Applicability of Learning From Experience to Sellafield Post-Operation Clean Out and Decommissioning Programmes

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ASTRACT

Nuclear cycle facilities, such as recycling plants, over the world differ in their design and operation history. Transferability of Learning From Experience (LFE), Best Practices and Decommissioning tools and techniques may not appear as relevant as it would be for a fleet of reactors. Moreover Regulatory, Economic and Social Drivers may differ from one country to another.

Technical Drivers being comparable, AREVA and Sellafield Ltd (SL) have conducted various benchmarks and technical peer reviews to consider LFE from AREVA's Post-Operation Clean Out (POCO) and Decommissioning projects (such as UP2-400 on the La Hague site) and those performed for customers (such as CEA's UP1 on the Marcoule site). The intention is that Sellafield can benefit from AREVA experience and incorporate some recommendations in their own programmes.

These reviews highlighted not only that investigation tools and methods as well as Decommissioning techniques are fully transferable, but also that strategic, technical and organizational key recommendations are applicable.

1. *End-state definition (for each programme step) has a strong impact on POCO and Decommissioning scenarios.*

2. *A waste-driven strategy is essential for the overall programme cost and schedule management, and it avoids detrimental activities and short-term decisions made under pressure that may have negative impacts on the Programme.*

3. *Safety issues associated with POCO and decommissioning programmes are different from the commercial operations environment.*

4. *An extensive characterization plan (with physical and radiological surveys and active sampling) is essential to underpin the final POCO / decommissioning scenario and build a plant configuration baseline that will be updated as the decommissioning progresses.*

5. Transition from operations to decommissioning requires a major change in culture; the organization must adapt to the new decommissioning environment.

6. Securing specific competencies, resources and knowledge management of the facility is a key to success.

Sellafield and AREVA have shown LFE sharing between operators is key to optimize future POCO and decommissioning programmes.

Context, AREVA and Sellafield POCO Programmes

Sellafield Ltd and AREVA operate very unique nuclear cycle facilities:

- For AREVA: UP2-400, UP2-800, UP3 recycling facilities on the La Hague site, and CEA's UP1 recycling facility on the Marcoule site, both located in France,
- For Sellafield Ltd: the Magnox reprocessing and Thorp recycling facilities located in Great Britain.

Two AREVA-operated plants (UP1 and UP2-400) have already been shut-down and are under decommissioning. Sellafield Thorp and Magnox reprocessing are to shut-down in 2018 and 2020.

All the recycling plants differ in their design and operation history, thus transferability of Learning From Experience (LFE), best practices and decommissioning tools and techniques may not appear as relevant as it would be for a fleet of reactors, where repeatability will drive costs down. Moreover regulatory, economic and social drivers may differ from one country to another.

Still AREVA and Sellafield Ltd share comparable technical challenges: Marcoule UP1 reprocessing plant is very similar to Magnox reprocessing and Marcoule SPF ('*Stockage de Produits de Fission*', Fission Product Storage) is comparable to Sellafield High Activity Liquid Evaporation and Storage (HALES) in terms of functions and design.

As a member of the Sellafield Ltd parent body organisation, it was natural for AREVA to share its experience with Sellafield Ltd, as an input for their preparation of the Post Operations Clean Out Programme (POCO-PRG) for the Spent Fuel Management and other Sellafield facilities.

The first review covered programmatic topics: Scenario and schedule tools and development, safety case, management of skills & interfaces, research and development (R&D), waste management, initial knowledge of facility & equipment. The second review focused on the Sellafield HALES POCO project and covered: definition of the scope of the HALES POCO; initial state; end-state; rinsing plan; interfaces; and safety case strategy.

These reviews were based on recognized applicable LFE from AREVA. They helped provide a peer review of ongoing plans and identified gaps that would represent risks moving the programme forward.

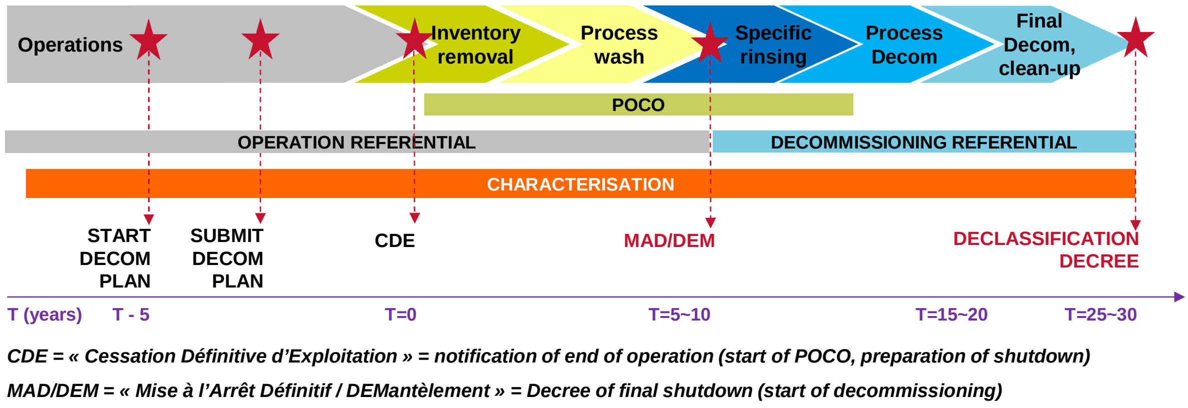

Figure 1: AREVA Typical Decommissioning and Termination schedule

POCO is scheduled to start immediately following the end of scheduled operation of the Sellafield Reprocessing plants in 2018 (THORP) and 2020 (Magnox reprocessing). POCO planning has started with the setting up of a dedicated site POCO programme, charged with the development of a systematic approach to POCO. The aims of the LFE reviews with AREVA were to:

i) Provide an overview of the overall approach to POCO planning, and

ii) Perform a technical assessment of the proposals so far developed for the POCO of the Sellafield HALES facility

The outcome of the overall review was that the approach being developed by Sellafield was consistent with that already used by AREVA. The outcome of the HALES review is addressed in detail below.

This paper provides a brief overview of AREVA SPF and Sellafield HALES POCO programmes and details key findings of the technical and LFE exchanges of AREVA and Sellafield Ltd teams.

Focus on Marcoule SPF POCO AREVA Experience

The Marcoule site was the host of the very first French electricity-generating nuclear reactors (3 gas-graphite reactors operated between 1956 and 1984) and spent fuel reprocessing plant (UP1 and various ancillary facilities operated between 1958 and 1997). The reprocessing plant was shut down 15 years ago and since then, POCO, decommissioning, dismantling and waste retrieval activities have been under way.

An important part of this decommissioning programme concerns the vitrification facility of Marcoule (AVM – '*Atelier de Vitrification de Marcoule*' or Marcoule Vitrification Facility). This facility includes 20 tanks devoted to interim storage of highly active solutions (SPF '*Stockage de Produits de Fission*' or Fission Product Storage) awaiting vitrification.

The main objectives of the POCO / rinsing phase were to decrease the radioactivity in equipment before dismantling, to minimize the amount of highly radioactive waste resulting from rinsing to be vitrified, and to minimize the number of glass canisters to be produced.

Characterization / Initial state

Considering the lack of basic data available (e.g. at the very best only the order of magnitude of ambient irradiation was known) the project's top priority consisted of drawing up an inventory of the physical and radiological initial state.

From early 1998, an ambitious design and development programme was initiated in order to characterize the physical and radiological states, to select the decontamination reagents and to provide the data required to prepare the safety demonstrations.

This programme was set up following three main axes and was conducted from 1998 to 2003:

- Characterization of insolubles and deposits contained in the tanks,
- Development of reagents to enable the dissolution of these compounds,
- Physical and radiological characterization of tanks (e.g. the initial radiological characterization of the facility required 28 core drilling operations in the cell walls).

On the basis of the dissolution reagents defined during this test phase, a specific rinsing operation of fission product solution storage tanks was successfully carried out in 2004 at the Marcoule Pilot Facility (APM – '*Atelier Pilote de Marcoule*'). A technical and economic study was performed early 2005 to compare a decommissioning scenario with and without preliminary rinsing operations of fission product solution tanks. The study concluded that the decommissioning scenario of the SPF facility with specific preliminary rinsing operations would be the best solution.

Rinsing Programme Definition

In 2006, the rinsing programme was defined:

- During the period 2007 to 2010, rinsing of all tanks and equipment with specific reagents, and
- During the period 2009 to 2010, vitrification of concentrated liquid solutions.

This strategy aimed at producing less than 5% "B" type waste (long lived active waste) from the decommissioning operations of the tanks, as well as reducing the dose rate and the risks by simplifying remote dismantling. Clean-up operations began in 2007 and radiological surveys were conducted to monitor the efficiency of the decontamination process.

The impact on glass production was studied and techno-economic studies concluded that the rinsing programme should designed to ensure that the effluents would in the end produce a glass compatible with the licensed glass specification, and with no or limited impact on the vitrification facility operation.

Rinsing Programme Operation and Follow-up

A specific organization was created on the basis of the experience feedback from operations performed in the UP-1 scope gathering all project parties involved: the operator, the rinsing project team and experts (from different fields)

To drive performance, the decisional project team, as close as possible to the operator, managed the time schedule, specified and analysed the nuclear measurements and characterizations, anticipated the reagents procurement, specified the operating instructions, organized the material balances and gathered experience feedback.

To improve the knowledge of the fission products tanks radiological condition, a significant nuclear measurement programme was undertaken. This allowed refining the radiological state, the rinsing efficiency and modifying the operating instructions as appropriate (feedback loop), or even applying specific rinsing programme.

Evaporation Capacity

When the rinsing programme was defined, there were some uncertainties on the evaporation capacity (lifetime and ability to manage the rinsing effluents). In order to de-risk the program, an additional evaporation capacity was built.

Applicability to La Hague UP2-400

The LFE from the Marcoule rinsing project has then been applied to the POCO of La Hague UP2-400 reprocessing plant that was commissioned in 1966 and shut in 1998 – except for the HAPF (*'Haute Activité Produit de Fission'*) evaporation function that still operates for concentration of effluents from the other La Hague facilities.

The fact that some fission product storage tanks are still under operation requires the construction of a rinsing scenario that takes into account the schedule for the emptying of these tanks (note: this situation is very similar to Sellafield's HALES facility). To avoid any detrimental activities, a global rinsing scenario was built on the entire SPF perimeter. This scenario also takes into account the management of rinsing effluents. The characterization phases and initial rinsing operations are under way.

Focus on Sellafield HALES POCO Programme

It is recognised that potentially the largest POCO challenges at Sellafield are in the HALES plant areas. There are significant challenges arising from the extremely high radiation dose rates, potentially high solids inventories as well as from the age, design, and condition of the plant. This is particularly true for the oldest storage tanks where there is little availability of installed sampling systems; incomplete knowledge of condition and behaviour of settled solids; and minimal installed capability for settled solids agitation and transfer.

The HALES POCO programme has been in development for circa 10 years with significant supporting development programmes to underpin the strategies. The key areas of development being around characterisation capability in high dose environments, solids inventory determination and reagent dissolution. The baseline approaches for the HALES facilities are to acid wash tanks with installed agitation systems and reagent wash those without. The objectives of the AREVA review were to review HALES POCO development to date and to identify where AREVA technologies and LFE could be integrated into HALES programmes to reduce schedule and cost.

The AREVA experiences described above were used to consider and compare potential approaches to POCO delivery. This includes AREVA experience on installing additional sampling and agitation systems; characterisation in high dose facilities; and use of non-standard reagents for decontamination.

Exchanges between AREVA and Sellafield Ltd, key findings

Sellafield and AREVA have shown that LFE sharing between operators can help to optimize future POCO and decommissioning programmes. The exchanges highlighted not only that both organisations were approaching POCO planning in a broadly similar way, but also that the technical aspects such as investigation tools and methods as well as Decommissioning techniques, and POCO techniques are fully transferable. Key strategic, technical and organizational common findings are:

1. End-state definition (for each programme step) has a strong impact on POCO and decommissioning scenarios.
2. A waste-driven strategy is essential for the overall programme cost and schedule management, and it avoids detrimental activities and short-term decisions made under pressure that may have negative impacts on the Programme.
3. Safety issues associated with POCO and decommissioning programmes are different from the commercial operations environment.
4. An extensive characterization plan (with physical and radiological surveys and active sampling) is essential to underpin the final POCO / decommissioning scenario and build a plant configuration baseline that will be updated as the decommissioning progresses.
5. Transition from operations to decommissioning requires a major change in culture; the organization must adapt to the new decommissioning environment.
6. Securing specific competencies, resources and knowledge management of the facility is a key to success.

More detail on each point is given below.

• *POCO End State Definition has a strong impact on POCO and decommissioning scenarios*

A number of transition points can be identified throughout the course of a decommissioning programme and can be defined as interim states. At each transition point, the question of establishing a standby/surveillance period or continuing decommissioning operations can be raised. Benefits and costs must then be balanced against internal and external drivers, which can be technical, financial, societal, regulatory or other.

The definition of an interim state is often driven by limits on finances or resources, target radiological conditions, or unavailability of support capabilities (waste treatment and storage plants). The interim state being defined either as:

- A step change in hazards reduction allowing the surveillance costs of the plant to be significantly reduced,

- An interim period allowing for the decay of radio nuclides that significantly eases subsequent operations, after activity and hazards have been decreased to a level compatible with a long surveillance period, ensuring that no activities are undertaken that might prevent further decommissioning,

- An unavoidable standby phase because of technical interdependencies, to await lifting of constraints.

AREVA LFE is that POCO of highly active storage facilities must be conducted to the maximum extent, with specific reagents or mechanical re-suspension and suction of solids if needed to retrieve the highest possible amount of radiological activity (mainly debris and deposits) and to condition it through vitrification.

If POCO is focused on process equipment only, it does not remove the plant hazards that have the most impact on reduction of surveillance costs. In particular, for facilities with significant plant history, potential contamination of cells and ventilation ducts would remain.

A long surveillance period is challenging and very costly: the safety case will require strong monitoring capabilities with related maintenance costs (e.g. ventilation) throughout the period.

The plant condition at the end of POCO must be well enough documented to allow further decommissioning activities at a time when no current operator is still present.

- ***A Waste-driven strategy is essential for the overall programme cost and schedule management***

Since wastes represent a significant share of the total cost of a Decommissioning programme, the cost of waste should be part of the scenario definition.

One of the drivers of the waste strategy is to avoid detrimental activities and decisions under pressure (regulatory, schedule, costs…) that will prevent long term management of decommissioning from a safety standpoint (e.g. encapsulation, long-term immobilization, etc.) or will result in costs and delays (e.g. waste retrieval, repackaging, etc.).

Specifically applied to POCO, the waste strategy aims at:

- Retrieving isolated wastes with classical or special techniques to use waste routes while they are available (e.g. vitrification, effluent treatment), and

- Treating contaminated material and equipment to use cheaper waste routes, by means of rinsing and decontamination operations that benefit from existing effluents routes.

Rinsing operations present several advantages, including:

- Minimal investment in the sense that few modifications or equipment supplies are needed to conduct the operations compared to standard in situ decontamination, and

- Minimal dosimetry to operators because they conduct rinsing operations from a distance, using existing shielded processes.

Rinsing operations thus provides the highest ratio of radioactivity retrieved and safely conditioned per pound spent.

- ***Safety issues associated with POCO differ from those associated with Operation***

Once the facility is operated outside of its reference case, the risks and associated safety cases are very different.

The safety case examination process is long and must be planned well in advance, while the scenario can change over time and make the reference case obsolete. Therefore the safety case analysis must be prepared in conjunction with the scenario of concern, not separately.

It is important to maximize how much POCO can be done under the commercial operations safety case (e.g. initial rinsing, removal of contaminated parts). Using reagents, and particularly the specific reagents selected for targeted rinsing, can require changes to the safety case because of a risk of release of radioactive materials, due to:

- Corrosion caused by the action of the reagents used or products formed (nitrous fumes, etc.),
- Uncontrolled reactions between reagents used during rinsing operations and deposits produced by operation,
- The emission of substantial volumes of gas produced by the chemical reactions, and
- Foam in evaporators.

Criticality risk is to be monitored and managed during POCO, as large masses of deposits with unexpected content can be mobilised. Deposits and accumulations of fissile materials need to be monitored as far as possible by representative gamma and neutron counting and sampling.

The surveillance phase following the end of POCO requires the development of a safety evaluation plan and surveillance program. Safety equipment and ventilation upgrade or renewal may be needed.

- ***Extensive characterization is essential to underpin the final POCO / decommissioning scenario***

The performance of a POCO programme is primarily dependent on the depth of knowledge of the initial condition of the plant, and subsequent evolution through rinsing operations.

Knowledge of the plant condition, by physical and radiological surveys as well as sampling, is critical for risk management and to validate end points and transition periods. The POCO end point and handover to decommissioning will include a “configuration pack”, at component, system, and structure levels.

Furthermore, a wide range of people need access at all times to the knowledge of the plant condition: Investigation teams that need to elaborate their program, design teams who need to define their scenario, operators who need to know the plant condition and schedule maintenance, and safety practitioners who need to ensure the compliance with safety case.

The early derivation of a plant configuration report, as a general backbone for the entire plant programme, is a real asset. It can generate very significant savings throughout the deployment of the programme by reducing the costs of information gathering, appropriation and sharing.

Capturing operators' knowledge of the facility and its history is also very important. The teams in charge of strategy and scenario definition should work closely with the operators and conduct many visits of the installation.

Extensive initial radiological characterization (dose rate measurements, gamma scanning, active sampling, etc.) and visual inspection (video, 3D scan, etc.) are essential to the programme definition (selection of reagents, definition of rinsing sequences, safety case underpinning, risk management, etc.). As AREVA LFE demonstrates, investigations are feasible in high dose rate environment and in congested cells.

Physical sampling is needed to test the candidate reagents on "real" deposits, whose behaviours differ from simulants, to define the appropriate treatment sequence and underpin safety case preparation.

The setting-up of an integrated team for the characterisation programme delivery, both realization of measurements (and sampling) and interpretation of results, is very efficient.

Monitoring the rinsing sequences is important to follow the efficiency of the different reagents, and answer to safety requirements (e.g. criticality).

• *Transition from commercial operations to decommissioning is a major change in culture*

Transitioning from the commercial operations phase to the decommissioning and dismantling phase of a nuclear facility is a major challenge in terms of changes required in the organization and impact on human resources. Indeed, the operations environment is characterized by a stable operational state, with minimum uncertainties, a stable work force, and a top-down management culture (and moreover - for commercial operations - the activity generates cash). When shutting down the facility and switching to decommissioning and dismantling, the situation is almost reversed. One needs to focus on new and continuously changing references (even the structures of the buildings are to be demolished), dealing with the unexpected (e.g.: as-built drawings, history of operations, orphan wastes, etc.), requiring brand new skills (and consuming cash).

The key lesson learned at AREVA, to ensure a successful transition, is to recognize the need for, and ensure implementation of, an explicit performance improvement and change management programme as early as possible within a decommissioning and dismantling project. The culture must be adapted to ensure on time delivery and control costs.

AREVA faced such challenge in the recent decommissioning and dismantling projects the company managed, and developed the corresponding change management skills and process. Salient features of this process and main results are further described below.

AREVA's performance improvement process is defined and organized around the following sequence:

- Perform detailed diagnostic of the current organisation;

- Establish the vision for the future;
- Set precise improvement plan;
- Define objectives for the year;
- Align everybody to implement the plan ("let's do it"), and
- Ensure its long term sustainability (develop standards to ensure continuity of improvement in the future years and facilitate deployment of the method in other projects).

The process is derived from experience gained in the conventional manufacturing industry (such as metals works, automobile industry, electrical equipment production, etc.) on the basis of well-known standards such as lean management, 6 sigma and total productive maintenance (TPM). AREVA has successfully adapted these processes to the nuclear operations and decommissioning programmes.

Our overall performance improvement plan is focused upon the following 7 key areas:

- Human resources and organization management: This is the first and foremost subject to address when looking for change and implementing an efficient change management culture. It is all about people. Specific efforts must be deployed to convince the management line at every level of the importance and the necessity of the change. Moreover, personnel transition is a major challenge to ensure that the workforce and staff have the required skills and are efficiently prepared to take over the new decommissioning and dismantling activities.
- Dismantling strategies and scenario: challenge the current scenario and look for potential areas of savings. The next area with most significant cost savings potential for the decommissioning and dismantling project.
- Waste management & logistics: challenge the established routes and methods and find more cost effective solutions for waste retrieval, segmentation, conditioning and disposal.
- Regulatory monitoring and controls: challenge the process, most of the time inherited from the operation phase, and consequently not optimized to support the decommissioning and dismantling phase, leading to un-necessary additional expenses.
- Dismantling operations: optimisation of the actual operations in the field.
- Site management and operations: The third potentially largest area for cost savings. Site management concerns all the activities supporting and surrounding the plant itself (fixed costs or "hotel costs"). Transitioning from operation to decommissioning and dismantling provides several opportunities to stream-line the organization, and mode of operation, leading to significant savings.
- Supply chain: revision of the supply chain to adapt it to the new site activity.

- ***Securing specific competencies, resources and knowledge management***

Following on from the end of operations, Sellafield plants will transition from operations directly into POCO. The Sellafield strategic model then suggests a period, maybe decades, of surveillance and maintenance before final decommissioning. It is planned that POCO activities will be delivered by the incumbent plant workforce. This model creates a clear need to create and retain good quality records of plant operations, POCO operations, plant configuration, facility characterisation and operational experience so that knowledge will be retained throughout the surveillance and maintenance period and be available for the decommissioning activities.

The ability to record, retain, recognise and access specific facility knowledge, will be key to successful, efficient and effective delivery of future life-cycle phases. Management of this knowledge will require consideration of, and significant investment in, information, repositories and archives, etc. (tools); individual knowledge, experience and skills (people); and information management systems (processes).

Knowledge management strategies need to be developed for facilities that are coming to the end of their operational life. The strategies need to recognise that one of the main customers of an effective knowledge management process will be the future workforces who operate facilities under the surveillance and maintenance phase and undertake decommissioning. Knowledge management needs to be implemented in a focussed, co-ordinated and impartial manner that delivers long-term management of critical knowledge and skills. This will ensure creation, retention and continued accessibility of information on plant status and configurations achieved at the end of operations and at the end of POCO. Knowledge and learning relating to the facility and how ‘end of POCO’ configuration and status were achieved must be created and retained to support future decommissioning phases.

To promote and enhance the identification and retention of critical knowledge required to support the POCO and decommissioning phases, a process of transfer and capture of people's experience and learning should be implemented at the facility level. Facility specific knowledge retention and transfer plans need to be developed in order to mitigate against loss of facility specific critical knowledge and skills. Co-ordinated delivery will uncover knowledge whilst long-term management is necessary to ensure its retention and transfer.

An effective and robust LFE process should be developed to support the POCO programme by identifying opportunities where valuable LFE from ongoing activities and experiences can be recorded. This LFE can be made accessible for the future user, whilst also moulding an LFE culture where opportunities are identified and LFE is actively used to support decision making processes.

To guarantee successful implementation of a POCO knowledge management strategy, governance is required to encourage a strong knowledge management culture within the facilities. This will require trained resources to be part of an organisation who will implement and coordinate the POCO knowledge management processes across all facilities to follow the POCO delivery phase and future decommissioning.