¹	4.87E+02	1.11E+00	-	3.71E+01	5.25E+02
Pu239 ²	8.04E+01	1.84E-01	-	6.13E+00	8.68E+01
Pu240 ²	1.17E+01	2.67E-02	-	8.88E-01	1.26E+01
Pu241 ²	2.39E+00	5.47E-03	-	1.82E-01	2.58E+00
Pu242 ²	9.33E-01	2.14E-03	-	7.11E-02	1.01E+00
Np237 ²	2.91E-01	6.67E-04	-	2.22E-02	3.14E-01
Th232 ²	2.91E-01	6.67E-04	-	2.22E-02	3.14E-01
Am241 ²	1.75E-01	4.00E-04	-	1.33E-02	1.89E-01
Np237 ¹	-	-	1.16E+02	1.10E-01	1.16E+02
Pu238 ³	-	-	1.17E+00	1.11E-03	1.17E+00
Pa233 ³	-	-	3.80E-06	3.60E-09	3.80E-06
U233 ³	-	-	1.17E-08	1.11E-11	1.17E-08
Th229 ³	-	-	4.69E-15	4.44E-18	4.69E-15

¹ Decay corrected to 1981: $A=A_0\exp((-0.693t)/\text{half-life})$

² Based upon isotopic fraction compared to Pu-238

³ Based upon isotopic fraction compared to Np-237

This inventory is then allowed to decay for 44 years within a separate GoldSim mixing cell until it is released into the source zone in 2025 (assumed date of decommissioning). The 2025 inventory is given in Table 7.

Table 7. 235-F Base 2025 Inventory

	PuFF Cells 1-5 (g)	PuFF Cells 6-9 (g)	Actinide Billet Line (g)	Rest of Building 235-F (g)
Ac227	4.91E-13	1.12E-15	0.00E+00	3.74E-14
Am241	2.16E+00	4.95E-03	0.00E+00	1.65E-01
Np237	3.98E-01	9.11E-04	1.16E+02	1.40E-01
Pa231	2.16E-09	4.96E-12	0.00E+00	1.65E-10
Pb210	4.66E-09	1.07E-11	1.12E-11	3.55E-10
Pu238	3.44E+02	7.88E-01	8.28E-01	2.62E+01
Pu239	8.03E+01	1.84E-01	0.00E+00	6.12E+00
Pu240	1.16E+01	2.66E-02	0.00E+00	8.84E-01
Pu241	2.96E-01	6.78E-04	0.00E+00	2.26E-02
Pu242	9.33E-01	2.14E-03	0.00E+00	7.11E-02
Ra226	1.29E-06	2.95E-09	3.10E-09	9.82E-08
Ra228	1.17E-10	2.67E-13	0.00E+00	8.88E-12
Th228	3.86E-11	8.84E-14	0.00E+00	2.94E-12
Th229	4.24E-10	9.70E-13	1.55E-07	1.79E-10
Th230	9.20E-03	2.11E-05	2.21E-05	7.01E-04
Th232	2.91E-01	6.67E-04	0.00E+00	2.22E-02
U233	4.69E-06	1.07E-08	1.62E-03	1.90E-06
U234	1.40E+02	3.21E-01	3.38E-01	1.07E+01
U235	1.00E-01	2.29E-04	0.00E+00	7.62E-03
U236	5.31E-02	1.22E-04	0.00E+00	4.05E-03
U238	7.46E-05	1.71E-07	0.00E+00	5.68E-06

A second case will be considered that adds the assay 1σ uncertainty to the inventory for PuFF Cells 1-5 and PuFF Cells 6-9 (the Rest of Building and Actinide Billet Line inventories are the same as used in 2012). This second case is referred to as the “bounding” case. As was done previously, the inventory was then decay corrected to 1981 as given in Table 8. After decaying for 44 years, the 2025 inventory is listed in Table 9.

Table 8. 235-F Bounding 1981 Inventory

Radionuclide	PuFF Cells 1-5 inventory (g)	PuFF Cells 6-9 inventory (g)	Actinide Billet Line inventory (g)	Rest of Building 235-F inventory (g)
Pu238*	5.66E+02	1.30E+00	-	5.09E+01
Pu239*	9.36E+01	2.14E-01	-	8.42E+00
Pu240*	1.36E+01	3.10E-02	-	1.22E+00
Pu241*	2.78E+00	6.36E-03	-	2.50E-01
Pu242*	1.09E+00	2.48E-03	-	9.76E-02
Np237*	3.39E-01	7.76E-04	-	3.05E-02
Th232*	3.39E-01	7.76E-04	-	3.05E-02
Am241*	2.04E-01	4.65E-04	-	1.83E-02
Np237**	-	-	1.62E+02	1.52E-01
Pu238**	-	-	1.64E+00	1.54E-03
Pa233**	-	-	5.32E-06	4.99E-09
U233**	-	-	1.64E-08	1.54E-11
Th229**	-	-	6.56E-15	6.16E-18

* Based upon isotopic fraction from PuO₂ powder

** Based upon isotopic fraction from NpO₂ powder

Table 9. 235-F Bounding 2025 Inventory

	PuFF Cells 1-5 (g)	PuFF Cells 6-9 (g)	Actinide Billet Line (g)	Rest of Building 235-F (g)
Ac227	5.71E-13	1.31E-15	0.00E+00	5.14E-14
Am241	2.51E+00	5.75E-03	0.00E+00	2.26E-01
Np237	4.63E-01	1.06E-03	1.62E+02	1.94E-01
Pa231	2.52E-09	5.76E-12	0.00E+00	2.27E-10
Pb210	5.42E-09	1.24E-11	1.57E-11	4.88E-10
Pu238	4.01E+02	9.16E-01	1.16E+00	3.60E+01
Pu239	9.35E+01	2.14E-01	0.00E+00	8.41E+00
Pu240	1.35E+01	3.09E-02	0.00E+00	1.22E+00
Pu241	3.45E-01	7.88E-04	0.00E+00	3.10E-02
Pu242	1.09E+00	2.48E-03	0.00E+00	9.76E-02
Ra226	1.50E-06	3.43E-09	4.34E-09	1.35E-07
Ra228	1.36E-10	3.10E-13	0.00E+00	1.22E-11
Th228	4.49E-11	1.03E-13	0.00E+00	4.04E-12
Th229	4.93E-10	1.13E-12	2.17E-07	2.48E-10
Th230	1.07E-02	2.45E-05	3.10E-05	9.63E-04
Th232	3.39E-01	7.76E-04	0.00E+00	3.05E-02
U233	5.46E-06	1.25E-08	2.27E-03	2.62E-06
U234	1.63E+02	3.73E-01	4.73E-01	1.47E+01
U235	1.16E-01	2.66E-04	0.00E+00	1.05E-02
U236	6.18E-02	1.41E-04	0.00E+00	5.56E-03
U238	8.68E-05	1.99E-07	0.00E+00	7.81E-06

Scenarios

- Grout the entire first floor (including area directly below PuFF cells)
- Grout the entire first and second floors (including area directly below PuFF cells)

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