Content-Specific Challenges for Uranium Hexafluoride

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Abstract

At any moment, there can be ~20,000 cylinders containing natural or low-enriched uranium hexafluoride (UF_6) in global circulation among nuclear fuel cycle facilities. The number of nuclear power plants is projected to increase (in both existing and new nuclear power countries), and this increase will lead to an increase in the number of UF_6 cylinders in circulation. The UF_6 content of these cylinders can be attractive to a potential proliferator because only a few more steps are required to process the UF_6 into material that could be used for a nuclear weapon. A unique identifier, facility monitoring systems, and a global registry for these cylinders could help operators, inspectorates, and States protect against these cylinders falling into the wrong hands. Currently, official cylinder identification numbers are stamped on a nameplate welded to the end of each cylinder, but most facility operators apply a separate site-specific identification marking (e.g., bar code, sticker, etc.) for on-site use because the nameplates are difficult to read and cannot be read be remotely. Reading the nameplates can be further complicated by the small text that is used, the physical configuration used for cylinder storage (e.g., stacked close together), and eventual degradation of the nameplates themselves (through use and exposure to the elements). The difficulty in reading the cylinder identifications can lead to transcription errors and to increases in the time operators are exposed to cylinders while performing receipt, shipment, and inventory activities. Researchers at Oak Ridge National Laboratory and other U.S. Department of Energy laboratories are designing a concept for a global cylinder identification and monitoring system to improve cylinder identification and provide for facility cylinder monitoring systems that can be used by both industry and inspectorates.

Background

The nuclear fuel cycle (Figure 1) involves many facilities that handle uranium hexafluoride (UF_6) cylinders, including conversion, enrichment, and fuel-fabrication facilities. Natural UF_6 is produced at conversion facilities and is shipped in model 48Y cylinders to enrichment facilities. Enriched UF_6 is produced at enrichment facilities and is shipped to fuel fabrication facilities in model 30B cylinders. Due to current demands and the recent construction of nuclear power plants, the number of cylinders circulating has increased, and it is speculated that it will continue to do so. The number of cylinders transported globally between facilities is estimated to be less than 20,000 per year [~9,000 model 48Y cylinders of natural uranium and ~7,000 model 30B cylinders of low enriched uranium (LEU)].[1]

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[1] G. Eccleston et al., "Monitoring Uranium Hexafluoride (UF_6) Cylinders," ORNL/TM-2009/128, June 2009.

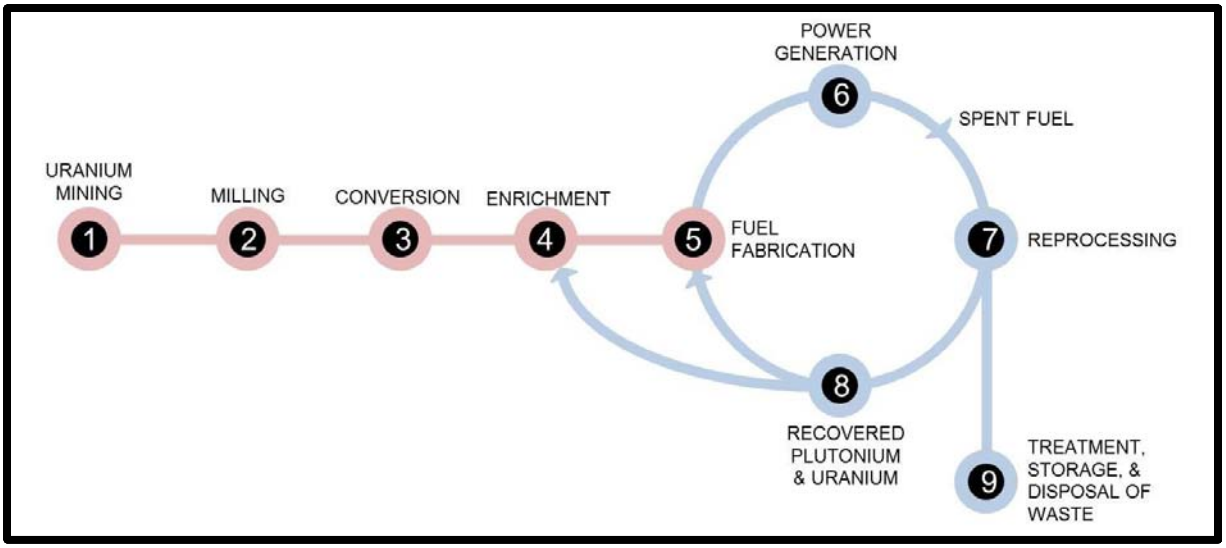

Figure 1. Nuclear Fuel Cycle.

When not being transported or connected to the process, UF_6 cylinders are typically stored on site in areas that can contain hundreds, or even thousands, of cylinders. Figure 2 shows an external storage area containing several hundred model 48Y cylinders. Each of these cylinders has a serial number that is stamped on a nameplate (which is welded to the end of the cylinder during fabrication). As shown in the figure, cylinders can be stacked closely together, making it difficult to access and read the nameplates. The nameplates themselves are often exposed to weather that can lead to degradation.

Figure 2. External storage area containing model 48Y cylinders.

Because the serial numbers on the nameplates can be difficult to read, operators currently use a variety of methods to apply additional markings or labels to improve their ability to identify cylinders. According to a 2011 paper published by URENCO, operators often do not use the number etched on the cylinder's nameplate as their identifying marker. [2] Operators have been known to mark the cylinders with stickers, stencils, or grease pencils to help identify the cylinders. As shown in Figure 3, it is not uncommon to see a cylinder with multiple markings, including additional nameplates, multiple adhesive labels, painted markings, and bar codes. Multiple and often conflicting markings make cylinder identification for both operators and inspectorates more difficult and time-consuming.

Figure 3. Examples of additional markings and labels applied by operators to improve ability to identify cylinders.

Safeguards Challenges

The UF_6 itself is well monitored as it is produced, processed, transported, and stored both domestically and internationally, but the cylinders themselves are not monitored to the same degree. There are no international standards for identification formats or numbering schemes. Some companies and States have registries for the cylinders that they license or own, but there is not a "global" registry that collects all available information and contains the last reported location for each cylinder. There are increasing nonproliferation concerns that cylinders containing UF_6 are becoming more attractive to potential proliferators if the proliferators have access to enrichment technology to convert the UF_6 into highly enriched uranium (HEU) that could be used for a nuclear weapon.[3] Each model 48Y and 30B cylinder can contain ~50 kg ^{235}U, which is equivalent to two significant quantities (SQs) of HEU. Further calculations show that even a modestly sized clandestine enrichment facility (10,000–25,000 SWU/year) operating with natural uranium as its feed material could be capable of producing an SQ of HEU in less than 1 year (i.e., less than the timeliness goal used by the International Atomic Energy Agency (IAEA) for detecting the diversion of a cylinder). If a full model 30B cylinder containing LEU in the 3.5% to 5% ^{235}U range were fed, this same plant could produce an SQ of HEU in a considerably shorter time period.[4]

[2] P. Friend et al., "URENCO's Position on Standardising the Identification of UF_6 Cylinders" INMM, 2011.
[3] J. M. Whitaker et al., "Preliminary Next Generation Safeguards Initiative Concept of Operations for a cylinder-Monitoring System," ESARDA, 2013.
[4] White-Horton et al., "Global Cylinder Identification and Monitoring System: Nonproliferation Concerns and Baseline Definition," ORNL/TM-2013/169, May 2013.

Concept

In April 2011, the National Nuclear Security Administration's Next Generation Safeguards Initiative (NGSI) launched a 5 year program to investigate a unique identification system for UF_6 cylinders and to develop a cylinder-monitoring concept that could be used by facility operators and the IAEA. The ultimate objective of the program is to demonstrate at a proof-of-concept level the principal elements of a global monitoring scheme that uniquely identifies UF_6 cylinders throughout their life cycle. NGSI has engaged and will continue to engage the IAEA Safeguards Department as appropriate throughout.[5]

The research conducted over the first year of the program allowed the team to develop a concept for a global cylinder identification and monitoring system. It comprises three key elements: a unique identifier (UID) for cylinders, unattended UID reader systems, and a global registry of cylinders. The identification and monitoring system would focus initially on model 30B and 48Y cylinders in active circulation. The application of a UID would be implemented over a 3 to 5 year time frame as cylinders come due for recertification. Over the long term, NGSI would work with the appropriate stakeholders on national and international standards to include the UID as a cylinder fabrication requirement.

The UID is the cornerstone of the global cylinder identification and monitoring system. Each cylinder would have a UID that can be used for identification and monitoring and would be designed for use across the entire UF_6 cylinder industry. It would also be robust enough to withstand the expected environmental conditions and cylinder-handling practices and to have a life expectancy of 10 to 30 years. A fundamental feature of the UID is that it can be independently used by both the plant operator and the IAEA. High-level functional requirements include a standardized format/design that can be remotely read and that would meet IAEA tamper-indicating standards. The UID would not replace the current cylinder nameplate, but it could be correlated with the identification number stamped on the nameplate.[6]

The UID readers could either be handheld systems or installed unattended systems. Operators, regulators, and IAEA inspectors could have independent and/or shared capabilities for reading the cylinder UIDs. Unattended readers could be installed at strategic locations that could benefit operators and/or the IAEA (e.g., cylinder receipt and dispatch areas, accountability scales, feed stations). For unattended readers, the information for reading cylinder UIDs would likely need to be integrated with a cylinder database to verify that a read UID is in fact present in the database. Cylinders read for the first time (and not in the database) would need to be "registered" (i.e., the ID would be issued/recorded). The operator would have the capability to read the cylinder UID and enter information into facility databases that monitor information related to the location, status, and utilization of cylinders. Any negotiated IAEA system could collect information through the use of unattended readers as well as handheld readers that might be utilized by inspectors during on-site inspections. Information to be submitted to a global registry could be collected either manually, with handheld readers, or with unattended reader systems.[7]

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[5] K. R. Durbin et al., "Overview of Next Generation Safeguards Initiative UF_6 Cylinder Monitoring Project," ESARDA, 2013.
[6] J. M. Whitaker et al., "Preliminary Concept of Operations for a Global Cylinder Identification and Monitoring System," ORNL/TM-2013/278, August 2013.
[7] J. M. Whitaker et al., "Preliminary Concept of Operations for a Global Cylinder Identification and Monitoring System," ORNL/TM-2013/278, August 2013.

An access-controlled global cylinder registry would be established to maintain location and status information on all UF_6 cylinders in both nuclear weapon States and non-nuclear weapon States (beginning with the model 30B and 48Y cylinders in active circulation). The registry would receive cylinder-related information from the facility operators and/or national authorities. The information would include but would not be limited to

- the UID,
- the facility location,
- the cylinder owner, and
- the cylinder's status (e.g., full, empty).

For IAEA-safeguarded facilities, the safeguards-related information in the registry could be periodically synchronized or downloaded to an IAEA cylinder-monitoring system. Combining information from this global registry with current IAEA safeguards activities could provide for more timely detection of diversion and undeclared production of enriched UF_6. The IAEA would have a capability to generate a list of all cylinders in a State. The list would support State evaluations, annual inspection planning, and acquisition path analyses. A registry would also be especially valuable in IAEA efforts to reconcile cylinder transfers (i.e., transit matching) in a more timely manner.

Of fundamental importance, the registry could provide the IAEA with a technical basis for recognizing unregistered (potentially undeclared) cylinders. Depending on how frequently information is submitted to the registry and the IAEA safeguards department access to the registry, it is possible that IAEA inspectors could have access to cylinder receipt information prior to inspecting facilities. This information would be valuable in planning inspections (especially unannounced or short-notice random inspections) and in verifying operator receipts records.[8]

Benefits

The NGSI team feels that the IAEA would gain increasing benefits from each component of the proposed cylinder identification and monitoring system. A standardized cylinder identification format used across the industry would improve reporting to the State Systems of Accounting for and Control of Nuclear Material and the IAEA by reducing reading and transcription errors. The industry's use of a standardized format would reduce confusion in the various reporting systems because it would eliminate the need for companies to apply supplemental labels and identification numbers to the cylinders. The elimination of multiple identifiers could simplify IAEA on-site verification activities and efforts to reconcile cylinder transfers between facilities and States.

The potential impacts for the IAEA include investing time at the beginning to specify functional requirements as a user, establishing procedures and methodologies for using the information, approving for use and installing portable and installed UID readers, and negotiating modifications to current safeguards practices. Users must further ensure that the function requirements being established for the UID are sufficient to meet IAEA's tamper-indicating requirements. Implementing any new safeguards

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[8] J. M. Whitaker et al., "Preliminary Concept of Operations for a Global Cylinder Identification and Monitoring System," ORNL/TM-2013/278, August 2013.

methods and instruments will have time and cost implications for testing and approving for use, writing implementing procedures, training of inspectors, and long-term maintenance.

The IAEA would need to negotiate the use of portable readers with States (and facilities). Any installed instruments would require new software to be developed for processing cylinder UID information and would have to be approved for use by the IAEA and be acceptable to the host country (and facility operator). The resulting changes in the safeguards approach would have to be negotiated as well. A key consideration would be to determine how quickly the IAEA could receive notifications (i.e., to determine whether notices can be remotely transmitted off site periodically or that inspectors would have to physically visit the site to acquire the information). This aspect directly affects the timeliness of detecting scenarios that involve diversion or undeclared production.[9]

Current Status

In early 2013, details of this preliminary concept of operations were briefed to representatives of industry, national authorities, and inspectorates that could be affected by its implementation to solicit feedback, support, and recommendations for the path forward. As of July 2013, individual briefings have been conducted for representatives of domestic and international cylinder fabrication sites, conversion facilities, enrichment plants, and fuel fabrication facilities. The initial feedback was that all companies seemed interested in an industry-wide UID for cylinders. There were questions regarding the cost, who would apply the UID, and what would happen if a UID was destroyed or damaged. Some companies have looked or are looking at automated reading systems for the company labels that they create and apply to cylinders at their individual facilities. While all industry representative expressed general agreement with the high-level functional requirements established for the UIDs, they expressed concern over the potential cost to switch from the methodologies that they have proven acceptable at their respective facilities, and they have questioned what specific UID technology is being envisioned.

Although some companies and regulators have registries for cylinders under their ownership or jurisdiction, there is concern among industry representatives over what information would be contained in the global registry and who would have access. The NGSI project team has consistently received valuable feedback from candid discussions with cylinder-handling stakeholders throughout the project. This feedback is being incorporated into the concept of operations as it evolves.

Future Activities

Following the completion of the preliminary concept of operations, the team's next step is to investigate the currently available commercial off-the-shelf technology for both the UID and the reader systems. The team will also continue to work closely with stakeholders and the IAEA to ensure that the technology is allowable inside facilities and that it conforms to IAEA requirements for tamper-indicating devices during the selection process. The team must also further define the global registry, including its architectural structure; what data will be included; who will "own" the system (e.g., IAEA, the World Institute for Nuclear Security); and who will be granted access to the system. The team will also begin cost estimations and analysis of the lifecycle cost benefit. The hope is that the up-front cost will be less than

[9] J. M. Whitaker et al., "Preliminary Concept of Operations for a Global Cylinder Identification and Monitoring System," ORNL/TM-2013/278, August 2013.

10% of the cost of the cylinders and that, due to the system's time-saving measures, the up-front costs will be recouped shortly after implementation.

To conclude, the NGSI cylinder-monitoring program is focused on solutions that will help to strengthen the international safeguards system and will make it more effective and efficient. Implementing systemic changes, such as the global deployment of the conceptual UF_6 cylinder identification and monitoring system at nuclear facilities will be a long-term and multifaceted undertaking. NGSI looks forward to working closely with all relevant stakeholders to continue to strengthen the safeguards system and ensure that it becomes more efficient without compromising its effectiveness.