INNOVATIVE TECHNOLOGY
Summary Report

DOE/EM-0467

Remotely Operated Scabbling

Deactivation and Decommissioning
Focus Area

Prepared for
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Office of Science and Technology

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INNOVATIVE TECHNOLOGY
Summary Report

Remotely Operated Scabbling

OST Reference #2099

Deactivation and Decommissioning
Focus Area

Demonstrated at
Argonne National Laboratory-East
Argonne, Illinois

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 on the OST Web site at http://OST.em.doe.gov under "Publications."

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SECTION 1

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Technology Description

The objective of the Large-Scale Demonstration Project (LSDP) is to select and demonstrate potentially beneficial technologies at the Argonne National Laboratory East's (ANL) Chicago Pile-5 (CP-5) Research Reactor. The purpose of the LSDP is to demonstrate that using innovative and improved decontamination and decommissioning (D&D) technologies from various sources can result in significant benefits, such as decreased cost and increased health and safety, as compared with baseline D&D technologies. This report describes a demonstration of Pentek, Inc.'s Moose® technology to remove up to ¼-in of concrete from the floor. This demonstration is part of the CP-5 LSDP sponsored by the U.S. Department of Energy (DOE), Office of Science and Technology, Deactivation and Decommissioning Focus Area (DDFA).

The Pentek, Inc., remotely-operated scabbler, the Moose®, is designed to scarify large concrete floors and slabs in environments which require stringent control of airborne contamination and debris. The Moose® scabbler, Figure 1, utilizes a single-step floor scarification process with three integral sub-systems: the scabbling head assembly, the on-board high-efficiency particulate air (HEPA) vacuum system, and the six-wheeled chassis. Remote operation of the Moose® is performed using a small control panel attached to the Moose® by up to 300-ft of tether.

Figure 1. Pentek Moose® and control panel.

The scabbling head, Figure 2, utilizes seven 2 ¼-in-diameter reciprocating scabbling bits, each 9-point tungsten carbide-tipped, which pulverize the surface delivering 1,200 hammer impacts/min. Dust and debris are captured by the two-stage positive filtration HEPA vacuum system that deposits the waste directly into an on-board 23-gal waste drum. The six-wheeled chassis has independent skid steering which allows the Moose® to pirouette 360-degrees about its geometric center.

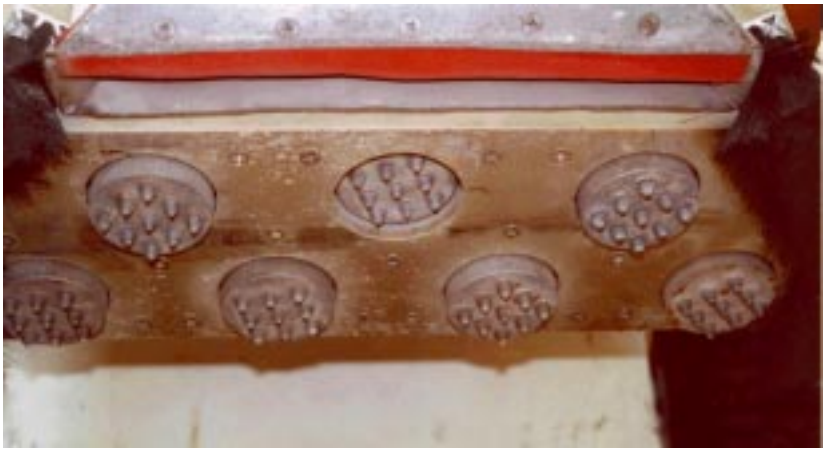

Figure 2. Scabbling head.

The ANL baseline technology, mechanical scabbling, uses a manually driven floor/deck scaler suitable for thick coating removal and the surface preparation of large areas of concrete floors. Mechanical scabbling 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 capturing large pieces of debris; however, an attached dust collection/vacuum system was not 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.

The advantages of the remotely-operated scabbler, the Moose®, over the baseline mechanical scabbling technology include the following:

- The simultaneous collection of dust and debris by the on-board vacuum system. This reduces the need for respirator protection from airborne radiological and toxic particulate hazards.
- Remote operation of the Moose® reduces personnel exposure by allowing the operator to remain up to 300 ft from the Moose®.
- Remote operation also eliminates any arm/hand vibrations from the equipment which improves worker comfort and reduces fatigue thereby resulting in safer operation.

Technology Status

CP-5 is a heavy-water moderated and cooled, highly enriched, uranium-fueled thermal reactor designed to supply neutrons for research. The reactor, which had a thermal-power rating of 5 megawatts, 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 DOE Complex and private sector nuclear facilities. CP-5 possesses 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.

The Pentek, Inc., remotely-operated scabbling technology, Moose®, was evaluated as part of the LSDP for concrete removal of 620 ft^2 of flooring on the service floor of the CP-5 Research Reactor. The evaluation period (August 25 to 29, 1997) included the mobilization, demonstration, and demobilization of this technology. Radiological surveys were performed both before and immediately after the demonstration. The purpose of these surveys was to determine the level of decontamination achieved through the removal of the floor coatings by the remotely-operated scabbling system.

Pentek, Inc., personnel operated the Moose® 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. Florida International University - Hemispheric Center for Environmental Technology (FIU-HCET) performed the data collection, including benchmarking and cost information. The U.S. Army Corps of Engineers (USACE) performed the analysis of the cost data and ICF Kaiser, International, performed the analysis of the benchmarking information.

Key Results

The key results of the demonstration are as follows.

- The Pentek, Inc., Moose® successfully removed an average of 1/8-in concrete from the 620 ft^2 of flooring in the demonstration area at a rate of 130 ft^2/h for a crew of two persons.
- The remotely-operated scabbling, Moose®, technology removed coatings from within 7-8 in from the union of the floor and the wall.
- The Moose® was operated from a control panel outside of the demonstration area connected by a 50-ft tether allowing the operator to work without wearing PPE such as tyveks or a respirator. However, due to the confined size of the demonstration area, a second operator, wearing PPE, was located with the Moose® at all times to rearrange hoses.
- The Moose® was very maneuverable. Being only 26-in-wide, it passed through doorways and down hallways with few problems. Because of its ability to turn on its geometric center, the Moose® was able to turn corners and even enter a small elevator.
- The cost analysis shows utilizing the Moose® to decontaminate floor areas greater than 2,100 ft^2 should result in cost savings over the baseline technology.
- Removal of concrete from the floor reduced the contamination levels in the demonstration from a maximum of 105,000 dpm/100 cm^2 total beta/gamma fixed contamination to a new maximum level of 3,500 dpm/100 cm^2 with the majority of the contamination now at or below background levels.
- Contamination found on the unit after the demonstration was located on moving pieces where there was exposed grease.

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

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Technology Schematic

Pentek's remotely-operated Moose®, Figure 3, is designed to scarify large concrete floors and slabs in environments which require stringent control of airborne contamination and debris. Three integral sub-systems comprise the Moose® scabbler: the scabbling head assembly, the on-board HEPA vacuum system, and the six-wheeled chassis. The scabbling head houses seven independent reciprocating tungsten carbide-tipped bits with the pistons being driven by compressed air. Dust and debris are captured by the 2-stage positive filtration HEPA vacuum system that deposits the waste directly into an on-board 23-gal waste drum. The six-wheeled chassis has independent skid steering allowing the Moose® to pirouette 360-degrees about its geometric center, resulting in a 29-in turning radius. It is capable of scabbling to within approximately 6-in of walls and other obstructions. The Moose® is operated by a control panel connected by a tether and can be located from 50-ft to 300-ft away from the scabbler.

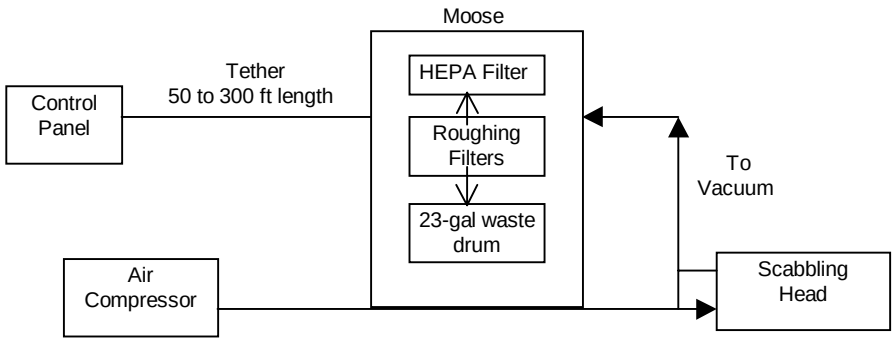

Figure 3. Process diagram of the remotely-operated scabbler.

Operational parameters for the Moose® are as follows:

- Dimensions (L x W x H) — 66 in x 29 in x 74 in
- Weight — 1,650 lbs
- Motor(s) — Dual 90 volt DC drive motors
- Cutting width: — 14 in
- Vendor advertised production rate — 250 to 450 ft^2/h at 1/16-in surface removal
- Vendor rated vacuum flow — 280 cubic feet per minute (cfm)
- Primary roughing filter cartridges — Three units
- Secondary HEPA filter — Three circular units (99.97 percent efficient at 0.3 micron particulate size)
- Standard waste drum — 23 U.S. gal

The utilities required for the operation of the Moose® at the CP-5 LSDP included a 375 cfm air compressor and a 110 V AC, 15 A, single phase power source.

- The Moose® can be remotely-operated, allowing the operator to remain 50-ft to 300-ft away from the unit, depending on the length of the tether. The CP-5 demonstration utilized a 50-ft tether.
- A second operator was located inside the demonstration area to arrange hoses and cords away from the Moose®. This operator was needed because of the small demonstration area. For larger areas, a hanger unit would be placed on the back of the Moose® to hold the hoses out of the way.
- The control panel, attached to the Moose® by a tether, included toggle switches for each track of wheels. Using these switches, the Moose® was rotated (e.g., turned around corners) by moving one track forward and the other backwards. Operations such as raising and lowering the scabbling head, turning the scabbler on or off, regulating the speed of the Moose® and the speed for both tracks were performed using switches on this control panel. There was also a meter which counted the number of hours the Moose® had been scabbling and an alarm light to indicate when the waste drum on the Moose® was full.
- The Moose® removed approximately 1/16-in of concrete with every forward pass or 1/8-in with every complete forward and backward pass.
- Simultaneous with the decontamination of the floor, the dust and debris was vacuumed into an on-board 23-gal waste drum by a vacuum shroud located just in front of the scabbling head.
- After concrete removal was completed, the floor was vacuumed using a small HEPA vacuum cleaner. This was effective in removing any remaining debris from the floor as well as most of the scuff-marks left by the Moose® tires.
- Decontamination of the Moose® included removing the filters from the vacuum system, vacuuming the inside of the vacuum, and wiping the equipment using damp rags and a degreasing solution such as Surface Prep 77. The scabbling head was taken apart and each piece wiped. Most locations of the Moose® were accessible for decontamination. Contamination was primarily found on moving parts with exposed grease (e.g., the translating cylinder) and exposed hexagonal bolts.
- The main waste stream from this operation is a mixture of powder and small pieces of paint and concrete. Secondary waste includes the roughing and HEPA filters, 4-ft of vacuum hose, PPE, and damp rags used during equipment decontamination.

SECTION 3

Demonstration Plan

The demonstration of the remotely-operated scabbling, Moose®, technology from Pentek, Inc., was conducted according to the approved test plan, *CP-5 Large-Scale Demonstration Project: Test Plan for the Demonstration of the Remotely Operated Scabbling Technology at CP-5* (Strategic Alliance for Environmental Restoration, 1997). The objective of the demonstration was to remove ¼-in of concrete from 620 ft^2 of 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.

Radiological surveys for both fixed and removable radioactivity were conducted both before and immediately after the demonstration. The purpose of these surveys was to determine the level of decontamination achieved by the concrete removal.

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 ¼-in of concrete from the floor. Additional field measurements collected included secondary waste generation, potential personnel exposure, and ease of equipment operation. The performance of the remotely-operated scabbling technology was evaluated against that of the baseline technology, which is manual mechanical scabbling.

Treatment Performance

Table 1 presents both the results of the demonstration of the Pentek, Inc., Moose® and a comparison with the baseline technology.

Table 1. Performance data

Criteria	Pentek, Inc., Moose®, remotely-operated scabbling	Baseline manual mechanical scabbling
Applicable surface	1/8-in concrete removal from floor (1)	1/4-in concrete removal from floor
Production rate (removal rate only)	130 ft^2/h for a crew of two	200 ft^2/h for a crew of two
Amount and type of primary waste generated	37 ft^3 of a mixture of powdery and small pieces of paint chips and concrete	An estimated 24 ft^3 of a mixture of powdery and large pieces of paint chips and concrete (as this requires manual cleanup, no vacuum system is attached)
Type of secondary waste generated	Roughing filters - three units HEPA filter - three units Vacuum hose - 4-ft section	Tent-enclosure materials and worn pistons/scabbling bits
Airborne radioactivity generated by equipment	All airborne radiological measurements were at or below background levels.	As the baseline technology is not connected to a vacuum system, up to 10 percent of debris generated can become airborne.

Table 1. Performance data (Continued)

Criteria	Pentek, Inc. Moose®, remotely-operated scabbling	Baseline manual mechanical scabbling
Noise level	106 dBA at Moose®, hearing protection is required.	84 dBA (per vendor, not measured).
Capability to access floor-wall unions	No closer than 7-8 in, 14-16 in around circular wall.	No closer than 1 in
Development status	Commercially available.	Commercially available. Compatible vacuum systems are also available.
Ease of use	Training = not applicable, service provider. Remotely operated, equipment operator can be located outside of contamination area.	Training required = 2 h/person. Walk behind, push-floor model. Moderate-to-heavy vibrations can cause operator fatigue.
End-point condition	Concrete surface is slightly rough but is even.	Paint coating is removed, leaving a rough, bare concrete surface.
Worker safety	Tripping hazard caused by multiple hoses.	Flying concrete poses a potential eye hazard.

(1) Pentek, Inc., removed 1/8-in of concrete instead of the ¼-in required by the test plan because there were not enough 23-gal waste drums to accommodate the waste from ¼-in removal.

Radiological surveys of the demonstration area were performed before and after the demonstration. Table 2 lists the total fixed beta/gamma contamination results for the locations of elevated gross direct beta readings.

Table 2. Radiological results

Location	Total β/γ (dpm/100cm^2) contamination, pre-demonstration	Total β/γ (dpm/100cm^2) contamination, post-demonstration
1	1,000	<1,000
2	1,500	<1,000
3	8,300	<1,000
4	3,000	(1)
5	7,400	<1,000
6	1,500	<1,000
7	105,000	3,500
8	2,100	(1)
9	10,000	<1,000
10	39,000	(1)
11	74,000	(2)
12	25,000	(2)
13	10,000	(2)

(1) The contamination was located along the edge of the floor where the Moose® could not reach; therefore, it was not removed.

(2) Background levels in the area were too high to obtain accurate readings.

SECTION 4

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Technology Applicability

Pentek, Inc.'s remotely-operated scabbling technology, Moose®, is a commercially available technology, the primary application of which is hazardous coating and concrete removal from large floor areas. During the August 25 to 29, 1997, technology demonstration at CP-5, the Moose® was evaluated as an alternative to the manual mechanical scabbling technology for concrete removal from large floor areas.

The advantages the Pentek, Inc., Moose® offers over manual mechanical scabbling include:

- The simultaneous collection of dust and debris by an on-board vacuum system. This unit significantly reduces the amount of airborne dust generated during the D&D process; thus, it has the potential to lead to a significant reduction in respiratory protection and personal protective equipment (PPE) requirements, especially in highly contaminated facilities.
- Remote operation of the Moose® allows the operator to remain from 50 to 300 ft away from the equipment. As in the demonstration, this could allow the operator to remain outside of the contamination area, leading to a significant reduction in both respiratory and PPE requirements.

The shortcoming of the Moose® is the fact that it will only accommodate the 23-gal waste drums. The drums become filled after 45 min of scabbling and it requires two people to don PPE, enter the area, and change the drum. While the majority of the 5-min drum change-out can be completed with only one person, the second person is required to help lower the heavy (over 200 lb) drum to the floor.

Competing Technologies

In addition to the remotely-operated scabbling technology, a number of other technologies are available to D&D professionals for removing concrete from floor surfaces.

Examples of competing technologies include:

- mechanical scabbling (ANL baseline technology),
- centrifugal shot blast,
- milling,
- grit blasting, and
- high pressure and ultra-high pressure water blasting.

Patents/Commercialization/Sponsor

This demonstration used an existing commercial technology. The Moose® is owned by Pentek, Inc., from whom it can be purchased or rented with either Pentek equipment operators or with a Pentek instructor who will teach site personnel how to operate the equipment. Pentek, Inc., owns the patent on the Moose®.

SECTION 5

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Introduction

This cost analysis compares the relative costs of the remotely-operated scabbling technology (innovative) and manual mechanical scabbling technology (baseline) and presents information which 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 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 (such as elimination of cost factors which are not part of normal work, but are included in the demonstration to evaluate equipment performance). These are allowed only when they will not distort the fundamental elements of the observed data (e.g., do not change the productivity rate, quantities, and work elements) and eliminate only those activities which 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., Moose®, Remotely Operated Scabbling Technology* (Strategic Alliance for Environmental Restoration, 1997) provides additional cost information.

Methodology

This cost analysis compares the innovative Moose® remotely-operated scabbler used to remove the top surface of concrete floors to a baseline technology consisting of a concrete floor surface removal by conventional manual mechanical scabbling. Costs for the innovative technology are derived from a demonstration of the Moose® at the CP-5 Reactor by vendor personnel assisted and supervised by ANL facility personnel. Work process activities were timed and quantities were measured so that production rates could be determined.

Data collected during the demonstration of the innovative technology include 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.

The baseline technology was not demonstrated concurrently with the innovative technology. The baseline is developed from actual scabbling activities performed under similar conditions to those of the innovative technology demonstration. Labor, equipment, production rates, and productivity loss factors (PLF) were provided by site personnel at ANL or from similar work being performed elsewhere. Baseline information has been developed from the following sources:

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

Since the baseline costs are not based on observed data, additional efforts are applied in setting up the baseline cost analysis to assure unbiased and appropriate production rates and crew costs. Specifically, a team consisting of members from the Strategic Alliance and the USACE reviewed the estimate assumptions to ensure a fair comparison.

The selected basic activities being analyzed come from the *Hazardous, Toxic, Radioactive Waste Remedial Action Work Breakdown Structure and Data Dictionary* (HTRW RA WBS) (USACE, 1996). The HTRW RA WBS, developed by an interagency group, is used in this analysis to provide consistency with the established national standards.

Some costs are omitted from this analysis so that it is easier to understand and to facilitate comparison with costs for the individual site. The ANL indirect expense rates for common support and materials are omitted from this analysis. Overhead and general and administrative (G&A) rates for each DOE site vary in magnitude and in the way they are applied. Decision makers seeking site-specific costs can apply their site's rates to this analysis without having to first retract the rates used at ANL. The impact resulting from this omission is judged to be minor because overhead is applied to both the innovative and 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. Costs for site-owned equipment are based upon an hourly rate for Government ownership that is computed using the Office of Management and Budget (OMB) Circular No. A-94 (OMB 1992). Quoted rates for the vendor's costs are used in this analysis for performing the work and includes the vendor's G&A, overhead, and fee mark-up costs. Additionally, a 9.3 percent cost for procurement is added by ANL to all vendor charges. The analysis uses an 8 h work day with a 5-day week. The production rates and observed duration used in the cost analysis do not include "non-productive" items such as work breaks, loss of dexterity (due to cumbersome PPE), and heat stress. These "non-productive" items are accounted for in the analysis by including a PLF. The PLF is a historically based estimate of the fraction of the workday that the worker spends in non-productive activities.

Cost Data

Table 3. Innovative technology acquisition costs

Acquisition Option	Item	Cost
Equipment purchase (quote from Pentek)	• Pentek Moose®	$165,000
Vendor provided service (quote from Pentek)	• Daily rate: (Includes two trained operators, Moose® remote scabbler and hoses, ground transportation, and travel and living expenses. Based on an 8-h day) • Weekly rate: (Includes items listed above for the daily rate based on 40 h work week) • Overtime rate: • Replacement Parts: (includes HEPA filters, roughing filters, replacement hoses, and wear on scabbling bits)	$1,995 $8,125 $270/h for each h in excess of 8 h/day $2,400 one-time flat rate charge and $68.90 for each disposable 23-gal waste drum
Equipment rental	(Currently, Pentek has no established rental rate for just the equipment.)	

Observed unit costs and production rates for principal components for both the innovative and baseline technologies are presented in Table 4.

Table 4. Summary of unit costs and production rates for removal of concrete surface on 618 ft^2 of floor

Innovative technology			Baseline technology		
Cost element	**Unit cost**	**Production rate**	**Cost element**	**Unit cost**	**Production rate**
Set up equipment in the work area	$618.00/ea	2.5 h/ea	Set up a containment tent at the work area	$3.11/$ft^2$	4.8 ft^2/min
Remove concrete utilizing Moose®	$6.68/$ft^2$ (1)	130 ft^2/h for 1/8-in of concrete removal	Move equipment to work area and set up	$211/ea	2 h/ea
			Remove concrete	$1.85/$ft^2$ (1)	200 ft^2/h for 1/4-in of concrete removal
			Dismantle the temporary tent	$0.80/$ft^2$	4.8 ft^2/min

(1) The unit cost for concrete removal includes actual concrete removal, waste drum changeouts, and associated costs. It does not include fees for waste disposal since these are specific to ANL and are calculated at the same rate for both the innovative and baseline technologies. The unit cost also does not include setting up equipment, HP Technician (HPT) support, PPE, costs associated with productivity loss, or vendor service acquisition costs (for ANL, 9.3 percent of vendor incurred costs). The unit cost is calculated by summing related costs and dividing them by the area of concrete removal (618 ft^2). See the cost summary tables in Appendix C of this report for a detailed breakdown of costs for both the innovative and baseline technologies.

Summary of Cost Variable Conditions

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

Table 5. Summary of cost variable conditions

Cost variable	Moose® remotely-operated scabbling	Baseline mechanical scabbling
Scope of Work		
Quantity and type of material	618 ft^2 of concrete floor surface removed to a depth of 1/8 in.	Not actually demonstrated, but assumed to be 618 ft^2 of concrete floor surface removed to a depth of ¼ in.
Location	Service floor of the CP-5 research reactor building	Assumed to be the same floor location as the Moose® demonstration
Nature of work	Removal, containerization and disposal of the concrete floor surface to remove contamination	Removal, containerization and disposal of the concrete floor surface to remove contamination
Work Environment		
Worker protection	Anti-contamination coveralls with hood and respirator	Anti-contamination coveralls with hood and respirator
Level of contamination	Classified as a contamination area	Classified as a contamination area
Work Performance		
Acquisition means	Vendor supplied service	Site personnel with site-owned equipment

Cost Comparisons

Figure 4 is a chart displaying a comparison of costs between the innovative and baseline technologies broken down by major work category. Costs shown are taken from calculations made in Tables C-2 and C-3 of Appendix C for the innovative and baseline technologies, respectively. The comparison is based on removing the surface layer on 618 ft^2 of concrete floor. As noted in Table 5, this represents the actual floor area where the concrete surface was removed to an average depth of 1/8 in using the Moose® technology, but is a hypothetical floor area for the baseline technology which consists of using a conventional scabbling device to remove the floor surface down to a depth of 1/4 in. The inconsistency in depth of removal between the innovative and baseline technologies is the result of the vendor not providing enough waste drums to facilitate removing an additional 1/8 in of the floor surface.

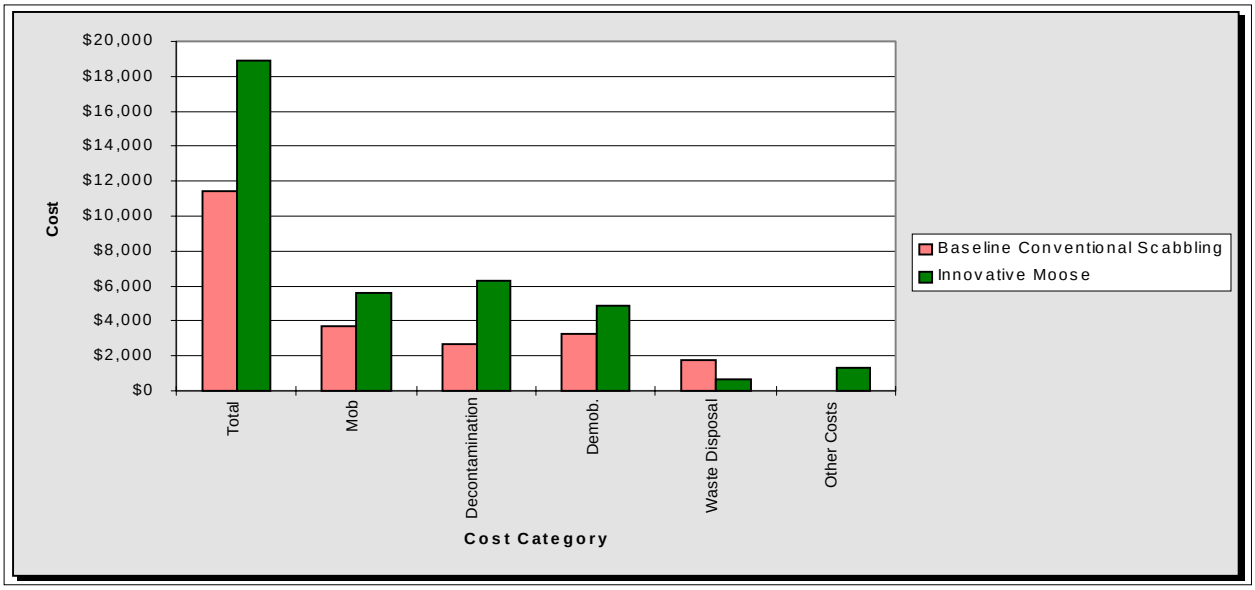

Figure 4. Comparison of costs.

Figure 5 is a comparison of costs for the innovative and baseline technologies extrapolated from the demonstration floor area of 618 ft^2 to a hypothetical floor area of 2,500 ft^2. The extrapolation is included in the analysis to provide an estimate of costs for jobs in the range of normal D&D work. It also demonstrates the relative effect of job size on mobilization and demobilization costs as well as displaying a cross over threshold where costs for the baseline technology exceed costs for the innovative technology. Costs for removing the concrete surface on the larger floor area are calculated in Tables C-2.1 and C-3.1 of Appendix C for the innovative and baseline technologies, respectively. The comparison is made as a straight line extrapolation starting from the total cost calculated for a floor area of 618 ft^2 to the total cost calculated for a floor area of 2,500 ft^2. In addition, the comparison includes an extrapolation of costs based on a weekly service rate currently being offered by the vendor. Assumptions made for comparisons are explained in more detail in the following cost conclusions.

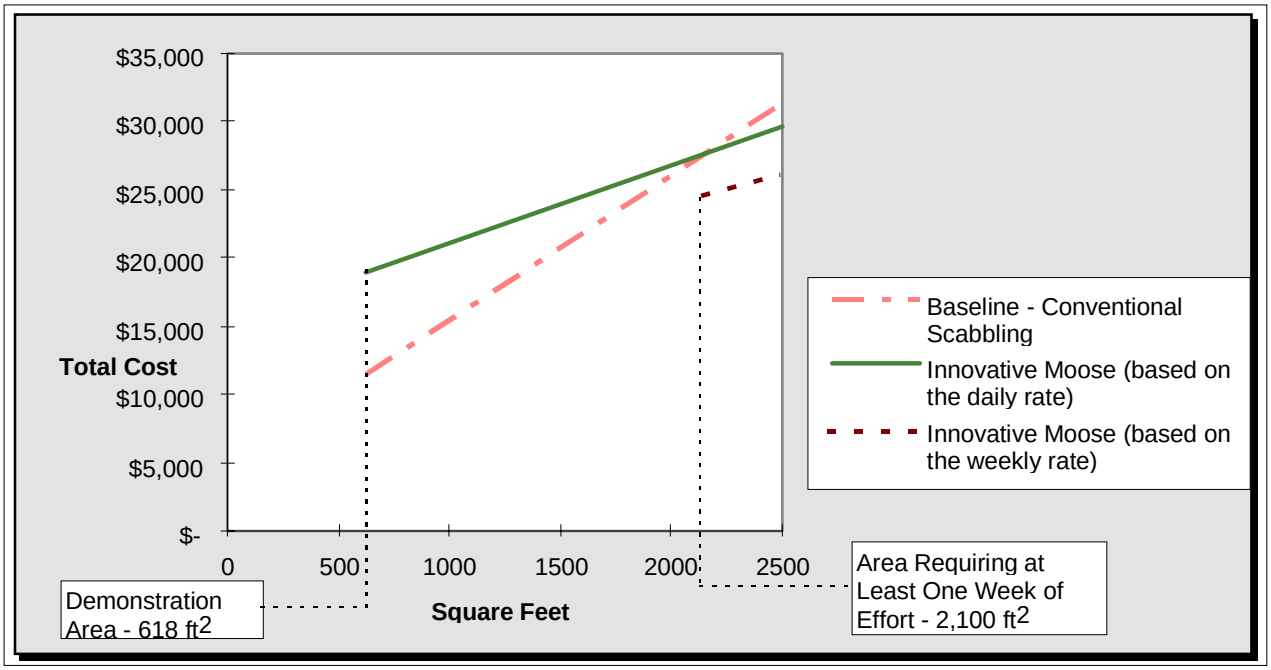

Figure 5. Extrapolation of costs.

Cost Conclusions

For the demonstrated floor area of 618 ft^2, the Moose® is the more expensive technology. Figure 4 shows that it is more expensive in every WBS category except waste disposal. For mobilization, the bulk of the cost difference is the result of getting vendor personnel to the job site. The Moose® equipment was transported from Coraopolis, PA, to Chicago, IL, in a rented truck driven by the two vendor personnel. The time for transportation was charged out by the vendor at the full service rate for two operators and equipment, as if the equipment were in use. To reduce this cost, potential users of the technology may want to reach some kind of agreement with the vendor to either ship equipment to the job site and then fly in the operators, or establish a separate and reduced rate for operator transit time. This obviously becomes a more critical factor the farther away the job site is from Coraopolis, PA.

Another factor contributing significantly to the difference in cost is the vendor's flat replacement parts fee. This fee is shown in Table 3 and includes HEPA and roughing filters and a length of vacuum hose that goes from the scabbler head to the filter packs. All of these items must be disposed of at the end of every job involving contaminated floor surfaces, regardless of the size of the job. Replacement scabbling bits are also part of the fee even though the bits actually used were able to be decontaminated and returned to the vendor. Finally, the fee includes routine maintenance on the device which must occur at the end of every job, regardless of size. Potential users of the technology may want to have the vendor itemize costs for each of the replacement parts in order to remove some of the obscurity from the "one flat-charge for everything" approach and to facilitate returning, at no charge, components of the device that can be successfully decontaminated.

Waste disposal ends up being less expensive for the innovative technology than for the baseline technology. This is partly due to less material being removed with the innovative technology (1/8 in removed versus 1/4 in for the baseline), but is primarily the result of disposal expenses for the containment tent that is required when using the baseline technology. For the baseline technology, the larger the floor area for removal, the more prominently the containment tent figures in

For the innovative technology, the time period to perform work will be a minimum one week for floor areas at least 2,100 ft^2 in size. This is based on observations of actual time to perform work with the Moose® and also includes time for site orientation and training, daily work briefings and safety meetings, and other work-associated items such as waste drum changeouts and equipment decontamination. It does not include travel time to and from the vendor's home office in Coraopolis, PA, since this would not be considered actual time to perform work. The vendor gives a price break for jobs equaling or exceeding a one week duration by offering a weekly rate. This rate is shown in Table 3 and works out to $1,625.00/day or $203.13/h for the vendor service versus $249.37/h for the vendor service based on the quoted daily rate. (Hourly rates are based on 40-h work weeks and 8-h work days).

For comparison purposes, Figure 5 shows two cost extrapolations for the innovative technology. One indicates extrapolated costs based on the vendor's daily rate. The other indicates extrapolated costs based on the vendor's weekly rate and starts at a hypothetical job size of 2,100 ft^2. Both extrapolation are taken out to a hypothetical job size of 2,500 ft^2. A potential user of the Moose® technology would be wise to select a job size of at least 2,100 ft^2 in order to take advantage the price break currently being offered by the vendor. Figure 5 also indicates the cross-over point where baseline costs exceed costs for the innovative technology. Based on the vendor's daily rate charge , this occurs at approximately 2,350 ft^2, but note the distinct cost advantage the innovative technology holds over the baseline technology when the vendor's weekly rate is utilized. The reason the baseline technology becomes more expensive on jobs over 2,100 ft^2 in size is due to costs associated with the containment tent. Refer to the tables in Appendix C for a detailed breakdown of costs for the both the innovative and baseline technologies.

[redacted]

Regulatory Considerations

The regulatory and permitting regulations related to use of the remotely-operated scabbling technology at the ANL CP-5 Research Reactor consist of the following:

- 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 issued by the U.S. Department of Transportation (DOT) and DOE:

- 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) requirements should be considered:

- 40 CFR Subchapter I Solid Waste

Waste acceptance criteria (WAC) from the following disposal facilities used by ANL include:

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

Waste form requirements/criteria specified in these WACs 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. These are the same regulations that govern the baseline technology, manual mechanical scabbling.

Safety, Risks, Benefits, and Community Reaction

With respect to safety issues, Pentek, Inc's Moose® is considered to be relatively safe. Controlled remotely, the equipment operator can be located up to 300 ft from the equipment during operation. When working in a large open floor area, a hanger unit is attached to the back of the Moose® keeping the air compressor hose and the tether up and out of the way of the equipment. The vacuum system uses the same patented dustless drum exchange feature as the Pentek, Inc., VAC-PAC® vacuum.

The use of the remotely-operated scabbling technology rather than manual mechanical scabbling would have no measurable impact on community safety or socioeconomic issues.

[redacted]

Implementation Considerations

The Pentek, Inc., system demonstrated at CP-5 is a commercially available technology and has been used at various military and nuclear facilities. There are no implementation considerations for use of the Moose® in the decontamination of concrete floors.

Technology Limitations and Needs for Future Development

The Moose® would benefit from the following design improvements.

- Pentek should attempt to eliminate the necessity for a second operator, in PPE, to be located inside the decontamination area to move hoses and cords.
- It is recommended that a second vacuum connection be placed at the rear of the scabbling unit to collect small pieces of debris that may be missed by the vacuum connection currently located in the front of the scabbling head. This could eliminate the need for using a portable vacuum cleaner at the end of the decontamination process.
- A means to lower the full waste drum to the floor should be developed which would eliminate the potential for personnel injury (e.g., back injury). Suggestions include either mechanically lowering the full waste drum from the Moose® to the floor or transferring the full drum to a hand-operated lift. These suggestions could also eliminate the need for a second person to enter the contamination area for drum change-outs.
- It would be helpful if the Moose® had the option to use 55-gal drums instead of just 23-gal drums. In a highly contaminated area, this could reduce the number of times a person has to enter the contaminated area for drum change-outs by half, thus reducing personnel exposure.
- It is strongly recommended that all greased fittings and nuts and bolts be covered and protected from contamination. This could greatly reduce the amount of decontamination that needs to be performed at the end of a job.

Technology Selection Considerations

The Pentek, Inc., remotely-operated scabbling technology, the Moose®, is an effective technology for the removal of concrete from large floor areas. Being controlled remotely, the equipment operator is able to be located as much as 300 ft from the equipment. The equipment is maneuverable, able to move through standard doorways, and rotate along its geometric center with a tight 29 in turning radius.

APPENDIX A

[redacted]

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APPENDIX B

[redacted]

Acronyms/Abbreviations	Description
ACE	Activity cost estimate
ALARA	as low as reasonably acceptable
ANL	Argonne National Laboratory
β/γ	beta/gamma
cfm	cubic feet per minute
CFR	Code of Federal Regulations
cm^2	centimeters squared
CP-5	Chicago Pile-5
D&D	decontamination and decommissioning
dBA	decibels
DDFA	Deactivation & Decommissioning Focus Area
Decon	decontamination
DOD	Department of Defense
DOE	Department of Energy
DOT	Department of Transportation
dpm	disintegration per minute
EPA	Environmental Protection Agency
Equip	equipment
ESH	Environment, Safety and Health
FIU-HCET	Florida International University - Hemispheric Center for Environmental Technology
ft	foot or feet
ft^2	square feet (foot)
ft^3	cubic feet (foot)
G&A	general and administrative markup cost
gal	gallon
H&S	health and safety
HEPA	high efficiency particulate air
HP	Health Physics
HPT	Health Physics technician
h	hour
HTRW	hazardous, toxic, radioactive waste
IH	Industrial hygiene
in	inches
IUOE	International Union of Operating Engineers
lb	pound(s)
LF	linear feet (foot)
LLW	low-level waste
LS	lump sum

Acronyms/Abbreviations	Description
LSDP	large scale demonstration project
min	minute
mm	millimeter
NESP	National Environmental Studies Project
OMB	Office of Management and Budget
OSHA	Occupational Safety and Health Administration
PLF	productivity loss factor
PPE	personnel protective equipment
psi	pounds per square inch
psig	pounds per square inch gauge
pt	point
RA	remedial action
rad	radiological
Resp	respirator
SAFSTOR	safe storage
TC	total cost
Tech(s)	technician(s)
TQ	total quantity
UC	unit cost
USACE	United States Army Corps of Engineers
WAC	waste acceptance criteria
WBS	work breakdown structure
WM	waste management

APPENDIX C

[redacted]

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

Innovative Technology - Moose® Remotely Operated Scabbling Technology

MOBILIZATION (WBS 331.01)

Transport Equipment

This cost element includes transportation of the Moose® scabbling equipment from Coraopolis, PA to the ANL CP-5 Research Reactor facility. It includes renting a truck and driving 436 miles from Coraopolis to Chicago. Transportation was done by the two vendor personnel who operated the device. Cost is based on a quote from Pentek for the service rate for two operators and Moose® equipment, truck rental, and travel expenses. This cost is broken down into regular and overtime hours each of which is charged out differently by the vendor.

Per Diem for Vendor

The per diem rate was established by ANL and applied to each of the two vendor operators for the total number of days for them to travel to the site, complete the work, and return to Pittsburgh.

Vendor Orientation and Site Safety Training

This cost is for on-site training for one of the vendor operators (the other operator had previously received the training). The training consisted of a 4-h CP-5 orientation and safety course that ANL offers on a regular basis for contractors who are new to the CP-5 facility.

Unpack Equipment and Move to Work Area

This cost element accounts for moving the Moose® equipment from receiving area to the elevator to the reactor service floor. Unpacking and moving to the work area required the two vendor operators and 1 ANL decontamination (decon) technician.

ANL DOP Test of HEPA Filter and Noise Level Measurement

These are routine test given to decon equipment entering the CP-5 facility and were given to the Moose® and associated equipment by one ANL IH Technician.

Pre-Rad Survey Equipment

This cost element includes frisking the incoming Moose® and associated equipment with a NE frisker and a gas proportional counter and taking eight swipes at various locations on the equipment to check for previous radiological contamination and establish the pre-work rad-count condition of the equipment. The survey was conducted by one ANL HPT.

Get Moose® Equipment Into the Elevator and Set Up in the Work Area

This cost element includes the time for a routine set up of the equipment, but also includes the time it took to disassemble the scabbler head from the Moose® in order to fit it on the elevator for transportation to the work area. Obviously, it is not expected that disassembling the scabbler head will be necessary at every potential work situation and, thus, this cost item tends to inflate the total cost. Equipment was partially disassembled, reassembled and then set up by the two vendor operators.

Install 200 LF of Air Hose from Compressor to Work Area

Compressor hose was run from the rented compressor to the work area by four ANL decon technicians. Compressor hose was temporarily attached to the ceiling using heavy-duty plastic ties.

Daily Meetings

A job-briefing meeting and a safety meeting were conducted on each of the 3 days of removal work. The meetings consisted of the two vendor operators and two ANL decon technicians.

Remove Concrete Floor Down 1/8 Inch

This cost element represents concrete removal only. It includes time for one vendor operator to man the control panel on the Moose® and the other operator to direct the first operators actions, move hoses, etc. It also includes the time required for five waste drum changeouts which were performed by both vendor operators with the Moose® held on standby. As opposed to all previous work elements, which are measured as either lump sum or one each activities, concrete removal is measured on a per square foot basis in order to establish a per square foot unit cost.

In addition to concrete removal, the vendor also performed a final vacuuming of the demonstration area using a small portable vacuum cleaner belonging to ANL. It was assumed that this activity is performed for both the baseline and innovative technology and therefore was not included in the costs for this element.

HPT Support to Concrete Removal

ANL required a daily escort for the vendor crew while they worked in a contaminated area. An ANL HPT served this function and was present for roughly half the duration of the removal work.

Waste Drum Changeouts

This activity required both vendor operators to remove the 23-gal waste drum from the Moose® and roll it to just outside the work area where ANL decon technicians removed it from the CP-5 facility. The cost item only accounts for vendor operator time to remove the drum. Costs for the ANL decon technicians to dispose of the material is accounted for under the “Waste Disposal” category.

Equipment Operating Costs

This cost element covers rental for the air compressor and a flat charge from the vendor for Moose® replacement parts. The air compressor was rented locally. Replacement parts include HEPA filters, roughing filters, vacuum hose, and the scabbling bits. Routine maintenance on the Moose® is also included in the replacement parts charge. It should be noted that scabbler bits were able to be decontaminated at the end of the work so that ANL was able to release them back to the vendor.

Productivity Loss

This is defined as loss from productivity occurring during the course of the work due to breaks, As Low As Reasonably Achievable (ALARA), respiratory encumbrances, etc. (Costs for PPE and donning and doffing of PPE are included in a separate line item discussed below). A PLF is calculated in accordance with the National Environmental Studies Project (NESP) document AIF/NESP-036, Guidelines for Producing Commercial Nuclear Power Plant Decommissioning Cost Estimates as modified for operations at the ANL CP-5 facility. This factor is then applied to work activities associated with performing the actual removal work (for both the vendor operators and the ANL HPT) to come up with a total productivity loss in hours. The following calculation shows how the PLF is derived:

Base	1.00
+Rad/ALARA	0.20
= Subtotal	1.20
+	
Resp. Prot.	1.00 (no factor included, actual work time was recorded)
=Subtotal	1.20
+	
Breaks	.10
=Total	1.30

Donning/Doffing Personal Protective Equipment

This cost element provides for the personal protective clothing used during the work activity by the vendor operators. Labor costs for donning and doffing PPE are taken from the time recorded to actually perform the activity. Costs for PPE material are predominantly from the ANL activity cost estimates for 1996 (costs for outer gloves, glove liners, and respirator cartridges are from commercial catalogs). PPE material costs are totaled on a per worker per day basis and are itemized in the following table.

Table C-1. Personal protective equipment

Equipment	Quantity in Box	Cost Per Box	Cost Each	No. of Reuses	Cost Each Time Used	No. Used Per Day	Cost Per Day
Respirator			1,933	200	10	1	10.00
Resp 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)			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

DEMOBILIZATION (WBS 331.21)

Demobilizing Equipment

This work activity includes disassembling air hoses, decontaminating Moose® equipment, exit surveying the equipment, and associated donning/doffing of PPE to perform the activities. Air hoses were disassembled by ANL decon technicians; decontamination of the Moose® equipment was performed by the two vendor operators; and the equipment was exit surveyed by the ANL HPT. Costs for donning and doffing of PPE were taken from recording the time for the activity and costs for the PPE material as outlined in the table above.

Productivity Loss

The PLF is as calculated above (under Decontamination) and is applied to all of the workers and time associated with actually decontaminating and free-releasing the Moose® equipment.

Transport Equipment from Work Area to Truck

This activity consists of the two vendor operators and one ANL decon technician moving the Moose® equipment from the work area back to the rented truck.

Return Trip to Coraopolis, PA

As with the trip to ANL, the return trip was charged at the full service rate for two vendor operators and equipment. It is also broken down into regular and overtime hours. The return trip took less time, however, due to fewer traffic delays.

WASTE DISPOSAL (WBS 331.18)

Waste Disposal Fees

This cost element accounts for the fee charged by the commercial facility for dumping the waste at their site. Waste disposal is measured in ft^3 of waste disposed. This cost is represented as an all-in-one disposal fee rate/ft^3 from the same 1996 estimate and covers all three activities of Waste Disposal.

OTHER COSTS

ANL Procurement Costs

ANL attaches a 9.3 percent cost of procurement to all vendor supplied materials and services. Thus, this cost element is added onto every line item representing a vendor charge.

Table C-2. Innovative technology cost summary

Work Breakdown Structure (WBS)	Unit Cost (UC) Labor Hour	Labor Rate	Equipment Hour	Equipment Rate	Other Rate	Total UC	Total Qnty (TQ)	Unit of Measure	Total Cost (TC)1	Crew	Comments
MOBILIZATION (mob)- WBS 331.01								**Subtotal:**	**$ 5,660**		
Transport Equipment from Coraopolis, PA to Chicago, IL											
Regular Hours	8	$249.37				$ 1,995	1.0	each	$ 1,995	2 vendor	See note no. 3 below.
Overtime Hours	4	$270.00				$ 1,080	1.0	each	$ 1,080	2 vendor	See note no. 4 below.
Truck Rental					$ 485.00	$ 485	1.0	trip	$ 485		Includes Penske truck rental @ $360.00 for unlimited miles plus an allowance of $125.00 for gas.
Per Diem for Vendor Personnel											Based on a min. $95.00/day per vendor crew member.
For Travel Days					$ 190.00	$ 190	2.0	days	$ 380	2 vendor	
For Work Days					$ 190.00	$ 190	1.0	days	$ 190	2 vendor	
For Other Days					$ 190.00	$ 190	1.0	days	$ 190	2 vendor	Other category includes time for orientation, training, equip setup, etc.
Vendor Orientation and Site Safety Training	4	$249.37				$ 997	1.0	each	$ 997	1 vendor	One vendor crew member attended a 4-h ANL site safety training course.
Unpack Equipment and Move to Work Area	1	$282.97				$ 283	1.0	each	$ 283	2 vendor; 1 ANL decon.	Includes removing the Moose from the truck, getting it to an elevator, and testing it prior to entering CP-5.
ANL DOP Test of HEPA Filter & Noise Level Measurement	0.55	$56.00				$ 31	1.0	each	$ 31	1 ANL IH	Tests conducted by an ANL IH.
Pre-Rad Survey Equipment	0.5	$56.00	0.5	$0.71		$ 28	1.0	each	$ 28	1 ANL HPT	HPT surveyed the equipment with a NE frisker and a gas proportional counter.
DECONTAMINATION (decon) - WBS 331.17								**Subtotal:**	**$ 6,323**		
Set Up Equipment in Work	2.48	$249.37				$ 618	1.0	LS	$ 618	2 vendor	
Install 200 LF of Air Hose from Compressor to Workarea	1.58	$134.40				$ 212	1.0	LS	$ 212	4 ANL decon techs	
Daily Meetings											
Pre-Work Briefing	0.22	$316.57				$ 70	1.0	each	$ 70	2 vendor; 2 ANL decon	Labor rate calculated by adding vendor rate of $249.37 plus ANL decon tech rate of $33.60/tech.
Safety	0.08	$316.57				$ 25	1.0	each	$ 25	2 vendor; 2 ANL decon	
Remove Concrete Floor Down 1/8-inch	0.0077	$249.37				$ 2	**618**	SF	$ 1,187	2 vendor	The concrete floor was removed to only 1/8-in depth because the vendor did not bring enough waste barrels for 1/4-in of concrete removal.
HPT Support to Concrete Removal	4.7586	$56.00				$ 266	1.0	each	$ 266	1 ANL HPT	The ANL HPT acted as an escort for the removal operation.
Waste Drum Changeouts	0.083	$249.37			$ 68.90	$ 90	5	each	$ 448	2 vendor	
Equip. Operating Costs											
Air Compressor Rental					$ 405.00	$ 405	1.0	week	$ 405	N/A	375 CFM air compressor @ $405.00 for the week. (Cost quoted from Pentek)
Replacement Parts					$ 2,400.00	$ 2,400	1.0	each	$ 2,400	N/A	Replacement parts are charged out by Pentek at a one-time flat rate. Parts include HEPA and roughing filters and scabbling bits.
Productivity Loss	1.5521	$305.37				$ 474	1.0	LS	$ 474	2 vendor; 1 ANL HPT	Factor 1.68 includes radiation/ALARA and work breaks.
Donning/Doffing Personal Protective Equipment (PPEs)	0.4998	$249.37			$ 92.66	$ 217	1.0	LS	$ 217	N/A	One vendor crew member in PPE during decon. Both vendor crew members in PPE during waste drum changeout.
DEMOBILZATION (demob) - WBS 331.21								**Subtotal:**	**$ 4,833**		
Demob Equipment											
Disassemble Air Hoses	1	$33.60				$ 34	1.0	LS	$ 34	1 ANL decon	
Decontaminate Equipment	4.2	$249.37				$ 1,047	1.0	LS	$ 1,047	2 vendor	
Exit Survey Equipment	1.5	$56.00	1.5	$0.71		$ 85	1.0	LS	$ 85	1 ANL HPT	HPT surveyed the equipment with a NE frisker and a gas proportional counter.
Donning/Doffing PPE for Equip. Decon	0.2	$305.37			$ 139.00	$ 200	1.0	LS	$ 200		PPE used by two vendor crew members and one ANL HPT.
Productivity Loss	2.86	$249.37				$ 712	1.0	LS	$ 712		Factor 1.68 per '96 ACE sheets. Includes radiation/ALARA, respiratory, and work breaks.
Transport Equipment from Work Area to Truck	0.88	$249.37				$ 219	1.0	trip	$ 219	2 vendor	
Return Trip to Coraopolis, PA											
Regular Hours	8	$249.37				$ 1,995	1.0	LS	$ 1,995	2 vendor	Same as note no. 3 except the return trip took 10 hours total.
Overtime Hours	2	$270.00				$ 540	1.0	LS	$ 540	2 vendor	Same as note no. 4 except there were only 2 overtime h.
WASTE DISPOSAL - WBS 331.18								**Subtotal:**	**$ 685**		
Shipping & Disposal Fees					$ 52.80	$ 53	13.0	CF	$ 685		LLW (Low-Level Waste) disposal.
OTHER COSTS								**Subtotal:**	**$ 1,370**		
ANL Procurement Costs					$ 1,369.78	$ 1,370	1.0	each	$ 1,370		Cost calculated @ 9.3 percent of the total vendor costs.
								Total	**$ 18,870**		

Table C-2.1 Innovative technology cost summary (extrapolated scenario)

Work Breakdown Structure (WBS)	Unit Cost (UC) Labor Hour	Labor Rate	Equipment Hour	Equipment Rate	Other Rate	Total UC	Total Qnty (TQ)	Unit of Measure	Total Cost (TC)1	Crew	Comments
MOBILIZATION (mob)- WBS 331.01								**Subtotal:**	**$ 5,628**		
Transport Equip from Coraopolis, PA to Chicago, IL											
Regular Hours	8	$203.13				$ 1,625	1.0	each	$ 1,625	2 vendor	See notes nos. 2 & 3 below.
Overtime Hours	4	$270.00				$ 1,080	1.0	each	$ 1,080	2 vendor	See note no. 4 below.
Truck Rental					$ 485.00	$ 485	1.0	trip	$ 485		Includes Penske truck rental @ $360.00 for unlimited miles plus an allowance of $125.00 for gas
Per Diem for Vendor Personnel											Based on a min. $95.00/day per vendor crew member.
For Travel Days					$ 190.00	$ 190	2.0	days	$ 380	2 vendor	
For Work Days					$ 190.00	$ 190	4.0	days	$ 760	2 vendor	
For Other Days					$ 190.00	$ 190	1.0	days	$ 190	2 vendor	Other category includes time for orientation, training, equip. setup, etc.
Vendor Orientation and Site Safety Training	4	$203.13				$ 813	1.0	each	$ 813	1 vendor	One vendor crew member attended a 4-h ANL site safety training course.
Unpack Equipment and Move to Work Area	1	$236.73				$ 237	1.0	each	$ 237	2 vendor; 1 ANL decon.	Includes removing the Moose from the truck, getting it to an elevator, and testing it prior to entering CP-5.
ANL DOP Test of HEPA Filter & Noise Level Measurement	0.55	$56.00				$ 31	1.0	each	$ 31	1 ANL IH	Tests conducted by ANL IH.
Pre-Rad Survey Equipment	0.5	$56.00	0.5	$0.71		$ 28	1.0	each	$ 28	1 ANL HPT	HPT surveyed the equipment with a NE frisker and a gas proportional counter.
DECONTAMINATION (decon) - WBS 331.17								**Subtotal:**	**$ 12,438**		
Set Up Equipment in Work	2.48	$203.13				$ 504	1.0	LS	$ 504	2 vendor	
Install 200 LF of Air Hose from Compressor to Work Area	1.58	$134.40				$ 212	1.0	LS	$ 212	4 ANL decon techs	
Daily Meetings											
Pre-Work Briefing	0.22	$270.33				$ 59	4.0	each	$ 238	2 vendor; 2 ANL decon	
Safety	0.08	$270.33				$ 22	4.0	each	$ 87	2 vendor; 2 ANL decon	
Remove Concrete Floor Down 1/8-in	0.0077	$203.13				$ 2	**2500**	SF	$ 3,910	2 vendor	The concrete floor was removed to only 1/8-in depth because the vendor did not bring enough waste barrels for 1/4-in of concrete removal.
HPT Support to Concrete Removal	19.25	$56.00				$ 1,078	1.0	each	$ 1,078	1 ANL HPT	The ANL HPT acted as an escort for the removal operation.
Waste Drum Changeouts	0.083	$203.13			$ 68.90	$ 86	18	each	$ 1,544	2 vendor	
Equip. Operating Costs											
Air Compressor Rental					$ 405.00	$ 405	1.0	week	$ 405	N/A	375 CFM air compressor @ $405.00 for the week. (Cost quoted from Pentek)
Replacement Parts					$ 2,400.00	$ 2,400	1.0	each	$ 2,400	N/A	Replacement parts are charged out by Pentek at a one-time flat rate. Parts include HEPA and roughing filters and scabbling bits.
Productivity Loss	6.2232	$259.13				$ 1,613	1.0	LS	$ 1,613	2 vendor; 1 ANL HPT	Factor 1.68 includes radiation/ALARA and work breaks.
Donning/Doffing Personal Protective Equipment (PPEs)	1.7493	$203.13			$ 92.66	$ 448	1.0	LS	$ 448	N/A	One vendor crew member in PPE during decon. Both vendor crew members in PPE during waste drum changeout.
DEMOBILZATION (demob) - WBS 331.21								**Subtotal:**	**$ 3,762**		
Demob Equipment											
Disassemble Air Hoses	1	$33.60				$ 34	1.0	LS	$ 34	1 ANL decon	
Decontaminate Equipment	4.2	$203.13				$ 853	1.0	LS	$ 853	2 vendor	
Exit Survey Equipment	1.5	$56.00	1.5	$0.71		$ 85	1.0	LS	$ 85	1 ANL HPT	HPT surveyed the equipment with a NE frisker and a gas proportional counter.
Donning/Doffing PPE for Equip. Decon	0.2	$259.13			$ 139.00	$ 191	1.0	LS	$ 191		PPE used by two vendor crew members and one ANL HPT.
Productivity Loss	1.26	$203.13				$ 256	1.0	LS	$ 256		Factor 1.68 per '96 ACE sheets. Includes radiation/ALARA, respiratory, and work breaks.
Transport Equipment from Work Area to Truck	0.88	$203.13				$ 179	1.0	trip	$ 179	2 vendor	
Return Trip to Coraopolis, PA											
Regular Hours	8	$203.13				$ 1,625	1.0	LS	$ 1,625	2 vendor	Same as note no. 3 except the return trip took 10 hours total.
Overtime Hours	2	$270.00				$ 540	1.0	LS	$ 540	2 vendor	Same as note no. 4 except there were only 2 overtime hours
WASTE DISPOSAL - WBS 331.18								**Subtotal:**	**$ 2,772**		
Shipping & Disposal Fees					$ 52.80	$ 53	52.5	CF	$ 2,772		LLW (Low-Level Waste) disposal.
OTHER COSTS								**Subtotal:**	**$ 1,701**		
ANL Procurement Costs					$ 1,700.94	$ 1,701	1.0	each	$ 1,701		Cost calculated @ 9.3 percent of the total vendor costs.
								Total	**$ 26,302**		

NOTES TO TABLE C-2

1. TC = UC x TQ (where TC = total cost; UC = unit cost, and TQ = total quantity).
2. The crew rate of $249.39/h is based on a daily service rate quote from Pentek of $1,995/day for two operators and the Moose equipment. The rate is prorated for an 8-h day.
3. The total travel time from Coraopolis, PA to Chicago, IL was 12 h, 8 h of which were charged at the prorated crew rate.
4. The additional 4 h of travel was charged at a prorated hourly overtime rate. This rate was quoted from Pentek at $270/h for two operators and the Moose equipment.

NOTES TO TABLE C-2.1

1. TC = UC x TQ (where TC = total cost; UC = unit cost and TQ = total quantity)
2. The crew rate of $203.13/h is based on a weekly service rate quote from Pentek of $8,125/week for two operators and the Moose equipment. The rate is prorated for a 40-h work week.
3. The total travel time from Coraopolis, PA, to Chicago, IL, was 12 h, 8 h of which were charged at the prorated crew rate.
4. The additional 4 h of travel was charged at a prorated hourly overtime rate. This rate was quoted from Pentek at $270/h for two operators and the Moose equipment.

MOBILIZATION (WBS 331.01)

Construct Temporary Facilities (airborne contaminant enclosure)

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 and HPT coverage. It includes the building materials. Dismantling of the "tent" is in the demobilization account.

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

Equipment Transport

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 forklift and the operators, the decon workers loading and hauling the subject construction equipment, and the hourly charges for the equipment transporting (and transported).

Assumption: Distance to a site warehouse varies, but is less than 2 miles. The flatbed truck and pneumatic forklift are rentals using rates from the Dataquest construction equipment rental rate book. Loading takes 2 h.; driving, 0.5 h; and returning to the equipment pool, 0.25 h.

Note: This scenario equals the innovative technology scenario for comparative purposes.

Unload Equipment

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

Assumptions: A 2 hour period to unload/unpack the equipment is assumed. Procurement's effort to receive purchased equipment and complete paperwork is excluded. Forklift operator is included in the crew rate, and forklift rental rate is $11.65/h, taken from Dataquest construction equipment pricing book.

Survey Equipment

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

Assumptions: Equipment survey is required.

Training

This cost element captures the cost of Site and health and safety (H&S) related training required for subcontractor personnel or other unqualified personnel.

Assumptions: No cost to this element. Personnel on site already are trained.

Radiological Survey

This cost element is for radiological surveying to characterize the workplace prior to the demonstration.

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

Set-Up or Move Equipment and check it out

This cost element includes time to lay out the equipment and hoses in preparation for the days 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. Set up excludes the erection costs of a temporary containment tent. It is covered in the mobilization activity.

Assumptions: The May 1996 Activity Cost Estimate (ACE) sheets included scaffolding because the scope also involved walls. The analysis scope is for the floor only. Therefore, the baseline 4 h were reduced to 2 h, eliminating 50 percent of the time assumed to be for scaffolding.

Remove Floor Surface Concrete

This cost element consists of:

- Scabble the floor concrete making one pass of ¼-in depth including replacing consumable scabbler bits that wear with use.
- The activity consists of one decon worker scabbling with a machine, one decon worker as support or tender and one HPT as the rad monitor and/or escort.
- HPT activity is taking readings of the area and/or the rubble during removal at full time participation along with the decon personnel.
- The manual function to clean up and package the concrete rubble into containers is required. Transporting it to disposal collection area is excluded.
- The production rate will vary depending upon the thickness of the concrete to remove to obtain acceptable radiation readings.
- Cost of scabbling equipment and consumable bits is in this cost element.
- Cost of PPE is included. See Table C-2 in Innovative Technology section.
- Any lost time from production is included. This involves daily safety meetings, daily work planning reviews, dressing out with PPEs, heat or temperature stress, work breaks, etc., which is accounted for through the PLF.

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 are required. Those three people handle the scabbling, sampling, clean up, and containerizing as a team for which the estimate is separated into two sub-elements of cost by craft.
- One 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. Standby time is necessitated by this activity.

- Production rate in this analysis is 200 ft^2/h for the one machine, a Model SF-11, Trelawny, one person scabbling (67 ft^2/man-h as a net effective rate for a three person crew). The scabbler is priced using the $9.95/h from the 1996 ACE sheets including all assumptions made at that time.
- A safety meeting occurs and is in the baseline factor for loss of productivity.

Health and Safety

A factor applied to productive hours (the PLF) to compensate for safety meetings, dressing and undressing in PPE, etc.

Assumption: The PLF used, 1.49, and the PPE costs are 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 per day calculation for PPE is the same as shown in the previous Innovative Technology section.

WASTE DISPOSAL (WBS 331.18)

Waste Collection

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 to package into containers the primary waste generated by the decon activity.

Assumptions: Baseline waste generated is calculated at 0.03 ft^3/ft^2 as taken from the May 1996 ACE sheets that amounts to 19.5 ft^3 including a 70 percent efficiency factor. The secondary waste consists of a couple of bags of expended scabbling bits, used PPEs, and swipes. Not applicable as such, but it is covered in the All-in-one rate/ft^3 below.

Transport to disposal site

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

Assumption: Not applicable as such, but it is covered in the All-in disposal fee rate/ft^3 below.

Disposal Fees

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

Assumptions: This cost is represented as an All-in disposal fee rate/ft^3 from the same 1996 estimate and covers all three activities of 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 and HPT coverage. It includes gathering up and containerizing the waste building materials. PPEs and a PLF are included.

Assumptions: Labor required is three persons for 3 h per ANL to dismantle and load up waste.

Survey and Decontaminate Equipment

Definition: This cost element provides for 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 costs to decontaminate it. Costs include HPT labor plus decon crew standby or assistance time, including the use of PPEs and experiencing a PLF.

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

Pack Up and Load Equipment

Definition: This cost element covers time and equipment required for crew to pack up and load 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 origin.

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

Table C-3. Baseline cost summary (manual mechanical scabbling technology)

Build containment tent	0.0035	$ 101		$ 2.76	$3.11	**822**	SF	$ 2,559	3 decon techs	Includes material costs.
HPT for Tent	2.9	$ 56		$ 13.20	$174	1	LS	$ 174	1 HPT	Covers building tent only. Other decon waste at 0.25 CF at $52.78/CF.
Transport Equip - load at warehouse	2	$ 147	2	$ 32.51	$ 359	1	Trip	$ 359	1 teamster; 1 operator; 1 decon tech	
Drive to site	0.5	$ 147	0.5	$ 42.46	$ 95	1	Trip	$ 95	1 teamster; 1 operator; 1 decon tech	Includes scabbler equipment.
Unload Equipment at site and survey	2	$ 203	2	$ 42.46	$491	1	Trip	$ 491	1 teamster; 1 operator; 1 decon tech; 1 HPT	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:**	**$ 2,665**		**SCOPE: 618 SF**
Move Equip to Work Area	2	$ 67.2	2	$ 38.47	$ 211	1	LS	$ 211	2 decon techs	Includes equipment standby.
Removal of concrete floor coatings	0.005	$ 67.2	0.005	$ 38.47	$ -	$ 0.53	**618**	SF	$ 327	2 decon techs	One machine at 200 SF/h including replacements, total 3.25 h.
Equip Operating costs										Varies with life of bits.
Wear on Scabbling Bits					$ 0.22	$ 0.22	618	SF	$ 135	N/A	Per operating cost calculation which is similar to Pentek consumable rates/SF.
Air Compressor Rental			3.09	$ 7.00		$ 21.62	1	LS	$ 22	N/A	Air compressor, 250 cfm.
Air Tools Used			3.09	$ 0.27		$ 0.84	1	LS	$ 1	N/A	
HPT Sample rubble and surface radioactivity	0.010	$ 56.0				$ 0.55	618	SF	$ 341	1 HPT	One HPT at $56/h, same h as decon plus manual loading.
Load Rubble in containers	0.162	$ 67.2	0.162	$ 38.47	$ -	$17.10	18.5	CF	$ 317	2 decon techs	Waste at .021 CF/SF with 70 percent efficiency = .03.
PPE					$ 139	$ 139	2.0	day	$ 278		Three men @ $46.33/day.
Productivity Loss	1.000	$123.2	1.000	$ 38.47		$ 162	6.39	H	$ 1,034		Factor: 2.05 per '96 ACE sheets.
DEMOBILZATION (demob) - WBS 331.21								**Subtotal:**	**$ 3,290**		
Decon and Survey Equipment	2	$ 67	2	$ 38.47		$ 211	1	LS	$ 211		
HPT work effort	9.9	$ 56			$ 13.20	$ 570	1	LS	$ 570	1 HPT	Other decon waste at 0.25 CF @ $52.78/CF.
PPE during decon			7.09		$ 278	$ 278	2.00	day	$ 556		Crew of three plus three extra for tent dismantlement.
Productivity Loss	1.0	$ 123	1.00	$ 38.47		$ 162	5.09	H	$ 823		Figured at 2.05 per 1996 ACE sheets.
Move Equipment and Load out	2	$ 147	2	$ 42.46		$ 379	1	LS	$ 379	1 teamster; 1 operator; 1 decon tech	Assumed reverse of the mobilization.
Return to warehouse	0.5	$ 147	0.5	$ 32.51	$ -	$ 90	1.0	trip	$ 90	1 teamster; 1 operator; 1 decon tech	Assumed reverse of the mobilization.
Dismantle temporary tent	0.0035	$ 101	0.0035	$ 38.47	$ 0.32	$ 0.80	822	SF	$ 661	3 decon techs	Three decon workers, 2 h @ $33.60/h plus materials.
WASTE DISPOSAL - WBS 331.18								**Subtotal:**	**$ 1,754**		
Shipping and Disposal Fees					$ 52.78	$ 52.78	33.2	CF	$ 1,754		From '96 ACE.
								Total	**$ 11,416**		

1. TC=UC x TQ (where TC=total cost; UC=unit cost, and TQ=total quantity).
2. All workers are ANL personnel.

Table C-3.1 Baseline cost summary (manual scabbling technology - extrapolated scenario)

Work Breakdown Structure (WBS)	Unit Cost (UC) Labor Hour(H)	Rate	Equipment H	Rate	Other Rate	Total UC	Total Qnty (TQ)	Unit of Measure	Total Cost (TC)1	Crew Composition 2	Comments
MOBILIZATION (mob)- WBS 331.01								**Subtotal:**	**$ 11,990**		
Build containment tent	0.0035	$ 101			$ 2.76	$3.11	**3325**	SF	$ 10,352	3 decon techs	Includes material costs.
HPT for tent	11.6	$ 56			$ 13.20	$665	1	LS	$ 665	1 HPT	Covers building tent only. Other decon waste at 0.25 CF @ $52.78/CF.
Transport Equip - load at warehouse	2	$ 147	2	$ 32.51		$ 359	1	Trip	$ 359	1 teamster; 1 operator; 1 decon tech	
Drive to site	0.5	$ 147	0.5	$ 42.46		$ 95	1	Trip	$ 95	1 teamster; 1 operator; 1 decon tech	Includes scabbler equipment.
Unload Equipment at site and survey	2	$ 203	2	$ 42.46		$491	1	Trip	$ 491	1 teamster; 1 operator; 1 decon tech; 1 HPT	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:**	**$ 6,542**		**SCOPE: 618 SF**
Move Equip to Work Area	2	$ 67.2	2	$ 38.47		$ 211	1	LS	$ 211	2 decon techs	Includes equipment standby.
Removal of concrete floor coatings	0.005	$ 67.2	0.005	$ 38.47	$ -	$ 0.53	**2500**	SF	$ 1,321	2 decon techs	One machine at 200 SF/h including replacements, total 3.25 h.
Equip Operating costs											Varies with life of bits.
Wear on Scabbling Bits					$ 0.22	$ 0.22	2500	SF	$ 547	N/A	Per operating cost calculation which is similar to Pentek consumable rates/SF.
Air Compressor Rental			12.5	$ 7.00		$ 87.44	1	LS	$ 87	N/A	Air compressor, 250 cfm.
Air Tools Used			12.5	$ 0.27		$ 3.42	1	LS	$ 3	N/A	
HPT Sample rubble and surface radioactivity	0.006	$ 56.0				$ 0.35	2500	SF	$ 868	1 HPT	One HPT at $56/h, same h as decon techs plus manual loading.
Load Rubble in containers	0.040	$ 67.2	0.040	$ 38.47	$ -	$4.23	75.0	CF	$ 317	2 decon techs	Waste at 0.021 CF/SF with 70 percent efficiency = 0.
PPE					$ 139	$ 139	4.0	day	$ 556		Three men @ $46.33/day.
Productivity Loss	1.000	$123.2	1.000	$ 38.47		$ 162	16.28	H	$ 2,631		Factor 2.05 per '96 ACE sheets.
DEMOBILZATION (demob) - WBS 331.21								**Subtotal:**	**$ 8,047**		
Decon and Survey Equipment	2	$ 67	2	$ 38.47		$ 211	1	LS	$ 211		
HPT work effort	27.7	$ 56			$ 13.20	$ 1,567	1	LS	$ 1,567	1 HPT	Other decon waste at 0.25 CF @ $52.78/CF.
PPE during decon			16.21		$ 278	$ 278	4.00	day	$ 1,112		Crew of three plus three additional for tent dismantlm
Productivity Loss	1.0	$ 123	1.00	$ 38.47		$ 162	14.21	H	$ 2,297		Figured at 2.05 per 1996 ACE sheets.
Move Equipment and Load out	2	$ 147	2	$ 42.46		$ 379	1	LS	$ 379	1 teamster; 1 operator; 1 decon tech	Assumed reverse of the mobilization.
Return to warehouse	0.5	$ 147	0.5	$ 32.51	$ -	$ 90	1.0	trip	$ 90	1 teamster; 1 operator; 1 decon tech	Assumed reverse of the mobilization.
Dismantle temporary tent	0.0035	$ 101	0.0035	$ 38.47	$ 0.24	$ 0.72	3325	SF	$ 2,391	3 decon techs	Three decon workers, 2 h @ $33.60/h plus materials
WASTE DISPOSAL - WBS 331.18								**Subtotal:**	**$ 4,734**		
Shipping and Disposal Fees					$ 52.78	$ 52.78	89.7	CF	$ 4,734		From '96 ACE.
								Total	**$ 31,313**		

1. TC=UC x TQ (where TC=total cost; UC=unit cost, and TQ=total quantity).
2. All workers are ANL personnel.

APPENDIX D

[redacted]

Technology Description

A technology assessment of scabbling technologies performed FIU-HCET in June, 1996, combined the evaluation of several pieces of equipment, Figure D-1, owned by Pentek, Inc. Scabbling systems use mechanical force generated by compressed air to impact the surface and remove material. In most scabbling equipment, a series of tungsten bits are driven in a piston action to impact the surface. Other scabblers operate on the same principle as a pneumatically operated needle scaler using specially hardened needles to remove the concrete.

Figure D-1. Pentek, Inc. equipment.

Four pieces of equipment were demonstrated at FIU-HCET for concrete removal of the 800-ft^2 surface: the Moose®, Squirrel®-III, Squirrel®-I, and the Corner-Cutter®. *The specifications for the Moose® can be found in Section 2, Technology Description, of this ITSR.* Specifications for the remaining equipment are included in Table D-1 below.

Table D-1. Equipment specifications.

Criteria	Squirrel®-III	Squirrel®-I	Corner-Cutter®
Floor unit or hand-held	Floor unit	Hand-held	Hand-held
Weight	50 lb	35 lb	9 lb
Dimensions	12 in high (excluding handle) and 12 in length	28 in high	14 in length
Cutting width	6 in	2-1/4 in	1 3/4 in

Table D-1 (cont.)

Criteria	Squirrel®-III	Squirrel®-I	Corner-Cutter®
Media used and number	Three scabbling bits, each 1 ¾-in-diameter, 9-pt tungsten carbide tipped	One scabbler bit, 2 ¼-in-diameter, 9-pt tungsten carbide tipped	3-mm-diameter steel needles
Utilities required	Air compressor (75-90 cfm minimum)	Air compressor (50 cfm vacuum source minimum	Air compressor (50 cfm vacuum source minimum)
Vendors advertised production rate	20-30 ft^2/h at 1/16-in surface removal	30 ft^2/h for 1/8-in to ¼-in removal	20-30 ft^2/h flat surfaces 30-60 linear ft/h edges
Air consumption	60 cfm @ 80 psig	30 cfm @ 90 psig	5 cfm @ 90 psig

System Operation

- The Moose® was remotely controlled from a control panel located 50 ft from the equipment.
- The Squirrel®-III was a stand-behind push model operated by squeezing a lever on the handle.
- The Squirrel®-I was a hand-held model operated by squeezing the handle. The operator was required to kneel or bend to use this piece of equipment on floors. This equipment was demonstrated on hard to reach sections of the floor (e.g., in corners and on the floor right against the walls).
- The Corner-Cutter® was a hand-held gun operated by squeezing a lever on the handle. The operator was required to kneel or bend to use this piece of equipment on floors. This equipment was demonstrated on hard to reach sections of the floor (e.g., in corners and on the floor right against the walls).
- Simultaneous to the decontamination of the floor, the substrate debris was vacuumed using the vacuum system integrated on the Moose®. For the smaller units, the vacuum hose from the Moose® was detached from the scabbling head and then attached to the Squirrel® or Corner-Cutter® equipment.
- Small pieces of debris were left on the floor after concrete removal and the entire floor was vacuumed once the demonstration was completed.

Demonstration Plan

In a project for the Fernald Environmental Management Project, Fluor Daniel Fernald contracted the FIU-HCET to evaluate and test commercially available technologies for their ability to decontaminate radiologically contaminated concrete flooring. The results of this project are presented in the final report, *Analysis of Potential Concrete Floor Decontamination Technologies.*

The demonstrations were held at the FIU campus on 20 ft x 40 ft concrete slabs prepared specifically for these demonstrations. The concrete slabs were 6-in thick and had a final compressive strength of 5700 psi. One-half of the slab (20 ft x 20 ft) was coated with an epoxy urethane coating. A 6 in dike surrounded each test section to aid in the evaluation of the technology's capability to remove concrete at the interface of a floor and a wall. These demonstrations were not conducted in a radiological environment.

During the demonstration, FIU-HCET evaluators 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. Additional field measurements collected include secondary waste generation, operation/maintenance requirements, and benefits and limitations of the technology. To determine the depth of removal, a state of Florida certified surveyor performed a 57-point survey of each test area prior to and proceeding the demonstration to determine the average depth of removal. In addition, to enhance the technology assessment process, the International Union of Operating Engineers (IUOE) provided a review of the health and safety factors pertinent to the test.

Treatment Performance

Table D-2 presents the results of the FIU-HCET demonstration of the Pentek, Inc., scabbling technology.

Table D-2. Performance data

Criteria	Combined scabbling equipment
Applicable surface	Expected to perform 1-in-concrete removal.
Depth achieved	Between ½-in and 1-in concrete removed.
Production rate	33 ft^2/h combined for four pieces of equipment (1)
Type of primary waste generated	Fine powder and small pieces of concrete.
Type of secondary waste generated	Vacuum filters and needles from Corner-Cutter®.
Noise level	101.4 dBA maximum (1). Hearing protection required.
Capability to access floor-wall unions	None of the equipment could reach any closer than ¾-in.
Development status	Commercially available.
Ease of use	The Moose® is remotely-operated. The Squirrel®-III is a walk-behind floor model. The hand-held equipment, Squirrel®-I and Corner-Cutter®, require the operator to be in a bending or kneeling position.
End-point condition	Removed between ½-in and 1-in concrete over surface.
Worker safety	Tripping hazards from hoses and cords. For hand-held equipment, the operator is stooping, bending, kneeling, and lifting. Arm-hand vibration.

(1) Individual measurements for each piece of equipment were not performed.

Implementation Considerations

The Pentek line of equipment has been used successfully in DOE, military, and commercial nuclear facilities. There are no implementation considerations for use of these equipment.

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