INNOVATIVE TECHNOLOGY
Summary Report

DOE/EM-0343

ROTO PEEN Scaler and VAC-PAC® System

OST Reference # 1943

Deactivation and Decommissioning Focus Area

Demonstrated at
Chicago Pile 5 (CP-5) Research Reactor
Large-Scale Demonstration Project
Argonne National Laboratory - East
Argonne, Illinois

INNOVATIVE TECHNOLOGY
Summary Report

Purpose of this document

Innovative Technology Summary Reports are designed to provide potential users with the information they need to quickly determine if a technology would apply to a particular environmental management problem. They are also designed for readers who may recommend that a technology be considered by prospective users.

Each report describes a technology, system, or process that has been developed and tested with funding from DOE's Office of Science and Technology (OST). A report presents the full range of problems that a technology, system, or process will address and its advantages to the DOE cleanup in terms of system performance, cost, and cleanup effectiveness. Most reports include comparisons to baseline technologies as well as other competing technologies. Information about commercial availability and technology readiness for implementation is also included. Innovative Technology Summary Reports are intended to provide summary information. References for more detailed information are provided in an appendix.

Efforts have been made to provide key data describing the performance, cost, and regulatory acceptance of the technology. If this information was not available at the time of publication, the omission is noted.

All published Innovative Technology Summary Reports are available online at http://em-50.em.doe.gov.

TABLE OF CONTENTS

SECTION 1

SUMMARY

Technology Summary

The Pentek, Inc., milling technology, comprising the ROTO PEEN Scaler and the VAC-PAC® waste collection system, is a fully developed and commercialized technology used to remove hazardous coatings from concrete and steel floors, walls, ceilings, and structural components.

The ROTO PEEN Scaler, the basic hand-held tool shown in Figure 1, weighs 6.5 lb, has a cutting width of 2 in, is pneumatically driven, and works with a variety of interchangeable cutting media such as cutting wheels and 3M™ Heavy-Duty Roto Peen Flaps. It was designed to remove lead-based paints and radioactive and other hazardous contaminants from flat areas and large vertical surfaces, including the interface near walls and within confined spaces. The ROTO PEEN Scaler operates independently or in conjunction with the Pentek VAC-PAC® waste collection system (Figure 2).

The VAC-PAC® high-efficiency particulate air (HEPA) filter and vacuum system is a portable unit offering two-stage positive filtration of hazardous particulates, including radioactive particles and lead-based paint. The VAC-PAC® also has a patented controlled-seal drum fill system, which allows the operator to fill, seal, remove, and replace the waste drum under controlled vacuum conditions. Skills and training required to operate the Pentek milling technology are minimal because the equipment is relatively easy to operate.

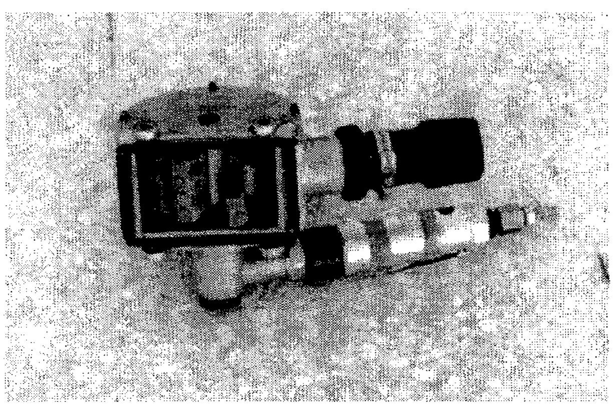


Figure 1. Pentek's ROTO PEEN Scaler.

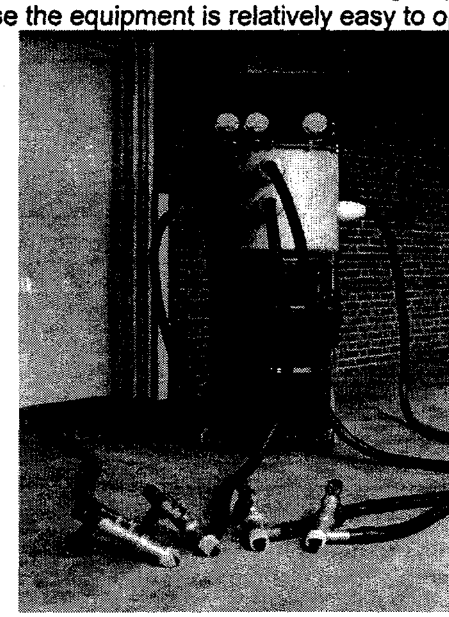


Figure 2. Pentek's VAC-PAC®.

Potential markets exist for the innovative ROTO PEEN milling system at the following sites: Nevada, Oak Ridge Y-12 and K-25, Paducah, Portsmouth, Rocky Flats D&D sites, and the Savannah River Site. This information is based on a revision to the OST Linkage Tables dated August 4, 1997.

Advantages

The main advantage of the Pentek milling technology over the baseline technology, mechanical scabbling, is the simultaneous collection of dust and debris by the VAC-PAC®, which is connected to the ROTO PEEN Scaler. Mechanical scabbling uses a floor/deck scaler suitable for thick coating removal and surface preparation of large areas of concrete floors. This unit is equipped with eleven 1-in-diameter pistons that impact the floor at a rate of 2,300 blows/min/piston. An aluminum shroud surrounds the pistons to capture large pieces of debris; however, an ancillary dust collection/vacuum system is not being used. Instead, a containment system (i.e., a plastic tent) is erected over the area to be decontaminated to minimize the potential release of airborne dust and contamination.

Using the Pentek milling system's dust collection/vacuum system significantly reduces the amount of airborne dust generated during the decontamination and decommissioning (D&D) process and reduces personnel exposure, which may lead to a significant reduction in respiratory protection and personnel protective equipment (PPE) requirements, especially in highly contaminated facilities.

The ROTO PEEN Scaler also can remove only the coating, specific layers of the coating, or the coating and concrete. The size of the ROTO PEEN Scaler makes the unit ideal for use in tightly confined areas that the mechanical scabbler would be too large to access.

Demonstration Summary

This report describes a demonstration of the Pentek, Inc., milling system to remove the paint coating from 650 ft^2 of concrete flooring on the service floor of the Chicago Pile-5 (CP-5) Research Reactor. CP-5 is a heavy-water moderated and cooled, highly enriched, uranium-fueled thermal reactor designed to supply neutrons for research. The reactor had a thermal-power rating of 5 megawatts and was operated continuously for 25 years until its final shutdown in 1979. These 25 years of operation produced activation and contamination characteristics representative of other nuclear facilities within the Department of Energy (DOE) complex and the commercial nuclear sector. CP-5 contains many of the essential features of other DOE and commercial nuclear facilities and can be used safely as a demonstration facility for the evaluation of innovative technologies for the future D&D of much larger, more highly contaminated facilities.

This Pentek, Inc., milling technology demonstration is part of the CP-5 Large-Scale Demonstration Project (LSDP) sponsored by the DOE Office of Science and Technology (OST), Deactivation and Decommissioning Focus Area (DDFA). The objective of the LSDP is to select and demonstrate potentially beneficial technologies at the Argonne National Laboratory-East (ANL) CP-5 Research Reactor. The purpose of the LSDP is to demonstrate that using innovative and improved D&D technologies from various sources can result in significant benefits, such as decreased cost or increased health and safety, when compared with baseline D&D technologies.

The demonstration period (December 9–12, 1996) included the mobilization, demonstration, and demobilization of the Pentek milling system. Radiological surveys were performed both before and immediately after the demonstration to determine the level of decontamination achieved by the ROTO PEEN milling system's removal of floor coatings. The vendor was not required to remove additional concrete from the floor area if the final radiological levels were still found to be elevated at the end of the demonstration.

Pentek personnel operated three identical hand-held ROTO PEEN Scalers for the demonstration. ANL personnel from the CP-5 Project and the Environment, Safety, and Health (ESH) Division provided support in the areas of health physics (HP), industrial hygiene (IH), waste management (WM), and safety engineering. Data collection, including benchmarking and cost information, was performed by Florida International University - Hemispheric Center for Environmental Technology (FIU-HCET). The cost analysis was performed by the U.S. Army Corps of Engineers (USACE), and benchmarking activities were performed by ICF Kaiser, International.

Key Results

The key results of the demonstration are as follows:

- The Pentek ROTO PEEN Scalers removed the paint coating from the 650 ft^2 of concrete flooring in the demonstration area at an average rate of 40.6 ft^2/h/scaler.
- This technology is best used in confined areas and around and under obstacles. It is capable of removing coatings to within one-half inch from the edge of walls and obstructions.
- Removal of the coatings from the concrete floor was sufficient to reduce the radiological levels from an original area of elevated fixed total beta/gamma contamination measuring 800 cm^2 (0.86 ft^2) with a maximum hot spot of 13,500 dpm/100 cm^2 to an elevated contamination area of only 200 cm^2 (0.22

ft^2) with the same hot spot reduced to 5,900 dpm/100 cm^2 fixed total beta/gamma. The contamination levels for the remaining floor were at or below background levels before the demonstration.

- The Pentek VAC-PAC® dust-collection system, which was connected to the ROTO PEEN Scalers tested, has the potential to significantly reduce the amount of airborne radioactivity during D&D activities and, therefore, potentially to reduce PPE requirements, especially respiratory protection. This feature is beneficial in contrast to the mechanical scabbling technology, which requires that a plastic tent containment system be erected around the area to be decontaminated.

- Investigators recommend that, if the ROTO PEEN Scaler is to be used for the decontamination of large floor spaces, one or multiple ROTO PEEN Scaler(s) be mounted on a lawn-mower-type apparatus to increase production rates and allow the operators to decontaminate large floor areas while standing rather than on their hands and knees.

Contacts

Technical

Linda Lukart-Ewansik, Pentek, Inc., Decontamination Products Division, (412) 262-0725, pentekusa@aol.com

Demonstration

Leonel E. Lagos, Test Engineer, Florida International University-Hemispheric Center for Environmental Technology, (305) 348-1810, leonel@eng.fiu.edu

Susan C. Madaris, Florida International University-Hemispheric Center for Environmental Technology, (305) 348-3727, madariss@eng.fiu.edu

CP-5 Large-Scale Demonstration Project or Strategic Alliance for Environmental Restoration

Richard C. Baker, U.S. Department of Energy, Chicago Operations Office, (630) 252-2647, richard.baker@ch.doe.gov

Steve Bossart, Federal Energy Technology Center, (304) 285-4643, sbossa@fetc.doe.gov

Terry Bradley, Strategic Alliance Administrator, Duke Engineering and Services, (704) 382-2766, tlbradle@duke-energy.com

Web Site

The CP-5 LSDP Internet address is http://www.strategic-alliance.org.

Other

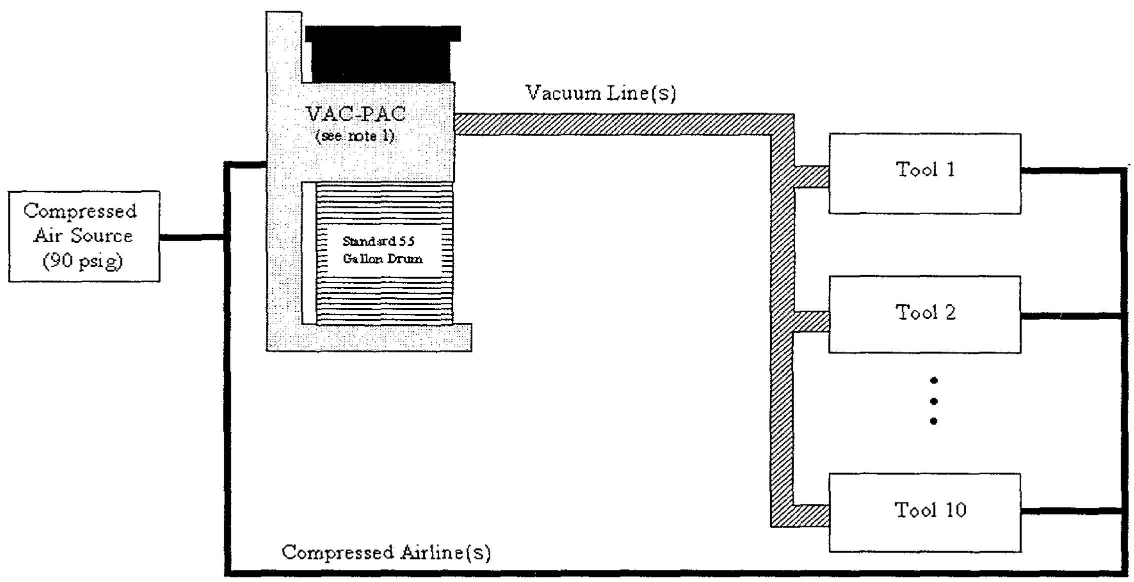
All published Innovative Technology Summary Reports are available online at http://em-50.em.doe.gov. The Technology Management System, also available through the EM50 Web site, provides information about OST programs, technologies, and problems. The OST Reference # for ROTO PEEN Scaler with VAC-PAC® System is 1943.

SECTION 2

TECHNOLOGY DESCRIPTION

Technology Schematic

The Pentek ROTO PEEN Scaler is a hand-held tool marketed to remove coatings from concrete, steel, brick, and wood. Manufactured of solid cast alloy, the ROTO PEEN Scaler is rugged, and its lightness makes it highly portable and easy to maneuver. It is designed to treat vertical and horizontal surfaces such as beams, girders, tank shells, and areas near walls and in confined spaces. Figure 3 is a schematic of the Pentek system.



1) The VAC-PAC® system can support the operation of up to 10 tools, each located up to 100 ft away.

Figure 3. Schematic of the Pentek decontamination system.

Interchangeable cutting media are available for various applications. The operator can select from a variety of 3M™ Heavy-Duty Roto Peen Flaps for the removal of coatings, tight mill scale, or concrete scarification. Type A flaps, used for concrete scarification, were used at the CP-5 demonstration. These flaps are studded with rows of tungsten carbide cutters and mounted on a rotating hub. Pentek personnel also demonstrated the use of star cutter metal wheels on a 9-ft^2 section of floor at CP-5. Because the application of the star cutter metal wheels exceeded the scope of this demonstration, this equipment is not discussed further in this document.

The vendor's operational parameters for the Pentek ROTO PEEN Scaler include the following:

- Required vacuum source — 75 ft^3/min
- Air consumption at 90 psig — 30 standard ft^3/min
- Dimensions (L x W x H) — 6 in x 2½ in x 4 in
- Weight — 6.5 lb
- Speed — User adjustable up to 2,400 rpm
- Cutting width — 2 in
- Pentek advertised production rate — 30 to 50 ft^2/h on flat surfaces

The ROTO PEEN Scaler is not designed specifically for corners or edges. However, Pentek markets a second tool, the CORNER-CUTTER®, for this purpose. In addition, an optional right-angled ROTO PEEN Scaler is available with a right-angled motor/drive for access to narrow spaces such as I-beams and stair risers. Neither of these tools were applied during the CP-5 demonstration.

The Pentek VAC-PAC® was used in conjunction with the ROTO PEEN Scaler during the CP-5 demonstration. The objective of the demonstration was to remove the contaminated paint coating from 650 ft^2 of concrete flooring on the service floor of the ANL CP-5 Research Reactor facility. The debris removed by the ROTO PEEN Scaler was collected in this vacuum system. The VAC-PAC® features Pentek's patented controlled-seal drum fill system, which allows the waste drum to be filled, sealed, removed, and replaced under controlled vacuum conditions. With this system, the operator's exposure to the contents of the waste drum and the possibility of releasing airborne contamination during drum-change operations is minimized.

Several models of the VAC-PAC® are available, including models with different vacuum flow rates and electric- and air-powered models. Model 24, the largest air-powered unit, was demonstrated at CP-5. The vendor's specifications for this unit are as follows:

• Rated vacuum flow	600 ft^3/min
• Air consumption @ 85 psig	280 standard ft^3/min
• Rated static lift	100 in water gauge
• Dimensions (L x W x H)	48 in x 28 in x 72 in
• Weight	Approximately 750 lb
• Primary roughing filter cartridges	Three at 8-in diameter, 95 percent efficient at 1 micrometer (μm)
• Secondary HEPA filter	One @ 12 in x 24 in, 99.97 percent efficient at 0.3 μm
• Standard waste drum	23, 52, or 55 U.S. gal

System Operation

- The ROTO PEEN Scaler is operated by using a squeeze trigger mounted on the handle of the scaler unit. The unit travels on small wheels along the floor and is led using the handle on the top of the unit.

- As the floor is being decontaminated, the debris generated is vacuumed into the VAC-PAC® and drummed for disposal.

- Skills and training required to operate the Pentek milling technology are minimal because the equipment is relatively easy to operate.

- Utilities required for the operation of the Pentek milling system at the CP-5 LSDP included an air compressor (minimum 370 psi) and a 115-V, 20-amp electrical current source.

- Decontamination of the ROTO PEEN Scaler is relatively easy. The scaler comes apart for easy wiping. The VAC-PAC® system is also easily wiped down after the filters are removed.

- Primary waste generated by the coating removal process consists of a light, powdery mixture of paint and concrete. Secondary waste consists of spent Roto Peen flaps, vacuum hoses, the roughing and HEPA filters in the VAC-PAC®, and any material used during equipment decontamination (e.g., damp rags).

SECTION 3

PERFORMANCE

Demonstration Plan

The demonstration of the Pentek milling technology was conducted according to the approved test plan, *CP-5 Large-Scale Demonstration Project: Test Plan for the Demonstration of Milling Technology at CP-5* (Strategic Alliance for Environmental Restoration 1996). The objective of the demonstration was to remove the contaminated paint coating from 650 ft^2 of concrete flooring on the service floor of the ANL CP-5 Research Reactor facility. The concrete is approximately 40 years old and is covered with multiple layers of paint. The paint has worn through in many locations, exposing the subcoatings. Because the depth of the contamination in the concrete floors at CP-5 was unknown, the decision to perform coating removal was based on the potential future need to reuse the floor space where demonstrations were held. Coating-removal techniques tend to yield a smooth surface that can be repainted or covered easily. In contrast, concrete-removal technologies have the potential to produce an uneven, rough surface that could be difficult to reuse.

Radiological surveys for both fixed and removable contamination were conducted both before and immediately after the demonstration to determine the level of decontamination achieved by the coating removal. The vendor was not required to remove additional concrete from the demonstration area if the final radiological levels were still found to be above acceptable levels.

During the demonstration, evaluators from FIU-HCET collected data in the form of visual and physical measurements. Time studies were performed to determine the production rate of the technology and implementation costs. The end-point condition left by the demonstration was compared with the requirement of removing the coating and any subcoatings to produce a bare concrete floor. Additional field measurements collected included secondary waste generation, potential personnel exposure, and utility consumption. The milling technology was evaluated against the baseline technology, mechanical scabbling.

Treatment Performance

Table 1 summarizes the results of the Pentek milling technology demonstration and compares them with the baseline technology.

Table 1. Performance data

Criteria	Pentek milling technology	Baseline mechanical scabbling technology*
Applicable surface	Coating removal from painted concrete floor.	¼ in concrete removal from floor.
Production rate (removal rate only)	40.6 ft^2/h	200 ft^2/h
Amount and type of primary waste generated	2.54 ft^3 of very powdery paint chips (contained by the VAC-PAC® as generated).	Amount estimated to be 19.5 ft^3 of a mixture of powdery and large pieces of paint chips and concrete; requires manual cleanup; no vacuum system is attached.

Table 1. (continued)

Criteria	Pentek milling technology	Baseline mechanical scabbling technology*
Type of secondary waste generated	Roto Peen flaps Roughing filters and high-efficiency particulate air (HEPA) filter Vacuum hoses - 50-ft sections.	Tent-enclosure materials and worn pistons/scabbling bits.
Airborne radioactivity generated by equipment	All airborne radiological measurements were at or below background levels.	Not connected to vacuum system; therefore, up to 10 percent of debris generated can become airborne.
Noise level	94 dBA in work area, hearing protection is required.	84 dBA (per vendor, not measurements).
Capability to access floor-wall unions	No closer than ½ in.	No closer than 1 in.
Development status	Commercially available.	Commercially available; compatible vacuum systems are also available.
Ease of use	Minimal training required for use. Operators work on hands and knees for floor areas, resulting in a need for frequent breaks.	Training required: 2 h/person. Walk-behind, push-floor model. Moderate-to-heavy vibrations can cause operator fatigue.
End-point condition	Paint coating was removed, leaving a smooth, bare concrete surface.	Paint coating is removed, leaving a rough, bare concrete surface.
Worker safety	Tripping hazard because of hoses. Rotating and cutting hazards.	Flying concrete poses a potential eye hazard.

* Baseline was not demonstrated and data are from vendor-supplied information and engineering estimates.

Radiological surveys of the demonstration area were performed before and after the demonstration. The total fixed beta/gamma contamination results for the locations of elevated gross direct beta readings are listed in Table 2. Immediately after the coating was removed by Pentek personnel, ANL ESH-HP spot-checked known elevated locations in the demonstration area. Two of the seven locations were above background levels (actual values were not documented). Pentek personnel subsequently removed an additional 1/16 in of concrete from these areas beyond the requirements of this demonstration. Nonetheless, the contamination was deeper than the depth of concrete removed.

Table 2. Radiological results

Location	Total area (cm^2)	Total β/γ (dpm/100cm^2) contamination - pre-demonstration	Total β/γ (dpm/100cm^2) contamination - post-demonstration
1	200	7,500	*
2	100	9,400	*
3	100	7,800	*
4	100	13,500	5,900
5	100	6,700	*
6	100	9,700	3,300
7	100	3,300	*

* Results were at or below background levels of no greater than 1,500 dpm/100cm^2.

SECTION 4

TECHNOLOGY APPLICABILITY AND ALTERNATIVES

Technology Applicability

The Pentek milling technology is a fully mature and commercialized technology that is used to remove hazardous coatings from confined areas of concrete and steel on floors, walls, ceilings, and structural components. During the December 9–12, 1996, technology demonstration at CP-5, the ROTO PEEN Scaler was evaluated as an alternative to the mechanical scabbling technology for the removal of coatings from large areas of concrete floor.

The advantages of the Pentek milling technology are summarized below.

- The ROTO PEEN Scaler is well designed as evidenced by
  - the solid cast alloy construction, which allows the unit to hold up under the normal wear and tear of field operations;
  - the speed and ease with which the 3M™ Heavy-Duty Roto Peen Flaps could be replaced during the demonstration; and
  - the ease with which the scaler could be disassembled for decontamination.
- The VAC-PAC® is well designed so that
  - the controlled-seal drum fill system allows waste drums to be filled, sealed, removed, and replaced while minimizing the possibility of operator exposure or the release of airborne contamination;
  - the HEPA and roughing filters are easily accessible; and
  - the VAC-PAC® provides ports for multiple tool operation.

The major shortfall of the Pentek ROTO PEEN Scaler is that coating removal from a large floor surface is extremely labor intensive. Although this technology was effective in removing the coatings from the test area, the operators were required to work on their hands and knees for several hours at a time. Consequently, they had to stop every few minutes to stretch or adjust their PPE. The best use of this technology is for the decontamination of confined spaces around and under obstacles (e.g., staircases).

Competing Technologies

In addition to milling technologies, a number of other technologies are available to D&D professionals for removing coatings from concrete floor surfaces.

Competing technologies include the following:

- mechanical scabbling (ANL baseline technology),
- centrifugal shot blast,
- flashlamp,
- carbon dioxide blasting,
- grit blasting,
- high-pressure and ultra-high pressure water blasting,
- sponge or soft-media blasting,

- laser ablation,
- wet ice blasting, and
- various chemical-based coating removal technologies.

Several competing technologies also exist in the category of milling. These technologies differ with respect to

- cutting media (e.g., star cutter metal wheels versus 3M™ Roto Peen Flaps),
- equipment design (e.g., floor model versus hand-held), and
- operation (e.g., remote versus manual).

Data comparing the performance of the Pentek milling system to the competing technologies listed above is not available.

Patents/Commercialization/Sponsor

This demonstration used an existing and fully developed commercial technology. The ROTO PEEN Scaler and the VAC-PAC® are owned by Pentek, Inc., from whom they may be purchased. The patent for the VAC-PAC® is owned by Pentek, Inc. The Heavy-Duty Roto Peen Flaps used by Pentek during this demonstration are manufactured by 3M™ Company and can be purchased by Pentek. No issues related to patents, commercialization, or sponsorship are pending.

SECTION 5

COST

Introduction

This cost analysis compares the relative costs of the ROTO PEEN Scaler and VAC-PAC system and the mechanical scabbling technology and presents information that will assist D&D planners in decisions about use of the innovative technology in future D&D work. This analysis strives to develop realistic estimates that represent actual D&D work within the DOE complex. However, this is a limited representation of actual cost because the analysis uses only data observed during the demonstration. Some of the observed costs will include refinements to make the estimates more realistic. These adjustments are allowed only when they do not distort the fundamental elements of the observed data related to productivity rate, quantities, or work elements. They eliminate only those activities that are atypical of normal D&D work. Descriptions contained in later portions of this analysis detail the changes to the observed data. The *CP-5 Large-Scale Demonstration Project Technology Data Report for the Pentek, Inc., Milling Technology* (Strategic Alliance for Environmental Restoration, 1997) provides additional cost information. Appendix B contains more detailed cost information.

Methodology

This cost analysis compares two decontamination technologies, the innovative milling technology and the baseline mechanical scabbling technology. The milling technology was demonstrated at the CP-5 facility under controlled conditions using vendor personnel and equipment. Work process activities were timed and quantities were measured so that production rates could be determined.

Data collected during the demonstration included the following:

- activity duration,
- work crew composition,
- equipment and supplies used to perform the work steps,
- frequency and cost of worn part replacement, and
- utility consumption.

A demonstration of the baseline mechanical scabbling technology was not performed. Baseline information has been developed from the following sources:

- the existing CP-5 budget or planning documentation,
- historical experience at ANL, and
- the experience-based judgment of D&D personnel at ANL.

Because the baseline costs are not based on currently observed data, additional effort has been exerted in structuring the baseline cost analysis to ensure unbiased and appropriate production rates and crew costs. Specifically, a team consisting of members from the Strategic Alliance (ICF Kaiser, an ANL D&D technical specialist, and a test engineer for the demonstration) and USACE reviewed the assumptions to ensure a fair comparison.

The cost analysis data are displayed in a predetermined activity structure. The activities are extracts from the *Hazardous, Toxic, Radioactive Waste Remedial Action Work Breakdown Structure and Data Dictionary (HTRW RA WBS)* (USACE, 1996.) The *HTRW RA WBS* was developed by an interagency group, and its use in this analysis provides consistency with established national standards.

Some costs are omitted from this analysis to facilitate site-specific use in cost comparison. The ANL indirect expense rates for common support and materials are omitted from this analysis. Overhead rates for each DOE site vary in both magnitude and the way they are applied. Decision makers seeking site-specific costs can apply their site's rates to this analysis without having to retract ANL's rates. This omission does not sacrifice the accuracy of the cost-saving data because overhead is applied to both the innovative and the baseline technology costs. Engineering, quality assurance, administrative costs, and taxes on services and materials are also omitted from this analysis for the same reasons indicated for the overhead rates.

The standard labor rates established by ANL for estimating D&D work are used in this analysis for the portions of the work performed by local crafts. Additionally, the analysis assumes an 8-h work day and a 5-day week.

The equipment hourly rates, representing the Government's ownership, are based on general guidance contained in Office of Management and Budget (OMB) Circular No. A-94, revised (OMB, 1992), for cost-effectiveness analysis. The rate consists of ownership and operating costs. Operating costs consist of fuel, filters, oil, grease, and other consumable items and repairs, calibrations, maintenance, and overhauls.

Summary of Cost Variable Conditions

The DOE complex presents a wide range of D&D work conditions because of its variety of functions and facilities. The working conditions for an individual job directly influence the manner in which D&D work is performed. As a result, the costs for an individual job are unique. The innovative and baseline technology estimates presented in this analysis (Table 3) are based on a specific set of conditions or work practices found at CP-5. This table is intended to help the technology user identify work differences that can affect cost.

Table 3. Summary of cost variable conditions

Cost variable	Pentek milling technology	Baseline mechanical scabbling technology
	Scope of Work	
Quantity and type of material	650 ft^2; coated concrete floor.	650 ft^2, comparable to demonstration area but approximately one-quarter of original baseline scope of 2,542 ft^2.
Location	Service floor of Chicago Pile-5 (CP-5) Research Reactor, including open areas, edges, foundation vertical edges, and under cramped stairway.	CP-5 Research Reactor; same service floor area, open areas only.
Nature of work	Reduce radiological levels. Remove coatings only (paint chips).	Reduce radiological levels. Remove ¼ in of concrete (inherent in equipment along with coating).
	Work Environment	
Level of contamination	The demonstration area is not a high-radiation area. All contamination was fixed.	Assumed baseline would be the same as that of the demonstration area.
Level of contamination during D&D activity	No airborne contamination was generated. The vacuum system component of the equipment contained debris continuously.	Concrete chips and dust (airborne) created by equipment.
Temporary protection	No airborne exposure. No tent. Protective clothing (PCs) and respirator were donned, but to a lesser degree than required by the baseline.	Temporary tent required; estimated to cover 133 percent of area being worked; 865 ft^2 used. Requires PCs and respirator for comparison.

Table 3. (continued)

Cost variable	Pentek milling technology	Baseline mechanical scabbling technology
	Work Performance	
Means of acquisition	Subcontracted vendor demonstrated a provided service of craft and equipment. This analysis is based on using site craft and owned as well as some rental equipment.	Local craft workers with site-owned and some rental equipment.
Scale of production	1. Demonstrated both in large, open areas and tight spaces. 2. Crew size varied from two to three, each with a ROTO PEEN Scaler. 3. Equipment: small, hand-held, 2-in cut width.	1. Based on a large, open area and some tight areas inaccessible for the size of machine. 2. Crew of three: one with machine and two supporting members. 3. Equipment: large, floor, walk-behind model, 11-in cut width.
Production rates (crew size)	Net average of 40.6 ft^2/person-hour for crew of three persons[1].	Assumed constant rate: 200 ft^2/h for the person running the machine. Net effective production with three persons on crew is 67 ft^2/person-hour.
Primary waste	2.54 ft^3	19.5 ft^3
Secondary waste	Vacuum hoses, worn flaps, PPE, swipes, filters: estimated 12.16 ft^3.	Worn scabbling bits, swipes, PPE: estimated 7.35 ft^3 (1 drum).
Work process steps	Mill off the surface coatings using three machines simultaneously with continuous vacuum collection into closed container.	1. Scabble the surface area to ~¼ in depth with one machine, leaving debris and airborne contaminants. 2. Sample rubble [health physics technician (HPT)]. 3. Manually clean up and load into containers (steps not quantified; no earned value).
End condition	Coating removed; radiation reduced.	Coating and ¼ in concrete removed. Presumably, radiation would be reduced as well as or better than by milling because of the depth of cut (not demonstrated).

[1] As the demonstration progressed and the areas being decontaminated became more complex (e.g., under stairwells and around obstructions), the production rate decreased. On the first day, 510 ft^2 of open flooring was decontaminated at a production rate of 45.1 ft^2/h. On the second day, only 97 ft^2 was worked at a production rate of 36.5 ft^2/h. On the third day, the final 43 ft^2 was completed at a production rate of 21.2 ft^2/h.

Potential Savings and Cost Conclusions

For the conditions and assumptions stated, the innovative milling technology results in cost savings of 40 percent over the baseline mechanical scabbling alternative for this demonstration scope of 650 ft^2. Figure 4 presents a summary and comparison of the potential savings offered by the two technologies.

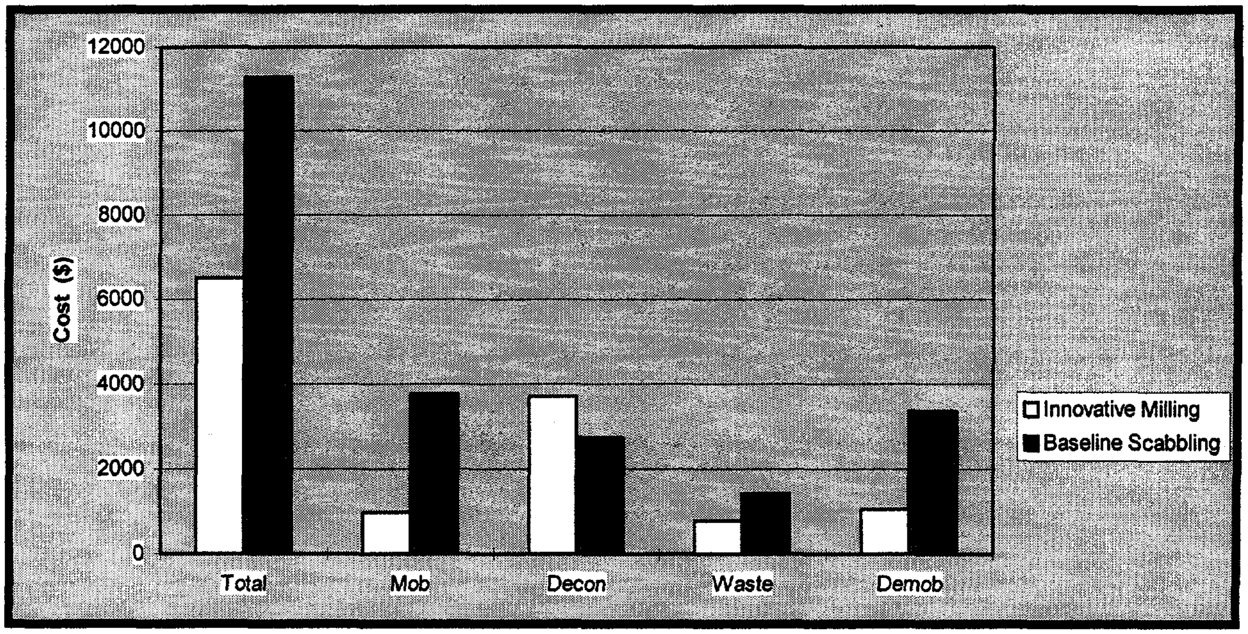


Figure 4. Technology cost comparison.

The major savings derived from Pentek's milling technology stem from the elimination of the need to construct a temporary structure to contain airborne contaminants. The innovative technology does not require the construction of a temporary structure because all debris is vacuumed continuously as it is generated.

Waste disposal constitutes the next largest savings. Removed coating generates a considerably smaller quantity of waste than does a ¼-in depth of concrete and coating removal. Minor savings include those resulting from (1) the elimination of rubble loading because the vacuum dumps directly into a closed-drum container and (2) sampling, which is not necessary because the system is closed. The savings from these activities will vary with the size of the area to be decontaminated.

Other potential cost differences at various sites may include the following:

- production rates of the machine model and its cut width and depth capabilities,
- mobilization and demobilization of equipment and personnel,
- training of new personnel,
- site health and safety requirements, and
- the size of the area undertaken as a single project.

The production rates and operating costs for milling and mechanical scabbling vary depending upon site-specific conditions and the model of the machine selected. The available production rates range from 30 ft^2/h to more than 490 ft^2/h. The width of cut affects the production rate and ranges from 2 to 18 in. Some wide-cut, large floor models are easy to use but hard to maneuver in tight spots, whereas the small, hand-held units work well under stairways but cause worker fatigue. Removal activities using mechanical scabbling with superior production rates actually cost less than the milling technology.

This analysis assumes government ownership. If vendor services are used, additional costs to mobilize and train personnel are incurred. Moreover, depending on any given site situation, a health and safety requirement beyond regulatory minimal requirements could be imposed, requiring that a tent-like structure be erected even though the innovative technology does not create airborne contamination.

Some sites will choose to discard the mechanical scabbling or scaling/milling equipment at the end of a small project or keep the equipment for extended use and future projects. Amortizing equipment ownership costs over a greater scope results in lower unit rates. For instance, the primary roughing filters and the secondary HEPA filter, used for only 650 ft^2, were discarded following the demonstration. The filter costs of \$989 resulted in a unit cost of \$1.52/ft^2 or \$159.15/h for the 6.2 productive hours in use, a relatively high cost element. However, the design of the filter system provides for automatic blow-back cleaning about every 30 seconds, which increases the life of the roughing filters to about 9 months to 1 year of continuous, normal use and the life of the HEPA filter to about 1 year. For the cost analysis, a life of 1 year and 500 h of use is assumed, which equates to about 52,420 ft^2, yielding a reduction in the two unit costs to \$0.019/ft^2 and \$1.98/h, respectively. Thus, the reduction in unit cost is dramatic, but the planned use of each technology depends on each site.

All factors discussed affect costs for both technologies. Users should compute the estimated potential savings for D&D work by substituting the expected quantities, mobilization distance, equipment investments, and production rates into Appendix B, Table B-2 to determine site-specific costs.

SECTION 6

REGULATORY AND POLICY ISSUES

Regulatory Considerations

The regulatory/permitting issues related to use of the Pentek milling technology at the ANL CP-5 Research Reactor consist of the following safety and health regulations. These regulations also apply to the baseline mechanical scabbling technology.

- Occupational Safety and Health Administration (OSHA) 29 *Code of Federal Regulations* (CFR) 1926

—1926.300 to 1926.307	Tools–Hand and Power
—1926.400 to 1926.449	Electrical–Definitions
—1926.28	Personal Protective Equipment
—1926.52	Occupational Noise Exposure
—1926.102	Eye and Face Protection
—1926.103	Respiratory Protection

- OSHA 29 CFR 1910

—1910.101 to 1910.120 (App E)	Hazardous Materials
—1910.211 to 1910.219	Machinery and Machine Guarding
—1910.241 to 1910.244	Hand and Portable Powered Tools and Other Hand-Held Equipment
—1910.301 to 1910.399	Electrical–Definitions
—1910.95	Occupational Noise Exposure
—1910.132	General Requirements (Personal Protective Equipment)
—1910.133	Eye and Face Protection
—1910.134	Respiratory Protection
—1910.147	The Control of Hazardous Energy (Lockout/Tagout)

- 10 CFR 835 — Occupational Radiation Protection

Disposal requirements/criteria include the following Department of Transportation (DOT) and DOE requirements:

- 49 CFR Subchapter C — Hazardous Materials Regulations

—171	General Information, Regulations, and Definitions
—172	Hazardous Materials Table, Special Provisions, Hazardous Materials Communications, Emergency Response Information, and Training Requirements
—173	Shippers–General Requirements for Shipments and Packagings
—174	Carriage by Rail
—177	Carriage by Public Highway
—178	Specifications for Packagings

- 10 CFR 71 — Packaging and Transportation of Radioactive Material

If the waste is determined to be hazardous solid waste, the following Environmental Protection Agency (EPA) requirement should be considered:

- 40 CFR Subchapter I Solid Waste

Waste Acceptance Criteria (WAC) from the following disposal facilities are used by ANL:

- *Hanford Site Solid Waste Acceptance Criteria* WHC-EP-0063-4
- *Barnwell Waste Management Facility Site Disposal Criteria* S20-AD-010
- *Waste Acceptance Criteria for the Waste Isolation Pilot Plant* WIPP-DOE-069

The waste form requirements/criteria may require the stabilization or immobilization of final waste streams because of their powdery consistency. This requirement would be valid for any aggressive coating/concrete-removal technology.

Since the ROTO PEEN milling system is designed for the decontamination of structures, there is no regulatory requirement to apply CERCLA's nine evaluation criteria. However, some evaluation criteria required by CERCLA, such as protection of human health and community acceptance, are briefly discussed below. Other criteria, such as cost and effectiveness, were discussed earlier in this document.

Safety, Risks, Benefits, and Community Reaction

With respect to safety issues, the Pentek milling technology is considered to be relatively safe. The cutting media used by the ROTO PEEN Scaler, the 3M™ Heavy-Duty Roto Peen Flaps, are fully contained within the scaler unit, thus reducing the potential risk to the operator's fingers. The contaminated waste debris generated during the coating removal process is simultaneously vacuumed away by the VAC-PAC®, thereby efficiently reducing the risk to the operator posed by flying paint, concrete chips, or airborne radioactive dust. In contrast, mechanical scabbling, the baseline technology, does not incorporate a vacuum system; thus, up to 10 percent of the debris can become airborne during the D&D process. In addition, the VAC-PAC® controlled-seal drum fill system minimizes the risk of a release of airborne contamination during the handling of the waste drum.

However, when the Pentek ROTO PEEN Scaler is used for large-area decontamination, the ergonomics of the system require that operators work for long periods of time on their hands and knees, limiting the amount of time they can work without short breaks to stretch or rearrange their PPE. Moreover, the hoses connecting the scaler to the vacuum system constitute a hindrance for the operators because they have to be moved or rearranged frequently. Thus, it is recommended that this system be used for small floor areas or confined areas.

The use of the milling technology rather than mechanical scabbling would have no measurable impact on community safety or environmental and socioeconomic issues.

SECTION 7

LESSONS LEARNED

Implementation Considerations

The Pentek ROTO PEEN milling system demonstrated at CP-5 is a fully developed and commercially available technology. No implementation considerations were identified.

Technology Limitations and Needs for Future Development

The Pentek ROTO PEEN technology would benefit from the following design improvements:

- For use on large, open floor areas, it is recommended that the ROTO PEEN Scaler be adapted to allow the operator to operate the unit while standing. This larger unit could be adapted to use additional 3M™ Flaps, thereby increasing both the cutting width from the current 2 in and the productivity rate for the decontamination of large areas.

- When the HEPA filter is seated in the VAC-PAC®, it is clamped in place and then measured on each side to ensure that it is centered in the unit. To facilitate the filter installation process, it is suggested that a guide be built in the VAC-PAC® to ensure the proper placement of the HEPA filter before it is secured in place with clamps.

Technology Selection Considerations

The Pentek ROTO PEEN milling system composed of the ROTO PEEN Scaler and the VAC-PAC® is an established and proven technology for the removal of coatings from metal, concrete, brick, and wood. When used on a large floor area, the technology proves to be labor intensive and requires that the operators take several short breaks to stretch, readjust PPE, and move hoses. Although the milling technology demonstrated the ability to remove coatings, the vendor states that the ROTO PEEN Scaler is also capable of removing concrete up to a depth of ¼ in.

APPENDIX A

REFERENCES

Argonne National Laboratory. *CP-5 Cost Estimate,* rev. 1, Argonne, IL. 1996.

Chem-Nuclear Systems, Inc. *Barnwell Waste Management Facility Site Disposal Criteria Chem-Nuclear Systems, Inc., Barnwell Office,* S20-AD-010, rev. 11. 1995.

Dataquest. *Rental Rate Blue Book for Construction Equipment,* Vol. 1, p. 3-1, Machinery Information Division of K-111 Directory Corporation, San Jose, CA. 1997.

TLG Engineering, Inc. *Guidelines for Producing Commercial Nuclear Power Plant Decommissioning Cost Estimates,* Vols. 1 and 2, Table 3.7 c-2, Atomic Industrial Forum, Bethesda, MD. 1986.

Nuclear Energy Services, Inc. *Decommissioning Cost Estimate for Full Decommissioning of the CP-5 Reactor Facility,* prepared for Argonne National Laboratory. 1992.

Office of Management and Budget. *Cost Effectiveness Analysis,* Circular No. A-94 revised, Washington, D.C. 1992.

Pentek, Inc. *ROTO PEEN Scaler For Dustless Coating Removal from Steel, Concrete, Brick, and Wood*, Bulletin No. M-700, Pennsylvania. 1996.

Pentek, Inc. *VAC-PAC® High Performance H.E.P.A. Vacuum/Drumming Systems*, Bulletin No. M-406, Pennsylvania. 1994.

Reape, A.G. "Productivity Study for Hazardous and Toxic Waste Remediation Projects," *Cost Engineering,* Vol. 38, No. 2. 1996.

Strategic Alliance for Environmental Restoration. *CP-5 Large Scale Demonstration Project, Test Plan for the Demonstration of Milling Technology at CP-5*, Hemispheric Center for Environmental Technology, Miami. 1996.

Strategic Alliance for Environmental Restoration. *CP-5 Large Scale Demonstration Project, Technology Data Report for the Pentek, Inc. Milling Technology,* Hemispheric Center for Environmental Technology, Miami. 1997.

U.S. Army Corps of Engineers. *Construction Equipment Ownership and Operating Expense Schedule,* EP-1110-1-B, Headquarters USACE, Washington, D.C. 1995.

U.S. Army Corps of Engineers. *Hazardous, Toxic, Radioactive Waste Remedial Action Work Breakdown Structure and Data Dictionary,* Headquarters USACE, Washington, D.C. 1996.

U.S. Department of Energy. *Hanford Site Solid Waste Acceptance Criteria,* WHC-EP-0063-4, page change number 5, Westinghouse Hanford Company, Washington. 1993.

U.S. Department of Energy. *Decommissioning Handbook*, DOE/EM-0142P, Office of Environmental Restoration, Oak Ridge, TN. 1994.

U.S. Department of Energy. *Waste Acceptance Criteria for the Waste Isolation Pilot Plant,* DOE/WIPP-069, Revision 5, U.S. Department of Energy. 1996.

APPENDIX B

TECHNOLOGY COST COMPARISON

This appendix contains definitions of cost elements, descriptions of assumptions, and computations of unit costs that are used in the cost analysis.

Innovative Milling Technology—ROTO PEEN Scaler and VAC-PAC®

Mobilization (mob) (WBS 331.01)

Equipment Transport

Definition: This cost element provides for the transportation of the site-owned decontamination equipment from its storage area to a staging area near the facility to be decontaminated. Therefore, this cost includes a truck, a forklift, and their operators; the decontamination (decon) workers that load and haul the subject construction equipment; and the hourly charges for the equipment transportation.

Assumption: The distance to a site warehouse varies, but a distance of less than 2 mi is assumed. The flat-bed truck and pneumatic forklift are rented using rates from the *Rental Rate Blue Book for Construction Equipment* (Dataquest, 1997). Loading takes 2 h; driving, 0.5 h; returning the vehicles to the equipment pool, 0.25 h.

Note: *This scenario diverges from the actual demonstration conditions that mobilized vendor personnel* and equipment from Pittsburgh, PA.

Unload Equipment and Survey Equipment

Definition: This cost element provides for unloading the construction equipment. It includes the time taken by the decon crew to unload equipment from the truck using a forklift, move the equipment to a staging area, and unpack it for survey. The site HPT does a radiological survey of the equipment to ensure that contaminated equipment is not brought on-site. Duration includes HPT/escort standby during unloading activity and decon crew standby during the HPT survey.

Assumptions: Of the observed 4 h, 2 h are assumed for unloading and unpacking the equipment. The other 2 h are assumed to be for the survey activity. The sum of the two activities totals the 4 h of the demonstration.

Training

Definition: This cost element captures the cost of the site and Health and Safety-related training required for subcontractor personnel or other unqualified personnel.

Assumptions: Local site personnel are already trained. No applicable costs result from this assumption.

Decontamination of the Reactor Building Floor (WBS 331.17)

Radioactivity Surveys of the Area

Definition: This cost element covers radiological surveying to characterize the workplace, which will facilitate the elaboration of a work plan well before starting the decontamination effort.

Assumption: Not applicable. This analysis has no cost effect. This activity is assumed to be completed before decontamination.

Set Up, Move and/or Check Out Equipment

Definition: This cost element includes time to lay out the equipment and hoses in preparation for the day's work. With the air supply compressor outside the facility, air hoses are strung through doors, penetrations, and cable hangers to the work area. The scalers, hand tools, air manifolds, and other incidental consumables are taken to the work area from the staging area.

Assumptions: Equipment move and setup are assumed to take 2 h based on observed times during the demonstration and the vendor's experience.

Remove Floor Surface Coatings

Definition: This cost element consists of the following activities.

- Milling the coatings off the concrete floor and the operational maintenance involving the replacement of the rough and HEPA filters and the consumable tool parts that wear.
- Three decon workers who simultaneously remove the coatings by working from a single air manifold and a single VAC-PAC®.
- Packaging of primary waste into the VAC-PAC® is automatic. Cleanup consists of a final hand vacuuming of very little additional debris, which is carried out while the decontamination of the last small area is being completed.
- Cost of the VAC-PAC® and ROTO PEEN Scaler is built into the decontamination activity. Consumable equipment and supplies are listed as a subbreakout of this cost element because of the variability of this element.
- Cost of PPE (see unit cost derivation in Table B-1).
- Any lost time from production is included as a factor; this includes safety meetings, daily work planning reviews, donning and doffing PPE, heat or temperature stress, and work breaks.
- Transporting final waste stream to the disposal collection area is excluded.

Assumptions:

- The quantity scope for the demonstration is 650 ft^2, which is consistent with the scope discussed for the baseline technology.
- Three decon workers, all actively milling, are employed in the demonstration.
- An HPT is not needed to accomplish the main task but is included as a standby or escort.
- The innovative milling technology eliminates the vacuuming step because the VAC-PAC® is connected to and continuously vacuums the debris from the ROTO PEEN Scaler(s), eliminating the need for HPT readings and manual containerizing.
- One decon crew worker is qualified to change the worn flap parts while other workers continue milling by swapping machines as necessary.

- Production rates used are 122 ft^2/h/three-person crew (or 40.6 ft^2/h/person) for the demonstration based on observed, timed activities that coincided favorably with the vendor's advertised production range of 40 to 50 ft^2/h/scaler.

- A 15 min safety meeting is held on two mornings during the demonstration.

- PPE changes and other related productivity losses are not measured in the demonstration but are experienced. A productivity loss factor (PLF) of 1.49 is applied to the milling demonstration activities, as illustrated herein:

Base		1.00
+ Radiation/as low as reasonably acceptable (ALARA)		0.20
+ Protective clothing	0.15	
Subtotal		1.35
x Respiratory protection		1.00 (no factor needed; covered in the observed times)
Subtotal		1.35
x Breaks		1.10
Total		1.49

Health and Safety Factor

Definition: A factor applied to productive hours to compensate for loss of production as a result of attending safety meetings, donning and doffing PPE, work breaks, heat and cold work stress, etc.

Assumption: A PLF of 1.49 from the baseline 1996 ANL Activity Cost Estimate (ACE) sheets is used to make the innovative case comparable to the baseline.

Table B-1. Personnel protective equipment cost/day calculation

Equipment	Quantity in box	Cost/Box ($)	Cost each ($)	No. of reuses	Cost each time used ($)	No. used/day	Cost/Day/Person ($)
Respirator			1,933	200	10	1	10.00
Respirator Cartridges			9.25	1	9.25	2	18.50
Booties	200	50.00	0.25	1	0.25	4	1.00
Tyvek™	25	85.00	3.4	1	3.4	4	13.60
Gloves (inner)	12	2.00	0.17	1	0.17	8	1.36
Gloves (outer pair)			7.45	10	0.75	1	0.75
Glove (cotton liner)	100	14.15	0.14	1	0.14	8	1.12
Total							$46.33

The PPE costs are taken predominantly from the ANL ACE sheets; however, the costs for outer gloves, glove liners, and respirator cartridges are taken from commercial catalogs.

Waste Disposal (WBS 331.18)

Waste Disposal Collection

Definition: This cost element accounts for the time and equipment required to pick up containers and assemble them in a designated area before transportation.

Assumptions:

- During the demonstration of this technology, only 2.5 ft^3 of primary waste (paint chips) is generated and vacuumed directly into a barrel or container.
- The secondary waste consists of several bags of expended flaps, the expendable vacuum hoses, used PPE, and swipes handled after the work is completed.
- This account activity is not measured during the demonstration, but the times used are accounted for within the total hours.
- Secondary waste is similar to those items in the baseline.
- Cost is represented per cubic foot and is covered in the following sections.

Transport to the Disposal Site

Definition: This cost element accounts for the charges for the volume of waste being shipped to a commercial off-site facility.

Assumption: Cost is covered in the all-in-one disposal fee rate per cubic foot described herein.

Disposal Fees

Definition: This cost element accounts for the fees charged by the commercial facility for dumping the waste at their site.

Assumptions: An all-in-one disposal fee rate per cubic foot covers any and all activities of these three items under Waste Disposal. Fees are those listed in the 1996 ANL ACE sheets.

Demobilization (demob) (WBS 331.21)

Survey and Decontaminate Equipment

Definition: This cost element provides for the radiological survey of the equipment by a site HPT to ensure that contaminated equipment does not leave the site or work area and for the decontamination costs for such equipment. Costs include HPT labor and decon crew standby or assistance time.

Assumptions: Of the total observed 3.75 h, 2 h are dedicated to survey and decon.

Pack Up and Load Equipment

Definition: This cost element covers the labor and equipment time involved in packing and loading the equipment for return to the point of origin.

Assumptions: Of the total observed 3.75 h, 1.75 h are assumed for boxing up and loading the equipment. This assumption is based on observed times during the demonstration and the use of a forklift and an operator for 2 h of the total duration.

Personnel and Equipment Transport

Definition: Transport of equipment back to the warehouse.

Assumption: Return trip mileage is less than 2 mi and is basically the reverse of mobilization. The estimate assumes that the local crew members add no transportation costs to the project.

Cost Analysis

The cost for performing work using the milling technology consists of the following activities:

- mobilizing the equipment,
- unloading to a staging area,
- setting up the equipment and hoses,
- removing the floor coatings by milling,
- replacing all worn consumable flaps,
- using PPE,
- decontaminating the reusable equipment,
- collecting all waste,
- handling the drums containing the waste,
- demobilizing back to the point of origin, and
- disposal fees.

The projection of demonstration costs to reflect a commercial cost for the scope of work includes the adjustments made as a result of the following assumptions.

- The VAC-PAC® and ROTO PEEN Scaler(s) are purchased by a site and delivered to and received by the warehouse. The ANL procurement indirect expense (PIE) rate of 9.3 percent is applied to equipment and services purchased (included in the hourly rate for equipment purchased).

- Mobilization consists of loading large and small tools at the warehouse tool room using a forklift, hauling these tools to the facility using a site truck, unloading them near the work area using site personnel, and returning the transport equipment to the equipment pool. The transport equipment is priced at commercial rental rates for convenience. The reverse holds for demobilization.

- A labor crew of three workers is hired locally and requires no mobilization or training because of previous qualifications.

- The technology demonstrated is for removal of coatings only.

- The hourly rates for government-owned equipment are based on amortizing the initial purchase price, including shipping costs, over the service life of the equipment using the discount rate of 5.8 percent prescribed in the OMB Circular No. A-94, revised (Office of Management and Budget, 1992). A service life of 5 to 15 yr (depending on the individual piece of equipment) is used with an assumed use of 500 h/yr.

- No difference exists between the PPE requirements of this technology and those of the baseline.

- The milling production rate used in the cost analysis is 40.6 ft^2/person-hour spent milling, which is calculated from a demonstration (demo) time of 16 h to complete 650 ft^2. All include coating removal and flap replacement when worn.

- The size of demonstration area is 650 ft^2.

- Flaps were changed twice (three sets used) on each of the three milling machines in the course of the demo (the last flap changed had only minor wear when the demonstration concluded). This analysis assumes one change (two sets used) as more representative of the flap changes required for a job this size.

- The roughing filters, designed with a continuous cleaning feature, and the HEPA filters are reusable over several jobs or larger quantities. Filter life is assumed to be 9 mo to 1 yr (or 500 h of use) based on the conservative extrapolation of information provided during a telephone conversation with Ben Nichols of Pentek.

- Markup of labor and equipment costs for the ANL overhead rate is not included.

- Because vendor personnel are not used, their transportation and training are excluded. This diverges from the demonstration.

- A PLF of 1.49 is applied to the milling demonstration activities. The data are taken from the 1996 ACE sheets and the CP-5 cost-estimate qualifications, pages 1.12 through 1.14 of 1.33, issued by the ANL Technology Development Division of the D&D Project.

- Radiological survey of the floor, both before and after milling, is excluded as a characterization activity.

Base		1.00
+ Height factor		0.00 (not applicable because work is on the floor)
+ Radiation/ALARA		0.20
+ Protective clothing	0.15	
= Subtotal		1.35
x Respiratory protection		1.00 (no factor required; covered in the observed times)
= Subtotal		1.35
x Breaks		1.10
= Total		1.49

The activities, quantities, production rates, and costs observed during the demonstration form the basis of the values shown in Table B-2.

B-2. Innovative milling technology cost summary (Pentek system)

Work Breakdown Structure (WBS)	Unit Cost (UC) Labor Hour	Labor Rate	Equipment Hour	Equipment Rate	Other Rate	Total UC	TQ Qnty	Unit of measure	Total cost (TC) note	Note: TC=UC x TQ; Qnty = Quantity; TQ = Total Quantity Comments
MOBILIZATION (mob) WBS 331.01								**Subtotal:**	**$ 972**	
Transport equipment (equip) - load at warehouse	2	$ 147	2	$ 32.51		$ 359	1	Trip	$ 359	Truck, forklift, teamster, operator, and two decon workers for 2 h
Drive to site	0.5	$ 147	0.5	$ 42.46		$ 95	1	Trip	$ 95	Same as above, 0.5 h; add scabbler
Unload equip at site and survey	2	$ 203	2	$ 42.46		$491	1	Trip	$ 491	Same as above, 2 h; add HPT for survey
Return equip	0.25	$ 80	0.25	$ 32.51		$28	1	Trip	$ 28	
DECONTAMINATION (decon) - WBS 331.17								**Subtotal:**	**$ 3,705**	**SCOPE: 650 ft^2**
Move equip to work area and set up	2	$ 101	2	$ 43.10		$ 288	1	Lump Sum (LS)	$ 288	On-site labor three decon technicians (techs) @ $101/crew for 2 h plus equip standby
Scarify concrete floor (milling)	0.009	$ 101	0.009	$ 43.10	$ -	$ 1.28	650	ft^2	$ 832	One three-person crew doing 112.5 ft^2/h including flap replacements; no operating costs
Health Physics Technician (HPT)	1	$ 56				$ 56.00	6	h	$ 324	Standby full-time and assist when necessary
Equip operating costs										
Replacement flaps					$ 1.65	$ 1.65	650	ft^2	$ 1,073	Three milling units x six flaps/unit x two changes x $29.87/flap for 650 ft^2
Air compressor costs			0.009	$ 15.85		$ 91.61	1	LS	$ 92	Air compressor, 750 ft^3/min
Air tools/filters consumables			1.000	$ 25.86		$ 25.86	5.8	h	$ 149	Assumed filter life = 500 h
Sample rubble and surface								ft^2	$ -	No sampling required with technology.
Load rubble in containers					$ -	$ -	2.5	ft^3	$ -	Auto-vacuumed. Waste generated = 2.5 ft^3
Safety/Planning Meetings	1.0	$ 157				$ 157	0.5	h	$ 78	
Personnel Protective Equip (PPE)					$ 185	$ 185	1.2	day	$ 222	Three decon techs plus one HPT x $46.33/day
Productivity loss	1.00	$ 101	1.00	$ 68.96		$ 170	3.8	h	$ 647	Productivity loss factor (PLF) = 1.49 per 1996 activity cost estimate (ACE); includes $25.86
DEMOBILZATION (demob) - WBS 331.21								**Subtotal:**	**$ 1,054**	
Demob equip										
Decon and survey equip	2	$ 101	2	$ 43.10	$13.20	$ 301	1	LS	$ 301	Other cost is for waste generated by decon at 0.25 ft^3 @ $52.78/ft^3; time per demo
HPT work effort	2	$ 56				$ 112	1	LS	$ 112	
PPE during decon			2.98		$ 185	$ 185	0.37	day	$ 69	Three decon techs plus one HPT x $46.33/day
Productivity loss	0.98	$ 157	0.98	$ 43.10		$ 200	1.0	h	$ 196	Figured at 1.49 per 1996 ACE sheets
Move equip and load out	1.25	$ 181	1.25	$ 75.61		$ 320	1	LS	$ 320	Reverse of mobilization; time per demo
Return to warehouse	0.5	$ 80	0.5	$ 32.51	$ -	$ 56	1.0	Trip	$ 56	Reverse of mobilization'; time per demo
WASTE DISPOSAL - WBS 331.18								**Subtotal:**	**$ 774**	
Disposal fees-primary and secondary					$52.78	$ 52.78	14.7	ft^3	$ 774	From 1996 ACE, Table 2.0, pg. 1.11 of 1.33
								Total	**$ 6,505**	

Mobilization (WBS 331.01)

Construct Temporary Facilities (Airborne Contaminant Enclosure)

Definition: This cost element provides for the supply and erection of a temporary structure to contain airborne contaminants in the area being decontaminated. It includes decon workers, HPT coverage, and building materials. Dismantling of the structure is accounted for in the demobilization account.

Assumptions: Conceptual scope definition is from ANL D&D personnel. A temporary enclosure for airbornes is erected using unistrut material ($2.00/lin ft plus $1.00/lin ft for fittings and connections) such as studs, beams, and bracing for walls and ceiling and visqueen ($.01/ft^2) as the enclosing membrane. Labor consists of three decon workers ($33.60/h) for 3 h to erect the enclosure, requiring no PLF or PPE. This activity is completed before mobilizing for the decon activities described below.

Equipment Transport

Definition: This cost element provides for transportation of the site-owned decontamination equipment from its storage area to a staging area near the facility being decontaminated. Therefore, this cost includes a truck and a forklift and their operators, the decon workers' loading and hauling of the subject construction equipment, and the hourly charges for the equipment transportation.

Assumption: The distance to a site warehouse varies but is less than 2 mi. The flat-bed truck and pneumatic forklift are rentals using rates from the *Rental Rate Blue Book for Construction Equipment* (Dataquest, 1997). Loading takes 2 h; driving, 0.5 h; and returning to the equipment pool, 0.25 h.

Note: This scenario is identical to that for the innovative technology for purposes of comparison.

Unload Equipment

Definition: Unloading delivered equipment includes time required for the decon crew to unload the equipment from the truck using a forklift, move the equipment to a staging area, and unpack for the radiological survey. This activity is combined with the survey activity described below.

Assumptions: A 2-h period is assumed for unloading/unpacking the equipment. Procurement's effort to receive purchased equipment and complete paperwork is excluded. A forklift operator is included in the crew rate, and the forklift rental rate is $11.65/h, as per Dataquest (1997).

Survey Equipment

Definition: This cost element provides for the radiological survey of the equipment by a site HPT to ensure that contaminated equipment is not brought on-site. Costs include crew standby time plus HPT labor. This activity is combined and concurrent with the unloading activity described earlier.

Assumptions: Equipment survey is required.

Training

Definition: This cost element captures the cost of site and Health and Safety-related training required for subcontractor personnel or other unqualified personnel.

Assumptions: There is no cost for this element. Personnel on-site are already trained.

Decontamination of the Reactor Building Floor (WBS 331.17)

Radiological Survey

Note: This cost element is for radiological surveying to characterize the workplace, which will facilitate the elaboration of a work plan well before starting the decontamination effort.

Assumption: Not applicable. There is no cost effect for this analysis. This activity is assumed to be completed before decontaminating the area.

Set Up or Move Equipment and Check it Out

Definition: This cost element includes the time needed to lay out the equipment and hoses in preparation for the day's work. With the air supply compressor outside the facility, air hoses are strung through doors, penetrations, and cable hangers to the work area. The scabblers, hand tools, air manifolds, waste containers, and other incidental consumables are taken to the work area from the staging area. Setup excludes the erection costs of a temporary containment tent, which are covered in the mobilization activity.

Assumption: The May 1996 ACE sheets included scaffolding because the scope also involved walls. The analysis scope is for the floor only. Therefore, the baseline time of 4 h was reduced to 2 h by eliminating the 2 h of time assumed to be for scaffolding.

Remove Floor Surface Concrete

Definition: This cost element consists of the following activities.

- Scabbling the floor concrete by making one pass of ¼ in removed, including replacing consumable scabbler bits that wear with use.
- One decon worker scabbling with a machine, one decon worker as support or tender, and one HPT as the radiation monitor and/or escort.
- HPT takes readings of the area and/or the rubble during removal at full-time participation along with the decon personnel.
- Manual cleanup and packaging of the concrete rubble into containers (transportation to the disposal collection area is excluded).
- Varying production rates depending upon the thickness of the concrete to be removed to obtain acceptable radiation readings.
- Cost of scabbling equipment and consumable bits.
- Cost of PPE (see Table B.1).
- Any lost time from production, including daily safety meetings, daily work planning reviews, dressing up with PPE, heat or temperature stress, work breaks, etc., which is accounted for through a factor.

Assumptions:

- The quantity scope for the baseline is the same as the demonstration, 650 ft^2 for comparison equality.
- One crew of two decon workers and one HPT is required. These three people handle the scabbling, sampling, cleanup, and containerizing as a team for which the estimate is separated into two sub-elements of cost by craft.
- One mechanical scabbling machine is used.
- Baseline technology produces primary waste that is manually vacuumed up, radiologically monitored, and packaged. It amounts to 19.5 ft^3.

- The decon crew workers are qualified to change the worn bits. Stand-by time is necessitated by this activity.

- Production rate in this analysis is 200 ft^2/h for one machine, a Model SF-11, Trelawny, one person scabbling (67 ft^2/person-hour as a net effective rate for a three-person crew). The scabbler is priced using the $9.95/h rate taken from the 1996 ACE sheets, including all assumptions made at that time.

- A safety meeting occurs and is in the baseline PLF.

Health and Safety

Definition: A factor applied to the PLF to compensate for safety meetings, donning and doffing PPE, etc.

Assumption: The PLF used, 1.49, and the PPE costs are taken predominantly from the ANL baseline 1996 ACE sheets (costs for outer gloves, glove liners, and respirator cartridges are priced from commercial catalogs).

Note: The cost/day calculation for PPE is the same as that presented in the Innovative Technology section.

Waste Disposal (WBS 331.18)

Waste Collection

Definition: This cost element accounts for the time and equipment required to pick up containers and assemble them in a designated area. It does not cover the time and equipment required to package the primary waste generated by the decon activity into containers.

Assumptions: Baseline waste generated is calculated at 0.03 ft^3/ft^2 as taken from the May 1996 ACE sheets, which amounts to 19.5 ft^3, including a 70 percent efficiency factor. The secondary waste consists of several bags of expended scabbling bits, used PPE, and swipes. This is not *applicable* as such but is covered in the all-in-one rate per cubic foot described in the following sections.

Transport to disposal site

Definition: This cost element accounts for the charges for the shipment of the volume of waste to a commercial off-site facility.

Assumption: This is not applicable as such but is covered in the all-in-one disposal fee rate per cubic foot described below.

Disposal Fees

Definition: This cost element accounts for the fee charged by the commercial facility for dumping the waste at its site.

Assumptions: This cost is represented as an all-in-one disposal fee rate per cubic foot from the same 1996 estimate and covers all three activities that fall under Waste Disposal.

DEMOBILIZATION (WBS 331.21)

Remove Temporary Facilities (Airborne Contaminant Enclosure)

Definition: This cost element provides for the dismantling of a temporary structure used to contain airborne radioactivity during decontamination activities. It includes decon workers, HPT coverage, and gathering up and containerizing the waste building materials. PPE and PLF are also included.

Assumptions: Labor required consists of three persons for 3 h to dismantle and load up waste.

Survey and Decontaminate Equipment

Definition: This cost element provides for the radiological survey of the equipment by a site HPT to ensure that contaminated equipment does not leave the site or work area or to ready it for the next use. It covers the costs of decontaminating the equipment. Costs include HPT labor plus the decon crew's standby or assistance time, including the use of PPE and PLF.

Assumptions: Survey and decontamination require 2 h based on an allocation from the 4 h in the original baseline.

Pack Up and Load Equipment

Definition: This cost element covers the time and equipment required for the crew to pack up and load the rental and owned equipment in a truck for return.

Assumptions: Time required is 2 h to pack and load up using a forklift for 2 h of the total duration.

Personnel and Equipment Transport

Definition: The account covers the cost to transport the equipment back to the point of origin.

Assumption: The estimate assumes local crew members incur no personnel transportation costs to the project. The transport of the equipment is the same as in the mobilization account, except in reverse.

COST ANALYSIS

The cost of performing the work consists of the following activities:

- mobilizing the site-owned equipment from a warehouse,
- unloading the equipment at the staging area,
- moving it into the work area,
- scarifying the concrete with the mechanical scabbling tool,
- sampling the rubble and floor surface for radioactivity,
- loading the rubble into transfer containers and transferring the waste,
- demobilizing the equipment,
- charges for waste disposal, and
- returning the equipment to the warehouse.

The baseline includes the following assumptions:

- Mobilization consists of a forklift loading tools at the warehouse tool room, a rented truck hauling them to the facility and unloading them near the work area using site personnel, and returning the transport equipment to the equipment pool.

- The construction of a temporary enclosure is necessary to contain airborne contaminants during the work operation. The conceptual scope, provided by ANL D&D personnel, involves unistruts as studs, beams, and braces and visqueen as walls and ceiling. Erection requires three persons 3 h, as does the dismantling activity following decontamination.

- Setup involves moving equipment into the work area, stringing the air hoses from the compressor outside, dressing up, and other preparatory activities.

- Work is performed by local site craft using a site-owned mechanical scabbling tool and other owned and rented equipment. The crew consists of two decon workers and one HPT (acts as the escort). Additional administrative, engineering, and supervisory personnel are excluded from the analysis, assuming their costs are accounted for in distributed costs and are equal in both cases.

- Concrete removal is to a depth of one-quarter inch. Waste is vacuumed manually and placed in containers. The ¼-in depth makes the baseline comparable to the innovative technology.

- Production rate is 200 ft^2/h/one decon tech scabbling (200 ft^2/h/person) and one decon tech performing all other supplemental removal activities. The HPT assists full-time by checking the radioactivity level of the rubble.

- The scabbling activity includes the time for replacement of worn bits by the qualified decon tech.

- The factor for waste volume generation is 0.03 ft^3/ft^2, including a 70 percent efficiency bulking factor.

- Equipment operating costs are listed separately from hourly ownership rates because the consumable usage may vary by site.

- Pricing for the scabbler is taken from the 1996 ACE sheets with all applicable assumptions used in that document. ANL personnel indicated the scabbler would be discarded at the end of the CP-5 project.

- The decontamination area is modified to 650 ft^2 to match the demonstration area.

- The PLF, applied to the productive work hours, accounts for health and safety (H&S) considerations that typically occur. The calculation is as follows. (Markup of labor and equipment costs for the ANL overhead rate is not included.)

Base		1.00
+ Height factor		0.00 (not applicable; work is on the floor)
+ Radiation/ALARA		0.20
+ Protective clothing	0.15	
= Subtotal		1.35
x Respiratory protection		1.38
= Subtotal		1.86
x Breaks		1.10
= Total		2.05

The activities, quantities, production rates, and costs used in the baseline calculations are shown in Table B-3.

Table B-3. Baseline cost summary (Scabbling technology)

Work Breakdown Structure (WBS)	Unit Cost (UC) Labor Hour	Labor Rate	Equipment Hour	Equipment Rate	Other rate	Total UC	TQ Qnty	Unit of measure	Total cost (TC) note	Note: TC=UC x TQ; Qnty = Quantity; TQ=total quantity Comments
MOBILIZATION (mob) - WBS 331.01								**Subtotal:**	**$ 3,775**	
Build containment tent	0.0035	$ 101			$ 2.68	$3.03	865	ft^2	$ 2,622	Three decon, 3 h @ $33.60 plus materials
Health physics technician (HPT) for tent	3.0	$ 56			$ 13.20	$181	1	Lump sum (LS)	$ 181	Covers building tent only; other-decon waste at 0.25 ft^3 at $52.78/$ft^3$
Transport equipment (equip) - load at warehouse	2	$ 147	2	$ 32.51		$ 359	1	Trip	$ 359	Truck, forklift, teamster, operator, and two decon workers for 2 h
Drive to site	0.5	$ 147	0.5	$ 42.46		$ 95	1	Trip	$ 95	Same as above, 0.5 h, add scabbler
Unload equip at site and survey	2	$ 203	2	$ 42.46		$491	1	Trip	$ 491	Same as above, 2 h, add HPT for survey
Return truck/forklift	0.25	$ 80	0.25	$ 32.51		$28	1	Trip	$ 28	
DECONTAMINATION (decon) - WBS 331.17								**Subtotal:**	**$ 2,726**	**SCOPE: 650 ft^2**
Move equip to work area	2	$ 67.2	2	$ 38.47		$ 211	1	LS	$ 211	On-site labor two decon technicians (techs) @ $33.60/h for 2 h plus equip standby
Removal of concrete floor coatings	0.005	$ 67.2	0.005	$ 38.47	$ -	$ 0.53	650	ft^2	$ 343	Two decon workers; one machine at 200 ft^2/h including replacements, total 3.25 h
Equip operating costs										Varies with life of bits, replacement frequency
Consumable (consum) bit wear					$ 0.22	$ 0.22	650	ft^2	$ 142	Per operating cost calculation, which is similar to Pentek consumable rates/ft^2
Air compressor costs			3.25	$ 7.00		$ 22.73	1	LS	$ 23	Air compressor, 250 ft^3/min
Air tools consum			3.25	$ 0.27		$ 0.89	1	LS	$ 1	
HPT sample rubble and surface radioactivity	0.010	$ 56.0				$ 0.54	650	ft^2	$ 350	One HPT at $56/h, same hours as decon plus manual loading
Load rubble in containers	0.154	$ 67.2	0.154	$ 38.47	$ -	$16.26	19.5	ft^3	$ 317	Waste at 0.021 ft^3/ft^2 w/ 70 percent efficiency = 0.03
Personnel protective equip (PPE)					$ 139	$ 139	2.0	day	$ 278	Three persons x $46.33/day
Productivity loss	1.000	$ 123.2	1.000	$ 38.47		$ 162	6.56	h	$ 1,061	Factor: 2.05 per 1996 activity cost estimate (ACE) sheets
DEMOBILZATION (demob) - WBS 331.21								**Subtotal:**	**$ 3,363**	
Decon and survey equip	2	$ 67	2	$ 38.47		$ 211	1	LS	$ 211	
HPT work effort	10.2	$ 56			$ 13.20	$ 587	1	LS	$ 587	Other: decon waste at 0.25 ft^3 at $52.78/$ft^3$
PPE during decon			7.25		$ 278	$ 278	2.00	day	$ 556	Crew of three plus three for tent dismantle
Productivity loss	1.0	$ 123	1.00	$ 38.47		$ 162	5.25	h	$ 848	Figured at 2.05 per 1996 ACE sheets
Move equip and load out	2	$ 147	2	$ 42.46		$ 379	1	LS	$ 379	Assumed reverse of the mobilization
Return to warehouse	0.5	$ 147	0.5	$ 32.51	$ -	$ 90	1.0	Trip	$ 90	Assumed reverse of the mobilization
Dismantle temporary tent	0.0035	$ 101	0.0035	$ 38.47	$ 0.32	$ 0.80	865	ft^2	$ 692	Three decon, 3 hr @ $33.60 plus materials
WASTE DISPOSAL - WBS 331.18								**Subtotal:**	**$ 1,417**	
Disposal fees--primary and secondary					$ 52.78	$ 52.78	26.9	ft^3	$ 1,417	From 1996 ACE, Table 2.0, pg. 1.11 of 1.33
								Total	**$ 11,282**	

APPENDIX C

ACRONYMS AND ABBREVIATIONS

ACE	Activity cost estimate (sheets)
ALARA	as low as reasonably acceptable
amp	amplifier
ANL	Argonne National Laboratory
CFR	*Code of Federal Regulations*
cm	centimeter(s)
CP-5	Chicago Pile-5
dBA	decibels
D&D	decontamination and decommissioning
DDFA	Deactivation and Decommissioning Focus Area
Decon	Decontamination
Demo	Demonstration
demob	demobilization
DOE	U.S. Department of Energy
DOT	Department of Transportation
dpm	disintegration per minute
EPA	Environmental Protection Agency
Equip	equipment
ESH	Environment, Safety, and Health
ft	foot (feet)
FIU-HCET	Florida International University - Hemispheric Center for Environmental Technology
gal	gallon(s)
h	hour(s)
H&S	health and safety
HEPA	high-efficiency particulate air
HP	health physics
HPT	Health Physics Technician
HTRW RA WBS	*Hazardous, Toxic, Radioactive Waste Remedial Action Work Breakdown Structure and Data Dictionary*
IH	industrial hygiene
in	inch(es)
lb	pound(s)
LS	lump sum
LSDP	Large-Scale Demonstration Project
µm	micrometer(s)
mi	mile(s)
min	minute(s)
mob	mobilization
OMB	Office of Management and Budget
OSHA	Occupational Safety and Health Administration
OST	Office of Science and Technology
PCs	protective clothing
PIE	procurement indirect expense
PLF	productivity loss factor
PPE	personnel protective equipment
psi	pounds per square inch
psig	pounds per square inch gallons
RA	remedial action

rpm	revolutions per minue
qnty	quantity
TC	total cost
tech	technician
TQ	total quantity
UC	unit cost
USACE	U.S. Army Corps of Engineers
V	volts
WAC	waste acceptance criteria
WBS	work breakdown structure
WM	waste management