SAFEGUARDS MEASURES TO MONITOR SPENT FUEL TRANSFERS FROM NUCLEAR POWER PLANTS TO DRY STORAGES IN ARGENTINA AND BRAZIL

Horácio Lee, Fábio C. Dias, Luis Machado da Silva, Sonia Fernández Moreno, Carlos Llacer, Leonardo Dunley, Anibal Bonino, Marcos Moreira, Max Facchinetti

Brazilian-Argentine Agency for Accounting and Control of Nuclear Materials (ABACC), Rio de Janeiro, Brazil

Abstract

In order to meet verification requirements during and after the transfer of spent fuel assemblies from spent fuel ponds to dry storages at nuclear power plants in Argentina and Brazil, ABACC in coordination with IAEA needs to implement specific safeguards measures.
In Argentina and Brazil, two new dry storages are currently under construction. In Brazil, it is located in the Angra site and consists of canisters that will be able to receive spent fuel assemblies from both Angra 1 and Angra 2 PWR-type reactors. The canisters will be loaded into storage modules that will be placed vertically in an external area.
The dry storage in Argentina is located in the Atucha I PHWR-type reactor and consists of vertical underground silos constructed in a dedicated building connected to the spent fuel building. A special flask will be used to transfer the spent fuel assemblies to the silos.
This paper presents possible safeguards measures to be applied at both storages. The monitoring systems are based on unattended NDA (gamma and neutron) and containment devices, in combination with surveillance cameras. In addition, 2D Laser technology is proposed to be used at Atucha I to compose a dual containment and surveillance (C/S) system.

1. Introduction

Argentina and Brazil decided to establish a common system of accounting and control of all nuclear materials (SCCC) and create ABACC in 1991, as an independent international organization responsible for implementing the bilateral safeguards system established by the SCCC [1].
In 1994 the countries negotiated and concluded a comprehensive safeguard agreement (CSA) with the IAEA and ABACC. This CSA is known as the “Quadripartite Safeguards Agreement” [2].
An important characteristic of the CSA is the promotion of cooperation among all parties to achieve and maintain effective and efficient implementation of safeguards. In this framework, the application of concepts, approaches and methods is a dynamic process that many times rely on the development of new technologies. The safeguards measures to be applied on the new dry storages in Brazil and Argentina are one of the key cooperative initiatives which negotiations are ongoing.

2. Safeguards Requirements

Any safeguards approach or procedure to be applied at nuclear facilities in Argentina and Brazil has to comply with the IAEA and ABACC common Safeguards Criteria. [3]
For spent fuel elements designated as difficult-to-access, evaluation of the C/S systems, if positive, serves as a basis for drawing adequate conclusions for the material balance evaluation and for the timely detection of potential diversion. This can be implemented under certain conditions. The same applies to the spent fuel transfers out of the power reactors and which will be placed in long-term storages under safeguards. It is worth noting that in the case of Atucha I NPP, the spent fuel transfers will take place inside the facility, while in the case of Angra nuclear site, the transfers will take place from the reactors to an outside storage.
Among the criteria and conditions to any safeguards approaches like the ones that ABACC in coordination with IAEA is considering for these storages and the respective spent fuel transfers, the followings ones are worthy to note:
-The IAEA and ABACC have approved the designation of the fuel elements as difficult to access due to design features of the facility (i.e., the storage).[4]
- The conditions that the C/S system should meet need to be agreed in advance. Sufficient assurance against interventions should be obtained before accepting a given designed system.
- Procedures to evaluate the C/S system need also to be in place.
- All credible diversion scenarios should be covered by the proposed system and the components of the system should be functionally independent and not subject to a common failure or tampering mode (i.e., condition to be dual).
- The nuclear material has to be verified prior to becoming difficult-to-access by item counting, item identification (where feasible) and NDA, using sampling plans that provide a high detection probability for gross or partial defects.

3. Atucha I Nuclear Power Plant (PHWR type)

3.1 Description of the facility

The Atucha I NPP is an operating on load pressurized heavy water reactor (PHWR), consisting of a 362 MWe single unit and two spent fuel (SF) buildings with a receiving/maneuvering and storage pond in one and a storage pond in the other. All ponds are continuously monitored by ABACC/IAEA surveillance systems.
The reactor uses heavy water as moderator and slightly enriched uranium (0.851% U235) as fuel.[5]
All SFs discharges are accounted by a VXI-based irradiated fuel monitor (VIFM) composed of gamma and neutron detectors upon transfer to the SF receiving pond and prior to being stored in the SF storage ponds. Pin removal or substitution is not foreseen in this facility.
The dry storage (“Almacenamiento en Seco de Elementos Combustibles Quemados – ASECQ”) has been conceived as an extension of the SF controlled area where a vertical underground SF storage facility is being built.

3.2 Proposed Safeguards Measures

ABACC in coordination with IAEA has been working in the development of a safeguards “difficult to access dual system” concept based on an Unattended Monitoring Systems (UMS). The objective of the UMS is to maintain continuity of knowledge (CoK) over the Spent Fuel Assemblies (SFs) during the transfer process to the storage silos without the need for continuous inspector presence during the transfer campaigns.
The UMS would be based on a combination of surveillance and NDA systems aiming at performing attribute testing and item counting in compliance with specific safeguards criteria. Surveillance cameras will be able to monitor all underwater flask movements, including its loading with SF assemblies, and ensure the operation of the NDA systems without any type of

physical interference. The detectors will be installed underwater and with a geometric configuration (positioning) that allows, in connection with time stamped data, the determination of the material flow (loading or unloading of the flask). The Continuity of Knowledge (CoK) on the verification is maintained during the transfer of the transport container (CT) loaded with a full canister to the dry storage vault by NDA (neutron detection) and surveillance systems.
Continuous surveillance is maintained over the entire process of loading SFs into a canister and storing it in a Silo Unit (US). Declarations regarding the schedule of all process stages involved should be made by the operator through encrypted and authenticated mailboxes to the IAEA and ABACC.
Once the transfers are finished, a dual C/S system must be used to maintain CoK on the silos. Since conventional sealing may be quite difficult to implement due to physical and radiological limitations and restrictions associated with cabling and access of inspectors respectively, a new safeguards tool named Laser Curtain for Containment (LCCT) will be employed. This technology is capable of detecting and identifying movements inside the dry storage building such as removal of silo lid and loading/unloading of a canister. Surveillance cameras will constitute the other C/S component.[6]
Individual sealing of the US might be performed using metal seal or other type of seal. The need will be decided on a case by case basis upon agreement between ABACC, the IAEA, the National Authority (ARN) and the operator of the facility.

3.3 Safeguards Implementation in Atucha I Dry Storage

During the SF transfer campaign, the activities in order to verify the information provided in the mailbox declarations are carried out as part of the normal activities during quarterly routine inspections. It includes retrieval of all NDA, LCCT and surveillance data by accessing the relevant servers that will be installed in a room with no specific radiological requirements. This will facilitate and speed up the routine inspections.
Specific measures to ensure proper operation of the UMS systems may be considered, for instance state of health (SoH) data transmission and additional inspections. These measures will be discussed and agreed as part of the safeguards approach.

Figure 1: Site view of Atucha NPPs

4. Angra 1 and 2 Nuclear Power Plants (PWR type)

4.1 Description of the facility

The Angra 1 Nuclear Power Plant (PWR type), consists of a 640 MWe single reactor with 121 fuel assemblies in the core. The Angra 2 Nuclear Power Plant (PWR type), consists of a 1350 MWe single reactor with 193 fuel assemblies in the core and the spent fuel assemblies irradiated in the reactor core are stored in spent fuel ponds. [7]
The project of the dry storage ("Unidade de Armazenamento Complementar a Seco de Combustível Irradiado"- UAS) was presented for international bidding on 2016. The long cooled spent fuel assemblies will be transferred using canisters to the dry storage.
Both reactors (Angra 1 and 2) will use a common spent fuel dry storage. At the first stage it is planned to transfer 15 storage modules containing a total of 510 fuel elements, 222 Angra 1 SFs and 288 Angra 2 SFs. The construction of the storage site is progressing well and the site received the 15 overpack-modules on April 2020. [8]
ABACC and the IAEA are discussing the key safeguards measures to be implemented, as presented below.

4.2 Proposed Safeguards Measures

The verification of the nuclear material before final storage can only be accomplished by verifying the SF elements in the pond during their loading in the canisters, since the spent fuels will be stored in an area where the material will not be easily accessible for SG verification, so there is a need to apply a difficult-to-access concept with application of a dual C/S safeguards system.
Before the SFs are loaded into the canister, they should be verified by item counting and high detection probability (90%) for partial defect test. The Digital Cerenkov Viewing Device (DCVD) is considered to be used for this verification, subject to prior tests to confirm its applicability.
During the loading campaign, all SFs in the reactor ponds are maintained under continuous surveillance and inspector´s presence at the main phases of the transfer process, especially for reverification of the spent fuel assemblies before their transfer to the storage.
An external surveillance system monitors the transport of the transfer cask with a full canister out of the pond. To reinforce the Continuity of Knowledge (CoK) of the partially filled canisters in the pond, a temporary redundant underwater (UW) surveillance system could be installed in this area.
The CoK of the loaded transfer flask must be guaranteed at all times after the flask leaves the pond, for which different measures/alternatives could be applied. At the decontamination area it is proposed to apply an additional, temporary and redundant surveillance system (for example "standalone" NGGS cameras), to reinforce the coverage of the permanent surveillance system during the operational activities at that place.
The transit of the transfer flask and the storage module could be escorted by ABACC and IAEA inspectors. Nevertheless, other alternatives should be analyzed to reinforce the maintenance of the CoK, and to cover any period of inspectors' absence.
Neutrons detectors could be placed on the transfer flask to monitor the transfer of the full canister until unloading in the modules, but in this case, surveillance must be added to the transport unit.
In the case of the transfer flask, and depending on the radiation protection restrictions defined by the operator, temporary seals and / or radiation detectors could be applied to maintain the CoK in case of stops in the transfer campaign.
The provisional/temporary attachment of metal and / or COBRA seals on the lid (using the sealing device proposed for the final storage) seems to be the most efficient alternative to cover prolonged stops, without the presence of inspectors. ABACC, the IAEA and the National Authority (CNEN) are negotiating a sealing system to ensure immobilization of the modules once they are placed at the final position in the storage area.

4.3 Safeguards Implementation in Angra NPP Dry Storage

The monitoring system proposed to the UAS maintain the continuity of knowledge (CoK) on the SF through a combination of surveillance, sealing and NDA measurements but with continuous inspector´s presence during the SF transfer campaign.
At the spent fuel pond area, monitoring through NDA and surveillance of (i) the loading of SF into the canister and (ii) the transfer of the transport cask with the canister out of the pond. This will be achieved installing underwater cameras and using the DCVD system.
At the spent fuel pond to the decontamination area, monitoring through surveillance already installed on the SF pond area and evaluate if new cameras are required to surveillance at the high level in the SF pond in Angra 2.

Figure 2: Site view of Angra NPPs

A sealing system could be applied on the lid of the canister or a NDA system based on neutron detector and surveillance could be explored.
If any other area for transport cask parking is possible before final storage, other measurements for surveillance and immobilization could be required (ex. sealing of the cask to the transport unit) in case of a long time without presence of inspector. At the end of the cask transit, the seals could be removed and verified.
Monitoring through surveillance and neutron measurement the presence of SF in transport cask during the unloading of a full canister into the module and after the transfer, the inspectors will confirm the emptiness of the transfer cask by visual observation or by using a radiation detector.
As previously noted, the dual C/S System ABACC/IAEA requires that all credible diversion paths are covered by two C/S devices which are functionally independent and not subject to a common tampering or failure mode. For the dual C/S COBRA and Metal seals could be applied.
During the campaigns IAEA and ABACC inspectors will be present to confirm and witness the declared activities, verify the loading of canister and the transfer of the transport container and observe loading into the designated SF module.
In case of unattended systems are used, neutron detectors and surveillance review can confirm the transfer of spent fuel assemblies to the dry storage module.

5. Conclusions

The development of safeguards procedures in Atucha I has been started since the early information of the project of the dry storage in a close coordination between ABACC and the IAEA.

The cooperation of the National Authority (ARN) and the Operator has been crucial for the successful designing and development of the system. The first visit at the facility occurred in 2015 when the project was presented in details and the agencies started to work in a procedure considering the wet and dry storage are in interconnected buildings.

The construction of the new facility has been more often visited during last years for design information verification to follow the progress of the construction key milestones and to prepare for equipment installation.

The new safeguards project also considers to minimize the radiological impact during inspections by having all safeguards´ cabinets relocated in a room out of radiological controlled area. The decision of the Operator to build a special area outside the control one, where all the C/S systems data computer equipment are located, will greatly facilitate the inspection activities related to these transfers.

During the period of the transfer of SF assemblies to the dry storage, the introduction of UMS system would represent significant savings on inspection effort. A new technology based on the 2D laser will be employed for containment during the transfer of SFs. However, once the storage silos are all loaded, ABACC is also considering a complementary or alternative containment measure, such as a long-term sealing.

The decision of building a dry storage at the Angra NPP location, was taken by Brazil in 2016. Since then ABACC is doing consultations with the National Authority, CNEN, and the Operator to establish the best approach for this facility. ABACC prepared a procedure that is under negotiations with IAEA.

In Brazil, IAEA and ABACC are also discussing an immobilization system to be applied to the modules and the possibility, in addition of using the DVCD for verification of SFs loading to the canister. Once agreement between ABACC and the IAEA is achieved, a safeguards procedure will be presented officially to the National Authority (CNEN) for analysis and concurrence.

The safeguards approaches being developed for the dry storages in Brazil and Argentine considered different application formats due the characteristics of the projects. In the case of Argentine, the system will be based fully in an UMS, while in Brazil will be a mix between inspector presence during some stages of the transfer and a C/S dual system.

Among the lessons learned throughout the process of monitoring the construction of these deposits, ABACC considers it important to share the following:

The possibility of developing an effective and efficient safeguards procedure is subject to the provision of early and timely design information. Any relevant changes should be also communicated promptly. The use of new technologies could result in a less intrusive safeguards scheme. However, the need of testing and the assessment of such technologies should be planned in advance. The cooperation of the National Authorities and the Operators is essential to conclude adequate safeguards procedures, specially to introduce measures in an early phase of the construction of a new facility.

6. References

[1] Agreement between the Republic of Argentina and the Federative Republic of Brazil for the Exclusively Peaceful Use of Nuclear Energy, The Bilateral Agreement INFCIRC/395 (1991).

[2] Agreement between the Republic of Argentina, the Federative Republic of Brazil, The Brazilian-Argentine Agency for Accounting and Control of Nuclear Materials and the International Atomic Energy Agency for the Application of Safeguards, IAEA INFCIRC/435 (1991).

[3] Safeguards Criteria for Storage Facilities, IAEA Safeguards Manual – Chapter 9 (2007).

[4] Special Criteria for Difficult-to-Access Fuel, IAEA Safeguards Manual – Annex 04 (2007).

[5] http://www.na-sa.com.ar/centrales-nucleares/atucha-1/, 2020

[6] Laser Curtain for Containment (LCCT) Advance Technology: Testing for Dual Use as a Component at Spent Fuel Dry Storage in Atucha I NPP, INMM 61st Annual Meeting (2020).

[7] https://www.eletronuclear.gov.br/Nossas-Atividades/Paginas/default.aspx, 2020

[8] https://www.eletronuclear.gov.br/Imprensa-e-Midias/Paginas/Eletronuclear-recebe-módulos-de-armazenamento-da-UAS.aspx, 2020