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Lecture #1C

"An Overview of U.S. Decommissioning Experience - A Basic Introduction"

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ABSTRACT

This paper presents an overview of the U.S. experiences in the decommissioning technical area. Sections included are: (1) an overview of the magnitude of the problem, (2) a review of the U.S. decommissioning process, (3) regulation of decommissioning, (4) regulatory and funding requirements for decommissioning, and (5) a general overview of all on-going and completed decommissioning projects to date in the U.S. The final section presents a review of some issues in the decommissioning area currently being debated in the technical specialists community.

1. INTRODUCTION

This paper presents an overview of the United States (U.S.) decommissioning experience for all types of nuclear facilities. It also presents an overview of some technical and management issues for the future direction of decommissioning in the U.S. at both Nuclear Regulatory Commission (NRC) and Department of Energy (DOE) regulated facilities. This paper will cover the broad area of U.S. decommissioning experience and other papers/lecturers will cover more detailed information on several types of nuclear facilities and specific facilities that have been decommissioned.

2. MAGNITUDE OF THE PROBLEM

The U.S. decommissioning experience has evolved from two principal sources: 1) the U.S. DOE (and its predecessor agencies) research and development (R&D) program and nuclear weapons production efforts, and 2) the U.S. commercial nuclear power industry and radioactive material users industry regulated by the U.S. NRC.

While many of the large DOE R&D programs that used the nuclear facilities in the past have gradually reduced their funding of various programs, the by-products of their research remain to be dealt with - namely, the decommissioning of these facilities. While many of the NRC regulated facilities will most likely continue well into the new millenium with their licensed activities, some of these are also likely to shutdown with time and will ultimately require decommissioning. As a result of the U.S. pioneering program in the nuclear field, we already have considerable expertise in the decommissioning area. There has been fairly good execution of these decommissioning projects with only a few surprises experienced along the way. Lets first take a look at the magnitude of the situation both worldwide as well as in the U.S.

If you want to see the magnitude of the decommissioning problem in the world community of research reactors you only need to look at the data presented below. In the U.S. alone nearly 75% of the operating research reactors are over 31 years old using an assumed 40 year operating life for a research reactor. Further evaluation of this figure shows that about 50% of these reactors are over 35 years of age. This trend is not only a problem here in the U.S., but is a worldwide trend.

Worldwide Status of Research Reactors - December 1996

Area	Operating	Under Construction	Planned	Shutdown
North America	74	2	0	168
Western Europe	69	1	0	92
Eastern Europe	45	3	2	15
Asia - Pacific	54	3	2	13
Latin America	18	0	0	4
Africa - Middle East	13	3	3	3
Totals	273	12	7	295

Over 50% of the operating research reactors worldwide are over 30 years of age.

Worldwide Age Distribution for Operating Research Reactors

Age (years)	Percent
1-9	8.8
10-19	13.6
20-29	23.9
30-39	51.5
40-45	2.2

In the U.S. specifically, as of January 1, 1998, the age of the operating research reactors can be broken down as follows:

U.S. Age Distribution for Operating Research Reactors

Age (years)	Number of Reactors
<20	2
20-30	9
31-35	11
36-40	15
>40	5

The U.S. nuclear R&D community is likely to continue to see a decline in the number of operating research reactors unless some significant steps are taken to reinforce support for the continued operation of these facilities. Research budgets decline or may be re-focused on other programs resulting in the closure of some reactors. Those reactors or nuclear facilities that do continue to operate may be more financially strapped. This situation has caused many universities and other reactor operators to carefully consider continued operation of their reactors. The current annual fee for a research reactor is about $57,000 - for a commercial nuclear power plant it is about $3,000,000. As operating margins are squeezed, sometimes these are difficult costs to continue to fund.

In the U.S. there are two nuclear facility regulatory bodies, the U.S. Department of Energy and the U.S. Nuclear Regulatory Commission. Both of these bodies regulate the use of radioactive materials and the operation of nuclear facilities including decommissioning. The USDOE is responsible for DOE managed sites and the USNRC is responsible for all other sites. Lets first review the general decommissioning process.

3. THE U.S. DECOMMISSIONING PROCESS

In the United States at both DOE and NRC regulated sites, the same general sequence of steps are used for decommissioning. These are: safe shutdown, site or facility characterization, decommissioning planning/engineering, field operations, final radiation survey, and final project close-out. Most of these items are self-explanatory as to what they encompass, therefore, I will not go into further detail here. All of these activities will be covered in detail in lectures presented during the training course.

The operator of the facility will evaluate the options for decommissioning and proceed down the selected path interacting with the regulators and the public to status them on the work progress.

The regulator will need to be advised of the planned activities in the decommissioning of the nuclear facility. A decommissioning plan is usually required and submitted to the regulator for their review, and approval. As the project progresses, the regulator is periodically briefed on the progress of the decommissioning work programs and inspections may be performed. The public may also be briefed due to an interest in on-going work at the site and its effects on their daily lives.

Once the work is completed, a final project report is prepared and a final radiation survey performed on the site. Following the submittal of this documentation, the regulator may elect to perform an independent verification survey to ensure compliance with radiological clean-up criteria prior to a authorizing release of the site and license termination. License termination signifies formal closure of the decommissioning activity.

4. REGULATION OF DECOMMISSIONING

The decommissioning process (as is the operations process) is a dual-regulated activity in the U.S. depending on who owns the facility. Under provisions of the Atomic Energy Act of 1954 (as amended) the Department of Energy (and its predecessors) have regulatory responsibilities for all DOE sites. All other nuclear facilities (including other government agencies and departments as well as privately owned ones) are regulated under the auspices of the NRC. The NRC was established in 1974 as an independent agency of the U.S. government. The enactment of the Energy Reorganization Act of 1974 gave birth to the NRC while maintaining the original DOE regulatory role for its facilities. The NRC mission is to ensure adequate protection of the public health and safety, the common defense and security, and the environment in the use of nuclear materials in the United States. Its scope of responsibility includes regulation of:

- Commercial nuclear power reactors; nonpower research, test, and training reactors,
- Fuel cycle facilities; medical, academic, and industrial uses of nuclear materials,
- The transport, storage, and disposal of nuclear materials and waste.

The DOE was granted its authority under the Atomic Energy Act of 1954. This arrangement of regulatory authority continued through the mid-1990's and still continues today. In general, DOE manages its facilities with the same responsibilities as the NRC, only its regulatory basis is different . However, there is a possible change on the horizon to this dual regulatory system. In the mid-1990's, the U.S. Congress proposed immediate transfer of the DOE regulatory authority to the NRC for all DOE facilities. As an alternative to this, the DOE established a "Working Group on External Regulation" to recommend to the Secretary of the DOE an appropriate course of action. After reviews and much debate, the Working Group recommendations were: (1) NRC should be the external nuclear safety regulator and (2) the transition to NRC regulation should be phased - in over several years. A pilot program was established in 1997; the first pilot project (Lawrence Berkeley National Laboratory) is underway today.

State governmental organizations vary in the level of active participation in decommissioning projects being performed within their states. In some states, depending upon the facility operating history, there may be a high level of interest in the plans for and the states input into the planning process. In other cases, usually due to a good established relationship at the working level with the facility operators, there may be merely an informational exchange or informal type of rapport between the operators and the regulatory body. However, at other sites there may have been past operating incidents (i.e., releases, non-compliances, non-cooperative fronts) that may cause the state regulators to take significant interest (to the point of binding written agreements of due dates for various documents, actions, and resulting penalties for non-compliances). This is a highly variable component and the staff and management must clearly understand

what the expectations of the state regulatory body are and what their wishes are relative to involvement in the decommissioning process.

5. GENERAL REGULATORY REQUIREMENTS AND FUNDING FOR DECOMMISSIONING

The NRC has established regulations and guidance on research reactor and nuclear power plant decommissioning. These generally address provisions for funding decommissioning and submission of a decommissioning plan to the regulator. There are regulatory guides and policies for decommissioning activities which deal with standard format and content of plans and use of decommissioning funds. The NRC has specific requirements for the filing of decommissioning plans with their offices prior to either license termination or expiration and a premature shutdown.

Prior to any decommissioning activity, the NRC will issue a decommissioning order to allow for work to proceed. NRC performs inspections during decommissioning which are consistent with its "Inspection Manual" guidelines. At the completion of the decommissioning and prior to license termination the NRC will have an independent site radiation survey performed to verify that the decommissioning clean-up criteria have been achieved by the licensee. Then the NRC will issue an order terminating the license and releasing the site.

Prior to the early 1990's, the early phases of decommissioning activities were handled and approached by power plant operators as a major maintenance-type activity typical of a routine plant outage. However, due to some concerns raised by several concerned parties, the NRC changed the regulations to require a public hearing, a Post-Shutdown Decommissioning Activities Report, and a review of the proposed decommissioning activity before any work to permanently terminate plant activities are allowed to proceed. This provided the regulator and the public a mutually agreed to "hold point." The decommissioning of research reactors follows a slightly less rigorous regime.

The USDOE uses an analogous approach to regulating its decommissioning process, as well as the routine operation of its nuclear facilities. A series of DOE Directives, Technical Standards, and Implementation Guides serve to direct the decommissioning phase of various DOE nuclear facilities.

Funding for commercial nuclear power plant decommissioning comes from a separate decommissioning fund which is set aside by the utility and monitored by the regulator to ensure that funds are accrued to support the eventual decommissioning of the facility. A similar arrangement is in place for corporate and private university operated research reactors. State operated research reactors (at universities) are allowed to stipulate that funds will have to be authorized by the state government to fund decommissioning of the reactor at the time of its shutdown.

6. COMMERCIAL REACTOR DECOMMISSIONING

In the remainder of this paper, U.S. decommissioning experiences are reviewed in the research reactor area, the commercial nuclear power plant areas, and other nuclear related/decommissioning areas. I will point out here that later in the Training Course, there will be a lecture specifically on U.S. research reactor decommissioning experiences and there will be other detailed case studies at specific sites by several site representatives, so here, I will try to only summarize these experiences. I may be a little more detailed in my description of some of the experiences in decommissioning of commercial nuclear power plants. One experience common to all decommissioning practitioners is - they designed these reactors to be efficiently operated - not efficiently or easily decontaminated and decommissioned. There are lots of valuable lessons learned from the completed decontamination and decommissioning that should be incorporated into future designs.

Over the years leading up to the beginning of routine decommissioning projects, little general guidance or specific documented experiences existed in the literature for the operator to use in planning the decommissioning of a specific facility. Then during the late 1970's and early 1980's (see Appendix A) a series of studies were performed by the Pacific Northwest Laboratory (PNL) for the U.S. Nuclear Regulatory Commission (USNRC) which were intended to provide a review of the technical, safety, and cost details for the eventual decommissioning of a number of typical nuclear facilities. These were somewhat of what could be called "Benchmark Studies" since the NRC used these "conceptual" benchmarking decommissioning studies to modify existing regulations and to develop new regulations pertaining to nuclear facility decommissioning. Pacific Northwest Laboratory updated the earlier studies to reflect the impacts of some current events with relevance to decommissioning. The results of these studies provided the USNRC with the necessary technical support for preparation of its Final Decommissioning Rule and also provided updated information for the Final Generic Environmental Impact Statement on Decommissioning. In addition, this information compiled in these reports has proven to be useful to numerous licensees in planning for the decommissioning of their facilities. These reports are listed in Appendix A for your information.

Although no large commercial reactors have undergone complete decommissioning yet, (see Table 1) decades of experience in dismantling small experimental and commercial reactors, combined with experience performing major plant upgrades and repairs of large operating units, suggests that decommissioning large commercial nuclear power can be mostly accomplished using existing technologies. Most of the technologies routinely used are the same ones used for demolishing other industrial facilities and buildings and include torches, saws, milling machines, and controlled explosives. If waste disposal options are limited or absent, then more advanced technologies may be desirable to allow for the maximizing of waste segregation. Many shutdown commercial nuclear power plants are the results of premature plant life cessation. Limited experience in decommissioning has shown that decommissioning presents no unusual hazard either to

the work force or to the public in the conduct of the decommissioning process. The NRC reviews each proposed reactor decommissioning plan on a case-by-case basis using technical guidelines. The commercial nuclear power plant industry gained the majority of its experience from decommissioning two demonstration plants - Shippingport and Pathfinder. To date the largest commercial nuclear power plant to be fully decommissioned (i.e., greenfield) is the 72 MW Shippingport pressurized water reactor. No large reactors have been fully decommissioned yet and the few reactor decommissionings performed to date offer little indication of the potential costs for future large reactor decommissioning projects because of their low contamination levels and small size.

Elk River Reactor

The Elk River Reactor was shutdown in 1968 after four years of operation. Dismantlement started in 1971 and was completed in 1974 at a cost of $6.15 million. The site was released for unrestricted re-use.

Sodium Reactor Experiment

The Sodium Reactor Experiment was operated over a seven year period that ended in 1964. Dismantlement was started in 1976 and was completed in 1983 at a total cost of about $16.6 million.

Pathfinder

The Pathfinder nuclear power plant operated for only a two year period - 1965 to 1967 - and was then shutdown due to a condenser tube leak. Final dismantlement operations started in 1989 and were completed in 1991.

As previously mentioned, all of these plants were relatively small units, operated for relatively short periods and contained far less contamination than the large commercial nuclear power plants yet to be decommissioned.

Shippingport Decommissioning

The Shippingport decommissioning has received to date the most international attention of any U.S. nuclear power plant dismantlement project. The plant was owned by the U.S. Government but was operated by Duquesne Light Company. The reactor went critical in 1957 and operated for the next 25 years. The dismantling was commenced in 1985 and completed in 1989 at a total cost of just over $91 million.

Table 1

Retired Commercial Nuclear Power Plants in the United States and Their Decommissioning Status

Plant	Design rating and type	Operating license issued	Shut Down date	Decommissioning approach and status
Pathfinder	66-MW BWR	1964	1967	DECON completed 1991.
Shippingport	72-MW PWR	1957	1982	DECON completed 1989.
Elk River	22-MW BWR	1962	1968	DECON completed 1974.
Trojan	1,155-MW PWR	1975	1993	DECON in progress.
San Onofre Unit 1	436-MW PWR	1967[b]	1992	Decommissioning planning in progress.
Haddam Neck	560-MW PWR	1967	1996	Decommissioning plan under development,
Yankee Rowe	175-MW PWR	1961[b]	1992	DECON in progress.
Rancho Seco	918-MW PWR	1974	1989	SAFSTOR.
Shoreham	820-MW BWR	1989	1989	DECON completed 1995.
Fort St. Vrain	330-MW HTG	1973	1989	DECON completed 1996.
La Crosse	48-MW BWR	1967	1987	SAFSTOR.
Three Mile Island Unit 2	926-MW PWR	1978	1979	Monitored storage; plant shutdown in 1979 due to reactor accident.
Dresden Unit 1	200-MW BWR	1959	1978	SAFSTOR.
Humboldt Bay Unit 3	65-MW BWR	1962	1976	SAFSTOR.
Indian Point Unit 1	265-MW PWR	1962	1974	SAFSTOR.
Peach Bottom Unit 1	40-MW HTG	1966	1974	SAFSTOR.
Fermi Unit 1	61-MW SCF	1963	1972	SAFSTOR.
Bonus	17-MW BWR	1964	1968	ENTOMB.
Carolinas-Virginia Tube Reactor (CVTR)	17-MW PTHW	1962	1967	SAFSTOR.
Piqua	11-MW OCM	1962	1966	ENTOMB completed 1969.
Hallam	75-MW SCGM	1962	1964	ENTOMB completed 1968.
Vallecitos	5-MW BWR	1957	1963	SAFSTOR.
Sodium Reactor Experiment	10-MW SCGM	1957	1964	DECON completed 1983.
Saxton	3-MW PWR	1962	1972	DECON in progress.

[b]Due to a delay in the issuance of the formal operating licenses, the date of initial commercial operation is given here instead.

KEY: BWR = boiling water reactor; HTG = high-temperature gas-cooled reactor; OCM = organic-cooled and moderated; PTHW = pressure tube, heavy water reactor; PWR = pressurized water reactor; SCF = sodium-cooled, fast reactor; SCGM = sodium-cooled, graphite-moderate reactor.

Fort St. Vrain Decommissioning

The Fort St. Vrain high temperature, gas cooled reactor owned by Public Service Company of Colorado operated for a 10 year period from 1979 to 1989. Due to a combination of factors, a decision was made to permanently shutdown in 1989. Over the period 1991-1995, plant decommissioning (nuclear portion only) was performed at a cost of $189 million. The plant has subsequently been converted to a natural gas fueled power generating station re-using the formerly nuclear powered turbine system.

Shoreham Reactor

The Shoreham Reactor was operated intermittently at low power between 1985 and 1987, and was permanently shutdown in 1989. The plant dismantlement started in January 1992 and was completed in December 1994 at a cost of $181 million.

TMI-Unit 2 Reactor

The TMI Unit 2 was a 906 MW pressurized water reactor which operated only for about 1 year prior to a partial core meltdown on March 28, 1979. The operating utility, General Public Utilities (GPU) Nuclear placed the facility into a monitored storage condition pending the eventual shutdown of TMI-Unit 1.

Rancho Seco

The Rancho Seco pressurized water reactor was rated at 873 MW and operated for 15 years before its shutdown in 1989, due to a local referendum on the plants operation. The facility is currently in SAFSTOR.

Yankee Rowe

This 185 MW pressurized water reactor operated for a period of 31 years when it was officially shutdown in 1992, 8 years before its operating license was due to expire. Work is nearly 80% complete now at the plant with full unrestricted site release being the decommissioning objective.

Trojan

The Trojan nuclear power plant is the largest plant to shutdown to date - a 1175 MW pressurized water reactor. The Unit had operated for about 17 years (1975-1992) but had been off-line in its latter years due to steam generator tube leaks. The operating utility, Portland General Electric elected to shutdown the plant and forego the costly steam generator replacement needed to keep the plant operational. Some large component removal activities have been performed with DECON as the selected decommissioning mode.

San Onofre

The San Onofre Nuclear Generating Station (SONGS) Unit 1 operated from 1968 until 1992 when the licensee Southern California Electric permanently retired the plant. The plant is currently in SAFSTOR condition.

Zion

The Zion Station is comprised of two 1085 MWe four loop pressurized water reactor units and is situated near Lake Michigan north of Chicago, IL. Both units started commercial operation in late 1973 and were permanently shutdown in 1996 (#2) and 1997 (#1). The Zion station shutdown was based on economics - operating costs, the amount of power it was expected to produce, and the cost of the power in a deregulated U.S. electrical market. The units will be placed in a "secured mode" until 2014 when final station decommissioning is planned.

Additional and potentially important experience will be gained from future D&D of Federal nuclear remediation programs associated with former weapons complex and surplus research programs related facilities. Areas of potential benefit include decontamination, waste minimization, and radiation protection. Additional experience will be gained from other clean-up activities in the DOD (formerly DOE) FUSRAP Program covering former nuclear processing facilities and the NRC Site Decommissioning Management Plan (SDMP) for select nuclear materials sites.

7. RESEARCH REACTOR DECOMMISSIONING

As presented earlier, much of the decommissioning experience here in the U.S. is from decommissioning of research reactors at universities and DOE sites. A sampling of some of the non-power producing reactors decommissioned to various degrees is presented in Table 2. Over the last 50 years, the DOE owned sites designed, built, and studied numerous methods of power generation and numerous test facilities for research programs focusing on commercializing the nuclear technology. The academia community has used many similar facilities for R&D programs of interest to their research staff. Since 1960, more than 40 research reactors (less than a watt to 256 MW) have been retired most of them relatively small units. Many of these research reactors were located at universities (such as the University of Kansas Research Reactor and the UCLA Research Reactor) and others were located at DOE R&D nuclear technology R&D sites (Idaho National Engineering and Environmental Laboratory, Argonne National Laboratory, Ames Laboratory, and Santa Susana Field Laboratory). There has also been a number of other reactors that do not fall in either of these grouping which have been decontaminated and decommissioned. These include: military research reactors (Army Material Research Reactor) and corporate research reactors (Cintichem and Northrop).

All of these reactors were decommissioned under the applicable NRC or DOE regulations to ensure safe, economic, and timely decommissioning of these facilities. Nearly all of

this work was performed using standard 'off-the-shelf' available tools and technologies. As I mentioned earlier, several of these will be presented as case studies by speakers later in the Training Course.

Ultra-High Temperature Reactor Experiment (UHTREX) Reactor

The Ultra-High Temperature Reactor Experiment (UHTREX) Facility was constructed in the late 1960's at Los Alamos National Laboratory in Los Alamos, New Mexico. The reactor operated to demonstrate the high temperature, gas cooled reactor technology, but was shutdown in 1970 after operating for only about one year.

Decommissioning began in 1988 and was completed in 1990. The general approach was to remove all contaminated components and equipment, decontaminate surfaces, remove other non-contaminated equipment to allow for the facility to be re-used. The reactor vessel was removed in one piece and transported to an on site disposal facility.

The DOE funded this work at a total cost of $2.9 million U.S. dollars. The cost breakout was:

Characterization	17%
Management	34%
Decontamination/Dismantling	46%
Documentation/Restoration	3%

Ames Laboratory Research Reactor

The Ames Laboratory Research Reactor operated from 1966 to 1977 on the Iowa State University campus in Ames, Iowa. Heavy water was used as the coolant and moderator. Decommissioning of the reactor started in 1978 and was completed in 1981.

The DOE funded this work at a total cost of about $4.3 million U.S. dollars. The cost breakout was:

Decontamination/Dismantling	$2.3 M	52%
Management Staff	$1.2 M	28%
Waste Management	$0.6 M	14%
Site Restoration	$0.2 M	6%
	$4.3 M	

Table 2

Sampling of Non-Power Producing Reactors Decontaminated and Decommissioned

Reactor	Status	Operator	Year D&D Completed
Army Material Research Reactor (AMRR)	DECON	US Army	1993
JANUS Reactor	DECON	Argonne National Laboratory	1997
Experimental Boiling Water Reactor (EBWR) Facility	DECON	Argonne National Laboratory	1996
Chicago Pile #5 Research Reactor	DECON	Argonne National Laboratory	*
Saxton Nuclear Experimental Reactor	SAFSTOR	General Public Utilities (GPU) Nuclear	*
Cintichem Reactor	DECON	Hoffman-LaRoche	1997
Organic Moderated Reactor Experiment (OMRE)	DECON	Idaho National Engineering and Environmental Laboratory	1979
Ames Laboratory Research Reactor	DECON	Iowa State University	1980
Special Power Excursion Reactor Test (SPERT) Reactors	DECON	Idaho National Engineering and Environmental Laboratory	1970's-1980's
Boiling Reactor Experiment (BORAX-V) Facility	DECON/ ENTOMB	Idaho National Engineering and Environmental Laboratory	1992
Air Force Nuclear Engineering Test Reactor	ENTOMB	U.S. Air Force	-----
Northrop Corp. TRIGA Mark F Reactor	DECON	Northrop Corp.	1986
Air Force Ground Test Reactor	DECON	U.S. Air Force	1974
Ultra High Temperature Reactor Experiment (UTHREX)	DECON	Los Alamos National Laboratory	1990
Michigan State University Research Reactor	DECON	Michigan State University	1990
University of California-Los Angeles Research Reactor	DECON	Univ. of California at Los Angeles	1993
University of California-Berkeley Research Reactor	DECON	Univ. of California at Berkeley	1991
University of Kansas Research Reactor	DECON	University of Kansas	1993
Georgia Institute of Technology Research Reactor	DECON	Georgia Tech.	*
University of Washington Research Reactor	DECON	University of Washington	*
Sandia Engineering Reactor	DECON	Sandia National Laboratory	-------
Shield Test and Irradiation Reactor (STIR)	DECON	Santa Susana Field Laboratory	1975
Southeast Fast Oxide Reactor (SEFOR)	SAFSTOR	USDOE/Univ. of Arkansas	-------
Lynchburg Pool Reactor (LPR)	DECON	Babcock &Wilcox	1982
Virginia Polytechnic Institute Research Reactor	DECON	Virginia Polytechnic Institute	1988
Walter Reed Research Reactor (WRRR)	DECON	Walter Reed Medical Center	1972
Westinghouse Nuclear Training Reactor	DECON	Westinghouse	1988
Numerous AGN-201/211 and L-77 reactors.	DECON	Universities	-------
Over 70 nuclear submarine reactor compartments buried.	DECON	U.S. Navy	-------
N/S Savannah	SAFSTOR	U.S. Government	1970's

* = decommissioning in progress.

JANUS Reactor

The JANUS Reactor operated on the Argonne National Laboratory (ANL) Site near Chicago, IL from 1963 through 1992. JANUS was a 200 kW heterogeneous light water moderated tank type reactor used for various biological research programs. Decommissioning started in late 1995 and was completed in late 1997 at a total cost of about $2.1 million U.S. dollars.

Surveillance and Maintenance	$250 K	12%
Decontamination and Dismantling	$925 K	44%
Waste Management	$170 K	8%
Management	$295 K	14%
Engineering	$250 K	12%
Characterization	$210 K	10%

Cintichem Reactor

The Cintichem Reactor operated initially under the ownership of Union Carbide Corporation for production of radioisotopes. The last owner was Cintichem who used it for the same purpose. The operating period for this pool-type research reactor was 1961-1990. The facility decommissioning started in 1990 and the project completed in 1997. Total cost was over $100 million. A detailed case study will be presented late in the training course on this project.

SNAP 8 Experimental Reactor (S8ER)

The SNAP 8 Experimental Reactor (S8ER) Facility was located at the Santa Susana Field Laboratories near Canoga Park, CA and was built for testing small compact or space type reactors under full power conditions. The reactor power rating was 550 kWt. The reactor and associated NaK systems were removed in 1965, just after research program work was terminated after 6 years at the facility. The decommissioning started in 1976 and was completed in 1978. The project cost was about $490 K including waste transport and disposal, all labor and all management costs. The area was released for unrestricted re-use.

8. USNRC SITE DECOMMISSIONING MANAGEMENT PLAN (SDMP) SITES

The USNRC has identified numerous sites (see Appendix B) contaminated with radioactive materials that require special attention to ensure timely decommissioning. The SDMP was established in 1990 to alleviate concerns expressed by the U.S. General Accounting Office which believed that the staff might not be applying a consistent strategy to ensure timely decommissioning of sites. These sites do not pose immediate threats to public health and safety, but the residual radioactivity levels exceed existing NRC criteria for site unrestricted release.

Most of these sites involve unique and difficult issues that will require special attention to ensure timely decommissioning. The NRC may place a facility on the SDMP Sites listing if the site has:

- Problems with the viability of the responsible organization (e.g., the licensee for the site is unable or unwilling to pay for decommissioning),
- Large amounts of soil contamination or unused settling ponds or burial grounds that may make the waste difficult to dispose of,
- The long-term presence of contaminated, unused buildings,
- A previously terminated license, or
- Contamination or potential contamination of the groundwater from on-site wastes.

As of October 1997, the SDMP site list contained 39 sites in 11 states. Since the SDMP program was started 21 sites have been removed and 20 subsequently added to the inventory.

With the resolution of generic policy issues related to consistent and timely decommissioning, these SDMP projects are now planned to be integrated into the other decommissioning projects within the NRC and will not be managed as a program per se.

9. LARGE COMPONENT MAINTENANCE/REMOVAL

Another area of the commercial nuclear power plant industry with implications in decommissioning is the large component maintenance activity. The closest many commercial nuclear power plant operators will come to decommissioning without being in a final shutdown condition is this type of an operation. Commercial nuclear power plant decommissioning projects performed to date have taken advantage of intact one piece removal of major components in decommissioning in a similar manner to that used in performing these maintenance activities. In the U.S. (as of December 1997) there have been about 20 successful commercial nuclear power plant steam generator replacement projects and there have also been numerous uses of this same technique in decommissioning specifically at Shippingport, Pathfinder, and Trojan.

Table 3

U.S. Commercial Nuclear Power Plant
Steam Generator Replacements

Plant	Number of Steam Generators/Reactor Unit	Work Period
Surry 1 and 2	3	1980-81
Turkey Point 3 and 4	3	1982-83
Point Beach 1	2	1984
Robinson	3	1984
Cook 2	4	1989
Indian Point 3	4	1989
Palisades	2	1991
Millstone 2	2	1993
North Anna 1 & 2	3	1993-1996
Summer	3	1994
Catawba-1	4	1996
McGuire 1&2	4	1997
Salem 1	4	1996-1997
Bryon 1	2	1998
St. Lucie 1	2	1998*
Braidwood 1	4	1998*

*Underway

10. U.S. NAVAL REACTORS DECOMMISSIONING

Beginning in the late 1950's, the U.S. Navy was building and operating a fleet of ships on which nuclear powered submarines played a critical defense role for the United States. Over the years since then, submarines, cruisers, and aircraft carriers have been deployed with nuclear powered propulsion systems.

Inactivation of Fleet Submarines

Late in 1992, the U.S. Navy established the Nuclear Powered Ship and Submarine Recycling Program (NPSSRP) at the Puget Sound Naval Shipyard. The program will eventually perform the scrapping and disposition of all U.S. Navy nuclear powered vessels. This process is normally done in 2 phases:

Phase 1: Vessel Stripping - The vessel is dry docked and all weapons, sensors, electronics, reusable equipment, hazardous and radioactive material, and nuclear fuel is removed. This work may be done at one of several U.S. Navy shipyards: Puget Sound (WA), Portsmouth (NH), Norfolk (VA), or Charleston (SC).

Phase 2: Reactor Vessel Removal and Vessel Scrapping - The vessel is dry docked and the reactor compartment is removed, the remainder of the vessel cut up into easily handled size pieces, and then appropriately disposed of as either clean or radioactive material. If decontaminated it is sold as scrap; if radioactive, it is handled and shipped to a radioactive waste disposal site. The reactor compartment is shipped intact to the DOE-Hanford Reservation for disposal at their burial ground. The trend of a reduced force level goal for naval submarines will continue to make this a very busy area of decommissioning. To date, 71 reactor compartments have been removed and sent to the burial grounds for disposal.

Prototypes

The U.S. Navy used several naval reactor prototypes located at the Idaho National Engineering and Environmental Laboratory near Idaho Falls, ID and at the Windor, CT and West Milton, NY training sites as training platforms for their personnel on operation of naval nuclear propulsion systems. Several of these prototypes are now undergoing dismantling and others are undergoing safe shutdown.

11. OTHER MILITARY REACTOR DISMANTLING

Over the years, other numerous U.S. military reactors have been dismantled after testing at U.S. military bases both in the U.S. and at foreign U.S. military bases. Several of these were prototypes used for training of naval reactor operators. Predominantly there were experimental power plants concepts that operated for only a short period and then were dismantled. Table 4 shows a summary of these reactors. Economic concerns over the operating costs of these reactors ultimately lead to their shutdown and eventual dismantling.

12. DOE REMEDIATION PROGRAMS

Deactivation Program

Some deactivation projects have grown out of the shutdown of the nuclear weapons production facilities and other facilities which are now surplus to the current mission of a site as a result of underutilization and/or privatization of some functions.

Table 4 Listing of Shutdown Military Reactors

Reactor	Reactor Type	Location	Operator	Operation Period	Status
Test and Research					
Aerospace Systems Test Reactor	(LWR)	Fort Worth, TX	U.S. Air Force	1954-1971	Decomm. in 1974
Ground Test Reactor	(Pool)	Fort Worth, TX	U.S. Air Force	1953-1973	Decomm. in 1974
Nuclear Engineering Test Reactor	(Tank)	Dayton, OH	U.S. Air Force	1965-1970	Decomm. (ENTOMB)
Army Materials Research Reactor	(Pool)	Watertown, MA	US Army	1960-1970	Decomm. in 1993
Diamond Ordnance Radiation Facility	(TRIGA)	Forest Glen, MD	US Navy	1961-1977	Decomm.
Naval Research Reactor	(Pool)	Washington, DC	US Navy	1956-1970	Decomm. in 1971
Walter Reed Research Reactor	(Homog.)	Washington, DC	US Navy	1962-1970	Decomm. in 1972
Electric Power Prototypes					
Stationary Low Power Plant #1 (SL-1)		Idaho Falls, ID	US Army	1958-1961	
Mobile Low Power Plant #1 (ML-1)		Idaho Falls, ID	US Army	1961-1965	
Gas Cooled Reactor Experiment (GCRE)		Idaho Falls, ID	US Army	1960-1962	
Propulsion Experiments and Prototypes					
Aircraft Reactor Experiment (ARE)	(Molten Salt)	Oak Ridge, TN	U.S. Air Force	1954-1954	Decomm. in 1955
Heat Transfer Reactor Experiment - 1		Idaho Falls, ID	U.S. Air Force	1956-1957	Preserved as Museum
Heat Transfer Reactor Experiment - 2		Idaho Falls, ID	U.S. Air Force	1957-1961	Preserved as Museum
Heat Transfer Reactor Experiment - 3		Idaho Falls, ID	U.S. Air Force	1958-1961	Preserved as Museum
Destroyer Reactor Prototype (D1G)	(PWR)	West Milton, NY	U.S. Navy	1962-1996	Decomm. underway
Large Ship Reactor Prototype (A1W) 2 units	(PWR)	Idaho Falls, ID	U.S. Navy	1958-1994	
Natural Circulation Test Plant (S5G)	(PWR)	Idaho Falls, ID	U.S. Navy	1965-1995	
Small Submarine Reactor Prototype (S1C)	(PWR)	Windsor, CT	U.S. Navy	1959-1993	Decomm. underway
Submarine Advanced Reactor Prototype (S3G)	(PWR)	West Milton, NY	U.S. Navy	1958-1991	Decomm. underway
Submarine Intermediate Reactor Mark A (S1G)	(sodium)	West Milton, NY	U.S. Navy	1955-1957	Partially dismantled
Submarine Thermal Reactor (STR) Facility (S1W)	(PWR)	Idaho Falls, ID	U.S. Navy	1953-1989	
Defense Power Reactor Applications					
Portable Medium Power Plant #1 (PM-1)		Sundance, WY		1962-1968	
Portable Medium Power Plant #2A (PM-2A)		Camp Century, Greenland		1960-1963	Dismantled in 1964
Portable Medium Power Plant #3A (PM-3A)		M°Murdo Sound, Antarctica		1962-1973	Decomm.
Stationary Medium Power Plant #1 (SM-1)		Fort Belvoir, VA		1957-1973	
Stationary Medium Power Plant #1A (SM-1A)		Fort Greely, AK		1962-1972	
STURGIS Floating Nuclear Power Plant (MH-1A)		USS STURGIS (Mobile, AL) and Panama Canal Zone		1967-1976	No longer in service

A significant deactivation project in the latter category is underway at Oak Ridge National Laboratory (ORNL) in its "Isotopes Facilities Deactivation Project." This project entails safely and efficiently deactivating 19 facilities in its former isotope production areas into safe, stable, and environmentally sound condition for extended periods of safe storage. As of late 1997, work was completed on 12 facilities, was underway on six others, and one facility had been transferred out of the program for re-use by another program. Work is planned to be completed over a nine year period at a cost of about $46 million. A second set of high ranking facilities for deactivation are also being deactivated at ORNL. These deactivation activities are high priority due to the presence of higher radiation levels and, in several cases, the presence of spent fuel at these former reactor facilities.

ORNL Facilities in "Isotope Facilities Deactivation Project (IFDP)"

Building No.	IFDP Facilities	Floor Space
3026-C	Krypton-85 Enrichment Facility	11,680 square feet
3026-D	Segmenting Hot Cell Facility	27,000 square feet
3028	Alpha Powder Facility	34,108 square feet
3029	Source Development Laboratory	2,273 square feet
3030	Radioisotope Production Lab C	720 square feet
3031	Radioisotope Production Lab D	720 square feet
3032	Radioisotope Production Lab E	720 square feet
3033	Radioactive Gas Processing Facility	720 square feet
3033-A	Actinide Fabrication Facility Annex	945 square feet
3034	Radioisotope Area Services	600 square feet
3038	Radioisotope Laboratory	11,680 square feet
3093	Storage Cubicle for Krypton	176 square feet
3099	Storage Pad Building for 3031 & 3032	894 square feet
3517	Fission Production Development Lab	18,034 square feet
3118	Radioisotope Production Lab H	909 square feet
7025	Tritium Target Facility	612 square feet

ORNL Facilities in "High Ranking Facilities Deactivation Project (HRFDP)"

Bldg./Area	HRFDP Facilities
7700	Tower Shielding Facilities
3019B	High Radiation Level Analytical Facility
7602	Integrated Process Demonstration Facility
3010	Bulk Shielding Facilities

At the Hanford site, the deactivation process has been completed on a former large operating nuclear facility - the Plutonium Uranium Extraction (PUREX) Facility. Work is underway on several other facilities at this same site.

Decommissioning Programs

Over the last 25 years, the DOE has implemented several major remediation projects/programs. These programs have and continue to focus on legacies of past research programs and weapons production programs. These programs are described in the following sections.

The one program of these which has been considered the most successful is the Uranium Mill Tailings Remedial Action (UMTRA) Project. This project remediated former uranium mill sites which over the years were used to mill uranium ores for fulfillment of government contracts. These sites pose two problems: residual mill tailings and contaminated ground water. The U.S. Congress enacted the Uranium Mill Tailings Radiation Control Act of 1978 (UMTRCA) to provide direction to the various Federal agencies in performing the clean-up of these sites. The UMTRCA directed the U.S. Environmental Protection Agency to promulgate the required soil guideline clean-up standards, the DOE to perform the clean-up and the NRC to oversee and certify the clean-up and to license the new disposal sites/cells for material from the clean-up. It is a 90% federal funded and 10% state funded clean-up program. It is remediating 24 sites located in 9 states; currently 20 sites have been released after clean-up. Two sites are in final construction of disposal cells and two others are in the process of being removed from the authorized remediation list. In the course of these clean-ups, 12 UMTRA disposal sites have been created and licensed by the NRC. The sites cleaned-up under this program are Title 1 or abandoned mill tailings sites used for the weapons program. Title II sites are those licensed by NRC or agreement states. Tables 5 and 6 contain current data on both Title I and II uranium facilities

The second DOE remediation program is the Formerly Utilized Sites Remedial Action Program (FUSRAP). This program (recently transferred to the U.S. Department of Defense from the U.S. Department of Energy) is remediating sites formerly used in the Manhattan Project which remain radioactively contaminated from past AEC, ERDA, and DOE operation/activities. In general, these sites require clean-up of low levels of radioactivity than were readily detectable at the time of past remediation clean-up efforts.

This program was established in 1974 and will remediate over 46 sites in 14 states. The majority of these projects are old industrial sites that still require remediation or facilities which have been previously released for re-use and now require spot clean-up to comply with new standards for release/re-use. To date, a total of 25 of the sites have been completed, sites yet to be remediated are in the St. Louis area or in the north eastern portion of the United States. A listing of sites in this program are included in Table 7.

Table 5

UMTRAP Uranium Mills either Decommissioned or Undergoing Decommissioning

Site (last operation)	Site Area (ha)	Estimated Waste Volume (m^3)
Monument Valley, AZ (1968)	22.5	Incl. in Mexican Hat, UT
Tuba City, AZ (1966)	137.2	1.26×10^6
Durango, CO (1963)	51	2.04×10^6
Grand Junction, CO (1970)	50.2	3.58×10^6
Gunnison, CO (1962)	29.2	6.55×10^5
Maybell, CO (1964)	98.9	2.43×10^6
Naturita, CO (1963)	20.2	4.52×10^5
New Rifle, CO (1972)	42.8	3.13×10^6
Old Rifle, CO (1958)	24.3	Not available
Slick Rock, CO – NC site (1957)	10	4.72×10^5
Slick Roc, CO – UC site (1961)	34	Incl. in NC site
Lowman, ID (1960)	12	1.01×10^5
Ambrosia Lake, NM (1963)	275.6	3.50×10^6
Shiprock, NM (1968)	29.1	2.14×10^6
Belfield, ND (1965)	14	1.21×10^5
Bowman, ND (1967)	26	Ind. in Belfield, ND
Lakeview, OR (1961)	16.2	7.31×10^5
Canonsburg, PA (1957)	11.6	2.26×10^5
Edgemont, SD	N.A.	3.4×10^4
Falls City. TX (1973)	182.5	4.17×10^6
Green River, UT (1961)	19.9	3.01×10^5
Mexican Hat, UT (1965)	101.7	2.78×10^6
Salt Lake City, UT (1968)	24.3	2.08×10^6
Converse County, WY (1965)	8.3	2.4×10^5
Riverton, WY (1963)	85.8	1.43×10^6

Table 6

Non-UMTRAP Uranium Mills either Decommissioned or Undergoing Decommissioning

Site (Operator)	Rated Capacity (t ore/day)	Status	Est. Tailings vol. (m^3)
Uravan, CO (UMETCO Minerals)	1,180	Decomm.	5.9×10^6
Ambrosia Lake, NM (Quivira Mining)	6,350	Shutdown (1985)	18.8×10^6
Bluewater, NM (Anaconda)	5,440	Decomm.	13.6×10^6
L-Bar, NM (Sohio Western Mining)	1,450	Decomm.	1.2×10^6
Church Rock, NM (United Nuclear)	2.720	Decomm.	2.0×10^6
Grants, NM (Anaconda)	5,440	Decomm. 1987	13.6×10^6
Grants, NM (Homestake Mining)	3,080	Decomm.	12.7×10^6
Edgemont, SD (TVA)	680	Decomm. 1983	1.2×10^6
Falls City, TX (Continental Oil)	3,080	Decomm. 1981	6.5×10^6
Ray Point, TX (Exxon-Felder Facility)	1,000	Decomm. 1987	2×10^5
Panna Maria, TX (Rio Grande Resources)	2,720	Decomm.	3.9×10^6
Moab, UT (Atlas)	1,270	Decomm.	6.0×10^6
Lisbon, UT (Rio Algom)	680	Decomm.	2.2×10^6
Sherwood, WA (Western Nuclear)	1,810	Decomm.	1.5×10^6
Ford, WA (Dawn Mining)	410	Shutdown (1982)	1.8×10^6
Gas Hills, WY (American Nuclear)	860	Decomm.	3.3×10^6
Lucky M[c], WY (Pathfinder)	2,540	Decomm.	6.6×10^6
Split Rock, WY (Western Nuclear)	1,540	Decomm.	4.4×10^6
Gas Hills, WY (UMETCO)	1,270	Decomm.	4.6×10^6
Highland, WY (Exxon)	2,900	Decomm.	6.4×10^6
Bear Creek, WY (Rocky Mtn. Energy)	1,810	Decomm.	2.7×10^6
Petrotomics, WY (Petrotomics)	1,360	Decomm.	3.9×10^6
Shirley Basin, WY (Pathfinder)	1,630	Decomm.	4.7×10^6
Sweetwater, WY (Minerals Exploration)	2,720	Shutdown (1983)	1.3×10^6

Table 7

DOE FUSRAP Program Sites Listing

Site	Location	Completion Date
University of California (selected areas)	Berkeley, CA	1982
Combustion Engineering Site	Windsor, CT	
Seymour Specialty Wire	Seymour, CT	1993
Madison Site	Madison, IL	
Granite City Steel	Granite City, IL	1993
National Guard Armory	Chicago, IL	1988
University of Chicago (selected areas)	Chicago, IL	1987
W. R. Grace & Company	Curtis Bay, MD	
Shpack Landfill	Norton, MA	
Chapman Valve	Indian Orchard, MA	1995
Ventron Corporation	Beverly, MA	1997
General Motors	Adrian, MI	1995
Latty Avenue Properties	Hazelwood, MO	
St. Louis Airport Site	St. Louis, MO	
St. Louis Airport Site Vicinity Properties	St. Louis, MO	
St. Louis Downtown Site	St. Louis, MO	
Maywood Site	Maywood, NJ	
Wayne Site	Wayne/Pequannock, NJ	
Middlesex Sampling Plant	Middlesex, NJ	
DuPont and Company	Deepwater, NJ	
Kellex/Pierpont	Jersey City, NJ	1981
Middlesex Municipal Landfill	Middlesex, NJ	1986
New Brunswick Site	New Brunswick, NJ	1996
Acid/Pueblo Canyon	Los Alamos, NM	1982
Bayo Canyon	Los Alamos, NM	1982
Chupadera Mesa	White Sands Missile Range, NM	1984
Niagara Falls Storage Site	Lewiston, NY	
Colonie Site	Colonie, NY	
Ashland 1 Site	Tonawanda, NY	
Ashland 2 Site	Tonawanda, NY	
Praxair Site	Tonawanda, NY	
Seaway Industrial Park	Tonawanda, NY	
Bliss & Laughlin Steel	Buffalo, NY	
Niagara Falls Storage Site Vicinity Properties	Lewiston, NY	1986
Baker and Williams Warehouses	New York, NY	1993
Luckey Site	Luckey, OH	
Painesville Site	Painesville, OH	
Alba Craft	Oxford, OH	1995
B & T Metals	Columbus, OH	1996
Baker Brothers	Toledo, OH	1996
Associate Aircraft	Fairfield, OH	1995
HHM Safe Co.	Hamilton, OH	1995
Albany Research Center	Albany, OR	1991
Aliquippa Forge	Aliquippa, PA	1994
C.H. Schnoor	Springdale, PA	1994
Elza Gate Site	Oak Ridge, TN	1992

In the mid-1970's, a large inventory of nuclear energy R&D and weapons R&D/production related facilities were identified as surplus by the DOE. Many were neglected after termination of the various R&D programs. To address this problem, the DOE established the Surplus Facilities Management Program (SFMP); this program was subsequently merged into the larger Environmental Restoration Program and lost its identity as a separate program. Some typical facilities decommissioned under this program are shown in Table 8.

The West Valley Demonstration Project is a DOE decommissioning and high level waste (HLW) vitrification project performed at the site of the only commercial nuclear fuel reprocessing plant to operate in the U.S. The plant operated from 1966 to 1972. In 1980, the West Valley Demonstration Project Act was passed by the U.S. Congress and directed that the site be remediated and that it demonstrate HLW solidification techniques on the stored waste there and eventually dispose of it in a national repository. This project did involve some significant decommissioning work since the HLW vitrifying process would be installed in parts of the former fuel reprocessing cells. This decommissioning occurred in the early to mid 1980's. Work is currently underway on the HLW vitrification process. Substantial experience was gained in the decommissioning of the numerous hot cell facilities.

Shared Cost Decommissioning

The USDOE supported several privately-owned facilities in the performance of research work on DOE nuclear programs as well as the companies own work over the years. These facilities included: 1) General Atomics (near San Diego, CA) - included a Hot Cell Facility used for numerous examinations of materials for the gas cooled reactor program, 2) Battelle Columbus Laboratory performed nuclear R&D work for the DOE in their facilities in the period 1943-1986. Two sites were used: one in downtown Columbus, OH (King Avenue Site) and another in a rural setting (West Jefferson Site). At the West Jefferson site, nuclear activities included: fabrication of uranium fuels, reactor development, submarine propulsion, fuel reprocessing, and safety studies. The hot cell facility and a former research reactor are located at this site. The six buildings at this location are all currently undergoing decommissioning. At the King Avenue Site, nine buildings are undergoing decommissioning. Decommissioning at these sites is being done on a shared cost basis and is nearly complete at several of the facilities.

Table 8

Some Selected Decommissioning Projects Completed at DOE Facilities

Site	Facility
Fernald Site (Fernald, OH)	Plant #7 (Pilot Plant) Plant #1 (Ore Sampling) Plant #4 (Green Salt Plant)
Mound Site (Miamisburg, OH)	Special Metallurgical (SM) Building
Los Alamos National Laboratory (Los Alamos, NM)	• Los Alamos Molten Plutonium Reactor Experiment (LAMPRE) • Ultra-High Temperature Reactor Experiment (UHTREX)
Argonne National Laboratory (Argonne, IL)	• Building 350 Plutonium Gloveboxes • Building 212 Plutonium Gloveboxes • East Area Surplus Facilities • Experimental Boiling Water Reactor (EBWR) • JANUS Biological Irradiation Reactor
Idaho National Engineering & Env. Lab. (Idaho Falls, ID)	• Organic Moderated Reactor Experiment (MORE) • Special Power Excursion Reactor Test Facilities • Numerous small facilities • BORAX-V Reactor
Nevada Test Site (Mercury, NV)	• Nuclear Rocket Development Station (Area 25)
Oak Ridge National Laboratory (Oak Ridge, TN)	• Numerous small facilities • Fission Product Development Lab. (some cells) • Curium Source Fabrication Facility
Hanford Site (Richland, WA)	• Production reactor ancillary facilities • Physics Test Reactor (Bldg. 309) • Plutonium Recycle Critical Facility • 201-C Strontium Semiworks
Santa Susana Field Laboratory (Santa Susana, CA)	• SNAP Ground Prototype Test Facility (Bldg. 059) • Nuclear Materials Development Facility (Bldg. 055) • SNAP 8 Experimental Reactor (Bldg. 010)
Savannah River Site (Aiken, SC)	• 232-F Tritium Extraction Facility • Production reactor aucillary facilities

Beneficial Re-Use of Facilities

After decommissioning has been completed it is not an uncommon occurrence for facilities and sites to be beneficially re-used rather then demolished. This has occurred at several reactor facilities - namely Fort St. Vrain and Pathfinder - which have been repowered using natural gas as a fuel source. Numerous former research reactor areas have been re-used after decommissioning:

- Former Sodium Reactor Experiment Facility - reused for warehousing of high value equipment items,
- Former Nuclear Materials Development Facility - reused for laser R&D programs,
- Former INEL research reactor buildings being used for waste management activities,
- Former EBWR Facility here at ANL-East will be reused as a packaged TRU waste storage facility.

13. FUSION REACTORS - THE TOKAMAK FUSION TEST REACTOR

The Tokamak Fusion Test Reactor (TFTR) located at the USDOE Princeton Plasma Physics Laboratory operated from 1983 to 1997. The machine was shutdown at that time due to completion of its mission and an increasing emphasis on the International Thermonuclear Experimental Reactor (ITER) program and a general funding reduction in fusion research. Preliminary planning on TFTR decommissioning has been completed, but to date, no final decommissioning plan or physical dismantling work has been started and the facility is in a safe shutdown condition. The exact timetable for dismantling of the vacuum vessel, coils, and neutral beamlines has not yet been established, but considerable planning has been performed on how the work could be performed.

14. DEPARTMENT OF DEFENSE MILITARY INSTALLATIONS

The United States Department of Defense has undertaken a program to perform environmental restoration activities (including decommissioning) at over 700 military installations in the U.S. and U.S. territories. Some of these bases will be permanently closed after environmental restoration activities are complete and the areas then transferred out of the government and into private ownership. Some bases will remain in operation after completion of remediation activities. While the majority of these sites are looking at non-radioactive remediation concerns, there are a number which have an identified concern over radioactive contaminants. A table of these sites is shown in Table 9.

The Department of Defense may enter into site agreements with other Federal regulatory agencies, such as EPA and NRC, or state agencies which set forth clean-up timelines. In general, timing of actions on clean-up are tied to whether the contaminant is a high risk and whether the site is a BRAC site. Many of these sites have on-site burial grounds for

radioactive wastes or nuclear facilities (hot cells, etc.) that require D&D prior to base closure.

15. FUEL FABRICATION FACILITIES DECOMMISSIONING

Several fuel fabrication facility decommissioning projects have been completed in the U.S. These projects involved removal and size reduction of various glovebox lines, support systems, and the structures in which they were located.

Westinghouse Nuclear Fuel Facility, Cheswick, PA

The Westinghouse Advanced Reactors Division and Nuclear Fuel Division operated the Cheswick Pilot Plant Facility from 1969 to 1979 when it was shut down. Decommissioning of its 61 gloveboxes started in 1980 and was completed in 1984. The plant was used for development and fabrication of mixed oxide fuels.

General Electric Fuels Laboratory, Vallecitos, CA

This General Electric facility performed mixed oxide fuel fabrication and development work during the period 1959-1979. Decommissioning was started in 1979 and completed in 1982 at a total cost of about $3.8 million. This work consisted of the removal of 22 gloveboxes and support systems from the facility and the decontamination of the facility to allow for its release. The work was jointly funded by both Westinghouse and the USDOE since the facility was used by the Fast Reactor Program of DOE as well as for private Westinghouse D&D work.

The cost breakdown was:

Project Planning	$0.2 M
Eq. Decommissioning/Disposal	$2.5 M
SNM Management	$0.5 M
Management	$0.6 M
Total	$3.8 M

UNC Naval Products, Uncasville, CT

The UNC Naval Products facility was located in Uncasville, CT and operated from the 1950's to 1990 as a DOE contractor under an NRC Special Nuclear Material license fabricating nuclear reactor cores and components for the U.S. Navy Nuclear fleet. Cutbacks in the defense industry from the end of the Cold War left the facility with a redundant mission. All work at the facility was transferred to other sites. The decommissioning occurred over a three year period 1990 - 1993 and the site license was terminated in 1994 with no future site use restrictions. Work was performed using in-house forces and specialized contractors. The facility was able to be decommissioned to a state of unrestricted release and is now interestingly being used as a gambling casino.

Table 9 DoD Sites Undergoing Environmental Remediation with a Radiological Contaminant Component.*

Service	Facility	Location	Base Closure (BC) or Compliance Clean-up (CCU)	Concern	Comments
Army	Aberdeen Proving Ground	Aberdeen, MD	CCU	LLRW	
Air Force	Bergstrom AFB	Austin, TX	BC	LLRW	RWDA
Air Force	Carswell AFB	Ft. Worth, TX	BC	LLRM	Buried Munitions
Navy	Charleston Naval Shipyard and Naval Station	Charleston, SC	BC	Decontamination Agents	
Navy	Dahlgren Naval Surface Warfare Center	Dahlgren, VA	CCU	LLRM	Depleted Uranium
DLA	Defense Electronics Supply Center (former Gentile Air Force Station)	Kettering, OH	BC	LLRW	RWDA
Air Force	England AFB	Alexandria, LA	BC	LLRW	Completed - 1996
Army	Fitzsimmons Army Media Center	Denver, CO	BC	Radioactivity	RWDA
Air Force	Former Larson AFB	Moses Lake, WA	CCU	Radioactive Materials	
Army	Fort McClellan	Fort McClellan, AL	BC	Radioactive Sources	Hot Cell - Bldg. 3192-D&Ded - 1996
Navy	Indian Head Naval Surface Warfare Center	Indian Head, MD	CCU	LLRM	
Navy	Jacksonville NAS	Jacksonville, FL	CCU	LLRW	RWDA
Army	Jefferson Proving Grounds	Madison, IN	BC	Depleted Uranium	
Air Force	Kelly AFB	San Antonio, TX	BC	LLRW	RWDA
Air Force	McChord AFB	Tacoma, WA	CCU	Radioactive Waste	
Air Force	O'Hare Air Reserve Facility	Chicago, IL	BC	LLRW	
Navy	Orlando Naval Training Center	Orlando, FL	BC	LLRW	
Army	Seneca Army Depot	Romulus, NY	CCU	Radioactive Isotopes	RWDA
Air Force	Tinker AFB	Oklahoma City, OK	CCU	LLRM	RWDA
Army	U.S. Army Research Laboratory (formerly AMTL)	Watertown, MA	BC/CCU	Radionuclides	Completed decontamination of Rad. Materials areas in 1995

*Department of Defense Environmental Restoration Program Annual Report to Congress for Fiscal Year 1996

LLRW: Low Level Radioactive Waste
LLRM: Low Level Radioactive Material
RWDA: Radioactive Waste Disposal Areas

NFS Fuel Processing Facilities, Erwin, TN

Facilities previously used for processing highly enriched uranium (HEU), low enriched uranium (LEU), U-233, thorium and mixed oxide materials were decontaminated and released for re-use at the Nuclear Fuel Services, Erwin facility. The facilities were all located within a high security protected area used for DoD work. All processing equipment and supporting structures were removed. Some areas required application of strippable coatings to decontaminate them and others required scabbling, acid leaching and removal of load bearing walls to facilitate decontamination. In these operations, certain technologies were developed to optimize waste processing utilizing an ultra-high pressure water jet system, a high capacity shear/baler unit and a non-destructive assay system.

Rockwell International Hot Laboratory (RIHL)

The RIHL was constructed for the remote handling, disassembly, and examination of irradiated nuclear reactor fuel assemblies and test specimens. The facility was used over a 30 year period for those activities, but also included some use for the manufacturing of sealed sources and machining of radioactive Cobalt-60. In 1987, the facility was shutdown and DOE assumed responsibility for its decommissioning which was conducted under the Rocketdyne NRC license. The above-ground structure has been demolished and work is currently underway on the basement portion of the building and outside yard area. Work will be completed on this project in 1998.

16. THE U.S. DECOMMISSIONING COMMUNITY

This section summarizes the state of the technical profession of "decommissioning," technical information exchange, training of personnel, and professional affiliations and technical standards from technical societies.

The Profession

The U.S. decommissioning technical specialist community is still a predominantly small group. There is a core group of technical specialists - managers, engineers, health physicists, waste management specialists, and others who have practiced in the technical area for over the last 20 to 25 years. Some of these were drawn into the profession directly from college, others from nuclear navy or other military programs, and others have just happened to find themselves in the technical field. This latter new component of the technical community consists of former operators of facilities that are now shutting down and are slowly being added to the decommissioning technical community as more nuclear facilities shutdown. Some universities are offering degree programs now in the areas of Environmental Management, Waste Management, and related areas and these are now becoming a common occurrence along with still the continuing, but dwindling programs in the nuclear engineering area. Also, a number of contract service firms now offer decommissioning services to licensees. Product and service directory guides are

prepared by several industry magazines to aid operators looking for service contractors with decommissioning expertise.

The following are buyers guides with the number of firms listed that offer decommissioning services:

- Radiation Protection Management (34)
- Nuclear Plant Journal (33)
- Nuclear News Buyers Guide (143)

The Meeting Place

Until the mid-1980's there were only three significant (topical) meetings on specifically decommissioning in the U.S. There were three topical meetings held in the 1970's and early 1980's - two in Idaho (one in Idaho Falls, in 1975 and another in Sun Valley, in 1979) and another in 1982 in Seattle, WA. All other technical/professional society meetings only gave decommissioning a mere passing interest by holding a session on it at each meeting that usually attracted maybe five or six papers. The USNRC hosted an International Decommissioning Planning Conference in Bethesda, MD in 1985. With the quickening of the pace at which weapons complex facilities and some commercial nuclear power plants and other facilities were closing in the late 1980's and early 1990's, more frequent decommissioning topical meetings were held. In 1987, the International Decommissioning Meeting was held in Pittsburgh, PA near the Shippingport Decommissioning Project. At about the same time the American Nuclear Society (ANS) began hosting a bi-annual SPECTRUM conference on Hazardous and Radioactive Waste Management - the first of these was in Niagara Falls, NY in 1986. Then the USDOE began holding bi-annual technical progress meetings focusing on the DOE site clean-up programs including D&D. These meetings complimented the annual "WM" or Waste Management Conferences held each year in late February in Tucson, AZ. Now, it is an annual occurrence that D&D is prominent in any of a number of technical meetings in a given year:

- 1994 ANS Embedded Topical Meeting on DD&R, Washington, DC
- 1994 DOE International Decommissioning Conference, Knoxville, TN,
- 1995 ANS Topical Meeting on Decommissioning, Chicago, IL,
- 1996 ANS Embedded Topical Meeting on DD&R, Washington, DC,
- 1997 ANS Topical Meeting on DD&R, Knoxville, TN.

The above listing does not even begin to touch on related areas such as health physics related conferences or other related aspects of decommissioning such as remote operations or waste management.

A centralized excellent source of information on decommissioning beyond these meeting is through the Remedial Action Program Information Center (RAPIC) in Oak Ridge, TN. RAPIC can provide searches of their database of technical documents on decommissioning sorted by keyword and often have a paper copy of the same report for your use.

The Internet has hundreds of references to on-going decommissioning projects and activities worldwide. This tool can be used to effectively monitor the on-going activities of the decommissioning technical community.

Technical information exchange through reports and papers are important and should be a part of every decommissioning project.

The Professional Affiliations

As mentioned in the previous section, the DOE and later the American Nuclear Society (ANS) were actively working at holding periodic meetings on the decommissioning topic in order to facilitate technical informational exchange among not just decommissioning, but the entire hazardous and radioactive waste management and site clean-up industry. As the magnitude and pace of the work progressed, many technical/professional societies began to form small to medium sized sub-groups focusing on decommissioning. Several organizations which are fairly active on decommissioning are: the ANS, the American Society for Testing & Materials (ASTM), and the International Society for Decontamination and Decommissioning Professionals (ISDDP). The ASTM is very active in the development of technical standards for use in decommissioning. A sampling of some relevant decommissioning standards developed by ASTM are shown in Table 10.

Training

In addition, training courses have started to be offered by some of these same technical societies to their members on specific areas of decommissioning as well as the overall technical area of decommissioning. These courses are open to members as well as to non-members in the technical community.

17. ISSUES

In the decommissioning technical community there are numerous issues that can directly impact the timing of and approach taken to implementing a decommissioning project. In this section, several of these issues are presented to the reader.

Table 10

■	EXXXX (97)	Standard Guide for Preparing Characterization Plans for Decommissioning Nuclear Facilities,
■	EXXXX (97)	Standard Guide for Selection and Use of Portable Radiological Survey Instruments for Performing In Situ Radiological Assessments in Support of Decommissioning,
■	E1819 (96)	Standard Guide for Environmental Monitoring Plans for Decommissioning of Nuclear Facilities,
■	E1760 (96)	Standard Guide for Unrestricted Disposition of Bulk Materials Containing Residual Amounts of Radioactivity,
■	E1281 (96)	Standard Guide for Nuclear Facility Decommissioning Plans,
■	E1278 (96)	Standard Guide for Radioactive Pathway Methodology for Release of Sites Following Decommissioning,
■	E1168 (95)	Standard Guide for Radiological Protection Training for Nuclear Facility Workers,
■	E1167 (96)	Standard Guide for Radiation Protection Program for Decommissioning Operations,
■	E1034 (95)	Standard Specification for Nuclear Facility Transient Worker Records.

Commercial Nuclear Utilities and the Effects of Deregulation of Electrical Rates

Many states in the U.S. are moving toward deregulation of the retail electricity generation market. As this transition to a competitive market has begun to take shape, there are concerns over 1) decommissioning funding if new owners take over a nuclear plant and 2) the impact this cost-competitiveness will have on continued operation of nuclear units. Some NRC safety assessments have identified deficiencies that may stem from low-cost energy producer economic pressures.

Disposal of High Level Radioactive Waste

For the commercial nuclear industry and research reactor industries, many sites are saddled with the costs of not being able to free release a site due to the delay in the DOE acceptance of their spent fuel for either storage or disposal. Until either a final or an interim solution is developed and implemented, this is a stumbling block for the former reactor sites to be released from their license. This problem does not affect the larger DOE sites like it does the commercial nuclear plant and research reactor sites since license termination is not an issue at many DOE sites.

Cost/Benefit Analysis

Some sites may not require clean-up to levels as stringent as previously deemed appropriate when a comparison is made of the benefits gained and the cost incurred to clean up a site. Future programs and projects may see an increased emphasis on using a cost/benefit approach once the cost to fully free release sites is reviewed.

Metal Recycling

Metal recycling costs for most DOE regulated facilities are too expensive for the operators to take advantage of recycling their decommissioning metal waste. Increasing pressures are being placed on the DOE sites to define their real operating costs rather then subsidizing operating costs in order to provide a true evaluation and an incentive for recycling of metals. Along with this is the issue of the establishment of a release standard for volumetrically activated materials.

Site Release Criteria

The USNRC has completed its review of comments received at various public meetings on residual contamination levels at decommissioned sites. The result is the establishment of a dose based standard for decommissioned sites and the maximum allowable dose limit permitted if the restrictions on site access fail. This continues to be a hotly debated topic.

License Renewal for Commercial Nuclear Power Plants

If license renewal or extensions of current licenses are not allowed, many plants may begin to come off-line in the early part of the next century. This will place an increased emphasis in the decommissioning area.

NRC Regulation of DOE Facilities

This new approach to regulating nuclear operations at DOE sites is currently only a pilot program, but this continued transition to NRC regulation of all DOE facilities could present some changes to the decommissioning process.

18. SUMMARY

The U.S. nuclear industry has considerable experience in the decommissioning of various types of facilities. Decommissioning experience include:

- commercial reactors,
- research reactors,
- naval prototypes and submarine propulsion systems,
- former defense related installations,
- former research related installations.

Many of the decommissioning projects performed to date have been on smaller units. Proven technologies and equipment have been available to safely dismantle these facilities. However, as the larger facilities come due for decommissioning, the need for better technologies and approaches for decommissioning are likely to be needed in order to manage the worker exposures and to, in general, more efficiently perform this work. Work is underway on the deployment of enhanced technologies for future decommissioning projects where the use of these are deemed beneficial.

What are some key things that should be remembered from all of these collective decommissioning experiences? Experience is the best teacher. The more experienced team members are in performing decommissioning, the more effective they will be in performing the work. Another important point to remember is that good planning and accurate records searches are essential to try to prepare and eliminate opportunities for any surprises on the project. Another critical area is to establish and maintain close regulator interactions.

Hopefully this overview has pointed out the broad areas of U.S. decommissioning experience and will benefit you in the conduct of your decommissioning projects.

BIBLIOGRAPHY

Magnitude of the Problem

"Planning and Management for the Decommissioning of Research Reactors and Other Small Nuclear Facilities," TRS #351, IAEA, 1993.

"Decommissioning Techniques for Research Reactors," TRS #373, IAEA, 1994.

International Atomic Energy Agency, "Directory of Nuclear Research Reactors, 1994," August 1995, STI/PUB/983, IAEA.

International Atomic Energy Agency, "Reference Data Series #3, Nuclear Research Reactors in the World, December 1996 Edition," November 1996, ISBN 92-0-104696-0.

The U.S. Decommissioning Process

"Decommissioning," S.H. Weiss, U.S. NRC, presented at the DOE/GAN Decommissioning Workshop, ANL-East Site, Argonne, IL, September 1997.

"NRC Technical Tips #24: Decommissioning Nuclear Power Plants," available on the Internet @ http://www.nrc.gov, U.S. Nuclear Regulatory Commission.

"Nuclear Reactors Built, Being Built, or Planned: 1996," prepared for USDOE, Office of Nuclear Energy by the USDOE Office of Scientific and Technical Information, DOE/OSTI-8200-R60, August 1997.

Nuclear Energy Institute Fact Sheet "Decommissioning of Nuclear Power Plants - June 1996."

Commercial Reactor Decommissioning

ComEd "In the News: ComEd Announces Permanent Shutdown of Zion Station; Unicom takes $515 Million Write-Off," January 15, 1998, ComEd Offices of Public Affairs.

ComEd, Zion Station Fact Sheet, Unicom Internet Home Page.

"Shoreham: Highlights of a Successful Decommissioning Project," M. Siva Kumar (TTX Associates) and F. Petschauer (BNL), presented at WM'96, Tucson, Arizona, February 25-29, 1996.

"Trojan Reactor Vessel and Internals: The Plans for a One Piece Removal," (viewgraphs), M.B. Lackey, Portland General Electric, presented at TLG Services Inc., Decommissioning Conference, Captiva Island, Florida, October 1996.

"Large Component Cradle Design and Grouting Technologies," L.A. Zuchowski Jr., Burns and Roe, presented at TLG Services Inc. Decommissioning Conference, Captiva Island, Florida, October 1996.

"Yankee Rowe: Beginning the Final Chapter," in Nuclear Engineering International, February 1997, p. 30.

"Sodium Reactor Experiment Decommissioning Final Report," Carroll, J.W. Conner, C.C., Harris, J.M. Marzec, J.M., and B.F. Ureda, Rockwell International, ESG, - DOE-13403, prepared 1983.

"Shippingport Station Decommissioning Project - Final Project Report," Westinghouse Hanford Company/SSDP, DOE/SSDP-0081, 1989.

"Final Elk River Reactor Program Report," United Power Association, COO-651-93, November 1974.

"Aging Nuclear Power Plants: Managing Plant Life and Decommissioning," U.S. Congress Office of Technology Assessment, September 1993, Report #OTA-E-575.

"Shoreham Decommissioning: Project Summary and Lessons Learned," prepared by Long Island Power Authority (F. Petschauer - Principal Investigator), for EPRI, EPRI TR-106148, February 1996.

"First Big U.S. Reactor Dismantled," by A. Soast in Engineering News-Record, July 18, 1994.

"Fort St. Vrain Defueling and Decommissioning Overview," viewgraphs by Don Warembourg, Decommissioning Program Director, Public Service Company of Colorado.

Research Reactor Decommissioning

"Decommissioning the UHTREX Reactor Facility at Los Alamos, New Mexico," LA-12356, Miguel Salazar and John Elder, Los Alamos National Laboratory, August 1992.

"Final Report - Decommissioning of the Ames Laboratory Research Reactor," A.F. Voigt, B.W. Link, R.G. Struss, M.D. Voss, J. Cummings, and J. Haugen, IS-4789, January 1982.

"Decontamination and Dismantlement of the JANUS Reactor at Argonne National Laboratory - East, Project Final Report," C. Fellhauer, F. Clark (ANL) and G. Garlock (MOTA Corp.), etc.

"Lessons Learned from the D&D of Army Materials Technology Laboratory (AMTL) Base Closure Facility," by T. Kivett, D. Ferrigno, Morrison - Knudsen Corporation, Fran Donovan (U.S. Army Corp of Engineers) and D. Neely (SEG), presented at the 1994 International Symposium on Decontamination and Decommissioning, Knoxville, TN, April 25-28, 1994 (CONF - 940406).

"Final Decommissioning of the UCLA Boelter Reactor Facility," S. State and J. Gordon (Dames and Moore) and J. Takahashi and A. Huda (UCLA), presented at Waste Management '93 Conf., Tucson, AZ, February 28 - March 4, 1993, CONF - 930205.

"Cintichem Decommissioning Experience: The Final Chapter," J.J. Adler and L.A. Glander, presented at the TLG Decommissioning Conference, Captiva Island, FL, October 1996.

"S8ER Facilities Decommissioning Final Report," A.M. Stelle, Rockwell International, AI Division, Canoga Park, CA, February 1979, ESG-DOE-13237.

USNRC Site Decommissioning Management Plan (SDMP) Sites

"Site Decommissioning Management Plan," by D.N. Fauver, M.F. Weber, T.C. Johnson, and J.D. Kinneman, U.S. N.R.C., Div. Of Waste Management, NUREG-1444, Supplement 1, November 1995.

Large Component Maintenance/Removal

Power Engineering, "Steam Generator Replacements Continue," T. Hansen, April 1997, pp. 32-37.

"Fast Track Steam Generator Disposal at Salem Generating Station," H. Cruickshank and J. Gomeringer (PSE & G) and R. Killen (Raytheon Engineering and Construction), presented at American Nuclear Society Topical Meeting on "Decommissioning, Decontamination, and Reutilization of Commercial and Government Facilities," September 7-12, 1997, Knoxville, TN.

U.S. Naval Reactors Decommissioning

Personal Communication, Shelia Woody (Fluor Daniel Hanford) to L. Boing (ANL), February 10, 1998.

"U.S. Naval Nuclear Powered Submarine Inactivation, Disposal, and Recycling," September 1993, U.S. Department of Navy.

"Overview of Nuclear Submarine Inactivation and Scrapping/Recycling in the United States," M. MacKinnon, III and J.G. Burritt, U.S. Navy (retired) in Nuclear Submarine Decommissioning and Related Problems, 1996, L.G. LeSage and A.A. Sarkisov (editors), Kluwer Academic Publishers.

Other Military Reactor Dismantling

"Stationary Low-Power Reactor No. 1 (SL-1) Accident Site Decontamination and Dismantlement Project," by E.F. Perry, Lockheed Martin Idaho Technologies, presented at ER'95 Conference, Denver, Colorado, August 1995, CONF-950868.

"Removal of the PM-2A Nuclear Power Plant from Camp Century," presented by J.P. Franklin, U.S. Army, Transactions of ANS, 1965 Annual Meeting, June 1965.

"The PM-3A Antartic Reactor," U.S., AEC, and U.S. Navy.

"Nuclear Power Plant for Camp Century," by J.W. Barnett, Corps of Engineers, The Military Engineer, #355, pp. 363-364.

"Removal of Nuclear Reactor Core - Camp Century," by J.P. Franklin and W.T. Stockhausen, U.S. Army Corp of Engineers, The Military Engineer, #373 pp. 328-330.

"The Story of Nukey Poo," O. Wilkes and R. Mann, Bulletin of the Atomic Scientists, October 1978.

"PM-1 Nuclear Power Plant - Hazards Summary Evaluations," MND-M-1853, October 1959. (The Martin Company, Nuclear Division.)

DOE Remediation Programs

"Environmental Restoration Site Summary Fact Sheet - General Atomics Site," USDOE-EM Program, July 1997.

"Environmental Restoration Site Summary Fact Sheet - Battelle Columbus Laboratories - King Avenue," USDOE-EM Program, July 1997.

"Environmental Restoration Site Summary Fact Sheet - Battelle Columbus Laboratories - West Jefferson Site," USDOE-EM Program, July 1997.

"Deactivating a Major Nuclear Fuels Reprocessing Facility Cost Effectively," G.J. LeBaron, J.P. Hayfield Jr., and J.D. Legard, B&W Hanford Company, presented at X-Change 97 Conference, Miami, Florida, December 1-5, 1997.

"Isotopes Facilities Deactivation Project at Oak Ridge National Laboratory," R.E. Eversole, Lockheed Martin Energy Systems (LMES), presented at the ANS Topical Meeting on Decommissioning, Decontamination, and Reutilization of Commercial and Government Facilities, September 7-12, 1997, Knoxville, TN.

"Final Deactivation Project Report on the Alpha Powder Facility, Building 3028, at Oak Ridge National Laboratory, Oak Ridge, Tennessee," prepared by Isotopes Facilities Deactivation Project, Lockheed Martin Energy Systems, ORNL/ER-399, April 1997.

"Final Report on the Decontamination of the Curium Source Fabrication Facility," R.W. Schaich, ORNL, Surplus Facilities Management Program, December 1983, ORNL/TM-8376.

Fusion Reactors – The Tokamak Fusion Test Reactor

Personal Communication, Michael Bell, Princeton Plasma Physics Laboratory (PPPL) to L.E. Boing, Argonne National Laboratory (ANL), February 17, 1998.

"Environmental Assessment - The Tokamak Fusion Test Reactor Decontamination and Decommissioning Project and the Tokamak Physics Experiment at the Princeton Plasma Physics Laboratory," May 1994, U.S. Department of Energy, DOE/EA-0813.

"Preliminary Decontamination and Decommissioning Plan for the Tokamak Fusion Test Reactor," Princeton Plasma Physics Laboratory, February 1993.

Fuel Fabrication Facilities Decommissioning

"Decommissioning of Babcock and Wilcox's Fuel Conversion Plant," by R.V. Carlson, A.E. Haase, and R.S. Kingsley, Babcock and Wilcox's Transactions of the ANS, 1994 Winter Meeting, Washington, D.C., November 1994, pp. 653-654.

"Re-use of Decontaminated Nuclear Fuel Processing Facilities," Norman Brandon, NSFI, Transactions of ANS Meeting, Philadelphia, PA, June 25-29, 1995 (Vol. 72).

"Decontamination and Decommissioning of a Plutonium Fabrication Facility," R.A. Hunt, D. Paine, and M.L. West, Ecotek, Erwin, TN, presented at WM '90 Conference, Tucson, AZ, February 25 - March 1, 1990, CONF - 900210, Vol. 1.

"General Electric Fuels Laboratory Decontamination and Decommissioning," by M.L. Thompson, E.F. Kurtz, and G.C. Berg, General Electric Co., July 1982, GEFR-00616-1.

"Decontamination and Decommissioning of the Westinghouse Nuclear Fuel Facility at Cheswick, Pennsylvania," by J.V. Denero, R.A. Lange, M.L. Ray, J.L. Shoulders, and H.C. Woodsum, Westinghouse Electric Corporation, Nuclear Energy Systems, WCAP-10574, June 1984 (2 volumes).

"Successful D&D of a Uranium Fuel Cycle Manufacturing Plant," Robert J. Gregg, UNC Naval Products.

"Decontamination and Decommissioning of NRC Licensed Fuel Cycle Facilities: The Licenses Perspective," Robert J. Gregg, UNC Naval Products.

"Rockwell International Hot Laboratory Decontamination and Dismantlement Interim Progress Report 1987-1996," Rocketdyne Division, Boeing North American Inc., Doc. #ETEC 020-AR-0002, May 1997.

"Decontamination and Decommissioning of the Kerr-McGee Cimarron Plutonium Fuel Plant," Walter H. Spencer, Cimarron Corporation report to USDOE-Richland Operations Office under Contract #DE-AC06-83RL 10382.

The U.S. Decommissioning Community

"Beneficial Re-use of Decommissioned Former Nuclear Facilities," by L. Boing, ANL, presented at the ANS Topical Meeting on Decommissioning, Decontamination, and Reutilization of Commercial and Government Facilities, September 7-12, 1997, Knoxville, TN.

Issues

"The Nuclear Horizon: What is the Future?" by Shirley Jackson, USNRC chairman speech to the NIST, Gaithersburg, MD, February 6, 1998 (speech #98-06).

"Nuclear Power in a Competitive Era," by Shirley Jackson, USNRC chairman, speech to the NARUC, Fort Myers, FL, January 23, 1997 (speech #97-01).

"Decommissioning U.S. Reactors: Current Status and Developing Issues," EPRI-NP-5495, January 1998.

Other

"Decontamination and Dismantlement of the Argonne National Laboratory Map Tube Facility," by L. P. Moos (ANL), G. Subbaraman, P.H. Horton (Rockwell International), D.L. Fleming (ESPO Engineering), and J.B. Wescott (ANL), Trans. of the ANS, 1994 Winter Meeting, Washington, D.C., November 1994, p. 635.

"Particle Accelerator Decommissioning," J.H. Opelka, R.L. Mundis, G.J. Marmer, J.M. Peterson, B. Siskind, and M.J. Kikta, ANL/ES-82, December 1979.

APPENDIX A

1. Schneider, K.J., Jenkins, C.E., *Technology, Safety and Costs of Decommissioning a Reference Nuclear Fuel Reprocessing Plant*, NUREG-0278, Vols. 1&2, U.S. Nuclear Regulatory Commission Report by Pacific Northwest Laboratory, Richland, Washington, 1977.

2. Smith, R.I., Konzek, G.J., Kennedy, Jr., W.E., *Technology, Safety and Costs of Decommissioning a Reference Pressurize Water Reactor Power Station*, NUREG/CR-0130, U.S. Nuclear Regulatory Commission Report by Pacific Northwest Laboratory, Richland, Washington, 1978.

3. *Decommissioning of Nuclear Facilities - An Annotated Bibliography*, NUREG/CR-0131, U.S. Nuclear Regulatory Commission Report by Pacific Northwest Laboratory, Richland, Washington, 1979.

4. *Decommissioning of Nuclear Facilities - A Review and Analysis of Current Regulations*, NUREG/CR-0671, U.S. Nuclear Regulatory Commission Report by Pacific Northwest Laboratory, Richland, Washington, 1979.

5. *Facilitation of Decommissioning of Light Water Reactors*, NUREG/CR-0569, U.S. Nuclear Regulatory Commission Report by Pacific Northwest Laboratory, Richland, Washington, 1979.

6. Jenkins, C.E., Murphy, E.S., Schneider, K.J., *Technology, Safety and Costs of Decommissioning a Reference Small Mixed Oxide Fuel Fabrication Plant*, NUREG/CR-0129, Vols. 1&2, U.S. Nuclear Regulatory Commission Report by Pacific Northwest Laboratory, Richland, Washington, 1979.

7. Smith, R.I., Polentz, L.M., *Technology, Safety and Costs of Decommissioning a Reference Pressurized Water Reactor Power Station*, NUREG/CR-0130, Addendum, U.S. Nuclear Regulatory Commission Report by Pacific Northwest Laboratory, Richland, Washington, 1979.

8. Murphy, E.S., Holter, G.M., *Technology, Safety and Costs of Decommissioning a Reference Low-Level Waste Burial Ground*, NUREG/CR-0570, Vols. 1&2, U.S. Nuclear Regulatory Commission Report by Pacific Northwest Laboratory, Richland, Washington, 1980.

9. Oak, H.D., Holter, G.M., Kennedy, Jr., W.E., Konzek, G.J., *Technology, Safety and Costs of Decommissioning a Reference Boiling Water Reactor Power Station*, NUREG/CR-0672, Vols. 1&2, U.S. Nuclear Regulatory Commission Report by Pacific Northwest Laboratory, Richland, Washington, 1980.

10. Elder, H.K., Blahnik, D.E., *Technology, Safety and Costs of Decommissioning a Reference Uranium Fuel Fabrication Plant*, NUREG/CR-1266, Vols. 1&2, U.S. Nuclear Regulatory Commission Report by Pacific Northwest Laboratory, Richland, Washington, 1980.

11. Murphy, E.S., *Technology, Safety and Costs of Decommissioning Reference Non-Fuel-Cycle Nuclear Facilities,* NUREG/CR-1754, U.S. Nuclear Regulatory Commission Report by Pacific Northwest Laboratory, Richland, Washington, 1981.

12. Denham, D.H., Eddy, P.A., Hawley, K.A., Jaquish, R.E., Corley, J.P., *Technology, Safety and Costs of Decommissioning a Reference Low-Level Waste Burial Ground Environmental Surveillance Programs,* NUREG/CR-0570 Addendum, U.S. Nuclear Regulatory Commission Report by Pacific Northwest Laboratory, Richland, Washington, 1981.

13. Elder, H.K., *Technology, Safety and Costs of Decommissioning a Reference Uranium Hexafluoride Conversion Plant*, NUREG/CR-1757, U.S. Nuclear Regulatory Commission Report by Pacific Northwest Laboratory, Richland, Washington, 1981.

14. *Monitoring for Compliance with Decommissioning Termination Survey Criteria*, NUREG/CR-2082, U.S. Nuclear Regulatory Commission Report by Oak Ridge National Laboratory, Oak Ridge, Tennessee, 1981.

15. *Technology and Cost of Termination Surveys Associated with Decommissioning of Nuclear Facilities*, NUREG/CR-2241, U.S. Nuclear Regulatory Commission Report by Oak Ridge National Laboratory, Oak Ridge, Tennessee, 1982.

16. Wittbrock, N.G., *Technology, Safety and Costs of Decommissioning Nuclear Reactors at Multiple-Reactor Stations*, NUREG/CR-1755, U.S. Nuclear Regulatory Commission Report by Pacific Northwest Laboratory, Richland, Washington, 1982.

17. Konzek, G.J., Ludwick, J.D., Kennedy, Jr., W.E., Smith, R.I., *Technology. Safety and Costs of Decommissioning Reference Nuclear Research and Test Reactors*, NUREG/CR-1756, Vols. 1&2, U.S. Nuclear Regulatory Commission Report by Pacific Northwest Laboratory, Richland, Washington, 1982.

18. Murphy, E.S., Holter, G.M., *Technology, Safety and Costs of Decommissioning Reference Light Water Reactors Following Postulated Accidents*, NUREG/CR-2601, Vols. 1&2, U.S. Nuclear Regulatory Commission Report by Pacific Northwest Laboratory, Richland, Washington, 1982.

19. Holter, G.M., Murphy, E.S., *Technology, Safety and Costs of Decommissioning a Reference Pressurized Water Reactor Power Station - Effects on Decommissioning of Interim Inability to Dispose of Waste Off-Site,* NUREG/CR-0130, Addendum 2, U.S. Nuclear Regulatory Commission Report by Pacific Northwest Laboratory, Richland, Washington, 1983.

20. Holter, G.M., Murphy, E.S., *Technology, Safety and Costs of Decommissioning a Reference Boiling Water Reactor Power Station - Effects on Decommissioning of Inability to Dispose of Wastes Off-Site*, NUREG/CR-0672, Addendum 1, U.S. Nuclear Regulatory Commission Report by Pacific Northwest Laboratory, Richland, Washington, 1983.

21. Konzek, G.J., *Technology, Safety and Costs of Decommissioning Reference Nuclear Research and Test Reactors - Sensitivity of Decommissioning Radiation Exposure and Costs to Selected Parameters,* NUREG/CR-1756, Addendum, U.S. Nuclear Regulatory Commission Report by Pacific Northwest Laboratory, Richland, Washington, 1983.

22. Ludwick, J.D., Moore, E.B., *Technology, Safety and Costs of Decommissioning Reference Independent Spent Fuel Storage Installations*, NUREG/CR-2210, U.S. Nuclear Regulatory Commission Report by Pacific Northwest Laboratory, Richland, Washington, 1984.

23. Holter, G.M., Murphy, E.S., *Technology, Safety and Costs of Decommissioning a Reference Pressurized Water Reactor Power Station - Classification of Decommissioning Wastes*, NUREG/CR-0130, Addendum 3, U.S. Nuclear Regulatory Commission Report by Pacific Northwest Laboratory, Richland, Washington, 1984.

24. Murphy, E.S., *Technology, Safety and Costs of Decommissioning a Reference Boiling Water Reactor Power Station - Classification of Decommissioning Wastes*, NUREG/CR-0672, Addendum 2, U.S. Nuclear Regulatory Commission Report by Pacific Northwest Laboratory, Richland, Washington, 1984.

25. *Technology, Safety and Costs of Decommissioning Reference Nuclear Fuel Cycle and Non Fuel Cycle Facilities Following Postulated Accidents*, NUREG/CR-3293, Vols. 1&2, U.S. Nuclear Regulatory Commission Report by Pacific Northwest Laboratory, Richland, Washington, 1985.

26. Moore, Jr., E.B., *Technology, Safety and Costs of Decommissioning Nuclear Reactors at Multiple-Reactor Stations - Effects on Decommissioning of Inability to Dispose of Wastes Off-Site*, NUREG/CR-1755, Addendum 1, U.S. Nuclear Regulatory Commission Report by Pacific Northwest Laboratory, Richland, Washington, 1985.

27. Elder, H.K., *Technology, Safety and Costs of Decommissioning Reference Nuclear Fuel Cycle Facilities - Classification of Decommissioning Wastes*, NUREG/CR-4519, U.S. Nuclear Regulatory Commission Report by Pacific Northwest Laboratory, Richland, Washington, 1986.

28. Final Rule Amendments to 10 CFR Parts 30, 40, 50, 51, 70, and 72: General Requirements for Decommissioning Nuclear Facilities, Federal Register, 53 FR 24018, June 27, 1988.

29. Konzek, G.J., Smith, R.I., *Technology, Safety and Costs of Decommissioning a Reference Pressurized Water Reactor Power Station - Technical Matters Related to Preparation of the Final Decommissioning Rule*, NUREG/CR-0130, Addendum 4, U.S. Nuclear Regulatory Commission Report by Pacific Northwest Laboratory, Richland, Washington, 1988.

30. *Technology, Safety, and Costs of Decommissioning a Reference Boiling Water Reactor Power Station - Technical Matters Related to Preparation of the Final Decommissioning Rule*, NUREG/CR-0672, Addendum 3, U.S. Nuclear Regulatory Commission Report by Pacific Northwest Laboratory, Richland, Washington, 1988.

31. Short, S.M., *Technology, Safety and Costs of Decommissioning Reference Non-Fuel Cycle Nuclear Facilities - Corrependium of Current Information*, NUREG/CR-1754, Addendum 1, U.S. Nuclear Regulatory Commission Report by Pacific Northwest Laboratory, Richland, Washington, 1989.

32. Konzek, G.J., Smith, R.I., *Technology, Safety and Costs of Decommissioning Reference Light Water Reactors Following Postulated Accidents - Re-evaluation of the Clean-up Costs for the Boiling Water Reactor (BWR) Scenario 3 Accident from NUREG/CR-2601*, NUREG/CR-2601, Addendum 1, U.S. Nuclear Regulatory Commission Report by Pacific Northwest Laboratory, Richland, Washington, 1990.

33. *Comparison of Two Decommissioning Cost Estimates Developed for the Same Commercial Nuclear Reactor Power Station*, NUREG/CR-0672, Addendum 4, U.S. Nuclear Regulatory Commission Report by Pacific Northwest Laboratory, Richland, Washington, 1990.

34. Miles, T.L., *Cost Update - Technology, Safety and Costs of Decommissioning Reference Independent Spent Fuel Storage Installations*, PNL-8806, 1994.

35. Liu, Y., *Cost Update - Technology, Safety and Costs of Decommissioning a Reference Uranium Fuel Fabrication Plant*, PNL-9965, 1994.

36. Miles, T.L., Liu, Y., *Cost Update - Technology, Safety and Costs of Decommissioning a Reference Uranium Hexafluoride Conversion Plant*, PNL-10615, 1995.

37. Konzek, G.J., Smith, R.I., Bierschbach, M.C., McDuffie, P.N., *Revised Analyses of Decommissioning for the Reference Pressurized Water Reactor Power Station*, NUREG/CR-5884, U.S. Nuclear Regulatory Commission Report by Pacific Northwest Laboratory, Richland, Washington, 1995.

38. Smith, R.I., Bierschbach, M.C., Konzek, G.J., McDuffie, P.N., *Revised Analyses of Decommissioning for the Reference Boiling Water Reactor Power Station - Effects of Current Regulatory and Other Considerations on the Financial Assurance Requirements of the Decommissioning Rule and on Estimates of Occupational Radiation Exposure*, NUREG/CR-6174, U.S. Nuclear Regulatory Commission Report by Pacific Northwest Laboratory, Richland, Washington, 1996.

39. Haffner, D.R., Villegas, A.J., *Technology, Safety and Costs of Decommissioning a Reference Large Irradiator and Reference Sealed Sources*, NUREG/CR-6280, U.S. Nuclear Regulatory Commission Report by Pacific Northwest Laboratory, Richland, Washington, 1996.

APPENDIX B

Site Decommissioning Management Plan Site List*

Advanced Medical Systems, Inc., Cleveland, OH

Current List

AAR Manufacturing
Army, Department of, Jefferson Proving Ground, Jefferson, IN
Babcock & Wilcox, Parks Township, PA
Babcock & Wilcox, Shallow Land Disposal Area, Vandergrift, PA
BP Chemicals America, Inc., Lima, OH
Cabot Corporation, Boyerton, PA
Cabot Corporation, Reading, PA
Cabot Corporation, Revere, PA
Chemetron Corporation, Bert Avenue, Cleveland, OH
Chemetron Corporation, Harvard Avenue, Cleveland, OH
Clevite, Cleveland, OH
Dow Chemical Company, Bay City and Midland, MI (sites)
Elkem Metals, Inc., Marietta, OH
Fansteel, Inc., Muskogee, OK
Hartley and Hartley (Kawkawlin) Landfill, Bay County, MI
Heritage Minerals, Lakehurst, NJ
Horizons, Inc., Cleveland, OH
Kaiser Aluminum, Tulsa, OK
Kerr-McGee, Cimarron, OK
Kerr-McGee, Cushing, OK
Lake City Army Ammunition Plant (formerly Remington Arms Company), Independence, MO
Michigan Department of Natural Resources
Minnesota Mining and Manufacturing (3M), Pine County, MN
Molycorp, Inc., Washington, PA
Molycorp, Inc., York, PA
Northeast Ohio Regional Sewer District/Southerly Plant, Cleveland, OH
Permagrain Products, Media, PA
Pesses Company, METCOA Site, Pulaski, PA
RMI Titanium Company, Ashtabula, OH
Safety Light Corporation, Bloomsburg, PA
Schott Glass Technologies, Duryea, PA
Sequoyah Fuels Corporation, Gore, OK
Shieldalloy Metallurgical Corporation, Cambridge, OH
Shieldalloy Metallurgical Corporation, Newfield, NJ
Watertown Arsenal/Mall, Watertown, MA
Watertown GSA, Watertown, MA
Westinghouse Electric Corporation, Waltz Mill, PA
Whittaker Corporation, Greenville, PA

Sites Removed Due to Completion on Date Shown:

Mallinckrodt, St. Louis, MO; 1990
Kerr-McGee, West Chicago, IL; November 1, 1990
Allied Signal Aerospace - Bendix Division, Teterboro, NJ; February 28, 1992
Bud Company, Philadelphia, PA; April 21, 1993
Old Vic, Cleveland, OH; December 6, 1993
Amax, Incorporated, Wood County, WV; June 7, 1994
Chevron Corporation, Pawling, NY; July 6, 1994
West Lake Landfill, Bridgeton, MO; June 16, 1995
Pratt & Whitney, Middletown, CT; October 4, 1995
UNC Recovery Systems, Wood River Junction, RI; October 12, 1995
Magnesium Elektron, Inc., Flemington, NJ; November 17, 1995
Alcoa, Cleveland, OH; April 9, 1996
Fromme, Detroit, Michigan; July 26, 1996
Babcock & Wilcox - Apollo, PA; January 17, 1997
RTI, Inc., Rockaway, NJ; January 24, 1997
Texas Instruments, Attleboro, MA; March 13, 1997
Engelhard Corp., Nuclear Metals, Inc., and Wyman-Gordon Company (transferred to Massachusetts), Plainfield, MA; March 21, 1997.
Department of Army, Aberdeen Proving Ground, MD; March 27, 1997
Anne Arundel County/Curtis Bay Depot, July 31, 1997