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A Field Evaluation of a Prototype Global Identifier for UF_6 Cylinders

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Abstract

The U.S. Department of Energy's National Nuclear Security Administration (DOE/NNSA), members of the U.S. national laboratories, UF_6 industry stakeholders, and international inspectorates have been working together on a concept for a global identifier for UF_6 cylinders. This initiative has identified efficiency gains for facility operations, State and/or regional regulation, and inspections by the International Atomic Energy Agency (IAEA). The global identifier to be affixed to the cylinder would feature a standardized string of alphanumeric characters marked with a large font and a barcode for automated reading. Four years of active engagement among the stakeholders have resulted in a preferred design of the global identifier, the drafting of implementation guidelines for industry, and a set of user requirements for full utilization by the IAEA.

Although this project was initiated by the DOE/NNSA to address international non-proliferation concerns, it has become an industry-driven initiative. A key activity leading to the eventual acceptance of the global identifier design is a successful demonstration of ….. When designing the objectives of a field evaluation, the NNSA team worked closely with a World Nuclear Transport Institute (WNTI) Working Group on UF_6 Cylinder Identification and staff from the IAEA Department of Safeguards to determine the features that would provide the most benefit. The WNTI Working Group consists predominately of industry members associated with cylinder fabrication, UF_6 conversion, UF_6 enrichment, fuel fabrication, and cylinder transport. Even though the global identifier would be implemented by industry, the DOE/NNSA team recognized that receiving user requirements from the IAEA was necessary to provide for its full utilization of the global identifier for safeguards purposes which would serve as a catalyst for its eventual implementation.

In April of 2016, the DOE/NNSA and IAEA teams conducted a simulated field exercise to demonstrate the key features of the global identifier in an operational setting and to evaluate potential IAEA benefits from its use. For the evaluation, a simulated cylinder raft containing ~50 UF_6 cylinders was created at IAEA offices in Vienna, Austria. Three separate IAEA inspection teams conducted an item counting and tag-checking exercise representing three levels of utilization of the global identifier features. The first group of inspectors performed the exercise using their current inspection methods. For the second

group, global identifiers were added to the simulated cylinders and the inspectors read the standardized identification information from the global identifier. The third inspector group used barcode readers to read the cylinder identification from the barcode included with the global identifiers. This paper describes the preparation and execution of the simulated field exercise, its results, and the next steps for the Global Cylinder Identifier Project.

Introduction

Standardized cylinders are an integral part of the nuclear fuel cycle, and are used to transport natural and low-enriched UF_6 among conversion, enrichment, and fuel fabrication plants.[1] Over the course of a typical year, approximately 20,000 model 30B and 48Y UF_6 cylinders are transferred between facilities; the total number of cylinders stored on site among the plants can exceed 150,000. While the number of cylinders and cylinder shipments is relatively low when compared with routine non-nuclear shipments (e.g., FedEx and UPS, which handle millions of packages a day), having the ability to effectively inventory and monitor nuclear shipments is extremely important for safety, security and nuclear non-proliferation.

The standards for fabricating these cylinders require that they possess a nameplate containing various information including model numbers, serial numbers and cylinder owner. However, the font size of the characters engraved on these nameplates is small and difficult to read. The ability to read the information is further degraded over time due to overall wear and tear to the nameplates over the cylinder lifecycle, which can exceed 40 years. To address the challenge of being able to read the cylinder identification, many companies will attach a company-specific supplemental label or marking to a cylinder (often a sticker) for their on-site use. Over time, an individual cylinder can collect a variety of many labels and markings with different identification numbers as it travels among facilities.

From a non-proliferation perspective, it is extremely desirable to be able to quickly and accurately reconcile the shipping and receiving reports on cylinders in transit and inventory cylinders in storage on site. Each individual cylinder can contain up to 50 kg of ^{235}U – nearly a significant quantity of low-enriched uranium as defined by the IAEA. Any potential confusion/incorrect recording due to the challenges associated with the cylinder identification presents complications to verification organizations, State authorities, and facility operators.[2]

Contributing Organizations

The primary organizations leading the effort to establish a global identifier for UF_6 cylinders have been the DOE/NNSA, representatives from the UF_6 cylinder handling industry, and the IAEA.

DOE/NNSA

In 2009, a DOE/NNSA-sponsored study was released that recommended an improved monitoring system for UF_6 cylinders to mitigate safety, security, and proliferation risks associated with UF_6 commerce.[3] A key recommendation from the study is that an improved monitoring system would be reliant upon a capability to uniquely identify each individual cylinder. In 2011, the DOE/NNSA formally kicked off a 5-year project to develop a concept for and to demonstrate, at the proof of concept level, a UF_6 cylinder identification and monitoring system. After reviewing and analysing standards for fabricating UF_6 cylinders[4], the operational lifecycle of cylinders[5], potential diversion and undeclared production scenarios involving cylinders[6], and current methods for detecting diversion and misuse scenarios[7], a multi-laboratory team issued a preliminary concept of operations in 2013.[8] A fundamental feature of the system was a unique identifier that could be used by both the facility operators and the verification organizations.

Following the completion of the preliminary concept, the team spent approximately 18 months meeting with members of industry (cylinder fabricators, conversion plants, enrichment plants, fuel fabricators, and State authorities) to solicit feedback and tour their facilities, when appropriate, to observe how cylinders are stored and handled on site.

DOE/NNSA Stakeholders Meeting

In the spring of 2014, the DOE/NNSA team hosted a meeting of UF_6 cylinder stakeholders in Washington, D.C. to share collective feedback, provide most recent information, and to discuss next steps. Participants included State regulators [Canadian Nuclear Safety Commission (CNSC), the Nuclear Regulatory Commission (NRC), Brazilian-Argentine Agency for Accounting and Control of Nuclear Materials (ABACC)], domestic industry (Columbiana Hi-Tech, Worthington), foreign industry [Energie de France (EdF), Areva, Cameco)], U.S. national laboratory staff, academia (Kennedy Center – Harvard) and the IAEA. Overall, the attendees agreed upon specific benefits from a standardized identification method – especially one that provided for automatic reading of the cylinder identification. Following the meeting, the industry stakeholders proposed to establish a working group through the World Nuclear Transport Institute (WNTI).[9]

WNTI Working Group

A WNTI Working Group (WNTI-WG) on UF_6 Cylinder Identification was officially created in May 2014 and immediately began working on its scope, objectives, and schedule. It is being jointly chaired by a representative from a commercial UF_6 handling facility and a representative from a DOE/NNSA national laboratory*. The scope, as adopted, was to establish an industry-wide identification format that provides for uniquely identifying UF_6 cylinders and to investigate methods for making the unique

* The WNTI Working Group is co-chaired by Marc-Andre Charrette of Cameco and Michael Whitaker of Oak Ridge National Laboratory (co-author of this paper).

identifier machine-readable and independently verifiable by the IAEA. Since its inception, the entire working group organized numerous teleconference calls, conducted two face-to face meetings in conjunction with the annual WNTI meetings in December in 2014 and 2015, and occasionally held ad hoc meetings. Currently the WNTI-WG is in the final deliberations of a guidelines document for the global identifier which is expected to be published in 2017. More information about the details of the recommended guidelines requirements agreed upon by the WNTI working group can be found in an associated PATRAM paper entitled "WNTI Working Group on UF_6 Cylinder Identification"[†] being presented at this symposium.

IAEA Integration

An important driver for DOE/NNSA to initiate its project was to explore practices that could increase the efficiency of conducting IAEA safeguards activities and to strengthen the overall effectiveness of safeguards implementation. The IAEA Safeguards Department staff had been apprised of the effort through a variety of international conferences and meetings and were active participants in key events such as the 2014 stakeholders meeting described above. Following the meeting, the IAEA co-authored a paper describing the potential benefits of a global ID system for UF_6 cylinders that was presented at the 2014 safeguards symposium hosted by the IAEA at its headquarters in Vienna, Austria.[10] The paper identifies several advantages for the IAEA with a global identifier and concludes that automated machine-readable global identifier would improve reporting by reducing transcription errors, improve timeliness in cylinder reconciliation, and reduce time in the field needed for verification activities, giving inspectors additional time for other activities when on site.

The IAEA was invited by the WNTI -WG to attend its annual meetings in 2014 and 2015 to provide input and feedback in the development of its guidelines document. During these meetings the IAEA representatives discussed potential benefits in conducting inspections and presented ideas of how the IAEA would be able to authenticate the identifier to further its usefulness for IAEA safeguards purposes.

In February 2015, the IAEA and DOE/NNSA held a technical meeting to review the current status on the concept of operations resulting from recent engagement with industry stakeholders, to review the schedule and scope of work for the WNTI-WG, and to discuss future contributions from the IAEA. Following the meeting, the IAEA initiated an official Support Program task with the United States to formalize its involvement in the activity to ensure that safeguards are considered early in the concept development and to position itself to take full advantage of the concept. The U.S. accepted the task in August 2015. The work scope includes the following activities:

- Preparation of a report on IAEA safeguards use cases and opportunities for increased

[†] Charette, M.-A., and Whitaker, J. M., "WNTI Working Group on UF_6 Cylinder Identification," PATRAM 2016, The 18th International symposium on the Packaging and Transportation of Radioactive Materials, September 2016.

safeguards effectiveness;
- Development of a list of IAEA-specific user requirements for the identifier;
- IAEA participation in WNTI-WG and interaction with stakeholders; and
- IAEA participation in a proof-of-concept demonstration.

The initial task was to develop the IAEA safeguards use cases associated with three levels of utilization of a global identifier:

- IAEA use of an industry applied cylinder identifier that contains a more readable, standardized identification format;
- IAEA use of an industry applied identifier that contains machine-readable identification information (e.g., barcode); and
- IAEA independent authentication of the identifier itself.

These use cases served as the basis for a joint IAEA-DOE/NNSA evaluation in April 2016.

DOE-IAEA Evaluation of a Global Identifier

The DOE/NNSA project plan includes a 'field trial' to be conducted to demonstrate at proof-of-concept level how the concept would work in a real-world setting to confirm the IAEA's ability to utilize the identifier. This field trial was initially envisioned to take place at an actual facility containing a large inventory of cylinders, but it became apparent that the objectives could more effectively be accomplished with a simulated exercise being conducted at IAEA offices in Vienna, Austria.

For the exercise, DOE/NNSA created a simulated cylinder storage raft of model 30B cylinders and surrogate global identifiers for the cylinders containing a barcode. In addition, a representative capability for scanning the barcodes directly from the identifiers was provided. The exercise was designed to assess, in particular, the IAEA safeguards use cases associated with cylinder item counting and tag-checking and to evaluate the impact on IAEA inspection effort associated with the implementation of the cylinder global identifier being proposed by WNTI.

Simulated Cylinder Yard

To create the simulated storage raft, the NNSA team used life-sized images of model 30B cylinders. Each image showed the valve end of a cylinder with the nameplate containing the identification information and other supplemental marking and labels as typically applied by plant operators (Figure 1). Approximately 50 cylinder images were printed on a series of high resolution posters. The posters were positioned two high to give a realistic representation of cylinders stacked 2 high, as they are at many storage locations.

Figure 1. Photographs of Model 30B cylinders used to create a simulated cylinder raft.

Surrogate Global Identifier

A set of surrogate global identifiers based on the current design being evaluated by the WNTI-WG was created for the cylinders. The working group is currently recommending that the cylinder identification be standardized using a 10-digit alpha-numeric character string consisting of 4 letters designating each individual company that owns cylinders followed by 6 numbers assigned by that company. The ID management approach being recommended by WNTI would provide for standardization of the identification format across the industry and a means for each company to ensure that an assigned identification number is not inadvertently duplicated. The global identifier itself would contain this identification information engraved as a character string and displayed as a 2D barcode to provide for machine-readability capability. The surrogate global identifiers used for the exercise were printed on cardstock and consisted of this alphanumeric ID and the data matrix 2D barcode representation of that ID.

Figure 2. Example of the global identifier containing the standardized identification format created for use during the simulated field evaluation (l) and a prototype plate for use by industry (r).

Barcode Reader System

A barcode reader system consisting of a barcode scanner and a tablet computer was provided to read the surrogate global identifiers. The barcode reader was representative of commercial readers capable of reading the 2D barcodes engraved on metal surfaces as intended for the global identifier. The tablet computer was loaded with rudimentary, demonstration software for matching a scanned identification number with a pre-loaded list of identification numbers. The software also provided a capability to match storage locations. As a series of global identifiers are scanned, the matching software provided listings of 1) remaining unmatched identifiers, 2) confirmed matches, and 3) scanned identifiers not present on the pre-loaded list.

Test plan

The test plan that was developed enabled the DOE/NNSA team to evaluate the benefit of adding a global identifier to the cylinders and to further assess benefits when a barcode scanner and simple software were also available for inspector use.

Three separate IAEA inspection teams conducted an item counting and tag checking exercise. Each team, consisting of 3 inspectors, was provided a written inventory list of the approximately 50 cylinders and was asked to conduct item counting and tag checking activities. Unbeknownst to the inspection teams, the inventory list contained several mistakes including cylinders moved to different locations in the raft, cylinders moved out of the raft, characters transposed on the list compared to the actual cylinder ID, an unlisted cylinder, and a duplicated cylinder shown in two locations (the first location included a sticker with a customer identifier and equipment number that did not match the serial number on the nameplate).

Simulated Field Exercise

Each of the three inspection teams attended a 'pre-inspector' briefing that included instructions provided by the IAEA exercise lead. They were also provided with a sample of the inventory list and shown example cylinder images representative of the ones used in the actual exercise (Figure 1). Once the inspector teams were familiar with the exercise they were provided with the actual cylinder inventory list and taken to the simulated cylinder raft. A 'plant representative' was present to serve as an escort through the raft and to respond to questions when asked (for example, the teams generally had conversations with him upon the discovery of a discrepancy).

The first team of inspectors performed the exercise using their current inspection methods to read the identification information from the nameplates shown in the photographs.

Prior to the start of the second team, the surrogate global identifiers with the standardized identification information marked with a larger font and a 2D barcode were added to the cylinder photographs. The second team of inspectors performed the same exercise but read the identification information from the global identifier instead of from the nameplate.

The third inspector team conducted the exercise with the provided barcode reader system to read the cylinder identification from the barcode included with the surrogate global identifier. The written inventory list of containing cylinder identification and storage location information had been preloaded onto the tablet. Using the matching results displayed on the tablet screen, the inspection team conducted the tag checking exercise without using pencil and paper.

Figure 3 provides photographs of the three inspection teams.

Figure 3: (left) Team 1 (center) Team 2 (right) Team 3 performing the tag checking during the simulated field exercise.

Following the completion of the exercise, each team was debriefed by the IAEA and DOE/NNSA exercise organizers. The IAEA lead reviewed the exercise and the discrepancies contained in the inventory listing. All the participants discussed the impact of the global identifier in the inventory activity and the ability to detect and resolve discrepancies.

Observations

The feedback from the inspection teams on the simulated cylinder raft included the following:

- The raft was representative of what they typically encountered in the field – although there were certainly less cylinders than would typically be encountered (as some sites have thousands of cylinders and require several days for verification activities) and the cylinders in the exercise were more accessible (as cylinders are often positioned very closely together, making it difficult to navigate the narrow aisles);
- The 2-high orientation is very typical, although some sites have cylinders stacked 3-high; and
- The ability to read the cylinder identification from the nameplate on the images was similar to the challenge of reading them in the field, and the variety of different cylinder nameplates was also representative.

In regards to the exercise design, the inspection teams reported that:

- Regardless of which site they visit, paper work can always be challenging; and
- Discrepancies do happen and they had experienced similar discrepancies to those created in the exercise.

In regards to the global identifier:

- The larger size of characters on the global identifier was easier to read;
- Having the global identifier applied at a consistent location made it easier to find;
- Having a standardized format in regards to the use of numbers and letters made it easier to read and transcribe; and
- Overall, the global identifier provided more confidence in confirming the operator list.

When discussing the potential use of an authenticated global identifier (not part of the exercise) the inspector teams stated that authentication would provide further confidence that they were tag checking the cylinders intended, and that IDs had not been falsified or replaced.

The observers of the exercise noted that the inspectors were thorough in looking for cylinder IDs on the list, but the global identifier allowed the inspectors to perform the exercise quicker and easier, once the inspectors were familiar with the system. For the third team using the barcode scanner, additional time was necessary to become familiar with the scanning equipment and to have confidence in the scanning software. A number of suggestions were provided on ways to improve the software and how to present the information to the inspectors.

Take Away Points

Overall, the NNSA team and the IAEA participants feel that the IAEA can benefit from the WNTI global identifier effort, as the global identifier will likely reduce time required to perform cylinder item counting and tag checking. Reducing the time to perform item counting and tag checking will provide more time to perform other inspection activities, as well as reduce radiation exposure, increase the probability of finding discrepancies while in the cylinder raft (for instance, the automated reader can quickly point out a duplicated or missing cylinder from the inventory list), and may provide for more frequent inventory activities. Automated reading and software tools could facilitate data fusion through faster resolution of discrepancies and cross correlating with existing IAEA information.

Next Steps

Following the NNSA team's return to the U.S., dialog has continued with the IAEA, and has focused on ways to improve the software. To further catalyse adoption by industry, over the summer of 2016, a team at ORNL tested how well commercial off the shelf direct part mark barcode readers read barcodes of various sizes marked on various types of metals with various surface finishes, and at various orientations and curvatures (e.g., a global ID placed on the inside of a cylinder skirt would have some curvature and may be more difficult to read). These variables were tested using 8 different barcode scanners, over various distances to determine if commercial barcode scanners are available for the desired global ID and envisioned use case.

The team has had preliminary joint conversations with the IAEA and the Joint Research Institute in Ispra, Italy concerning potential authentication technologies including epoxy, glass beads, and weld scan verifications. These conversations will have a tangential effect on application/implementation, and efforts will be made to keep additional costs low.

Upon completion of the WNTI guidelines document, the final draft will be sent to the IAEA for comment. Following publication of the WNTI guidelines document and initial implementation by industry, the IAEA can eventually begin using the authenticated version of the global ID.

Conclusions

As the project approaches the 5-year mark, the simulated field evaluation in Vienna proved to be a fitting culmination, and demonstrated to the IAEA (and to industry through briefings) that the global ID will be beneficial to all. This successful demonstration now allows future work to focus on implementation which is anticipated to be next on the horizon following the publication of the WNTI guidelines document.

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