Global Identification and Monitoring of UF_6 Cylinders

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Abstract
An expansion of global commerce in nuclear material will accompany the forecast worldwide renaissance in nuclear power. The increased commerce amplifies the risk that uranium hexafluoride (UF_6) in cylinders could be mishandled, intentionally stolen, or diverted. While there are typically few problems with UF_6 cylinder shipments, the complicated logistics of international truck, rail, and sea transport can increase difficulty in locating shipments at any given time and significantly delay transport and reporting. The recognized threat of undeclared enrichment plants has made UF_6 more attractive for attempted diversion. A global system of registering, identifying, and monitoring UF_6 cylinders would provide more robust and timely assurance that no UF_6 is mishandled or diverted.

The Office of Nonproliferation and International Security (NA-24) of the U.S. Department of Energy's (DOE's) National Nuclear Security Administration (NNSA) has formed a multi-laboratory team to focus on universal UF_6 cylinder identification and global monitoring. The team produced an overview report discussing the current situation and potential solutions and identified future tasks that fall into three general categories. The first category involves policy initiatives to bring together all relevant stakeholders—facility operators and industry, state regulators and government agencies, international inspectorates, and technology developers—to reach consensus on universal identification and the importance of cylinder monitoring. Such policy-level discussions would include standardization of components, protocols, and procedures. The second category concerns a deeper investigation of the concepts involved, reflected in the research and publication of papers and technical reports. Such background work is merely the "tip of the iceberg" but may facilitate acceptance of a global regime by the stakeholders. The third category involves technology assessments and field trials to enable the development of theoretical concepts into practical approaches. This paper gives an overview of the progress to date and examines the next steps for governments and international agencies (from the policy side) and industry and national laboratories (from the technology and development side).

Introduction
The nuclear industry is experiencing a surge in both the number of facilities under construction in states with existing nuclear energy programs and the number of states pursuing nuclear energy for the first time. This potential nuclear renaissance will be accompanied by a proportional increase in global commerce to supply nuclear fuel and, more specifically, by an increase in the number of UF_6 cylinder shipments. Since relatively few states have commercial uranium enrichment facilities, UF_6 cylinders must often travel long distances between sites. Currently, conversion plants ship an estimated 9100 cylinders—each containing approximately 8400 kg of natural uranium—to enrichment plants each year. In turn, the enrichment plants ship roughly 6600 cylinders—each containing approximately 1500 kg of reactor-grade uranium (containing 3–5% ^{235}U)—to nuclear fuel fabrication plants. Thus, the overall number of UF_6 cylinders in transport each year is fewer than 20,000. This number is small when compared to other items routinely tracked in international commerce.

Some in the nuclear industry and safeguards community are proposing the development of new standards to uniquely identify UF_6 cylinders.[1,2] Current identification labels are not consistent across manufacturers and become difficult to read when subjected to harsh industrial and environmental conditions. Due to these differences and the significant wear current labels endure over time, identification of cylinders requires excessive effort from safeguards inspectors and facility personnel, as they must individually locate and visually read each cylinder. Using a standardized, unique identifier permanently attached to each cylinder in a verifiable manner would decrease operator burden and free inspectors to use their time more effectively, and would also help facilitate the shift to a more functional tracking system. However, unique identification alone would not suffice; new tracking technologies must be incorporated as part of the unique identifier to automate identification and enable global monitoring. One suggested method is for the nuclear safeguards community to work directly with industry, both to develop a central registration database with unique cylinder identifiers containing embedded tracking technology and data storage, and to initiate negotiations to implement a global cylinder monitoring regime. The optimal system must include collaboration among industry, the International Atomic Energy Agency (IAEA), and other stakeholders (e.g., cylinder manufacturers and nuclear transport regulators).

Background

NNSA has launched the Next Generation Safeguards Initiative (NGSI) to develop advanced safeguards approaches, technologies, equipment, and expertise to meet current and future proliferation challenges. Under this initiative, NNSA and the DOE national laboratories are studying the monitoring of UF_6 cylinders; this effort aligns with a wider U.S. nuclear energy policy to provide greater security for nuclear fuel and waste, including guidelines for tracking, controlling, and accounting for nuclear material in transport.

UF_6 is shipped and stored in steel cylinders. Traditional safeguards that focus on nuclear material do not require reporting the location of the cylinders themselves. There are two models of stainless steel cylinders (48Y and 30B) primarily used to store and transport most UF_6, both in the United States and abroad. Type 48Y cylinders are used to store and transport natural uranium and depleted uranium; the smaller 30B cylinders are used to store and transport reactor-grade uranium product enriched up to 5% ^{235}U. Each cylinder is manufactured to the appropriate ISO or ANSI standard, which calls for a nameplate engraved with the manufacturer's identification number and the purchaser's serial number. These nameplates vary in size, and each manufacturer typically has its own numbering system or employs the numbering system assigned by the original purchaser. In addition, each facility tends to use its own cylinder marking and identification methods. As a cylinder passes from site to site around the world, it can accumulate several different numbers by means of metal plates, sticky labels, paint, or even marker pen. An improved identification system is needed if cylinders are to be uniquely identified and located.

[1] R. Babcock, et al., "Benefits of an international database for UF_6 cylinders," 2008 Annual Meeting of the INMM, Nashville, Tennessee, July 2008.
[2] P. Friend, D. Lockwood, and D. Hurt, "A concept for a world-wide system of identification of UF_6 cylinders," 2009 Annual Meeting of the INMM, Tucson, Arizona, July 2009.

Previous UF_6 Cylinder Monitoring Work under NGSI

The safeguards community has been contemplating the concept of global monitoring of UF_6 cylinders for a number of years, as one aspect of the perception that nuclear materials in transit between facilities present a potential weak point in the current implementation of safeguards. In addition, those in industry who work with UF_6 cylinders have been considering advanced methods of identification and tracking, while the technology to do so has evolved considerably in nonnuclear applications.

Conference papers in 2008 and 2009 (referenced above) brought this issue to the forefront, and NNSA responded in 2009 by sponsoring an overview report on the subject that led to a more concerted effort on related tasks in 2010. At the same time, some in industry began to consider internal implementation and inter-corporate engagement on standardization. These efforts are described below.

2009 Overview Report

NNSA, through the NGSI, has formed a multi-laboratory team to focus on universal UF_6 cylinder identification and global monitoring. The team produced an overview report discussing the current situation and potential solutions.[3] The report identifies several benefits to both industry and safeguards that could be gained from a global cylinder identification and monitoring system:

- ensuring proper processing, shipment, and delivery of all cylinders;
- improving safeguards and industrial efficiency by automating inventory taking and transit matching;
- enhancing safeguards effectiveness through more timely detection of potential cylinder misuse and diversion;
- discouraging the use of unregistered cylinders to conceal undeclared production or diversion of UF_6; and
- supporting IAEA State–level assessments and global information analysis to verify nuclear material commerce and cylinder shipments between states.

The report recommends that NNSA proceed with actions in six areas related to monitoring of UF_6 cylinders:

1. initiate discussions with industry, the IAEA, and other stakeholders to identify and negotiate a preferred structure for a global UF_6 cylinder monitoring system;
2. begin limited cylinder monitoring projects to identify gaps and limitations to monitoring and provide recommendations for design and implementation of monitoring technologies;
3. work with industry and stakeholders to develop and implement a cylinder registry system with a tamper-indicating unique cylinder identifier incorporating tracking and data storage technology;

[3] G. Eccleston, et al., "Monitoring Uranium Hexafluoride (UF_6) Cylinders," ORNL/TM-2009/128, Oak Ridge National Laboratory, June 2009.

4. develop and demonstrate a prototype monitoring and registration database with capabilities to receive and send cylinder identity, location, movement, use, and material quantity;
5. review monitoring options and develop and demonstrate secure methods to identify, locate, and track cylinders and to transmit this information to a monitoring database; and
6. pursue further analysis to review the best ways to (a) use UF_6 cylinder monitoring to improve the effectiveness and efficiency of IAEA safeguards and (b) optimize the system to provide benefits to industry, safeguards, and counterterrorism organizations.

These future tasks fall into three general categories. The first category involves policy initiatives to bring together all relevant stakeholders—facility operators and industry, state regulators and government agencies, international inspectorates, and technology developers—to reach consensus on universal identification and the importance of cylinder monitoring. Such policy-level discussions would include standardization of components, protocols, and procedures. The second category concerns a deeper investigation of the concepts involved, reflected in the research and publication of papers and technical reports. Such background work is merely the "tip of the iceberg" but may facilitate acceptance of a global regime by the stakeholders. The third category involves technology assessments and field trials to enable the development of theoretical concepts into practical approaches.

The team proposed three alternatives to UF_6 cylinder tracking: (1) implementing a global system to track cylinders using existing information; (2) implementing technology to provide point-to-point cylinder tracking (point-to-point tracking could range from manual barcode logging to automatic reading and logging at fixed points); and (3) implementing continuous path cylinder tracking. Continuous path tracking can range from "live" (near real time) continuous tracking for the entire route to obtaining data to the end of the transport that provides information on the entire route for analysis. These three options were compared to assess the benefits, costs, and risks to industry, nuclear safeguards, and security.

UF_6 Cylinder Stakeholders

The first task was to develop a comprehensive list of stakeholders in a global monitoring system: primarily UF_6 users and cylinder manufacturers, but also cylinder transport companies; regulators and standards organizations for UF_6 cylinders and nuclear material transport; and state, regional, and international safeguards organizations.

Representatives from companies involved with UF_6 cylinders have expressed interest in universal cylinder identification, and some—most visibly the safeguards and security staff at URENCO—are attempting to form an industry working group to look at the issue. The list of stakeholders will be used by those involved with this effort to ensure that all interested parties are invited to participate in such a working group. Researchers first developed an open source list of all companies that use UF_6 cylinders, specifically nuclear fuel cycle companies in uranium enrichment, UF_6 conversion, and fuel fabrication. At the same time, researchers attempted to identify all current cylinder manufacturers by contacting representatives of companies on the list to find additional contacts and identify companies that had been missed.

Researchers at ORNL have so far identified more than 20 companies in the "UF_6 users" category. These include state-run energy agencies (e.g., the Comisión Nacional de Energía Atómica in Argentina), fully state-owned corporations (e.g., Atomenergoprom in Russia and the China National Nuclear Corporation), and multinational nuclear fuel services companies (e.g., AREVA and Cameco). ORNL has communicated so far with three active UF_6 cylinder manufacturers: Plaatijzerindustrie B.V. in the Netherlands, Sotralentz in France and Romania, and Westerman in the United States. Conversations with one cylinder manufacturer provided the insight that UF_6 users typically buy new cylinders near the original source of the UF_6 they are purchasing, thereby limiting the distance that empty cylinders must be shipped. For example, a Japanese company purchasing uranium conversion services from a plant in Canada would likely buy new UF_6 cylinders from a manufacturer in North America.

A more difficult part of the task of identifying stakeholders was limiting the scope to those directly involved with UF_6 cylinders. There are numerous state and regional agencies that may be tangentially linked through more general nuclear or transport regulations but do not have a significant stake in the identification or monitoring of cylinders. Likewise, there are several uranium trading companies that buy and sell uranium and fuel cycle services but do not actually operate any nuclear facilities and have no practical relevance for how the cylinders are identified or monitored. Whether to classify these and other entities as stakeholders for future engagement will likely depend on conversations with them and their partners to determine their interest in participating in the industry working group.

Roadmap Development

To lay out a five-year program to work on this issue under NGSI, NNSA sponsored a two-day workshop in May 2010 hosted by the Savannah River National Laboratory. The goal of the meeting was to define a program to achieve, within five years, a proof-of-concept demonstration of a cylinder monitoring system and the necessary high-level activities under that program to support such a demonstration. To facilitate discussion of these high-level program activities, the working group divided into three subgroups following an initial general discussion of the need for and challenges to establishing a global UF_6 monitoring system. The three subgroups focused on the main bodies of technical and related institutional work that must be accomplished.

More specifically, the first working group focused on problem definition, stakeholder interests, and related policy and regulatory actions, with discussions concentrating on defining a strong baseline understanding of all stakeholder interests and concerns regarding the international safeguards and industry operational impacts, potential information requirements for a global monitoring system, and a feasible concept of operations. The second working group discussed the state of monitoring technology and tracking devices, the unique operational challenges that tracking cylinders would pose, the leveraging opportunities offered from ongoing investments by other programs in developing tracking and monitoring systems for various purposes (e.g., commercial, military, homeland security), and the timing and scope of UF_6-specific monitoring technology activities needed to support a proof-of-concept demonstration at the end of the five-year period. The third subgroup focused on key elements of developing a registry database that is essential to any monitoring or tracking system. In addition, they discussed potential opportunities to adapt the existing information management systems currently used for reporting and tracking nuclear materials.

The working group agreed that five years is the appropriate timeframe for developing this solution to the stage where a demonstration at the proof-of-concept level could take place, allowing time for adaptation of tracking technologies to meet the specific operational challenges of the approach developed and for development of the needed registry database. The participants anticipate that the notional program plan developed as a result of the workshop will eventually lead to actionable items that should make the project "shovel ready" when NNSA makes the decision to move forward with this effort.

URENCO Cylinder Identification Initiative

URENCO, an operator of gas centrifuge enrichment plants in Europe and the United States, has taken the lead within industry on an effort to standardize and implement a system for uniquely numbering UF_6 cylinders. Their motivations for doing so include the safeguards benefit of being able to more rapidly identify cylinders during inspections and detect unregistered cylinders that may indicate illicit activity. But their primary motivation is the benefit to the operators in their own facilities, who currently must contend with confusing and often contradictory labeling on cylinders. Each certified UF_6 cylinder has a welded nameplate with a manufacturer's serial number and owner's identification number, but these numbers are not unique across companies, and facilities often assign their own numbers, complete with adhesive labeling, to each cylinder as it passes through their control. In addition, standardized labeling with unique numbering could enable automated logistics and inventory approaches.

URENCO is attempting to engage other cylinder users and manufacturers in forming an industry working group that can address this issue. This engagement often involves directly communicating with competitors, identifying that they all have the same difficulties, and convincing them to participate in the working group to find a solution that would have benefits for all while minimizing costs. URENCO's vision for this working group is agreement on one cylinder numbering convention with some form of centralized registration, use of these registered numbers on all paperwork and uniform labels with predefined content, and eventual modification of standards to include compulsory, permanent fixing of such labels to new and recertified cylinders.

At the same time, URENCO is moving forward with implementing an intermediate solution at its own facilities, which may serve as a stepping-stone model for a future industry-wide system. The URENCO initiative (as shared by URENCO staff) has three components: unique numbering, labeling, and use of the number and label in cylinder management.[4]

UF_6 Cylinder Standards

As should be apparent based on the several references to industry standards above, it is crucial in this effort to examine the various standards related to UF_6 cylinders (ANSI, ASME, ASTM, ISO, etc.) and specifically identify the process for modifying those standards to adopt changes related to a universal

[4] URENCO is organizing an evening meeting to launch their initiative during the 2010 PATRAM week for all parties interested in the subject (maximum 25 people). Invitations to the meeting have been sent to some PATRAM attendees, but if you wish to attend you can contact Rudi Valley from URENCO Nederland BV in-person at the PATRAM meeting or by phone (+31 651 207 912) for more information. The presentation will take about one hour and another hour is reserved for questions and discussion.

cylinder identification system. The goal of this task should not initially be to actually modify the standards but to lay the groundwork for whatever modifications are deemed necessary by the industry working group on cylinder identification.

There are numerous standards and regulations that relate to UF_6 cylinders. The IAEA safety standard TS-R-1, “Regulations for the Safe Transport of Radioactive Material,” and the NRC regulation 10 CFR Part 71, “Packaging and Transportation of Radioactive Material,” provide general guidelines for safe nuclear material transport, including activity limits, hypothetical accident situations, and material classifications. These regulations are referenced by many other state and regional regulators. In the United States, transport of UF_6 is also regulated by the Department of Transportation, especially through 49 CFR Part 173.420, which specifically refers to ANSI N14.1.

ISO-7195, “Packaging of UF_6 for Transport,” and ANSI N14.1, “UF_6—Packaging for Transport,” provide specific standards for the manufacturing, testing, and certification of UF_6 cylinders, and reference many additional standards for UF_6 cylinder fabrication, especially related to the specific materials used for various components.

These standards require that each cylinder have an attached nameplate. Information contained on the nameplate includes the standard to which the cylinder is certified, the model type, the company names of the manufacturer and purchaser, the date of manufacture, safety limits, and recertification information. In addition, each nameplate includes space for the appropriate inspection stamp and national registration number as required by local regulations. In the United States, this means an ASME “U” inspection stamp (for pressure vessels) and registration number from the National Board of Boiler and Pressure Vessel Inspectors. Furthermore, each nameplate includes a serial number provided by the purchaser of the vessel; this number represents the purchaser’s numbering system and is not necessarily unique across all cylinders.

ASTM A516 and EN 10028-3 provide standards for steel used in pressure vessels such as UF_6 cylinders, while cylinder nameplates must be made from steel that conforms to ASTM A240 or EN 10088-2. Likewise, all material used in cylinder stiffening rings, lifting lugs, couplings, valve components, etc., must comply with the applicable ASTM or EN standards. These and other standards also provide other criteria for packaging of UF_6 for transport, including the requirements for in-service inspections, cleanliness, and maintenance; cylinder loadings; shipping details; and cylinder overpacks. Any global cylinder identification and monitoring system will have to take into account the impact on these standards, especially those parts related to the cylinder nameplates and registration requirements. In addition, standards and regulations related to nuclear material control and accounting, such as ANSI N15.8 and 10 CFR Part 74, may be impacted by a proposed UF_6 cylinder monitoring system, especially with regard to how cylinder numbers are reported to state and international authorities.

All of these standards related to UF_6 cylinders and transport are in addition to the standards for the UF_6 itself, which include ASTM C787, “Standard Specification for UF_6 for Enrichment,” and ASTM C996, “Standard Specification for UF_6 Enriched to Less Than 5% ^{235}U.” These standards involve such things as isotopic and purity limits for commercial use and approved sampling methods. Modifications to these standards probably are not relevant to cylinder identification and monitoring.

Next Steps and Future Work

In the coming months, NNSA will be coordinating with the DOE multi-laboratory team to develop a comprehensive strategy for moving forward with this project and eventually implementing a universal cylinder monitoring system. Industry representatives, especially the safeguards and security staff at URENCO, are gathering participants for an industry working group to consider universal identification and registration of cylinders. Overall, this should remain an industry-led effort, as effective implementation will require at least some level of voluntary participation by stakeholders. Any proposal must therefore include clear benefits for facility operators, even if the benefit is just reduced safeguards burden. NNSA, through NGSI, can support this effort in many ways, especially with development of theoretical concepts, assessment of relevant technologies, and field trials of proposed systems. In addition, NNSA can provide a gateway for the industry working group to work with relevant governmental and international authorities, such as the IAEA, the Nuclear Suppliers Group, and the parties of the relevant treaties and agreements that manage such things as nuclear commerce and access to enrichment technology.