ABACC EXPERIENCE IN APPLYING SURVEILLANCE AT CENTRIFUGE ENRICHMENT FACILITIES

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Abstract

ABACC has been involved in the application of safeguards to sensitive enrichment facilities of different sizes in the last 16 years. The selection of safeguards tools to be used in the safeguards approaches for these enrichment plants was always guided by the necessity of reducing intrusiveness and by the protection of sensitive information, being the latter a permanent concern of the Agencies and the Operator, without loosing efficiency and effectiveness [1].

In the past, the use of surveillance systems was very limited or even avoided; however, in the recent years this powerful tool more and more turned to be a usual system applied in this type of plant.

The application of surveillance on centrifuge enrichment plants is always a great concern since sometimes it may deal with sensitive confidential images. Surveillance systems as safeguards tools in enrichment plants may have different purposes, such as perimeter control, control of the nuclear material flow, verification of special plant points where diversion may occur, and they are also used as safeguards instruments for design information verification. For each of these applications the surveillance system shall have to comply with special safeguards and technical requirements depending on the application under consideration. However, the system to be used shall be safeguards efficient and cost effective.

This paper presents the different applications of surveillance systems as a tool to implement the proposed safeguards approach at enrichment facilities safeguarded by ABACC, taking into account the non-disclosure of sensitive information and the optimization of the inspection. The use of surveillance at various locations of the plant, including the cascade hall, is analyzed in connection to the purpose of the safeguards approach and diversion scenarios. Technical requirements of these surveillance systems are also discussed taking in consideration the availability of the equipment and the feasibility to be used during safeguards inspections.

The paper addresses also the benefits and difficulties of incorporating new technologies to surveillance systems, such as interactivity with other safeguards instruments and remote access, when these systems are applied at enrichment facilities.

I. Introduction

The sensitivity of the centrifuge technology, located mainly in the cascade hall, makes questionable the use of human or equipment surveillance. In order to protect the information, the presence of the inspectors or any type of equipment in which images could be recorded is limited.

The first safeguards approach for centrifuge enrichment plants was discussed during the Hexapartite Safeguards Project (HSP) [2]. The objective was to develop a safeguards approach for centrifuge enrichment plants taking into consideration the sensitive nature of the information to be handled, considering very intrusive the presence of inspectors in the cascade hall. It was discussed at that time the concept of "inspection-free" safeguards for the cascade hall. The HSP analyzed the possibility of relying on surveillance systems, with restrictions, but the surveillance technology at that time was not evolved enough for a reliable application.

The final orientation from the HSP was to have an approach based on nuclear material accountancy and its verification and on unannounced inspections called Limited Frequency Unannounced Access (LFUA). The LFUA inspections were to be applied under certain conditions, considering among others the time (for access and for the inspection inside the cascade hall), the scope of the verification activities (path to be followed by inspectors, number of inspectors, etc), the type of activities (visual observation, etc.), and the nationality of the inspectors (from a technology holder country). The participants in the Hexapartite Working Groups envisaged that some form of C&S would be applied to the cascade boundary, but no final decision was taken, since the possibility of hindering the operation would be a counterpoint for operator's acceptance. On the HSP findings there were recommendations to make use of this tool as soon as the technology would progress, but in fact it was never applied, relying the safeguards on the LFUA tools.

From that time, the development in centrifuge technology advanced, and the enrichment plants became more flexible. Simultaneously the technology reached other States that were not part of the original HSP group. The basic line of the HSP remains, but it was necessary to revise the project to cover the following issues:

- States that were not in the original HSP group;
- Some plants are bigger than the ones considered at the project;
- The flexibility of the process in small plants, due to technology, change the assumption that research and development plants do not need unannounced inspections;
- The full applicability of the LFUA, that could not be considered as an unexpected inspection in some facilities;

Concurrently the surveillance technology progressed. The systems became more reliable and with larger capacity.

The necessity of more precise and effective enrichment safeguards approaches was imposed as a mandatory rule. The IAEA's Program 93 + 2 called for the use of swipe sampling and detailed DIV in such type of plant. The use of surveillance systems in centrifuge enrichment plants, mainly in the process area, was yet denied by operators. During that time some surveillance applications were applied in R&D plants, as boundary verification.

After 2000, the Model Safeguards Approach for gas centrifuge was reviewed and IAEA emitted in 2006 some recommendations; those concerning to surveillance were the following:

- Application of surveillance at feed and withdrawal stations with possible connection to authenticated sealing; (in the past that activity was done to grant fast access during unannounced inspections)
- A complete, thorough and periodic DIV

Presently we are living the changes where surveillance is starting to be applied in the process area of enrichment plants, particularly in the cascade halls.

II. Surveillance Application at Centrifuge Enrichment Plants

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We present below the most common surveillance applications for enrichment plants, the correspondent diversion scenario [3] that they would cover and the related characteristics of the surveillance system to be used.

a) Feed and Withdrawal

Containment and surveillance measures could be applied at the feed/withdrawal station to assure that only previously verified UF_6 feed cylinders are connected. This measure is applied to cover the scenarios of: undeclared production of LEU feeding declared material (substitution of material in such way that the U and U-235 balances match) and undeclared production of LEU feeding undeclared material through a declared F/W-station.

A solution that integrates cameras and active seals seems to be the best approach considering both the cost and the state of the art in the area of integrated monitoring. ABACC is studying this type of systems for its application in centrifuge and gaseous diffusion plants.

When verifying the feed cylinder, the inspectors would install an active seal on it (the indication of seal connected should be automatically recorded at that time). Later, the operator, under surveillance, would make the "reading" of the seal and then would proceed to detach it. Both reading signals, the first one while the seals are still connected to confirm its "health", and the second reading performed once the seal is opened, should be recorded, and constitute an input to the surveillance system. The cameras themselves should be able to assure that no cylinder can be connected without being detected and the combination of active seals and cameras should be able to confirm that only verified cylinders have been connected to feed the cascade during the time period. [4].

The surveillance tool in this case helps also to make the inspection more effective, because during the unannounced inspections one of the activities to be executed in a short time is the verification of the connected cylinders. With the surveillance, the inspectors may dedicate the initial time of the inspection to other activity.

The operator activities performed at F/W stations are of long duration in time; as a consequence, the surveillance does not require a short interval between images and the scope and resolution of the pictures should be such that a wide image and general activities shall be kept recorded.

b) Strategic Points of Possible Feed and Withdrawal

The enrichment installations are industrial buildings with a high complex distribution of pipes, valves and instruments. For operational reasons, these plants are sometimes flexible in points where the operator needs to purge the system, to adapt a measurement instrument or to be able to perform maintenance. Undeclared production of LEU or HEU, feeding undeclared material through a clandestine F/W station is the scenario under concern.

Such points shall be analysed carefully, considering the possibility of being used as a clandestine feed and/or withdrawal point. The safeguards inspectorate has a tendency to require that the operator or either reduce the plant flexibility or to apply containment to these points. This solution is not always possible and surveillance systems may be used to cover all or part of these points, mitigating the possible deviation scenarios.

Since the image to be recorded shall contain details of these connection points and broad view is not always possible or allowed, the surveillance usually requires a short sampling interval between images and a high resolution of the regions under analysis.

c) Design Information Verification

The DIV is the activity performed to confirm the validity of the information provided in the DIQ and to verify that no changes have been introduced in the configuration of the cascades, main headers, F/W station, general vacuum station, strategic points and building (general containment). In addition, the absence of clandestine piping or unidentified support equipment introduced in the facility could be confirmed in these activities.

The important diversion scenarios considered here are the misuse of the installation, not operating as declared, and possible undeclared production of LEU/HEU feeding undeclared material through external pipes.

The general verification is very broad and the way to be executed is tailored to the installation. Surveillance systems may have an important role on this activity, and they may be used when time and knowledge can be saved, or when some particular restriction of human access is imposed by the process or operation conditions.

For the case of saving time and knowledge, the technology evolution now offers systems that can monitor large quantity of pictures, as complex pipe lines and cumbersome interconnections, which can be analyzed once as a reference image and be re-verified by an imaging system [5]. For instance, new laser scanning systems can monitor changes in very complex scenes, with resolutions in the order of mm. The surveillance in this case should have the capability to acquire wide scenarios and have good resolution, even for the situation of infinite depth of focus.

Surveillance may be also applied when direct access of the inspectors is forbidden, due to process limitation or to protect sensitive information. New devices have been developed to fulfil this application.

Again, DIV activities are performed during unannounced inspections, where time poses as an important variable in the effectiveness of the verification. Surveillance allows capturing the necessary data, leaving the detailed analysis for the reviewing period, usually an activity without time duration constraints..

c) Special Applications

Even though the safeguards approaches for enrichment plants have been standardized for the majority of the plants worldwide, the sensitive characteristic of the process and the construction lay out of the installation sometimes require some special safeguards measures or arrangements. The use of perimeter, where the inspectorate establishes boundaries for restricting the flow of nuclear material in such a way that it can control that only the declared material is processed, is a safeguard measure normally applied to small or research & development facilities. Containment is the favorite safeguards tool for this application. However, the movement of operators and items used in this process can be properly monitored by surveillance.

Special surveillance systems are required for the application. The characteristics of the surveillance system may also vary from fast to slow image acquisition and for sharp or broad picture image. The scenario covered is related with the use of undeclared material, but it will cover also DIV and boundaries verification.

III. Surveillance at Centrifuge Enrichment Plants Safeguarded by ABACC and IAEA

Surveillance Systems: Technical Overview

ABACC applies surveillance systems in both, enrichment laboratory facilities, plants with small capacity for R&D purpose, and a commercial production plant. The requirements for both facilities are different, and the following sections describe its main features and/or restrictions.

A common feature of the surveillance systems applied in all enrichment facilities is the joint use between ABACC and IAEA. As the equipments can, in some cases, be used by only one of the agencies (it is the case of some unannounced inspections), the design of the containment systems applied to the equipment must take into account this restriction. To handle this situation, seals are configured in two-agencies mode and used to enclose all the equipment used during unannounced inspections. As an example, VACOSS seals can be used for this purpose.

Another common restriction is the confidentiality of the information. In both cases the images can not be retrieved from the facility. Also, all points of interest must be covered, but by no means can the image of the cascades be registered by the surveillance systems.

Laboratory and Development Facilities

In the enrichment laboratory or development facilities under control of ABACC, the safeguards approach uses surveillance only during unannounced inspections, to verify that no nuclear material crossed the perimeter since the moment of the inspection triggering. Normally, the surveillance review begins two hours after the inspection announcement. This is a typical boundary control approach.

As the cylinders containing material are small enough to be carried out by hand, it is needed to acquire images at a high frequency. Typical PTI (Picture Taking Interval) of 1 or 2 seconds are employed.

Due to commercial confidentiality issues, a strict restriction on the visual content of the surveillance is required. The images available to the agencies inspections are restricted to the access doors to the perimeter, and only during the 2-hours period since the inspection triggering until the review starts. The images can not be retrieved from the facility, so the technical and safeguards review must be completed at the facility, during the inspection time.

To ensure that no loss of Continuity of Knowledge (CoK) occurs, a highly redundant surveillance system was adopted. Two identical (but separate) EMOSS (Euratom Multi-Optical Surveillance System) systems are installed per facility, covering the same scenarios. And both systems have 2 cameras covering two different parts of the region of interest. In this way, a complete failure of one of the systems can occur, but CoK is still maintained by the other redundant system. At present, ABACC is studying the application of an up-to-date surveillance system that fulfils or exceeds the requirements imposed by this particular application.

Commercial Plant

In the case of the commercial plant, another approach is used. A more complex permanent surveillance scheme is applied on several points, oriented to specifically verify all the feed points in the plant. The purpose is to verify that no more feed material was connected to the plant than the operator’s declaration.

Surveillance is used during both, interim and unannounced inspections. During interim inspections the complete period is reviewed, for all the cameras. During unannounced inspections only the period since the inspection triggering is checked, for a selected group of cameras looking at some critical points. Typically F/W stations and strategic F/W points are covered in this way.

Being surveillance a critical part of the safeguards approach, it is important to use high reliability equipment for these applications. So, a highly redundant system is used, to minimize the probability of loss of CoK. For redundancy, more cameras are used, and some of them are used only as back-up of the main cameras.

All these requirements impose the use of a high reliable, multi-camera surveillance system. DMOS (Digital Multi-Optical Surveillance System) system based on DCM-14 cameras was adopted by ABACC.

Being a multi-camera system, the review process is much more complex and time consuming. So, all features of the review system that simplify the process are employed by the inspector during technical and safeguards review. The software used to analyze the high volume of images collected during a surveillance period (normally comprising a 3 months period) is GARS (General Advanced Review System). Using this software, several technical tests on the surveillance can be automated, and regions of interest can be defined, to minimize the time employed during the review.

In this plant also applies the restriction in the images retrieval. So, all the review activities must be completed at the facility, in a specially allocated room, during the time of the inspection. This restriction inhibits the use of remote monitoring systems. As a further improvement, ABACC is planning the application of remote transmission of State of Health information from the surveillance system to the agencies headquarters, in order to anticipate any failure that can conduct to a loss of CoK, and facilitate a prompt action to solve any technical problem of the surveillance system.

IV. Challenges and New Systems

As information technology evolves, new devices and systems suitable to enhance currently used systems appear. In some cases, the proper integration of existing and proved commercial of the shelves technologies also produces new approaches to solve problems or increase flexibility and robustness while designing complex surveillance systems, or tools to aid the inspectorate in difficult tasks as a DIV of a complex plant.

New generations of surveillance systems are being designed and tested, that uses compact, fast PTI (even in the limit of live video) and high quality image acquisition devices, high redundancy for data storage, flexible and fast transmission schemes, and strong authentication and encryption of data.

The deployment of distributed remote surveillance networks is also devised, by designing autonomous surveillance cells capable to acquire, locally store and transmit over internet the images. This approach offers a simple way to install complex and robust schemes of remote monitoring and surveillance systems.

Important technological advances are also appearing, providing the capability to integrate with other sensors, in order to increase the scope and robustness of the surveillance, not only by increasing the duplication of images, but also by complementing with information of a different origin and nature, like infrared, gamma or neutron radiation fields associated to items or processing components. This approach is also under research to be applied with 3D Laser Range Scanning, to enhance the 3D laser images acquired in complex rooms with layers of radiation maps obtained from the same scenario. Not only the change of an element position can be easily detected, but also changes in its content can be identified, if nuclear material is involved in the process.

On the other hand, the increase in complexity and data volume makes more and more difficult to handle the information produced, stored, transmitted and reviewed. Removable storage media of higher capacity, higher access speed and higher reliability must be introduced in the currently used surveillance systems, to replace old devices.

This increase in data volume also makes necessary the development of new advanced digital analysis tools, to automate the review process; otherwise, the time spent during inspections tends to be much higher than reasonable.

Another way to improve the efficiency of surveillance systems is the design of more compact image acquisition devices, to offer a higher flexibility to configure the surveillance regions, the coverage and the quality of the images to be analyzed, focused only, or mainly, in the regions that the safeguards approach requests.

All these technological tools are applicable, but not limited, to enrichment plants.

V. Future Trends

Technology is having a major role on surveillance systems. The capacity to store images has been growing at the same pace that the digital computing power and peripheral accessories. The images resolution and quality has been increased also very fast. The capacity, quality and reliability of the surveillance system are increasing and the costs have been more affordable.

The technology is migrating to the area of integrated monitoring, where multiple tools are being put together in the same piece of equipment. That is also the case of surveillance. Integrated applications that merge surveillance and containment are already in safeguards use. Also the integrated application of surveillance and system information is a reality, like the remote transmission of surveillance or seal/surveillance authentication.

The future soon will bring what we may call "integrated surveillance", where the surveillance image will be integrated to other nuclear material verification technology. That would be the case where the image may be archived jointly with a nuclear profile in the same picture. These profiles could be a gamma, a neutron or a physical measurement, like the isotopic enrichment.

This would be a very powerful tool, for instance, the image of a UF6 cylinder would carry also a fingerprint of the radiation profile, related to Uranium mass, and of the isotopic composition. This could be also extended to other parts of the process or plant. However, the sensitive of the enrichment process will continue to receive special attention when new surveillance technology may disclosure proliferation information.

The integrated surveillance will contribute to simplify the safeguards approach, to optimize the inspection effort and to make the safeguards more effective.

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