STUDY OF ALTERNATIVE CONTROL MEASURES FOR SMALL CENTRIFUGE ENRICHMENT FACILITIES

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ABSTRACT

The safeguards objectives for enrichment facilities are the detection of the diversion of declared nuclear material and of facility misuse. The safeguard approach currently applied for commercial centrifuge enrichment facilities are based on the Hexapartite Project. However in the case of small centrifuge plants, limited inventories and restricted visual access to the cascades, the misuse scenarios seems to overcome the diversion strategies, particularly the unrecorded production of direct use material from LEU. In such cases access to cascade hall and F/W station is normally required on unannounced basis and at times not predictable by the state/operator.
Due to the characteristic of the facilities controlled by ABACC, facility specific alternatives control schemes were developed and implemented. These alternatives safeguards approaches have covered the main safeguards requirements for R&D laboratories and centrifuges in cascade operation testing facilities. At present, studies are being carried out to apply safeguard controls to the initial steps of construction of one commercial facility. The conditions to apply the hexapartite approach are not met because the cascades are covered due to the operator's requirement to protect sensitive information. The studies consider also alternative means for some measurement equipment that need to be developed.
A concise analysis of some misuse strategies considered for small centrifuges plants is presented. The main control elements of some alternatives approaches are described based on unannounced inspections and transitory or permanent perimeter control in cases were the visual access to the cascades is restricted.

INTRODUCTION

The standard safeguards approach currently applied to centrifuge enrichment facilities is based on the Hexapartite Project/1/. Due to the characteristic of the facilities controlled by ABACC – R&D laboratories and cascade operation testing facilities, which do not have a routine operation and the need to protect sensitive information – alternative safeguards approaches have been developed by ABACC, in cooperation with the IAEA and Brazil/2/. At present, the challenge is to apply safeguards to the initial steps of construction of one commercial facility that one can consider a small commercial centrifuge enrichment facility. Also in this case the standard safeguards approach cannot be directly applied because the cascades are covered due to the operator's requirement to protect sensitive information.

The objective of this paper is to assess potential safeguards approaches to be applied to this small commercial centrifuge enrichment facility, which is presented as an example case. The facility will

produce regularly uranium enriched up to 5% from natural uranium. Cascades are connected in parallel with a common vacuum system and F/W station.

A concise analysis of the main elements used as control tools and the coverage of the relevant misuse/diversion scenarios on both alternative approaches are presented in order to assess their applications to the example case.

DIVERSION SCENARIOS FOR SMALL CENTRIFUGE ENRICHMENT FACILITIES

The safeguards' objectives for enrichment facilities encompass the detection of the diversion of declared nuclear material and facility misuse. Diversion scenarios on declared nuclear material include inflating the MUF and or concealment of diverted material introducing gross, partial or bias defect into uranium or isotopic content in some items, complemented with data falsification.

Relevant scenarios of facility misuse include the production of high-enriched uranium (HEU) or low-enriched uranium with enrichment higher than 5%; and undeclared production of low enriched uranium with enrichment lower than 5%.

While the installed separative work capacity and the throughput are small, misuse scenarios are the dominant concern from the safeguards point of view, particularly those associated with feeding the plant with undeclared LEU.

SAFEGUARDS REQUIREMENTS

For facilities with inventory or throughput higher than one significant quantity (SQ), a set of safeguards activities are required that include: Periodic accounting and operating records auditing; annual material balance evaluation; annual physical inventory verification; internal flow verification (feed, product and tails cylinders) and inventory changes verification (domestic and international transfers, category changes, measure discards, retained wastes, blending, etc.); periodic verification of operator's measurement system; simultaneous verification of similar stratums, at different facilities, in order to prevent the presence of borrowed nuclear material during the PIV; and design information verification.
Additional measures (i.e. swipe environmental sampling, unannounced inspections, perimeter control) shall also be implemented in order to confirm the absence of unrecorded production of direct use material, or any other misuse of the facility and to confirm the enrichment level is not higher than declared.

All inspection activities involving declared nuclear material can be implemented under the framework of INFCIRC /153 or similar agreements. To increase the credible assurance of the absence of undeclared nuclear materials, inspection activities should be agreed upon between the parties or implemented under other framework.

SAFEGUARDS APPROACH

The safeguards approach for a given facility is a complete set of safeguards measures and procedures that result from the analysis of some credible diversion strategies, the safeguards goals, the legal framework and external factors or boundary conditions applicable to such facility.
The external factors for the example case can be summarized as follow: several cascades are connected in parallel; panels cover the centrifuge cascades and do not allow visual access to the centrifuges; separative work capacity of each cascade is declared; a permanent perimeter by containment and surveillance can be established around the cascade hall; the F/W station is fully separated from the cascade hall; unannounced access of inspector to the cascade hall is possible with one hour delay; there is no transit of cylinders through the cascade hall; surveillance systems can not be used inside the cascade hall; process scales can be accessed by inspectors; Non-Destructive measurement can be performed in the cascade hall; Sampling for destructive analysis from connected tail and product cylinders is possible; containment can be applied to strategic points and advance operative declaration is provided periodically.

Taking into account these boundary conditions, two specific safeguards approaches are presented in this paper and compared with the standard safeguards approach. The first one was developed by ABACC in cooperation with Brazil and the second one was proposed by the IAEA. The following safeguards measures are common for all approaches: Environmental swipe sampling taking to detect production of uranium enriched higher than declared; nuclear material accountancy to evaluate the correctness and consistency of the accounting and operative information; C&S at the F/W station to maintain the knowledge of connected feed and withdraw cylinders; and unannounced access to the cascade hall to detect any change in the configuration.

Specific elements of approaches alternative 1 and 2 are: a permanent perimeter by C&S measures is established around the cascade hall. All entries to and exits from the perimeter are measured by NDA for radiation signature. Unannounced inspections are performed to cascade hall and F/W-Station.
Alternative 1 requires U and U-235 mass balance and SWU balance closing three times per year at randomly selected opportunities. Advance notification on operational program is provided using a mailbox. NDA measurements through the panels are exceptionally used to detect a quantity (as to produce 1 SQ of product) of undeclared nuclear material, at the beginning of cascade operation or to restore the perimeter after losing its integrity.

In alternative 2 an enrichment and flow monitoring system is proposed. In this case, the U and U-235 mass balance and SWU balance could be closed at any time, and precisely once per year during the PIV.

The elements of each approach are summarized in Table 1.

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ELEMENTS	ALTERNATIVE 1	ALTERNATIVE 2	STANDARD
Scope	Less than 20,000 SWU/y (Low capacity)	Less than 20,000 SWU/y (Low capacity)	Up to about 1000 t SWU/y (Commercial capacity)
Visual access to centrifuges	Not required	Idem alternative 1	Required
Design Information Verification	Configuration of F, P, T lines into the cascade hall and continuity of perimeter.	Idem alternative 1	Confirm the cascade configuration: pipes, and the absence of clandestine F/W-Stations
Permanent perimeter control by C/S and NDA.	Yes; Perimeter integrity verification and all perimeter exits verified by C/S and NDA measures.	Idem alternative 1	No
Swipe sampling	During announced and unannounced inspections.	Idem alternative 1	Idem alternative 1
Closing SWU balance	Mailbox information on monthly basis and closing SWU balance at random 3 times per year.	Use of enrichment and flux monitors[1].	Closing SWU balance once per year
Scope of unannounced inspections	To the cascade hall and F/W-Station	Idem alternative 1	To the cascade hall
Access delay during unannounced inspection	1 hour	Idem alternative 1	2 hours
Frequency of announced inspections	1 PIV and 3 interim inspections per year	1 PIV and 5 interim inspections per year	1 PIV and 12 interim inspections per year
Frequency of unannounced inspections	Up to 4 per year	At least 12 per year	4 to 12 per year
Verification of declared cylinder	Before the connection to the process and after the disconnection from the process.	Idem alternative 1	Idem alternative 1
NDA measures in the cascade hall to detect an accumulated quantity of undeclared nuclear material behind the panel	Neutron and gamma measurement. Reference profile required. At the beginning of cascade operation or to restore the perimeter after losing its integrity.	During unannounced access to the cascade hall; Reference profile required.	No
Confirmation that only declared cylinders are connected to the process	Use of unique identifier (seals) in each cylinder; Application of surveillance at F/W-Station	Application of surveillance at F/W-Station and integrated VACOSS seals on F, T, P cylinders and feed autoclaves	Application of containment/ surveillance at F/W-Station[2]

[1] In development, not yet available for routine use; high cost foreseen; very intrusive due to the need of process operational data.

[2] Safeguards measures not foreseen in the original Hexapartite Project

Table 1: Summary comparison between Alternatives and Standard Approaches

ASSESSMENT OF EFFECTIVENESS OF PROPOSED APPROACHES

Table 2 presents a summary of the assessment of approach effectiveness, taking into account reasonable diversion and misuse scenarios.

Diversion/Misuse Scenario	Concealment Methods	Safeguards Measures Alternative 1	Safeguards Measures Alternative 2	Safeguards Measures Standard
1. Diversion of declared uranium.	- Removal and/or substitution with natural uranium, depleted uranium or dummy (Diversion into the MUF and/or creation of defective items).	- Closing U and U-235 mass balance through the verification of the inventory and inventory changes.	Idem alternative 1	Idem alternative 1
2. Undeclared production of LEU less than 5% feeding undeclared material through declared F/W-station	- SWU diversion; - Undeclared UF6 feed cylinders are brought to the F/W-station and connected to the process;	- Closing the SWU balance at random three times per year; - Mailbox information on monthly basis; - Verification of all feed cylinders before connecting to the process; - Verification that all cylinders connected are the previously verified during announced and unannounced inspections to F/W station; - Use of C/S measures at the F/W Station to maintain the continuity of knowledge over the cylinders.	- Use of enrichment and flow monitoring system[1]; - Verification of all feed cylinders before connecting to the process; - Verification that all cylinders connected are the previously verified during announced inspections to F/W station; - Use of C/S measures at the F/W Station.	- Closing SWU balance once per year - Use of C/S measures at the F/W Station;[2] - Verification of all feed cylinders before connecting to the process; - Verification that all cylinders connected are the previously verified during announced inspections to F/W station;

[1] In development, not yet available for routine use; high cost foreseen; very intrusive due to the need of process operational data.

[2] Safeguards measures not foreseen in the original Hexapartite Project

Table 2: Summary comparison between alternative and standard approaches

Diversion/Misuse Scenario	Concealment Methods	Safeguards Measures Alternative 1	Safeguards Measures Alternative 2	Safeguards Measures Standard
3. Undeclared production of LEU feeding undeclared material through a clandestine F/W-station located outside the perimeter.	- SWU diversion; - Clandestine F/W Station; - Clandestine piping penetrating the cascade hall.	- Verification of absence of clandestine lines penetrating the F/W-station and/or the cascade areas during an unannounced inspection (DIV); - Use of C/S measures at the perimeter. - Use of pictures to facilitate the DIV	Idem alternative 1	Idem alternative 1
4. Undeclared production of LEU feeding undeclared material through a clandestine F/W-station inside the perimeter and outside the panels	- SWU diversion; - Clandestine F/W-station in cascades corridors; - Undeclared UF6 and empty cylinders are hidden inside the panels during a C/S fail. - Undeclared product cylinders are removed during a C/S fail.	- Permanent perimeter control; - Verification of all perimeter exit by NDA measurements; - Verification of continuity of the lines into the cascade hall. - Verification of absence of any clandestine F/W equipment into the cascade hall during UI.	Idem alternative 1	- Verification of continuity of the lines from the F/W-station to the cascade hall during an unannounced inspection; - Verification of absence of clandestine F/W station during UI.

[1] In development, not yet available for routine use; high cost foreseen; very intrusive due to the need of process operational data.

Table 2(continued): Summary comparison between alternative and standard approaches

DIVERSION/MISUSE SCENARIO	CONCEALMENT METHODS	SAFEGUARDS MEASURES ALTERNATIVE 1	SAFEGUARDS MEASURES ALTERNATIVE 2	SAFEGUARDS MEASURES HEXAPARTITE PROJECT
5. Undeclared production of LEU feeding undeclared material through a clandestine F/W-station inside the panels .	- SWU diversion; - Undeclared UF6 and empty cylinders are hidden inside the panels during a C/S fail. - Undeclared product cylinders are removed during a C/S fail.	- Permanent perimeter control; - Verification of all perimeter exits by NDA. - NDA through the panels, at the beginning of cascade operation or to restore the perimeter after losing its integrity	- Permanent perimeter control; - Verification of all perimeter exits by NDA measurements; - NDA measurements trough the panels during unannounced inspections	Not applicable due to unrestricted access
6. Production of HEU or LEU higher than 5% enrichment	- SWU diversion; - Cascades reconfiguration.	All methods above plus swipe environmental sampling;	All methods above plus swipe environmental sampling;	All methods above plus swipe environmental sampling;

[1] In development, not yet available for routine use; high cost foreseen; very intrusive due to the need of process operational data.

[2] Safeguards measures not foreseen in the original Hexapartite Project

Table 2 (continued): Summary comparison between alternative and standard approaches

CONCLUSION

Both alternatives 1 and 2 are based on permanent perimeter and consequently limited in the range of applicability. The main difference between alternative 1 and 2 are the availability of some specific new equipment, still under development, and the cost of implementation involved for each alternative. The alternative 1 uses an ad-hoc procedure to replace the enrichment and flow monitoring system not yet available for commercial use. This procedure requires an operation very close to declaration.

The analysis presented in this paper show that both alternatives considered for small centrifuge enrichment facilities reach an adequate coverage for the most credible diversion/misuse scenarios. However, any approach based on permanent perimeter is naturally limited to low installed capacities, due to the impact of the store capacity of the current surveillance system, the quantity of cameras required, the characteristics of the cascade hall and the detection probability associated with the NDA measurements foreseen into the cascade hall.

Even though the main diversion/misuse scenarios have been adequately covered by both alternatives, the safeguard approach should evolve towards more standardize models, strengthened at any weak point before reaching the capacity for producing HEU in short time.

REFERENCES

[1] R. Gerstler et al., Das Hexapartite Safeguards-Projekt, Atomwirtschaft, January 1994, pp. 32–36.

[2] H. E. Vicens, M. Marzo, "Considerations on Safeguards Approach for Small Centrifuge Enrichment Facilities", The 7th International Conference on Facility Operations – Safeguards Interface, Feb. 29 – March 5, 2004, Charleston, South Carolina, USA.