COOPERATION ON NONDESTRUCTIVE ASSAY ISOTOPIC ENRICHMENT MEASUREMENT SYSTEMS UNDER THE DOE/NNSA-ABACC SAFEGUARDS COOPERATION AGREEMENT

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ABSTRACT

The United States Department of Energy/National Nuclear Security Administration (DOE/NNSA) and the Brazilian-Argentine Agency for Accounting and Control of Nuclear Materials (ABACC) agreed to cooperate on the testing and evaluation of isotopic enrichment measurement software. The project is significant because it provides a regional forum for technical experts to evaluate and standardize isotopic enrichment measurement software used to verify operator declarations for enriched uranium. DOE/NNSA and ABACC initiated the project by establishing an Isotopics Measurements Working Group (IMWG) that will test existing software packages and provide guidance for standardizing and upgrading the software to broaden the applicability, improve the data quality, and ensure that software quality assurance objectives are being met. This paper describes the objectives and scope of the project, the structure and organization of the IMWG, the methods and procedures for testing and evaluating the various software programs, and the current development status of the IMWG activities.

INTRODUCTION

In 1994, DOE/NNSA and ABACC signed a technical cooperation agreement where both parties agreed to cooperate on research, development, testing, and evaluation of technology, equipment, and procedures in order to improve international nuclear materials safeguards technologies in South America. Under this agreement, DOE/NNSA provides ABACC with training and technical assistance on nuclear material control, accountancy, verification, and advanced containment and surveillance technologies. In the 12 years since this cooperation began, several projects were undertaken to improve measurement methods, safeguards approaches, and inspection procedures.

Under Action Sheet 14 (AS14), which was signed on April 18, 2005, ABACC and DOE agreed to cooperate on the testing and evaluation of isotopic enrichment measurement software. Currently, ABACC and DOE are using various versions of software and hardware to determine the isotopic abundances for uranium. Inconsistencies between the versions of the software have resulted in data discrepancies that often have to be manually corrected. The goal of AS14 is to evaluate the variety of isotopic software analysis packages that are currently used by DOE and ABACC to verify operator declarations for enriched uranium and provide guidance for standardizing and upgrading the software to broaden the applicability, improve the data quality, ensure that software quality assurance procedures are being met, and control the final product's distribution. AS14 does not include an evaluation of the commercial gamma spectroscopy acquistion codes that are used as input for various automated isotopic abundance and enrichment codes.

IMWG

To accomplish the objectives of AS14, ABACC and DOE established the IMWG to study methods and instruments used to perform isotopic measurements for uranium. The scope of the IMWG is to identify, test, and evaluate available gamma spectroscopy evaluation codes used to determine the isotopic abundance and enrichment of uranium samples. The tests and evaluations will identify the strengths and weaknesses of available codes and make recommendations for improving and standardizing software used to evaluate uranium spectra. The results of the study will provide guidance for development of a standard uranium spectral analysis software package that better meets the needs of the end user and is consistent with regional and international quality assurance requirements for the safeguards community.

The DOE and ABACC technical coordinating committee for AS14 developed a charter that defines the IMWG participants, mission and structure. The IMWG has two co-chairs for coordinating the technical work, one each delegated by DOE/NNSA and ABACC. The working group includes 15 technical experts from or associated with safeguards laboratories within Argentina, Brazil, and the United States. Technical experts from the European Commission Joint Research Center and the International Atomic Energy Agency (IAEA) may participate as observers. Once the working group publishes its findings, the group may evolve into an international forum where the software can be assessed and utilized beyond the regional context. At this point, the establishment of a Coordination Group may be required to replace the two working group chairs.

TEST PLANS

The IMWG devised effective test and evaluation plans that provide uniformity in the test and evaluation processes for each of the evaluated codes. The test plans identify all hardware, software, standards, methods, and procedures used to test and evaluate specific analysis codes at each lab. The tests will evaluate agreed-upon attributes for the various types of software that are being used to determine isotopic abundances for uranium. Each identified software package will be tested for the following: 1) versatility with respect to analysis of spectral files, 2) ease of use, 3) flexibility for variation of input and output parameters, 4) agreement with known standards, 5) ability to provide accurate results across a broad spectrum of matrices and sample densities and sizes, and 6) generation of accurate correction factors and proper error reporting. Appendix A provides more detail on the types of software that will be evaluated and the current version number of each software package.

Tests and evaluations will be conducted for two analysis techniques: 1) uranium enrichment and 2) uranium isotopics. Software packages that use the enrichment meter, peak fitting, and peak ratio methods will be evaluated for the uranium enrichment technique. The IMWG will also use peak ratio software for evaluation of uranium isotopics.

At the kick-off meeting held in August 2005 at ABACC Headquarters in Rio de Janeiro, Brazil, the technical experts defined the types of hardware that should be used during the evaluation. Subject matter experts from Los Alamos National Laboratory (LANL), Lawrence Livermore National Laboratory (LLNL), and Oak Ridge National Laboratory (ORNL) resolved additional issues concerning the hardware during a videoconference on 8 February 2006. A consensus was reached on the following hardware combinations:

- Sodium Iodide (NaI) system – detector 1 in. diameter x 2 in. length;
- High Purity Germanium (HPGe) system – detector type planar and/or coaxial;
- Cadmium Zinc Telluride (CZT) system – detector 1500 mm^3;
- Standards – The New Brunswick Laboratory Standard Reference Material-969 uranium oxide set of depleted, natural and enriched standards is the baseline reference material used for the measurements (additional primary or secondary standards may also be used);
- Collimators/shielding/attenuators etc. – Each laboratory will define its material types, geometrics and configuration and will inform other IMWG members for approval;
- MCA-166 – GBS-Elektronik GmbH[1] multi-channel analyzers (MCAs) will be used for collecting all photon spectra. Spectral information from HPGe detectors will be stored in 4096 channels, with gain adjusted for a bin width of 0.075 keV / channel (the default gain setting suggested by the Multi-Group Analysis Uranium (MGAU) software package). The spectra from NaI detectors will be stored in 512 channels, with gain adjusted for having the U235 – 186 keV peak at channel 300. Other MCAs may also be used within each laboratory's test plan;
- Standardized parameters will be used to the extent possible, and spectral results will be stored in ORTEC's '*.spc' file format; or WINSPEC-I '*.spe' file format;
- Spectra for the low-count-rate tests will be obtained by varying the source-to-detector distance;
- Spectra for high count rates will be obtained by varying the source-to-detector distance or by co-location of a ^{241}Am source with the uranium standard (where feasible);
- Spectra will be obtained from the standard sources with no attenuation and the same sources attenuated by the following materials: steel; aluminum; stainless steel; monel; and
- Count times should be based on obtaining adequate counting statistics to reach the analysis uncertainty goals for portable MCA systems outlined in the International Target Values[2] (ITV).

For the first test plan, each laboratory is primarily responsible for testing the software packages listed in Table 1. Individual laboratories may be asked to analyze spectra collected at another laboratory. The spectra will be available for each of the other participants for duplicate evaluation with other independent codes.

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[1] This is the MCA primarily used by ABACC.

[2] See Millennium Edition of International Target Values that is a corrected report of an edition originally published by the IAEA as report STR-327 dated April 2001 [http://www.inmm.org/topics/contents/JNMMPaperITV.pdf].

Table 1. Software to be tested by each laboratory for the first test plan

	ORNL	LLNL	LANL	ABACC
Enrichment meter method	WinU235			Win U235 WinUF6 MGAU
Peak fitting method	NaIGEM	--	--	NaIGEM
Peak ratio method	U/Pu, MGAU	MGA++,U235HI	PC-FRAM	--

The results of the software analyses are tabulated in spreadsheet format. At a minimum, this spreadsheet will contain data to determine the following: ^{235}U Enrichment (wt. %), uncertainty (1 sigma), % error, full width half maximum (FWHM), % dead time, and the peak fitting parameters used.

TEST PLAN STATUS

The laboratories supporting the IMWG have initiated implementation of their test plans. Once individual laboratory tests are complete, the IMWG members will meet at a designated laboratory, where the co-chairs and laboratory experts will compile all results from the tests and coordinate analysis and evaluation of the test results. AS14 will remain open through fiscal year 2008, or until all activities included in the action sheet are completed. The initial status for the first round of testing for each of the laboratories is provided below.

The test plan for LLNL utilizes three HPGe systems, two different ORTEC MCAs, three different sets of standards, and various thicknesses of aluminum and stainless steel absorbers. To date, LLNL has collected and analyzed more than 1000 spectra using 0.075keV/channel gain at optimal geometry. The spectra were saved in both .spc and .spe formats.

The primary purpose for the LANL measurements is to evaluate the performance of the software codes as a function of peak resolution and peak shape. LANL set up the data acquisition systems to obtain spectra that vary in peak shape charachteristics (e.g., variations in the FWHM or resolution and variations in the low tails of the peak). LANL used two HPGe detector systems (one planar and one coaxial), the ORTEC DSPEC Plus MCAs, and eight sets of standards. Variations in the rise time of the DSPEC Plus from 0.2 up to 8.0 µs were made to obtain spectra with various peak shape characteristics. In order to obtain spectra with various shapes, they used a rise time of 4.0 µs and manually adjusted the PZ to produce peaks with low-energy tails of various sizes.

ORNL is conducting measurements with two sets of standards (0.31 wt.% to 93.17 wt.% U^{235}). The instrumentation configuration includes three NaI detectors system and two HPGe (one planar and one coaxial) detectors systems in various combinations with the following MCAs; MCA-166, ORTEC® DART, ORTEC® digiDART, and Canberra InSpector 2000. A set of aluminum, iron and monel absorbers are used to simulate various container materials. To date, approximately 1800 spectra have been collected.

ABACC is conducting measurements with two NaI detectors system and two HPGe (planar) detectors systems, the MCA-166 – GBS Elektronik MCA, one set of SRM-969 standards, and a set of aluminum, iron and monel absorber materials. To date, more than 500 spectra have been collected and analyzed.

The results from gamma spectra are being collected and a data bank of these spectra is already available in a shared file server for the IMWG participants. Analyses of these spectra applying the various software codes are in process. By the end of this fiscal year, a report will be completed that consolidates the results of this first test plan, after which the IMWG participants will meet to discuss the results. Based on the conclusions of the first test plan, the additional actions will be recommended and a second round of test plans will be proposed.

CONCLUSION

Through AS14, the DOE/NNSA and ABACC agreed to cooperate to test and evaluate uranium isotopic/enrichment measurement software currently used by both institutions. For completion of tasks defined by AS14, DOE/NNSA and ABACC established an IMWG, developed a charter for the working group, and started the execution of independent test plans for each of the participating laboratories. The IMWG will evaluate and approve all tests conducted under AS14. The results of the tests and evaluation will be published in a final report that will include recommendations for standardization. In addition, AS14 will promote dialogue within the international safeguards community to develop and improve gamma ray spectroscopy codes in a controlled and transparent manner.

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Appendix A

Enrichment Software Comparison Chart									
Analysis Type	Analysis Method	Detector Type	Software Systems	Version	Vendor	Platform	Max. Wall Thick (Steel)	Fresh Material	MOX
Uranium Enrichment	Enrichment Meter Method	NaI CZT HPGe	WinU235	1.00.0011	GBS	98/2000/XP or NT	15 mm	Yes	Confirm U235
			WinUF6	1.00.0014	GBS	98/2000/XP or NT			
			IMCA	2.0b	Canberra	98/2000/XP or NT			
	Enrichment Meter Method	HPGe	U-Pu*	3.2	Canberra	98/2000/XP or NT	15 mm	Yes	Confirm U235
			MGAU	4.0	Ray Gunnink	Windows			
	Peak Fitting Method	NaI	NaIGEM	1.52a	Ray Gunnink	Windows	15 mm	Yes	Confirm U235
	Peak Ratio Method	CZT	CZTU	1.0	ORTEC	98/2000/XP	5 mm	No	Verify/ Confirm U235
			MGAU	4.0	Ray Gunnink	Windows			
Uranium Isotopics	Peak Ratio Method	HPGe	U-Pu*	3.2	Canberra	98/2000/XP or NT	5-15 mm	No	Verify/ Confirm U235
			U235HI	1.1	LLNL	98/2000/XP or NT			
			MGAU	4.0	Ray Gunnink	Windows			
			PC-FRAM	4.2	LANL	98/2000/XP or NT			
				4.3	ORTEC	98/2000/XP or NT			
				4.4	Canberra	98/2000/XP or NT			
			Isotopic	3.10	ORTEC	98/2000/XP			
			MGA++	1.06	ORTEC	98/2000/XP or NT			
				1.2	LLNL	98/2000/XP or NT			