INNOVATIVE TECHNOLOGY
Summary Report

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Soft Media Blast Cleaning

Deactivation and Decommissioning
Focus Area

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INNOVATIVE TECHNOLOGY

Summary Report

Soft Media Blast Cleaning

OST Reference #1899

Deactivation and Decommissioning
Focus Area

Demonstrated at
Fernald Environmental Management Project
Building 1A and 30B
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

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 the DOE's projects and to others in the D&D community. The benefits sought include decreased health and safety risks to personnel and the environment, increased productivity, and decreased cost of operation.

This report describes the Soft Media Blast Technology (SMBT), which was demonstrated as part of the DOE's Fernald Environmental Management Project (FEMP) Plant 1 LSDP. The demonstration was performed with specific reference to waste disposal criteria in effect at FEMP. The criteria are derived from their Decontamination and Decommissioning Implementation Plan, which requires that debris and segmented process equipment suitable for disposal in the FEMP's on-site disposal facility (OSDF). Debris are considered appropriate for placement in the OSDF if, on visual inspection, they satisfy the following criteria:

> *"…surfaces shall be free of visible process material as determined by a FERMCO representative. The definition of visible process material is: Visible process residues (green salt, yellow cake, etc.) on the interior or exterior surfaces of materials that are obvious to the eye, and when rubbed, would be easily removed. Stains, rust, corrosion, and flaking do not qualify as visible process material."*

The present baseline technology for cleaning materials prior to disposal is a high-pressure water cleaning system that removes visible contaminants from surfaces such as walls, floors, equipment, and structural beams. The primary limitation of the baseline technology is that it generates such large quantities of wastewater that it can only be used for general decontamination of non-process-enriched materials. Consequently, all process-enriched uranium materials (materials with greater than 1.0 wt % U-235) are currently disposed of off-site at the Nevada Test Site (NTS).

The innovative technology described in this report is the SMBT manufactured by AEA Technologies, Inc., which meets the waste disposal criteria by performing material decontamination, as opposed to the general washing performed by the current baseline technology. The technology not only removes surficial or visual contamination, but decontaminates materials sufficiently so that they may be disposed of at the OSDF instead of at the more costly NTS.

The SMBT was evaluated against two baseline technology scenarios: washing of non-process-enriched materials with a high-pressure water stream followed by disposal in the OSDF and direct disposal of process-enriched uranium materials at the NTS.

Technology Summary

Baseline Technology

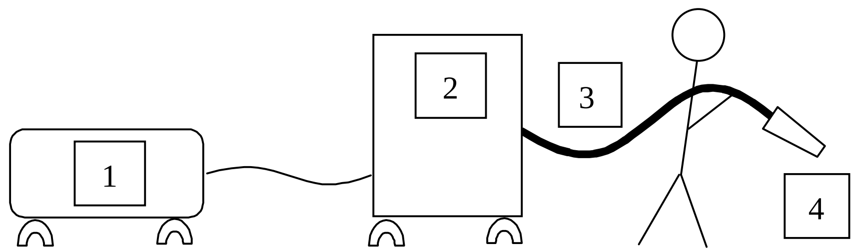
The baseline technology for the Plant 1 LSDP was a Hotsy Model 550B high-pressure water cleaning system, which delivers a heated stream of water and detergent at a flow rate of 2.2 gal/min and a pressure of 1000 psi. This system measures 38 in. high by 44 in. long by 26 in. wide and weighs 270 lb excluding fuel.

This technology uses the kinetic energy of the pressurized water stream to remove surface contaminants from the material being cleaned. This physical removal mechanism can be enhanced through the addition of a detergent and/or by heating the water. After the water stream impacts the surface being cleaned, the water containing the contaminants falls to the floor, where it is confined by a dike or berm and collected in

a sump for transfer from the cleaning area. The material being cleaned is typically placed on a pallet so that it does not sit in the contaminated water that collects within the cleaning area.
The water was not heated and no detergent was added for this demonstration; therefore, the primary system components used during the cleaning process were the "cleaning gun" (nozzle, wand, spray trigger, and high-pressure hose) and the electrically driven pump used to achieve a pressure of 1000 psi.

Innovative Technology

The SMBT propels a soft blast media against the surface to be decontaminated, using mechanical abrasion and contaminant absorption to clean the surface. Compressed air is used to propel soft blast media, which is ejected through a hose and nozzle arrangement. A process flow diagram for the system is shown in Figure 1.



1. Compressed Air Source: clean dry air; 250 ft^3/min (constant at blast hopper), minimum 1-in. for air supply line; 120 psi line pressure at blast hopper.
2. Feed Unit: air supply and media flow can be regulated at the hopper for desired results.
3. Blast Hose: 1 1/2-in. recommended to be no longer than 25 ft from blast hopper to work area.
4. Dead Man manual blast nozzle: 3/8-in. nozzle and 1/8-in. nozzle available.

Figure 1. Process flow diagram for the soft media blast cleaning technology.

The soft blast media is propelled against the surface being cleaned by a portable pneumatically powered Feed Unit, shown in Figure 2. The soft blast media can be recycled by manually collecting it from the work area and feeding it through a separate Classifier Unit, which mechanically removes large debris and powder residues from the cleaning media after use. The unit vibrates, causing the media to fall downward through a series of separation screens that separate the debris from the reusable media. The media must be manually collected and loaded into the Classifier Unit for separation, then the recycled media must be manually returned to the Feed Unit for reuse.

Figure 2. Portable pneumatically powered feed unit.

This technology is unique in that the soft sponge-like media, unlike normal abrasive media, can absorb contamination, reducing the quantities of airborne contaminants and waste generated. The media breaks down after being reused several times and is then separated from the recyclable media by the Classifier Unit.

Some advantages of the SMBT over the baseline technology are:

- The soft blasting media permits the cleaning of materials contaminated with enriched uranium, thereby providing a substantial cost savings by reducing the quantity of material disposed of at the NTS.

- The soft blast media can be recycled, reducing the overall cost of using this technology.

- The baseline technology waste stream is a liquid, while the SMBT waste stream is of a solid matrix and therefore easier to contain, which substantially reduces operational and cleanup costs. Liquid waste streams are typically more difficult to contain, generate more volume per unit of containment, and are therefore more expensive to dispose of.

- The aggressiveness of this cleaning technology can be controlled through the selection of the blast media. Furthermore, the cleaning intensity achieved with the selected blast media can be controlled by varying the blast air pressure.

The SMBT is fully developed and commercialized and has been used in a variety of applications such as paint removal and cleaning electrical motors, transformers, and hydraulic and fuel oil lines. It has also been applied within the commercial nuclear sector in the United States and is being supplied through a U.S. affiliate of a British company. An example of the use of the SMBT in the commercial nuclear sector is the decontamination of the internal surface of the reactor coolant system piping at the steam generator interface during steam generator replacement projects.

Demonstration Summary

The SMBT was demonstrated and evaluated in Building 1A at the FEMP between August 19 and September 5, 1996. This time span includes the mobilization and demobilization phases of the demonstration. The SMBT is designed and offered as a surface decontamination system, while the baseline technology provides only a surficial cleaning or washing to comply with visual inspection criteria.

The primary difference between these two types of work is that surface decontamination requires more intense effort to achieve the desired result. The main objective of the baseline technology is to provide a general surface washing, with the success criterion being a visual inspection to verify that there is no visible residue on the equipment. The main objective of the demonstrated technology is to remove contaminants from materials, with the success criterion being sufficiently low contaminant levels of enriched uranium to allow disposal in Fernald's OSDF.

The SMBT was evaluated and compared to the following two baseline scenarios:

1. Washing of non-process-enriched materials with a high-pressure water stream followed by disposal in the OSDF.

2. Direct disposal of process-enriched uranium materials at the NTS.

The performance objectives for the demonstration were:

- Decreased volume of liquid waste
- Increased production rate in ft^2/h
- Improved cleaning effectiveness
- Decreased use of personal protective equipment (PPE)
- Decreased man-hours
- Decreased airborne contamination

Key Results

Some of the key results for this demonstration were:

- The SMBT clearly reduced the volume of liquid waste since the media is of a solid matrix.

- The production rate measured for the SMBT was 92 ft^2/h, while that for the baseline technology was 363 ft^2/h. The production rate for the SMBT was slower than that for the baseline technology; however, the baseline technology only cleaned materials while the SMBT also decontaminated them.

- The SMBT clearly improved cleaning effectiveness by successfully decontaminating materials for disposal in the OSDF.

- The SMBT also required less PPE for operation, except for double hearing protection due to the increased noise, which also decreased stay times in the work zone.

Some of the key cost results for this demonstration were:

- The comparative unit costs for the two technologies were \$1.53 per ft^2 of debris cleaned for the Hotsy system and \$4.60/ft^2 for the SMBT.

- The SMBT had 75% less cost for disposal of the tank contaminated with process-enriched uranium because the SMBT was able to decontaminate the tank sufficiently to permit disposal in Fernald's On-Site Disposal Cell, which is relatively inexpensive. Conversely, this tank would not be sufficiently decontaminated by the Hotsy baseline system, which would require its more costly disposal at the Nevada Test Site.

- Mobilization and demobilization was more costly for the SMBT than for the Hotsy Model 550B.
- The break-even point for the SMBT when compared with direct disposal at the NTS (the point at which the savings from its use offsets the higher fixed costs of deploying it) was approximately 900 ft^2 of area to be cleaned.
- The SMBT was more costly when compared with the Hotsy Model 550B in meeting visual acceptance criteria.

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SECTION 2

TECHNOLOGY DESCRIPTION

Overall Process Definition

The technology used in this demonstration was the AEA Technologies' SMBT. A simplified process flow diagram is presented in Figure 1. The system relies on a pneumatically driven pump to propel soft blast media at a surface requiring decontamination. The portable pneumatic pump sends the media-laden air stream through a hose and nozzle system. There are also two additional stand-alone units that can be used in conjunction with the pump, hose, and nozzle that were not used for this demonstration: the Classifier Unit, which is used to separate the larger intact media from the finer pieces of disintegrated media, and the Blast Media Wash Unit, which washes the media so that it can be recycled.

The overall purpose in using the SMBT is to remove surficial contaminants through the abrasive action of the soft blast media striking the contaminated surface. The media not only loosens and removes the contaminants, but captures the contaminants in the media matrix and breaks apart after repeated use. The final result is a decontaminated surface and a waste composed of contaminants and soft blast media. The soft media can be recycled until it has broken apart sufficiently to be separated by the Classifier Unit.

System Operation

The SMBT is an example of a technology developed outside the nuclear D&D arena that has addressed nuclear D&D needs. This technology originated as a process for surface preparation and cleaning; such as the removal of grease, old paint, and rust from surfaces prior to their being painted/coated or undergoing some other process.

The SMBT can consist of one, two, or three process components. The primary and only required process component is the Feed Unit with integrated control panel (see Figure 2). This component is portable and is produced in several sizes to accommodate the needs of a variety of end users. Optional components include the Classifier and Blast Media Wash Units. Not provided as part of the SMBT is an air compressor, which is needed to provide the motive force for the blast media.

The blast media used with this technology is provided in six grades that are designated by their color. The six grades of blast media are:

- Green: non-aggressive cleaning media (no abrasive)
- White: low-abrasion cleaning media (impregnated with plastic chips)
- Brown: low-aggressive cleaning media (impregnated with Starblast®)
- Yellow: medium-aggressive cleaning media (impregnated with garnet)
- Silver: very-aggressive cleaning media (impregnated with aluminum oxide)
- Red: high-aggressive cleaning media (impregnated with steel grit)

Both the green and brown blast media were used in this demonstration. The media, because of its high transport velocity, impacts the surface with high energy, but due to its soft structure, it has very little bounce back. Also, because of its structure, it absorbs and traps the contaminants on impact and carries them away from the substrate for easy disposal. The SMBT has an operational line pressure of 20 to 85 psi.

The soft media blasting process begins by loading the selected blast media into the Feed Unit's hopper. A fully loaded feed hopper can hold approximately one 50-lb bag of media. The media from the pressure vessel is first fed into a metering chamber using a variable speed auger and is then fed into the transport air stream. During the demonstration, the blast pressure was set at 45 psi. At this setting, the feed hopper is emptied in approximately 30 min.

Also available with the SMBT is a Classifier Unit. This component facilitates the recycling of the blast media. The spent media is manually collected from the work area and placed into the electrically powered

Classifier Unit. This unit vibrates causing the used cleaning media to pass through a series of progressively finer screens, while the intact or recyclable media is captured and sent back through the system.

Another component that can be provided is a Blast Media Wash Unit. This is a portable, closed-cycle device which centrifugally launders the sponge media. The contaminated media wash water is collected, filtered, and reused with the Blast Media Wash Unit. This unit is used to remove grease, oils, and other materials that may adhere to the blast media. The usefulness of this component may be limited in that before the blast media could be reused, it must be completely dry. Moist blast media can clog the pressure vessel even with its internal actuator in operation. In fact, if the sponge media is exposed to the atmosphere, it can absorb enough humidity to cause clogging problems. The operation of a Blast Media Wash Unit would be subject to any and all of a site's critical control requirements when being used to clean D&D debris contaminated with process-enriched uranium residue.

The air blast media mixture is transported from the Feed Unit via a 1 1/4-in. inside diameter (id) hose fitted with a venturi-style tungsten carbide blast nozzle. This hose, which can be up to 25 ft long, comes fitted with a "dead-man auto-shutoff switch." During this demonstration both a 3/8-in. and 1/2-in. id nozzle were used. The 3/8-in. nozzle was ideal for cleaning crevices and other similar difficult-to-access areas. The 1/2-in. nozzle was best for general surface decontamination.

An air compressor was not provided with the SMBT, but it does require a source of compressed air that can provide, at a minimum, the following:

- clean, dry air
- 250 ft^3/min of air
- 120 psi line pressure at the Feed Unit

An air compressor was rented by the D&D contractor for this demonstration.

SECTION 3

PERFORMANCE

Demonstration Plan

The SMBT was demonstrated and evaluated at the FEMP between August 19, and September 5, 1996. This time span included mobilization, demobilization, and a 1-week demonstration period of four 10-h days. The demonstration included the cleaning of the segmented remains of Settling Tank F2-56, which was contaminated with process residue enriched to 1.34 wt.% U-235. The SMBT was set up in the northeast quadrant of the first floor of Building 1A, and the blasting was performed in an enclosure (measuring approximately 20 ft × 20 ft × 10 ft) fabricated of plastic sheets hung from existing structures within Building 1A.

As previously stated, the demonstration was designed to compare performance of the SMBT against two baseline scenarios: washing of non-process-enriched materials with a high-pressure water stream followed by disposal in the OSDF and direct disposal of process-enriched uranium materials at the NTS.

The Demonstration Plan was tailored to evaluate an improved technology and corresponding performance objectives were established. Those objectives were:

- Increased production rates
- Decreased generation of liquid wastes
- Improved cleaning effectiveness
- Decreased PPE use
- Decrease required man-hours
- Decreased off-site shipments of radioactively contaminated materials to NTS
- Decreased airborne contamination

During the demonstration, the Feed Unit and accompanying hose and nozzle assembly were evaluated. A decision was made not to use the Classifier Unit due to uncertainties regarding its successful decontamination. As a result, the soft media blast material was not recycled. At the end of each day the used blast media was swept up, shoveled into plastic bags, and removed from the demonstration area.

The SMBT was factory set with a blast pressure of 60 psi and a media flow of 20 lb. However, after evaluating several setting variations, the demonstration workers preferred a blast pressure of 45 psi and media flow of 20 to 25 lb. A full feed hopper lasted approximately 30 min at these settings.

Operation of the SMBT requires an air compressor; the air compressor provided for this demonstration exceeded the parameters specified in Section 2:

- clean, dry air
- 375 ft^3/min of air
- 150 psi line pressure at the feed unit

During the demonstration, the SMBT was operated by laborers provided by the D&D contractor. The laborers claimed that the system was easy to learn and posed no operating problems. The data package shows that the operation of the SMBT required three laborers. One laborer remained with the Feed Unit, the second laborer functioned as a material handler, and the third laborer operated the blasting wand. The demonstration also required the part-time assistance of a forklift operator who was not considered part of the cleaning crew. The forklift operator was used only to stage debris cleaned or decontaminated during the demonstration.

Treatment Performance

The SMBT's performance can be evaluated by comparing its results to the performance objectives set for the demonstration. Those objectives were listed in the previous section and are now addressed in greater detail.

Increased Production Rates

Due to the complexities of the demonstration, it was difficult to ascertain if an increase in production rate was attained. One of the primary factors was the difficulty of comparing high-pressure water washing with the SMBT. The key distinction between the two systems was that water washing resulted in *visually cleaned* surfaces whereas the SMBT *cleaned or decontaminated* 100% of the debris surface, which required a greater level of effort/time. The measured production rates for the Hotsy system and the SMBT were 363 and 92 ft^2/h, respectively.

Another factor that adversely effected the SMBT's productivity and economic competitiveness was the limited worker exposure times permitted in and around the cleaning enclosure. The SMBT generated so much noise that workers were limited to 1 h/d in the operational zone and were required to wear double hearing protection. Operating the baseline technology did not impose limited worker stay times in the work zone. The sound-based worker stay time at the FEMP is more limiting than that used in the commercial sector and more than likely eliminates any possible application of this technology at the Fernald Site without significant review and evaluation by Industrial Hygiene.

Decreased Volume of Liquid Waste

Total compliance with this objective was achieved by using the SMBT. No liquids were required to operate or decontaminate the SMBT. The Hotsy system is designed to deliver a stream of water at a flow rate of 2.2 gal/min at a pressure of 1000 psi.

Improved Cleaning Effectiveness

The cleaning effectiveness of the SMBT was found to be superior to that of the baseline system. Radiation surveys were conducted on some of the D&D debris before and after being cleaned with the system. This surveying effort was keyed to the tank segments designated as contaminated with process-enriched uranium residues. In the majority of cases, the post-cleaning survey results indicated radiation levels below the minimum detectable count rate (MDCR) of the radiation detection instrument being used. For example, a pre-cleaning survey indicated 18,000 $dpm/100cm^2$, and a subsequent post-cleaning survey indicated results below the MDCR. In only one instance did the system fail to significantly reduce the pre-cleaning fixed contamination level. In this case, the full capabilities of the system were not used in an effort to reduce the airborne levels of lead. The aggressiveness of cleaning is directly proportional to the amount of airborne contaminants generated.

Decreased PPE Use

The PPE required to operate the SMBT was less restrictive than that for the Hotsy system. Operating the SMBT required only one set of protective clothing, while operating the Hotsy system required the same set plus an outer waterproof layer. Another substantial difference in PPE requirements was hearing protection. Double hearing protection was required for the SMBT due to the noise levels it produced. The PPE required for both technologies is presented in Table 1.

The SMBT produced noise levels between 106 and 113 dB during the demonstration. Due to the elevated noise levels, the worker stay time for the SMBT was limited to 1 h within the enclosure with the SMBT system operating. This 1-h stay time was calculated based on American Conference of Governmental Industrial Hygienists (ACGIH) recommendations, but the Occupational Safety and Health Administration (OSHA) recommendation for the same noise level is a 4-h work zone stay time. The application of the DOE-required, 1-h exposure limit rendered this technology not viable at FEMP. The technology provider acknowledged that hearing protection was required, but the laborers were not limited to exposure times of less than 8 h when this technology was used in the commercial sector. Further analyses including octave band analysis and noise dosimetry over several days of operation would be necessary to more accurately characterize the noise exposure conditions and possibly allow longer stay times in the work zone. Using engineering controls may also allow longer stay times in the work zone.

Table 1. PPE requirements

Hotsy System PPE Requirements	SMBT PPE Requirements
Cotton coveralls, hood and booties	Cotton coveralls, hood and booties
Rubber shoe covers	Rubber shoe covers
Nitrile gloves with liners	Nitrile gloves with liners
Impermeable Saranex disposable suit	Cotton work gloves
Rubber boots	Double hearing protection

Decreased Man-Hours

As previously stated, the SMBT was compared with two baseline approaches: washing of non-process-enriched materials with a high-pressure water stream followed by disposal in the OSDF and direct disposal of process-enriched uranium materials at the NTS.

The SMBT did exhibit an increase in man-hours; however, the more rapid baseline technology was performing a wash operation subject to visual acceptance criteria while the SMBT was performing a decontamination process. The Hotsy system required two laborers for its operation, while the SMBT required three laborers.

Decreased Off-Site Burial Shipments

The technology decontaminated items that otherwise would have been sent to the NTS. In the case of the FEMP, this could result in a significant cost savings. The total of all costs incurred to dispose of wastes at NTS averages approximately $27.65/ft^3 or $0.93/lb based on shipping containers holding 100% of the allowable load. Any decrease in the quantity of disposed material would represent immediate savings.

In the case of the SMBT, 2.8 ft^3 were cleaned by the system. The weight of those tanks was estimated to be 1,410 lb, representing a net disposal cost of approximately $1,311 at the NTS. The cost of disposal at the FEMP OSDF is $3.33 per ft^3. If the debris were disposed of at the OSDF instead of at the NTS, the net cost savings would be:

$$(1,410 \text{ lb} \times \$0.93/\text{lb}) - (2.8 \text{ ft}^3 \times \$3.33/\text{ft}^3) = \$1,302.$$

Decreased Airborne Contamination

A review of the demonstration data indicates that the SMBT increased the levels of airborne contaminants in the work area during decontamination operations. U-238 and other metals were found in the air sampling analysis, which indicated that the system can produce airborne contaminants from many types of surficial contamination. The air sampling data also indicates that airborne levels of U-238 inside the enclosure were either comparable to or less than the airborne levels of U-238 in other areas of the facility in which D&D activities were being performed. A direct comparison against the baseline technology cannot be made since pre- and post-washing measurements were not taken to evaluate airborne contaminants due to the presence of droplets of water/moisture. The data generated from air sampling and analyses are presented in Appendix B.

General Observations

Some of the general observations regarding system performance are:

- The wand provided with the SMBT was awkward and was quickly modified to improve its ergonomic usability.
- Features such as debris geometry (e.g., corners and angle iron) did not present any cleaning problems.

- The system successfully decontaminated surfaces contaminated with process-enriched uranium materials.
- The SMBT is an acceptable alternative to disposing of process-enriched uranium materials at the NTS.
- The brown media was successful in removing thick dirt. The brown media quickly removed all surface materials including paint, even though efforts were made to moderate the process settings to reduce the aggressiveness of this media.
- The brown media generated significant quantities of dust and did occasionally spark upon impact on metal surfaces. Dust generated by the green media was significantly less than that generated by the brown media.
- Of the two wand sizes (3/8-in. and 1/2-in.) provided with the SMBT, the 1/2-in. wand was used most of the time. This was due to the fact that most of the D&D debris cleaned with this technology consisted of tank segments, which were more suited to the wider stream of sponge media that was produced with the larger diameter nozzle.
- The technology was noisy; however, the laborers stated that it did not seem noisy when wearing double hearing protection. Double hearing protection was worn during the demonstration and further noise dosimetry studies may be warranted to determine if the worker stay times in the work area can be increased.
- The wand diameter did not effect the noise level.
- There was little need for communication between the D&D laborers while using the SMBT. When communication was necessary, the nozzle handle was released, stopping the system's operation and reducing the noise level in the work area.
- The blast media scattered throughout the blast enclosure. However, the simple plastic enclosure did an excellent job of confining the blast media.

During the demonstration, a decision was made to not recycle media, resulting in higher waste volumes. The decision to not recycle the blast media was based on a concern that both the Feed Unit and Classifier would not be able to be successfully decontaminated following repeated recycling of contaminated blast media. If this were the case, the LSDP would have to pay for this equipment and possibly dispose of the equipment as waste. It is probable that other applications could reuse the blast media and reduce the quantity of waste.

SECTION 4

TECHNOLOGY APPLICABILITY AND ALTERNATIVE TECHNOLOGIES

Competing Technologies

The surfaces of D&D debris that will be placed in the FEMP's OSDF must first be washed, with the cleaning acceptance criterion being no visible residue on the debris. The competing technology for this demonstration was high-pressure water cleaning, which uses the kinetic energy of the cleaning media to remove surface contaminants. Both the Hotsy Model 550B and the SMBT use a form of high-pressure cleaning with the differences being the cleaning media used and the efficiency of contaminant removal.

Other competing technologies include:

Ice Blasting

Compressed air carries the media to a nozzle, which accelerates the media and impinges the surface. The media scrape the coating, rust, and contamination from the surface. A vacuum system which surrounds the nozzle removes the media and the surface removed. The vacuum system separates the usable media from the remaining debris, and the media is reused in the system. Compressed air or electricity may power the vacuum system. Many systems can operate a single nozzle or multiple nozzles, increasing production rates. Various grades and types of media are available to customize the media to the surface conditions. Media type and the surface being removed can significantly affect the amount of secondary waste to be managed.

Carbon Dioxide Blasting

This technology has a refrigerated liquid carbon dioxide (CO_2) supply and a system for converting the liquid to a solid media that is used for coating removal. Compressed liquid is allowed to expand in a pressure-controlled chamber in which the temperature drops, causing a mixture of CO_2 vapor and solid CO_2 snow to form. The snow is collected, compressed, and extruded through a die to produce pellets of a selected size and hardness as needed for decontamination. The CO_2 pellets remove the coating and perform decontamination by a combination of impact, embrittlement, thermal contraction, and gas expansion. The frozen pellets provide thermal shock and cause cracking.

Technology Applicability

The SMBT is a fully mature and commercialized technology that has been used in a variety of applications such as paint removal and cleaning electrical motors, transformers, and hydraulic and fuel-oil lines. It has also been used for applications within the commercial nuclear sector in the United States and is being supplied through a U.S. affiliate of a British company. An example of the system's use in the commercial nuclear sector is the decontamination of the internal surface of the reactor coolant system piping at the steam generator interface during steam generator replacement projects. In the completed technology demonstration, however, the SMBT was evaluated as an alternative to high-pressure water cleaning of D&D debris and segmented process equipment/components of varying sizes and shapes. The demonstration application did differ significantly from its typical application.

The post-demonstration assessment of the SMBT is summarized below:

- The SMBT was compared to two baseline scenarios: washing of non-process-enriched materials and disposal of process-enriched uranium materials at the NTS. The SMBT did not clean as quickly as and generated more noise than the Hotsy Model 550B. The SMBT required less PPE for operation. When compared to disposing process-enriched uranium materials at the NTS, the SMBT clearly represented a cost savings. Process-enriched uranium materials were successfully decontaminated to allow for on-site disposal at the OSDF, an option that was not possible using the baseline washing technology.

- The SMBT generated a significant amount of noise, which required the use of double hearing protection and reduced times in the work zone (1 h per day as a result of average sound levels ranging between 106 and 113 dB). It may be possible to increase stay times in the work zone if further noise dosimetry studies can clarify the issue or generate other solutions.
- The brown media was reported to be very abrasive even when using a low transport pressure. The brown media readily removed thick dirt; however, this media also generated dust.
- A three-man team was recommended for system operation.

Patents/Commercialization/Sponsor

The SMBT is fully developed and commercialized and has been used in a variety of applications such as paint removal and cleaning electrical motors, transformers, and hydraulic and fuel oil lines. It has also been applied within the commercial nuclear sector in the United States. The technology can be obtained from AEA Technologies.

SECTION 5

COST

Introduction

A cost analysis was performed to evaluate the SMBT and any potential cost savings it may offer against two baseline technologies for cleaning or disposing of debris: (1) the Hotsy Model 550B for cleaning of non-process-enriched material and (2) disposal at the NTS for process-enriched uranium material. 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., did not change the production rates, quantities, work element, etc.,) and eliminated only those activities that are atypical of normal D&D work. Descriptions contained in later portions of this analysis detail any changes to the observed data. The *Detailed Technology Report for the Soft Media Blast Cleaning Technology* (FEMP, 1997) for this demonstration provides additional cost information and is available upon request from the FEMP.

Methodology

This cost analysis compares an innovative cleaning system (the SMBT) with a conventional power washing system (the Hotsy Model 550B) and with a baseline disposal method (disposal at the NTS). Both D&D technologies were demonstrated at Fernald Plant No. 1 using debris removed from the interior of Plant No. 1. Ultimately, the debris will be placed in a proposed OSDF. The demonstrations were performed by D&D contractor personnel. The Hotsy Model 550B Power Washer was owned by the D&D contractor, and the SMBT was rented from the vendor for the duration of the demonstration.

The demonstration was observed by members of the Integrating Contractor Team (ICT) for the Fernald Plant No. 1 LSDP. A representative of the Plant No. 1 D&D contractor was assigned to monitor the demonstrations and collect performance data. The ICT provided data on labor, materials, supplies, and other costs.

Cost and performance data were collected for each technology during their respective demonstrations. The cost for disposal at the NTS was provided by the ICT and is derived from historical data. The following cost elements were identified in advance of the demonstrations, and data were collected to support a cost analysis based on these elements:

- mobilization (including necessary training)
- D&D work
- waste disposal
- demobilization (including equipment decontamination)
- required PPE

Mobilization costs included costs for transporting technology equipment to the site, training the crew members to use the technology equipment or site-specific training of vendor personnel, installing temporary work areas, and installing temporary utilities.

The D&D work performed was the washing of debris removed from the interior of Plant No. 1. Washing was performed to the degree necessary to allow disposal of the debris in the OSDF.

Demobilization included the removal of temporary work areas and utilities, decontamination of technology equipment, disposal of wastes generated by removal of temporary work areas and utilities, and decontamination and removal of technology equipment from the site.
PPE costs include all clothing, respirator equipment, and hearing protection required for the protection of crew members during the demonstration. It was assumed that four changes of reusable PPE clothing items were required for each crew member. 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 also 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 or one shift.

Cost Analysis

Non-Process-Enriched Material

A comparison of the major cost elements for cleaning non-process-enriched material is shown in Table 2:

Table 2. Summary cost comparison non-process-enriched material.

SMBT (Innovative)			**HOTSY MODEL 550B** (Baseline)		
Cost Driver	**Unit Cost**	**Production Rate**	**Cost Driver**	**Unit Cost**	**Production Rate**
Mobilization[1]	$9,034	N/A	Mobilization[1]	$1,206	N/A
D&D Work	$4.19/ft^2	92 ft^2/h	D&D Work	$0.17/ ft^2	363 ft^2/h
Waste Disposal (OSDF)	$0.25/ ft^2	N/A	Waste Disposal (OSDF)	$1.18/ ft^2	N/A
Demobilization[1]	$3,300	N/A	Demobilization[1]	$100	N/A
PPE	$0.16/ ft^2	N/A	PPE	$0.18/ ft^2	N/A

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

Mobilization costs were higher for the SMBT because the equipment consists of one large unit that must be transported to the site. The Hotsy Model 550B is a smaller unit. No costs were identified for mobilization of the Hotsy Model 550B because it was already at the site; however, actual mobilization costs for the Hotsy Model 550B would be minimal. Costs for training and equipment familiarization were also higher for the SMBT.

The cost of performing D&D work was higher for the SMBT because of its higher capital cost for equipment, its need for an additional crew member, and its lower production rate.

Waste disposal costs were lower for the SMBT because it used soft media as a surfacing cleaning media as opposed to a water stream. The SMBT generated wastes that were less costly to collect and dispose of than the water wastes generated by the Hotsy Model 550B.

Demobilization costs were significantly higher for the SMBT due to the cost of equipment decontamination. The Hotsy unit was located outside the area where the D&D work was performed. In addition, the Hotsy unit does not recycle wash media (water). Therefore, no decontamination is required. Due to its limited maximum hose length, the SMBT unit had to be placed within the D&D work area during the demonstration and required decontamination before being removed from the site. The SMBT's classifier unit, which recycles the sponge blasting media, would also require decontamination; however, that unit was not used during the demonstration and is not included in the cost analysis.

The SMBT was less costly for PPE because it permitted significantly less expensive PPE to be worn by the crew members.

The comparative unit costs for the cleaning of debris contaminated with non-process-enriched residue were: $1.53/ ft^2 for the Hotsy system and $4.60/ft^2 for the SMBT. These costs include D&D work, waste disposal, and PPE.

Therefore, for cleaning debris contaminated with non-process-enriched residue, the SMBT offered no cost savings over the baseline alternative. The SMBT was more costly for mobilization, D&D work, and demobilization. The Hotsy Model 550B was more costly for waste disposal and PPE. No break-even point analysis was performed.

Process-Enriched Uranium Material

A comparison of the major cost elements for cleaning process-enriched uranium material is shown in Table 3:

Table 3. Summary cost comparison process-enriched uranium material

SMBT (Innovative)			DISPOSAL AT NTS (Baseline)		
Cost Driver	**Unit Cost**	**Production Rate**	**Cost Driver**	**Unit Cost**	**Production Rate**
Mobilization[1]	$9,034	N/A	Mobilization[1]	0	N/A
D&D Work	$4.19/ft^2	92 ft^2/h	D&D Work	0	N/A
Waste Disposal (OSDF)	$0.25/ft^2	N/A	Waste Disposal (NTS)	$18.08/ft^2	N/A
Demobilization[1]	$3,300	N/A	Demobilization[1]	0	N/A
PPE	$0.16/ft^2	N/A	PPE	0	N/A

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

Mobilization costs were higher for the SMBT because the equipment consists of one large unit that must be transported to the site. Costs for training and equipment familiarization were also higher for the SMBT. There are no mobilization or training costs associated with disposal at NTS.

The cost of performing D&D work was higher for the SMBT. No D&D work was required for disposal at NTS.

Waste disposal costs were lower for the SMBT because the debris was decontaminated sufficiently to allow disposal in the OSDF. Costs are significantly higher for disposal of wastes at NTS. Disposal costs are based on the 112 ft^3, full-height, white metal boxes used to transport wastes to the NTS for disposal. The unit disposal cost used in the cost analysis and the disposal costs used in the calculations in Section 3 were provided by Fluor Daniel Fernald (FDF). In addition to the cost of the boxes, the unit cost includes the following elements: (1) site check-in of boxes including inspection, (2) filling of boxes with waste material, (3) pick-up, weighing, final inspection, and generation of paper trail, and (4) loading and shipping boxes to NTS including tipping fees. The unit cost is based on historical data for boxes previously disposed of at NTS.

Demobilization costs were higher for the SMBT due to the cost of equipment decontamination. There were no demobilization or equipment decontamination costs associated with disposal at NTS.

The comparative unit costs for the cleaning of debris contaminated with process-enriched uranium residue are $18.08/ft^2 for disposal at the NTS and $4.60/ft^2 for disposal at the OSDF. These costs include D&D work, waste disposal, and PPE.

Unit costs for disposal in the OSDF were projected by FDF, as the OSDF was not in operation at the time the demonstration was conducted. Unit costs for disposal in the OSDF include all costs for (1) transporting the waste to the OSDF and (2) properly placing wastes in the OSDF including placing and compacting fill material. The cost analysis for the SMBT includes the latest unit disposal cost provided by FDF for the OSDF.

Therefore, for the demonstrated application, the SMBT had 75% less cost for disposal of the tank contaminated with process-enriched uranium because the SMBT was able to decontaminate the tank sufficiently to permit disposal in Fernald's On-Site Disposal Cell, which is relatively inexpensive. Conversely, this tank would not be sufficiently decontaminated by the Hotsy baseline system, which would require its more costly disposal at the Nevada Test Site. The SMBT was more costly for mobilization, demobilization, D&D work, and PPE. Disposal costs at the NTS were higher.

Because the fixed costs for mobilization and demobilization were higher for the SMBT, a simple break-even point analysis was performed. This analysis shows the approximate area requiring cleaning at which the savings from using the SMBT will offset the higher fixed costs of its deployment. The analysis was performed using the following equation for both technologies:

$$y = Mx + b$$

where y = the total cost of a technology deployment ($),
M = the unit cost for use of a technology ($/ft^2),
x = the amount of work to be performed using a technology (ft^2),
b = the fixed costs for a technology deployment ($).

Figure 3 contains a graph of the break-even point analysis.

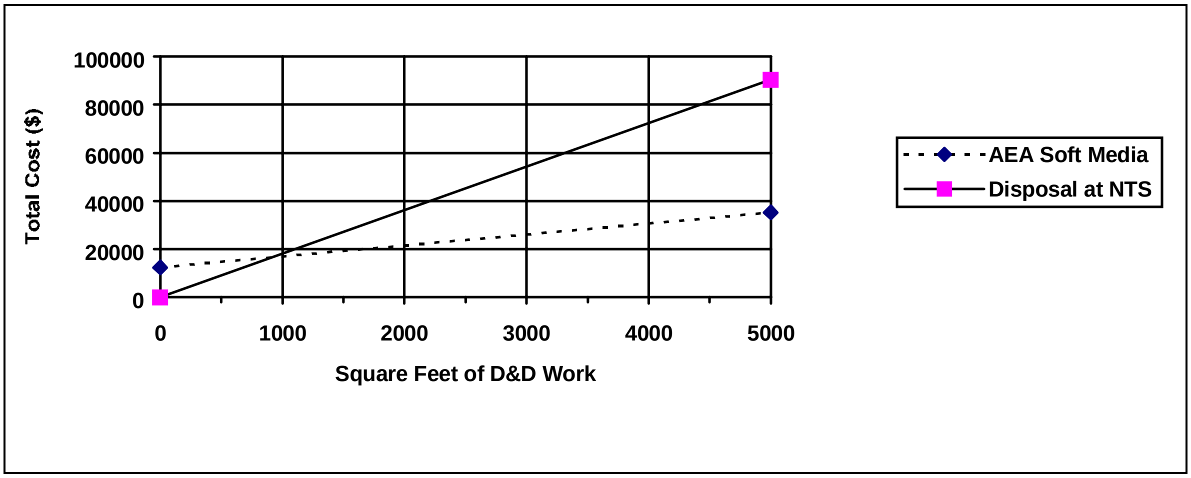

Figure 3. Break-even point analysis for process-enriched uranium residue contamination.

The break-even point occurs at approximately 900 ft^2 of area to be cleaned.

SECTION 6

REGULATORY/POLICY ISSUES

Regulatory Considerations

In effect, the use of the SMBT was simply the substitution of one mechanical cleaning system for another established mechanical cleaning system. For their use in the Plant 1 LSDP, neither the SMBT nor Hotsy systems involved regulatory or permitting issues.

Safety, Risks, Benefits, and Community Reaction

There are two safety issues that should be addressed. First, both systems employ a pressurized cleaning media. However, there is a significant difference in the pressures at which these systems operate. The Hotsy system generates a 1,000-psi stream of water that may injure a laborer inadvertently exposed to it at a close range (e.g., within 1 ft of the nozzle). The SMBT demonstration was performed using a 45-psi line pressure. Although eye and possibly skin protection is required when using the SMBT, the potential for significant bodily injury is much lower for this system than for the Hotsy system.

Second, the SMBT generates a high noise level. During the demonstration, average sound levels recorded ranged between 106 and 113 dB. Consequently, double hearing protection and 1-h stay times in the work zone were required when working with this system at the FEMP. The noise levels generated by the SMBT coupled with the hearing protection standards imposed to protect the laborers severely impact on the overall viability of this system. However, it might be possible to increase worker stay times through further noise dosimetry and/or acoustical engineering controls.

SECTION 7

LESSONS LEARNED

The lessons learned are based on observations of the technology demonstration and the debriefing of the D&D laborers.

Implementation Considerations

An implementation issue or consideration is the noise generated by the SMBT. For this technology to become viable within the DOE Complex, it will be necessary for the technology provider to reduce the noise level produced by this system by modifying the technology or using engineering controls. In addition, the user should consider the application of acoustically designed work areas to mitigate noise exposure levels.

The blast media used in this demonstration was not recycled. The decision to not recycle the blast media was based on a concern that both the Feed and Classifier Units would not be successfully decontaminated following the repeated recycling of contaminated blast media. If this were the case, the LSDP would have to pay for this equipment and possibly dispose of the equipment as waste. It is probable that other applications could reuse the blast media and reduce the quantity of waste.

The objective for decontamination technologies is normally to minimize the amount of decontamination required, and, if possible, to design the unit so that only lower-cost items would require disposal and replacement. It is recommended that the design of the SMBT be modified to meet these objectives so that the Classifier Unit could be used in future applications.

Technology Commercialization

Areas related to the operation or use of the SMBT that would benefit from design improvements prior to commercialization are:

- This technology would be best suited for use in a centralized facility. Appropriate waste types would be processed through this facility. It would be designed to minimize noise levels and have all necessary material handling equipment and media recycling capabilities. The cost for such a facility would be recovered over the entire site D&D program. The facility could be operated by the prime contractor or a D&D contractor.

- The nozzle/handle arrangement provided with the system was awkward to use and required continued bending at the waist. The ergonomic design of the wand should be altered to allow workers to stand upright while operating the system.

Technology Selection Considerations

The SMBT is an established and proven technology. The primary applications for this system have been surface cleaning (removal of grease, rust, and paint) and radiological decontamination. In the completed technology demonstration, however, the SMBT system was evaluated as an alternative to high-pressure water cleaning of D&D debris and segmented process equipment/components of varying sizes and shapes. In this application, the SMBT was not economically viable.

However, the SMBT was also used to clean D&D debris that was scheduled for disposal at NTS and could not be cleaned using water. The SMBT was able to clean and decontaminate this debris, and, as a result, it has been redirected for disposal in the FEMP's OSDF. The cost analysis for this application of the SMBT indicates that it can save money provided the magnitude of the cleaning effort is at least 900 ft^2. Thus, critical selection criteria for this technology are the application and the magnitude of the application. The reuse of media should further improve the economics of this system. Additional economic benefits might be able to be achieved through the use of a centralized soft-media blast facility. Such a facility should be considered for any process that will be used repeatedly over a long-term D&D

program. The decision to use a centralized facility should be based on a detailed site-specific assessment.

APPENDIX A

REFERENCES

B&W Nuclear Environmental Services, Inc. *Work plan.* Lynchburg, Virginia: B&W NESI.

Fluor Daniel Fernald. 1997. *Detailed technology report for the soft media blast cleaning technology (AEA Technologies, Inc.)*. U.S. Department of Energy's Fernald Environmental Management Project. Cincinnati, Ohio.

Fluor Daniel Fernald. *Decontamination and decommissioning implementation plan of the Fernald environmental management project.* U.S. Department of Energy's Fernald Environmental Management Project. Cincinnati, Ohio.

The Hotsy Corporation. *Hotsy Model 550B operating instructions and parts manual.* Englewood, Colorado: The Hotsy Corporation.

Sponge-Jet, Inc. *The sponge blast method.* Eliot, Maine: Sponge-Jet, Inc.

APPENDIX B

Air Sampling Data: SMBT Operation

Table B-1. Summary of airborne uranium-238 concentrations in building 1A during the sponge blasting demonstration

DATE	SURVEY NUMBER	AIRBORNE U-238 LEVELS AS PERCENTAGE OF DERIVED AIR CONCENTRATION (DAC)	
		BLDG. 1A GENERAL AREAS	INSIDE DEMO ENCLOSURE
08/27/96	96-08-04-379	169	
	96-08-04-377	17	
	96-08-04-378	219	
	96-08-04-374		660
08/28/96	96-08-04-395	204	
	96-08-04-394	133	
	96-08-04-393	1	
	96-08-04-396	281	
	96-08-04-397	111	
	96-08-04-391		25
08/29/96	96-08-04-412	6	
	96-08-04-410	104	
	96-08-04-411	192	
	96-08-04-413	31	
	96-08-04-407		101

Table B-2. Quantity of metals removed from the air in the AEA system enclosure and collected on filter paper in an air sampling unit

	WEIGHT OF METAL IN µg/FILTER	
FIELD SAMPLE NUMBER	**41440**	**41436**
DATE	**08/28/96**	**08/29/96**
METALS		
COPPER	220	11
IRON	22000	1200
LITHIUM	0.28	0.098
MAGNESIUM	130	79
MANGANESE	87	82
MOLYBDENUM	4.1	ND[(a)]
NICKEL	48	2.6
LEAD	1100	1300

Table B-3. Adjusted concentrations of airborne U-238

DATE	SURVEY NUMBER	RATIO OF MONITORING TIME TO DEMONSTRATION TIME (Minute/Minute)	AIRBORNE U-238 LEVELS AS A PERCENT OF DAC	
			REPORTED VALUE	**ADJUSTED VALUE**
08/27/96	96-08-04-374	420/151 = 2.78	660	1830
08/28/96	96-08-04-391	445/177 = 2.51	25	70
08/29/96	96-08-04-407	360/91 = 3.96	101	400

APPENDIX C

List of Acronyms and Abbreviations

Acronym/Abbreviation	Description
ACGIH	American Conference of Governmental Industrial Hygienists
cm^2	square centimeter
DAC	derived air concentration
D&D	deactivation and decommissioning
dB	decibel
DDFA	Deactivation and Decommissioning Focus Area
DOE	U.S. Department of Energy
dpm	disintegrations per minute
FDF	Fluor Daniel Fernald
FEMP	Fernald Environmental Management Project
ft	foot
ft^2	square foot
ft^3	cubic foot
gal	gallon
h	hour
id	inside diameter
in.	inch
ICT	Integrating Contractor Team
lb	pound
LSDP	Large-Scale Demonstration Project
MDCR	minimum detectable count rate
min	minute
NTS	Nevada Test Site
OSDF	On-site disposal facility
OSHA	Occupational Safety and Health Administration
PPE	Personal protective equipment
psi	pounds per square inch
SMBT	Soft Media Blast Cleaning Technology

APPENDIX D

Cost Data

Soft Media Blast Technology Cost Summary

Tables 1, 2, and 3 summarize the fixed, scaleable, and total costs, respectively. The fixed cost summary represents the start-up costs necessary to deploy a technology, and the scaleable cost summary represent costs dependent on quantity.

Table D-1. Fixed cost summary soft media blast technology demonstration

Title ID	Description	Quantity	Unit	Output	Manhrs	Labor	Equipmnt	Materials	Other	Total
33A	**Power Washer (Baseline)**	**1150**	**SF**							
33A.01	Mobilization	1	EA		12	$389	$0	$817	$0	$1,206
33A.21	Demobilization	1	EA		0	$0	$0	$0	$100	$100
33A	**Total Power Washing**	**1150**	**SF**		**12**	**$389**	**$0**	**$817**	**$100**	**$1,306**
33B	**Soft Media Blast Cleaner (Innovative)**	**405**	**SF**							
33B.01	Mobilization	1	EA		130	$4,201	$0	$1,698	$3,135	$9,034
33B.21	Demobilization	1	EA		64	$1,928	$13	$1,359	$0	$3,300
33B	**Total Soft Media Blast Cleaner (Innovative)**	**405**	**SF**		**194**	**$6,129**	**$13**	**$3,057**	**$3,135**	**$12,334**
33C	**Ship Debris to NTS**	**405**	**SF**							
33C	**Total Ship Debris to NTS**	**405**	**SF**		**0**	**$0**	**$0**	**$0**	**$0**	**$0**

Table D-2. Scaleable cost summary soft media blast technology demonstration

Title ID	Description	Quantity	Unit	Output	Manhrs	Labor	Equipmnt	Materials	Other	Total	Unit Cost
33A	**Power Washer (Baseline)**	**1150**	**SF**								
33A.17	D&D Work	1150	SF	363	6	$190	$5	$0	$0	$195	$0.17
33A.18	Disposal	1150	SF		0	$0	$0	$0	$1,354	$1,354	$1.18
33A.90	PPE	1150	SF		0	$0	$0	$0	$208	$208	$0.18
33A	**Total Power Washing**	**1150**	**SF**		**6**	**$190**	**$5**	**$0**	**$1,562**	**$1,757**	**$1.53**
33B	**Soft Media Blast Cleaner (Innovative)**	**405**	**SF**								
33B.17	D&D Work	405	SF	92	19	$580	$30	$1,086	$0	$1,696	$4.19
33B.18	Disposal	405	SF		0	$0	$0	$0	$100	$100	$0.25
33B.90	PPE	405	SF		0	$0	$0	$0	$64	$64	$0.16
33B	**Total Soft Media Blast Cleaner (Innovative)**	**405**	**SF**		**19**	**$580**	**$30**	**$1,086**	**$164**	**$1,860**	**$4.59**
33C	**Ship Debris to NTS**	**405**	**SF**								
33C.18	Disposal	405	SF		0	$0	$0	$0	$7,324	$7,324	$18.08
33C	**Total Ship Debris to NTS**	**405**	**SF**		**0**	**$0**	**$0**	**$0**	**$7,324**	**$7,324**	**$18.08**

Table D-3. Total cost summary soft media blast technology demonstration

Title ID	Description	Quantity	Unit	Output	Manhrs	Labor	Equipmnt	Materials	Other	Total	Unit Cost
33A	**Power Washer (Baseline)**	**1150**	**SF**								
33A.01	Mobilization	1	EA		12	$389	$0	$817	$0	$1,206	$1,206.00
33A.17	D&D Work	1150	SF	363	6	$190	$5	$0	$0	$195	$0.17
33A.18	Disposal	1150	SF		0	$0	$0	$0	$1,354	$1,354	$1.18
33A.21	Demobilization	1	EA		0	$0	$0	$0	$100	$100	$100.00
33A.90	PPE	1150	SF		0	$0	$0	$0	$208	$208	$0.18
33A	**Total Power Washing**	**1150**	**SF**		**18**	**$579**	**$5**	**$817**	**$1,662**	**$3,063**	**$2.66**
33B	**Soft Media Blast Cleaner (Innovative)**	**405**	**SF**								
33B.01	Mobilization	1	EA		130	$4,201	$0	$1,698	$3,135	$9,034	$9,034.00
33B.17	D&D Work	405	SF	92	19	$580	$30	$1,086	$0	$1,696	$4.19
33B.18	Disposal	405	SF		0	$0	$0	$0	$100	$100	$0.25
33B.21	Demobilization	1	EA		64	$1,928	$13	$1,359	$0	$3,300	$3,300.00
33B.90	PPE	405	SF		0	$0	$0	$0	$64	$64	$0.16
33B	**Total Soft Media Blast Cleaner (Innovative)**	**405**	**SF**		**213**	**$6,709**	**$43**	**$4,143**	**$3,299**	**$14,194**	**$35.05**
33C	**Ship Debris to NTS**	**405**	**SF**								
33C.18	Disposal	405	SF		0	$0	$0	$0	$7,324	$7,324	$18.08
33C	**Total Ship Debris to NTS**	**405**	**SF**		**0**	**$0**	**$0**	**$0**	**$7,324**	**$7,324**	**$18.08**

Baseline PPE

Table D-4. Baseline PPE summary sheet soft media blast technology demonstration

Crew Size:	1
Daily Shift Length:	10 hrs
Useful Life of Reusable PPE Items:	200 hrs

Reusable PPE - Daily Requirements[1]
(Zero out unused PPE items)

Item	Quantity	UOM	Unit Cost	Total Cost
Cotton coveralls (yellow)	4	EA	$5.90	$23.60
Cotton hoods (yellow)	4	EA	1.16	4.64
Cotton shoe covers (yellow)	4	Pair	1.84	7.36
Leather welding apron	0	EA	20.00	0.00
Leather welding gloves	0	Pair	7.00	0.00
Full-face respirators	4	EA	174.00	696.00
Reusable PPE laundry costs[2]	1	Load	1.39	1.39
Hourly Reusable PPE Cost			**=**	**$3.66**

Disposable PPE - Daily Requirements[3]
(Zero out unused PPE items)

Item	Quantity	UOM	Unit Cost	Total Cost
Tyvek suits	0	EA	$4.09	$0.00
Saranex suits	4	EA	23.77	95.08
Mar-mac fire-resistant coveralls	0	EA	3.36	0.00
Cotton glove liners	4	Pair	0.28	1.12
Cotton work gloves	0	Pair	0.54	0.00
Nytrile gloves	4	Pair	0.24	0.96
Rubber shoe covers	4	Pair	12.28	49.12
Rubber boots	4	Pair	29.30	117.20
Ear plugs	0	Pair	0.12	0.00
Ear protectors	0	EA	18.72	0.00
Respirator cartridges	4	Pair	11.74	46.96
Hourly Disposable PPE Cost			**=**	**$31.04**
TOTAL HOURLY PPE COST			**=**	**$34.71**

[1]Reusable PPE items - four changes required for each worker. 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]Disposable PPE items - four changes required for each worker each day. Expected life = 10 hours (length of shift).

Table D-5. Innovative PPE summary sheet soft media blast technology demonstration

Crew Size:	1
Daily Shift Length:	10 hrs
Useful Life of Reusable PPE Items:	200 hrs

Reusable PPE - Daily Requirements[1]
(Zero out unused PPE items)

Item	Quantity	UOM	Unit Cost	Total Cost
Cotton coveralls (yellow)	4	EA	$5.90	$23.60
Cotton hoods (yellow)	4	EA	1.16	4.64
Cotton shoe covers (yellow)	4	Pair	1.84	7.36
Leather welding apron	0	EA	20.00	0.00
Leather welding gloves	0	Pair	7.00	0.00
Full-face respirators	4	EA	174.00	696.00
Reusable PPE laundry costs[2]	1	Load	1.39	1.39
		Hourly Reusable PPE Cost	**=**	**$3.66**

Disposable PPE - Daily Requirements[3]
(Zero out unused PPE items)

Item	Quantity	UOM	Unit Cost	Total Cost
Tyvek suits	0	EA	$4.09	$0.00
Saranex suits	0	EA	23.77	0.00
Mar-mac fire-resistant coveralls	0	EA	3.36	0.00
Cotton glove liners	4	Pair	0.28	1.12
Cotton work gloves	4	Pair	0.54	2.16
Nytrile gloves	4	Pair	0.24	0.96
Rubber shoe covers	4	Pair	12.28	49.12
Rubber boots	0	Pair	29.30	0.00
Ear plugs	4	Pair	0.12	0.48
Ear protectors	4	EA	18.72	74.88
Respirator cartridges	4	Pair	11.74	46.96
		Hourly Disposable PPE Cost	**=**	**$17.57**
		TOTAL HOURLY PPE COST	**=**	**$21.23**

[1]Reusable PPE items - four changes required for each worker. 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]Disposable PPE items - four changes required for each worker each day. Expected life = 10 hours (length of shift).

Table D-6. Deployment PPE summary sheet soft media blast technology demonstration

Crew Size:	0
Daily Shift Length:	10 hrs
Useful Life of Reusable PPE Items:	200 hrs

Reusable PPE - Daily Requirements[1]
(Zero out unused PPE items)

Item	Quantity	UOM	Unit Cost	Total Cost
Cotton coveralls (yellow)	0	EA	$5.90	$0.00
Cotton hoods (yellow)	0	EA	1.16	0.00
Cotton shoe covers (yellow)	0	Pair	1.84	0.00
Leather welding apron	0	EA	20.00	0.00
Leather welding gloves	0	Pair	7.00	0.00
Full-face respirators	0	EA	174.00	0.00
Reusable PPE laundry costs[2]	0	Load	1.39	0.00
Hourly Reusable PPE Cost			**=**	**$0.00**

Disposable PPE - Daily Requirements[3]
(Zero out unused PPE items)

Item	Quantity	UOM	Unit Cost	Total Cost
Tyvek suits	0	EA	$4.09	$0.00
Saranex suits	0	EA	23.77	0.00
Mar-mac fire-resistant coveralls	0	EA	3.36	0.00
Cotton glove liners	0	Pair	0.28	0.00
Cotton work gloves	0	Pair	0.54	0.00
Nytrile gloves	0	Pair	0.24	0.00
Rubber shoe covers	0	Pair	12.28	0.00
Rubber boots	0	Pair	29.30	0.00
Ear plugs	0	Pair	0.12	0.00
Ear protectors	0	EA	18.72	0.00
Respirator cartridges	0	Pair	11.74	0.00
Hourly Disposable PPE Cost			**=**	**$0.00**
TOTAL HOURLY PPE COST			**=**	**$0.00**

[1]Reusable PPE items - four changes required for each worker. 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]Disposable PPE items - four changes required for each worker each day. Expected life = 10 hours (length of shift).