SOGIN Enriched Uranium Extraction (EUREX) Plant Spent Fuel Pool Cleaning and Decontamination Utilizing the SMART™ SAFE™ Solution - 9317

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ABSTRACT

SOGIN's EUREX facility in Italy was developed as a pilot plant functional testing laboratory for spent fuel reprocessing. This facility was operated successfully for many years since 1970 and was eventually shutdown consistent with Italy's suspension of all nuclear operations.

At the time of suspension, the EUREX facility still had spent nuclear fuel assemblies in storage from a nearby PWR. Other fuel assemblies from an Italian AGR had remained stored in the spent fuel pool for the 20 years or so waiting for removal and reprocessing abroad. Being Magnox fuel elements, their recovery for the transport produced a huge amount of sludge in the pool. During this time, sediment, dirt, corrosion products, fuel cladding, etc. has collected within the fuel pool as a crud layer dispersed throughout. Most of this crud has accumulated on the horizontal surfaces of the pool and fuel element assemblies, while some remains as a suspended colloidal material. Furthermore many other contaminated metal components, used during the operation years, where still inside the pool.

Due to a pool leak discovered in 2006, SOGIN speeded up its pool decommissioning program, making also available the transfer of the spent fuel to a nearby interim repository, with the goal to completely drain the pool in the shortest period of time. In order for SOGIN to successfully transfer the fuel assemblies from their current storage basket locations to the spent fuel transfer cask, the bulk of the crud

needed to be removed. This cleanup operation was deemed necessary to minimize the suspension of contamination in the water during underwater handling operations. This would reduce the decontamination efforts on the transfer cask upon removal, once loaded with the spent fuel, and enhance safety by reducing potential underwater visibility issues.

The operations were completed in July 2008 with the release to the environment of the pool water, thoroughly purified and without any relevant radiological impact.

The EUREX project consisted of a four phased approach with each phase briefly described herein:

- Phase I: Feasibility Study and Safety Case
- Phase II: Pool Crud Collection & Fuel Element Cleaning
- Phase III: Handling Systems Revamping, Fuel and obsolete components removal
- Phase IV: Pool Draining, Water Treatment & Pool Re-Sealing

INTRODUCTION

The EUREX (Enriched Uranium Extraction) reprocessing plant operated between 1970 and 1983, and was prepared for decommissioning in the following period. In 2004 a leak was detected originating from the plant Spent Fuel Pool (SFP).

Described in this paper are the operations to facilitate and complete draining of the SFP by spring of 2008, following the successful out of water loading of spent fuel that occurred in the first half of 2007, and final discharge outside the plant. Criteria for such an environmental discharge were extremely challenging and required an innovative and flexible water treatment system to accomplish this task.

Phase I: Feasibility Study and Safety Case

This phase of the work was completed and presented to the SOGIN Plant in 2006 with a subsequent order to proceed with equipment procurement, shipping and staging in early 2007.

Phase IIA: Initial Pool Cleaning and Crud Collection

This initial phase was carried out in the first and second quarter of 2007 and entailed the gross cleaning of the crud and loose dirt present in the fuel pool to support the efficient spent fuel removal work. Usually fuel pool crud collection is achieved using an underwater vacuum system and poly-based cartridge filters to contain the collected crud. Being that this crud was assumed to possess spent fuel fragments and other fissionable material debris, a specialized collection system was developed to address those concerns and also minimize the total waste volume generated in the process. The system included an underwater vacuum system, specially designed 15 cu. ft. collection vessels with filtration internals and a mixed-bed deep-bed filter media consisting of two layered GAC mesh sizes, in-line strainer device and assorted suction hose nozzles.

The Phase II work was completed successfully and within schedule allowing SOGIN to perform the spent fuel transfer operations.

Phase IIB: Final Pool Crud Collection and Fuel Element Cleaning

This phase commenced in October 2007 with a more detailed cleaning of the horizontal surfaces first. The same equipment is being used to complete this task and will include removing floor grating and other structural items to completely expose all of the spent fuel pool walls and floors. At the completion of the gross cleaning in the former inaccessible areas, a wall and floor washer was attached to the vacuum suction hose and used to scrub the residual crud deposits on all surfaces in the pool. All the crud and debris loosened by the scrubber was deposited directly into the collection vessels being deployed as part of the system during this phase.

Phase III: Handling systems revamping, Fuel and obsolete components removal

Started together with Phase I and completed during Phase II, this activity consisted mainly of:

- Modifications of the pool and fuel bridge cranes, in order to match actual safety criteria for spent fuel handling
- Removal of all obsolete systems and components still present in the pool, many of them of big dimensions
- Removal of the spent fuel from the pool.

This last issue, due to limited pool dimensions, required an out-of-water cask loading, and designing a shielded shuttle to transfer each of the 54 fuel assemblies in the transport cask. A total of 10 transports to a nearby fuel interim repository were performed between May and July 2007.

Phase IV: Pool Draining, Water Treatment and Pool Re-Sealing

At the completion of the detailed cleaning and removal of all underwater objects, the water was slowly drained out of the fuel pool, treated and the exposed walls and floors painted for residual contamination control. The challenge here was the extremely low discharge levels for cesium (Cs), strontium (Sr), americium (Am) and plutonium (Pu) in an alpha-containing wastewater. The process flow diagram (PFD) to accomplish the final water treatment included the Seeding and Filtration Electronically, or SAFE™ Solution Electrocoagulation (EC) System, with Ion Specific Media (ISM) fines Addition (SMART™ Seeding) Tanks; six electrolytic cells; and floc, sludge, settling and clean tanks. As a final polishing precaution, a SMART™ Ion Specific Media (ISM) skid polished the clean/product EC tank prior to the final plant monitoring/discharge tank. The vessels were specific for Cs, Sr and the actinides (Am and Pu).

Due to the high levels in the pool, the presence of alpha and the safety case presented, the hot portion of the system was designed to be enclosed in an intermodal container to serve as secondary containment and minimize dose to workers for ALARA reasons. The proposed containerized system was a 30 gpm SAFE™ System. This system has completed the project and is currently being decontaminated for storage.

In July 2008, after the necessary controls, 700 m^3 of treated water removed from the pool, have been released to the near Dora Baltea river with an estimated radiological impact of no relevance.

This paper will outline the waste forms encountered, challenges overcome, subsequent treatment train selection, the on-going treatment, results of the project, final pool draining and coating, and future goals of this D&D and treatment technology.

The Eurex Pilot Plant

The EUREX pilot reprocessing plant, designed to reprocess Material Testing Reactor (MTR) spent fuel, was built in Saluggia (north-west Italy) in the 1960's, in order to complete the R&D program of Italian Committee for Nuclear Energy (CNEN), providing design data for a future industrial reprocessing plant. Operations started in October 1970 with MTR fuel reprocessing until 1977 and replicated, after major plant modifications, in 1980-83 on irradiated CANDU fuel bundles. (72 spent fuel bundles were treated in the plant.)

Initial programs were developed from initial plant programs, to commercial fuel and until 1972 PWR, AGR and BWR spent fuel was received and stored in the pool. When reprocessing programs were definitely cancelled after the Italian nuclear phase-out, 54 spent fuel elements from the Trino PWR, 48 pins from an irradiated Garigliano BWR fuel element and 10 fuel plates from a dismantled MTR element from Petten (NL) were present in the SFP.

Also some 500 spent Latina AGR fuel elements present at the time, were sent abroad at the end of 80's and their recovery for the transport after 20 years of storage produced a huge amount of sludge in the pool, a part of which was removed just after the operation [1]. Some of the fuel elements were Magnox fuel, thus the high amount of sludge present during decontamination operations.

Eurex Spent Fuel Pool Description

The EUREX SFP is a 675 m^3 concrete basin, 5.5 m to 7.5 m deep and divided into three sections, the deepest one devoted to fuel cask loading and unloading. The peripheral part of the pool is surrounded by a 65-70 cm wide trough, extending 3.5 m above the basin enclosure buildings floor height.

The SFP trough is filled with sand and gravel, probably for shielding purposes and seven dip probes are inserted at equally spaced intervals around it, extending the full length of the trough. Each of the probes is equipped with a water sensor (Figure 1).

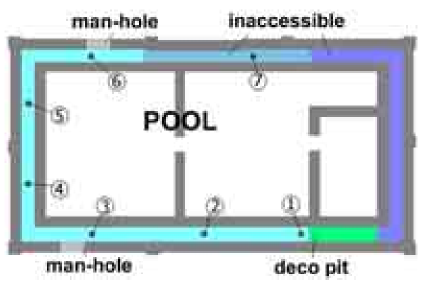

Figure 1. Plan of EUREX SFP with water probes location.

The pool floor and walls are constructed of concrete, having just paint as a liner. The structure was built in the 60's and received its first irradiated fuel in 1968.

Eurex Spent Fuel Pool Situation

Decommissioning Program Main Steps

The sizing on light and small MTR fuel and related transport casks, the characteristics of a pilot – mor than industrial – reprocessing facility and the relatively aged design of the EUREX SFP which was built and went into operation 5 years before the plant, when nuclear regulatory laws were not yet in full force in Italy, presented unique challenges for the SFP decommissioning.

The SFP decommissioning project listed the main issues to solve:

1. To adjust pool handling devices (crane and fuel bridge) to meet actual safety regulatory guides
2. To procure (design, licensing and construction) a cask dimensionally suitable for the pool
3. To remove the remaining spent fuel
4. To remove obsolete equipment present in the pool
5. To remove the sludge from the bottom.

Loss of Containment

At the beginning of 2004, phases 1 and 2 were in progress when a leak, occurring from the pool, was detected in the trough and later in the surface water table. 35 m^3 of water was recovered from the trough in the year.

This event gave a further thrust to the program and alternatives to cask procurement and spent fuel arrangement, scheduled to be sent to abroad for reprocessing after 2010 were studied.

This new program has directed to complete the pool emptying and draining in only three years.

Accelerated Program

In order to shorten the most time-consuming steps of the program (transport cask procurement and fuel removal to reprocessing), three strategic decision were made by Sogin:

1. Accelerate and conclude the handling devices revamping program
2. Reuse an existing licensed transport cask (AGN-1), to be loaded out of the water
3. Transfer immediately the fuel to another site
4. Assess a cleaning and draining program for the pool.

Water Contamination Issue

Due to the presence of a thin sludge layer on the pool bottom, which is highly alpha contaminated and easily resuspended, any operation involving underwater equipment movement and/or extraction had to be performed with adequate protective clothes (double overcoat, full face mask with filter) and with a dedicated protective clothing change point.

This issue made every operation delicate, heavy duty and time consuming, requiring a detailed and daily updated scheduling of works.

Handling Devices Revamping

After a detailed study about the intervention feasibility, between August and September 2006, the 48 ton bridge crane of the pool has been modified, in compliance with NUREG regulations, reducing the load capacity to 27 ton (Figure 2).

Figure 2. Load test after crane revamping.

The 8 m long fuel bridge, servicing the storage area of the pool, was substituted with a new one.

Obsolete Equipment Removal

Between 2006 and 2007, some 80 tons of mainly metallic equipment, used in past activities of storage and handling of spent fuel, were removed from the pool. Some very large equipment (height over 2 meters, weight over 2 tons – Figure 3) removal required special handling tools and devices, in order to perform operations safely, limiting as far as possible any airborne contamination.

Figure 3. Metal basin 5 m long during extraction from EUREX SFP.

Special boxes were designed in order to contain extracted equipment for storage after removal (Figure 4).

Figure 4. Four m long, 3 m wide metal extracted structure storage box during transport.

Three special shielded containers (500 – 1000 ℓ volume) have been designed, fabricated and used in order to evacuate highly irradiating items (Figure 5): such as some 1300 MTR fuel elements terminal with aluminium parts having high activation, and eleven 5 ℓ bottles containing radioactive slurries from past pool cleaning.

Figure 5. Two shielded containers for activated MTR terminals.

Spent Fuel Evacuation

Spent fuel removal from the pool was the major issue in the overall pool remediation schedule as no licensed cask fitting EUREX SFP sizes and lifting mean permissible loads was available in the short time needed. Light and small single-element casks use demanded too much time to transfer all the fuel elements outside the pool therefore this option was abandoned. Also a temporary storage outside the pool needed to be found because transfer for reprocessing was scheduled several years after the required SFP draining.

An accelerated program to remove the irradiated fuel from the EUREX SFP (52 Trino PWR elements, 48 Garigliano BWR pins, 10 Petten MTR plates) has been established according to these main strategic issues:

1. Reuse, with an internal basket modification, an AGN-1 transport cask (50 tons), Sogins property, to load 6 Trino elements or all the Garigliano and Petten fuel
2. To load the cask outside the water, designing a shielded shuttle to move the fuel from the pool to the cask
3. To transfer the fuel to the nearby Avogadro repository, where some 20 tons of Sogin spent fuel were already in storage. The small distance (less than 1 km) between EUREX and Avogadro reduced the transport licensing duties

From May to July 2007 ten fuel transfers were performed, removing all the irradiated fuel (2 tons) from EUREX SFP.

Out Water Cask Loading

Fuel elements characteristics
The 52 Trino PWR spent fuel elements were in storage inside the EUREX SFP since 1972. Due to the limited pool depth, they were stored in a horizontal position, inside nine 6-place tilting frames (Figure 6).

Figure 6. Trino PWR elements in storage.

Each frame was moved to the loading area of the pool and tilted in a vertical position; each fuel element was then lifted inside the shielding shuttle (part of the element stands outside the water) and put inside a special capsule (fuel bottle).

Loading of Garigliano half pins and Petten plates inside their capsules did not need the shielding shuttle due to their limited height (50-70 cm).

Shielding Shuttle, Capsules and Special Lid

In order to ensure limited exposure during the fuel loading in the cask outside the water, each Trino element was charged in a shielded capsule (Figure 7).

Figure 7. Shielded capsules during loading.

To load fuel elements inside capsules and to transfer loaded capsules inside the cask, a 20 ton shielded shuttle (transfer bell) to host fuel (bare or encapsulated) was employed (Figure 8).

Figure 8. Shielded shuttle.

The shielding during the 6 sequential transfers of capsules inside the cask was guaranteed by a special cask lid with mobile shields (drawers, Figure 9).

Figure 9. Special cask lid, one mobile shield open.

AGN-1 Cask Transfer

The repetitive sequence for each transfer (one per week) required the following:

1. Fuel loading inside capsules in the EUREX SFP
2. Capsule loading into the cask, outside the water
3. Cask tilting to horizontal position on transport trailer (Figure 10)
4. Cask transfer to Avogadro
5. Fuel unloading in Avogadro
6. Empty cask return to EUREX for a total of ten transfers within 2½ months.


Figure 10. Cask loading on trailer.

Dose Records

A dose less than 50 µSv (neutron + gamma) has been measured for the most exposed operator during a complete cask loading sequence.

Pool Cleaning and Draining

Sludge Removal

In order to remove the contaminated sludge at the EUREX SFP bottom, an underwater cleaning system was used (NUKEM / Energy*Solutions* Wall & Floor Washer™, and the sludge collected in specially configured Sludge Collection Vessels, Figure 11).


Figure 11. Sludge collection vessel.

The system recovered about 50 GBq of fission products and transuranic sludge, facilitating pool operations and subsequent water treatment and draining.

Water Treatment and Draining

The EUREX SFP remediation project goal was to have the pool completely treated and drained.

After the removal of obsolete equipment, irradiated fuel and bottom sludge, the last step, started in March 2008, was the water treatment and draining. The treated water, 675 m^3 total has been processed and was released, with a special authorization, within the licensed operational discharge limits, to an outside holding pond by June 2008. Subsequently, this treated water was released to the Dora Baltea River by July 2008.

Estimated dose for this release has been kept below the non relevant value (< 10 μSv) to the critical (most exposed) group of the public.

The water treatment was performed using a 30 gpm SAFE™ ElectroCoagulation (EC) System coupled with SMART™ media seeding for cesium, strontium, americium and plutonium floculation and removal; ultrafiltration (UF) for floc removal, and final activity polishing with Ion Specific Media, ISMs (See Figure 12 for the EC cells and control panel and Figure 13 for the sealand contained equipment layout).

Figure 12. ElectroCoagulation (EC) cells.

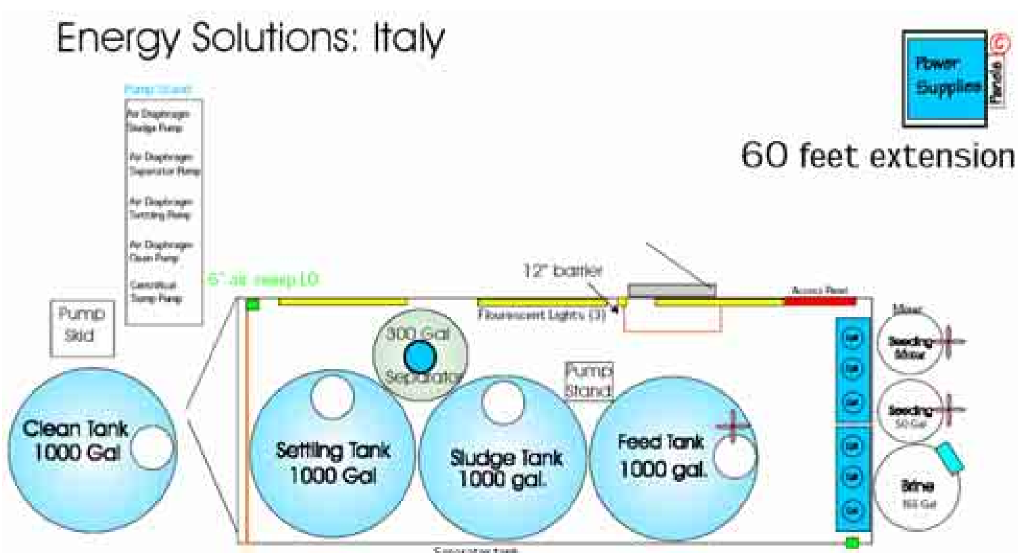

Figure 13. SAFE™ System Layout

The actual extremely challenging discharge criteria, compared with those originally proposed and those from original samples, for total alpha and total beta of <10 Bq/L and <80 Bq/L respectively; required this coupling of highly ion specific and huge capacity seeding agents with the EC process.
The EC subsequently flocced this activity out as a larger, filterable solid. See Table 1 for the radioisotopes present, anticipated and actual Decontamination Factors (DFs) required to meet these goals.

Activity Proposed Bq / l		Target DF (Decon. Factor)	Activity Original Water Sample	New DF for Same Output	Initial Activity Actual Pool Water	Final required DF
Sr-90	690	220	5 380	1 715	31 000	> 19 000
Cs-137	2200	260	5 930	700	32 000	> 15 238
Total α	280	200	940	670	127 000	> 21 167
Total β	—	—	—	—	122 000	> 1 649

Table 1. Decontamination Factors required for total gamma, beta and alpha removal.

Figure 14 illustrates the total beta and alpha effluent activities over a one month period.

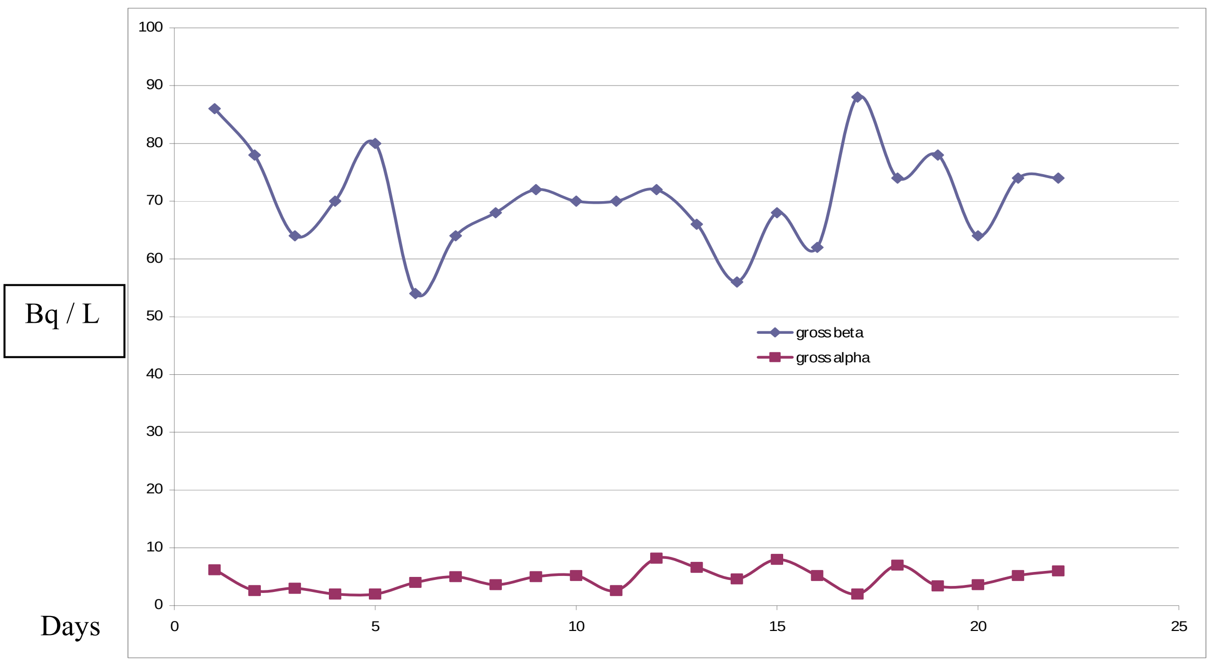

Figure 14. Total effluent activities recorded for a one month operation.

The final state of the EUREX SFP is empty and with walls and bottom painted in order to fix surface contamination. See Figure 15.

Figure 15. Spent Fuel Pool completely drained and sealed

The treated water was first moved to an outdoor holding pond prior to final permitted discharge to the river. See Figure 16 of the holding pond before and after discharge.

Figure 16. Before and after final discharge of holding pond.

Further Steps

Within the end of this year further investigations about the radiological conditions of the trough filling material and of the building will be performed, giving the basic data for further decommissioning steps (building structure demolition).

Conclusions

In a very short timeframe after the SFP leak was detected, the EUREX SFP remediation project was put in place and completed.

In slightly something more than a couple of years, the 40 years of operational legacy of the pool has been solved, anticipating its decommissioning.

Obsolete equipment, irradiated fuel, contaminated sludges have been safely removed and properly stored, waiting for final treatment and conditioning.

Like few others experiences in the world, some two tons of irradiated commercial fuel has been removed from the pool and loaded into transport cask out of the water.

Some 700 m^3 of contaminated water has been purified and was properly released outside the plant.

Very limited dose uptake by workers and the population has been achieved on this challenging project.

References

1. M. GILI et al. "L'esperienza di stoccaggio prolungato a secco per elementi combustibili tipo Magnox nella piscine dell'impianto EUREX di Saluggia" *(Long-time dry storage experience for Magnox fuel elements in the EUREX plant pool)* (1991).