

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

Bertram A. Pohl and Daniel E. Archer

March, 2004

U.S. Department of Energy

Lawrence
Livermore
National
Laboratory

DISCLAIMER

This document was prepared as an account of work sponsored by an agency of the United States Government. Neither the United States Government nor the University of California nor any of their employees, makes any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness, or usefulness of any information, apparatus, product, or process disclosed, or represents that its use would not infringe privately owned rights. Reference herein to any specific commercial product, process, or service by trade name, trademark, manufacturer, or otherwise, does not necessarily constitute or imply its endorsement, recommendation, or favoring by the United States Government or the University of California. The views and opinions of authors expressed herein do not necessarily state or reflect those of the United States Government or the University of California, and shall not be used for advertising or product endorsement purposes.

This work was performed under the auspices of the U. S. Department of Energy by the University of California, Lawrence Livermore National Laboratory under Contract No. W-7405-Eng-48.

This report has been reproduced
directly from the best available copy.

Available to DOE and DOE contractors from the
Office of Scientific and Technical Information
P.O. Box 62, Oak Ridge, TN 37831
Prices available from (423) 576-8401
<http://apollo.osti.gov/bridge/>

Available to the public from the
National Technical Information Service
U.S. Department of Commerce
5285 Port Royal Rd.,
Springfield, VA 22161
<http://www.ntis.gov/>

OR

Lawrence Livermore National Laboratory
Technical Information Department's Digital Library
<http://www.llnl.gov/tid/Library.html>

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

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 than 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

^{133}Ba Photon Data:

| 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 one Curie of ^{133}Ba emits $4.88\text{e}+10$ photons/second ($3.7\text{e}+10*1.32$)

For 10 grams of Pu with 5.8% ²⁴⁰Pu:

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 ¹³³Ba activity=21.7μCi (1.06e+06/4.88e+10)

For 1000 grams of HEU with 93.5% ²³⁵U:

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 ¹³³Ba activity=24.7μCi (1.20e+06/4.88e+10)

Comparison of Pu Neutron Emission Rates with ²⁵²Cf

²⁵²Cf Neutron Data:

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

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

For 200 grams of Pu with 5.8% ²⁴⁰Pu:

Using 1050 fission neutrons/second/gram of ²⁴⁰Pu 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 ²⁵²Cf activity=3.47μCi (1.49e+04 / 4.30e+09)

In terms of grams:

1 gram of ²⁵²Cf 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) | 24.7 μ Ci ¹³³ Ba |
| 10g ²³⁹ Pu (gamma) | 21.7 μ Ci ¹³³ Ba |
| 200g Pu (neutron), with 17mm of lead shielding | 3.47 μ Ci or 6.36e-09 grams of ²⁵² Cf |