# Global Monitoring of Uranium Hexafluoride ($UF_6$) Cylinders
# Next Steps in Development of Action Plan

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## Abstract

Over 40 industrial facilities world-wide use standardized uranium hexafluoride ($UF_6$) cylinders for transport, storage and in-process receiving in support of uranium conversion, enrichment and fuel fabrication processes. $UF_6$ is processed and stored in the cylinders, with over 50,000 tU of $UF_6$ transported each year in these International Organization for Standardization (ISO) qualified containers. Although each cylinder is manufactured to an ISO standard that calls for a nameplate with the manufacturer's identification number (ID) and the owner's serial number engraved on it, these can be quite small and difficult to read. Recognizing that each facility seems to use a different ID, a cylinder can have several different numbers recorded on it by means of metal plates, sticky labels, paint or even marker pen as it travels among facilities around the world. The idea of monitoring movements of $UF_6$ cylinders throughout the global uranium fuel cycle has become a significant issue among industrial and safeguarding stakeholders. Global monitoring would provide the locations, movements, and uses of cylinders in commercial nuclear transport around the world, improving the efficiency of industrial operations while increasing the assurance that growing nuclear commerce does not result in the loss or misuse of cylinders. It should be noted that a unique ID (UID) attached to a cylinder in a verifiable manner is necessary for safeguarding needs and ensuring positive ID, but not sufficient for an effective global monitoring system. Modern technologies for tracking and inventory control can pair the UID with sensors and secure data storage for content information and complete continuity of knowledge over the cylinder. This paper will describe how the next steps in development of an action plan for employing a global $UF_6$ cylinder monitoring network could be cultivated using four primary UID functions—identification, tracking, controlling, and accounting.

## Introduction

International transport, storage and in-process use of $UF_6$ held in qualified cylinders is currently being accounted for in a number of ways and on multiple levels, the highest being nuclear material inventory declarations made to the International Atomic Energy Agency (IAEA). Reporting requirements vary depending on agreements made with the IAEA and nature of shipments or receipts, i.e., mass, domestic or international and whether the country is a nuclear weapon state (NWS) or non-nuclear weapon state (NNWS). A basic flow chart of the reporting requirements can be seen in Figure 1[1].

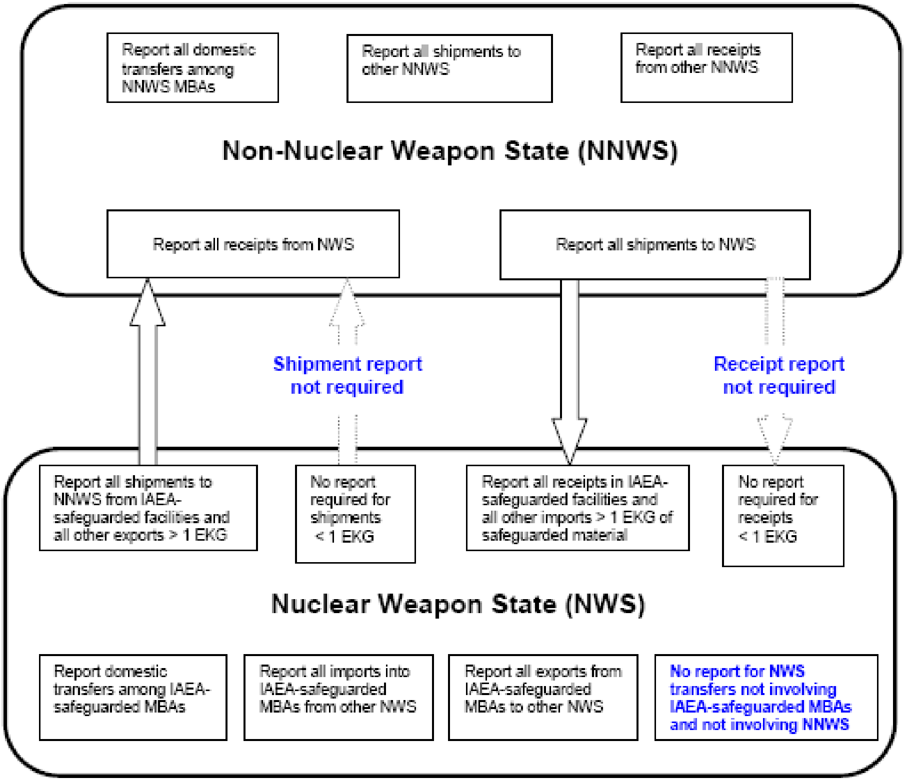


Figure 1. Reporting requirements for nuclear material shipping & receiving

Facilities in NNWS are obligated to inform the IAEA of changes in their material balance of nuclear material by providing an inventory change report within 30 days of shipment or receipt of nuclear material. The 30 day rule inherently creates a lag in accounting for these large nuclear material transfers, and in the case of NWS under voluntary offer that time limit is not applicable.

Escalating efforts to bring a global monitoring system to key stakeholders using, regulating and verifying $UF_6$ cylinders is a result of the identified challenges of determining information on $UF_6$ cylinders containing significant amounts of fuel grade uranium. Recognizing that facilities do not use a UID, cylinders can have several different numbers recorded on them by means of metal plates, sticky labels, paint or even marker pen as they travel between facilities around the world.

## Cylinder Identification

Industry stakeholders utilizing $UF_6$ in the nuclear fuel cycle must identify $UF_6$ cylinders by assigning an ID to each container, however once the cylinder is on a site ID numbers may be modified to reflect batches held within the container. Since there is not an internationally agreed upon method to identify $UF_6$ cylinders being transported between stakeholders, ID numbers are inconsistent. Numbering schemes will vary depending upon; country regulator requirements, type, location, and company practices. Individual data registries collecting and reporting information to country regulators and the IAEA are not conducive to monitoring the actual container, and depend on batch numbers (contents designators) to identify its contents.

The IAEA Safeguards Manual[2] describes item identification as an examination of an identification marking affixed to an item or intrinsically part of that item. Tags, however, are normally associated with item counting and verification sampling plans, meaning they merely establish a link between a listing used in verification and the items they stand for.

Inspectors performing routine inspections in cylinder lay down areas or rafts, which may contain hundreds of cylinders, encounter several different numbers assigned to $UF_6$ cylinders and applied by various means. In Figure 2[1], 48Y cylinders can be seen with both the boiler plate and additional information stenciled on the side of the cylinder. Item identification requirements of the IAEA safeguarding criteria for stratification code UF (uranium hexafluoride), dictate that container identification be verified during routine and physical inventory verification inspections. Physical inventory taking is commonly done by hand and verified later creating an opportunity for transcription errors.

Figure 2. $UF_6$ Cylinders

## Cylinder Monitoring

$UF_6$ cylinders themselves are not being consistently monitored by State system of accounting and control (SSAC), industry or IAEA, as they are transported to/from fuel cycle facilities, seen in Figure 3[1], including across country borders. Although, the declared nuclear material contained within each cylinder is monitored and accounted for by the IAEA using several types of non-destructive and destructive analysis technologies prior to shipment and receipt. Global monitoring of $UF_6$ cylinders would provide location, movements and uses of cylinders in commercial nuclear material transportation around the world, improving the efficiency of industrial operations while increasing the assurance that growing nuclear commerce does not result in the loss or misuse of cylinders designated for $UF_6$.[1]

Location determination and cylinder contents are needed for industry stakeholders and SSAC response organizations to mitigate unidentified nuclear materials being held at maritime ports, airways and borders. Actual locations of cylinders in transit contribute to a need for pathway analysis of cylinder movements allowing determination of prevalent cylinder users throughout the world, in addition to providing continuity of knowledge over large quantities of nuclear materials.

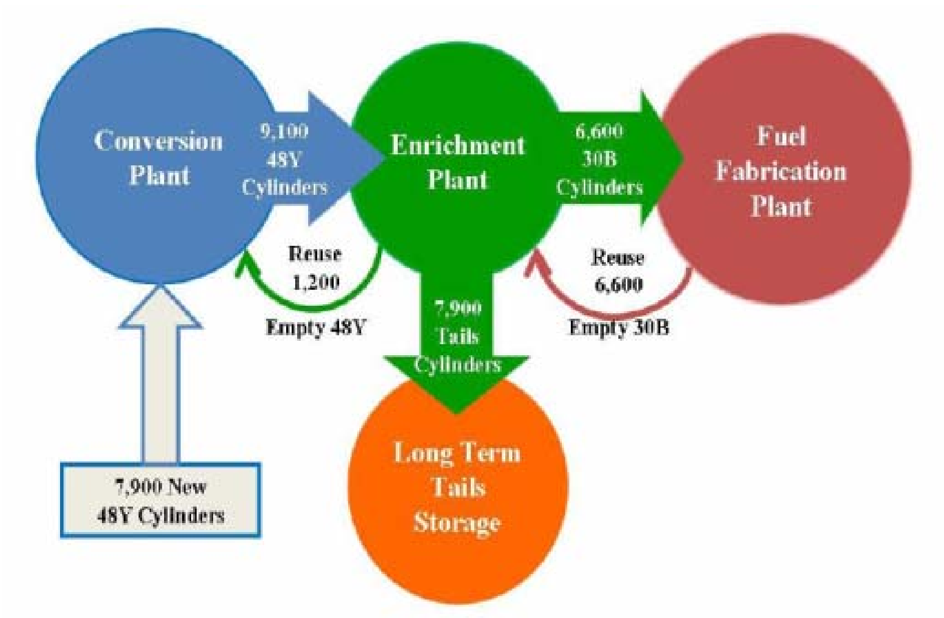


Figure 3. Cylinder Flow in Fuel Cycle

Nuclear supplier's group (NSG) trigger list of material and equipment (INFCIRC/254) monitored for export/import controls by national legislation, including the technology directly associated with any item on the list, does not include $UF_6$ cylinders. Addition of these containers would add a new dimension to the conceptual safeguarding techniques of the IAEA in both item identification and transit matching of shipping/receiving declarations. Importance of this addition should not be understated, especially in relation to the amount of nuclear material being transported within each cylinder.

## Accounting challenges

Accounting for the nuclear material being shipped or received in $UF_6$ cylinders on a daily basis around the globe is currently being performed by IAEA safeguarding approaches at facilities in NNWS and NWS (voluntary offer). Maritime ports, airways and borders are areas of interest for cylinder physical location and attribute specific information, but are not currently part of any State level approach. Accountancy measures at individual facilities, ensures nuclear material inventory and in-process flow is verified. Several methods and technologies are currently being used to perform this task by the IAEA and SSACs.

## $UF_6$ Working Group Meeting

The United States Department of Energy, National Nuclear Security Administration (NNSA) recently completed a $UF_6$ cylinder monitoring study (Monitoring Uranium Hexafluoride $UF_6$ Cylinders, June 2009) which recommended several key milestones in developing a global approach to monitoring these cylinders. The study had an international safeguards focus and included recognition and concurrence of industry's need of cylinder UIDs and monitoring.

Savannah River National Laboratory hosted a working group meeting of experts in May of 2010 to develop an action plan and proposed schedule for addressing the global monitoring of $UF_6$ cylinders issue. Members of the working group included many researchers, engineers and computer specialists from the DOE and members of the IEAE secretariat. The working group addressed the following recommendations from the 2009 report:

- *Identify the preferred structure for a global $UF_6$ cylinder monitoring regime*
- *Develop a registry and cylinder monitoring database*
- *Select a monitoring approach or a set of complementary approaches*
- *Demonstrate capabilities to identify, locate, track, and report on cylinders*
- *Work with industry to implement a unique cylinder identification system*
- *Initiate limited and focused cylinder monitoring projects*

The working group meeting involved problem solving techniques which presented opportunities for the members to breakout into subgroups; industry and policy initiatives, monitoring devices, and cylinder data registry. At the end of this workshop, flowcharts and action lists developed by the three breakout groups were used to cultivate the path forward and possible ownership of actions for the global monitoring of $UF_6$ cylinders action plan. The path forward is plotted onto a schedule of significant activities and milestones that can be assigned as action items, with responsibilities for providing deliverables at key points.

*Stakeholder and Policy*

During the working group meeting, the industry and policy initiatives breakout group worked to further develop flow charts that identified challenges and benefits to stakeholders identified by the 2009 study: 1) International Atomic Energy Agency (IAEA), 2) State system of accounting and controls (SSAC), and 3) Industry. References were made to a meeting held on May 18, 2010 with a group of stakeholders in industry (NMMSS users) that discussed the global monitoring issue and highlighted industry's lack of unanimity in this regard. Industry concerns such as proprietary information protection, socializing $UF_6$ cylinder registration and locating points of interest were discussed. There was a general consensus that the IAEA would be the ideal organization to own the data registry, because of its international status and nuclear material safeguarding responsibilities. It was identified that SSAC participation in the process would be required and that input from regulators would be essential in the early stages of plan development. It was determined that exploring the possibility of adding $UF_6$ cylinders to the nuclear supplier's group (NSG) safeguards trigger list (INFCIRC/254) or Additional Protocol INFCIRC/540 Annex I/II list of specified equipment and non-nuclear material for the reporting of exports and imports would be a key milestone for this project.

The industry and policy initiatives breakout group primarily focused on identifying how stakeholders would be involved in the scope of this project—cylinder handling parameters cradle to grave. Each stakeholder has very different interests at the core of their mission, creating many obstacles in finding an acceptable solution which will suit everyone's needs. Industry needs are obliviously different than those of the SSAC or IAEA. Given the fact that industry must follow international guidelines and legislative mandates ordered by regulating organizations, industry stakeholders are also members of a global competitive business. For example, manufacturers of cylinders have little involvement in the use of their products after cylinders are sold, but permanently attached name plate data at time of fabrication becomes a key element in identification of the cylinder.

*Monitoring Device*

The monitoring technology discussion that arose from the monitoring device breakout group brought many challenges to light. Several milestones were captured by overarching actionable items in the pursuit of acquiring global monitoring capabilities of $UF_6$ cylinders. Agreed upon national laboratory experts will need to work closely with national and international experts throughout the world to ensure that an acceptable solution will be provided to the IAEA, industry and SSACs. Type and availability of technology were discussed with identified needs for development. The agreements reached between parties and the information that can be stored in a database vs. monitoring device will change requirements of the system.

*Cylinder data registry*

Cylinder data registry challenges and benefits were examined by a third breakout group during the working group meeting, which led to several activities and milestones being incorporated into the plan forward for organizing large amounts of data. Key stakeholder roles and responsibilities for accumulation of data for international safeguards, security, proprietary information and emergency response needs were discussed. Further studies are needed that will lead to identifying an international organization (i.e. IAEA) maintaining a working data registry akin to a program already in use (i.e. LANMAS). It is also important to remember that dissemination of data needed for industry to perform inventory controls, IAEA safeguarding needs and SSAC involvement will drive essential components of the data registry and must be agreed upon early in this project.

The cylinder data registry group also focused on identifying the type of system and its capabilities would be required to maintain and track $UF_6$ cylinders, as well as issuing the UID itself. It was difficult to define certain aspects of user needs since determining required registry information is dependent on stakeholder, policy and technological driven decisions. An action to determine if the data registry will be operated from a central server and/or individual State/region servers is tied to functionality of the core system and will need to be addressed as the project matures. However, it was agreed amongst group members that the system should be a stand alone system that enhances current safeguard regimes.

Execution of roles and responsibilities of stakeholders in the development, maintenance and data entry requirements of the registry will determine its success or failure. The database should be scaled to fit a multitude of functions; stakeholder needs, policy requirements, location identification, emergency response interests and illicit trafficking.

## Path Forward

Results from the global $UF_6$ cylinder monitoring working group meeting were intended to better define a long range plan for identifying and solving the problem of monitoring $UF_6$ cylinders.. The working group of U.S. experts, from across the DOE Complex, were tasked with shaping a path forward, using recommendations from the Monitoring Uranium Hexafluoride ($UF_6$) Cylinders Report. The working group developed flowcharts and listed required components of a feasible solution, leading them to define activities and milestones needed to accomplish this difficult task.

During the brainstorming sessions of each group international engagement became a fundamental theme of discussion. Roles and responsibilities of international stakeholders, i.e. cylinder manufactures, facilities, IAEA, and regulating bodies, will become part of the plan forward for this team of experts, which are needed to solve the cylinder monitoring problem. Leaders from various global fuel cycle facilities will be brought together to define boundaries for the project and plan forward.

Essential to the success of the project is calling on IAEA experience in $UF_6$ cylinder nuclear material verification. The IAEA has accumulated a large practical understanding of this issue from many years of International Nuclear Inspector's visits and inspections at facilities in NNWS and NWS, which will be incorporated into any devised scheme of international monitoring.

*Development of a UID Label*

The term UID system and the actual label should be separated to prevent confusion of the unique number or sequence that is labeled on each cylinder and is used consistently throughout its life cycle, regardless of where or how it is recorded. This provides a separation between the UID and the technology that could eventually be incorporated in the overall UID system. This degree of separation allows for progress in the multilateral agreements needed to implement a UID label, while also considering different types of technology that could be utilized in UID system. During the meeting an eight character sequence was discussed since it could be implemented into current states systems, but more research will have to be performed.

*Benefits to stakeholders*

Grouping the benefits to stakeholders into three primary categories of solutions are an over arching theme to this project. The first being to study human interface characteristics that will provide stakeholders (IAEA, industry and SSAC) reductions in errors, improvement in overall efficiency and minimization of dose to personnel. The second category of solutions will determine security and safety needs of the stakeholders, ensuring all nuclear materials in $UF_6$ cylinders is being monitored. Lastly, determining cost benefits to industry, SSAC and IAEA will help promote the continued application of global monitoring and provide stakeholders with indication of practical savings.

Industry impact of applying monitoring devices to all the $UF_6$ cylinders currently being used in international commerce will be positive in many ways. But to ensure a complete picture of the problems that may be encountered, it will be very important to develop a pathway analysis of cylinder movements from cradle to grave in the early development of this project. Information requirements that industry will provide to a central industrial server and/or individual Sate/region server will hopefully not be too different that what is already being provided in today's market.

Benefits to the IAEA will need to be explored fully through a study that will determine what is needed most in a global monitoring network, authentication of that data and dissemination of usable information for international safeguards. Important to engagement with the IAEA will be the advantage of gaining knowledge from many years of experience through a survey of lessons learned.

Development of a complete benefits and risks analysis associated with improving SSAC reporting and monitoring of nuclear materials within country borders and during export will more quickly and efficiently allow each state to meet their timeliness goals set forth by the Nuclear Nonproliferation Treaty. Assessment of maritime, road and air pathways for cylinder illicit trafficking will become much easier to accomplish when near real time data can be provided to proper authorities.

Broad experience will be called upon to form the group of experts needed in development of a suite of $UF_6$ monitoring device(s), data registries, device readers and attachment capabilities. Comprehensive studies by these experts will identify technical options or alternatives for global monitoring of $UF_6$ cylinders.

## Conclusion

Qualified cylinders carrying uranium hexafluoride ($UF_6$) are currently being transported internationally, stored and used in nuclear fuel cycle processes all over the world. Stakeholders involved in the industrial use, accounting declarations (SSAC) and international safeguarding (IAEA) are keen on development and implementation of a global $UF_6$ cylinder monitoring scheme. Location, movements and uses of cylinders could be provided to stakeholders in a multitude of ways that could evolve and improve commercial nuclear material accounting around the world. Efficiency of industrial operations would be increased, along with an assurance that growing nuclear commerce does not result in the loss or misuse of cylinders containing nuclear material in the form of $UF_6$. The path forward in implementing a global monitoring plan will need to consider several key elements; benefits to stakeholders, impact to industry, government regulator change requirements, IAEA concerns and uses, development of cylinder movement monitoring device(s), and storage and access of data. However, true success of monitoring all $UF_6$ cylinders around the globe will be measured by consistent international engagement with the project.

## Works Cited


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