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Return of SAFARI-1 US origin HEU Fuel (Spent) to Savannah River

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ABSTRACT

SAFARI-1 research reactor HEU spent fuel of US origin was returned to the US at the Savannah River Site on 16 August 2011. The South African DoE, Necsa and the US NNSA have been working for many years to finalise the project. In relocating the 6.3 kg ^{235}U in the HEU spent fuel the experience in safety, security, safeguards, transport logistics and the project management will be presented. The spent fuel aged about 30 years was relocated from dry storage in the pipe store at the Necsa site to the pool in SAFARI-1. Preparatory work for the campaign involved NNSA training, equipment and site preparation at the reactor and nuclear licensing of the loading operation at the reactor as well as the transportation by road to the harbour and by ship to international waters. The effective project management, licensing and experienced personnel for all operations resulted in the smooth completion of the project.

1. INTRODUCTION AND BACKGROUND SAFARI-SHIPMENT

The initial discussions between SAFARI-1 Research Reactor located on the site of the South African Nuclear Energy Corporation (Necsa) at Pelindaba near Pretoria and the US Department of Energy (DOE) started in 2004. By the end of 2008 the SA Department of Energy (DoE) and the government approved the spent fuel of US origin repatriation project subject to that adequate training will be provided and that the project will be without cost to SA. The contractual negotiations continued through 2009 and the agreement between Necsa and NNSA was finally signed in August 2010. Thereafter project management process was fully implemented and a tight schedule was followed until loading and shipment during July 2011 and arrival at US Savannah River Site on the 16th August 2011.

The bulk of the repatriation activities took place in the aftermath of the Fukushima nuclear disaster which posed additional challenges in the licensing approvals, external communication and security arrangements. Two further major nuclear milestones were reached by South Africa during the first half of 2011 which also put nuclear activities prominently in the public domain namely:

- In the week after Fukushima nuclear disaster the SA government approved the integrated resource plan which made provision for the construct 9.6 GW nuclear power plants over the next 20 years,
- South Africa signed the Non- Proliferation treaty (NPT) and Comprehensive Safeguards Agreement (CSA) in 1991 and the Additional Protocol (AP) in 2002. The IAEA informed SA that it had received the broader safeguards conclusion i.e. that there is no undeclared nuclear material and no undeclared nuclear facilities in the State.

2. LICENSING AND REGULATORY APPROVALS

The 49 cropped MTR spent fuel elements of US origin were stored in a pipe store and were under the control of the Nuclear Liabilities Management Department of Necsa with its own nuclear license. However, only the SAFARI-1 nuclear license made provision for off-site transportation of nuclear material and thus the licensing of the spent fuel repatriation had to be done through the SAFARI-1 nuclear license. Whereas the initial drafts of the licensing documents were ready for first submissions to the regulator, the National Nuclear Regulator (NNR) of South Africa placed a Fukushima Directive on Necsa, in particular, SAFARI-1 Research Reactor which impacted on the licensing resources in Necsa and SAFARI-1.

2.1 MTR Spent Fuel

In total 49 cropped MTR fuel elements ~ 28 years out of the reactor core were part of the shipment:

- 40 Standard fuel assemblies (17 Inner and 2 outer fuel plates) were removed after approximately 45% to 55% burn-up.
- 6 Control rod assemblies (15 Inner fuel plates) were removed after 50% to 75% burn-up.
- 3 Half fuel assemblies (8 inner and 2 outer fuel plates) were removed after approximately 40% to 60% burn-up.

2.2 NNR Licensing Approvals

To the National Nuclear Regulatory (NNR) a Licensing Strategy and Action Plan documents were prepared and submitted for approval to the NNR. The Licensing Strategy document prescribed the following documents to be submitted for approval:

- The NAC-LWT cask was being used to transport three different fuel types and was already internationally licensed for the MTR fuel as NAC had previously shipped similar fuel from several MTR reactor an in particular SAFARI-1 sister reactor the HFR Petten Research Reactor in the Netherlands. The NAC-LWT safety case documents were submitted to the NNR in late 2010 but with a revised version becoming available early 2011 it was resubmitted;
- The Transport Plan which included the following activities:
  - Transfer of spent reactor elements from the SAFARI-1 pool to a NAC-LWT transport cask;
  - Transport of the NAC-LWT transport casks by road to the port on a single consignment;
  - Transferring the loaded casks onto a dedicated marine vessel for the marine transport of nuclear material; and
  - Passage of the marine vessel out of SA territorial waters.
- The Transport Plan covered security arrangements which were later presented in a separate secret classified document to the NNR for approval.

2.3 Additional Approvals

The following additional external approvals were obtained from:

- SA DoE for an export permit;
- SA Department of Transport and various provincial road agencies for notification of the road transport route (the route passes through five of SA's nine provinces); and
- IAEA safeguards with verification activities as agreed on.

The following internal approvals were obtained:

- Safety assessments on the fuel handling procedure and transport plan were evaluated by the SAFARI-1 Reactor Safety Committee (RSC); and
- The RSC recommended approval to the SAFARI-1 Reactor Safety Approval Committee (SARSAC) whose members are independent of any SAFARI-1 personnel; and
- SARSAC ratified the RSC safety categorization of the project and reviewed the RSC recommendation.

Final approval for the project to proceed past the hold point was:

- SARSAC Approval
- NNR Authorizations
- SHEQ project checklist signed off by Necsa Licensing Department

3. PROJECT MANAGEMENT

Project preparation meetings were held with all foreign stakeholders GTRI, NNSA, NAC, Edlow International, IAEA and with local stakeholders DoE, DoT, NNR, Security Agencies as well as internal Necsa departments such as Licensing, SHEQ, Nuclear Liabilities Management, Security and Safeguards and with NTP Logistics. The project was managed and coordinated by a dedicated project manager from beginning of2009. The project management process was done in accordance with a project management plan and Gantt chart schedules which were regularly updated. The whole project was managed in accordance with ISO 9001:2008 and SHEQ requirements.

The project scope included:

- Negotiation and conclusion of an agreement with NNSA which was approved in August 2010;
- All operational activities on Necsa site and during transport until loading of the consignment onto the shipping vessel;
- Import of the empty containers and export of the loaded casks;
- Obtain NNR authorization for relevant activities;
- Meet the Necsa SHEQ project approval requirements as stipulated in the INS-0800 checklist;
- Meet all Safeguard requirements;
- Meet all Security requirements;
- Manage all communications; and
- Coordinate and assist NNSA with the implementation of the Skills Transfer programme.

A technical project meeting was held between Necsa project management, SAFARI-1, DOE and NAC at Necsa SAFARI-1 site in December 2010 to initiate the technical details of the project. During this meeting, the SAFARI-1, US DOE and NAC project teams assessed the site layout and infrastructure, selected a cask loading method, reviewed the cask documentation and proposed a detailed project schedule.

The process to be licensed to repatriate the applicable spent reactor fuel elements was be described in detail in a Transport Plan and included the following activities:

- Transfer of spent reactor elements from the SAFARI-1 pool to a NAC-LWT transport cask;
- Transport of the NAC-LWT transport casks by road to the port on a single consignment;
- Transferring the loaded casks onto a dedicated marine vessel for the marine transport of nuclear material; and
- Passage of the marine vessel out of SA territorial waters.

All maintenance of the NAC-LWT casks, packing and preparations for shipment of all support equipment and parts was performed at NAC's storage and maintenance facility located at Wampum, Pennsylvania, USA.

All cost associated with this project including a comprehensive skills transfer program was covered by the NNSA.

4. FUEL INSPECTION

After approximately 12 years of dry storage the cropped fuel elements were transferred back to SAFARI-1 storage pool. Visual inspection of the 49 cropped fuel elements was done at several stages during the transfer process by SAFARI-1 personnel and an acceptance inspection before final shipment to the USA by two persons from the Savannah River Storage site.

The cropped fuel elements were visually inspected in the hot cell and video footage were taken of the fuel. The video footage was verified by the Savannah River inspection team and as a result of the good quality of the footage the inspector only sampled 13 fuel assemblies to be inspected. The 13 fuel elements were visually inspected in the SAFARI-1 hot cell and no defects were observed and fuel was found to be in excellent condition after ~40 years.

5. SITE PREPARATION

5.1 Description of Area

The external loading area was established within the security perimeter of the parking area to the North-East of the reactor building. The changes and services provided to the external loading area, included:

- Erection of a security perimeter fence and security infrastructure;
- Setting up a temporary radiological zone;
- Designing and building a concrete plinth on which the NAC- LWT casks were located during loading;
- Securing the two NAC-LWT casks on their base plates to the concrete plinths;
- Equipment associated with the handling and loading operations;
- Portable lights for night time operation; and
- Utility services and supply lines from the SAFARI-1 reactor building.

5.2 Concrete Plinth

A level 6 x 6 m concrete slab was erected in the area to accommodate the set-up of the NAC-LWT casks. The concrete slab provides a square level surface onto which the base plates of the NAC-LWT casks were secured. The loading capacity and drawings of the plinth were verified and approved by the civil engineering group.

5.3 Plant Support and Utilities

Plant support services supplied by SAFARI-1 include the following:

- helium gas
- electricity
- demineralised water
- compressed air
- rigging equipment
- crane services
- forklifts
- lighting
- gamma spectrometry analyses

5.4 Site Selection

The site for the external loading area was selected on the basis of:

- Open area available
- Condition of available area
- DTS transfer route distance
- Condition of transfer route
- Security arrangements
- Utilities and waste services
- Feasibility to establish radiological controlled areas
- Short route allows for improved security during transfer of the material,
- Allows for the establishment of a suitably secured area
- Suitable to accommodate a radiological controlled area

5.5 Security

The spent fuel needs to be in a Class 4 security area, particularly since it is being loaded and not merely being transported. Therefore an electrified security fence with camera system coupled to the existing SAFARI-1 security system was installed. The area was under 24 hour surveillance with regular patrols by SAFARI-1 and Necsa security personnel.

5.6 Access Control

All external personnel received Necsa orientation and induction to the SAFARI-1 processes and building layout. NAC personnel were registered as Necsa radiation workers and were subjected to a whole body count and medical examination. Access control by means of an Access Control Permit to the reactor and the LWT cask loading area was done.

6. RADIOLOGICAL PROTECTION PROGRAMME

Radiological protection activities formed part of the work instructions and were also prescribed in Necsa SHEQ radiological work permits and SAFARI-1's Work Permit System.

6.1 Waste Management

Waste management was provided by SAFARI-1 in accordance with the SAFARI-1 waste management programme. To this extent, the waste management programme controls radioactive liquid waste, solid waste, gaseous effluents and special or industrial waste.

6.2 Liquid Effluent Management

In terms of radioactive liquid effluent management, SAFARI-1 provided two 210 litre drums for draining of the NAC-LWT casks after SIP testing. These drums were sized to allow for sufficient excess capacity (420 litres versus 260 litres required). During the SIP testing process, a plastic pond was placed under the drums to cater for any accidental spillage during the filling process. After the SIP test, the drums were transferred to the SAFARI-1 reactor building for draining into the LA/MA drain systems.

6.3 Solid Waste Management

Very little solid waste (plastic sheets, gloves and cleaning material) was generated. As a precaution SAFARI-1 would if any significant quantities of solid waste was generated to be collected it in solid waste drums at the East beam port area in the reactor building

6.4 Gaseous Effluent Management

No gaseous ventilation other than the normal building ventilation was needed.

7 INTERFACES WITH SERVICE PROVIDERS

Interfaces regarding the management of service providers to SAFARI-1 for the duration of the project include the following:

- US DOE (National Nuclear Security Administration)
- Savannah River Nuclear Solutions
- NAC International
- NTP Logistics a subsidiary of Necsa (NTPL)
- IAEA and the South African State System of Accounting and Control (SSAC) of Safeguards

In light of the above-mentioned NAC provided equipment and rendered assistance and supervision during use of their equipment, namely the NAC-LWT suite of equipment as well as the NAC DTS suite of equipment. NTPL was the logistics service provider and were contracted to fulfil responsibilities associated thereto within South Africa territory.

7.1 Safeguards

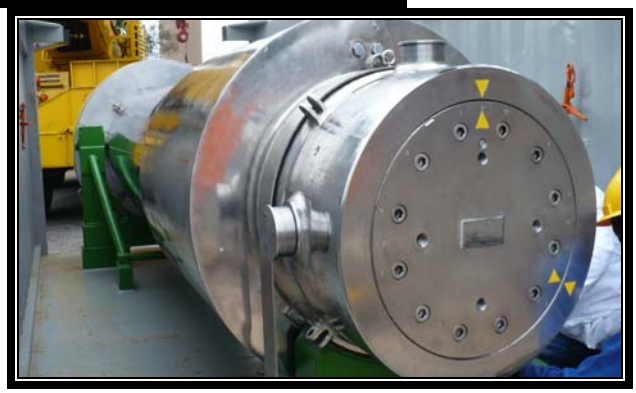
IAEA Safeguard Inspectors fulfilled verification activities regarding the shipment of fissile material. Most of the safeguards authorities of the SA SSAC have been delegated to the Nuclear Safeguards Management (NSM) Department of Necsa. Within SAFARI-1 a Safeguards Implementation Officer (SIO) was responsible for nuclear material accounting, witnessing the return shipment of the spent fuel from the pipe store to the SAFARI-1 spent fuel pool, verifying storage in the pool and witnessing the loading into the DST cask and transfer to the NAC-LWT. An inspector from NSM participated in these activities.

The return of the spent fuel from the pipe store was coordinated carefully with spent fuel being transported to the pipe store. Although SA obtained the broader safeguards conclusion the new integrated safeguards approach was not approved as yet and transfer of spent fuel from the SAFARI-1 reactor to the Thabana Pipe Store still required the full time presence of IAEA inspectors for verification and maintaining continuity of knowledge. For the spent fuel repatriation project the following verification activities were agreed on with the IAEA which saved much on manpower resources and allowed the transfer to be completed on schedule without affecting the reactor production schedule:

- Identification, verifying and accompanying spent fuel transport cask to the difficult to access storage in the pipe store. Continuity of knowledge was maintained throughout the transfer of spent fuel, temporary seal of half-filled pipes and permanent sealing of full pipes;
- The reverse procedure was followed for spent fuel of US origin returned to SAFARI-1 with the difference that the pipes which contained only a few elements at the top were unsealed, removal witnessed and resealed. Pipes which were completely filled with US origin spent fuel were unsealed and Necsa could proceed with removal and transfer without IAEA inspector witnessing;
- Just before start of the loading campaign into the NAC-DTS the IAEA performed an item counting inspection in the pool. The NAC-LWT casks were not IAEA sealed because the final destination was a Nuclear Weapons State where it could re-verified if necessary.

7.2 Transport Containers and Support Equipment

NAC provided equipment and rendered assistance and supervision during use of their equipment, namely the NAC-LWT suite of equipment as well as the NAC DTS suite of equipment. NTPL was the logistics service provider and were contracted to fulfill responsibilities associated thereto.



Cask Receipt/Inspection/Unloading Area Cask Survey prior to setting up casks

NAC-LWT Cask Loading Area TN 7/2 Cask Loading Preparation Area

The full complement of 5 ISO containers were utilized with 2 ISO containers used for the NAC-LWT casks and 3 ISO containers used for auxiliary equipment. The ISO containers were received in a dedicated area where they underwent comprehensive smear swipe testing to check for potential contamination including the equipment transport containers.

7.3 Cask Loading Operation:

The SAFARI-1 research reactor has a pool not sufficiently deep to receive the NAC-LWT packages nor has the building headroom and space to accommodate the main cask. Due to limited crane capacity (25 ton) to conduct this exercise inside any building the decision was made from the beginning to perform loading outside the facility and therefore a 80 ton mobile crane was deployed. The following areas of SAFARI-1 accommodated the loading and transfer operations:

- Storage pool (spent fuel assembly handling and loading into NAC MTR-42 fuel baskets, loading of fuel baskets into NAC DTS cask);
- Areas immediately adjacent to the storage pool (lay-down working areas);
- Beam port floor (transfer activities);
- North truck door area (transfer and decontamination activities); and
- External security area adjacent to the North truck door (DTS and NAC-LWT cask transfer activities).

The DTS cask was loaded via the NAC DTS pool adapter, which spanned the storage pool. Loading and transfer operations required that the areas immediately adjacent to the pool be utilised as lay-down and working areas. After being loaded, the DTS cask was transferred with the overhead crane to the area next to the North truck door area, at which point it was transferred onto DTS equipment and transported by forklift through the North truck door and adjacent external security area to the NAC-LWT cask loading area outside.

Equipment and infrastructure within the facility was not subjected to design changes or modifications in order to accommodate transfer and loading operations. However, the storage pool and north truck door area was cleared of obstruction to accommodate these activities. Existing plant support services and DTS equipment that was utilised during the transfer operations, with due process adhered to in respect of SAFARI-1's safety related protocols and practices.

SAFARI-1's current interfaces with security, safeguards and IAEA representatives as established for transfer of spent fuel elements were used during these activities. The SAFARI-1/NAC International interface was managed by SAFARI-1, with SAFARI-1 personnel performing operations inside SAFARI under supervision of experienced NAC personnel.

The applicable areas were zoned as blue radiation and white contamination areas. These zonings required radiological protection requirements, control over operations, emergency response procedures and PPE requirements as applicable to radiological safety. Continuous invigilation and smear sampling by an RPO formed part of the radiological protection measures applicable to these areas. The area utilised for decontamination of DTS equipment had sufficient wet absorbing sheeting and bags to isolate and contain contamination in case of such an eventuality.

All loading activities were controlled and managed in accordance with SAFARI-1 licensed conditions specified in the nuclear license as well as conditions of work established with the special license approval received from the National Nuclear Regulator for this once off transfer. All modifications to the work procedures and conditions of work was assessed and incorporated into the radiological safety assessment, work procedures, conditions of work as well as the operational and quality control checklists.

The following operational activities were applicable as part of the operational preparation:

- Preparation of the security area (i.e. fence gate security personnel and lightning);
- Proof of statutory compliance for lifting and rigging equipment was verified by SAFARI-1 operational and QHSE personnel with control measures;
- Verify training of SAFARI-1-1 operating personnel to be valid for in pool activities and training of the DTS cask and LWT cask loading process was performed on arrival of the NAC equipment. Further training of SAFARI-1 personnel was performed under supervision of NAC personnel as per SAFARI-1 operational procedures;
- SAFARI-1 and NAC operational personnel involved in performing the fuel transfer activities were Suitably Qualified and Experienced Persons (SQEP) and were regarded as authorized in fuel handling activities;
- The storage pool has been prepared to accommodate the fuel loading activities and to minimize the impact on medical isotope production activities;
- The external loading site and security area was prepared w.r.t loading activities as well as for security measures to be implemented during the loading;
- Special plant equipment required was coordinated with the NAC personnel and internally within SAFARI-1;
- Equipment was verified on arrival and functionally checked before commencement of the fuel loading activities; and
- A statement of operational readiness w.r.t. fuel loading activities within the SAFARI-1 facility was issued to the Licensing and SHEQ departments of Necsa.

The photos below provide a pictorial overview of the cask loading operation. This method was new to SAFARI-1. However, it is a well-proven process which has been used in more than 20 facilities worldwide and all activities at SAFARI-1 went well and no problems were experienced.

NAC provided excellent technical guidance to SAFARI-1 during the cask loading operation which was scheduled from the 04 – 14 July 2011. The actual loading and testing of the two NAC-LWT casks was completed ahead of schedule.

9 TRANSPORTATION

The convoy of two loaded casks with attendant 3 containers of equipment was transported under high security to a nearby port. After a long maritime voyage, the casks were delivered safely at the Savannah River, South Carolina. This transport plan covers all aspects of the transport of the USA-origin SAFARI-1 HEU spent fuel and auxiliary equipment from the Pelindaba site of Necsa to the elected harbour, loading of the consignment onto a marine vessel as well as the passage of the marine vessel up to leaving the territorial waters of South Africa.
The strategy was divided into three phases:

- Phase 1: Pre-Transport Planning.
- Phase 2: Pre-Transport Readiness/Fitness Verification.
- Phase 3: Loading and transport.

The transport of the SAFARI-1 HEU spent fuel from Pelindaba to the harbour was handled by NTPL as the logistics management service provider and transport from the harbour to the USA was handled by Edlow International Corporation that contracted an INF 2 marine vessel for the marine transport of the loaded fuel casks to the USA.

10 CONCLUSION:

From approval of the contract between Necsa and NNSA in August 2010 the spent fuel repatriation project was completed within one year after the initial discussions, feasibility study, SA governmental approval and contractual negotiations which had taken several years. The actual schedule was fixed early 2011 for loading into the NAC-LWT to take place during June 2011. The Necsa Steering Committee which monitored the project management plan and the related activities found that due to the short time left for the licensing documents to be prepared and approvals to be obtained that the schedule was ambitious and to mitigate risks a buffer of one month was built into the schedule. This strategy worked well with all approvals in place for loading and shipment which then started early in July 2011.

The cask loading operations was accomplished efficiently by the experienced SAFARI-1 operators and NAC team. Only minor occupational health, safety and radiological incidents (i.e. wearing of safety hats and minor transgressions in the temporary demarcated radiological area were reported by the NNR) were reported during the operation with no delay to the schedule. The transportation to the harbour, loading onto the marine vessel and the thorough emergency and security planning, effective security escort and shipment to Savannah River Site was well accomplished without incident. The communication strategy to only inform stakeholders and the public (through the Pelindaba Safety Communication Forum) on a need to know bases and as determined by the NNR worked well and the news of the repatriation project was for the first time made public by the NNSA after arrival of the spent fuel in Savannah River Site.