EPRI's Decommissioning Technology Program

The EPRI Decommissioning Technology Program assists nuclear plant operators in their efforts to minimize the cost and risks of decommissioning through enhanced planning, applying lessons learned by other utilities with retired plants, and the use of advanced technology.

By Christopher J. Wood and Sean Bushart

The Electric Power Research Institute (EPRI) is the research and development arm of the electricity generating companies in the United States. Of the four technical sectors—environment, generation, power delivery, and nuclear power—nuclear is the biggest. Although most of the work in the nuclear sector involves supporting the existing reactors and the design and implementation of new plants, EPRI has also been involved in the decommissioning of nuclear power plants ever since the first large U.S. power plants started decommissioning activities in the mid-1990s.

Until 15 years ago, utility plant closures had been limited to small plants, such as Humboldt Bay, LaCrosse, and the Peach Bottom-1 high-temperature gas-cooled reactor (HTGR). With the exception of Pathfinder and Saxton, these plants were placed in SAFSTOR mode, with only limited demolition activities. Also, some larger plants of earlier design had ceased operation, including the Fermi-1 liquid metal reactor, the Dresden-1 boiling water reactor (BWR), and the Indian Point-1 pressurized water reactor (PWR). However, decommissioning work was limited at those plants, as they were on multiunit sites with large modern units.

With the exception of Three Mile Island-2, which suffered an accident in 1979, the first large plants to cease operation were the Trojan PWR (1100 MWe) and the Rancho Seco PWR (900 MWe). These plants were shut down as a result of economic issues and public vote, respectively. In the 1990s several other plants closed, primarily for economic reasons. These included the Big Rock Point BWR and the San Onofre-1, Yankee Rowe, Maine Yankee, and Connecticut Yankee PWRs. Two atypical closures in this period were the Fort St. Vrain HTGR and the Shoreham BWR (which never saw full power operation).

The most recent plants to cease operation were the Zion PWRs and the Millstone-1 BWR. In both cases, regulatory issues had had a serious impact on the utility's nuclear plant operations, and the least economic plant was closed during that period. Since then, the economic viability of nuclear power plants has improved in a major way, and the emphasis has changed from plant closure to license renewal. Barring unforeseen problems, no further plant closures are anticipated in the next few years.

The year 2005 saw the achievement of major milestones for three nuclear power plants, with the license termination of Trojan, Saxton, and Maine Yankee. Together with the transformation of the U.S. Department of Energy's Rocky Flats facility into a nature park, these license terminations make it clear that the nuclear industry has successfully demonstrated the technology for effective decommissioning of heavily radioactive facilities.

Initially, the EPRI program had the prime objectives of capturing the experiences of the first major decommissioning activities and providing technical assistance to the electric utilities starting down that course of action. In several cases, the closure had been premature and unanticipated, and the delays in moving to decommissioning status caused considerable extra expense. Later, the EPRI program added the objectives of demonstrating advanced technology and providing technical support for industry initiatives on regulatory issues, led by the Nuclear Energy Institute (NEI), and assisting power plants to evaluate technologies developed in the DOE's large program. The most recent phase of the EPRI program focuses on license termination issues, addressing specific technical problems and archiving the best practices for use in the distant future when some of the currently operating plants in the United States close down. Providing technical assistance to utilities on plant-specific issues will continue to be an important part of the program.

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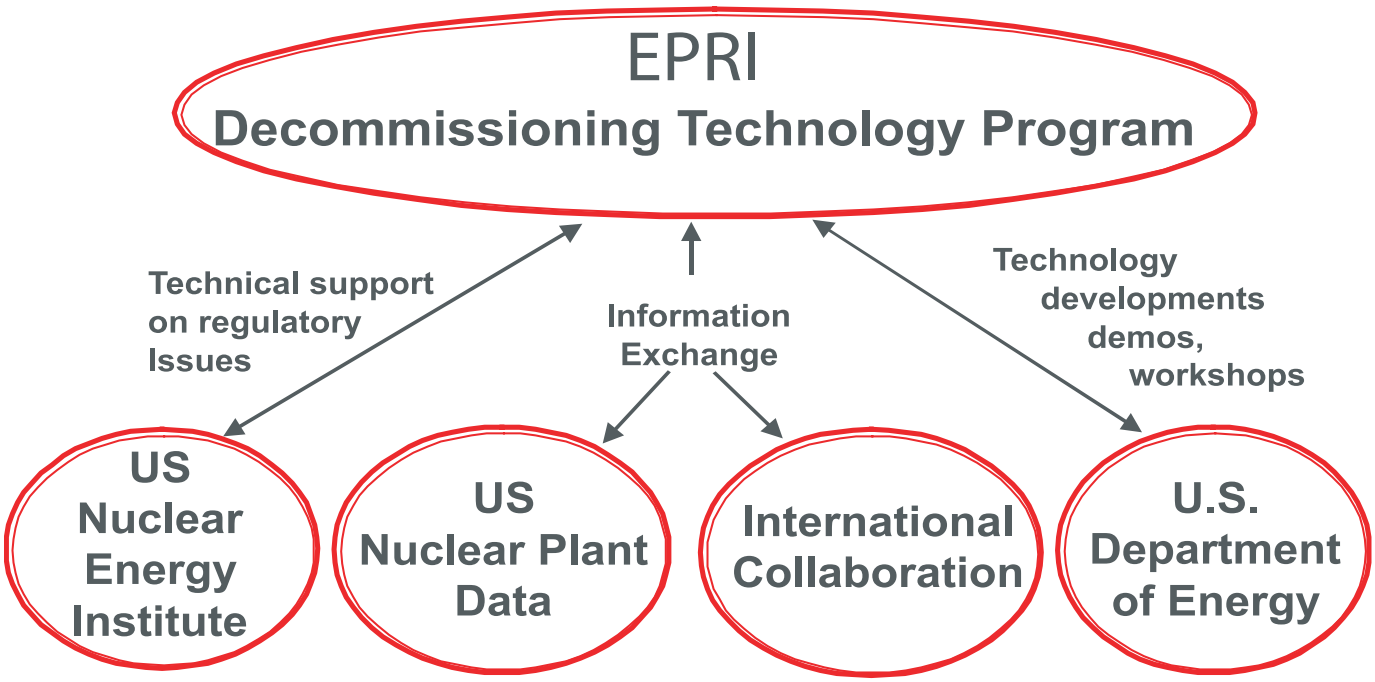

Fig. 1. Interactions of the EPRI Decommissioning Technology Program.

solved issues in low-level waste management, site characterization, radiation dose modeling for site release, and license termination plans (LTPs). Anticipating and addressing the needs of utilities facing premature (unplanned) shutdown of nuclear units in the future is an important goal. Capturing the lessons learned from current decommissioning work at power plants and archiving that information for future use includes the preparation of guidance documents on license termination issues.

The international membership in the program has grown significantly over the past few years and continues to increase. The comprehensive list of reports and software developed in this program has proved to be a valuable asset to international utilities wishing to evaluate U.S. experience and the latest technology developments. In addition to the preparation of international versions of EPRI reports and software, which enable international organizations to more effectively assess the results of work carried out in the United States, EPRI holds annual workshops specifically for international cofunders. The first international workshop on decommissioning and low-level radioactive waste management technology was held in Thurso, Scotland, in September 2002. Designed specifically for international members, this conference included a visit to the U.K. Atomic Energy Authority's (UKAEA's) Dounreay facility. The second workshop was held in Bristol, England, in September 2003 and included a visit to Berkeley Power Station of BNFL Magnox Generation. The third workshop was held in Lyon, France, at the end of September 2004, under the sponsorship of Electricité de France, which arranged a visit to Super Phenix fast reactor. This workshop included a special session on the treatment and disposal of graphite from gas-cooled reactors. The fourth workshop was held in Madrid, Spain, in October 2005, under the sponsorship of Union Fenosa and ENRESA (Empresa Nacional de Residuos Radioactivos), which included a visit to the Spanish radioactive waste disposal facility.

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Now, the decommissioning circle is being completed with workshop conclusions made available to the operating plants—a direct benefit of the technology developed under the decommissioning program. With the uncertain availability of LLW disposal sites during the longer term, these results and techniques may well become important contributors to future economic operation.

Figure 1 depicts the interactions between the EPRI program and that of other organizations, and Fig. 2 shows key elements of the program, within the overall goal of reducing the risks and costs of decommissioning nuclear power plants.

EPRI work emphasizes technology developments, as distinct from regulatory and licensing issues, which continue to be the responsibility of NEI. However, EPRI is participating in a number of joint projects by providing

technical support to NEI to address regulatory issues in decommissioning, including license termination, material recycle, and site release.

EPRI Technical Support Products

Planning for Decommissioning

Utility experiences in recent years show that significant cost savings will result from advance planning for the eventual closure of nuclear power plants. EPRI has developed a manual that includes a framework for planning ahead for plant decommissioning by drawing upon the experiences of utilities currently involved in decommissioning. It identifies important advance planning decisions, tasks, and contributing disciplines; establishes activity precedence relationships; and defines data requirements. The manual also describes actions that utilities can take prior to plant shutdown to ease the transition to decommissioning status.

Effective planning is a key to cost control, a critical aspect of decommissioning. EPRI developed this manual to make available the lessons learned about advance planning from in-progress plant decommissioning projects. From these lessons they further developed a decision framework to cover the following specific tasks for use in planning for decommissioning:

- Identify key decisions and tasks in the advance planning process.
- Establish ordered relationships and dependencies between the key decisions and tasks.
- Identify the key disciplines required to support the decision process and tasks.
- Identify data that will support the decision process and tasks.

Listed in the manual are some 65 decommissioning activities to support tactical level planning, consolidated into 32 advance planning tasks that define planning requirements at the discipline level. These activities are consolidated into elements on a precedence diagram, which lends order to the decision processes. The precedence relationships identify the tasks by lead discipline:

- Management/Finance/Human Resources.
- Licensing/Operations/Training/Quality Assurance.
- Engineering.
- Environmental Management and Occupational Health and Safety.

Lessons learned from current decommissioning efforts suggest that more advance planning is needed for both the radiological (site survey) and nonradiological (hazardous materials) aspects of decommissioning. The EPRI decision framework for decommissioning advance planning gives the nuclear power plant operator the opportunity to substantially lower both the cost and risk of the decommissioning process. Guidance for three time frames—premature shutdown, planned shutdown in three to five years, and long-term operation (data collection and contingency planning)—will aid utilities in preparing for eventual plant closure. Utility managers currently involved in decommissioning power plants offered considerable input and advice, enabling decommissioning projects to gather the best practices of utilities already in the decommissioning phase.

Waste Management

A nuclear facility that is pursuing decommissioning is faced with a wide variety of waste types and waste management options. The various options for waste condi-

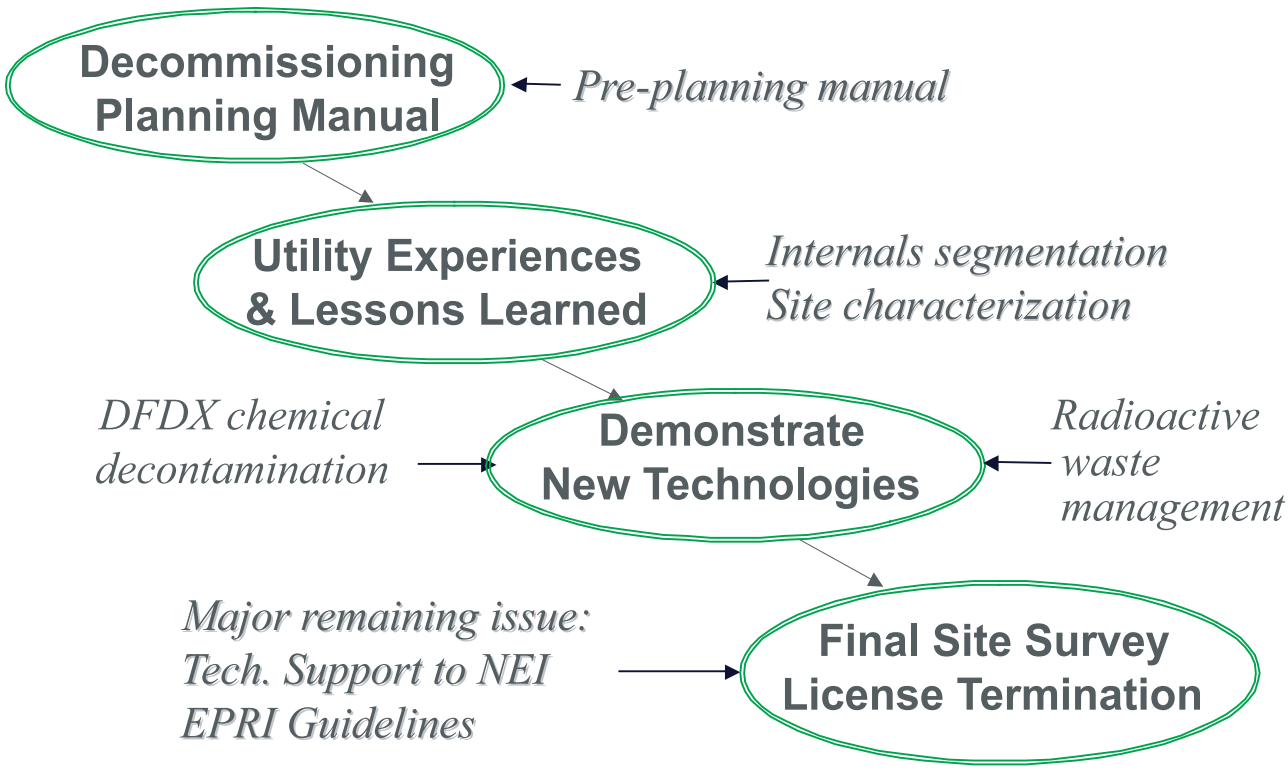

Fig. 2. The EPRI Decommissioning Technology Program has the goal of reducing the risks and costs of decommissioning nuclear power plants.

Fig. 3. Filter housing decontaminated to background radiation levels.

tioning (volume reduction) and disposal have increased in number and cost complexity over the past decade. This has created a need for a computer program capable of analyzing both existing and alternative waste management costs and volumes to identify the optimum approach for disposition of each waste type. EPRI developed the Decommissioning Waste Manager computer program to meet this need. It analyzes decommissioning waste volumes, weights, labor, characterization, packaging, shipping, treatment, storage, disposal, and related cost elements with the intent of quantifying the existing decommissioning waste management program for any given waste generator.

The Decommissioning Waste Manager computer program follows the successful implementation of EPRI's Solid, Liquid, and Mixed Waste Manager computer programs. Together, the four programs make up EPRI's Waste Logic suite of computer programs. The various programs have been tested, demonstrated, and/or installed at more than 50 commercial nuclear power stations and have served as catalysts for reducing industry-wide waste management costs by more than $60 million annually. Waste Logic programs have been used to identify significant cost savings at UKAEA's Dounreay facility in Scotland. It is now being expanded to a multisite database format to accommodate large decommissioning waste management projects, such as the one at the Dounreay site.

Although most decommissioned plants on single-unit sites in the United States are opting for rapid deconstruction, reactor pressure vessel (RPV) extended SAFSTOR options may be desirable for decommissioning plants with disposal and/or transportation limitations. Also, dose and cost savings may result by delaying some segmentation tasks until significant radionuclide decay has occurred. A recent evaluation of the impact of RPV SAFSTOR strategies for PWRs and BWRs concluded that RPV SAFSTOR may be a desirable option for decommissioning plants in certain circumstances, in particular for BWRs due to the radiological characteristics of their larger RPVs. In addition, EPRI has been updating its extensive set of guidelines for the interim onsite storage of low- and intermediate-level wastes. Recent reports have been published on the interim storage of greater-than-Class-C wastes, the optimization of waste containers for storage, and waste volume and segregation strategies for the interim storage of Class B and C wastes.

Termination of Nuclear Plant Licenses

The U.S. Nuclear Regulatory Commission requires utilities to submit LTP documents years prior to the site license termination. The new license termination regulations involve numerous complex regulatory guidance documents. This complexity has resulted in the majority of initial LTP submittals experiencing numerous setbacks or delays in the NRC approval process. EPRI developed guidance to assist those engaged in future preparation by offering a comprehensive, user-friendly report that examines the radiological components of license termination. This guide assembles the lessons learned by those utilities currently undergoing the license termination process. This experience, coupled with consolidation of the important aspects of available regulatory guidance, benefits the next generation of utilities considering decommissioning and termination of their NRC Part 50 licenses.

The guide specifically considers regulatory requirements and guidance, site characterization, dose modeling, site remediation, and final status survey. The appendices provide examples of a sampling plan and a conceptual schedule for site characterization. This report serves as a technical reference addressing a wide range of issues pertaining to the radiological aspects of license termination.

Technology Developments

Control of radiation exposure during demolition activities has been a significant challenge at several plants. The EPRI Decontamination for Decommissioning (DFD) process was developed to address this issue. The results obtained in early applications of the EPRI DFD process at Big Rock Point and Maine Yankee demonstrated the benefits of taking this approach. There are significant potential benefits, both economic and environmental, in recycling materials from retired nuclear facilities for new controlled uses within the nuclear industry. The EPRI DFDX Process, developed from the DFD process, is an efficient and economic decontamination method for preparing materials for recycle. This technology includes processing of the radioactive solution using electrochemical ion exchange to produce a minimal volume of metallic waste. This process has been demonstrated on reactor samples at Studsvik's facility in Sweden and on contaminated material from a fuel reprocessing facility at UKAEA Dounreay in Scotland. Figure 3 shows a filter housing decontaminated to background radiation levels.

EPRI has collected the good practices and lessons learned by three nuclear power plants using chemical decontamination processes on the reactor coolant systems:

- Apply as soon as possible after final closure, when equipment is still operational, expert staff are still available, and exposure saving benefits are maximized.
- Use reactor coolant pumps, as good fluid circulation is important.
- Evaluate materials corrosion, as there may be some problems with susceptible components.
- LLW volumes are not determined by decontamination process alone, as unexpected sources of corrosion products may be found, and it may be necessary to dilute resins with less active material to avoid higher waste classifications.
- Contingency planning is vital, as one should anticipate the unexpected. Flexibility in procedures and planning will reduce potential delays.

Lessons Learned by Organizations Involved in Decommissioning Nuclear Plants

From a review of experiences in planning decommissioning work and in the development of LTPs, EPRI developed a list of good practices:

- Maintain good relationships with internal and external stakeholders: staff, local communities, and government agencies.
- Establish an employee retention plan; it is essential to keep key staff.
- Produce a baseline historical site assessment and site characterization. Sample to determine the extent of radiological and hazardous material contamination for the entire site.
- Improve contamination control both inside and outside restricted areas.

A nuclear facility that is pursuing decommissioning is faced with a wide variety of waste types and waste management options. The various options for waste conditioning (volume reduction) and disposal have increased in number and cost complexity over the past decade.

- Characterize LLW onsite: type, volume, weight, and isotopic mix.
- Identify and characterize mixed waste (hazardous/radioactive) onsite.
- Inspect and characterize spent fuel for damage.
- Prepare design documents for spent fuel disposal: a dry storage facility and handling systems.
- Locate and characterize previous onsite disposals and "spills," including onsite burial and exemptions under previous regulations.
- Maintain strong document control.
- Enhance groundwater monitoring, particularly for tritium.

The Future

Future work includes material release, license termination studies, advanced decontamination technology for the disposal of retired components, and improved LLW processing methods. The management of groundwater contamination, particularly tritium, was discussed in detail during a technology workshop in Providence, R.I., in November 2005 and will continue to be an important area of investigation. Results from this work will directly benefit operating plants, as well as future decommissioning plants. EPRI will continue to record lessons learned from the decommissioning of U.S. plants. These lessons are already being utilized by international plants, whose experiences will in turn be recorded for future applications worldwide.

The graphite moderators of retired gas-cooled nuclear reactors present difficulties during demolition activities. In fact, no moderators of CO_2-cooled power reactors have been dismantled to date. The international participants in the EPRI Decommissioning Technology Program discussed the issues at the Lyon workshop in 2004. Subsequently, a review of the options for the treatment

of graphite from gas-cooled reactors has been prepared, including a discussion of recycling, disposal, and safety-related issues. This comprehensive review provides valuable source material on the current state of knowledge and points the way to further work on specific problem areas. As a result, EPRI has initiated a detailed study of graphite dust explosions and will examine other topics later.

Valuable Experience

Considerable progress was made in 2005 in the decommissioning of shutdown nuclear power plants in the United States. Major milestones included license termination at Trojan, Maine Yankee, and Saxton. The U.S. industry has now demonstrated the successful decommissioning of three nuclear power plants, showing that it is practical and economically feasible, with no risk to the public. Major components have been removed at all the remaining plants in the process of demolition. The experience gained over the past several years is valuable to organizations initiating new decommissioning projects.

Thinking back to the mid-1990s, we remember that public perception then was that decommissioning could not be done, and there was not enough money to do it anyway. Of course, challenges remain, but overall, progress has been impressive and exceeded expectations. Archiving the lessons learned remains a key goal of the EPRI program, for the experience gained over the past several years will be valuable in the future to organizations initiating new decommissioning projects. ■

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