Integration of Improved Decontamination and Characterization Technologies in the Decommissioning of the CP-5 Research Reactor

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Abstract

The aging of research reactors worldwide has resulted in a heightened awareness in the international technical decommissioning community of the timeliness to review and address the needs of these research institutes in planning for and eventually performing the decommissioning of these facilities. By using the reactors already undergoing decommissioning as test beds for evaluating enhanced or new/innovative technologies for decommissioning, it is possible that new techniques could be made available for those future research reactor decommissioning projects. Potentially, the new technologies will results in: reduced radiation doses to the work force, larger safety margins in performing decommissioning and cost and schedule savings to the research institutes in performing the decommissioning of these facilities. Testing of these enhanced technologies for decontamination, dismantling, characterization, remote operations and worker protection are critical to furthering advancements in the technical specialty of decommissioning. Furthermore, regulatory acceptance and routine utilization for future research reactor decommissioning will be assured by testing and developing these technologies in realistically contaminated environments prior to use in the research reactors. The decommissioning of the CP-5 Research Reactor is currently in the final phase of dismantlement. In this paper we present results of work performed at Argonne National Laboratory (ANL) in the development, testing and deployment of innovative and/or enhanced technologies for the decommissioning of research reactors.

I. Introduction

The decontamination and decommissioning (D&D) of nuclear reactors and related facilities as they reach the end of their useful operating life is recognized as a major problem worldwide. Estimates performed by the authors and a number of other specialists quote the anticipated costs at about a trillion U.S. dollars and the time span of the activities at about 5 decades. A subset of this large activity is the case of D&D of research and test reactors. Currently there are 274 operating research and test reactors around the world and 296 in various stages of shutdown[1]. Many U.S. research reactors are reaching the end of their operating life. See Figure 1. Many of these facilities are located in countries where there is limited, if any, experience in D&D methods and technologies.

Given the magnitude of the problem — both in its temporal and fiscal dimensions — it is clear that the development, demonstration and deployment of new technologies would be effective in

Non-power reactors licensed to operate in the U.S.

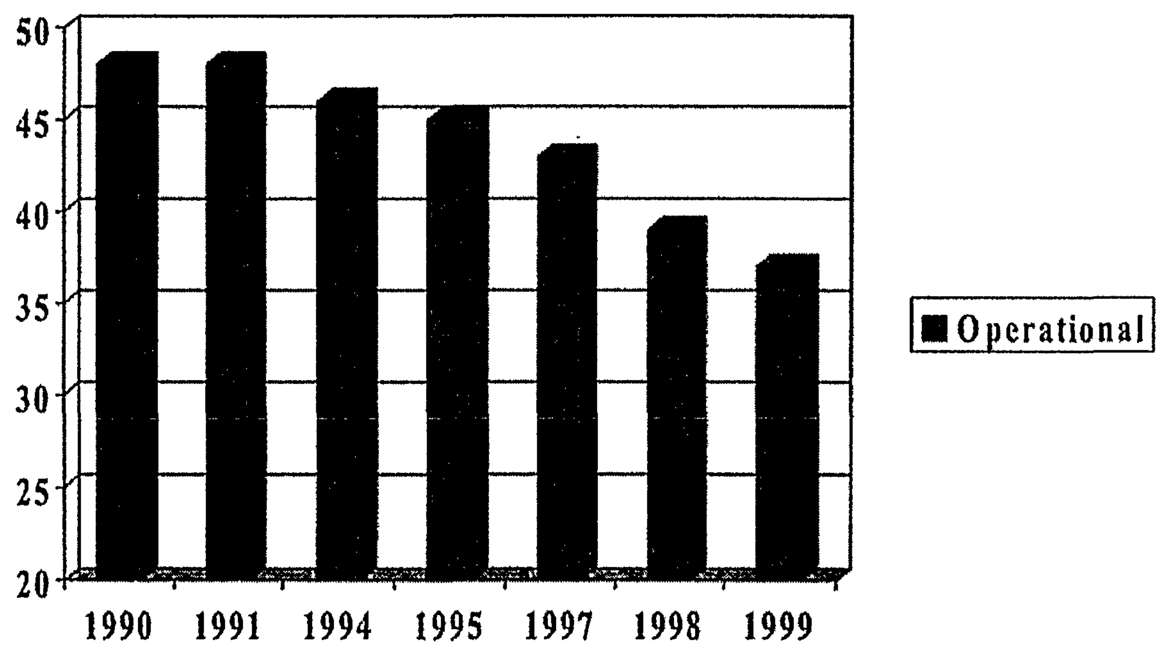


Figure 1.

improving the cost and safety performance of D&D operations. At Argonne National laboratory (ANL), a D&D Technology Center has been established to undertake such a development program. Argonne is uniquely qualified to undertake such a task, having been created as a follow-up to Enrico Fermi's CP-1 reactor experiment in 1942 and having led the development of essentially all classes of nuclear reactors in use today. Working on the development and use of technologies that will be used to close the life cycle of nuclear plants is a natural extension of ANL's prior work. These technology demonstrations were integrated into and compared to baseline technologies which had been planned to be used in performing the decommissioning of the ANL-East CP-5 Research Reactor.

Within the USA, D&D activities have been conducted by some of the nuclear utilities, the U.S. Department of Energy (DOE) and several universities (using contractors). The US DOE has the most active program at present[2-4], and in that segment, ANL has the most comprehensive broad based program comprised of an operations component, a technology development component and a technology demonstration component. In addition, there is an educational component, aimed at providing training to students, D&D practitioners from around the world, and D&D regulators from around the world. An IAEA training course on decommissioning is scheduled to be held at ANL in October 2000.

II. CP-5 Research Reactor Site History/Description

A major component in the Decommissioning Program is the dismantlement of the CP-5 Research Reactor detailed further in this section[5].

The Chicago Pile No. 5 (CP-5) Research Reactor Facility, situated on approximately three acres in the southwestern section of the Laboratory, was the principal nuclear reactor used from 1954 to 1979 for the production of neutrons for scientific research. During its lifetime, the reactor generated in excess of 5.4×10^8 thermal kilowatt-hours and was used to irradiate more than 27,000 samples for research purposes. In September 1979, the reactor was shutdown for the final time, and in 1980 all nuclear fuel and the heavy water that could be drained from the process systems was shipped off-site. The facility was placed into dry lay-up pending funding for decommissioning.

During decontamination and decommissioning (D&D) of this facility (Figures 2-4), all radioactive components, equipment, and structures associated with CP-5 will be disassembled and removed. In late fiscal year (FY) 1999, the Laboratory determined that there is no longer a need to reuse the CP-5 building structure. Therefore, the goal of this project is to leave the building in a final physical end state that allows the structure to be demolished in the future when appropriate funding becomes available.

Figure 1. CP-5 reactor tank with bioshield and lead removed.

Figure 2. Reactor pedestal concrete being removed using Brokk demolition machine.

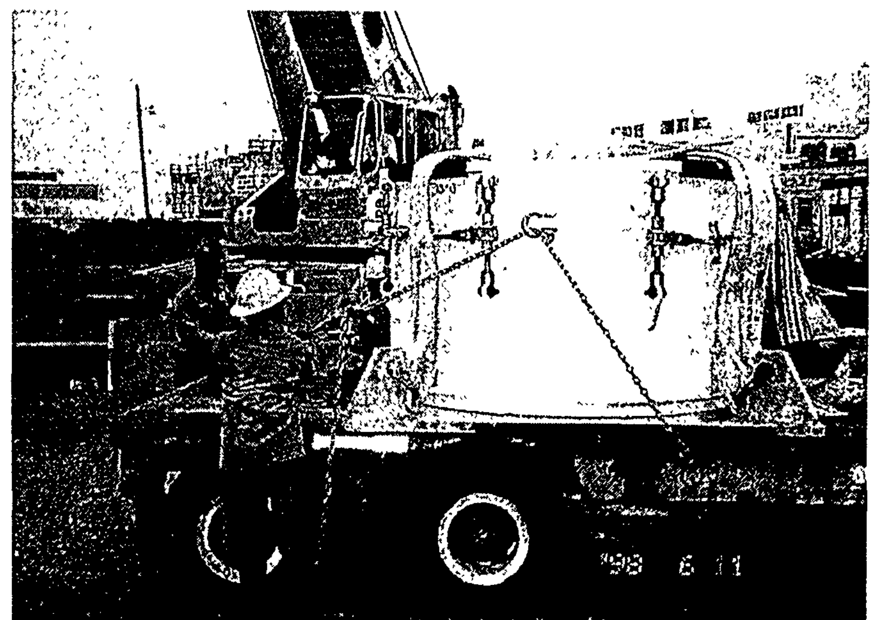


Figure 3. Reactor shield plug being transferred to interim storage.

Remedial Concerns

Volumes of contaminated media at CP-5 have been estimated at approximately 40,000 ft^3 of contact-handled (dose rates less than 200 mR/hr), low-level radioactive waste, 1,000 ft^3 of remote-handled (dose rates greater than 200 mR/hr), low-level radioactive waste, and 2,600 ft^3 of mixed (radioactive and hazardous) waste. For final disposition, project waste is transferred to the Laboratory's Waste Management Operations group who arrange for it to be shipped for disposal at the DOE Hanford Site.

Project Goals and Activities

Minimal funding was allocated by the DOE for CP-5 decommissioning between the years 1990 and 1996. However, with the funding which was provided, the following tasks were completed: outbuilding demolition, reactor cooling and process systems removal, facility roof repair, and cleanup of the reactor floor, yard area, and storage area.

Additional funding in the 1997-1999 period allowed for completion of the following tasks:

- D&D of reactor fuel pool
- removal of reactor vessel and components
- removal of reactor bioshield
- asbestos abatement

During this period, the CP-5 facility was selected as the site of the first DOE Large Scale Demonstration Project (LSDP) supported by the U.S. DOE Assistant Secretary for Environmental Management Office of Science and Technology (EM-50). In FY 1997-1998 period, 23 field-test-ready D&D technologies were demonstrated at the CP-5 facility. In FY 1999, an outside contractor was hired to complete the CP-5 D&D Project.

Tasks remaining to be completed to finish the D&D work are:

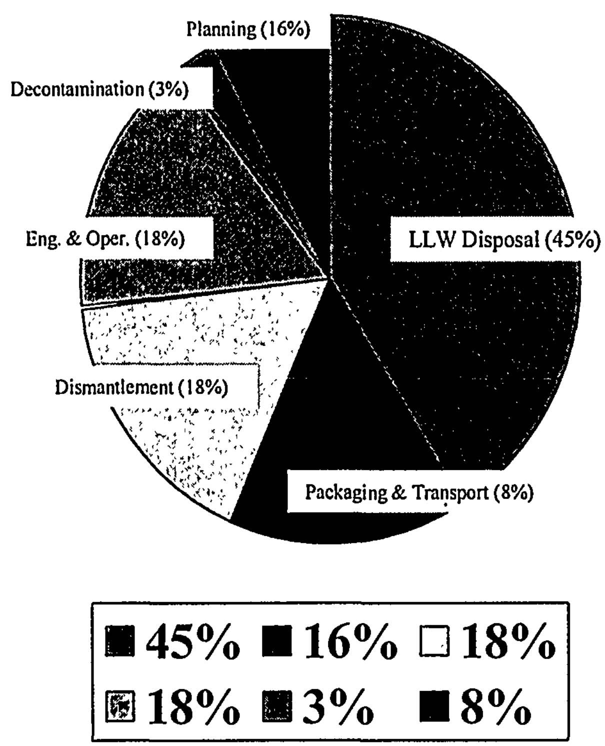
- remove ventilation system and retention tanks
- prepare rod storage area and hot cells for final building disposition
- complete final facility decontamination and waste packaging
- perform final radiological survey
- complete project closeout activities and final report preparation.

At the completion of all tasks, scheduled for July 2000, the CP-5 facility building will be transferred to Laboratory surplus facilities for eventual demolition.

Technology Development

The need for new technologies is derived from both experiences in the field and from an assessment of the costs and safety implications of the various operational steps in D&D. For example, in cases where there is a large cost associated with a specific phase of decommissioning, payoffs from improvements could be significant; and therefore, worth the investment put into the development of new technologies. Figure 5 shows an assessment of typical costs for D&D operations for a nuclear utility and the high payoff areas for technology development. Technologies are being developed at numerous sites within the U.S. In addition to

Breakdown of Commercial D&D Costs



High Payoff Areas

- Radioactive Material Recycle and Reuse
- Advanced Decontamination Methods
- Robotics Systems
- Advanced Materials Cutting Technologies
- Worker Protection/Safety
- Sensors for Characterization

Figure 5. Decision on Technology Needs

ANL and the other DOE national laboratories, work is in progress at several universities and industries. Taken together, this forms a full set of technologies - some novel and innovative, others adaptations of existing technologies - to best suit the D&D tasks. The areas in which technology development work is being carried out at ANL are listed below in Table 1.

The ANL technology work ranges from basic research (for example, in developing a fundamental understanding of the chemical bonds on contaminated surfaces - which can lead to the development of methods to "surgically" break the bonds with minimal energy expenditure and secondary waste production), to purely applications development (for example, design and development of interface hardware and software to apply robotics technology to specific applications)[6]. On an intermediate level is the development of a system to utilize ANL developed chelating agents for chemical decontamination of piping. Present data suggest that this method produces high decontamination factors with a considerable reduction in secondary waste generation compared to current methods. Another example is the demonstration of the use of laser systems with fiber optic beam delivery systems for use in decontamination and cutting operations[7].

In addition to the technologies deployed at CP-5 listed in Table 2, there are technology elements like risk assessment, safety analysis, waste minimization/pollution prevention, site characterization methods, etc., that are also being developed at ANL[8]. These methods have been utilized on ANL site D&D tasks and applied to other US DOE sites and at utility sites. The experience so gained can also be applied to assist the research and test reactor community worldwide.

Technology Demonstrations

Prior to its acceptance by a commercial D&D operation, it is necessary to demonstrate a laboratory developed technology under near prototypic conditions. A number of technologies that show promise in a laboratory setting may prove to be unusable in the contaminated radioactive environment typical of a D&D operation. A number of the research and test reactors at the ANL sites have reached their end of life and are being used as tests beds for the demonstration of enhanced D&D technologies. In conjunction with the ongoing D&D of the CP-5 reactor, a program of demonstrations of D&D technologies was undertaken under the sponsorship of the U.S. Department of Energy's Environmental Restoration and Technology Development Programs. The program was managed by the Strategic Alliance for Environmental Restoration comprised of ANL, two nuclear utilities, two large engineering companies and a major university[9].

A formal technology selection process was defined and utilized for the selection of appropriate demonstrations. One member from each of the Strategic Alliance partners was included in a Technology Selection Committee which evaluated candidate technologies against a set of metrics to judge suitability for the demonstration. The selected technologies were required to develop detailed test plans and safety assessments, and final approval for testing was contingent upon approvals of the test plan or safety assessments as well as satisfactory fulfillment of several institutional and financial considerations.

Table 1
Technologies Under Development at Argonne National Laboratory

- Chemical Decontamination
- Robotics Applications
- Laser Decontamination
- Cutting Technologies
- Sensor Development
- Sodium-Cooled Reactor D&D Technologies

Table 2
Final Technologies Demonstrated at the CP-5 Research Reactor

Characterization
- Mobile Automated Characterization System
- In-situ Object Counting System
- Pipe Explorer
- X-Ray Fluoresence
- Gamma Cam Radiation Imaging System
- SRA Surface Contamination Monitor
- Pipe Crawler
- Field Transportable Beta Counting System

Decontamination
- Empore Membrane Separations
- Centrifugal Shot Blaster
- Rotopeen with Captive Shot
- Milling Decontamination
- Flashlamp
- Advanced Recyclable Concrete Demolition System
- Carbon Dioxide Blasting
- Pegasus Coating Removal System

Dismantlement
- Swing Free Crane
- Dual Arm Work Platform
- ROSIE Remote Work System
- BROKK Remote Control Concrete Demolition System

Worker Health & Safety
- NU-FAB Suit
- FRHAM-TEX Cool Suit

The technologies selected could be classified into four distinct categories:

- Facility Characterization
- Robotics/Dismantlement
- Facility and Equipment Decontamination
- Worker Protection/Containment

In total, 86 innovative technologies were evaluated as part of this process. Of these, 41 were accepted for demonstration. For a number of reasons, 18 of the selected technologies were unable to go through the entire demonstration process and twenty three technologies were actually demonstrated. The demonstration process consisted of the significant size of the demonstration (e.g., square foot of area to be decontaminated; length of piping to be examined, etc.) within which the innovative technology was operated. Data were taken on various technical, safety and cost parameters and these were compared against corresponding data for baseline technologies. The improvements (or lack thereof) in performance were tabulated. The database so compiled is clearly going to be extremely valuable for D&D planners in making their decisions on the appropriate technologies for their D&D operations.

Of the 23 technologies demonstrated[10] listed on Table 2, 9 are characterization technologies, 8 are decontamination technologies, 4 are dismantlement technologies, and 2 are worker health and safety technologies. Several of these presented significant benefits to the D&D operations while others were only of marginal benefit. Final reports on the technologies and data have been widely available to the D&D community. Detailed, evaluated results have been prepared, and distributed and more will be in the near future[11-29]. A project final report has also been prepared and distributed[30]. These evaluations will assist planners of future D&D operations in selecting appropriate technologies for the work.

III. Results

In this section, details are provided on select technologies which might be of most interest to others planning for decommissioning of research reactors. (See Table 3).

Surface Contamination Monitor and Survey Information Management System (SCM/SIMS)[15]

The SCM/SIMS is designed to perform both alpha and beta radiation surveys and to then document the measured data. A motor driven cart houses the position-sensitive gas proportional counter with a variable width of detection ranging from 0.5-5.0 meters. The SIMS component of SCM/SIMS is a series of software programs which processes and analyzes the collected data into either a standardized or a customized data report.

For test areas, this technology was from 2 to 28 times faster than the manual survey baseline technique. The fact that the system automatically generated the data reports with minimal operator intervention was probably the greatest benefit.

Table 3.

Technology	Vendor	Deployments	Performance Compared to Baseline	Cost Compared to Baseline	Baseline Technology Cost	Innovative Technology Cost	References
SCM/SIMS	Shonka Research Associates, Inc.	NPP & DOE	From 2x – 28x faster	3x faster due to primarily the data analysis	alpha - $0.13/sq ft beta/gamma - $0.34/sq ft	alpha - $0.07/ sq ft beta/gamma - $0.02 – 0.12/sq ft	DOE/EM-0347; DOE/EM-0433
GammaCam Radiation Imaging System	AIL Systems, Inc.	NPP & DOE	3x faster; less radiation exposure to worker	20% cheaper than the baseline	$0.34/sq ft	$0.28/sq ft	DOE/EM-0345
In-Situ Object Counting System (ISOCS)	Canberra Industries Inc.	DOE	Easy to use	70% cost savings	$140/test	$56/test	DOE/EM-0477
Pipe Crawler Internal Piping Characterization System	Radiological Services Inc.	DOE	Little secondary waste & greatly reduced waste volumes	45% cost savings	$272/ft for dismantle & dispose	$36/ft	DOE-EM-0355
Pipe Explorer	Science and Engineering Associates Inc.	NPP & DOE	Used for both video & rad measurements	about 2x cheaper per unit area	$272/ft for dismantle & dispose	$150/ft	DOE/EM-0440
Centifugal Shot Blaster	Concrete Cleaning Inc.	DOE	2x faster	For large areas is very cost effective	$18/sq ft	$50/sq ft	DOE/EM-0346; DOE/EM-0441
3M Empore	3M Company	DOE	Same as baseline	50% of baseline	$2.50-$3.70/gal	$1.71/gal	not published yet
Dual Arm Work Platform	Oak Ridge National Laboratory	DOE	Greatly reduced worker rad exposure	50% of baseline	$3.00-$11.00/lb; $150/ft	$2.30-$6.50/lb; $110/ft	DOE/EM-0389
Swing Reduced Crane	Convolve Inc.	DOE	2x faster	(insufficient data)			DOED/EM-0475

GammaCam™ Radiation Imaging System[13]

The GammaCam™ system is designed to provide remote two-dimensional information on both the positive and relative strengths of gamma ray radiation fields. The source of the gamma field can be from a few to several hundred feet away from the observer. The system consists of a portable sensor head and a portable computer for control. The sensor head contains both gamma ray and visual imaging systems. The benefit of this technology is primarily in reduced worker doses and it also provides a two dimensional color image of gamma radiation fields on a corresponding black and white photo image.

This approach, when compared to the baseline approach, was found to be 3 times faster.

In-Situ Object Counting System (ISOCS)[29]

The ISOCS is a portable, in-situ Germanium based spectroscopy system specifically designed to provide information on types and amounts of radioactive material. The system consists of a Germanium detector/portable cryostat; a cart to hold the unit; lead shielding and collimators, a portable spectroscopy analyzer; along with a portable personal computer and the in0situ calibration software.

When this system was deployed and tested at CP-5, it was easy to use and provided reasonable agreement between the baseline data and that obtained using ISOCS. The most significant benefit to using ISOCS was that it provided a realtime, non-intrusive assay information without the typical delays often encountered in off-site sample analysis. The cost of ISOCS was about 70% of the baseline cost of counting with off-site analysis.

Pipe Crawler® Internal Piping Characterization System[18]

The Pipe Crawler® system is a radiological characterization/free release survey technology. The Pipe Crawler® is a manually deployed pipe inspection system consisting of: a crawler, an array of G-M tubes connected to an external data processing and storage system. An option with this system is a video camera and tape recording system that can be used with the unit. Piping diameter amenable to this technology can range from 2"-18" in diameter and can extend up to 200 feet away from the unit.

At the CP-5 facility this technology was used to characterize rod storage area tubes and 2 vent lines. Benefits of the technology included: reductions in cost of excavating embedded piping systems, reduced waste volumes and very little secondary waste in using the technology. The use of Pipe Crawler® was over 8 times cheaper than to excavate and dispose of the material.

Pipe Explorer™ [26]

The Pipe Explorer™ System is a characterization technique/method for transporting a variety of tools into piping or ducting. The system uses a pneumatically operated air-tight tubular membrane as a protective envelope for towing radiation detectors and video cameras into pipe. The membrane envelope is pressurized and then provides a safe, clean conduit for the sensors to travel through. This system can be used up to 200 feet away from the base unit and in piping/ducting ranging from 2" to 40" in diameter. Deployments have been completed at both commercial NPP and DOE sites. The protective membrane feature allows workers to avoid handling potentially contaminated materials and also prevents contamination of the equipment in the membrane. In addition, since the membrane slowly rolls, the contamination does not move with the membrane.

Centrifugal Shot Blast System[14]

This system consists of a shot blast unit which propels steel shot at a high rate of speed in order to abrade concrete and concrete coated surface. Spent shot is collected by vacuum and reused until fully spent. Fully spent shot is vacuumed into a HEPA filtered dust collection system (55 gallon drum). The application of this technology at CP-5 was for the removal of contaminated paint from a concrete floor area of about 800 square feet. The removal rate using this technique was about 310 square feet per hour – nearly 50% over the baseline production rate. This unit is self propelled and reduced operator fatigue; the use of the vacuum dust/debris collection system assists in reducing airborne dust concentrations.

Dual Arm Work Platform[20]

The Dual Arm Work Platform (DAWP) is a robotic system used to work in radioactive and other hazardous work areas where exposure levels preclude or limit human intervention. The DAWP consists of a platform base, two Schilling Titan III six degrees-of-freedom hydraulically driven manipulators, a remote viewing system, a lighting system, a tool control system and a tether that supplies hydraulics, power and control signals to drive the DAWP functions.

The DAWP was used at the CP-5 facility as a work platform for dismantlement of the reactor vessel (RV) bioshield complex. When compared to the baseline technology for RV/bioshield complex removal, the DAWP resulted in about a 50% savings in cost over the baseline approach.

Swing-Reduced Crane System[28]

This system was designed for and deployed to the CP-5 facility to minimize the swinging action induced in loads being moved by a crane and to enhance the operator's ability to remotely control positioning of loads. The system uses a No-Sway™ crane controller to control the motion of the crane bridge/trolley. This allows the crane operators to move the crane in precise steps without swinging the load. Other features used in this system at CP-5 included: a radio control system for remote crane operation, a motorized rotating black, a remote operation camera and a digital load cell. On certain key lifts at CP-5, the use of the system reduced the swing time by 60% or more. To accurately assess the usefulness of this technology, more extensive use of the technology on another project is needed. It was used on a limited basis in our project.

3M Empore™ Membrane Separation Technology

This 3M developed membrane separation technology provides a method to clean-up radioactively contaminated water. The technique employed consists of enmeshing surface-active particles in a web-like matrix, which has been formed into a membrane. The membrane takes the form of a cartridge filter for use in a standard commercial cartridge filter housing. At high flow rates, this technology is capable of removing beta and gamma particles to below detectable limits. The technology was used at CP-5 to remove soluble Cs-137 and Co-60 from the fuel pool. Empore was used to process 4500 gallons of pool water at a rate of 0.5 gpm. The initial concentrations of Cs-137 and Co-60 were 0.6 pCi/l and 0.2 pCi/l respectively; after filtering the levels of both dropped to below 0.02 pCi/l.

Benefits of the technology included: generation of less secondary waste, cartridge sorbents can be selected for specific contaminant, and the sorbent material was more efficient than an ion-exchange treatment option. The experience at CP-5 resulted in the ability to process 650 gallons of water/day at a cost of about 50% of the baseline approach of evaporation.

IV. Applications to Research Reactors Worldwide

As stated earlier, a large number of research facilities will need to be decommissioned in the not too distant future. the experience and expertise necessary to undertake this task is often in short supply in many of the countries where the reactors are located. The experiences gained by ANL in research and test reactor D&D operations, technology development and demonstrations could be utilized very effectively in assisting the organizations responsible in planning and execution of the decommission. Areas in which ANL could provide support include:

- Characterization planning and evaluation
- D&D plan
- Procedures preparation
- Safety and environmental evaluations
- Risk based materials release considerations
- Technology insertions and utilization
- End of project survey planning and execution

Mechanisms need to be found to enable the experience base to be shared and utilized effectively in the safe and economical decommissioning of research and test reactors worldwide.

V. Future Programs

Future reports on this work will focus on the performance of individual technologies as tested in the decommissioning work place. Certain decommissioning technologies are currently being deployed in the U.S. at sites outside ANL and evaluated for potential application on future reactor D&D projects. The next report will present some of the most promising of these in detail.

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