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COMPARISON OF THREE GAMMA-RAY ISOTOPIC DETERMINATION CODES: FRAM, MGA, AND TRIFID*

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The isotopic distribution of plutonium and the americium concentration are required for the assay of nuclear material by calorimetry or neutron coincidence counting. The isotopic information is used in calorimetric assays to compute the effective specific power from the measured isotopic fractions and the known specific power of each isotope. The effective specific power is combined with the heat measurement to obtain the mass of plutonium in the assayed nuclear material. The response of neutron coincidence counters is determined by the ^{240}Pu isotopic fraction and contributions from the other plutonium isotopes and ^{241}Am . The effects of the ^{240}Pu isotopic fraction and the other neutron-contributing isotopes are combined as ^{240}Pu effective. This is used to calculate the mass of nuclear material from the neutron counting data in a manner analogous to the effective specific power in calorimetry.¹ Comparisons of the precision and accuracy of calorimetric assay and neutron coincidence counting often focus only on the precision and accuracy of the heat measurement (calorimetry) compared to the precision and accuracy of the neutron coincidence counting statistics.² The major source of error for both calorimetric assay and neutron coincidence counting often lies in the determination of the plutonium isotopic distribution as determined by gamma-ray spectroscopy. Thus, the selection of the appropriate isotopic distribution code is of paramount importance to good calorimetric assay and neutron coincidence counting. The three gamma-ray isotopic distribution codes in most common use, FRAM,³ MGA,⁴ and TRIFID,⁵ have been compared at the Los Alamos Plutonium Facility under carefully controlled conditions of similar count rates, count times, ^{240}Pu isotopic fractions, and the matrices of the measured nuclear material.

The comparison data reveal that the selection of the isotopic determination code must be tailored to the matrix and the ^{240}Pu isotopic fraction of the nuclear material to be assayed. The codes FRAM and TRIFID use a related method to extract the isotopic ratios from the gamma-ray spectra and both codes use a similar method to correct for inhomogeneities in the distribution of the americium and plutonium. The principal difference is that TRIFID uses the spectral data from two detectors: a planar detector to obtain a spectrum in the region from 120 to 450 keV and a coaxial detector to obtain spectral data in the region between 630 and 725 keV. The data from the higher energy region are used to optimize the determination of the ^{240}Pu and ^{241}Am . FRAM uses the spectral data from 120 to 420 keV and only uses one planar detector to obtain the spectrum. When the precision and accuracy of the measurement of the effective specific power and ^{240}Pu effective as determined by FRAM and TRIFID are compared at similar count rates and count times, FRAM emerges with a slight overall advantage. The precision and accuracy of the effective specific power and ^{240}Pu effective are slightly better when measured by TRIFID for weapons grade material. However, for other enrichments of ^{240}Pu , FRAM performs as well (2% ^{240}Pu) or better (12% ^{240}Pu) than TRIFID without the complications of a second detector and set of electronics. The comparisons with MGA are not as straightforward. MGA primarily uses data from the 100-keV x-ray region of the spectrum. A newer version of MGA uses a second coaxial detector to obtain data in the 600-keV region of the spectrum. These data are used to detect sample inhomogeneity, but MGA does not interpret the results or correct for the inhomogeneity. MGA delivers better precision and accuracy for effective specific power and ^{240}Pu effective than either FRAM or TRIFID for pure weapons

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grade plutonium metal (6% ^{240}Pu) or oxide material. At increasingly higher levels of ^{240}Pu , FRAM gradually meets and slightly exceeds the precision and accuracy of MGA for the measurement of effective specific power. As the ^{240}Pu increases, MGA retains a modest advantage in the precision and accuracy for the measurement of ^{240}Pu effective. MGA was unable to measure the plutonium isotopic ratios for an oxide with 2% ^{240}Pu .

The comparison data suggest that for the assay of pure, homogeneous, weapons grade plutonium metal or oxide MGA delivers the best precision and accuracy for the measurement of effective specific power and ^{240}Pu effective. However, when materials with a wide variety of matrices, possible inhomogeneities, and varying ^{240}Pu isotopic fractions are to be assayed, FRAM is the best choice.

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