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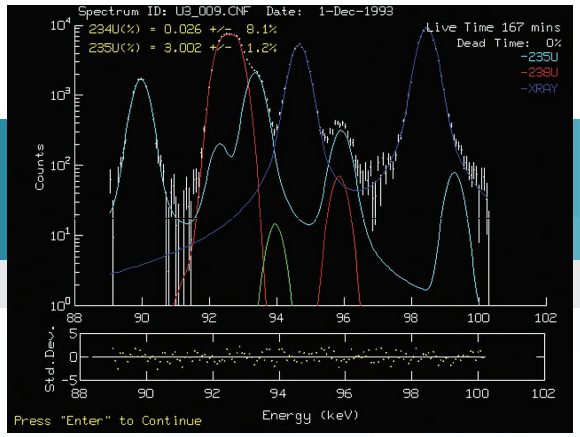
MGAU

Multi-Group Analysis for Uranium



Nuclear | Healthcare | Homeland Security & Defense | Labs and Education | Industrial and Manufacturing

KEY FEATURES

- Determines uranium isotopics (enrichment) accurately in non-destructive assay applications
- Sophisticated analysis using multiplet deconvolution eliminates the need for efficiency calibration based on matrix density, matrix type, or container characteristics
- In the enrichment meter mode, only one calibration measurement is required
- Integrated into CANBERRA waste and safeguards instruments to perform analysis with minimal operator interaction; batch mode for repeated measurements
- Standalone analysis mode available if expert review is needed of spectra, fit residuals, and results
- Developed in collaboration with top experts in safeguards NDA applications

KEY BENEFITS

- Fast and accurate uranium isotopics measurements
- No calibration standards required for isotopics measurements
- Ease of use for setup and operations; minimal operator training is required

APPLICATIONS

- Nuclear Safeguards
- Inventory control at enrichment facilities
- Waste measurements

INTRODUCTION

The accurate non-destructive assay of uranium bearing materials to determine uranium content is vital in nuclear safeguards, waste management, and fuel cycle process control measurements. In a climate of heightened concern for the possible diversion of special nuclear materials, there is a need in the nuclear community for continued maintenance and advancement of accurate uranium detection and verification tools.

Uranium measurements are typically difficult because of varying container shapes, container wall thicknesses, uranium chemical forms and other complications. Multi-Group Analysis for Uranium (MGAU) was designed to improve the accuracy of these measurements over traditional methods, while simplifying or eliminating the setup and calibration steps necessary with other methodologies. MGAU can therefore be used with minimal setup, by operators requiring minimal training, and it is easily applied to applications involving routine, repetitive measurements.

DESCRIPTION

In its normal mode MGAU uses information from the low energy region which includes both gamma and X-rays from 84 to 205 keV. The primary enrichment information is derived from the ^{235}U and ^{238}U emissions in the 90-94 keV energy range. Several peaks detected in the measured spectrum itself are used to develop a relative efficiency curve; i.e. the detector efficiency as a function of energy is determined, taking into account the amount of attenuation caused by the sample container, and the amount of self-absorption in the uranium material itself. This process eliminates the need for an efficiency calibration prior to making sample measurements.

In the enrichment-meter mode, MGAU utilizes the ^{186} keV gamma line from ^{235}U decay and requires just one calibration measurement with a reference standard of known enrichment and known container wall thickness. The results of this calibration measurement are automatically stored for further use on any samples with known container wall thicknesses. The enrichment meter mode is useful for very thick container walls where poor counting statistics in the spectrum may limit the results from the normal mode, and also can be used for analyzing uranium samples where the uranium isotopes are not in equilibrium with their daughter products (freshly separated uranium).

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USER INTERFACE AND OPERATING MODE

MGAU is intended to run with minimum user interaction and is performed interactively via the Genie™ 2000 Gamma Acquisition and Analysis program or in a batch mode via the MGAU batch commands. In both cases the analysis process requires little or no user interaction. For challenging measurements where expert review and user feedback on the intermediate analysis steps is desired, MGAU offers an additional standalone mode. Here interactive graphical displays are available showing the relative efficiency curve information, peak fitting results and corresponding residuals in the complex 100 keV region. The user can choose which mode to use for enrichment measurements: under Genie 2000, the analysis lends itself to automation, while the standalone mode may be preferred for expert review.

FLEXIBLE GAIN SETTINGS

The general recommendation for MGAU analysis is to have the detector energy-calibration gain setting at approximately 0.075 keV/channel. It is not a limitation, however, to allow for measurements that may require different gain settings. Typically for large Non-Destructive Assay (NDA) Systems the setting of 0.095 keV/channel gain is used to allow for an energy range up to about 1.5 MeV in a single 16k spectrum. MGAU can be used to analyze such spectra, and the code retrieves the initial energy calibration directly from the spectrum file or uses the user input.

ANALYSIS FEATURES

MGAU provides accurate ^{235}U enrichment results, as well as ^{234}U and ^{238}U relative abundances. The analysis algorithms that are used to determine the ^{234}U abundance have recently been improved thereby providing additional accuracy to the isotopic measurement results. Apart from the standard isotopic analysis required for most normal uranium bearing materials, MGAU also handles a variety of known measurement challenges. These include ^{236}U and ^{232}U analysis in recycled uranium, the analysis of fresh samples using a separation date, and accounting for the presence of natural thorium. MGAU also accounts for the impact on the relative efficiency curve when a significant amount of shielding material is present, and can also handle small and dilute samples that are more typical of forensic and waste measurements rather than the traditional safeguards measurements. In addition the traditional enrichment-meter analysis is enhanced to handle not only steel containers, but also monel which is more typical of UF_6 cylinders. These analysis features are discussed in more detail in reference [2] given below. Performance data as a function of enrichment for non-shielded and shielded materials is summarized in Tables 1 and 2.

Table 1. Average Measured-to-Declared enrichment ratio results from MGAU.

(Typical results when using good instruments and proper measurement procedures.)

Enrichment Range	Average Measured-to-Declared Enrichment Ratio (MGAU V4.2)		No. of Spectra
	Ratio*	Average Reported Uncertainty, %	
Depleted uranium	1.003	5.7	15
Natural uranium	0.998	2.7	14
1-5 wt% of ^{235}U	1.003	0.9	42
10-20 wt% of ^{235}U	1.003	0.8	18
25-75 wt% of ^{235}U	1.003	0.7	22
>90 wt% of ^{235}U	1.009	2.1	17

*Ratio is based on the analysis of a large set of typical uranium spectra of various enrichments (128 spectra total)

Table 2. Average Measured-to-Declared enrichment ratio results from MGAU in the presence of steel absorbers.

(Typical results when using good instruments and proper measurement procedures.)

Enrichment Range	Average Measured-to-Declared Enrichment Ratio (MGAU V4.2)		No. of Spectra
	Ratio*	Average Reported Uncertainty, %	
Depleted uranium	1.052	27.5	4
Natural uranium	1.018	15.2	12
1-5 wt% of ^{235}U	1.024	4.8	6
20-50 wt% of ^{235}U	0.998	1.9	12
>90 wt% of ^{235}U	0.989	7.3	5

*Ratio is based on the analysis of a large set of typical uranium spectra of various enrichments acquired with 4-8 mm thick steel absorbers (39 spectra total)

REPORTING

Besides the measurement results, MGAU reports the measured to declared enrichment value based on the user-declared value specified prior to the analysis. In addition MGAU reports the peak areas and relative efficiencies obtained when performing the isotopic analysis for nine major peaks in the 90-205 keV region. This information is also stored for each spectrum in Genie 2000 CAM parameters and can be retrieved for use in other applications.

DETECTOR CHOICE

The CANBERRA LEGe is the detector of choice for MGAU due to its exceptional low energy peak shape and resolution characteristics over a wide range of count rates. Such a high performance detector is recommended as MGAU operates in regions of the spectrum where very complex gamma/X-ray multiplets are encountered. The recommended value for energy resolution is of the order of 550 eV at 122 keV, but this is not necessarily a restriction for all measurement situations. Above 650 eV the software will issue a warning on the resolution, but it has been shown to work with detectors up to a resolution of 800 eV [3]. Therefore MGAU can be also used with BEGe detectors (typically used on NDA Systems) and portable Ge detetctors such as the Falcon 5000® [4].

Test data (summarized in Table 1) show excellent correlation between MGAU results in the normal mode and known standard values. Accuracies in the 1–2% range for most common samples are typical. MGAU can measure enrichment ranges from depleted up to 93% ^{235}U with optimum accuracies in the 3–20% enrichment range. Measurements require only short acquisition times (a few minutes) and only seconds of analysis time. Similar accuracies can be achieved in the enrichment meter mode as long as the walls are well characterized.

SPECIFICATIONS

REQUIREMENTS

- Genie 2000 MultiGroup Analysis for Uranium V4.2 is supported under the following Operating Systems: Windows® XP Professional Edition SP3; Windows Vista® Professional/ Enterprise Edition. SP2; Windows 2000 Server 2003 R2. Compliance testing was also performed utilizing 32-bit Microsoft® Windows 7.
- MGAU V4.2 requires Genie 2000 installation and can be installed using Genie 2000 Version 3.1, but V3.2 or higher versions are required for qualified compatibility.
- MGAU V4.2 is distributed only in the English language.
- The Stand-Alone and Genie versions of MGAU should not be run simultaneously on the same datasource.

ORDERING INFORMATION

- Model # S507C – Multi Group Analysis for Uranium V4.2.
- Model # S500C – Genie 2000 V3.2.1 or higher.

PERFORMANCE

Typical performance results for MGAU are shown in Tables 1 and 2. Table 2 shows results for samples that were measured in the presence of steel absorbers ranging from 4-8 mm. In each table the average performance is classified by a range of enrichments typical of standard applications. For each enrichment range several standards of known enrichment were analyzed and the average performance is shown for the analyzed spectra. The number of spectra analyzed in each range is also shown.

REFERENCES

1. R. Gunnink, W.D. Ruhter, P. Miller, et al., “MGAU: A NEW ANALYSIS CODE FOR MEASURING U-235 ENRICHMENTS IN ARBITRARY SAMPLES”, UCRL-JC-114713, Livermore, 1994.
2. A. Bosko, S. Philips, T. Gerent, and R. Gunnink, “MGAUV4.2: THE LATEST EVOLUTION IN THE MULTI-GROUP ANALYSIS CODE FOR URANIUM”, Proceedings of the 52nd Annual Meeting of the Institute of Nuclear Materials Management, Palm Desert, CA (2011).
3. A. Bosko, S. Croft, S. Philips, R. Gunnink, “IMPACT OF THE DETECTOR ENERGY RESOLUTION ON THE PERFORMANCE OF MGA AND MGAU ISOTOPIC CODES”, J Radioanal Nucl Chem, Vol 282, No3 (2009).
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