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NGSI: Function Requirements for a Cylinder Tracking System

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Abstract:

While nuclear suppliers currently track uranium hexafluoride (UF_6) cylinders in various ways, for their own purposes, industry practices vary significantly. The NNSA Office of Nonproliferation and International Security's Next Generation Safeguards Initiative (NGSI) has begun a 5-year program to investigate the concept of a global monitoring scheme that uniquely identifies and tracks UF_6 cylinders. As part of this effort, NGSI's multi-laboratory team has documented the "life of a UF_6 cylinder" and reviewed IAEA practices related to UF_6 cylinders. Based on this foundation, this paper examines the functional requirements of a system that would uniquely identify and track UF_6 cylinders. There are many considerations for establishing a potential tracking system. Some of these factors include the environmental conditions a cylinder may be expected to be exposed to, where cylinders may be particularly vulnerable to diversion, how such a system may be integrated into the existing flow of commerce, how proprietary data generated in the process may be protected, what a system may require in terms of the existing standard for UF_6 cylinder manufacture or modifications to it and what the limiting technology factors may be. It is desirable that a tracking system should provide benefit to industry while imposing as few additional constraints as possible and still meeting IAEA safeguards objectives. This paper includes recommendations for this system and the analysis that generated them.

Introduction:

World demand for energy is increasing, and will continue to do so for the foreseeable future. It is expected that nuclear power will fill an increasing portion of base-load energy generation portfolios during this time, with a commensurate increase in the demand for fuel for these new reactors. This will require the construction of more, and larger, fuel cycle facilities including conversion, enrichment and fuel fabrication plants to supply the world's growing energy needs. Large enrichment plants currently exist in a number of countries including the US, Russia, UK, France, Germany and the Netherlands and more are being constructed. World enrichment capacity is currently over 45000 MTSWU across approximately eighteen enrichment plants currently in operation.[1] As the amount of enrichment capacity throughout the world grows, so too will the concerns about diversion from fuel cycle facilities. Therefore, there is a growing need to ensure that safeguards are effectively and efficiently applied to these facilities and the material they handle.

[1] http://www-nfcis.iaea.org

The attractiveness of a UF_6 cylinder to a proliferator varies throughout its lifecycle, generally peaking with 30B product cylinders containing enriched uranium. How attractive a cylinder is at a particular time depends on the needs and capabilities of the potential proliferator. The smaller the enrichment capacity of the State in question, the further through the fuel cycle a cylinder could need to be before it becomes attractive, since the State may have difficulty quickly enriching natural UF_6 as part of a "break out" attempt. If the State has access to a large amount of enrichment capacity, the diversion of cylinders containing natural UF_6, and even tails material, may be attractive.

The following table shows the number of days required to produce an SQ (in this case, specifically UF_6 at 90% enrichment containing 25 kg of ^{235}U) for plants of four different sizes with various feed enrichments and tails assays. These numbers assume that the entire plant is dedicated to HEU production.

The four hypothetical plant sizes are:

1. a "small" facility of 10,000 SWU/year, representing a notional pilot plant or clandestine facility of small size,
2. a "medium" facility of 25,000 SWU/year, representing a notional pilot plant or clandestine facility of an intermediate size,
3. a "large" facility of 1,000,000 SWU/year representing a commercial-sized enrichment plant, or
4. a "very large" facility of 10,000,000 SWU/year corresponding to the largest commercial facilities currently operating or planned.

Table 1 – Time to an SQ using a one batch enrichment process at a clandestine enrichment plant

Plant Size and Tails Assay	Days to SQ based on Feed Enrichment Level		
	Natural	5%	20%
Small, 0.2% Tails	341	93	30
Small, 0.4% Tails	256	77	27
Small, 0.6% Tails	212	69	25
Medium, 0.2% Tails	137	37	12
Medium, 0.4% Tails	103	31	11
Medium, 0.6% Tails	85	28	10
Large, 0.2% Tails	3.5	1	0.3
Large, 0.4% Tails	2.6	0.8	0.3
Large, 0.6% Tails	2.2	0.7	0.3
Very Large, 0.2% Tails	0.7	0.2	0.1
Very Large, 0.4% Tails	0.6	0.2	0.1
Very Large, 0.6% Tails	0.5	0.2	0.1

These numbers underscore the need to address the issue of UF_6 cylinder diversion, particularly scenarios that involve the diversion of LEU product. Even a 25,000 SWU/yr plant operating with a low tails assay using 20% enriched LEU as feed can produce one SQ in less than two weeks. Again, this assumes the entire plant is configured to produce HEU. It is worth noting that several Small Modular Reactor (SMR) designs require fuel of around this enrichment level. The diversion of a single full 30B cylinder containing 5% product will yield an SQ in 28 days once enrichment starts at a 25,000 SWU/yr clandestine plant with a tails assay of 0.6%. This same single cylinder may yield up to three SQ's in total.

Functional Requirements

The NNSA Office of Nonproliferation and International Security's Next Generation Safeguards Initiative (NGSI) initiated a five year program in April 2011 to investigate the concept of a global monitoring scheme that uniquely identifies and tracks UF_6 cylinders. The program has produced a series of reports in support of this goal. This included a report on the life cycle of UF_6 cylinders, a vulnerability assessment of those cylinders within the fuel cycle, and an assessment of how these vulnerabilities were addressed by current IAEA safeguards. The key findings from each of these reports are used here to develop some functional requirements for a deployable UID and/or cylinder tracking system.

In the current environment, there is no uniformity in the way UF_6 cylinders are tracked within facilities and countries, and there is no registry of UF_6 cylinders. This makes it difficult or impossible for an inspector to identify the origin of a particular cylinder during an inspection. With so much variation in the way cylinders are marked, there is nothing in the current regime to inherently flag a cylinder as suspicious (in origin). If a registry of cylinders were produced and maintained, and a UID applied to each cylinder, cylinders that did not appear in the registry (for example, cylinders produced for clandestine purposes that may be present in a safeguarded fuel cycle facility by chance during an inspection) would be inherently suspicious and trigger further scrutiny.

Another issue that emerged from the study was that of duplicating or swapping nameplates on cylinders. In this case it is assumed that a non nuclear weapon state (NNWS) could be capable of swapping the name plates on a pair of cylinders to conceal the contents of a cylinder, falsify a shipping manifest, etc. This is due to the fact that under certain circumstances plates are re-etched with new numbers and can be replaced with the result that industry practices undermine any safeguards utility of the current approach to nameplates. Therefore practices should be employed in which the swapping of nameplates becomes extremely difficult or impossible. The nameplates or UID should be robust enough to avoid the need to replace them in common operation so this does not become a burden on the operator.

Existing name plates can be difficult to read in normal operational conditions so it is common practice in industry to add additional markings unique to each individual user to cylinders for ease of recognition. It would be a benefit to both industry and the safeguarding of cylinders if the UID placed on the cylinder at the time of manufacture was more suitable for daily operations with the cylinder, making it the definitive means of identifying all cylinders in global commerce.

A convenient place for a UID would be the valve end of the cylinder, where the existing name plate is already located. Equipment for handling cylinders is typically designed to protect the valve itself so a UID placed near the valve should be similarly protected from damage during normal operation. This also facilitates easy access for inspection when the cylinder is stored since cylinders are often stacked in storage with the ends being more easily accessible than the cylinder wall.

A UID should have a life expectancy of around 10 years. Being pressure vessels, UF_6 cylinders need to be recertified every 5 years before they can be refilled, however, some cylinders may remain in storage yards for more than 5 years at a time (particularly tails cylinders). A new UID could be applied to older cylinders as they reached the end of their certification and were tested for recertification.

Any identification or tracking system *must* be designed so that it is close to impossible to remove and place on another cylinder except in the case where it might also be tamper indicating and therefore show that such an operation had occurred. The system must also not be duplicable which will likely require the use of some random element in the UID that would be destroyed or altered by removal from the cylinder (such as a reflective particle tag). Another possibility may be to use some intrinsic random property of the cylinder as a UID for example, imaging of the welding of the end sections of the cylinder or a grain pattern at a specific place on the cylinder (although paint on the cylinder will make this difficult).

In addition to these requirements, any UID or tracking system must be capable of enduring a range of environmental conditions a cylinder will be exposed to in normal operation. The most stringent of these will be the heat cycling a cylinder typically endures. Cylinders are typically exposed to moderate temperatures (235^0 F) in steam chests and autoclaves for filling and/or emptying. A UID or tracking system must not only be capable of enduring these temperatures but also must remain intact after repeated cycling from room temperature to the autoclave temperature.

Cylinders can potentially be stored for periods of years in uncovered yards, outdoors. Because of this the UID/tracking system must be able to endure wind, rain and damage from ultraviolet radiation, unless it is somehow protected from such things inherently.

The UID must also be resistant to both steam (from the steam chests) and the Hydrogen fluoride gas that could be produced from reaction between water and any leak of UF_6 from the cylinder.

It is also necessary that whatever UID or tracking system is applied to the cylinder should be rugged and resistant to the sort of stresses and shocks that may result from occasional mishandling of a cylinder. While any damage that may compromise the cylinder would likely require recertification of the cylinder for further use and allow for inspection of the UID, resistance to incidental damage would be desirable.

Finally, any addition of a UID or tracking system should attempt to offer as many benefits to users with as few additional burdens as possible. A system that can assist with the operator’s process control and inventory while offering improvements in the ability to safeguard cylinders will be the most acceptable solution for all stakeholders.

Conclusion

Global commerce in UF_6 is likely to increase markedly in the coming decades. Being able to account for this material and the cylinders containing it will require a larger and larger safeguards effort. A system that is consistent across states and prevents some of the possible diversion scenarios a state might use to conceal material from IAEA safeguards will become more important. This paper outlines some of the major operational and environmental considerations that such a system must be capable of enduring. Addressing all of these issues while providing added value to users will be key to the success of any UID/tracking system.