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Report to Congressional Requesters

September 1990

NUCLEAR RESEARCH AND DEVELOPMENT

Shippingport Decommissioning—How Applicable Are the Lessons Learned?

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Economic Development Division

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The Honorable Robert A. Roe
Chairman, Committee on Science,
Space, and Technology
House of Representatives

The Honorable Robert S. Walker
Ranking Minority Member, Committee on
Science, Space, and Technology
House of Representatives

In July 1989 you asked for information about the Department of Energy's (DOE) decommissioning of the Shippingport, Pennsylvania, nuclear power plant. You wanted to know whether DOE had met the goals described at the July 1986 hearings before your Committee. DOE's goals were to

- demonstrate that a large nuclear plant can be decommissioned safely and within the costs ($98.3 million) and time frame (April 1990) established,
- optimize contractor involvement to help transfer information to the private sector, and
- develop information to assist the nuclear industry with future decommissioning projects.

Specifically, you asked us to answer nine questions relating to these goals (app. II provides detailed answers to your questions). We are also providing some perspective on additional information that could assist the commercial nuclear power industry that was not addressed by Shippingport. We previously addressed some of the lessons learned from Shippingport in a June 1990 report to Representative Fazio who was interested in the relationship between Shippingport and the Rancho Seco, California, plant.[1] This report provides more details about Shippingport's decommissioning and addresses the usefulness of Shippingport's decommissioning to such commercial plants as Pathfinder, Peach Bottom, and Fort St. Vrain located in South Dakota, Pennsylvania, and Colorado, respectively.

[1]Nuclear R&D: Usefulness of Information From Shippingport Decommissioning for Rancho Seco (GAO/RCED-90-171, June 7, 1990).

Results in Brief

DOE generally met the goals that it had established for Shippingport. It completed all decommissioning activities in December 1989—4 months ahead of schedule—at a cost of $91.3 million—$7 million under its 1986 estimated cost. According to some utility representatives, the most significant benefit of Shippingport was that DOE demonstrated that technology existed to decommission a plant within the costs and time frame established. In addition, DOE used over eight contractors on the project and produced numerous annual or topical reports that officials believe will be useful to the commercial nuclear industry.

Although Shippingport increased the knowledge for decommissioning nuclear power plants, the benefits of the lessons learned will vary depending upon the timing and the decommissioning approaches selected by utilities. Very few utilities will be able to decommission their plants the way DOE decommissioned Shippingport, and it is possible that newer technology may be available by the time utilities do so. To illustrate, Shippingport was much smaller and less radioactively contaminated than other plants, and DOE removed the most highly radioactive component, the reactor pressure vessel, in one piece. Utilities operating commercial plants will probably have to disassemble (cut-up) the reactor pressure vessels because of their much larger size. Also, DOE disposed of all the low-level radioactive waste from the decommissioning activities at its Hanford, Washington, facility. Utilities will have to dispose of waste at commercial sites at substantially higher costs.

Overview of the Shippingport Project

In the mid-1950s, DOE and the Duquesne Light Company entered into a contract to build Shippingport and demonstrate electricity generation using nuclear power. On December 2, 1957, Shippingport, a 72-megawatt pressurized water reactor,[2] became the nation's first operating nuclear power plant. Over its 25-year life, the plant operated for about 80,324 hours and produced about 7.4-billion kilowatt-hours of electricity.

Under the contract, DOE owned the reactor and steam-generating portions of the plant while the utility owned the electricity-generating portion. According to a DOE official, the contract required DOE to return the site to safe conditions on or before 1994. Accordingly, in September 1985 DOE began the physical decommissioning of Shippingport. DOE completed these activities in July 1989, including dismantlement of the

[2]Pressurized water reactors are those cooled by water that is kept at high pressure to prevent it from boiling. The water passes through the nuclear fuel and is heated. The heat is then transferred to a secondary system where steam is produced.

nonradioactive structures; certified in October 1989 that the site was radiologically safe; and issued a final report on the project in December 1989.

In addition, DOE removed the fuel and sent it to its Idaho National Engineering Laboratory and disposed of about 216,000 cubic feet of low-level radioactive or mixed (radioactive and hazardous) waste at its Hanford, Washington, facility. Also, DOE removed the reactor pressure vessel intact and shipped it by barge to Hanford for disposal.

DOE Met Its Goals

DOE generally met the goals established for Shippingport. DOE completed the decommissioning activities in December 1989—4 months ahead of schedule—and $7 million under the estimated $98.3 million cost. Also, DOE used over eight contractors for various decommissioning activities to optimize contractor involvement and developed an extensive amount of data that officials believe will help future decommissioning projects.

Some Differences Between Shippingport and Commercial Plants

DOE's activities at Shippingport increased the base of knowledge for decommissioning commercial nuclear power plants. However, because of significant differences between Shippingport and other reactors and the manner in which Shippingport was decommissioned, it is questionable whether the lessons learned can be extensively applied to larger, more contaminated nuclear power plants that will be decommissioned in the future. For example, Shippingport was different from commercial plants because (1) the plant was more radiologically clean than other plants at the time of its shutdown, (2) DOE disposed of the pressure vessel in one piece instead of cutting it up or letting the radiation decay over many years before starting decommissioning, (3) DOE had predetermined sites to dispose of the spent fuel and low-level[3] and mixed waste, and (4) DOE had an elaborate management structure to conduct and oversee the decommissioning activities.

[3]Low-level waste is waste that is not classified as uranium mill tailings, high-level waste, or spent fuel and consists of discarded tools, rags, machinery, paper, protective clothing, and other items.

Low Radioactive Contamination

Over the plant's lifetime, some decontamination activities had been conducted; therefore, Shippingport—including the reactor pressure vessel[4]—was more radiologically clean than might be expected for a commercial plant. DOE estimates that at the time of shutdown the reactor pressure vessel contained about 30,000 curies[5] of radioactive material. Table 1 shows the estimated curie content for four plants that have been shut down, are awaiting the start of decommissioning, or have been partially decommissioned.

Table 1: Comparison of Shippingport to Four Other Plants[a]

Plants	Megawatts	Type of reactor	Amount of curies	Hours operated	Electric energy generated (in billion kilowatt-hours)
Shippingport	72	PWR[b]	>30,000[c]	80,324	>7.4[d]
Fort St. Vrain	330	HTGC[e]	900,000	21,360	4.3
Pathfinder	62	BWR[f]	30,000	12,000	.1
Peach Bottom	40	HTGC	>3,000,000[g]	32,375	1.4
Rancho Seco	913	PWR	>9,000,000[h]	51,595	44.0

[a]Although the plants shown in table 1 differ in design and size from Shippingport, the information is useful for illustrative purposes.

[b]Pressurized water reactor.

[c]Greater than 30,000 curies.

[d]Greater than 7.4 billion kilowatt-hours.

[e]High-temperature gas-cooled reactor.

[f]Boiling water reactor.

[g]Greater than 3 million curies.

[h]Greater than 9 million curies.

The utilities that own Fort St. Vrain and Rancho Seco expect to decommission or convert the plants to use other fuel; the utility that owns Pathfinder partially dismantled the plant in 1968 after shipping the fuel off-site. In 1990 the utility expects to start dismantling other parts of Pathfinder and complete these activities by the end of 1991. In addition, utilities owning seven small nuclear plants, including Peach Bottom,

[4]Generally, reactor vessels are large, steel cylindrical vessels that can weigh almost 1,000 tons and vary from about 45 to 70 feet in height. The walls of the vessels range from about 7- to 11-inches thick. Shippingport's vessel weighed about 153 tons and was about 25 feet high.

[5]A curie is a measure of the rate of radioactive decay.

have started to decontaminate them and put them into "safe storage" until a site is available to dispose of the high-level waste.[6]

Pressure Vessel Decommissioning

DOE removed the pressure vessel from Shippingport in one piece. The pressure vessel is the most highly contaminated part of a nuclear power plant. Although removing the vessel in one piece minimized worker exposure to radiation and reduced costs by about $7 million, DOE's approach did not provide the nuclear industry with information on the problems that may be encountered if utilities must cut-up this component. According to an official, other DOE decommissioning projects will cut-up reactor pressure vessels.

Three of the four utilities that we visited could not dispose of the pressure vessel in the same manner that DOE used at Shippingport. According to utility executives from Fort St. Vrain, Peach Bottom, and Rancho Seco, the size of the pressure vessels and the radioactive contamination they contain will preclude their shipping and disposing of this component in one piece. Only the utility that owns Pathfinder, whose reactor pressure vessel (32 feet by 12 feet) was about the same size as Shippingport (25 feet by 10 feet), said it expected to dispose of the vessel in one piece at a commercial site operated by U.S. Ecology in Richland, Washington.

Waste Management and Disposal

DOE had predetermined sites to dispose of the spent (used) fuel from Shippingport as well as the low-level and mixed waste generated from decommissioning activities. DOE sent the spent fuel to its Idaho National Engineering Laboratory. Currently, no disposal site exists for the spent fuel from commercial plants; DOE expects that the earliest a permanent site would be available is 2010.

Also, according to DOE officials, Shippingport did not generate any of the most highly radioactive low-level waste that can remain hazardous for a few hundred to tens of thousands of years (greater-than-Class C).[7] According to utility officials, Fort St. Vrain is expected to generate about 142 cubic feet of greater-than-Class C waste, and Rancho Seco will

[6]Humboldt Bay 3, California; Fermi 1, Michigan; Indian Point 1, New York; Vallecitos Boiling Water Reactor, California; Dresden 1, Illinois; LaCrosse, Wisconsin; and Peach Bottom 1, Pennsylvania.

[7]About 3 percent of low-level waste—greater-than-Class C—is contaminated with long-lived radioactive elements having concentrations greater than those specified in 10 C.F.R. Part 61 of NRC's regulations.

also generate such waste although officials could not estimate the volume. Currently, no disposal site exists for such waste generated from commercial operations.

Further, DOE disposed of other low-level waste at Hanford at significantly lower costs than utilities will experience. DOE disposed of about 214,000 cubic feet of waste for about $2.4 million (including the reactor pressure vessel). In 1986 low-level waste disposal costs at Hanford were $3.95 per cubic foot; by 1989 the cost had increased to about $27.60 per cubic foot, excluding packaging, transportation, labor, materials, taxes, or surcharges allowed by the Low-Level Radioactive Waste Policy Act, as amended.[8] After January 1993 low-level waste disposal costs could range from $50 to $590 or more per cubic foot as a result of the new facilities—possibly as many as 16—that will be built by states or interstate compacts to comply with the act and dispose of low-level waste. For example, utility officials estimate that decommissioning Rancho Seco will generate about 775,000 cubic feet of low-level waste and disposal costs could total about $24 million.

Management Structure

Because of the research and demonstration nature of Shippingport, DOE used an elaborate management structure to decommission the plant. DOE used over eight contractors to conduct the physical activities and three other contractors to oversee the activities conducted. According to DOE's Program Manager, DOE recognizes that utilities may not be able to institute the same type of management structure to decommission commercial plants. Further, at least 30 percent of DOE's costs related to physical decommissioning activities; the remaining 70 percent included engineering, oversight, management, and other activities, such as waste disposal. Utilities, faced with setting aside funds to decommission their plants and subject to scrutiny by public service commissions when doing so, most likely will not incur as high a level of oversight and management costs relative to physical decommissioning costs that occurred with Shippingport.

[8]To encourage the development of new low-level waste disposal sites, the act established surcharges ranging from $10 to $40 per cubic foot of waste disposed of between July 1986 and December 1992 and penalties of up to $120 per cubic foot of waste during calendar year 1992. In 1989 the surcharge was $20 per cubic foot.

Application of Lessons Learned Is Questionable

The applicability of the lessons learned from Shippingport will vary depending upon when utilities start to decommission their plants and the similarity of their efforts to the way that Shippingport was decommissioned. Thus, the lessons learned from Shippingport may diminish by the time a large number of utilities decommission their plants. The Nuclear Regulatory Commission (NRC), which issues licenses to, and oversees the safe operation of, commercial plants, estimates that by the year 2015 about one-half of the existing 113 operating licenses will terminate, and most of the remaining licenses will expire by about 2030.

However, utilities can apply to NRC to extend the plants' operating licenses, and because of the high cost of building new plants, a strong likelihood exists that utilities will do so. NRC currently expects that the license extension will be for 20 additional years. Also, under NRC's regulations, utilities can take as long as 60 years to complete decommissioning activities. Therefore, utilities may not decommission a large number of plants until well into the 21st century and new technology, such as remotely operated equipment and robotics, may lessen the usefulness of the technology used at Shippingport.

Utility officials that we contacted expressed various opinions about the usefulness of Shippingport to their circumstances. An official from Peach Bottom said that Shippingport provided useful information on constructing platforms to dismantle the plant and using a plasma arc torch to cut-up some components, but most other information would not be useful to decommissioning Peach Bottom. Rancho Seco officials said that DOE briefed them on dismantling Shippingport, and the report on asbestos removal will be applicable to their activities.[9] In addition, Fort St. Vrain officials said that they will use Shippingport's information to develop a decommissioning plan for the plant. Further, according to Humboldt Bay officials, they will not need specifics on decommissioning for at least 20 years, and until then, they could not determine whether Shippingport will be useful.

Shippingport Did Not Increase Basic Research Knowledge

One objective of the Shippingport project was to demonstrate that a nuclear power plant could be safely and economically decommissioned using existing technology, such as manually dismantling radioactive piping systems and components. Thus, DOE did not design the project to increase the basic research and development knowledge on methods or

[9]Shippingport Station Decommissioning Project, Asbestos Removal Topical Report, Mar. 18, 1988.

equipment needed to decommission a large plant. According to DOE officials, they relied on technology the nuclear industry used for the last 30 years to construct, maintain, or demolish plant systems and components. As a result, DOE did not need, nor was it required, to develop new technology, such as robotics, to decommission Shippingport.

Nevertheless, DOE recognizes that the nuclear industry could benefit from information in such areas as (1) decontamination methods, (2) waste reduction and minimization techniques, (3) methods to determine the specific radioactive materials and levels of contamination in waste, and (4) robotics for facility and plant equipment disassembly. In this regard, DOE has embarked on a 5-year program to develop new technology for the clean up of uranium enrichment, fabrication, and reprocessing facilities as well as plutonium production reactors. As part of this effort, DOE recognizes that the development of robotics and/or remote systems may be the only means to safely conduct decommissioning activities in highly radioactively contaminated facilities and minimize worker exposures.

In addition, DOE is exchanging information with the United Kingdom and Japan. The United Kingdom is decommissioning two gas-cooled reactors—Windscale and Berkeley—and is assessing the need to use robotics. Japan is funding a major demonstration project to decommission a nuclear reactor about 100 miles northeast of Tokyo. As part of the project, Japan has stimulated private sector research and development by inviting most of the country's largest industrial firms to develop advanced techniques for future decommissioning projects. In particular, the Japan Atomic Energy Research Institute in conjunction with Mitsubishi Heavy Industries developed a robotic arm to cut-up the reactor's internal parts, which were then put into a pool of water where they were further cut-up by a robotic saw developed by Hitachi.

In addition to international efforts, General Public Utilities has been using robotics to remove fuel and conduct other activities at the damaged Three Mile Island, Pennsylvania, plant. Although the accident created cleanup problems that should not be experienced at other plants, utilities may derive more useful information from the activities conducted at Three Mile Island than from Shippingport, particularly efforts to minimize worker exposures that were minimal at Shippingport.

Conclusions

DOE generally met the goals established for decommissioning Shippingport by completing these activities 4 months ahead of schedule and

$7 million under the estimated cost for the project. It also utilized contractors to conduct various decommissioning activities to extend the experience and knowledge to the private sector. However, because Shippingport was a smaller reactor and less radioactive than other reactors, lessons learned from its decommissioning are limited. For example, because Shippingport had a small pressure vessel, DOE was able to dispose of it whole whereas future pressure vessels will probably have to be cut up, thus increasing worker exposure to hazardous nuclear materials.

Further, many years may elapse before utilities dismantle a large number of plants. In the interim, decommissioning activities being conducted on higher radioactivity contaminated pressure vessels here and abroad will advance the state-of-the-art beyond the lessons learned at Shippingport, and information that will be developed under DOE's recently announced initiatives and by the United Kingdom, Japan, and Three Mile Island may be more useful than Shippingport. These efforts are directed at identifying new technology to reduce worker exposures.

To obtain this information, we contacted NRC, DOE, utility, and industry officials and reviewed numerous reports that DOE had prepared on the project. Our objectives, scope, and methodology are discussed in detail in appendix I. Appendix II contains responses to the questions raised in your request. Appendix III summarizes the decommissioning efforts of the four utilities that we visited.

We discussed the facts in the report with NRC, DOE, and utility officials and incorporated their views where appropriate. As requested, we did not obtain official agency comments on a draft of this report. Our work was conducted between August 1989 and June 1990 in accordance with generally accepted government auditing standards.

As arranged with your office, unless you publicly announce its contents earlier, we plan no further distribution of this report until 30 days from the date of this letter. At that time we will provide copies to Representative Fazio; the Secretary of Energy; and the Chairman, NRC. We will also make copies available to others upon request.

Please call me at (202) 275-1441 if you have any questions. Other major contributors to this report are listed in appendix IV.

Victor S. Rezendes
Director, Energy Issues

Contents

Abbreviations

DOE	Department of Energy
EPA	Environmental Protection Agency
GAO	General Accounting Office
NRC	Nuclear Regulatory Commission
ORAU	Oak Ridge Associated Universities
SMUD	Sacramento Municipal Utility District

Objectives, Scope, and Methodology

On July 21, 1989, the Chairman and the Ranking Minority Member, House Committee on Science, Space, and Technology, asked us for information about the Department of Energy's (DOE) decommissioning of the Shippingport, Pennsylvania, nuclear power plant. Specifically, we were asked to (1) determine whether DOE had met the goals described at July 1986 hearings before the House Committee on Science, Space, and Technology and (2) answer nine questions, some with several parts to them.

To obtain the information needed, we reviewed the Atomic Energy Act, the Energy Reorganization Act, and the Nuclear Regulatory Commission (NRC) regulations and guidelines. We also reviewed numerous DOE reports related to decommissioning Shippingport, such as the final environmental impact statement, annual progress reports, and topical reports relating to asbestos, contaminated concrete, and pressure vessel removal. We also reviewed DOE's final report on the project and the results of a survey conducted by Oak Ridge Associated Universities to confirm DOE's assessment of the radiological condition of the site. We also used information from five of our reports.[1]

In addition, we met or spoke with NRC staff in the Office of Nuclear Regulatory Research, DOE officials from the Office of Remedial Action and Waste Technology, and officials from the National Academy of Sciences, the Electric Power Research Institute, Oak Ridge Associated Universities, General Electric, French and British embassies, TLG Engineering, Inc., Nuclear Management Resources Council, American Nuclear Society, Pacific Gas and Electric Company, Worldwatch Institute, and Arkansas Power and Light.

We also contacted utilities that own the Peach Bottom, Pathfinder, Fort St. Vrain, Rancho Seco, and Humboldt Bay plants. We selected these plants because they have been shut down awaiting decommissioning or have been partially decommissioned. For example, in a June 1989 referendum, Californians voted to shut down Rancho Seco. Also in 1989, Fort St. Vrain officials decided to shut down the plant after years of operating problems. The utility that owns one Peach Bottom unit has started to decommission the plant. In addition, Northern States Power, which

[1] Nuclear R&D: Usefulness of Information From Shippingport Decommissioning for Rancho Seco (GAO/RCED-90-171, June 7, 1990). Nuclear Regulation: The Military Would Benefit From a Comprehensive Waste Disposal Program (GAO/RCED-90-96, Mar. 23, 1990). Nuclear Regulation: NRC's Decommissioning Procedures and Criteria Need to Be Strengthened (GAO/RCED-89-119, May 26, 1989). Nuclear Regulation: License Renewal Questions for Nuclear Plants Need to Be Resolved (GAO/RCED-89-90, Apr. 3, 1989). Nuclear Regulation: NRC's Decommissioning Cost Estimates Appear Low (GAO/RCED-88-184, July 29, 1988).

owns Pathfinder, had partially decommissioned the plant in 1968. Further, we spoke to a Humboldt Bay official because we were told that the plant was similar in design to Shippingport and has been partially decommissioned.

Responses to Questions Asked Concerning the Decommissioning of Shippingport

1. For how long and at what power levels did Shippingport operate over its lifetime? What were the total operating hours? How much time elapsed between the shutdown and start of decommissioning activities? What was the radiation level of the reactor at the outset of dismantlement?

Over its 25-year life, Shippingport operated for about 80,324 hours, produced about 7.4-billion kilowatt-hours of electricity, and operated at power levels of 60, 150, and 72 megawatts. The plant was shut down in October 1982 and physical decommissioning activities began in September 1985, almost 3 years later. At the time of shutdown, the radioactivity in the pressure vessel was about 30,000 curies; at the outset of decommissioning, about 16,000 curies.

2. Was the cost of the project consistent with the $98.3 million estimate that DOE presented at the July 1986 hearings? What were the actual costs and hours for labor, materials, equipment, and waste disposal?

DOE completed the Shippingport project for $91.3 million, or $7 million less than estimated. Because DOE kept costs and labor hours for the project by activity, such as engineering, decommissioning, and site management and support, we could not determine the costs or labor hours in the format requested. However, table II.1 shows the project's costs and labor hours based on DOE's work breakdown structure.

Table II.1: Breakdown of Project Costs and Forecasted Labor Hours Used to Decommission Shippingport

Description	Total costs (Millions)	Labor (in months)
Engineering (Phase I)	$6.1	NA[a]
Project management	10.6	719
Site management and services	6.8	584
Support and services	23.5	3,589
Engineering	1.1	19
Procurement	0.7	0
Solid waste management	2.1	185
System operations support	1.7	116
Utilities	1.6	0
Liquid waste management	1.3	87
Subtotal: Site management and support	**38.8**	**4,580**
Site modifications and services	5.2	482
Reactor pressure vessel preparation, removal, and transport	6.5	222
Remove piping and equipment	6.6	601
Remove primary components	1.3	105
Remove power and control systems	0.5	111
Remove structures	5.9	285
Remove containment chambers	0.4	35
Decontamination	2.3	457
Subtotal: Decommissioning activities	**28.7**	**2,298**
Home office support	1.6	40
Decommissioning operations fee	5.4	•
Other	0.2	•
Total	**91.3[b]**	**7,635[b]**

[a]DOE did not have information showing the labor hours used during the early engineering phase

[b]Totals do not add due to rounding.

At least 30 percent of the costs shown in table II.1 directly relate to the physical decommissioning of the plant; the remaining 70 percent includes engineering, oversight, management, and other activities.

3. Did DOE and General Electric maintain the project schedule? Can any lessons learned lead to shorter schedules in future decommissioning projects?

DOE completed Shippingport in December 1989, 4 months earlier than the expected April 1990 date. The only significant delay occurred early in the project when the contractor decided to remove asbestos all at once rather than throughout the project. Of the 36 control milestones for the

project, General Electric completed 16 earlier and 20 later than planned. According to DOE and utility officials that we contacted, Shippingport did not provide any specific lessons learned that could reduce schedules for future decommissioning projects. However, some utility officials recognize the need for effective up-front planning as occurred with Shippingport.

4. How has the project benefited the nuclear power industry? Has Shippingport identified areas for cost reductions in future decommissioning projects?

The transferability of the lessons learned from Shippingport to the commercial nuclear power industry varies depending on the needs of the individual contacted. The most significant benefit, according to some utility executives, is DOE demonstrated that technology exists to decommission a plant within the costs and time frame established. Others believe that only minimal benefits have been derived because DOE removed the reactor pressure vessel in one piece and did not use any new technology, such as robotics. Still others indicated that the value of Shippingport will decrease over time.

Currently, 11 commercial plants have been shut down, and the licenses for about one-half of the 113 operating plants will most likely not expire until the year 2015. Most of the remaining licenses will expire by about 2030. Prior to that, utilities will decide whether to shut the plants down or seek a license extension from NRC. NRC currently expects that the license extension period will be 20 years. Also, under NRC's regulations, utilities can take as long as 60 years to complete decommissioning activities. Therefore, many years may elapse before utilities begin to decommission a large number of plants.

Utility officials identified a few areas in which Shippingport may allow them to reduce future decommissioning costs. The areas cited include planning and scheduling, removing asbestos, and removing hazardous waste. The officials could not, however, estimate the savings that could be realized.

5. As a result of the Shippingport project, can the site be released for unrestricted use?

In October 1989 DOE certified that the site met the release criteria that had been established for Shippingport. DOE had required that public

exposures from the remaining contamination should not exceed 100 millirem[1] a year, and the level should be reduced if reasonably achievable to do so. DOE documentation indicates that public exposures will be less than 2 millirem annually. DOE contracted with the Oak Ridge Associated Universities (ORAU) to confirm its analyses. ORAU found some contaminated areas, and General Electric conducted additional cleanup activities to ORAU's satisfaction. In its November 1989 report, ORAU indicated that DOE had effectively decontaminated and decommissioned the site.

6. Has Shippingport validated NRC's decommissioning regulations?

Little relationship exists between NRC's decommissioning regulations and the Shippingport project. NRC's regulations primarily address decommissioning planning needs, timing, funding methods, and environmental review. The intent of NRC's regulations is to ensure that utilities decommission nuclear power plants in a safe and timely manner and that adequate funds will be available to conduct the needed activities. Shippingport's costs cannot be used to validate NRC's generic estimate—$105 million for a pressurized water reactor—because utilities will not be able to use the same methods and management structure that DOE used.

For example, most utilities will not be able to dispose of their reactor pressure vessels in one piece and will experience significantly higher low-level waste disposal costs than the $2.4 million (including the pressure vessel) that DOE incurred for Shippingport. Further, utilities will probably have to dispose of some greater-than-Class C waste. Shippingport, according to DOE officials, did not generate such waste. Because of these and other differences, Shippingport cannot be used to validate some of the costs that utilities will experience when decommissioning large plants.

In addition, Shippingport was not licensed by NRC; therefore, DOE did not have to obtain NRC's approval for the decommissioning activities conducted at the plant. Further, no federal agency or utility official that we contacted could identify any changes that should be made to NRC's regulations as a result of Shippingport.

We noted, however, that DOE set a 100 millirem per person per year residual contamination limit for Shippingport. NRC has been suggesting

[1]A millirem is a thousandth of a rem (Roentgen Equivalent Man), which is the measurement used to quantify the effects of radiation on man.

that utilities decontaminate to a level that would limit public exposures to 10 millirem a year—10 times less than DOE required. Ultimately, the Environmental Protection Agency (EPA) is responsible for setting the limits of residual contamination that can remain on-site. EPA has been developing such standards for several years but does not expect to make them final until 1993 at the earliest.

7. What changes should be incorporated in planning future decommissioning projects as a result of Shippingport? How should decommissioning plans incorporate improved methods to reduce worker exposures?

DOE spent over $6 million developing a decommissioning plan for the project. According to a DOE official, the planning conducted helped the project to be completed on time and under cost and allowed them to keep worker exposures within established limits. In the decommissioning plan, DOE's contractor proposed a worker exposure limit of about 1,010 person-rem for the project; the actual exposure was 155 person-rem. In addition, DOE completed the project without any serious radiological incidents, according to officials. Utility executives that we contacted said the lessons learned from DOE's planning efforts could facilitate their planning for future decommissioning projects.

However, Shippingport provided only limited information to reduce worker exposures on future projects where the pressure vessel would be cut-up. Shippingport was more radiologically clean at the start of decommissioning than could be expected for a much larger commercial plant (1,000 megawatts or greater). Also, DOE removed the most highly radioactive component—the reactor pressure vessel—in one piece.

8. What specific examples exist showing that Shippingport's technology transfer activities influenced other decommissioning projects, such as Three Mile Island? What special equipment did DOE use at Shippingport?

With the exception of Northern States Power that plans to remove the pressure vessel from Pathfinder in one piece, specific examples showing that Shippingport influenced other decommissioning projects do not exist. DOE developed extensive information on Shippingport, but the usefulness of the data will diminish the longer utilities wait to decommission their plants.

In addition, DOE did not develop any new technology, such as remotely operated equipment or robotics, to decommission Shippingport because

one of the project's objectives was to demonstrate that a nuclear plant could be safely and economically decommissioned using existing technology. Further, some of the lessons learned from the cleanup of the damaged Three Mile Island plant may be more useful to utilities than Shippingport.

9. Did DOE use information developed overseas to plan for, and decommission, Shippingport?

According to DOE officials, foreign countries did not provide any information that was used to help with decommissioning Shippingport. Although Japanese officials discussed their research and development projects with DOE, the agency determined that these activities were not cost-effective because of the exotic robotic techniques that were involved. A DOE official further said that he was aware of other international decommissioning projects, but the information was not applicable because the purpose of Shippingport was to demonstrate decommissioning techniques using present technology. However, foreign nationals from Japan, United Kingdom, and other countries participated in some of Shippingport's decommissioning activities. In addition, through its technology transfer program, DOE has provided both domestic and international utilities a great deal of information about the project.

Case Studies on Four Nuclear Power Plants

Pathfinder

Pathfinder, a 62-megawatt boiling water reactor[1] owned by Northern States Power Company, operated from 1964 to 1967. The plant, located about 6 miles from Sioux Falls, South Dakota, was shut down after investigations disclosed serious flaws with some components within the reactor pressure vessel. During its limited life, Pathfinder operated for about 12,000 hours, generating about 0.1-billion kilowatt-hours of electricity. At the time the plant was shut down, the radioactivity in the pressure vessel was about 30,000 curies.

Northern States started to decontaminate the plant in 1968 after removing the fuel and shipping it off-site. The utility also removed almost all contaminated pipe outside the reactor and fuel handling buildings and drained and filled the reactor pressure vessel with gravel. The utility did not decontaminate the piping system inside the reactor building or remove any of the pipe. After partially decontaminating the reactor and fuel handling buildings, Northern States sealed the areas to prevent unauthorized access.

In 1990 Northern States expects to begin decontaminating the previously sealed areas. The utility plans to dispose of most low-level radioactive waste, including the reactor pressure vessel and the shipping package, at a commercial site operated by U.S. Ecology in Richland, Washington. Because of the weight (78 tons) and size (12 feet x 32 feet) of the pressure vessel and the shipping package, the utility plans to rent a special rail car and train to transport it.

Company officials said that the decontamination activities completed in the 1960s represented about 25 to 35 percent of the plant's decommissioning and estimate that the total decommissioning costs will be about $20 million. According to these officials, Shippingport is more relevant to Pathfinder than other plants because the size and radioactivity levels are very comparable. They said that they will use the lessons learned from Shippingport to decontaminate and remove Pathfinder's pressure vessel. Northern States officials said that very little new knowledge was gained from Shippingport, but the knowledge gained through topical reports, seminars, feedback from contractors that participated in the project, and other information they requested confirmed that the method they selected to decommission Pathfinder is valid. They also stated that the nuclear industry, in general, could not use this same method to decommission other plants.

[1]Boiling water reactors are cooled by water that is allowed to boil as it passes through the nuclear fuel. The water is used directly to produce the steam that generates electricity.

Fort St. Vrain

Fort St. Vrain, a 330-megawatt high-temperature gas-cooled reactor, is owned and operated by the Public Service Company of Colorado. The plant, located about 35 miles north of Denver, began commercial operations in 1979. In August 1989 the utility shut the plant down after years of operating problems. During its life, Fort St. Vrain operated for about 21,360 hours, generating about 4.3-billion kilowatt-hours of electricity. At the time the plant was shut down, company officials estimate that the reactor contained about 900,000 curies of radioactive contamination.

Fort St. Vrain is different from Shippingport and the other 112 domestic nuclear power plants. For example, the plant used graphite to control the rate of fission inside the reactor pressure vessel whereas Shippingport and the other plants generally use water. Also, the fuel used in Fort St. Vrain differed from that used in Shippingport and other plants.

In November 1989 the utility began removing the spent fuel and had planned to send it to DOE's Idaho National Engineering Laboratory. However, the governor of Idaho ordered a halt to the shipments, and the company is now storing the fuel pending consideration of other such options as building a spent fuel facility. Public Service has not selected its final decommissioning option, but the company has requested proposals to determine the methods to be used and costs to dismantle the plant. According to the company's 1989 preliminary decommissioning plan, the costs for safestore would be around $81 million because the plant is relatively radiologically clean. Currently, the utility expects to convert Fort St. Vrain to a gas-fired plant.

These officials also stated that Shippingport provided useful information to plan, manage, and dismantle Fort St. Vrain as well as methods to control the spread of contamination during the physical decommissioning of the plant. Nevertheless, they also noted several significant differences between Shippingport and their plant. Of foremost importance was the small size of Shippingport and the removal of the reactor pressure vessel in one piece—an option that cannot be used for Fort St. Vrain.

Peach Bottom Unit 1

Peach Bottom Unit 1, a 40-megawatt prototype high-temperature gas-cooled reactor, is located about 80 miles southwest of Philadelphia. The plant, owned by the Philadelphia Electric Company, operated from June 1967 until October 1974. During the 7-year period, the plant operated for about 32,375 hours, generating about 1.4-billion kilowatt-hours of

electricity. At the time the plant was shut down, the radioactivity in the pressure vessel was more than 3 million curies.

Philadelphia Electric decided to safestore the facility and started to decontaminate the site in January 1976. The company completed these activities in February 1978, using about 179 person-months of labor, at a cost of about $3.5 million. The utility removed all radioactive liquids, drained refrigerants and cooling water,[2] and sent the spent fuel to DOE's Idaho National Engineering Laboratory. The company left the reactor vessel, piping systems, and steam generators in the plant, and officials estimate that they will not start to remove these components or otherwise decommission the plant for about 20 more years.

At that time, company officials said they would review the Shippingport information to determine whether they could apply it to Peach Bottom. These officials also noted that the usefulness of the Shippingport information will most likely decrease over time as new technology is developed.

Rancho Seco

Rancho Seco, a 913-megawatt pressurized water reactor, located about 25 miles southeast of Sacramento, California, is owned and operated by the Sacramento Municipal Utility District (SMUD). On June 7, 1989, SMUD shut down the plant in response to a voter referendum to close the plant. During its lifetime, Rancho Seco operated for about 51,595 hours and generated about 44-billion kilowatt-hours of electricity. Company officials estimate that the amount of radioactivity in the plant at shut down exceeded 9 million curies.

In 1987 SMUD completed a generic cost study for the plant and expects to submit a revised decommissioning plan to NRC by July 1991. The 1987 study showed that immediate dismantlement of both radioactive and nonradioactive structures ($210 million) would be less costly than mothballing the plant ($265 million). SMUD began to remove the fuel from the plant on November 28, 1989, and place it in an on-site storage pool. In addition, SMUD tried to sell the plant but was not successful in finding a buyer. Company officials told us that they may wait up to 50 years before dismantling the plant.

[2]Liquid or gas circulated through a nuclear reactor to remove or transfer heat. Some coolants are water, heavy water, carbon dioxide, liquid sodium, sodium-potassium alloy, and helium.

Nevertheless, they believe that the Shippingport experience will be helpful to them, particularly the asbestos removal report. According to SMUD officials, although about 60 percent of the information learned from Shippingport was either new or useful to them, they also cited numerous differences between Shippingport and Rancho Seco. For example, decommissioning Rancho Seco will generate greater-than-Class C waste—even if the plant is mothballed for 50 years; Shippingport generated no such waste, according to DOE officials. Also, low-level waste disposal costs for Shippingport were about $2.4 million (1986 dollars), whereas SMUD estimates that such costs for Rancho Seco will be about $24 million (1986 dollars). Furthermore, SMUD cannot remove, ship, and dispose of the Rancho Seco pressure vessel in one piece as DOE did at Shippingport.

SMUD officials did not believe that Shippingport demonstrated the cost-effective decommissioning of a large commercial nuclear plant because Shippingport was smaller, was relatively radiologically clean, and did not have to comply with NRC's requirements. Also, all waste from Shippingport was sent to a DOE facility, and the disposal costs were so low that the situation is not comparable to the nuclear industry. SMUD officials said that today low-level radioactive waste disposal costs for commercial nuclear plants are at least 10 times higher than those incurred by Shippingport.

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