EU/ABACC Cooperation: Strengthening Safeguards Capabilities through implementing new technologies

Use of Ultrasonic Sealing System as a Containment System at Spent Fuel Storage

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Abstract:

A sealing system has been designed by JRC/ISPRA in cooperation with ABACC and the IAEA in order to account for the difficulties in accessing spent fuel located in lower layers of spent fuel ponds.

The system consists of mechanical parts with an ultrasonic seal as containment measure combined with a surveillance system. The objective of the sealing arrangement is to maintain continuity of knowledge on nuclear material stored in the lower racks of the spent fuel ponds by preventing undeclared removal of this material. It will also introduce advantages by lowering the re-verification requirements at Physical Inventory Verifications (PIVs) and in case of surveillance failure.

For this application, ultrasonic seals have the necessary characteristics since they are designed to be attached underwater, they are very resistant to harsh environments like storage pools, they are easy to apply and they can be regularly verified. The verification of ultrasonic seals does not involve the replacement of cables or seals, thus improving inspector's productivity and decreasing the burden on the plant operator.

A six-month field trial will be conducted at the spent fuel storage at the *Central Nuclear de Atucha 1* (CNA1) – *Presidente Juan Domingo Perón,* after which ABACC and the IAEA will be able to assess whether the system meets the necessary requirements for safeguards use.

The overall impact on safeguards is discussed through a general approach to this facility. The key components of a possible safeguards approach that considers the implementation of this specific ultrasonic design are also briefly discussed.

Keywords: Nuclear Safeguards, International Cooperation, Ultrasonic seals, Containment System, Spent fuel storage.

1. Introduction

The *Central Nuclear de Atucha 1* (CNA1) is an on-load refuelling Pressurized Heavy Water Reactor (PHWR), where the spent fuels are stored in a closed packet way, in two layers at the storage pool, not allowing an easy way to verify the entire pool when it becomes necessary. More specifically, in case of fuel element verification, the accessibility of nuclear instrumentation to the lower layer of spent fuel is very complex and time consuming.

One way to maintain the Continuity of Knowledge (CoK) on the nuclear material at the spent fuel pond is to apply surveillance and containment measures at racks where these fuels are stored. It is important to guarantee that ABACC and IAEA maintain the CoK over multiple layers of the spent fuel storage with application of seals on fuel elements, racks or hangers.

The Ultrasonic Seals (US) have been used for this type of containment [1] [2] and they are already approved for safeguards use by both the IAEA (responsible for the implementation of the Nuclear Non-Proliferation Treaty – NPT) and by the European Commission's DG-Energy (responsible for the implementation of the EURATOM Treaty).

ABACC and the European Commission engaged into a collaborative project on strengthening the safeguards capabilities using the ultrasonic sealing system as containment and its general application [3]. ABACC and ARN evaluated the benefits of this system to be consolidated in a specific use on the spent fuel storage at CNA1 in Argentina.

The IAEA/ABACC approval process for application of this technology should go through evaluation of diversion scenarios considering the vulnerability aspects of the project and improvements required. The results of a field trial at the spent fuel storage planned for 2017 will support the final approval of the system, after which ABACC and the IAEA will be able to assess whether the system meets the necessary requirements for safeguards use.

2. Safeguards system based on containment and surveillance

The proposed sealing system already tested in CNA1 pond consists of a stainless steel bar attached on each external hanger of the fuel elements support devices. This attachment is provided by means of ultrasonic seals, in this way when the bar is installed, it disables any possibility to remove the fuel elements from the specific hanger, without breaking the seals.

The objective of the sealing arrangement at CNA1 is to maintain the CoK of the nuclear material stored in the lower and upper racks of the Spent Fuel (SF) ponds by preventing undeclared removal of this material. The dual system considered for these ponds consist of the ultrasonic seal system as containment and surveillance system based on the Next Generation Surveillance System (NGSS).

The IAEA contracted the development of the NGSS system to replace the DCM-14 cameras. NGSS basic level consists of a single camera taking, authenticating, and storing surveillance data.

The system will be applied in order to avoid item counting of the SF stored in the lower racks in the ponds during the annual Physical Inventory Verification (PIV) as well as their re-verification in case of surveillance failure.

The re-verification of spent fuel assemblies (SFAs) in tightly configurations in storage ponds is a challenge at the Atucha site since SFAs are stored in two layers in the spent fuel pond. A prototype Spent Fuel Neutron Counter (SFNC) has been used since November 2002 in verifying long decayed spent fuel stored in the upper layer.

The original SFNC which was developed and tested at the site jointly by the IAEA and ABACC used a fission chamber that was lowered into the gap among four adjacent fuel assemblies. In

fact, provided that a safe and reliable access of the neutron detector can be gained to the entire length of the assemblies in the lower level, the verification of the fuel in the lower layer could be done exactly in the same manner as the verification of the fuel in the upper layer. This has, so far, not been attempted, mainly because of the difficulty, seen in lowering the neutron detector between fuel assemblies of the upper and lower layer.

A specific project was signed in collaboration with Department of Energy (DoE) for developing a spent fuel gross defect system at CNA1 [4]. The objective was to develop a comprehensive database for the SFAs at both natural U and enriched 0.85w% covering the range of cooling times and burn-up present. An algorithm uses this database to predict expected signals when coupled with the SFNC at any location in the pond.

Although part of a project for optimizing the re-verification of spent fuel assemblies in the pond, the activity itself is still time consuming, so ABACC/IAEA are considering the containment project using the ultrasonic seals as a back-up component for surveillance, only in case of failures of these two components the re-verification would be applied.

3. Ultrasonic seals project

ABACC has agreed with JRC/ISPRA on a project of containment of Spent Fuel in Complex Storage Environment in 2012. The ultrasonic technology was chosen with a potential for future joint use with IAEA.

The requirements for the ultrasonic sealing system are mainly based on:

- CoK is guaranteed when sealing spent fuel pond;
- Seals on fuel elements, racks or hangers, guarantee knowledge over multiple layers of spent fuel storage;
- Ultrasonic seals are designed to be attached underwater, they are resistant to harsh environments, they are easy to apply and they can be regularly verified;
- Verification does not involve the replacement of cables or substitution of the seal, nor does it require the movement of spent fuel;
- This improves inspector's productivity, takes due care of radiation, safety considerations and decreases the disturbance to the plant operator;
- Seals technology are already used in other countries.

For this project a specific agreement with Argentinean National Authority (ARN) was signed and it considers training in the use of "Ultrasonic Seals" for the containment of spent fuels located in a complex storage environment and difficult to access for verification for safeguards purposes and their application in power reactor installations - demonstration of practical application in the CNA1.

3.1 Preliminary design

The first design was based on a sealing bar with two locking mechanisms, to be inserted over the hangers. The locking mechanisms were put instead of the two lateral extreme spent fuel rods as shown in Figure 1.

The seal bolt is tightened outside of the pond, by the inspector. The mechanism is spring loaded, once clamped on the hanger it can't be removed without first breaking the seal, opening the locking mechanism.

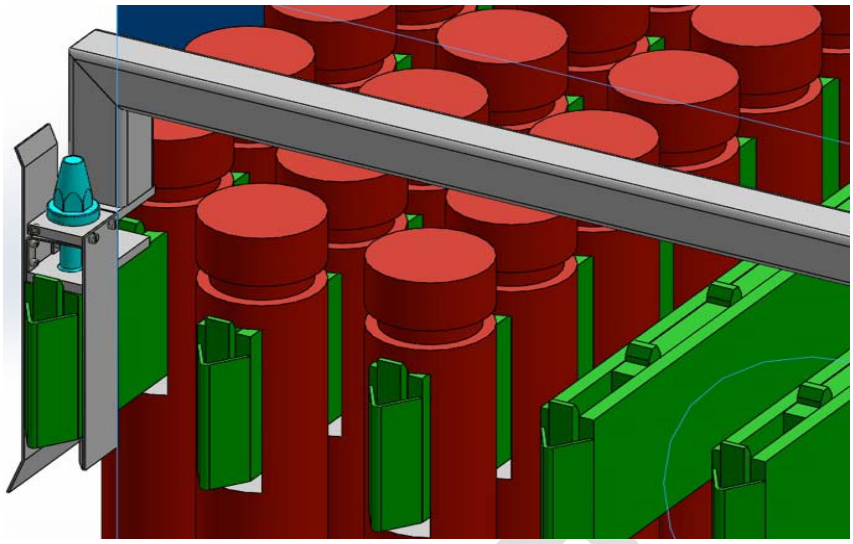

Figure 1: Close 3D view of the bracket locked on the hanger

This solution was not acceptable since the spent fuel storage positions blocked significantly reduces the SFAs storage capacity of the pond.

3.2 Alternative solution: locking with fuel bundle in position

The idea was to still use a bar with two locking mechanisms but the triangular tip of the two lateral hangers will be used, freeing the two positions for spent fuel assemblies. The seal bolt would be tightened underwater to close the locking systems by pushing rods under the triangular tips.

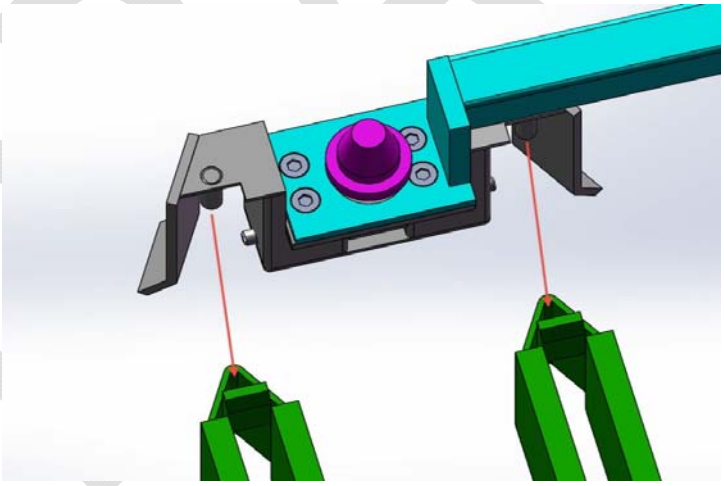

Figure 2: View of the two centering pins and associated positions on the racks

On the following Figure 3, we can see how the system was working.

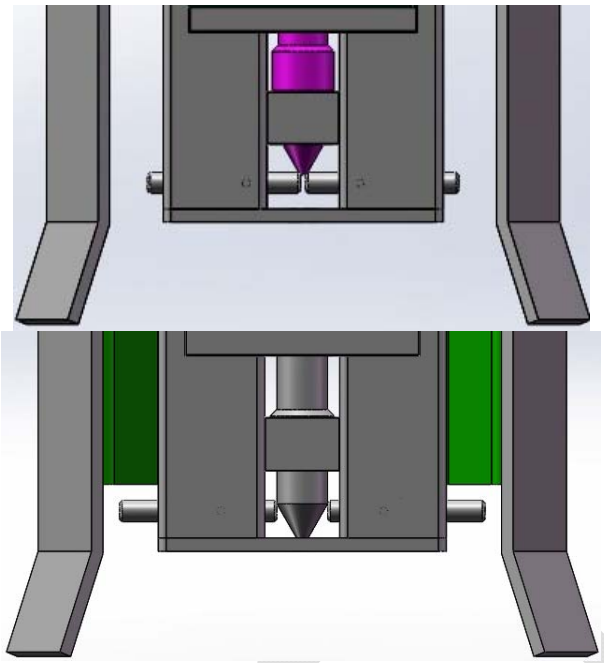

Figure 3: Unlocked, seal high, pins retracted (left) versus locked, seal in lower position, pins extracted (right)

3.3 First infield mission in Atucha

The first mission was done in June 2015 at CNA1 and ABACC/JRC took the opportunity to have access to a hanger outside of the pond (Figure 4) and they were able to discuss changes in the design.

Figure 4: View of the hangers outside of the pond

3.4 Proposed third design and associated prototype

Following the first mission and the comments received by Atucha's operators and ABACC technical staff, JRC updated the design accordingly and the locking mechanism fitted on only one triangle on each extremity of the hangers (and not two as on the previous design), in order to cope with the relative variability of the distance between two successive individual beams of the hangers.

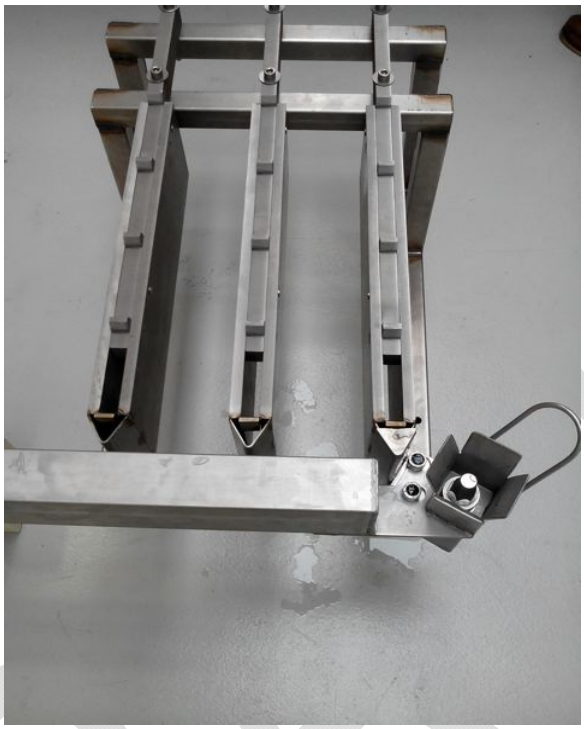

Figure 5: Mock up of the hangers and view of the locking system

3.5 Second infield mission in Atucha - Ultrasonic seals tests at the spent fuel pond

JRC and ABACC returned to Atucha in November 2015 with a foldable locking system with 4 m bar (cut in four separate 1 m bars), several locking mechanisms, two seals & tools. The equipment was tested on various elements outside CNA1 and the overall prototype system on the spare hangers. After this first step the bar and locking devices were tested in CNA1.

The bar was raised from the center with the crane and located on the first row of fuels in the pool five as shown in Figure 6. The plug-in process was easier than expected and the assistance from the steel bar ends practically was not required. The steel bar has a water tight design providing a low weight when it is submerged in the pond. The sealing bar was mounted over the hangers, seals tightened and then broken. Following the tests performed with the first prototype of sealing bar and locking mechanisms, ABACC and JRC validated the principle of locking on the triangular tip of the hanger on CNA1 hangers (underwater storage pond).

As shown in Figure 7 the system was attached and locked properly, when the steel rod is installed it disables any possibility to remove the fuel elements in the complete hanger.

Figure 6: Ultrasonic system installation with operator assistance in CNA1

Figure 7: Close view of sealing bar of hangers into the pond

4. Jointly Safeguards Approach and Scenarios

Based on the successful results obtained after spent fuel pond tests in Atucha and the training with inspectors and operators, ABACC contacted IAEA in 2016 to propose a common approach to use this technology.
After discussion of different diversion possible scenarios pointed out by the IAEA from the lower racks, the project [4] was improved to take into account these new considerations, it can be

seen from Figure 8 an example of these changes related to the locker system. A joint ABACC-IAEA procedure on the verification has been discussed based on the criteria for On-Load reactors [5], so that part of the spent fuel under dual C/S; both C/S systems should be evaluated as follows:

1. The surveillance system to be serviced and reviewed, during Physical Inventory Verification and interim inspections;
2. The ultrasonic seals to be verified with low detection probability and the containment to be examined, including visual observation on the integrity of the metal bars, during Physical Inventory Verification inspection.

The nuclear material subject to the dual system (C/S) is Pu and U contained in the SF from the nuclear power plant at Atucha (RAI1) which is stored in racks.

Figure 8 – Locking mechanism (new on the left and first model tested in CNA1 on the right)

Upon filling up the lower rack with SF, the upper rack will be staked on the lower one as a cover of the lower rack; the upper rack will be immobilized with the metal bar and sealed as described above. The diversion would require possibly tampering of the respective metal bars and removal or displacement of the associated upper racks allowing access to the lower levels. IAEA/ABACC identified improvements to be done and technical solutions have been discussed with JRC and a possible final schematic sealing system with protective arms should be applied during field trial, as presented in Figure 9.

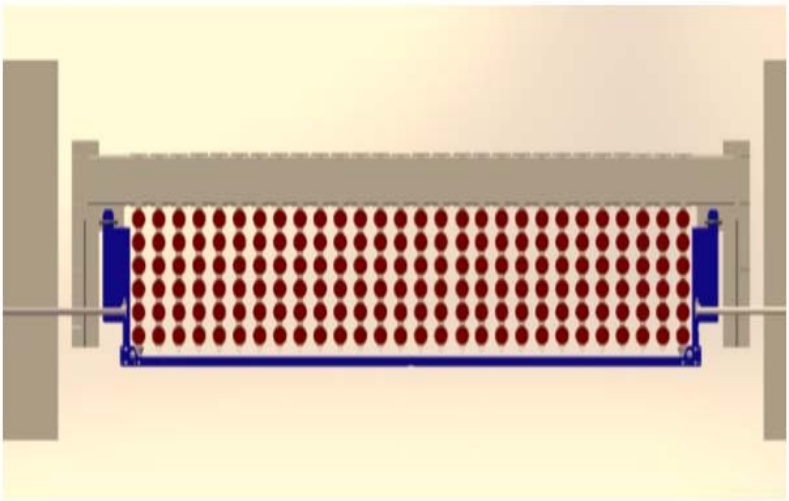

Figure 9: Schematic sealing system with protective arms.

5. Field Trial Perspective

The main purpose of sealing using ultrasonic technique is to maintain the CoK and avoid re-measurement. This is particularly important when applied to SF storages. ABACC, together with national authority and operator in Argentina, have been discussing the application of ultrasonic seals technologies, and, in particular, on how their use improves safeguards inspections without affecting operational tasks and turning activities less intrusive and more efficient.

Besides technical developments, safeguards approaches and scenarios should be discussed among all parties before ultrasonic seals system deployment. The parties involved are the state through ARN and the international safeguards agencies, ABACC and IAEA in order to ensure ultrasonic seals containment system success during safeguards implementation.

IAEA has been engaged in the evaluation process of the ultrasonic seal specific application for the CNA1 through the Safeguards Technical Service (SGTS) and different tasks need to be performed before final approval of the system.

The field trial, as part of the final IAEA/ABACC approval process, should start during the second semester of this year when JRC will be able to fabricate bars, seals and locking mechanisms to apply at least in one pond considering the final ABACC and IAEA remarks on the project. Meanwhile ABACC/ARN/IAEA would agree on the SF ponds selection, the procedures for evaluation of the system during the field trial and the final approval process for this ultrasonic sealing containment.

The use of new technologies in safeguards is important to enhance their effectiveness and efficiency. In this particular case, any future application of ultrasonic technology should be developed and implemented in such a way to allow joint use application between ABACC and IAEA, so the results from the containment provided by the ultrasonic seals during the field trial shall permit that ABACC and IAEA approve the technology for specific safeguards use in CNA1.

6. References

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