Composition of the U.S.DOE Depleted Uranium Inventory

The past use of uranium recycled from spent fuel for the feed of U.S. uranium enrichment plants raises a number of questions concerning the composition of the U.S. depleted uranium inventory. An assessment of the hazards resulting from the use of such depleted uranium (for whatever purpose) is only possible if the composition of the material is fully known. The follwing is a (still incomplete) compilation of currently accessible information.

A first look at the U.S. depleted uranium inventory shows that the material has no uniform quality, given already the wide range of tails assays (Table 1 and Fig. 1). These figures were published in 1992; the inventory since has increased by approx. 90,000 t U [DOE_1999c, p.1-18].
The following information on the characteristics of the depleted uranium used by the U.S. Department of Defense (DoD) is given in [AEPI_1995, p.23]:

> "Military Specification MIL-U-70457 stipulates that DU used by DoD must have a ^{235}U concentration of less than 0.3 percent [...] DoD actually uses DU containing approximately 0.2 percent ^{235}U."

and:

> "DU may have trace amounts (about 0.003 weight percent) of ^{236}U."

The majority of the depleted uranium produced so far still is located at the enrichment plants where it was generated, mostly in the chemical form of UF_6. Of the 118,784 t U in the 1992 depleted uranium stocks meeting the tails assay of less than 0.21 wt% U-235 used by DoD, 64% were located at Paducah, 17% at Portsmouth, and 19% at Oak Ridge.
Since each of these plants had a different operation history, the DU inventory of each plant has to be looked at separately.

Paducah enrichment plant (PGDP), Kentucky

The Paducah gaseous diffusion plant enriched the UF_6 from its natural assay of 0.71 wt% U-235 to about 2.75 wt% U-235. For further enrichment, the material was shipped to the Oak Ridge and Portsmouth plants.
In addition to natural uranium, also uranium recycled from spent fuel was fed into the Paducah enrichment cascade (Table 2 and Fig. 2). The recycled uranium introduced various isotopes not found in natural uranium into the cascade: fission products, such as Technetium-99; transuranics, such as Neptunium-237 and Plutonium-239; and the artificial uranium isotope of Uranium-236.
The spent fuel, from which uranium was recycled, originated from the Hanford and Savannah River military plutonium production reactors. This uranium was recycled, although its assay of U-235 was somewhat lower than in natural uranium (Table 2). This obviously must be seen in the context of the Cold War era, when uranium was a scarce resource. Due to the low burn-up of the military reactors, concentrations of artificial U-236 are comparatively low in this recycled uranium. The recycled uranium represents about 13% of the total feed to the plant. In single years, up to 65% of the feed were from recycled uranium.

Oak Ridge enrichment plant (ORGDP, K-25), Tennessee

The Oak Ridge gaseous diffusion plant processed natural uranium, pre-enriched uranium from Paducah, 5104 t U recycled from spent fuel of military reactors (Table 3), and a total of approx. 420 t U of uranium recycled from spent fuel of (mostly foreign) commercial reactors, the latter

representing about 1% of the total feed to the plant (Tables 4+5). Most of the latter material had U-235 assays higher than natural and a wide range of U-236 concentrations.

Portsmouth enrichment plant (PORTS), Piketon, Ohio

The Portsmouth gaseous diffusion plant processed natural uranium, pre-enriched uranium from Paducah, 1112 t U recycled from spent fuel of military reactors, and minor amounts of uranium recycled from spent fuel of miscellanous sources. The recycled uranium represented 0.35% of Portsmouth's total feed; in single years, the recycled uranium constituted up to 6.77% of the feed (Table 6).

Table 1: U.S. DOE Depleted Uranium Inventory as of June 30, 1992

U-235 Assay [wt %]	Paducah [t U]	Portsmouth [t U]	Oak Ridge [t U]	Total [t U]	Total [%]
< 0.21	75405	20628	22751	118784	32.87%
0.21 to < 0.24	752	2696	1823	5271	1.46%
0.24 to < 0.26	51883	39635	9546	101064	27.97%
0.26 to < 0.28	1129	1671	683	3483	0.96%
0.28 to < 0.31	28270	4584	1574	34428	9.53%
0.31 to < 0.50	59586	35300	0	94886	26.26%
0.50 to < 0.60	506	0	0	506	0.14%
0.60 to < 0.711	2931	0	0	2931	0.81%
Total	220462	104514	36376	361352	100.00%
Total [%]	61.01%	28.92%	10.07%	100.00%	

t = metric tonne
Source: [DOE_1994]

Fig. 1:

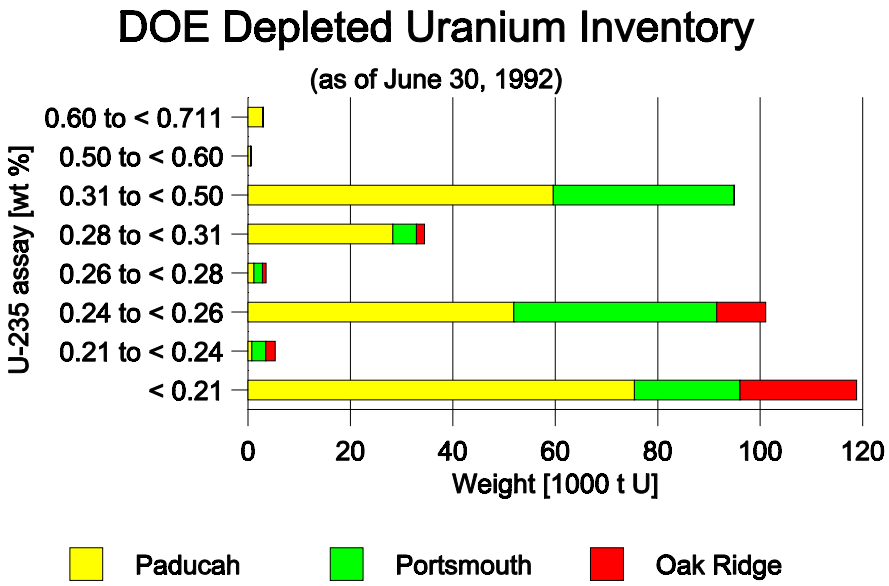
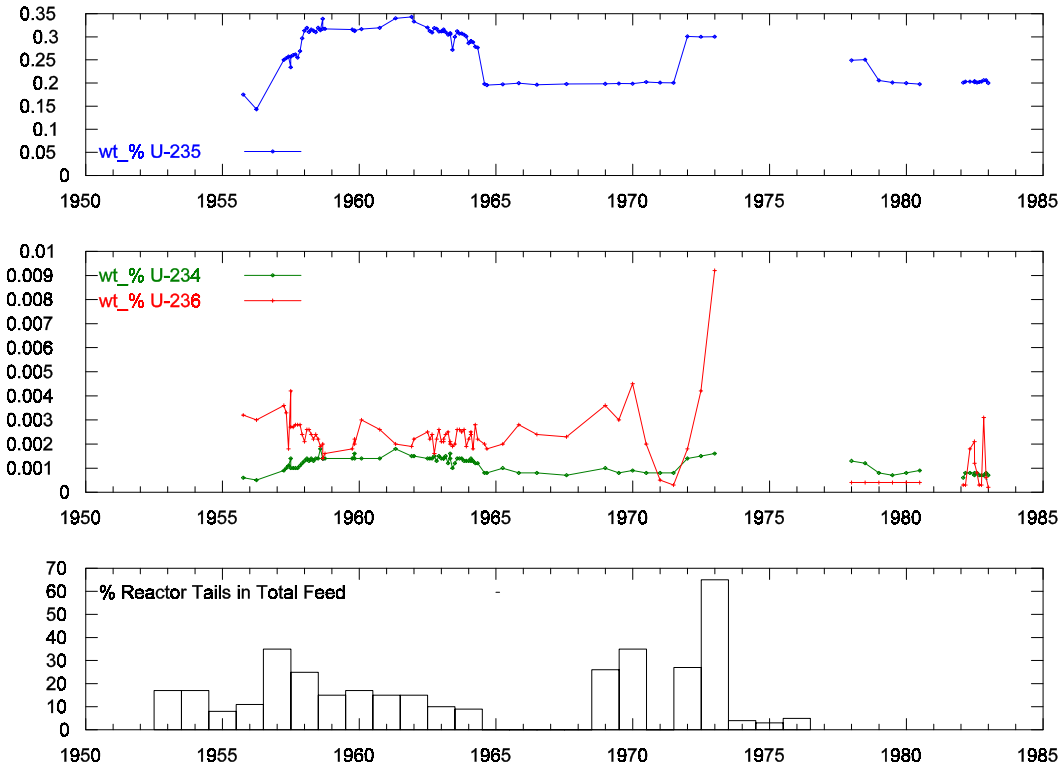


Table 2: Minor isotopes in reactor tails fed into Paducah cascade 1953 - 1976

	Depleted Reactor Tails		Enriched Reactor Tails	Total
Origin	Hanford	Savannah River	?	
Weight [short tons U]	95492	3622	2154	101268
U-235 [wt_%]	0.64%	0.59%	0.73%	0.64%
U-236 [wt_%]	0.011%	0.017%	0.041%	0.012%

1 short ton = 907.185 kg
Concentrations shown in the "Total" column are weighted averages (added by WISE Uranium)
Source:[DOE_1984, p. 35/41]

Fig. 2: Minor isotopes in Paducah cascade tails



Source: data: [DOE_1984, p. 29, 51-53], drawing: WISE Uranium

Table 3: Oak Ridge Domestic Reactor Tails Feed Summary 1958 - 1974 [short tons]

	Origin		
	Hanford	Savannah River	Total
1958	1596		1596
1959	487		487
1960	1256	88	1344
1961	242	932	1174
1962		318	318
1970	392		392
1974	316		316
Total	4289	1338	5627

1 short ton = 907.185 kg
Source: [DOE_1984, p. 31]

Table 4: Oak Ridge GDP Reactor Return Feed Summary: Toll Enrichment
[number of cylinders]

	Reactor Return Feed						Natural Feed	% Reactor Return Feed *)
	Euro-Chem (B)	BNFL (UK)	Cogéma (F)	German	Russian	Subtotal		
1969			10			10	252	0.98%
1970	2	2	10			14	549	0.63%
1971						0	223	0.00%
1972		2	17			19	333	1.41%
1973		7	28			35	524	1.64%
1974		15	16			31	497	1.54%
1975		14				14	563	0.62%
1976		9	3			12	592	0.50%
1977	5	13				18	565	0.79%
1978		4	12			16	492	0.81%
1979			11	2		13	187	1.71%
1980			28		3	31	340	2.23%
1981			53			53	369	3.47%
1982			8			8	659	0.30%
Total	7	66	196	2	3	274	6145	1.10%

*) assuming the following cylinder contents:

Cylinder capacity [short tons UF_6]	2.5	10	

Reactor Return cylinder capacity according to [KY/L-1239 p.14]
Natural Feed cylinder capacity assumed by WISE Uranium
1 short ton UF_6 = 0.907185 t UF_6 = 0.613 t U
Source: [DOE_1983, p. 13], percentages added by WISE Uranium

Table 5: U-236 Concentrations in Oak Ridge GDP Feed: Toll Enrichment [wt_% U-236]

	Reactor Return Feed						Total Feed *)
	Euro-Chem (B)	BNFL (UK)	Cogéma (F)	German	Russian	Subtotal *)	
1969			0.039%			0.039%	0.000%
1970	0.185%	0.050%	0.232%			0.199%	0.001%
1971							0.000%
1972		0.071%	0.158%			0.149%	0.002%
1973		0.045%	0.242%			0.203%	0.003%
1974		0.011%	0.176%			0.096%	0.001%
1975		0.012%				0.012%	0.000%
1976		0.011%	0.022%			0.014%	0.000%
1977	0.029%	0.057%				0.049%	0.000%
1978		0.051%	0.152%			0.127%	0.001%
1979			0.042%	0.028%		0.040%	0.001%
1980			0.254%		0.016%	0.231%	0.005%
1981			0.239%			0.239%	0.008%
1982			0.240%			0.240%	0.001%

*) weighted average, assuming the above cylinder sizes
Source: [DOE_1983, p. 14]; Subtotal and Total percentages added by WISE Uranium

Average tails assay of the domestic reactor tails fed to Oak Ridge: 0.64 wt_% U-235 for Hanford material, 0.60 wt_% U-235 for Savannah River material

Table 6: Portsmouth GDP Feed Summary 1955 - 1997 [t U]

	Hanford and Savannah River Reactor Tails	Total Feed	% Reactor Tails
1955	93.4	14112.4	0.66%
1956	363.1	9814.7	3.70%
1957	6.2	4516.5	0.14%
1958	64.2	4913	1.31%
1961	16.9	5804.7	0.29%
1970	168.2	4019.7	4.18%
1974	400	5907.4	6.77%
Total 1955 - 1997	1112	320817.2	0.35%

Source: [DOE_2000b, p.85/86] (years with no feed from reactor tails not shown in detail)

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