

Table 6b
Pu Isotopic Abundances (NDA)

Method	Technique	Instrument*	Material	Burnup	Shielding	²³⁹ Pu		²⁴⁰ Pu		²⁴⁰ Pueff		Specific power		Notes
						(% rel., k=1)		(% rel., k=1)		(% rel., k=1)		(% rel., k=1)		
						u(r)	u(s)	u(r)	u(s)	u(r)	u(s)	u(r)	u(s)	
HRGS	T1, LE	XMCG-D1	Pu	L	L	0.1	0.1	1.5	0.8	1.5	0.8	1.0	0.2	1
			Pu	H	L	0.6	0.3	1.2	0.4	0.9	0.3	0.6	0.3	1, 3
	T2, LE	XMCG-D1	Pu	H	L	0.7	0.3	1.2	0.6	1.5	0.5	0.6	0.3	1, 3
	T1, LE	XMCG-D1	MOX	H	L	1.0	0.4	2.6	0.8	2.6	0.5	1.0	0.7	6
	T1, HE	XMCG-D2	Pu	L	L/H	0.6	0.2	6.2	1.7	6.2	1.7	1.0	0.4	2
			Pu	H	L/H	2.1	0.6	6.2	1.7	5.6	1.6	1.5	0.9	2
	T1, HE	XMCG-D3	Pu	L	L/H	1.7	0.2	16.1	3.1	15.7	3.0	2.4	0.4	7, 11
		Pu	H	L/H	4.9	4.1	15.2	9.9	11.3	6.7	3.3	0.7	7, 11	
	XMCG-D3	MOX	H	L	2.6	1.9	6.7	6.0	3.4	2.7	2.7	3.1	10	
MRGS	T3/T4, HE	XMCC	Pu	L	L/H	2.5	1.5	20	15	N/A	N/A	N/A	N/A	4, 8
			Pu	H	L/H	3.5	2.5	15	10	N/A	N/A	N/A	N/A	4, 8
	T3/T4, HE	XMCL	Pu	L	L/H	2.5	2.0	20	15	N/A	N/A	N/A	N/A	5, 9
			Pu	H	L/H	3.5	3.0	15	15	N/A	N/A	N/A	N/A	5, 9

*click a hyperlink to open method's narrative

N/A: not applicable

Uncertainty categories:

ITV: are presented in black font

Prospective Values: are presented in blue font

Assumptions / considerations:

- 1 LANL data, FRAM v.6.1 analysis with parameter set GePlnr_Pu_060-230
- 2 LANL data, FRAM v.6.1 analysis with parameter set GeCoax_Pu_180-1010
- 3 Additional source of data from IAEA NML obtained using FRAM v.5.2 / MGA (10 analyses) 129 keV = 50000 cnts, OCR=22 kcps, LT=600 s. The prospective values were established based on both, LANL and IAEA dataset.
- 4 PAT analysis, MRGS Intercomparison exercise - XMCC: 413 keV = 2000 cnts (HBPU) and 20000 cnts (LBPU), OCR=10 kcps, LT=600 s.
- 5 PAT analysis, MRGS Intercomparison exercise - XMCL: 413 keV = 10000 cnts (HBPU) and 50000 cnts (LBPU), OCR=10 kcps, LT=600 s.
- 6 IAEA field data, FRAM v.6.1 analysis with parameter set GePlnr_Pu_060-230, 129 keV = 30000 cnts, achievable with standard IAEA XMCG-D1 setup at OCR=10 kcps for LT=600 s
- 7 LANL data obtained using two 1st generation Ortec Detective instruments. Data measured in 2005 and 2016. 28 data sets of 14 sources. 539 spectra. FRAM analysis with parameter set detective_pu_120-460_220210. Normalized to 600 s LT.
- 8 LANL data, FRAM v.6.1 analysis with parameter set CZT500_Pu_120-500 with correlated ²⁴⁰Pu option turned on in addition to correlated ²³⁸Pu and correlated ²⁴²Pu. 9 data sets, 299 spectra. Normalized to 600 s LT.
- 9 LANL data FRAM v.6.1 analysis with parameter set LaBr_Pu_200-750 with correlated ²⁴⁰Pu option turned on in addition to correlated ²³⁸Pu and correlated ²⁴²Pu. 21 data sets, 530 spectra. Normalized to 600 s LT.
- 10 IAEA field data, FRAM v.6.1 analysis with a modified parameter set "det_coax_120_800_2_ecgs" (interferences with Cs-137 and Ag-110 m), very high BUPu (²³⁹Pu isotope mass fraction < 55 %, 2-3 y after chemical purification, DU/Pu = 10), 129 keV = 5000 cnts, 208 keV = 700000 cnts, achievable with standard IAEA XMCG-D3 setup at OCR=5 kcps for LT=1000 s (DT < 20%)
- 11 EC-JRC data, steel filter up to 16 mm, lead filter up to 4 mm, 1400 spectra in 40 sets, analyzed with FRAM v.5.2 and parameter set Pu_Cx_180-1010.

Method categories:

- HRGS High Resolution Gamma Spectrometry
MRGS Medium Resolution Gamma Spectrometry

Technique categories:

- T1 Peak ratio, intrinsic efficiency calibration, "known" ²⁴²Pu
T2 Peak ratio, intrinsic efficiency calibration, ²⁴²Pu by isotopic correlations
T3 Peak ratio, intrinsic efficiency calibration, ²³⁸Pu and ²⁴²Pu by isotopic correlations
T4 Peak ratio, intrinsic efficiency calibration, ²³⁸Pu, ²⁴⁰Pu, and ²⁴²Pu by isotopic correlations
LE Analysis in the low energy range < 230 keV
HE Analysis in the high energy range > 120 keV

Instrument categories:

- XMCG HPGe detector coupled to any MCA, including portable equipment. Electrically or LN2 cooled.
XMCC CZT, >=500 mm³, coupled to any MCA
XMCL LABR, thickness ≥ 12.7 mm, diameter ≥ 25.4 mm, coupled to any MCA

Material categories:

- Pu PuO₂ clean powder, long time after chemical separation > 1 year

MOX Mixed oxide clean powder based on reactor grade Pu (RGPu), pellets, rods, assemblies: $10 < \text{NU-DU/RGPu} < 100$

Geometries (Shielding) categories:

L	Low	< 3 mm steel (or equivalent, intense X-ray peaks)
H	High	> 10 mm steel (or equivalent, no/low intensity X-ray peaks) and < 5 mm lead or equivalent

Burnup categories:

L	Low	^{239}Pu isotope mass fraction > 80 %
H	High	^{239}Pu isotope mass fraction $\leq$ 80 %

XMCG types:

D1	Energy resolution < 750 eV @ 122 keV. Active area $\geq 500 \text{ mm}^2$. Thickness $\geq 10 \text{ mm}$. Typical detectors in XMCG-D1 category: planar and semi-planar detectors (GL1015, BE1015, BE2830, BE3830, BE5030, Profile S/SP, GLP).
D2	Energy resolution < 1.0 keV @ 122 keV and < 2.0 keV @ 1332 keV. Relative efficiency $\geq 15 \%$. Typical detectors in XMCG-D2 category: semi-planar and small volume coaxial detectors (BE2830, BE3830, BE5030, Profile S/SP/C/M, GMX, Falcon, Aegis).
D3	Energy resolution < 1.5 keV @ 122 keV and < 2.3 keV @ 1332 keV. Relative efficiency $\geq 15 \%$. Typical detectors in XMCG-D3 category: portable electrically cooled coaxial detectors and large volume coaxial detectors (Micro-Detective (ECGS), Aegis, GC9023, Profile C/M, GMX).