INNOVATIVE TECHNOLOGY

Summary Report

Centrifugal Shot Blasting

OST Reference #1851

Deactivation and Decommissioning
Focus Area

Demonstrated at
Fernald Environmental Management Project – Plant 1
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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SUMMARY

Introduction

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

At the U.S. Department of Energy (DOE) Fernald Environmental Management Project (FEMP), the Facilities Closure and Demolition Projects Integrated Remedial Design/Remedial Action (RD/RA) work plan calls for the removal of one inch (1 in) depth of concrete surface in areas where contamination with technetium-99 has been identified. This report describes a comparative demonstration between two concrete removal technologies: an innovative system using Centrifugal Shot Blasting (CSB) and a modified baseline technology called a rotary drum planer.

Technology Summary

Problem

At the FEMP and throughout the DOE complex there are large areas of radiologically and chemically contaminated concrete that represent a costly, time-consuming and potentially hazardous removal problem for D&D managers. Much of the contamination resides within the upper 1 in of concrete. Removing this top layer of concrete in a safe, dustless fashion has been a challenging, expensive and lengthy process in the past. In certain areas at the FEMP, regulators overseeing the remediation have agreed that if the top 1 in of contaminated concrete can be removed and sent off-site for disposal, the rest of the concrete can be broken up and sent to the On Site Disposal Facility (OSDF), resulting in significant cost and schedule savings. The total volume of concrete being disposed has not changed, but this approach maximizes the amount of concrete being disposed in the less costly OSDF. Off-site shipment and disposal of the top 1 in of concrete at the FEMP is necessary due to regulatory requirements limiting the amount of technetium-99 allowed in the OSDF.

Technetium is a fission fragment generated when uranium is split in a nuclear reactor. Technetium is highly water-soluble, and the concern is that it could seep out of the OSDF should a leak develop in the liner system. Therefore, great care is exercised to exclude technetium from the OSDF.

Methods previously used to remove the surface of concrete floors have included diamond wire sawing, scarifiers and jackhammering. Each method has its own drawbacks, such as extremely slow production rates, large crew requirements, and the creation of airborne contamination. The only other alternative to remove surface layers of concrete has been to break the entire pad into pieces and ship it off-site for disposal, which is much more costly.

How it works (centrifugal shot blasting)

The CSB system propels hardened steel shot at high velocities (220 feet per second) onto concrete floor surfaces. After the shot is propelled onto the floor, the resulting impact causes the cement to fracture into small pieces, which are then captured by an integrated dust collection system. The majority of steel shot is conveyed back into the CSB technology for reuse by two mechanisms that complement each other: rebound and vacuum. After the shot is pulled into the CSB technology, it is separated from the concrete dust by an air-wash system consisting of strategically placed baffles. The shot is continually reused until it is reduced to the size of dust and conveyed to the dust collection system. The dust collector was a modified FARR model Mark IV TENKAY® self-cleaning dust collector capable of generating 1,700 cubic feet per minute (cfm) of negative airflow at the face of the CSB technology. Figure 1 depicts the CSB machine, while Figure 2 depicts the CSB dust collection system.

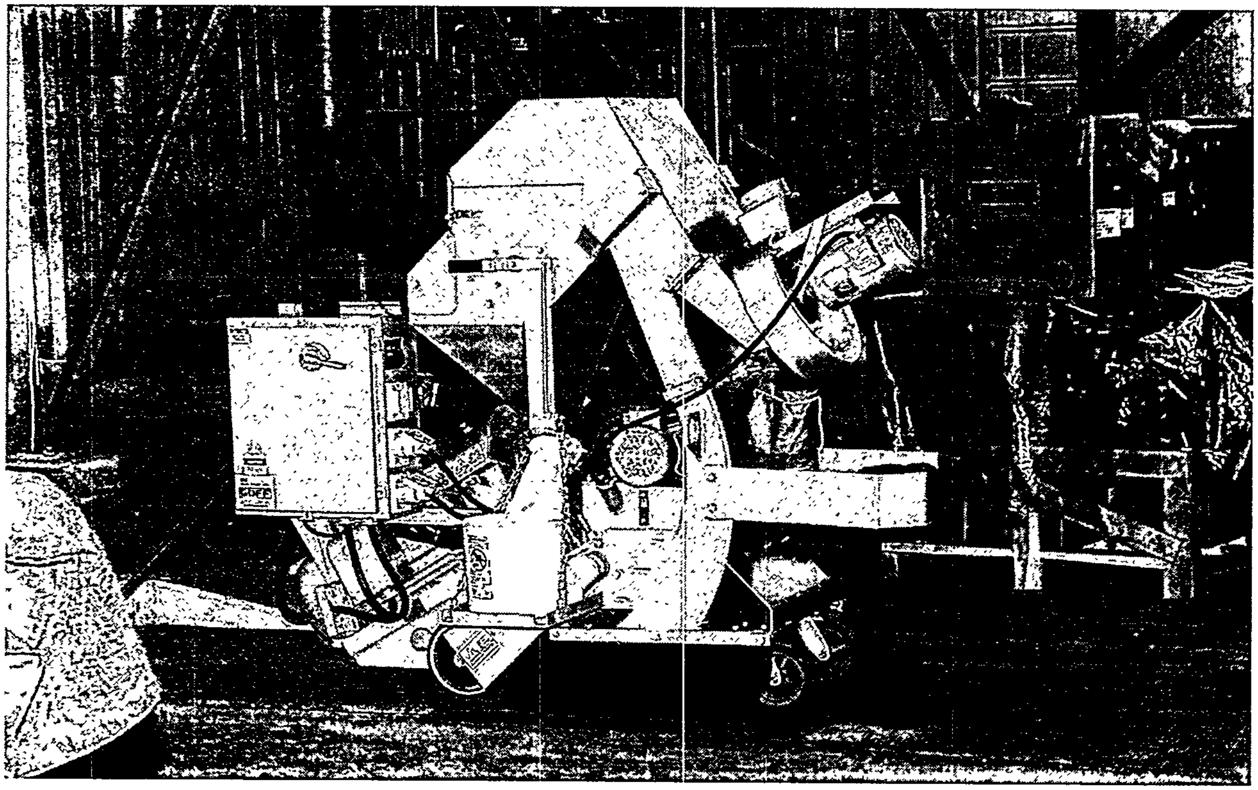

Figure 1. Centrifugal shot blasting technology.

How it works (rotary drum planer)

Attached to the front of a Bobcat high-flow model skid-steer loader, the rotary drum planer system uses the skid-steer's hydraulic system for power. The rotary drum planer used at the FEMP contained 62 replaceable tungsten-carbide teeth that cut a swath 16 in wide and up to 6 in deep (there are various models available from the manufacturer). The depth of cut is controlled by right and left shoes attached to twin hydraulic cylinders that can be lowered up and down by the operator. Another hydraulic cylinder allows the planer to move laterally across the front of the skid steer loader to remove concrete close to walls, curbs and other obstructions. When removing concrete, the rotary drum planer can be pushed or pulled by the skid-steer.

The rotary drum planer was modified to provide dustless operation with the capability to simultaneously capture the waste it generated by utilizing a VecLoader HEPA-Vac attached to a custom fabricated vacuum shroud covering the rotary drum planer, via a dust hose. When the VecLoader's hopper becomes full of material, the concrete removal operation is suspended while the VecLoader tender opens a chute on the machine and the resulting

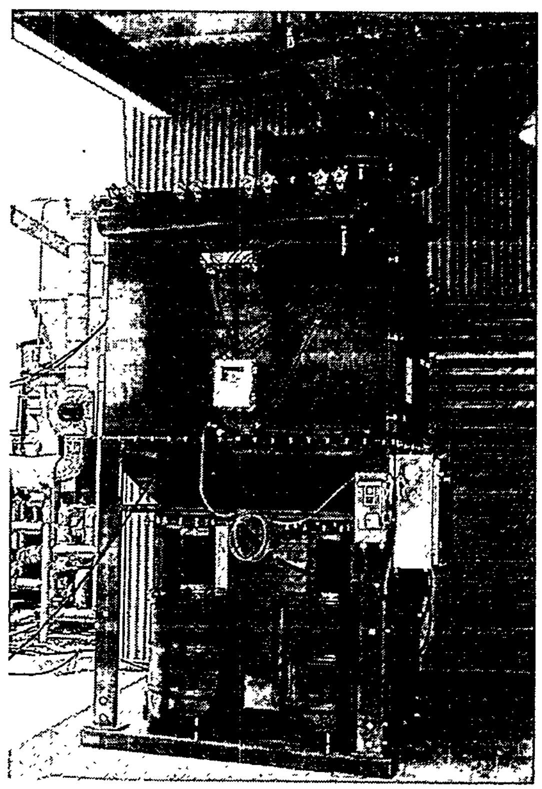

Figure 2. Dust collector for CSB technology.

material is deposited in a 55 gallon drum. The drum filling process is HEPA filtered and takes only a few minutes to complete.

The VecLoader was a successful technology demonstrated earlier in the Fernald Plant 1 LSDDP where it was proven to be more productive at removing insulation via vacuuming than the baseline method of removing insulation by hand. To learn more about the VecLoader, you can visit the OST Web site at http://em-50.em.doe.gov under "Publications" to read the Innovative Technology Summary Report (ITSR) on the technology. Figure 3 depicts the VecLoader dust collection system and Figure 4 depicts the Rotary Drum Planer used in Plant 9.

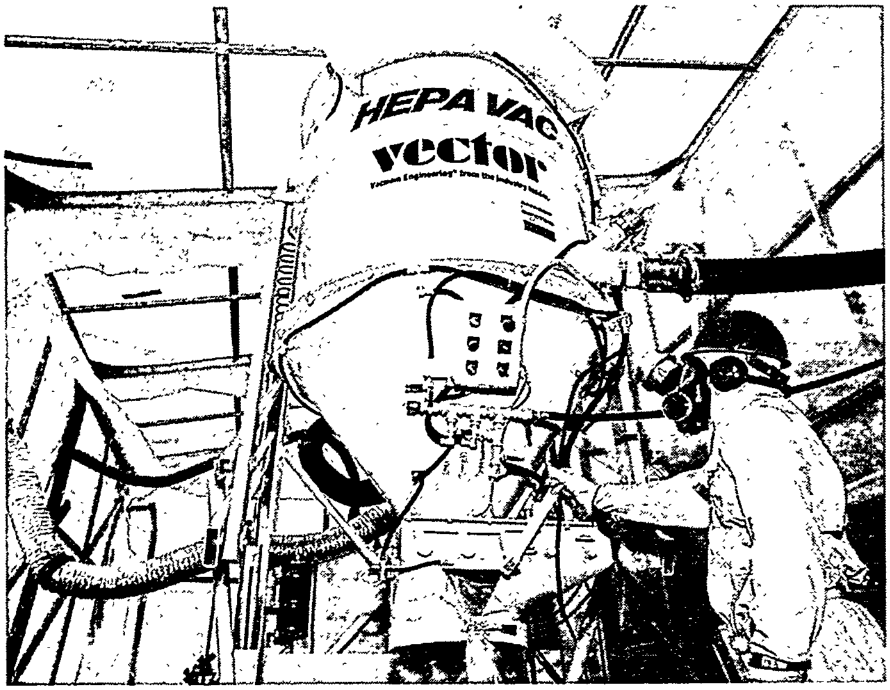

Figure 3. VecLoader HEPA Vac of type used in Plant 9.

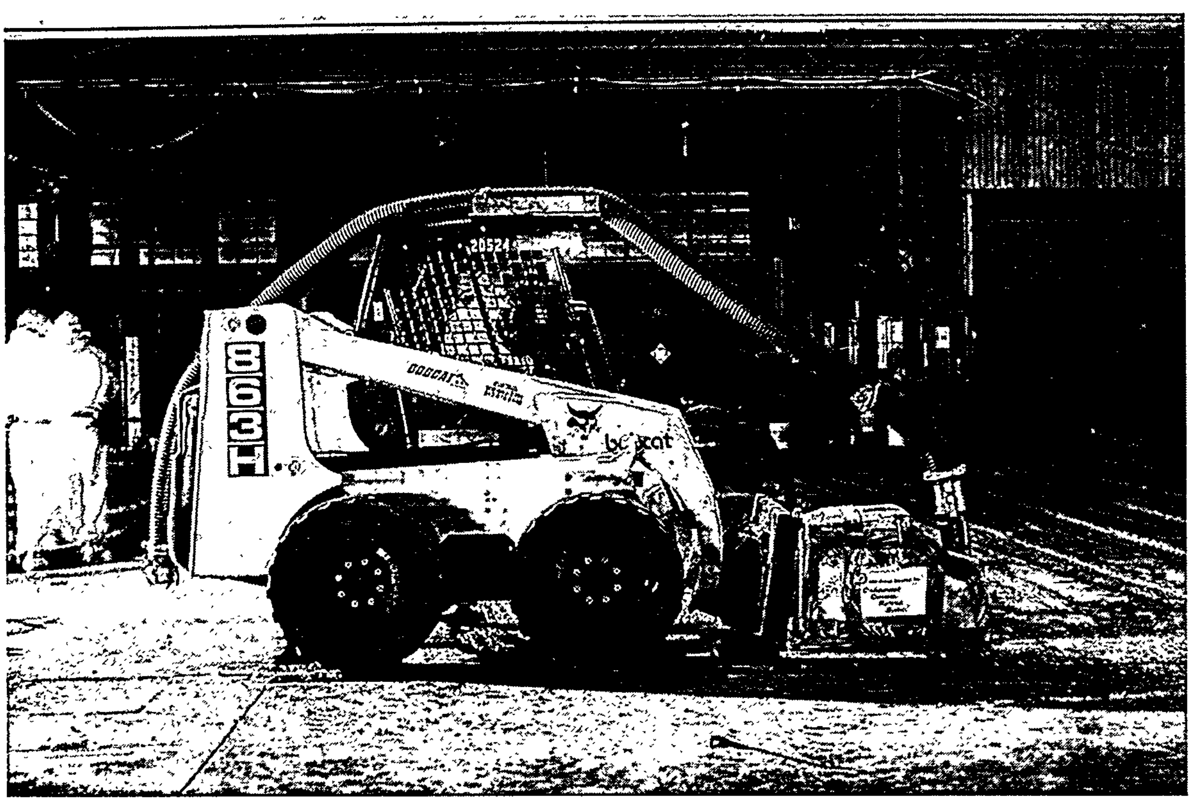

Figure 4. Rotary drum planer inside of Fernald's Plant 9.

Potential markets

The CSB technology demonstrated at the FEMP was originally designed to remove mastic from decks of aircraft carriers and has been modified to remove coatings and other surfaces, including concrete. In addition to remediating contaminated floors in the DOE complex, the CSB technology has been used to remediate floors in the commercial nuclear power industry, to remove chemically contaminated concrete, to prepare concrete surfaces for coatings, and to roughen slippery surfaces like those found on warehouse loading docks. The CSB technology demonstrated at the FEMP was a model 420E manufactured by Georg Fischer Disa Goff, Inc and operated by Concrete Cleaning Inc. The manufacturer has a variety of models available for different applications. This technology has been successfully used on floors only and has not been modified to accommodate concrete removal on vertical surfaces.

The rotary drum planer, with modifications to work in a nuclear environment has potential applications across the DOE complex and the commercial nuclear sector where heavy concrete removal is required over a relatively large area. Coupled with the VecLoader HEPA Vac, the rotary drum planer is a robust and reliable technology for horizontal concrete and asphalt removal in any contaminated environment.

Advantages over the baseline

Although the rotary drum planer generally outperformed the CSB technology at the FEMP, the CSB technology has advantages over other methods of concrete removal, including some advantages over the rotary drum planer. Compared to scarifiers, diamond wire sawing and jackhammering, the CSB technology is faster and safer for concrete removal. The CSB machine is less labor intensive than the other technologies, and it is less prone to generate airborne contamination when coupled with a suitable dust collector. Advantages that the CSB technology has over the rotary drum planer include the ability to blast over reinforcing wire, rebar, floor bolts, steel drains and other obstructions, the ability to work and maneuver in tight quarters, and the capability to remove very thin layers (e.g. 1/16 in) and leave the floor in a safe, smooth, useable condition.

While the CSB technology easily removed the top 1/8 in to 3/16 in of concrete, the technology had considerable difficulty in removing the remaining concrete down to the 1 in removal requirement. The difficulty can be attributed mainly to the large (up to 2 in diameter) natural riverine pebbles in the concrete. The large riverine pebbles caused the rebound/recycle mechanism of the CSB technology to be less effective, requiring more work to retrieve the shot from the floor with a magnet and refill the machine. The riverine pebbles were also harder than the concrete, leading to slower than expected production rates. Conversely, the rotary drum planer easily removed the concrete down to 1 in and in many places exceeded two inches in removal depth. The major delays associated with the rotary drum planer can be attributed to its vulnerability to reinforcing steel bars and wire mesh that was in close proximity to the surface, which resulted in broken teeth and entwined mesh on the drum. For concrete removal at depths equal to or greater than 3/16 in, in relatively large open areas, the rotary drum planer is the recommended technology for concrete removal. For concrete removal at depths between 1/8 in and 3/16 in and in confined areas, even at 1 in depth, the CSB technology is recommended because it has greater maneuverability and generates less waste per unit area. Table 1 highlights production rates and other parameters between the CSB technology and the rotary drum planer demonstrated and used at the FEMP.

Table 1. Comparison between two concrete removal technologies at the FEMP

	CSB Technology	Rotary Drum Planer
Production Rate	17.7 ft^2/hour	52.2 ft^2/hour
Removal Capability	Between 1/16 in and 1 in	Between 3/16 in and 6 in
Gap From Wall	Between 4 in and 5 in	Between 6 in and 10 in
Cut Width	20 in	16 in

This report covers concrete removal activities of the CSB technology and the rotary drum planer from June through September 1998.

The demonstration sites and descriptions

The CSB technology was demonstrated inside Fernald's Plant 8 in the muffle furnace area (process area 4) over an area of 1,464 ft^2. Plant 8, known as the Scrap Recovery Plant, processed various uranium bearing materials for re-use including uranium metal chips and turnings, off-specification green salt from the hydrofluorination plant, dust collector residues and sump cakes.

The rotary drum planer was deployed in Fernald's former Plant 9 (Special Products Plant), over an area of 22,600 ft^2. The handling of technetium-99 contaminated, recycled uranium materials from Hanford is believed to be the primary source of contamination in Plant 9.

Key results

The key results of the demonstration are as follows:

- The CSB technology easily removed the first 1/8 in to 3/16 in of concrete but had considerable difficulty removing the remaining concrete down to 1 in total depth.
- CSB would be ideal in situations where only a coating or thin layer of concrete needed to be removed.
- When removing only thin layers of concrete, 1/16 in to 1/4 in deep, the CSB technology is ideal because it leaves the floor in reusable condition (i.e., it is not so rough that it cannot be repainted and used safely).
- The CSB technology was able to blast over obstructions such as rebar, wire mesh and floor drains without any difficulty.
- Large diameter (≥ 2 in) riverine pebbles found just below the surface of the concrete impeded the technology's ability to remove the remaining concrete and also significantly contributed to poor maneuverability of the technology across the surface, which resulted in mechanical problems with the hydrostatic drive system (see Figure 5 for a picture of the large, exposed aggregate).
- Increasing the size of steel shot used from SAE size # S460 to SAE size # S550 increased the CSB technology's ability to abrade away the large riverine aggregate and surrounding concrete matrix.
- The CSB dust collector did not provide enough vacuum or velocity, which resulted in dust overloading the system when shot blasting over softer areas of concrete.

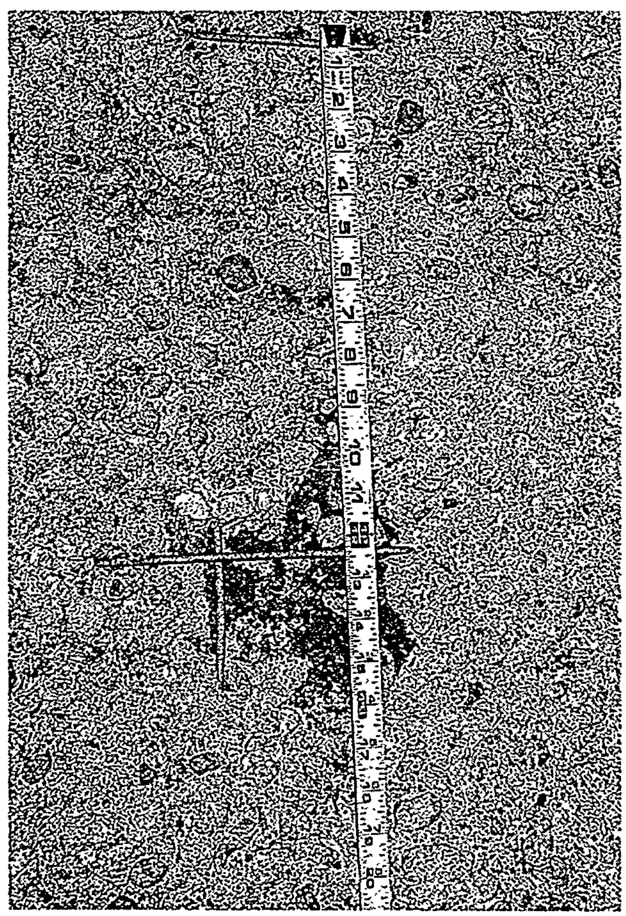

Figure 5. Large riverine aggregate found in Plant 8 concrete along with wire mesh.

- Loose shot left on smooth concrete floor surfaces resulted in a serious slipping hazard.

- Rubber seals around the base of the CSB technology needed frequent adjustment or replacement to contain errant shot.

- The CSB technology achieved a production rate of 17.7 ft^2 per hour at a cost of $34.25/$ft^2$, while the rotary drum planer achieved a production rate of 52.2 ft^2 per hour at a cost of $9.44/$ft^2$, as calculated by the United States Army Corps of Engineers (USACE).

- The rotary drum planer proved to be a more viable and robust technology for heavy concrete removal.

- Productivity using the rotary drum planer was improved when a second drum was made available for use; two drums allowed the subcontractor to continue running when a drum needed maintenance.

- The 6 in diameter vacuum hose leading from the rotary drum planer to the VecLoader would occasionally clog when the machine encountered a rubberized reinforcing material within the concrete.

- The rotary drum planer, equipped with the 3 in diameter cutting teeth, did not leave the floor in a reusable condition and was less precise in achieving 1 in depth removal; all areas > 1 in with some ≥ 3 in.

- Noise generated during the operation of the rotary drum planer and associated VecLoader required the use of double hearing protection but did not result in limited stay times.

Regulatory considerations

Regulatory considerations were limited to the generation of airborne dust during the CSB demonstration. The vendor was prohibited from generating visible dust during the demonstration and the HEPA filtration system had to pass a DOP test, whereby the efficiency of the filter had to be ≥ 99.97% at removing Dioctyl Phthalate (DOP) particulates 0.3 microns and larger in size. Air monitoring was performed during the demonstration to ensure that airborne radioactivity levels did not exceed 10 percent of the Derived Air Concentration (DAC) limits. Technical guidance and site training in the areas of radiation protection, health and safety and regulatory compliance were provided to the vendors by Fluor Daniel Fernald (FDF).

Commercial availability

Both technologies and their components are commercially available. However, the respective vendors performed modifications on the technologies and their components to enhance efficiency and productivity and to be able to conduct work in a radiological environment.

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Licensing

Centrifugal Shot Blasting is available as a service from Concrete Cleaning Inc.

The Rotary Drum Planer System described in this report is available as a service from NSC Energy Services, Inc.

Other

All published Innovative Technology Summary Reports are available on the OST Web site at http://em-50.em.doe.gov under "Publications." The Technology Management System, also available through the OST Web site, provides information about OST programs, technologies, and problems. The OST Reference number for Centrifugal Shot Blasting is 1851.

TECHNOLOGY DESCRIPTION

Overall Process Definition—CSB and rotary drum planer

Baseline approaches to remove contaminated concrete at the FEMP have included using jackhammers, scarifiers, or heavy equipment to break the entire pad into large pieces. Each of these concrete removal methods used various means of controlling airborne contamination, such as spraying water, integral HEPA filtration, and area HEPA filtration. Each of these D&D methods has drawbacks, such as slow production rates, excess waste generation, generation of airborne contamination and secondary waste, and large crew requirements. In an effort to find a better method of removing contaminated concrete, the CSB technology was demonstrated at the FEMP in an area that required the removal of 1 in of concrete to assess its ability to satisfy the following objectives:

- Reduce the quantity of concrete dispositioned off-site.
- Reduce the amount of secondary waste generated during the concrete removal process.
- Provide a cost-effective concrete decontamination process.
- Provide a direct comparison to baseline concrete removal technologies.

The CSB technology

At the FEMP, the CSB technology had three integral sub-systems: A dust collector with HEPA filtration, an air compressor capable of supplying 100 pounds per square inch (psi) of air at 50 cfm, and a generator capable of supplying 100 amps, 480 volts, in three-phase. The CSB technology consists of a 40 hp, 480 volt, three-phase motor; a blast wheel; a hopper for holding steel shot; a 5 hp booster motor attached to a material handling fan, and a control panel. The CSB technology abrades concrete by propelling hardened steel shot at the surface at high velocities (220 ft/sec). The impact of the shot causes the cement to fracture into small pieces (dust), which is then conveyed to the dust collection system. The operator of the CSB technology first starts the dust collector so that there is negative pressure at the blasting face. Next the 40-hp blast wheel motor is started, followed by the small booster motor and fan. After actuating the hydrostatic drive, the operator pulls a level that opens a gate from the steel shot hopper to the blast wheel. By opening or closing the feed gate, the operator can control the amount of shot feeding to the blast wheel and hence impacting the floor. The amount of concrete removed is a function of four variables: The amount and size of shot fed to the blast wheel, the speed of the CSB machine and the hardness of the concrete. Figure 6 shows the steel shot used in the demonstration.

Figure 6. Hardened steel shot used by CSB Technology.

The operator can determine the loading of shot fed to the blast wheel by reading an amp meter connected to the 40 hp motor; more shot fed to the blast wheel corresponds to a greater amp loading on the motor. A low reading on the amp meter tells the operator that the blast wheel is not loading with shot, hence the machine needs to be stopped and refilled. When blasting, another worker is required to use a large push-type magnet to pick up shot that is not captured by the rebound/recycle mechanism of the CSB technology. When the magnet picks up a full load of shot, it is positioned over a tarp and dumped. When the tarp becomes full, two people pick it up and pour the shot into a bucket. The CSB machine is then filled with recycled and, if required, new shot.

While blasting across the floor, the concrete dust and spent shot is continuously vacuumed into the CSB machine where the shot is separated from the dust by an air-wash system. The dust is then conveyed to the collector where it is fed into two 55-gallon drums. Eight canister type pre-filters clean the air before it is pulled through a nuclear grade HEPA filter, capable of removing ≥ 99.97% of particulates 0.3 microns and larger. The pre-filters are kept clean by an automatic blown-down system that is actuated when a sensor detects a programmable differential pressure threshold across the filters. A compressed air supply of at least 100-psi at 50 cfm is required to operate the filter blow-down system. When the drums become full, shot blasting is stopped and the drums are capped, lot marked, and replaced with two empty ones. The drum changeout operation required the service of two laborers and a fork-truck driver. Figure 7 represents a process schematic of the CSB technology and subsystems.

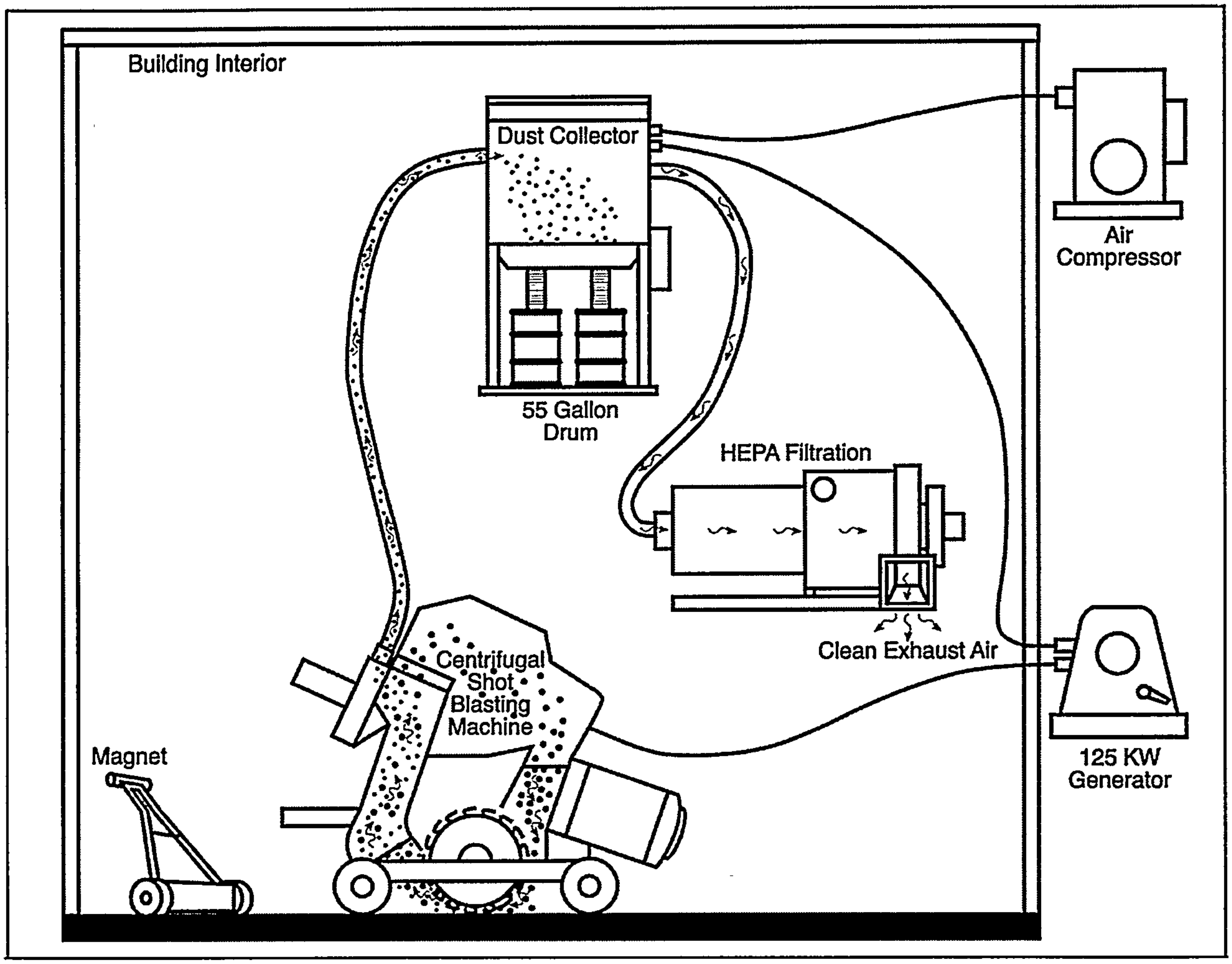

Figure 7. Centrifugal shot blast system.

A smaller CSB machine has been previously demonstrated at Argonne National Laboratory CP-5 LSDDP. In addition to a demonstration at CP-5, Concrete Cleaning Inc, has also performed concrete removal work for Babcock and Wilcox at their Parks Township, PA facility. The CSB technology demonstrated by Concrete Cleaning, Inc., is an applicable technology for coatings and concrete removal between depths of 1/16 and 5/16 in on flat horizontal surfaces, depending on the composition of the concrete. The CSB technology is also capable of decontaminating or removing coatings from flat plate steel in the same manner as concrete.

The rotary drum planer

The rotary drum planer machine used at the FEMP by NSC Energy Services consisted of a model 863H Bobcat skid steer loader equipped with an exhaust scrubber, a Melroe 16 in concrete planer and a Model 522 VecLoader HEPA Vac. While the rotary drum planer is being called the baseline in this demonstration, it could be considered an innovative technology as well, due to the modifications made to it by the subcontractor. A major change involved modifying the concrete removal process to make it dustless with simultaneous capture and drumming of waste. Additional modifications included constructing a vacuum shroud for the planer, adding insulation to dampen noise made by the planer and modifications to the drum and skid-steer to dampen harmonic vibrations. NSC Energy Services claims ownership of its modifications to the rotary drum planer for concrete removal in a radiological environment. Figure 8 represents a process schematic of the rotary drum planer concrete removal system.

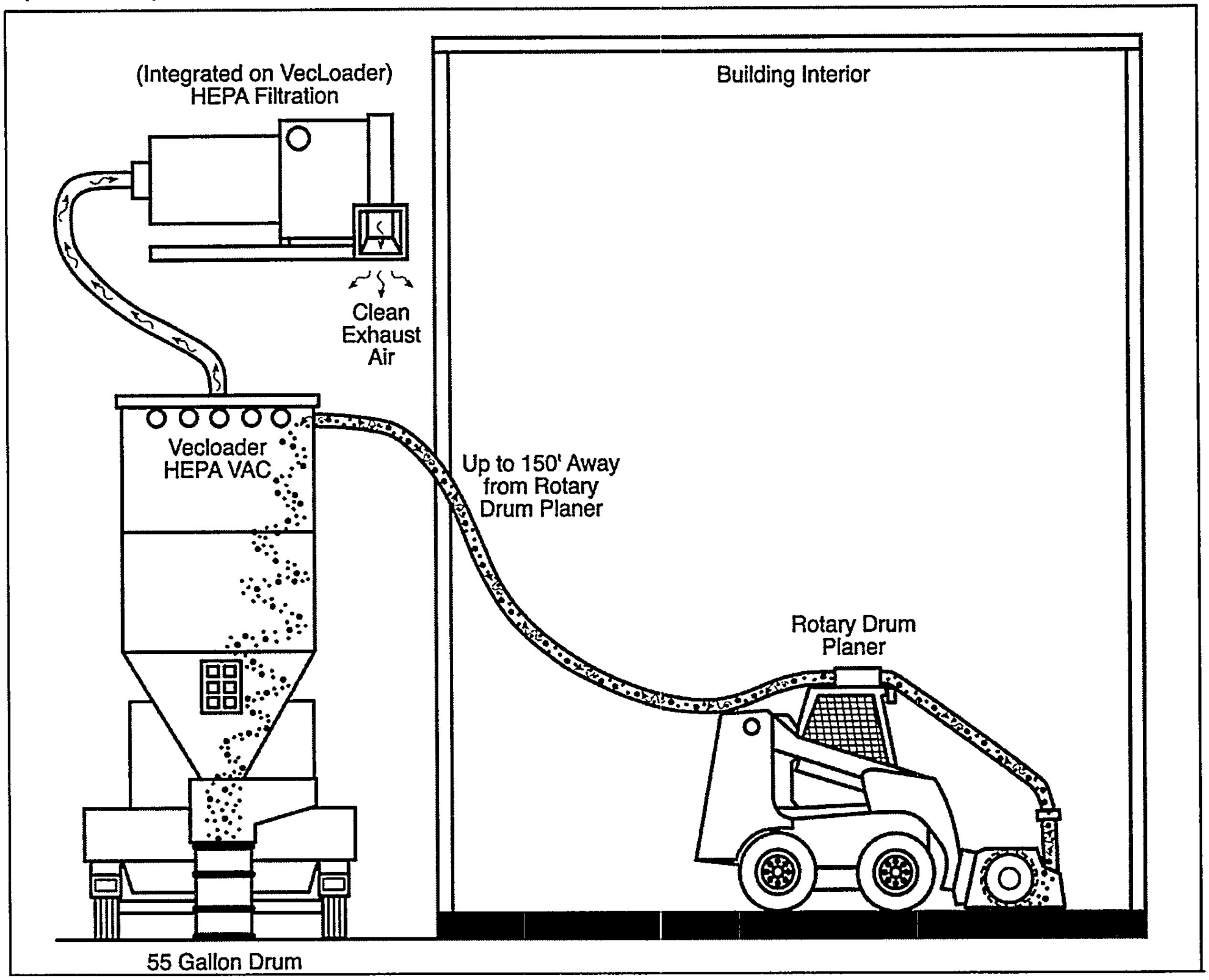

Figure 8. Rotary drum planer system process.

The only objective of modifying and operating the rotary drum planer by the Plant 9 D&D subcontractor, was to provide a robust, cost-effective and reliable method of removing 1 in of concrete over 22,600 ft^2. The skid steer's hydraulic system provides the power for turning the drum, raising, lowering and moving the planer from side to side. The rotary drum planer can remove concrete in either a forward or reverse direction. Concrete removal is a function of how fast the skid-steer is traveling and the hardness of the concrete. The rotary drum planer rips the concrete up into a combination of chunks (3 in to 4 in diameter), small pieces and dust, whereas practically all of the concrete waste generated by the CSB technology is in a fine, powdery form. The powerful vacuum of the VecLoader (up to 15 in mercury at the end of 150 ft of hose) easily picks up the dust, medium, and larger pieces of concrete. Chunks of concrete that are too large to fit through the hose are picked up by hand and placed in a drum. Waste entering the VecLoader is initially separated from the air via a cyclone separator where the majority of the waste drops out of the airstream and to the bottom of the hopper. The air is then pulled through a set of pre-filters and finally through a HEPA filter removing ≥ 99.97% of particulates 0.3 microns and larger, before being exhausted to the atmosphere.

The rotary drum planer system represents an applicable technology for concrete removal on flat surfaces, for depths between 3/16 in and 1 in depth over relatively large, open areas. Even though the rotary drum planer can achieve concrete removal depths to 6 in, this is relatively impractical due to the increased likelihood of running into rebar and other obstructions. Additionally, the extra time it would take to plane down 6 in of concrete over a large area would negate any cost savings and would be more expensive and labor intensive than removing the entire pad in pieces with heavy equipment.

System Operation

Table 2 summarizes the operational parameters and conditions, material and energy requirements, manpower needs, waste streams, and operational concerns and risks for the CSB and rotary drum planer technologies. It should be noted that the information presented below is specific to conditions encountered at the FEMP and may differ from site to site.

Table 2. Demonstration conditions

Working Conditions	
Rotary drum planer	**CSB technology**
Work area location	
Fernald's Plant 9 (Special Products Plant) process areas 2 and 4.	Fernald's Plant 8 (Scrap Recovery Plant).
Work area description	
1 in of concrete was removed over an area of 22,600 ft^2.	1 in of concrete was removed over an area of 1,464 ft^2.
Concrete characteristics	
Average concrete strength tested; 8,890 psi plus or minus 1,100 psi. Concrete was 45 + years old containing aggregate from 1/2 in to 1.25 in diameter.	Average concrete strength tested; 8,700 psi plus or minus 1,100 psi. Concrete was 45 + years old containing aggregate from 3/4 in to 2 in diameter.
Work area hazards	
Airborne contaminants including dust and radionuclides. Elevated noise levels. Moving, heavy machinery. Extreme vacuum in dust hose created by VecLoader. Tripping hazard from dust hose.	Airborne contaminates including dust and radionuclides. Elevated noise levels. Flying shot. Slipping hazard from loose shot left on the floor, Tripping hazard from electrical cords, airlines and dust hoses. Heavy machinery including the CSB technology, dust collector and a forklift.

Working Conditions continued	
Rotary drum planer	**CSB technology**
Equipment configuration	
The VecLoader was operated outside of Plant 9 inside of a temporary containment structure and was connected to the rotary drum planer by up to 150 ft of 6 in diameter material handling hose.	The generator and air compressor were operated outside of Plant 8 with electrical cords and an airline running to the equipment. The CSB technology, dust collector and HEPA unit were operated in Plant 8.
Labor, Support Personnel, Specialized Skills and Training	
Work crew	
One full time equipment operator. Two full-time laborers. One full-time equipment tender (oiler). One part-time forklift operator.	One CSB operator. Two full time laborers. Part time forklift operator.
Additional support personnel utilized during the demonstration	
Support personnel (surveyors) to verify 1 in depth removal requirement. Part-time radiological control technician. Support personnel to conduct DOP testing of HEPA filter on VecLoader. Electricians, millwrights and pipe fitters to assist with assembly and disassembly of equipment. Mechanic to make repairs to planer and Bobcat. Health and Safety personnel to perform sound level meter surveys and dosimetry and provide safety guidance.	One full-time data taker. Radiological technician. Support personnel (surveyors) to verify 1 in depth removal requirement. Support personnel to conduct DOP testing of HEPA filter. Electricians, millwrights and pipe fitters to assist with assembly and disassembly of equipment. Health and Safety personnel to perform sound level meter surveys and dosimetry and provide safety guidance.
Specialized skills	
Operator experience or training needed to operate the rotary drum planer and VecLoader.	Operator experience for operating CSB technology
Training	
All of the subcontractor's employees received 48 h of FEMP site specific training. Employees operating the VecLoader and rotary drum planer were either previously experienced or received training from the subcontractor's personnel who were previously experienced.	CSB vendor received 48 h of FEMP site specific training. FEMP laborers supporting the demonstration received briefing on the hazards of the CSB technology from the vendor.
Waste Management	
Primary waste generated	
Rotary drum planer	**CSB technology**
Fine concrete dust and concrete pieces (from 3 in to 4 in diameter).	Fine concrete dust packaged in 55-gallon drums.

Waste Management continued	
Rotary drum planer	**CSB technology**
Secondary waste generated	
Pre-filters used inside of VecLoader. HEPA filter. Dust hose. Disposable PPE. Worn out and broken planer teeth. Non-inflatable skid-steer tire treads.	Pre-filters used in dust collector. HEPA filter. Dust hose. Disposable PPE. Herculite sheeting. Spent steel shot.
Waste containment and disposal	
Concrete waste was conveyed from planer to VecLoader where it was conveyed into 55-gallon drums lined with plastic bags that are to be disposed at NTS. Miscellaneous waste to be disposed in OSDF.	Concrete dust was discharged directly into 55-gallon drums that are to be disposed at the Nevada Test Site (NTS). Miscellaneous waste to be disposed in OSDF.
Equipment Specifications and Operational Parameters	
Technology design purpose	
Heavy concrete removal with dust collection, packaging and control.	Removal of surface layers of concrete with dust collection, packaging and control.
Specifications of Bobcat model 863H	CSB specifications
Height: 81.2 in. Length: 135.8 in. Width: 74 in. Weight: 7,180 lb.	Height: 72 in. Length: 80 in. Width: 34 in. Weight: 2,700 lb.
Specifications of Melroe 16 in high flow rotary drum planer (note: planer used in Plant 9 was specially modified with vacuum shroud and anti-noise and vibration insulation)	Specifications of FARR dust collector
Height: 27 in. Length: 39 in. Width: 25 in. Weight: 1,616 lb.	Height: 127 in. Length: 76 in. Width: 57 in. Weight: 1,800 lb.
Specifications of VecLoader HEPA Vac	Specifications of HEPA unit and fan
Traveling Height: 136 in. Operating Height: 216 in. Traveling Length: 209 in. Operating Length: 300 in. Operating Width: 94 in Weight: 9,800 lb.	Height: 44 in. Length: 79 in. Width: 45 in. Weight: 1,000 lb.

Equipment Specifications and Operational Parameters continued	
Rotary drum planer	**CSB technology**
Portability	
The Bobcat and rotary drum planer can be towed on a suitable trailer by a one-ton or larger truck. The VecLoader HEPA Vac is already mounted on a trailer and can be towed by a one-ton or larger truck.	The CSB technology, dust collector and HEPA unit can be towed on a suitable trailer by a one-ton truck or hauled on a two-ton or larger truck.
Materials Consumed	
Rotary drum planer	**CSB technology**
Tungsten-carbide replacement teeth for rotary drum planer	Steel shot
Teeth were replaced every 40 h; approximately 470 teeth consumed for entire project.	800 lb.
Temporary enclosure for VecLoader HEPA Vac	Preparing work area
2 in x 4 in lumber and nails for framing enclosure. Herculite sheeting, nylon tie straps, and duct tape for covering the enclosure.	80 ft of yellow Herculite for constructing a barrier to contain stray shot.
Personal Protective Equipment (PPE)	
Reusable yellow coveralls. Reusable yellow rubber shoe covers. Reusable yellow hoods. Disposable yellow shoe covers. Disposable cotton glove liners. Disposable nitrile gloves. Disposable cotton work gloves. Disposable ear plugs. Ear protection—head phones (reusable). Powered Air Purifying Respirator (PAPR-reusable). Hard Hat (reusable). Breathing zone monitor (reusable).	Reusable yellow coveralls. Reusable yellow rubber shoe covers. Reusable yellow hood. Disposable yellow shoe covers. Disposable cotton glove liners. Disposable nitrile gloves. Disposable cotton work gloves. Disposable ear plugs. Hard Hat (reusable). Powered Air Purifying Respirator (PAPR–reusable). Breathing zone monitor (reusable). Personal Ice Cooling System (PICS) "cool suits" as needed for heat stress prevention.
Dust hose	
150 ft of 6 in diameter hose.	75 ft of 6 in diameter, smooth bore dust hose.
Fuel	
Diesel fuel to supply the Bobcat, VecLoader HEPA Vac and forklift.	Diesel fuel to supply the generator and air compressor. Propane to supply the forklift.
Insulation	Ice
Fiberglass, rubber and expanding foam insulation for dampening noise and vibrations from the rotary drum planer.	2-liter frozen ice bottles to supply cooling for the PICS.
Supporting Equipment	
Jackhammers	Air Compressor
Various size jackhammers used to remove concrete from around drains, floor bolts and other obstructions.	1 Ingersoll-Rand 750 cfm diesel powered air compressor (requirements are 100 cfm @ 50 psi).
Forklifts	
1 Yale model YA-12 rated at 5,000 lb.	1 Yale model YA-12 rated at 5,000 lb. 1 Hyster model rated at 8,600 lb.
Vacuum cart	Generator
1 custom fabricated vacuum cart attached to the VecLoader dust hose to vacuum up loose concrete and miscellaneous loose waste.	1 Onan model 067IT diesel generator with 125 kW output (requirements are 100 amps, 480 volts, three-phase).

Supporting Equipment continued	
Rotary drum planer	**CSB technology**
Spare rotary drum planer	Manlift
A spare 16 in high-flow Melroe planer was kept ready to keep downtime at a minimum during maintenance and breakdowns.	1 Grove model SM 2632E manlift.
Lazy Susan	Crane
A "Lazy Susan" or rotating turntable was used to rotate a pallet, containing four drums, underneath the VecLoader.	1 mobile 15-ton capacity crane.
Potential Operational Concerns	
Rotary drum planer	**CSB technology**
During rotary drum planer operation	During CSB technology operation
Moving equipment creates a potential collision hazard. Vacuum created by VecLoader can cause loose clothing and even appendages to become trapped in dust hose, causing potential injury. Communications are impaired when rotary drum planer and VecLoader are running and are impaired by respirators and hearing protection.	Escaping shot from underneath the machine represents a flying projectile hazard—proper PPE is necessary to prevent eye injuries and welting of the skin. Loose shot laying on un-scabbled concrete (smooth finish) represents an extreme slipping hazard. Communications are impaired when CSB technology and dust collector are running and are impaired by respirators and hearing protection.
Safety, health and environmental	
High noise levels. Heat stress. A catalytic scrubber was required on the exhaust of the Bobcat's diesel engine to prevent release of potentially harmful emissions. Potential release of radioactively contaminated dust to the environment	High noise levels. Heat stress. Potential release of radioactively contaminated dust to the environment.

SECTION 3

PERFORMANCE

Demonstration Plan

Demonstration Site Description

The CSB demonstration was conducted in accordance with the approved FDF *Project Safe Work Plan For The Demonstration of Centrifugal Shot Blasting Technology, Revision 2, August 19, 1998*. The CSB technology was demonstrated inside of Fernald's Plant 8, in the Muffle Furnace Area (process area 4), to remove 1 in of contaminated concrete, over an area of 1,464 ft^2. The removal and off-site disposal of the top 1 in of concrete from the first floor of the Plant 8 Muffle Furnace Area was identified as a requirement in *the OU3 Record of Decision for Final Remedial Action (ROD), (DOE, 1996)*, along with other areas in OU3 (Plant 9) containing the highest levels of technetium-99 in debris. Plant 8, the Scrap Recovery Plant, is a two-story structure measuring 239 ft x 280 ft x 37 ft high and consists of a structural steel frame on a reinforced poured concrete foundation with reinforced concrete ground floors, transite interior and exterior siding panels (insulation material between panels), and transite roof panels.

The rotary drum planer, for the surface removal of concrete, was operated in accordance with the NSC Energy Services *Surface Removal Of Concrete At Thorium/Plant 9 Complex, 1998*. The rotary drum planer was used to remove 1 in of concrete inside of Fernald's Plant 9, in process areas 2 and 4 over an area of 22,600 ft^2. Plant 9 (Special Products Plant), was a single-level, irregularly shaped building, measuring approximately 200 ft x 260 ft x 20 ft high. Plant 9 consisted of a structural steel frame with transite siding and roofing panels and a poured concrete base and floor.

Concrete in each of the locations was similar in cube compressive strength as measured by a Gilson Model HM-75 rebound hammer. The average cube compressive strength measured in Plant 9 was 8,890 psi, while the average cube compressive strength measured in the Muffle Furnace Area of Plant 8 was 8,700 psi with a variation of 1,100 psi for both areas. The aggregate uncovered in Plant 9 was slightly smaller (1/2 in to 1.25 in diameter) versus the aggregate uncovered in Plant 8 (3/4 in to 2 in diameter).

Demonstration Objectives

The primary reason for demonstrating the CSB technology was to assess its ability to remove 1 in of surface concrete, in a safer, more efficient and productive fashion than other methods. The objectives of the demonstration were to determine the CSB technology's ability to:

- reduce the quantity of concrete for off-site disposition (i.e., top 1 in versus the whole slab);
- remove 1 in of concrete more productively than other methods;
- reduce the amount of secondary waste generated during the process;
- remove concrete more cost effectively than other methods and;
- provide a direct comparison to other concrete removal technologies.

Demonstration Boundaries

The specific scope of work for the CSB technology was the removal of the top 1 in of concrete on the first floor of the Muffle Furnace Area (process area 4) of Plant 8, an area having dimensions of 31 ft x 55 ft, or 1,705 ft^2. Due to fixed pillars, steel floor drains, and raised piers supporting the legs of the Muffle Furnace, only 1,611 ft^2 had concrete that could be scabbled. The frame, sheet-metal, and other features on the CSB prevented it from scabbling concrete flush with vertical surfaces. This aspect, know as a standoff distance meant that the CSB removed 1 in of concrete from 1,464 ft^2 of the 1,611 ft^2 in the Muffle Furnace Area. Removal of the remaining concrete will occur during the D&D of Plant 8. Although the CSB technology was only used to remove concrete, the vendor reported that the machine is also capable of cleaning flat, plate steel as well. At this time, the CSB technology is not capable of removing concrete on vertical or non-flat surfaces. Figure 9 depicts the CSB technology in operation in Plant 8.

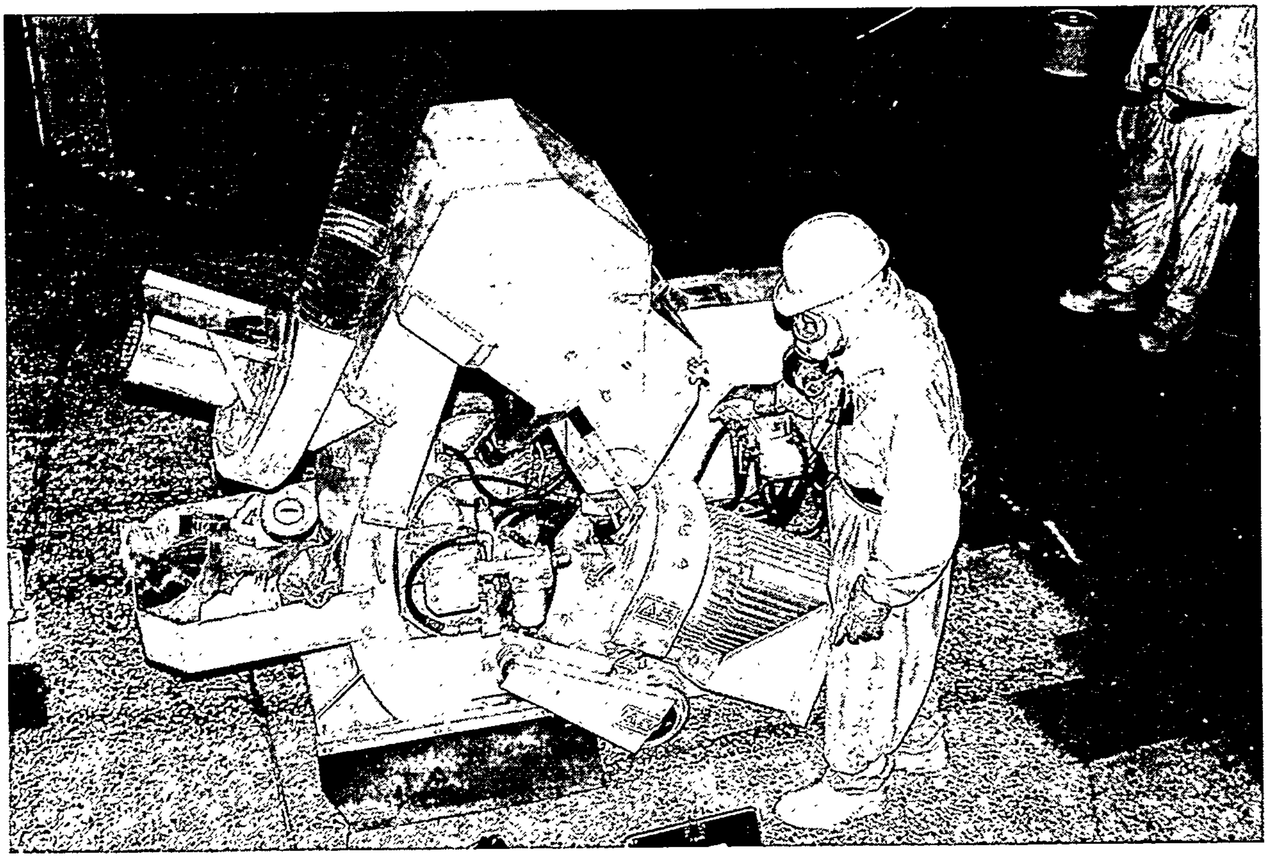

Figure 9. CSB technology operating in Fernald's Plant 8.

The rotary drum planer was utilized to remove 1 in of concrete on the first floor of Plant 9, in process areas 2 and 4 (enriched uranium casting and uranium machining areas, respectively), over an area of 22,600 ft^2. In addition to removing concrete, the rotary drum planer is also capable of removing asphalt, although it was not used for this task at Fernald.

Results

The CSB technology

After the CSB removed the first 1/4 in to 3/8 in of concrete, the aggregate, consisting of large diameter riverine pebbles, started to be exposed. The riverine pebbles proved to be much harder than the surrounding concrete matrix and were much harder to wear away. The matrix surrounding the riverine pebbles was more easily removed via the CSB technology; however, the pebbles tended to remain until the surrounding matrix was completely removed. Significantly greater quantities of riverine pebbles were encountered as the depth approached 1 in. These riverine pebbles were much stronger than the surrounding matrix and their removal was mostly as a result of erosion of the surrounding concrete matrix by steel shot rather than fragmentation of the stone itself.

Due to the rough (large, exposed pebbles) surface left after removing approximately 1/2 in of concrete, the CSB technology had difficulty traversing the exposed subsurface. The CSB technology was equipped with hard rubber tires, similar to the type found on a grocery cart, which would easily become stuck on the exposed pebbles. The operator would have to compensate for the stuck wheel by increasing the speed of the hydraulic drive on the side that was stuck in order to move the machine. This phenomenon would leave the floor uneven and cause the CSB technology to "crab-walk" across the floor, exacerbating the situation. Eventually, the wear and tear caused from traversing the rough, uneven floor, caused the hydraulic pump, which powered the hydrostatic drive, to fail.

For most of the Muffle Furnace Area, the CSB technology had to make on average, ten passes to achieve the 1 in removal requirement. However, in one small area approximately 2 ft by 10 ft where the original floor had been replaced with newer, softer concrete, the CSB technology achieved the 1 in removal requirement in only 3 passes.

The rotary drum planer

The rotary drum planer removed at least 1 in of concrete over 22,600 ft^2 in Plant 9, achieving a production rate of 52.2 ft^2/hr. More capable of removing 1 in of the FEMP's concrete than the CSB system, the rotary drum planer system also suffered fewer breakdowns, cost less per unit area to operate and had a stronger dust collection system than the CSB technology. Figure 10 depicts the rotary drum planer operating in Fernald's Plant 9.

The waste created by the rotary drum planer was a combination of concrete dust and chunks up to 4 in diameter, which resulted in less efficient waste packing than the dust created by the CSB.

The rotary drum planer achieved the 1 in removal requirement in only 1 pass. In fact, the challenge for the operator of the rotary drum planer was to keep the depth above 2 in to attain a higher productivity and to

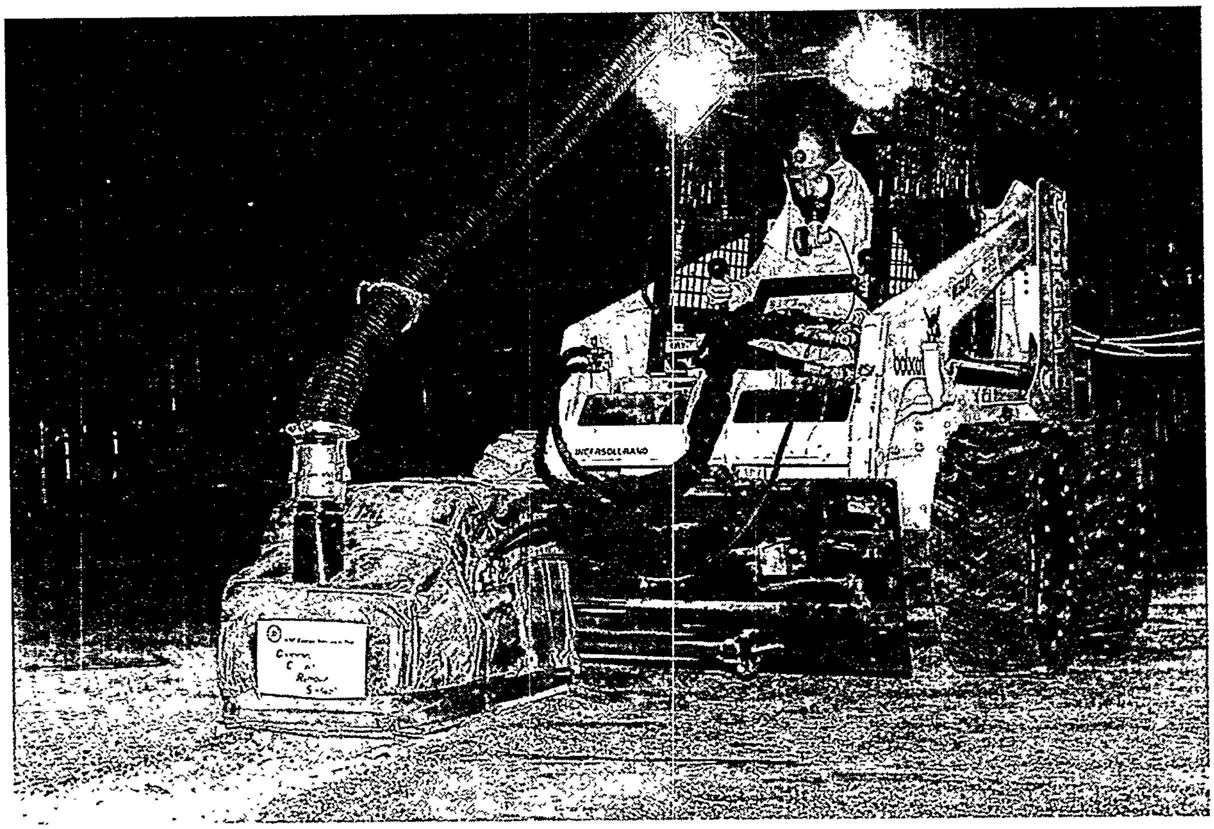

Figure 10. Rotary drum planer operating in Fernald's Plant 9.

reduce the quantity of waste generated. As concrete removal operations progressed in Plant 9, the operators of the rotary drum planer became more adept at maintaining removal depths to between 1.5 in and 2 in.

When encountering reinforcing steel bar, anchor bolts, or wire mesh less than 1 in from the surface, the rotary drum planer would break off its tungsten-carbide teeth, causing a breakdown. The rotary drum planer system also experienced difficulties when it encountered concrete reinforced with a rubber mesh substance. The planer would remove the concrete and rubber mix, but the resulting waste would plug in the dust hose leading to the VecLoader. After a loss of vacuum at the planer was noticed, scabbling operations would cease until D&D laborers using sledgehammers could jolt the clogs loose.

After scabbling for several weeks, the Plant 9 subcontractor purchased and modified a second planer so that during maintenance or breakdowns, the planers could be exchanged, increasing productivity.

The noise generated by the rotary drum planer was greater than that generated by the CSB technology, although the evaluation of worker noise exposure was limited to a representative characterization. Additional exposure monitoring would be required to more accurately reflect worker noise exposure conditions. Table 3 compares key operational and performance factors between the two concrete removal technologies.

Table 3. Comparison of key operational and performance factors for the CSB technology and rotary drum planer system

	CSB Technology	Rotary Drum Planer System
Area of concrete removed to 1 in depth	1,464 ft^2	22,600 ft^2
Number of passes required to achieve 1 in removal requirement	Average of 10	1
Number of 55-gallon drums of concrete waste generated; estimated to be 5.88 ft^3 of waste per drum	35	779
Drums of waste generated per ft^2 of concrete scabbled	0.024	0.034
Type of Secondary waste generated	8 pre-filters, 1 HEPA filter, 75 ft of 6 in diameter dust hose, misc. disposable PPE	28 pre-filters, 1 HEPA filter, 1 set of tire treads for skid-steer, 150 ft of 6 in diameter dust hose, misc. disposable PPE
Man hours required for removal	191 h	1,885 h
Crew hours required for removal	86 h	449 h
Production rate (ft^2/crew h)	17.7 ft^2/h[a]	52.2 ft^2/h[a]
Crew size	3.25[b]	4.2[c]
Noise level	88 dBA[d]	98 dBA[e]
Airborne radioactivity levels detected	The Derived Air Concentration (DAC) values reported were for U-238 because U-238 was the isotope of concern in both areas. All samples showed scabbling activities emitted less than 10% DAC except one which was reported at 16.09 DAC. Greater than 10% DAC is the action level for respiratory protection at the FEMP. As an added safety precaution, workers in both areas were wearing Powered Air Purifying Respirators (PAPRs).	
Standoff distance from vertical surfaces	4 in – 6 in	6 in – 10 in

	CSB Technology	Rotary Drum Planer System
Development status	Commercially available	Components commercially available, but special modifications made by NSC Energy Services to operate in a radiological environment.
Floor condition after scabbling	Between 1/16 in and 3/16 in, the CSB technology leaves the surface slightly rough, but in a condition suitable for re-using. At depths greater than 1/4 in, the surface becomes increasingly rougher.	Floor is left rough with groove marks running parallel to the direction of scabbling.
PPE	Single set of PPE, including a single set of hearing protection.	Single set of PPE with double hearing protection.
Ease of Use	Vendor training or prior experience running CSB technology required.	Vendor training or prior experience running equipment required.
Health and Safety	Flying shot represents a potential safety hazard and loose shot on un-scabbled floor represents an extreme slipping hazard.	High noise level and strong vacuum created by VecLoader represents potential health hazards.

[a] – production rates based on total area of concrete required to be scabbled.
[b] – 0.25, is equal to the amount of time required of a forklift operator to support the demonstration.
[c] - 0.2 is equal to the amount of time required of a forklift operator to support the rotary drum planer.
[d] – Based upon the average of three noise dosimetry measurements ranging in duration from approximately 5.5 h to 8.5 h.
[e] – Based upon one noise dosimetry measurement with a duration of approximately 3.5 h.

SECTION 4

TECHNOLOGY APPLICABILITY AND ALTERNATIVES

Competing Technologies

The rotary drum planer was the baseline technology to which the CSB technology was compared during the demonstration. However, there are many other concrete removal technologies on the market. At the FEMP, the process had to be dustless and not require the use of water. Some of the other technologies listed below are capable of removing concrete, but create dust or use water. Some of the other technologies also create a considerable amount of secondary waste, such as water or chemical waste.

Other concrete removal technologies:

- diamond wire sawing
- scarifiers (Pentek Moose®)
- jack-hammering
- large pneumatic concrete breakers and crushers mounted on heavy equipment to break up and remove entire concrete pad
- grit blasting
- high pressure and ultra-high pressure water blasting
- wet ice blasting

The advantages of the CSB technology over the rotary drum planer:

- greater maneuverability
- more precise in removing thin layers of concrete
- at depths between 1/16 in and 3/16 in, it leaves the floor in re-usable condition
- generates less waste per unit area due to the dust-like nature of the concrete waste
- can blast over floor drains, rebar, wire mesh, etc,

The disadvantages of the CSB technology:

- flying shot creates a potential safety hazard
- loose shot on finished floor surfaces represents a slipping hazard
- not adept at removing more than 3/4 in over a large area
- operating costs are more expensive compared to the rotary drum planer
- production rate slower compared to the rotary drum planer

The advantages of the rotary drum planer over the CSB technology:

- faster production rate
- lower operating costs
- more rugged; operated for longer periods of time without breakdowns

The disadvantages of the rotary drum planer:

- not as precise at removing thin layers of concrete, i.e., $\leq 3/16$ in
- ineffective if rebar, wire mesh or floor anchors are in proximity to surface
- cannot remove concrete close to floor drains, or operate over them
- cannot operate very effectively in small or cluttered spaces

Technology Applicability

Both the CSB and rotary drum planer are commercially available and fully mature. The rotary drum planer system, however, was specially modified to allow for dust and waste collection with the simultaneous drumming of waste. Both systems' dust collectors were fitted with a nuclear grade HEPA filter capable of removing ≥ 99.97% of all particles larger than 0.3 microns. The CSB technology was initially designed to remove the mastic off of aircraft carrier decks. Since then, however, the technology has been used to remove floor coatings, roughen slippery floor surfaces, and prepare floor surfaces for new coatings or substances. Concrete Cleaning Inc., the vendor who operated the CSB technology at the FEMP, reports that the machine is capable of cleaning flat plate steel as well as concrete.

The rotary drum planer technology has been widely used for the removal of concrete and asphalt in highways and parking lots for many years. The VecLoader HEPA Vac has been utilized in the asbestos abatement business and in the industrial sector for the removal of many different types of loose material for a considerable time. Both the rotary drum planer and the VecLoader HEPA Vac are self-powered and easily transported. These features make this system ideal for heavy concrete or asphalt removal in relatively large areas where the utilities have been disconnected. For health and safety purposes, the VecLoader should be isolated to minimize loud noise sources in the work area. If the skid-steer used to run the rotary drum planer is diesel, then a catalytic scrubber is needed on the exhaust system to limit the emission of harmful substances.

Patents/Commercialization/Sponsor

The CSB technology demonstrated at the FEMP was manufactured by Georg Fischer Disa Goff, Inc. of Seminole, Oklahoma. The manufacturer also makes different models of both portable and stationary shot blasting equipment. The dust collector used in the CSB demonstration was manufactured by FARR Company of Los Angeles, California. Concrete Cleaning Inc., of Otis Orchards, Washington was the vendor who performed the concrete removal using the CSB technology. The CSB technology demonstration was sponsored by the DOE's Office of Science and Technology, Large Scale Demonstration and Deployment Project. No regulatory permits were required to demonstrate the CSB technology at the FEMP.

The Bobcat skid steer loader and rotary drum planer used at the FEMP were manufactured by the Melroe Company of Fargo, North Dakota. The VecLoader HEPA VAC was manufactured by Vector Technologies, Ltd., of Milwaukee, Wisconsin. NSC Energy Services was the Fernald Plant 9 D&D subcontractor, who specially modified and coupled the two technologies together to offer a safe and efficient dust free process. No regulatory permits were required to operate the rotary drum planer system at the FEMP.

Technology contacts:

CSB Technology
Georg Fischer Disa Goff, Inc.
P.O. Box 1607
Seminole, Oklahoma 74868
Ph. 405-382-6900
http://www.goff.thomasregister.com

CSB Dust Collector
FARR Company
2201 Park Place
El Segùndo, California 90245
Ph. 310-727-6300
http://www.farrco.com

Technology contacts continued

Bobcat skid steer and Melroe Planer
Melroe Company
P.O. Box 6019
Fargo, North Dakota 58108
Ph. 701-241-8700
http://www.bobcat.com

VecLoader HEPA Vac
Vector Technologies, Ltd.
6220 North 43rd Street
Milwaukee, Wisconsin 53209
Ph. 800-832-4010
http://www.vector-vacuums.com

SECTION 5

COST

Methodology

A cost analysis was performed to evaluate and summarize the CSB technology against the rotary drum planer for removing the top 1 in of concrete floors contaminated with technetium-99. The objective is to assist decision-makers who are selecting from among competing technologies. This analysis strives to develop realistic estimates that represent actual D&D work within the DOE weapons 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 were eliminated or adjusted to make the estimates more realistic. These adjustments were allowed only when they would not distort the fundamental elements of the observed data (i.e. does not change the production rates, quantities, work element, etc.,) and eliminated only those activities which are atypical of normal D&D work. Descriptions contained in later portions of this analysis detail any changes to the observed data.

This cost analysis compares the CSB technology to a rotary drum planer modified by a D&D contractor. The CSB was demonstrated in Fernald's Plant 8, while the rotary drum planer was demonstrated in Fernald's Plant 9. The Technetium-99 contaminated concrete removed during the demonstrations was loaded into 55-gallon drums and will be disposed at the Nevada Test Site. The rotary drum planer was assembled from commercially available components and demonstrated by a D&D contractor. Surface Remediation Specialists demonstrated CSB with support from FDF. The CSB equipment was included as part of a vendor-provided service.

FDF observed both demonstrations. For CSB, a representative of FDF monitored the demonstrations and collected cost and performance data. For the Rotary Drum Planer, the D&D contractor conducting the demonstration collected the cost and performance data, with quality assurance oversight provided by FDF.

Cost Analysis

The following cost elements were identified in advance of the demonstrations, and data were collected to support a cost analysis based on those elements:

- mobilization (including necessary training)
- monitoring, sampling, testing, analysis (including DOP tests)
- D&D work (including surveying for verification of removal depth)
- waste disposal
- demobilization (including equipment decontamination)
- personal protective equipment

Mobilization includes the cost of getting technology equipment to the site, costs for training D&D workers on use of the technology equipment, costs for training vendor personnel, installation of temporary work areas, and installation of temporary utilities. The initial DOP test of filter systems is also included.

Monitoring, testing, sampling and analysis include the cost of performing DOP tests on the filter systems for each HEPA filter change.

D&D work includes removal of 1 in of contaminated concrete from the floors of Plants 8 and 9. Survey work to verify the depth of concrete removal is also included.

Waste disposal includes the cost of shipping all primary and secondary waste streams to the Nevada Test Site. Cost data for disposal at NTS were provided by FDF and are derived from historical data. Cost for disposal of the remaining concrete in the OSDF was not included because the cost would be almost the same for both technologies on a ft^2 basis; the following scenario illustrates this point. Assuming the rotary drum planer removed 3 in instead of the required 1 in (most areas between 1.5 in and 2 in depth), the thickness of the pad would be 21 in whereas the thickness of the pad remaining in Plant 8 would be 23 in because the CSB technology was more exact in removing only 1 in. The cost to dispose of an in place yd^3 of material in the OSDF is $7.50 or $.28 per ft^3. Therefore, the cost difference for disposing the remaining concrete slab in the OSDF is 2 in per ft^2 or .17 ft^3, which equates to the disposal cost being only $.05 more per ft^2 for the CSB technology.

Demobilization includes removal of temporary work areas and utilities, decontamination of technology equipment, disposal of wastes generated by removal of temporary work areas and utilities and technology equipment decontamination and removal of technology equipment from the site. The final DOP test is also included.

PPE costs include all clothing, respirator equipment, etc., required for protection of crewmembers during the demonstration. It was assumed that four changes of reusable PPE clothing items per day were required for each crewmember. Reusable PPE items were assumed to have a life expectancy of 200 h. The cost of laundering reusable PPE clothing items is included in the analysis. It was assumed that four changes of disposable PPE clothing items per day were required for each crew member. Disposable PPE items were assumed to have a life expectancy of 10 h (the shift length).

Comparative unit costs were determined per ft^2 of floor remediated.

Based on observation, the following modifications were made to cost and performance data to reflect a more realistic deployment of the technologies. Because of the huge difference in the areas remediated by the two technologies, the variable costs (dependent on areas remediated) for CSB were prorated to the same quantity as the rotary drum planer (22,600 ft^2). The rotary drum planer initially showed a production rate of 15.8 ft^2/h, which was less than CSB. This low production was due to the shutdown time required for planer maintenance. The D&D contractor countered this low production by adding a second planer to the crew. Thus, when the planer in use required maintenance, it could be quickly changed out. This additional planer boosted production to 52.2 ft^2/h. Because this is a modification that any prudent D&D contractor would make, the cost analysis for the rotary drum planer was based on use of two planers. The make-up and size of crews for both technologies are for a typical deployment of the technologies.

Cost Conclusions

A comparison of the major cost elements for removing one inch of contaminated concrete is shown in Table 4.

Table 4. Summary Cost Comparison

CENTRIFUGAL SHOT BLASTING (Innovative)			ROTARY DRUM PLANER (Baseline)		
Cost Driver	**Unit Cost**	**Production Rate**	**Cost Driver**	**Unit Cost**	**Production Rate**
Mobilization[1]	$9,500	N/A	Mobilization[1]	$3,386	N/A
Testing[2]	$586	N/A	Testing[2]	$195	N/A
D&D Work	$30.21/$ft^2$	17.7 ft^2/h	D&D Work	$4.30/$ft^2$	52.2 ft^2/h
Waste Disposal	$2.23/$ft^2$	N/A	Waste Disposal	$3.35/$ft^2$	N/A
Demobilization[1]	$6,195	N/A	Demobilization[1]	$5,895	N/A
PPE	$1.82/$ft^2$	N/A	PPE	$1.79/$ft^2$	N/A

[1] Total costs that are independent of the quantity of D&D work.

[2] Includes tests at each change of HEPA filters. Initial and final DOP tests are included in Mobilization and Demobilization.

Waste disposal costs were slightly higher for the rotary drum planer because it typically removed concrete to a greater depth than did CSB, thus generating a greater volume of waste. The rotary drum planer had less control over the depth of concrete removed than the CSB technology.

Demobilization costs were significantly higher for CSB due to the cost of equipment decontamination.

PPE costs were less for the rotary drum planer because it had a higher production rate. This shortens the duration required to remediate a given area and thus requires less PPE. Both technologies required essentially the same PPE system. The rotary drum planer required double hearing protection; however, the impact on unit cost was insignificant.

The comparative unit costs for the two technologies for the demonstrated application are:

$9.44/ft^2 - Rotary Drum Planer

$34.25/ft^2 - Centrifugal Shot Blasting

Therefore, for removal of the top 1 in of contaminated concrete floor slabs, CSB is more costly than the rotary drum planer. CSB was more costly for mobilization, D&D work, demobilization and personal protective equipment.

Because CSB showed no cost advantage over the rotary drum planer, no break-even or payback analyses were performed.

SECTION 6

REGULATORY AND POLICY ISSUES

Regulatory Considerations

The operation of the CSB technology and the rotary drum planer at the FEMP were governed by the following health and safety 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

- **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 Subchaptor 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 Subchapter 1** — Packaging and Transportation of Radioactive Material

Fernald site specific requirements

- **RM – 0021** Fluor Daniel Fernald Safety Performance Requirements Manual.
- **DOE order 440.1A** Worker Protection Management for DOE Federal and Contractor Employees.

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

- **40 CFR Subchapter 1** Solid Waste

Before either the CSB technology or the rotary drum planer could be operated at the FEMP, a number of site-specific requirements had to be fulfilled. Those requirements were as follows:

- An approved Safe Work Plan
- Complete a *Project Evaluation For Air Permit/Notification Requirements – Checklist*
- An approved Waste Management Plan
- Complete a Clean Air Act Assessment of potential radionuclide emissions during operations
- Complete a Nevada Test Site (NTS) Waste Acceptance Criteria Form
- Complete an Environmental As Low As Reasonably Achievable (ALARA) Review/Evaluation – Report And Check List
- Apply and receive an Approved Site Safety Assessment

Safety, Risks, Benefits, and Community Reaction

Since both the CSB and rotary drum planer technologies were designed for the decontamination of concrete floor surfaces, there is no regulatory requirement to apply CERCLA's nine evaluation criteria. Nonetheless, some evaluation criteria are discussed below. Other criteria such as cost and performance were discussed in Sections 3 and 5.

Worker Safety (CSB technology)

With respect to the CSB technology, flying shot escaping from underneath the machine and loose shot laying on smooth surfaces represent hazards to workers. Better seals need to be developed to prevent the shot from escaping underneath the machine when it is in operation. Instead of using the rubber seals, which quickly come out of adjustment and let shot escape, a better approach might be to use a "chain skirt" around the bottom of the machine. These "chain skirts" have been used for many years by agricultural machine manufacturers to prevent objects from flying out underneath chopper-type mowers. A "chain skirt" for the CSB technology, however, would consist of much smaller diameter chain than that used on a large chopper type mower, and would be several rows deep to contain the shot. Another advantage of the "chain skirts" is that they continue to provide coverage when the machine is traversing over uneven surfaces.

At the FEMP, a herculite shield was erected on stanchions around the work area to keep the loose shot off pathways and other areas outside of process area 4. Additionally, one laborer continuously pushed the shot collection-magnet over any areas with smooth surfaces. Loose shot on rough surfaces, such as those previously blasted did not represent a slipping hazard.

Worker Safety (rotary drum planer)

The powerful vacuum created at the end of the dust hose by the VecLoader represents a potential safety hazard to workers. Should the dust hose make a complete seal around an appendage, allowing the vacuum to reach maximum potential, then the possibility of serious injury increases. This can be prevented by a couple of simple measures such as using an angled dust hose tip and/or having a tender in radio contact at the VecLoader at all times. Another potential risk to workers is the buildup of carbon monoxide or other harmful emissions from the skid-steer running the planer. In Plant 9, NSC Energy Services lessened these risks by installing a catalytic scrubber on the exhaust of the skid-steer and set up carbon dioxide and carbon monoxide monitors inside of the work area. There were no reported problems with emissions during scabbling operations in Plant 9. Noise levels generated by both the rotary drum planer and VecLoader are potentially injurious and appropriate hearing protection measures must be utilized.

Community Safety, Community Reaction and Socioeconomic Impacts

The use of either the CSB or rotary drum planer technologies would have no measurable impact on community safety or socioeconomic issues. Community reaction to the two technologies would likely be positive since they are useful tools in helping to remediate the site. Additionally, by removing and sending only the top 1 in of concrete off-site for disposal, the DOE and taxpayer can expect significant cost savings.

Environmental Impact

The only potential negative environmental impact that could occur with either technology would be a release of contaminated dust to the environment by the dust collectors. However, this event would be highly unlikely, because the dust collector for the CSB technology was located inside of Plant 8 and the VecLoader HEPA Vac was located inside of a containment structure. A potential release of dust was made even more unlikely by electrical lockouts on the dust collectors, which prevented the scabbling technologies from operating in the event of a dust collector failure.

SECTION 7

LESSONS LEARNED

Implementation Considerations

The CSB technology, FARR dust collector, rotary drum planer, Bobcat skid steer and VecLoader HEPA Vac are commercially available systems. The rotary drum planer system was specially modified by NSC Energy Services to operate in a nuclear environment, providing dustless operation with simultaneous collection and bagging of waste. Each technology was operated by experienced personnel, with many years experience in their respective fields. Due to the complicated nature of each technology and the process knowledge needed to remove concrete safely and efficiently in a radiological environment, it is not recommended that either concrete removal process be attempted by inexperienced vendors.

Another factor to consider when undertaking a concrete removal process is not only determining the strength of the concrete to be removed but also its composition. The natural riverine pebbles turned out to be much harder than the surrounding concrete matrix leading to slower than expected production rates. The large riverine pebbles were also detrimental to the shot recycling mechanism, steering, and the hydrostatic drive of the CSB technology. Had the composition of the concrete been identified prior to the demonstration, adaptations such as using a larger sized shot and pneumatic tires could have been taken to compensate.

Technology Limitations and Needs for Future Development

The CSB technology and dust collector demonstrated at the FEMP could benefit from the following design improvements.

- An improved seal, such as a "chain skirt," around the bottom of the machine to prevent flying shot from escaping.
- A more powerful dust collector capable of generating greater airflow and vacuum. The dust collector used during the demonstration did not generate the required vacuum or airflow (12 in water, and 2,000 cfm are recommended by the CSB manufacturer).
- A better waste-to-drum transfer system on the dust collector; when full drums where removed from underneath the dust collector, residual dust would fall out of the dust collector, even after the flow gates had been tightly shut.
- An improved shot recycle mechanism, whereby more shot is captured by the machine instead of being left on the floor.

NSC Energy Service made design changes to the rotary drum planer system during the course of scabbling 22,600 ft^2 of concrete that made remarkable improvements in productivity. Those improvements included:

- Making available a second planer to utilize during breakdowns and regularly scheduled maintenance.
- Using flat, rubber treads instead of tires to eliminate harmonic distortions created during scabbling.
- Using a high-flow hydraulic model skid-steer to properly operate the planer attachment.

Technology Selection Considerations

For concrete removal at depths equal to or greater than 3/16 in, in relatively large open areas, the rotary drum planer is the recommended technology. For concrete removal at depths between 1/8 in and 3/16 in and in confined areas, even at 1 in depth, the CSB technology is recommended because it has greater maneuverability and generates less waste per unit area.

APPENDIX A

REFERENCES

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APPENDIX B

LIST OF ACRONYMS AND ABBREVIATIONS

Acronym/Abbreviation	**Description**
ALARA	As Low As Reasonably Achievable
CERCLA	Comprehensive Environmental Response, Compensation & Liability Act
cfm	cubic feet per minute
CFR	Code of Federal Regulations
CSB	Centrifugal Shot Blasting
D&D	Decontamination & Decommissioning
DOE	U.S. Department of Energy
DOP	Dioctyl Phthalate
DOT	U.S. Department of Transportation
EPA	Environmental Protection Agency
FDF	Fluor Daniel Fernald
FEMP	Fernald Environment Management Project
ft	foot/feet
ft^2	square feet
HEPA	High Efficiency Particulate Air filter
hp	horsepower
h	hour
in	inch
LSDDP	Large Scale Demonstration and Deployment Project
M&I	Management and Integration
NTS	Nevada Test Site
OSDF	On Site Disposal Facility
OSHA	Occupational Safety and Health Administration
OST	U.S. DOE's Office of Science and Technology
OU3	Operable Unit 3
PAPR	Powered Air Purifying Respirator
PPE	Personal Protective Equipment
psi	pounds per square inch
SAE	Society of Automotive Engineers
ROD	Record of Decision
USACE	United States Army Corps of Engineers

APPENDIX C

SUMMARY OF COST ELEMENTS

This sheet summarizes the fixed costs. It represents the start-up costs necessary to deploy a technology.

Title ID	Description	Quantity	Unit	Output	Manhrs	Labor	Equipmnt	Materials	Other	Total
33A	**Planing (Baseline)**	**22600**	**SF**							
33A.01	Mobilization	1	EA		8	$1,046	$0	$0	$2,340	$3,386
33A.02	Monitoring, Sampling, Testing	1	EA		8	$195	$0	$0	$0	$195
33A.21	Demobilization	1	EA		8	$195	$0	$0	$5,700	$5,895
33A	**Total Planing**	**22600**	**SF**		**24**	**$1,436**	**$0**	**$0**	**$8,040**	**$9,476**
33B	**Shot Blasting (Innovative)**	**22600**	**SF**							
33B.01	Mobilization	1	EA		0	$0	$0	$0	$9,500	$9,500
33B.02	Monitoring, Sampling, Testing	1	EA		24	$586	$0	$0	$0	$586
33B.21	Demobilization	1	EA		8	$195	$0	$0	$6,000	$6,195
33B	**Total Shot Blasting**	**22600**	**SF**		**32**	**$781**	**$0**	**$0**	**$15,500**	**$16,281**

This sheet summarizes the scaleable costs (costs dependent on quantity)

Title ID	Description	Quantity	Unit	Output	Manhrs	Labor	Equipmnt	Materials	Other	Total	Unit Cost
33A	**Planing (Baseline)**	**22600**	**SF**								
33A.17	Planing 1-in From Conc. Floor	22600	SF		1885	$46,061	$20,279	$30,736	$0	$97,076	$4.30
33A.18	Disposal	22600	SF		0	$0	$0	$0	$75,711	$75,711	$3.35
33A.90	PPE	22600	SF		0	$0	$0	$0	$40,528	$40,528	$1.79
33A	**Total Planing**	**22600**	**SF**		**1885**	**$46,061**	**$20,279**	**$30,736**	**$116,239**	**$213,315**	**$9.44**
33B	**Shot Blasting (Innovative)**	**22600**	**SF**								
33B.17	Blasting 1-in From Conc. Floor	22600	SF		2963	$72,221	$1,815	$53,336	$555,282	$682,654	$30.21
33B.18	Disposal	22600	SF		0	$0	$0	$0	$50,386	$50,386	$2.23
33B.90	PPE	22600	SF		0	$0	$0	$0	$41,041	$41,041	$1.82
33B	**Total Shot Blasting**	**22600**	**SF**		**2963**	**$72,221**	**$1,815**	**$53,336**	**$646,709**	**$774,081**	**$34.25**

This sheet summarizes the total costs incurred for the CSB demonstration and the rotary drum planer

Title ID	Description	Quantity	Unit	Output	Manhrs	Labor	Equipmnt	Materials	Other	Total	Unit Cost
33A	**Planing (Baseline)**	**22600**	**SF**								
33A.01	Mobilization	1	EA		8	$1,046	$0	$0	$2,340	$3,386	$3,386.00
33A.02	Monitoring, Sampling, Testing	1	EA		8	$195	$0	$0	$0	$195	$195.00
33A.17	Planing 1-in From Conc. Floor	22600	SF		1885	$46,061	$20,279	$30,736	$0	$97,076	$4.30
33A.18	Disposal	22600	SF		0	$0	$0	$0	$75,711	$75,711	$3.35
33A.21	Demobilization	1	EA		8	$195	$0	$0	$5,700	$5,895	$5,895.00
33A.90	PPE	22600	SF		0	$0	$0	$0	$40,528	$40,528	$1.79
33A	**Total Planing**	**22600**	**SF**		**1909**	**$47,497**	**$20,279**	**$30,736**	**$124,279**	**$222,791**	**$9.86**
33B	**Shot Blasting (Innovative)**	**22600**	**SF**								
33B.01	Mobilization	1	EA		0	$0	$0	$0	$9,500	$9,500	$9,500.00
33B.02	Monitoring, Sampling, Testing	1	EA		24	$586	$0	$0	$0	$586	$586.00
33B.17	Blasting 1-in From Conc. Floor	22600	SF		2963	$72,221	$1,815	$53,336	$555,282	$682,654	$30.21
33B.18	Disposal	22600	SF		0	$0	$0	$0	$50,386	$50,386	$2.23
33B.21	Demobilization	1	EA		8	$195	$0	$0	$6,000	$6,195	$6,195.00
33B.90	PPE	22600	SF		0	$0	$0	$0	$41,041	$41,041	$1.82
33B	**Total Shot Blasting**	**22600**	**SF**		**2995**	**$73,002**	**$1,815**	**$53,336**	**$662,209**	**$790,362**	**$34.97**