Department of Energy
Washington, DC 20585

January 19,2010

The Honorable John E. Mansfield
Vice-Chairman
Defense Nuclear Facilities Safety Board
625 Indiana Avenue NW, Suite 700
Washington, DC 20004-2901

Dear Mr. Vice-Chairman:

This letter is to inform you of the completion of Commitment 5.2.6, comprising Commitments 5.2.6.1 through 5.2.6.8, in the Department of Energy (DOE) *Implementation Plan for Defense Nuclear Facilities Safety Board Recommendation* 2007-01, dated October 24,2007.

Commitments 5.2.6.1 through 5.2.6.8 identify good practices with respect to training and qualification, design requirements for new facilities and equipment, standards for conducting *in situ* NDA holdup measurements, implementation standards, research and development, roles and responsibilities of NDA personnel, and oversight. A report documenting the good practices is attached.

If you have any questions or need further information, please contact me at (301) 903-4218.

Sincerely,

Richard H. Lagdon, Jr.
Chief of Nuclear Safety
Office of the Under Secretary
U.S. Department of Energy

cc:
K. Johnson, S-3
J. Poppiti, EM-21
M. Whitaker, HS-1.1
S. Petras, HS-1.1

Enclosure

CHIEF OF NUCLEAR SAFETY

CNS

TECHNICAL PAPER

TO SHARE AND DISCUSS NUCLEAR SAFETY ISSUES OF INTEREST

DNFSB Recommendation 2007-1, *Safety-Related* In Situ *Nondestructive Assay of Radioactive Materials*

Commitment 5.2.6 of the Implementation Plan:

Identify Good Practices Discovered During the State of the Practice Reviews with Respect to Training and Qualification, Design Requirements for New Facilities and Equipment, Standards for Conducting *In Situ* NDA Holdup Measurements, Implementation Standards, Research and Development, Quality Assurance, and Oversight

Introduction

The Department of Energy (DOE) issued the *Implementation Plan for Defense Nuclear Facilities Safety Board (DNFSB) Recommendation 2007-01*, Safety-Related *In Situ* Nondestructive Assay of Radioactive Materials (DNFSB Recommendation 2007-01), dated October 24, 2007. The Implementation Plan outlines a multi-task process to be carried out by a nondestructive assay (NDA) Technical Support Group (TSG) to address the issues raised in Recommendation 2007-01. A portion of that process involved the evaluation of the extent-of-condition of *in-situ* NDA programs in select DOE facilities managed by the Office of Environmental Management (EM) and the National Nuclear Security Administration (NNSA). These evaluations followed lines of inquiry (LOIs) developed by the TSG team members. The reports documenting this evaluation were completed at the end of October 2009. The purpose of this report is to document good practices observed both within the Department and commercially for implementation of *in-situ* NDA training and qualification.

The primary goal of the TSG site state-of-the-practice reviews is to establish a baseline for future complex-wide development and program enhancements of *in-situ* NDA. The first step in the continuing process is to document good practices in the topical areas required by the DOE Implementation Plan for DNFSB Recommendation 2007-1, understanding that there will be good practices that can be applied in multiple areas. These areas are 1) training and qualification; 2) design requirements for new facilities and equipment; 3) standards for conducting NDA holdup measurements; 4) implementation of standards; 5) research and development; 6) quality assurance; and 7) oversight. The individual reports will be followed by a final rollup report combining the individual topical area reports. This report, and the rollup good practices report, will not tie information to individual sites or facilities.

This report documents good practices (and, in some cases, best practices) observed during the individual state-of-the-practice reviews using information that was obtained during interviews covering the LOIs, document reviews, facility tours, work practice observations, follow-up questions, and presentations. The assessment of commercial good practices was primarily limited to observations of commercial vendors performing NDA at DOE facilities and conference interactions, including organizations such as ASTM International and the Institute for Nuclear Materials Management (INMM). Additionally, the TSG will supply good practices that, although they may not have been observed, are good practices from the experience of TSG team members. The additional good practices are presented here for consideration for future *in-situ* NDA program development and enhancement. Good practices in these reports are not intended to be prescriptive. Some good practices may be more readily applied to the issues at a particular site, but may not be the best approach for all sites. In several cases, good practices are possible solutions to issues such that one good practice may preclude the need for others. Practices that are considered most effective in the development of a technically strong *in-situ* NDA program are listed as best practices. These good practices do not attempt to address health and safety concerns associated with performing *in-situ* measurements.

Task 5.2.6.1: Training and Qualification Good and Best Practices

An NDA holdup training and qualification program should be designed to equip NDA holdup personnel to make reasonable quantitative estimates of fissile holdup masses in processing equipment and systems. The measurement needs of each facility are unique, and the training and qualification program should be tailored to meet the specific demands of a given facility. An NDA holdup group is typically composed of a diverse pool of personnel with differing education levels and skills, but who work collectively to complete all the requirements of a field measurement and analysis program. A well-developed training and qualification program takes into consideration the theoretical concepts, skills, and experience needed to make sound measurement judgments and assumptions. The good practices listed below have been adapted from recommendations given in ASTM C 1490-04, *Standard Guide for the Selection, Training and Qualification of Nondestructive Assay (NDA) Personnel*. The best practices listed have been compiled from site observations.

Training

Best Practices

- Additional training for NDA holdup professionals includes courses offered by commercial vendors and instruction by personnel in related disciplines such as material control and accountability (MC&A), nuclear criticality safety (NCS), production operations, waste management, quality, and statistics.
- Crosstraining is accomplished with organizations (e.g., MC&A and NCS) that rely on NDA holdup measurement data by sending designated representatives from these departments to a holdup training course.
- The supervisor of the NDA holdup group has attended a formal holdup measurement course.
- Training in the use of the software employed by the facility to acquire field data, calculate holdup quantities, and calibrate instruments is provided on an appropriate level to all NDA holdup personnel.
- Testing is included in the formal holdup course to verify and document understanding of the measurement theory and applications presented.

Good Practices

- Suitable training is developed for each category of NDA holdup personnel within a holdup program to enable each individual to perform the specific roles, duties, and tasks required by his or her position.
- The training program consists of a combination of classroom-style and on-the-job training, in compliance with training industry standards.
- The training for NDA holdup professionals includes a formal course taught by a national laboratory.
- A formal on-the-job training program is well defined and includes instruction by NDA holdup professionals and mentoring by experienced holdup personnel.
- Training is periodically updated with an ongoing training course that incorporates changes in procedures, instrumentation, and calculation methods and includes lessons learned.

Qualification

Best Practices

- Each individual's progress through a training program is tracked by use of qualification guides or checklists.
- Task-specific qualifications are defined for particularly complex tasks that capture the level of understanding needed for successful completion of the task.
- NDA holdup professionals are required to measure a holdup standard masked as an unknown on an annual basis to demonstrate their proficiency in quantitative measurements.

Good Practices

- Qualification requirements for each NDA holdup position are formally defined and take into consideration the authorities, duties, and responsibilities of each position.
- Qualifications are evaluated and documented using formal testing and demonstration of skills.
- Periodic renewal of qualifications is required for complex tasks; the frequency and the required performance demonstration is defined and documented.
- Records are maintained to document training participation and qualifications held.

Task 5.2.6.2: Design Requirements for New Facilities and Equipment

DNFSB Recommendation 2007-1 states that the "lack of design requirements for new facilities that would facilitate accurate holdup measurement" is one of the "three main issues [that] dominate the current technical and regulatory landscape regarding *in situ* NDA measurements." Additionally, the Recommendation elaborates on the issue:

> *Lack of Design Requirements for New Facilities*–Many of the problems that require *in situ* NDA to determine radioactive material holdup arose because facilities were designed and built before the need for NDA technology was evident. As a result, no consistent attempt was made to design facility systems to minimize holdup or facilitate its measurement. This historical trend should not be repeated in new facilities. The necessity of monitoring radioactive material holdup must be considered in the design of new facilities. For example, locations for monitoring can be selected during the design phase on the basis of the most likely locations for holdup to occur. Calibrations can then be performed at these locations *before* the facility begins operations to provide a baseline for future NDA measurements. Facilities can also be designed to minimize holdup in areas where it may be of concern.

Note: Two of the three sites observed had little or no design of new equipment or facilities underway. Consequently, observations at those two sites were based on historical design activities and not on current practice. No commercial equipment or facility design activities are included in this report.

Best Practices

- Effective communications between the NDA Holdup staff and the design engineers during the design and review process improves the ability for effective holdup minimization and measurement of the as-constructed facility and equipment.
- Ensure a high level of cooperation and communication between operations, engineering, criticality safety, and NDA measurement personnel during project conception and design.
- Electronic drawings mapping the measurement points are especially useful in areas of complicated piping.
- Assign knowledgeable NDA individuals to serve on or assist the design team for new equipment and facilities.
- Ensure that as-built drawings for Holdup purposes are confirmed with system engineers or visual inspection prior to use.
- Ensure that project and engineering procedures require the involvement of the various customer disciplines (e.g., NDA Holdup) at the conceptual stage and at the major design review milestones to define needs and requirements and to implement those needs and requirements as the design progresses.
- Ensure that the change control process requires NDA Holdup subject matter expert (SME) involvement to ensure NDA requirements and efficiencies are adequately incorporated.
- Ensure close communications between the process engineering, design engineering, nuclear criticality safety, and NDA Holdup staff for all design options that could impact holdup accumulation or measurement.

Proposed Best Practices

The TSG recommends the following best practices as components of a robust engineering and design program to ensure quality NDA and holdup measurements for new equipment and facilities, although they were not necessarily observed or fully implemented during the site visits.

Equipment and Facility Design Considerations:

- Designs incorporating lessons learned from current nuclear material operations.
- The use of engineered features such as filters to prevent accumulation, thereby minimizing the reliance on after-the-fact measurement as a means of control.
- Eliminate or minimize traps or low points that could contribute to accumulations.
- Ensure that new equipment and facility designs support operational methodologies that minimize the generation of dusts or mists that could lead to holdup accumulations.
- Ensure that potentially exposed surfaces can be readily cleaned to minimize residual holdup; i.e., provide a surface finish as specified in ASTM Standard A480#4, *Standard Specification for General Requirements for Flat-Rolled Stainless and Heat-Resisting Steel Plate, Sheet, and Strip*.
- Ensure that equipment and facility designs allow access to measurement points to ensure personnel safety.
- Ensure that measurement ports are accessible for measuring holdup on heavily shielded equipment or gloveboxes.

- Ensure that cleanout ports and access points are provided at accumulation points in the existing facility design.
- Minimize the potential for holdup accumulations by designing equipment without ledges and crevices where material could accumulate and that avoids dust and mist production, while considering source filtration and human factors engineering.
- Ensure that filter media are appropriate to minimize the transport of dusts or mists to downstream ductwork, piping, and systems that could require holdup measurement.
- Consider ultimate decontamination, decommissioning, and demolition methodologies and NDA holdup measurement needs.
- Ensure that joints and crevices have been sealed to prevent accumulations and collection of material.
- Minimize background radiation from adjacent equipment and processes by providing shielding or distance from proposed measurement points.
- Ensure that piping geometry is designed to provide a simplified field of view (e.g., minimized overlap or bundling) for holdup measurements; or, if space limitation or process design requires the close confinement of piping, ductwork, or system components, that placement allows for holdup measurements.

Analysis Considerations:
- Utilize NDA holdup measurements to support arguments of incredibility or to validate the assumptions in the nuclear criticality safety analyses (as opposed to the primary controls for criticality safety).
- Consider alternative methods for positively controlling or preventing the inadvertent accumulation and transport of fissile material rather than relying on after-the-fact measurement of undesirable accumulations.
- Ensure that process materials are well-characterized to enable the application of proper geometrical models and assignment of appropriate attenuation correction factors used in holdup measurement calculations, including extraneous process materials (e.g., oils).

Pre-start Considerations:
- Ensure that as-built drawings accurately reflect construction materials, material configurations, material thicknesses, and actual installation.
- Ensure that new and modified designs receive a Design Verification Review that includes walkdowns by the NDA Holdup staff.
- Ensure that the as-built installation was actually constructed to meet the design requirements for NDA Holdup measurements.
- Ensure that baseline or background measurements are made on required holdup measurement locations before operations commence.
- Establish a plan for initial holdup measurement frequencies and locations before operations commence.
- Ensure that the initial measurement frequency is based on historical accumulation data for previous or similar systems. Frequency may be modified based on actual accumulation experience.
- Ensure that proposed measurement locations provide sufficient space for placement of NDA instruments.

Task 5.2.6.3: Standards for Conducting NDA Holdup Measurements

DNSFB Recommendation 2007-1 points to a lack of standardization as a root cause of some sites making poor *in-situ* NDA measurements, as excerpted below.

> *Lack of Standardization*-DOE has not established requirements or guidance for performing *in situ* measurements in its Directives system. While the Board recognizes that measurement techniques can be highly location specific, a requirement to follow methods outlined in national consensus standards when performing in situ NDA measurements would reduce the errors and uncertainty of results. Commercial guidance for NDA is available in a series of standards published by the American Society for Testing and Materials (ASTM). This series addresses good practices for performing NDA measurements, methods for performing specific types of NDA measurements (for example, ASTM C-1133-03, NDA of low-Density Scrap and Waste by Segmented Passive Gamma Ray Scanning), and training and qualification of NDA personnel. While this guidance has been used informally at some sites, DOE has not required its use for NDA measurements.

DNSFB Recommendation 2007-1 states, in paragraph 2B.:

2. Establish requirements and guidance in a DOE directive or directives. The requirements and guidance should focus on *in situ* NDA programs that are used to demonstrate compliance with nuclear safety limits. Particular issues to be addressed should include…

    B. Application of standard protocols and methodologies, such as those given in the national consensus series issued by ASTM, for performing NDA measurements.

Standard methods are lacking in measurement techniques, interpretation of measurement data, estimating measurement uncertainty, and training and qualification programs for personnel. There is no standard approach for performing and managing holdup measurements. Significant variations in material types and deposit configurations and other variables often complicate standardization of holdup measurement methods. There is no agreed-upon method for reporting results to avoid confusion among stakeholders and measurement experts. One result is that sharing of information between entities is difficult and inconsistent. This impedes progress in solving measurement problems and hinders the application of lessons learned.

There is also a perception of conflicting requirements or guidance between and within different agencies and stakeholders. These perceptions may arise from a lack of knowledge and understanding of NDA technology capabilities and their limitations. Most of the confusion associated with an *in-situ* holdup measurement result is in regard to the measurement uncertainty and how stakeholders should interpret that uncertainty. There is also evidence that stakeholders combine the gram values with the uncertainty to obtain a single value to meet their intended purpose, but other stakeholders take the "new" value as the assay result and further apply their own manipulation of the already-altered data, potentially resulting in inappropriate use of the original data.

Inadequate quality assurance programs and inconsistencies in technical terminologies and definitions can lead to failure to meet stakeholder needs. Organizations and sites often interpret and define various holdup terminologies and quality objectives internally. Addressing this lack of standardization in holdup measurement terminology and requirements throughout the nuclear community and between their stakeholders is an important undertaking.

Currently, only one consensus standard exists that explicitly deals with NDA holdup measurements: ASTM C1455, *Standard Test Method for Nondestructive Assay of Special Nuclear Material Holdup Using Gamma-Ray Spectroscopic Methods*. The ASTM International standard emphasizes the activities involved in physically making measurements, and was developed by safeguards and NDA experts. A new INMM Accredited Standard Committee (ASC) consensus standard, BSR N15.xx-200x, *Administrative Practices for the Determination and Reporting of Results of Non-Destructive Assay Measurements of Nuclear Material in situ for Safeguards, Nuclear Criticality Safety, and Other Purposes,* will complement the existing ASTM International standard.

The new draft standard provides guidance on procedures, definition of terms, definition of data quality objectives, vocabulary used, standardized recordkeeping, consistent application of techniques, calculations, reporting of values, and uncertainties in a way that can produce consistent applications for the widest possible community of stakeholders.

It is important that terms are used consistently within the safeguards and NDA community, but equally important that all stakeholders using the results understand what is being reported with respect to quantity and uncertainty as well as the assumptions, corrections, or other variables that affect the measurement result and uncertainty.

Commercial entities do not play a role in site procedure development, but they do contribute to the consensus standard development process by ensuring that the latest commercial developments are integrated into the standards.

Measurement Program

Best Practices

- Effective communications between all interested stakeholders (i.e., operations personnel, NDA personnel, management) during the document creation and review process.
- Performing measurements in accordance with procedures.
- Refining holdup models based on comparisons with cleanout values or other quantification methods.
- Clear, concise procedures that are free of unnecessary detail and boilerplate information.
- Using a documented approach to measurements that addresses all of the relevant technical aspects of the measurements being made.
- Clearly defined, well-documented elements and objectives for the *in-situ* NDA Holdup Measurement Program Plan.

Good Practices

- Using a database to maintain a record of all measurement point locations, action values, required measurement frequencies, and measurement results.
- Developing electronic drawings to map the measurement points.
- Using a peer and management review process to produce good results, improve technical capabilities, and increase confidence that procedures are being followed.
- Holding Data Quality Objective meetings before measurements are made.
- Ensuring that procedures reference nationally accepted sources, such as DOE Orders or national consensus standards.

Changes to Procedures

Best Practices

- Maintaining comprehensive version control of procedures.
- Ensuring that procedures or mechanisms specify that modifications to equipment, operations, and processes result in a review of the NDA measurements.
- Integrating lessons learned into procedures.

Good Practice

- Using feedback from instrument operators to improve procedures.

Results and Calculations

Best Practices

- Performing a rigorous, well-documented uncertainty determination for each measurement, including a checklist to determine contributions to uncertainty.
- Ensuring that procedures use commonly accepted terms and definitions and describe the use of raw measurement data to calculate final gram quantities of nuclear material and the uncertainty of those values.

Best Practice not observed

- Using a rigorous version control process for software, including Excel spreadsheets.

Good Practices

- Reviews of data and results by subject matter experts and managers using formal review procedures and checklists.
- Using a standardized, highly detailed reporting format, including electronic copies of all ancillary information that was used to determine a result.

Task 5.2.6.4: Implementation of Standards

The primary purpose of this report is to identify good and best practices observed during the state-of-the-practice reviews with respect to *in-situ* NDA. Good and best practices not observed are reported at the end of each section where applicable. The TSG undertook this evaluation in response to the fact that, as stated in Recommendation 2007-1, DOE "...has not established specific programmatic requirements for *in-situ* NDA, even though this method is heavily relied upon for nuclear safety throughout the complex and is key to many DOE activities including the capability to perform accurate measurements and use the results to determine compliance with nuclear safety limits." Consensus standards include limited programmatic requirements for *in-situ* NDA as well as for NDA in general. Results of these observations are providing input into the development of new consensus standards. This report does not identify needs at facilities using *in-situ* NDA.

Measurement Program

Best Practices

- Using effective, routine, bidirectional communications with representatives of all involved organizations, including engineering, operations, Criticality Safety (CS), the DOE field office, and Material Control and Accountability (MC&A) from initial planning to final measurement reporting.
- Having access to an independent measurement group for technical review and periodic support.
- Limiting the use of holdup measurements to cases where NDA expertise indicates that technically defensible results are achievable.

Good Practices

- Standardizing measurement data reporting to ensure that all measurement results are available to all stakeholders.
- Selecting appropriate methods and modeling techniques.
- Undergoing or conducting routine self-assessments and external assessments.
- Using qualitative and quantitative screening measurements when appropriate.
- Maintaining staffing levels, including technical and maintenance staff, to meet anticipated customer needs.
- Having access to detailed facility histories, including process history.
- Possessing or having access to adequate measurement equipment, including spare parts and standards.
- Receiving management support to ensure adequate resources to meet customer needs.

Best Practice not observed

- Quantification of 100% of all possible holdup locations.

Source Term

Best Practices

- Selecting measurement locations based on walkdowns and drawings to ensure that no material is excluded.
- Using interactive electronic drawings to illustrate holdup locations and gram loading per area.

Good Practices

- Selecting measurement locations to ensure that all material loading is represented.
- Validating dimensions and thicknesses when possible, including the use of ultrasonic testing.
- Including source term determination uncertainty in overall uncertainty calculations.
- Correcting for finite source dimensions of deposits to reduce negative biases.

Backgrounds and Interferences

Best Practices

- Using routine spectral examination to ensure that interference peaks are identified.
- Considering interference sources and whether they have reached equilibrium.

Good Practices

- Ensuring that area background and Compton background are representative of the measurement and are correctly subtracted.
- Determining the optimum collimator or collimators for the measurement method.
- Using routine spectral examination to ensure that interference peaks are identified.
- Using adequate shielding for the energy levels being measured.
- Considering interference sources and whether they have reached equilibrium.

Attenuation

Best Practice

- Evaluating whether reported measurement results plus calculated uncertainty indicate infinitely thick density, and notifying customers when they do.

Good Practices

- Verifying attenuation calculations with transmission or differential peak absorption techniques, or both.
- Remeasuring at differing locations to evaluate changes in material disposition.
- Correct for all attenuators identified, including self-attenuation.

Enrichment/Isotopes

Best Practice
- Validating material type assumptions or process knowledge with measurements.

Good Practices
- Ensuring that energies from the holdup to be measured are within calibration ranges when using multi-radionuclide standards.
- Performing field verification measurements of all quantified isotopes.

Equipment

Good Practices
- Selecting the appropriate instrumentation for the selected method and material types.
- Evaluating interferences using equipment with high enough resolution to determine possible bias effects.
- Using gamma spectroscopic software capable of peak fitting and analyzing detector response.
- Using equipment capable of storing and transferring gamma-ray spectra.
- Using gain stabilization when using low-resolution detectors.
- Updating hardware and software as needed to improve measurement quality and best utilize resources.
- Utilize both gamma and neutron systems as needed.

Measurements

Best Practices
- Using the most accurate method available to measure cleaned-out material to validate modeling assumptions and calculations for each category and range measured.
- Using measurements to ensure that material is not in unexpected locations.

Good Practices
- Using values measured with known standards in configurations as similar as possible to *in-situ* measurements to validate modeling assumptions and calculations.
- Refining models used based on comparisons with cleanout values.

Calculations Including Uncertainty and Minimum Detectable Activity (MDA)

Best Practices
- Including deposit composition, measurement geometry, equipment configuration, calibration, and self-attenuation in evaluating systematic errors with statistical expertise for calculation and review.
- Performing measurements to validate MDA calculations in varying conditions.
- Using Monte Carlo or other advanced computer modeling to evaluate complex systematic error terms.

Good Practices

- Developing error propagation calculations that follow accepted statistical methods.
- Ensuring adequate statistical support for program development and routine reviews of calibration and measurement reports.

Best Practice not observed

- Using Monte Carlo or other advanced computer modeling to evaluate complex systematic error terms.

Task 5.2.6.5: Research and Development

An exhaustive bibliography of nuclear material holdup publications, reports, conference proceedings, and material obtained during the site visits for the time period January 2005 through November 2009 is listed in the following subsections. The references are grouped into the following categories: Measurement Results, Analysis Techniques, Software Development, Neutron Techniques, Criticality Safety, Miscellaneous, Hardware Development, and International. All of the references found for each of the categories are organized into separate subsections and listed at the end of the research and development section.

The largest numbers of publications are those reporting measurement results (10) followed by analysis techniques (9), neutron techniques (6), and criticality safety (6). The analysis techniques publications listed are dominated by Y-12 National Security Complex internal reports (4). The numbers in parentheses are the number of papers on that subject. Of the three papers dealing with software development, two refer to the same paper, which was given at two different conferences. Of the six papers using neutron techniques for holdup, all but one describe analysis techniques that were not developed for holdup specifically, but could be used as such, according to the author, or have been applied to holdup measurements. The one paper that does not address analysis techniques was a measurement results paper on the Tokai Reprocessing Facility.

All but one of the six criticality safety papers listed dealt with issues at the K-25/K-27 site and all but two were written or presented in 2008, after DNSFB Recommendation 2007-1 was issued. Of the eight papers listed under the miscellaneous subheading, all but three were associated with the International Workshop of Best Practices on Material Holdup Monitoring, which was held October 29 through November 3, 2006, at the Oak Ridge National Laboratory (ORNL). There were 109 participants, about 20 percent of whom were from outside the United States. Attendees from Canada, China, Japan, Russia, and South Africa participated, in addition to participants from countries of the European Union, the United Kingdom, and the International Atomic Energy Agency (IAEA).

None of the five hardware development papers were actually hardware developed specifically for holdup, and two of the five were the only commercial papers in the entire bibliographic listing. The authors were presenting hardware that could be used for holdup.

There is a single paper containing a U.S./international collaboration in each of the subsections Measurement Results, Analysis Techniques, and Neutron Techniques. Only six non-U.S. publications have been produced in the last five years covering these topics: IAEA reports, analysis technique, neutron technique, and hardware development. One of the international papers was presented at the Holdup Workshop at ORNL.

A review of research relevant to holdup leads to several conclusions. The U.S. is the leader in holdup measurements, technique development, and implementation. The development of new instrumentation specifically for holdup measurements has not occurred for at least the last five years, but there is evidence to suggest that the drought in instrumentation development has lasted 10 to 15 years. Improvements in analysis techniques and software continue to be developed predominantly by a handful of people within the DOE complex. Some commercial equipment advances in the last 10 years have benefited individuals performing holdup measurements even if the developments were not directly targeted for holdup. No new technology advances in the recent past or foreseeable future are likely to reduce holdup measurement uncertainties or reduce bias. All of the technological, analysis, and software advances lessen the burden on the analyst and measurement technician and should reduce mistakes and errors, but they will have no effect on the inherent uncertainties of the method, which are dominated by the physics of the situation. Russia, Japan, and South Korea are working on research in the area of holdup measurements, but only South Korea appears to be doing work independently of the U.S.

Measurement Results

Belian, A.P., Reilly, T.D., Russo, P.A., Tobin, S.J., Nikolaenko, N.N., Sokolov, G., Yasko, Y.V., Ustimovich, A., Strygin, G., Tchyrnuha, Y., Chahid, A., LeBrun, A., and Bourva, L. (2005, March). *Holdup Measurements at the Ulba Metallurgical Plant*, Los Alamos National Laboratory report LA-UR-05-2020.

Sadowski, E., Yourchak, R., Pretzello M., Mixon, B., Lynn, R. (2005, July 5). *Downgrade of the Savannah River Sites FB-Line*, WSRC-MS-2005-00094.

Keele, B., Chase, K., Cooper, T., Hurlbut, S., James, J., Jennings, V., Pestovich J., and Pestovich, J. (2005, July). [CD-ROM]. Status of Portable Non-Destructive Assay at the Plutonium Finishing Plant. *Proceedings of 46th Annual Meeting of the INMM*, Orlando FL.

Dewberry, R.A., Salaymeh, S.R., Casella, V.R., Moore, F.S. (2006, March). HEU measurements of holdup and recovered residue in the deactivation and decommission activities of the 321-M Reactor Fuel Fabrication Facility at the Savannah River Site, *Journal of Radioanalytical and Nuclear Chemistry. 267*(3), 515-531.

Dewberry, R., and Pak, D. (2007, May 4). Holdup measurements for three visual examination and TRU remediation glovebox facilities at the Savannah River Site, *Journal of Radioanalytical and Nuclear Chemistry.*

Bracken, D., Butler, G., Carrillo, L., Craven, J., Dempsey, M., Frame, K., Geist, W.H., Gonzales, M., Sprinkle, J., Valdez, J., and Vo, D. (2007, July). Holdup and Survey Measurements in Support of the TA-18 Facility Hazard-Category Downgrade, *Proceedings of the 48th Annual Meeting of the Institute of Nuclear Materials Management*, Tucson, AZ.

Dewberry, R.A., Casella, V.R., Sigg, R.A., Salaymeh, S.R., Moore, F.S. et al. (2008, March). Holdup measurements for three visual examination and TRU remediation glovebox facilities at the Savannah River Site, *Journal of Radioanalytical and Nuclear Chemistry. (275)*3, 541-554.

Berg, R.K., Brackenbush, L.W., Haggard, D.L., Hilliard, J.R., Mapili, G.M., et al. (2008, July). [CD-ROM]. Plutonium Hold-up Measurements at Pacific Northwest National Laboratory, *Proceedings of the 49th Annual Meeting of the INMM*, Nashville, Tennessee.

Oberer, R.B., Chiang, L.G., Norris, M.J., Gunn, C.A., and Adaline, B.C. (2009, May). *The use of Tl-208 gamma rays for safeguards, nondestructive-assay (NDA) measurements.* Y-12 National Security Complex Technical Report.

Vo, D., Bracken, D., Dempsey, M., Geist, W., Gonzales, M., Valdez, J., and Wenz, T. (2009, July). Nondestructive Assay Holdup Measurements with the Ortec Detective. *Proceedings of the 50th Annual Meeting of the Institute of Nuclear Materials Management*, Tucson, AZ.

Analysis Techniques

Oberer, R.B., Gunn, C.A., McGuire, S.A., Leete, R.S., and Chiang, L.G., (2005, October). *Estimating holdup measurement uncertainty for material control and accountability.* Institute of Nuclear Materials Management Central Region Chapter, Oak Ridge, Tennessee.

Oberer, R.B., Harold, N.B., Gunn, C.A., Brummett, M., and Chiang, L.G. (2005, October). *Filter paper: Solution to high self-attenuation corrections in HEPA filter measurements.* Technical Report Y/DK-2152, Y-12 National Security Complex.

Oberer, R.B., Gunn, C.A., and Chiang, L.G. (2006, May). *Inherent negative bias in the generalized geometry holdup (GGH) model.* Technical Report Y/DK-2181, Y-12 National Security Complex.

Oberer, R.B., Gunn, C.A., and Chiang, L.G. (2006, May). *Far-field approximation in the generalized geometry holdup (GGH) model*. Technical Report Y/DK-2176, Y-12 National Security Complex.

Oberer, R.B., Gunn, C.A., and Chiang, L.G. (2006, July). *The self attenuation correction for holdup measurements, an historical perspective*. Technical Report Y/DK-2187, Y-12 National Security Complex.

Ryazanov, B.G., Gorunov, V.K., Talanov, V.V., Shapsha, V.F., Pshakin, G.M., Dickman, D.A, Crawford, C.E. (2008, July). [CD-ROM] Russian Methodological and Training Center Results and Plans to

Support Upgrades and Sustainability. *Proceedings of the 49th Annual Meeting of the INMM*, Nashville, Tennessee.

Oberer, R.B., Chiang, L.G., Norris, M.J., Gunn, C.A., and Eblen, D.R. (2006, May). Determination of uranium concentration and attenuation correction in dense highly enriched uranium (HEU) material by the comparison of gamma rays from Tl-208, *Proceedings of the Institute of Nuclear Materials Management 49th Annual Meeting*, Nashville, Tennessee.

Vo, D., Bracken, D., Dempsey, M., Geist, W., Gonzales, M., Valdez, J., and Wenz, T. (2009, July). Nondestructive Assay Holdup Measurements with the Ortec Detective. *Proceedings of the 50th Annual Meeting of the Institute of Nuclear Materials Management*, Tucson, AZ.

Hayward, J., Ziocka, K-P., Abdul-Jabbarc, N., Solodova, A., Carrigan, J., Smith, S., Raffo-Caiadoa, A. (2009, July). A feasibility study of coded-aperture imaging and 3D-DIV for nuclear materials accountancy in enrichment plants. *Proceedings of the 50th Annual Meeting of the Institute of Nuclear Materials Management*, Tucson, AZ.

Software Development

Mayer II, R.L. (2005, February). *Peak Analysis Users Guide*, Portsmouth Gaseous Diffusion Plant Report POEF-344-05-071.

Gariazzo, C.A., Smith, S.E., Solodov, A.A. (2007, May). A Next-Generation Automated Holdup Measurement System (HMS-5). *29th ESARDA Annual Meeting*. Aix en Provence, France.

Gariazzo, C.A., Smith, S.E., Solodov, A.A. (2007, July). [CD-ROM]. A Next-Generation Automated Holdup Measurement System (HMS-5). *Proceedings of 48th Annual Meeting of the INMM*, Tucson, AZ.

Neutron Techniques

Belian, A.P., Russo, P.A., Weier, D. (2005, July). Utility of Monte Carlo Modeling for Holdup Measurements. LA-UR-05-5102. *INMM 46th Annual Meeting*, Phoenix, AZ.

Beddingfield, D.H., et al. (2005). *Measurement of the LASWS-1 and -2 Waste Storage Buildings at Tokai Reprocessing Facility*, Los Alamos National Laboratory Report LA-CP-05-1225.

Menlove, H.O., Swinhoe, M.T., Miller, M.C., Marlow, J.B., Hiruta, K., Shimizu, J., and Fujimaki, K. (2006, July). [CD-ROM]. Application of the Local Coincidence Veto Technique to Holdup Measurements in Glove Boxes. *Proceedings of the 47th Annual Meeting of the INMM*, Nashville, Tennessee.

Lee, S-Y., Beddingfield, D.H., and Pickrell, M.M. (2006). Calculation of neutron background at uranium enrichment facilities. *Transactions of the American Nuclear Society. 95*, 64-5.

Swinhoe, M.T., Marlow, J.B., and Menlove, H.O. (2007, July 1). Neutron list mode data for advanced safeguards. Los Alamos National Laboratory. Proceedings of GLOBAL 2007 conference on advanced nuclear fuel cycles and systems. 1667-1669.

Mullens, J.A., Hausladen, P.A., Bingham, P., Archer, D.E., and Mihalczo, J.T. (2008, June 15). *Use of Imaging for Nuclear Material Control and Accountability*. ESARDA Bulletin. *38*, 25-31.

Criticality Safety

Belian A.P., Russo P.A., and Weier, D.R. (2005, January). *Independent Review of Non-Destructive Assay for the K-25/K-27 D&D Project*. Los Alamos National Laboratory report LA-UR-05-0148.

Yeniscavich, W., Roarty, J.D., Zull, L.M., Massie, H.W., and Grover, D.J. (2005). Criticality concerns during decommissioning. *2005 ANS Topical Meeting on Decommissioning, Decontamination, and Reutilization. 2005,* 326-329.

Chandler, J.R. and Bartholomay, R.W. (2008). Approach for nuclear criticality safety during demolition of the K-25 building. *Transactions of the American Nuclear Societ*y. *99*, 385-6.

Haghighi, M.H., Howe, K.E., and Chandler, J.R. (2008, January 15). K25/K27 Characterization for Demonstrating Criticality Incredibility K-25 / K-27 D and D Project. *Proceedings of the 2007 ANS Topical Meeting on Decommissioning, Decontamination, and Reutilization - DD and R 2007*. 228-230.

Kimball, K.D. and Gauld, I.C. (2008). Impact of NDA uncertainties on NCS at the K-25 site, *Transactions of the American Nuclear Society*. *98*, 214-15.

Berg, R.K., Brackenbush, L.W, Haggard, D.L., Hilliard, J.R., Mapili, G.M., Mozhayev, A.V., Tanner, J.E., and Tomeraasent, P.L. (2008, July). [CD-ROM]. Plutonium Hold-up Measurements at Pacific Northwest National Laboratory. *Proceedings of the 49th Annual Meeting of the INMM*, Nashville, Tennessee.

Miscellaneous

Kim, H.D., Kang, H.Y., Song, D.Y., et al. (2005, April 1). Technology development for safeguards, Report no. KAERI/RR--2548/2004.

Pickett, C.A. and Coates, C.W. (2007, July). [CD-ROM]. International Workshop on Best Practices in Material Hold-Up Monitoring, *Proceedings of the 48th Annual Meeting of the INMM*, Tucson, AZ.

Lamb, F. (2008, Summer). Programmatic lessons learned during Rocky Flats holdup measurements supporting site closure. *Journal of Nuclear Materials Management. 36*(2), 31-34.

Cherry, R.C. (2008, Summer). A global perspective on nuclear material holdup measurements. *Journal of Nuclear Materials Management. 36*(2), 10-12.

Reilly, T.D., Sprinkle, Jr., and Tobin, S. (2008, Summer). Thoughts on holdup measurements and their uncertainty, *Journal of Nuclear Materials Management. 36*(2), 16-19.

Reilly, T.D. (2008, Summer). Gamma-ray assay of nuclear material holdup. *Journal of Nuclear Materials Management. 36*(2), 20-24.

Vo, D.T. (2008, June). Comparison of portable detectors for uranium enrichment measurements. *Journal of Radioanalytical and Nuclear Chemistry. 276*(3). 693-698.

Bracken, D.S. and Lamb, F.W. (2009, July). Progress and Goals for INMM ASC N15 Consensus Standard *Administrative Practices for the Determination and Reporting of Results of Non-Destructive Assay Measurements of Nuclear Material in Situ for Safeguards, Nuclear Criticality Safety, and Other Purposes* and *Implementation Plan for Defense Nuclear Facilities Safety Board Recommendation 2007-1* Safety-Related In Situ Nondestructive Assay of Radioactive Materials. *Proceedings of the 50th Annual Meeting of the Institute of Nuclear Materials Management*. Tucson, AZ.

Hardware Development

Hagenauer, R. (2005, November 15). A portable measurement system for nondestructive quantification of radioactivity in nonhomogeneous material. *Proceedings of international symposium on radiation safety management*. Oak Ridge, Tennessee. 3-10.

Chiang, L.G., Oberer, R.B., and Gunn, C.A. (2005, October). New holdup monitor for Y-12. Institute of Nuclear Materials Management Central Region Chapter. Oak Ridge, Tennessee.

Rowe, N.C. (2008, July). [CD-ROM]. Distributed Radiation Monitoring Via a Secure Wireless Sensor Platform. *Proceedings of the 49th Annual Meeting of the INMM*, Nashville, Tennessee.

Walford, G.V., Bogard, J.S., Smith, S.E., and Solodov, A.A. (2009, July). High performance, directional gamma ray detector solutions for the detection and quantification of critical materials. *Proceedings of the 50th Annual Meeting of the Institute of Nuclear Materials Management*. Tucson, AZ.

Raffo-Caiado, A.C., Ziock, K-P., Hayward, J., Smith, S., Solodov, A., Mihailescu, L., Vetter, K., Dougan, A., Burks, M., Gonçalves, J.G.M., Sequeira, V., Peixoto, O.J., Almeida, S., Galdoz, E., and Renha, Jr., G. (2009, July). Investigation of Combined Measurements with Three-Dimensional Design Information Verification System and Gamma-Ray Imaging Systems for International Safeguards Applications. *Proceedings of the 50th Annual Meeting of the Institute of Nuclear Materials Management*. Tucson, AZ.

International

Hunt, M. and Murakam, K. (2005, March). Upgrading nuclear safeguards in Kazakhstan, IAEA Bulletin. *46*(2), 26-27.

Lunqiang, W., Mengfu, W., Lianping, Z., and Suolong, Y. (2006, August 15). Primary study on holdup measurement of U-235 in pipe using gamma-ray spectrometry and Monte Carlo simulation. *Nuclear Science and Techniques. 17*(4), 241-245.

Deng, J-S., Li, Z., Gan, L., Lu, W-G., Dong, M-L., and Yuanzineng, K.J. (2007, November). Small angle-rotated detector emission tomography for measuring holdup in spherical container. *Atomic Energy Science and Technology. 41*(6), 742-745.

Johnson, S.J. (2008, Summer). Holdup determinations throughout the life cycle of a facility – an IAEA perspective. *Journal of Nuclear Materials Management. 36*(2), 13-15.

Oddou, R., Chevillon, J., Schoech, H., and Vincent, M. (2008, July). [CD-ROM]. Measurement of the plutonium weight in a melting furnace at CEA Bruyeres Le Chatel (France). *Proceedings of the 49th Annual Meeting of the INMM*, Nashville, Tennessee.

Bogdanov, S., Bezhunov, G., Ryazanov, B., Talanov, V., Thomas, G., and Dickman, D. (2009, July). The Role of the Russian Methodological and Training Center in Providing Nondestructive Assay Technical Assistance to Russian Enterprises. *Proceedings of the 50th Annual Meeting of the Institute of Nuclear Materials Management*, Tucson, AZ.

Task 5.2.6.6: Quality Assurance for *in-situ* NDA Holdup Measurements

According to DNFSB Recommendation 2007-1, "…three main issues dominate the current technical and regulatory landscape regarding *in situ* NDA measurements." The first issue listed is the "…lack of standardized requirements for performing measurements." This lack of standardization in the area of Quality Assurance (QA) does not appear to be a problem after the reviews of the three DOE sites. In fact, the QA state-of-the-practice reviews of the *in-situ* NDA holdup programs appear to be more than satisfactory. This is because the QA programs throughout the DOE complex are very mature. All DOE sites have had many internal and external reviews that examine the status of the QA programs from the point of view of DOE and the Criticality Safety and the Material Control and Accountability (MC&A). Any significant shortcomings discovered during these reviews would have been indicated in findings and corrected. The requirements for the NDA QA programs are all dictated by NQA-1 and are included in DOE Orders. All of the required good practices will not be covered here.

Program Management

Best Practices

- Management responsibility for the NDA QA and Quality Control (QC) programs resides with the site NDA professionals and scientists.
- NDA professionals and scientists review all measurement control data to identify out-of-control conditions and to initiate response actions.
- Software packages that automate and simplify operation and management of their respective NDA holdup QA programs and help minimize the chances of human error.

(Further detail: One of the software packages is commercially available. The second package is internally-developed *In-Situ* Measurement Database software with features for modeling for the actual field measurement.)

Good Practices

- Internal Measurement Control (MC) data are routinely reviewed by the MC&A organization (a DOE requirement).
- For each NDA instrument or system, many items, such as specified peak count rates, centroids, and full-width-half-maximum (FWHM), are tracked.

Documentation and Calibration

Best Practices
- Calibrations are performed on demand or at least annually.
- All calibrations and MC data are identified by established identification numbers and are filed with a prescribed retention schedule.
- Operations logbooks are kept on the instrument and system.
- Previously-mentioned automation packages have inherent MC functions that aid in satisfying calibration and documentation requirements.

Good Practices
- Calibration data routinely evaluated by MC&A personnel help to independently validate the performance status of the equipment.
- MC&A review functions are performed by a different organization from NDA Operations or Operations.

Nuclear Material Calibration Standards

Best Practices
- Standards are well-characterized, have a well-documented analysis trial with uncertainties, and have been reviewed and approved by the MC&A organization.
- The NDA professionals and scientists at the sites have utilized these available standards to meet the calibration needs of their measurement systems.

Good Practice
- Storing standards in a secure location, applying tamper-indicating devices (TIDs) where applicable.

Check Sources and Control Charts

Best Practices
- Use of two different standards during a typical MC measurement to obtain a wider range of data with one measurement, helping to validate the accurate operation of the NDA system.

- Use of a fixture to make routine, reproducible results very simple. The fixture design makes the MC data more sensitive for determining a change in the instrument.

Good Practices

- Review of control charts used to track specified MC values for each measurement system. An "out-of-control" situation is usually identified quickly and procedures were in place which dictates the appropriate steps to follow.
- All of the limits used in the MC programs are established by valid statistical methods and approved by the MC&A organizations.

Validating Measurement Results

Best Practice

- Validating *in-situ* holdup measurements is extremely difficult. When practical, holdup measurements are compared to cleanout values. This method is extremely difficult, expensive, and time-consuming. It has been used at all sites, but is not routinely performed.

Best Practice (proposed)

- Holdup measurement validation by alternate NDA methods is not routinely performed. An example of this validation might be a piece of equipment measured by classic Generalized Geometry Holdup (GGH) methodology and then later by a Segmented Gamma Scanner (SGS), or perhaps by an *In-Situ* Object Counting System (ISOCS) measurement.

Good Practice (proposed)

- Exploration of the effects on input parameters, including the use of comparisons with uncorrelated methods.

Task 5.2.6.7: Oversight – Good and Best Practices

DNFSB Recommendation 2007-1 includes guidance for establishing requirements in a DOE directive for *in-situ* NDA programs that are used to demonstrate compliance with nuclear safety limits through "…periodic assessments to ensure that NDA programs are using the best available technology." Oversight activities, as both internally and externally initiated reviews, often serve as assessments for effective readiness reviews, performance analyses, and demonstration of adherence to policies and programmatic or operational procedures. Assessments are also effective for identifying deficiencies and opportunities for improvement as well as noteworthy conditions and potential lessons learned. Commercial oversight activities and practices were not observed.

Best Practices

- Use of industry guidance publications (such as those published by INMM, American Nuclear Society (ANS), ASTM International) for performing oversight activities.
- Having internal and external NDA experts readily available for technical review, project guidance, and consultation.

- Clearly documenting where NDA results are credited for implementation or support of criticality safety.
- Periodically reviewing NDA reports by cognizant NDA customer organizations and external NDA experts for application of input data, NDA methodology, calculational accuracy, uncertainty analysis, and the usefulness of results according to Data Quality Objectives (DQOs).
- Planned assessments or oversight reviews according to a dedicated integrated evaluation plan (i.e., database) by Federal, contractor, or external organizations.
- Using an oversight/assessment review board to determine corrective actions for prioritization, accuracy, and consistency, including NDA personnel as appropriate.
- Development and implementation of an *in-situ* holdup surveillance program and inadvertent accumulation prevention program to include input and review from multiple organizations, including criticality safety, operations, Material Control and Accountability (MC&A), Quality Assurance (QA), and other DOE organizations to identify potential holdup locations, NDA or cleanout disposition, and follow-up practices. The programs should include periodic meetings of cognizant personnel for identification and discussion of issues.
- NDA assessments performed by NDA customer organizations (e.g., criticality safety, operations, MC&A, waste characterization, safeguards, QA) according to defined criteria with LOIs (including measurement observations) set according to the customer needs related to NDA.
- Management field observations of NDA implementation and associated systems.
- Comparing inventory or material removal results with applicable NDA results.
- Dedicated expert reviews of the applicability of the generalized geometry holdup (GGH) methodology for *in-situ* holdup, according to LA-14206 or other guidance.

Good Practices

- Establishing a dedicated NDA program with expert personnel for all areas of NDA implementation (e.g., manager, operators, technicians, scientists, and engineers)
- NDA self-assessments performed by the NDA organization according to defined criteria with LOIs set according to a dedicated procedure, known deficiency areas, recent trends, metric needs, or other areas of interest, including measurement observations.
- Performing external NDA oversight by compliance assessments, audits, discovery, evaluations, and program guidance by industry, Federal, or other experts within the DOE complex from within or without the organization.
- Incorporating radiation survey measurement data into *in-situ* holdup NDA for identification of potential holdup locations and guidance for consistency.
- Involvement with industry (e.g., INMM, ANS, ASTM International) or Federal workshops to develop NDA methods, ideas, and lessons, and to facilitate communication.
- Planned oversight activities to balance internal and external reviews by means of LOIs, document reviews, walkthroughs, interviews, and compliance- and performance-based assessments.
- Unplanned assessments as appropriate for ongoing oversight.
- Multiple lines of communication between NDA personnel and associated customers (e.g., criticality safety, operations, MC&A, waste characterization, safeguards, QA) in the form of DQO meetings, distribution of NDA reports, issue discussions or resolution forms, assessment reports, and interviews.

- Site assessment guidance defined in a manual and procedures.
- A centralized oversight database that documents the results of all oversight-related review activities. The database will include a detailed description of the oversight activity, results, findings, deficiencies, opportunities for improvement, noteworthy practices, corrective actions, progress, and tracking of closure results, documents, and approvals.
- Identification, reporting, and dissemination of NDA lessons learned internally and externally.
- An NDA-cognizant criticality safety engineer or officer to coordinate the application, implementation, and follow-up support for the *in situ* holdup program.
- Validation approval of an NDA measurement system (e.g., calibration, QA, uncertainty analysis)
- MC&A review of the QA program (e.g., system calibration, measurement control) for statistical accuracy and appropriate implementation.

Good and Best Practices not observed

- Technical experts performing periodic, independent evaluations of selected NDA analyses to verify measurement configuration, analysis methodology, technical accuracy, and uncertainty analysis, and to suggest improvements thereto.
- Definition and tracking of NDA metrics.
- NDA personnel performing assessments on the implementation of criticality safety through the proper use of NDA results, including uncertainties.

Task 5.2.6.8: Roles and Responsibilities of NDA Oversight Personnel

Adequate definition of roles and responsibilities should be established between all parties who rely on *in-situ* holdup measurements to meet safety requirements. This includes the Federal overseer, the line organization responsible for safety, and supporting organizations such as Nuclear Material Control and Accountability (NMC&A), NCS, the NDA holdup group, and contractor management. The extent of such definition should be tailored to meet the specific demands of a given facility. The Best Practices listed below have been compiled from site observations.

Best Practices

- Roles and responsibilities are clearly defined in both NDA program and NCS program procedures.
- Federal safety oversight responsibilities are clearly defined with a particular emphasis on overseeing the NDA-NCS interface.
- The overall responsibility for conducting nuclear material holdup measurements and coordinating the activities of applicable support organizations such as Radiological Control, NCS, and NMC&A is centralized and codified.
- Procedures provide for clear and effective communications between interfacing organizations.
- Procedures define the functions, assignments, responsibilities, and reporting relationships necessary to support line management oversight of safety.
- A clearly defined mechanism exists with which technical recommendations that require funding for implementation may be brought to line management for resolution and disposition.