INNOVATIVE TECHNOLOGY
Summary Report

DOE/EM-0578

En-Vac Robotic Wall Scabbler

Deactivation and Decommissioning Focus Area

Prepared for
U.S. Department of Energy
Office of Environmental Management
Office of Science and Technology

April 2001

INNOVATIVE TECHNOLOGY
Summary Report

En-Vac Robotic Wall Scabbler

OST/TMS ID 2321

Deactivation and Decommissioning Focus Area

Demonstrated at
Idaho National Engineering and Environmental Laboratory
Large-Scale Demonstration and Deployment Project
Idaho Falls, Idaho

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 whether 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
SUMMARY

Introduction

The U.S. Department of Energy (DOE) continually seeks safer and more cost-effective technologies for use in decontamination and decommissioning (D&D) of nuclear facilities. To this end, the Deactivation and Decommissioning Focus Area (DDFA) of the DOE's Office of Science and Technology (OST) sponsors Large-Scale Demonstration and Deployment Projects (LSDDP). At these LSDDPs, developers and vendors of improved or innovative technologies showcase products that are potentially beneficial to DOE's projects and to others in the D&D community. Benefits sought include decreased health and safety risks to personnel and the environment, increased productivity, and decreased cost of operation.

The Idaho National Engineering and Environmental Laboratory (INEEL) LSDDP generated a list of statements defining specific needs or problems where improved technology could be incorporated into ongoing D&D tasks. One of the stated needs was for a Robotic Wall Scabbler that would reduce costs and shorten schedules in DOE's Decommissioning Project.

This demonstration investigated the associated costs and time required to remove paint from the Test Area North (TAN-607) Decontamination Shop walls by comparing the En-vac Robotic Wall Scabbler against the baseline technology.

Technology Summary

Baseline Technology

The baseline technologies consist of the Pentek Vac Pac System with the Pentek Rotopeen and Needle Gun hand-held attachments. This system only removes paint from the surface of concrete.

Innovative Technology

The En-vac Robotic Wall Scabbler is a remote-controlled scabbling unit with individually motor-controlled wheels that moves horizontally and vertically along floors, walls, and ceilings, adhering to the surface with the help of a high-vacuum suction created at its base (see Figures 1 and 2). The complete En-vac Blasting System consists of the En-vac robot, a recycling unit, a filter, and a vacuum unit, and uses an abrasive, steel-grit blasting technology for the scabbling process. By comparison, this innovative system has the ability to scabble much deeper than the baseline technology.

Figure 1. En-vac Robotic Wall Scabbler

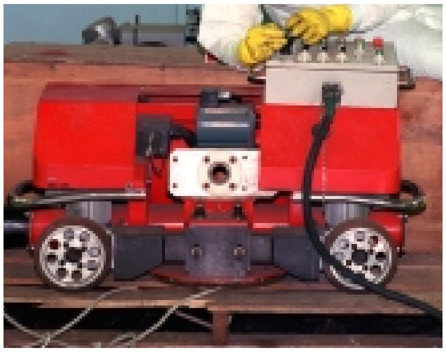

Figure 2. En-vac control unit with joystick sitting on top of the corner scabbler

Demonstration Summary

The En-vac Robotic Wall Scabbler technology was demonstrated in March 2000 at the INEEL Test Area North (TAN) Facility to decontaminate and remove paint and/or concrete from the TAN-607 Decontamination (Decon) Shop walls. The En-vac robot's scabbling performance was compared against a hand-held scabbling unit using a grinding technology made by Pentek.

Key Points

The key results of the demonstration are summarized below. Detailed descriptions and explanations of these results are in Section 3.

- The En-vac Blasting System performed five times faster than the baseline technology.
- The En-vac Blasting System produced less debris on the floor than the baseline technology, speeding up clean-up time and reducing the spread of contaminated material.
- Workers received lower radiation exposure due to less time spent in contaminated areas.
- Accelerated work schedules are possible because a greater surface area can be scabbled in less time.
- The En-vac Blasting System also has the capability to scabble deeper than the baseline technology.

Contacts

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Cost Analysis
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Web Site
The INEEL LSDDP Internet web site address is http://id.inel.gov/lsddp.

Licensing
No license required.

Permitting
No permitting activities were required to support this demonstration.

Other
All published Innovative Technology Summary Reports are available on the OST web site at http://em-50.em.doe.gov under the “Publications” heading. The Technology Management System, also available through the OST web site, provides information about OST programs, technologies, and problems. The OST Reference Number for the En-vac Robotic Wall Scabbler is 2321.

SECTION 2
TECHNOLOGY DESCRIPTION

Overall Process Definition

Demonstration Goals and Objectives

The overall purpose of this technology demonstration was to assess the benefits that may be derived from using the En-vac Robotic Wall Scabbler versus the baseline technology, which is the Pentek VAC-PAC Model 12A vacuum unit with the hand-held scabbling attachment. The primary goal of the demonstration was to collect operational data to make a comparison between the En-vac Robotic Wall Scabbler and the baseline technology in the following areas:

- Cost
- Productivity rates
- Ease of use
- Limitations and benefits.

A secondary goal of the demonstration was to provide the D&D program with data on an innovative technology that would allow the D&D project manager to disposition a room or facility at an accelerated rate.

Description of the Technology

The En-vac Blasting System is an abrasive blasting technology consisting of the En-vac robot, a recycling unit, a filter, and a vacuum unit (see Figure 3). The En-vac system is heavy, with the heaviest piece weighing 6,800 pounds. All of the equipment is capable of being lifted by industrial forklift or mobile carry crane. The cost of the entire system is approximately $390,000. The System uses abrasive steel grit or steel shot as the surface removal media and can scabble, via the robot, on both horizontal and vertical surfaces. A safety harness arrangement must be prepared and properly rigged to suit the circumstances. The weight of the robot and supporting hoses must be calculated along with the resulting loads imposed by the rigging angles, forces and vectors. Harness attachment points must be selected for maximum safety.

The main components of the En-vac robot are the blast housing, lip seal, four motor and wheel drive-steer assemblies, blast nozzle with oscillator motor, and vacuum control device. The robot adheres to working surface by vacuum contained in the sealed blasting chamber. The vacuum unit creates the vacuum to prevent any fugitive dust or grit emissions from the working surface of the blasting operation. The recycling unit continuously provides abrasive grit to the robot through the blast hose. Spent blast grit and blast residue are returned from the robot to the recycling unit through the vacuum hose. The recycling unit processes the spent abrasives and separates the blast residue. Blast residues are collected and stored for later disposal.

The main components of the Pentek system is the VAC-PAC, a H.E.P.A. filtration vacuum and waste drumming system that can simultaneously support three Corner-Cutters (Needle Guns) up to 100 feet away. The VAC-PAC system is portable and its design incorporates a controlled-seal drum fill system that allows the operator to fill, seal, remove, and replace the waste drum under controlled vacuum conditions. The entire vacuum system is mounted on the VAC-PAC's powered lift mechanism. The wheeled lift permits easy transport and positioning of the VAC-PAC. Waste materials are deposited directly into a waste drum, this assures positive control of waste and dust, which minimizes the possibility of releasing airborne contamination during drum changes. The Corner-Cutter attachment is a fully pneumatic, piston-driven needle gun with reciprocating needles for both concrete and steel. The Corner-Cutter vacuum shrouding system has been specifically designed to provide simultaneous collection of airborne and particulate hazards generated by the scabbling process.

Figure 3. En-vac Blasting System

System Operation

Table 1 summarizes the operational parameters and conditions of the En-vac Robotic Wall Scabbler demonstration.

Table 1. Operational Parameters and Conditions of the En-vac Robotic Wall Scabbler Demonstration.

Working Conditions	
Work area locations	• TAN-607 Facility
Work area access	Access is controlled by locked door.
Work area description	• Work area inside the TAN–607 Decon Shop is posted as a controlled area and radiological controlled area requiring training for entry.
Work area hazards	• Tripping hazards • Airborne contamination
Equipment configuration	The En-vac system was transported to the job site by the vendor.
Labor, Support Personnel, Specialized Skills, and Training	
Work crew	• Two Laborers and one Equipment Operator • Two En-vac vendor operators • One Electrician
Additional support personnel	• One data taker • One health and safety observer (periodic) • One test engineer • One photographer
Specialized skills/training	• No specialized training
Waste Management	
Primary waste generated	• Concrete and paint
Secondary waste generated	• Disposable personal protective equipment (latex gloves,tyveks and rubber boots)
Waste containment and disposal	• Grit was recycled many times before it was collected as waste, which greatly reduced the volume of secondary waste.
Equipment Specifications and Operational Parameters	
Technology design purpose	• To remove coatings from various masonry and carbon steel surfaces.
Specifications	• Thee large units • 10,000 lbs
Portability	• The En-vac system is not portable once set up.
Materials Used	
Work area preparation	Conduit and some piping were removed for the demonstration.
Personal protective equipment (PPE)	• Two pair rubber latex gloves • Two pair safety glasses • Tyvek, respirators and shoe covers
Utilities/Energy Requirements	
Power, fuel, etc.	• The En-vac system requires a maximum of 640-scfm compressed air with an air dryer, and 440Vac, 3-phase, 60-Hz, 120-kVA-peak demand electrical power.

SECTION 3
PERFORMANCE

Demonstration Plan

Problem Addressed

Most DOE facilities remove lead-based paint using a hand-held scabbler. The En-vac Robotic Wall Scabbler is remotely operated and removes paint 5 times faster than the hand-held scabbler reducing workers exposures to hazardous waste and accelerating work schedules.

Demonstration Site Description

Test Area North was established in the 1950s by the U.S. Air Force and Atomic Energy Commission Aircraft Nuclear Propulsion Program to support nuclear-powered aircraft research. Upon termination of this research, the area's facilities were converted to support a variety of other DOE research projects. The Decon shop is located in the southwest corner of the TAN-607 building in the TAN Technical Services Facility (TSF) Area (see Figure 4). Decon shop operations began in 1957 and continued for 30 years, providing radiological decontamination of tools and small equipment from INEEL and non-INEEL facilities. Because of a decline in business activity and cost of maintenance, decon shop operations terminated in 1987.

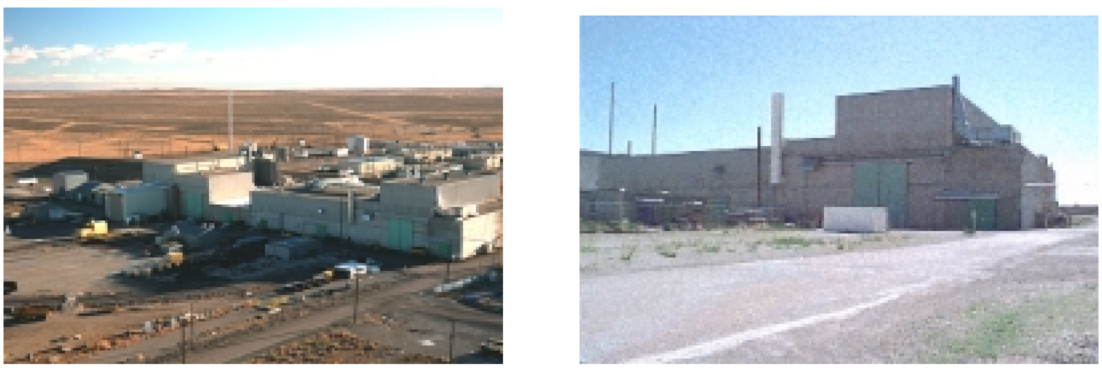

Figure 4. Aerial view of the TAN Facility Site and TAN-607 Decon Shop Building.

Major Objectives of the Demonstration

The major objectives of this technology demonstration were to evaluate the En-vac Robotic Wall Scabbler against the baseline technology in several areas including:

- Cost effectiveness
- Productivity Rates
- Ease of use
- Limitations and Benefits.

Major Elements of the Demonstration

Both the baseline technology and the En-vac Robotic Wall Scabbler were used to remove lead-based paint from painted concrete walls (see Figure 5). The demonstration areas on the walls consisted of grids of 45 ft^2 and 60 ft^2 in size. Data from the demonstration indicated that the En-vac Robotic Wall Scabbler data is about 5 times faster than the baseline technology.

Figure 5. En-vac removing paint from wall in the Decon Shop

Results

Both the baseline and innovative En-vac technologies were evaluated under identical physical conditions. Every attempt was made to allow work to proceed under normal conditions with no bias. All parties involved in the demonstration were requested to perform the work normally with no special emphasis on speed or efficiency. Both technologies were demonstrated on the same painted surface. A performance comparison between the two technologies appears in Table 2.

The operator placed the En-vac robot on the wall and attached it to the auto tension winch. The auto tension winch is a safety device consisting of a winch and cable system tethered to the wall and connected to the robot which prevents accidental damage to the robot equipment and nearby personnel in case of a loss of power or vacuum. The auto tension winch also assists in repositioning the robot on the wall after moving around piping and conduit, as the robot is not capable of scabbling on small piping (20 in. or less in diameter). The robot scabbled to a depth of 1/8 inch on the walls, removing three layers of paint and surface concrete, and within 8 inches of piping and other obstructions in the TAN 607 Decon Shop. No debris was found on the floor, and the air samplers detected no airborne contamination because all operation is contained in a closed loop system that concurrently separates the paint and concrete residue and spent blast media from the clean blast media. The spent blast media can be reused up to ten times by utilizing this recycling process. A final filter on the vacuum unit inlet removes 99.999% of all particulate larger than 1 micron from the system exhaust. This process creates more waste than the baseline because the En-vac system adds spent blast media and scabbles deeper than the baseline technology. The entire En-vac system including the robot was decontaminated and released free of radioactive contamination.

The optional Accessory Corner Robot can be quickly installed on the same working umbilical, using the same support equipment as the En-vac robot. The corner robot is designed to remove a 20 inch path by using the winch system to move along wall corners. Due to inaccessible corners in the Decon Shop, the optional En-vac corner scabbler was not demonstrated.

The Pentek VAC PAC system setup is faster than the En-vac system setup and proved to be more mobile than the En-vac system. Waste material from the Pentek system is deposited directly into a waste drum. The attachments used in this demonstration were the Pentek Corner-Cutter and Rotopeen. The

Rotopeen attachment created a large amount of debris, which could result in a spread of contamination, therefore the use of the Rotopeen attachment was terminated. The Corner-Cutter proved to be effective in removing paint on piping, corners, and other obstructions. No debris was detected from the use of the Corner-Cutter. The Corner-Cutter is much slower than the En-vac robot, but would be ideal for smaller scabbling jobs with piping and corners. The area scabbled by the Corner-Cutter remained smooth, whereas, the area scabbled by the En-vac was rough in texture.

Table 2. Performance Comparison Between the En-vac Robotic Wall Scabbler and the Baseline Technology.

Performance Factor	Baseline Technology Pentek Hand-held Scabbler	En-vac Robotic Wall Scabbler
Personnel/equipment/ time required to obtain data or paint chips	Personnel: • Two Laborers Equipment: • One Pentek Vac Pac Model 12A • Rotopeen scabbling head • Needle Gun scabbling head. Time: • 3 hours and 15 minutes to scabble 45 ft^2 of painted concrete	Personnel: • Two En-vac Operators Equipment: • 1 En-vac robot • Recycling unit • Filter and Vacuum unit Time: • 36 minutes to scabble 60 ft^2 of painted concrete
Preparation time	• 2 hours to transport equipment to TAN from another facility • 2 hours to setup equipment	• 24 hours to transport equipment to the INEEL • 3 hours to setup equipment
Total time per technology	• 3 hours and 15 minutes to scabble 45 ft^2	• 36 minutes to scabble 60 ft^2
PPE requirements	Both technologies required the same level of PPE. The number of workers required to wear PPE is the same for both technologies.	
Superior capability	• The Pentek system can scabble closer around obstruction than the En-vac • The Pentek system weighs less. • The Pentek system is more mobile than the En-vac.	• The En-vac System scabbles faster than the Pentek. • The En-vac system can scabble deeper on concrete surfaces than the Pentek.

SECTION 4
TECHNOLOGY APPLICABILITY AND ALTERNATIVES

Competing Technologies

Baseline Technology

The baseline technology for this demonstration was the Pentek Vac Pac Model 12A unit with hand-held scabbler attachments (Roto-peen and needle gun). There are various manufacturers that produce variations of the baseline technology.

Other Competing Technologies

Other competing technologies include the Robotic Climber from Bartlett. The Bartlett Robotic Climber uses high pressure water to scabble concrete and decontaminate surfaces. Because the system uses water, which would create a liquid secondary waste, the decision was made not to use the Bartlett Robotic Climber.

Technology Applicability

The innovative En-vac technology is fully developed and commercially available for the Department of Defense. Its superior performance over the baseline technology makes it a prime candidate for deployment throughout the industry.

Patents/Commercialization/Sponsor

The En-vac Robotic Wall Scabbler is available commercially as a service from:

MAR-COM, Inc,
8970 N. Bradford St.
Portland, OR 97203
Phone: (503) 285-5871
Fax: (503) 285-5974

Tom Maples, President

SECTION 5
COST

Introduction

The baseline technology costs are approximately 1/2 of the cost of the innovative technology for a job where 180 ft^2 of wall is decontaminated. For jobs with more than 10,000 ft^2 of work and having large walls (15 ft X 40 ft in size), the innovative technology can save approximately 17% over the baseline technology method.

Methodology

Cost analyses are based on Government ownership of the innovative technology and baseline technology equipment with the exception of renting an air compressor and generator for the innovative technology. The observed activities for both the innovative and baseline technologies include mobilization, set-up, donning/doffing PPE, operating the equipment to decontaminate the wall, moving to the next wall when the previous wall is completed, radiological surveying of the wall, demobilization, and disposal. The innovative technology involved additional activities that were not required for the baseline, such as engineering calculations for the anchor bolt installations, installing anchor bolts, making operational adjustments to the equipment, and removing and replacing the equipment on the wall when moving to the next wall. In the demonstration, the vendor's crew operated the innovative equipment. This cost analysis assumes that both the innovative technology and the baseline technology equipment is operated by site labor and uses a crew consisting of two laborers, one Radiological Control Technician (RCT), one industrial hygienist, and one job supervisor for both the technology cost estimates.

Some of the observed activity durations were adjusted before using them in the cost analysis to eliminate some of the artificial affects on the work imposed by the need to collect data, first time use of the equipment at the INEEL, and other effects associated with the demonstration. For example, the equipment set up required nine hours for the demonstration. But, two hours was used in the cost analysis as being representative of typical real work situations.

The cost for the baseline technology includes disposal of 3.68 ft^3 of steel grit, concrete, and paint chip waste plus the PPE used. The cost for the innovative technology includes disposal of 1.84 ft^3 of concrete and paint chip waste plus the PPE used.

The labor rates for the INEEL-furnished crewmembers and equipment are based on standard rates for the INEEL site. Additional details of the basis of the cost analysis are described in Appendix B.

Cost Data

Costs to Purchase the Technology

At this time, the innovative technology is only available by purchasing the equipment from the vendor. The vendor is developing an option to lease the equipment, but this is not yet available. The detail costs of the equipment used in this demonstration are shown in Table 3.

Table 3. Improved Technology Acquisition Costs

Acquisition Option	Item Description	Cost
Purchase	En-vac Robot, Vacuum and Control Unit, Filter Unit, Joy Stick Controller,	$390,000
Rent Equipment	Not Available	

NOTE: In addition to the equipment shown above, a generator and air compressor were rented. The generators and air compressors from the site-owned fleet were not large enough for use with the innovative technology equipment.

Unit Costs and Fixed Costs

Table 4 shows the unit costs, fixed costs, and production rates for the innovative and baseline technologies. These costs are based on a job size of 180 ft^2 of wall decontamination and are developed from Appendix B, Tables B-2 and B-3.

Table 4. Summary of Costs and Production Rates

Cost Element	Innovative Cost	Production Rate	Baseline Cost	Production rate
Mobilization	$1,313 each	N/A	$361	N/A
D&D Work	$37.41/ ft^2	23 ft^2/hr obstructed area 146 ft^2/hr unobstructed area	$20.52/ ft^2	15 ft^2/hr obstructed area 45 ft^2/hr unobstructed area
Demobilization	$1,142 each	N/A	$133	N/A
Waste Disposal	$150/$ft^3$	N/A	$150/$ft^3$	N/A

Note: The unit costs for the D&D Work shown above are based on the averaged costs for donning/doffing PPE, set up radiation control zone, installing anchors, operational adjustments, decontaminating the wall surface, removal, moving and set up at the next wall, wipe down of the wall, and survey of the wall as shown in Table B-2 and Table B-3 of Appendix B

Break-Even Point

The innovative technology has higher costs for mobilization and demobilization (associated with picking up and dropping off the rental equipment) and higher costs for the equipment rates. These higher costs make the innovative technology less cost effective for small intermediate-sized jobs if the average size of the walls is relatively small (average of 60 ft^2 of area for individual walls). But the innovative technology becomes cost effective for large jobs with large walls because of its much higher production rate. Figure 6 shows the cost for the innovative and baseline technologies as a function of job size. In Figure 6, the costs for small jobs are based on an average wall size of 60 ft^2; the average wall size for large jobs is assumed to be 600 ft^2 (15 ft X 40 ft). The innovative and baseline technologies are approximately equal for job sizes of 1500 ft^2, where the individual wall sizes are larger than 60 ft^2 but smaller than 600 ft^2.

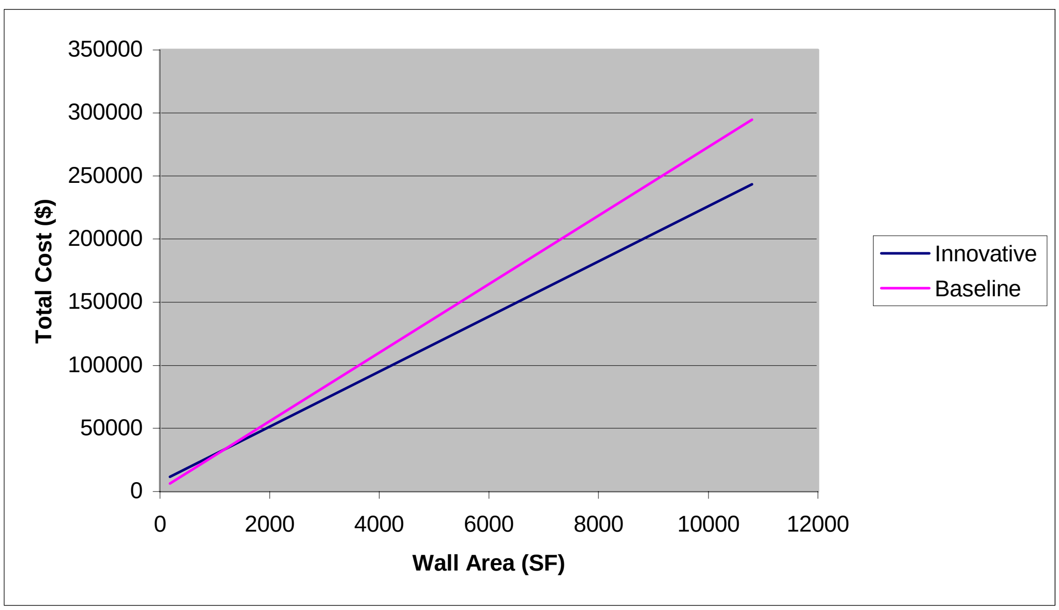

Figure 6. Break-even Point

Payback Analyses

The innovative technology would not pay back the cost of the equipment purchase for jobs similar in size to the demonstration. Assuming large jobs of 10,000 ft^2 and consisting of individual walls having average sizes of 600 ft^2, the innovative technology would save approximately $51,207 over the baseline, or $5.12/$ft^2$ of wall decontaminated. At this rate of savings, it would require approximately 69,770 ft^2 of wall decontamination to make up for the differences in purchase price of the innovative and baseline technology equipment (innovative $390,000 - baseline $32,780 = $357,220. $357,220/$5.12 = 69,770 ft^2).

Observed Costs for Demonstration

Figure 7 summarizes the observed costs for the innovative and baseline technologies based on a job size of 180 ft^2. The details of these costs are shown in Appendix B and include Tables B-2 and B-3, which can be used to compute site-specific cost by adjusting for different labor rates, crew makeup, etc.

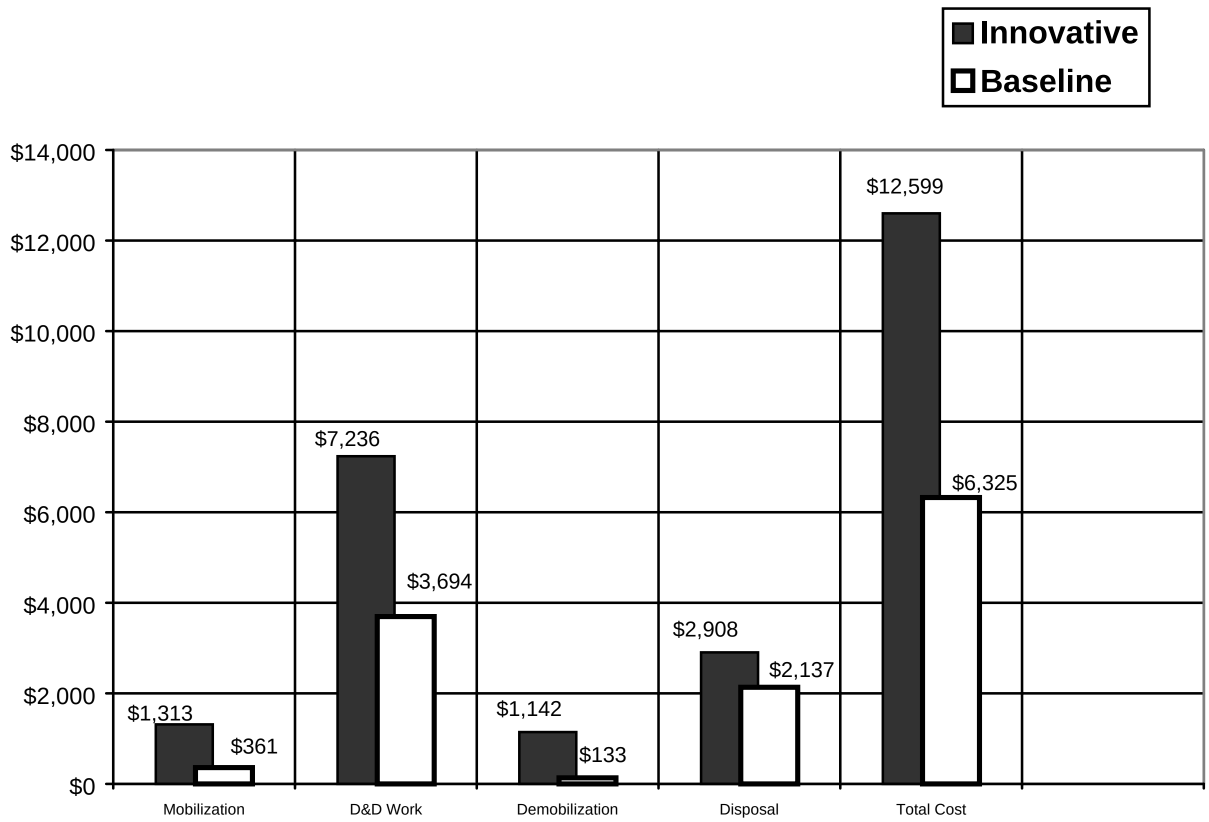

Figure 7. Summary of Technology Costs.

Cost Conclusions

Mobilizing and demobilizing for the innovative technology costs more than for the baseline technology because of the innovative technology's higher equipment costs and because of the need to transport the rented air compressor and generator to and from the site.

For decontaminating walls in this demonstration, the innovative technology was substantially more expensive. This was primarily the result of the equipment costs and the additional steps in the process required for the innovative technology. An hourly rate of $52.74/hr was used in this cost analysis for the innovative technology equipment based on amortizing the purchase price over a 15-year service life. An hourly rate of $11.99/hr ($9.64 for the Vac Pac plus $1.12 for the Corner Cutter plus $1.23 for the Roto-Peen) was used in this cost analysis for the baseline technology equipment based on amortizing the purchase price over a 5-year period for the Roto-Peen and over a ten year service life for the Vac Pac and the Corner Cutter. Consequently, the innovative equipment costs are approximately four times more expensive than the baseline and approximately seven times more expensive if the rented air compressor and generator are considered. In addition to the higher equipment rates, the innovative technology requires additional steps in the wall decontamination process that are not needed for the baseline technology. These additional steps for the innovative technology include anchor installation, attaching the equipment to the anchors and tethers, and removing the equipment from the anchors and tethers when moving to the next wall. These activities may require special types of labor, such as mechanics and workers that are certified for lifting heavy weights. The use of special workers interrupts the work while these workers are tracked down and brought to the work area. For small jobs, the innovative technology may require more time than the baseline technology because of these added steps. The innovative technology's production rate is three times greater than the production rate for the baseline technology. But, the innovative technology's higher production rates does not make up for its higher equipment rates and added steps in the process for small jobs or jobs with small walls (wall size is approximately 60 ft^2). For large jobs with large walls (600 ft^2 or greater), the innovative technology's higher production rate does result in significant savings despite its higher equipment rates.

The waste disposal costs for the baseline technology are approximately 1/2 the costs for the innovative technology for this demonstration. The baseline and innovative technologies generate similar volumes of concrete and paint chip waste, but the innovative also generates steel grit waste. For small jobs, the innovative technology may take longer than the baseline and, as a result, generates more waste PPE than the baseline. The innovative technology's waste PPE should, however, be a smaller volume than the baseline technology's waste PPE for large jobs. In large jobs, the innovative technology's higher production rate should compensate for the added steps in the work process. Disposal costs at the INEEL are assumed to be \$150/ft^3 of waste based on historic costs observed at the INEEL for operation of the disposal cell. These costs do not include costs for transportation, packaging the waste, closure of the disposal facility, or long-term maintenance and surveillance.

The innovative technology is not cost effective for small jobs because of its greater equipment cost and additional steps in the work process. But for large jobs with large walls, the innovative technology's higher production rate compensates for the equipment cost and may provide savings over the baseline technology.

SECTION 6
REGULATORY AND POLICY ISSUES

Regulatory Considerations

There were no regulatory issues with the innovative technology during this demonstration.

Safety, Risks, Benefits, and Community Reaction

Safety issues associated with the use of the En-vac Robotic Wall Scabbler are primarily electrical and falling hazards of the robot. These risks are easily mitigated through the use of a Safety Engineer. The risks associated with the use of the En-vac Robotic Wall scabbler are routinely acceptable to the public.

SECTION 7
LESSONS LEARNED

Implementation Considerations

The En-vac Robotic Wall Scabbler is a mature technology that performed well during the INEEL demonstration. Operating the robot unit required no special skills to use; however, the En-vac system required the user to be trained to operate the equipment. According to the operators, this technology was much easier and faster to complete a large surface area than the baseline technology. The system was user-friendly and able to remove paint at a faster rate than the baseline technology. Items that should be considered before implementing the En-vac Robotic Wall Scabbler include the following:

- Area survey should be conducted prior to scabbling to ensure that conduit and piping are removed.
- The En-vac system is more efficient in large areas.
- Anchor points are needed to support the robot in case of emergency power shutdown.
- The En-vac system requires an airflow rate of 640-scfm, compressed air pressure at 100 psig.
- Requires 440-Vac, 3-phase, 60-Hz, 120-kVa-peak demand electrical power.

Technology Limitations and Needs for Future Development

The En-vac robot was able to remove all paint present in the area being scabbled. However, the En-vac robot technology cannot scabble as close to obstruction as the baseline technology. The En-vac system does have hand-held attachments, which would allow close scabbling around objects.

Future development might include downsizing and combining the three larger components (vacuum unit, filter, and recycling unit) to make it more mobile. This would enhance the capability of this technology and assist with the transportation process. Another enhancement might be to place a radiation-monitoring probe on the system so that radioactive measurements can be made to determine if the debris is radioactive.

Technology Selection Considerations

Based on the INEEL demonstration, the En-vac Robotic Wall Scabbler technology is a better methodology for large area surface removals than the baseline technology. The En-vac robot can provide a cleaner and faster removal on a large area and provide an accelerated work schedule because a greater surface area can be scabbled in less time.

The initial capital investment into this technology could be paid off in a relatively short time depending upon the amount of area needing to be decontaminated. As shown with this demonstration, a 77% labor savings was calculated. However, if the end user has limited use for this technology, it may be too costly.

APPENDIX A
REFERENCES

MHI Marine Engineering, Ltd., revised 11/98, *En-vac Robot Blasting System, Standard Specifications*

Pentek Inc., 9/92, *Pentek's Dustless Decontamination and Surface Preparation System*, BP-92027

APPENDIX B
Cost Comparison Details

Basis of Estimated Cost

The activity titles shown in this cost analysis come from observation of the work. In the estimate, the activities are grouped under higher-level work titles per the work breakdown structure shown in 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 established national standards.

The costs shown in this analysis are computed from observed duration and hourly rates for the crew and equipment. The following assumptions were used in computing the hourly rates:

- The innovative technology and the baseline technology equipment are assumed to be owned by the Government.
- The equipment hourly rates for the Government's ownership are based on general guidance contained in Office of Management and Budget (OMB) Circular No. A-94, *Cost Effectiveness Analysis.*
- The equipment rates for Government ownership are computed by amortizing the purchase price of the equipment, plus a procurement cost of 5.2% of the purchase price, and the annual maintenance costs.
- The equipment hourly rates assume a service life of 15 years for the innovative technology equipment, ten years for the vac-pac and corner cutter, and 5 years for the Roto-Peen. An annual usage of 800 hours per year for the innovative technology equipment and 500 hours per year for the baseline technology equipment is assumed.
- Some of the equipment used during the demonstration are commonly included in the site motor pool, such as forklifts, trucks, etc. The equipment rates for these types of equipment are based on standard fleet rates for INEEL.
- The generator and the air compressor used for the innovative technology equipment were rented because INEEL did not have any site-owned equipment of this size available. The rental rates paid for the generator and air compressor during the demonstration are the rates used in this cost analysis for the innovative technology.
- The standard labor rates established by the INEEL are used in this estimate and include salary, fringe, departmental overhead, material handling markups, and facility service center markups.
- The equipment rates and labor rates do not include the Bechtel BWXT Idaho, LLC (BBWI) general and administrative (G&A) markups. The G&A are omitted from this analysis to facilitate understanding and comparison with costs for the individual site. The 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 back out the rates used at the INEEL.

This analysis does not include costs for oversight engineering, quality assurance, administrative costs for the demonstration, or work plan preparation costs.

Activity Descriptions

The scope, computation of production rates, and assumptions (if any) for each work activity are described below.

Mobilization (WBS 331.01)

<u>*Transport and Unload:*</u> This item assumes transport of the equipment from an equipment storage area and includes unloading from the truck. The duration used in the cost analysis is based on the test engineer's judgment.

Transport Rented Equipment: This item applies only to the innovative technology and includes transport of the rented generator and the rented air compressor from a commercial, off-site business to the work area. The duration used in the cost analysis is based on the test engineer's judgment.

Equipment Set Up: This item includes unpacking, assembly, and connecting hoses. The durations are based to some degree on the time observed from the demonstration, but some adjustment has been made to eliminate delays that do not reflect typical work. The setup for the innovative technology equipment occurred over a nine-hour period. But, non-routine problems, such as having to fabricate an electrical cable to replace the cable for the En-vac that was lost during shipment, causes long delays. The duration used in the cost analysis is based on the test engineer's judgment of how much time would be required for typical jobs. Two hours is assumed for the innovative technology set up and 1.5 hours for the baseline technology setup.

Electrical Connection: In the case of the innovative technology, the hookup to power required connecting a cable from the equipment directly into the electrical box on the control panel. The electricians performed a phase check of the power to ensure that the correct amount of voltage was supplied. The innovative technology hookup to power required one hour of effort for the electrician. The baseline equipment was plugged into a conventional electrical receptacle. In the case of the baseline, no electrician was required and no separate line item activity for the plugging in the equipment is shown in the estimate.

D&D Work (WBS 331.17)

Pre-Job Briefing: The duration for the pre-job safety meeting is based upon the observed time for the demonstration. The labor costs for this activity are based upon an assumed crew (rather than the actual demonstration participants); all subsequent activities are also based on the assumed crew.

Don Personal Protective Equipment (PPE): This activity includes the labor and material cost for donning the articles of clothing listed below. The duration of the donning and the number of donning events are based on observations of the demonstration.

Table B-1. Cost for PPE (per man/day)

Equipment	Cost Each	Number of Times Used Before Discarded	Cost Each Time Used ($)	No. Used Per Day	Cost Per Day ($)
Rubber over boots (pvc yellow 1/16 in thick)	$12.15	30	$0.41	1	$0.41
Glove liners pr. (cotton inner)	$0.40	1	$0.40	2	$0.80
Rubber Gloves pr. (outer)	$1.20	1	$1.20	2	$2.40
Hoods (yellow)	$6.47	1	$6.47	1	$6.47
Coveralls (white Tyvek)	$3.30	1	$3.30	1	$3.30
Coveralls (green scrubs)	$4.63	1	$4.63	1	$4.63
Respirator (full face)	$222	50	$4.44	1	$4.44
Cartridges	$751	1	$7.51	2	$15.02
TOTAL COST/DAY/PERSON					**$37.47**

Set Up Rad Control Zone: This activity includes the effort for one RCT to establish the Radiological Control Zone. The activity duration used in the cost analysis are based on the times observed during the demonstration.

Calculations for Anchors: The calculation of the loads and design requirements for the anchor holding the En-vac tether was performed by a structural engineer from the INEEL and required one hour of effort. The calculation during the demonstration was performed while the work crew waited. This cost analysis assumes that the calculation could be performed at an earlier time so that the work crew is not held up while the calculations are being completed.

Install Anchors: This activity includes drilling the concrete wall and installing the anchors for the En-vac tether. This effort covers only the initial wall. Installing anchors in subsequent walls is accounted for in the Remove, Move, and Set Up activity. A mechanic performed this work for the demonstration, and the observed duration was used in the cost analysis.

Operational Adjustments: This activity includes adjusting the depth of removal by the innovative technology equipment and other refinements of the equipment operation. The activity duration used in the cost analysis is based on the times observed during the demonstration.

Decontaminate Wall—Obstructed Area: This activity includes the scabbling of the surface and paint removal from concrete walls. The production rates reflect work in portions of the wall with pipes, conduits, corners, junction of floor and wall, and other features that slow the work. The production rate for the baseline technology is 15 ft^2/hr based on the duration and area observed during the demonstration. The production rate for the innovative technology is 23 ft^2/hr based on scabbling performed during the demonstration on one wall having significant pipes, conduits, etc.

Decontaminate Wall— Unobstructed Area: This activity includes the scabbling of the surface and paint removal from concrete walls. The production rates reflect work in portions of the wall free of features that slow the work. The production rate for the baseline technology is assumed to be 45 ft^2/hr based on observed production rates from a demonstration conducted at the Chicago Pile 5 Reactor at Argonne National Laboratory and on the manufacturer's experience. The production rate for the innovative technology is based on averaging the production rates for three wall areas observed during the demonstration as shown below:
Area 1: 36 ft^2 in 0.20 hr = 180 ft^2/hr
Area 2: 36 ft^2 in 0.233 hr = 155 ft^2/hr
Area 3: 96 ft^2 in 0.93 hr = 102 ft^2/hr
Average = 146 ft^2/hr

Consumables - Baseline Technology: Consumables for the baseline technology include wear of the Roto-Peen flaps, vac-pac hoses, corner cutter needle, and the replacement of the vac-pac HEPA filters. The demonstration did not directly measure these items. Costs for consumables were computed for the Roto-Peen flap replacement, corner cutter needle wear, and for the vac-pac HEPA filters replacement based on the manufacturer's experience. Costs for replacing the vac-pac hoses were computed based on demonstrations of the Roto-Peen at the Argonne National Laboratory at the Chicago Pile 5 Reactor.

- The Corner Cutter has an average life of 50 hrs (manufacturer's experience) at a production rate of 15 ft^2/hr (from demonstration) results in replacing the needle every 750 ft^2. The needle cost is $39.95 and results in a $0.05/$ft^2$. Assume that the Corner Cutter is used on 1/10 of the wall while the Roto-Peen is used on 9/10 of the wall. Consequently, for each square foot scabbled, the Corner Cutter is used 1/10 ft^2 and needle wear is $0.05 X 1/10 = $0.005/$ft^2$.

- Vac-Pac filters have a one-year life (manufacturer's experience) and cost $432.69 for the HEPA filter and $175.28 for the roughing filter. Assuming that the vac-pac operates approximately 500 hours per year, the cost per hour of operation is $1.22/hr for filter replacement. Assuming a production rate of 35 ft^2/hr (average of manufacturer's estimated production rates for the Corner Cutter [25 ft^2/hr] and the Roto-Peen [45 ft^2/hr]) the cost per square foot is $0.03.

- Roto-Peen flaps have a 45-hour operation life (manufacturer's experience) and cost $29.30 per flap with six flaps required for each change-out. Assuming that the Roto-Peen has a production rate of 45 ft^2/hr (manufacturer's experience), the cost per square foot is $0.09. Assume that the Corner Cutter is used on 1/10 of the wall while the Roto-Peen is used on 9/10 of the wall. The Roto-Peen is used 9/10ft^2 for each square foot scabbled and flap replacement is $0.09 X 9/10 = $0.08/$ft^2$.

- The Vac-Pac uses approximately 50 feet of hose at a cost of $633.50. The hose lasts approximately 2,550 ft^2 (based on manufacturer's experience) of surface removal and the cost per square foot is $0.25.

As such, the total cost for the baseline technologies consumables is $0.37/$ft^2$.

Consumables—Innovative Technology: Consumables for the innovative technology include wear of the hoses to the HEPA filter system, steel grit, and HEPA filter replacement.

- The HEPA filters are replaced after 100 hours of scabbling concrete or after 300 hours of metal surface cleaning. The cost for seven filters (one complete change out) is $924. Assuming a production rate of 146 ft^2/hr for 9/10 of the area (En-vac) and a production rate of 23 ft^2/hr for 1/10 of the area (corner robot), the cost per square foot for filters is \$924 / {100 hr X (146 ft^2/h X 9/10 + 23 ft^2/hr X 1/10) } = \$0.07/ft^2.

- Steel grit varies in price, but an average purchase price is \$448/drum (1,700 lbs) plus \$65.45/drum salvage charge plus shipping (\$711.46 to Idaho Falls Idaho from Portland, Oregon) for a total cost of \$0.72/lb. Approximately 100 lbs of steel grit was used to decontaminate 2029 ft^2 of area in the demonstration (2029 ft^2 included 180 ft^2 of wall area from this demonstration and 1849 ft^2 of floor area not directly considered in this demonstration) for an average of 0.049 lbs/ft^2. The cost per square foot is \$0.72/lb X 0.049 lbs/ft^2 X 9/10 (assuming the En-vac is used 9/10 of the time and the needle gun is used 1/10 of the time) = \$0.035/ft^2.
- Hoses for the En-vac equipment consist of blast hose, with the required length varying from 50 ft to 100 ft. Cost for 100 ft of hose is \$648.21. The hose typically lasts for 400 - 600 hrs of work (per the manufacturer's experience). Assuming a production rate of 146 ft^2/hr for 9/10 of the area (En-vac) and a production rate of 23 ft^2/hr for 1/10 of the area (corner robot), the cost per square foot for hose is \$648.21 / {500 hr X (146 ft^2/hr X 9/10 + 23 ft^2/hr X 1/10)} = \$0.01/ft^2.

As such, the total cost for the innovative technologies consumables \$0.12/ft^2

Remove, Move, Set Up: This activity is for disconnecting the innovative equipment from the tethers and anchors, moving to the next wall, and connecting the tethers to new anchors. The activity includes installing anchors in the subsequent walls, arranging to bring laborers that are certified for moving heavy objects from some nearby ongoing job to help move the En-vac, and moving it to the new wall. The activity duration used in the cost analysis are based on the times observed during the demonstration.

Move to Next Wall: This activity is for moving the baseline equipment from a completed wall to a new wall. The activity duration used in the cost analysis is based on the test engineer's judgment.

Wipe Down Walls: This activity prepares for the eventual radiological survey of the wall by cleaning the loose debris from the surface of the wall. The activity duration used in the cost analysis is based on the times observed during the demonstration.

Doff PPE: This activity accounts for the labor costs for doffing PPE and is based on the duration observed in the demonstration.

Survey Walls: This activity consists of the radiological survey of the wall using a Ludlum model 2A Survey Meter. The activity duration used in the cost analysis is based on the production rate observed during the demonstration.

Demobilization (WBS 331.21)

Decontaminate and Survey Out: This activity includes decontamination of the equipment used in the work and survey out of the equipment and crew. The activity duration used in the cost analysis is based on the production rate observed during the demonstration.

Return to Storage: This activity includes transporting the equipment back to the storage area and unloading. The activity duration is based on the test engineer's judgment.

Return Rented Equipment: This activity includes returning the rented generator and the air compressor used for the innovative technology portion of the demonstration to the rental company. The activity duration is based on the test engineer's judgment.

Disposal (WBS 331.18)

Transport and Unload: This activity includes loading the waste onto a truck, transport to the disposal area, and unloading. The activity requires 1 hour to load, 1/2 hour to transport, and 1 hour to unload for each trip based on previous experience at the INEEL.

Disposal Concrete and Paint Chips: The quantity of waste for the innovative technology is 100 lbs of steel grit and 20 lbs of concrete debris which together result in waste generated in the course of scabbling 2029 ft^2. The quantity of waste for the baseline technology is 10 lbs of concrete debris that results in waste generated in the course of scabbling 45 ft^2. Disposal costs at the INEEL are assumed to be \$150/ft^3 of waste based on historic costs observed at the INEEL for operation of the disposal cell. These costs do not include costs for transportation, packaging the waste, closure of the disposal facility, or long-term maintenance and surveillance.

Disposal of PPE Waste: This cost analysis assumes 1 ft^3 of PPE waste for the workers loading the waste for the baseline technology. The cost analysis assumes the five operators of the equipment generate 3.3 ft^3 of PPE waste each day of operation based on the judgment of the test engineer.

Cost Estimate Details

The cost analysis details are summarized in Tables B-2 and B-3. The tables break out each member of the crew, each labor rate, each piece of equipment used, each equipment rate, each activity duration and all production rates so that site specific differences in these items can be identified and a site specific cost estimate may be developed.

Table B-2. Innovative Technology Cost Summary

Work Breakdown Structure	Unit	Unit Cost $/Unit	Quantity	Total Cost	Computation of Unit Cost							Comments
					Prod Rate	Duration (hr)	Labor Item	$/hr	Equipment Items	$/hr	Other $	
Facility Deactivation, Decommissioning, & Dismantlement								**Total Cost =**				**$ 12,598.85**
Mobilization (WBS 331.01)										Subtotal =		$ 1,313.11
Transport & Unload	ea	71.47	1	$ 71.47		0.50	TD, LB, 1/4HO	76.87	FB, EV, 1/4FL	66.07		
Transport Rented Equip.	ea	470.84	1	$ 470.84		3.00	TD, LB, 1/4HO	76.87	FB, GN,AC, 1/4FL	80.08		
Equipment Set Up	ea	613.66	1	$ 613.66		2.00	2LB, RCT, IH, JS	187.34	EV, GN, AC	119.49		
Electrical Connection	ea	157.14	1	$ 157.14		1.00	EL	37.65	EV, GN, AC	119.49		
		0.00		$ -								
D&D Work (WBS 331.17)										Subtotal =		$ 7,236.32
Pre-Job Briefing	ea day	157.59	4	$ 630.34		0.50	2LB, RCT, IH, JS	187.34	EV, GN, AC, ML, SM	127.83		
Don PPE	ea day	266.14	4	$ 1,064.57		0.25	2LB, RCT, IH, JS	187.34	EV, GN, AC, ML, SM	127.83	187.35	$37.47/PPE X 5=$187.35
Set Up Rad Control Zone	ea	21.04	1	$ 21.04		0.58	RCT	35.77	SM	0.50		
Calculations for Anchors	ls	67.94	1	$ 67.94		1.00	EN	67.94				
Install Anchors (initial wall)	ea	40.95	2	$ 81.90		0.12	MC,2LB,RCT,IH,JS	223.15	EV, GN, AC, ML, SM	127.83		
Operational Adjustments	ea	157.59	1	$ 157.59		0.50	2LB, RCT, IH, JS	187.34	EV, GN, AC, ML, SM	127.83		
Decon Wall-Obstructed	sf	13.70	12	$ 164.44	23		2LB, RCT, IH, JS	187.34	EV, GN, AC, ML, SM	127.83		Production rate = 23sf/hr
Decon Wall-Unobstructed	sf	2.16	168	$ 362.66	146		2LB, RCT, IH, JS	187.34	EV, GN, AC, ML, SM	127.83		Production rate = 146sf/hr
Consumables	sf	0.12	180	$ 21.60							0.12	Steel grit, filters, & hoses
Remove, Move, Set Up	ea	945.51	3	$ 2,836.53		3.00	2LB, RCT, IH, JS	187.34	EV, GN, AC, ML, SM	127.83		
Wipe Down Walls	sf	3.50	180	$ 630.34	90		2LB, RCT, IH, JS	187.34	EV, GN, AC, ML, SM	127.83		Production Rate = 90sf/hr
Doff PPE	ea day	78.79	4	$ 315.17		0.25	2LB, RCT, IH, JS	187.34	EV, GN, AC, ML, SM	127.83		
Survey Walls	sf	4.90	180	$ 882.22	16.4		2RCT	71.54	2SM, ML	8.84		Production rate = 16.4sf/hr
Demobilization (WBS 331.21)										Subtotal =		$ 1,141.92
Decon & Survey Out	ea	599.61	1	$ 599.61		3.00	2RCT	71.54	EV, GN,AC,ML,2SM	128.33		
Return En-Vac to Storage	ea	71.47	1	$ 71.47		0.50	TD, LB, 1/4HO	76.87	FB, EV, 1/4FL	66.07		
Return Rented Equipment	ea	470.84	1	$ 470.84		3.00	TD, LB, 1/4HO	76.87	FB, GN,AC, 1/4FL	80.08		
Disposal (WBS 331.18)										Subtotal =		$ 2,907.49
Transport & Unload	ea	225.49	1	$ 225.49		2.50	TD, LB, 1/4HO	76.87	FB, 1/4FL	13.33		
Concrete & Paint Chips	cf	150.00	3.68	$ 552.00							150	Disposal fee = $150/cf
Disposal PPE	cf	150.00	14.20	$ 2,130.00							150	Disposal fee = $150/cf

Labor and Equipment Rates used to Compute Unit Cost

Crew Item	Rate $/hr	Abbrev-iation	Crew Item	Rate $/hr	Abbreviation	Equipment Item	Rate $/hr	Abbrev-iation	Equipment Item	Rate $/hr	Abbrev-iation
Heavy Equipment Op	38.65	HO	Driver	34.35	TD	Forklift	3.30	FL	Flatbed Truck	12.50	FB
Laborer	32.86	LB	Job Supervisor	51.53	JS	Rented Generator	20.00	GN	Manlift	7.84	ML
Radiation Control Tech	35.77	RCT	Industrial Hygienist	34.32	IH	Rented Air Compressor	46.75	AC	Survey Meter	0.50	SM
Electrician	37.65	EL	Engineer	67.94	EN	En-Vac	52.74	EV			
Mechanic	35.81	MC									

Notes:

1. Unit cost = (labor + equipment rate) X duration + other costs, or = (labor + equipment rate)/production rate + other costs
2. Abbreviations for units: ls = lump sum; ea = each; and, loc = location; ft^3 = cubic feet.
3. Other abbreviations: PPE = personal protective equipment Decon = decontaminate

Table B-3. Baseline Technology Cost Summary

Work Breakdown Structure	Unit	Unit Cost $/Unit	Quantity	Total Cost	Prod Rate	Duration (hr)	Labor Item	$/hr	Equipment Items	$/hr	Other $	Comments
					Computation of Unit Cost							
Facility Deactivation, Decommissioning, & Dismantlement							**Total Cost =**					**$ 6,324.61**
Mobilization (WBS 331.01)										Subtotal =		$ 360.53
Transport and Unload	ea	49.77	1	$ 49.77		0.50	LB, TD	67.21	FB, VP, CC, RP, AC	32.33		
Equipment Set Up	ea	310.76	1	$ 310.76		1.50	2LB, RCT, IH, JS	187.34	VP, CC, RP, AC	19.83		
D&D Work (WBS 331.17)										Subtotal =		$ 3,694.31
Pre-Job Briefing	ea day	107.76	3	$ 323.27		0.50	2LB, RCT, IH, JS	187.34	VP,CC,RP,AC,SM, ML	28.17		
Don PPE	ea day	241.23	3	$ 723.68		0.25	2LB, RCT, IH, JS	187.34	VP,CC,RP,AC,SM, ML	28.17	187	$37.47/PPE X 5=$187.35
Set Up Rad Control Zone	ea	21.16	1	$ 21.16		0.58	RCT	35.77	SM	0.50		
Decon Wall-Obstructed Ai	sf	14.37	12	$ 172.41	15		2LB, RCT, IH, JS	187.34	VP,CC,RP,AC,SM, ML	28.17		Production rate = 15sf/hr
Decon Wall-Unobstructed	sf	4.79	168	$ 804.57	45		2LB, RCT, IH, JS	187.34	VP,CC,RP,AC,SM, ML	28.17		Production rate = 45sf/hr
Consumables	sf	0.37	180	$ 66.60							0.37	flaps + hose +filters + needle
Move to Next Wall	ea	35.92	3	$ 107.76		0.17	2LB, RCT, IH, JS	187.34	VP,CC,RP,AC,SM, ML	28.17		
Wipe Down Walls	sf	2.39	180	$ 431.02	90		2LB, RCT, IH, JS	187.34	VP,CC,RP,AC,SM, ML	28.17		Production rate = 90sf/h
Doff PPE	ea day	53.88	3	$ 161.63		0.25	2LB, RCT, IH, JS	187.34	VP,CC,RP,AC,SM, ML	28.17		
Survey Walls	sf	4.90	180	$ 882.22	16.4		2RCT	71.54	2SM, ML	8.84		Production rate = 16.4sf/hr
Demobilization (WBS 331.21)										Subtotal =		$ 133.28
Decon & Survey Out	ea	83.51	1	$ 83.51		0.83	2RCT	71.54	VP,CC,RP,AC,2SM,ML	28.67		
Return to Storage	ea	49.77	1	$ 49.77		0.50	LB, TD	67.21	FB, VP, CC, RP, AC	32.33		
Disposal (WBS 331.18)										Subtotal =		$ 2,136.49
Transport & Unload	ea	225.49	1	$ 225.49		2.50	TD, LB, 1/4 HO	76.87	FB, 1/4FL	13.33		
Concrete & Paint Chips	cf	150.00	1.84	$ 276.00							150	$150/cf waste disposal cost
Disposal PPE	cf	150.00	10.90	$ 1,635.00							150	$150/cf waste disposal cost

Labor and Equipment Rates used to Compute Unit Cost

Crew Item	Rate $/hr	Abbrev-iation	Crew Item	Rate $/hr	Abbrev-iation	Equipment Item	Rate $/hr	Abbrev-iation	Equipment Item	Rate $/hr	Abbrev-iation
Heavy Equipment Op	38.65	HO	Driver	34.35	TD	Pentek Vac Pac	9.64	VP	Flatbed Truck	12.50	FB
Laborer	32.86	LB	Job Supervisor	51.53	JS	Pentek Corner Cutter	1.12	CC	Fork Lift	3.30	FL
Radiation Control Tech	35.77	RCT	Industrial Hygienist	34.32	IH	Pentek Roto-Peen	1.23	RP	Air Compressor	7.84	AC
Electrician	37.65	EL				Manlift	7.84	ML	Survey Meter	0.50	SM

Notes:

4. Unit cost = (labor + equipment rate) X duration + other costs, or = (labor + equipment rate)/production rate + other costs
5. Abbreviations for units: ls = lump sum; ea = each; and, loc = location; ft^3 = cubic feet.
6. Other abbreviations: PPE = personal protective equipment.
   Decon = decontaminate.
   Equip = equipment.

APPENDIX C
ACRONYMS AND ABBREVIATIONS

$/ft^2$	Dollar per square foot
CFA	Central Facility Area
D&D	Decontamination and Decommissioning
DDFA	Deactivation and Decommissioning Focus Area
Decon	Decontamination
DOE	Department of Energy
G&A	General and Administrative
lbs	Pounds
INEEL	Idaho National Engineering and Environmental Laboratory
LSDDP	Large Scale Demonstration and Deployment Project
loc	Location
psig	Pressure per square inch gauge
NETL	National Energy and Technology Laboratory
OMB	Office of Management and Budget (OMB)
OST	Office of Science and Technology
PPE	Personal Protective Equipment
RCT	Radiological Control Technician
TAN	Test Area North