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Evaluation of coating Removal and Aggressive Surface Removal Surface Technologies Applied to Concrete Walls, Brick Walls, and Concrete Ceilings

Final Report
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Disclaimer

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EXECUTIVE SUMMARY

The treatment of radioactively contaminated concrete surfaces is a concern during the decontamination and decommissioning (D&D) process. As buildings undergo the D&D process, concrete floors, walls, and ceilings contaminated with radionuclides such as uranium, thorium, tritium, plutonium-238 and technetium-99 must be decontaminated before final disposal [1]. This project tests and evaluates commercially available and innovative technologies for the aggressive removal of ¼ to one inch of surface from concrete and brick walls, and the removal of coatings from concrete walls and ceilings. This investigation supports the U.S. Department of Energy (DOE) objectives of reducing risks to the environment and human health in support of its restoration projects at Fernald Environmental Management Project (FEMP) and Mound Environmental Management Project (MEMP). This project was performed at the Hemispheric Center for Environmental Technology (HCET) at Florida International University (FIU) where one innovative, and four commercially available decontamination technologies were evaluated under standard, non-nuclear testing conditions. The performance data generated by this project will assist DOE site managers in the selection of the safest, most efficient, and most cost-effective decontamination technologies to accomplish their remediation objectives.

The aggressive surface removal technologies tested were as follows:

Pentek's WallWalker™. This innovative robotic scabbling technology removed an average of 1/3 inch of coated concrete wall surface at a rate of 6.5 square feet per hour.

NELCO's Porta Shot Blast™ (JHJ-2000). This centrifugal shot blasting technology removed an average 1/14 inch of coated brick wall surface at a rate of 17.05 square feet per hour.

LTC's PTC-6. This scabbling technology removed an average 1/13 inch of uncoated concrete wall surface at a rate of 11.9 square feet per hour.

The coating removal technologies tested were as follows:

Pegasus' PCRS-7. This chemical coating removal system did not remove the coating.

Surface Technology System's Advanced Recyclable Media System (ARMS™). This sponge blasting technology removed coating of concrete ceiling at a rate of 127.0 square feet per hour.

1. INTRODUCTION

1.1 BACKGROUND OF THE FERNALD ENVIRONMENTAL MANAGEMENT PROJECT AND THE MOUND ENVIRONMENTAL MANAGEMENT PROJECT

The Fernald Environmental Management Project (FEMP), formerly known as the Feed Materials Production Center, was one of the main U.S. Department of Energy (DOE) facilities producing high-purity uranium metal products for use by different federal agencies. The Mound Environmental Management Project (MEMP) facility was one of the main DOE locations involved in research and development, engineering, production, and surveillance of components for DOE nuclear weapons; separation, purification, and sales of stable isotopes; and conducting DOE programs in nuclear safeguards and waste management, heat-source testing, and fusion fuel system. Production activities at the FEMP and MEMP facilities ceased in 1989 and 1991, respectively. However, during the operation periods at these sites, many buildings, and facilities, and equipment associated with production were contaminated to varying degrees. The majority of concrete material is considered to be radiologically contaminated from ½ inch to one inch below the surface. Primary radiological contaminants found at the Fernald site include uranium, thorium, and technetium-99. The Mound site primarily has uranium, thorium, tritium, and plutonium-238 contaminants. In accordance with the requirements of the Comprehensive Environmental Response, Compensation, and Liability Act of 1980 (CERCLA), the highest priority mission at the Fernald and Mound sites is environmental restoration to reduce risks to human health and the environment as expediently as possible.

1.2 PURPOSE OF THIS INVESTIGATION

The purpose of this investigation was to test and evaluate innovative and commercially available technologies for the surface decontamination of walls and ceilings. This investigation supports the DOE's objectives of reducing risks to human health and the environment through its restoration projects at FEMP and MEMP. This project was performed at the Hemispheric Center for Environmental Technology (HCET) at Florida International University (FIU), where one innovative and four commercially available decontamination technologies were evaluated under standard, non-nuclear testing conditions. The performance data generated by this project will assist DOE site managers in the selection of the safest, most efficient, and most cost-effective decontamination technologies to accomplish their remediation objectives.

1.3 METHODOLOGY

FIU-HCET provided a test site where various types of surfaces were constructed to simulate walls and ceilings found at FEMP and MEMP. A list of technologies was compiled from the vendors who responded to the *Commerce Business Daily* advertisement; after consultations with FEMP and MEMP, vendors were invited to participate in the bidding process. Five technologies were then selected to participate in this project. Vendors demonstrated their decontamination

technologies on identical surfaces while FIU-HCET evaluators collected performance data. Representatives from the International Union of Operating Engineers (IUOE) were present during technology demonstrations to assess health and safety factors. A separate report will be generated by IUOE based on their evaluation of these factors.

2. KEY RESULTS

This section provides an overview of some of the most significant performance data obtained during this project.

2.1 AGGRESSIVE SURFACE REMOVAL

Figure 1 presents a summary of the average depth of removal attained by each of the aggressive technologies tested on the various surfaces. Table 1 presents the standard deviation of removal depth on the various surfaces. Figure 2 presents the production rates of the aggressive surface removal technologies in square feet per hour. Table 2 presents the actual and vendor specified removal depths on various surfaces. Table 3 presents the removal gaps observed on the various surfaces. The most appropriate technology for a particular project and site must be determined by the integration of many factors with the factor that is the most important for a particular site (e.g., production rate, cost. health and safety, and secondary waste generation).

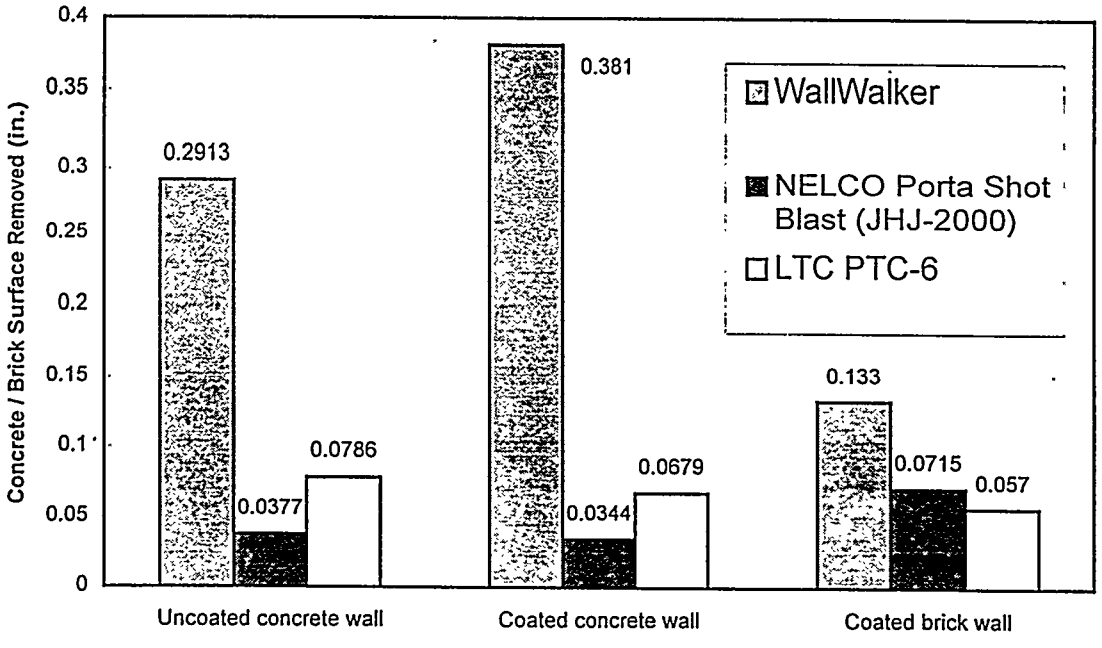

Figure 1. Average depth of removal achieved by aggressive surface removal technologies.

Table 1.
Standard Deviation of Depth of Removal on the Various Surfaces

Technology	Surface Type	Average Depth of Removal (in.)	Standard Deviation
WallWalker™	Uncoated Concrete	0.2913	±0.0910
	Coated Concrete	0.3810	±0.1966
	Coated Brick	0.1330	±0.0640
NELCO Porta Shot Blast™ JHJ-2000	Uncoated Concrete	0.0377	±0.0168
	Coated Concrete	0.0354	±0.0316
	Coated Brick	0.0715	±0.0382
LTC PTC-6	Uncoated Concrete	0.0786	±0.0314
	Coated Concrete	0.0679	±0.0229
	Coated Brick	0.0570	±0.0438

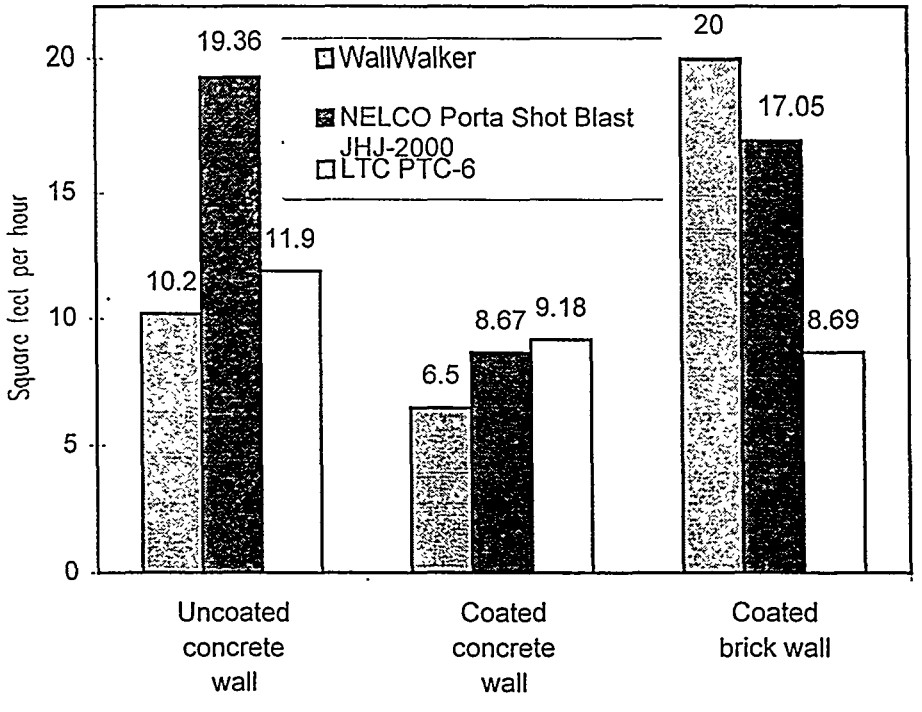

Figure 2. Production rates, in square feet per hour, achieved by the aggressive surface removal technologies.

Table 2.
Actual and Vendor Specified Removal Depth on Various Surfaces

Technology	Actual Average Removal Depth (inch)	Removal Depth Specified by Vendor
WallWalker™	Uncoated concrete wall: 0.2913 Coated concrete wall: 0.381 Coated brick wall: 0.133	½ inch, (0.50 inch) on concrete walls ¼ inch, (0.25 inch) on brick walls
Nelco Porta Shot Blast™ (model JHJ-2000)	Uncoated concrete wall: 0.0377 Coated concrete wall: 0.0344 Coated brick wall: 0.0715	¼ inch, (0.250 inch) on concrete walls 1/8 inch, (0.125 inch) on brick walls
LTC PTC-6	Uncoated concrete wall: 0.0786 Coated concrete wall: 0.0679 Coated brick wall: 0.0570	½ inch, (0.50 inch) on concrete walls ¼ inch, (0.250 inch) on brick walls
PCRS-7	Coated concrete wall and ceiling; did not remove the coating	coating removal
ARMS™	Coated concrete wall and ceiling; removed the coating	coating removal

Table 3.
Removal Gaps Observed on the Various Surfaces

Technology	Wall surfaces	Ceiling to wall interface (inch)	Floor to wall interface (inch)	Wall to wall interface [Left side] (inch)	Wall to wall interface [Right side] (inch)
WallWalker™	uncoated concrete	23 ¼	6 ½	no wall	24
	coated concrete	35 ¼	7	no wall	10 ½
	coated brick	7 ¾	7 7/8	no wall	21
NELCO Porta Shot Blast™ (JHJ-2000)	uncoated concrete	4 ¾	6 ½	11	no wall
	coated concrete	6 ¼	9 ¼	11 7/8	no wall
	coated brick	2	9 ½	11	no wall
LTC PTC-6	uncoated concrete coated concrete coated brick	no gaps on all surfaces	no gaps on all surfaces	no gaps on all surfaces	no gaps on all surfaces

2.2 COATING REMOVAL

The PCRS-7 chemical coating removal system was demonstrated by Pegasus International and the Advanced Recyclable Media System (ARMS™) was demonstrated by Surface Technology System. These tests were performed during the same period of time as the aggressive removal technologies. These data are valuable information for site personnel requiring a lesser degree of surface removal or for delicate surfaces where damage to the substrate is not desirable.

The PCRS-7 chemical coating removal did not remove the coating and no production rate was determined. The reasons why the chemical did not remove the coating were not determined. A previous test of the PCRS-5 was effective in removing the coating from the concrete floor in an open area. A speculative reason could be that the wall and ceiling surfaces were not exposed to sunlight and the surfaces were enclosed. The ARMS™ technology test results are as follows:

- The ARMS™ absolute production rate on the coated concrete wall based on multiple passes: 43.92 ft^2 per hour.
- The ARMS™ absolute production rate on the coated ceiling based on one pass: 127.0 ft^2 per hour.

The lowered production rate on the coated concrete wall was due to an additional Ply-Mastic primer on the wall. Surface Technology System's operator performed multiple passes on the

coated wall to remove the primer. On additional passes intended to remove the primer, the media was hitting the concrete and generating large amounts of dust particles. Operators performed one pass on the coated ceiling to minimize the generation of dust. See Appendix A for the definition of absolute production rate.

2.3 HEALTH AND SAFETY RESULTS

The IUOE was responsible for taking health and safety-related data during the technology demonstrations.

Table 4 presents a summary of the dust and noise level from the IUOE draft report. Please contact the IUOE at (304) 253-8670 to obtain the detailed report.

Table 4.
IUOE Dust and Noise Data

Technology	Dust Level (mg/m^3)	Noise Level (dB)
WallWalker™	Level of 0.0 was recorded at area of operators*. Level of 64.9, 46.7, and 106.5 were recorded at scabbler head.	Maximum levels observed during sampling period at operator's station was 116.0, 96.6, 100.8, and 99.6. The highest instantaneous level was > 140.
NELCO Porta Shot Balst™ JHJ-2000	Operator 1 personal dust sampling was 15.2. Operator 2 personal dust sampling was 16.6.	Maximum levels observed during sampling was > 116.6 and 106.7 for operator 1. Operator 2 observed 104.3 and 108.4.
LTC PTC-6	Operator 1 personal dust sampling was 28.6. Operator 2 personal dust sampling was 30.82.	Maximum levels observed during sampling was 116.4 for operator 1 and 114.7 for operator 2. The peak exposure seen for operator 1 was 142.9 and 135.8 for operator 2.
PCRS-7	(Organic vapor readings) Up to1.5 ppm was observed during removal of chemical. Up to 2.0 ppm was observed during sprayer application of chemical. Up to 5.0 ppm was observed during spatula application of chemical.	No noise results.
ARMS™	Area sampling was performed. At the end of each sampling period, ¼ inch-3/4 inch of visible dust was observed on sampling filter. Personal samples observed 2729.8 for the operator shoveling blasting media, and 232.6 for the operator of the blasting nozzle.	Maximum level observed during sampling was 129.2 for operator 1 and 136.9 for operator 2. The highest instantaneous level was > 140.

* Control unit was located approximately 15 ft. away from the scabbler head.

3. ENGINEERING STUDY APPROACH

3.1 STUDY OBJECTIVES

The objective of this study was to perform comparative analyses of commercially available and innovative surface removal technologies applicable to the D&D of FEMP's and MEMP's facilities. The bases for these comparative analyses included the following:

- End point achieved;
- Production rate; and
- Technology benefits and limitations.

3.2 EXPERIMENTAL DESIGN AND PROCEDURES

3.2.1 Selection of Technologies for This Study

Established sources and databases were used to categorize the technologies and perform the initial screening of technology types. These sources and databases included:

- DOE/EM-0142P *Decommissioning Handbook* [2];
- ORNL/M-2751 *Oak Ridge National Laboratory Technology Logic Diagram* [3];
- EGG-WTD-11104 *Idaho National Engineering Laboratory Decontamination and Decommissioning Technology Logic Diagram* [4];
- DOE/ORO/2034 *Contaminated Concrete: Occurrence and Emerging Technologies for DOE Decontamination* [5];
- Remedial Action Program Information Center (RAPIC) Database [6]; and
- Hemispheric Center for Environmental Technology Decontamination and Decommissioning Database [7].

The request for prospective bidders was advertised in the November 27, 1996 issue of *Commerce Business Daily*. Bidders were selected considering their number of years of work experience in nuclear decontamination, and references of previous work performed using the selected technology.

Considering the source and database review, qualified bids received, and input from FEMP and MEMP project engineers, the following innovative and commercially available technologies were tested:

- WallWalker™ [innovative];
- LTC PTC-6 [commercial];

- PCRS-7 [commercial];
- NELCO Porta Shot Blast™ (JHJ-2000)[commercial]; and
- Advanced Recyclable Media System (ARMS™) [commercial].

3.2.2 FIU-HCET Technology Assessment Site

The FIU-HCET technology assessment site is shown in Figure 3. Each test bay consists of a concrete pad with 10-foot- high concrete or brick walls on three sides and, in some bays, a concrete ceiling covering half of the pad. All masonry walls, floors, and ceilings at the assessment site have a thickness of 8 inches. The brick walls were built onto concrete walls after the concrete walls were poured. Each test surface measures approximately 20 feet by 10 feet to yield an area of approximately 200 square feet.

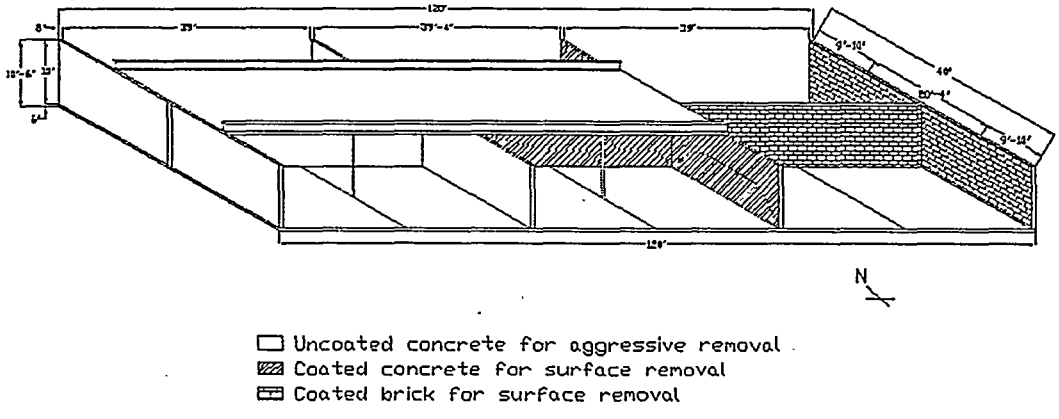

Figure 3a. FIU-HCET technology assessment site schematic.

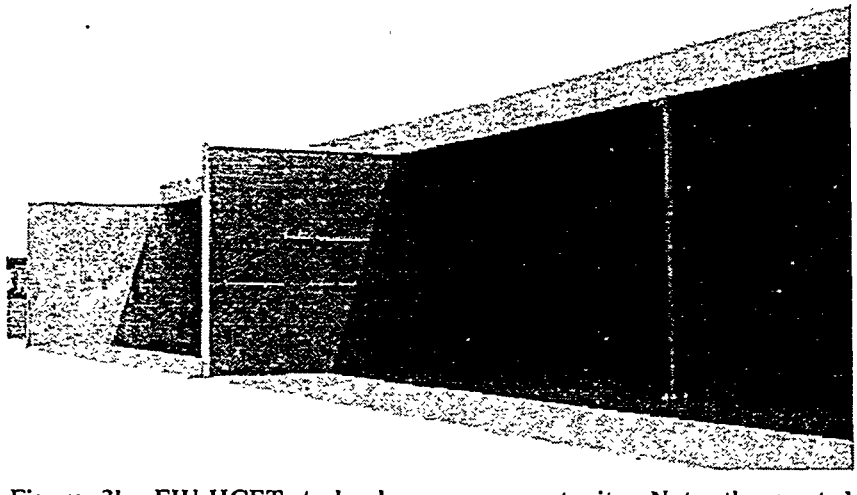

Figure 3b. FIU-HCET technology assessment site. Note the coated concrete wall (foreground) and uncoated concrete wall (background).

A preliminary review of the FEMP and other DOE sites indicated wide variability in the composition and types of the concrete used. This variability complicated the selection of the proper mix design for the construction of the concrete test areas. A 4000-psi mix was specified [8]. After the concrete was poured, for 3, 7, and 28 days, compression tests were performed, yielding, after the 28 days, a concrete compressive strength minimum of 4000 psi on all testing areas.

The FIU-HCET technology assessment site is surrounded by a 6-foot-high chain link fence to provide security and restrict access to the area. A trailer and an air conditioned metal shed, which serves as a field office, changing facility and cool-down area for the vendor, HCET and IUOE representatives, are located adjacent to the assessment site test pads. During technology assessments, each test bay was covered by a tent with three side walls which served as a wind buffer and sun shield.

During construction of the walls, snap ties were used to hold the forms that shaped the wall together. After the concrete was set, the forms were removed exposing the snap ties on the surface of the concrete wall. The majority of the snap ties were cut as deep as 1 inch into the surface of the wall. However, some were left closer to the surfaces. The holes on the wall were patched with concrete after the snap ties were cut.

The selected coating was purchased from Michael A. Bruder & Son Architectural Industrial Coatings. The coating determination was made using FEMP's paint specification for acid resistant surfaces. The coating applied to the brick wall, concrete wall and concrete ceiling consisted of one 8-mils-thick (wet) coat of Ply-Mastic primer, which dried to an approximate thickness of 7 mils. A 3-mils-thick (wet) finish coat of Ply-Thane 890 was then applied, which dried to an approximate thickness of 1 ½ mils. Material Safety Data Sheets (MSDS) were provided to vendors for waste characterization.

3.2.3 Technology Assessment Methods

End point achieved

Technology vendors demonstrated their respective technology in the manner that they deemed most efficient. The goal for the coating removal systems was complete coating removal. The goal for the aggressive surface removal system was removal of up to 1 inch of surface material. To determine the depth of surface removal, Precision Measuring Corp. performed a 200-point survey at 1-foot intervals on each test area for aggressive surface removal prior to the technology testing. After the testing, a second survey of the same 200 points was performed to determine the depth of removal. Only the points that had undergone aggressive surface removal were used to calculate the average depth of removal. The accuracy of the surveying instrument was ± 0.01 inch.

Production rates

Production rates were determined by measuring the total surface area removed divided by the total number of hours of equipment operation required to complete the task. The site-specific production rate and the absolute production rate are defined in Appendix A.

Technology benefits and limitations

Benefits and limitations were obtained by conducting field demonstrations and performing a literature search of the individual technologies. If a conflict existed between published information and field demonstration, the data obtained in the field testing were used.

3.3 TECHNOLOGY ASSESSMENT DATA COLLECTED

Data were collected by direct measurement and observation; by querying vendors and technologists; and from literature supplied by the vendors [9]. Table 5 presented below details the data requirements and the collection method employed during the technology evaluation.

Table 5. Data Requirements and Sample Collection Methods

Data Requirements	Sample Collection Methods
GENERAL INFORMATION	
Technology Description	Vendor supplied; field inspection
Basic Equipment Description	Vendor supplied; field verification
Support Equipment	Vendor supplied; field inspection
COST DATA	
Estimated Capital Cost	Vendor supplied
Support Equipment Cost	Vendor supplied; outside reference sources
Maintenance Cost	Vendor supplied
Media Cost	Vendor supplied

Table 5. Data Requirements and Sample Collection Methods (Continued)

OPERATIONAL DATA	
Production Rate	Field calculation
End Point Achieved	Outside reference source (survey)
Labor Classification	Vendor supplied; field verification
Benefits	Vendor supplied; field verification
Limitations	Vendor supplied; field verification
Media Type	Vendor supplied; field verification
Media Quantity	Vendor supplied; field verification
Utility Requirements	Vendor supplied; field verification
Environmental Conditions	Field observation; outside reference source
Waste Management	Vendor supplied; field inspection
Primary/Secondary Waste Condition	Field observation
Primary/Secondary Waste Volume (ft^3/ft^2)	Field calculation
Secondary Waste Characteristics	Field observation
Equipment Portability	Vendor supplied; field verification
Operation/Maintenance Requirements	Vendor supplied; field verification
IMPLEMENTATION DATA	
Equipment Availability	Vendor supplied
References	Vendor supplied; outside reference source
Health and Safety Concerns	Vendor supplied; field observation (IUOE*)

* International Union of Operating Engineers

4. TECHNOLOGY DESCRIPTIONS

4.1 AGGRESSIVE REMOVAL TECHNOLOGIES

4.1.1 WallWalker™

The WallWalker™ robotic scabbler consists of a motion control system and a scabbler head. The motion control system controls the position, velocity and acceleration of the scabbler head over a vertical surface. This system works by independently controlling the lengths of two separate cables that may be attached to the left and right sides of the wall by mounting brackets, or alternately may be secured to a free-standing jib structure. The scabbler head uses a new low-friction static seal that maintains vacuum flow while maximizing the vacuum pressure between the scabbler head and the wall. The scabbler head houses three pistons, each mounted on an independent suspension to allow for surface height fluctuations and to maintain optimum normal force on the wall. The three piston heads are designed to rotate about a central axis perpendicular to the wall as the scabbler head travels across the wall. The scabbler head has three wheels that allow it to move across the vertical surface. Figures 4 and 5 show the jib structure setup and mounting brackets setup, respectively.

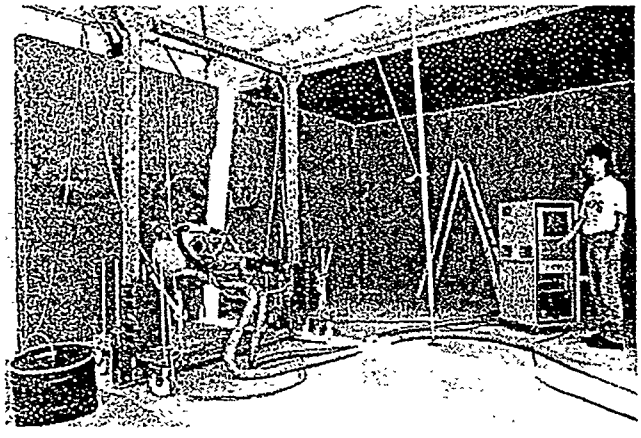

Figure 4. WallWalker™ with jib structure setup on uncoated concrete wall.

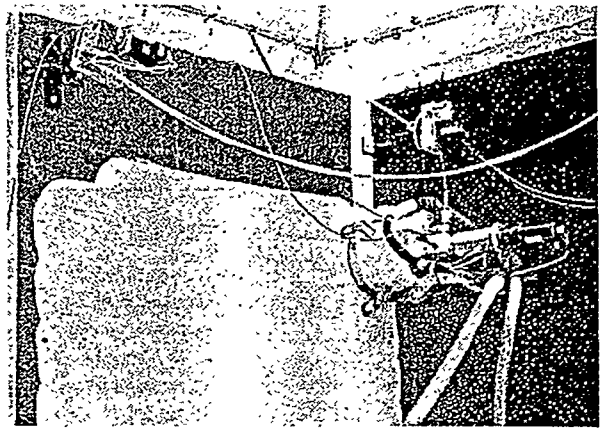

Figure 5. WallWalker™ with mounting bracket setup on coated concrete wall.

4.1.2 NELCO Porta Shot Blast™ (JHJ-2000)

NELCO manufactures 12 different Porta Shot-Blast machines that are custom-configured to meet users specific requirements. NELCO portable shot blasting machines are available in a wide range of sizes to suit most surface preparation requirements. NELCO's patented blast wheel

design produces a uniform blast pattern, resulting in a smooth, uniform surface profile with no hot spots or grooves as are produced by blasters with center-fed wheel designs. Machines are available for indoor and outdoor use, can be used on vertical or horizontal surfaces, and are powered by propane, diesel, gasoline, electric, or pneumatic engines. NELCO will custom-build shot blasters to suite specific customer requirements.

The NELCO Porta Shot Blast™ (JHJ-2000) is a hand-held portable steel shot blaster. This unit has a 1" x 1.7" blast pattern and a ½ HP electric/pneumatic motor. The debris accumulates in the dust collector and the shot accumulates in the hopper, after rebounding from the work surface. Gravity then pulls the shot into the impeller where it is recycled. The blaster holds approximately 2 pounds of shot. Horizontal, vertical, and overhead hoppers are included. This unit is also equipped with a dual safety shut-off valve. Figures 6 and 7 show the NELCO Porta Shot Blast™ JHJ-2000 in operation.

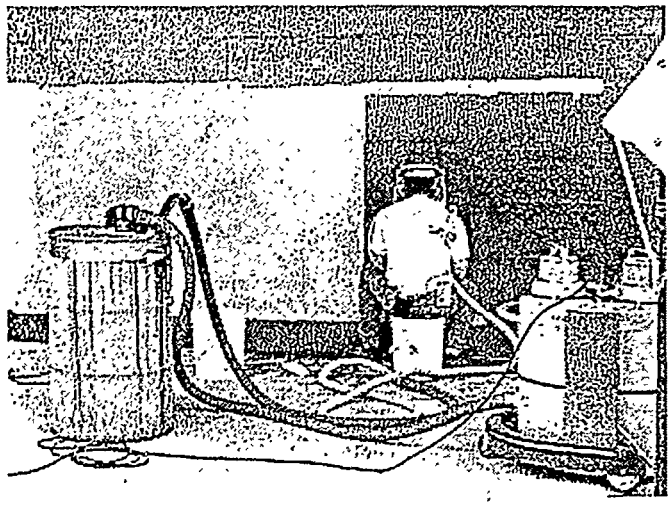

Figure 6. Rear view of operator using the NELCO Porta Shot Blast™ (JHJ-2000) on a coated wall. Note the waste collection drum (left) and Nilfisk vacuum with HEPA filter (right).

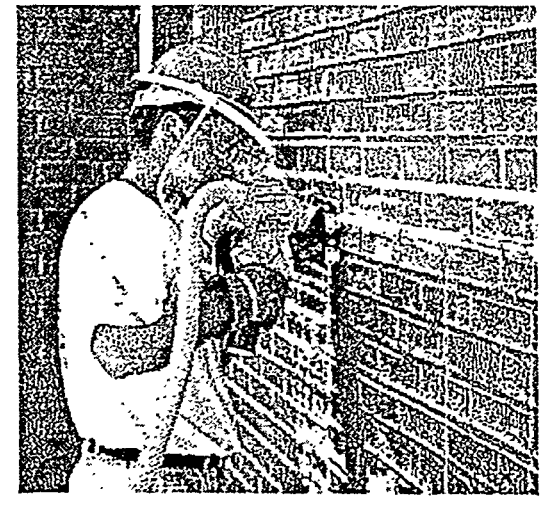

Figure 7. Side view of operator using the NELCO Porta Shot Blast™ (JHJ-2000).

4.1.3 Power Tool Center (PTC-6)

The LTC PTC-6 uses compressed air from an air source connected via air hoses to the control panel, which connects to the individual units to regulate the air pressure. The decontamination tools use air pressure to pound or cut the paint from the surface. A separate compressed air flow powers the vacuum generator which is regulated by the control panel. The vacuum generator creates a vacuum connected to the power tools and leading to the dust chamber (which is located inside the SWATS™ drum) to collect the dust and paint chips from the surface being

decontaminated. A third compressed air flow cleans the filters by pulsing air through a pipe with slots. The blasts of air shake the dust and debris from the filter fabric. The recommended vacuum working pressure is 120 psi under full operational flow. Figures 8 and 9 show the PTC-6 and the decontamination tools used for the demonstration.

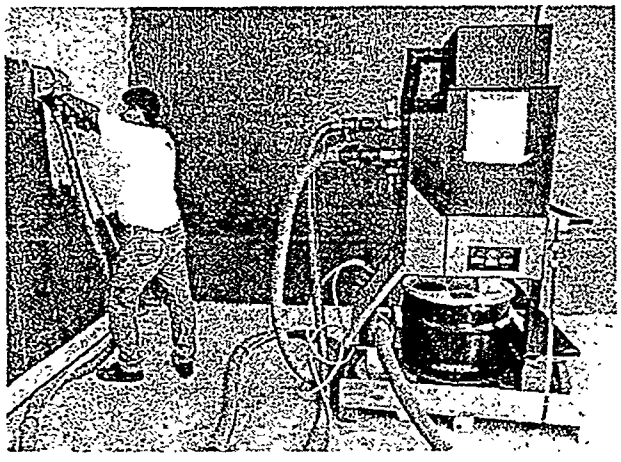

Figure 8. An operator using the PTC-6 with Roto-Peen equipped with Starcutter metal wheels. Note the PTC-6 waste collection system with the SWATS™ drum beneath the dust chamber.

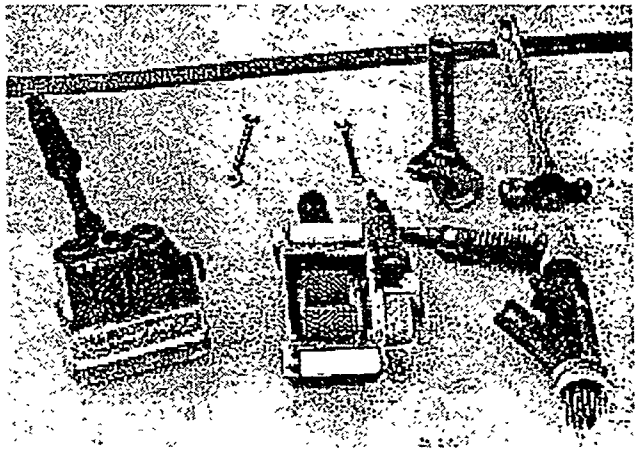

Figure 9. Attachments used with the LTC PTC-6. Shown from left to right: Scaler Hammer, Roto-Peen equipped with Starcutter metal wheels, and Needle Gun.

4.2 COATING REMOVAL TECHNOLOGIES

4.2.1 Pegasus Coating Removal System (PCRS-7)

PCRS-7 is a chemical coating removal method that has been developed by Pegasus International, Inc. for the removal of chemically resistant coatings (i.e., epoxies, urethanes, chlorinated coatings, rubber, elastomeric coatings, aluminum, vinyls, mastics, and most marine coatings). The PCRS-7 is an organic solvent mixture. It is light beige in color, slightly sweet in odor, and is supplied in 1-, 5-, or 55-gallon plastic buckets. Depending on the substrate and operating conditions, PCRS-7 is applied by pouring directly from the bucket or from a smaller container, and long- or short-handled spreaders or trowels are used to distribute it evenly across the surface. It can also be applied using a sprayer. Once distributed, the chemical is covered by a single layer of white freezer paper. Removal of the PCRS-7 and primary waste is achieved by lifting up and removing the paper, followed by scraping the surface using trowels or large plastic shovels. Figure 10 shows the operating equipment used for spraying PCRS-7. An example of a coated surface following coating removal with PCRS-7 is shown in Figure 11. Appendix D details the MSDS for PCRS-7.

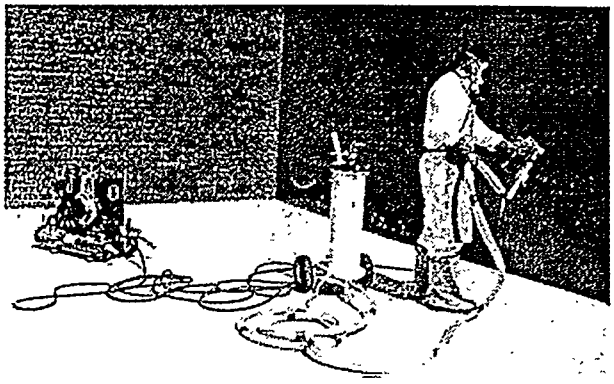

Figure 10. Operating equipment for PCRS-7 spray application. From left to right: air compressor, paint sprayer, and sprayer nozzle.

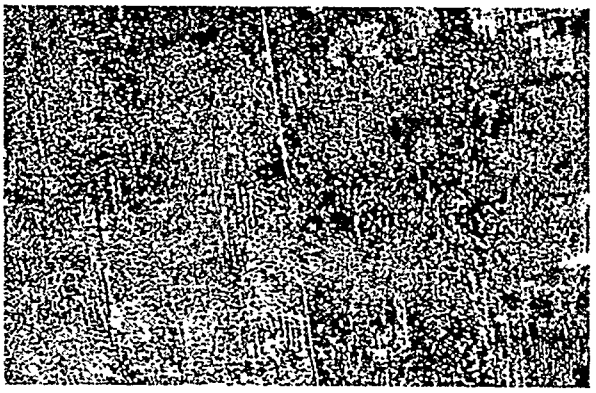

Figure 11. Coated ceiling following treatment with PCRS-7.

4.2.2 Advance Recyclable Media System (ARMS™)

The ARMS™ equipment consists of the feed unit and the sifter unit. The feed unit is a portable, pneumatically powered device that propels the cleaning media against the surfaces to be decontaminated. The cleaning media is contained in the hopper mounted atop the unit. The media is fed to an auger device that mixes the cleaning media with compressed air. The sifter unit is a machine that mechanically removes large debris and powdery residues from the cleaning media after use. The unit vibrates causing the media to fall downward to a series of separation screens, which separate the debris from the media. The reusable media drastically reduces the waste generated per square foot of surface treated. Figures 12 and 13 show the ARMS™ feed unit and the sifter unit, respectively, at the demonstration. Appendix D details the MSDS for the ARMS™.

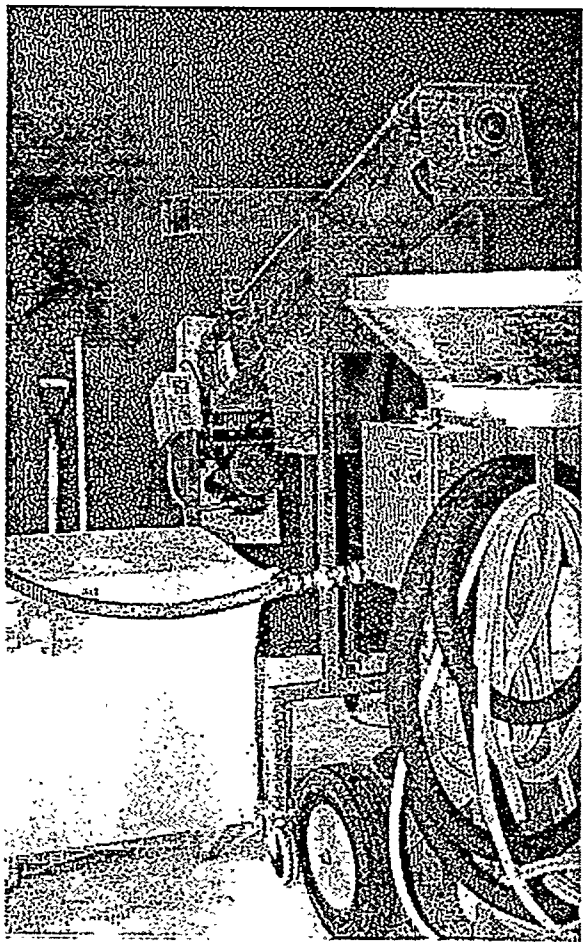

Figure 12. Front of ARMS™ feed unit.

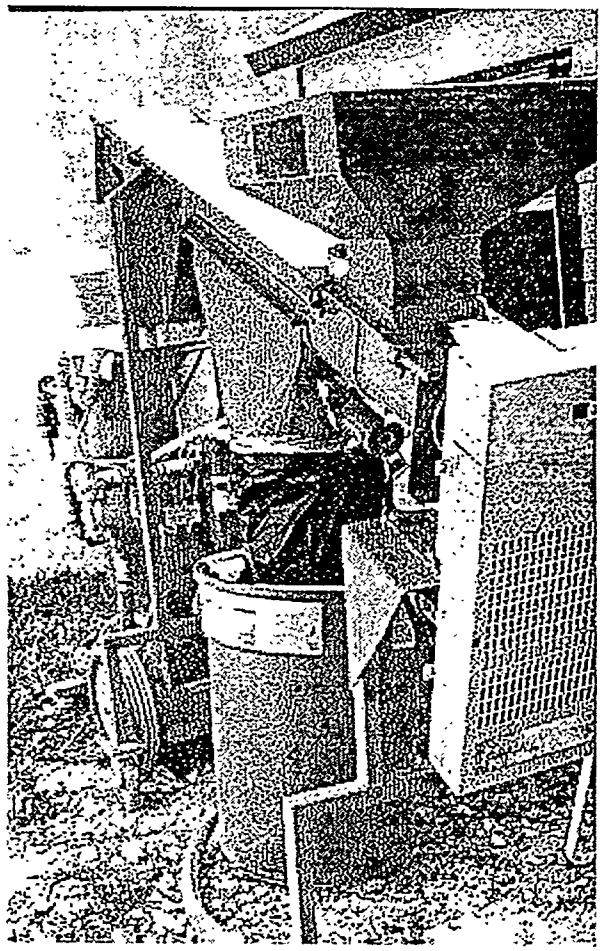

Figure 13. Operator blasting the coated concrete wall.

5. LESSONS LEARNED

5.1 DEVIATIONS FROM SCOPE OF WORK

The goal of this study was to determine the relative suitability of selected decontamination technologies for deployment at the FEMP and MEMP remediation sites.

5.1.1 Deviation from Site Specifications

An additional coat of Ply-Mastic primer coating was applied to all of the coated concrete walls before applying the blue Ply-Thane 890 finish coating. The additional coat of Ply-Mastic primer was necessary because the first coat of primer did not completely seal the concrete wall. The application of the Ply-Mastic consisted of two 8-mils thick (wet) coats of Ply-Mastic primer which when dry, were approximately 14 mils thick.

5.1.2 Technology Implementation Deviations

WallWalker™

The WallWalker™ robotic scabbler used two different support structures to hold it against the wall. A jib structure was used during the decontamination of the uncoated concrete wall and coated brick wall, while mounting brackets were used to support the WallWalker™ during the decontamination of the coated concrete wall. During the brick wall surface removal process, brittle fragments the bricks broke off and became wedged in the vacuum intake causing the WallWalker™ to bounce across the surface of the wall. Each time this occurred, operations had to be stopped to remove of the brick fragments before decontamination could continue. The snap ties in the concrete walls affected the operation of the WallWalker™ by breaking the low-friction vacuum seal surrounding the scabbling head. Each time the head passed over an area of wall containing a relatively superficial snap tie, the snap tie tore the foam seal, thereby causing a loss in the negative vacuum pressure of the system. The effect of the loss of negative vacuum pressure was twofold in that it resulted in a reduction in primary waste recovery, and decreased the adherence of the scabbler head to the wall surface. Once damaged, the low-friction vacuum seal of the scabbling head had to be completely replaced before operations could resume.

LTC PTC-6

LTC operators were instructed to operate the three tools (Scaler Hammer, Needle Gun, and Roto-Peen equipped with Starcutter metal wheels) separately so as to permit concise, tool-specific data collection. Unfortunately, the LTC operators insisted on mixing the use of the tools, making the collection of separate performance data for each tool impossible. As a result, the data collected were based on the combined operation of the three tools. The entire decontamination procedure was not completed as planned, because LTC was not equipped to perform the procedure, and had not procured the necessary tools.

Advance Recyclable Media System (ARMS™)

Surface Technology System (STS) operators concluded ceiling decontamination operations leaving several patches of primer remaining on the ceiling's surface. STS operators noted the remaining primer but declined to continue working on the ceiling as they wished to keep within the self-imposed time restraints they had allotted for this demonstration.

5.2 RECOMMENDATIONS FOR TECHNOLOGY ENHANCEMENT

With the exception of the prototype WallWalker™ which is still in the developmental stage, all the other technologies tested during this project are fully developed and commercially available. All the technologies tested exhibited performance and operational limitations that would benefit from design improvements. The following recommendations are intended to address specific limitations identified during this project.

One general design improvement that would significantly enhance all three of the aggressive surface removal technologies assessed during this study would be the addition of an integrated removal depth and/or radioactivity sensor. The incorporation of an in situ sensor technology into these existing decontamination technologies would allow field operators to know precisely when the required removal depth or acceptable contaminant levels have been reached.

5.2.1 WallWalker™

- The WallWalker™ was unable to access areas (up to 24 inches in width) along the perimeter of the wall between the surface being treated and the adjacent walls, ceiling and floor. The inaccessible area (also referred to as the removal gap) left by this technology is relatively large when compared to other technologies, and could negatively impact this technology's standing when under consideration for certain jobs. Design improvements that would reduce the removal gap left by this technology are highly recommended.

- As the scabbler moved across the surface, the exposed snap ties ripped the low-friction vacuum seal surrounding the head. A redesign of the seal using more tear-resistant material(s) would minimize this problem and reduce the operational down-time required for maintenance. The redesign should also simplify the process of removing and replacing the seal by reducing the large number of screws on the seal mounting bracket. Another welcomed improvement would be pre-fabricated seals that do not need to be cut down to the appropriate size following installation.

- The WallWalker's™ scabbler head frequently lost contact with the wall. For the most part, this occurred when overlapping scabbling paths were used to achieve deeper surface removal. A consequence of overlapping is that the scabbler head travels across an uneven surface profile. Depending on the degree of scabbling path overlap and how uneven the resulting surface profile was, the scabbler head would lose its vacuum seal and consequently lose contact with the wall. It was observed that when the scabbling path was not overlapped, the scabbler head lost contact with the wall much less frequently. An operational recommendation to improve

the performance of this technology would be to minimize the degree of overlap of the scabbling path during decontamination.

- Loss of contact also occurred when large chunks of brick were dislodged from the surface and became trapped between the scabbler head and the surface. This problem could be reduced by using a stronger vacuum, and increasing the size of the vacuum intake to facilitate the removal of larger chunks of debris.

- Whenever power to the control motors that lifted the scabbler head was interrupted, the head fell in a controlled (but unstoppable) fashion along its support cables. This could result in damage to the equipment and, in some circumstances, create a hazardous condition for workers. A braking mechanism that automatically engages when power is interrupted should be incorporated into the design.

5.2.2 NELCO Porta Shot Blast™ Model JHJ-2000

- The vacuum collection system used during the operation of this technology (Nilfisk GS625) was inadequate to prevent the loss of steel shot. Blast media lost in this way reduces its recyclability and increases the time and labor required to dispose of the secondary waste produced during technology operation. Furthermore, blast media lost in this manner introduces a potential projectile hazard for personnel in the immediate area, as well as facilitating the cross contamination of adjacent areas. A stronger vacuum system is recommended to improve blast media recovery.

- The blast head of this centrifugal shot blaster is equipped with a removable blast shield that is affixed with velcro. The function of the blast shield is to prevent the loss of the primary waste and steel shot by containing it for collection by the vacuum system. Problems were encountered when the blast shield became detached or tore during operations, resulting in the loss of shot. The use of a more resilient blast shield (possibly a brush blast shield) is strongly recommended.

5.2.3 LTC PTC-6

- The LTC PTC-6, using the Roto-Peen equipped with Starcutter metal wheels, the Scaler Hammer, and the Needle Gun, was capable of scabbling the entire wall surface. The hand-held units required that the operators exert a great deal of pressure onto the surface of the wall and resulted in significant operator fatigue. In addition, the hand-held units produced strong vibrations that also contributed to the fatigue experienced by the operators. Ergonomic redesign of these hand-held units is strongly recommended to reduce the strain placed on operators during decontamination and to ensure that cumulative worker health problems do not result from extended periods of operation.

- The Starcutter metal wheels used in the Roto-Peen hand-held unit were quickly and easily replaced; however, replacement was required every one to two hours because they wore out very quickly. A cost/benefits analysis of using Starcutter metal wheels made of more durable

metals should be considered for future operations. For example, Starcutter metal wheels made of tungsten carbide are currently available, but they are substantially more expensive than the wheels used for this study.

5.2.4 PCRS-7

- The PCRS-7 organic solvent mixture did not completely remove the coating from the concrete wall and ceiling surfaces. Even though the complete application/removal process was performed twice on each surface, the PCRS-7 was unable to remove the coatings, and left a surface that had an intact (though apparently slightly abraded) blue epoxy coating. As is the case for all chemical coating removal systems, the degree of effectiveness of a particular coating remover is directly related to the coatings that are to be removed, and the properties of the surface the coating adheres to. The only way to unequivocally determine the effectiveness of a coating remover is to perform a test patch on the desired surface.

- The application of the PCRS-7 using spraying equipment was relatively easy and fast compared to hand application, but the PCRS-7 appeared to have corroded the interior surface of the plastic hoses used. Even though the hoses were flushed with water following the first application of PCRS-7, their structure was sufficiently degraded to rupture on the second use. A more chemically-resistant hose must be used with this system to prevent chemical spills and to reduce the amount of hose that would have to be placed in the secondary waste stream for a given remediation project.

- Long strips of freezer paper were placed on top of the applied PCRS-7 to reduce drying and thereby increase the activity time of the chemical on the surface coating. Unfortunately, after a few hours, the majority of the strips had fallen off of the wall and ceiling. A more effective method should be developed to reduce the drying of the chemical that would not introduce the chemical cross contamination risks and additional waste products inherent in this method.

5.2.5 Advanced Recyclable Media System (ARMS™)

- The ARMS™ required an enclosed area to capture the media bouncing off of the cleaning surfaces and a ventilation system to recycle the air inside the enclosure. A large amount of thick dust was generated during operation, completely obscuring the view of the demonstration area. It was not clear whether the dust being generated was due to the soft consistency of the concrete or degradation of the media. Although the system has been tested on different concrete surfaces, minimal dust has been generated.

- Even when two 2000 cfm HEPA filter vacuum units were used, the dust level still obscured the view. A more powerful vacuum system is recommended.

- A vapor generator was used to suppress the dust; however, because it did not appreciably reduce the dust generated during equipment operation, its use was discontinued. A more aggressive vapor generation system that employs water with the addition of detergents is

recommended because this type of system has been shown in previous demolition studies to significantly reduce airborne particles.

- Collecting the media by shoveling it from the floor into the sifter unit should be improved. A large vacuum system capable of picking up the media and automatically dumping it into the sifter unit would eliminate the need for shoveling.

6. REFERENCES

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APPENDIX A

TECHNOLOGY DATA REQUIREMENTS: DEFINITIONS

TECHNOLOGY DATA REQUIREMENTS: DEFINITIONS

The following is an explanation of the information presented in tabular form in Appendices B and C. These tables present a summary of the technologies tested by this study. Appendix B presents aggressive surface removal technologies: WallWalker™, NELCO Porta Shot Blast™, and LTC PTC-6. Appendix C presents coating removal technologies: Advanced Recyclable Media System (ARMS™) and PCRS-7. The information is organized in Technology Overview tables, followed by Utility/Media Requirement tables, and Vendor Data tables. The text below describes each of these tables and their elements.

TECHNOLOGY OVERVIEW TABLES

The technologies shown in Tables B.1, B.2, B.3, C.1, and C.2 are described in terms of operating principles and equipment used. Technology class name, technology description, capital cost, benefits, limitations, production rate, labor classification, environmental conditions, characteristics of waste and support equipment are described in the technology overview tables.

Technology Class

Decontamination technologies have been categorized based on the physical principles employed during this operation. This classification system has been developed at FIU-HCET and is based on a system outlined in the *Decommissioning Handbook*[5].

Technology Description

The technology class description provides an introduction to the broad technology category. Details such as a description of the media are used, how the media are propelled, the vacuum system (if used), and the process by which the coating or contaminant is removed are provided.

Estimated Capital Cost

Capital cost represents the purchase cost of the technologies tested. These figures were obtained from the technology vendors as of September 1997.

Benefits

Benefits were obtained by performing a literature search of the individual technologies and conducting field demonstrations. If a conflict existed between published information and the field demonstrations, the data observed in the field testing were used. This section provides an overview of the potential benefits.

Limitations

Limitations were obtained by performing a literature search of the individual technologies and conducting field demonstrations. If a conflict existed between published information and the field demonstrations, the data observed in the field testing were used. This section provides an overview of the potential limitations.

Production Rate

Site-Specific Production Rate (ft^2/hr): The total area of surface media removed divided by the total number of hours required to complete the task at a given site. Site-specific production time begins immediately following equipment mobilization and ends at job completion, just prior to equipment demobilization. Site-specific production time include breaks taken by operators, equipment adjustments and maintenance, surface media adjustments (for moveable surface media), handling of removed media, and consultations with test site administrators. Site-specific time does not include extended operator breaks (such as meals), test interruptions resulting from inclement weather, or the time required to correct major equipment failure.

Absolute Production Rate (ft^2/hr): The total area of surface media removed divided by the total number of hours of equipment operation required to complete the task. Absolute production time includes only the time the equipment is in operation, and does not include time spent in site-specific activities or maintenance.

The number of square feet of the concrete wall divided by the number of hours required to finish the entire 20 × 10 ft. wall or ceiling is the absolute production rate. If a major equipment failure occurs, the time required to complete this major repair is not included in the calculation of the production rate. This production rate is expected to be higher than the site-specific production rate.

Environmental Conditions

A description of the work environment created by the operation of the technology is provided. These descriptions include presence or absence of visible emissions, water fog created in enclosure, visible air turbulence, and so forth.

Characteristics of Waste

This section describes the physical condition of the secondary waste as determined by visual observation. These observations include 1) fine powder with no observable difference from the media and the concrete or brick, and 2) small pieces of media mixed with concrete or brick.

Support Equipment

This section provides an overview of the major piece of equipment required to support the operation of the technology.

UTILITY/MEDIA REQUIREMENT TABLES

Tables B.4 and C.3 describe the technology class, the technology name, the end point achieved, media type, media quantity, utility requirements, operation and maintenance requirements, and availability of equipment. Vendor information was also used and verified by field measurements.

Technology Name

The specific name of the technology as obtained from the vendor is provided.

End Point Achieved

The end point achieved by the technology is described under this category. The options for this category are coating removal, < ¼ inch removal, and > ¼ inch < ½ inch removal or the actual maximum, minimum and average depth of removal measured.

Media Type

This section presents the general classification of the media used. Specific grades of media are recorded. The type of media varied with the required depth of removal and the required surface finish.

Media Cost

Vendor information was used to determine the cost of the media per pound. In the case of the technologies that use bits, the cost for a complete bit replacement was divided by the number of operating hours required before bit replacement. The bit replacement cost and the number of operating hours required before bit replacement were obtained from the vendor. Field observations of media replacement are also included.

Media Quantity

The quantity of media required per hour of operation was obtained from the vendor, and observation results are also included.

Utility Requirements

The types of utilities required to operate the technology are presented in this section. The utilities used during the field testing are shown. In many cases, optional power sources are available for each type of equipment. Utilities needed to operate the containment and ventilation system or any support equipment are shown in the tables. Also included is diesel fuel used by generator or compressor.

Operating/Maintenance Requirements

The operational/maintenance requirements provide an account of the types of operational and maintenance activities performed during the hours of operation.

Availability of Equipment

The availability of equipment and supplies was obtained from the individual technology vendors. Long-lead procurement items are differentiated from equipment and supplies that are off-the-shelf items.

Equipment Portability

Equipment portability is broken down into four categories. These categories include equipment that can be moved by one person; equipment that requires two people to move; equipment that requires a forklift to move; or trailer-mounted equipment.

VENDOR DATA TABLES

Tables B.5 and C.4 provide a list of the vendors that participated in this study. The technology name, company name, address, phone and fax numbers, and type of services are provided.

Technology Name

Technology.

Vendor Name

Name of the company contracted to demonstrate the technology at FIU-HCET.

Address, Phone and Fax numbers

This section provides the address and phone and fax number of the company that performed the demonstration.

Services

This section details the type of services provided by the company. The three types of services are service provider, equipment provider, or service and equipment provider.

HEALTH AND SAFETY ISSUES

A separate report is available from the International Union of Operating Engineers related to the health and safety issues of the technologies. Please contact the IUOE at 304-253-8674 to obtain this report.

APPENDIX B

DATA REQUIREMENTS FOR WALLWALKER™, NELCO PORTA SHOT BLAST™ (JHJ-2000), AND LTC PTC-6

Technology Class	Technology Description	Estimated Capital Cost	Benefits	Li
Robotic Scarification Technology Name: WallWalker™ No model number. Prototype innovative technology	The WallWalker™ robotic scabbler consists of a motion control system and a scabbler head. The motion control system controls the position, velocity, and acceleration of the scabbler head over a vertical surface. This system works by independently controlling the lengths of two separate cables that may be attached to the left and right sides of the wall by mounting brackets or, alternately, may be secured to a free-standing jib structure. The scabbler head uses a new low-friction static seal that maintains vacuum flow while maximizing the vacuum pressure between the scabbler head and the wall. The scabbler head houses three pistons, each mounted on an independent suspension to allow for surface height fluctuations and to maintain optimum normal force on the wall. The three piston heads are designed to rotate about a central axis perpendicular to the wall as the scabbler head travels across the wall. The scabbler head has three wheels that allow it to move across the vertical surface.	Motion Control System (3475) $150,000 (1997) VAC-PAC 24A $40,000 (1997) Scabbler Head $65,000 (1997) Total: $255,000 (1997)	Remote-operated machinery reduces strain on operators and allows for greater safety margins between workers and potential process hazards. The scabbler head unit can be reconfigured for controlled steel abrasive blasting, water blasting, carbon dioxide pellet blasting, and sodium bicarbonate wet blasting, as well as power tool cleaning operations. Can also be used to apply coatings. The motion control system allows for a high degree of precision and repeatability across surfaces. Minimizes safety issues associated with elevated work areas. Operations can be conducted for long hours.	Deconta coverag inches c edges, a (This is the supp used). When n bracket the supp the remc between wall wa Gaps be friction the surf the whe head are planes. a possib dust and causes t head to from the Cannot rain.

Table B.1
hnology Overview

ations	Production Rate	Labor Classification	Environmental Conditions	Characteristics of Waste	Support Equipment
nation within 7 orners, protrusions pendent on structure nting ere used for t structure, l gap e ceiling and bout 2 ft. een the low- tic seal and occur when of scabbler t different is allows for release of ebris, and scabbler se contact urface. operated in	Uncoated Concrete Absolute: 10.2 ft²/hr Site Specific: 8.56 ft²/hr Average removal depth: 0.3038 inches Coated concrete Absolute: 8.17 ft²/hr Site Specific: 6.90 ft²/hr Average removal depth: 0.3810 inches Coated brick: Absolute: 20 ft²/hr Site Specific: 15.18 ft²/hr Average removal depth: 0.1350 inches	2 Equipment Operators	No visible dust No fumes Sound measurements of 90 dB at 10 feet from scabbler head Sound measurements of 104 dB at scabbler head	Uncoated concrete: Concrete powder, fine and gray. Resembles fine sand. Waste Volume: 0.0377 (ft^3/ft^2) Coated concrete: Concrete powder, fine and gray. Resembles fine sand. Waste Volume: 0.0535 (ft^3/ft^2) Coated Brick: Brick powder, fine and red with some blue and white chips. Waste Volume: 0.0263 (ft^3/ft^2)	Air Compressor (LEROI) 375-cfm $ 21,749 (1997) Rental for compressor for one week was: $ 375 (1997)

Technology Class	Technology Description	Estimated Capital Cost	Benefits	Limitations
Steel Abrasive Blasting Technology Name: NELCO Porta Shot Blast ™ Model Number: JHJ-2000	Hand-held portable steel shot blaster. This unit has a 1 inch by 1.7 inch blast pattern and a ½ horsepower electric/pneumatic motor. The debris accumulates in the dust collector and the shot accumulates in the hopper after rebounding from the work surface. Gravity then pulls the shot into the impeller, where it is recycled. Blaster holds approximately 2 pounds of shot. Horizontal, vertical, and overhead hoppers are included. This unit is also equipped with a dual safety shut-off valve.	NELCO Porta Shot Blast™: $3,000 Total: $3,000	Shot is continuously recycled while the shot feed spout is open. Machine can be operated either forward or backward while blasting. Can be used on both concrete and metal surfaces. Blast media is relatively inexpensive. This unit can be used in almost any plane of operation by using different attachments.	Not effective for coating removal. Not effective for concrete removal. Not recommende large surface area A severe loss of s results when the b seals lose contact the surface

Table B.2
hnology Overview

	Production Rate	Labor Classification	Environmental Conditions	Characteristics of Waste	Support Equipment
vy p or t st ith	Un-Coated Concrete: Absolute: 19.36 ft²/hr Site Specific: 15.19 ft²/hr Average removal depth: 0.0377 in. Coated Concrete: Absolute: 8.67 ft²/hr Site Specific: 6.71 ft²/hr Average removal depth: 0.0344 in. Coated Brick: Absolute:17.20 ft²/hr Site Specific: 12.44 ft²/hr Average removal depth: 0.0715 in.	1 Equipment Operator	No fumes. Visible dust. Sound measurements of 79 dB at 25 ft. Sound measurements of 95 dB next to operator. Projectile hazards from flying steel shots.	Uncoated concrete: Fine, gray, concrete powder. Resembles fine sand. Waste Volume: N/A Coated concrete: Fine, gray, concrete powder with blue and white chips. Waste Volume: N/A Coated Brick: Fine, brown, brick powder with blue and white chips. Waste Volume:.N/A	Vacuum Cleaner: NilfiskGS625 $4,000 Floor Magnet: $500

Technology Class	Technology Description	Estimated Capital Cost	Benefits	Limitations
Scarification Technology Name: LTC Power Tool Center Model Number: LTC PTC-6	The LTC Needle-Gun is a hand-held needle scaler that operates within an evacuated enclosure called a shroud, which prevents the release of dust, debris, and airborne contaminants into the environment. The delivery system for the scaler consists of thin metal needles that rotate 360 degrees with a back and forth motion to scabble the desired surface media. The LTC Roto Peen scaler is a hand-held unit that operates within an evacuated enclosure called a shroud, which prevents the release of dust, debris, and airborne contaminants into the environment. The delivery system for the scaler consists of starcutter wheels that scabble the desired surface media. The LTC shrouded scaler hammer is a hand-held unit that operates within an evacuated enclosure called a shroud, which prevents the release of dust, debris, and airborne contaminants into the environment. The delivery system for the scaler consists of heavy duty pistons that move in a back and forth motion to chip away at the desired surface media.	Starcutter: $1,495 (1996) Needle Gun: $995 (1996) Scaler Hammer: $1210 (1997) LTC PTC-6: $17,706 (1996) Total: $ 21,406	Combination of tools allows technology to cover 100% of the wall surface. Up to 6 operators can work at the same time.	Can not be used under wet conditi or on wet surface Not field verified Not effective for aggressive remov of concrete or bri surface greater th 1/8 inch thick.

le B.3
y Overview

Production Rate	Labor Classification	Environmental Conditions	Characteristics of Waste	Support Equipment
Uncoated concrete Absolute: 11.87 ft^2/hr Site Specific: estimated 6.9 ft^2/hr Average removal depth: 0.0786 inches Coated concrete Absolute: 9.18 ft^2/hr Site Specific: estimated 5.12 ft^2/hr Average removal depth: 0.0679 inches Coated brick Absolute: 8.69ft^2/hr Site Specific: estimated 5.69 ft^2/hr Average removal depth: 0.057 inches Note: All values noted are in 2 man hours. Coated concrete wall: NG: 163 minutes, ST: 509 minutes, HM: 118 minutes Coated brick wall: NG: 154 minutes, ST: 448 minutes, HM: 23 minutes Un-coated concrete wall: NG: 83 minutes, ST: 402 minutes, HM: 323 minutes NG: Needle Gun ST: Roto-Peen equipped with Starcutter metal wheels HM: Scalar Hammer	1 Equipment Operator	No fumes Visible dust Sound measurements of 120 dB at 20 feet from operator. High reading of 120 dB Low reading of 98 dB	Uncoated concrete: Fine, gray concrete powder. Resembles fine sand. Waste Volume: 0.0127 (ft^3/ft^2) Coated concrete: Fine, gray concrete powder with small blue and white chips. Resembles fine sand. Waste Volume: 0.0127 (ft^3/ft^2) Coated Brick: Fine, brown brick powder with chunks of white and blue chips. Waste Volume: 0.0126 (ft^3/ft^2)	Air compressor (Ingersollrand 250 cfm rented from Blanchard Machinery). Air dryer: no information available from vendor

Technology Class	Technology Name	End Point Achieved	Media Type	Media Cost
Robotic Scarification	WallWalker™	Average depth of removal on walls (inches) uncoated concrete: 0.3038 coated concrete: 0.3810 coated brick 0.1350	Tungsten bits	$300.00/ set of scabbling bits and spiral pins
Steel Abrasive Blasting	NELCO Porta Shot Blast™ Model # JHJ-2000	uncoated concrete: 0.0377 coated concrete: 0.0344 coated brick: 0.0715	Steel shot (#390)	$0.40 per pound
Scarification	LTC Power Tool Center Scaler Hammer Needle Gun Roto-Peen equipped with Starcutter metal wheels	uncoated concrete: 0.0786 coated concrete: 0.0679 coated brick: 0.0570	Scaler Hammer: tungsten carbide Needle Gun: 3-mm flat tip beryllium copper spark Roto-Peen: Starcutter metal wheels	$147.00/set of three (1996) $21.00/ needle set (1996) $225.00/ Assembly (1996)

* Based on absolute time

ble B.4
ia Requirements

Media Quantity	Utility Requirements	Operation and Maintenance Requirements	Availability of Equipment	Equipment Portability
One set of scabbling bits and spiral pins should be replaced every 2400 square feet (vendor provided info)	Compressed air and two 110-volt 15-amp electrical outlets.	VAC-PAC 24A requires 1 HEPA filter and 3 roughing filters. Seal (gasket) needs to be replaced after it gets worn out.	Pentek stocks most standard replacement parts. Specialty machined items can be replaced within a week.	Forklift for VAC-PAC and other supporting equipment. Blast head can be moved by two people.
Coated brick wall: 29.4 lbs/hr* Coated concrete wall: 13.11 lbs/hr* Uncoated concrete wall: 13.23 lbs/hr*	Two 110-volt, 15-amp electrical outlets	Adjust and clean shrouds and blast shields, change of hoppers for different orientations, change wear plates, lubricate bearings, clean or replace vacuum filter as required. Average replacements done every: Blades: 20,000 ft^2 Wear plate: 100,000 ft^2 Side liners: 250,000 ft^2 Top liner: 350,000 ft^2 Blast wheel: 1,000,000 ft^2 Seals: 30,000 ft^2	Electronic components require a minimum 2-week delivery time.	One person hand held
30-40 hours usage on concrete surface before replacement (vendor data)	Compressed air	Uncoil hoses to prevent unnecessary bends. Filter must be cleaned and dust bunker emptied at least every two hours of operation. The time varies on surface being cleaned, time, and the coating thickness. Lubricate air or pneumatic tool with 150 VG 22 grade for better performance.	2-3 weeks N/A	Forklift for PTC-6 and dryer. Tools are hand held.

Table B.5
Vendor Data

Technology Name	NELCO PORTA SHOT BLAST™ (JHJ-2000)	WALLWALKER™	LTC PTC-6
Vendor Name	Pegasus International, Inc.	Pentek, Inc.	LTC Americas, Inc.
Vendor Address	106 Railroad Street Schenley, PA 15682	1026 Fourth Avenue Coraopolis, PA 15108-1659	22446 Davis Drive, Suite 142 Sterling, VA 20164
Phone Number	(412) 845-2838	(412) 262-0725	(800) 822-2332 (703) 406-3005
Fax Number	(412) 845-1794	(412) 262-0731	(703) 406-4523
Services	Equipment and service provider	Equipment and service provider	Equipment and service provider

APPENDIX C

DATA REQUIREMENTS
FOR PCRS-7 AND ADVANCED MEDIA RECYCLING SYSTEM (ARMS™)

Technology Class	Technology Description	Estimated Capital Cost	Benefits	
Coating Remover Technology Name: Pegasus Chemical Coating Removal System (PCRS) Model Number: PCRS-7	PCRS-7 is a chemical coating removal method that has been developed by Pegasus International, Inc. for the removal of chemically resistant coatings (i.e. epoxies, urethanes, chlorinated coatings, rubber, elastomeric coatings, aluminum, vinyls, mastics, and most marine coatings). The PCRS-7 is an organic solvent mixture, light beige in color, slightly sweet in odor, and supplied in 1-, 5-, or 55-gallon plastic buckets. Depending on the substrate and operating conditions, PCRS-7 is applied by pouring directly from the bucket or from a smaller container, and long- and/or short-handled spreaders or trowels are used to distribute it evenly across the surface. It can also be applied by using a sprayer to spray the coating on to the surface. Once distributed, the chemical is covered by a single layer of white freezer paper. Removal of the PCRS-7 and primary waste is achieved by lifting up and removing the paper, followed by scraping the surface using trowels and/or large plastic shovels.	Service prices range from $48 to $100 per gallon (1997). Data provided by vendor. Total of 40 gallons used for the coated concrete wall and concrete ceiling. Applied twice. Approximate area covered: Wall: 200 ft² Ceiling: 200 ft²	High viscosity allows it to remove coatings from non-horizontal surface geometries.	Rei is r con for eva con a la clot pap cov the to d eva Fre not con

Table C.1
chnology Overview

Limitations	Production Rate	Labor Classification	Environmental Conditions	Characteristics of Waste	Support Equipment
oval efficiency uced under tions favorable ccelerated oration. To ensate for this, inated fibrous or freezer can be used to the surface of pplied PCRS-7 crease the oration rate. er paper did old for ceiling guration.	Uncoated Concrete Absolute: 0 ft²/hr Site Specific: 0 ft²/hr Average removal depth: 0 inches Coated Concrete Absolute: 0 ft²/hr Site Specific: 0 ft²/hr Average removal depth: 0 inches Coated Brick Absolute: 0 ft²/hr Site Specific:0 ft²/hr Average removal depth: 0 inches	2 General Laborers (Spray applied) 1 General Laborer (Hand applied)	Hand applied: No mists Spray applied: Mists Fumes exist on both application No dust For spray application, sound measurements of 90 dB at 30 feet from wall and ceiling.	Not applicable	Ultra Air Sprayall: $3,500 Air compressor (35 psi): $1,250.00

Technology Class	Technology Description	Estimated Capital Cost	Benefits	Limitation
Sponge Blasting Technology Name: Advanced Recyclable Media System (ARMS™) No model number	The ARMS equipment consists of the feed unit and the sifter unit. The Feed Unit is a portable pneumatically powered device that propels the cleaning media against the surfaces to be decontaminated. The cleaning media is contained in the hopper mounted atop the unit. The media is fed to an auger device which mixes the cleaning media with compressed air. The sifter unit is a machine that is used to mechanically remove large debris and powdery residues from the cleaning media after use. The unit vibrates causing the media to fall downward to a series of separation screens, which separate the debris from the media. The reusable media drastically reduces the waste generated per square foot of surface treated.	Arms Feed Unit: $10,800.00 Arms Sifter: $7,200.00 Arms Vapor Generator: $5,400.00 Total: $ 23,400	Recyclable media Environmentally friendly Lower volume of waste	Containment an ventilation requi for air exchange Media is recycle shoveling by ha

Table C.2
nology Overview

	Production Rate	Labor Classification	Environmental Conditions	Characteristics of Waste	Support Equipment
	Coated concrete wall: 43.92 ft^2/hr Coated concrete ceiling: 127.0 ft^2/hr Note: The higher production rate of the coated concrete ceiling was the result of the vendor deciding to perform one pass over the coated surface; whereas the coated concrete wall performed multiple passes until all primer on wall was removed.	2 equipment operators	High levels of dust making visibility a problem. No fumes. Sound measurements of 110 dB at 10 feet from the operator.	Coated concrete wall: Fine, gray concrete powder mixed with particles of aluminum oxide media. Waste Volume: 4.25 (ft^3/ft^2) Coated concrete ceiling: Gray, sand-like mixture with some fine gray concrete powder. Waste Volume: 1.84 (ft^3/ft^2)	15-kW generator Air compressor (250 cfm) High air circulation HEPA Filter for enclosed test area.

Technology Class	Technology Name	End Point Achieved	Media Type	Media Cost	T Utility/Me
Coating remover	Pegasus Chemical Coating Removal System PCRS-7	Coating removal	Chemical coating PCRS-7	$125 per 5 gallon bucket (1997) (vendor data)	
Sponge blasting	Advanced Recyclable Media System (ARMS™)	Coating removal	Aluminum oxide fiber	$70-$90/50 lb bag (vendor data)	

e C.3
Requirements

Media Quantity	Utility Requirements	Operation and Maintenance Requirements	Availability of Equipment	Equipment Portability
10 gallons used for first and 10 gallons used for second application on the coated concrete wall. 10 gallons used for first and 10 gallons used for second application on the coated concrete ceiling. Total : 40 gallons used	Compressed air (35 psi) for sprayer	Clean-up of rollers, brushes and sprayers. Workers should avoid skin contact and inhalation of vapors. Any possible ignition source should be removed as the vapors form an explosive mixture with air. PCRS-7 should be stored in a cool, well-ventilated area away from oxidizers.	2-3 weeks	One person
15 ft^3/hr (vendor supplied information)	Compressed air and 110 volts 15 amps	ARMS™ unit needs motor oil . Grease Sifter shaft.	ARMS™: 8 weeks Media: 2 weeks	One person

Table C.4
Vendor Data

Technology Name	PCRS-7	ADVANCED RECYCLABLE MEDIA SYSTEM (ARMS™)
Vendor Name	Pegasus International, Inc.	Surface Technology System
Vendor Address	106 Railroad Street Schenley, PA 15682	75 East Market St. Akron OH, 44308
Phone Number	(412) 845-2838	497-5905 (330) 376-2700
Fax Number	(412) 845-1794	(330) 374-0101
Services	Service provider	Equipment and service provider

APPENDIX D

MATERIAL SAFETY DATA SHEETS FOR PCRS-7 AND ARMS™ ALUMINUM OXIDE FIBER MEDIA (TYPE B)

Pegasus Coatings
MATERIAL SAFETY DATA SHEET

PRODUCT:
P.C.R.S. 7
MSDS DATE OF PREPARATION/REVISION: APRIL 15, 1996

MANUFACTURER: Pegasus International, Inc.
106 Railroad Street
Schenley, PA 15682, USA

INFORMATION PHONE: (412) 295-0066
EMERGENCY PHONE: (800) 457-4280

HMIS HAZARD RATINGS
Health 2
Flammability 1
Reactivity 0
Personal Protection C
0=Least; 1=Slight
2=Moderate; 3=High
4=Extreme

SECTION I INGREDIENTS

INGREDIENT	CAS NO.	WT%	EXPOSURE LIMITS
Dibasic ester	1119-40-0 627-93-0	10-25	10 mg/m3 TWA *
n-Methyl-2-pyrrolidone	872-50-4	20-50	None established
Aluminum silicate	1332-58-7	20-40	10 mg/m3 TLV-TWA 10 mg/m3 PEL-TWA (total dust)
Nonylphenol ethoxylate	68412-54-4	1-5	None established
Non-hazardous ingredients		10-30	

* Dibasic ester is a mixture composed mainly of dimethyl glutarate (CAS 1119-40-0) and dimethyl adipapte (CAS 627-93-0). The exposure limit listed is recommended by the manufacturer.

SECTION II PHYSICAL DATA

BOILING POINT (@ 760 mmHg): Not available
SPECIFIC GRAVITY (H2O=1): >1
VAPOR PRESSURE (@ 20 C mm Hg): 0.1 (dibasic ester)
VOLATILE: 85%
VAPOR DENSITY (AIR=1): 3.4 (n-methyl-2-pyrrolidone)
EVAPORATION RATE (Butyl alcohol = 1): <1
SOLUBILITY IN WATER: Partial
pH: Not available
COEFFICIENT OF WATER/OIL: Not available
VOC Content: 6.35 lbs/gal (762 g/l)

APPEARANCE AND ODOR: Light brown paste with a slight, sweet odor. There is no odor threshold data available for any of the components.

SECTION III FIRE AND EXPLOSION HAZARD DATA

FLASH POINT: 266F / 130 C
METHOD: COC
FLAMMABLE LIMITS: (vol % in air) LEL - 0.99 UEL - 7.9
AUTOIGNITION TEMPERATURE: Not available
EXTINGUISHING MEDIA: Water spray or fog, foam, carbon dioxide, dry chemical.
SPECIAL FIREFIGHTING PROCEDURES: Firefighters should wear full emergency equipment and NIOSH approved positive pressure self-contained breathing apparatus. Cool exposed intact containers with water spray or stream.
UNUSUAL FIRE AND EXPLOSION HAZARDS: At elevated temperatures containers may rupture. Vapors form explosive mixtures with air. Decomposition products may be hazardous.

SECTION IV HEALTH HAZARD DATA

INHALATION: Mist and vapors may cause irritation to the eyes, mucous membranes and upper respiratory tract and blurring of vision.

SKIN CONTACT: May cause irritation. Prolonged skin contact may cause burns. Widespread or prolonged contact may cause absorption of n-methyl -2-pyrrolidone with symptoms similar to ingestion.

EYE CONTACT: Vapors may cause irritation and blurred vision. Direct contact may cause corneal opacity and edema (swelling).

INGESTION: May cause gastrointestinal irritation, vomiting, diarrhea, headache, and abdominal pain.

CHRONIC EFFECTS OF OVEREXPOSURE: Repeated skin contact may cause dermatitis.

MEDICAL CONDITIONS AGGRAVATED BY EXPOSURE: Individuals with chronic respiratory or skin diseases may be at increased risk from exposure to this material.

TOXICOLOGY DATA: This product has not been tested as a whole. Toxicity values for the components are:

	LD50	LC50
Dibasic ester	8191 mg/m3 oral rat	>11 mg/l/4 hr rats
n-Methyl-2-pyrrolidone	7000 mg/kg oral rat 8000 mg/kg skin rabbit	No data available
Aluminum Silicate	No data available	No data available

None of the components is listed as a carcinogen or suspect carcinogen by NTP, IARC or OSHA.

None of the components have been found to be mutagenic.

None of the components are known to cause sensitization in animals or humans.

n-Methyl-2-pyrrolidone has been found to cause toxicity in the fetus of laboratory animals exposed during pregnancy. None of the components are known to cause adverse reproductive effects or teratogenic effects in animals or humans.

SECTION V EMERGENCY and FIRST AIR PROCEDURES

EYE CONTACT: Immediately flush eye with water for at least 15 minutes while lifting the upper and lower lids. Get immediate medical attention.

SKIN CONTACT: Wash thoroughly with soap and water until no traces of the chemical remain. Remove contaminated clothing immediately and launder before reuse. Get medical attention if irritation develops.

INHALATION: Remove victim to fresh air. If breathing has stopped give artificial respiration. If breathing is difficult have qualified personnel administer oxygen. Get immediate medical attention.

INGESTION: If conscious, give 2 glasses of water to dilute. Do not induce vomiting. Never give anything by mouth to a person who is unconscious or convulsing. Get immediate medical attention.

SECTION VI REACTIVITY HAZARD DATA

STABILITY: This material is stable.
CONDITIONS TO AVOID: Not applicable.
INCOMPATIBILITY: Strong acids, bases, strong oxidizers and reducing agents.
HAZARDOUS DECOMPOSITION PRODUCTS: Thermal decomposition may yield carbon monoxide, carbon dioxide and oxides of nitrogen.
HAZARDOUS POLYMERIZATION: Will not occur.
CONDITIONS TO AVOID: Not applicable.

SECTION VII SPECIAL PROTECTION INFORMATION

RESPIRATORY PROTECTION: None needed under normal use conditions. If mist is generated and for large jobs where the recommended exposure limit may be exceeded use a NIOSH approved respirator with organic

vapor cartridges and a dust/mist pre-filter. For higher concentrations (greater that 10 times the recommended exposure limit) an approved supplied air respirator (with escape bottle if required) or self-contained breathing apparatus may be required. Selection of respiratory protection depends on the contaminant type, form and concentration. Select in accordance with OSHA 1910.134 and good Industrial Hygiene practice.

VENTILATION: Good general ventilation (equivalent to outdoors) should be adequate under normal conditions. If the recommended exposure limit is exceeded increased mechanical ventilation such as local exhaust may be required.

GLOVES: Butyl rubber or other impervious gloves are required.

PROTECTIVE CLOTHING: Impervious apron, boots and other clothing are recommended if needed to prevent contact or if splashing is possible.

EYE PROTECTION: Chemical safety goggles and/or face shield required. Do not wear contact lenses.

OTHER PROTECTIVE EQUIPMENT: For operations where contact can occur, a safety shower and an eye wash facility should be available.

SECTION VIII SPILL OR LEAK PROCEDURES

STEPS TO BE TAKEN IN CASE MATERIAL IS RELEASED OR SPILLED: Wear appropriate protective clothing to prevent eye and skin contact. Remove all sources of ignition. Dike spill and collect into closable containers for disposal with inert absorbent. Wash spill area with water. Prevent runoff to storm sewers and ditches leading to natural waterways. Report spill as required by local and federal regulations.

WASTE DISPOSAL METHOD: Dispose in accordance with all local, state and federal regulations.

SECTION IX SPECIAL PRECAUTIONS

PRECAUTIONS TO BE TAKEN IN HANDLING AND STORING: Protect containers from physical damage. Store in a cool, well ventilated area away from oxidizers and other incompatible materials.

Avoid eye and skin contact. Avoid breathing vapors. Use only with appropriate protective equipment. Immediately remove and launder contaminated clothing before re-use. Wash thoroughly after handling and before eating, drinking, smoking or using toilet facilities.

OTHER PRECAUTIONS: Empty containers retain product residues. Follow all MSDS precautions in handling empty containers.

SECTION X REGULATORY INFORMATION

DOT INFORMATION: Not regulated

OSHA HAZARD CLASSIFICATION: Irritant, toxic

EPA SARA 311 HAZARD CLASSIFICATION: Acute health.

WHMIS CLASSIFICATION: D-2 Other toxic effects

TOXIC SUBSTANCES CONTROL ACT: All of the components of this product are listed on the TSCA inventory.

CALIFORNIA PROPOSITION 65: This product contains no California Proposition 65 regulated chemicals.

SECTION XI SARA TITLE III SECTION 313 INFORMATION

COMPONENT	CAS#	WT%
n-Methyl-2-pyrrolidone	872-50-4	20-50

Prepared by: Denese A. Deeds, CIH
Industrial Health & Safety Consultants, Inc.
Shelton, CT
5/18/92

Revised: 12/10/92
Revised Section I - Ingredients and Section IV - Health Hazard Data

Revised: 12/19/94 Add VOC Content Section II

Revised: 04/15/96 Revised SARA 313 Section

MATERIAL SAFETY DATA SHEET
ARMS™ Aluminum Oxide Fiber Media (Type B)

Section 1 - CHEMICAL PRODUCT AND COMPANY IDENTIFICATION

PRODUCT NAME	ARMS™ Aluminum Oxide Fiber Media (Type B)
PRODUCT FAMILY	Blasting material
EFFECTIVE DATE	9/17/96

MANUFACTURER:
Advanced Recyclable Media Systems, Inc.
P.O. Box 13486
Research Triangle Park,
North Carolina 27709
Tel: 919-941-0847

EMERGENCY TELEPHONE NUMBERS:
Transportation: CHEMTREC 800-424-9300 24 hours every day
Transportation: 919-941-0847 8:30am - 6:00pm EST M-F
Health: 919-941-0847 8:30am - 6:00pm EST M-F

Section 2 - COMPOSITION, INFORMATION ON INGREDIENTS

COMPONENT	% by Wt.	CAS#
Proprietary composition		

Contains alpha alumina and titanium dioxide subject to inhalation TLV and PEL regulations. See Section 11 of MSDS.

Section 3 - HAZARDS IDENTIFICATION

EMERGENCY OVERVIEW No significant or unusual hazards.

POTENTIAL HEALTH EFFECTS

EYE CONTACT	May cause eye irritation and tearing. Avoid direct contact.
SKIN CONTACT	Frequent or prolonged contact may cause irritation
INHALATION	Prolonged or excessive inhalation may cause respiratory tract irritation and mucous membrane irritation.
INGESTION	Ingestion of large quantities may cause gastrointestinal irritation.

CARCINOGENICITY

NTP	Not listed
IARC	Not listed
OSHA	Not listed

Section 4 - FIRST AID MEASURES

EYE CONTACT	Flush immediately with plenty of water to remove particulates. Seek medical attention if irritation persists.
SKIN CONTACT	Wash with soap and water..
INHALATION	Remove to fresh air
INGESTION	Consult physician for any symptoms.

Section 5 - FIRE FIGHTING MEASURES

FLASH POINT	Non-flammable
LOWER FLAME LIMIT	Not applicable
HIGHER FLAME LIMIT	Not applicable
AUTOIGNITION TEMPERATURE	Not applicable
FLAMMABILITY CLASSIFICATION	Non-Flammable, non-combustible, non volatile
FLAMMABLE PROPERTIES	Non-Flammable, non-combustible, non volatile
EXTINGUISHING MEDIA	Use extinguishing media for primary source of fire
SPECIAL FIRE FIGHTING PROCEDURES	If involved in fire, use water spray, foam, dry chemical or CO_2
HAZARDOUS COMBUSTION PRODUCTS	Oxides of carbon and nitrogen, toluene, hydrogen cyanides due to urethane content.
UNUSUAL FIRE & EXPLOSION HAZARD	None

Section 6 - ACCIDENTAL RELEASE MEASURES

SPILLS Avoid raising dust Wear NIOSH approved dust/mist respirator. Vacuum or sweep up.

Section 7 - HANDLING AND STORAGE

HANDLING Wash thoroughly after handling. Use only in well ventilated area. Avoid contact with eyes.
STORAGE Avoid high heat--over 300°F.

Section 8 - EXPOSURE CONTROLS, PERSONAL PROTECTION

ENGINEERING CONTROLS	Good general ventilation should be used. Ventilation rates should be matched to conditions.
EYE PROTECTION	Wear safety glasses. Avoid eye contact.
SKIN PROTECTION	Gloves are recommended.
RESPIRATORY PROTECTION	None required where adequate ventilation conditions exist. For conditions where exposure to dust is apparent, a dust/mist respirator should be worn.

Section 9 - PHYSICAL AND CHEMICAL PROPERTIES

PHYSICAL FORM	Solid
COLOR	Brown with gray
ODOR	None
pH	Not applicable
VAPOR PRESSURE (mm Hg)	Not applicable
VAPOR DENSITY (Air=1)	Not applicable
BOILING POINT	Not applicable
MELTING/FREEZE POINT	Not applicable
SOLUBILITY IN WATER (77°F)	Insoluble
SPECIFIC GRAVITY	35-37 lbs./cu. ft.
EVAPORATION RATE (Water=1)	Not applicable

Section 10 - STABILITY AND REACTIVITY

CHEMICAL STABILITY	Stable
CONDITIONS TO AVOID	High temperatures
INCOMPATIBLE MATERIALS	Strong oxidizing agents.
DECOMPOSITION PRODUCTS	Oxides of nitrogen and carbon, toluene and hydrogen cyanides may form if decomposed in a fire due to urethane component.
HAZARDOUS POLYMERIZATION	Will not occur.

Section 11 - TOXICOLOGICAL INFORMATION

No information available for product in its final form. Product as shipped contains no particles of respirable size range. If product is broken down in use, alpha alumina and titanium dioxide are subject to inhalation limits:
OSHA - PEL/TWA 5 mg/cu.m.

Section 12 - ECOLOGICAL INFORMATION

No data available on product in its final form.

Section 13 - DISPOSAL CONSIDERATIONS

RCRA STATUS No component is regulated as hazardous waste under RCRA (40 CFR 261). If discarded in its purchased form, this product would not be a hazardous waste either by listing or by characteristic. However, under RCRA it is the responsibility of the product user to determine, at the time of disposal, whether a material containing the product or derived from the product should be classified as hazardous waste.

Section 14 - TRANSPORT INFORMATION

D.O.T. SHIPPING NAME	None
D.O.T HAZARD CLASS	Non Hazardous
N.A. I.D NUMBER	Not Applicable
U.N. I.D. NUMBER	Not Applicable
PRODUCT LABEL	ARMS™ Aluminum Oxide Media (Type B)

Section 15 - REGULATORY INFORMATION

TSCA STATUS	All components of this product are listed on the TSCA inventory.	
CERCLA REPORTABLE QUANTITY	Notification of spills is not required.	
OSHA STATUS	Nonhazardous.	
SARA TITLE III		
SECTION 302 EXTREMELY HAZARDOUS SUBSTANCES	None	
SECTION 311/312 HAZARD CATEGORIES	Immediate (acute) health:	No
	Delayed (chronic) health:	No
	Fire hazard:	No
	Sudden release of pressure:	No
	Reactive:	No
SECTION 313 TOXIC CHEMICALS	None	

RCRA STATUS

No component is regulated as hazardous waste under RCRA (40 CFR 261). If discarded in its purchased form, this product would not be a hazardous waste either by listing or by characteristic. However, under RCRA it is the responsibility of the product user to determine, at the time of disposal, whether a material containing the product or derived from the product should be classified as hazardous waste.

Section 16 - OTHER INFORMATION

REASON FOR ISSUE:	Update of 16 - Other Information
APPROVAL DATE:	9/17/96
SUPERSEDES DATE:	8/20/96

HMIS HAZARD RATING:		NFPA HAZARD RATING:	
Health	0	Health	0
Flammability	0	Flammability	0
Reactivity	0	Reactivity	0
PPE	C	Specific Hazard	

4 = Extreme 3 = High
2 = Moderate 1 = Low
0 = Minimal

PPE: A = Glasses
B = Goggles, Gloves
C = Glasses, Gloves, Apron Clothing

	Health	Fire Hazard	Reactivity	Specific Hazard
4	Deadly	<73°F	May detonate	Oxidizer OXY
3	Extreme Hazard	<100°F	Shock & Heat	Acid ACID
2	Hazardous	<200°F	Violent Chemical	Alkali ALK
1	Slightly Hazardous	>200°F	Unstable if heated	Corrosive COR
0	Normal Materials	will not burn	Stable	DO NOT USE W. Radiation RAD

NOTE -

All information appearing herein is based upon data obtained from manufacturers and or recognized technical sources. We believe the information is current and accurate as of the date of this MSDS. It is given in good faith, but, no warranty expressed or implied is made. Since the use of this information and the conditions of the use of the product are not under the control of Advanced Recyclable Media Systems, Inc. it is the user's responsibility to determine conditions of safe use of the product. Please consult your Advanced Recyclable Media Systems, Inc. representative for further information.

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