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Remediation Case Studies:
Debris and Surface Cleaning Technologies, and Other Miscellaneous Technologies

Volume 13

Federal Remediation Technologies Roundtable
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Prepared by the

Member Agencies of the Federal Remediation Technologies Roundtable

Remediation Case Studies: Debris and Surface Cleaning Technologies, and Other Miscellaneous Technologies

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Environmental Protection Agency
Department of Defense
U.S. Air Force
U.S. Army
U.S. Navy
Department of Energy
Department of Interior
National Aeronautics and Space Administration
Tennessee Valley Authority
Coast Guard

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NOTICE

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FOREWORD

This report is a collection of six case studies of debris and surface cleaning technologies, and other, miscellaneous technologies, prepared by federal agencies. The case studies, collected under the auspices of the Federal Remediation Technologies Roundtable, were undertaken to document the results and lessons learned from technology applications. They will help establish benchmark data on cost and performance which should lead to greater confidence in the selection and use of cleanup technologies.

The Roundtable was created to exchange information on site remediation technologies, and to consider cooperative efforts that could lead to a greater application of innovative technologies. Roundtable member agencies, including the U.S. Environmental Protection Agency, U.S. Department of Defense, and U.S. Department of Energy, expect to complete many site remediation projects in the near future. These agencies recognize the importance of documenting the results of these efforts, and the benefits to be realized from greater coordination.

The case study reports and abstracts are organized by technology in a multi-volume set listed below. Remediation Case Studies, Volumes 1-6, and Abstracts, Volumes 1 and 2, were published previously, and contain 54 case studies. Remediation Case Studies, Volumes 7-13, and Abstracts, Volume 3, were published in September 1998. Volumes 7-13 cover a wide variety of technologies, including debris and surface cleaning technologies, and other, miscellaneous technologies (Volume 13). The 6 case studies in this report include completed full-scale remediations and large-scale field demonstrations. In the future, the set will grow as agencies prepare additional case studies.

1995 Series

Volume 1: Bioremediation, EPA-542-R-95-002; March 1995; PB95-182911

Volume 2: Groundwater Treatment, EPA-542-R-95-003; March 1995; PB95-182929

Volume 3: Soil Vapor Extraction, EPA-542-R-95-004; March 1995; PB95-182937

Volume 4: Thermal Desorption, Soil Washing, and In Situ Vitrification, EPA-542-R-95-005; March 1995; PB95-182945

1997 Series

Volume 5: Bioremediation and Vitrification, EPA-542-R-97-008; July 1997; PB97-177554

Volume 6: Soil Vapor Extraction and Other In Situ Technologies, EPA-542-R-97-009; July 1997; PB97-177562

1998 Series

Volume 7: Ex Situ Soil Treatment Technologies (Bioremediation, Solvent Extraction, Thermal Desorption), EPA-542-R-98-011; September 1998

Volume 8: In Situ Soil Treatment Technologies (Soil Vapor Extraction, Thermal Processes), EPA-542-R-98-012; September 1998

1998 Series (continued)

Volume 9:	Groundwater Pump and Treat (Chlorinated Solvents), EPA-542-R-98-013; September 1998
Volume 10:	Groundwater Pump and Treat (Nonchlorinated Contaminants), EPA-542-R-98-014; September 1998
Volume 11:	Innovative Groundwater Treatment Technologies, EPA-542-R-98-015; September 1998
Volume 12:	On-Site Incineration, EPA-542-R-98-016; September 1998
Volume 13:	Debris and Surface Cleaning Technologies, and Other Miscellaneous Technologies, EPA-542-R-98-017; September 1998

Abstracts

Volume 1:	EPA-542-R-95-001; March 1995; PB95-201711
Volume 2:	EPA-542-R-97-010; July 1997; PB97-177570
Volume 3:	EPA-542-R-98-010; September 1998

Accessing Case Studies

The case studies and case study abstracts are available on the Internet through the Federal Remediation Technologies Roundtable web site at: http://www.frtr.gov. The Roundtable web site provides links to individual agency web sites, and includes a search function. The search function allows users to complete a key word (pick list) search of all the case studies on the web site, and includes pick lists for media treated, contaminant types, and primary and supplemental technology types. The search function provides users with basic information about the case studies, and allows them to view or download abstracts and case studies that meet their requirements.

Users are encouraged to download abstracts and case studies from the Roundtable web site. Some of the case studies are also available on individual agency web sites, such as for the Department of Energy.

In addition, a limited number of hard copies are available free of charge by mail from NCEPI (allow 4-6 weeks for delivery), at the following address:

U.S. EPA/National Center for Environmental Publications and Information (NCEPI)
P.O. Box 42419
Cincinnati, OH 45242
Phone: (513) 489-8190 or
(800) 490-9198
Fax: (513) 489-8695

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INTRODUCTION

Increasing the cost effectiveness of site remediation is a national priority. The selection and use of more cost-effective remedies requires better access to data on the performance and cost of technologies used in the field. To make data more widely available, member agencies of the Federal Remediation Technologies Roundtable (Roundtable) are working jointly to publish case studies of full-scale remediation and demonstration projects. Previously, the Roundtable published a six-volume series of case study reports. At this time, the Roundtable is publishing seven additional volumes of case study reports, primarily focused on soil and groundwater cleanup.

The case studies were developed by the U.S. Environmental Protection Agency (EPA), the U.S. Department of Defense (DoD), and the U.S. Department of Energy (DOE). The case studies were prepared based on recommended terminology and procedures agreed to by the agencies. These procedures are summarized in the Guide to Documenting and Managing Cost and Performance Information for Remediation Projects (EPA 542-B-98-007; October 1998). (The October 1998 guide supersedes the original Guide to Documenting Cost and Performance for Remediation Projects, published in March 1995.)

The case studies present available cost and performance information for full-scale remediation efforts and several large-scale demonstration projects. They are meant to serve as primary reference sources, and contain information on site background and setting, contaminants and media treated, technology, cost and performance, and points of contact for the technology application. The studies contain varying levels of detail, reflecting the differences in the availability of data and information. Because full-scale cleanup efforts are not conducted primarily for the purpose of technology evaluation, data on technology cost and performance may be limited.

The case studies in this volume describe six applications of debris and surface cleaning technologies, and other, miscellaneous technologies. These include a process used to decontaminate piping and debris contaminated with explosives; three technologies used to treat concrete floor covered with radioactive-contaminated paint; an encapsulation process used to treat radioactive-contaminated lead bricks; and a multilayer cap on a landfill. The capping project is a full-scale application; all others were conducted as field demonstrations.

Table 1 provides a summary including information on technology used, contaminants and media treated, and project duration for the six debris and surface cleaning technologies, and other, miscellaneous technologies in this volume. This table also provides highlights about each application. Table 2 summarizes cost data, including information on quantity of media treated. In addition, Table 2 shows a calculated unit cost for some projects, and identifies key factors potentially affecting project cost. (The column showing the calculated unit costs for treatment provides a dollar value per unit of groundwater treated or contaminant removed.) Cost data are shown as reported in the case studies and have not been adjusted for inflation to a common year basis. The costs should be assumed to be dollars for the time period that the project was in progress (shown on Table 1 as project duration).

While a summary of project costs is useful, it may be difficult to compare costs for different projects because of unique site-specific factors. However, by including a recommended reporting format, the Roundtable is working to standardize the reporting of costs to make data comparable across projects. In addition, the Roundtable is working to capture information in case study reports that identify and describe the primary factors that affect cost and performance of a given technology. Key factors that potentially affect project costs for the remediation projects in this volume include economies of scale, concentration levels in contaminated media, required cleanup levels, completion schedules, matrix characteristics, and other site conditions.

Table 1. Summary of Remediation Case Studies: Debris and Surface Cleaning Technologies, and Other Miscellaneous Technologies

Site Name, State (Technology)	Principal Contaminants*						Media (Quantity Treated)	Project Duration	Highlights
	Chlorinated Solvents	BTEX and/or TPH	PAHs	Pesticides/Herbicides	Explosives	Radioactivity			
Alabama Army Ammunition Plant, AL (Transportable Hot-Gas Decontamination)					●		Explosives: contaminated piping and debris	12/4/95 - 3/15/96	Demonstration and validation testing to determine effectiveness of treating explosives-contaminated materials using the Hot-Gas Decontamination System
Chicago Pile 5 (CP-5) Research Reactor, Argonne National Laboratory, IL (Centrifugal Shot Blast)						●	Concrete floor covered with radioactive - contaminated paint (800 ft^2)	1/28/97 - 2/4/97	Demonstrate a modified centrifugal shot blast unit compared to mechanical scabbing
Chicago Pile 5 (CP-5) Research Reactor, Argonne National Laboratory, IL (Rotary Peening with Captive Shot)						●	Concrete floor covered with radioactive - contaminated paint (425 ft^2)	1/28/97 - 2/4/97	Demonstrate Roto Peening with captive shot compared to mechanical scabbing
Chicago Pile 5 (CP-5) Research Reactor, Argonne National Laboratory, IL (Roto Peen Scaler with VAC-PAC^R System)						●	Concrete floor covered with radioactive - contaminated paint (650 ft^2)	12/9/96 - 12/12/96	Demonstrate Roto Peen Scaler with VAC-PAC^R System compared to mechanical scabbing; hand held unit
Envirocare of Utah, UT (Polyethylene Macroencapsulation)						●	lead bricks: radioactive - contaminated (500,000 lb)	Fiscal Year 1996	Determine production-scale feasibility of this technology for mixed lead waste

Table 1. Summary of Remediation Case Studies: Debris and Surface Cleaning Technologies, and Other Miscellaneous Technologies (continued)

Site Name, State (Technology)	Principal Contaminants*						Media (Quantity Treated)	Project Duration	Highlights
	Chlorinated Solvents	BTEX and/or TPH	PAHs	Pesticides/Herbicides	Explosives	Radioactivity			
Lawrence Livermore National Laboratory (LLNL) Site 300 - Pit 6 Landfill OU, CA (Cap)	●					●	2.4 acre multilayer cap over a landfill	Installed Summer 1997	Multilayer capping of a landfill

* Principal contaminants are one or more specific constituents within the groups shown that were identified during site investigations.

Table 2. Remediation Case Studies: Summary of Cost Data

Site Name, State (Technology)	Technology Cost ($)*	Quantity Treated	Quantity of Contaminant Removed	Calculated Cost for Treatment**	Key Factors Potentially Affecting Technology Costs***
Alabama Army Ammunition Plant, AL (Transportable Hot-Gas Decontamination)	C: $689,500 O: $3,337	Not provided	Not provided	Not calculated	Cost for full-scale application at other sites will vary based on labor costs, equipment transportation costs, and selected operating conditions
Chicago Pile 5 (CP-5) Research Reactor, Argonne National Laboratory, IL (Centrifugal Shot Blast)	Total: $23,000	800 ft^2	Not provided	Not calculated	The centrifugal shot blast has a lower incremental operating cost than mechanical scabbing resulting in savings for areas greater than 1,900 ft^2
Chicago Pile 5 (CP-5) Research Reactor, Argonne National Laboratory, IL (Rotary Peening with Captive Shot)	Total: $4,500	425 ft^2	Not provided	Not calculated	Cost for this technology was lower than mechanical scabbing; no temporary structure needed to contain airborne contaminants
Chicago Pile 5 (CP-5) Research Reactor, Argonne National Laboratory, IL (Roto Peen Scaler with VAC-PAC[R] System)	Total: $6,500	650 ft^2	Not provided	Not calculated	Cost for this technology was lower than mechanical scabbing; no temporary structure needed to contain airborne contaminants
Envirocare of Utah, UT (Polyethylene Macroencapsulation)	Not provided	Not provided	Not provided	Total: $90-100/$ft^3$ O: $800/55-gal drum (average)	Costs for full-scale application depends on ability to use virgin or recycled polymer; affects the melt index needed to provide adequate flow characteristics
Lawrence Livermore National Laboratory (LLNL) Site 300 - Pit 6 Landfill OU, CA (Cap)	Construction: $1,500,000	2.4 acres	Not applicable	Not applicable	Substituting geosynthetic materials for natural materials in portions of the cap saved over $500,000

Technology Cost*
C = Capital costs
O = Operation and maintenance (O&M) costs

Calculated Cost for Treatment**
Calculated based on sum of capital and O&M costs, divided by quantity treated or removed. Calculated costs shown as "Not Calculated" if an estimate of costs or quantity treated or removed was not available. Unit costs calculated based on both quantity of media treated and quantity of contaminant removed, as appropriate.

*** For full-scale remediation projects, this identifies factors affecting actual technology costs. For demonstration-scale projects, this identifies generic factors which would affect costs for a future application using this technology.

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Debris and Surface Cleaning Technologies, and Other Miscellaneous Technologies

Case Studies

Transportable Hot-Gas Decontamination System at Alabama Army Ammunition Plant Site, Alpine, Alabama

Transportable Hot-Gas Decontamination System at Alabama Army Ammunition Plant Site, Alpine, Alabama

Site Name:
Alabama Army Ammunition Plant

Location:
Alpine, Alabama

Vendor:
L&L Special Furnace Co., Inc.
Aston, PA

Prime Contractor:
Roy F. Weston, Inc.
1 Weston Way
W. Chester, PA 19380

Additional Contacts:
U.S. Army Environmental Center
Environmental Technology Division
Edgewood Area
Aberdeen Proving Ground, MD 21010-5401

Contaminants: Chlorinated Explosives contaminated materials and debris, including TNT-, RDX-, and Tetryl-contaminated materials

Technology:
Transportable Hot-Gas Decontamination (HGD) furnace
- Natural gas or propane-fired, box-type furnace with integrated ceramic-fiber lining
- Manually loaded and unloaded batch process
- Furnace components are skid mounted, approximately 16 ft by 8 ft
- Heated by 1 million Btu per hour, high velocity nozzle-mix Eclipse Burner equipped with UV sensor and Industrial Risk Insurers (IRI) class gas safety system
- Combustion air to burner set at a fixed rate that maintains excess air capacity to promote lower furnace chamber temperatures between 300 and 600° F
- Capacity to treat 3,000 lb of contaminated materials
- Gases directed into thermal oxidizer combustion chamber

Period of Operation:
12/4/95 - 3/15/96

Cleanup Type:
Demonstration and validation tests

Cleanup Authority:
Validation test conducted under guidelines for treatability studies.

Regulatory Point of Contact:
Information not provided

Waste Source:
Contamination of process-related equipment, sewers, piping, and structures resulting from manufacture, storage, testing, and disposal of explosives

Purpose/Significance of Application:
Demonstration and validation testing to determine effectiveness of treating explosives-contaminated materials using the Hot-Gas Decontamination System

Type/Quantity of Media Treated:
Explosives-contaminated piping and debris

Transportable Hot-Gas Decontamination System at Alabama Army Ammunition Plant Site, Alpine, Alabama (continued)

Regulatory Requirements/Cleanup Goals:
No permitted limits for system emissions or operating conditions for this demonstration.

Results:
- Verified effectiveness of HGD system equipment in decontaminating explosives.
- Defined optimum processing times and temperatures for TNT-, RDX-, and Tetryl-contaminated materials.
- Collected air emissions data to support future system permitting efforts.
- Achieved complete removal of TNT, RDX, Tetryl, and their breakdown constituents to levels below method detection levels (250°F/hour ramp to 600°F treatment temperature with a 1-hour goal).

Cost:
- Total capital equipment cost of the HGD system was $689,500.
- Total operating costs were $3,337.
- Total estimated validation costs are approximately $90,000.

Description:
The United States Army Environmental Center (USAEC) has been conducting laboratory investigation and pilot-scale studies of the hot-gas decontamination (HGD) process since 1978. The results from these investigations and studies verified the effectiveness of the HGD technology for treating chemical agents and explosives, however, post-test recommendations indicated that equipment designed specifically for the HGD concept would improve system efficiencies and process optimization goals. As a result, USAEC contracted the design and procurement of system equipment specifically for the treatment of explosives-contaminated materials by the HGD process. The resultant equipment design was delivered to USAEC's test site at the Alabama Army Ammunition Plant (ALAAP) located in Alpine, Alabama for demonstration and validation testing.

The demonstration and validation testing was conducted between December 4, 1995, and March 15, 1996. System trials proved the HGD Equipment to be fully functional and capable of maintaining anticipated treatment temperatures. The HGD Equipment system was optimized to enable the complete destruction of explosives contamination at a furnace ramp rate of 250°F/hr, treatment temperature of 600°F, and a treatment time of 1 hour. In general, the HGD system is designed to meet all applicable regulatory performance standards contained in following sections of 40 CFR:
- RCRA incinerator standards (40 CFR, Part 264, Subpart 0)
- Miscellaneous Unit Standards (40 CFR, Part 264, Subpart X)
- Boiler and Industrial Furnaces Standards (40 CFR, Part 266, Subpart H)
- TSCA incinerator standards (40 CFR, Part 761.70 (b))

1. INTRODUCTION

1.1 BACKGROUND

For many years, the United States Army has engaged in a wide variety of operations involving the handling and disposal of explosives materials at various military installations. Past operations at these installations have included the manufacture, storage, testing, and disposal of explosives that have resulted in the contamination of process-related equipment, sewers, piping, and structures. As a result of these activities, the Army currently owns a large inventory of materials that are contaminated with explosives.

Demilitarization of explosives-contaminated process equipment and structures has proven to be difficult and expensive for the Army. Currently acceptable methods for decontamination of explosives-contaminated materials include 3X treatment methods such as steam cleaning and power washing, and 5X treatment methods that involve heating contaminated materials to a minimum temperature of 1,000 °F for 15 minutes. Although steam cleaning effectively decontaminates the surfaces of contaminated materials to a 3X condition, contaminants may still be present in the surface voids or equipment internals. At present, there is no analytical method available that accurately determines the contaminant concentration remaining in the pores of treated materials. In order for the materials to be released from government control (i.e., landfilled, scrapped, or reused), the materials must meet 5X treatment criteria.

In some instances, the 5X treatment process is controlled by flashing contaminated materials within an enclosed oven, but more commonly the process is uncontrolled and accomplished by open air burning and/or open detonation (OB/OD). Because environmental regulations are becoming more rigorous every year, it is likely that the practice of OB/OD for decontamination of explosives-contaminated materials will be severely limited or disallowed because OB/OD results in nonregulated air emissions. Although flash ovens allow for control of process off-gases, the process is essentially an incineration process that currently carries negative perceptions by both the public community and regulatory agencies. Materials decontaminated using either OB/OD or flashing methods are usually not suitable for reuse and must be scrapped or landfilled.

In summary, these currently accepted decontamination methods have proven a need for a technology that is easy to use, capable of destroying undesirable emissions, and does not result in complete destruction and loss of equipment and/or structures. The HGD technology discussed in this report meets these requirements. Subsection 1.2 presents the history of the HGD technology and subsequent sections present the transportable HGD system equipment listed at the Alabama Army Ammunition Plant (ALAAP). Specific details regarding site layout, utilities, operating costs, and system performance will be provided.

1.2 HISTORY

The U.S. Army Environmental Center (USAEC, formerly United States Army Toxic and Materials Agency or USATHAMA) began conducting laboratory investigations and pilot-scale studies in 1978 to evaluate the effectiveness of the HGD technology on explosives- and agent-contaminated materials and structures.

Based on promising laboratory work with chemical warfare agents, a pilot-scale study using agent-spiked samples was conducted at Dugway Proving Ground, Utah[1] from February 1986 to October 1987. This controlled pilot-scale study successfully demonstrated the ability of the hot-gas process to decontaminate agent from a concrete and steel structure.

To further evaluate the HGD process on agent, USAEC selected a mustard thaw pit at the Rocky Mountain Arsenal in 1994 for a field demonstration of the HGD process.[2] Three tanks (two 2,600-gallon tanks and one 250-gallon tank) were also left in the mustard pit during the field demonstration to test the effectiveness of the hot-gas process in decontaminating process equipment. This field demonstration once again proved the effectiveness of the HGD process. Mustard agent was successfully decontaminated from the concrete pit, contaminated steel tanks, and process off-gases.

Based on the successful pilot-study results at Dugway (February 1986 to October 1987), USAEC determined to investigate the effectiveness of the HGD process on explosives-contaminated materials. Pilot-scale tests using the HGD process to treat explosives contamination were conducted at the Cornhusker Army Ammunition Plant.[3] Results from the Cornhusker tests indicated that the HGD process seemed to be effective at treating explosives-contaminated materials. To verify this finding, USAEC contracted for additional hot-gas studies to be conducted at the Hawthorne Army Ammunition Plant [4,5] using an existing flash

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1 Pilot Plant Testing of Hot-Gas Building Decontamination Process; Task Order 1. Report No. AMXTH-TE-CR-87130. Prepared by Battelle Columbus Division. 30 October 1987.

2 Final Technical Report, Field Demonstration of the Hot-Gas Decontamination System. Report No. SFIM-AEC-ET-CR-95011. Prepared by Battelle Pacific Northwest Laboratories, Parsons Engineering Science, Inc., and Battelle Columbus Operations. February 1995.

3 Pilot Plant Testing of Caustic Spray Hot-Gas Building Decontamination Process; Task Order 5. Report No. AMXTH-TE-CR-87112. Prepared by Arthur D. Little, Inc. August 1987.

4 Task Order 2; Pilot Test of Hot Gas Decontamination of Explosives-Contaminated Equipment at Hawthorne Army Ammunition Plant (HWAAP) Hawthorne, Nevada. Report No. CETHA-TE-CR-90036. Prepared by Roy F. Weston, Inc. July 1990.

5 Demonstration Results of Hot Gas Decontamination for Explosives at Hawthorne Army Depot. Report No. SFIM-AEC-ET-CR-95031. Prepared by The Tennessee Valley Authority Environmental Research Center. September 1995.

chamber modified for the hot-gas process. Explosives-contaminated machinery and piping and metal debris, such as shell casings, were treated in one study in 1989 by WESTON. Explosives contained within munitions, such as ship mines, depth bombs, and 106-mm 5-inch projectiles, were treated in a second series of tests in 1994 by the Tennessee Valley Authority Environmental Research Center (TVA). The results from these studies verified the effectiveness of the HGD process in treating explosives-contaminated materials, but indicated that equipment enhancements would be required to optimize the process.

Based on engineering data gathered during the Hawthorne pilot studies, WESTON, under contract to USAEC, was requested to design and supply an HGD system that would be transportable and easily procured through commercial sources. This equipment was delivered to ALAAP located near Childersburg, Alabama, to conduct demonstration tests using clean, noncontaminated debris, and validation testing using explosives-contaminated piping and debris.

Demonstration and validation tests conducted between December 1995 and March 1996 by WESTON at ALAAP optimized treatment conditions for explosives-contaminated materials and debris, and modified the transportable HGD system equipment to enhance heat distribution in the furnace and general system operability.

The transportable HGD system equipment that was demonstrated and validated at ALAAP is the subject of this Cost and Performance Report. This Cost and Performance Report will provide an equipment and system description, installation and utility requirements, operating cost, and system performance for various treatment waste quantities and feed rates.

2.
PROCESS EQUIPMENT DESCRIPTION

The Hot-Gas Decontamination system consists of the following major components:

- HGD furnace.
- Interconnection Duct.
- Induced Draft (I.D.) Fan.
- Thermal Oxidizer.
- 24-Foot Stack with an 8-Foot Extension.
- Data Logging and Monitoring System.
- Remote Control System.
- Continuous Emissions Monitoring (CEM) System.

This equipment, whose general arrangement and process flow are depicted in Figure 2-1 and Figure 2-2, respectively, was used to conduct successful equipment demonstration and validation testing at ALAAP between December 1995 and March 1996. System modifications performed during this period are incorporated in the equipment descriptions provided in this section.

2.1 HGD FURNACE

The HGD furnace was supplied and manufactured by L&L Special Furnace Co., Inc., of Aston, Pennsylvania. The furnace is a natural gas or propane gas-fired, box-type furnace with integrated ceramic-fiber lining. The HGD furnace system includes:

- Furnace Chamber.
- Burner and Gas Train.
- Burner Control System.
- Burner Combustion Air Blower.
- Local Control Panel.
- Remote Control Panel.

All of the furnace components, except for the remote control panel, are skid-mounted for easy transportability. The furnace skid is approximately 16 feet long by 8 feet wide. The remote control panel is shipped separately and requires mounting in a remote control area.

The furnace is heated by a 1 million British thermal units (Btu) per hour, high-velocity nozzle-mix Eclipse Burner equipped with an ultraviolet (UV) sensor and an Industrial Risk Insurers (IRI) class gas safety system. The pilot and burner flames are monitored by a pilot and flame scanner system. Once all system interlocks are confirmed and the pilot flame is established, the main

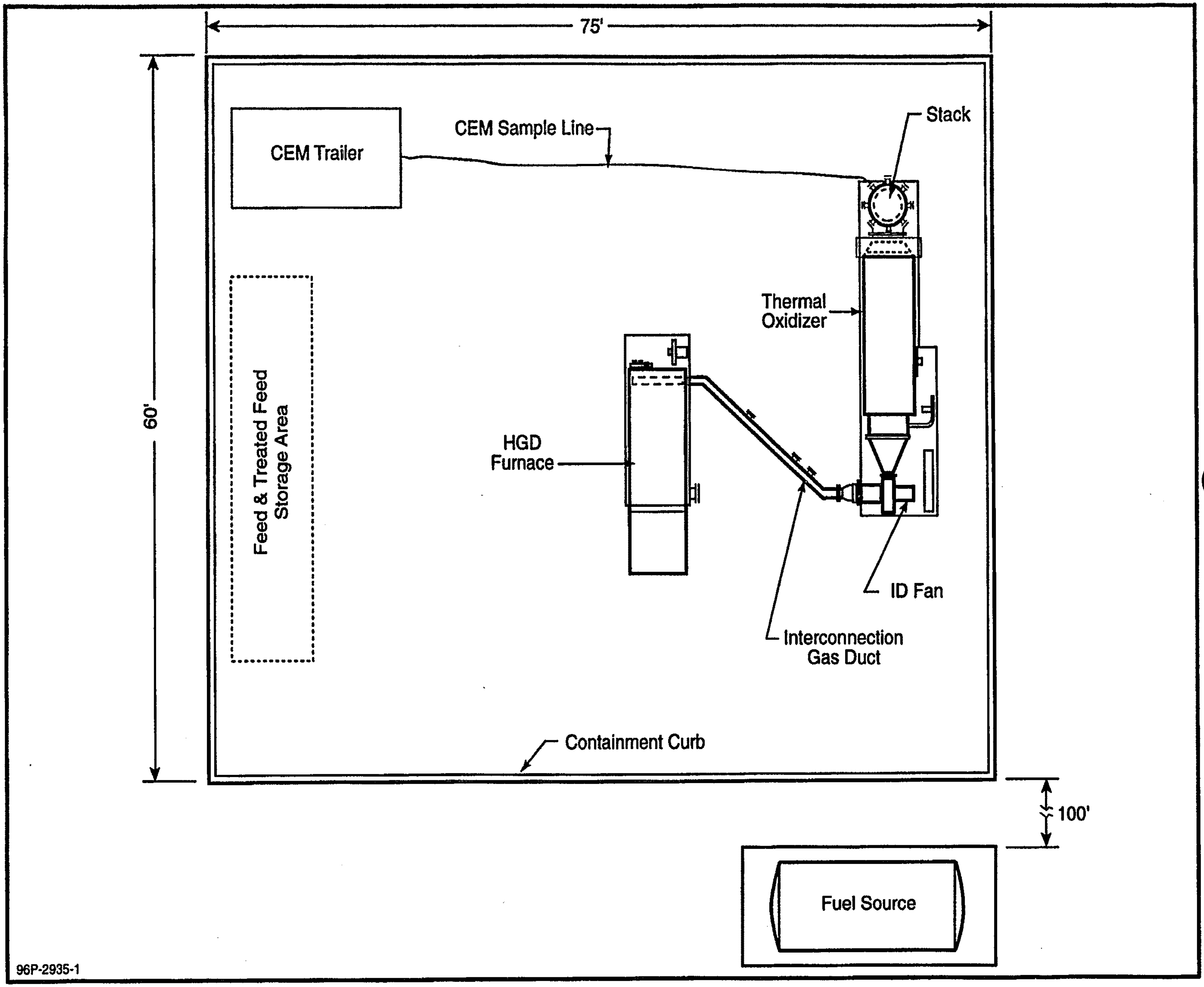
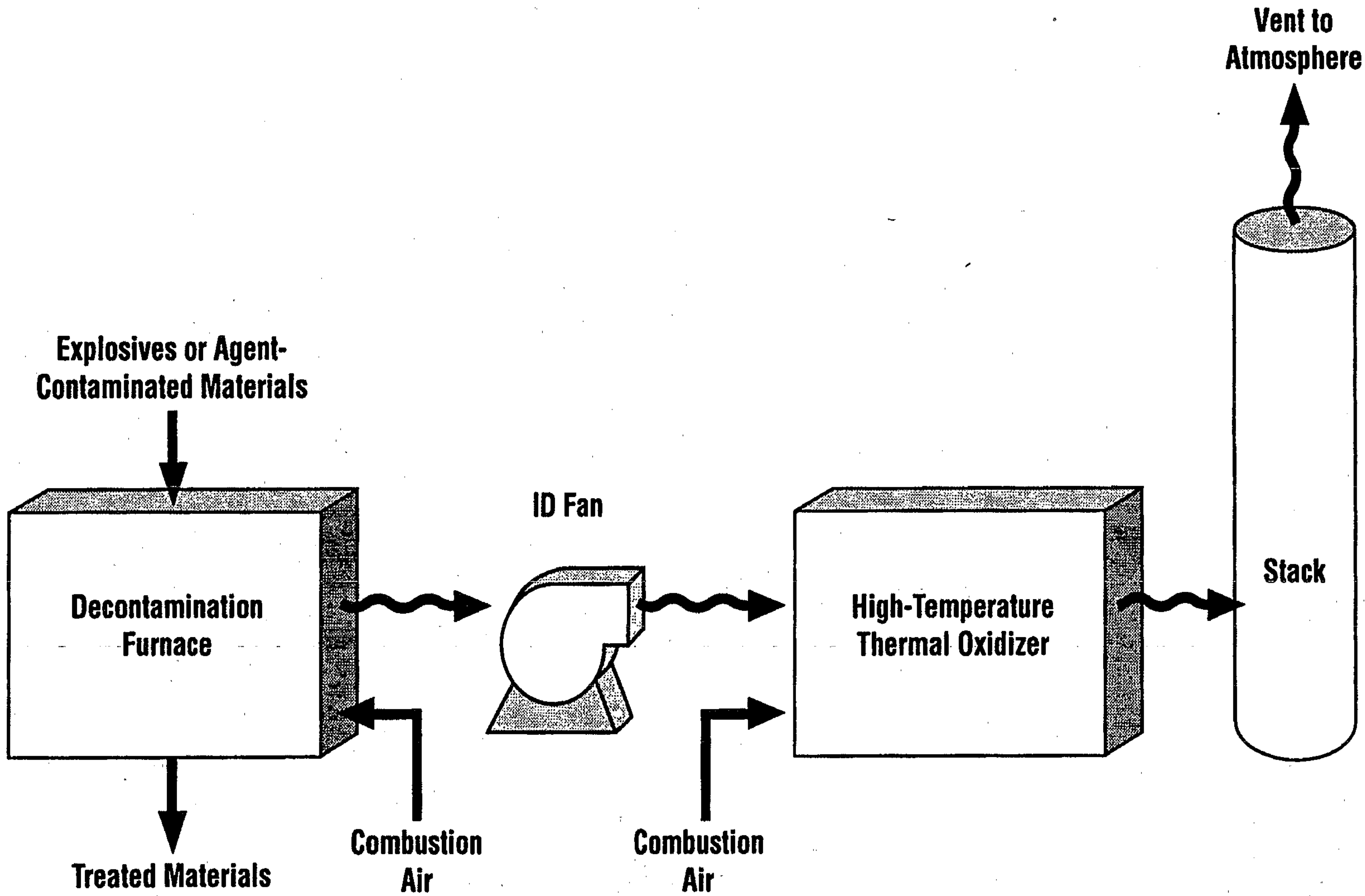


FIGURE 2-1 HGD SYSTEM GENERAL ARRANGEMENT

WESTON MANAGERS DESIGNERS/CONSULTANTS



96P-2957-1 9/18/96

FIGURE 2-2 HGD SYSTEM PROCESS FLOW

fuel valves automatically open and the main flame is lit. The burner flame is acknowledged through the flame scanner. Failure to detect a flame signal once operations begin results in an automatic shutdown of gas flow to the furnace.

Gas flow to the furnace is controlled automatically based on the furnace chamber temperature. Combustion air to the burner is set at a fixed rate that maintains excess air capacity to promote lower furnace chamber temperatures between 300 and 700 °F.

A local control panel, located on the furnace skid, allows a few operating tasks to be performed locally. For example, an emergency stop pushbutton is located on this panel. However, despite the local panel, all furnace monitoring and control is accomplished through the remote control panel during decontamination operations.

The HGD process is a batch process. Each batch run involves:

- Loading the furnace.
- Starting the I.D. fan.
- Starting and heating the thermal oxidizer to 1,800 °F.
- Selecting and programming a furnace treatment temperature and soak time.
- Starting and heating the furnace to the selected treatment temperature.
- Treating contaminated materials at the selected treatment temperature.
- Decreasing the furnace temperature to shutoff.
- Cooldown of the furnace load.
- Shutting down the thermal oxidizer.
- Shutting down the I.D. fan.
- Unloading treated materials from the furnace.

All contaminated materials treated by the transportable HGD system must be manually loaded and unloaded. Loading materials into the furnace involves placing the contaminated materials onto racks and then loading the racks into the furnace using a forklift. A full furnace load consists of a total of **3,000 lb** of contaminated materials. This load limitation is based on the strength of the refractory floor and the required thermal input to heat the load. The 3,000 lb includes the weight of the materials plus the weight of the racks used to hold the contaminated materials in the furnace during treatment.

A total explosive limit of no more than 1 lb total explosives contamination per 3,000 lb of contaminated material (one furnace load) was imposed by permitting limitations established by the State of Alabama. The standard design and construction of the furnace exceeds this limitation; however, it is strongly suggested that proper explosion rating calculations be performed by qualified personnel before increasing the explosives load limitation of the furnace beyond 1 lb.

Because the furnace is manually loaded, the furnace has been equipped with a number of safety features:

- A protective cage mounted at the burner outlet.
- A kick-out door.
- Door switch (ZSO-208).

The protective cage is located inside the furnace, at the top of the furnace chamber. Its location prevents the placement or stacking of contaminated materials directly in front of the burner flame. The kick-out door, which is located within the main furnace door, is provided to allow a means of escape from the furnace chamber should personnel accidentally become locked inside the furnace. Door switch ZSO-208 is associated with the main furnace door and supports a control interlock condition that prevents system startup unless the main furnace door is closed.

Temperature of the furnace exit-gas is monitored by three separate temperature transmitters connected to a temperature controller. The controller maintains the desired furnace temperature by automatically adjusting fuel flow to the burner. An independent high-temperature switch provides over-temperature protection for the furnace. The furnace chamber temperature is documented on a real-time basis, by a circular chart recorder located on the furnace remote control panel.

The temperature of the treated material is measured by five thermocouples, which are connected to their respective temperature transmitters through a jack panel located on the furnace. The jack panel has room for up to 12 load thermocouples; however, only five transmitters were used to support treatment operations. Seven additional transmitters can be installed, if required. The five transmitters are connected to the data logging and monitoring system, where the transmitter signals are recorded for archiving and future use, and trended by a real-time graphics display, located in the control area.

2.2 I.D. FAN, THERMAL OXIDIZER, AND STACK

The thermal oxidizer system was furnished by Arrtech Environmental Systems, Inc., of Tulsa, Oklahoma. The thermal oxidizer system consists of the following elements:

- I.D. Fan.
- Thermal Oxidizer Combustion Chamber.
- Burner and Gas Train.
- Air Pre-Mix System.
- 24-Foot Exhaust Stack with an 8-Foot Extension.
- Local Control Panel.
- Remote Control Panel.

The thermal oxidizer has a horizontal combustion chamber equipped with a 2.75-million-Btu-per-hour burner. The system, with the exception of the remote control panel and stack, is skid-mounted for transportability. The equipment skid is approximately 29 feet long by 7.5 feet wide. The oxidizer is nominally designed to thermally treat approximately 3,400 lb/hr of contaminated off-gases from the furnace at a treatment temperature of 1,800 °F for a minimum residence time of 2 seconds. The maximum capacity of the thermal oxidizer is equivalent to the maximum capacity of the I.D. fan, which is rated for 4,758 lb/hr at 70 °F.

The thermal oxidizer combustion chamber is constructed of carbon steel and lined with a ceramic-fiber refractory. A turbulator, located halfway down the combustion chamber length, provides maximum combustion efficiency by creating turbulent flow conditions within the combustion chamber.

The burner assembly consists of a Maxon Air Flow Model LV5 gas manifold burner with an HG-4 mixer. The pilot and burner flames are monitored by a pilot and flame UV scanner system. Once all system interlocks are confirmed and a pilot flame is established, the main fuel valves automatically open and the main burner ignites. The burner flame is acknowledged through a flame scanner. Failure to detect a flame signal once the main flame has lit results in an automatic shutdown of fuel flow to the thermal oxidizer.

The Maxon burner is designed to use oxygen from the furnace exit-gas stream for combustion; however, a combustion air fan has been supplied with the burner system to provide pre-mix air to the burner in order to maintain excess oxygen levels in the combustion zone of the thermal oxidizer at all times. A temperature transmitter connected to a temperature controller monitors and controls the combustion chamber exit-gas temperature by modulating the fuel gas control valve.

Furnace exit-gases are directed into the thermal oxidizer combustion chamber through the I.D. fan. The I.D. fan is a centrifugal-type fan manufactured by Chicago Blower and is rated for 2,250 cubic feet per minute (cfm) at 650 °F. The I.D. fan has been sized to maintain a negative 0.5 inches water column (in. w.c.) of pressure in the furnace to prevent fugitive emissions and force the furnace exit-gas stream through the thermal oxidizer combustion chamber and out of the exhaust stack. The I.D. fan inlet is connected to the furnace chamber through an interconnection duct.

The stack, which is located at the discharge end of the thermal oxidizer system, is approximately 24 feet high with a 29-inch inside diameter (i.d.). The stack is shipped on its side, separate from the thermal oxidizer skid. The stack is outfitted with four test ports for periodic emissions sampling and one CEM port for continuous emissions monitoring of the system exit-gases. An 8-foot stack extension, containing four additional sampling ports, has been provided to support the ability to conduct a full suite of emissions tests during permit-related activities. The stack extension is not necessary for operations unless otherwise required by local permit.

2.3 CONTINUOUS EMISSIONS MONITORING (CEM) SYSTEM

The site-specific application of a CEM system will depend heavily on regulatory and facility operating requirements. The CEM system, which was used to support the transportable HGD system test programs at ALAAP, was a leased unit; therefore, the information provided below is for information only. This information can be used as a guide to procuring or leasing similar CEM system equipment to support future HGD projects.

The leased CEM unit was an extractive-type sampling system that had two fully operational sample systems with redundant analyzers and its own data acquisition and control system. The redundant analyzers were used as on-line backups to replace the primary analyzers in the event of calibration or analyzer failure. The CEM system was located in a self-contained, heated and air-conditioned trailer on the equipment pad near the HGD furnace. Refer to Figure 2-1.

The function of the CEM system is to sample, monitor, and log the gaseous emissions leaving the stack, and to sample, monitor, and log the exit-gases leaving the furnace during process operations. This sampling is accomplished by using one sample probe located at the stack and a second sample probe located at the interconnection duct. The combustion products that were continuously monitored at the stack by the CEM system during the test programs at ALAAP were CO, CO_2, O_2, NO_x, THC, and SO_2. The combustion products that were continuously monitored at the interconnection duct, between the furnace exit and thermal oxidizer inlet, were THC and NO_x.

A summary of the analyzers supplied with the leased CEM system and the manufacturer's performance specifications is presented in Table 2-1. A summary of the sample extraction and conditioning equipment that was provided with the leased CEM system is presented in Table 2-2.

2.4 REMOTE CONTROL AND SYSTEM INTERLOCKS

The HGD process is relatively simple to control. Furnace chamber temperature, thermal oxidizer temperature, and system draft are the process parameters that are critical to HGD system operations. To ensure operator safety while treating explosives-contaminated materials, all HGD system operations are controlled by the operator from the equipment-specific remote control panels located in the remote control area. No personnel are permitted on the equipment pad during system operations.

Each of the HGD system remote control panels were designed to be self-contained and able to operate independently of the other equipment panel. However, control interlock conditions have been installed to prevent system operations from starting or continuing when operating conditions pose an equipment-, treatment-, or safety-related problem. The interlocks create an interdependency between the furnace and thermal oxidizer systems that would not exist without the interlocks.

Critical operating parameters associated with the HGD process, including emissions data from the CEM, are monitored from the remote control area using the HGD data logging and monitoring system. Specifics regarding the data logging and monitoring system are provided in Subsection 2.5. Figure 2-3 illustrates the interconnection cabling, which allows both remote control operation and data logging and monitoring of the HGD system operating parameters.

Table 2-1
Summary of Continuous Emission Monitoring (CEM) Equipment

CEM Specifications	Parameter					
	O_2	CO_2	CO	NO_x	THC	SO_2
Number of CEMs	2	2	2	2	2	1[b]
Manufacturer Model Number	Servomex 1400	Infrared IR-730	Thermo Electron 48	Thermo Electron 10 AR	J.U.M. Engineers VE7	Bovar 721
Principle of operation	Paramagnetic	Nondispersive infrared absorption	Gas correlation filter infrared absorption	Chemiluminescence	Flame ionization detector	Nondispersive ultraviolet
Range **Accuracy**	0-25% ± 0.5%	0-20% ± 0.2%	0-500 ppm ± 2.5 ppm	0-250 ppm ± 2.5 ppm	0-100 ppm ± 1.0 ppm	
Analyzer stability over 24 hours (percent span)[a]	2.0%	1.0%	1.0%	1.0%	1.0%	

[a]Since the system is calibrated daily and the ambient temperature is maintained on-line at all times, this drift will be negligible.

[b]Each analyzer is dedicated to a sample point, no spare analyzer is provided.

Table 2-2

Sample Extraction and Conditioning Equipment

Item	Description	Performance Parameters	Locations
Sample probe and cooling section	Inconel tubing with 316 stainless-steel fittings.	Reduce gas temperature < 400 °F.	Sample port in thermal oxidizer exhaust stack (CO, CO_2, O_2, and NO_x, SO_2, THC). Sample port in furnace exhaust to duct (NO_x only).
Sample box	Carbon steel box with ceramic insulation and fitting connections for calibration gas introduction.	Maintains sample temperature at $\geq$ 300 °F.	Insulated closure adjacent to the sample port at the thermal oxidizer exhaust stack.
Sample line	Heated Teflon TFA tubing.	Maintain sample temperature at $\geq$ 300 °F.	Between sample location and CEM trailer, as required.
Main thermal oxidizer exhaust sample (for CO, CO_2, NO_x, SO_2, and O_2) conditioning system and auxiliary furnace exhaust sample (NO_x only)	Heated filter, pump, mechanical refrigeration chiller, condensate trap, coalescing filter, pressure regulator, and flow meters. Teflon and stainless-steel construction.	Exit dew point at $\geq$ 38 °F; removal of particulate > 0.3 micron.	In CEM trailer; draws wet sample directly from heated sample line; delivers cool, dry conditioned sample directly to CO, CO_2, NO_x, SO_2, and O_2 analyzers.
THC sample conditioning system, thermal oxidizer exhaust	Heated fine filter.	Removal of particulate > 0.3 micron.	Internal to THC analyzer; draws sample directly from heated sample line.

2.5 DATA LOGGING AND MONITORING SYSTEM

To allow for data acquisition and monitoring capabilities during process operations, data highway cabling must be installed, which interconnects the local furnace and thermal oxidizer system control panels, the remote furnace and thermal oxidizer control panels, the CEM monitoring system, and the remote control area-based personal computer (PC). The data highway cable daisy-chains between communication interface cards in the remote control area PC, and modules located at the CEM and at each of the local and remote control panels. The RS-485 I/O cards provide the interface necessary to transfer process instrument data (4-20 mA signals) from the field instrument to the remote control area PC. Data received at the remote control area PC are then used by the data logging and monitoring program to provide system archiving, real-time trending, and up-to-the minute process operating values. This scheme is illustrated by the Data Logging and Monitoring System illustration in Figure 2-4.

The data acquisition and monitoring system (data logger) used to support data logging and monitoring is a Windows-based program operated from a Pentium platform. The program allows the operator to:

- View and monitor real-time operational data on a graphical display illustrating the system equipment.
- Track historical operating data (trends) for selected process parameters.
- Archive operational data from each test run for later reduction and analysis.

The data logging and monitoring system uses the GENIE software package, which was written and supplied by American Advantech Corp. of Sunnyvale, California. GENIE software must be programmed by the user, and was programmed by WESTON to support the data acquisition needs of the HGD system equipment. Although the software capability exists, GENIE was not programmed for interactive control of the HGD equipment because interactive, remote system control is accomplished through the use of the equipment-specific remote control panels located in the remote control area.

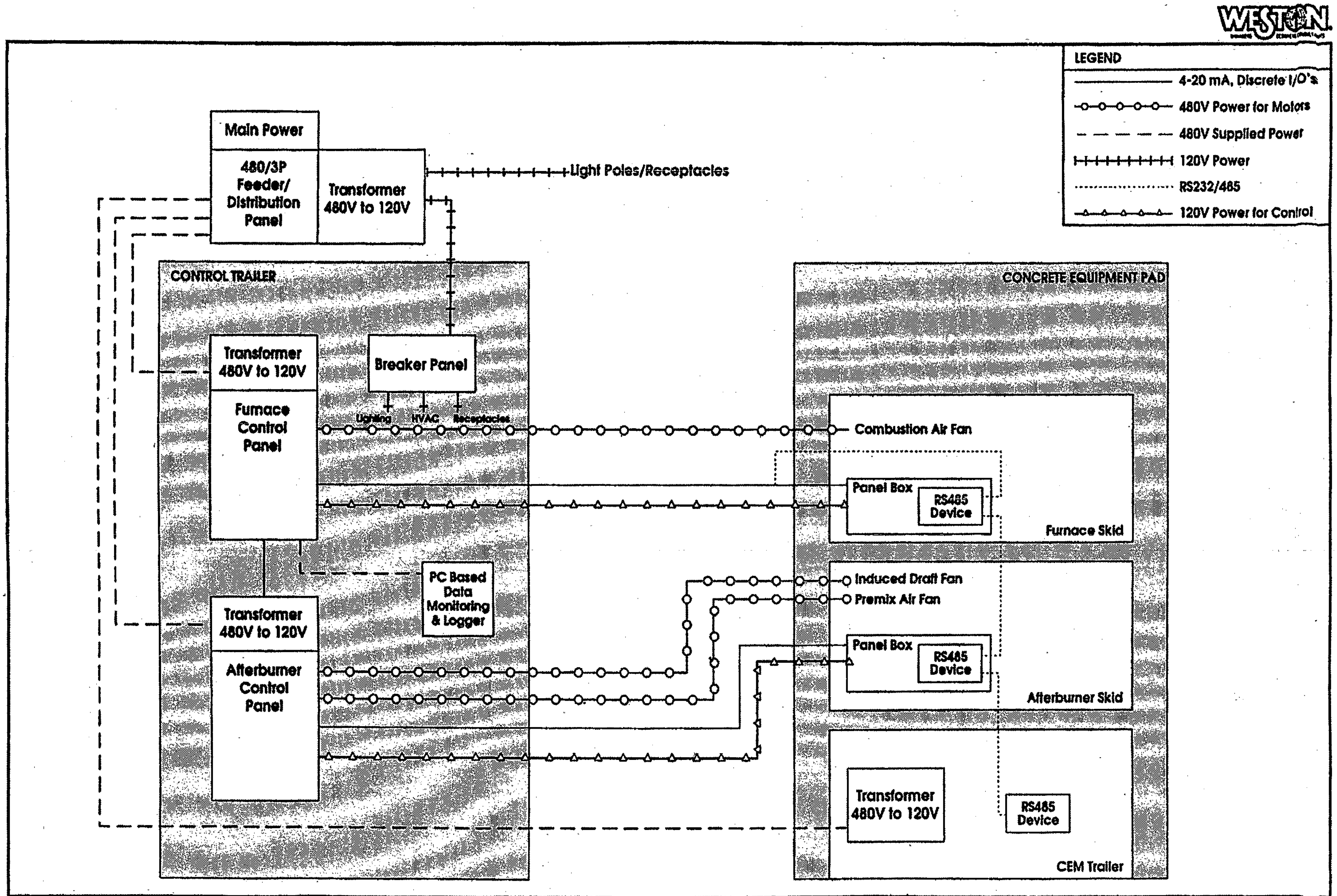


FIGURE 2-3 INTERCONNECTION WIRING DIAGRAM

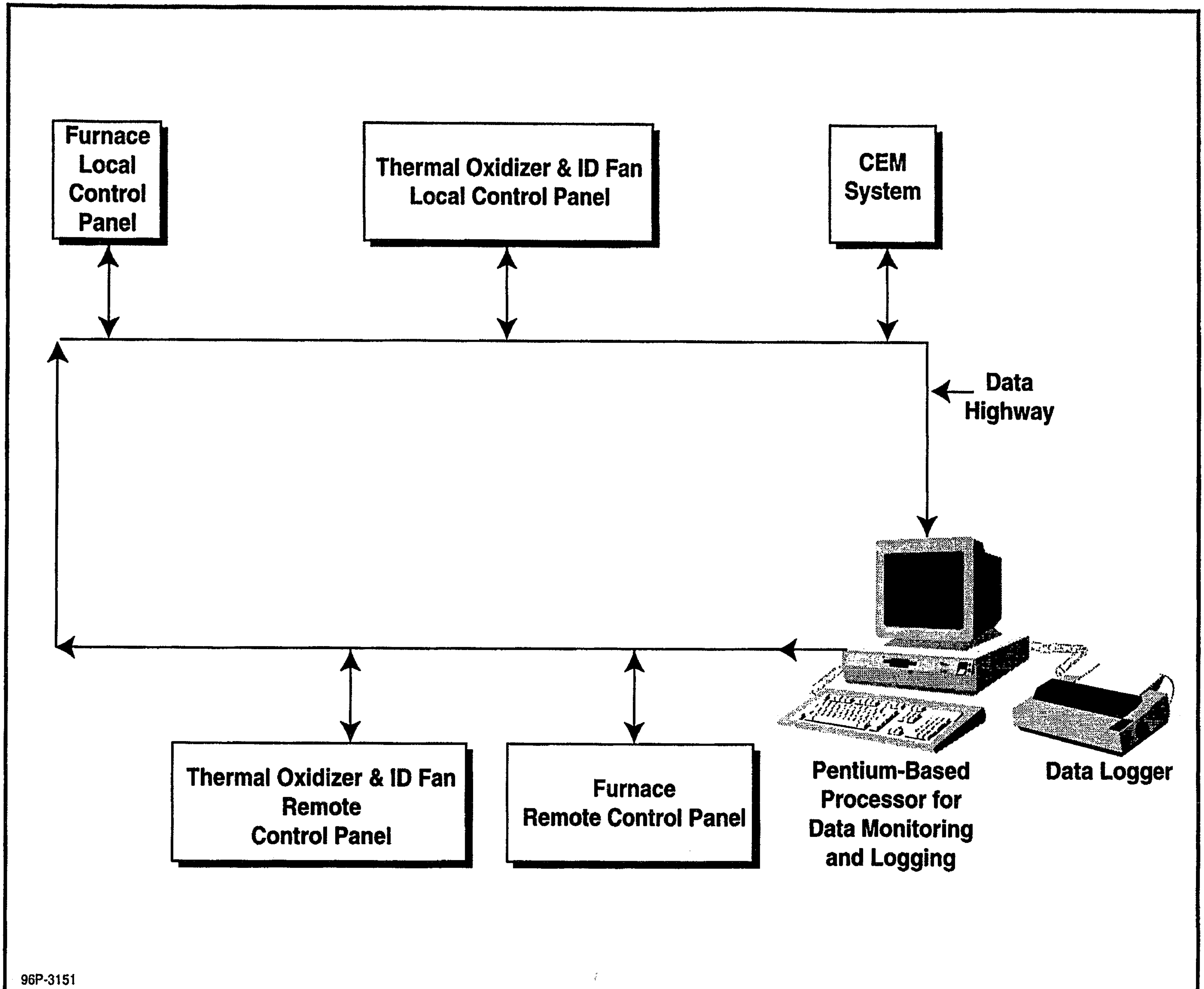


FIGURE 2-4 HGD SYSTEM DATA LOGGING AND MONITORING SYSTEM

3. INSTALLATION REQUIREMENTS

3.1 INSTALLATION REQUIREMENTS

As illustrated in Figure 2-1, the overall physical dimensions of the HGD system are relatively small and require minimal real estate (60 feet by 75 feet). However, in selecting the proper installation, environmental and safety requirements directly associated with the contaminant to be treated must be considered. For example, the installation must meet quantity-distance requirements associated with storage and use of explosives, as well as static electricity control and grounding requirements as defined by AMC-R-385-100 and AR 385-64. In the case of chemical contamination, quantity-distance requirements are not an issue; however, the installation must address applicable chemical hazards standards and recommendations. In all cases, National Fire Protection Association (NFPA) requirements must be met. Stormwater runoff and management must be addressed, as required by local regulation.

Figure 3-1 illustrates the site layout used for the demonstration and validation testing of the HGD system equipment installed at ALAAP. In accordance with AMC-R-385-100 and AR 385-64, the HGD equipment was located a minimum of 670 feet away from any manned location (i.e., remote control area buildings, etc.) and a minimum of 350 feet from a railroad or active roadway. The propane fuel storage tank was located 100 feet from the HGD equipment in accordance with NFPA requirements. All stormwater runoff from the equipment pad was collected and directed to an existing water treatment plant associated with an unrelated ongoing remediation effort at ALAAP.

3.2 REGULATORY PERFORMANCE STANDARDS

The HGD process is classified as a thermal treatment system. Regulatory performance standards for processing hazardous and toxic wastes using a thermal treatment system are outlined in Chapter 40 of the Code of Federal Regulations (40 CFR).

The transportable HGD system is designed to meet all applicable regulatory performance standards contained in the following sections of 40 CFR:

- Resource Conservation and Recovery Act (RCRA) incinerator standards specified in 40 CFR, Part 264, Subpart O.
- Miscellaneous Unit standards specified in 40 CFR, Part 264, Subpart X.
- Boiler and Industrial Furnace standards specified in 40 CFR, Part 266, Subpart H.

- Toxic Substances Control Act (TSCA) incinerator standards specified in 40 CFR, Part 761.70(b).

3.3 REGULATORY APPROVAL REQUIREMENTS

Federal and state regulatory agency approval must be obtained prior to the start of any operations using the transportable HGD system equipment. Requirements for approval will primarily depend on:

- Classification of the site with regard to the Comprehensive Environmental Response and Liability Act (CERCLA).
- The type of contaminants to be treated (RCRA, TSCA, or nonhazardous).
- The levels of contaminants (higher concentrations of contaminants may trigger air emissions limitations, which vary throughout the country).

Permit/approval requirements* for an HGD treatment system are expected to be as follows:

Type of Waste	CERCLA Site	Non-CERCLA Site
RCRA	Part B Permit State Air Permit	Part B Substantive Technical Information Requirements State Air Permit Substantive Technical Information Requirements
TSCA	TSCA Permit State Air Permit	TSCA Permit Substantive Technical Information Requirements State Air Permit Substantive Technical Information Requirements
Nonhazardous	State Air Permit	State Air Permit Substantive Technical Information Requirements

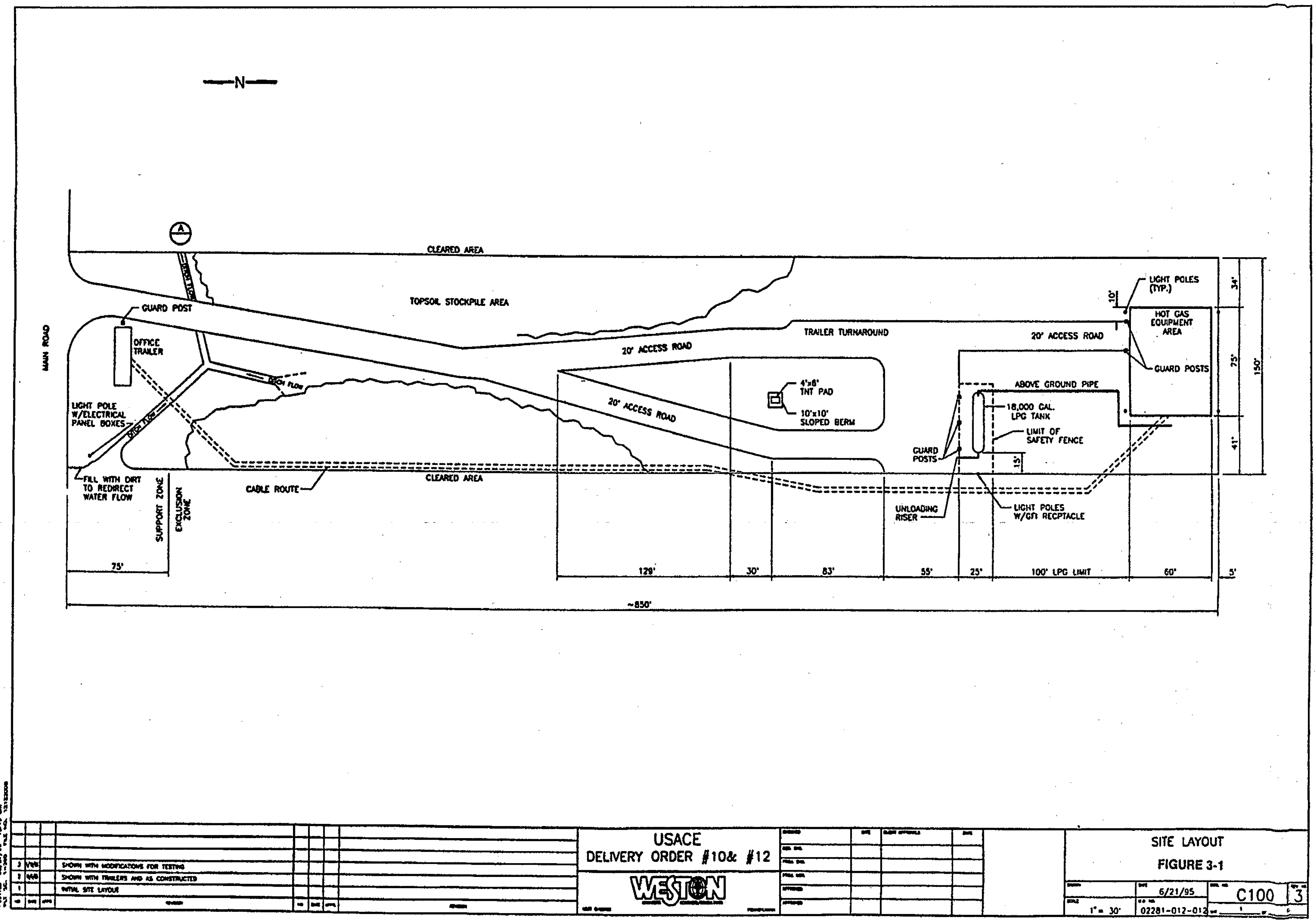
3.4 UTILITY REQUIREMENTS

At a minimum, the HGD system equipment requires both electricity and fuel in accordance with the requirements noted below:

Electrical: 90-amp service, at 480 VAC, 3 phase, 60 hertz

Fuel: Natural gas or propane, 3.75 million Btu/hour (37.5 therms/hour) at 20 psig

* Federal and state regulatory agencies must be contacted to verify permit/approval requirements.

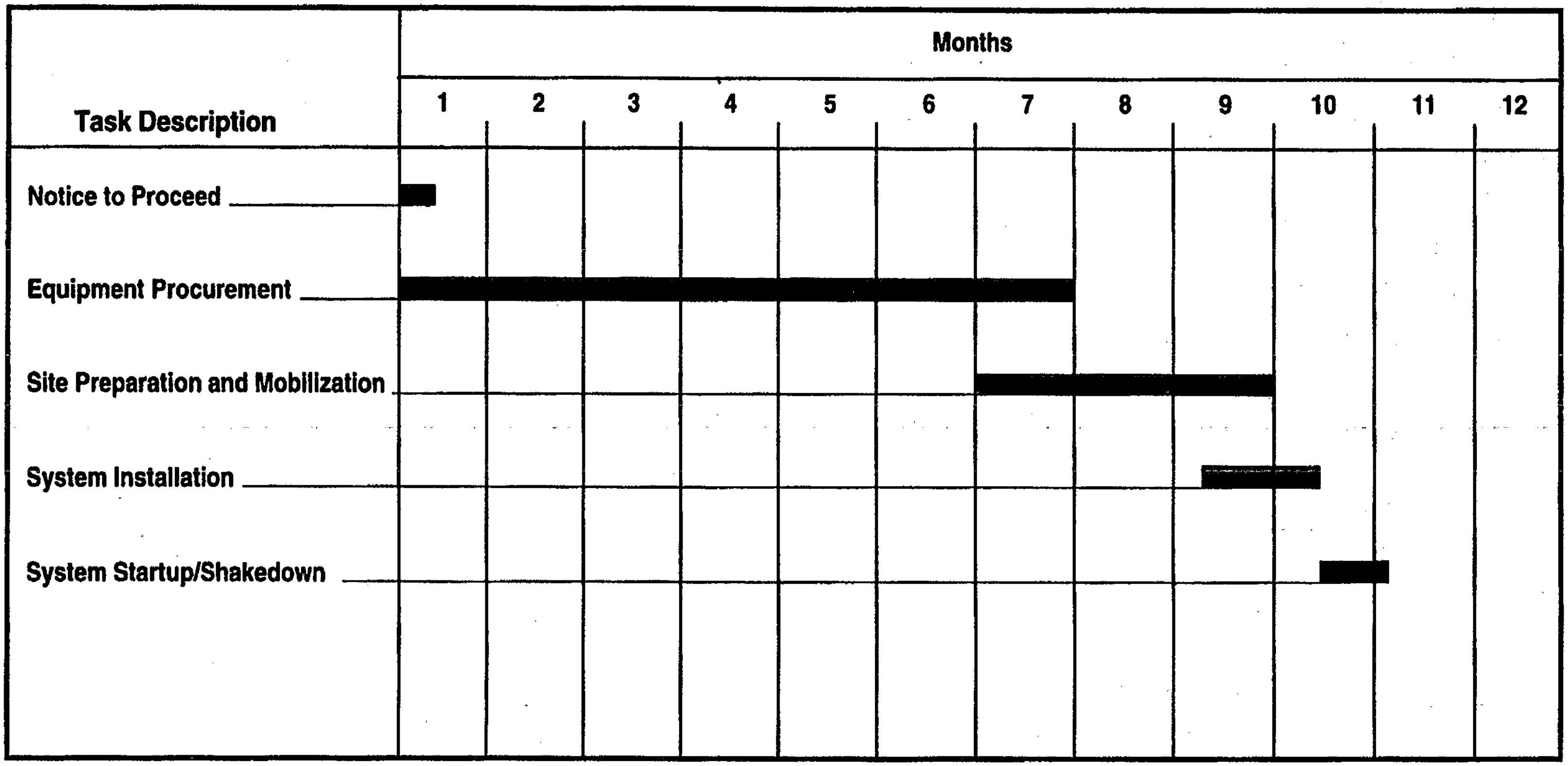


N
MAIN ROAD
CLEARED AREA
TOPSOIL STOCKPILE AREA
GUARD POST
OFFICE TRAILER
LIGHT POLE W/ELECTRICAL PANEL BOXES
FILL WITH DIRT TO REDIRECT WATER FLOW
SUPPORT ZONE
EXCLUSION ZONE
CABLE ROUTE
20' ACCESS ROAD
TRAILER TURNAROUND
4'x8' TNT PAD
10'x10' SLOPED BERM
ABOVE GROUND PIPE
18,000 GAL. LPG TANK
LIMIT OF SAFETY FENCE
GUARD POSTS
UNLOADING RISER
LIGHT POLES W/GFI RECPTACLE
LIGHT POLES (TYP.)
HOT GAS EQUIPMENT AREA
75'
129'
30'
83'
55'
25'
100' LPG LIMIT
60'
5'
~850'
10'
15'
34'
75'
41'
150'
3 SHOWN WITH MODIFICATIONS FOR TESTING
2 SHOWN WITH TRAILERS AND AS CONSTRUCTED
1 INITIAL SITE LAYOUT
USACE
DELIVERY ORDER #10& #12
WESTON
SITE LAYOUT
FIGURE 3-1
6/21/95
1" = 30'
02281-012-012
C100
3

Other utilities, such as telephone service or water, are not necessary for the operation of the HGD system, but may be required to meet site-specific health and safety requirements. The daily operating schedule may require site lighting for night-time operations. Water should be considered for periodic equipment washdowns and cleanup.

3.5 PROCUREMENT AND INSTALLATION SCHEDULE

A generic project schedule to procure and install a transportable HGD system is illustrated in Figure 3-2. This schedule is based on the actual project schedule to procure and install the transportable HGD system at ALAAP. Please note schedule task durations may vary depending on project or site-specific requirements.



96P-3208 9/20/96

FIGURE 3-2 HGD SYSTEM PROJECT SCHEDULE

4. HGD SYSTEM COST

The total costs associated with the transportable HGD system can be broken down into the following cost items, and are further detailed in Subsections 4.1 through 4.4.

- Capital equipment costs.
- Installation and startup costs.
- Operating costs.
- Validation testing costs.

4.1 CAPITAL EQUIPMENT COSTS

All capital equipment costs provided in this subsection are based on the skid-mounted, transportable HGD system that was procured for USAEC in fiscal 1995. All instrumentation and electrical systems supplied with the transportable HGD equipment were capable of remote and local operations, and qualified to operate in National Electrical Code (NEC) and NFPA Class 1, Division 2, Group D environments.

Furnace $156,000

Includes furnace, 1 million Btu/hr gas-fired burner, burner controls, combustion air blower, and local and remote control panels.

Thermal Oxidizer $180,000

Includes 2.75 million Btu/hr gas-fired thermal oxidizer, stack, air pre-mix system, and local and remote control panels.

Interconnection Duct $5,500

Includes materials and fabrication costs.

I.D. Fan $9,000

Centrifugal-type rated for 2,250 cfm at 650 °F (700 °F maximum operating temperature) remote controlled variable frequency drive.

Miscellaneous Equipment $35,000

Power and instrument cables, computers, software, treatment racks, uninterruptable power supply.

Continuous Emission Monitoring System (Optional) $286,000

Extractive-type, redundant system for monitoring O_2, CO, CO_2, THC, SO_2, and NO_x. System meets 40 CFR 60, Appendix A and B requirements.

Control Trailer (Optional)

8 feet by 40 feet with office space and restroom. $18,000

4.2 INSTALLATION AND STARTUP COSTS

Installation costs will vary from site to site and from job to job because of local conditions, labor costs, and equipment transportation costs. Items that should be considered in estimating installation costs are identified in Subsections 4.2.1 through 4.2.3.

4.2.1 Site Preparation

Site preparation costs can be expected to vary, depending on the location and condition of the site to be used. Site preparation items can also have a significant impact on installation costs, especially if a selected site is undeveloped. Site preparation items that may be required prior to mobilization of the HGD equipment to the selected site include the following:

- Site clearing and grubbing.
- Site grading.
- Installation, static control, lightning protection grid, and grounding grid.
- Equipment pad installation.
- Installation of site lighting.
- Installation of an electrical service.
- Installation of telephone service.
- Installation of a fuel source.
- Installation of water service.
- Installation of sanitary sewer system.
- Installation of fire protection.

4.2.2 Transportation and Mobilization to Site

The transportable HGD system is mobilized using three low-boy-style trailers (one each for the furnace, the thermal oxidizer, and the stack and miscellaneous equipment). A low-boy style trailer would be required for either the CEM or the control trailer should either item be required to support operations. The skid-mounted equipment can be removed from the trailers, by a crane or heavy forklift, and placed on an equipment pad, as required for operations. A 1-day crane or heavy forklift rental is adequate to support this operation.

4.2.3 System Shakedown and Startup

System shakedown to verify electrical connections, instrument calibrations, and general system operating integrity should be performed prior to actual treatment of contaminated materials by the HGD system equipment. Approximately four persons, for 3 weeks, are required to perform shakedown. Shakedown operations include:

- Installation of interconnecting instrument and control cabling.
- Instrument calibration and checkouts.
- System functionality testing.

4.3 OPERATING COSTS

The pricing listed below is based on one transportable HGD system operated at ALAAP between December 1995 and March 1996. Costs are expected to vary from site to site depending on the costs of labor and utilities and selected operating conditions.

Electricity:	$100/day per unit
Propane:	$725/day per unit
Propane delivery system equipment (15,000 GWC storage tank):	$40/day per unit
CEM calibration gases:	$60/day per system
Incidentals and miscellaneous parts:	$60/day per unit
Labor (assume 3 workers: 1 control area operator and 2 laborers/mechanics):	$2,352[1]/day

All costs per day noted above assume a 24-hour day and a minimum processing rate of 4 batch runs per 24-hour day.

4.4 VALIDATION TESTING COSTS

Depending upon site-specific regulatory and facility requirements, validation testing including stack emissions testing may be required. Based upon stack emissions testing conducted at ALAAP, the estimated cost for validation testing is approximately $90,000 and can be expected to last approximately 7 days. This cost assumes standard laboratory turnaround times.

[1] Labor costs per 24-hour day assumes all labor is employed directly by the user at the following rates: $26.00/hr for control area operators; $15.00/hr for laborers; and a 1.75 multiplier for taxes and fringes.

5. SYSTEM PERFORMANCE

5.1 DEMONSTRATION AND VALIDATION TEST PROGRAMS

A successful demonstration test program, using the transportable HGD system equipment and clean, noncontaminated materials, was conducted between 4 and 8 December 1995 at ALAAP. The demonstration test was conducted to verify:

- General system performance.
- Ease of operation.
- System repeatability.

As a result of demonstration test operations, system modifications were made with the following results:

- Minimization of furnace cold spots.
- Improvement of the overall heat distribution profile within the furnace.
- Reduction of furnace heat-up times to < 2.5 hours.
- Maximization of system operating efficiencies.

After completing the demonstration tests and modifications, a validation test program was conducted from 4 January to 15 March 1996 at ALAAP. The validation test program was conducted under the federal guidelines regulating a treatability study; therefore, no permitted limits for system emissions or operating conditions were specified. The objectives of the validation test program were as follows:

- To verify the effectiveness of the HGD system equipment in decontaminating explosives (TNT, RDX, and Tetryl).

- To define optimum processing times and temperatures for TNT-, RDX-, and Tetryl-contaminated materials.

- To collect air emissions data to support future system permitting efforts.

Eighteen test runs were conducted at treatment temperatures ranging from 300 °F to 600 °F. A full furnace load was composed of 3,000 lb of TNT-, RDX-, and Tetryl-contaminated metal piping, clay piping, and concrete block, as well as explosives-contaminated debris from another remediation project at ALAAP. No more than 1 lb total explosives was processed in any test run.

5.2 RESULTS OF THE VALIDATION TEST PROGRAM

The validation test of the transportable HGD system equipment was a success. Results of the tests are highlighted below.

- The optimum operating conditions for achieving complete removal of TNT, RDX, Tetryl, and their breakdown constituents to levels below method detection levels is:
  - 250 °F/hour ramp to 600 °F treatment temperature with a 1-hour soak.
- NO_x monitoring at the furnace exit indicates that the bulk of explosives decontamination occurs during the furnace ramp (250 °F to 600 °F) period.
- Post-treatment analytical testing consistently indicated removal efficiencies for TNT, RDX, and Tetryl of 99.9999%, based on an initial quantity of 1 lb total explosives.
- The HGD process effectively processed explosives-contaminated debris to microgram quantities while achieving at least 99.99% destruction and removal efficiency.
- The transportable HGD system is a fully instrumented and monitored process which together with the control system ensures repeatability test after test.

5.3 EMISSIONS RESULTS

Stack emissions data were collected during the first three validation test runs and CEM data were collected during all test runs. Results indicate the following:

- No detectable explosives contamination was observed in the stack emissions from the HGD system equipment.
- Volatile and semivolatile sampling was conducted to evaluate for products of incomplete combustion and breakdown compounds. Results indicated:
  - Only acetone, which was used to make the spike mixtures, was found in any significant quantities.
  - Only nontarget semivolatile compounds were identified. Semivolatile samples were analyzed for target compound list compounds.

A summary of the HGD system emissions results is located in Table 5-1.

Table 5-1

Transportable HGD System Equipment Emissions Results

Hazardous Air Pollutant	Existing Standard (as of June 1996)	Test Run Average
Total hydrocarbons (ppmv)	12	<1.0
Carbon monoxide (ppmv)	100	<1.0
Particulate (gr/dscf at 7% O_2)	<0.08	0.0004
Hexavalent chromium (µg/dscm)	NA	12.18
Low-volatility metals (µg/dscm) (antimony, arsenic, beryllium, chromium)	210 (currently) 60 (proposed)	15.03
Semivolatile metals (µg/dscm) (lead and cadmium)	270 (currently) 62 (proposed)	2.33
Total chlorine (ppmv) (HCl and Cl_2)	280	0.36
Mercury (µg/dscm)	50	0.04
Dioxins/furans (ng TEQ/dscm)	0.2	0.03

5.4 CONTINUOUS EMISSIONS MONITORING RESULTS

Total hydrocarbons (THC), sulfur dioxide (SO_2), nitrous oxides (NO_x), carbon monoxide (CO), and carbon dioxide (CO_2) emissions measured by the CEM system were significantly below the limits usually associated with permitting.

NO_x levels monitored in the furnace exit-gas duct indicated increased NO_x activity during ramp-up periods and a return to baseline NO_x levels after the furnace chamber temperature reached approximately 400 °F. Future studies with HGD hope to use NO_x levels in the furnace exit-gas as an indicator of a completed decontamination batch run.

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Centrifugal Shot Blast System at Chicago Pile 5 Research Reactor
Argonne National Laboratory, Argonne, Illinois

Centrifugal Shot Blast System at Chicago Pile 5 Research Reactor Argonne National Laboratory, Argonne, Illinois

Site Name: Chicago Pile 5 (CP-5) Research Reactor Argonne National Laboratory	**Contaminants:** Radioactive-contaminated paint	**Period of Operation:** 1/28/97 to 2/4/97
Location: Argonne, Illinois		**Cleanup Type:** Demonstration
Vendor: Mike Connacher Concrete Cleaning, Inc (509) 226-0315	**Technology:** Centrifugal Shot Blast: - Shot blast unit manufactured by George Fisher (GOFF®). Unit operated with two 1/4 horsepower, variable speed drives, and has a 13-inch cutting width. The vendor advertised production rate is 200-250 ft^2/hr. - HEPA-filter dust collection system manufactured by George Fisher (GOFF®). Six primary roughing filter cartridges, one secondary HEPA filter unit; vendor rated vacuum flow of 850 cubic ft/min	**Cleanup Authority:** Project performed as part of DOE's Large-Scale Demonstration Project, Office of Science and Technology, Deactivation and Decommissioning Focus Area
Additional Contacts: Susan C. Madaris Test Engineer Florida International University (305) 348-3727 Richard Baker DOE (630) 252-2647		**Regulatory Point of Contact:** Information not provided
Waste Source: Contaminated paint coating on concrete floor	**Type/Quantity of Media Treated:** Radioactively contaminated concrete floor - 800 ft^2 of concrete flooring covered with contaminated paint	
Purpose/Significance of Application: Demonstrate a modified centrifugal shot blast unit and compare results with those for mechanical scabbing		

Regulatory Requirements/Cleanup Goals:
The objective of the demonstration was to evaluate the performance of the modified centrifugal shot blast system to remove contaminated paint coating from 800 ft^2 of concrete flooring and to compare the results of this technology with those from the baseline technology of mechanical scabbing.

Results:
- Use of the dust collection system significantly reduced the amount of airborne dust generated during the blasting process and has the potential to lead to the use of less respiratory protection and PPE requirements; the unit is self-propelled and has the potential to reduce operator fatigue; the unit can be adjusted to remove the coating layer only, specific layers of coating, or coating and up to ½ inch of concrete; the end-point condition of the surface in the demonstration was smooth, bare concrete.
- Reduced total fixed beta/gamma contamination levels from pre-demonstration levels as high as 5,300 dpm/100 cm^2 to below background levels (1,500 dpm/100 cm^2).
- Problems were encountered with the dust collection system assembly and disassembly and with steel shot escaping the unit. According to DOE, additional improvements are needed to make the unit safer and more efficient for use at a DOE facility.
- The main advantage of the modified centrifugal shot blast system over the baseline technology is the ability to simultaneously collect dust and debris using a dust collection system attached to the shot blast unit.

Centrifugal Shot Blast System at Chicago Pile 5 Research Reactor Argonne National Laboratory, Argonne, Illinois (continued)

Cost:
- The report presents a detailed cost analysis of this technology compared to the baseline technology.
- Cost analysis results show the total cost for centrifugal shot blast was higher than mechanical scabbing (about $23,000 versus about $13,000) and had higher costs for mobilization/demobilization and decontamination for the 800 ft^2 demonstration. However, because the incremental cost for centrifugal shot blast is lower, this technology was projected to be less expensive than the baseline for areas greater than 1,900 ft^2.

Description:
Concrete Cleaning, Inc. demonstrated a modified centrifugal shot blast system for removing radioactive contaminated paint from concrete flooring. This demonstration was part of the Chicago Pile-5 (CP-5) Large-Scale Demonstration Project sponsored by DOE, Office of Science and Technology, Deactivation and Decommissioning Focus Area, to demonstrate the benefits of using innovative and improved decontamination and decommissioning technologies. CP-5 was a heavy-water moderated and cooled, highly enriched, uranium-fueled thermal reactor designed to supply neutrons for research and was operated for 25 years before being shut down in 1979.

For this demonstration, Concrete Cleaning modified a standard centrifugal shot blast machine (manufactured by George Fisher) to increase efficiency and speed of substrate removal. Concrete Cleaning considers the modifications to be proprietary and has applied for a patent. The shot blast machine was equipped with a HEPA filter dust collection system that had been modified to replace the refuse pan provided by the manufacturer. The system was modified with a funnel-drum lid system that directed the waste directly into a standard waste drum. This modification reduced the potential for airborne releases by eliminating the need to transfer waste from the pan into the drum for disposal. As the unit was moved across the floor, the shot and substrate debris were vacuumed through the shot blast unit, and passed through an abrasive recycling system. The heavier shot was returned to the unit while the spent shot (too small in size to reuse) was sent to the dust collection system. The demonstration showed that the main advantage of the Concrete Cleaning centrifugal shot blast technology compared to mechanical scabbing was the simultaneous collection of dust and debris. The report includes a detailed comparison of the two technologies. In addition, the results of radiological surveys performed before and after the demonstration showed that blasting had reduced total fixed beta/gamma contamination levels from pre-demonstration levels as high as 5,300 dpm/100 cm^2 to below background levels (1,500 dpm/100 cm^2).

Several problems were encountered during the demonstration. Steel shot escaping from the unit presented a potential projectile hazard, the magnetic roller was not effective in collecting steel shot left on the floor, and there were problems with the dust collection system assembly and disassembly. According to DOE, additional improvements are needed to make the unit safer and more efficient for use at a DOE facility. The report includes results of a detailed cost analysis comparing the centrifugal shot blast technology with mechanical scabbing. While the baseline technology was less expensive for the scope and conditions of the demonstration, for areas larger than about 1,900 ft^2, the centrifugal shot blast technology was projected to be less expensive because of lower incremental costs.

SECTION 1

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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.

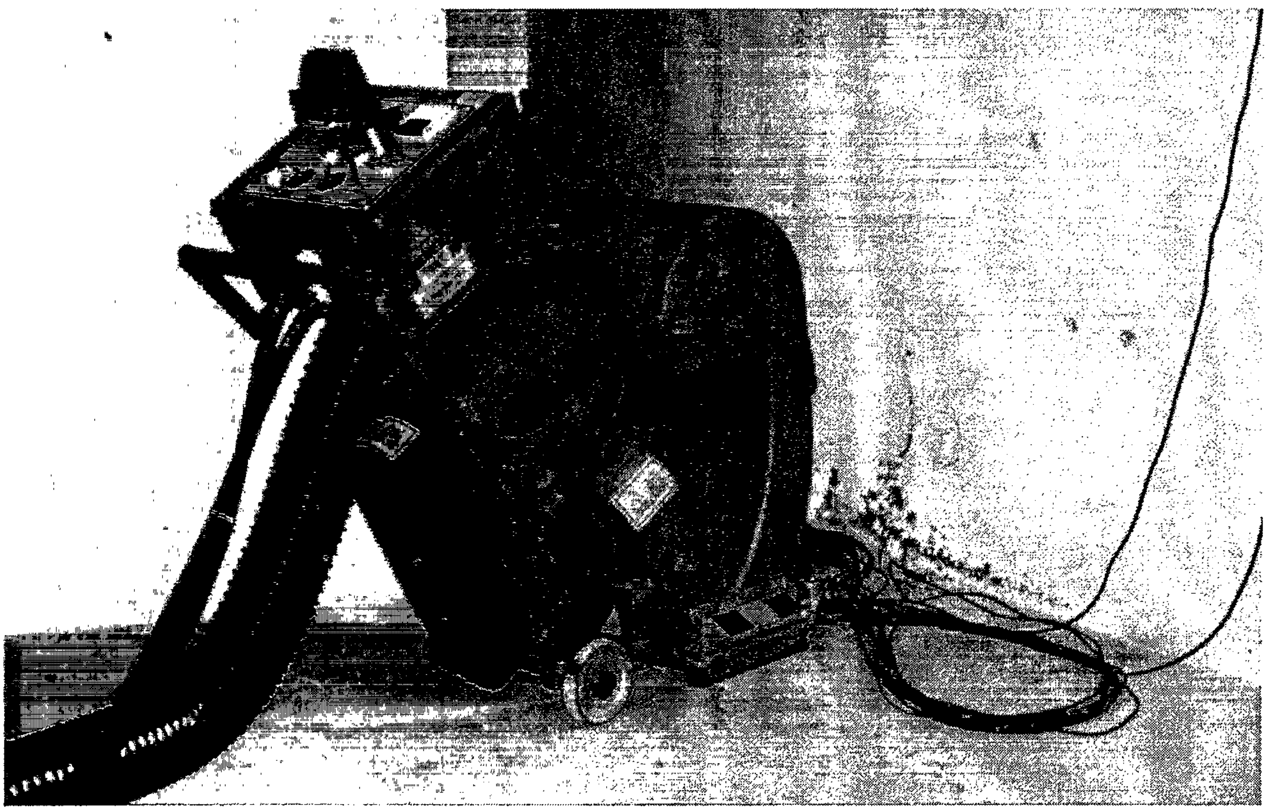

Figure 1. Centrifugal shot blast unit.

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.

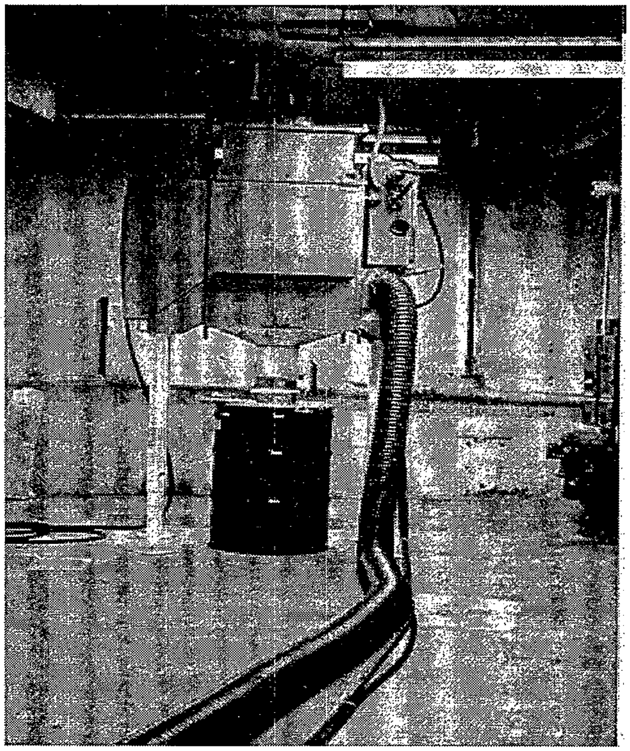

Figure 2. Dust collection system.

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.

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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.

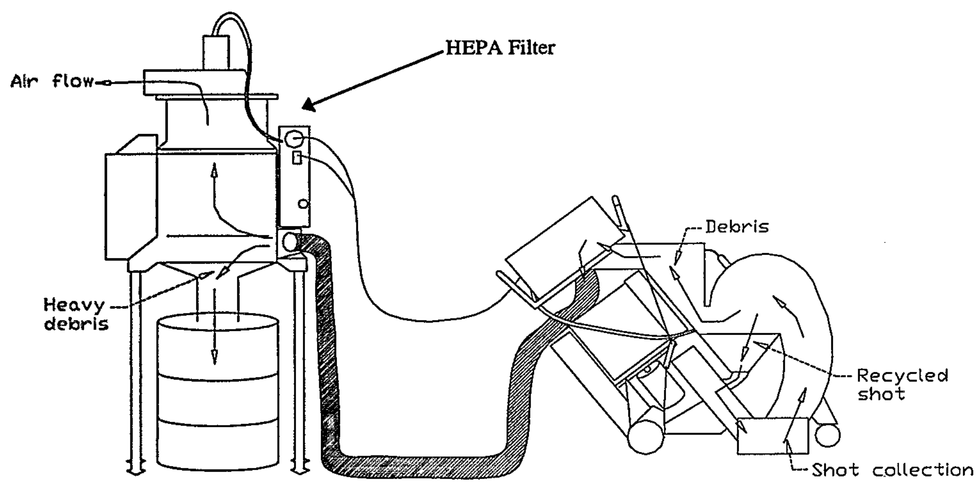

Figure 3. Schematic of the centrifugal shot blast system.

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

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.

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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

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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.

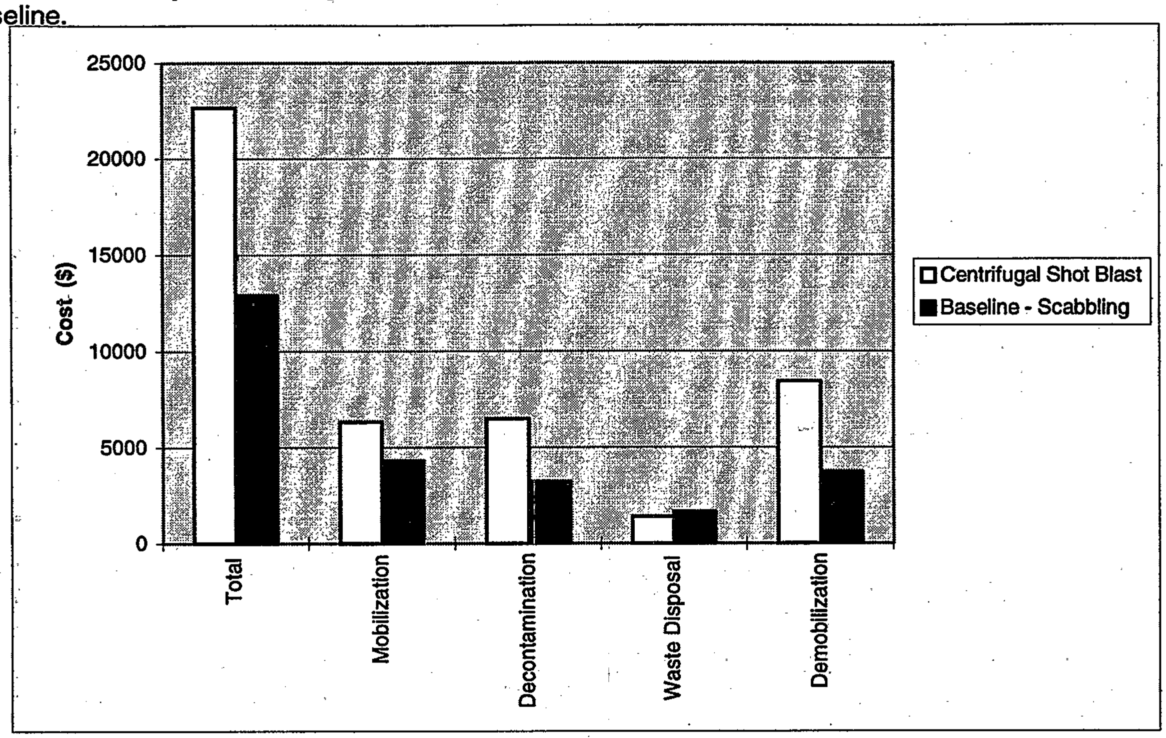

Figure 4. Technology cost comparison.

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 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

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

[redacted]

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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^2 as 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

[redacted]

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.

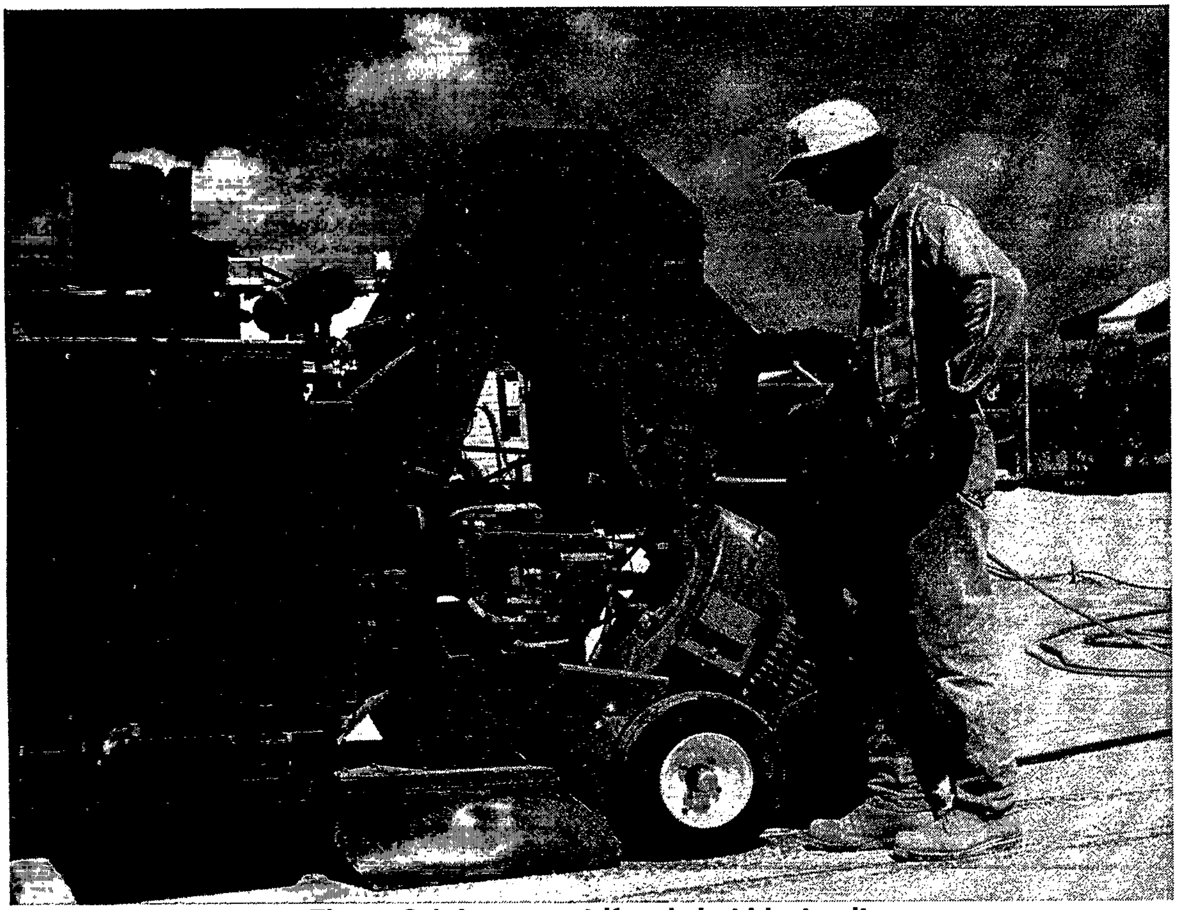

Figure C-1. Large centrifugal shot blast unit.

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

[redacted]

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

Rotary Peening with Captive Shot at Chicago Pile 5 Research Reactor
Argonne National Laboratory, Argonne, Illinois

Rotary Peening with Captive Shot at Chicago Pile 5 Research Reactor Argonne National Laboratory, Argonne, Illinois

Site Name:
Chicago Pile 5 (CP-5) Research Reactor
Argonne National Laboratory

Location:
Argonne, Illinois

Contaminants:
Radioactive-contaminated paint

Period of Operation:
1/28/97 to 2/4/97

Cleanup Type:
Demonstration

Vendor:
Peter J. Fritz
Michael W. Lovejoy
3M Abrasive Systems Division
(612) 736-3655/(612) 733-7181

West Environmental
Pentek, Inc
EDCO

Additional Contacts:
Ed Wiese
Cedric Andres
Argonne National Laboratory
(630) 252-2000

Technology:
Rotary Peening with Captive Shot:
- 3M Heavy Duty Roto Peen (HDRP) flaps supporting tungsten carbide shot mounted on a rotating hub
- EDCO CPM-4 concrete planer - cutting width of 5.5 inches and capable of rotating the Roto Peen at 1,800 rpm
- Pentek VAC-PAC® model 24 vacuum system - 600 ft^3/min; primary roughing filter cartridges with 95% efficiency at 1 micron; secondary HEPA filter with 99.97% efficiency at 0.3 micron
- Pb Sentry vacuum monitor (for vacuum pressure)

Cleanup Authority:
Project performed as part of DOE's Large-Scale Demonstration Project, Office of Science and Technology, Deactivation and Decommissioning Focus Area

Regulatory Point of Contact:
Information not provided

Waste Source: Radioactive-contaminated paint coating on concrete floor

Purpose/Significance of Application: Demonstrate Rotary Peening with captive shot and compare results with those for mechanical scabbing

Type/Quantity of Media Treated:
Radioactively contaminated concrete floor - 425 ft^2 of concrete flooring covered with contaminated paint

Regulatory Requirements/Cleanup Goals:
The objective of the demonstration was to evaluate the performance of Rotary Peening with Captive Shot to remove contaminated paint coating from 425 ft^2 of concrete flooring and to compare the results of this technology with those from the baseline technology of mechanical scabbing.

Results:
- Reduced radiological levels in 5 of 6 areas tested to below background levels. For one location, levels were reduced from 70,000 to 16,000 dpm/100 cm^2. A possible reason for the remaining radioactivity was a crack in the floor that trapped contamination (could not be removed superficially).
- Removed paint coatings at a rate of 71 ft^2/hr with a two-person crew and a 5.5-inch cutting width.
- Vacuum system performed sufficiently to maintain airborne radioactivity levels at background levels.
- Removed floor's paint coating with minimal concrete removal, resulting in minimal waste generation.
- The main advantage of the modified centrifugal shot blast system over the baseline technology is the ability to simultaneously collect dust and debris using a dust collection system attached to the shot blast unit.

Rotary Peening with Captive Shot at Chicago Pile 5 Research Reactor Argonne National Laboratory, Argonne, Illinois (continued)

Cost:
- The report presents a detailed cost analysis of this technology compared to the baseline technology.
- Cost analysis results show the total cost for Roto Peen with captive shot was 50% lower than the baseline of mechanical scabbing (about $4,500 versus about $9,500). The major contributor to the savings was that the Roto Peen with captive shot blast did not require a temporary enclosure (about $2,400).

Description:
3M's Rotary Peening with Captive Shot system was demonstrated at the Chicago Pile 5 (CP-5) Research Reactor at Argonne National Laboratory. This demonstration was part of the Chicago Pile-5 (CP-5) Large-Scale Demonstration Project sponsored by DOE, Office of Science and Technology, Deactivation and Decommissioning Focus Area, to demonstrate the benefits of using innovative and improved decontamination and decommissioning technologies. CP-5 was a heavy-water moderated and cooled, highly enriched, uranium-fueled thermal reactor designed to supply neutrons for research and was operated for 25 years before being shut down in 1979.

The 3M Heavy Duty Roto Peen (HDRP) flap consists of tungsten carbide shot attached to a flexible, heavy duty material and mounted on an aluminum rotating hub. As the hub rotates, the shot particles on each flap impact against the surface and mechanically fracture and remove coatings. A concrete planer (EDCO Model CPM-4), used to drive the Roto Peen, had a cutting width of 5.5 inches and was capable of rotating the Roto Peen at 1,800 rpm. The dust collection system was a Pentek VAC-PAC® model 24 vacuum system. A Pb Sentry vacuum monitor (proprietary design by West Environmental) was used to interrupt the electrical supply to the concrete planer when a variation in vacuum pressure at the CPM-4 was detected. The demonstration showed that the main advantage of the Roto Peen with captive shot technology compared to mechanical scabbing was the simultaneous collection of dust and debris. The report includes a detailed comparison of the two technologies. In addition, the Roto Peen technology reduced radiological levels to below background levels in all but one area. For one location, levels were reduced from 70,000 to 16,000 dpm/100 cm^2. The elevated readings were attributed to a possible crack in the floor which trapped contamination and could not be removed superficially. The technology removed paint coatings at a rate of 71 ft^2/hr, and removed floor's paint coating with minimal concrete removal, resulting in minimal waste generation.

The report includes results of a detailed cost analysis comparing the centrifugal shot blast technology with mechanical scabbing. Cost analysis results show that the total cost for Roto Peen with captive shot was 50% lower than the baseline of mechanical scabbing. The major contributor to the savings was that the Roto Peen with captive shot blast did not require a temporary enclosure.

SECTION 1

[redacted]

Technology Description

Roto Peen with captive shot removes coatings and surface contamination from concrete floors. The objective of treating radioactively contaminated concrete floors during the Deactivation and Decommissioning (D&D) process is to reduce the surface contamination levels to meet regulatory criteria for unrestricted use.

How it Works

Roto Peen uses centrifugal force to remove coatings and surface contamination from concrete floors. A series of 3M™ Heavy Duty Roto Peen flaps supporting tungsten carbide shot are mounted on a CPM-4 Concrete Planer provided by EDCO. The planer provides the correct rotational speed for the Roto Peen. A vacuum system, the VAC-PAC® Model 24 provided by Pentek, is then attached to the concrete planer. It is a pneumatically driven vacuum system with isolated filters that permit the waste generated to be collected directly into a drum. The system is also outfitted with a Pb Sentry from West Environmental to monitor vacuum pressure at the planer. This proprietary system will shut off electrical power to the concrete planer should the detected vacuum drop below a safe threshold. The EDCO Concrete Planer is designed to remove paints and other surface contaminants from flat, horizontal areas. It has a cutting width of 5.5 in and the depth of removal is determined by the rate of speed with which the unit is driven.

Demonstration Summary

The U.S. Department of Energy (DOE) Chicago Operations Office and DOE's Federal Energy Technology Center (FETC) jointly sponsored a Large-Scale Demonstration Project (LSDP) at the Chicago Pile-5 Research Reactor (CP-5) at Argonne National Laboratory-East (ANL). The objective of the LSDP is to demonstrate potentially beneficial D&D technologies in comparison with current baseline technologies. As part of the LSDP, Roto Peen with captive shot was demonstrated March 17-20, 1997, to treat a 20 x 25 ft area of radioactively contaminated concrete floor on the service level of the CP-5 building.

Handled by two CP-5 ANL operators, the 3M™ Roto Peen technology removed the coatings from a 425 ft^2 area at a rate of 71 ft^2/h. The coating removal left a uniform appearance on the Roto Peen finished surface. The radiological levels of the original floor were thus reduced from 70,000 to 16,000 $dpm/100cm^2$ on one hot spot and below or at background levels on the other parts of the area. There was no airborne generation detected.

Figure 1. 3M™ Roto Peen demonstration.

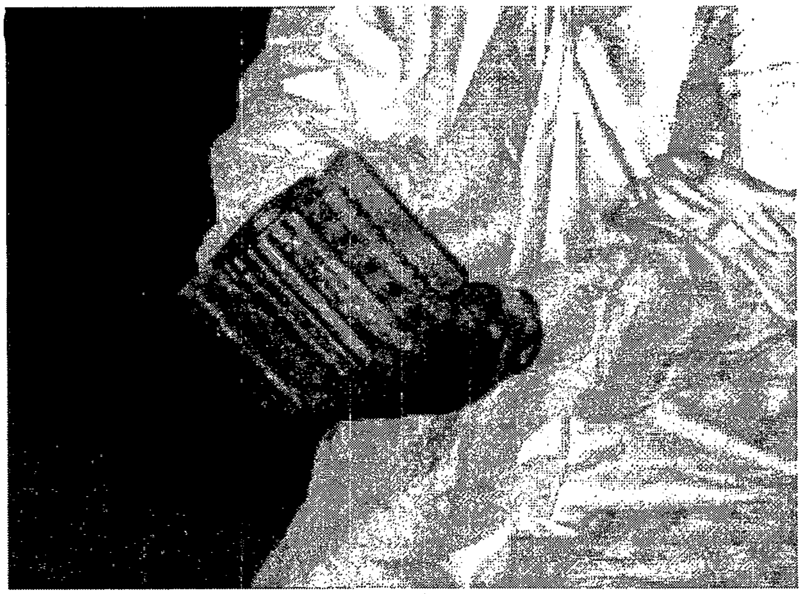

Figure 2. Heavy duty Roto Peen flaps.

Benefits

In comparison with the baseline technology, which is mechanical scabbling, the main advantage of the Roto Peen technology is that the dust and debris are collected simultaneously during the coating removal. Thus the amount of airborne and loose contamination generated is considerably reduced.

The 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., plastic tent) is erected over the area to be decontaminated to minimize the potential release of airborne dust and contamination.

Key Results

- The Roto Peen with captive shot technology was able to remove paint coatings at a rate of 71 ft^2/h with a two-person crew and a 5.5-in cutting width machine and reduce contamination levels on the floor to background levels.
- The vacuum system component of the Roto Peen technology performed sufficiently to maintain airborne radioactivity levels in the area of the demonstration at background levels. In contrast, the baseline technology of scabbling has the potential for high levels of airborne contamination.
- The Roto Peen technology was able to remove the floor's paint coatings with very little concomitant concrete removal. This resulted in minimal waste generation of 2.1 ft^3 of powder. The baseline technology of scabbling would result in higher waste generation because a measurable depth (¼ in to ½ in) of concrete is removed along with the floor coatings.

Technology Contacts

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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 Roto Peen with captive shot is 1812.

SECTION 2

The technology uses 3M™ Heavy Duty Roto Peen (HDRP) flaps supporting tungsten carbide shot mounted on a rotating hub. The particular unit demonstrated is supported by an EDCO CPM-4 concrete planer that maintains the correct rotational speed for the Roto Peen. This concrete planer is connected to a vacuum system, the VAC-PAC® model 24 provided by Pentek, and driven by an air compressor that remained outside the CP-5 facility during the demonstration. A Pb Sentry, from West Environmental, is mounted to the concrete planer and is used to monitor adequate vacuum pressure at the planer.

3M™ Heavy Duty Roto Peen

The 3M™ Heavy Duty Roto Peen flap consists of tungsten carbide shot attached to a flexible, heavy duty material and mounted on an aluminum hub. As the hub rotates, the shot particles on each flap impact against the surface, mechanically fracturing and removing coatings. The shot remains captive to the tool and under complete control by the operator.

Several different types of flaps are available for removing coatings from steel or concrete surfaces. Type A, for hard concrete, was demonstrated at CP-5. Using different units, the 3M™ system is also capable of removing coatings from walls and pipes.

Concrete Planer

The concrete planer used to drive the 3M™ Heavy Duty Roto Peen is provided by EDCO. Specifically, the EDCO model CPM-4 floor unit, which requires 208 VAC at 30 amp single phase to rotate the Roto Peen at 1,800 rpm and has the following specifications:

- Weight: 180 lb
- Height: 38 in
- Width: 18 in
- Length: 38 in
- Cutting width: 5.5 in

The cutting width of the concrete planer used in this demonstration was 5.5 in but larger units with cutting widths up to 12 in are available from EDCO.

Pb Sentry Vacuum Monitor

The Pb Sentry is West Environmental proprietary technology designed for this application. The electrical source to the planer is passed through the Pb Sentry, which interrupts the electrical supply to the concrete planer when a variation in vacuum pressure at the CPM-4 shroud is detected. The level of vacuum pressure is monitored via a tube connected at the vacuum port on the shroud that runs back to the Pb Sentry. The settings on the monitor are adjustable for both upper and lower vacuum pressure readings.

Vacuum System

Pentek's VAC-PAC® used in conjunction with the Roto Peen offers two-stage positive filtration of particulate. The debris removed by the Roto Peen flaps are collected in this vacuum system that also features Pentek's patented controlled seal drum system that allows the operator to fill, seal, remove, and replace the waste drum under controlled vacuum conditions. This minimizes the operator's exposure to the waste and the possibility of releasing airborne contamination during drum change.

Several standard VAC-PAC® models are available from Pentek, with various specifications and performance capabilities. The model 24 used at CP-5 is air-powered by an air compressor that remains outside the facility. The air compressor is a Leroy 750, diesel fueled with 300 ft^3/min at 100 psig because of the 300 ft of air line hose from the air compressor to the vacuum system.

The VAC-PAC® model 24 has the following parameters:

- Rated vacuum flow: 600 ft^3/min
- Rated static lift: 100 in Water Gauge
- Weight: 750 lb
- Height: 72 in
- Width: 28 in
- Length: 48 in

- Primary roughing filter cartridges: Three at 8 in diameter
  Efficiency: 95 percent at 1 micron

- Secondary HEPA filter: One at 12 in × 24 in
  Efficiency: 99.97 percent at 0.3 micron

For the operation of the vacuum system, the utilities require a 110 VAC at 15 amp electrical current source and 75 ft of 3-in diameter reinforced vacuum hose connecting the CPM-4 unit to the VAC-PAC®.

Coating Removal

The demonstration was conducted according to the approved test plan, *CP-5 Large-Scale Demonstration Project: Test Plan for the Demonstration of 3M™ Heavy-Duty Roto Peen and VAC-PAC® System.*

The demonstration area was located on the service level of the CP-5 building in an area approximately 20 x 25 ft. The concrete floor had multiple layers of contaminated paint on the surface. The area is enclosed to the west by 8 linear feet (lin ft) of cabinets and 12 lin ft of hoses running along the wall and to the east by 5 lf of concrete wall and 15 lf of steel floor plate. The north and south ends are open areas. The Roto Peen machine was able to maneuver within 1 in of the floor plate and within 12 in of the cabinets and hoses.

The CP-5 operators were required to wear one layer of Tyvek, a full-faced air purifying respirator, work boots, and gloves. Due to the temperature in the room being very hot, the two operators were replacing each other approximately every 30 min during the demonstration. After the low vacuum setting was adjusted, the concrete planer would automatically shut off as soon as the operators lifted it up to move it. Using the 3M™ Roto Peen technology, the operators removed the surface paint coating from approximately 425 ft^2 of concrete floor in the demonstration area at a rate of approximately 71 ft^2/h. The depth of removal, determined by the rate of speed with which the concrete planer is driven, was about 1/16 in. This removed all the coatings from the concrete surface and achieved a uniform appearance on the finished surface. The finished surface has slight groove lines in it but is otherwise smooth.

Cabinets that were in the demonstration area for another operation at CP-5 were covered with plastic as a precautionary measure. The hoses connected to those cabinets were left on the floor adjacent to the wall. As a precaution to prevent damage to the hoses, the unit was not operated within 1 ft of the hoses. However, the unit was able to remove concrete floor coatings about 1-2 in from other obstacles.

Radiological Results

The first survey, prior to the demonstration, showed that six portions of the 425 ft^2 area contained elevated fixed total beta/gamma contamination. The radiological levels for these six locations ranged from approximately 6,000 to 70,000 dpm/100 cm^2 and were at or below background levels for the remaining parts of the floor.

After the coating removal, results of the second survey of the area indicate that five of the six contaminated locations were at or below background levels. The contamination of the sixth location was reduced from 70,000 to 16,000 dpm/100 cm^2. Pre- and post- demonstration results are listed in Table 1. The elevated readings in the sixth location could possibly be the result of a crack in the area that has trapped the contamination and cannot be removed by superficial decontamination methods.

Table 1. Radiological results

Location	Total Area (cm^2)	Pre-demonstration Total β/γ (dpm/100cm^2)	Post-demonstration Total β/γ (dpm/100cm^2)
1	300	6,300	< 500
2	100	12,200	< 500
3	100	10,500	< 500
4	100	6,300	< 500
5	100	7,300	< 500
6	400	70,700	16,000

Following the coating removal demonstration, it took three people approximately 80 min to clean the concrete planer (without the Roto Peen flaps) and the vacuum system, using wet rags. A final survey of the equipment did not show any contamination, and it was released to the vendors.

Waste Generation

Because the shot remains captive to the tool, the primary waste generated by the Roto Peen was the actual concrete and paint debris removed from the floor. Via the vacuum system, the waste was collected into a standard 55 gal drum. After the demonstration, the investigation of the drum showed that approximately 2.1 ft^3 (120 lb) of primary waste, in the form of powdery concrete and paint chips, was generated. All airborne radiological measurements were found to be at or below background levels. The vacuum system was sufficient to contain the dust generated during decontamination.

Survey smears taken from the outside of the secondary waste bags, containing Tyveks, high-efficiency particulate air (HEPA) cartridges, gloves, shoe covers, Roto Peen flaps, roughing filters, HEPA filter, the vacuum hose, rags and smear papers, did not show any removable contamination (see Appendix B). However they were handled as contaminated trash for disposal.

Summary of Demonstration Results

The results of the demonstration of the 3M™ Roto Peen technology are listed in Table 2 below:

Table 2. Performance data

Criteria	Innovative technology: Roto Peen with captive shot	Baseline technology: mechanical scabbling
Applicable surface	Coating removal from painted concrete floor (horizontal unit demonstrated: other units capable of decontaminating walls and pipes)	¼ in concrete removal from floor
Production rate (coating removal rate only)	71 ft^2 /h	200 ft^2/h
Depth of removal	1/16 in	¼ to ½ in
Cutting width	5.5 in	Variable
Minimum crew size	Two people	Three people
Amount and type of primary waste generated	2.1 ft^3 of powdery mixture of paint and concrete (contained by vacuum system)	Amount estimated to be 24 ft^3 of a mixture of powdery and large pieces of paint chips and concrete (requires manual cleanup: no vacuum system is attached)
Type of secondary waste generated	Used personnel protective equipment (PPE), filters, flaps, hoses, rags, smear papers	Used PPE, tent enclosure, worn pistons
Airborne radioactivity generated by equipment	No visible dust during the demonstration; airborne activity levels were at or below background at all times	Not connected to vacuum system; up to 10% of debris generated can become airborne
Noise level	100 dBA @ 5 ft	84 dBA (per vendor)
Capability to access floor-wall unions	1-2 in is required	1 in
Developmental status	Commercially available components	Commercially available; compatible vacuum systems are also available
Safety concerns	Main hazards are heavy equipment operation and noise	Flying concrete pieces pose eye hazard: airborne activity; heavy equipment operation hazards; noise
Set-up time	Minimal	Prerequisite erection of temporary airborne enclosure

SECTION 4

Technology Applicability

In order to meet regulatory criteria for unrestricted use, any site that has a need for coating removal from concrete floors would benefit from the use of the 3M™ Roto Peen technology. Demonstrated from March 17-20, 1997, as an alternative to the scabbling technology for removing coating layers from a large area of concrete floor, this technology showed several advantages:

- The shot remained captive to the 3M™ Heavy Duty Roto Peen flaps considerably reducing the amount of waste, which was mainly paint chips with a powdery consistency. Therefore, the secondary waste consisted only of protective clothing, Roto Peen flaps, filters, the vacuum hose, some tape, smear papers, and rags.

- The CPM-4 concrete planer provided by EDCO is well designed. It is very easy to operate and replacement of the flaps can be done in a minimal amount of time. There was no need to vacuum the floor after the coating removal was done, because no dust was left on the floor after the pass of the concrete planer.

- The VAC-PAC® is efficient and well designed. The controlled-seal drum fill system allows waste drums to be filled, sealed, removed, and replaced while minimizing the possibility of operator exposure or the release of airborne contamination. The HEPA filter and roughing filters are also easily accessible.

- The Pb Sentry was designed to function transparently. It adds an important worker safety feature to the overall system by cutting off power to the planer should the detected vacuum drop below a safe threshold, and it automatically shuts off the machine when it is lifted from the floor.

The ease of operating the equipment, no generation of airborne dust, and less secondary waste make the 3M™ Roto Peen technology a useful tool in reducing project costs. The only disadvantage was the slow rate of the coating removal. However larger units are available from EDCO, which may greatly increase the rate of removal.

There are a number of technologies currently available to D&D professionals for the purpose of removing coatings from concrete floor surfaces.

Other technologies available are:

- mechanical scabbling (the ANL baseline technology),
- milling,
- centrifugal shot blast,
- flashlamp,
- carbon dioxide blasting,
- grit blasting,
- high pressure and ultra-high pressure water blasting,
- sponge or soft-media blasting,
- laser ablation,
- wet ice blasting, and
- various chemical based coating removal technologies.

Data comparing the performance of Roto Peen with captive shot to all the competing technologies listed above is not available.

SECTION 5

[redacted]

Introduction

This cost analysis compares the relative costs of the innovative and baseline technologies and presents information that will assist D&D planners in decisions about use of the innovative technology in future D&D work. This analysis strives to develop realistic estimates that represent actual D&D work within the U.S. DOE complex. However, this is a limited representation of actual cost, because the analysis uses only data observed during the demonstration. Some of the observed costs will include refinements to make the estimates more realistic. These are allowed only when they do not distort the fundamental elements of the observed data of productivity rate, quantities, or work elements. They eliminate only those activities that are atypical of normal D&D work. Descriptions contained in Appendix B of this analysis detail the changes to the observed data. The *CP-5 Large-Scale Demonstration Project, Data Report for the Demonstration of the 3M™ Heavy-Duty Roto Peen and VAC-PAC®* (ANL, 1997) provides additional cost information.

Methodology

This cost analysis compares two decontamination technologies, an innovative Roto Peen with captive shot technology and the baseline, a conventional mechanical scabbling technology. The Roto Peen with captive shot technology was demonstrated at CP-5 under controlled conditions with facility personnel operating vendor-provided equipment. Work process activities were timed and quantities were measured to determine production rates.

Data collected during the demonstration included the following:

- activity duration,
- work crew composition,
- equipment and supplies used to perform the work steps,
- utilities consumed, and
- waste generation.

A concurrent demonstration of the baseline scabbling technology was not performed. Baseline information is developed from the following sources:

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

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

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

Some costs are omitted from this analysis so that it is easier to understand and to facilitate comparison with costs for the individual site. The ANL indirect expense rate for materials and subcontracts is included in this analysis at 9.3 percent but will vary at other sites. Overhead rates for each DOE site vary in magnitude and in the way they are applied and are excluded in this cost analysis. Decision makers seeking site specific costs can apply their site's rates to this analysis without having to first retract ANL's rates except the 9.3 percent for materials and subcontracts. This omission does not sacrifice the cost saving accuracy, because overhead is applied to both the innovative and baseline technology costs. Engineering, quality assurance, administrative costs, and taxes on services and materials also are omitted from this analysis for the same reason indicated for the overhead rates.

The standard labor rates, established by ANL for estimating D&D work, are used in this analysis because all the work was performed by local crafts. Additionally, the analysis uses an eight hour work day with a five day week.

The equipment hourly rates, representing the government's ownership, are based on general guidance contained in Office of Management and Budget (OMB) circular No. A-94 for Cost Effectiveness Analysis. The rate consists of ownership and operating costs. Operating costs consist of fuel, filters, oil, grease and other consumable items plus repairs, maintenance, overhauls and calibrations.

Summary of Cost Variable Conditions

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

Table 3. Summary of cost variable conditions

Cost Variable	Innovative technology: Roto Peen with captive shot	Baseline technology: mechanical scabbling
Scope of Work		
Quantity & Type of Material	425 ft^2; coated concrete floor	425 ft^2, comparable to demo area, but approx. 1/6 of original baseline scope of 2,542 ft^2, concrete floor
Location	Service floor of CP-5 including open areas, and edges	CP-5; same service floor area, open areas only
Nature of work	Reduce radiological levels. Remove coating (and 1/16 in of concrete)	Reduce radiological levels. Remove ¼ in of concrete (inherent in equipment) along with coating
Work Environment		
Level of contamination	Six portions on the floor have elevated fixed total beta/gamma contamination	Assumed baseline would be same as demonstration area
Level of airborne contamination during D&D activity	No airborne exposure, therefore no tent required. Vacuum system integral with equipment. Debris continuously contained in drums	Concrete chips and dust (airborne) created by equipment. Temporary tent required; estimated to cover 133% of area being worked
Personnel protection eq. (PPE) requirements	PPE worn: clothes, gloves, respirators as a requirement, despite no airborne contaminants	Temporary tent required; 565 ft^2 used. Requires PPE and respirator, same as demonstration

Table 3. Summary of cost variable conditions (cont.)

Cost Variable	Innovative technology: Roto Peen with captive shot	Baseline technology: mechanical scabbling
Work Performance		
Acquisition means	Subcontracted vendor provided equipment and consumable captive shot flaps. This analysis is based on site craft using that equipment, but as government owned and some equipment as rental	Site craft workers with site owned and some rental equipment
Scale of production	1. Demonstrated in large unconfined areas 2. Crew size: 2; 1 with machine, 1 supporting person 3. Equipment: floor, walk behind model, 5.5" cut width	1. Based on large open area and some tight areas inaccessible for the size of machine 2. Crew size: 3; 1 with scabbling machine and 2 supporting people 3. Equipment: Large, floor walk behind model, 11" cut width
Production rates (crew size)	Experienced a rate of **71 ft^2/h** for the person running the EDCO CPM-4 concrete planer - net effective production with two persons on crew is **35.5 ft^2 per person-hour**	Assumed constant rate: **200 ft^2/h** for the person running the pneumatic machine - net effective production with three persons on crew is **67 ft^2/person-hour**
Primary waste	2.84 ft^3	12.8 ft^3
Secondary waste	Vacuum hoses, worn flaps, PPE and swipes, filters: estimated 16 ft^3	Worn scabbling bits, swipes, PPE: estimated 14.7 ft^3 (2 drums)
Work process steps	1. Remove the surface coating and concrete, using one electric driven machine with continuous vacuum collection into closed drum container	1. Scabble the surface area to ~ ¼ in depth with one pneumatic machine leaving debris and airborne contaminants 2. Sample rubble health physics technician (HPT) 3. Manually clean up and load into containers by other worker
End condition	Coating and 1/16 in concrete removed; radiation reduced to at or below background level	Coating and ¼ in concrete removed; Assumed radiation would be reduced as well or better due to depth of cut (not demonstrated)

Potential Savings and Cost Conclusions

For the conditions and assumptions stated, the innovative technology Roto Peen with captive shot saves approximately 50 percent over the baseline scabbling alternate for this demonstration scope of 425 ft^2. Figure 3 is a summary and comparison of the potential savings between the two technologies.

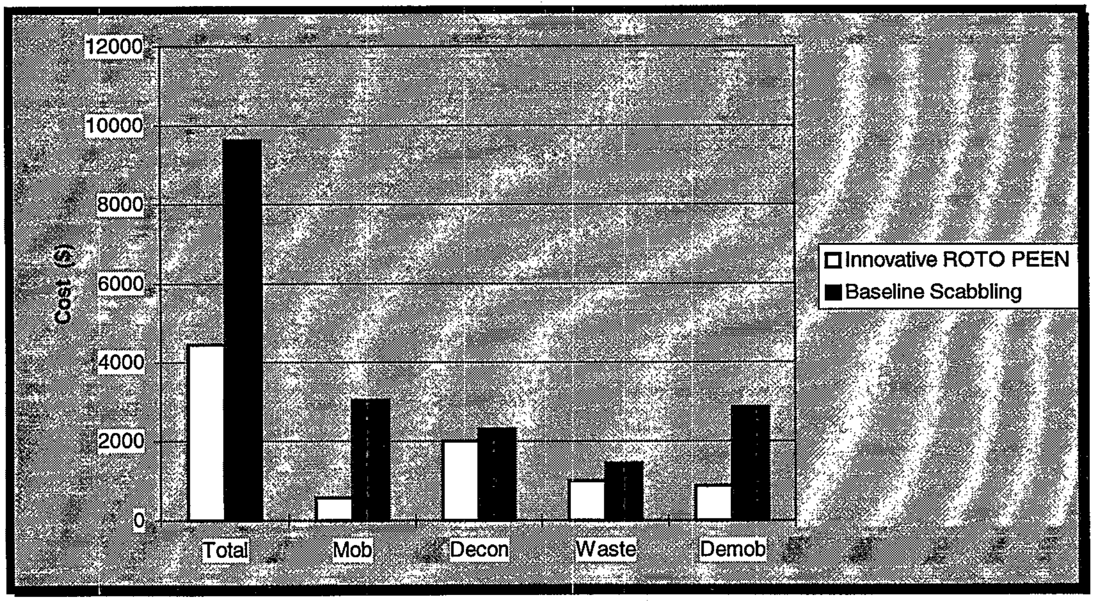

Figure 3. Total and major work breakdown.

The major contributor to the savings is the elimination, in the baseline mobilization and demobilization phases, of a temporary structure to contain the airborne contaminants. That amounts to $2,405. The innovative technology does not require a temporary enclosure because all debris is continuously vacuumed as it is generated. Minor savings include rubble loading, which is eliminated because the vacuum dumps directly into a closed drum container. Waste disposal is the next largest savings. Removal of 1/16 in of concrete generates a smaller quantity of waste than does a ¼-in depth of concrete. The savings from all these activities will vary with the size of the area to be decontaminated.

Other potential cost differences at various sites can include:

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

The production rates and operating costs for scabbling and Roto Peen with captive shot will vary depending upon site specific conditions and the model of the machine selected. The available production rates range from 30 ft^2/h to over 450 ft^2/h.The width of cut affects the production rate and ranges from 2 in to 18 in. Some wide cut, large floor models are easy to use but hard to maneuver in tight spots, whereas the small hand-held units work well in confined spaces such as underneath stairways, but cause worker fatigue. Scabbling, with its superior production rate, actually costs less than Roto Peen with captive shot technology for the coating removal activity. However, the extra handling and cleanup of the debris from the scabbler and the resultant productivity loss results in higher costs for the total decontamination activity.

This analysis assumes government ownership of equipment. If vendor services are utilized at other sites, there will be additional costs for mobilizing and training vendor personnel.

Depending on the situation at any given site, a health and safety requirement beyond regulatory minimums could be imposed that would still require a tent-like structure be erected even though the innovative technology eliminates airborne contamination.

Some sites will choose to discard the scabbling or concrete planer at the end of a small project or keep it for extended and future projects. That depends on the investment made and decontamination possible for continued use. Amortizing equipment ownership over greater scope will result in lower unit rates. The primary roughing filters and the secondary HEPA filters, used for only 425 ft^2, were discarded following the demonstration. The \$989 cost of filters resulted in a unit cost of \$2.33/ ft^2 or \$164.83/h for the 6 productive hours in use, a relatively high cost element. However, the design of the filter system provides for automatic blow-back filter cleaning about every 30 seconds. This increases the life of the roughing filters to about 9 months or 1 yr of continuous, normal use and the HEPA filter to about 1 yr. For the cost analysis, a life of 1 yr and 500 h of use for both filters is utilized, which equates to cleaning 35,420 ft^2/yr. Assuming that volume of use reduces the two unit costs to \$0.0279/ft^2 and \$1.98/h, respectively. This is a dramatic reduction in unit cost that depends on the planned use of the technology at each site.

All factors discussed above affect costs for both technologies. A user should compute the estimated potential savings for D&D work by substituting the expected quantities, mobilization details, equipment investment, and production rates into Table B-1 to calculate a site-specific cost for their situation.

SECTION 6

Regulatory Considerations

The regulatory/permitting issues related to the use of the 3M™ Roto Peen technology at the ANL CP-5 Research Reactor consisted of the following safety and health regulations:

- 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

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

- 10 CFR 835 — Occupational Radiation Protection

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

- 49 CFR Subchapter C Hazardous Materials Regulation

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

- 40 CFR Subchapter 1 — Solid Waste

These are the same regulations that govern the baseline technology of mechanical scabbling.

The waste form requirements/criteria specified by disposal facilities are used by ANL:

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

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

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

Safety, Risks, Benefits, and Community Reaction

The Roto Peen technology incorporates a vacuum system to collect the dust of the removed coating. During the demonstration, no increase in airborne activity levels above background was detected. It is possible that the requirement for operators to have respiratory protection may be eased, allowing for greater worker efficiency and time savings.

The use of the Roto Peen technology rather than scabbling would have no measurable impact on community safety or socioeconomic issues.

SECTION 7

[redacted]

The 3M™ Heavy Duty Roto Peen technology demonstrated on the service floor of the CP-5 Research Reactor is a commercially available product that does not have any implementation issues. The setup time is very short and the equipment is easy to operate. It is very clean and does not generate airborne dust.

The setup of the low vacuum point on the Pb Sentry, which automatically shuts off the machine when it is lifted from the floor, should be done before starting the work. It needs to be calibrated to the vacuum system being used.

The demonstrated unit has a slow rate of coating removal but larger units are available and would allow the operators to increase the rate of removal.

The 3M™ Roto Peen technology is a superficial decontamination method and cracks or joints in the area which have trapped contamination cannot be effectively decontaminated.

To meet regulatory criteria for unrestricted use, any site that has a need for contaminated coating removal from concrete floors without any contaminated cracks would benefit from the use of the 3M™ Roto Peen technology.

APPENDIX A

[redacted]

Strategic Alliance for Environmental Restoration, CP-5 Large-Scale Demonstration Project, *Test Plan for the Demonstration of 3M™ Heavy-Duty Roto Peen and VAC-PAC® System*, Argonne National Laboratory, March 1997.

Strategic Alliance for Environmental Restoration, CP-5 Large-Scale Demonstration Project, *Data Report for the Demonstration of 3M™ Heavy Duty Roto Peen and VAC-PAC® System*, Argonne National Laboratory, June 1997.

APPENDIX B

TECHNOLOGY COST COMPARISON

This appendix contains the activity dictionaries with definitions of cost elements, descriptions of assumptions and some computations of unit costs. It also contains the cost analyses.

Activity Dictionary

Innovative Technology -- 3M™ Heavy Duty Roto Peen with captive shot (with a VAC-PAC® and Pb Sentry)

Mobilization (mob) (WBS 331.01)

Equipment Transport

Definition: This cost element provides for transportation of the site-owned decontamination (decon) equipment from its storage area to a staging area near the facility being decontaminated. Therefore, this cost includes a truck and forklift, the teamster and operator, and the riggers loading and hauling the subject construction equipment and the hourly charges for the transporting equipment and that being transported.

Assumption: Distance to a site warehouse varies, but less than 2 mi is assumed. The pickup truck and pneumatic forklift are rented using rates from the Dataquest construction equipment rental rate book. Loading takes 0.5 h and driving takes 0.25 h for a duration of 0.75 h. Returning the transportation equipment to the equipment pool takes 0.25 h and is a concurrent activity. Therefore, 1 h is priced. See note under off-load activity.

Note: This scenario diverges from the actual demonstration conditions wherein the vendor mobilized their representatives and equipment from both Minneapolis, MN, and Pittsburgh, PA.

Off-load and Unpack Equipment and Pre-survey Equipment

Definition: This cost element provides for three activities with different crews. It includes 1) the riggers time to off-load equipment from the truck using a forklift, 2) the decon workers to move the equipment to a staging area and unpack it for survey, and 3) a radiological survey of the equipment by an HPT to ensure that contaminated equipment is not brought on site. Duration includes decon crew standby during HPT pre-survey.

Assumptions: 3.5 h are assumed for off-loading, unpacking, and surveying the equipment.

Note: The first day (8 h) consisted of four activities observed, but not timed. The duration has been allocated as follows: Equipment transport (previous activity), 0.75 h; this activity of three sub-activities, 3.5 h; set up and move in (a following activity), 2.25 h; and lost time not attributable to D&D activities but to facilitate the demonstration, 1.5 h. However, this distribution was further based on similar activities observed and timed during the demobilization phase. The crews involved varied in composition.

Training

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

Assumptions: <u>There is no cost applicable</u> due to the assumption that local site personnel are trained already. However, the vendor personnel were trained in order to carry out the demonstration.

Decontamination of the Reactor Building Floor (WBS 331.17)

Radioactivity Surveys of the Area

Definition: This cost element is for radiological surveying to characterize the workplace to facilitate making a work plan well before starting the decontamination effort.

Assumption: Not applicable and no cost effect for this analysis. This activity is assumed completed prior to decontamination activities.

Set Up, Move and/or Check Out Equipment

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

Assumptions: The duration for moving equipment and set up is assumed to be 2.25 h based upon observed demonstration time during the demobilization phase. See note above under off-load.

Remove Floor Surface Coatings

Definition: This cost element consists of:

- Removing the coatings off the concrete floor and operational maintenance of replacing the roughing and HEPA filters with clean ones and consumable parts that wear.
- The activity labor consists of two decon workers.
- Cost of equipment is included in the activity, and consumable equipment and supplies are listed as a sub-breakout of this cost element because it is so variable.
- Packaging of primary waste is automatic into the VAC-PAC® and its container.
- Transporting to disposal collection area is excluded.
- Cost of PPE is included. See unit cost derivation in the next table.
- Any lost time from production is included as a factor. This involves safety meetings, daily work planning reviews, dress-out with PPE, heat or temperature stress, and work breaks.

Assumptions:

- The quantity scope for the demonstration is 425 ft^2.
- Two decon workers are used. One actively operating the EDCO CPM-4 floor model concrete planer which utilizes the Roto Peen with captive shot to remove the coatings. The other assists with hoses and electric power cords.
- An HPT is not necessary to accomplish the main task (and not priced).
- Production rates used are 71 ft^2/h per two person crew (or 35.5 ft^2 h per person) for the demonstration based on observed, timed activities. The crew composition is shown in Table B-1. The time observed was 6 h.
- One decon crew worker is qualified to change out the worn Roto Peen with captive shot flap parts. The other decon worker is on standby while changing flaps.
- The equipment configuration eliminates the vacuuming step because the VAC-PAC® is connected to and continuously vacuums debris from the EDCO CPM-4.

- A 20 min safety meeting was held on two mornings (not counted in the 6 h).
- PPE changes and other related productivity losses were not measured in the demonstration but experienced. A productivity loss factor (PLF) of 1.49 is applied.

Productivity Loss Factor

Definition: A factor applied to productive hours to compensate for loss of production while attending safety meetings, dressing and undressing in PPE, work breaks, heat and cold work stress, etc.

Assumption: A PLF from the baseline 1996 activity cost estimate (ACE) sheets of 1.49 is used to make the innovative case comparable to the baseline.

PPE Cost Per Day Calculation

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

The PPE costs are predominantly from the ANL activity cost estimate (ACE) sheets. (Costs for outer gloves, glove liners, and respirator cartridges are from commercial catalogs.)

Waste Disposal (WBS 331.18)

Waste Disposal Collection

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

Transport to the Disposal Site

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

Disposal Fees

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

Assumptions: (for all three of the accounts above combined as one price)

- During the demonstration of this technology, only 2.84 ft^3 of primary waste (paint and some concrete chips) was generated and directly vacuumed into a barrel or container.

- The secondary waste consists of a bag of the expendable vacuum hose, used PPE, and swipes handled after the work is completed. (Estimated at 16 ft^3, not supported by demo data.)

- Cost is represented as an All-in Disposal fee rate per ft^3 for contact-handled (<200 mrem/h) low level radioactive waste (LLW) and covers a base rate, transportation costs, container cost and/or cask rental, and ANL indirect costs.

Demobilization (WBS 331.21)

Survey and Decontaminate Equipment

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

Assumptions: Demonstration times observed are 80 min for decontamination of equipment by two decon workers and an HPT and 1 h for survey by HPT only.

Pack Up and Load Equipment

Definition: This cost element covers the labor and equipment time to pack up and load out the equipment onto a truck for returning to a point of origin.

Assumptions: Demonstration times observed are 2 h for boxing up using two decon workers and 30 min for loading the equipment using three riggers and a teamster.

Personnel and Equipment Transport

Definition: Transport of equipment back to the warehouse involves obtaining transport equipment from the equipment pool, driving loaded truck to the warehouse, and off-loading at the warehouse.

Assumption: Return trip mileage to a warehouse is less than 2 mi and is basically the reverse of mobilization. Crafts involved are thee riggers and a teamster. Equipment included is a pickup truck, forklift, and the decon equipment. The estimate assumes a duration of 45 min plus 15 min for a concurrent activity.

Note: This scenario diverges from the actual demonstration conditions wherein the vendor demobilized their representatives and equipment back to both Minneapolis, MN, and Pittsburgh, PA.

Cost Analysis

Innovative Technology -- Roto Peen with captive shot (and a VAC-PAC® and a Pb Sentry)

The cost for performing work using the Roto Peen with captive shot technology consists of the following activities:

1) mobilization of equipment;
2) unloading to a staging area;
3) set-up of equipment and hoses;
4) removal of the floor coating (about 1/16 in of concrete) using an EDCO CPM-4 floor model concrete planer using a Roto Peen with captive shot, a Pb Sentry, and a VAC-PAC®;
5) replacement of consumable flaps when necessary;
6) use of PPE;
7) decontamination of the reusable equipment;
8) collection of all waste;
9) handling the drums containing the waste;
10) demobilization back to point of origin; and
11) disposal fees.

The projection of demonstration costs to reflect a commercial cost for the scope of work includes adjustments as a result of the assumptions shown below:

- An EDCO CPM-4 concrete planer with a Pb Sentry and a VAC-PAC® (assuming long-term need) are purchased by a site and delivered to and received by the warehouse. The procurement indirect expense (PIE) rate for ANL of 9.3 percent has been applied to equipment and services purchased in determining the hourly rate.
- Mobilization consists of loading with a forklift large and small tools at the warehouse tool room, hauling them with a site truck (at rental rates) to the facility, unloading them at a staging area using site personnel, and returning the transporting equipment to the equipment pool. The reverse holds for demobilization. Three riggers and a teamster are involved.
- A decontamination labor crew of two ANL facility workers, hired locally, require no mobilization or training because of previous qualifications.
- The technology demonstrated is coating removal, but additionally about 1/16 in of concrete is removed from a test area of 425 ft^2.
- Hourly rates for Government owned equipment are based on amortizing the initial purchase price, including its shipping costs, over the service life of the equipment using a discount rate prescribed in the OMB circular No. A-94 of 5.8 percent. Service life of 5 to 15 yr (depending on the individual piece of equipment) is used with an assumed use of 500 h/yr.
- There is no difference in the PPE requirements between this technology and the baseline, and in fact, PPE were worn.
- The observed time of 6 h removing coatings from 425 ft^2 results in a production rate of 71 ft^2/h. The definition also encompasses assistance in handling air and electrical cords and a prorated allowance for captive shot flap replacement. Because of the two-person crew, the effective production rate becomes 35.5 ft^2/person-hour.
- The captive shot flaps were not changed in the course of the demo. The flaps had 10 h of previous wear when the demonstration started and added 6 h more during it. This analysis assumes one change is necessary every 30 h, or 2,100 ft^2, of use, a portion of which has been considered in the analysis. The lifetime of the flaps will depend on the type of surface being cleaned.
- The primary waste generation volume factor is 0.0067 ft^3/ft^2 including a 78 percent bulking factor.
- The VAC-PAC® roughing filters, designed with a continuous cleaning feature, and the HEPA filters are reusable over several jobs or larger scope quantities. Filters are expected to last 9-12 mo (assumed 1 yr at 500 h of use) based on conservative extrapolation of information provided during a phone conversation with a Pentek representative.
- Radiological survey of the floor before and after the task is excluded because it is a characterization function.
- Mark-up of labor and equipment costs for the ANL overhead rate is excluded.

- A PLF of 1.49 is applied to the Roto Peen with captive shot demonstration activities. The data is adjusted from the ACE sheets, CP-5 Cost Estimate qualifications, page 1.12 through 1.14 of 1.33 issued by ANL Technology Development Division of the D&D Project. While the demonstration was timed and conducted wearing PPE, the time was not recorded separately for safety meetings and suiting up and suiting off. The details are:

Base	1.00	
+ Height factor	0.00	(not applicable, since work is on the floor)
+ Radiation/ALARA	0.20	
+ Protective Clothing	0.15	(to account for dress-out)
= Subtotal	1.35	
x Respiratory Protection	1.00	(no factor required, covered in the observed times)
= Subtotal	1.35	
x Breaks	1.10	
= Total	1.49	

The activities, quantities, production rates and costs observed during the demonstration form the basis of the values shown in Table B-1, Innovative Technology Cost Summary.

TABLE B-1 INNOVATIVE TECHNOLOGY COST SUMMARY

Work Breakdown Structure (WBS)	Unit Cost (UC) Labor		Equipment		Other	Total	TQ	Unit of	Total Cost	Note: TC=UC x TQ Note: Qnty = Quantity; TQ = Total Quantity
	Hour (hr)	Rate	Hour	Rate	Rate	UC	Qnty	Measure	(TC) note	Comments
MOBILIZATION (mob)- WBS 331.01								Subtotal:	$ 567	
Transport Equipment (Eq.) - Load at warehouse	0.5	$ 161	0.5	$ 25.41		$ 93	1	Lump Sum (LS)	$ 93	Truck, forklift, teamster, & 3 riggers for 4.5 h total to mobilize
Drive to staging & Unload Eq.	0.75	$ 161	0.75	$ 39.39		$ 150	1	Trip	$ 150	
Return Transport Eq. to pool	0.25	$ 80	0.25	$ 25.41		$26	1	Trip	$ 26	
Unpack equipment	2	$ 67	2	$ 13.01		$160	1	LS	$ 160	
Pre-survey equipment	1	$ 123	1	$ 13.01		$136	1	LS	$ 136	
DECONTAMINATION (decon) - WBS 331.17								Subtotal:	$ 2,000	SCOPE: 425 square feet (ft^2)
Move eq. to work area & set up task equipment	2.25	$ 67	2.25	$ 37.78		$ 236	1	LS	$ 236	On-site labor 2 decon technicians (techs) @ $67.20/crew for 2.25 h plus Eq. standby
Scarify concrete floor	0.01408	$ 67	0.014	$ 37.78	$ -	$ 1.48	425	ft^2	$ 628	Production rate: 71 ft^2/h by 1 person while another assists. No flap replacement. Operating costs are below. Duration is 6 h.
HPT escort/ as needed	0	$ 56				$ -	6	h	$ -	Not required
Eq. Operating costs										
Replacement Flaps			1	$ 60.27		$ 60.27	6	h	$ 361	1 drum x 50 Roto Peen flaps per drum x 1 changes x $30.14/flap for 1,750 ft^2=~$60.27/hr
Air Compressor costs			1.000	$ 17.32		$ 17.32	6	h	$ 104	Air Compr. 750 cubic feet per minute (ft^3/min)
Air tools/filters consumables			1.000	$ 3.55		$ 3.55	6.0	h	$ 21	Assumed filter life = 500 h
Sample rubble & surface								ft^2	$ -	**No sampling required with technology**
Load Rubble in containers					$ -	$ -	2.84	ft^3	$ -	**Auto-vacuumed.** Waste generated=2.84 CF
Personnel Protective Eq. (PPE)					$ 93	$ 93	1.1	day	$ 103	2 decon techs @$46.33/day
PRODUCTIVITY LOSS	1.00	$ 67	1.00	$ 118.92		$ 186	2.9	h	$ 546	Factor: 1.49 per ACE sheets from ANL
DEMOBILZATION (demob) - WBS 331.21								Subtotal:	$ 873	
Demob Equipment										
Decon Equipment including HPT	1.33	$ 123	1.33	$ 13.01	$ 13.20	$ 194	1	LS	$ 194	"Other" is for waste generated by eq. decon at .25 ft^3 @ $52.78/ft3. Time per demo.
Survey Eq. for free release	1	$ 56	1	$ 13.01		$ 69	1	LS	$ 69	1 HPT, 1 h per demo time
PPE during decon			1.98		$ 139	$ 139	0.25	day	$ 34	2 decon techs, 1 HPT @$46.33/day
PPE during survey			1.49		$ 46	$ 46	0.19	day	$ 9	1 HPT at $46.33/day
PRODUCTIVITY LOSS	1.00	$ 123	1.00	$ 13.01		$ 119	1.1	h	$ 136	Figured at 1.49 per 1996 ACE sheets
Pack up equipment	2	$ 67	2	$ 13.01		$ 160	1	LS	$ 160	Reverse of mobilization. Time per demo.
Pool eq. to staging area	0.25	$ 80	0.25	$ 25.41		$ 26	1	trip	$ 26	Reverse of mobilization. Time per demo.
Load truck and return to whse	0.75	$ 161	0.75	$ 39.39		$ 150	1	LS	$ 150	Reverse of mobilization. Time per demo.
Unload at warehouse	0.5	$ 161	0.5	$ 25.41	$ -	$ 93	1.0	LS	$ 93	Reverse of mobilization. Time per demo.
WASTE DISPOSAL - WBS 331.18								Subtotal:	$ 994	
Disposal Fees-Prime & 2nd					$ 52.78	$ 52.78	18.8	ft3	$ 994	From 1996 ACE, Table 2.0, pg. 1.11 of 1.33
								Total	**$ 4,433**	

Mobilization (WBS 331.01)

Construct Temporary Facilities (Airborne Contaminant Enclosure)

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

Assumptions: Conceptual scope definition is from ANL D&D personnel. A temporary enclosure for airborne contaminants is erected using unistrut material ($2.00 per 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 cover. Labor consists of three decon workers ($33.60/h) for 2 h to erect a size of 565 ft^2.

NOTE: Since this decontamination test area (425 ft^2) is smaller than the area basis (650 ft^2) used in development for another demonstration, the area for this tent is reduced to 565 ft^2. The time to erect has been reduced to 2 h from 3 h in a direct proportion to the area reduction ratio (565 ft^2/865 ft^2). No PLF or PPE are used during erection but are during dismantling. This activity is completed prior to mobilizing for the decon activities. The unit rate is 2 h/565 ft^2 or 0.0035 h/ft^2.

Equipment Transport

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

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 Dataquest construction equipment rental rate book. Loading takes 2 h; driving, 0.5 h; and returning to the equipment pool, 0.25 h.

Unload Equipment

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

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

Survey Equipment

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

Assumptions: Equipment survey is required.

Training

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

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

Decontamination of the Reactor Building Floor (WBS 331.17)

Radiological Survey

Note: This cost element is for radiological surveying to characterize the workplace to facilitate making 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.

Set Up or Move Equipment and Check it Out

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

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

Remove Floor Surface Concrete

Definition: This cost element consists of:

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

Assumptions:

- The quantity scope for the baseline is the same as the demonstration, 425 ft^2 for comparison equality.
- One crew of two decon workers and one HPT are required. Those three people handle the scabbling, sampling, cleaning up, and containerizing as a team for which the estimate is separated into two sub-elements of cost by craft.
- One scabbling machine is used.

- Baseline technology produces primary waste that is manually vacuumed up, radiological monitored, and packaged. It amounts to 19.5 ft^3.
- The decon crew workers are qualified to change out the worn bits. Stand-by time is necessitated by this activity.
- Production rate in this analysis is 200 ft^2/h for the one machine, a Model -11, Trelawny. The net effective production rate is 67 ft^2/person-hour due to the three-person crew. The scabbler is priced at an ownership hourly rate of $9.95/h based on pricing information from ANL D&D personnel.
- A safety meeting occurs and is in this analysis through use of the 2.05 PLF.

Productivity Loss Factor

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

Assumption: The PLF used, 2.05, and the PPE costs are predominantly from the ANL baseline 1996 ACE sheets. (Costs for outer gloves, glove liners, and respirator cartridges are priced from commercial catalogs.)

Note: The cost per day calculation for PPE is the same as in the Innovative Technology section in this appendix.

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

Transport to Disposal Site

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

Disposal Fees

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

Assumptions (for all three of the accounts above combined as one price):

- Primary waste generated of 19.5 ft^3 is calculated at 0.03 ft^3/ft^2 including a 70 percent efficiency bulking as taken from the May 1996 Activity Cost Estimate sheets.
- The secondary waste consists of a couple of bags of expended scabbling bits, used PPE and swipes, and no vacuum hoses. Assumed 14.7 ft^3.
- Not applicable, as such, to each of the detailed accounts, but all three accounts are covered with a single rate per ft^3.
- Cost is represented as an All-in Disposal fee rate per ft^3 for contact handled (<200 mrem/h) LLW and covers a base rate, transportation costs, container cost and/or cask rental, and ANL indirect costs.

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. It includes decon workers and HPT labor. It includes gathering up and containerizing the waste building materials. PPE and a PLF are included due to the airborne contamination.

Assumptions: As originally defined by ANL personnel for another demonstration, labor required is three persons for 3 h to dismantle and load up waste. However, the time has been reduced to 2 h due to the size reduction for a smaller tent than the other demonstration basis.

Survey and Decontaminate Equipment

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

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

Pack Up and Load Equipment

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

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

Personnel and Equipment Transport

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

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

Cost Analysis

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

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

The baseline includes the following assumptions:

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

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

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

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

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

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

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

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

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

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

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

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

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

The activities, quantities, production rates, and costs used in the baseline calculations are shown in Table B-2.

TABLE B-2 BASELINE COST SUMMARY (SCABBLING TECHNOLOGY)

Work Breakdown Structure (WBS)	Unit Cost (UC) Labor Hour(h)	Labor Rate	Equipment Hr	Equipment Rate	Other Rate	Total UC	TQ Qnty	Unit of Measure	Total Cost (TC) note	Note: TC=UC x TQ Note: Qnty = Quantity; TQ=total quantity Comments
MOBILIZATION (mob)- WBS 331.01								Subtotal:	$ 3,025	
Build containment tent	0.0035	$ 101			$ 3.07	$3.41	565	ft^2	$ 1,930	3 decon wrkr, 2 h @ $33.60 plus materials
Health Physics Tech (HPT) for Tent	2.0	$ 56			$ 13.20	$123	1	LS	$ 123	Covers building tent only. Other: decon waste at .25 ft^3 at $52.78/$ft^3$
Transport Equipment (Eq.) - load at warehouse	2	$ 147	2	$ 32.51		$ 359	1	Trip	$ 359	Truck, forklift, teamster, operator, & two decon workers for 2 h
Drive to site	0.5	$ 147	0.5	$ 42.46		$ 95	1	Trip	$ 95	Same as above, 0.5 h, add scabbler
Unload Equipment at site & survey	2	$ 203	2	$ 42.46		$491	1	Trip	$ 491	Same as above, 2 h, add health physics tech (HPT) for survey
Return truck/forklift	0.25	$ 80	0.25	$ 32.51		$28	1	Trip	$ 28	
DECONTAMINATION (decon) - WBS 331.17								Subtotal:	$ 2,296	SCOPE: 425 Square Feet (SF) (Sq Ft)
Move Eq. to Work Area	2	$ 67.2	2	$ 38.47		$ 211	1	LS	$ 211	On-site labor 2 decon technicians(techs) @ $33.60/h for 2 h plus Eq. Standby
Removal of concrete floor coatings	0.005	$ 67.2	0.005	$ 38.47	$ -	$ 0.53	425	ft^2	$ 225	Two Decon workers; one machine at 200 ft^2/h including replacements, total 3.25 h.
Eq. Operating costs										Varies with life of bits, replacement frequency
Consumable (consum) Bit wear					$ 0.22	$ 0.22	425	ft^2	$ 93	Per operating cost calculation which is similar to PENTEK consumable rates/ft^2
Air Compressor costs			2.125	$ 7.00		$ 14.86	1	LS	$ 15	Air Compressor,250 ft^3/min
Air tools consum.			2.125	$ 0.27		$ 0.58	1	LS	$ 1	
HPT Sample rubble & surface radioactivity	0.012	$ 56.0				$ 0.68	425	ft^2	$ 287	One HPT at $56/h, same hrs as decon.plus manual loading.
Load Rubble in containers	0.235	$ 67.2	0.235	$ 38.47	$ -	$24.86	12.8	ft^3	$ 317	Waste at .021 ft^3/ft^2 w/ 70% efficiency= .03.
Personnel Protective Eq. (PPE)					$ 139	$ 139	2.0	day	$ 278	3 men x $46.33/day
PRODUCTIVITY LOSS	1.000	$123.2	1.000	$ 38.47		$ 162	5.38	Hr	$ 870	Factor: 2.05 per '96 ACE sheets
DEMOBILZATION (demob) - WBS 331.21								Subtotal:	$ 2,850	
Decon & Survey Equipment	2	$ 67	2	$ 38.47		$ 211	1	LS	$ 211	
HPT work effort	8.1	$ 56			$ 13.20	$ 468	1	LS	$ 468	Other: decon waste at .25 ft^3 at $52.78/$ft^3$
PPE during decon			6.16		$ 278	$ 278	2.00	day	$ 556	Crew of 3 plus 3 for tent dismantle
PRODUCTIVITY LOSS	1.0	$ 123	1.00	$ 38.47		$ 162	4.16	Hr	$ 672	Figured at 2.05 per 1996 ACE sheets.
Move Equipment & Load out	2	$ 147	2	$ 42.46		$ 379	1	LS	$ 379	Assumed reverse of the mobilization.
Return to warehouse	0.5	$ 147	0.5	$ 32.51	$ -	$ 90	1.0	trip	$ 90	Assumed reverse of the mobilization.
Dismantle temporary tent	0.0035	$ 101	0.0035	$ 38.47	$ 0.36	$ 0.84	565	ft^2	$ 474	3 decon wrkr, 2 h @ $33.60 plus materials
WASTE DISPOSAL - WBS 331.18								Subtotal:	$ 1,449	
Disposal Fees-Prime & 2nd					$ 52.78	$ 52.78	27.5	ft^3	$ 1,449	From '96 ACE, Table 2.0, pg. 1.11 of 1.33
								Total	$ 9,621	

APPENDIX C

Technology Description

The 3M™ Heavy Duty Roto Peen Flap technology was demonstrated at the Hemispheric Center for Environmental Technology at Florida International University from April 30 to May 2, 1996. The 3M™ Heavy Duty Roto Peen Flap is tungsten carbide shot brazed to a hardened steel rivet that is supported by a flexible flap. The shot rivet is kept captive to the equipment by mounting the flaps in a slotted hub. Three different size planers were demonstrated, Figure C-1; each has different cutting widths for use on different areas of the floor space (e.g., main open area of floor, near edges, and around obstructions). Table C-1 includes the specifications for each of these pieces of equipment.

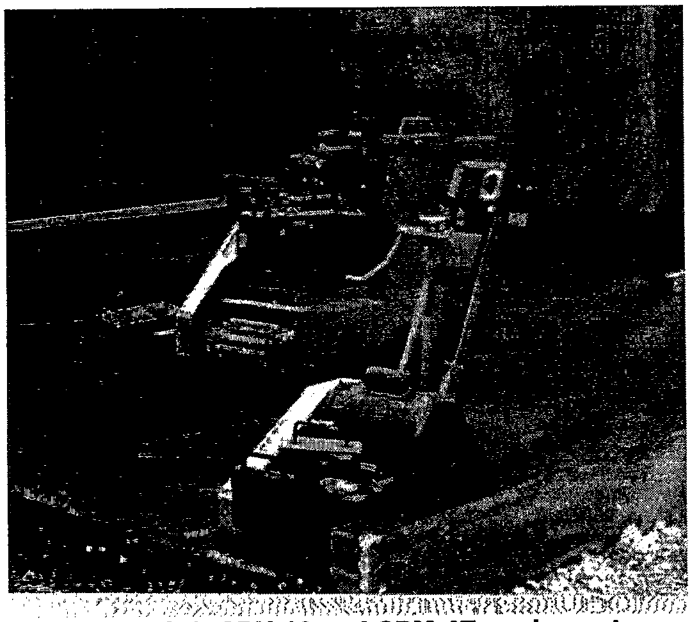

Figure C-1. CPU-10 and CPM-4E equipment.

Table C-1. Equipment specifications

Criteria	CPU-10-18KE	CPM-4E	PEENA CLEANER
Manufacturer	EDCO	EDCO	Unique Systems
Floor unit or hand-held	Floor unit	Floor unit	Hand-held
Weight	575 lb	180 lb	9 lb
Dimensions (WxLxD)	24 in x 45 in x 38 in	18 in x 38 in x 38 in	14.5 in x 9 in x 9 in
Speed	1,700-1,800 rpm	1,800 rpm	1,200-3,700 rpm adjustable
Cutting width	10 in	5.5 in	2 in
Media used	3M™ Heavy Duty Roto Peen flaps - Type A	3M™ Heavy Duty Roto Peen flaps - Type A	3M™ Heavy Duty Roto Peen flaps - Type A
Amount of media required (no. of flaps)	200 flaps	50 flaps	10 flaps

Criteria	CPU-10-18KE	CPM-4E	PEENA CLEANER
Vendor advertised life of flaps	30 h	30 h	30 h
Utilities required	Propane	220 volt 1 phase	110 volt 15 amp
Able to attach a vacuum source	Yes	Yes	Yes

A non-nuclear vacuum system, manufactured by Tornado, was demonstrated with the equipment described above. The Tornado vacuum directed the dust and debris generated from the coating removal into a 55-gal drum collection system. However, the system did not have HEPA filters.

System Operation

- The CPU-10 was self-propelled and required one hand placed on the rail at all times to steer the equipment with the other hand operating the speed control. The unit has hydrostatic forward and reverse drive, a depth control, an engage/disengage lever for the scaling head, an oil alert, a meter for monitoring the number of hours the head has been operating, and a lifting bail.
- The CPM-4 was a stand-behind push unit with variable depth control. This unit also has an engage/disengage lever to raise and lower the scaling head.
- The PEENA Cleaner is hand-held and requires one hand on the trigger at all times to operate with the other hand on the handle located at the top of the unit to push the equipment across the floor.
- The floor to be decontaminated must be dry to ensure that the substrate removed does not clog the hoses.
- Simultaneous to the decontamination of the floor, the dust and debris are vacuumed by the equipment and the debris collected in a 55 gal drum.

Demonstration Plan

In a project for the Fernald Environmental Management Project, Fluor Daniel Fernald contracted the Hemispheric Center for Environmental Technologies at Florida International University (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 Florida International University 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. 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-2 presents the results of the FIU-HCET demonstration of 3M™'s Heavy Duty Roto Peen flaps using various types/sizes of floor equipment.

Table C-2. Performance data

Criteria	EDCO CPU-10-18KE	EDCO CPM-4E	PEENA CLEANER
Applicable surface	Coating removal, main floor area	Coating removal, edges of floors	Coating removal, edges of floors
Production rate for a one-person crew	298 ft^2/h	95 ft^2/h	107 ft^2/h
Floor space worked	740 ft^2	50 ft^2	10 ft^2
Type of primary waste generated	A fine powder	A fine powder	A fine powder
Type of secondary waste generated	Roto Peen flaps	Roto Peen flaps	Roto Peen flaps
Media used	3M™ Roto Peen flaps, Type A	3M™ Roto Peen flaps, Type A	3M™ Roto Peen flaps, Type A
Noise level	91.9 dBA (1)	(1)	(1)
Capability to access floor-wall unions	No closer than 5 in	No closer than ¾ in	No closer than ¾ in
Section of floor space worked	Open area, no obstructions	Edge of floor next to walls	Edge of floor next to walls and around obstructions
Development status	Commercially available	Commercially available	Commercially available
Ease of use	Self-propelled floor unit`	Stand-behind push model	Hand-held unit requires operators to be on hands and knees
End-point condition	Smooth, flat surface	Smooth, flat surface	Smooth, flat surface
Worker safety	Tripping hazard from hoses and cords. Exposed rotating machinery. Burn hazard from muffler.	Tripping hazard from hoses and cords.	Arm-hand vibration.

[1] Individual measurements for noise control were not performed. This number represents an average across the entire demonstration.

Implementation Considerations

- Technology requires an integral HEPA vacuum system to meet the U.S. DOE's radiological control requirements.
- The vacuum shroud on the EDCO equipment could not be adjusted to ensure a good seal of the interface with the concrete. This resulted in small pieces of debris being expelled from the vacuum shroud.
- The vacuuming of debris from the EDCO equipment was more efficient when the equipment was used in the direction which allowed the material to move toward the vacuum connection. When the equipment was operated in the opposite direction, minimal debris was vacuumed from the floor.

APPENDIX D

[redacted]

ACE	activity cost estimate (sheets)
ALARA	as low as reasonably achievable
amp	amplifier
ANL	Argonne National Laboratory
β/γ_2	beta/gamma
cm^2	square centimeters
CFR	*Code of Federal Regulations*
CP-5	Chicago Pile-5
D&D	decontamination and decommissioning
dBA	decibels
DDFA	Deactivation and Decommissioning Focus Area
Decon	Decontamination
Demo	Demonstration
Demob	Demobilization
DOE	U.S. Department of Energy
DOT	U.S. Department of Transportation
dpm	disintegrations per minute
EPA	U.S. Environmental Protection Agency
Eq.	equipment
ESH	Environment, Safety, and Health
FCCM	facilities capital cost of money
FETC	Federal Energy Technology Center
FIU-HCET	Florida International University - Hemispheric Center for Environmental Technology
ft^2	square feet
ft^3	cubic feet
h	hour(s)
H&S	health and safety
HDRP	Heavy Duty Roto Peen
HEPA	high efficiency particulate air
HPT	health physics technician
HTRW	hazardous, toxic, radioactive waste
IUOE	International Union of Operating Engineers
in	inch (es)
lb	pound (s)
lin ft	linear foot (feet)
LLW	low-level waste
LS	lump sum
LSDP	Large-Scale Demonstration Project
mi	mile (s)
min	minute (s)
Mob	mobilization
mrem	millirem
OMB	Office of Management and Budget
OSHA	Occupational Safety and Health Administration
PIE	procurement indirect expense
PLF	productivity loss factor
PPE	personnel protective equipment

psi	pounds per square inch
psig	pounds per square inch gallons
Qnty	quantify
RA	remedial action
Resp.	respirator
rpm	revolutions per minute
TC	total cost
TQ	total quantity
UC	unit cost
USACE	U.S. Army Corps of Engineers
VAC	volts alternating current
WAC	waste acceptance criteria
WBS	work breakdown structure
WM	waste management
WMO	waste management operations

Roto Peen Scaler with VAC-PAC® System at Chicago Pile 5 Research Reactor
Argonne National Laboratory, Argonne, Illinois

Roto Peen Scaler with VAC-PAC® System at Chicago Pile 5 Research Reactor Argonne National Laboratory, Argonne, Illinois

Site Name:
Chicago Pile 5 (CP-5) Research Reactor
Argonne National Laboratory

Location:
Argonne, Illinois

Contaminants:
Radioactive-contaminated paint

Period of Operation:
12/9/96 - 12/12/96

Cleanup Type:
Demonstration

Vendor:
Pentek Inc.

Additional Contacts:
Susan C. Madaris
Leonel E. Lagos
Test Engineers
Florida International University
(305) 348-3727/1810

Technology:
Roto Peen Scaler with VAC-PAC® System
- Hand-held (6.5 lb) tool with a cutting width of 2 inches
- Pneumatically driven
- Works with a variety of cutting media and cutting wheels
- Dust collection system - portable Pentek VAC-PAC® System; high-efficiency HEPA filter (scaler can be used with or without this system)

Cleanup Authority:
Project performed as part of DOE's Large-Scale Demonstration Project, Office of Science and Technology, Deactivation and Decommissioning Focus Area

Regulatory Point of Contact:
Information not provided

Waste Source: Contaminated paint coating on concrete floor

Purpose/Significance of Application: Demonstrate Roto Peen Scaler with VAC-PAC® System and compare results to those for mechanical scabbing

Type/Quantity of Media Treated:
Radioactively contaminated concrete floor - 650 ft^2 of concrete flooring covered with contaminated paint

Regulatory Requirements/Cleanup Goals:
The objective of the demonstration was to evaluate the performance of the Roto Peen Scaler with VAC-PAC® System to remove contaminated paint coating from 650 ft^2 of concrete flooring and to compare the results of this technology with those from the baseline technology of mechanical scabbing.

Results:
- Removed paint coating at an average rate of 40.6 ft^2/hr/scaler; capable of removing coatings to within ½ inch of walls and obstructions - can be used in confined areas.
- Reduced total fixed beta/gamma contamination levels from pre-demonstration levels as high as 13,500 dpm/100 cm^2 (hot spot) to below background levels, with the hot spot reduced to 5,900 dpm/100 cm^2.
- Use of the dust collection system significantly reduced the amount of airborne dust generated during the scaling process and has the potential to lead to the use of less respiratory protection and PPE requirements

Cost:
- The report presents a detailed cost analysis of this technology compared to the baseline technology.
- Cost analysis results show the total cost for Roto Peen Scaler with VAC-PAC® System was 40% lower than the baseline of mechanical scabbing (about $6,500 versus about $11,000). The major contributor to the savings was that the Roto Peen Scaler with VAC-PAC® System did not require a temporary enclosure.

Description:
The Pentek, Inc. Roto Peen Scaler with VAC-PAC® System was demonstrated at the Chicago Pile 5 (CP-5) Research Reactor at Argonne National Laboratory. This demonstration was part of the Chicago Pile-5 (CP-5) Large-Scale Demonstration Project sponsored by DOE, Office of Science and Technology, Deactivation and Decommissioning Focus Area, to demonstrate the benefits of using innovative and improved decontamination and decommissioning technologies. CP-5 was a heavy-water moderated and cooled, highly enriched, uranium-fueled thermal reactor designed to supply neutrons for research and was operated for 25 years before being shut down in 1979.

The Roto Peen Scaler with VAC-PAC® System is a hand-held tool weighing 6.5 lbs, with a cutting width of 2 inches. The scaler is designed to work with a variety of cutting media, including cutting wheels and the 3M Heavy Duty Roto Peen flaps. The unit can be used with or without the Pentek VAC-PAC® System. The VAC-PAC® is portable and has a patented controlled-seal drum fill system that allows the operator to fill, seal, and replace the waste drum under vacuum conditions. The demonstration showed that the main advantage of the Roto Peen Scaler with the VAC-PAC® System, compared to mechanical scabbing, was the simultaneous collection of dust and debris. The report includes a detailed comparison of the two technologies. In addition, the technology removed paint coating at an average rate of 40.6 ft^2/hr/scaler and was able to remove coatings to within ½ inch of walls and obstructions. The scaler also reduced radiological levels to below background levels and use of the dust collection system significantly reduced the amount of airborne dust generated during the scaling process.

The report includes results of a detailed cost analysis comparing the Roto Peen Scaler with VAC-PAC® System with mechanical scabbing. Cost analysis results show that the total cost for Roto Peen Scaler with VAC-PAC® System was 40% lower than the baseline of mechanical scabbing. The major contributor to the savings was that the Roto Peen Scaler with VAC-PAC® System did not require a temporary enclosure.

SECTION 1

[redacted]

Technology Summary

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

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

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

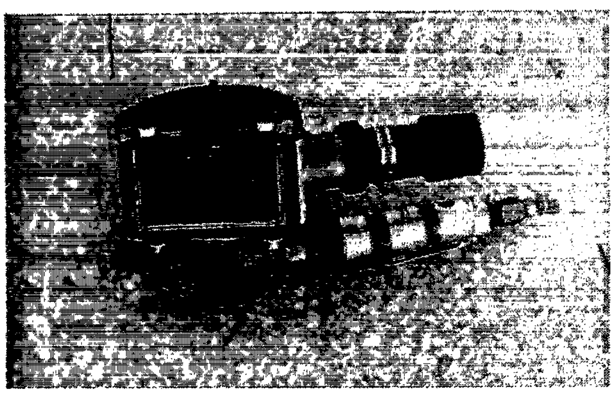

Figure 1. Pentek's ROTO PEEN Scaler.

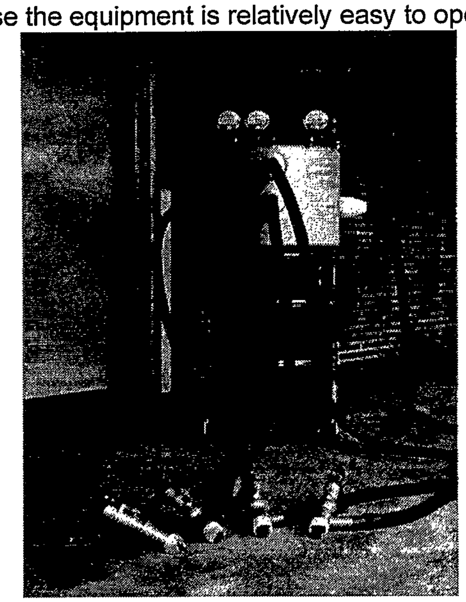

Figure 2. Pentek's VAC-PAC®.

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

Advantages

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

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

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

Demonstration Summary

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

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

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

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

Key Results

The key results of the demonstration are as follows:

- The Pentek ROTO PEEN Scalers removed the paint coating from the 650 ft^2 of concrete flooring in the demonstration area at an average rate of 40.6 ft^2/h/scaler.
- This technology is best used in confined areas and around and under obstacles. It is capable of removing coatings to within one-half inch from the edge of walls and obstructions.

- Removal of the coatings from the concrete floor was sufficient to reduce the radiological levels from an original area of elevated fixed total beta/gamma contamination measuring 800 cm^2 (0.86 ft^2) with a maximum hot spot of 13,500 dpm/100 cm^2 to an elevated contamination area of only 200 cm^2 (0.22 ft^2) with the same hot spot reduced to 5,900 dpm/100 cm^2 fixed total beta/gamma. The contamination levels for the remaining floor were at or below background levels before the demonstration.

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

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

Contacts

Technical

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Demonstration

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

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

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

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

Web Site

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

Other

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

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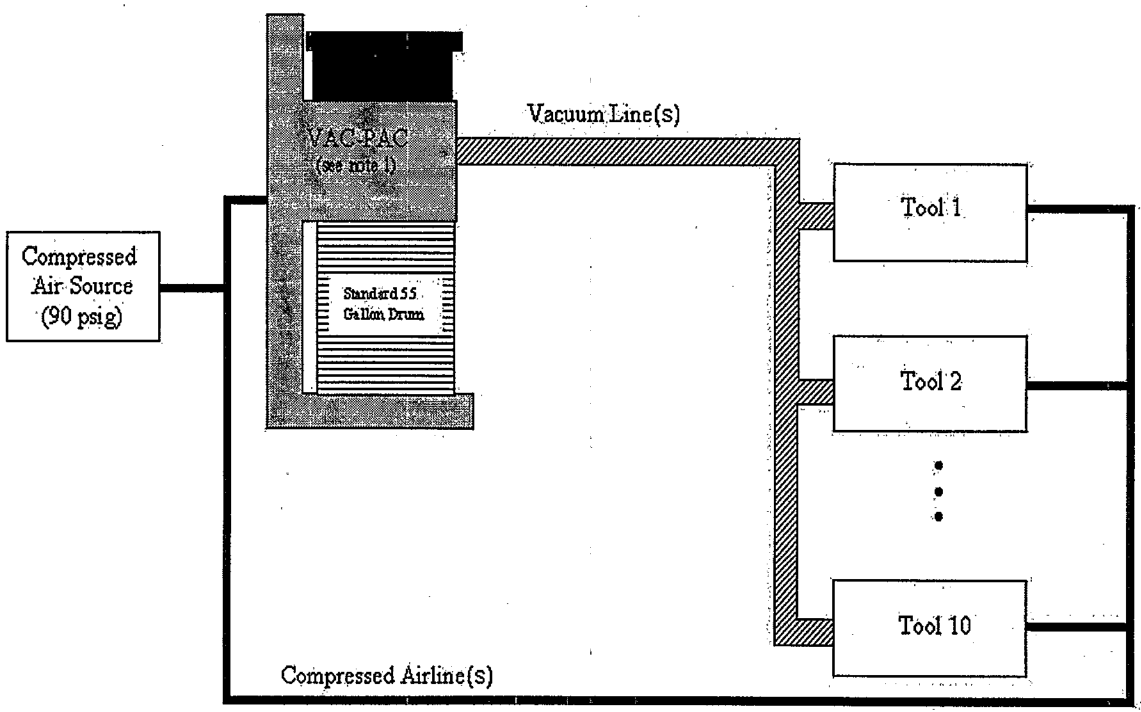
Technology Schematic

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



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

Figure 3. Schematic of the Pentek decontamination system.

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

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

• Required vacuum source	75 ft^3/min
• Air consumption at 90 psig	30 standard ft^3/min
• Dimensions (L x W x H)	6 in x 2½ in x 4 in
• Weight	6.5 lb
• Speed	User adjustable up to 2,400 rpm

- Cutting width — 2 in
- Pentek advertised production rate — 30 to 50 ft^2/h on flat surfaces

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

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

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

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

System Operation

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

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

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

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

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

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

SECTION 3

Demonstration Plan

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

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

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

Treatment Performance

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

Table 1. Performance data

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

Table 1. (continued)

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

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

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

Table 2. Radiological results

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

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

[redacted]

Technology Applicability

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

The advantages of the Pentek milling technology are summarized below.

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

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

Competing Technologies

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

Competing technologies include the following:

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

- sponge or soft-media blasting,
- laser ablation,
- wet ice blasting, and
- various chemical-based coating removal technologies.

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

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

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

Patents/Commercialization/Sponsor

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

SECTION 5

[redacted]

Introduction

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

Methodology

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

Data collected during the demonstration included the following:

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

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

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

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

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

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

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

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

Summary of Cost Variable Conditions

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

Table 3. Summary of cost variable conditions

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

Table 3. (continued)

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

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

Potential Savings and Cost Conclusions

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

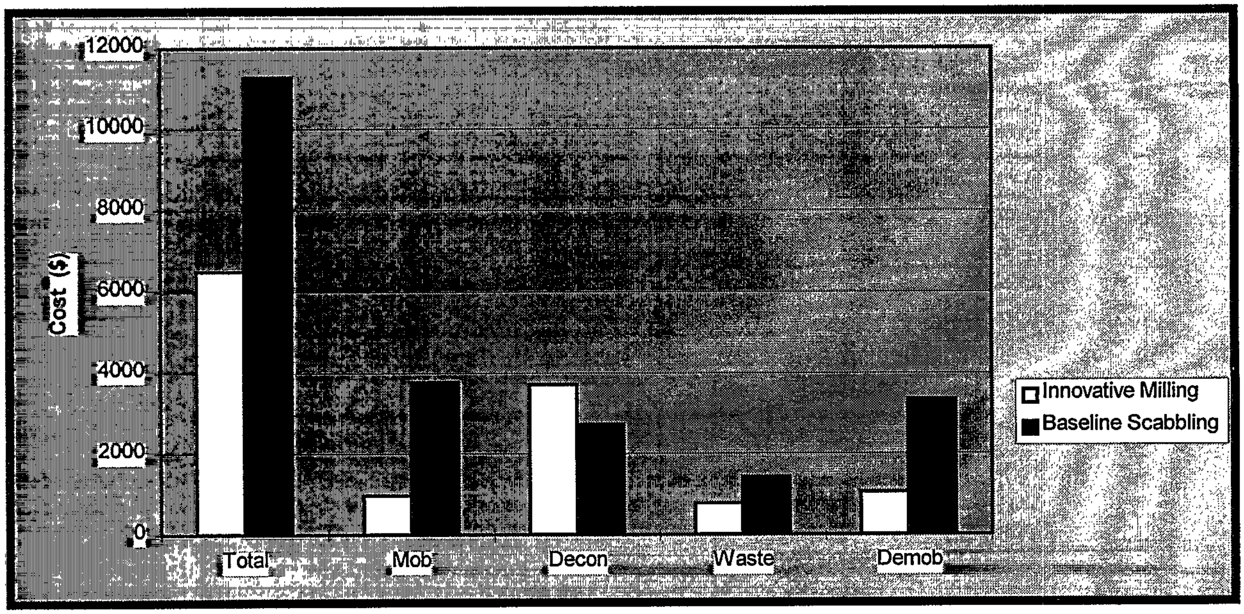


Figure 4. Technology cost comparison.

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

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

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

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

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

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

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

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

[redacted]

Regulatory Considerations

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

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

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

- OSHA 29 CFR 1910

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

- 10 CFR 835 — Occupational Radiation Protection

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

- 49 CFR Subchapter C — Hazardous Materials Regulations

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

- 10 CFR 71 — Packaging and Transportation of Radioactive Material

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

- 40 CFR Subchapter I		Solid Waste

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

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

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

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

Safety, Risks, Benefits, and Community Reaction

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

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

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

Implementation Considerations

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

Technology Limitations and Needs for Future Development

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

- For use on large, open floor areas, it is recommended that the ROTO PEEN Scaler be adapted to allow the operator to operate the unit while standing. This larger unit could be adapted to use additional 3M™ Flaps, thereby increasing both the cutting width from the current 2 in and the productivity rate for the decontamination of large areas.
- When the HEPA filter is seated in the VAC-PAC®, it is clamped in place and then measured on each side to ensure that it is centered in the unit. To facilitate the filter installation process, it is suggested that a guide be built in the VAC-PAC® to ensure the proper placement of the HEPA filter before it is secured in place with clamps.

Technology Selection Considerations

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

APPENDIX A

[redacted]

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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 Milling Technology—ROTO PEEN Scaler and VAC-PAC®

Mobilization (mob) (WBS 331.01)

Equipment Transport

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

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

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

Unload Equipment and Survey Equipment

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

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

Training

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

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

Radioactivity Surveys of the Area

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

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

Set Up, Move and/or Check Out Equipment

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

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

Remove Floor Surface Coatings

Definition: This cost element consists of the following activities.

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

Assumptions:

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

- One decon crew worker is qualified to change the worn flap parts while other workers continue milling by swapping machines as necessary.

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

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

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

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

Health and Safety Factor

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

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

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

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

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

Waste Disposal (WBS 331.18)

Waste Disposal Collection

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

Assumptions:

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

Transport to the Disposal Site

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

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

Disposal Fees

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

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

Demobilization (demob) (WBS 331.21)

Survey and Decontaminate Equipment

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

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

Pack Up and Load Equipment

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

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

Personnel and Equipment Transport

Definition: Transport of equipment back to the warehouse.

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

Cost Analysis

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

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

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

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

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

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

- The technology demonstrated is for removal of coatings only.

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

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

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

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

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

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

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

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

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

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

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

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

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

Work Breakdown Structure (WBS)	Unit Cost (UC) Labor Hour	Labor Rate	Equipment Hour	Equipment Rate	Other Rate	Total UC	TQ Qnty	Unit of measure	Total cost (TC) note	Note: TC=UC x TQ; Qnty = Quantity; TQ = Total Quantity Comments
MOBILIZATION (mob) WBS 331.01								**Subtotal:**	**$ 972**	
Transport equipment (equip) - load at warehouse	2	$ 147	2	$ 32.51		$ 359	1	Trip	$ 359	Truck, forklift, teamster, operator, and two decon workers for 2 h
Drive to site	0.5	$ 147	0.5	$ 42.46		$ 95	1	Trip	$ 95	Same as above, 0.5 h; add scabbler
Unload equip at site and survey	2	$ 203	2	$ 42.46		$491	1	Trip	$ 491	Same as above, 2 h; add HPT for survey
Return equip	0.25	$ 80	0.25	$ 32.51		$28	1	Trip	$ 28	
DECONTAMINATION (decon) - WBS 331.17								**Subtotal:**	**$ 3,705**	**SCOPE: 650 ft²**
Move equip to work area and set up	2	$ 101	2	$ 43.10		$ 288	1	Lump Sum (LS)	$ 288	On-site labor three decon technicians (techs) @ $101/crew for 2 h plus equip standby
Scarify concrete floor (milling)	0.009	$ 101	0.009	$ 43.10	$ -	$ 1.28	650	ft²	$ 832	One three-person crew doing 112.5 ft²/h including flap replacements; no operating costs
Health Physics Technician (HPT)	1	$ 56				$ 56.00	6	h	$ 324	Standby full-time and assist when necessary
Equip operating costs										
Replacement flaps					$ 1.65	$ 1.65	650	ft²	$ 1,073	Three milling units x six flaps/unit x two changes x $29.87/flap for 650 ft²
Air compressor costs			0.009	$ 15.85		$ 91.61	1	LS	$ 92	Air compressor, 750 ft³/min
Air tools/filters consumables			1.000	$ 25.86		$ 25.86	5.8	h	$ 149	Assumed filter life = 500 h
Sample rubble and surface								ft²	$ -	No sampling required with technology.
Load rubble in containers					$ -	$ -	2.5	ft³	$ -	Auto-vacuumed. Waste generated = 2.5 ft³
Safety/Planning Meetings	1.0	$ 157				$ 157	0.5	h	$ 78	
Personnel Protective Equip (PPE)					$ 185	$ 185	1.2	day	$ 222	Three decon techs plus one HPT x $46.33/day
Productivity loss	1.00	$ 101	1.00	$ 68.96		$ 170	3.8	h	$ 647	Productivity loss factor (PLF) = 1.49 per 1996 activity cost estimate (ACE); includes $25.86
DEMOBILZATION (demob) - WBS 331.21								**Subtotal:**	**$ 1,054**	
Demob equip										
Decon and survey equip	2	$ 101	2	$ 43.10	$13.20	$ 301	1	LS	$ 301	Other cost is for waste generated by decon at 0.25 ft³ @ $52.78/ft³; time per demo
HPT work effort	2	$ 56				$ 112	1	LS	$ 112	
PPE during decon			2.98		$ 185	$ 185	0.37	day	$ 69	Three decon techs plus one HPT x $46.33/day
Productivity loss	0.98	$ 157	0.98	$ 43.10		$ 200	1.0	h	$ 196	Figured at 1.49 per 1996 ACE sheets
Move equip and load out	1.25	$ 181	1.25	$ 75.61		$ 320	1	LS	$ 320	Reverse of mobilization; time per demo
Return to warehouse	0.5	$ 80	0.5	$ 32.51	$ -	$ 56	1.0	Trip	$ 56	Reverse of mobilization'; time per demo
WASTE DISPOSAL - WBS 331.18								**Subtotal:**	**$ 774**	
Disposal fees-primary and secondary					$52.78	$ 52.78	14.7	ft³	$ 774	From 1996 ACE, Table 2.0, pg. 1.11 of 1.33
								Total	**$ 6,505**	

Mobilization (WBS 331.01)

Construct Temporary Facilities (Airborne Contaminant Enclosure)

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

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

Equipment Transport

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

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

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

Unload Equipment

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

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

Survey Equipment

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

Assumptions: Equipment survey is required.

Training

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

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

Decontamination of the Reactor Building Floor (WBS 331.17)

Radiological Survey

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

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

Set Up or Move Equipment and Check it Out

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

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

Remove Floor Surface Concrete

Definition: This cost element consists of the following activities.

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

Assumptions:

- The quantity scope for the baseline is the same as the demonstration, 650 ft^2 for comparison equality.
- One crew of two decon workers and one HPT is required. These three people handle the scabbling, sampling, cleanup, and containerizing as a team for which the estimate is separated into two sub-elements of cost by craft.
- One mechanical scabbling machine is used.

- Baseline technology produces primary waste that is manually vacuumed up, radiologically monitored, and packaged. It amounts to 19.5 ft^3.
- The decon crew workers are qualified to change the worn bits. Stand-by time is necessitated by this activity.
- Production rate in this analysis is 200 ft^2/h for one machine, a Model SF-11, Trelawny, one person scabbling (67 ft^2/person-hour as a net effective rate for a three-person crew). The scabbler is priced using the $9.95/h rate taken from the 1996 ACE sheets, including all assumptions made at that time.
- A safety meeting occurs and is in the baseline PLF.

Health and Safety

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

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

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

Waste Disposal (WBS 331.18)

Waste Collection

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

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

Transport to disposal site

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

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

Disposal Fees

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

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

DEMOBILIZATION (WBS 331.21)

Remove Temporary Facilities (Airborne Contaminant Enclosure)

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

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

Survey and Decontaminate Equipment

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

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

Pack Up and Load Equipment

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

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

Personnel and Equipment Transport

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

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

COST ANALYSIS

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

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

The baseline includes the following assumptions:

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

APPENDIX C

[redacted]

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

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

Polyethylene Macroencapsulation at Envirocare of Utah, Inc.
Salt Lake City, Utah

Polyethylene Macroencapsulation at Envirocare of Utah, Inc.
Salt Lake City, Utah

Site Name:
Envirocare of Utah

Location:
Salt Lake City, Utah

Contaminants:
Radioactive waste

Period of Operation:
Fiscal Year 1996

Cleanup Type:
Demonstation

Vendor:
Envirocare of Utah, Inc.

Technology:
Polyethylene Macroencapsulation:
- Davis-Standard 4.5-in single-screw extruder feed hopper, two-stage rotating augerlike screw, heat-controlled barrel, and output die assembly:
- Extruder equipped with five electric clamshell-type barrel heating zones and two die heating zones with thermocouple controllers and cooling loop
- Output capacity of 2000 lb/hr
- Temperature of melted polyethylene exiting extruder - 300-350°F
- Virgin polymer (LDPE) with a melt index of 2 g/min initially used for demonstration; changed to LDPE with melt index of 9 g/min

Cleanup Authority:
RCRA
- Cooperative agreement

Additional Contacts:
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Regulatory Point of Contact:
Information not provided

Waste Source: Lead bricks

Purpose/Significance of Application: Determine production-scale feasibility of this technology for mixed lead waste

Type/Quantity of Media Treated:
Radioactively contaminated lead bricks/disposed of 500,000 lb of macroencapsulated waste

Regulatory Requirements/Cleanup Goals:
- Waste must meet the RCRA Land Disposal Restrictions for debris (40 CFR 268.2) prior to disposal (encapsulation).

Results:
- Initial use of an LDPE with a low melt index (2 g/min) and recycled platics proved impractical. The polyethylene was too viscous (requiring manual assistance to mix with wastes) and the properties of the plastics varied from batch to batch, making use for production-scale imprateical.
- A change to a LDPE with a melt-index of 9 g/min (blend of 2 g/min and 60 g/min) proved to be optimal for production-scale.

Polyethylene Macroencapsulation at Envirocare of Utah, Inc. Salt Lake City, Utah (continued)

Cost:

- Costs were shared between Envirocare and DOE under the terms of the cooperative agreement. Envirocare paid for equipment and supplies, facility construction and modification, permitting and personnel training, and provided facilities for the treatment and disposal of wastes. DOE paid for the treatment and disposal of the encapsuated waste. DOE's cost for disposal of about $1 million for 500,000 lb or $1.92/lb
- An estimate of current costs for polymer macroencapsulation are $90 to $100/cubic foot. Polyethylene macroencapsulation operating costs at DOE sites average about $800/55-gal drum.

Description:

Envirocare of Utah, Inc. (Envirocare) located in Salt Lake City, Utah, is licensed and RCRA-permitted to treat and dispose of low-level radioactive and mixed waste. Under a cooperative agreement between the DOE Idaho Operations Office (DOE-ID) and Envirocare , a demonstration of a polyethylene macroencapsulation extrusion process, developed by DOE at Brookhaven National Laboratory, was conducted at Envirocare's Utah facility to evaluate the technology for mixed waste lead and debris. The company obtained the required RCRA-permit modification to operate this technology, and, under the cooperative agreement, waste streams from 23 DOE sites were shipped to Envirocare.

The polyethylene macroencapsulation extrusion process heats, mixes, and extrudes the polyethylene into the waste container in one operation. The four basic components of the extruder are the feed hopper, rotating auger-like screw, heat-controlled barrel, and output die assembly. The polyethylene is masticated by the rotating screw, heated gradually, and mixed. The melted polyethylene is conveyed from the extruder at 300-350°F and poured directly into the waste container where it flows around and into the waste matrix voids to encapsulate the waste. The polyethylene melt has sufficient heat capacity to provide a fusion bond at the cold polyethylene interface resulting in a continuous monolithic pour. For the demonstration, Envirocare used a Davis-Standard 4.5 inch single-screw extruder with an output capacity of 2000 lb/hr. A virgin polymer (LDPE) with a relatively low melt index of 2 g/min was chosen for this demonstration because Envirocare planned to augment the polymer feed with recycled plastics. During the demonstration, Envirocare determined that the use of this polymer was not well suited for production-scale operations for two reasons: (1) the extrudate was overly viscous and would not flow around the waste without manual assistance and (2) the recycled plastics had inconsistent properties from batch to batch, and therefore would not be efficient for production-scale operations. Envirocare experimented with composite LDPE mixtures with varying melt indexes before determining that LDPE with a melt index of 9 g/min (blend of materials with melt indexes of 2 and 60 g/min) provided the optimum feed stock for production-scale operations. (Envirocare found that using LDPE with high melt indexes ranging from 24 to 60 g/min were prone to cracking.) During the demonstration and throughout the cooperative agreement, Envirocare has continued to expand its process capabilities; the process has been proven effective for package sizes ranging from 5-gal buckets to 55-gal drums in 110-gal overpacks. Based on the results of the demonstration, Utah state regulators have developed specific waste acceptance criteria for the macroencapsulation process. Details of these criteria are presented in the report, along with an analysis of technology applicability and alternatives.

Through the cooperative agreement, Envirocare paid for equipment and supplies, facility construction and modification, permitting and personnel training, and provided facilities for the treatment and disposal of wastes. DOE paid for the treatment and disposal of approximately 500,00 lb of mixed waste lead and debris (lead bricks) that had been macroencapsulated using this process. The cost for this disposal was about $1 million or $1.92/lb. This amount includes substantial treatability study activities and costs for Envirocare to experiment with scale-up and process improvements. An estimate of current costs for polymer macroencapsulation are $90 to $100/cubic foot. Polyethylene macroencapsulation operating costs at DOE sites average about $800/55-gal drum.

SECTION 1

[redacted]

Technology Description

The lead waste inventory throughout the U.S. Department of Energy (DOE) complex has been estimated between 17 million and 24 million kilograms. Decontamination of at least a portion of the lead is viable but at a substantial cost. Because of various problems with decontamination and its limited applicability and the lack of a treatment and disposal method, the current practice is indefinite storage, which is costly and often unacceptable to regulators.

Macroencapsulation is an approved immobilization technology used to treat radioactively contaminated lead solids and mixed waste debris. (Mixed waste is waste materials containing both radioactive and hazardous components.) DOE has funded development of a polyethylene extrusion macroencapsulation process at Brookhaven National Laboratory (BNL) that produces a durable, leach-resistant waste form.

This innovative macroencapsulation technology uses commercially available single-screw extruders to melt, convey, and extrude molten polyethylene into a waste container in which mixed waste lead and debris are suspended or supported (Figure 1). After cooling to room temperature, the polyethylene forms a low-permeability barrier between the waste and the leaching media.

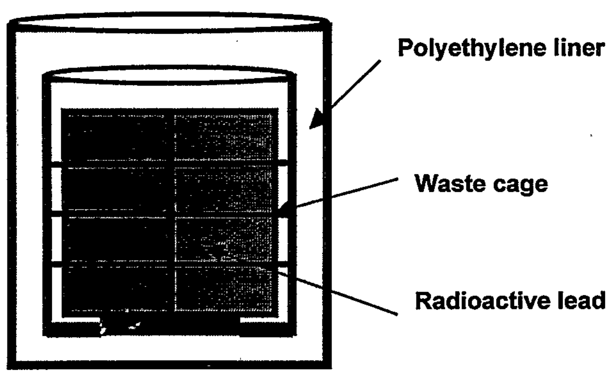

Figure 1. Cross-section of macroencapsulated final waste form.

Polyethylene macroencapsulation offers many technological and economic advantages:

- Polyethylene extruders are commercially available and have a long history of industrial use. Except for a specialized pour nozzle, the equipment and materials used in the process are available off the shelf.
- Polymer extrusion technology can be scaled or tailored to site-specific conditions and can be readily incorporated into existing treatment trains.
- Macroencapsulation offers low capital and operating costs and is readily commercialized.
- The process operates at low temperatures, needs no off-gas treatment, and generates only small quantities of recyclable secondary waste (i.e., molten polyethylene waste).
- The polyethylene encapsulate is one of the most commonly used polymers and is relatively inexpensive compared to other treatment processes. Polyethylene is extremely tough and flexible, has excellent chemical resistance, and is easy to process.

- Macroencapsulation produces a waste barrier that is durable, leach resistant, and compliant with Nuclear Regulatory Commission (NRC) guidelines and Resource Conservation and Recovery Act (RCRA) requirements for disposal of mixed waste lead and debris.

Demonstration Summary

Under a cooperative agreement (DE-FC07-95ID13372) between the DOE Idaho Operations Office (DOE-ID) and Envirocare of Utah, Inc., a polyethylene macroencapsulation process developed by DOE at BNL was transferred to Envirocare, whose facility is located approximately 80 miles west of Salt Lake City, UT. The polyethylene macroencapsulation extrusion process was demonstrated and implemented in fiscal year 1996 by Envirocare, which is fully licensed and permitted to treat and dispose low-level radioactive and mixed waste.

Under the terms of the cooperative agreement, each party contributed approximately equal resources of $1 million:

- Envirocare provided equipment and supplies, facility construction/modification, permitting, and personnel training.
- DOE paid for treatability studies for multiple waste streams and treatment and disposal of approximately 500,000 lb of mixed waste lead and debris.

Envirocare already had a RCRA permit to operate as a hazardous waste treatment/storage/disposal facility. The company was required to obtain a modification to its RCRA Part B permit from the state of Utah to operate the macroencapsulation equipment for processing mixed waste lead and debris. Under the cooperative agreement, waste streams were shipped to Envirocare from 23 DOE sites: Argonne National Laboratory–East, Battelle Columbus, Bettis Atomic Power Laboratory, BNL, Charleston Naval Shipyard, Energy Technology Engineering Center, Fernald, Formerly Utilized Sites Remedial Action Program (FUSRAP) Colonie Site, General Atomics, Idaho National Engineering and Environmental Laboratory, Lawrence Livermore National Laboratory, Los Alamos National Laboratory (LANL), Laboratory for Energy-Related Health Research, Knolls Atomic Power Laboratory (KAPL), KAPL Kesselring Site, Mare Island Naval Shipyard, Nevada Test Site (NTS), Norfolk Naval Shipyard, Oak Ridge National Laboratory, Paducah Gaseous Diffusion Plant, Pearl Harbor Naval Shipyard, Pinellas, and Puget Sound Naval Shipyard.

- The Pinellas Site eliminated its entire remaining mixed waste inventory under the agreement. Under separate contracts, Fort St. Vrain and the Kansas City Plant also eliminated their entire remaining mixed waste inventories using macroencapsulation at Envirocare. Eighty Navy sites eliminated lead waste streams.

- The FUSRAP Colonie Site and NTS eliminated entire waste streams. DOE-ID and Envirocare extended the final completion milestone to include the remaining 500 lb of the NTS waste stream.

- DOE-ID, Envirocare, and LANL renegotiated the cooperative agreement to allow LANL to ship 60,000 lb of mixed waste lead, the site's entire inventory, to Envirocare for treatment and disposal.

  - This change required an expansion of the cooperative agreement total processed waste quantity from 500,000 to 520,000 lb. LANL Waste Management Operations (EM-30) provided the additional budget (approximately $40,000) required to fund the expanded allocation.

  - LANL estimates a savings of more than $824,000 by working an agreement with Envirocare through the Mixed Waste Focus Area (MWFA) rather than negotiating a separate agreement.

Key Results

- High-melt-index polyethylene (>50 g/10 min) has better flow characteristics and produces higher quality final waste forms than the relatively low-melt-index polyethylene Envirocare used in the early stages of the demonstration and implementation.

- For large-scale pours, low-density polyethylene (LDPE) is more successful than high-density polyethylene because it has a lower shrinkage factor.

Contacts

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Licensing Information

All equipment and materials are commercially available.

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 polyethylene macroencapsulation is 30.

SECTION 2

[redacted]

Overall Process Definition

The polyethylene macroencapsulation extrusion process involves heating, mixing, and extruding the polyethylene in one basic operation. An extruder consists of four basic components: feed hopper, rotating augerlike screw, heat-controlled barrel in which the screw rotates, and an output die assembly to shape the final product (Figure 2).

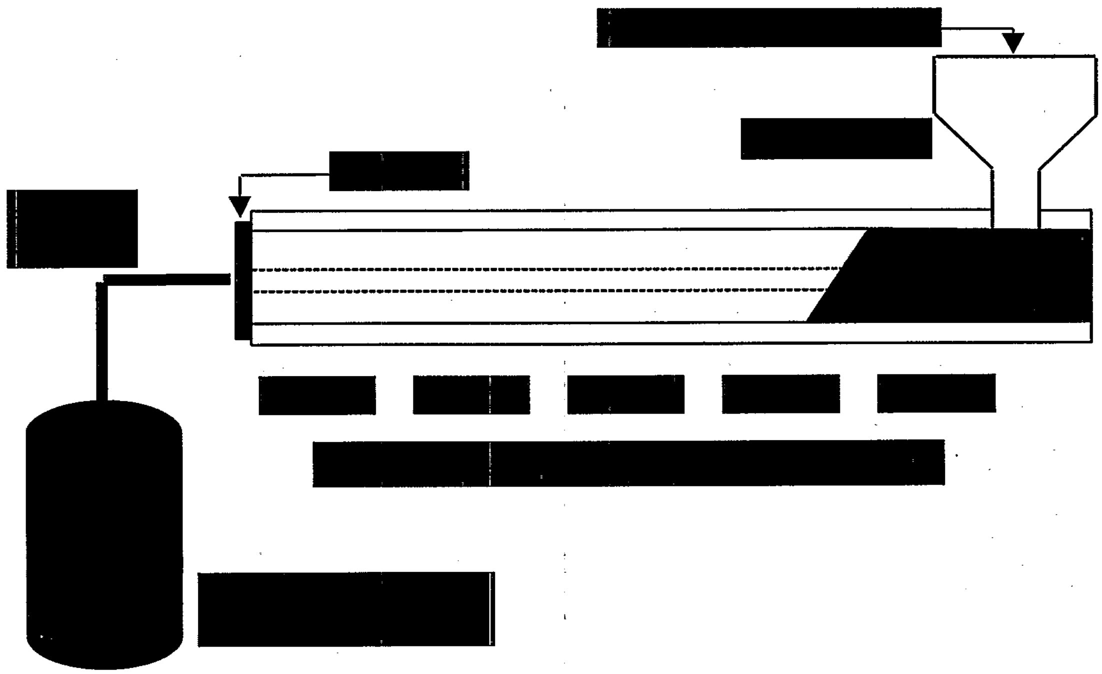

Figure 2. Macroencapsulation process schematic.

Envirocare used a Davis-Standard 11.4-cm (4.5-in) single-screw extruder with an output capacity of 900 kg/h (2000 lb/h).

- The extruder was equipped with five electric clamshell-type barrel heating zones and two die heating zones with thermocouple controllers to provide gradual heating of the polyethylene. A solid-state, dual-probe anticipatory temperature-control system held the barrel temperatures to ±1°F.

- The extruder cooling loop consisted of distilled water circulation; a flow-through, water-cooled heat exchanger; and individual zone flow indicators.

- The extruder was equipped with a two-stage screw driven by a 150-hp motor, feed transfer and metering sections in the first stage, and vent and metering sections in the second stage. (The vent is not needed for macroencapsulation applications.) A Maddock mixing section was at the end of the metering section.

The drag-induced flow associated with the rotating screw produces a pressure buildup that forces the fluid through the die.

- The rotating screw of a conventional plasticating extruder has three geometrically different sections:
  - The feed section has deep flights, and material is generally solid state.
  - The transition section connects the feed section and the metering section. The depth of the screw channel decreases linearly from the feed section to the metering section, thus causing a compression of material in the screw channel. Compression is essential to proper functioning of the extruder.
  - The metering section has shallow flights and is located closest to the die assembly.

- Once inside the extruder, the polyethylene is conveyed through the barrel by the motion of the rotating screw. As the polyethylene moves forward, it is masticated under pressure because of compressive effects of a gradual reduction in the channel area between the screw and barrel.

- The polyethylene is melted by the gradual transfer of thermal energy from shear energy produced by the screw and from electric heaters mounted on the barrel. The heat buildup from barrel friction cannot be consistently predicted and must be compensated for by regulating the resistance band heaters using external blowers.

- A Maddock mixing section at the end of the metering section increases dispersive mixing, producing a more homogeneous thermal profile in the extrudate and more consistent flow characteristics:

  - Longitudinal splines in the mixing section force molten polymer over barrier flights.
  - The Maddock mixer is a pressure-consuming section reducing the output of the extruder.
  - The longitudinal geometry with constant channel depth results in a stagnant region; thus, this design is not suitable with materials of limited thermal stability.

  Because polyethylene is a thixotropic material, the extra shear energy (frictional heat) imparted by the Maddock mixer also reduces the viscosity of the extrudate.

- The melted polyethylene is conveyed from the extruder at 300–350°F (150–160°C) and is usually poured directly into the waste container, where it flows around and into the waste matrix voids, completely encapsulating the waste. The LDPE melt has sufficient heat capacity to provide a fusion bond at the cold LDPE interface, resulting in a continuous monolithic pour.

- Because of the properties of polyethylene, approximately 3% shrinkage will occur upon cooling. This shrinkage must be accounted for in developing waste container configurations.

For the initial demonstration, Envirocare used virgin high-density polyethylene with a melt index of 2 g/10 min. This particular polyethylene was chosen because Envirocare planned to augment its polymer feed with recycled plastics. This plan proved impractical for two reasons:

- The extrudate was overly viscous and would not flow around the waste without manual assistance (hand-packing) by the operators.

- Recycled plastics have inconsistent properties batch to batch, making them inefficient for production-scale operations.

Envirocare modified its process to use LDPE with a melt index of 24 g/10 min. Although LDPE with higher melt indexes flows better, it is more prone to cracking. Currently, Envirocare blends LDPE with melt indexes of 2 g/10 min and 60 g/10 min to create a composite melt index of 9 g/10 min. This formulation flows freely enough to fill voids in the waste matrix without hand-packing, while minimizing cracks.

SECTION 3

Demonstration Plan

Envirocare conducted technology demonstrations during fiscal year 1996 to support its permitting process. Prior to this test phase, state of Utah regulators witnessed polymer encapsulation process demonstrations at Rocky Flats Environmental Technology Site (RFETS). During the demonstration at Envirocare, Utah regulators worked with researchers at BNL to better understand the macroencapsulation process. These interactions greatly influenced Envirocare's RCRA permit requirements as defined by the Utah regulators.

Concurrently, the MWFA issued a letter to solicit interest throughout the DOE complex for participation in the cooperative agreement. Twenty-three sites responded, and more than one thousand tons of waste was identified for inclusion in the demonstration. The MWFA developed a seminar package to train participants to complete the waste profiles required by Envirocare. Waste shipment began in early summer 1996.

Treatment Performance

The encapsulating polymer used during the initial demonstration phase of the cooperative agreement was not well suited for production-scale operations. The relatively low melt index (2 g/10 min) of virgin LDPE resulted in overly viscous extrudate that had to be hand-packed in the waste receptacle. Envirocare tried materials with melt indexes of 24 g/10 min and then 60 g/10 min, finding that the higher melt index polyethylene was prone to cracking.

Envirocare experimented with composite LDPE mixtures until determining that LDPE with a melt index of 9 g/10 min (made by blending materials with melt indexes of 2 and 60 g/10 min) provides an optimum feed stock for production-scale operations. During the demonstration phase and throughout the cooperative agreement, Envirocare continued to expand its process capabilities. The process has now been proven effective for package sizes ranging from 5-gal buckets to full 55-gal drums in 110-gal overpacks.

Based on results of the demonstration phase at Envirocare and interactions with BNL and RFETS, Utah state regulators imposed specific waste acceptance criteria for the macroencapsulation process, examples of which are discussed below.

- Surface-coating material must be of one of the following two types:
  - Polymeric organics (e.g., resins and plastics) are acceptable, but nonpolymerics such as waxes are not allowed. Plastic wrap is also unacceptable.
  - Jackets of inert materials are allowed but must be composed of metal or inorganic materials; metal jackets must be in direct surface contact with macroencapsulated material through lamination, welding, molten pouring, or similar technique. Other inorganic materials may be used as jackets, but they must not be carbon-based compounds or substances.
- Cracks or gaps in the macroencapsulation monolith can result in substantial surface exposure to leaching media. This possibility led to the following waste acceptance criteria:
  - Waste shall not protrude through the surface or the waste form.
  - The waste form shall be created to prevent interior voids or air pockets containing waste.

- The preceding requirement has been superseded by the following: Nonwaste protrusions from hangers or spacers may be present. Such protrusions shall be cut off at the surface of the waste form. Gaps between the encapsulation material and such protrusions are not acceptable.

- Buoyant waste forms can "float" when the waste is placed in planar arrays and back-filled with flowable grout. To prevent this, waste forms submitted for disposal must have a minimum density of 70 lb/ft^3 (about 1.1 g/ml).

- Utah originally required minimum coverage around the waste form of 2 in. of polyethylene to meet the regulatory specification to reduce potential for exposure to leaching media. However, thick layers of LDPE have a tendency to crack, with higher melt indexes being the worst. Consequently, Utah modified the Envirocare permit and waste acceptance criteria as follows: "...a minimum exterior surface-coating thickness of 1 in. for waste forms up to 30-gallons (4 ft^3) and 2 in. for larger volumes unless a demonstration is made to and approved by the Executive Secretary for an alternative minimum thickness based on waste type."

[redacted]

Competing Technologies

The Debris Rule (57 FR 37194, August 18, 1992) identified extraction or destruction technologies as alternatives to macroencapsulation of debris wastes. The materials sent to Envirocare were not decontaminable. Mixed waste processed at Envirocare under the cooperative agreement had already undergone unsuccessful decontamination attempts because of volumetric contamination.

Polymer encapsulation was devised as an alternative to grout/cement encapsulation. The advantages of polymer encapsulation are lower leachability and permeability and greater impact resistance, durability, and resistance to environmental degradation after disposal.

At least two other polymer macroencapsulation technologies are available:

- Several companies offer container-type technologies for macroencapsulation. Waste is placed in premanufactured polyethylene containers and the containers are sealed using a variety of techniques. Fillers can be added to minimize void space in the container. One such technology developed by Arrow-Pak has been implemented at Hanford. It involves supercompaction of "soft waste debris" (e.g., Tyveks, Kimwipes) in 55-gal drums into "pucks" that are then overpacked in a polymer sleeve and sealed. However, these systems are acceptable only for macroencapsulation of debris. A technology ruling equivalent to 40 CFR 268.42(b) would have to be obtained to use this process for radioactively contaminated elemental lead.
- Thermoset polymer encapsulation technologies are also available. These technologies are attractive for their flexibility and high mobility, but base resin costs are significantly higher than those of polyethylene.

Technology Applicability

Macroencapsulation is specifically limited to treatment of radioactively contaminated elemental lead and mixed waste debris. Macroencapsulation has been successfully demonstrated on several mixed waste streams, including radioactive lead, leaded gloves, debris contaminated with beryllium fines, and filters.

Polymer encapsulation technologies are appropriate for the wastes sent to Envirocare because they are contact-handled wastes with half-lives <30 years. Low levels of ionizing radiation (<100 megarad) will not adversely impact the structural integrity of the final waste form. Testing conducted at BNL indicated that polymers could withstand an accumulated radiation dose of 100 megarad without significant hydrolysis.

Macroencapsulation is not appropriate for any RCRA Land Disposal Restricted (LDR) material other than radioactive lead solids (D008) or hazardous debris as defined by RCRA.

Technology Maturity

- Screw-type extruders were first employed in the United States by the rubber industry and were adapted for the extrusion of various thermoplastics in 1938. The use of extruders to process various thermoplastic materials is commonplace in industry today.
- Polymer macroencapsulation has been extensively tested at Rocky Flats (Getty and Riendeau 1995).
- Polymer extrusion technology can be scaled or tailored to site-specific conditions and can be readily incorporated into existing treatment trains or manufacturing processes.

Patents/Commercialization/Sponsor

Envirocare of Utah, Salt Lake City, UT has acquired this technology from DOE through Cooperative Agreement DOE DE-FC07-95ID13372. There are no known patents issued.

Twenty-three federal sites participated in the cooperative agreement macroencapsulation program at Envirocare. Cooperative Agreement DOE DE-FC07-95ID13372 is the primary end-user sponsorship document. Envirocare issued certificates of disposal to all sites that participated in the cooperative agreement.

Envirocare has also treated radioactively contaminated lead solids and mixed waste debris using the macroencapsulation technology for nonfederal entities.

SECTION 5

Methodology

Implementation of macroencapsulation at Envirocare was effected through a cooperative agreement between Envirocare and DOE-ID.

- Under the agreement, Envirocare paid for equipment and supplies, facility construction/modification, permitting, and personnel training. Envirocare acquired an amendment to its operating license from the state of Utah to macroencapsulate mixed waste. Under the cooperative agreement, Envirocare also provided facilities for treatment and disposal of these wastes.

- DOE paid for the treatment and disposal of approximately 500,000 lb of mixed waste lead and debris using polyethylene macroencapsulation technology.

Cost Analysis and Conclusions

Capital Costs

- The appropriate polymer extruders for this application cost between $50,000 and $160,000. Actual costs incurred by Envirocare are considered proprietary information and not disclosed.

- Ancillary equipment, such as feed hoppers and transfer systems, total approximately $10,000.

Operating Costs

- Approximately 500,000 lb of radioactively contaminated lead bricks was encapsulated in LDPE and disposed of in Envirocare's RCRA Subtitle C disposal facility for a cost to DOE of approximately $1,000,000, or $1.92/lb. This amount includes substantial treatability study activities and is based on the process as it existed at the time. This cost also includes resources for Envirocare to experiment with scale-up and process improvement efforts.

- Current contracting cost for polymer macroencapsulation at Envirocare is dependent on the amount and type of waste to be processed. However, a reasonable range is between $\$90/ft^3$ and $\$100/ft^3$. (Envirocare does not base treatment contract costs on a per-pound basis.)

- Commercial surface decontamination of lead costs approximately $2.00/lb. Recent experience has shown that up to 50 percent of contaminated lead cannot be sufficiently decontaminated for clean recycling purposes. Consequently, this material must be treated in accordance with LDRs and disposed of. The following brief analysis contrasts the costs of disposal of 500,000 lb of contaminated lead through polymer macroencapsulation with those for decontamination of the same amount with a 50 percent release rate:

Disposal	500,000 lb @ $1.70/lb	$850,000
Purchase of new lead	250,000 lb @ $0.35/lb	87,500
Total		$937,500
Decontamination	500,000 lb @ $2.00/lb	$1,000,000
Disposal of waste lead	250,000 lb @ $1.70/lb	425,000
Total		$1,425,000

- Polyethylene macroencapsulation operating costs at a DOE site average approximately $800/55-gal drum. These costs are based on the following assumptions:

  — There is a 1-in annular space between the drum and the waste.
  — Virgin polyethylene is used as the encapsulating material. Significant cost savings may be realized using recycled plastic.
  — Downdraft tables or glove bags are used for radiation containment.
  — The process uses two operators.

- Because macroencapsulation is an approved treatment technology, waste form qualification testing is not required. Off-gas monitoring is also not required. These factors lead to significant cost savings compared to destruction and separation technologies.

- Virgin LDPE costs approximately $0.61/lb or less depending on purchase volume. Recycled material costs about one-third as much, but supplies of appropriate recycled LDPE tend to be unreliable.

- LANL estimates a savings of more than $824,000 for treatment of its 60,000 lb of radioactive lead by working an agreement with Envirocare through the MWFA rather than negotiating a separate agreement.

SECTION 6

Regulatory Considerations

The waste streams treated in this demonstration were subject to the Resource Conservation and Recovery Act (RCRA) but not the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA).

- By RCRA definition, macroencapsulation is specifically limited to treatment of radioactively contaminated elemental lead solids and mixed waste debris.

- Macroencapsulation, which is the RCRA technology-based treatment standard for radioactively contaminated elemental lead, is defined in 40 CFR 268.4 as "Application of surface-coating materials such as polymeric organics (e.g., resins and plastics), or use of a jacket of inert inorganic materials to substantially reduce surface exposure to potential leaching media." Macroencapsulation specifically does not include any material that would be classified as a tank or container according to 40 CFR 260.10.

- The Debris Rule defines macroencapsulation as encapsulation with "surface-coating materials such as polymeric organics (e.g., resins and plastics) or use of a jacket of inert inorganic materials to substantially reduce surface exposure to potential leaching media." This definition does not include the container restriction that is identified for macroencapsulation of lead.

- Currently, macroencapsulated debris contaminated with a listed waste must be managed as a RCRA hazardous waste. Proposed regulatory modifications (i.e., DOE's response and recommendations to the U.S. Environmental Protection Agency's proposed Hazardous Waste Identification Rule) would exclude immobilized mixed debris from RCRA Subtitle C restrictions after treatment. This exclusion would be similar to the one provided for hazardous debris treated by extraction or destruction technologies.

- Permit requirements for implementation of this technology at other facilities are expected to include

  — RCRA permitting depending on site-specific requirements,
  — National Environmental Policy Act review (categorical exclusion), and
  — radioactive materials license.

Air permits are unlikely to be required.

- Because macroencapsulation is a technology-based treatment standard, the process used must be approved by local regulatory agencies as meeting the definition of MACRO, as provided in 40 CFR 268.2 prior to disposal in a RCRA Subtitle C landfill.

- Radiological exposures to personnel must be kept "as low as reasonably achievable" pursuant to DOE regulations.

Worker Safety Issues

- Hughes Associates evaluated the relative fire hazards associated with a production-scale polyethylene extrusion process. The results of the study indicate that fire hazards associated with the process are common to industrial extruder processes and not unique to the intended application. Fire hazards associated with the extruder include the potential for overheat conditions, electrical power faults, and ignition of combustible lubricants. The primary fire hazard associated with the polyethylene extrusion process is the storage of raw polyethylene, but the hazard is minor because of the low flammability of polyethylene.
- Molten polyethylene can cause severe burns, so precautions for worker safety are necessary.
- A properly operated polymer macroencapsulation process requires minimum operator input other than drum placement at the output of the extruder.
- Level B or C personnel protection is required depending on waste characteristics and process ventilation.

Community Safety, Potential Environmental Impacts and Exposures

The risk to community is very low. Macroencapsulation waste barriers meet LDR requirements, and the physical process used to encapsulate waste has very low accident and release potential.

Benefits

- Polymer extruders are easy to install and operate.
- The process operates at low temperature, needs no off-gas treatment, and does not generate secondary wastes.
- The process produces compliant, leach-resistant, and durable final waste forms.
- The process has low profile and requires little space.

Potential Socioeconomic Impacts and Community Perceptions

- Polymer macroencapsulation has minimal economic or labor force impact.
- The polymer extrusion macroencapsulation process is not generally considered to be a viable alternative to incineration. As pointed out earlier, this process is not cost-effective for "soft debris," which is primarily combustible waste and can be incinerated.
- No adverse public or tribal input regarding macroencapsulation technology was received. Stakeholders have expressed preference for this technology over cement/grout encapsulation technology because of long-range stability.

SECTION 7

Technology Selection Considerations

- Polyethylene macroencapsulation is a good treatment option for lead and debris wastes contaminated with low levels of radioactivity.
- The technology is competitive with separation and destruction technologies for debris wastes contaminated with low levels of volatile organic compounds.
- Polyethylene macroencapsulation has been demonstrated at Envirocare and various DOE sites to be effective in the treatment of radioactively contaminated lead and debris wastes.
- Several studies have been conducted to evaluate the long-term mechanical stability of the final waste form. In particular, the waste form's response to biodegradation, photodegradation, radiolysis, chemical attack, and fire were examined:
  - Polymers are highly resistant to microbial attack. Ecological concerns over the ability of plastics to resist microbial degradation have precipitated numerous studies on the biodegradability of plastics and potential techniques for enhancing it. All of these studies concluded that, under normal conditions, biodegradation rates for polyethylene are negligible.
  - Photodegradation of polyethylene exposed to ultraviolet radiation can cause deterioration of structural integrity; however, this failure mechanism is unlikely since radioactive waste forms are not exposed to the sun.
  - Low levels (<100 megarad) of ionizing radiation will not adversely impact the structural integrity of the final waste form. Four chemical reactions are generally responsible for the effects of radiation on polyethylene: cross-linking, chain scission, increased unsaturation, and oxidation. Of these, cross-linking is the predominant effect. Increased unsaturation has little effect on the mechanical properties, but it occurs with nearly the same yield as cross-linking. Each of these two reactions results in the production of hydrogen on a 1:1 basis. Chain scission is a minor reaction, occurring at a rate of about 5 percent of cross-linking and increased unsaturation. Oxidation is generally neglected, but it could play a significant role. The occurrence of each of these reactions is linearly dependent on the absorbed dose of radiation.
  - Experiments conducted to evaluate the thermal stability of the waste form conclusively demonstrated that no exothermal reaction hazards exist. In the event of a hot fire, however, the waste form is likely to burn. The flash-ignition temperature of polyethylene is 340°C, and the auto-ignition temperature is 430°C.
  - Polyethylene's resistance to chemical attack is one of the main reasons for its widespread use in many diverse applications. At ambient temperatures, polyethylene is insoluble in virtually all organic solvents and is resistant to many acids and caustic solutions.

Implementation Considerations

- LDPE with a melt index of approximately 9 g/10 min has adequate flow characteristics with minimal surface cracking, as compared to material with extremely low (2 g/10 min) or extremely high (60 g/10 min) melt indexes. This material provides a cost-effective production-scale process with higher quality final waste forms.

- Because it has a lower shrinkage factor, LDPE is more successful than high-density polyethylene for large-scale pours.
- The annular space between the waste and the container is a critical parameter in ensuring complete coverage and minimizing cracking.
- To minimize fire hazards associated with the process, a Hughes Associates study recommended the use of noncombustible lubricants, thermal limit switches to shut down the extruder in the event that a heating unit overheats, and routine maintenance and cleaning. Hughes Associates also recommended limitations on the quantity and arrangement of stored polyethylene to reduce the fire hazard.

Technology Limitations and Needs for Future Development

- The rationale for minimum layer thickness, leaching performance, durability, and effect of void spaces should be addressed, particularly since some of these issues affected the acceptance criteria for Envirocare. Development of technically defensible positions on these issues will assist in future regulatory review and permitting processes and lead to a more cost-effective final waste form.
- Research should be conducted to determine whether compaction technologies should be incorporated with macroencapsulation to improve waste loading.
- The polymer encapsulation process with LDPE is relatively intolerant of the presence of free liquids and organics. Encapsulation of mixed waste forms containing free liquids or organics will require additional investigation and site-specific regulatory interaction and approval.

APPENDIX A

[redacted]

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Charlesby, A. *Atomic Radiation and Polymers.* Pergamon, New York, 1960.

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Kalb, P. D., J. H. Heiser, III, and P. Columbo. *Polyethylene Encapsulation of Nitrate Salt Wastes: Waste Form Stability, Process Scale-up, and Economics.* BNL-52293, Brookhaven National Laboratory, Upton, NY, January 1991.

Moriyama, N., et al. "Incorporation of Radioactive Spent Ion Exchange Resins in Plastics," *Journal of Nuclear Science and Technology*, **12**(6), 363–69 (1975).

Rauwendaal, C. *Polymer Extrusion.* Hanser, New York, 1990.

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Cap at DOE's Lawrence Livermore National Laboratory Site 300, Pit 6 Landfill OU

Cap at DOE's Lawrence Livermore National Laboratory Site 300, Pit 6 Landfill OU

Site Name: Lawrence Livermore National Laboratory (LLNL) Site 300 - Pit 6 Landfill Operable Unit (OU)	**Contaminants:** Volatile Organic Compounds: - Trichloroethene (TCE) Radionuclides: - Tritium	**Period of Operation:** Installed Summer 1997; groundwater monitoring scheduled for 30 years (post-closure care)
Location: Livermore, CA		**Cleanup Type:** Full-scale
Vendor/Consultants: Lockheed-Martin Energy Systems Inc. Oak Ridge, TN Weiss Associates Emeryville, CA	**Technology:** Cap Multilayer cap that consists of (top to bottom): - Topsoil and vegetative layer (2-feet) - Geocomposite drainage layer/biotic barrier (high-density polyethylene (HPDE) netting between synthetic filter fabric) - HDPE/geosyntheic clay layer (60-mil HDPE liner over bonded bentonite clay layer) - General fill (compacted native soil; 2-feet thick) - Georigid reinforcement (HDPE flexible grid material; two to three layers separated by 6-inches of general fill)	**Cleanup Authority:** CERCLA - Removal Action Federal Facility Agreement
Additional Contacts: Michael G. Brown Deputy Director DOE/OAK Operations Office L-574 Lawrence Livermore National Laboratory Lawrence, CA 94551 (510) 423-7061 John P. Ziagos Site 300 Program Leader L-544 Lawrence Livermore National Laboratory Lawrence, CA 94551 (510) 422-5479		**Regulatory Point of Contact:** Information not provided
Waste Source: Waste debris and biomedical waste from operations at Site 300	**Type/Quantity of Media Treated:** Cap - 2.4 acre multilayer cap over a landfill	
Purpose/Significance of Application: Multilayer capping of a landfill		
Regulatory Requirements/Cleanup Goals: The CERCLA compliance criteria analysis for the Pit 6 landfill removal action include overall protection of human health and the environment; compliance with the Applicable or Relevant and Appropriate Requirement (ARARs), long-term effectiveness and permanence; reduction in toxicity, mobility, and volume; short-term effectiveness; and implementability.		

Cap at DOE's Lawrence Livermore National Laboratory Site 300, Pit 6 Landfill OU (continued)

Results:
- A summary is included in the report comparing the CERCLA objectives to the performance of the landfill. The cap is meeting the objectives for protection of human health and the environment, reduction of mobility of the waste, short-term effectiveness and implementability.
- While the landfill cap construction meets all ARARs, capping alone may not meet State requirements for protection of beneficial uses of groundwater. In addition, a cap does not reduce the toxicity and volume of buried waste and contaminated groundwater. At the time of this report, the post-closure monitoring plan was still being written.

Cost:
- Total cost of constructing the landfill cap was $1,500,000, including design, mobilization and preparatory work and site work.
- Total cost of the removal action was $4,100,000, including costs for preliminary/preconstruction activities, construction activities and projected costs for 30 years of landfill O&M and groundwater monitoring.

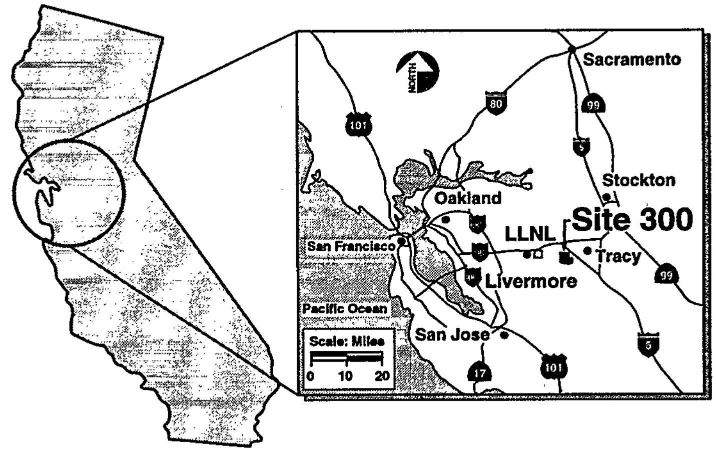
Description:
Lawrence Livermore National Laboratory Site 300 is a DOE experimental test facility located near Livermore California. Pit 6 Landfill OU was the location of buried waste including laboratory and shop debris and biomedical waste, including radioactive wastes. From 1964 to 1973, approximately 1,900 cubic yards of waste were disposed of in three unlined debris trenches and six animal pits. The trenches, located near the center of the landfill, were each about 100 feet long, 10 feet deep, and 12 to 20 feet wide. The animal pits, located in the northern part of the landfill, were each about 20 to 40 feet long, 16 feet deep, and nine feet wide. VOC and tritium were detected in soil and groundwater at the site. TCE concentrations in the groundwater have declined from levels as high as 250 ug/L in 1989 to 15 ug/L in 1997 (slightly above the federal and state MCL of 5 ug/L). Trace concentrations of chloroform, cis-1,2-dichloroethene, and tetrachloroethene are also present in the groundwater. The maximum activity of tritium currently detected in groundwater is 1,540 pCi/L, below the MCL of 20,000 pCi/L.

In the summer of 1997, a 2.4 acre multilayer cap was placed over the three trenches and six animal pits. The cap extended more than 25 feet beyond the perimeter of the trenches and pits due to uncertainties in the exact location of the waste and to cover areas where VOCs in the subsurface had potential to cause worker inhalation exposure. The cap consists of a vegetative/topsoil layer, a geocomposite drainage layer underlain by a geosynthetic liner over a bonded bentonite clay layer, and compacted general fill which includes georigid reinforcement. A summary is included in the report comparing the CERCLA objectives to the performance of the landfill which indicates that the cap is meeting the objectives for protection of human health and the environment, reduction of mobility of the waste, short-term effectiveness and implementability. While the landfill cap construction meets all ARARs, capping alone may not meet State requirements for protection of beneficial uses of groundwater. In addition, a cap does not reduce the toxicity and volume of buried waste and contaminated groundwater. A Post-Closure Monitoring Plan was being written at the time of the report and will establish a Detection Monitoring Program and a Corrective Action Monitoring Program. Several observations and lessons learned from this application related to implementation are included in the report, along with information on technology advancements.

Total cost of constructing the landfill cap was $1,500,000, including design, mobilization and preparatory work and site work. Total cost of the removal action was $4,100,000, including costs for preliminary/preconstruction activities, construction activities and projected costs for 30 years of landfill O&M and groundwater monitoring.

1. SUMMARY

From 1964 to 1973, approximately 1,900 cubic yards of waste was placed in nine unlined debris trenches and animal pits at the Pit 6 Landfill at Lawrence Livermore National Laboratory Site 300. The material buried included laboratory and shop debris, and biomedical waste. Contaminants potentially associated with the waste include organic solvents, radionuclides, PCBs, and metals. Plumes of volatile organic compounds (VOCs) and tritium in ground water emanate from the landfill. The primary VOC released is trichloroethene (TCE). In 1997, a 2.4-acre engineered cap was constructed over the landfill as a CERCLA removal action, isolating the waste from rain water or surface water infiltration and eliminating safety concerns related to potential subsidence. The total cost of constructing the landfill cap was about $1,500,000. Selectively substituting geosynthetic for natural materials saved over $500,000. Total past and projected project costs are approximately $4,100,000.



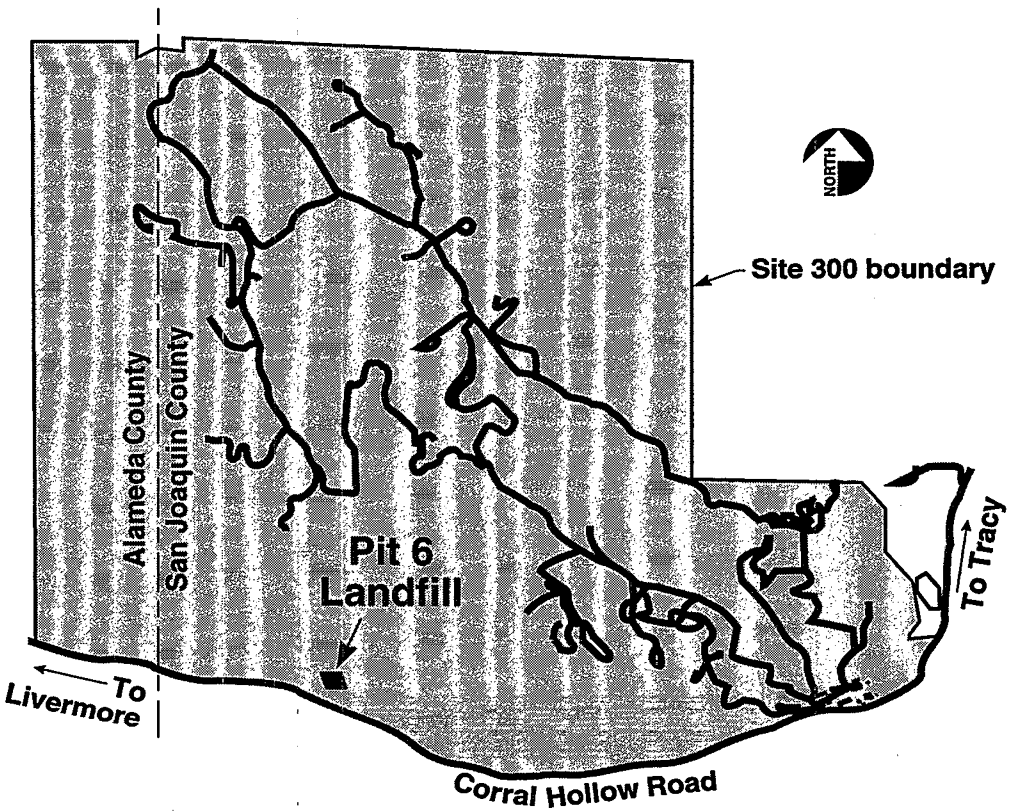
Location of LLNL Site 300.

Pit 6 Landfill and overlying rifle range prior to cap construction; view looking south (May 1997).

2. SITE INFORMATION

Identifying Information

- Facility: Lawrence Livermore National Laboratory (LLNL) Site 300.
- Operable Unit: Pit 6 Landfill (OU 3).
- Regulatory Drivers: Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA), Site 300 Federal Facility Agreement.
- Type of Action: Landfill capping and ground water monitoring as a CERCLA non-time-critical removal action.
- Period of Operation: Capping completed in September 1997. Post-closure maintenance and monitoring will continue.



Location of the Pit 6 Landfill at LLNL Site 300.

Technology Application

A cap has been constructed over the Pit 6 Landfill to: (1) isolate the buried waste from rain water and/or surface water infiltration, (2) divert surface water from the covered area, (3) eliminate safety hazards from subsidence into void spaces in the buried waste, (4) mitigate risk from potential inhalation of vapors from the subsurface, and (5) reduce ground water recharge near the contaminant pumes.

Site Background

LLNL Site 300 is a DOE experimental test facility located in the rugged, semiarid Altamont Hills east of Livermore, California. The Pit 6 Landfill lies near the southern boundary of Site 300 along Corral Hollow Road, and is situated on an alluvial terrace about 40 feet above the Corral Hollow Creek flood plain. The landfill received about 1,900 yd^3 of material from LLNL and Lawrence Berkeley Laboratory from 1964 to 1973. Waste was placed in three debris trenches and six smaller animal pits. A disposal log was kept by LLNL, but is not sufficiently detailed to permit full characterization of the waste.

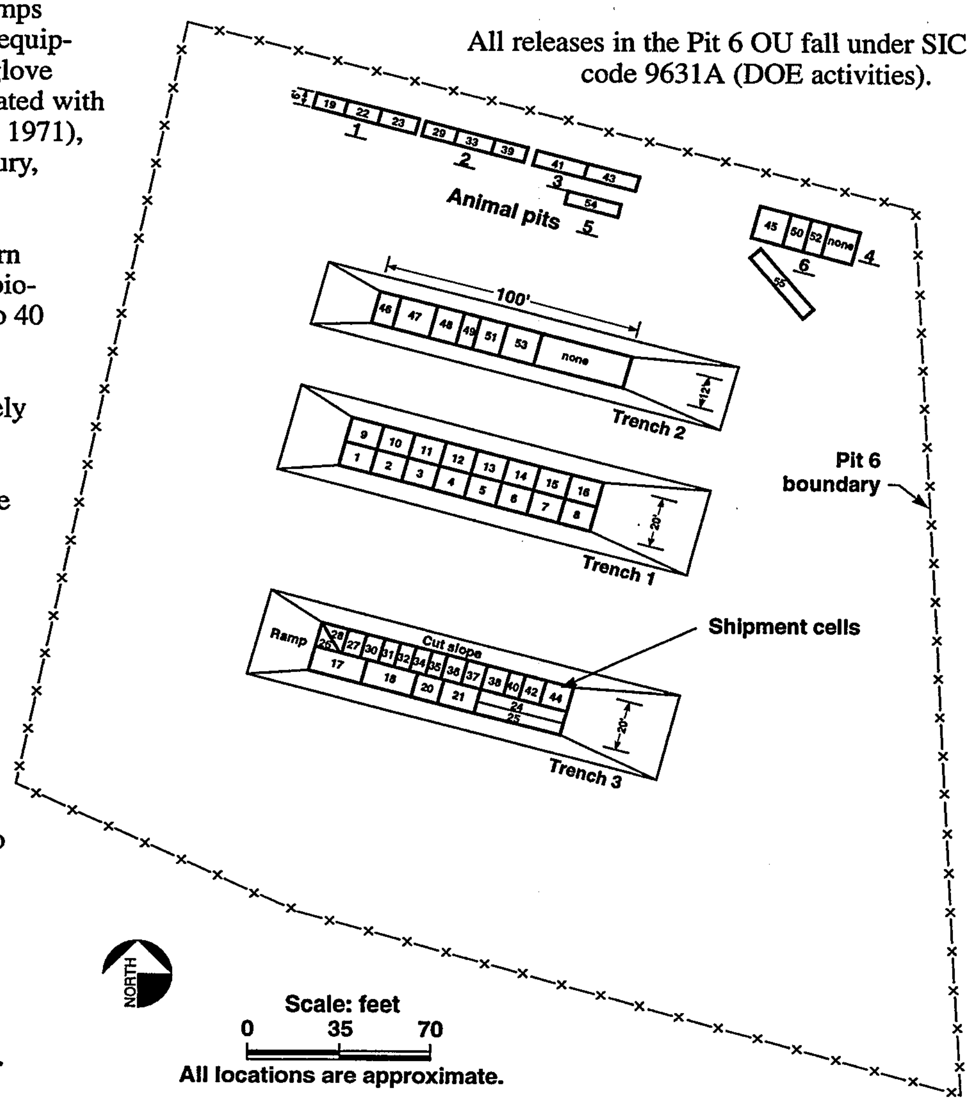
Laboratory and shop debris was placed in trenches 1, 2, and 3, located in the central part of the landfill. Each trench was about 100 feet long, 12 to 20 feet wide, and 10 feet deep. Debris was placed in 42 shipment cells, with a total volume of approximately 1,750 yd^3. Records indicate that the trench waste includes capacitors, drums and tanks, compressed gas cylinders, lamps and ignition tubes, shop and laboratory equipment and waste, ductwork, filters, and glove boxes. Contaminants potentially associated with the debris include uranium (exhumed in 1971), thorium, beryllium, VOCs, PCBs, mercury, and cutting oil.

The six animal pits located in the northern part of the landfill received waste from biomedical experiments. Each pit was 20 to 40 feet long, 9 feet wide, and about 16 feet deep. Waste was placed in 13 shipment cells, with a total volume of approximately 150 yd^3. The waste consisted of animal carcasses, blood, milk, feces, and urine. Records indicate that up to 42 radioactive isotopes were present in the waste, with an estimated total activity at time of burial of 0.7 to 2.1 Curies (Ci). This includes about 0.5 Ci of tritium buried in two shipment cells; 99.96% in cell 55 and 0.04% in cell 23. The half lives of the buried isotopes range from 12.8 hours to 30 years. Some of the decay products of the original isotopes have longer half lives, but the activity of these daughter products is estimated to be below background. The total activity remaining in the animal pits after at least 24 years of burial is estimated to be 0.12 to 0.18 Ci.

After burial, all waste was covered with several feet of native soil. The landfill was not constructed with liners, containment structures, or leachate control systems. Due to safety considerations, no intrusive investigations of the buried material have been performed. A rifle range used for training exercises by LLNL was located directly over the landfill.

Documents prepared for the Pit 6 OU include the Site-Wide Remedial Investigation report (Webster-Scholten, 1994); a Feasibility Study (Devany et al., 1994), which was later redesignated as an Engineering Evaluation/Cost Analysis (EE/CA); an addendum to the EE/CA (Berry, 1996); and an Action Memorandum (Berry, 1997). A Post-Closure Plan is in preparation.

All releases in the Pit 6 OU fall under SIC code 9631A (DOE activities).



Pit 6 Landfill.

Site Contacts

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3. MATRIX AND CONTAMINANT DESCRIPTION

Matrix Identification

Approximately 1,900 yd^3 of laboratory and shop debris and animal waste are buried in the Pit 6 Landfill. VOCs and tritium have been released contaminating ground water, soil, and bedrock.

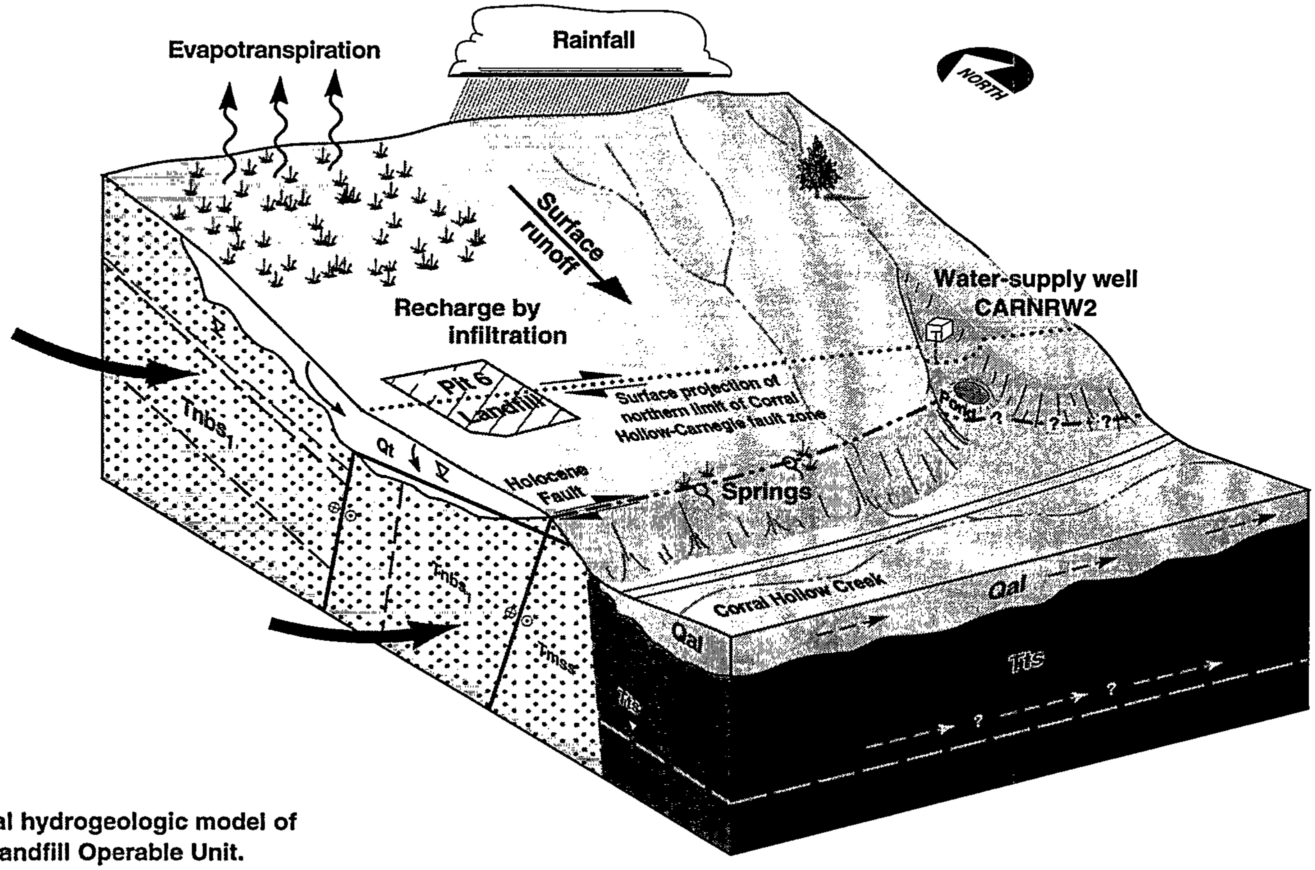
Hydrogeology

The Pit 6 Landfill is located on a Quaternary-age alluvial terrace up to 55 feet in thickness. The alluvium overlies Tertiary-age sedimentary bedrock. The landfill is situated along the northern limit of the Corral Hollow-Carnegie Fault Zone. North of the fault zone, bedrock dips southward at 5 to 20 degrees. Within the fault zone, bedrock is nearly vertical to overturned. Evidence of Holocene activity has been observed along a fault strand located about 150 feet south of the landfill.

Ground water is about 30 to 50 feet below ground surface beneath the landfill. While ground water elevations can vary seasonally by several feet, the water table remains at least 15 feet below the bottom of the buried waste. Shallow, unconfined ground water flows to the southeast at an estimated average rate of 30 to 70 feet per year.

During the winter rainy season, ground water has been observed flowing intermittently from springs along the edge of the alluvial terrace. These springs have been dry for the past several years as water levels declined.

Hydrogeology (cont.)



Conceptual hydrogeologic model of the Pit 6 Landfill Operable Unit.

Contaminant Physical Properties

Physical properties of VOCs released from the Pit 6 Landfill.

Contaminant	Vapor pressure (mm Hg)	Henry's Law constant (atm-m^3/mol)	Density constant (g/cm^3)	Water solubility (mg/L)	K_{ow}	K_{oc}
Chloroform	160	3.23E-03	1.4890	8.00E+03	79.43	43.65
cis-1,2-Dichloroethene	208	7.58E-03	1.2837	3.50E+03	5.01	49.00
Tetrachloroethene	14	1.53E-02	1.6227	1.50E+02	398.11	263.03
Trichloroethene	58	9.10E-03	1.4642	1.10E+03	338.84	107.15

Vapor Pressure: The higher the vapor pressure, the more volatile.
Henry's Law Constant: Compounds with constants greater than 1E-3 readily volatilize from water.
Density: Compounds with a density greater than 1 have a tendency to sink (i.e., DNAPLs); compounds with a density less than 1 have a tendency to float (i.e., LNAPLs).
Water Solubility: Highly soluble chemicals can be rapidly leached from wastes and soils and are mobile in ground water; the higher the value, the higher the solubility.

Octanol-Water Partition Coefficient (K_{ow}): Used in estimating the sorption of organic compounds on soils (high K_{ow} tends to adsorb more easily).
Organic Carbon Partition Coefficient (K_{oc}): Indicates the capacity for an organic chemical to adsorb to soil because organic carbon is responsible for nearly all adsorption in most soils (the higher the value, the more it adsorbs).

Contaminant Physical Properties (cont.)

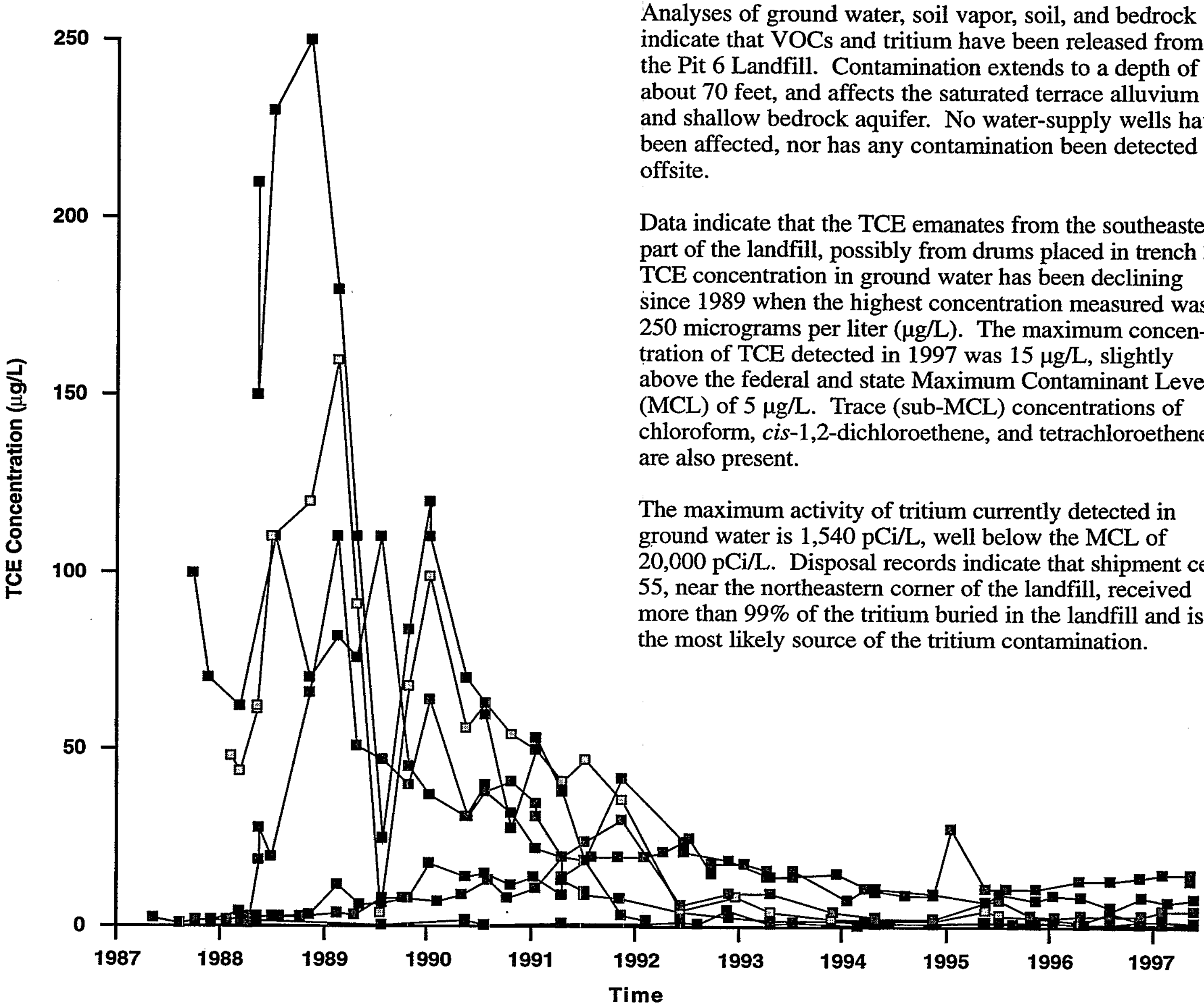
Tritium is the only radioactive isotope of hydrogen. It contains two neutrons in the nucleus, in addition to one proton that all hydrogen isotopes share. Thus, it has an atomic number of 1, an atomic weight (mass number) of 3, and is three times heavier than a hydrogen atom. Due to radioactive decay, tritium has a physical half-life of 12.26 years. It decays to a stable isotope of helium with the emission of a low-energy beta particle. Tritium concentration in ground water is typically expressed in units of radioactivity, or activity per unit volume as picoCuries per liter (pCi/L).

Nature and Extent of Contamination

Analyses of ground water, soil vapor, soil, and bedrock indicate that VOCs and tritium have been released from the Pit 6 Landfill. Contamination extends to a depth of about 70 feet, and affects the saturated terrace alluvium and shallow bedrock aquifer. No water-supply wells have been affected, nor has any contamination been detected offsite.

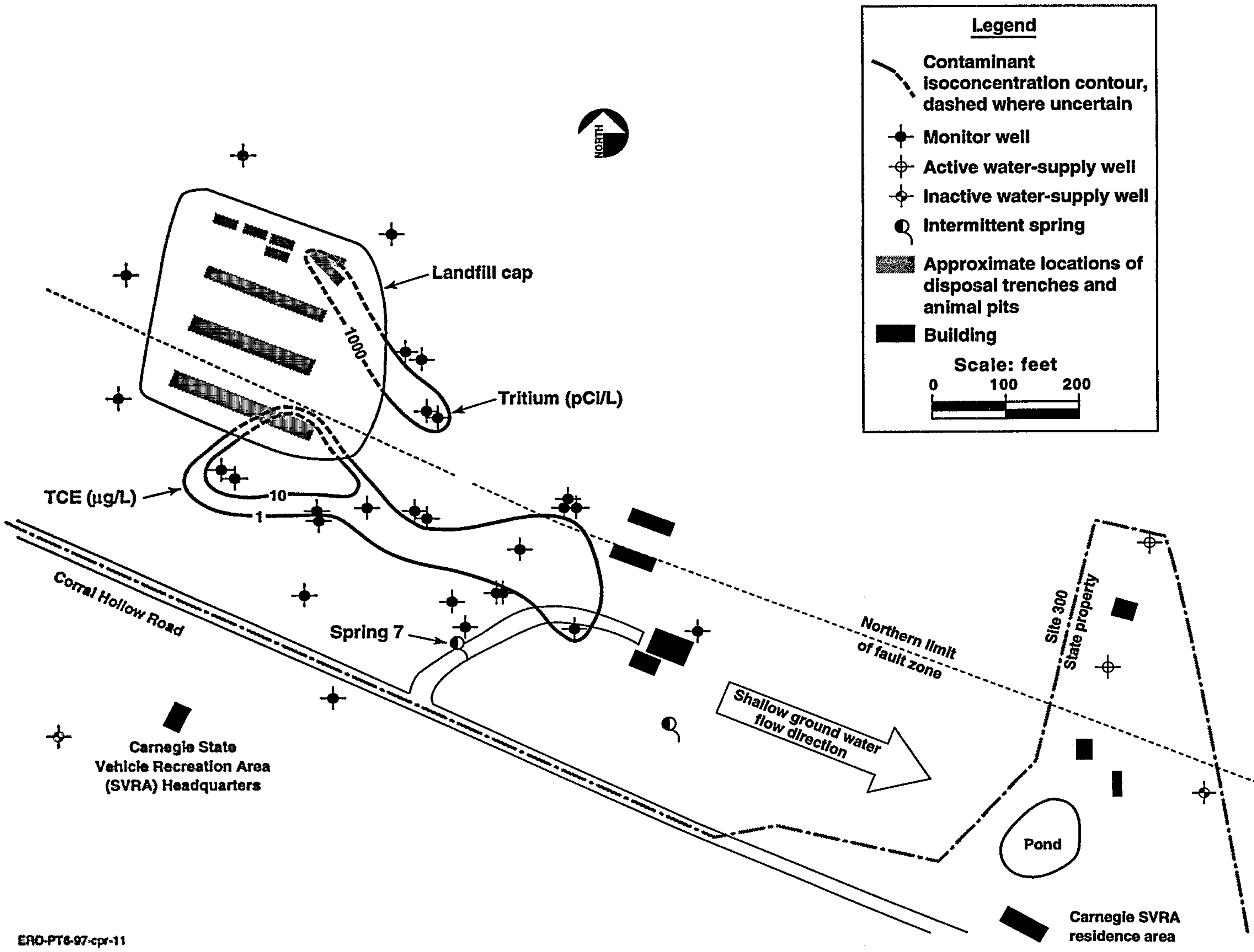
Data indicate that the TCE emanates from the southeastern part of the landfill, possibly from drums placed in trench 3. TCE concentration in ground water has been declining since 1989 when the highest concentration measured was 250 micrograms per liter (µg/L). The maximum concentration of TCE detected in 1997 was 15 µg/L, slightly above the federal and state Maximum Contaminant Level (MCL) of 5 µg/L. Trace (sub-MCL) concentrations of chloroform, *cis*-1,2-dichloroethene, and tetrachloroethene are also present.

The maximum activity of tritium currently detected in ground water is 1,540 pCi/L, well below the MCL of 20,000 pCi/L. Disposal records indicate that shipment cell 55, near the northeastern corner of the landfill, received more than 99% of the tritium buried in the landfill and is the most likely source of the tritium contamination.



TCE concentration in ground water monitor wells at the Pit 6 Landfill.

Nature and Extent of Contamination (cont.)



Distribution of contaminants in ground water (1997).

4. REMEDIATION DESCRIPTION

Primary Technology

The primary remedial technology selected for the Pit 6 Landfill OU is capping. In the summer of 1997, a multi-layer cover was placed over the three trenches and six animal pits in the landfill to isolate the buried waste, prevent future rainwater infiltration, prevent further void space collapse and associated safety hazards, and reduce ground water recharge near the VOC plume. The cap also prevents the potential flux of VOC vapors to the surface. To control surface water, a diversion and drainage system was constructed along the perimeter of the cap.

The contents of the trenches and animal pits will remain in place. Rising ground water inundating the waste is unlikely because the water table historically has been at least 15 feet below the bottom of the waste, and the cap and drainage diversion system will reduce recharge by infiltration. TCE and tritium in ground water will continue to be monitored. Final cleanup standards for ground water will be determined in the forthcoming Site-Wide Record of Decision.

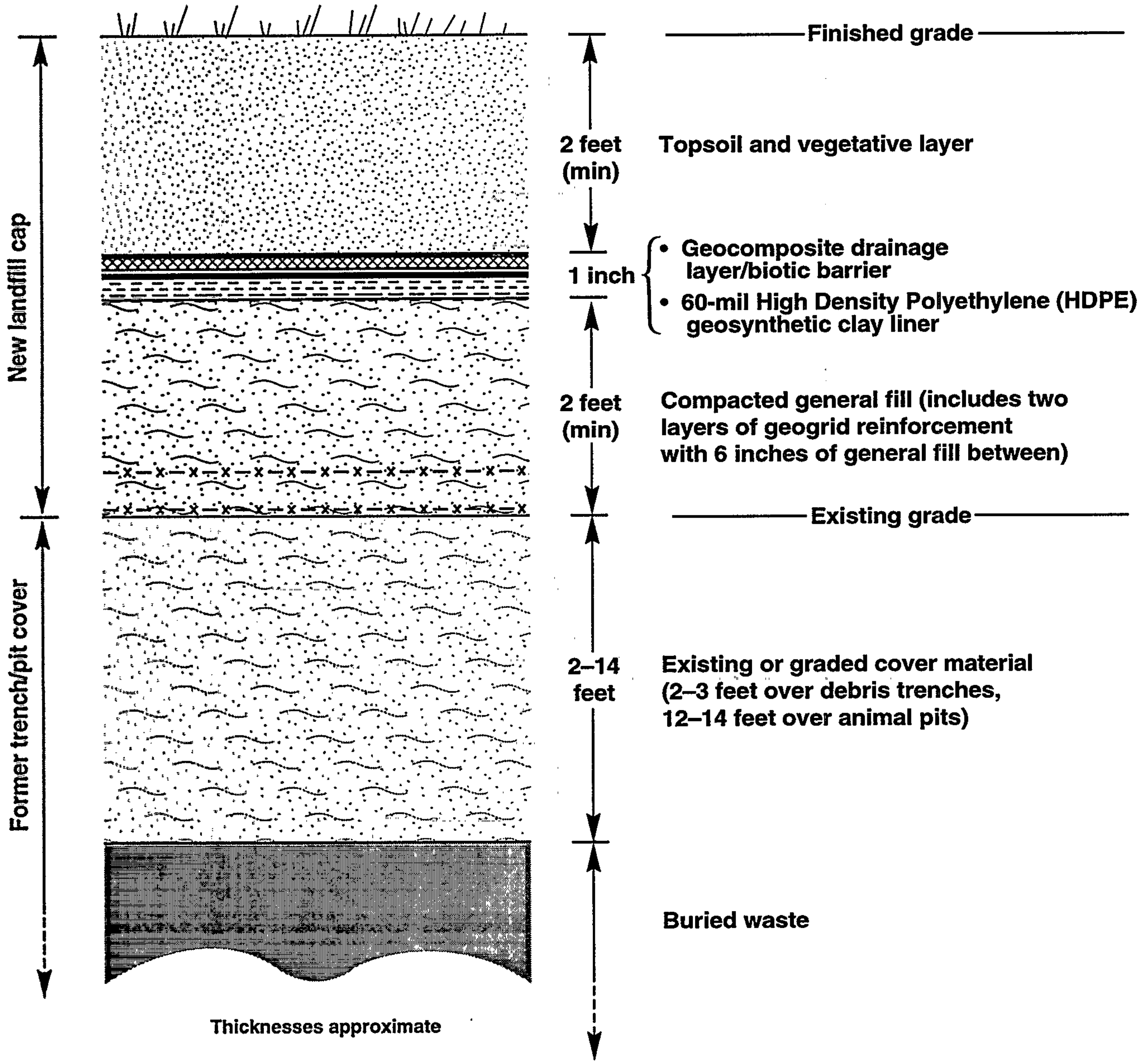
Key Design Criteria

The Pit 6 Landfill cap is about 2.4 acres in size, extending more than 25 feet beyond the perimeter of the buried waste trenches and animal pits. In some areas, the cap was extended farther due to uncertainties in the exact location of the buried waste and to cover areas where VOCs in the subsurface had potential to cause worker inhalation exposure.

The cap consists of several layers, and meets the performance criteria of preventing rainwater infiltration into the buried waste, mitigating potential damage by burrowing animals and vegetation, preventing safety hazards due to potential collapse of void spaces in the buried waste, and mitigating potential flux of VOC vapors through the soil.

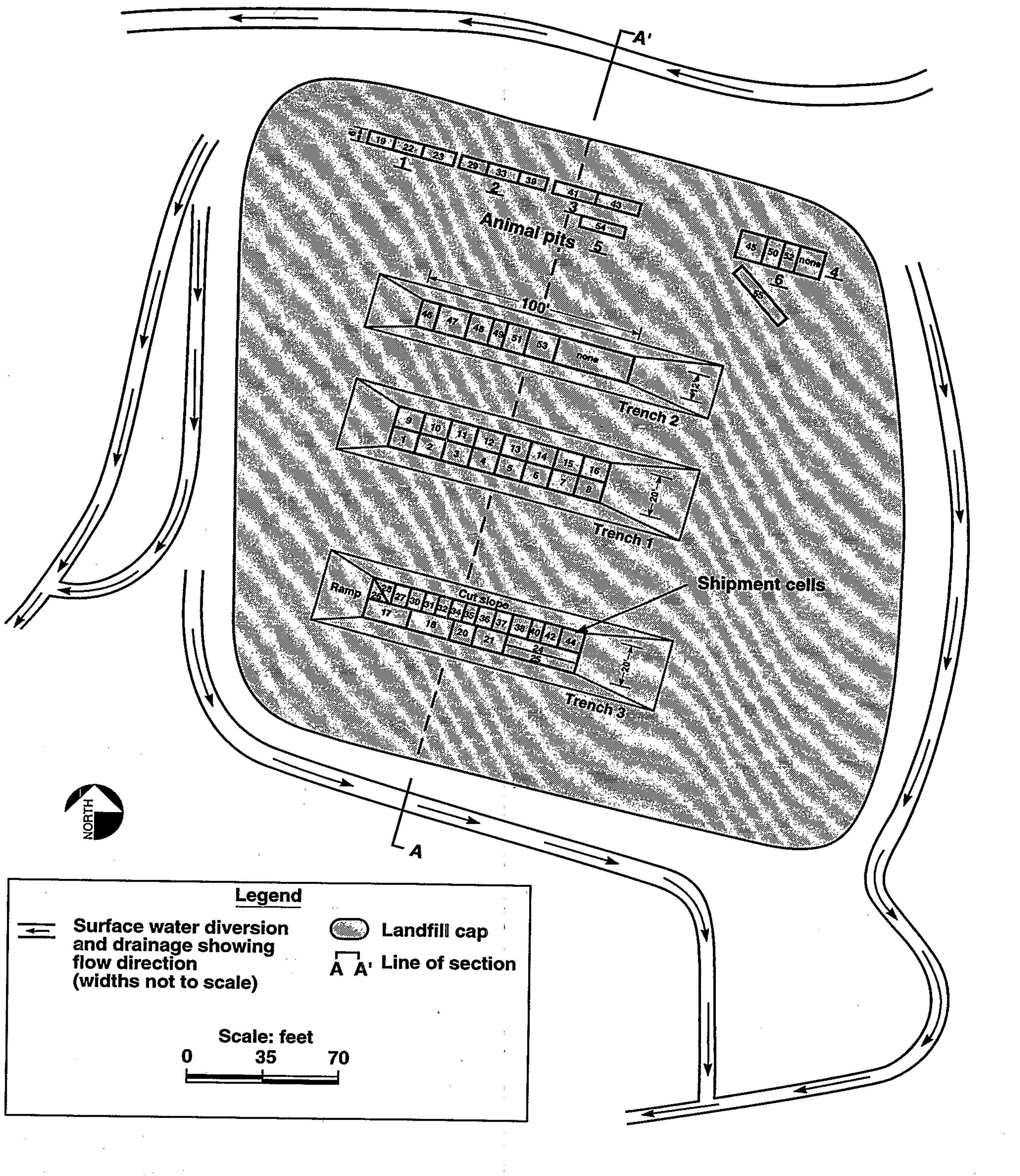
The northern diversion channel is lined with rip-rap and will capture runoff from the slope north of the landfill and divert it to a natural drainage divide to the west. Drainage channels on the east, west, and south sides of the landfill cap are lined with concrete and will collect and drain rainwater that runs off the cap as well as rainwater that has infiltrated through the vegetative layer and drained to the perimeter through the geocomposite drainage layer.

Key Design Criteria (cont.)



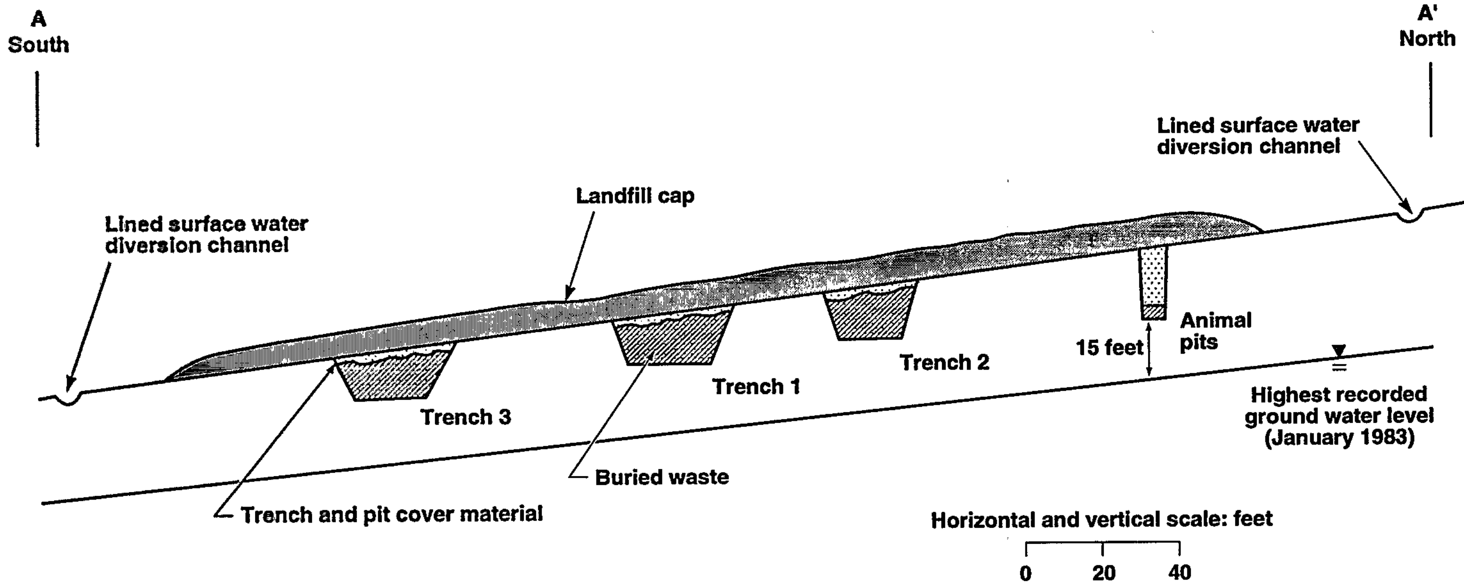
Typical section of the Pit 6 Landfill cap.

Key Design Criteria (cont.)

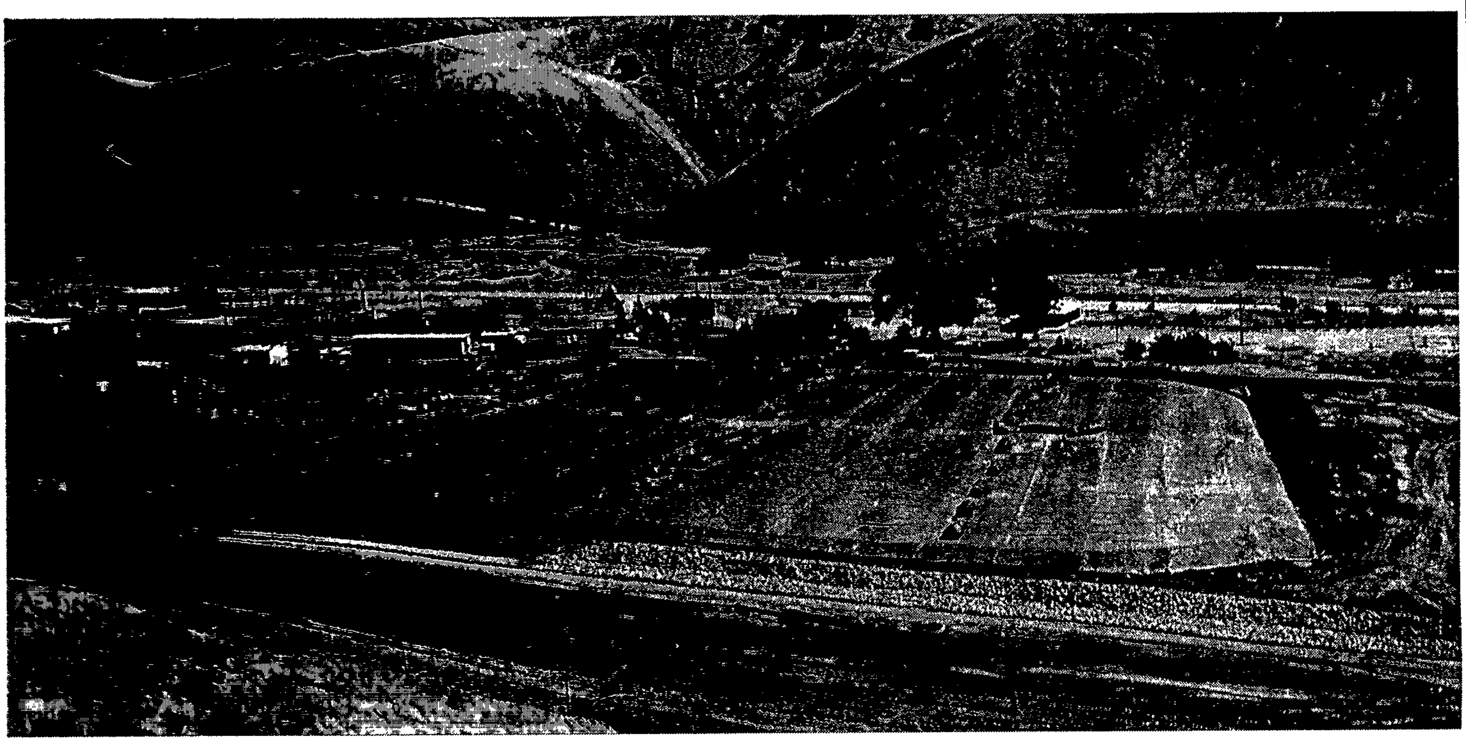


Pit 6 landfill cap and surface water diversion and drainage system.

Key Design Criteria (cont.)



Cross section of the Pit 6 Landfill.



Pit 6 Landfill liner during installation; view looking south (July 1997).

Key Design Criteria (cont.)

Components of the landfill cap.

Layer (top to bottom)	Description and purpose
Topsoil and vegetative layer	A minimum of 2 feet of native soil to protect underlying liner system. Prevents majority of infiltration by capturing rainwater and allowing evapotranspiration and/or runoff before water reaches the liner. Vegetation minimizes erosion. Grasses selected with root depths that will not impact underlying liner system.
Geocomposite drainage layer/biotic barrier	High-Density Polyethylene (HDPE) netting sandwiched between synthetic filter fabric. High transmissivity material drains infiltrating water to the perimeter of the landfill cap, preventing water from ponding on underlying liner. Material will also serve as a deterrent to burrowing animals.
HDPE/geosynthetic clay liner	60-mil HDPE liner over bonded bentonite clay layer. Very low permeability prevents rainwater infiltration into buried waste. Bentonite clay layer acts as an expansive sealant in the unlikely event of a liner puncture. Liner also prevents potential upward flux of VOC vapor.
General fill	Compacted native soil to provide a level surface for liner placement. Design specifies a thickness of 2 feet to mitigate damage to liner system from potential local earthquakes.
Geogrid reinforcement	HDPE flexible grid material to provide short- and long-term structural support over potential void spaces in the buried waste. Two or three layers (depending on location) separated by 6 inch lifts of general fill. Geogrid reinforcement provides increased safety during and after construction.

5. REMEDIATION PERFORMANCE

Design concern	Performance goals	Performance criteria
Infiltration	Minimize surface water infiltration to prevent leachate generation.	Vegetative/topsoil layer 2 feet thick (minimum) to maximize evapotranspiration. Geocomposite drainage layer prevents ponding of infiltrated rainwater on liner. Combined 60-mil HDPE liner and 0.25-inch-thick geosynthetic clay liner provides a permeability of less than 4×10^{-12} cm/sec.
Subsidence caused by void space collapse in buried waste	Ensure long-term integrity of cap and safety of onsite workers.	Geogrid reinforcement layers used to bridge potential void spaces. Strength of layers capable of supporting loads from new rifle range structure and a 2.5-ton service truck.
Surface water control	Protect cap from storm water run-off and run-on.	Perimeter drainage system including concrete-lined ditches, rip-rap-lined channel, and corrugated metal culverts with capacity for a 24-hour Probable Maximum Precipitation storm event.
Vapor control	Prevent the possible escape of low concentration VOC vapors to the surface to mitigate potential inhalation exposure to onsite workers.	Low permeability liner used to prevent water infiltration also prevents vapor escape. Buried waste will not produce methane so gas buildup not a concern.
Burrowing animals	Prevent damage to liner system by burrowing animals.	Geocomposite drainage layer to deter animals. Periodic inspections to be conducted.
Earthquake damage	Minimize potential for liner integrity compromise as a result of a seismic event that could potentially occur on a fault located about 150 feet south of the landfill.	Used probability assessment to determine Peak Ground Acceleration (PGA) with a 10% chance of being exceeded in 50 years. Determined that 2-foot-thick general fill layer beneath liner is sufficient to prevent damage to liner as a result of 4.4-g PGA.
Post-closure use	Cap must accommodate installation of a new rifle range to replace the one demolished during construction.	An additional geogrid reinforcement layer was placed over a portion of the landfill to bear the load of the rifle range structure.

Monitoring

Post-closure ground water monitoring will include analyses for substances confirmed to have been released from the Pit 6 Landfill debris trenches and animal pits (VOCs and tritium), as well as for those potentially present in the buried waste (beryllium, PCBs, mercury, and radionuclides). Ground water samples will be collected quarterly, and statistical analyses performed on the results. Ground water elevation will also be measured quarterly. The Post-Closure Plan will establish: (1) a Detection Monitoring Program to identify future releases, and (2) a Corrective Action Monitoring Program to assess the performance of the landfill cap. Both programs will be periodically evaluated as part of Site 300 CERCLA Five-Year Reviews.

Risk Reduction

The baseline risk assessment for Pit 6 presented in the Site-Wide Remedial Investigation Report (Webster-Scholten, 1994) concluded that potential exposure to VOCs volatilizing from shallow soil in the vicinity of the rifle range above Pit 6 presented a maximum excess lifetime cancer risk to onsite workers of 5 in 1,000,000 (5×10^{-6}). The landfill cap is designed to mitigate this risk by preventing upward flux of VOCs from the subsurface.

Surface water, when present at spring 7, presents a maximum excess lifetime cancer risk to onsite workers of 4 in 100,000 (4×10^{-5}). This spring has not flowed since the summer of 1992, and no exposure pathway currently exists.

The cap is designed to reduce recharge to the shallow aquifer, and may prevent flow from spring 7 from occurring in the future. If flow resumes and VOC concentrations are detected at levels that pose a risk, contingency measures will be implemented which may include access controls and ground water remediation.

Ground water modeling indicates that there is little possibility of VOCs reaching offsite water supply wells; the nearest are located at the Carnegie State Vehicle Recreational Area, over 800 feet southeast of the Pit 6 ground water plume.

6. REMEDIATION COSTS

Cost elements for the Pit 6 Landfill.

General activity areas (WBS)	WBS second level cost elements (WBS)	Cost items	Costs ($K)	Subtotal ($K)
Preliminary/ Preconstruction Activities (32)	• RI/FS (32.02)	• Feasibility Study (Engineering Evaluation/Cost Analysis) and related work - Alternative evaluation - Conceptual design - Ground water extraction modeling - Document preparation - Regulatory interface	844	1,401
		• Addendum to EE/CA	47	
		• Public Workshop/Action Memorandum	65	
	• Remedial Design (32.03)	• Landfill Cap Design - Title I design document - Title II design document	398	
		• Post-closure plan	47	
Construction Activities (33)	• Mobilization and Preparatory Work (33.01)	• Contractor selection/site preparation - RFP distribution/contractor selection - Controlled burn of vegetation - Security coordination - Construction site fencing installation - Archaeological and ecological clearances - Coordination with other facility operations	53	1,078
	• Site Work (33.03)	• Removal Action Construction: - Demolish rifle range - Construct landfill cap	698	
		• Construction quality assurance and report	89	
		• Construction management	238	
Post-Construction Operations and Maintenance: Removal Action (34)	• Monitoring, Sampling, Testing, and Analysis (34.02)	• Landfill Operation and Maintenance (30 yrs in present-worth dollars) - Inspections, surveys, reporting - Maintenance and repairs	121	1,612
		• Ground water monitoring (30 yrs in present-worth dollars) - Sampling - Analysis	1,491	
		Total Pit 6 Landfill Removal Action		$4,091K

7. REGULATORY ISSUES

All remediation activities are carried out under CERCLA and in accordance with the Site 300 Federal Facility Agreement. Regulatory agencies overseeing the Pit 6 OU include the U.S. EPA, California Regional Water Quality Control Board–Central Valley Region, and California Department of Toxic Substances Control.

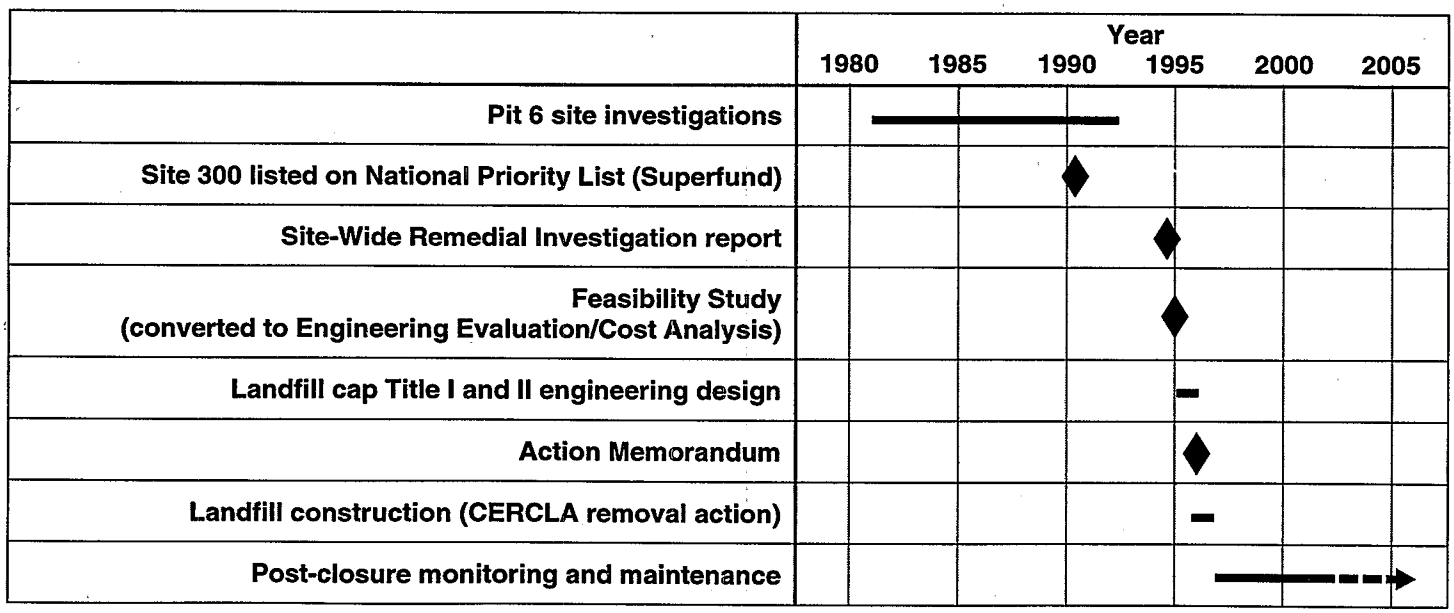
As part of the DOE/LLNL program of streamlining the CERCLA process, the landfill capping was conducted as a non-time-critical removal action. Federal and State regulatory agencies approved of this approach, which resulted in accelerating the project schedule by a full year. DOE authorized capping to proceed through an Action Memorandum.

Final ground water cleanup standards for the OU will be established in the forthcoming Site-Wide Record of Decision. If natural attenuation of the VOC plume continues, it is possible that no further action will be necessary. However, if VOC concentrations do not decline to meet cleanup standards, or if plume migration accelerates, active measures such as ground water extraction and treatment may be required.

CERCLA compliance criteria analysis for the Pit 6 Landfill removal action.

Objective/criteria	Summary of analysis
Overall protection of human health and the environment	Landfill cap: (1) reduces possibility of future releases from the buried waste, (2) prevents any potential direct exposure to the waste, (3) removes potential safety hazard from subsidence, and (4) reduces inhalation risk from VOCs in subsurface soils and exposure potential for sensitive ground-dwelling species.
Compliance with Applicable or Relevant and Appropriate Requirements (ARARs)	Landfill cap construction meets all ARARs, but capping alone may not meet State requirements for protection of beneficial uses of ground water.
Long-term effectiveness and permanence	Landfill cap reduces possibility of future releases by preventing surface water infiltration, prevents direct exposure to waste, and reduces potential inhalation exposure to VOCs in subsurface soil. May not protect all beneficial uses of ground water. Cap requires inspection and maintenance to ensure integrity and is subject to damage by rain, erosion, settlement, and seismic activity. Fence, signs, and site access restrictions will manage inhalation health risks at spring 7, if necessary.
Reduction in toxicity, mobility, and volume	Landfill cap reduces mobility of waste by preventing surface water infiltration. Toxicity and volume of buried waste and contaminated ground water are not reduced.
Short-term effectiveness	Safety monitoring and construction procedures minimize possible releases and worker exposure during landfill cap construction and monitoring. Human exposure and contaminant release could occur from cave-ins, rupture of waste containers, and dust generated during cap construction.
Implementability	Technically and administratively implementable. Equipment and materials for cap readily available. Landfill cap grading and compacting activities could cause additional releases by disturbing buried containers. Landfill cap construction requires demolition and replacement of rifle range.

8. SCHEDULE



9. OBSERVATIONS AND LESSONS LEARNED

Implementation Considerations

Implementing landfill cap design and construction as a non-time-critical removal action reduced the number and size of required regulatory documents needed for approval and accelerated the project by one full year. A major component of schedule acceleration was paralleling design work with regulatory and community input and approval to reduce review time and edits.

It is important to provide bidding contractors sufficient time to prepare competitive bids, essentially because there are a limited number of qualified geosynthetic installation contractors available. Due to tight scheduling, there was a a short bid submittal time frame for the Pit 6 landfill cap (about two weeks) that may have reduced the number of bids submitted and inhibited competition for the work.

The successful construction contractor's bid was within allowable cost tolerances, but all other bids were significantly higher. This may have been a result of bidders not having been allowed sufficient time to analyze specifications in detail, with the effect of added contingencies being included by bidders.

The landfill cap design specifications were required to accommodate constructing and operating a new rifle range on top of the cap. The geogrid structural reinforcement layer, combined with restrictions on using motor vehicles on the cap, will minimize the potential for damage caused by the collapse of void spaces in the buried waste.

Technology Advancements

Selectively substituting geosynthetic materials for natural materials saved over $500,000. Using a HDPE/geosynthetic clay liner in place of one to two feet of clay virtually eliminated concerns over possible desiccation cracks, low moisture content, and compaction of the impermeable liner during hot weather construction. Additionally, installation was much faster and quality assurance was more controllable.

Over $300,000 of these savings were realized by substituting a geocomposite drainage layer for a conventional cobble layer to protect the underlying liner from burrowing animals. Weight over the buried waste was reduced and overall cover height was kept to a minimum. However, data are limited on the performance of the geocomposite drainage layer to deter burrowing animals. A geocomposite drainage layer has been used successfully at other sites, but careful inspections will be conducted to ensure continued integrity of the cap.

Installing the HDPE/geosynthetic clay liner (July 1997).

10. REFERENCES

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Webster-Scholten, C. P. (Ed.) (1994), *Final Site-Wide Remedial Investigation Report, Lawrence Livermore National Laboratory Site 300,* Lawrence Livermore National Laboratory, Livermore, Calif. (UCRL-AR-108131).

11. VALIDATION

Signatories:

"This analysis accurately reflects the current performance and projected costs of the remediation."

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