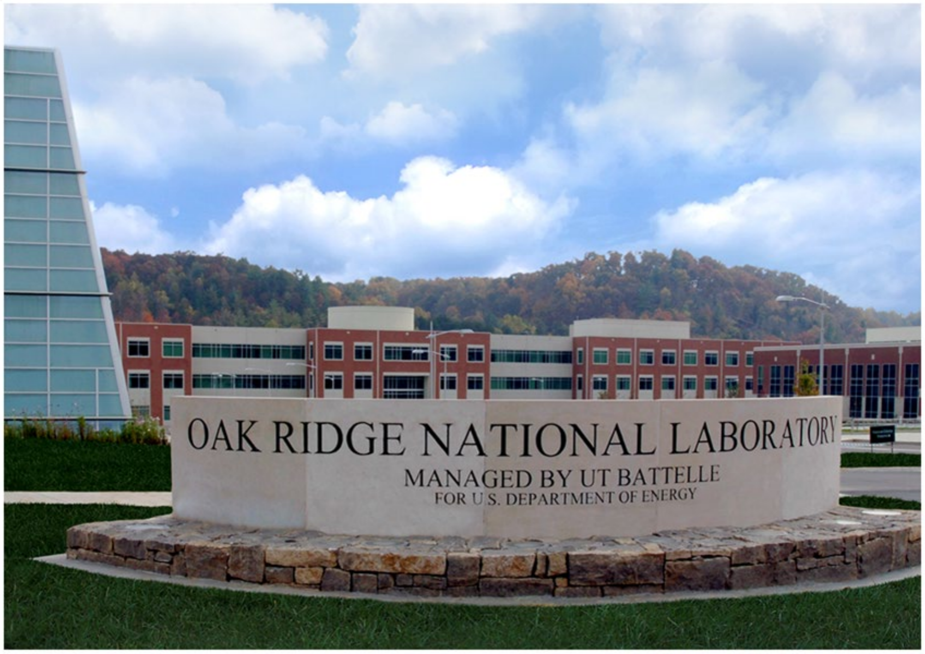
ORNL/TM-2020/1512

Workshop on Improving Holdup Monitoring in the US



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OAK RIDGE NATIONAL LABORATORY
MANAGED BY UT-BATTELLE FOR THE US DEPARTMENT OF ENERGY

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Nuclear Nonproliferation Division

WORKSHOP ON IMPROVING HOLDUP MONITORING IN THE US

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May 2020

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We extend our thanks to the workshop speakers. Their willingness to openly share lessons learned, challenges, and unique solutions provided the foundation for this technical exchange. Also, we wish to thank the breakout session facilitators for engaging the participants and capturing the thoughts and ideas from each of the sessions. Lastly, we appreciate the participation of the attendees, without whom, the workshop would not have been a success.

ACRONYMS

DOE	Department of Energy
EM	environmental management
GGH	generalized geometry holdup
HPGe	high purity germanium detector
IAPP	Inadvertent Accumulation Prevention Program
MC&A	material control and accountability
NCS	nuclear criticality safety
NDA	nondestructive assay
ORNL	Oak Ridge National Laboratory
TJIV	Technical Justification for Inventory Values

EXECUTIVE SUMMARY

The characterization and quantification of nuclear deposits, or residual nuclear material retained in process equipment, generally referred to as *holdup*, continues to challenge nuclear processing facilities in DOE program areas such as nuclear criticality safety, material control and accountability, environmental management. The efficiency and effectiveness of nuclear operations in these facilities depends heavily on the results from nondestructive techniques designed to measure nuclear materials *in situ*. The traditional methods used to measure holdup were established more than 30 years ago and assume unrealistic conditions for most measurement cases. These blind, *in situ* measurements present unique challenges due to the following attributes: unique, non-ideal geometries; unknown deposit thicknesses; lack of representative calibration standards; large number of holdup deposit locations; and poor accessibility for many measurement locations. These difficulties and the poor assumptions made to handle them have resulted in measurement uncertainties that are often too large for many programs to effectively utilize.

In an effort to address and identify solutions to the current holdup challenges facing the US nuclear industry, Oak Ridge National Laboratory hosted the Technical Workshop on Improving Holdup Monitoring in the US. The two-day workshop held August 21–22, 2019, was attended by 35 holdup measurement practitioners, program managers, stakeholders from US Department of Energy sites, the Nuclear Regulatory Commission, and representatives from commercial industry. The primary objectives were to identify critical elements of a successful and defensible holdup measurement program; identify technical challenges, needs, and potential improvements associated with measurement of holdup; and share best practices and lessons learned from recent accumulation events.

Fourteen presentations were delivered on holdup topics including necessary elements for effective program management, measurement needs, emerging technologies and other measurement solutions, and lessons learned from recent events. These presentations highlighted best practices related to accumulation monitoring, considerations and proactive steps to facilitate holdup in new facility designs, imaging solutions to improve holdup assumptions, and new software developed in support of holdup measurements. Breakout sessions were also employed to determine additional needs and identify potential solutions to common holdup challenges. The primary discussions focused on causes and prevention of material accumulations, needs for uranium and plutonium measurements, and reduction of measurement uncertainty, all of which were explicitly identified as critical needs during the 2018 *Workshop on Technical and Programmatic Needs for a Sustainable NDA Program for the US DOE*.

The holdup workshop resulted in the following key findings:

- Communication between management, measurement programs, and operations must be improved to enhance the effectiveness of holdup measurement programs.
- Holdup measurement uncertainty is dominated by the unknowns associated with the material distribution.
- Sustainable measurement systems are needed for both uranium and plutonium applications to maintain compatibility with changing operating systems.
- High background and other challenging measurement environments complicate holdup measurements.

To address these conclusions, the following actions are recommended:

- Implement improved process change protocols to effectively communicate with all stakeholders so that appropriate analyses can identify the potential for and prevent holdup accumulation.

- Invest in measurement personnel through training and development opportunities. The creation of a holdup measurement training qualification program (similar to that of the criticality safety program) would provide an opportunity to transfer knowledge from senior level experts to early- and mid-career professionals and establish a baseline for training all holdup personnel.
- Investigate technologies that may help reduce measurement uncertainties (e.g., imaging systems or other technologies) that help inform the material distribution assumptions. The extent to which measurement uncertainty may be reduced should be determined.
- Improve measurement techniques and expand analysis algorithms to handle non-ideal (but realistic) measurement scenarios.
- Share lessons learned through supported technical exchanges and measurement round-robins.

In summary, this holdup workshop provided a valuable means of exchanging technical information to support a strong, effective, and more efficient nondestructive assay community. The holdup workshop participants helped identify the significant challenges and critical needs associated with holdup measurements across the nuclear complex. To effectively address these shortcomings, a concentrated effort is necessary to strengthen the management of holdup measurement programs, an investment in both equipment and personnel must be made, and improvements to measurement systems and analysis algorithms must be achieved. Collectively, these efforts would help construct a well-defined holdup measurement infrastructure. The benefits of such a well-organized holdup program would be recognized by nuclear criticality safety, material control and accountability, and environmental management programs and benefit US nuclear facility operations.

1. INTRODUCTION

1.1 MOTIVATION AND BACKGROUND

Inadvertent nuclear material accumulations reported over the last decade indicate a critical and ongoing need for defensible holdup programs in US nuclear facilities. The characterization and quantification of nuclear material holdup continues to challenge nuclear criticality safety (NCS), environmental management (EM), and safeguards and security programs. Ultimately, inadequate holdup measurement programs negatively impact operational effectiveness of domestic nuclear facilities. The 2019 Technical Workshop on Improving Holdup Monitoring in the US was organized to help establish, support, and maintain defensible holdup measurement practices in the US. The objectives of this technical workshop were to

- identify the elements of a successful and defensible holdup measurement program,
- identify specific challenges and needs associated with measurement of plutonium and uranium *in situ*, and
- share lessons learned about recent accumulation events and identify ways to reduce the likelihood of such events moving forward.

This workshop provided a valuable means of exchanging technical information to support a strong, effective, and more efficient nondestructive assay (NDA) community, which is a critical need identified during the 2018 Workshop on Technical and Programmatic Needs for a Sustainable NDA Program for the US Department of Energy (DOE) [1].

Additionally, the following needs were identified and addressed as related to holdup measurements:

- System or process for locating/characterizing *in situ* material in large process equipment/items
- Reduction in total measurement uncertainties for NDA methods
- Enhanced algorithms and software for NDA applications to increase measurement capability

Workshop Organization

The Workshop on Improving Holdup Monitoring in the US was hosted at Oak Ridge National Laboratory (ORNL) from August 21 to 22, 2019. Thirty-five attendees from various DOE National Nuclear Security Administration and EM sites, national laboratories, the Nuclear Regulatory Commission and commercial fuel fabrication sites participated in the workshop. A list of attendees and affiliations is provided in Appendix A.

The two-day workshop included 14 holdup-related presentations by attendees, four technical breakout sessions, and two technology demonstration sessions held in the Safeguards Laboratory at ORNL. The workshop opened with a review of the Workshop on Technical and Programmatic Needs for a Sustainable NDA Program for the US DOE. Details related to holdup challenges were emphasized. The other presentations focused on holdup measurement programs, specific holdup challenges, innovative solutions and emerging technologies, and lessons learned. The agenda is provided in Appendix B. Breakout sessions on (1) uranium-specific holdup challenges, (2) plutonium-specific holdup challenges, (3) avoiding inadvertent accumulations, and (4) reducing measurement uncertainty also provided participants an opportunity to contribute meaningful thoughts and ideas on holdup measurement topics.

2. SUMMARY OF PRESENTATION TOPICS

The topics presented during the workshop can be divided into four main categories:

- Elements/management of a robust and effective holdup measurement program
- Holdup measurement needs
- Holdup measurement solutions and emerging technologies
- Lessons learned

Many positive aspects of the Y-12 National Security Complex's extensive holdup measurement program were shared including an overview of the overarching holdup program and details related to implementation of the Technical Justification for Inventory Values (TJIV) and the Inadvertent Accumulation Prevention Program (IAPP). The TJIV and IAPP discussions provided an opportunity for others to learn about and consider implementation of these accumulation monitoring best practices at their own sites. NDA experts involved with the design of the Uranium Processing Facility at Y-12 were also able to share experiences and establish connections for sharing additional lessons learned. Holdup measurement needs at Savannah River were presented with an emphasis on integrating NDA considerations into new facility designs.

Unique measurement solutions and updated technologies used for holdup measurements were also presented. Topics included the use of a commercial gamma imager (PHDS GeGI) to clear gloveboxes at Savannah River, a new multichannel analyzer acquisition (MCAA) system to support field measurements at Y-12, and an updated holdup measurement software package (SNAPSHOT) under development at ORNL to replace the increasingly obsolete Holdup Measurement System (HMS-4) program. The potential use and added value of imaging technologies and improved algorithms for holdup monitoring were also presented. There was sizeable interest in exploring imaging technology to improve holdup monitoring in many applications. Lessons learned from recent "near misses" were also shared to help prevent mistakes moving forward.

3. SUMMARY OF CHALLENGES/NEEDS IDENTIFIED DURING BREAKOUT SESSIONS

Specific holdup monitoring/measurement challenges, needs, and recommendations identified during the technical breakout sessions are presented in the following subsections.

3.1 AVOIDING INADVERTENT ACCUMULATIONS

One of the greatest challenges associated with holdup monitoring is identifying potential locations of holdup. These challenges become evident when reviewing the uptick in inadvertent accumulations and "near misses" discovered at various sites during the last five years. The purpose of the Inadvertent Accumulation breakout session was to identify common factors that lead to these unexpected accumulations and possible ways to mitigate them. During this breakout session, several questions were posed, and the responses are summarized below.

What are the common factors leading to inadvertent material accumulations?

Most accumulations are a result of process changes that are not communicated and fully assessed. All appropriate stakeholders are rarely informed of seemingly insignificant process changes resulting in unidentified risks in the proposed processes. In one example shared during the workshop, engineering drawings that would have helped identify the secondary path for material accumulation were not properly reviewed. In addition, "incredible" accumulation points often get categorized once, and these points generally do not get reevaluated for new potential accumulation unless a known cause for a potential accumulation has been established. Participants acknowledged that more work and thought is put into reviewing new processes than a process change. Recognizing that process changes should be evaluated with as much rigor as new processes, implementing better process change controls, and establishing formal communication paths would help reduce the potential of unidentified accumulation points. Ultimately, periodic reassessment of all potential accumulation locations is advised.

What monitoring programs exist? How effective are they?

Y-12 has implemented two programs to monitor for potential accumulations. The TJIV program is a streamlined approach to keeping inventory holdup values current and controlling holdup. It serves as the technical basis for the nuclear material control and accounting holdup measurement schedule. The program involves analyzing holdup quantities and accumulation rates in systems and prioritizing their measurement frequency according to their effect on the inventory difference. High impact zones greatly influence the inventory difference, but low impact zones have little or no impact on the inventory difference. Most influential are cleanout zones, which are defined as regions where holdup cannot be accurately measured because of location, deposit thickness, or other obstacles to NDA measurement, and cleanout, rather than measurement, is recommended.

The IAPP was developed to address concerns from an event where an unexpected accumulation of enriched uranium was discovered in a large geometry filter housing. The IAPP meets requirement 3.e. Fissile Material Accumulation Control in Chapter III Nuclear Criticality Safety of DOE O 420.1c Facility Safety. The IAPP aims to improve the communication between all stakeholders and implement a formalized method to evaluate, document, and develop recommendations for effective control of potential enriched uranium accumulation in new processes and process changes. The program helps ensure that subject matter experts are involved in the assessment of holdup accumulations, assessments are updated when necessary, and engineering controls are implemented, when possible, to reduce reliance on measurements where excessive holdup deposits are likely.

The Uranium Holdup Survey Program is an additional program used to qualitatively monitor holdup deposits in process equipment at predetermined locations. The data are used to inform stakeholders of unwanted accumulations or changes to accumulated deposits. The Uranium Holdup Survey Program supports and informs both NCS and nuclear material control and accounting programs.

Would permanent detection solutions be effective?

Fixed measurement systems have been proposed to monitor holdup deposit changes; however, most subject matter experts do not see this as a sustainable solution. Measurement hardware and software changes quickly, and installed systems promptly become obsolete. Many fixed/continuous monitoring systems deployed in the past have been abandoned in place and now hinder access to ideal measurement points.

If permanent/fixed systems can be maintained and positioned in such a way that they do not reduce access to measurement points, they may be useful. Installed systems do not require high efficiency or advanced detectors because long count times are possible. In principle, permanent detection systems can provide daily or more frequent information with less expense and result in lower exposure rates for measurement personnel. Monitoring changes in dose rates in areas where accumulations have occurred should be evaluated to determine effectiveness as an indication of material accumulation.

Could imaging technology be used to identify potential accumulations?

Although gamma imagers have limited ability to determine deposit thickness and may not improve assay quality, the general consensus of participants was that these imagers may be useful for searching for and identifying hot spots, large accumulations, and unexpected material holdup especially in difficult-to-access areas. They may also provide a means to reduce assumptions about deposit geometry, thereby reducing overall measurement uncertainty. The images themselves provide visual evidence that may help stakeholders gain confidence and buy-in from customers about the presence or absence of materials. It was judged that high-quality images would be especially helpful for EM programs and missions.

Pipe "crawlers" are currently being investigated to look for and measure holdup from inside pipes. This may provide useful information for EM programs, but this method cannot be used in operational facilities where access to the inside of the process equipment is limited. There are additional challenges and considerations that need to be addressed before imaging technologies can be effectively implemented. The effect of environmental conditions (high background), dead-time, and Compton scattering effects must be studied. The influence of other surrounding materials (such as depleted uranium) should also be evaluated. Implementation of wide scale imaging techniques must consider cost and time needed to scan or assess an area for the presence of an accumulation. In high background environments, count times will likely be extremely long. If the imaging systems can run unattended, count times will likely not be an issue. The size of imaging devices (including all necessary supporting equipment) must be also be considered since accessibility is often a challenge in process facilities. A study on the rate that accumulations occur in various process equipment would be helpful to plan imaging campaigns in the most efficient manner.

Are the potential consequences of criticality from unidentified/unmeasured holdup deposits effectively communicated?

Recent lessons learned and "near misses" confirm that the importance of small details and their impact on criticality safety are not well understood. These seemingly minute details that could help recognize or identify potential accumulations points are often not communicated. Formalized and documented assessments with appropriate subject matter expert buy-in will help ensure important details are captured and analyzed properly. Adequate measurement resources (e.g., equipment and staff) are not allocated as needed to appropriately deal with holdup challenges. Increased budget for equipment and human resources should significantly benefit holdup measurement programs and reduce operational risks in nuclear facilities.

Can holdup monitoring be improved during the design of new process lines/facilities?

NDA needs must be considered during all planning phases for new facilities. Subject matter experts with in-depth knowledge of holdup must be included on the design team to communicate measurement needs and ways to mitigate holdup. For new facilities, this might include ideas for built-in measurement access points, selection of processing equipment that reduces holdup accumulation, and increased communication between operations and material control and accountability (MC&A) and NCS programs. Leveraging expertise from other production/processing sites would also help identify major concerns.

3.2 MANAGING MEASUREMENT UNCERTAINTIES

The reduction of measurement uncertainty associated with NDA is of interest to every program that uses NDA data. Holdup measurement uncertainties are used for accountability, criticality safety, waste disposal, and planning and operations. Measurement uncertainties are particularly high for holdup measurements because of the unknown condition of the holdup deposit. Gross geometry and self-attenuation assumptions are often made to facilitate the vast throughput of the measurements required to ensure safe and secure working conditions. New technology and methodologies to reduce the uncertainty associated with *in situ* measurements are desperately needed. The following questions were posed during the Measurement Uncertainty breakout session.

How accurate or precise do holdup measurements need to be?

The large uncertainties associated with holdup measurements provide little confidence in the measured results. The accuracy and precision needed depends on the situation and the program using the measured data (e.g., safety needs conservative values and MC&A needs best estimates). The accuracy requirements for a measurement may also depend on the material-at-risk value and associated degree of confidence that is needed. Accuracy and precision requirements should be aligned when possible and communicated to all stakeholders to ensure measurement performance meets the need.

What measurement methods are currently used and what limits their accuracy?

Sodium iodide, high-purity germanium (HPGe), and to some extent lanthanum bromide detectors are most often used to measure holdup deposits. For uranium-based applications with prevalent NaI-based and $LaBr_3$-based systems, region-of-interest type analyses are often applied. The primary advantage of this type of system/analysis is that relatively short measurements at many hundreds or thousands of locations can be performed per inventory period. Although these traditional gamma-ray measurements support high throughput, they are limited by self-shielding, interfering isotopes, changing backgrounds, and layers of increasingly obsolete hardware. HPGe systems require much longer count times but are better for analyzing complex spectra caused by material interferences. These systems are often employed for complex geometries like gloveboxes where traditional methods cannot be applied.

Neutron slab detectors are also used but to a lesser extent. These neutron-based systems are better suited to measure large pieces of equipment where infinitely thick deposits and high attenuation are likely, but they are limited by neutron multiplication in the deposit, varying chemical forms, presence of moderators, and high backgrounds.

Are there specific aspects of the holdup program that dominate the uncertainty?

The material distribution (i.e., geometry) is the biggest unknown, yet these details are needed for current measurement analyses. Most holdup measurements rely on the generalized geometry holdup (GGH) method, which uses crude geometry models (points, lines, or areas) to determine the total mass of a deposit. The unknown distribution of the material in the process pipes/fixtures leads to increased modeling errors or uncertainty. Detector positioning and incomplete knowledge of the process piping also increase the uncertainty. Separating the measurement signal from the background can be difficult in some processing environments and contributes to the high measurement uncertainties.

How do we improve assumptions regarding material deposits/distributions? Can imaging be used to reduce the uncertainty in these assumptions?

Gamma- and neutron-imaging techniques may be a useful tool in reducing geometry assumptions used in holdup models and should be investigated in more depth to determine usefulness and practicality in holdup applications. Special studies on the usefulness of imaging technology under normal and extreme operating and environmental conditions should be performed.

What other ways could we reduce overall measurement uncertainty?

The following actions (in no particular order) were suggested to help reduce total measurement uncertainty:

- Providing more training/development opportunities for measurement staff
- Investing in new or updated measurement hardware
- Employing qualitative imaging techniques to improve geometry assumptions
- Enhancing processing and analysis of LaBr spectra
- Improving room-temperature detectors
- Reducing the weight mechanically cooled HPGe detectors
- Improving localization methodologies for material deposits
- Implementing better accumulation monitoring solutions
- Improving holdup measurement algorithms to include volumetric deposits
- Including better self-attenuation and other external corrections (e.g., distribution of the material and isotopic interferences)
- Automating more quality controls on holdup measurements

3.3 URANIUM CHALLENGES AND NEEDS

Uranium and plutonium comprise most of the nuclear material processing in domestic nuclear facilities. Thus, most holdup measurement techniques focus on these two material types; each of which present some distinct measurement challenges. The Uranium Challenges and Needs breakout session was dedicated to the current and future needs of the uranium sites. The details from these discussions are provided in the table below.

What are the most common uranium holdup challenges and needs?

For many years, the GGH methodology has been used for holdup measurement of highly enriched uranium materials. Updated algorithms and analysis routines are desperately needed to measure low-enriched uranium; material in the presence of contaminants and interferences (where region-of-interest methodologies break down); large, volumetric sources or infinitely thick deposits; and materials in high background environments. In addition, "special" or one-off cases pose a significant measurement challenge because there is generally no precedent, representative standards, or validated model for these situations.

Even under ideal conditions, equipment sustainability is a challenge. The current equipment used to measure holdup is based on obsolete electronics and analysis software not compatible with current computer operating systems. DOE sites must salvage—or even cannibalize—old measurement equipment to maintain measurement capabilities. Formalized requirements for defensible holdup measurement programs would ensure that resources are available to adequately staff and perform these measurements.

More representative calibration standards appropriate to the challenges encountered in the field are needed by all sites. A survey of other physical standard needs should be developed and distributed to better understand the gap in the holdup community. The decommissioned gaseous diffusion enrichment plant in Portsmouth has developed special holdup standards that are used to calibrate measurement equipment and demonstrate job performance. The development process for these standards can be shared with the community. Resources should be made available for other sites to manufacturer needed calibration standards.

Ultimately, communication across DOE is the biggest challenge. Methods, equipment, and standards are being developed by each site, contractor, or vendor, independent of each other's needs and with virtually no coordination or collaboration. A framework is needed for sharing information on technical developments in uranium holdup quantification. The Institute for Nuclear Material Management NDA Working Group meeting might serve as a forum to share information, but a DOE-funded and focused effort that facilitates knowledge retention and is accessible to all sites/contractors/vendors would be most effective. Focal points for this repository should include

- best practices and equipment for holdup measurements,
- measurement challenges and solutions,
- development of "blind" NDA holdup challenges, and
- creation of a holdup measurement training qualification program (like the criticality safety qualification program).

What are potential solutions to these uranium holdup challenges?

The following tasks may help mitigate and resolve some of the challenges associated with the measurement of uranium holdup:

- Improvement of communication pathways to address needs and to demonstrate importance of more effective holdup monitoring to upper management
- Evaluation of gamma imaging techniques and/or pipe crawling robots to locate and inform modeling of holdup deposits
- Evaluation and demonstration of *quantitative* imaging techniques
- Advancement of high-resolution spectroscopy and analysis capability for large deposit holdup measurements
- Development of advanced differential attenuation techniques to improve holdup analysis
- Use of transmission sources to determine deposit thicknesses
- Improvement in neutron detector applications and analysis for holdup measurement
- Provision of consistent, effective, and in-depth training to improve operator ability

3.4 PLUTONIUM CHALLENGES AND NEEDS

Holdup measurements in plutonium facilities continue to challenge measurement personnel. Many holdup challenges experienced in uranium processing facilities are also experienced in plutonium production facilities. The common needs include better communication, development and acquisition of more appropriate calibration standards, and increased support for human resources and measurement equipment. However, additional challenges exist for plutonium operations. The specific challenges and needs identified during the Plutonium Challenges and Needs breakout session are discussed in this section.

What are the primary plutonium holdup measurement challenges?

One of the most challenging measurements is trying to quantify total grams inside large gloveboxes. A glovebox poses a difficult geometry with limited access points. The geometry of the deposit does not generally meet the point, line, or area assumptions used in the GGH model. These assumptions limit the ability to accurately apply traditional GGH methods. The difficulty in measuring holdup in gloveboxes is a significant problem since holdup in gloveboxes can approach criticality limits. One example discussed during the session stated that measured values are needed for a 60 ft × 30 ft × 30 ft glovebox. Methodologies to accurately measure these types of processing equipment must be developed.

Plutonium holdup measurement locations are often in high background environments with higher energy gamma-ray and much higher neutron rates compared to uranium operations. The shielded detector systems used for uranium holdup measurements are not optimized for plutonium gamma-ray signatures. Additional interferences from high ^{241}Am content are also a challenge. HPGe detectors are often used for plutonium measurements to help mitigate some of these issues. However, these detectors are limited in tight spaces, require cooling, and require much longer count times. Better measurement equipment and algorithms customized for plutonium analyses are needed.

What are some potential solutions to these plutonium-specific holdup problems and challenges?

The use of neutron detectors and neutron counting techniques should be studied in-depth. In ideal environmental conditions, neutron systems could provide better quantitative values where isotopics and chemical form are known; however, background mitigation would be challenging. Imaging technologies should also be evaluated to help identify material distributions in gloveboxes. A better understanding of the material distribution would result in improved models, reducing the uncertainty on glovebox measurements. Improvements in high-resolution detection at room temperature would benefit many NDA measurement applications, including holdup. Advanced analysis methods to deal with volumetric sources and plutonium-specific challenges are needed.

In general, what is needed to improve holdup measurements?

The following list provides needs and improvements that may support more effective plutonium holdup measurements:

- In-depth studies of neutron-based holdup measurement applications
- Evaluation of high-pressure gas detectors, like the ones used in the United Kingdom, for holdup measurements
- Accessible test facility with a clean glovebox and appropriate test materials that could be used by all sites to improve large geometry assumptions
- Better housekeeping to help reduce holdup and material balance issues
- Improved communication between sites and programs
- Development of smaller, room-temperature high-resolution gamma detectors
- Improved analysis routines targeted at Pu measurements

4. POST-WORKSHOP HOLDUP MEASUREMENT SURVEYS

Overall, participants were very engaged and willing to share opinions on the state of US holdup measurement programs. To capture additional information, workshop participants completed a short survey. Participants had many good things to say about the workshop, and they saw benefits in connecting with others in the field. This section summarizes the comments provided on the surveys.

Do current holdup measurement practices meet your programmatic needs (e.g., timeliness, accuracy, precision)?

Most managers indicated that current holdup practices are capable of meeting measurement requirements as they are applied to current processes, but they are doubtful that current practices will be able to meet the needs of new or future processes. Representatives from both NCS and MC&A programs indicated the need for better, more accurate computation of total measurement uncertainty. Survey respondents noted that the greater issue of mitigating or minimizing holdup through effective engineering control and through effective cleanout was not discussed. Extensive cleanouts are difficult, risky, and costly. They provide accurate but imprecise accountability values.

How do you stay current on holdup measurements made in other facilities and what new technology is available or emerging? How might the community connect more fruitfully and cross stakeholder boundaries?

Many participants indicated that technical workshops are a great way to be involved and engaged with the NDA community. Participants also stay involved and current by attending conferences, training, and tours; through collaborations with universities or other lab research groups; and through word of mouth. Recognizing that better communication between NDA experts would be beneficial, many recommended establishing an open dialog or a shared repository where information can be shared on measurement methods and equipment. Unique measurements challenges, approaches, and analysis methods for those measurements could be shared between sites. In addition to better communication and information sharing between sites, participants expressed a desire for improved communication with vendors. Users would like a process to better communicate the needs of the NDA community to the vendors.

What technical workshop topic would be most beneficial the NDA community?

A few suggestions were provided for future workshops. Some participants mentioned it would be helpful for the workshop to include hands-on measurement time. This could involve exercises on how to apply NDA to different systems. Participants also want more information on neutron measurement techniques, new technologies, and emerging NDA techniques.

How do you receive primary education and training qualifications? Do you feel there are enough training, education, and professional development opportunities with respect to NDA?

Many participants agreed that more training options are necessary, and some even mentioned standardized training across sites would be useful. Currently, most sites primarily use on-the-job training, but some also use national laboratory or vendor training options. All respondents believe that a standardized training curriculum would be beneficial.

What advancements in NDA techniques or topical areas would be most beneficial?

When asked about their most pressing concern/need/wish/vision regarding holdup or NDA, the following topics were repeatedly identified: better training, improved uncertainty analysis, portable measurement systems (such as electrically cooled HPGe), continuous development of instruments and technology, and improved software and equipment. Responses also indicated a substantial interest in more portable neutron systems, gamma and neutron imaging, and deposit mapping techniques.

Do you think you have adequate calibration standards for holdup measurements? Please explain? If not, what material types, enrichments, forms, would be helpful?

Participants expressed a need for more standards for holdup calibration verification, for training and mock-up, and modeling investigations. For uranium programs that rely on GGH methods, a large quantity (set) of certified calibration standards is not needed. However, sources to validate the calibrations and for training and for mock-up and modeling investigations are needed. One participant responded that calibrations are performed by analyzing gross counts versus cleanout data and lab analyses, but standards are not available for validation. Another site has developed custom standards to complement its NIST-traceable standards. More NIST-traceable standards, especially in the mid-enrichment level range and in the various deposit forms (solid, metals, oxides, etc.), would be valuable. More massive (greater than tens of grams) standards in a range of enrichments and standards with realistic and complex geometries are also needed.

For plutonium operations, holdup standards are rare. There is a significant need for plutonium standards in the form of liquids, oxides, and metals. Availability of a mock-up glovebox with many sources to test equipment and advanced methodologies would also be advantageous.

5. SUMMARY

NDA measurements are a crucial element of safe and secure nuclear operations across the within the DOE complex and civilian nuclear fuel cycle. The measurement of holdup inside process equipment is an especially challenging NDA application; however, it is a critical application necessary to ensure nuclear materials are properly accounted for in support of NCS, EM, and safeguards and security programs. Unfortunately, holdup measurements are plagued by large uncertainties, aging equipment, and inappropriately applied assumptions in traditional analysis algorithms. Unintentional accumulation of nuclear material could threaten to halt nuclear operations in the US altogether. A focused effort on improving holdup monitoring must be made to increase effectiveness of all programs in support of US nuclear operations.

The two-day Workshop on Improving Holdup Monitoring in the US brought holdup experts, technology developers, program managers, and other stakeholders across many disciplines came together to discuss the pressing issues surrounding nuclear material holdup. Current technical and programmatic challenges, recent accumulation events, and emerging technologies with potential to improve holdup measurements were discussed. The prevention of material accumulation, reduction of measurement uncertainties, and improvements for uranium and plutonium applications were the primary topics of discussion.

Based on input from the workshop participants, several recommendations have been developed to help strengthen and address the shortcomings of most holdup measurement programs. These recommendations include

- strengthening communications between all stakeholders and programs to convey the importance of holdup monitoring, to facilitate the sharing of information, and to ensure goals and objectives for each program are being met;
- sharing lessons learned through supported technical exchanges and measurement round-robins;
- investing in the professional development of holdup personnel through supported training opportunities; creating a holdup measurement training qualification program;
- improving localization and geometry assumptions through a comprehensive study on qualitative imaging techniques and their applicability to holdup; and
- improving measurement techniques and analysis algorithms to handle non-ideal measurement scenarios.

These actions, if supported and implemented properly, would support improved holdup monitoring programs that would enable reduced measurement uncertainties and benefit all stakeholders in achieving their current requirements and future challenges.

APPENDIX A. WORKSHOP PARTICIPANT LIST

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APPENDIX B. AGENDA

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Workshop on Improving Holdup Monitoring in the US

Day 1: Wednesday, August 21, 2019

Time	Presentation	Presenter
8:30 – 8:50	Welcome – Introductory Remarks	Cary Crawford
8:50 – 9:10	Review Holdup Challenges Identified in 2018 NDA Workshop	Angie Lousteau
9:10 – 9:30	Holdup Management at Y-12	Daniel Hamm
9:30 – 9:50	Holdup Measurement Needs at SRS	Dave Dolin
9:50 – 10:20	Group Photo and Coffee Break	All
10:20 – 10:40	NMC&A Implementation of the Technical Justification Inventory Values	Harold Wheat
10:40 – 11:00	Some Recent Holdup Issues at NRC-Licensed Fuel Cycle Facilities	Jim Rubenstone
11:00 – 11:20	Y-12 Inadvertent Accumulation Prevention Program	Chris Haught
11:20 – 11:40	Recent Accumulation Discoveries and Responses	Luis Castellanos
11:40 – 1:00	Lunch – Sharing of lessons learned	All
1:00 – 1:20	Resolution of an Inventory Difference Loss Trend Due to Holdup	Jeff Coleman
1:20 – 1:40	Unique Holdup Challenges and Solutions at Bldg. 235-F	Kalee Fenker
1:40 – 2:00	Development of MCAA for Field Holdup Measurements	David Davis
2:00 – 2:20	MCMC for UQ in Imaging	Keith Bledsoe
2:20 – 2:40	Scene Data Fusion for 3D Gamma-ray Imaging	Ren Cooper
2:40 – 3:00	Coffee Break	All
3:00 – 3:20	Imaging	Klaus Ziock
3:20 – 3:40	Snapshot: Next Generation Holdup Measurement Software	Angie Lousteau
3:45 – 5:00	Technology Demonstrations	All

Day 2: Thursday, August 22, 2019

Time	Event	
8:30-8:40	Plan of the Day	Angie Lousteau
8:40 – 10:10	Breakout Session 1: Avoiding Inadvertent Accumulations Breakout Session 2: Managing Measurement Uncertainties	All
10:10 – 10:30	Coffee Break	All
10:30 – 12:00	Breakout Session 3: Pu Challenges and Needs Breakout Session 4: U Challenges and Needs	All
12:00 – 1:15	Lunch – Prepare debriefs from breakout sessions	All
1:15 – 2:15	Report: Breakout Session 1 Report: Breakout Session 2 Report Breakout Session 3 Report Breakout Session 4	TBD
2:15 – 2:30	Coffee Break	All
2:30 – 2:45	NDA Surveys	All
2:45 – 3:15	Workshop Summary	Angie Lousteau
3:15 – 3:30	Closing Remarks	Cary Crawford
3:30 – 4:30	Technology Demonstration	All