MIRION TECHNOLOGIES

Radiation Safety. **Amplified.**

FRAM

Fixed-Energy, Response Function Analysis with Multiple Effciency

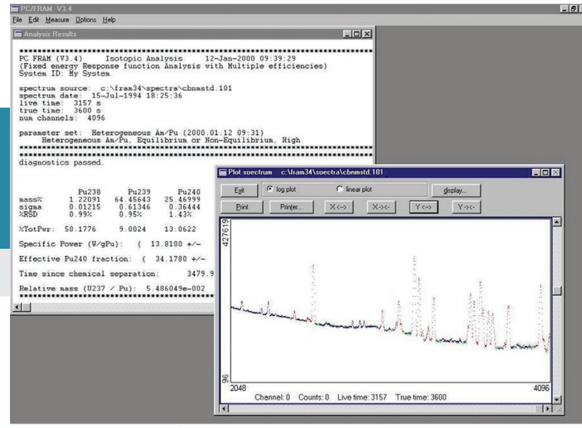

Figure 1 –
Example of spectrum display and analysis result printout capabilities

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KEY FEATURES

- Determines relative plutonium isotopic abundances or uranium isotopic abundances in non-destructive assay applications
- Uses spectra collected with HPGe detectors
- Incorporates a sophisticated peak fitting and multiplet deconvolution algorithm to analyze complex peak regions
- Requires no efficiency calibration for matrix density, thickness or container characteristics
- Developed by Los Alamos and licensed to CANBERRA

DESCRIPTION

FRAM (**F**ixed-Energy, **R**esponse Function **A**nalysis with **M**ultiple Efficiency) is a code developed by Los Alamos to analyze pulse-height spectra generated by high-resolution gamma-ray detectors. It has been used primarily to determine the isotopic composition of plutonium in special nuclear materials. Its design and flexibility allow it to easily measure ratios and distributions of isotopes other than plutonium in arbitrary items.

In nuclear safeguards, FRAM complements calorimetry and neutron coincidence counting by allowing measurements to be interpreted in terms of total plutonium mass.

Table 1 – Material Types Measured with FRAM

- ^{240}Pu (2% – 95%) of total plutonium
- ^{241}Pu – ^{237}U (nonequilibrium)
- Am/Pu in heterogeneous combinations
- ^{241}Am (0.01% to >50%)
- ^{235}U/Pu mixed (MOX) ratios from 0.005 – 35
- ^{234}U, ^{235}U, ^{238}U relative abundances, (no plutonium present), 0.2 to >97% ^{235}U
- Materials in shielded or heavy-walled containers (≥13 mm Pb for plutonium, ≥16 mm steel for uranium)
- ^{243}Am – ^{239}Np
- ^{244}Cm
- ^{237}Np
- ^{238}Pu (80%)

MEASUREMENT PRINCIPLES

In its principal application, FRAM analyzes photopeaks in the spectrum of plutonium gamma rays detected by a high-purity germanium detector. This spectrum contains peaks from the plutonium isotopes $^{238-241}$Pu, ^{241}Am and often other isotopes such as ^{235}U or ^{237}Np. FRAM combines this information to produce isotopic ratios independent of sample size, shape, physical and chemical composition, measurement geometry, and container characteristics. The results are obtained using only the spectral data and known fundamental nuclear branching fractions and half lives and do not require calibration with standards.

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A requirement that the plutonium in the sample has one isotopic composition is usually satisfied. However, certain important cases in which the ^{241}Am is not homogenous with the plutonium can also be analyzed using the "multiple efficiency" characteristics built into the FRAM code. This allows FRAM to improve the results on elementally (Am/Pu) heterogeneous pyrochemical residues. The multiple efficiency feature of FRAM can also be applied to other types of elementally heterogeneous materials. The physical and chemical characteristics of the measured item need not be uniform or even well known. Items may contain mixtures of solids and powders with no ill effect as long as the plutonium is isotopically uniform.

FRAM is primarily an analysis package, although it is capable of simple control of data acquisition hardware as well. The end results are displayed in their own window as shown in Figure 1. It is also possible to display the spectrum in various ways, including showing the fitted results on each peak region. FRAM also contains an MCA emulator display and displays the spectrum during data acquisition.

PERFORMANCE

The isotopic fractions themselves are usually the desired result for quality control and process measurements. For nuclear safeguards, two additional quantities are most often the end results of the isotopic measurement process. These integral quantities, the effective specific power P_{eff}(W/g Pu) and the effective ^{240}Pu fraction $^{240}Pu_{eff}$, are derived from the measured isotopic fractions, and known nuclear constants. They are used to interpret calorimetry measurements (P_{eff}) and neutron coincidence counter measurements ($^{240}P_{ueff}$) respectively.

Over a wide range of measurement and sample conditions FRAM performance falls into ranges shown in Table 2.

Table 2 –
Typical Ranges of FRAM Measurement Characteristics

Measurement Time	20 min to 1 hr
Sample Size	100 mg to many kg (limited by criticality)
Precision (relative standard deviation)	P_{eff} – 0.2% to 0.5% $^{240}Pu_{eff}$ – 0.8% to 3.0%
Bias	Peff – <0.3% $^{240}Pu_{eff}$ – <1.0% Individual isotopes – <1.0% (^{238}Pu to ^{241}Pu)

MEASUREMENT HARDWARE

While FRAM is primarily an analysis package, it does include a simple method for data acquisition. It can set the preset, start and stop spectrum acquisition, and save the spectra to a file using the following CANBERRA MCA devices:

- DSA-2000 Digital Spectrum Analyzer
- Model 556A AIM with ICB NIM
- InSpector™ Portable MCA
- InSpector 2000 DSP Portable MCA
- AccuSpec Boards
- System 100 Boards

The details of the MCA setup are defined with the Genie™ 2000 MID Editor Setup Wizard. This utility program leads the user through a simple set of selections to define the MCA configuration. More complex cases are defined using the MCA Input Definition Editor itself.

If the front end electronics are not programmable, the use of the MID Editor Setup Wizard, or the MID Editor itself is usually all that is required to define the configuration. The FRAM code can then be used as a stand-alone package. If the front end electronics are programmable, they need to be setup using the Genie 2000 software since FRAM does include any controls for such adjustments.

OPERATING PLATFORMS

FRAM is available to work with the Genie 2000 software suite on the Windows® 95, Windows 98 and Windows NT® operating systems.