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AUTHOR(S): Stewart R. Fischer
William L. Partain
Teresa Sype

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Los Alamos
Los Alamos National Laboratory
Los Alamos, New Mexico 87545

LESSONS LEARNED FROM COMMERCIAL EXPERIENCE WITH NUCLEAR PLANT DEACTIVATION TO SAFE STORAGE

Stewart R. Fischer and William L. Partain
Los Alamos National Laboratory

Teresa Sype
Sandia National Laboratories

ABSTRACT

The Department of Energy (DOE) has successfully performed decontamination and decommissioning (D&D) on many production reactors it. DOE now has the challenge of performing D&D on a wide variety of other nuclear facilities. Because so many facilities are being closed, it is necessary to place many of them into a safe-storage status before conducting D&D—for perhaps as much as 20 yr. The challenge is to achieve this safe-storage condition in a cost-effective manner while remaining in compliance with applicable regulations. The DOE Office of Environmental Management, Office of Transition and Management, commissioned a lessons-learned study of commercial experience with safe storage and transition to D&D. Although the majority of the commercial experience has been with reactors, many of the lessons learned presented in this paper are directly applicable to transitioning the DOE Weapons Complex.

INTRODUCTION

The Department of Energy (DOE) Weapons Complex consists of numerous sites and facilities located in 32 states. As a result of the demise of the Cold War, many of these facilities have been permanently closed, and others are targeted for closure over the next 2 decades. Many of these facilities have been engaged in hazardous materials processing or testing since the 1940s and 1950s, resulting in a technical and economic challenge for environmental cleanup.

Congress has given the DOE Office of Environmental Management the responsibility to address the environmental challenges posed by the shutdown of numerous DOE facilities. Because there are so many facilities being closed, it is necessary to place many of them into a safe-storage status before conducting decontamination and decommissioning (D&D)—for perhaps as much as 20 years. The challenge is to achieve this safe-storage condition in a cost-effective manner while remaining in compliance with applicable regulations.

Transitioning facilities to a safe-storage condition brings up many questions, some of which are whether to perform decontamination now with the help of an experienced work force, how well must the facility's present status be characterized, what utility systems must remain operational, what existing and new hazards are to be protected against during the prolonged safe storage, what kind and extent of surveillance is required, how the downsizing of the work force is dealt with, and how DOE responds to the stakeholders' concerns.

The commercial nuclear industry also has been struggling with similar questions and the DOE-EM Office of Transition and Management tasked Sandia National Laboratories and Los Alamos National Laboratory with reviewing and documenting commercial experiences with nuclear facility deactivation to safe storage and transition to D&D status. Visits by project members to a number of nuclear facilities, interviews via telephone and fax machine, and reviews of documents were performed to describe general issues from the perspective of the regulator and the regulated. Although the majority of the commercial experience has been with reactors, many of the lessons learned presented in this paper are directly applicable to transitioning the DOE Weapons Complex.

US Nuclear Regulatory Commission (NRC) and DOE regulations, guidelines, and utility experiences were reviewed to develop a definition of safe storage (SAFSTOR). SAFSTOR is considered to be an interim period in the life cycle of a nuclear facility during which the facility is kept in a safe, nonoperating, environmentally sound condition that requires minimal surveillance and maintenance. SAFSTOR provides a means to satisfy the requirements for the protection of the public while minimizing the initial commitments of time, money, occupational radiation exposure, and waste disposal space.

This paper presents the results of a study[1] and survey conducted by Los Alamos and Sandia based on interviews conducted at the Fort St. Vrain (FSV), Pathfinder, Rancho Seco, Shoreham, and Trojan nuclear facilities, in addition to limited document reviews of pertinent activities at the Dresden, Fermi, Humboldt Bay, Shippingport, and Yankee Rowe plants.

RESULTS

The results of this study are summarized under 10 categories.

Hazard Characterization

As is the case for nuclear utilities, for DOE facilities, the type and scope of deactivation, safe-storage and decontamination activities will be determined by the facility hazards; i.e., the hazards present at a site must be relatively well characterized before any deactivation, safe-storage or decontamination activities are implemented. In general, utilities found that characterization activities must be undertaken in an intelligent manner, i.e., they concluded there was not enough money or time to be absolutely certain that every nook and cranny had been characterized adequately. Utilities used unique methods to guide characterization of their sites, many of which would work at DOE sites; for example, the grid and color code system used at the Pathfinder Plant, where areas anticipated to be contaminated used a smaller grid (and different color) than those areas that were unlikely to be contaminated. FSV took 35,000 radiological data points and used a bar code system to track this information. Trojan divided characterization into four major areas: environment (roads, ponds, yards, etc.), structures (all on-site buildings), systems, and activated systems. The plant systems area was divided into four categories: known contaminated, potentially contaminated, indeterminate, and clean systems. Each of these categories was characterized differently. In a similar manner, the DOE and its contractors need to take a rational approach to characterization consistent with expected risks.

In some instances (i.e., for reactor fission and activation products), the safe-storage period will result in a significant reduction in radiation, contamination levels, and risk associated with future cleanup. However there would appear to be less to gain, for DOE facilities with transuranics. A key consideration to defer decontamination activities during deactivation to SAFSTOR until years later, at the end of the safe-storage period, is the reduction in worker dose although this has to be balanced against the loss of knowledgeable plant staff and operable process systems that may not be available in the future.

Management/Programmatic Issues

Utility experience demonstrates that the DOE should have a well-established facility endpoint defined before planning deactivation, safe-storage or D&D activities. A wide variety of activities and associated technologies are necessary to take a site from its current state, through deactivation activities, and finally to its maintenance in safe storage. The drivers of the management process are the decision on disposition of the site and the current hazards. This means that management of a safe-storage project must begin with the end in mind; every system, component, area, etc., must have a description of its safe-store condition established before any activities begin. Equally important is a clear knowledge of the hazards present. Basically, one must know where one is going and where one is so that the activities performed are always moving in the right direction.

Once the two endpoints are established, i.e., where one is and where one is going, the various paths that can be followed can be explored. Along each path are numerous activities. The task of management is to evaluate and choose the best path (and its associated activities). When evaluating the various deactivation and/or D&D activities (and technologies), there are a number of factors to consider: (1) risks to human health and safety (both public and worker), (2) availability and costs, (3) potential to cause environmental damage, (4) concerns of stakeholders, (5) regulatory issues, (6) effectiveness of the technology in performance of deactivation and safe-storage tasks, (7) interactions and integration between technologies and other activities performed at the sites, and (8) recycle and reuse opportunities. All of these factors were addressed by the commercial nuclear facilities; however, the scope of deactivation for these facilities is much smaller than the scope for DOE facilities.

The primary drivers leading to utility decisions to go to SAFSTOR are the lack of set-aside funding for immediate D&D and the lack of a high-level waste (HLW) repository for spent fuel. For DOE, the drivers are limitations in the methodology established to prioritize facilities for deactivation or D&D and insufficient funding to clean up the entire Complex at once. DOE is investigating the use of risk-based decision models to assist with the facility prioritization process. One of the major problem areas for the model will be keeping up with constantly changing and increasing numbers of regulations and specifications and how to prioritize across multiple sites located in different states.

Requirements and Regulatory Issues
Numerous regulatory requirements, standards, and guidance prescribed by the NRC, the Department of Transportation, the Environmental Protection Agency (EPA), US Occupational Safety and Health Agency, and the States must be observed during the transition phase. Utility experience has shown the importance of being very proactive with the regulators and involving them in the planning and decision-making process. Cost-benefit studies have been successful in negotiations with the State regulators.

Site and material release levels have not been determined, but draft rules have been developed by a joint NRC/DOE/EPA task force working on the site release criteria for sites licensed by the NRC. The EPA is expected to establish similar site release rules for DOE sites within the next 2 yr. During the period of this study, there was not a lower "limit" for acceptable radioactivity levels. At commercial plants undergoing D&D, it was important to develop an acceptable methodology that would receive regulatory acceptance because the dismantlement/decontamination approach selected would not result in a "bare walls" plant after completion of physical decommissioning. SAFSTOR radiological endpoints appear to be determined by each utility on a site-by-site basis.

Utility experience suggests that the DOE and its contractors should revise the facility Safety Assessment Report, Operational Safety Requirements, Technical Specification Requirements, etc., to be consistent with the revised status of a facility as soon as possible after shutdown. Considerable cost savings are possible through reduced training, maintenance, and surveillance efforts and the associated reduced staffing requirements.

Transitioning Facility Risk Issues
Utilities felt that there were no significant radiological risks to surveillance and maintenance personnel during SAFSTOR. However, because of the reduction or elimination of preventative maintenance, risks from degradation of equipment and facilities over time are of concern. Some utilities chose to maintain containment ventilation to prevent the build-up of molds and fungi to avoid future health risks that might increase if things were welded shut. The only safety-related equipment kept operational at most nuclear plants was that associated with operation of the spent-fuel pool. It is important to look at the potential hazard implications of removing a system from service before deactivating it. In general, potential accidents evaluated during the SAFSTOR period have a low probability, are few in number, and are of minor consequence in comparison with accidents associated with reactor operations.

The Trojan Plant used a decision-analysis approach to prioritize decommissioning alternatives. The prototype model performed a high-level economic analysis focused on timing, prioritizing decommissioning activities, understanding risks, including transportation risk and uncertainties associated with decommissioning. Alternative approaches were evaluated considering waste costs, timing of component removal, and radiation levels.

For many of the DOE facilities shutdown for long periods of time, there is expected to be significant degradation of the physical plant, which may need to be upgraded before entering SAFSTOR. Most accidents occurring during SAFSTOR and decommissioning are normal, industrial-type accidents. FSV performed a probabilistic risk assessment for nuclear and nonnuclear hazards. The main hazards identified included fires, tornadoes, and industrial-type accidents. When evaluating FSV's accident scenarios, fire was the most threatening with respect to radiological releases to workers and to the public. It was also more likely to occur. If a scenario had a likelihood of occurrence of less than 1E-4 it was ignored. However, if its likelihood was greater than 1E-3, mitigative actions were taken to ensure that it would not occur. There are numerous unique radiological hazards for many of the DOE facilities that will have to be addressed on a facility-by-facility basis.

Cost Increases and Uncertainty

Every utility contacted felt that prompt decontamination and dismantlement was the least costly D&D option provided that adequate funding and low-level and high-level waste repositories were available. Lacking sufficient funding and/or the availability of waste repositories, SAFSTOR was the only feasible option. Utilities recognized that there was risk associated with SAFSTOR, including the loss of knowledgeable plant workers, uncertainty regarding future risks of the SAFSTOR process (such as the regulatory environment and public attitude), probable increases in low-level waste (LLW) disposal costs, and a continuing long-term liability/cost for plant insurance, surveillance and maintenance. Although the utilities anticipated some cost-savings as a result of the decay of fission and activation products during SAFSTOR, this will not be the case for DOE because much of the contamination is long-lived transuranics (TRU).

For utilities, LLW disposal costs represent the major portion of, and uncertainty in, projected decommissioning costs. For example, at Rancho Seco, original LLW costs were $\$1.00/ft^3$, and current estimates exceed $\$440/ft^3$ at Ward Valley, assuming a 1996 opening. Based on an estimated 7300 yd^3 of LLW, the Sacramento Municipal Utility District (SMUD) estimates about $100 million for LLW disposal costs and recognizes that costs might go higher. To address further the uncertainties associated with LLW storage, SMUD constructed a $5 million LLW storage building in case Ward Valley does not open or is delayed. To reduce SAFSTOR costs, SMUD is planning to build an on-site Independent Spent Fuel Storage Installation (ISFSI), which SMUD estimates will cost $16 million to build, with operating costs of about $2.6 million/yr as compared with $10.6 million to keep the spent-fuel pool operating. The major cost savings will be in operating and maintenance personnel.

Historically, costs for LLW disposal have risen at a higher rate than inflation. Shipping costs are sensitive to fuel-cost changes and distance to the disposal facility. Removal costs depend on the amount of remotely operated equipment available in the future when dismantling occurs and the higher cost of that equipment vs the savings in labor costs.

DOE disposal costs have not been a problem in the past, but with the new open environment, stakeholders are more likely to object to new LLW repositories. The availability of inexpensive LLW storage is vital to cost-effective D&D. In addition, the DOE TRU-waste repository opening has been delayed.

Stakeholder Concerns

In contrast to the near total lack of stakeholder interest expressed after utilities shut down nuclear plants, the DOE has experienced considerable continuing stakeholder interest at nearly all of its sites. This high level of interest is a result of ongoing revelations about past and current practices as well as concerns over the potential loss of jobs, economic impact, loss of tax revenue, etc. Utility experience suggests that the DOE needs to have an effective program for involving and sharing information with stakeholders, the local community, and government officials. This will allow DOE to anticipate stakeholder reactions and plan for contingencies. An example of this philosophy, which was used by FSV, is illustrated by the removal of the spent fuel from FSV. The utility intended to begin defueling and shipment of the fuel to the Idaho National Engineering Laboratory in early 1991. However, Governor Andrus of Idaho strenuously objected, and a series of legal maneuvers ensued. The fuel was scheduled to be removed and shipped to permit the start of decommissioning in January 1992, and these complications delayed that schedule. However, the utility had foreseen this possibility and had moved ahead with construction of an ISFSI, which subsequently was used to store the spent fuel.

Programs that have been effective for the utilities have many good ideas for sharing information with the public that DOE can use. At several of the plants, local community groups, including children, are invited to visit the site. Senior plant personnel attend meetings in the community and answer questions about what was being done and planned at the plant. Quarterly news flyers were sent out to the local community to share plant information, and discussions included what work was currently in progress and what had been done. Communications with the nuclear community—local, society, industrial, and environmental groups—also occurred.

In addition to creating and maintaining a trusting relationship with the public, DOE needs to create a good working relationship with appropriate regulatory bodies. The success of D&D activities at the utilities was assisted by a good working relationship with regulators.

Waste Minimization and Avoidance of Mixed-Waste Generation

The lack of availability of waste disposal sites and the variable, but generally high, disposal costs provide a strong motivation to utilities to minimize generation of radiologically contaminated waste. The high waste disposal costs provide incentive to the utilities to compact waste, decontaminate equipment, or recycle if possible. Waste minimization procedures used by utilities included compaction, smelting, reuse, and free-release (if it was cost-effective). Additional cost savings were obtained by preplanning loading and unloading and using self-shielding for packaging.

For the DOE, there appears to be less incentive to minimize LLW generation because of the availability of DOE repositories. However, as was noted by the Shippingport Plant, waste disposal operations are highly sensitive to changes in regulation and are the area of D&D most likely to be affected by public opinion. Both DOE and the utilities have a common political problem with the treatment and disposal of mixed wastes, and this would be a good area for joint programs. The utilities have made the identification and minimization of mixed wastes a high priority item in their SAFESTOR activities.

Industry Involvement

All utilities appear to use the services of experienced engineering contractors to perform or independently validate cost estimates for decommissioning activities. In addition, contractor assistance often is used for radwaste management, to provide for decommissioning expertise, and to provide additional radiation protection and health physics support. Many utilities plan to use specialty consultants and contractors to assist in document preparation, spot decontamination, waste packaging, and disposal services. The utilities' experience is most similar to the DOE Environmental Restoration Management Contractor (ERMC) approach, but they did not have as much choice as DOE because they lacked the large staff of experts within the utility organization.

It is important to know the types of technologies available in private industry. Contact then can be made with the company and a demonstration of that technology given to determine the applicability, reliability, and safety associated with that technology. It is also important to look for technologies under development by DOE that can be adapted for commercial use, resulting in a joint work agreement between DOE and private industry.

Utilities found that sharing experiences between facilities undergoing deactivation appeared to be worthwhile. Therefore, the establishment of, and participation in, a decommissioning support group [e.g., Energy Facility Contractors Group (EFCOG)] where similar facilities undergoing decommissioning can share experiences, lessons learned, etc., is recommended for DOE.

Recycle and Reuse Opportunities

Commercial utility salvage efforts to date suggest that, in general, salvage sales and asset recovery programs have demonstrated limited potential to provide a significant income. The primary saving often appears to be avoidance of disposal costs, which has the potential to save DOE money. Some major components can be decontaminated and disposed of by a waste recovery vendor. In some cases, a large percentage of the metallic inventory can be sent to a waste recovery vendor and decontaminated to levels permitting unrestricted use at a significant cost savings. Even though the scrap values may be low, they offset the associated removal and reprocessing costs.

Another valuable suggestion from the commercial nuclear industry is to look for reuse opportunities for buildings and equipment at a site. Pacific Gas and Electric reduced the number of occupied buildings from five to one and is looking at other uses for the buildings. Potential uses include using them as a vocational technical school or environmental monitoring and training center.

Some avenues available to private utilities are not really feasible options for DOE; i.e., utilities can donate equipment or facilities to educational/charitable institutions and receive a tax deduction. However to reduce/eliminate remediation costs, DOE may consider selling or paying a third party to take ownership of a facility, thereby eliminating SAFSTOR or D&D remediation costs.

In a similar manner, DOE may be able to "reuse" facilities and on-site equipment for applications in the commercial sector. In many instances, DOE has a commitment to make every effort to maintain the local economy and provide jobs as the facility transitions.

Technology Development or Enhancement Needs
Existing D&D techniques appear to be sufficient to meet the needs of the commercial nuclear industry. The Trojan management felt that the technology is at hand to cut up and remove large components and decontaminate components and structures. Northern States Power viewed decommissioning as a high volume of low-technology work. Decontamination and disassembly techniques to be used by the Long Island Power Authority are consistent with those used routinely throughout the nuclear industry (*in situ* chemical decontamination, ultra-high-pressure water lancing, abrasive grit blasting, conventional cutting tools, diamond wire saw cutting, underwater plasma-arc, and metal-disintegration machining equipment). The minimization and stabilization of mixed wastes is an area that needs additional technology development.

CONCLUSIONS

Lessons learned and results of the survey of commercial nuclear plant D&D experiences are related to the DOE environment and used to make some suggestions for ways that DOE can deactivate facilities to achieve a designated safe-storage state in a timely, cost-effective manner while still providing minimal risk to health and safety. It is important not to be limited to the suggestions discussed in the preceding paragraphs. Individuals struggling with issues in the environmental remediation environment may develop other valuable suggestions from the information provided.

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