INNOVATIVE TECHNOLOGY
Summary Report

DOE/EM-0469

VecLoader HEPA Vacuum Insulation Removal System

Deactivation and Decommissioning
Focus Area

Prepared for
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Office of Science and Technology

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INNOVATIVE TECHNOLOGY
Summary Report

VecLoader HEPA Vacuum Insulation Removal System

OST Reference #1784

Deactivation and Decommissioning
Focus Area

Demonstrated at
Fernald Environmental Management Project – Building 1A
Fernald, Ohio

INNOVATIVE TECHNOLOGY
Summary Report

Purpose of this document

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

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

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

All published Innovative Technology Summary Reports are available on the OST Web site at http://OST.em.doe.gov under "Publications."

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SECTION 1

SUMMARY

Introduction

The United States Department of Energy (DOE) continually seeks safer and more cost-effective remediation technologies for use in the deactivation and decommissioning (D&D) of nuclear facilities. To this end, the Deactivation and Decommissioning Focus Area (DDFA) of the DOE's Office of Science and Technology sponsors Large-Scale Demonstration Projects (LSDPs) at which developers and vendors of improved or innovative technologies showcase products that are potentially beneficial to DOE's projects and to others in the D&D community. Benefits sought include decreased health and safety risks to personnel and the environment, increased productivity, decreased costs and shortened schedules.

The U.S. Department of Energy (DOE) Fernald Environmental Management Project's (FEMP's) Decontamination and Decommissioning (D&D) Plan requires that interior and exterior walls of buildings that are being demolished be disassembled and all insulating materials removed prior to demolition. This report provides a comparative analysis of the baseline manual insulation removal technique currently employed at the FEMP, with an innovative vacuum insulation removal system.

Technology Summary

Baseline Technology

The baseline approach involves workers manually removing the insulation from walls and placing it in plastic bags for disposal. Figure 1 shows a worker removing mineral wool insulation from the walls in Building 1A of Plant 1 at the FEMP. The insulation is misted with water before removal to suppress dust and airborne fibers. Access to the various sections of the walls is by a mechanical lift, ladders, and movable scaffolding.

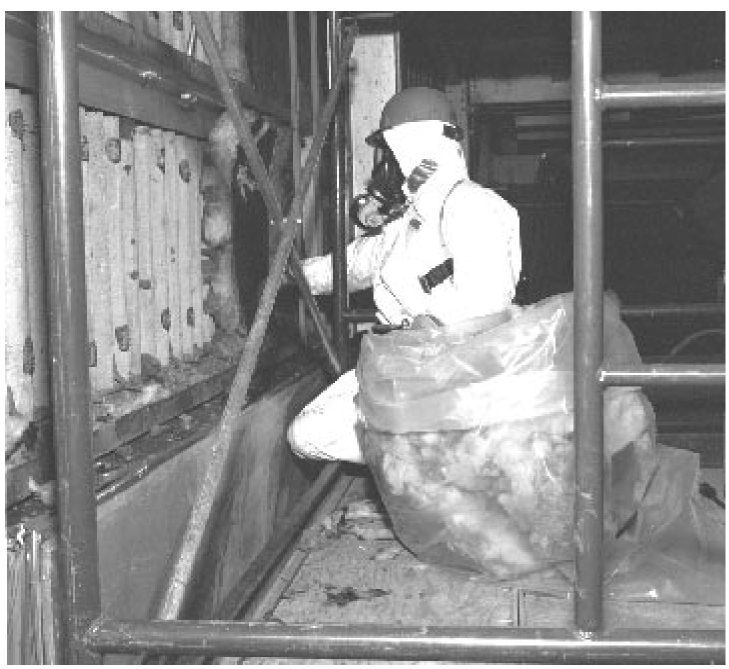

Figure 1. Worker manually removing insulation from walls.

Innovative Technology

The innovative approach employs the VecLoader®[1] HEPA VAC 522™ insulation removal system. The VecLoader is manufactured by Vector Technologies Ltd. of Milwaukee, Wisconsin.

Figure 2. The VecLoader® HEPA VAC 522™.

How It Works

At the heart of the system is a powerful vacuuming unit capable of suctioning 1,700 cubic feet of air per minute at a vacuum of 15 inches of mercury. The vacuum is powered by a 102 horsepower John Deere diesel engine and incorporates a cyclone separator and a high-efficiency particulate air (HEPA) filter for trapping and containing contaminants. All components are mounted on a readily transportable trailer (see Figure 2). The VecLoader is designed to vacuum any material - liquid, slurry, or solid - that can be drawn through its 5-inch diameter smooth bore vacuum hose. The integrated engine/vacuum generates very high noise levels, and in a typical configuration, the VecLoader is located outside the work area, and the vacuum hose is run up to 500 feet to the work area. Figure 3 shows a worker on a manlift using the VecLoader vacuum to remove insulation from walls in Building 1A. The insulation is drawn into the VecLoader's Cyclone Separator where it is sprayed with water to promote clumping, trapped, and discharged directly into plastic waste collection bags that are then sealed for disposal (see Figure 4). Air exiting the separator passes through a nuclear-grade HEPA filter before being exhausted to the atmosphere.

[1] VecLoader® is a registered trademark of Vacuum Engineering Corporation (VEC) of Milwaukee, Wisconsin.

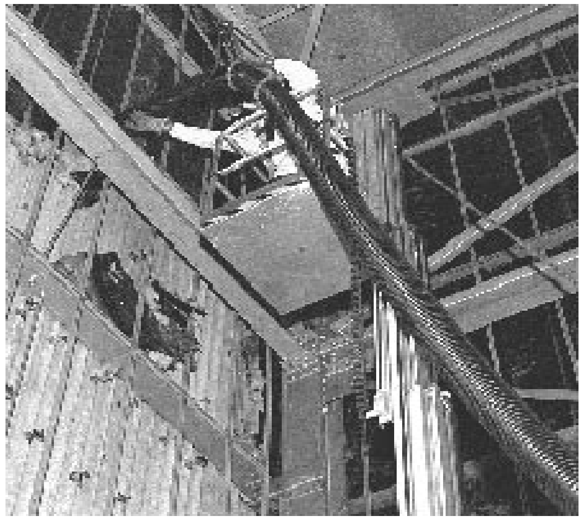

Figure 3. Worker removes insulation using the VecLoader HEPA vacuum system.

Figure 4. Insulation removed by the VecLoader being discharged by worker into plastic bags.

Demonstration Summary

The comparative demonstration between the baseline and innovative insulation removal technologies was conducted in Building 1A of Plant 1 at the FEMP between August 5, 1996, and September 16, 1996. The demonstration period included mobilization, demonstration, and demobilization of the technologies.

The purpose of the demonstration was to evaluate the effectiveness and efficiency of the VecLoader HEPA VAC 522 system as an alternative to the manual baseline approach for removing insulation from buildings undergoing D&D. The objectives of the demonstration were to determine whether the VecLoader could realize benefits over the baseline technology in the areas of increased productivity, reduced cost, reduced health and safety risks to workers and the environment, and reduced waste volume. A critical determinant would be the VecLoader's ability to reduce workers' contact with insulation material and minimize their exposure to airborne contaminants such as radionuclides that over the years had become entrained in the insulation.

Both technologies were used to remove four-inch-thick mineral wool insulation. The baseline technology was demonstrated on sections of the north, south, and west walls of Building 1A, which is an open area, where the walls extend four stories high to the ceiling. The VecLoader was demonstrated on sections of the west and northwest walls of the building in an open area where the walls extend two stories high. An outside containment structure was built to house the VecLoader due to concerns for release of contaminants to the atmosphere.

The primary participant in the conduct of the demonstration was Babcock and Wilcox (B&W) Services, Inc., the FEMP's D&D contractor on Plant 1. Workers provided by B&W Services, Inc., demonstrated both technologies. The technology supplier trained the workers in the operation of the VecLoader system. Fluor Daniel Fernald (FDF), the FEMP's management and integration contractor, provided technical support in radiation protection, health and safety, and regulatory compliance. The United States Army Corps of Engineers (USACE) performed a cost analysis.

Key Results

The key results of the FEMP demonstration are summarized below. Detailed cost and performance data are presented in Sections 3 and 5 of this report.

- The VecLoader is a safer, more effective, and cost-efficient means of removing insulation from walls than the baseline manual removal method. Figure 5 compares the key performance indicators of the two technologies.

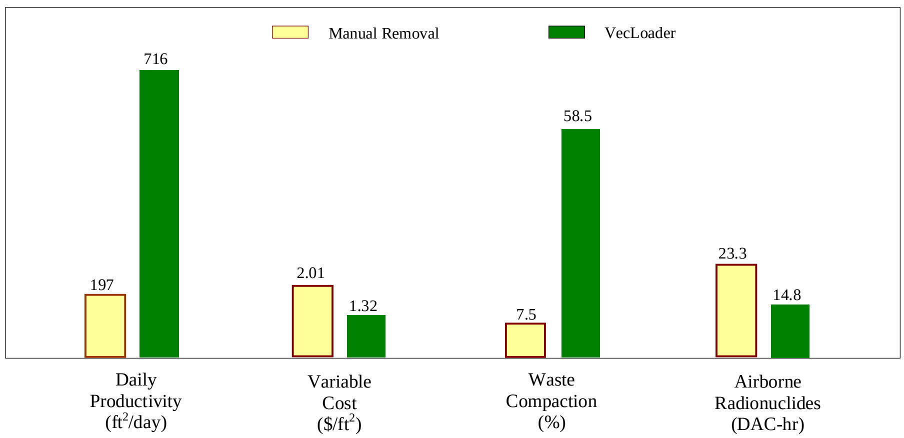

Figure 5. Comparison of the key performance indicators of the VecLoader HEPA VAC 522 insulation removal system versus manual insulation removal.

Productivity

- The VecLoader technology vacuumed four-inch-thick insulation from walls at a rate of 220 square feet per hour of operation (or 73 cubic feet per hour), 21% faster than manual removal. Taking account of all the steps involved in the insulation removal process (donning/doffing protective clothing, rest periods, moving lifts and scaffolding, etc.), in a typical work day the VecLoader's removal rate was 716 square feet per day. This was 263% faster than the 197 square feet per day achieved by the manual process (see Table 2 in Section 3). This significant increase in productivity could potentially accelerate a facility's cleanup schedule.

Cost of Performing D&D Work

- The unit variable cost of removing four-inch-thick insulation with the VecLoader was $1.32 per square foot, 34% less than manual removal.

- The fixed cost of mobilizing and demobilizing the VecLoader equipment was $6,077 (compared to no costs for manual removal). However, because the unit cost of removal is 34% lower for the VecLoader, these fixed costs can be recouped if the area of four-inch insulation to be removed is greater than 8,800 square feet (or 2,933 cubic feet).

- The full capital cost of $88,952 for the VecLoader can be recovered within 180 work days if the unit will be used to remove more than 120,000 square feet of four-inch insulation.

Performance

- The VecLoader system easily removed insulation from walls. It was straightforward to operate and initial problems with hose plugging and coordinating vacuuming cycles with changing of waste collection bags were quickly resolved.

Health and Safety

- The diesel engine and vacuum of the VecLoader generated very high noise levels (up to 108 decibels on the A scale (dBA)) and workers were required to wear double hearing protection when working in the vicinity of the equipment. In addition, a conservative 2-hour stay time was established for the crew operating the equipment based on standards set by the American Conference of Government Industrial Hygienists (ACGIH).

- The powerful vacuum created by the VecLoader could cause serious bodily harm.

- Both insulation removal technologies expose workers to the risk of falling while working on an elevated work platform.

- Workers come into direct contact with insulation during manual removal, increasing their risk of exposure to insulation fibers and/or radionuclides. When using the VecLoader, they did not directly contact the insulation.

Airborne Contamination

- Levels of airborne radionuclides in the work area were on average 36% lower when using the VecLoader vacuum than with the manual removal method.

- Levels of airborne insulation fiber were not measured, but they can be expected to be lower when using the VecLoader, which is equipped with a nuclear-grade HEPA filtration system.

- Accumulated waste in the VecLoader’s cyclone separator was bagged and safely removed without contaminating the work area.

Waste Disposal

- The VecLoader compacted the insulation removed from walls by a factor of 58.5% compared with 7.5% compaction for manual removal. Waste disposal costs were correspondingly lower for the VecLoader. Insulation removed from Building 1A was disposed of as low-level waste in the FEMP on-site disposal facility.

Permits, Licenses, and Regulatory Considerations

The technology demonstrations involved handling radioactively contaminated materials and use of power tools and machinery. Technical guidance and site training in the areas of radiation protection, health and safety, and regulatory compliance (see Section 6) were provided by Fluor Daniel Fernald (FDF), Management and Integration (M&I) contractor to the DOE. Neither technology required permits for their demonstration at Plant 1. All workers were required to have completed their 40-hour certification in Hazardous Material Health and Safety Training.

Commercial Availability

The VecLoader is a fully developed and commercially available technology that is used in the commercial sector primarily for dust and debris collection and asbestos removal. It has also been used for similar purposes at DOE sites, including FEMP and Oak Ridge National Laboratory.

Technology Limitations and Needs for Future Development

The operation and performance of the VecLoader could be improved if the following problems encountered during the demonstration were addressed in future developments of the system:

- The 5-inch diameter vacuum hose was difficult and cumbersome to maneuver. The alternative 2.5-inch diameter hose was more maneuverable, but its small bore was less productive and made it susceptible to frequent plugging.
- Occasionally, the powerful suction caused the vacuum hose to stick to the wall, and it was difficult to release it.
- Communication was difficult between the vacuum hose operator and the VecLoader operator due to the distance between them and high noise levels generated by the equipment. This impeded the synchronization of vacuum cycles with the changing of waste collection bags and moving scaffolding.
- Locating clogs in the vacuum line was difficult.
- The VecLoader operator had no way of knowing how much insulation was being suctioned into the cyclone separator or when the waste needed to be discharged into the waste collection bags.
- When the waste collection bags were filled with the damp insulation, it was difficult to lift and twist them before sealing to reduce the risk of contaminants escaping.

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Website

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Other

All published Innovative Technology Summary Reports are available at http://em-50.em.doe.gov. The Technology Management System, also available through the EM50 website, provides information about OST programs, technologies, and problems. The OST reference number for the VecLoader HEPA Vacuum Insulation Removal System is 1784.

SECTION 2

TECHNOLOGY DESCRIPTION

Overall Process Definition

The baseline approach to removing insulation from buildings at the FEMP involves workers manually detaching the insulation from walls and placing it in plastic bags for disposal (see Figure 1). This process creates considerable airborne insulation fiber. It also places workers in direct contact with the insulation that is sometimes made of asbestos - a known health hazard. In addition, many of the buildings at the FEMP were used for radiological research and testing, and over the years, airborne radionuclides have become entrained in the insulation posing a health risk for workers removing the insulation. The VecLoader vacuum insulation removal, HEPA filtration, and waste packaging system was selected for demonstration at the FEMP for its potential to

- reduce airborne contamination (radionuclides and insulation fiber),
- increase productivity (insulation removal rate),
- reduce waste volume,
- reduce costs,
- reduce worker contact with insulation, and health and safety risks, and
- reduce personal protective equipment (PPE) requirements.

The VecLoader HEPA VAC 522 is an integrated trailer-mounted system comprised of a diesel engine-powered vacuum, a cyclone separator, and a HEPA filter (see Figure 6). The equipment is normally run outside the building being decontaminated because of the high noise level that it generates and to avoid contamination of its components, particularly interior components. It uses a flexible smooth-bore 5-inch vacuum hose up to 500 feet in length to access the work area.

During operation, a worker holds the vacuum hose against the exposed insulation (see Figure 3) and the powerful vacuum shreds and sucks the insulation from the wall. The insulation waste stream is drawn first into a cyclone separator where it is sprayed with water as it enters. The wet insulation begins to clump as it spins at high speed in the cyclone separator. Larger particles of insulation clump together, decelerate, and settle to the bottom of separator. Insulation that collects on the sides of the cyclone separator is conveyed to the bottom of the separator by a built-in hydraulic auger. The waste is periodically removed from the separator by activating a bypass discharge valve that releases it directly into a plastic waste disposal bag (see Figures 4 and 5). The plastic bag is then manually sealed and ready for disposal. For the demonstration, single bags were used for waste collection and disposal except in a few instances when the insulation was moisture-laden and heavy, in which case double bags were used.

From the cyclone separator, the waste air stream is drawn into a nuclear grade HEPA filter where remaining particulates (greater than 0.3 microns) are trapped and filtered air is exhausted to the atmosphere.

The VecLoader HEPA VAC 522 comes mounted on a dual-axle four-wheeled tandem trailer that is equipped with hydraulic surge brakes and parking brakes. It is transported by towing with a truck of one-ton capacity or higher. Two fifty-gallon tanks that are also mounted on the trailer supply fuel for the system. The entire system operates under negative pressure that minimizes the risk of releasing contaminants back into the air. Nonetheless, as a precaution against accidental spillage or release of contaminants, a temporary enclosure was constructed around the equipment. As a further precaution, the air in the enclosure was exhausted through a secondary HEPA filter. The VecLoader is also equipped with an emergency pickup vacuum hose (see Figure 6) to clean up accidental spills.

Figure 6 illustrates the key features of the VecLoader HEPA VAC 522 insulation removal system. Appendix B lists the system's specifications.

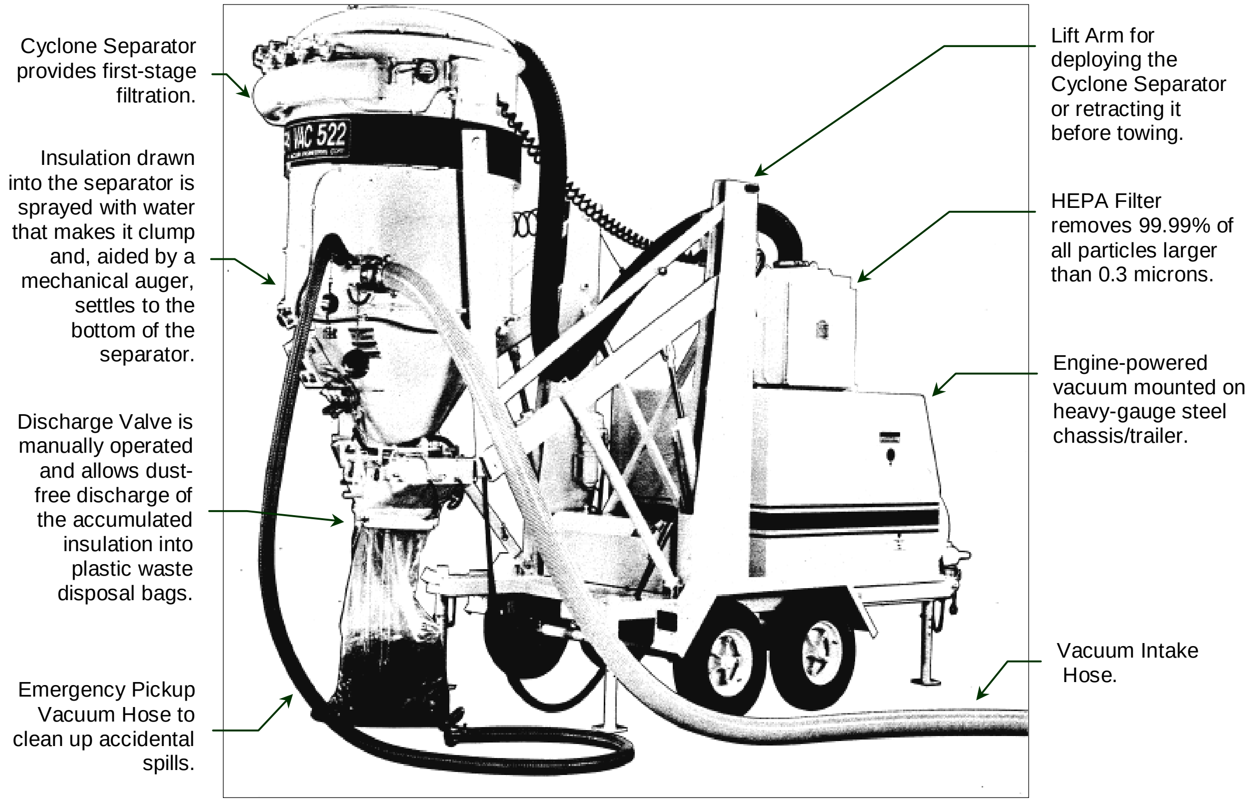

Figure 6. VecLoader® HEPA VAC 522™ insulation removal system.

Vector Technologies Ltd. of Milwaukee, Wisconsin, manufactures and markets a full suite of powerful industrial vacuums including the VecLoader HEPA VAC 522. The company also manufactures abrasive blasting and surface preparation equipment, portable dust collectors and baghouses, asbestos and hazardous waste removal equipment, and other conveyance products for hazardous and non-hazardous material handling. VecLoader vacuums have provided solutions to industry and contractors for the recovery, removal, and transportation of a wide range of materials such as cement, petrochemical products, sand, activated carbon, fly ash and roofing rock, liquids, waste water and slurries. Other solutions include recovery and reclassification systems for steel grit used in blasting equipment and other abrasives and hazardous materials like lead dust and asbestos. Industries where Vector Technologies has provided vacuum solutions include emergency response/spill recovery, site remediation, surface preparation, utilities, chemical/petrochemical, wood/paper/pulp, primary metals/mineral processing, cement, steel, nuclear remediation, waste water treatment, hazardous waste remediation, and roofing.

The VecLoader has also seen application at DOE sites, including FEMP and Oak Ridge National Laboratory, where it is used for insulation removal and dust collection. The powerful vacuums manufactured by Vector Technologies have potential application at DOE sites for integration with technologies that generate dust or coarse, gravelly, or heavy waste particles such as those generated during scabbling and shot blasting.

System Operation

Table 1 summarizes the operational parameters and conditions of the VecLoader HEPA vacuum insulation removal system during the FEMP demonstration.

Table 1. Operational parameters and conditions of the VecLoader HEPA vacuum insulation removal system demonstration

Working Conditions	
Work area location	Building 1A at FEMP's Plant 1.
Work area description	Insulation was removed from the west and northwest walls of Building 1A in an open area where the walls extend two stories high. The VecLoader was housed outside Building 1A in a temporary wooden frame enclosure (16 ft x 32 ft x 16 ft) covered with 6-mil poly sheeting.
Work area hazards	Airborne contaminants including dust, radionuclides, and insulation fibers High noise levels Powerful vacuum Tripping hazard from hoses Falling hazard from working on scaffolding, mechanical lifts, and ladders Heavy machinery
Equipment configuration	The VecLoader was operated outside Building 1A, and the vacuum hose was run to the work area inside the building.
Labor, Support Personnel, Specialized Skills, Training	
Work crew	Three full-time D&D workers One part-time (25%) equipment operator to operate the diesel engine (this operator could be shared with other ongoing activities in the area)
Additional support personnel used for the demonstration	One full-time data taker One full-time radiation technician One full-time health and safety observer Support personnel to build the containment structure for the vacuum
Specialized skills	Not required
Training	The vendor provided training to the D&D workers in the areas of operating the vacuum, the cyclone separator, the waste discharge valve, and the vacuum hose. The equipment operator was trained on operating the diesel engine. All vendor-supplied workers received FEMP-specific training required to enter the exclusion zone.
Waste Management	
Primary waste generated	Mineral wool insulation packaged in plastic waste disposal bags
Secondary waste generated	Disposable PPE HEPA Filters Vacuum hose and couplings Material used for constructing the temporary containment structure for the vacuum
Waste containment and disposal	The VecLoader discharges the removed insulation directly into plastic bags that were sealed for disposal.
Equipment Specifications and Operational Parameters	
Technology design purpose	Collection and containment of particulates, solids, liquids, or slurries
Dimensions	Traveling height (cyclone separator retracted) 11 ft 4 in. Operating height (cyclone separator deployed) 18 ft 0 in. Traveling length (cyclone separator retracted) 17 ft 5 in. Operating length (cyclone separator deployed) 24 ft 2 in.
Weight	9,800 lb.
Portability	The unit can easily be towed with a truck of one ton capacity or greater.

Table 1. Operational parameters and conditions of the VecLoader HEPA vacuum insulation removal system demonstration (continued)

Materials Used	
Work area preparation	2 in x 4 in lumber and screws for framing the temporary enclosure Poly sheeting (6 mil) and duct tape for covering the enclosure Hoses and plumbing for temporary water supply for VecLoader
Personal protective equipment	Double hearing protection for outside crew, single hearing protection for the inside crew Single PPE for both inside and outside crews
Supporting equipment	Rented mechanical lift (a 2-person scissors lift), scaffolding and ladders.
Utilities/Energy Requirements	
Equipment	Fuel for the VecLoader's diesel engine
Water	Temporary water supply to the VecLoader's cyclone separator for spraying the insulation
Work area	Not required
Potential Operational Concerns	
Operating	The 5-inch vacuum hose is large and likely too heavy for a single worker on the mechanical lift to operate. The powerful vacuum sometimes causes the vacuum hose to stick to the wall. Communication between the inside and outside work crews is impaired because workers must wear hearing protection against the high noise levels generated by the VecLoader equipment.
Safety/health	High noise levels
Environmental	Potential release of airborne radionuclides and insulation fiber to the atmosphere

SECTION 3

PERFORMANCE

Demonstration Plan

Demonstration Objectives

The principal goal of the demonstration was to establish whether the VecLoader HEPA vacuum system could safely and effectively remove insulation from walls. This determination would be based on the VecLoader's ability relative to the baseline manual method, to achieve the following objectives:

- reduced airborne contamination (radionuclides and insulation fiber)
- increased productivity (insulation removal rate)
- reduced waste volume
- reduced costs
- reduced worker contact with insulation
- reduced health and safety risks
- reduced personal protective equipment (PPE) requirements.

Demonstration Site Description

The demonstration of the VecLoader was conducted according to the approved B&W Services, Inc., test plan, *Plant 1: VecLoader HEPA Vacuum Insulation Removal System*. Both the baseline and innovative technologies were demonstrated in Building 1A of Plant 1 at the FEMP. Building 1A is a four-story irregularly shaped process building covering a base area of 16,600 square feet and has an interior volume of 830,000 cubic feet. It has a structural steel frame, transite walls (interior and exterior) and roofing, and a poured concrete floor. Sandwiched between the interior and exterior transite walls is a four-inch-thick layer of mineral wool insulation that must be removed before dismantling the building. Building 1A was the main receiving point for all enriched materials that were processed at Plant 1. Over the years, airborne radionuclides contaminated the insulation in the walls of the building.

The baseline approach to removing insulation at the FEMP involves a worker manually dislodging it from the walls and stuffing it into plastic bags for disposal. The manual process is slow, costly, generates considerable airborne contamination, and brings workers in direct contact with radionuclide-contaminated insulation.

Demonstration Boundaries

The VecLoader system was demonstrated on mineral wool insulation; however, the system's powerful vacuum is capable of removing other forms of insulation, and its HEPA VAC filtration system makes it ideally suited for removing hazardous materials such as asbestos insulation. The system was not assessed on its ability to remove roofing insulation. The VecLoader is also designed to vacuum other media such as gravelly residues, liquids, and slurries, but these capabilities were not tested.

Treatment Performance

The VecLoader successfully demonstrated its ability to safely and effectively remove insulation from walls. Handling the VecLoader's vacuum hose required some physical exertion on the part of the workers, and the equipment generated potentially injurious noise levels; however, the technology is easy to use and problems that arose were quickly resolved. Table 2 compares the key performance indicators of the baseline and innovative technologies that were assessed during the demonstration. A detailed cost benefit analysis is presented in Section 5.

Table 2. Comparison of key performance indicators of insulation removal technologies

	Manual Removal (Baseline)	VecLoader System (Innovative)
Area of 4-in.-thick insulation removed	1,161 ft^2	1,476 ft^2
Volume of insulation removed	387 ft^3	492 ft^3
Resulting waste volume	358 ft^3	204 ft^3
Waste compaction	7.5%	58.5%
Technology operating time	6 h 23 min	6 h 43 min
Instantaneous productivity [a] (insulation removed per hour of technology operation)	182 ft^2/h or 61ft^3/h	220 ft^2/h or 73 ft^3/h
Total process time (total hours of work)	47 h 15 min	16 h 31 min
Overall process productivity [b] (insulation removed per hour of work)	24.6 ft^2/h or 197 ft^2 /day	89.5 ft^2/h or 716 ft^2 /day
Crew size	3 workers	3¼ workers
Average productivity per crew member	61 ft^2/h or 20ft^3/h	68 ft^2/h or 23 ft^3/h
Unit variable cost of removing insulation	\$2.01 / ft^2	\$1.32 / ft^2 [c]
Fixed cost of mobilizing/demobilizing technology	\$0.00	\$6,077.00 [d]
Total (variable + fixed) unit cost (based on demonstration scale)	\$2.01 / ft^2	\$5.44 / ft^2
Break-even point	For job sizes less than 8,800 ft^2, it is more cost effective to remove insulation manually (see Figure 7).	
Capital cost recovery point	For project sizes greater than 120,000 ft^2, it is more cost effective to purchase a VecLoader (see Figure 8).	
Radiological airborne contaminants [e] Breathing zone area (BZA) ambient reading (DAC-hr)	Average: 23.3 Maximum: 41.9	Average: 14.8 Maximum: 32.7
Breathing zone area (BZA) corrected reading (DAC-hr) (equals ambient reading divided by 50 which is the protection factor of the respirators worn by workers)	Average: 0.5 Maximum: 0.8	Average: 0.3 Maximum: 0.7
Noise level	***Inside the work area:*** Data not available	***Inside the work area:*** Data not available ***Adjacent to the VecLoader:*** Average: 95 dBA Maximum: 108 dBA
PPE requirements	Single PPE	Single PPE plus - double hearing protection and a 2-hour stay time limit for the outside crew or - single hearing protection for the inside crew.

a Instantaneous productivity is the rate at which the technology removes insulation from walls. It does not take account of time needed for donning/doffing PPE, moving rigging, rest breaks, etc.

b Process productivity is the rate at which the technology removes insulation from walls taking into account all steps in the process including donning/doffing PPE, moving rigging, rest breaks, etc.

c Includes the rental cost of the VecLoader system.

d Includes the cost of transporting the VecLoader to and from the work site, constructing a containment structure around the equipment, and decontaminating the equipment after use.

e See Appendix B for definitions. Levels of airborne insulation fiber were not measured.

Airborne Contamination

Radiological data were collected in the work area while each technology was being demonstrated. Airborne levels of radionuclides in the worker's breathing zone were on average 36% lower when the VecLoader was being operated than during manual removal.

Levels of airborne insulation fiber were not evaluated; however, the VecLoader can be expected to generate significantly lower levels since the insulation is sucked directly from the walls into its cyclone separator and HEPA filtration system. During manual removal, fiber and dust are released into the air when the insulation is pulled from the walls and stuffed into the disposal bags.

Air monitoring samples taken in the VecLoader's containment structure were HEPA-compliant. Therefore, the structure may not be necessary for future operations.

Productivity

The VecLoader removed insulation 21% faster than the baseline manual method. The work time used in calculating removal rates is the time spent actually removing and bagging insulation and does not include donning/doffing PPE, rest periods, moving rigging, etc. When these activities are taken into consideration, the VecLoader's productivity is 263% faster than manual removal. Factors that contribute to the VecLoader's high productivity are its powerful vacuum that shreds and sucks insulation from the walls. In addition, the VecLoader continuously removes insulation while it is operating and simultaneously packages the waste. During manual removal, a single worker alternates between removing insulation, stuffing it into bags, and sealing the bags.

The baseline technology required a crew of three workers, while the VecLoader required a crew of three full-time workers and one part-time (25%) diesel engine operator. Although the VecLoader required a slightly larger crew, each crew member was 11.5% more productive than those performing manual removal. The productivity of the VecLoader crew can be expected to increase further as they become more proficient at using the equipment and synchronizing vacuum cycles with changing waste disposal bags and moving the scaffolding. Even further efficiency could be attained if a large bladder bag or a liner in a dumpster or rolloff box were used to collect the waste ejected from the VecLoader thereby reducing the time to change waste disposal bags.

Waste Volume

The waste generated by both technologies comprised the removed insulation packaged in plastic disposal bags. The amount of water used during manual removal to control insulation fibers and dust was about the same amount used by the VecLoader's cyclone separator. However, a separate liquid waste stream was not generated since in both cases the water was absorbed by the insulation.

A significant advantage of the VecLoader system was its ability to reduce the volume of insulation removed by 58.5% versus 7.5% compaction during manual removal.

Waste disposal bags used by the VecLoader were changed whenever the system was shut down for repositioning of the mechanical lift. Consequently, most of the disposal bags were only filled to about 58% of their capacity. As workers become more familiar with the operation and cycle timing of the VecLoader, greater efficiency in bag usage may be achieved.

Worker Health and Safety

Both technologies involve working from an elevated platform and carry the risk of workers falling.

The powerful vacuum generated by the VecLoader could cause bodily harm. Vector Technologies Ltd. markets angled nozzles with handles that reduce this risk.

During manual removal, workers come into direct contact with the insulation that increases their exposure to airborne radionuclides and insulation fiber. This exposure is significantly reduced when using the VecLoader, making it the safer of the two technologies.

PPE Usage

Both technologies required the same level of PPE. In the case of the VecLoader, workers had to wear hearing protection against the high noise levels generated by the equipment. Instantaneous sound level measurements taken inside the enclosure registered as high as 108 dBA, and a preliminary noise dosimetry study determined an average exposure level of 95 dBA. These are well over the 85 dBA action level prescribed by OSHA or the 80 dBA action level prescribed by ACGIH. Based on DOE Order 440.1 Chapter 4, Section 1, Paragraph 1, the FEMP complies with the OSHA or ACGIH threshold limit value that provides the higher level of protection, i.e., 80 dBA. Based on ACGIH guidelines, workers in the VecLoader's containment structure wore double hearing protection and only worked two-hour shifts. The two-hour stay time may indeed be conservative since it is based on a worker being routinely exposed to the noise source for eight hours per day, forty hours per week. During the demonstration, the VecLoader ran intermittently for a total of 6.7 hours over a period of 16.5 hours, i.e., about 40% of the time. Therefore, longer stay times may be safely achievable.

SECTION 4

TECHNOLOGY APPLICABILITY AND ALTERNATIVE TECHNOLOGIES

Technology Applicability

The VecLoader is a fully mature and commercially available industrial vacuuming system designed primarily for the removal of asbestos-containing insulation. Vacuum systems are used extensively throughout the DOE complex for dust and debris containment during D&D activities. The VecLoader is a powerful integrated vacuum, waste packaging, and HEPA filtration system that is self-powered and easily transported. These features make the VecLoader well suited for hazardous waste containment and cleanup of buildings that no longer have accessible utilities.

Current uses of the VecLoader within the DOE complex include insulation removal and dust/debris collection. Other potential DOE applications for the VecLoader include removal of roofing gravel, cleanup of spills, removal of dust from buildings before implosion, and collection and containment of hazardous liquids, waste water, and slurries.

Competing Technologies

The baseline approach that competes with the VecLoader HEPA vacuum insulation removal system is manual insulation removal. No other technologies have been identified as viable alternatives.

The advantages that the VecLoader offers over the baseline approach for removing insulation are

- lower airborne insulation fiber and radionuclides,
- reduced worker contact with insulation,
- higher productivity,
- greater waste compaction and lower waste disposal costs, and
- lower cost of operation if the amount of insulation to be removed is greater than 8,800 square feet (or 2,933 cubic feet).

The disadvantages of the VecLoader system are

- high capital equipment cost and mobilization/demobilization costs which can be recovered only if the total quantity of four-inch insulation to be removed is greater than 120,000 square feet, and
- high equipment noise levels that required wearing of hearing protection and reduced worker stay times, and resulted in impaired communication between workers.

Patents/Commercialization/Sponsor

VecLoader vacuuming systems are manufactured by Vector Technologies Ltd. of Milwaukee, Wisconsin, from which they can be purchased. The systems and their names are protected in the United States under several patents and trademarks. No permits were required to demonstrate the VecLoader HEPA VAC 522 at the FEMP.

Additional information on products and services offered by Vector Technologies, as well as their customers and trading partners, may be found at their Internet website: http://www.vector-vacuums.com/2_TRADEPRT.html

SECTION 5

COST

Introduction

The U.S. Army Corps of Engineers (USACE) performed the cost benefit analysis presented in this section. The analysis compares the relative costs of using the innovative and baseline technologies to remove insulation from walls in Building 1A of Plant 1 at the FEMP. The purpose of the cost analysis is to present validated demonstration data collected during the LSDP in a manner that will enable D&D decision-makers to select the preferred technology for their specific applications. It strives to develop realistic estimates that are representative of work performed within the DOE complex; however, the reader should be aware that it is only a limited representation because it uses only data observed during the limited duration of the demonstration and is based on prevailing conditions at the FEMP. Some of the observed costs have been eliminated or adjusted to make the estimates more realistic. These adjustments have been made only when they do not distort the fundamental elements of the observed data (i.e., they do not change productivity rates, quantities, work elements, etc.) or when activities are atypical of normal D&D work. Additional cost information and demonstration data are contained in the *Detailed Technology Report for the VecLoader HEPA Vacuum Insulation Removal System*, FEMP, December 1997, which is available on request from the FEMP.

Methodology

This cost analysis is based on data collected during the demonstration that included duration of activities, work crew composition, equipment used in the performance of work, and supplies used. Members of the Integrating Contractor Team (ICT) for the FEMP Plant 1 LSDP observed the demonstrations. A representative from B&W Services, Inc., collected the data and entered them into a predetermined data collection structure that ensured consistency with other technology demonstrations. The ICT provided data on the costs of labor, materials, supplies, and services used during the demonstration. The following cost elements were identified in advance of the demonstration, and data were collected to support the cost analysis based on these elements:

- **Mobilization** includes the cost of transporting equipment to the demonstration site, training the crew members to use the equipment, providing crew members (including vendor-provided personnel) with FEMP site-specific training, constructing temporary work areas, and installing temporary utilities.

- **D&D Work** includes direct costs associated with insulation removal, such as the cost of labor, utilities consumed, supplies, and the amortized cost of using the equipment during the demonstration.

- **Waste Disposal** is the cost of disposing of the primary waste products of the demonstration, i.e., the removed insulation packaged in plastic waste disposal bags.

- **Demobilization** includes removal of support equipment such as riggings and manlifts, disconnection of temporary utilities, dismantlement of temporary work areas (including associated secondary waste disposal), and equipment decontamination and removal from the site.

- **Personal Protective Equipment** includes the cost of all protective clothing, respirators, hearing protection, etc., worn by crew members during the demonstration.

The cost estimates for the baseline and the innovative technologies follow the *Hazardous, Toxic, Radioactive Waste Remedial Action Work Breakdown Structure and Data Dictionary* (USACE 1996) for collecting costs into cost elements for reporting.

The VecLoader may be acquired only by purchasing it from its vendor, Vector Technologies Ltd. Through a special arrangement with the vendor, it was rented for the duration of the demonstration. However, the cost analysis assumes that prospective users would have to purchase the VecLoader; therefore, costs were based on the cost of ownership. An hourly equipment rate was calculated using procedures outlined in EP 1110-1-8, *Construction Equipment Ownership and Operating Expense Schedule, Region II*, U.S. Army Corps of Engineers, August 1995. The hourly rate is based on the $88,952 capital cost of the VecLoader, a discount rate of 5.6%, equipment life of 10,000 operating hours as advised by the vendor, estimated yearly usage of 1,040 hours, and estimated operating and repair costs.

For the baseline technology, scaffolding, ladders, and a genie lift were used to gain access to work areas. A mechanical scissors lift was used during removal of insulation with the VecLoader. The comparative unit costs for these items were calculated based on reported rental rates (see Table 3). The calculations showed that using either access method adds only \$0.01/ ft^2 to the cost of removing insulation.

The fixed cost elements (i.e., those independent of the quantity of D&D work, such as equipment mobilization and demobilization – see Appendix C) were calculated as lump sums. The variable cost elements (i.e., those dependent on the quantity of D&D work, such as labor and equipment usage costs) were calculated as costs per square foot of four-inch insulation removed. Because of the relatively small amounts of D&D work performed by each technology (1,161 ft^2 for the baseline and 1,476 ft^2 for the VecLoader), inclusion of the fixed costs in the unit costs would greatly skew the latter. Therefore, for the purpose of comparing the relative costs of using the technologies, fixed costs were not included in the unit costs shown in Table 4. This is standard practice in commercial unit price guides such as those published by the R. S. Means Company.

Where work activities were performed by the D&D contractor, labor rates used were those in effect at the FEMP at the time of the demonstration. Contractor indirect costs were omitted from the analysis since overhead rates can vary greatly among contractors and locations. Site-specific costs such as engineering, quality assurance, administrative costs, and taxes were also omitted from the analysis. Where appropriate, D&D decision-makers may modify the FEMP base unit costs determined by this analysis to include their respective site-specific indirect costs.

PPE costs are duration-dependent. Four changes of PPE clothing were required for each crew member per day. Reusable PPE items were estimated to have a life expectancy of 200 hours. Disposable PPE items were assumed to have a life expectancy of 10 hours - the length of the daily shift. The cost of laundering reusable PPE clothing items is included in the analysis (see Appendix C).

Costs for the on-site disposal of solid waste from the demonstrations were estimated by FDF since the on-site waste disposal facility was not in place during the demonstrations and actual rates were not known.

The following modifications were made to the cost data for the VecLoader to reflect a typical technology deployment:

- A diesel engine operator was part of the VecLoader crew throughout the demonstration. This operator would not be required full-time during a typical deployment; therefore, the VecLoader crew was modified for the analysis to show an operator for only 25% of the time.

- A containment structure was built around the VecLoader due to concerns for potential release of airborne contaminants. Since air monitoring at the exhaust of the HEPA filters showed them to be HEPA-compliant, costs for installation, removal, and disposal of the containment structure were excluded from the analysis.

Cost Analysis

The DOE complex presents a wide range of D&D work conditions. The baseline and innovative technology estimates presented in the analysis are based on a specific set of conditions and work practices found at Fernald Plant No. 1. Table 3 presents some of the FEMP-specific factors that have a direct bearing on the costs of removing insulation manually or with the VecLoader. This information is intended to help the technology user identify work differences that can result in cost differences.

Table 3. Summary of cost variable conditions

Cost Variable	Manual Insulation Removal	VecLoader Insulation Removal
Scope of Work		
Type of insulation removed	4-in.-thick mineral wool insulation	
Quantity of insulation removed	1,161 ft^2	1,476 ft^2
Nature of work	A worker manually removes the insulation from the walls and stuffs it into plastic waste disposal bags.	A worker manually operates the VecLoader's vacuum hose to remove the insulation from the walls. The VecLoader collects the removed insulation, and a second worker periodically discharges it directly into plastic bags for disposal.
Work Environment		
Building use	Formerly used as the receiving point for enriched materials.	
Description of test area	Four-story-high walls with 4 inches of insulation sandwiched between inside and outside transite panels.	Two-story-high walls with 4 inches of insulation sandwiched between inside and outside transite panels.
Test area access	Scaffolding, ladders and 1-person genie lift.	2-person mechanical lift.
Contaminants in insulation	Dust and radionuclides entrained in the insulation over years of operation of the plant. Full-face respiratory protection with nuclear-grade HEPA filter cartridges was therefore required.	
Test area preparation	Inside transite panels and wall studs were removed providing access to the insulation. Preparation time was not included when calculating production rates.	
Work Performance		
Technology/Service acquisition means	Workers provided locally by B&W Services, Inc. - FEMP's D&D contractor.	Workers provided locally by B&W Services, Inc. - FEMP's D&D contractor. VecLoader system leased from Vector Technologies Ltd. under special arrangement for demonstration. Normally, the equipment would have to be purchased.
Equipment configuration	N/A	The VecLoader was located outside the contaminated work area. Only one vacuum hose was used to remove insulation, but the system can support multiple hoses removing insulation at the same time (typically 2 or 3). This would increase productivity and reduce costs.
Compliance requirements	FEMP's OSDF waste acceptance criteria for low-level waste; miscellaneous compacted material; maximum dimensions 8 ft x 4 ft x 1.5 ft.	
		ACGIH standards used to determine double hearing protection requirements and 2-hour stay time for workers.
Support equipment	8 ft. step ladder purchased at $209. Scaffolding purchased at $4,500. 1-person genie lift rented at $325/month.	2-person scissors lift rented at $400/month.

Table 3. Summary of cost variable conditions (continued)

Work crew	3 full-time workers: - 1 to manually remove insulation - 2 to move/position scaffolding, ladder, genie lift.	3¼ full-time workers: - 1 to operate vacuum hose - 1 to move/position mechanical scissors lift - 1 to operate VecLoader and bag waste - 1 part-time (25%) diesel engine operator
Worker training	Minimal training required.	All workers viewed a 2-hour training video on the VecLoader's startup, operation, shutdown, and safety procedures. The diesel engine operator received an additional 10-hour run-in-time training.
Demonstration Plan		
Work process	• Position lift or ladder • Don safety harness • Spray insulation with water • Manually remove insulation • Place insulation in disposal bag • Seal bags and lower to ground crew.	• Position lift • Don safety harness • Start vacuum • Vacuum insulation from wall • Discharge waste into disposal bag and change bag • Stop vacuum to relocate lift.
Costs		
Capital cost of equipment	N/A	VecLoader HEPA VAC 522 system - $84,500 300 foot smooth bore vacuum hose - $4,452
Estimated cost of labor	Diesel engine operator - $41/h All other work crew members (see above) - $31/h	
FEMP OSDF waste disposal rates	Unbulked waste $ 8.00/ft^3 Trash $ 4.30/ft^3	

Cost Conclusions

Table 4 compares the major cost elements associated with using the baseline and innovative technologies to remove 4-inch-thick insulation.

For the conditions and assumptions of the FEMP demonstration, the unit cost of removing insulation was

- $1.32 per square foot with the VecLoader and
- $2.01 per square foot by manual removal.

Table 4. Costs of using the manual removal and VecLoader technologies

	Manual Insulation Removal			VecLoader Insulation Removal		
Cost Elements	**Fixed Costs [1]**	**Variable Costs [2]**	**Unit Costs [3]**	**Fixed Costs [1]**	**Variable Costs [2]**	**Unit Costs [3]**
Mobilization [1]	$0	-	-	$3,618	-	-
D&D Work [2]	-	$477	$0.41 / ft^2	-	$598	$0.41 / ft^2
Waste Disposal [2]	-	$1,533	$1.32 / ft^2	-	$1,015	$0.69 / ft^2
PPE [2]	-	$318	$0.27 / ft^2	-	$333	$0.23 / ft^2
Demobilization [1]	$0	-	-	$2,459	-	-
Total	**$0**	**$2,328**	**$2.01 / ft^2**	**$6,077**	**$1,946**	**$1.32 / ft^2**

1. These costs are independent of the quantity of D&D work performed and therefore not included in unit costs.
2. These costs are dependent on the quantity of D&D work performed.
3. The cost of removing one square foot of four-inch insulation. Excludes fixed costs (see paragraph 5 of Methodology above)

Mobilization costs were higher for the VecLoader because the equipment had to be transported to the site. Costs for training and equipment familiarization were also higher for the VecLoader. No mobilization costs were identified for the baseline technology.

The cost of performing D&D work was the same for both technologies despite the VecLoader's higher productivity. This is due to the VecLoader's need for an additional, part-time crew member, and its higher capital cost.

Waste disposal costs were lower for the VecLoader because it achieved a 58.5% compaction of the insulation versus 7.5% for manual removal.

PPE costs were lower for the VecLoader despite the need for wearing hearing protection that was not required during manual removal. This is due to its higher production rate that reduced the time (and number of shifts) required for insulation removal and therefore reduced the amount of PPE required.

Demobilization costs were higher for the VecLoader due to the cost of equipment decontamination and removal from the work site. Manual removal of insulation did not require any equipment decontamination.

For the VecLoader, the calculated instantaneous production rate of 220 square feet per hour was lower than the 300 square feet per hour predicted by the technology vendor. This is considered reasonable for work performed in a D&D environment that has more rigorous operational, health, and safety restrictions.

Break-Even Analysis

Insulation removal with the VecLoader costs $0.69 per square foot (or approximately 34%) less than manual removal. However, due to the VecLoader's higher fixed costs (see Table 4), the total cost of performing a small quantity of D&D work could prove more expensive than manual insulation removal.

The following break-even analysis determines the minimum job size that would justify using the VecLoader over the manual removal method. The break-even analysis assumes that the equipment is already owned and its amortized cost is included in the cost of performing D&D work. The analysis determines whether it is cost-effective to mobilize the VecLoader for a particular size job or to remove the insulation manually.

Figure 7 compares the total cost (fixed plus variable) of performing various job sizes of insulation removal using the two technologies. At a job size of approximately 8,800 square feet – the break-even point – both technologies have the same total cost (fixed plus variable) of operation. It is the point at which the fixed costs of mobilizing and demobilizing the VecLoader ($6,077) are offset by the variable cost savings realized from using the VecLoader ($0.69 per square foot) i.e., $\$6,077 \div \$0.69 / ft^2 = 8,800\ ft^2$.

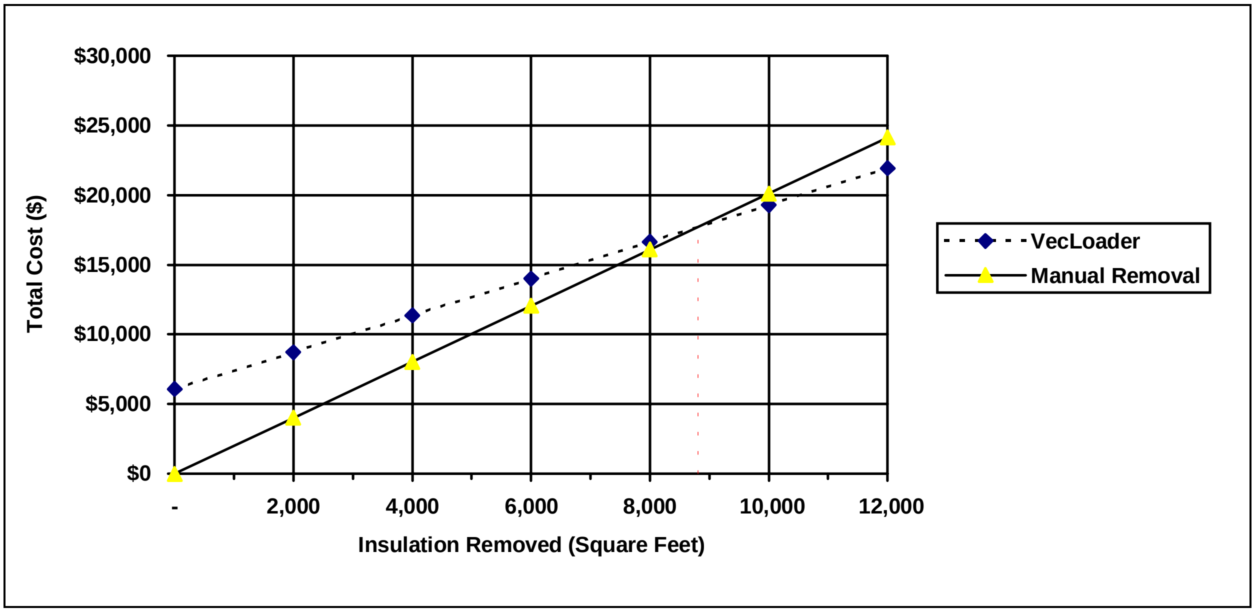

Figure 7. Break-Even Analysis: Although the unit cost of insulation removal is lower for the VecLoader, the total cost of using this technology is higher for job sizes less than 8,800 ft^2. This is due to the higher fixed costs ($6,077) of mobilizing and demobilizing the VecLoader. For job sizes less than 8,800 ft^2, it is more cost-effective to remove insulation manually.

Capital Cost Recovery Analysis

The capital cost recovery analysis estimates the total quantity of insulation that would have to be removed to justify purchasing the VecLoader. The analysis assumes that the capital cost of the VecLoader is expensed at the time of purchase and there is no amortized capital cost included in the cost of performing D&D work. If the amortized capital cost is excluded from the cost of performing D&D work (Table 4), the unit cost of removing insulation with the VecLoader is $1.22 per square foot and the cost saving over manual removal is $0.79 per square foot.

Figure 8 compares the total cost (capital plus fixed plus variable) of performing various job sizes of insulation removal using the two technologies. At a job size of approximately 120,000 square feet – the capital cost recovery point – both technologies have the same total cost (capital plus fixed plus variable) of operation. It is the point at which the capital cost ($88,952) and the fixed costs of mobilizing and demobilizing the VecLoader ($6,077) are offset by the variable cost savings realized from using the VecLoader ($0.79 per square foot) i.e., ($6,077 + $88,952) ÷ $0.79 / ft^2 = 120,000 ft^2.

Note: The above calculations assume that the VecLoader is used as demonstrated at the FEMP with a single vacuum hose. However, the system is capable of supporting two or three hoses without a significant decline in the performance of each. Although this capability was not evaluated at the FEMP, it would be expected to considerably boost the system's productivity and cost-effectiveness. In addition, the VecLoader's higher productivity could potentially accelerate a project's schedule and realize further cost savings that would offset its capital cost even faster.

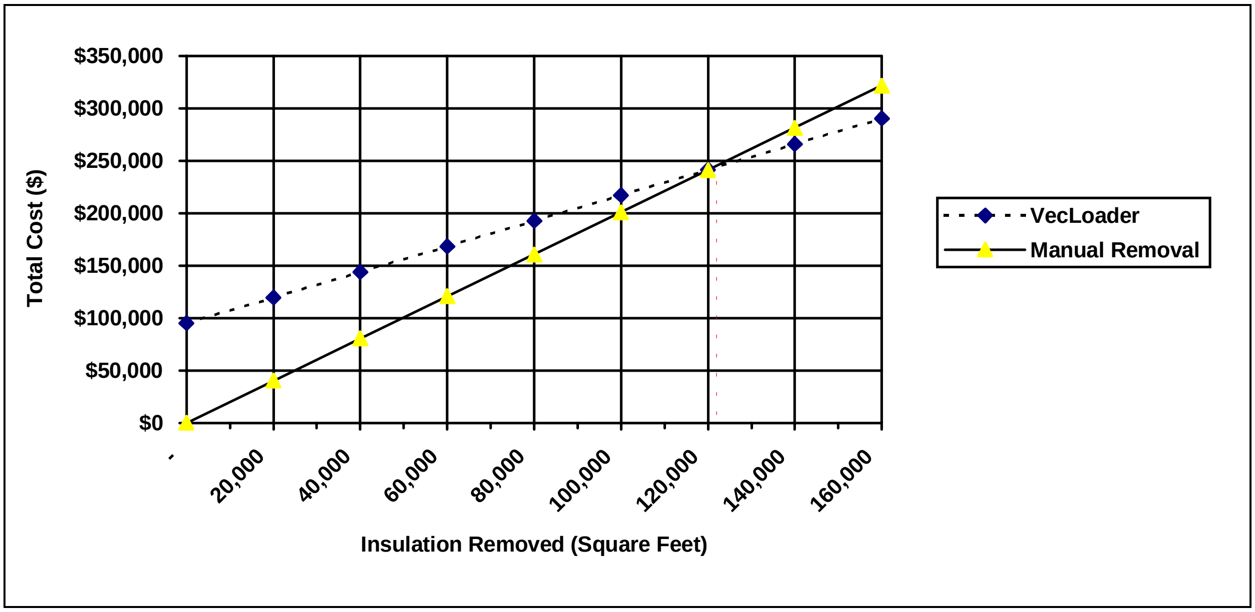

Figure 8. Capital Cost Recovery Analysis: The capital cost and fixed costs of the VecLoader are recovered after removing approximately 120,000 square feet of 4-inch insulation. If a project is estimated to have less than this amount of insulation, it may not be cost-effective to purchase a VecLoader for this purpose.

Scale-up Considerations

Plant 1 at the FEMP contained about 28,400 square feet of insulation. This is considerably less than the capital cost recovery point of 120,000 square feet; therefore, it would not have been cost-effective to purchase a VecLoader for a job of this size. However, the FEMP originally contained about 700,000 square feet of insulation. Using the VecLoader to remove this quantity of insulation would have resulted in savings of approximately $458,000 and possibly accelerated cleanup schedules. Since Plant 1 is typical of the type of construction found throughout the DOE complex, the VecLoader has the potential to realize significant cost savings in the demonstrated application.

Table 5 provides an estimate of the total costs and completion times that can be expected for removing various quantities of four-inch-thick insulation. The estimates assume that the capital cost of the VecLoader is amortized over its useful life. For all job sizes, the VecLoader is faster. Up to the capital cost recovery point of approximately 120,000 square feet, the total cost of removing insulation manually is lower than with the VecLoader. However, in selecting an insulation removal technology, project managers should take into consideration the significantly reduced work schedule that is achievable using the VecLoader.

Table 5. Estimated project costs and completion time for insulation removal

	Manual Insulation Removal ***	VecLoader Insulation Removal ***	Variance (VecLoader - Manual)
Technology productivity *	182 ft^2/h	220 ft^2/h	+21%
Process productivity **	197 ft^2/day	716 ft^2/day	+263%
Total cost and process time for removal of:			
1,000 ft^2	$2,010 5.1 days	$96,249 1.4 days	$94,239 -3.7 days
10,000 ft^2	$20,100 51 days	$107,229 14 days	$87,129% -37 days
100,000 ft^2	$201,000 508 days	$217,029 140 days	$16,029 -368 days
120,290 ft^2	$241,783 611 days	$241,783 168 days	$0 -443 days
200,000 ft^2	$402,000 1,015 days	$339,029 279 days	-$62,971 -736 days
300,000 ft^2	$603,000 1,523 days	$461,029 419 days	-$141,971 -1,104 days

* The technology productivity is the rate at which the technology removes insulation from walls. It does not take account of the time needed for donning/doffing PPE, moving rigging, rest breaks, etc.

** The process productivity is the rate at which the technology removes insulation from walls taking into account all steps in the process including donning/doffing PPE, moving rigging, rest breaks, etc.

*** Costs are based on the full cost of deploying and using the technology (i.e., capital plus fixed plus variable costs) and expensing the capital cost of equipment at the time of purchase.

SECTION 6

REGULATORY/POLICY ISSUES

Regulatory Considerations

The operation of the VecLoader HEPA vacuum insulation removal system at the FEMP Building 1A was governed by the following safety and health regulations:

- **Occupational Safety and Health Administration (OSHA) 29 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

- **Occupational Safety and Health Administration (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

Safety, Risks, Benefits, and Community Reaction

Since the VecLoader HEPA VAC 522 system was designed specifically for removing and containing hazardous and/or contaminated materials including insulation, there are no regulatory requirements to apply CERCLA's nine evaluation criteria. Nonetheless, some evaluation criteria such as protection of human health and community acceptance are discussed below. Other criteria such as cost and effectiveness were discussed in Sections 3 and 5.

The VecLoader's powerful vacuum poses a health hazard to workers. Use of an angled vacuum head with handles available from Vector Technologies Ltd. would reduce this risk. Noise levels generated by the equipment are potentially injurious, and appropriate hearing protection measures such as those prescribed by ACGIH must be observed. On the positive side, the VecLoader substantially reduces levels of airborne contaminants and reduces the worker exposure to these health hazards.

Waste generated by the VecLoader insulation removal process consisted of insulation packaged in plastic bags and the vacuum hose. These were added to the existing low-level waste streams for the FEMP project to be disposed of in the on-site disposal facility.

A further benefit of the VecLoader would be its potential to accelerate cleanup schedules because it is more than three times as fast as manual removal.

Community reaction to use of the VecLoader would likely be positive since it reduces airborne contamination and worker exposure to contaminants and radionuclides. Its ability to reduce waste volume and accelerate schedules should also meet with community acceptance.

SECTION 7

LESSONS LEARNED

Implementation Considerations

VecLoader vacuums are fully developed and commercially available systems. The VecLoader HEPA VAC 522 is transportable and easily deployed at project sites.

For future operations of the VecLoader, a complete training program should be implemented before its use. Before the FEMP demonstration, the vendor provided equipment training on the VecLoader without actually performing insulation removal. Subsequently, when the workers actually began removing insulation in the controlled area, they encountered problems and questions. Unfortunately, because these on-site problems were not anticipated, the vendor’s representatives did not have the proper respirator training that would have allowed them to enter the enclosure that had been built around the VecLoader. Therefore, they could provide no additional hands-on assistance. This resulted in problems and delays on the first day of operation.

The size and type of hose used on the VecLoader should be re-evaluated. The 2.5-inch diameter hose that was used initially was not effective due to repeated plugging, and the workers complained that the 5-inch hose was too heavy and difficult to maneuver. They suggested using a 4-inch hose, possibly of a lighter weight composition than the one used in the demonstration. Also, there was no handle or nozzle at the end of the hose and the workers simply held the hose directly with their hands, which made it harder to maneuver. On occasion, the end of the hose stuck to the wall due to the strong vacuum. The workers suggested using an aluminum nozzle with handles and an angled head that Vector Technologies Ltd. sells as optional equipment. It might also be helpful if a vacuum control button or an air intake shunt is built at the beginning of the hose, so that the hose operator can easily control the vacuum action.

The hose weighed approximately 300 pounds, which was too much additional weight for a one-person lift when working above floor level. During the demonstration, a switch had to be made to a larger capacity two-person lift. In addition, the hose was tied to a support on the ceiling that made maneuvering it more manageable.

Communication between members of the work crew was problematic due to the high noise levels and the distance between the operator of the VecLoader and the operator of the vacuum hose. Although a remotely operated communication light system was included with the VecLoader to allow each crew member to signal the other when the vacuum needed to be stopped, communication was still somewhat difficult. For example, the light system cannot indicate whether a normal or an emergency shut-down procedure should be effected. A wireless headset with a throat microphone would improve communication.

It was difficult for the operator of the VecLoader to ascertain whether insulation was entering the cyclone separator or whether the separator needed to be purged. A transparent piece of hose immediately before the cyclone separator and a window or sight glass on the cyclone separator would allow a visual determination of how much waste was being vacuumed or accumulating. Further, a clear hose of suitable strength for the vacuum line would facilitate locating and clearing clogs.

The moistened insulation discharged into the waste disposal bags sometimes made them heavy and difficult to handle. A rotating platform or carousel under the bags would allow twisting their tops before disconnecting and sealing them, without having to lift them.

APPENDIX A

REFERENCES

Fluor Daniel Fernald*, Detailed Technology Report for the VecLoader HEPA Vacuum Insulation Removal System, Large-Scale Technology Demonstration Project,* U.S. Department of Energy's Fernald Environmental Management Project, Cincinnati, Ohio, February 1998.

U.S. Army Corps of Engineers (USACE), *Hazardous, Toxic, and Radioactive Waste Remedial Action Work Breakdown Structure and Data Dictionary*, USACE, 1996.

U.S. Army Corps of Engineers (USACE), *Construction Equipment Ownership and Operating Expense Schedule, Region II*, USACE, August 1995.

APPENDIX B

VECLOADER HEPA VAC SPECIFICATIONS

Engine	
Model	John Deere 4239T
Type	Diesel, fuel injected
Number of Cylinders	4
Rated Speed	2100 RPM
Idle	1000 RPM
Power	
Maximum intermittent without fan	102 HP
Continuous @2,200 RPM without fan	91 HP
Weight	915 lb.
Blower	
Model	Roots 616RCS-JH
Rated Speed	2750 RPM
Pressure Rise-Maximum (inlet)	15 Hg.
Temperature Rise-Maximum (inlet at ambient temperature)	230 F
Rated	1700 CFM
Air Compressor	
Model	Ingersoll-Rand 242
Type	Two-stage, two cylinder, air cooled
Hydraulic Pump	
Model	MTE C205-L
Clutch	
Model	Rockford PTA 41025
Battery	
Power	12v, 110 amp
HEPA Filter	
Manufacturer	Watman, Filtra 2000, (F-1506) Rated 99.99% efficient at 0.3 micron or equal
Capacities	
Fuel Tanks (Front and Rear)	50 gallons each
Hydraulic Oil Reservoir	14 gallons
Dimensions	
Width of HEPA VAC	7ft 10in
Traveling Height of HEPA VAC	11ft 4in
Operating Height of HEPA VAC	18ft 0in
Traveling Length of HEPA VAC	17ft 5in
Operating Length of HEPA VAC	24ft 2in
Weight of HEPA VAC	9,800 lb.
Maximum Operating Height of HEPA VAC from bottom of discharge spout to ground	8ft 6in

APPENDIX C

SUMMARY OF COST ELEMENTS

Table C.1. Breakdown of major cost elements

Fixed Costs

	Quantity	Unit	Man hrs	Labor	Equip.	Materials	Other	Total
Manual Removal (Baseline)	1,161	ft^2						
Mobilization			0	$0	$0	$0	$0	$0
Demobilization			0	$0	$0	$0	$0	$0
Total Manual Removal	**1,161**	**ft^2**	**0**	**$0**	**$0**	**$0**	**$0**	**$0**
VecLoader (Innovative)	1,476	ft^2						
Mobilization			92	$2,811	$9	$25	$773	$3,618
Demobilization			50	$1,578	$125	$0	$756	$2,459
Total VecLoader	**1,476**	**ft^2**	**142**	**$4,389**	**$134**	**$25**	**$1,529**	**$6,077**

Variable Costs

	Quantity	Unit	Man hrs	Labor	Equip.	Materials	Other	Total	Unit Cost
Manual Removal (Baseline)	1,161	ft^2							
D&D Work			21	$467	$10	$0	$0	$477	$0.41
Disposal			0	$0	$0	$0	$1,533	$1,533	$1.32
PPE			0	$0	$0	$0	$318	$318	$0.28
Total Manual Removal	**1,161**	**ft^2**	**21**	**$467**	**$10**	**$0**	**$1,851**	**$2,328**	**$2.01**
VecLoader (Innovative)	1,476	ft^2							
D&D Work			22	$445	$153	$0	$15	$598	$0.41
Disposal			0	$0	$0	$0	$1,015	$1,015	$0.68
PPE			0	$0	$0	$0	$333	$333	$0.23
Total VecLoader	**1,476**	**ft^2**	**22**	**$445**	**$153**	**$0**	**$1,348**	**$1,946**	**$1.32**

Total Costs

	Quantity	Unit	Man hrs	Labor	Equip.	Materials	Other	Total	Unit Cost
Manual Removal (Baseline)	1,161	ft^2							
Mobilization			0	$0	$0	$0	$0	$0	$0
D&D Work			21	$467	$10	$0	$0	$477	$0.41
Disposal			0	$0	$0	$0	$1,533	$1,533	$1.32
Demobilization			0	$0	$0	$0	$0	$0	$0.00
PPE			0	$0	$0	$0	$318	$318	$0.28
Total Manual Removal	**1,161**	**ft^2**	**21**	**$467**	**$10**	**$0**	**$1,851**	**$2,328**	**$2.01**
VecLoader (Innovative)	1,476	ft^2							
Mobilization			92	$2,811	$9	$25	$773	$3,618	$2.45
D&D Work			22	$445	$153	$0	$0	$598	$0.41
Disposal			0	$0	$0	$0	$1,015	$1,015	$0.68
Demobilization			50	$1,578	$125	$0	$756	$2,459	$1.67
PPE			0	$0	$0	$0	$333	$333	$0.23
Total VecLoader	**1,476**	**ft^2**	**164**	**$4,834**	**$287**	**$25**	**$2,877**	**$8,023**	**$5.44**
VecLoader Unit Cost excluding Fixed Costs									**$1.32**

Table C.2. Personal protective equipment costs and requirements per crew member

Cost Assumptions:

Daily Shift Length: 10 hours

Useful Life of Reusable PPE Items: 200 hours

Reusable PPE - Daily Requirements[1]

			Manual Removal of Insulation (Baseline)		VecLoader Vacuum System (Innovative)	
Item	**Unit Cost**	**Unit**	**Quantity**	**Total Cost**	**Quantity**	**Total Cost**
Cotton coveralls (yellow)	$5.90	Ea.	4	$23.60	4	$23.60
Cotton hoods (yellow)	1.16	Ea.	4	4.64	4	4.64
Cotton shoe covers (yellow)	1.84	Pair	4	7.36	4	7.36
Leather welding apron	20.00	Ea.	0	0.00	0	0.00
Leather welding gloves	7.00	Pair	0	0.00	0	0.00
Full-face respirators	174.00	Ea.	4	696.00	4	696.00
Reusable PPE laundry costs[2]	1.39	Load	1	1.39	1	1.39
Hourly Reusable PPE Cost				**$ 3.66**		**$ 3.66**

Disposable PPE - Daily Requirements[3]

			Manual Removal of Insulation (Baseline)		VecLoader Vacuum System (Innovative)	
Item	**Unit Cost**	**Unit**	**Quantity**	**Total Cost**	**Quantity**	**Total Cost**
Tyvek suits	$4.09	Ea.	4	$16.36	4	$16.36
Saranex suits	23.77	Ea.	0	0.00	0	0.00
Mar-mac fire-resistant coveralls	3.36	Ea.	0	0.0	0	0.00
Cotton glove liners	0.28	Pair	4	1.12	4	1.12
Cotton work gloves	0.54	Pair	0	0.00	0	0.00
Nytrile gloves	0.24	Pair	4	0.96	4	0.96
Rubber shoe covers	12.28	Pair	4	49.12	4	49.12
Rubber boots	29.30	Pair	0	0.00	0	0.00
Ear plugs	0.12	Pair	0	0.00	0	0.00
Ear protectors	18.72	Ea.	0	0.00	0	0.00
Respirator cartridges	11.74	Pair	4	46.96	4	46.96
Hourly Disposable PPE Cost				**$11.45**		**$11.45**
TOTAL HOURLY PPE COST				**$ 15.11**		**$ 15.11**

[1]Requires four changes per worker each day. Expected life = 200 hours.

[2]One day's reusable PPE for one crew member is one laundry load. Cost per laundry load is $1.39. Data provided by Fluor Daniel Fernald.

[3]Requires four changes per worker each day. Expected life = 10 hours (the length of one shift).

APPENDIX D

ACRONYMS AND ABBREVIATIONS

Acronym/Abbreviation	Description
ACGIH	American Conference of Governmental Industrial Hygienists
CERCLA	Comprehensive Environmental Response, Compensation and Liability Act
CFR	Code of Federal Regulations
D&D	Deactivation and Decommissioning
DAC	Derived air concentration (see definition below)
dBA	Decibels weighted on “A” scale
DDFA	Deactivation and Decommissioning Focus Area
DOE	Department of Energy
FDF	Fluor Daniel Fernald
FEMP	Fernald Environmental Management Project
FIU	Florida International University
ft^2, SF	Square feet
HCET	Hemispheric Center for Environmental Technology (at Florida International University)
h	Hour
lb.	Pounds
LSDP	Large-Scale Demonstration Project
M&I	Management and Integration
OSHA	Occupational Safety and Health Administration
OSDF	On-site disposal facility
OST	Office of Science and Technology
PPE	Personal protective equipment
USACE	United States Army Corps of Engineers

Definitions

- The Derived Air Concentration (DAC) is the term applied to the concentration of a radionuclide in air that, when breathed by the average worker for a working year, would result in an individual receiving his/her annual occupational dose limit. The DAC is expressed in units of micro-Curies per milliliter (μCi/ml).

- DAC-hrs is the airborne radioactivity concentration in DAC multiplied by the time a worker spends in the area (in hours).

- The corrected DAC-hrs is the DAC-hrs divided by the protection factor of the respirator being used. If no respirator is used, the protection factor is 1. The protection factors for the respirators used at the FEMP are 50 for a full-face air-purifying respirator (negative pressure) and 1,000 for a powered full-face air-purifying respirator (positive pressure).