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Abstract

Under the U.S.-Russian Material Protection, Control and Accounting (MPC&A) Program, the Material Control and Accounting Measurements (MCAM) Project has supported a joint U.S.-Russian effort to coordinate improvements of the Russian MC&A measurement system. These efforts have resulted in the development of a MC&A Equipment and Methodological Support (MEMS) Strategic Plan (SP), developed by the Russian MEM Working Group. The MEMS SP covers implementation of MC&A measurement equipment, as well as the development, attestation and implementation of measurement methodologies and reference materials at the facility and industry levels. This paper provides an overview of the activities conducted under the MEMS SP, as well as a status on current efforts to develop reference materials, implement destructive and nondestructive assay measurement methodologies, and implement sample exchange, scrap and holdup measurement programs across Russian nuclear facilities.

Introduction

For over a decade, the U.S. DOE has provided support to the development and implementation of safeguards measurements of nuclear material at Russian nuclear facilities under the U.S. – Russian Material Protection, Control and Accounting (MPC&A) agreement. Activities supported through this cooperation include implementation of MC&A measurement equipment, as well as the development, attestation and implementation of measurement methodologies and reference materials. These activities are currently coordinated by the U.S. MC&A Measurements (MCAM) Project and the Russian MC&A Equipment and Methodological Working Group (MEM WG).

The MCAM Project is part of the U.S. DOE International Material Protection and Cooperation Program's (NA-25) Office of National Infrastructure and Sustainability (ONIS). The MCAM team works closely with other U.S project teams involved in upgrading Russian nuclear sites, as well as with other teams within ONIS involved in development of measurement related regulations and inspections.

The MEM WG was created by Minatom in 2000 and was restructured by Rosatom in 2005. Presently, the MEM WG includes representatives from the seventeen facilities identified in Table 1, as well as two Rosatom Departments: the Department of Nuclear Materials and Department of State Secrets and Information Security.

Current activities are conducted under the framework of the MC&A Equipment and Methodologies Support Strategic Plan (MEMS SP) which was developed by the MEM WG with support and collaboration from the MCAM team. The objective of the MEMS Strategic Plan is to facilitate implementation of modern equipment and methodologies within the US-Russian MPC&A program at both the Rosatom (agency) and facility levels to lower the risk of theft or unauthorized use of nuclear materials and to increase effectiveness of the MC&A of nuclear materials. The MEMS SP identifies the status and needs in the areas of equipment, measurement methodologies and reference materials, Rosatom wide programs, regulatory documents, information support and training needed to establish an effective MC&A system. The MEMS SP is updated periodically by the MEM WG and reviewed by representatives of all organizations during an annual meeting.

Table 1. Organizations represented in MEM WG

VNIIA	All-Russian Institute of Automatics (Coordinator)
VNIIEF	All-Russian Scientific Research Institute of Experimental Physics
VNIINM	Bochvar All-Russian Scientific Research Institute for Inorganic Materials
VNIITF	All-Russian Scientific Research Institute of Technical Physics
MCC	Mining and Chemical Combine
NCCP	Novosibirsk Chemical Concentrates Plant
RIAR	Research Institute of Atomic Reactors
Luch	Luch Scientific Production Association
Mayak	Mayak Production Association
MSZ	Elektrostal Production Association Machine Building Plant
KRI	Khlopin Research Institute
Rosenergoatom	Concern for the Production of Electrical and Thermal Energy at Nuclear Power Plants
SGChE	Siberian Group of Chemical Enterprises
TVEL	TVEL Fuel Company
UEIE	Ural Electrochemical Integrated Enterprise
IPPE	Institute of Power Physics and Engineering
ECP	Electrochemical Plant

Prior to development of the MEMS SP, the U.S. DOE supported activities to improve measurement methods and reference materials at Russian facilities through collaboration with individual facilities and technical working groups that are now coordinated within the MEM WG. This paper will provide a summary of the major activities that have been completed to date through this cooperation as well as the current status of ongoing and planned future activities.

Reference Materials and Sources

Reference materials (RMs) are a critical element of the nuclear material measurement process. RMs are the foundation for calibration and operational checks of the measurement equipment used to determine quantitative and qualitative characteristics of nuclear materials required for control and accountability. Russian regulations require facility measurement programs to use RMs certified at the state (Rank 1) or agency (Rank 2) level whenever the measured values of special nuclear material are intended to be used for formal material accountancy purposes. The U.S. DOE has focused support in the area of RMs towards infrastructure necessary to develop RMs, as well as development and certification of primary RMs for assay of uranium and plutonium for MC&A purposes. A summary of the RMs developed with U.S. DOE support under the MCAM project is provided in Table 2.

Prior to restructuring of the MEM WG in 2005, the U.S. DOE provided support to a Reference Materials Working Group (RM WG), which was tasked with assessing the needs and capabilities of Russian nuclear facilities to develop reference materials and sources used to calibrate and demonstrate quality control of measurement systems. This RM WG coordinated the development of several RMs that were identified as being of highest priority for establishment of effective MC&A systems at Russian facilities. Specifically, reference materials used for calibration and quality control of destructive analysis measurements of uranium and plutonium isotopic composition and total mass were developed, certified and distributed to facilities in 2002.

Reference materials for calibration and quality control of gamma-ray non-destructive assay (NDA) measurement systems used to determine uranium enrichment and plutonium isotopic composition, primarily intended for use by inspectors, were also developed and certified with U.S. DOE support. Distribution of the plutonium NDA RMs took place in 2004-2005, and distribution of the uranium NDA RMs were completed in 2009. Sources and standards for testing and calibration of radiation monitors, including low mass standards containing uranium, plutonium as well as alternative gamma-ray and neutron emitting sources, were also developed with the coordination of the RM WG from 1999-2005, with delivery to facilities in 2004.

In 2002 work began on the development of Pu-242 RM spikes for measurement of Pu utilizing the Isotope Dilution Mass Spectroscopy (IDMS) method. These RMs were delivered to interested Russian facilities in 2005.

The version of the MEMS SP developed in 2005 identified needs for several additional RMs. These were further defined in 2007 when the MEM WG developed a plan for manufacturing and attesting RMs. This plan identified RMs that were needed within Russian facilities for day-to-day operation, as well as higher level RMs needed for measurement control of destructive assay systems and traceability.

Based on this plan, the MEM WG is coordinating the development of several RMs with support of the U.S. DOE. Specifically, 2nd Rank (agency) U_3O_8 RMs have been manufactured and attested, and are currently being delivered to Russian facilities. Activities to develop corresponding 2nd rank PuO_2 RMs are also underway with U.S. DOE support. Technical requirements for the RMs have been developed and the manufacturer of the materials being finalized. Additionally, technical requirements for U-233 RM spikes utilized for IDMS measurement of uranium mass fraction have also been developed, and manufacturing of the RMs is underway. To provide guidance to facilities in the production of facility specific working reference materials, the MEM WG has also developed and distributed a guidance document on the subject.

Based on a review performed in 2008, the need for additional standards and sources to test and calibrate radiation monitors utilized at Russian nuclear facilities was identified. In 2009, with support from the U.S. DOE, the MEM WG began activities to further define this need and establish technical requirements for the sources. These sources are planned for manufacture and distribution in 2010-2011, beginning with sources not containing special nuclear material.

Activities on development and implementation of an inter-laboratory sample exchange program to enhance traceability of measurement results and improve quality control were initiated in 2008, based on the U.S. DOE program implemented by New Brunswick Laboratory. Uranium samples to be utilized in the first exchange are being manufactured, and technical specifications for the plutonium samples are being developed. The first exchange of samples is expected in late 2010.

Table 2. Summary of RMs developed with support of the U.S. DOE MCAM project team

Material	Amount	Delivery	Manufacturer	Deployment
U_3O_8 for multiple analytical chemistry methods of uranium (U) assay	2000 units total,10 grams each for distribution, DA	2004	VNIINM/UEIE	18 Russia facilities with enriched U
PuO_2, for multiple analytical chemistry methods	500 units, 1 gram each, DA	2007	VNIINM/IPPE	All Russian nuclear facilities (8+) with Pu
PuO_2, mass spectrometry National reference material (low burnup)	200 units of 1/4 g each, DA	2007	VNIINM/IPPE	All Russian nuclear facilities (8+) with Pu
PuO_2, National reference material for mass spectrometry (high burnup)	200 units of 1/4 g each, DA	2007	VNIINM/IPPE	All Russian nuclear facilities (8+) with Pu
U_3O_8 NDA enrichment standards	15 sets, 5 enrichments per set, ~200 grams UO_2 per standard, NDA	2010	RIAR	15 Russian facilities with enriched U
U_3O_8 NDA enrichments standard	1 set, 5 enrichments	2010	VNIINM	Remain at Bochvar
PuO_2NDA isotopic (low burnup [%Pu240])	11 sets, 5 isotopic compositions, < 15 grams/set, NDA	2004	IPPE	11 Russian facilities with Pu
Pu-242 Spike for destructive analyses	4-5 milligrams in each of 200 ampoules, DA	2005	KRI	VNIIEF, IPPE, Mayak, KRI, SGChE, MCC, RIAR, VNIINM
Radiation Monitor Standards for calibration	24 Uranium + 34 Cesium surrogates, and 21 Curium neutron surrogates, NDA	2004	RIAR	All non-serial production nuclear facilities
U_3O_8 standards for DA of uranium (2nd rank)	~1,800 samples in 10g vials	2010 (expected)	VNIINM	10 primary U processing facilities
PuO_2standards for DA of Pu mass fraction and isotopic ratios (2nd rank)	~300 samples of 1g total Pu each	2011 (expected)	TBD	All Russian nuclear facilities (8+) with Pu
U-233 spike for IDMS measurement of uranium	500g	2011 (expected)	KRI	TBD
Portal Monitor Standards for calibration	TBD	2011 (expected)	Various	TBD

Measurement Methodologies

Measurement methodologies (MMs) and procedures are also critical element of the nuclear material measurement process. Methodologies are the procedures by which a site operates MC&A measurement equipment in accordance with established guidelines to determine quantitative and qualitative characteristics of nuclear materials required for control and accountability. Similar to the Department of Energy's requirement that measurements be qualified, Russian regulations require that all measurement results used to define accountability values be attested to the industry level or higher. MMs used to confirm the quantity and type of nuclear material only need facility-level attestation. .

Prior to implementation of the MEMS SP, the U.S. DOE provided support for the assessment of MC&A equipment and development of MMs primarily through direct interactions with Russian facilities. In general efforts by the MCAM project team were focused on establishing infrastructure needed to develop RMs described earlier. Specifically, support was provided for the development of several destructive assay MMs and techniques needed to manufacture and attest the state level U_3O_8 and PuO_2 RMs.

In 2007, the MEM WG performed an assessment of the MMs needed at Russian nuclear facilities for an effective MC&A system, and updated the MEMS SP to reflect these needs. Additionally, the MM needs were prioritized by their intended use (i.e. accounting vs. confirmatory), number of facilities needing the MM, and attractiveness of material being measured. In coordination with the U.S. DOE MCAM team, activities to develop and attest those MMs most important to completion of the MPC&A Program objectives have begun for several of these MMs. A status of MMs identified as being needed by the MEM WG is provided in Table 3.

MM development activities vary from facility specific implementation to Rosatom (industry) or State level attestation. Facility specific implementation support is primarily provided through direct interaction of U.S. DOE upgrade project teams and Russian facilities. The MEM WG coordinates these facility level activities with planning and review activities at the industry and state level. For each MM, a technical group is formed consisting of specialists from different Rosatom enterprises to provide the methodological and metrological support needed to implement the MMs at Rosatom enterprises.

Support has also been provided from the U.S. DOE for assessing measurements of returnable waste/byproducts (scrap) at Russian processing facilities. Based on this assessment, materials of high attractiveness were identified, and pilot efforts to improve measurements of scrap at NCCP and Mayak are underway. Coordination for these activities is provided by the MEM WG with support from the U.S.DOE. Due to the high level of impurities and inherent inhomogeneity of many of these materials, efforts are expected to continue through 2012 to develop appropriate RMs and MMs for measurements of these materials.

In 2008, similar activities were initiated to assess capabilities and improve the measurement of hold-up at Russian processing facilities. Based on this assessment, an international workshop on hold-up will be hosted by the MEM WG with U.S. DOE support in October, 2010, with efforts to improve MMs and training on hold-up measurements to take place in 2010-2012.

Table 3. Summary of activities to develop and attest MMs identified as needed by the MEM WG

Activity	Status	Start Date	Expected Completion Date
Development and attestation of MM for measuring U-235 mass using neutron coincidence counters.	Ongoing	Apr-07	Jan-12
Development and attestation of MM for measuring Pu isotopic composition using high resolution spectrometers (Canberra ORTEC and Green-Star) and FRAM.	Ongoing	Apr-07	Jan-12
Development and attestation of measurement methodology (MM) for measuring U isotopic composition using high resolution spectrometers (Canberra ORTEC and Green-Star) and FRAM.	Ongoing	Apr-07	Jan-12
Adaptation of industry-level measurement methodologies (MM) for measuring Pu isotopic composition (including materials containing Neptunium) using high resolution gamma spectrometers (Canberra and ORTEC) with MGA.	Ongoing	Apr-07	Jan-12
Adaptation of industry-level measurement methodologies (MM) for measuring U isotopic composition using high resolution gamma spectrometers (Canberra and ORTEC) with MGAU.	Ongoing	Apr-07	Jan-12
Development and attestation of MM for measuring Pu mass using neutron coincidence counters.	Ongoing	Apr-07	Jan-12
Development and attestation of measurement methodology for measuring plutonium mass fraction using coulometer PIK-200.	Ongoing	Apr-07	Jun-11
Development and attestation of IDMS MM for measuring U content.	Ongoing	Sep-08	Dec-10
Development and attestation of IDMS MM for measuring Pu content.	Ongoing	Sep-08	Dec-10
Development and attestation of MM for measuring U-235 content in different containers with UF6 and in-volatile materials using high resolution spectrometers (Canberra and ORTEC) and IMCA.	Planned	Jan-11	Dec-12
Development and attestation of MM for measuring U enrichment using foreign-made low resolution spectrometers.	Ongoing	Sep-09	Jun-11
Development and attestation of MM for identification of U and Pu using Russian-made low resolution spectrometers.	Ongoing	Sep-09	Jun-11
Development and attestation of MM for identification of U and Pu using foreign-made low resolution spectrometers.	Ongoing	Sep-09	Jun-11
Development and attestation of MM for mass spectrometric measurement of Pu isotopic composition.	Planned	Sep-10	Jun-12
Development and attestation of MM for ICP-MS measurement of U isotopic composition	Planned	Sep-10	Jun-12
Development and attestation of MM for ICP-MS measurement of Pu isotopic composition	Planned	Sep-10	Jun-12
Development and attestation of MM for mass spectrometric measurement of U isotopic composition.	Planned	Sep-10	Jun-12
Development and attestation of MM for alpha-spectrometric measurement of U and Pu isotopic content.	Ongoing	Sep-09	Jun-11

Measurement Equipment

Through the MPC&A program, significant amounts of equipment have been provided to Russian nuclear facilities to improve MC&A. The MEM WG, and prior to its formation its coordinating institute VNIIA, has provided assessment and review of both Russian and foreign made MC&A measurement equipment. Specifically, three editions of a catalog of MC&A equipment has been developed with U.S. DOE support. A review of the operational and maintenance status of MC&A measurement equipment has also been developed. Additionally, to support the needs identified in the MEMS SP, a comprehensive assessment of the status of and needs for MC&A measurement equipment was performed by the MEM WG in 2006.

Presently, activities to identify and test Russian-made equipment that could be used to replace foreign made systems or improve MC&A performance are underway, including the testing of a Russian made Thermal Ionization Mass Spectrometer (TIMS) and a Russian made liquid level meter. It is the view of both the MCAM project team and MEM WG that collaborative testing of Russian made MC&A measurement equipment to allow their implementation in Russian facilities is necessary to ensure the future sustainability of MC&A measurement equipment in Russia, as is establishment of the capability to maintain the equipment. Activities towards both ends are currently underway.

In addition to the development and publishing of the assessments and equipment catalogs identified above, with support from the U.S. DOE the MEM WG had the Handbook of Nuclear Safeguards Measurements Methods (NUREG/CR-2078) and the Passive Nondestructive Assay of Nuclear Materials manual translated into Russian and published.

Conclusion

A summary of the major activities related to MC&A measurements completed to date through collaboration between the MEM WG and MCAM project team under the U.S.-Russian MPC&A cooperation has been provided. While significant activities have taken place to develop and implement the infrastructure needed for an MC&A system at Russian facilities based on effective MC&A measurements, significant work remains to be completed.