Centrifugal Shot Blast System

Deactivation and
Decommissioning Focus Area

Prepared for

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INNOVATIVE TECHNOLOGY
Summary Report

Centrifugal Shot Blast System

OST Reference # 1851

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.

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SECTION 1

SUMMARY

Technology Description

This report describes a demonstration of Concrete Cleaning, Inc., modified centrifugal shot blast technology to remove the paint coating from concrete flooring. This demonstration is part of the Chicago Pile-5 (CP-5) Large-Scale Demonstration Project (LSDP) sponsored by the U.S. Department of Energy (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 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.

Concrete Cleaning, Inc., is a commercial service provider that uses modified centrifugal shot blast machines to remove concrete and concrete coatings. The shot blast unit, shown in Figure 1, propels hardened steel shot at a high rate of speed to abrade the surface of the concrete. The depth of removal is determined by the rate of speed at which the machine is traveling and the volume and size of shot fired into the blast chamber. The steel shot is recycled and reused until it is too small to be useable.

Figure 1. Centrifugal shot blast unit.

The centrifugal shot blast unit can be used with a variety of dust collection systems. Concrete Cleaning, Inc., modified a commercially available dust collection system with a high-efficiency particulate air (HEPA) filter (Figure 2) for this demonstration. The vacuum, which has a capacity of 850 cubic feet per minute (ft^3/min), was mounted on expandable legs and modified to permit the attachment of a 55-gal waste collection drum underneath.

Figure 2. Dust collection system.

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. 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 capturing large pieces of debris; however, an attached 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.

The main advantage of Concrete Cleaning, Inc.'s centrifugal shot blast technology over the baseline mechanical scabbling technology is the simultaneous collection of dust and debris by the dust collection system, which is connected to the shot blast unit. The dust collection system significantly reduces the amount of airborne dust generated during the D&D process, thus reducing personnel exposure, and may lead to a significant reduction in respiratory protection and personnel protective equipment (PPE) requirements, especially in highly contaminated facilities. The shot blast technology has a higher production rate than the baseline technology, which can result in the job's being completed earlier, thus reducing personnel exposure and costs. The unit is also self-propelled, thereby significantly reducing operator fatigue and increasing worker health and safety. The model of shot blast unit demonstrated at CP-5 also offers versatility as it can be adjusted to remove the entire layer of coating, specific layers of the coating, or the coating and up to one-half inch of concrete (total practical limit for unit).

Technology Status

The Concrete Cleaning, Inc., modified centrifugal shot blast system was evaluated as part of the LSDP in the removal of paint coatings from 800 ft^2 of concrete flooring on the service floor of the CP-5 Research Reactor. The evaluation period (January 28 to February 4, 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 modified shot blast system. The vendor was not required to remove additional concrete from the floor area if the final radiological levels were found to be elevated at the end of the demonstration.

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 year until its final shutdown in 1979. These 25 year 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.

Concrete Cleaning, Inc., personnel operated the centrifugal shot blast system 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 operations (WMO), 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.

Potential markets exist for the innovative centrifugal shot blast system at the following sites: Fernald Environmental Management Project, Los Alamos, Nevada, Oak Ridge Y-12 and K-25, Paducah, Portsmouth Gaseous Diffusion Site, and the Savannah River Site. This information is based on a revision to the OST Linkage Tables dated August 4, 1997.

Key Results

The key results of the demonstration are as follows.

- The Concrete Cleaning, Inc., centrifugal shot blast technology removed the paint coating from the 800 ft^2 of concrete flooring in the demonstration area at a rate of 310 ft^2/h.
- The centrifugal shot blast technology was able to remove coatings from within 2 to 5 in from the union of the floor and the wall and around obstructions.
- The shot blast unit is self-propelled which significantly reduces operator fatigue and has the potential to reduce exposure in highly contaminated areas.
- Removal of the coatings from the concrete floor was sufficient to reduce the contamination from levels up to 5,300 dpm/100 cm^2 fixed total beta/gamma to levels measuring at or below background levels of no greater than 1,500 dpm/100 cm^2.
- Concrete Cleaning, Inc.'s dust collection system, which is connected to the centrifugal shot blast unit, has the potential to significantly reduce the amount of airborne radioactivity during D&D activities, thereby potentially reducing PPE requirements, especially respiratory protection. This capacity 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.
- Modifications made by Concrete Cleaning, Inc., to the dust collection system are not adequately designed. Thus, improvements are required to increase the operational effectiveness of the system. The leg extensions that were added did not adequately support the dust collector, causing the unit to be unstable. The funnel and drum lid system was not flexible enough to allow the waste drum to be

easily removed from under the vacuum. Concrete Cleaning, Inc., has initiated corrective actions to eliminate these problems.

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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 the centrifugal shot blast system is 1851.

TECHNOLOGY DESCRIPTION

Technology Schematic

Centrifugal shot blasting is an abrasive blasting technology that propels hardened steel shot against contaminated surfaces at a high velocity to remove contaminants and substrate. Figure 3 is a schematic of the centrifugal shot blast system. The amount of substrate removed can be adjusted by varying the size and the amount of shot expelled from the blast chamber or the speed at which the blast unit travels over the substrate. The steel shot is collected by vacuum and recycled until it is spent (i.e., too small for reuse). The centrifugal shot blast unit is connected to a remote dust collection system using a 50-ft-long, 6-in-diameter vacuum hose. The debris generated and the spent shot are continually vacuumed into this HEPA filtered dust collection system and then deposited into a 55-gal drum. Compared to the baseline technology, the dust collector significantly reduces the potential for airborne dust and the release of radioactivity.

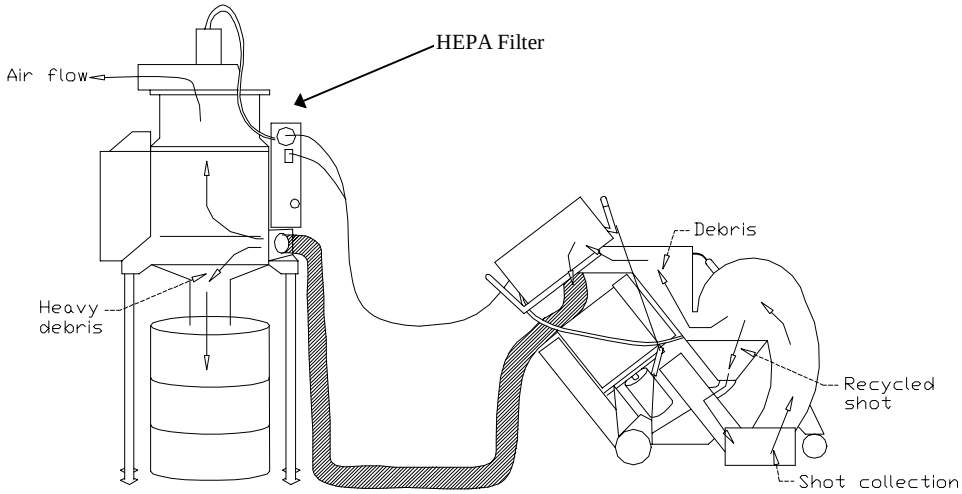

Figure 3. Schematic of the centrifugal shot blast system.

Concrete Cleaning, Inc., made modifications to a standard centrifugal shot blast machine (Figure 1) to increase the efficiency and speed of substrate removal. Concrete Cleaning, Inc., considers these modifications proprietary and has applied for a patent.

Operational parameters for the centrifugal shot blast unit (not including the dust collection system) are as follows:

- Manufacturer — George Fischer (+GF+, GOFF®)
- Dimensions (L x W x H) — 50 in x 16.5 in x 43 in
- Weight — 650 lb

- Speed — Two, ¼-hp, fully variable speed drives
- Cutting width: — 13 in
- Vendor advertised production rate — 200-250 ft^2/h

The objective of the demonstration at the ANL CP-5 Research Reactor facility was to remove the contaminated paint coating from 800 ft^2 of concrete flooring on the service floor. The centrifugal shot blast unit that Concrete Cleaning, Inc., utilized effectively demonstrated its ability to remove just the coating layer. This size of shot blast unit is also capable of removing up to ½ in of concrete. Larger units can remove 1 in or more of concrete from large, flat areas. Other shot blast units are capable of removing coatings or concrete from walls or small spaces. The larger unit was demonstrated at FIU in May 1996 as part of a project for the Fernald Environmental Management Project. A brief description of this demonstration is included in Appendix C.

Attached to the shot blast unit is the remote HEPA filtered dust collection system (Figure 2). In addition to the proprietary modifications to the shot blast unit, Concrete Cleaning, Inc., modified the dust collection system to allow the waste to be collected directly into a waste drum instead of into the refuse pan provided by the manufacturer. The roller casters on the dust collector were removed, and adjustable legs were bolted to the unit's frame in their place. A butterfly valve funnel and waste drum lid system was installed at the bottom of the unit where the refuse pan normally resides. These modifications permit a standard waste drum to be placed directly under the dust collector and then attached to the funnel-drum lid system. This modification reduces the potential for a release of airborne contaminants by collecting the waste directly in the proper disposal container instead of having to transfer the waste from the refuse pan into the waste drum.

The parameters for the dust collection system include the following:

- Manufacturer — GOFF®
- Dimensions (L x W x H) — 60 in x 27 in x 113.25 in (The expandable legs are 50.25 in high.)
- Weight — 700 lb
- Vendor rated vacuum flow — 850 ft^3/min
- Primary roughing filter cartridges — Six @ 8 in diameter x 16 in length
- Secondary HEPA filter — One unit (99.97 percent efficient at 0.1 micron particulate size)
- Standard waste drum — 23 or 55 U.S. gal

Once the dust collection system is connected to the external utility source, the shot blast unit is connected to the electrical panel mounted on the side of the dust collector. The utilities required for the operation of the centrifugal shot blast technology at the CP-5 LSDP included a 480-V, 3-phase, 60-A electrical current source.

System Operation

- The centrifugal shot blast machine is self-propelled, requiring only one operator to work behind the unit.
- The floor to be decontaminated must be dry to prevent the removed substrate from clogging the hoses and screens within the shot blast unit.
- A control panel attached to the rear of the shot blast unit includes the toggle switches used to steer the unit either left, right, forward, or in reverse. Dials control tracking and the speed at which the shot blast unit moves over the floor. The amount of shot released into the blast unit is controlled by a switch on the panel. Gauges measure both the amps generated by the unit and the number of hours the unit has been in operation. The control panel also features an emergency stop button.
- The amount of substrate removed in a single pass is controlled by the size and amount of shot released by the unit as well as the speed at which the unit moves over the floor.
- One hundred pounds of shot can be added to the shot blast unit at one time.
- Simultaneous with the decontamination of the floor, the shot and substrate debris are vacuumed through the shot blast unit. The mixture passes through an abrasive recycling system in which the larger/heavier pieces of shot are recycled back into the holding area. The smaller/lighter spent shot and substrate debris are lifted into the vacuum hose, then the dust collection system, and eventually the waste drum.
- Shot that escapes from under the shot blast unit or is not collected by the vacuuming unit is collected by the operator using a magnetic broom or roller. This shot is then recycled into the shot blast unit. For this demonstration, a total of 100 lb of shot was used and at the end of the demonstration over 70 lb of shot was still considered to be reusable.
- Decontamination of the centrifugal shot blast equipment includes removing filters from the dust collection system and wiping or vacuuming the inside and outside of both the shot blast unit and the dust collector. All locations of the dust collection system are easily accessible for decontamination; however, a few locations within the shot blast unit could not easily be reached. Concrete Cleaning, Inc., has discussed modifying the shot blast unit to make these areas more accessible.
- The main waste stream from this operation is a powdery mixture of paint chips, concrete, and spent shot. Secondary waste includes the roughing and HEPA filters in the dust collector, any shot used by the shot blast unit that was not spent but that cannot be free released because of radiological concerns, the 50-ft vacuum hose, PPE, and any material used during equipment decontamination (e.g., damp rags, plastic matting, or brushes).

SECTION 3

PERFORMANCE

Demonstration Plan

The demonstration of the centrifugal shot blast technology from Concrete Cleaning, Inc., was conducted according to the approved test plan, *CP-5 Large-Scale Demonstration Project: Test Plan for the Demonstration of Centrifugal Shot Blast Technology at CP-5* (Strategic Alliance for Environmental Restoration, 1996). The objective of the demonstration was to remove the contaminated paint coating from 800 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 technologies tend to yield a smooth surface that can be easily repainted or covered, whereas concrete removal technologies have the potential to leave an uneven, rough surface that could be difficult to reuse.

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 coating removal. The vendor was not required to remove additional concrete from the demonstration area if the final radiological levels were still 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 ease of equipment operation. The performance of the centrifugal shot blast technology was evaluated against that of the baseline technology, mechanical scabbling.

Treatment Performance

Table 1 presents both the results of the Concrete Cleaning, Inc., centrifugal shot blast technology demonstration and a comparison with the baseline technology.

Table 1. Performance data

Criteria	Concrete Cleaning, Inc., centrifugal shot blast technology	Baseline mechanical scabbling technology
Applicable surface	Coating removal from painted concrete floor.	¼ in concrete removal from floor.
Production rate (removal rate only)	310 ft^2/h	200 ft^2/h
Amount and type of primary waste generated	2.5 ft^3 of a powdery mixture consisting of paint, concrete, and spent shot (contained by the dust collector as generated).	An estimated 24 ft^3 of a mixture of powdery and large pieces of paint chips and concrete (this requires manual cleanup; no vacuum system is attached).

Table 1. (continued)

Criteria	Concrete Cleaning, Inc., centrifugal shot blast technology	Baseline mechanical scabbling technology
Type of secondary waste generated	1. Roughing filters - three units 2. High-efficiency particulate air (HEPA) filter - one unit 3. Vacuum hose - 50-ft section 4. Used steel shot - @ 100 lb	Tent-enclosure materials and worn pistons/scabbling bits.
Airborne radioactivity generated by equipment	All airborne radiological measurements were at or below background levels.	Since the baseline technology is not connected to a vacuum system, up to 10 percent of debris generated can become airborne.
Noise level	97 dBA in work area; hearing protection is required.	84 dBA (per vendor, not measured).
Capability to access floor-wall unions	No closer than 2 in. Up to 5 in at corners and confined spaces.	No closer than 1 in.
Development status	Modified blast unit available through Concrete Cleaning, Inc. Improvements to dust collector are required for efficient use.	Commercially available. Compatible vacuum systems are also available.
Ease of use	Training - Not applicable as Concrete Cleaning, Inc., is a service organization. Shot blast unit is a self-propelled floor model.	Training required = 2 h/person. Walk behind, push-floor model. Moderate-to-heavy vibrations can cause operator fatigue.
End-point condition	Paint coating is removed, leaving a smooth, bare concrete surface.	Paint coating is removed, leaving a rough, bare concrete surface.
Worker safety	Shot created projectile and slipping hazards. Tripping hazard caused by multiple hoses.	Flying concrete poses a potential eye hazard.

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/100 cm^2) contamination, pre-demonstration	Total β/γ (dpm/100 cm^2) contamination, post-demonstration
1	4,300	*
2	5,300	*
3	5,300	*

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

The following difficulties were encountered during the demonstration.

- During the operation of the shot blast unit, steel shot escapes from under the unit and can become a projectile hazard. To reduce this hazard, a temporary 4-ft-tall herculite wall was erected around the demonstration area, and all personnel except the equipment operator were restricted from this area during equipment operation. Regardless, occasional shot ricocheted off objects in the area and struck support personnel.
- The steel shot left on the floor by the shot blast unit is to be collected by the equipment operator using a magnetic roller attached to a broom handle. This shot is then to be recycled back into the shot blast unit or collected for disposal. However, during this demonstration, the magnetic roller was not effective in collecting the shot. At the end of the demonstration, the operator disconnected the flexible vacuum hose from the shot blast unit and vacuumed the shot from the floor while on his hands and knees.
- Several problems were encountered during the assembly and disassembly of the dust collection system. Improvements to the modifications already made by Concrete Cleaning, Inc., and to the HEPA filter unit of the dust collector are required to ensure safe and efficient assembly and disassembly of the equipment.

SECTION 4

TECHNOLOGY APPLICABILITY AND ALTERNATIVES

Technology Applicability

Concrete Cleaning, Inc., centrifugal shot blast technology is a commercially available technology. The primary application of this technology is hazardous coating and concrete removal from large floor areas. During the January 28 – February 4, 1997, technology demonstration at CP-5, the modified centrifugal shot blast system was evaluated as an alternative to the mechanical scabbling technology for the removal of coatings from large areas of concrete floor.

The main advantage the Concrete Cleaning, Inc., centrifugal shot blast technology offers over mechanical scabbling is the simultaneous collection of dust and debris by a dust collection system that is connected to the shot blast unit. The use of the dust collection vacuum system 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 PPE requirements, especially in highly contaminated facilities. The shot blast unit is also self-propelled, thereby significantly reducing operator fatigue. It can be adjusted to remove the entire coating layer, specific layers of the coating, or the coating and up to ½ in of concrete.

The major shortcoming of the centrifugal shot blast technology was the modifications made by Concrete Cleaning, Inc., to the dust collection system. The unit was modified to allow a HEPA filter to be added and the unit was lifted to allow a 55-gal drum to be attached to the waste discharge. However, there were problems with the modifications (e.g., the HEPA filter did not fit the holder, the legs on the dust collector were hard to put on and remove). Additional improvements are required to make this unit safer and more efficient to operate in a DOE facility.

Competing Technologies

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

Examples of competing technologies include:

- mechanical scabbling (ANL baseline technology),
- milling,
- 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.

In the category of centrifugal shot blasting there are several competing technologies and vendors.

Data comparing the performance of the modified centrifugal shot blast technology to all of the competing technologies listed above is not available.

Patents/Commercialization/Sponsor

This demonstration used an existing commercial technology. The centrifugal shot blast unit and dust collection system demonstrated at CP-5 were purchased and modified by Concrete Cleaning, Inc. Because this company is a service provider, it does not sell or rent the modified equipment. A patent for the modifications to the shot blast unit is pending.

SECTION 5

COST

Introduction

This cost analysis compares the relative costs of the innovative centrifugal shot blast system and the baseline mechanical scabbling technology and presents information which will assist D&D planners in decisions about the use of the centrifugal shot blast technology in future D&D work. This analysis strives to develop realistic estimates that represent actual D&D work within the U.S. DOE complex. However, this is a limited representation of actual cost because the analysis only uses 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 (e.g., do not change the productivity rate, quantities, and work elements) and 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, Technical Data Report for the Concrete Cleaning, Inc. Centrifugal Shot Blast Technology* (Strategic Alliance for Environmental Restoration, 1997) provides additional cost information.

Methodology

This cost analysis compares an innovative centrifugal shot blast technology used for the decontamination of floors to a conventional baseline technology, mechanical scabbling. The centrifugal shot blast technology demonstration took place at the CP-5 Reactor facility at ANL. The vendor provided personnel and equipment for which timed and measured activities were recorded to determine achievable production rates.

Data collected during the demonstration included the following:

- activity duration;
- work crew composition;
- equipment used to perform the activity;
- supplies used, including the replacement of machine parts and utilities; and
- training courses required and attended (e.g., radiation worker and site orientation classes).

A concurrent demonstration of the mechanical scabbling technology was not held. Baseline information was extracted from existing budget or planning documentation for CP-5, whereas the labor, equipment, production rate specifications, and productivity loss factors (PLF) were provided by site personnel at ANL.

The following documents and sources were used as references on the baseline technology:

- *Decommissioning Cost Estimate for Full Decommissioning of the CP-5 Reactor Facility* (Nuclear Energy Services, Inc., 1992);

- Activity cost estimate backup sheets, dated 5/15/96, for CP-5 decommissioning; and

- Current information from D&D personnel at ANL.

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

The selected basic activities analyzed are those recommended by 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, was used in this analysis to provide consistency with the 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 application. Decision makers seeking site-specific costs can apply their site's rates to this analysis without having to first retract ANL's rates. This omission does not sacrifice the cost saving's accuracy because overhead applies 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 uses an 8-h work day and a 5-day week.

The hourly equipment rates representing the Government's ownership are based on general guidance contained in the Office of Management and Budget (OMB) Circular No. A-94, revised for cost effectiveness analysis (OMB, 1992). The rate consists of ownership and operating costs. Operating costs consist of items such as fuel, filters, oil, grease, other consumable items, repairs, maintenance, overhauls, and calibrations. When the vendor does not provide an hourly rate, the equipment rates representing vendor ownership include required maintenance costs and allow for depreciation and the facility capital cost of money (FCCM) of 4.8 percent. These are computed in accordance with the *Construction Equipment Ownership and Operating Expense Schedule* (USACE, 1995).

Summary of Cost Variable Conditions

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

Table 3. Summary of cost variable conditions

Cost variable	Centrifugal shot blast technology	Baseline mechanical scabbling technology
Scope of Work		
Quantity and type of material	800 ft^2. The multiple layers of paint were of varying thickness and worn through in many locations.	800 ft^2. Equivalent to the demo area (approximately one-quarter of the baseline's area scope of 2,542 ft^2).
Location	Service floor of CP-5 Research Reactor.	CP-5 Research Reactor area (estimated, not observed).
Nature of work	Reduce radiological levels on the floor via paint removal.	Reduce radiological levels on floor via ¼-in-paint and concrete removal.

Table 3. (continued)

Cost variable	Centrifugal shot blast technology	Baseline mechanical scabbling technology
Work Environment		
Worker protection	Requires PPE and respirators, possibly to a lesser degree than the baseline.	Requires PPE, respirators, and construction of a temporary containment tent for airborne contaminants. The tent is estimated to cover 133 percent (1,064 ft^2) of the area being decontaminated at \$2.87/ft^2.
Level of contamination	Demonstration area was not a high contamination area. Contamination that was present was fixed.	Concrete chips and airborne dust created by the equipment.
Work Performance		
Acquisition means	Vendor provided service.	Local craft workers with rented equipment.
Scale of production	Demonstrated in an open area with some vertical edges. The centrifugal shot blast (CSB) had a 13-in-cutting width and was a self-propelled floor model.	Based on a large, unconfined area and a crew of three, one operating the machine and two supporting. The scabbler is a large floor model with an 11-in-cutting width.
Production rates	One machine at 310 ft^2/h (observed).	One scabbler at 200 ft^2/h (based on experience).
Equipment and crew	One GOFF® 15E13 CSB with Concrete Cleaning, Inc., modifications; a two-person vendor crew, one operating the machine and the other on standby; one health physics technician (HPT) supporting all activities.	One Trelawny Scale Force-11 scabbler and two decontamination technicians, one HPT supporting all activities.
Primary waste	2.5 ft^3 mix of paint and concrete powder.	24.0 ft^3 of paint and concrete rubble (based on historical experience).
Secondary waste and consumables	Filter hose, HEPA and roughing filters, PPE, cleaning brushes, plastic matting for the dust collector, and 100 lb of shot.	Worn scabbling bits, swipes, PPE, and the dismantled containment tent.
Work process steps	Blast the surface with one machine and collect debris and spent shot in the dust collector system connected to the shot blast unit.	Scabble the surface area, leaving debris and airborne contaminants. Sample rubble, and manually cleanup and load into containers.
End condition	Paint coating is removed, leaving a smooth, bare concrete surface.	¼-in mix of paint coating and concrete is removed, leaving a rough, bare concrete surface.

Potential Savings and Cost Conclusions

For the conditions and assumptions presented in Appendix B, the baseline mechanical scabbling technology results in savings of approximately 75 percent over the innovative centrifugal shot blast technology alternative for this demonstration area of 800 ft^2. Even though the baseline is less expensive for the scope and conditions of this demonstration, the centrifugal shot blast's lower incremental costs should result in savings for areas larger than approximately 1,900 ft^2. Figure 4 presents a comparison of the costs of mobilization, decontamination, demobilization, and waste disposal for the centrifugal shot blast and the baseline. As Figure 4 shows, the centrifugal shot blast has higher costs in the mobilization, decontamination, and demobilization cost categories. Waste disposal is the only cost category in which

the centrifugal shot blast is less expensive than the baseline. This is due to the fact that centrifugal shot blast removes only floor coatings versus the ¼-in coating and concrete removal performed by the baseline.

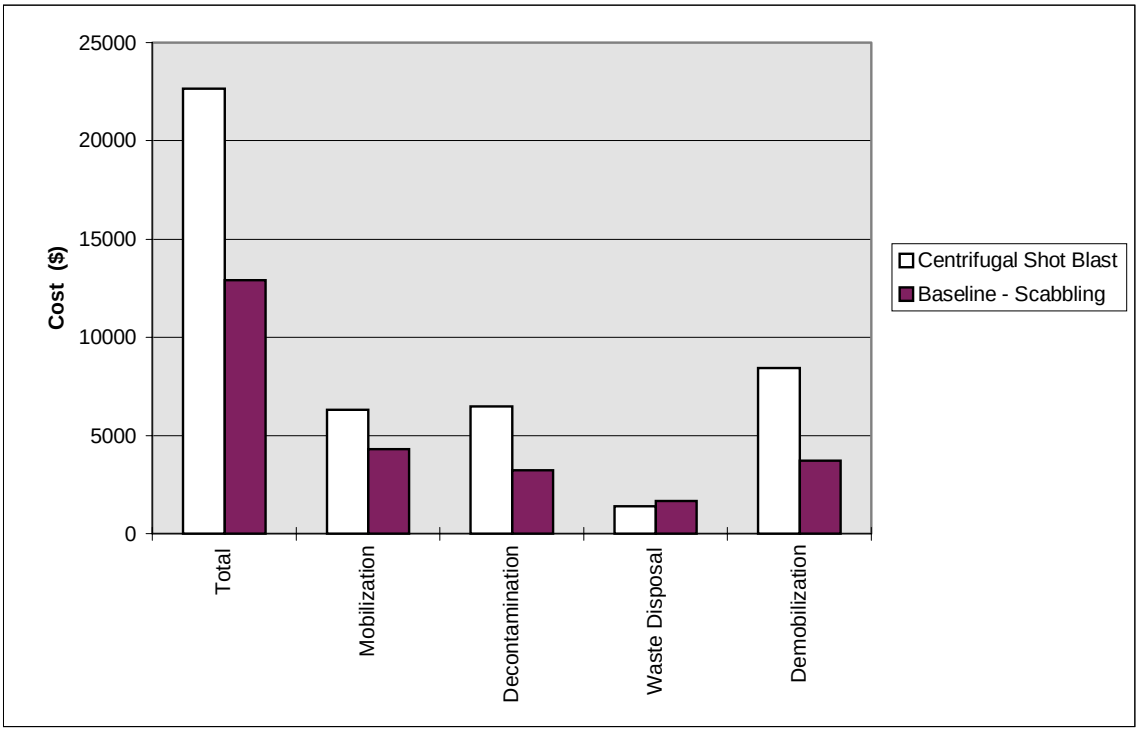

Figure 4. Technology cost comparison.

Although the baseline is less expensive than the centrifugal shot blast for the conditions of the demonstration, it should be recognized that the mobilization and demobilization costs for the centrifugal shot blast have an invariable relationship to its operating costs. In other words, the costs of the transport of the equipment and personnel for the centrifugal shot blast demonstration are a much larger percentage of the overall costs for the centrifugal shot blast than they would have been had the area being decontaminated been much larger. In contrast, the construction and dismantling of the containment tent for the baseline technology's mobilization and demobilization most likely have costs that increase in proportion with the size of the decontamination area.

Even though the centrifugal shot blast has higher decontamination costs for the 800 ft^2 demonstration area, this technology has a higher productivity rate, 310 ft^2/h versus 200 ft^2/h for the scabbler. The higher decontamination costs are a result of the relatively high level of initial consumables (e.g., 50-ft filter hose) required by the centrifugal shot blast. This level of consumables remains relatively constant, except for the minor cost of shot replacement, regardless of job size. In addition, the maintenance cost for high-wear parts during heavy coating and/or concrete removal for the centrifugal shot blast is \$0.03/ft^2 versus \$0.22/ft^2 for the baseline. Although maintenance costs did not prove to be a significant cost factor for the 800-ft^2 demonstration (~\$24 and ~\$176, respectively), it may be a significant factor for larger areas. To summarize these cost factors, the centrifugal shot blast has lower incremental costs for each additional square foot of decontamination.

Based on the cost relationships described above, the cost for the centrifugal shot blast is equal to the cost for the baseline technology at approximately 1,900 ft^2 for the conditions and assumptions of the demonstration. For areas beyond this square footage, the centrifugal shot blast technology is less expensive than the baseline.

It is important to note that the scabbler is estimated to render a removal depth of ¼ in of coating and concrete, whereas the centrifugal shot blast removes only the coating. Therefore, the volume of waste to

be disposed and the resulting costs are estimated to be much higher for the scabbler. In addition, because ANL assumes it will dispose of the scabbler at the end of its project, the resulting hourly rate is higher due to the abbreviated life-span and the absence of salvage value. Adjusting the hourly rate downward to reflect a full life-span does not significantly impact the costs or findings noted herein.

If a site is considering that a vendor provide either centrifugal shot blast or mechanical scabbling service, the costs for vendor travel, per diem, profit, and site-specific training must be considered as they were in this estimate. Concrete Cleaning, Inc., provided cost estimates for conditions similar to this demonstration. For areas of 5,000 ft^2 at \$7/ft^2 and \$14/ft^2 (coating only and ¼ in removal, respectively) and 40,000 ft^2 at \$5/ft^2 and \$12/ft^2 (coating only and ¼ in removal, respectively), the resulting total costs for 5,000 ft^2 are \$35,000 and \$70,000, respectively, and for 40,000 ft^2 are \$200,000 and \$480,000, respectively. Concrete Cleaning, Inc., provides centrifugal shot blast decontamination as a service only; no equipment rentals are allowed.

Mechanical scabbling equipment is available in a range of sizes offering different production rates (40 ft^2/h to over 495 ft^2/h). The centrifugal shot blast is offered in two sizes with production rates ranging from 250 ft^2/h for heavy removal to 3,000 ft^2/h for lightly coated surfaces. It should be noted that the smaller centrifugal shot blast can access within about 2 in from a wall, whereas the larger model accesses within about 10 in. The demonstration compares the smaller centrifugal shot blast with a larger scabbler. A potential user should investigate the appropriate equipment size for the job and assess any potential for savings on this basis.

A computation of the potential savings for D&D work should be estimated by substituting the expected quantities, mobilization distance, and other site-specific factors into Appendix B, Tables B-1 and/or B-2, so that a site-specific cost can be computed.

In conclusion, even though the baseline is less expensive for the conditions and assumptions of the 800-ft^2 demonstration, the centrifugal shot blast's lower incremental costs should result in savings for areas larger than approximately 1,900 ft^2.

SECTION 6

REGULATORY AND POLICY ISSUES

Regulatory Considerations

The regulatory and permitting regulations related to use of the Concrete Cleaning, Inc., centrifugal shot blast technology at the ANL CP-5 Research Reactor consist of the following. These same regulations 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 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 Packaging

—174 Carriage by Rail

—177 Carriage by Public Highway

—178 Specifications for Packaging

- 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 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.

Since the modified centrifugal shot blast technology 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 the document.

Safety, Risks, Benefits, and Community Reaction

With respect to safety issues, when the shot blast unit is in operation, the shot moving at a high velocity can escape from under the unit and become a projectile hazard. To protect observers during the demonstration, a temporary 4-ft containment wall was erected. However, a few pieces of shot ricocheted off walls and struck observers outside the containment area.

The contaminated waste debris generated during the coating removal process are simultaneously vacuumed up by the dust collection system, thereby efficiently reducing the risk to the operator posed by flying paint, concrete chips, or airborne radioactive dust. During the demonstration, no increase in airborne radioactivity levels above background levels was detected. This could lead to an easing of respiratory protection requirements, thus allowing for greater worker efficiency and time savings. In contrast, mechanical scabbling does not incorporate a vacuum system, and up to 10 percent of the debris can become airborne during the D&D process.

The use of the centrifugal shot blast technology rather than mechanical scabbling would have no measurable impact on community safety or socioeconomic issues.

SECTION 7

LESSONS LEARNED

Implementation Considerations

The Concrete Cleaning, Inc., system demonstrated at CP-5 is a commercially available technology. Design improvements in the HEPA filter unit and the modifications made by Concrete Cleaning, Inc., to the dust collection system should be incorporated into the system prior to implementation.

Technology Limitations and Needs for Future Development

The Concrete Cleaning, Inc., centrifugal shot blast technology would benefit from the following design improvements.

- A second vacuum connection should be placed at the rear of the shot blast unit to vacuum shot that is missed by the main part of the unit during the decontamination.

- A stronger magnetic roller or a portable vacuum system should be employed to collect steel shot that is left on the floor by the shot blast unit. This could significantly reduce the amount of time required for cleanup after the shot blast unit is used, thereby increasing the overall efficiency of the technology.

- A means should be found to reduce the amount of shot that escapes from under the shot blast unit during operation. This would make the technology safer to use during the D&D process.

Technology Selection Considerations

The Concrete Cleaning, Inc., centrifugal shot blast unit and dust collection system is a modified shot blast technology for the removal of coatings and concrete from concrete floors. Concrete Cleaning, Inc., provides its equipment as part of a service and does not rent or sell the modified shot blast unit. The Concrete Cleaning, Inc., system has been used at the U.S. Department of Defense's Fairchild Air Force Base. The unit used at CP-5 demonstrated its ability to remove coatings from concrete floors effectively. However, the vendor stated that this size unit is also capable of removing up to one-half inch of concrete. A larger-sized unit is available for the removal of 1 in or more of concrete from large flat areas.

APPENDIX A

REFERENCES

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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 TECHNOLOGY—Centrifugal Shot Blast

Mobilization (WBS 331.01)

Transport Equipment

Definition: The vendor crew, consisting of two decontamination (decon) technicians, drives the equipment via flatbed truck from Spokane, WA, to Chicago, IL (1,785 mi). Shipping weight is approximately 2,000 lb.

Assumption: According to the vendor, the crew will receive pay at one-half their normal rate while transporting the equipment. It is assumed the crew will average 50 mph at 10 h/day maximum, resulting in a 3.6-day' s drive time. The Chicago per diem of $110/day is assumed and incorporated into the labor rate, and equipment costs consist of rental and operating costs for a flatbed truck.

Site Training

Definition: This cost element covers the time vendor personnel spend in site-specific required training classes prior to commencing work.

Assumption: The vendor crew has had all the necessary hazardous worker training before arriving on-site. Therefore, only one day of site training is assumed to be required.

Unload the Equipment

Definition: Unloading the centrifugal shot blast equipment includes the time required for the vendor crew to off-load the equipment from the truck using a forklift provided by the site, move the equipment to a staging area, and unpack it for radiological survey.

Assumption: One-third of an hour is required to unload and unpack the equipment. This is based on observed times from the demonstration.

Survey-in the Equipment

Definition: This cost element provides for the vendor crew's wait-time while radiological surveys of equipment are conducted by a HPT to ensure that contaminated equipment is not brought on-site.

Assumption: One-third of an hour is required for the survey based on the time observed during the demonstration.

Health Physics Support

Definition: Cost for one HPT during all mobilization activities (includes both standby and survey time).

Assumption: HPT is present at all times.

Decontamination of Floor (WBS 331.17)

Survey of the Area for Radioactivity

Note: This cost element covers the radiological surveying performed 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 estimate. This activity is assumed to have been completed prior to decontaminating the areas assigned.

Move Equipment to the Work Area

Definition: The vendor crew moves the equipment by hand from the staging area to the demonstration area.

Assumption: Based upon observed times during the demonstration, a two-person vendor crew took 45 min to move all equipment 120 to 150 ft.

Prepare the Site and Equipment

Definition: This cost element includes time for the vendor crew to prepare the equipment for operation upon arrival at the demonstration area. This includes removing wheels from the dust collector, replacing the wheels with steel tube support legs, duct taping the metal joints of the centrifugal shot blast, and connecting power lines.

Assumption: Set-up takes 6.0 h based upon observed times during the demonstration.

Remove the Floor Coatings

Definition: This cost element consists of the two-person vendor crew blasting off the concrete floor coatings. One person operates the centrifugal shot blast while the other is on standby.

Assumption: Centrifugal shot blast will remove 800 ft^2 of coatings in 2.58 h at 310 ft^2/h.

Clean the Floor of Shot

Definition: This cost element consists of the vendor crew's using a magnetic roller broom or vacuum hose to pick up all remaining shot debris.

Assumption: It took 1.5 h to clean 800 ft^2 resulting in a productivity rate of 533.33 ft^2/h. The centrifugal shot blast had an observed shot waste rate of 30 lb/800 ft^2 during the demonstration. This is either broken and/or errant shot which the centrifugal shot blast could not recycle. Approximately 70 lb of the 100-lb-capacity of shot remained in the machine after coating removal.

Remove the Waste Drum

Definition: This cost element accounts for the time it takes the crew to remove the waste drum from the dust collector.

Assumption: During the demonstration of this technology, only 2.5 ft^3 of primary waste was generated. To match the baseline, secondary waste is not included. This consisted of six "4-ft^3 bags" of filters, the filter hose, spent shot, discarded PPE, and swipes. This cost is covered in the all-in-one rate/ft^3.

Table B.1. Personal Protective Equipment Cost Per Day Calculation

Equipment	Quantity in box	Cost per box	Cost each	No. of reuses	Cost each time	No. used per day	Cost per day
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
Gloves (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 activity cost estimates for 1996 (the costs for outer gloves, glove liners, and respirator cartridges are from commercial catalogs).

Assumption: The vendor crew and HPT require PPE during all decontamination, equipment cleaning, and breakdown activities.

Health Physics Support

Definition: Cost for one HPT during all mobilization activities (includes both standby and survey time).

Assumption: HPT is present at all times.

Health and Safety Productivity Loss Factor

Definition: A factor applied to productive hours to compensate for radiation/as low as reasonably achievable (ALARA), dressing in and undressing from protective clothing, and for breaks. This factor is based on the vendor crew time in Table B-2 for decontamination and demobilization activities requiring PPE.

Assumption: A productivity factor of 1.49 from the *CP-5 Cost Estimate* (Argonne National Laboratory, 1996).

Demobilization (WBS 331.21)

Clean/Decontaminate/Breakdown the Equipment

Definition: Time the vendor crew requires to clean, decontaminate, and breakdown the equipment. This cost element includes time for the removal of the steel tube support legs from the dust collector and their replacement with wheels. This also includes the removal of duct taping metal from the metal joints of the centrifugal shot blast, disconnecting the power lines, removal of the HEPA and roughing filters, demonstration site surveys by the HPT, and all other site and equipment breakdown activities.

Assumption: 6.9 h to clean, decontaminate, and breakdown the equipment based on observed times from the demonstration.

Survey and Return the Equipment to Staging Area

Definition: This cost element provides for crew wait-time while the equipment is being surveyed, time for any remaining decontamination, and the return of the equipment approximately 120 to 150 ft to the staging area.

Assumption: 45 min is required. Longer distances may require more time.

Load the Equipment onto the Truck

Definition: Time required for the vendor crew to load the centrifugal shot blast equipment onto the truck using a site-provided forklift.

Assumption: 1.2 h is required for packing and loading the equipment. This is based on observed times from the demonstration.

Health Physics Support

Definition: An HPT is present for all activities except for equipment transportation.

Assumption: The HPT is present during all activities except for transporting equipment.

PPE Cost Per Day Calculation

See Table B-1.

Assumption: Both the vendor crew and the HPT require PPE during all decontamination, equipment cleaning, and equipment breakdown activities.

Health and Safety Productivity Loss Factor

Definition: A factor applied to productive hours to compensate for Radiation/ALARA, donning and doffing protective clothing, and for breaks. This factor is based on the vendor crew time presented in Table B-2 for decontamination and demobilization activities requiring PPE.

Assumption: A productivity factor of 1.49 from the *CP-5 Cost Estimate* (Argonne National Laboratory, 1996).

Transport Equipment

Definition: Reverse of “Transport Equipment” under “Mobilization” above.

Assumption: Same as “Transport Equipment” under “Mobilization” above.

WASTE DISPOSAL (WBS 331.18)

Transport to Disposal Site

Definition: This cost element is for the charges for the volume of waste being shipped.

Assumption: Not applicable as such, but covered in the all-in-one shipping, packaging, and disposal rate/ft^3.

Disposal Fees

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

Assumption: All-in-one shipping, packaging, and disposal rate of \$52.78/ft^3.

COST ANALYSIS

The centrifugal shot blast vendor that supplied the equipment used for this demonstration was Concrete Cleaning, Inc. This vendor offers the centrifugal shot blast technology as a provided service only with no rentals. Concrete Cleaning, Inc., has made internal changes to the blast mechanism, shot and dust separation system, and to the dust collection system. The vendor claims these changes increase the productivity of the centrifugal shot blast and that their changes to the dust collection system reduce the potential for airborne contaminants. Centrifugal shot blast technology is also available from the

manufacturer as a rental; however, these machines do not have the Concrete Cleaning, Inc., modifications. The manufacturer quoted centrifugal shot blast rental rates of $795/day, $1,795/week, and $5,595/month, not including consumables.
The typical cost activities for performing work using the centrifugal shot blast technology consist of the following:

- mobilizing and demobilizing personnel and equipment to and from ANL;
- unloading and moving equipment to the staging area;
- preparing site and equipment;
- removing the floor coating;
- decontaminating and cleaning the reusable equipment;
- replacing centrifugal shot blast consumables, including PPE and high-wear parts;
- collecting all waste resulting from operation;
- handling waste drums containing the coating and concrete powder;
- full-time HPT support; and
- waste disposal charges.

The following assumptions were made regarding the centrifugal shot blast cost analysis:

- The decontamination is performed by a vendor-provided service.

- The centrifugal shot blast model used for this demonstration is the GOFF® 15E13 with a Model 816 Cartridge Dust Collector with modifications made by Concrete Cleaning, Inc., to the internal blast mechanism, shot and dust separation system, and the dust collection system.

- The centrifugal shot blast removed 800 ft^2 of coating in only 2.58 h, resulting in a production rate of 310 ft^2/h.

- The vendor crew consists of two Concrete Cleaning, Inc., employees who have already attended hazardous worker training.

- One HPT is present during all demonstration activities.

- Oversight engineering, quality assurance, and administrative costs for the demonstration are not included. These are normally covered by another cost element, generally as an undistributed cost.

- The centrifugal shot blast technology, with its integrally designed vacuum system, eliminates the need for erecting the containment barriers required for airborne contamination.

- Equipment part wear was estimated by the vendor to be $0.03/$ft^2$. According to the centrifugal shot blast manufacturer, normal part wear ranges between $0.02/$ft^2$ for light removal (thin coatings) to $0.05/$ft^2$ for heavy removal (1/4-in depth or more of coating and concrete).

- Costs for the construction of a temporary herculite wall and video setup are excluded because it is assumed that the operation of the centrifugal shot blast would not normally be videotaped and access to the work area is limited to those wearing PPE.

- Time spent (6 h) locating a replacement HEPA filter because of a centrifugal shot blast manufacturer error is excluded.

- The centrifugal shot blast has a 100-lb shot capacity, all of which is used during operation. The shot is continuously recycled by the machine's dust and shot separation system until it eventually becomes pulverized to the point it becomes waste. The observed shot waste rate is estimated at 30 lb/800 ft^2 or 0.0375 lb/ft^2. Thus, assuming the shot is purchased commercially at $0.50/lb, the net cost for shot waste is about $0.02/$ft^2$. Approximately 70 lbs of recyclable shot was assumed waste for this cost analysis.

- The ANL procurement rate of 9.3 percent is applied to all vendor costs.

- A productivity loss factor of 1.49 is applied to the centrifugal shot blast demonstration activities. The calculation of the following productivity factor is obtained from Table 3 in the *CP-5 Cost Estimate* (Argonne National Laboratory, 1996).

Base	1.00	
+ Height		0.00
+ Radiation/ALARA		0.20
+ Protective clothing	0.15	
= Subtotal		1.35
x Respiratory protection	1.00 (no factor required, included in the observed times)	
= Subtotal		1.35
x Breaks		1.10
= Total	1.49	

Depending on site conditions, additional health and safety (H&S) requirements could be imposed beyond the regulatory minimums, which require a tent-like structure even when using the centrifugal shot blast technology.

The activities, quantities, production rates, and costs observed during the demonstration are shown in Table B-2.

Table B-2. Centrifugal shot blast cost summary

Work Breakdown Structure (WBS)	Unit Cost (UC) Labor Hours	Labor Rate	Equipment Hours	Equipment Rate	Other Rate	Total UC	Total Quantity (TQ)	Unit of Measure	Total Cost (TC)[1]	Comments
MOBILIZATION (WBS 331.01)								**Subtotal:**	**$ 6,330**	
Transport equipment (equip)	10.0	$ 63.6	10.0	$ 52.1		$ 1,156	3.6	Days	$ 4,129	10 h/day drive, vendor crew from Spokane-Chicago, truck costs, labor = 1/2 normal rate
Site-specific training	8.0	$216.4	8.0	$ 31.9		$ 1,987	1.0	Day	$ 1,987	Site required training for vendor crew of two
Unload equip at site	0.3	$216.4	0.3	$ 31.9		$ 82	1.0	Each	$ 82	Vendor crew - 2 @ $99.01/h/each
Survey in equip	0.3	$216.4	0.3	$ 31.9		$ 82	1.0	Each	$ 82	Vendor crew wait-time for surveys
Health Physics Technician (HPT) support	0.7	$ 56.0			$ 13.2	$ 50	1.0	Each	$ 50	One HPT full-time
DECONTAMINATION (Decon) (WBS 331.17)								**Subtotal:**	**$ 6,480**	
Move equip to work area	0.8	$216.4	0.8	$ 31.9		$ 186	1.0	Each	$ 186	Vendor crew labor rate includes per diem costs
Site and equip preparation	6.0	$216.4	6.0	$ 31.9		$ 1,490	1.0	Each	$ 1,490	Vendor crew - 2 @ $99.01/h/each
Remove floor coatings	0.003	$216.4	0.003	$ 31.9	$ 0.03	$ 0.83	800	ft^2	$ 668	Production rate = 310 ft^2/h; equipment = 2 weeks @ $1,795 each + spare parts @ $738, includes cleaning floor of spent shot; other = part replacement rate @ $0.03/$ft^2$
Clean floor of shot	0.002	$216.4	0.002	$ 31.9	$ 0.02	$ 0.49	800	ft^2	$ 389	Crew vacuumed shot @ 533.33 ft^2/h; other = shot replaced @ 0.0375 lb/ft^2 * $0.50/lb
Consumables					$ 1,159	$ 1,159	1.0	Lump sum (LS)	$ 1,159	50 ft hose ($350); roughing/high-efficiency particulate air (HEPA) filters ($670), brushes ($5); and 70 lb extra shot ($35)
Remove waste drum	0.5	$216.4	0.5	$ 31.9		$ 124	1.0	Drum	$ 124	Remove waste drum from dust collector
Personal protection equip (PPE)					$ 139.0	$ 139	1.0	Days	$ 139	PPE for crew & HPT @ $46.33/day/person
HPT support	16.9	$ 56.0				$ 946	1.0	LS	$ 946	HPT to perform surveys, time includes PLF
Productivity loss factor (PLF)	1.0	$216.4	1.0	$ 31.9		$ 248	5.6	Hours	$ 1,379	Applied PLF of 1.49
DEMOBILIZATION (WBS 331.21)								**Subtotal:**	**$ 8,432**	
Clean/decon/breakdown	6.9	$216.4	6.9	$ 31.9		$ 1,721	1.0	LS	$ 1,721	Clean/decon/breakdown equip for shipment
Survey out/return equip	0.8	$216.4	0.8	$ 31.9	$ 13.2	$ 199	1.0	LS	$ 199	Equip moved ~135 ft while HPT performed final surveys; other = survey waste
Load equipment onto truck	1.2	$216.4	1.2	$ 31.9		$ 290	1.0	LS	$ 290	Vendor crew - 2 @ $99.01/h/each
HPT support	13.2	$ 56.0				$ 738	1.0	LS	$ 738	HPT to perform surveys; time includes PLF
PPE					$ 139.0	$ 139	2.0	Days	$ 278	PPE for crew and HPT @ $46.33/day/person
Productivity loss factor (PLF)	4.3	$216.4	4.3	$ 31.9		$ 1,077	1.0	LS	$ 1,077	Applied PLF of 1.49
Transport equipment	10.0	$ 63.6	10.0	$ 52.1	$ -	$ 1,156	3.6	Days	$ 4,129	Reverse of transport equipment for mobilization
WASTE DISPOSAL (WBS 331.18)								**Subtotal:**	**$ 1,399**	
Shipping and disposal fees					$ 52.8	$ 53	26.5	ft^3	$ 1,399	Low-level waste (LLW) disposal (1st and 2nd generation waste)
								Total:	**$ 22,640**	

(1) TC = UC * TQ

Mobilization (WBS 331.01)

Construct Contaminant Tent

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

Assumption: The conceptual scope definition is per ANL personnel. A temporary enclosure for airborne contamination is erected using Unistrut material ($2.00/lin ft plus $1.00/lin ft for fittings and connections) as studs, beams, and bracing for walls and ceiling and Visqueen ($.01/ft^2) as the enclosing membrane. Labor consists of three decon workers ($33.60/h) for 3 h to erect the tent, requiring no PLF or PPE. This activity is to be completed prior to mobilizing for the decon activities described below.

Load the Equipment at the Warehouse

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 forklift and their operators, the decon workers' loading and hauling the construction equipment, and the hourly charges for transporting the equipment.

Assumption: Distance to a site warehouse varies, but is less than 2 mi. The flatbed 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.

Unload the Equipment

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

Assumption: A 2-h period is assumed for unloading/unpacking the equipment. Procurement's effort regarding the receipt of purchased equipment and the completion of paperwork is excluded. A forklift operator is included in the crew rate, and the forklift rental rate is $11.65/h, taken from the *Rental Rate Blue Book For Construction Equipment* (Dataquest, 1997).

Survey the Equipment

Definition: This cost element provides for a 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 described above.

Assumption: 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.

Assumption: Not applicable. Personnel on-site are already trained.

Perform the Radiological Survey

Note: This cost element covers the performance of radiological surveying which will characterize the workplace to 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 completed prior to decontaminating the area.

Move and Set Up the Equipment

Definition: This cost element includes the required 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 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. This cost is covered in the mobilization activity.

Assumption: The *CP-5 Cost Estimate* (Argonne National Laboratory, 1996) sheets included scaffolding because the scope also involved walls. As this analysis scope is for the floor only, the 4 h specified in the baseline for both activities were reduced to 2 h, eliminating the 2 h of time assumed to be for scaffolding.

Remove Floor Surface Concrete

Definition: This cost element consists of the following.

- Scabbling the floor concrete by making one pass removing ¼ in, 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, and one HPT as the radiation monitor and/or escort.
- The 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).
- The production rate varies depending upon the thickness of the concrete that must be removed to obtain acceptable radiation readings.
- Cost of mechanical scabbling equipment and consumable bits.
- Cost of PPE (see Table B-1).
- Any lost time from production. This involves daily safety meetings, daily work planning reviews, donning and doffing PPE, heat or temperature stress, work breaks, etc., which are accounted for through a PLF.

Assumptions:

- The quantity scope for the baseline is the same as that for the demonstration, 800 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 24.0 ft^3.
- The decon crew workers are qualified to change worn bits. Standby time is necessitated by this activity.
- Production rate in this analysis is 200 ft^2/h for one machine (Trelawny Model SF-11), one person scabbling (67 ft^2/work hour as a net effective rate for a three-person crew). The scabbler is priced at an ownership hourly rate of $9.95/h.
- A safety meeting occurs and is accounted for in the baseline PLF.

Health and Safety

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

Assumption: The factor used, 2.05, and the PPE costs are predominantly calculated from the *CP-5 Cost Estimate* (Argonne National Laboratory, 1996) (the costs for outer gloves, glove liners, and respirator cartridges are priced from commercial catalogs.)

Note: The cost per day per person calculation for PPE is the same as that shown in the Innovative Technology section.

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 decon activities. It includes the cost of decon workers and HPT coverage. It also includes gathering and containerizing the waste building materials. PPE and a PLF are included.

Assumption: Labor required is three persons for three hours, per ANL personnel, to dismantle and load the waste.

Survey and Decontaminate the 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. This element also covers the costs to decontaminate it. Costs include HPT labor plus decon crew stand-by or assistance time, including the use of PPE and experiencing a PLF.

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

Pack Up and Load the 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: The time required to pack and load is 2 h using a forklift for the total duration.

Personnel and Equipment Transport

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

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

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^2as taken from the *CP-5 Cost Estimate* (Argonne National Laboratory, 1996) 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 it is covered in the all-in-one rate per cubic foot described below.

Transport to the Disposal Site

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

Assumption: This is not applicable as such, but is covered in the all-in-one disposal fee rate/ft^3 described below.

Disposal Fees

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

Assumption: This cost is represented as an all-in-one disposal fee rate/ft^3 from the same 1996 estimate and covers all three waste disposal activities.

Cost Analysis

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

- mobilizing the site-owned equipment from a warehouse,
- unloading at the staging area,
- moving the equipment 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 following are assumptions for the baseline:

- The site already owns the scabbler and will dispose of it at the end of the project with no salvage value.

- Mobilization consists of a forklift used to load the equipment at the warehouse, a rented truck to haul the equipment to the facility, site personnel to unload near the work area, and returning the transport equipment to the equipment pool.

- The construction of a temporary enclosure is necessary for the containment of airborne contaminants. The conceptual scope, provided by ANL D&D personnel, involves Unistruts as studs, beams, and braces and Visqueen as walls and ceiling. Construction and dismantling of the tent requires an equal amount of time. The containment tent is estimated to enclose 133 percent of the area being decontaminated.

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

- Equipment is set up by moving it into the work area, stringing the air hoses from the compressor, and dressing in PPE for the work.

- 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. 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, and debris is manually vacuumed up and placed in containers. The ¼-in depth makes the baseline comparable to the innovative technology.

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

- The replacement of worn scabbling bits can be done by the qualified decon technicians.

- The waste volume generation factor 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.

- The hourly rate for the scabbler is taken from the *CP-5 Cost Estimate* 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 800 ft^2 to match the demonstration area.

- The PLF, applied to the productive work hours, accounts for H&S considerations that typically occur. The calculation is as follows:

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 utilized in the baseline are shown in Table B-3.

Table B-3. Baseline Cost Summary (Scabbling Technology)

Work Breakdown Structure (WBS)	Unit Cost (UC) Labor Hours	Labor Rate	Equipment Hours	Equipment Rate	Other Rate	Total UC	Total Quantity (TQ)	Unit of Measure	Total Cost (TC)[1]	Comments
MOBILIZATION (WBS 331.01)								**Subtotal:**	**$ 4,308**	
Construct containment tent	0.003	$100.8			$ 2.58	$ 2.93	1,064	ft^2	$ 3,116	3 decon. workers @ $33.6 each to build and dismantle tent @ 133.3 percent of decon area
Load equipment (equip) at warehouse.	2.0	$146.9	2.0	$ 32.5		$ 359	1.0	Each	$ 359	(2) 10 h day drive, Oklahoma City-Chicago, 4.0 h load, teamster, plus truck rental
Transport equip to site	0.5	$146.9	0.5	$ 42.5		$ 95	1.0	Trip	$ 95	(2) 10h day drive, Oklahoma City-Chicago, 4.0 h load, teamster, plus truck rental
Unload equip at site and survey	2.0	$146.9	2.0	$ 42.5		$ 379	1.0	Lump Sum (LS)	$ 379	Forklift operator @ $39.85/h and decon crew @ $67.2/h, 0.25 ft^3 decon waste @ $52.78/$ft^3$
Return truck and forklift	0.3	$ 79.7	0.3	$ 32.5		$ 28	1.0	Trip	$ 28	Decontamination crew standby during survey
Health Physics Technician (HPT) support	5.7	$ 56.0			$ 13.2	$ 332	1.0	LS	$ 332	One @ $56/HR and 1/4 cf survey waste
DECONTAMINATION (Decon.) (WBS 331.17)								**Subtotal:**	**$ 3,240**	
Move equip to work area	2.0	$ 67.2	2.0	$ 38.5		$ 211.3	1.0	Each	$ 211	Decontamination crew @ $67.2/h
Scarify concrete floor	0.005	$ 67.2	0.005	$ 38.5		$ 0.53	800	ft^2	$ 423	Decontamination crew @ $67.2/h
Equip consumables:										Varies with bit life and replacement frequency
Bits					$ 0.22	$ 0.22	800	ft^2	$ 175	Consumable rates/ft^2
Air compressor			4.0	$ 6.40		$ 25.6	1.0	Each	$ 26	250 ft^3 per minute air compressor
Air tools			4.0	$ 0.25		$ 1.00	1.0	Each	$ 1	
Sample rubble/surface	0.01	$ 56.0				$ 0.54	800	ft^2	$ 431	One HPT
Load rubble in containers	0.15	$ 67.2	0.2	$ 38.5		$ 16.3	24.0	ft^3	$ 390	Waste @ .021 ft^3/ft^2 w/70 percent efficiency =
Personal protection equipment (PPE)					$ 139.0	$ 139.0	2.0	Days	$ 278	2 decon + 1 HPT @ $46.33/day/person
Productivity loss	1.0	$123.2	1.0	$ 38.5		$ 161.7	8.1	Hours	$ 1,306	Figured at 2.05 per 1996 Argonne National Laboratory (ANL) guidance
DEMOBILIZATION (WBS 331.21)								**Subtotal:**	**$ 3,702**	
Clean and decon equip	2.0	$ 67.2	2.0	$ 38.5		$ 211.3	1.0	LS	$ 211	Clean and decontaminate equip
Dismantle containment tent	0.003	$100.8	0.003	$ 38.5	$ 0.30	$ 0.78	1,064	ft^2	$ 834	3 decon workers @ $33.6 each dismantle tent; other = (0.0057 ft^3/ft^2 waste) * ($52.78/$ft^3$)
HPT	11.7	$ 56.0			$ 13.2	$ 666.4	1.0	LS	$ 666	Other = survey waste at 0.25 ft^3
PPE					$ 278.0	$ 278.0	2.0	Days	$ 556	PPE for equip decon and tent dismantle
Productivity loss	1.0	$123.2	1.0	$ 38.5		$ 161.7	6.0	Hours	$ 966	Figured at 2.05 per 1996 ANL guidance.
Move equip and load-out	2.0	$146.9	2.0	$ 42.5		$ 378.7	1.0	LS	$ 379	Includes site forklift and driver.
Return to warehouse	0.5	$146.9	0.5	$ 32.5		$ 89.7	1.0	Each	$ 90	Reverse of equip mobilization
WASTE DISPOSAL (WBS 331.18)								**Subtotal:**	**$ 1,655**	
Shipping & disposal fees					$ 52.8	$ 52.8	31.4	ft^3	$ 1,655	Low-level waste disposal (1st and 2nd generation
								Total:	**$ 12,905**	

(1) TC = UC * TQ

APPENDIX C

FLORIDA INTERNATIONAL UNIVERSITY DEMONSTRATION

Technology Description

Concrete Cleaning, Inc., demonstrated a larger centrifugal shot blast unit at Florida International University from May 20 to 24, 1996. Similar to the system demonstrated at CP-5, the larger centrifugal shot blast machine is an abrasive blasting technology that propels hardened steel shot against the contaminated surface at a high velocity to remove contaminants and substrate. The amount of substrate removed can be adjusted by varying the size and amount of shot expelled from the blast chamber or the speed at which the blast unit moves over the substrate. The steel shot is collected and recycled until it is spent (i.e., too small to reuse). A photograph of the large centrifugal shot blast unit is presented in Figure C-1.

Figure C-1. Large centrifugal shot blast unit.

This system combines the dust collection system and the shot blaster into a single unit with the debris being collected in a dust bin at the bottom of the machine. Concrete Cleaning, Inc., has performed modifications to the standard large centrifugal shot blast to increase the efficiency and speed of substrate removal. Like the smaller unit, Concrete Cleaning, Inc., considers these modifications proprietary and has applied for a patent.

The operational parameters of this centrifugal shot blast unit are as follows:

- Manufacturer: George Fischer (+GF+, GOFF®), Model 420E
- Dimensions (L x W x H): 96 in x 38 in x 72 in
- Weight: 4,000 lb
- Speed: Self-propelled variable speed drives:
  —Blast Wheel (320): 30 hp/3,600 rpm
  —Hydraulic Motor: 3 hp/1,800 rpm
  —Dust Collector: 3 hp/1,800 rpm
- Cutting width: 20 in
- Primary roughing filter cartridges: Quantity - 12
- Vendor rated vacuum flow: 1,200 ft^3/min
- Compressed air requirements: 90 psi
- Electrical requirements: 230/460 V, 3 phase
- Noise level: ~95 dBA per vendor

System Operation

- The centrifugal shot blast machine is self-propelled, requiring only one operator to work behind the unit.
- The floor to be decontaminated must be dry to ensure that the substrate removed does not clog the hoses and screens within the shot blast unit.
- A control panel attached to the rear of the shot blast unit includes toggle switches for steering the unit either left, right, forward, or in reverse. Dials control tracking and the speed at which the shot blast unit moves over the floor. The amount of shot released into the blast unit is controlled by a switch on the panel. Gauges measure the amps generated by the unit as well as the number of hours the unit has been in operation. The control panel also features an emergency stop button.
- The amount of substrate removed in a single pass is controlled by the size and amount of shot released by the unit as well as the speed at which the unit moves over the floor.
- Simultaneous to the decontamination of the floor, the shot and substrate debris are vacuumed by the shot blast unit. The mixture passes through an abrasive recycling system, where the larger/heavier pieces of shot are recycled back into the holding area. The smaller/lighter spent shot and substrate debris are removed to the dust collection system.
- Shot that has escaped from under the shot blast unit or was not collected by the vacuuming is collected by the operator using a magnetic broom or roller. This shot is then recycled into the shot blast unit.

Demonstration Plan

In a project for the Fernald Environmental Management Project, Fluor Daniel Fernald contracted 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 5,700 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. The difference of these survey readings was determined and then averaged to determine the average depth of removal. The accuracy of the survey instrument was ± 0.03 ft. 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 C-1 presents the results of the FIU-HCET demonstration of Concrete Cleaning, Inc.'s large centrifugal shot blast unit.

Table C-1. Performance data

Criteria	**Concrete Cleaning, Inc.'s Centrifugal Shot Blast Technology - Large Unit**
Applicable surface	Expected to perform 1-in concrete removal.
Production rate	173 ft^2/h
Type of primary waste generated	A fine powder mixed with spent steel shot. No visible difference can be observed between the spent shot and the powder.
Type of secondary waste generated	Dust collection filters and spent shot.
Media used	Hardened steel shot size S460 at a rate of 35 lb/h.
Noise level	Not available. Hearing protection required.
Capability to access floor-wall unions	No closer than 8-10 in.
Development status	Commercially available. Needs modifications for HEPA filter and direct waste disposal to drum.
Ease of use	Self-contained, requiring very little set-up time. Self-propelled unit reducing operator fatigue. Mostly for large open areas; not easily maneuverable. High maintenance is required because of the destructive nature of the process.
End-point condition	Removed between ½ in and 1 in concrete over surface. The surface was rough and uneven.
Worker safety	Shot can be a projectile and trip hazard. Uneven surfaces can cause excessive shot loss. Emptying of dust bin can generate airborne dust.

Implementation Considerations

- Technology requires an integral HEPA vacuum system to meet U.S. DOE's radiological control requirements.
- A waste drum collection system that reduces the probability of airborne contamination and is not as labor intensive as the emptying of the dust bin is required.
- Additional equipment is required to complete the task of removing concrete from an entire floor area. The large shot blast unit is capable of reaching only within 8-10 in from the floor to wall interface.

APPENDIX D

ACR

ALARA	as low as reasonably achievable
ANL	Argonne National Laboratory
CFR	*Code of Federal Regulations*
cm	centimeter(s)
CP-5	Chicago Pile-5
CSB	Centrifugal Shot Blast
D&D	decontamination and decommissioning
dBA	decibels
DDFA	Deactivation and Decommissioning Focus Area
Decon	decontamination
DOE	U.S. Department of Energy
DOT	U.S. Department of Transportation
dpm	disintegration per minute
EPA	U.S. Environmental Protection Agency
Equip	equipment
ESH	Environment, Safety, and Health
FCCM	facilities capital cost of money
FIU	Florida International University
ft	foot (feet)
ft^3/min	cubic feet per minute
gal	gallon(s)
h	hour(s)
H&S	health and safety
HCET	Hemispheric Center for Environmental Technology
HEPA	high-efficiency particulate air
hp	horsepower
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)
IUOE	International Union of Operating Engineers
lb	pound(s)
lin ft	linear foot (feet)
LLW	low-level waste
LS	lump sum
mi	mile(s)
min	minute(s)
LSDP	large scale demonstration project

OMB	Office of Management and Budget
OSHA	Occupational Safety and Health Administration
OST	Office of Science and Technology
PLF	productivity loss factor
PPE	personnel protective equipment
psi	pounds per square inch
Tech(s)	technician(s)
TC	Total Cost
TQ	Total Quantity
UC	Unit Cost
USACE	United States Army Corps of Engineers
V	volt(s)
WAC	waste acceptance criteria
WBS	work breakdown structure
WMO	Waste Management Operations