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# Deactivating a Major Nuclear Fuels Reprocessing Facility

Prepared for the U.S. Department of Energy
Assistant Secretary for Environmental Management

Project Hanford Management Contractor for the
U.S. Department of Energy under Contract DE-AC06-96RL13200

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# Deactivating a Major Nuclear Fuels Reprocessing Facility

G. J. LeBaron
J. P. Hayfield
J. D. Legard
B&W Hanford Company

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# DEACTIVATING A MAJOR NUCLEAR FUELS REPROCESSING FACILITY COST EFFECTIVELY

**Gregory J. LeBaron**
MSIN S6-15
B&W Hanford Company
Post Office Box 1200
Richland, Washington 99352-1200

**John P. Hayfield Jr.**
MSIN S6-15
B&W Hanford Company
Post Office Box 1200
Richland, Washington 99352-1200

**James D. Legard**
MSIN S6-15
B&W Hanford Company
Post Office Box 1200
Richland, Washington 99352

## ABSTRACT

This paper describes three key processes used in deactivating the Plutonium Uranium Extraction (PUREX) Facility, a large, complex nuclear reprocessing facility, 15 months ahead of schedule and $77 million under budget.

The organization was reengineered to refine its business processes and more effectively organize around the deactivation work scope. Multi-disciplined work teams were formed to be self-sufficient and empowered to make decisions and perform work. A number of benefits were realized by reengineering.

A comprehensive process to develop end points which clearly identified specific results and the post-project facility configuration was developed so all areas of a facility were addressed. Clear and specific end points allowed teams to focus on completing deactivation activities and helped ensure there were no unfulfilled end-of-project expectations.

The RCRA regulations require closure of permitted facilities within 180 days after cessation of operations which may essentially necessitate decommissioning. A more cost effective approach was adopted which significantly reduced risk to human health and the environment by taking the facility to a passive, safe, inexpensive-to-maintain surveillance and maintenance condition (deactivation) prior to disposition.

## NOMENCLATURE

*Closure* - Final state of a TSD unit as defined in the RCRA regulations.
*Deactivation* - The process of transitioning the facility from the operational state to a long-term, low-cost surveillance and maintenance state. The process includes stabilization, decontamination, surveillance and maintenance.
*Disposition* - The final process for a facility including decontamination, dismantlement, entombment, closure and site restoration.
*RCRA* - Resource Conservation and Recovery Act of 1976.
*TSD* - Treatment, storage or disposal units as defined in the RCRA regulations.

## BACKGROUND

Just as the Korean War entered its second year in June 1951, a determination was made to examine Program X, the development of a new irradiated fuel separation facility, later called the PUREX Facility. The facility was needed to process 200 metric tons of irradiated, aluminum-clad reactor fuel per month with the potential of increasing to 400 metric tons uranium per month. The PUREX Facility consists of a large concrete building 1,005 feet long, 104 feet high (with about 40 feet below grade), and 120 feet wide, with more than 50 smaller support buildings. Hot start up of the facility occurred in January 1956, just a little under three years from when construction began in April 1953.

In addition to processing aluminum clad reactor fuel, the PUREX Facility was modified to process other types of fuel, including the N-Reactor zircaloy-clad fuel, until PUREX was shut down in September 1972. The facility was prepared to restart in November 1983, and processed N-Reactor fuel intermittently until March 1990. The facility was shut down in a configuration that anticipated being restarted within a short period of time. Therefore, process solutions were left in various vessels and a significant volume of essential chemicals were left in storage. The U. S. Department of Energy (DOE) directed the facility to be deactivated in December 1992. PUREX thus became the first large reprocessing facility with active TSD units to be deactivated under the RCRA regulations.

## REENGINEERING BUSINESS PRACTICES FOR DEACTIVATION

Reengineering has been actively pursued in the U.S. since the early 1980s and has primarily focused on service-based companies, although manufacturing companies have successfully implemented reengineering in the last few years. Reengineering requires a strong commitment at all levels of the organization and, historically, takes 12 to 18 months from diagnostic review to implementation. Reengineering includes a learning process that continues for two to three years after initial implementation[1].

It is important that all employees involved in the reengineering process understand the magnitude of the changes that will occur as the project implements new business systems. It is also important to

understand that reengineering of projects will have implications for ongoing work scopes.

The business practices, including organizational changes, were reengineered from the operational practices to more effectively accomplish deactivation. Reengineering was conducted at PUREX and B Plant using the following process.

- Senior management commits to the change.
- Goals and objectives are established.
- Core business processes are defined.
- A compelling reason to change (case for action) is developed.
- A vision for the future is developed.
- Business processes and support activities are redesigned.
- Business redesigns are implemented.
- Business redesigns are measured against goals and objectives and adjustments are made as needed.
- Communication with affected employees throughout the process is critical and should allow all employees to contribute to the redesign.
- Change management is essential to the success of reengineering.

The PUREX Deactivation Project was structured with a specific defined scope, goals, schedules, and budgets similar to those for a construction project, any precedents for innovative approaches to safety and regulatory issues, stakeholder involvement, and technical achievements had already been implemented before reengineering. However, PUREX was selected to be reengineered because of the enthusiasm and willingness displayed by the Westinghouse, PUREX Plant Director to risk change, the demonstrable success of the PUREX Deactivation Project, and of management's belief that reengineering could enhance PUREX's existing strong performance. Therefore, a reengineering laboratory was initiated at the beginning of FY 1996.

The core principle guiding the reengineering of PUREX was that a holistic approach to the entire business system would be implemented. The PUREX management structure and work force organization were completely overhauled, work scope and responsibilities were reorganized, and training was developed to support the emergent order and culture. While efforts had been made earlier to develop project end points, the end points now became the central driving guide to all project work.

Information technology was thoroughly integrated into the new approach so that information could infuse streamlining, resource leveling, and employee empowerment throughout the new system. Likewise, the ways that safety planning and assessment, regulatory compliance, scheduling, and technical work were accomplished were adjusted. All work responsibilities were integrated into a team-based organization.

Many benefits of reengineering were cultural.

- Reengineering broke internal organizational barriers and there was greater interaction between the technical, planning, operational and maintenance people. This greater interaction resulted in better understanding of what needed to be done and empowered those working the field to do a better job.
- Teams were formed to take responsibility for certain end points. This allowed each team to take ownership of the end points and plan and schedule the work to accomplish them. Quantitative benefits could not be validated; however, management perceived that work was accomplished with fewer problems and in a shorter time.
- Teams were empowered to make decisions on how to accomplish the work and given the responsibility to see that work was completed according to the schedules they developed. This motivated workers based on ownership and the knowledge that their own performance on teams would be recognized.

The following is a measurable example of the benefits of reengineering.

- The number of people signing each work package at PUREX fell from an average of 14 prior to reengineering to only five within six weeks after implementation, reducing average cycle time drastically.

## Developing End Points

End point specifications define the facility conditions to be achieved prior to transferring a facility to those responsible for post-deactivation management, whether it is for surveillance & maintenance, decommissioning, or conversion for some future use. Irrespective of the future use of the facility, it is imperative that the project is specifically defined via a comprehensive process. Such a process, which clearly identified specific results and the post-project facility configuration, was developed and used during the PUREX Project.

The PUREX Project's target was facility deactivation or to achieve a safe, stable, and environmentally sound condition, for an extended period, as quickly and economically as possible and to minimize the cost of the follow-on surveillance and maintenance (S&M) phase. Once deactivated, the stable condition is to be maintained by means of a methodical S&M program, pending ultimate disposition which may not occur for tens of years. Therefore, the deactivation end points were driven by the PUREX Project objectives including:

- Protect the public and environment
- Facilitate S&M - protect workers - reduce cost
- Facilitate decommissioning
- Comply with regulations and requirements.

The above example of PUREX Project's objectives is provided only to demonstrate and emphasize that end points should be driven by the project objectives. The detailed specifications and actual specific end points will undoubtedly vary from facility to facility. Variations in project objectives and therefore end points are expected because of the differences among facilities with respect to mission, equipment and systems, containment, degree of inventory, contamination and ability to isolate contamination, facility environs, and a host of other factors.

Considering the uniqueness of each facility and its mission, it became apparent that an effective end point process must identify and employ some guiding principles or ground rules for specifying end points. Several guiding principles have been developed which form the foundation of the end point process. They apply to any project regardless of the specific objectives.

- The decision to create an end point should be driven by, and clearly linked to, top-tier program objectives, not by feasibility or capability. This is the central principle of the logic-based approach. End point determinations, along with allocation of resources and selection of methods, should all stem directly and clearly from program goals and top-tier objectives.
- The end point condition should employ defense-in-depth as a fundamental safety approach. As applied in deactivation, this involves three layers of protection: elimination of hazards, effective facility containment, and facility monitoring and control.
- End point decisions are integrally linked to decisions (and constraints) on resources and methods. Cost effectiveness is important. The goal is to achieve maximum safety improvement/risk reduction for every dollar spent.

**Table 1. End Point Development**

| | | |
|---|---|---|
| Hanford | $UO_3$ | Conversion of UNH to $UO_3$ |
| Hanford | PUREX | Largest defense nuclear reprocessing facility |
| Hanford | B Plant | Cesium and strontium recovery facility |
| West Valley | Nuclear fuel reprocessing facility | Nuclear fuel reprocessing facility |
| Rocky Flats | 779 | Plutonium development |
| Hanford | 324 | Waste technology laboratory |
| Hanford | 327 | Post-irradiation testing laboratory |
| Rocky Flats | 771 | Plutonium recovery |
| Rocky Flats | 774 | Ancillary building to 771 |
| Hanford | 209-E | Criticality mass laboratory |
| Hanford | 224-T | Plutonium nitrate processing facility with state permitted transuranic (TRU) waste storage area |

• A successful end point development requires ownership by all affected organizations including project planners, those who implement the plans, and the ultimate customers.

• Work teams in the field need clear, quantitative end points. They cannot work effectively with vague or functional objectives.

• Unless the final disposition of a facility has been defined, it is typically not known when or what the ultimate facility disposition will be. Therefore, end point decisions should not be driven by final disposition presumptions.

End point development is an iterative process. Some end point decisions may have to be revisited as the project proceeds.

Once the objectives of the project have been defined, the end points are developed in a hierarchical way, in successively more detailed levels, to the point of quantitative or otherwise explicit item-by-item end point specifications suitable for developing engineering work plans and performing field work packages. This paper will not discuss the mechanics of the end point development process, however, a handbook[2] has been developed to assist with this effort. Additionally, a computer software package was developed to further aid the end point specification process, the end point closure and documentation process.

End point specifications and specific end points have been developed for a multitude of facilities within the DOE complex as shown in Table 1.

These facilities vary in configuration, risks, and missions. However, the end point development process and the associated guiding principles have proven to be extremely effective.

## Meeting Regulatory Requirements

Regulatory requirements, including the hazardous waste regulations in the RCRA, have to be considered when deactivating or decommissioning a facility. These requirements can greatly affect how materials are handled. There are some general lessons learned or key principles that have been, or are being used at facilities such as the Uranium Tri-Oxide ($UO_3$), PUREX and B Plants in dealing with regulatory requirements that can significantly help reduce cost and time to deactivate a facility. Examples from the PUREX deactivation will be used to illustrate key principles.

The materials at PUREX when DOE directed the facility to be deactivated included:

≈ 6,000 gallons plutonium/uranium solution
≈ 168,000 gallons 11M radioactive nitric acid
≈ 200,000 gallons of water/dilute nitric acid
≈ 21,000 gallons of radioactive TBP/NPH organic
≈ 2,270,000 pounds of essential materials
≈ 3.4 metric tons fuel (2.9 MT aluminum-clad fuel and 0.5 MT zircaloy-clad fuel).

Key principles include the following.

♦ **If possible, identify that a facility will be deactivated before the final operation so product materials can be completely processed, systems flushed and wastes disposed of as part of the final operation.**

The RCRA regulations require closure of permitted TSD facilities within 180 days after cessation of operations which includes the disposition of materials that become waste 90-days after deactivation is declared. All materials listed above were products before the deactivation notice and could have been considered waste 90-days after the notice. Two things should be considered to effectively complete the deactivation:

1) If closure of waste units will require considerable resources and/or decommissioning, a more cost effective way to handle the facility than to close it would be to significantly reduce the risk to human health and the environment by taking it from its operational or standby status

to a passive, safe, inexpensive-to-maintain surveillance and maintenance condition (deactivation). This will require close relations with the regulators and stakeholders to help them understand the benefits of the alternate path. In the case of PUREX, the benefit was to allow considerable resources that would have been needed to close the waste units to be directed to other projects which presented a greater risk to human health and the environment.

2) Run out as much product, use as much of the essential materials and define the final vessel flushing and associated flush solution disposal as part of the final operating campaign. As part of the final vessel flushing, devise a plan so the vessels are left so as to meet the regulatory definition of "empty" or so they will not be left with hazardous waste.

In the case of PUREX, the DOE issued the deactivation notice after the final operating campaign and the facility had been shut down in a state ready to resume operations. Therefore, some innovative ideas were identified and the regulators were willing to work with the DOE to minimize waste and resources in accomplishing the deactivation. For example:

- The radioactive nitric acid remained a product so it could be shipped to the Sellafield, England, chemical reprocessing facility to be used in that process; and
- The essential materials remained products until they could be sold to another user. In some cases, it took more than a year to find a user willing to take the materials. Perseverance to modify government requirements, as well as a continuing demonstration to the regulators of efforts to place the materials, allowed more of the essential materials to be dispositioned as product and resulted in greater waste minimization.

If it is not possible, like at PUREX, to run the product and flush solutions out of the facility as part of the final operating campaign, it is advantageous to transfer solutions that will become wastes, to permitted waste storage vessels and/or consolidate the solutions into as few vessels as possible. At PUREX, eight vessels were permitted as TSD units during normal operation. The vessels, which contained process solutions 180 days after the deactivation notice, were determined to be dangerous waste storage vessels; thus, an additional 37 vessels had to be added to the Part A permit application.

The ideas and approaches mentioned above made sense but required extensive discussions with the regulators to gain their trust, understanding and support, and to develop agreements and milestones. Efforts to address these areas before they become issues reduces the time and effort to develop agreements with the regulators and reduces the risk to the DOE and the contractor of being in violation of regulations.

**♦ Involve the regulators and stakeholders early by: (1) helping them understand the capabilities and limitations of the facility, (2) developing an open and honest relationship with them, (3) showing the benefits of deactivation activities that are in everybody's interest to achieve, and (4) involving them in the decision making.**

A two-day session was held several weeks after the deactivation notice was issued to brief regulators and the DOE about hazards remaining in the facility and to solicit their involvement in determining the path forward. It became apparent that innovative ideas for handling the materials were needed to minimize waste and more cost effectively complete deactivation.

Follow-on discussions with the regulators were held to reach agreement about what would be done with respect to waste being stored in unpermitted vessels and the regulations requiring TSD units to be closed within 180 days after receiving the final waste shipment. It was clear that neither removal of the waste solutions nor closure could be done within the prescribed time period and it was in the interest of all involved not to spend resources at that time to close the permitted units. Closure would involve decommissioning which could not occur for many years and would require major resources; the Hanford land use plan had to be developed and agreed upon by all interested groups; an Environmental Impact Statement (EIS) had to be prepared to support decommissioning; and, a deactivated facility was of little risk to human health or the environment. Therefore, the decision was made to deactivate versus decommission the facility.

Discussions occurred between the Washington State Department of Ecology (Ecology), the Environmental Protection Agency (EPA), the DOE and the contractor to determine what would be done during deactivation to reduce risks and meet the intent of the regulations while being cost effective. Specifics agreed on included: how dangerous waste vessels would be flushed; what samples would be taken; which laboratory analyses would be performed; and what requirements would be applied to taking, handling and analyzing the samples, including quality assurance (QA) requirements. The agreement was documented and signed by the various parties. Further understandings about how the deactivation was to be performed were agreed upon when the End Point Specifications Document was approved.

Additional meetings were held between Ecology, the EPA and the DOE to agree upon the overall direction for facility deactivation (see the following key principle), to develop performance milestones to ensure the deactivation activities for PUREX were progressing, and to formalize these in the Hanford Federal Facility Agreement and Consent Order (Tri-Party Agreement or TPA)[3]. The agreement resulted in eight milestones and nine target dates against which the PUREX deactivation project could be tracked.

**♦ Develop and agree with the regulators and the stakeholders on a process to be used for handling a facility through disposition.**

The process for deactivating a complex facility in phases was developed and documented in the TPA[3]. The process identified what should be done, who (including which regulatory groups) should be involved in the various steps and what documentation would be required through the deactivation, surveillance and maintenance, and facility disposition phases. While developing the process with the regulators, it was essential to define terms and what each meant since it was clear at the beginning of the discussions that the same term was used to mean different things. It was determined that the three major phases for facilities would be: (1) transition (deactivation), (2) surveillance and maintenance, and (3) disposition. Processes conducted during each of these phases would include the following: (1) facility stabilization, decontamination, deactivation, and S&M during deactivation; (2) S&M with deactivation and decontamination on a case-by-case basis to further reduce facility S&M expenses; (3) decontamination, decommissioning, dismantlement, entombment, closure (as defined in the RCRA regulations) and site restoration during the disposition phase.

Defining the process in the TPA allowed stakeholders to review and comment on the process, thus including their values and comments. The portion of the flow sheet defining the transition process through deactivation is shown in Figure 1.

Developing end points allowed the regulators and other stake holders to better understand what was to be accomplished during deactivation and the what the end state of the facility would be. The end points also provided a method to demonstrate that the planned deactivation was proceeding.

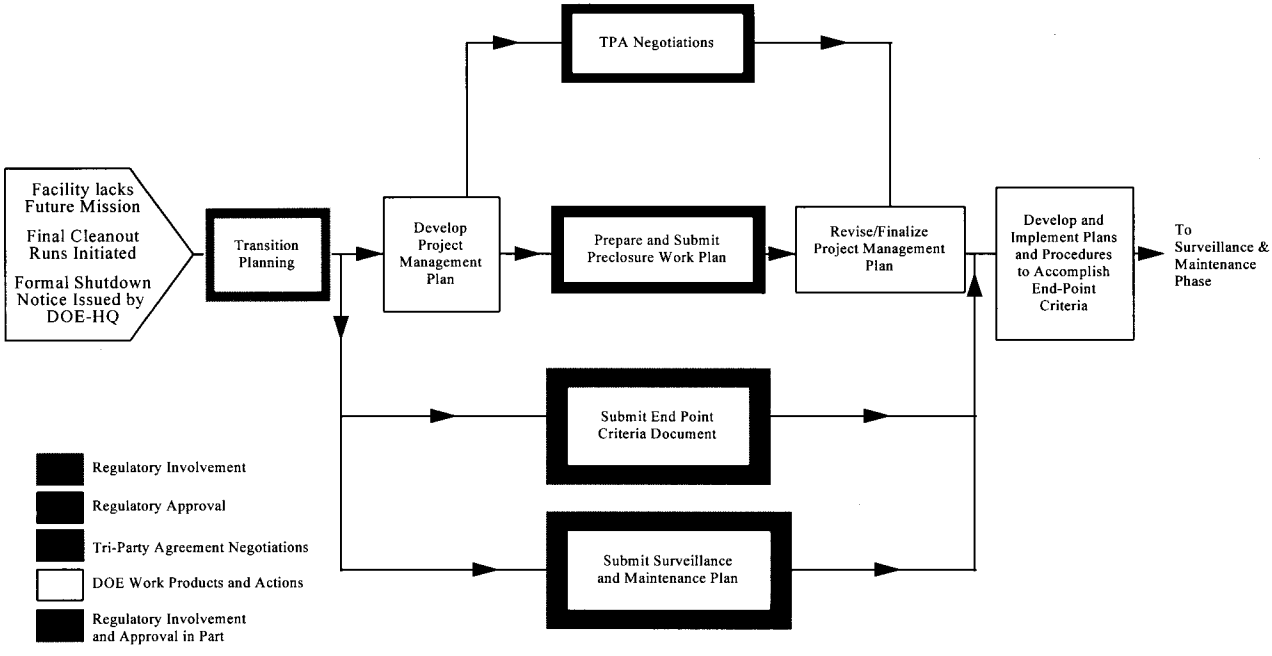


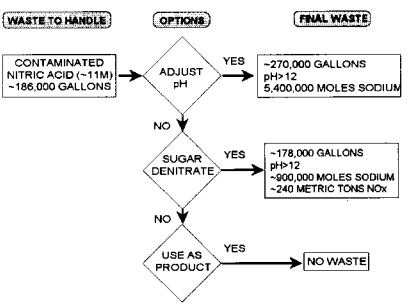

**Figure 1. Deactivation Phase Flowsheet**

**♦ Minimize waste and improve efficiency by involving people working at the facility in upcoming challenges and encouraging innovative ideas.**

The traditional method for disposal of waste from the PUREX Facility was to adjust the pH to greater than 12 and add sodium nitrite to minimize corrosion of the transfer lines and the underground waste storage tanks. However, this process would turn the ≈186,000 gallons of 11M radioactive nitric acid into approximately 270,000 gallons of waste with more than 5.4 million moles of sodium. Since sodium limits the ability to minimize waste that has to be vitrified and the intent is to vitrify the waste for future handling and storage, it was not desirable to add that much sodium.

The idea was presented to denitrate the nitric acid waste using sugar (Figure 2). This was a permitted treatment conducted as part of the waste treatment during PUREX operations. Sugar denitrating the nitric acid would result in less than 178,000 gallons of waste and less than 0.9 million moles of sodium that would have to be sent to the underground waste storage tanks. However, about 240 metric tons of NOx would be discharged to the atmosphere from the stack. The regulators were concerned about this and reluctant to agree to it.

FIGURE 2 - RADIOACTIVE NITRIC ACID HANDLING




Based on innovative ideas from employees, the idea to send the nitric acid to another chemical reprocessing facility (Figure 2) was proposed. After some research it was determined that the nitric acid could be sent to the Sellafield, England, facility where it could be used as a product instead of disposed as a waste. The acid was shipped, allowing the deactivation schedule end date to be moved forward, saving considerable money, avoiding future cost or liability in having to deal with waste, and minimizing waste by reusing the nitric acid versus introducing fresh acid.

**♦ Involve the regulators as the direction of the deactivation plans change and clearly identify the benefits of the change.**

Since there was no intent to close the dangerous waste units as identified in the regulations, the actions to deactivate each of the 45 hazardous waste vessels identified in the Part A permit had to be agreed to by Ecology and the EPA. In a series of meetings between DOE and Ecology, it was determined that each vessel had to be flushed so the remaining heel left in top empty vessels did not designate as dangerous waste; the sample had to be taken and analyzed according to RCRA protocol; and the sample had to be analyzed for a specified list of constituents.

An innovative recommendation was proposed and the regulators agreed to flush the vessels in groups or loops and take a sample of the flush solution in the final vessel according to the criteria. Solution in the final vessel would be representative of the remaining heels in all the vessels. For this to work, the heels in the vessels before the flush all had to have a pH less than 7 and the heels had to be small in relation to the flush volume. For the permitted waste vessels, this recommendation decreased the number of flushes required, minimized waste by moving the same flush solution from one vessel to another, required only 15 samples instead of 45, and reduced the resources required and cut costs. In addition, non-waste (process) vessels were included in the flush loops in order to eliminate the need for additional flushes and sampling those vessels. This process resulted in further waste minimization and cost savings.

Another innovative recommendation was to use a concentrator to boil off flush water at a low rate (around 4-12 liters per minute) and discharge the vapor out the stack with the air flow--essentially humidifying the air flow. Therefore, it would not be necessary to add caustic and sodium nitrite to the flush solution before sending it to underground waste storage tanks. The evaporator used could evaporate the water and discharge it out the stack without reducing the quality of the gaseous discharge. This process was more cost effective than if the central onsite evaporator had been used.

**♦ Use experienced people and lessons learned from other facilities to be more cost effective in conducting subsequent projects.**

A small team of key people involved in the planning and execution of deactivation was established as another innovative idea to cost effectively deactivate facilities. The team consisted of people who developed the program, coordinated the technical planning, negotiated the regulatory strategy and milestones, generated the end points, organized effective teams to accomplish the deactivation work, planned the work, lead the field deactivation teams and coordinated close out of the end points. The intent is for the team to assist other facilities, provide guidance in setting up and conducting deactivation and decommissioning projects or "jump starting" deactivation projects to get them on the fast track.

## ACKNOWLEDGMENTS

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