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^{133}Ba as a gamma-ray surrogate source for 1kg HEU and 10g ^{239}Pu and ^{252}Cf as a neutron surrogate for Pu

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DISCLAIMER

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Introduction:

Monte Carlo was performed for the purpose of relating gamma-ray signal strength from 1kg of HEU and 10g of ^{239}Pu (as described in the ASTM standards) to the radiation emitted from an amount of ^{133}Ba. A determination was made on the amount of ^{133}Ba that could act as a surrogate for the specified amounts of HEU and Pu. ^{133}Ba is not the ideal source to use as a surrogate for HEU because of its higher energies. ^{133}Ba was chosen as the surrogate since it has a half-life of 10.54 years, rather then the more ideal surrogate of ^{57}Co which has a half-life of 271 days.

A similar Monte Carlo was performed for the purpose of relating neutron signal strength from 200g of Pu (as described in the ASTM standards) to the radiation emitted from an amount of shielded ^{252}Cf. A determination was made on the amount of ^{252}Cf necessary to act as a surrogate for the 200g of Pu.

An ASTM standard source is a metallic sphere, cube, or right cylinder of SNM having maximum self-attenuation of its emitted radiation. For plutonium, the source should be at least 93% ^{239}Pu, less than 6.5% ^{240}Pu, and less than 0.5% impurities. A cadmium filter of at least 0.08cm thick should be used to reduce the impact of ^{241}Am. For uranium, the source should contain at least 95% ^{235}U and less than 0.25% impurities. For neutron detector testing, the neutron source shall be placed in a lead shielding container that reduces the gamma radiation from the source to 1% of its unshielded value.

Calculations and Results:

Comparison of Pu and HEU Photon Emission Rates with ^{133}Ba

<u>^{133}Ba Photon Data:</u>

E(keV)	%Photons/Disintegration
81.00	34.20
160.60	0.60
223.24	0.46
276.40	7.09
302.85	18.40
356.00	62.20
383.84	8.92

Thus 1.32 photons above 80keV per disintegration
So <u>one</u> Curie of ^{133}Ba emits 4.88e+10 photons/second (3.7e+10*1.32)

For 10 grams of Pu with 5.8% ^{240}Pu:

Internal activity = 1.15e+07 photons/second (from GAMGEN)
Escaping activity = 1.06e+06 photons/second (from MCNP) due to the self-attenuation of a 0.53603cm radius sphere.

Equivalent ^{133}Ba activity=21.7μCi (1.06e+06/4.88e+10)

For 1000 grams of HEU with 93.5% ^{235}U:

Internal activity = 7.07e+07 photons/second (from GAMGEN)
Escaping activity = 1.20e+06 photons/second (from MCNP) due to the self-attenuation of a 2.34556cm radius sphere.

Equivalent ^{133}Ba activity=24.7μCi (1.20e+06/4.88e+10)

Comparison of Pu Neutron Emission Rates with ^{252}Cf

^{252}Cf Neutron Data:

NuBar for the spontaneous fission of ^{252}Cf = 3.757 neutrons/fission
Decay Branching Ratio=0.03092 fissions/disintegration (0.96908 via α)
1 Curie=3.7e+10 disintegrations/second

Thus one Curie of ^{252}Cf emits 4.30e+09 neutrons/second i.e.
(3.7e+10 * 0.03092 * 3.757)

For 200 grams of Pu with 5.8% ^{240}Pu:

Using 1050 fission neutrons/second/gram of ^{240}Pu in a 1.455 cm radius sphere.
Shield by 17mm of lead for a 100x photon reduction.

Escaping neutron flux = 1.49e+04 neutrons/second (from MCNP)

Equivalent ^{252}Cf activity=3.47μCi (1.49e+04 / 4.30e+09)

In terms of grams:
1 gram of ^{252}Cf emits 2.34e+12 spontaneous fission neutrons/second
Thus one needs 6.36e-09 grams (1.49e+04 / 2.34e+12)

Summary:

Surrogates were determined for the cases listed above. The surrogate determinations are:

Original Source	Calculated Surrogate Source
1kg HEU (gamma)	24.7μCi ^{133}Ba
10g ^{239}Pu (gamma)	21.7μCi ^{133}Ba
200g Pu (neutron), with 17mm of lead shielding	3.47μCi or 6.36e-09 grams of ^{252}Cf