Technology Demonstration of Decontamination Gel and Strippable Coatings Applied via Remote Sprayer Platform - 11300

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ABSTRACT

The objective of the US Department of Energy Office of Environmental Management's (DOE-EM's) D&D Toolbox Project is to use an integrated systems approach to develop a suite of decontamination & decommissioning (D&D) technologies, a D&D toolbox, that can be readily used across the DOE complex to improve safety, reduce technical risks, and limit uncertainty within D&D operations. Florida International University's Applied Research Center (FIU-ARC) is supporting this initiative by identifying technologies suitable to meet specific facility D&D requirements, assessing the readiness of those technologies for field deployment, and conducting technology demonstrations of selected technologies. To meet the technology gap challenge for a technology to remotely apply strippable coatings, FIU-ARC identified and demonstrated a remote sprayer platform.

FIU-ARC selected the International Climbing Machines' (ICM's) robotic climber to perform this technology demonstration. The selected technology was previously demonstrated spraying fixative products at the hot cell mockup facility at FIU-ARC in November 2008 [1]. Based on the initial FIU demonstration and specific technical requirements identified at the DOE facilities, DOE requested that the follow-up demonstration be expanded to include strippable coatings and decontamination gels. FIU-ARC conducted a demonstration of the technology in coordination with ICM to evaluate the remote crawler machine's ability to spray strippable coatings and a decontamination gel on vertical surfaces of concrete and steel.

The technology evaluation documented the ability of the remote system to spray three different strippable coating products, including one decontamination gel, on vertical concrete and stainless steel surfaces. The technology performance, cost, and health & safety issues were evaluated during this technology demonstration.

The results confirmed that the technology was able to travel across the floor and climb-up the walls unassisted while being controlled remotely by the operator. The technology sprayed strippable coatings and a decontamination gel to the vertical wall surfaces of concrete and stainless steel and achieved a sufficient thickness of each product to promote the ability of the product to be stripped from the surface once dry. In addition, 12 of the 16 health and safety risk categories were either not applicable to this technology or received a risk rating of 1, indicating that the hazard may be present but not expected over background levels. Four categories received a rating of 2, indicating that some level of hazard above background level was known to be present. The cost of the products sprayed, using the actual coverage (ft^2) achieved during the demonstration, ranged from $2.02 to $4.25 per square foot or $21.72 to $45.7 per sq meter.

INTRODUCTION

Many facilities slated for decontamination and decommissioning (D&D) across the Department of Energy (DOE) complex pose hazards (radiological, chemical, and structural) which limit, and in many instances prevent, the use of traditional manual techniques. Efficient and safe D&D of the facilities will require the use of remotely operated technologies. In addition, the D&D of a radioactively contaminated facility normally requires that the surfaces be cleaned and stabilized to allow demolition to occur while maintaining worker radiation exposure as-low-as-reasonably-achievable (ALARA) and without spreading radioactive contamination. One decontamination step typically consists of applying a strippable coating (or similar material) to all contaminated surfaces to allow the removal of loose contamination prior to demolition. A study on available remote technologies for D&D activities, performed by Florida International University (FIU) and NuVision Engineering (NVE) [2], indicated that there was no remotely operated technology available to meet the need for the remote application of strippable coatings. This gap between the identified needs and the available technologies is especially critical for highly radioactively contaminated facilities, where physical access is typically very limited and where ALARA and other safety hazards may preclude human entry.

The objective of the D&D Toolbox Project is to use an integrated systems approach to develop a suite of D&D technologies (D&D toolbox) that can be readily used across the DOE complex to reduce technical risks, improve safety, and limit uncertainty within D&D operations. FIU is identifying technologies suitable to meet specific facility D&D requirements, assessing the readiness of those technologies for field deployment, and conducting technology demonstrations of selected technologies.

To meet the technology gap challenge for a technology to remotely apply strippable coatings, FIU identified and demonstrated a remote sprayer platform. FIU-ARC selected the International Climbing Machines' (ICM's) Robotic Climber to perform this technology demonstration. The selected technology was previously demonstrated spraying fixative products at the hot cell mockup facility at FIU-ARC in November 2008. Based on the initial FIU demonstration and specific technical requirements identified at the DOE facilities, DOE requested that the follow-up demonstration be expanded to include strippable coatings and decontamination gels. FIU-ARC conducted a demonstration of the technology in coordination with ICM to evaluate the remote crawler machine ability to spray strippable coatings and a decontamination gel on vertical surfaces of concrete and steel.

The selected technology was demonstrated at the ICM facility in Ithaca, NY under a contract with Florida International University's Applied Research Center. The technology evaluation documented the ability of the remote system to spray three different strippable coating products (Instacote CC Strip, Carboline ALARA 1146, and CBI Polymers DeconGel) on vertical concrete and stainless steel surfaces. The technology performance, cost, and health & safety issues were evaluated during this technology demonstration.

EXPERIMENTATION

Testing of the ICM climber technology with a custom spray applicator was conducted to demonstrate "proof-of-concept" to remotely spray various strippable coatings and decontamination gels on concrete and metal substrates at the ICM facility.

An FIU-ARC evaluator was present for the duration of the technology demonstration to record performance data and take photographs during the technology's operation. In addition, ICM captured videos during the technology's operation. During the demonstration, the FIU-ARC evaluator gathered data concerning the technology's operation, performance, maintenance, health and safety aspects, cost, benefits, and limitations, and the ability of the technology to be decontaminated. Data tables were prepared containing a list of specific data that was collected and evaluated.

The technology vendor was responsible for providing the operators for the technology equipment and the same operators were available throughout the duration of the demonstration to ensure continuity of operation and consistency of comments and feedback. The vendor was also responsible for maintenance of the technology equipment.

The testing protocol included the following:

1. Demonstration of the technology utilizing the custom spraying attachment in the building module. The operators and observers were just outside the building module, under a shade canopy. The surfaces sprayed included concrete and stainless steel panels installed on 3 walls within the building module. Table I describes the surfaces sprayed and Figure 1 provides a 3-dimension diagram of the building module design. Each of the three products (CC strip, ALARA 1146, and DeconGel) was applied to both concrete and stainless steel panels up to a height of 10 feet (3.05 meters).

Table I. Module Building Surfaces Sprayed With Strippable Coatings

Surface	Description	Panels	Dimensions
Wall A	Left wall (facing opening from outside module)	Concrete	10' x 12' (3.05m x 3.66m)
Wall B	Back wall (facing opening from outside module)	Concrete and stainless steel	10' x 12' (3.05m x 3.66m)
Wall C	Right wall (facing opening from outside module)	Stainless steel	10' x 14' (3.05m x 4.27m)

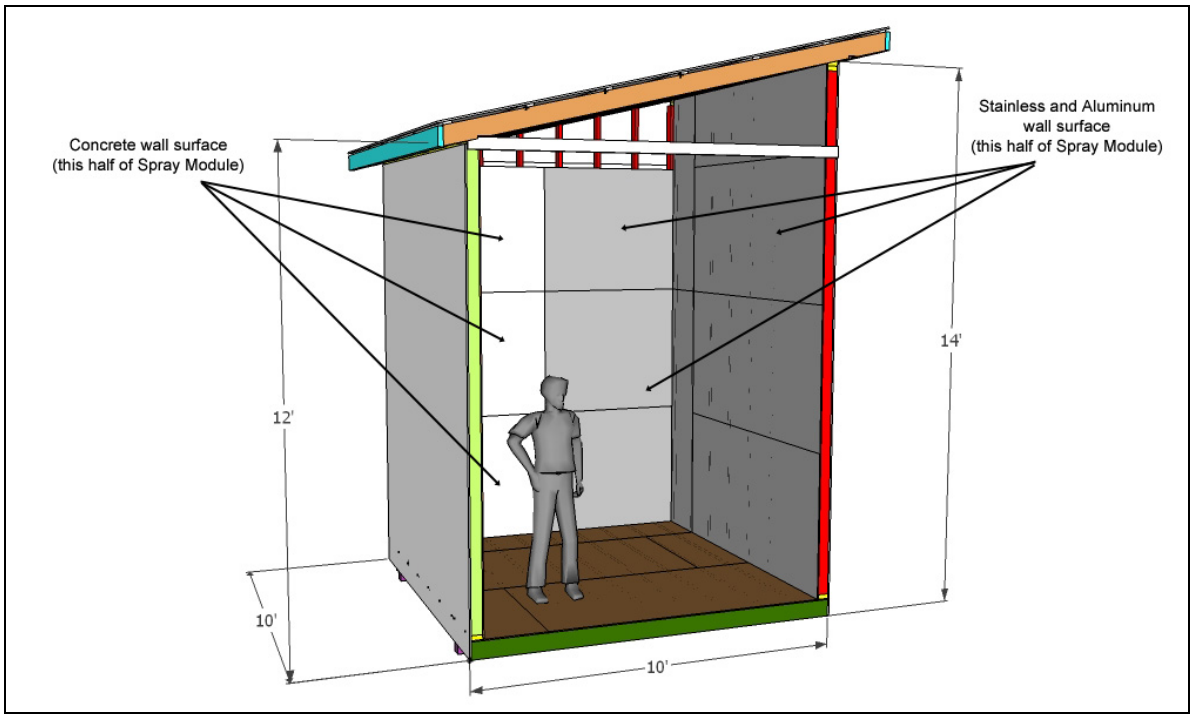

Fig. 1. 3-dimension diagram of the building module mockup design.

2. At the conclusion of the technology demonstration, the equipment was taken apart to document which parts are removable and what can not be reached for cleaning (decontamination).

    a. The need for equipment and personnel decontamination is highly field site – specific and requires consideration of the following factors:
        i. types of onsite contaminants
        ii. levels of contamination
        iii. personal protection levels utilized
        iv. work activities performed
        v. evaluation/testing parameters

    b. The test “decontamination” procedures were performed on all equipment and accessories that entered the building module.

    c. The decontamination consisted of the following:
        i. overall equipment clean up steps
        ii. equipment disassembly steps
        iii. equipment and accessories clean up
        iv. equipment’s cable removal & clean up
        v. collection/disposal of waste and consumables
        vi. PPE disposal/cleanup
        vii. clean up material collection/disposal

TEST SITE DESCRIPTION

The ICM facility is located at 630 Elmira Road in Ithaca, NY. ICM constructed an outdoor building module as shown in Figure 1 and installed panels of concrete and stainless steel on the interior walls. The building module is 10-ft wide x 10-ft deep x 12-14-ft high (3.05m wide x 3.05m deep x 3.66m to 4.27m high) and has one side open for observation (Figure 2). The technology demonstration was conducted under standard non-nuclear conditions.

ICM provided all utilities and services, such as water, power, phone, and sanitation services at the work location. Specifically, ICM provided the following for the technology demonstration:

1) Compressed air - 375 CFM (10.5 m^3/min) at 110 PSI (758,423 Pa)
2) Electric - 110 volts 20 amp service to operate:
   a. Climber with onboard vacuum and control station
   b. Sprayer
3) Trash disposal of items generated during demonstration
4) Collection and disposal of secondary waste generated by the technology
5) Strippable coating products for the demonstration

Fig. 2. Building module at ICM facility.

TECHNOLOGY DESCRIPTION

ICM climbers are small, remote-controlled, easily deployable, lightweight climbing machines with big payload capabilities. The machines can climb walls, ceilings or rounded surfaces. The inherent benefit is the patented seal that allows these lightweight climbers to climb over surface obstacles, uneven surfaces and surface contours, making them unlike any other climber. The machines weigh approx 30 pounds (13.61 kilograms) yet have a pull off strength of over 225 pounds (102.06 kilograms). Plus, the machines are reliable, robust and easy to operate. The climbers also have interchangeable attachments so the same climber can be used for an array of

missions by manually connecting the appropriate accessory. Held to the surface by vacuum force, the machines adhere to essentially any hard surface: metal, concrete, brick, etc. The patented, highly flexible seal ensures the machine is securely adhered as it moves the machine over surface obstacles such as bolt heads, plates, weld seams or virtually any surface irregularity.

The ICM climbing machines are remotely controlled by an operator from a control station, allowing the machine to access areas unsafe for manual D&D activities. For the purposes of this technology demonstration, the ICM climber was modified with a spray applicator. The following technology description of the climber, the technical specifications shown in Table II, and Figure 3 were obtained from the ICM Climbing Machine operations manual and the ICM website at http://www.icm.cc [3 and 4].

Table II. ICM Climber Specifications [3,4]

Primary Materials of Construction:	Carbon fiber / advanced composites
Climbing Machine Weight:	30 lbs (13.61 kg)
Width of Climber:	24 inches (0.61m)
Length of Climber:	24 inches (0.61m)
Height of Climber:	8 inches(0.20m)
Rate of travel:	2.5 - 3 inches/second (0.06 – 0.08 m/s)
Pull-Off Strength:	225 lbs (102 kg)
Power (Adhesion Vacuum):	24 Volt DC/110 Volt AC/15 amp

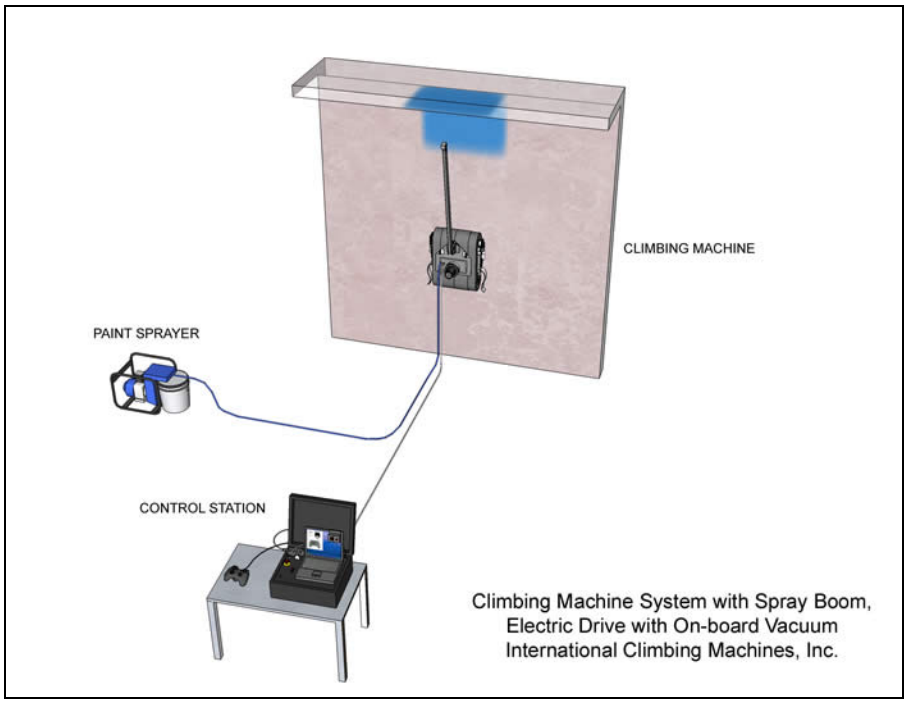

Fig. 3. ICM climber set-up [3,4].

The products sprayed include CC Strip (InstaCote Inc.), ALARA 1146 (Carboline), and DeconGel (CBI Polymers). Table III provides the manufacturer information for each product [5, 6, and 7].

Table III. Manufacturer Information for Strippable Coatings and Decontamination Gel

Product Manufacturer	Product Brand	Name of Product	Coverage (ft^2/gal)	Cost ($/gal)
Instacote Inc.	InstaCote	CC Strip	320 (8m^2/liter)	99 ($26.16/liter)
Williams Power Co.	Carboline	ALARA 1146	26 at 25 mils	105 ($27.74/liter)
CBI Polymers	DeconGel	1121 Spray	25-75 (0.627-1.875 m^2/liter)	170 ($44.91/liter)

CC Strip is described by its manufacturer as a removable high solids, latex based product designed for application to surfaces contaminated with beryllium, asbestos, radiological nucleotides (plutonium, uranium) or any other toxic or problematic particulate. CC Strip is applied as a liquid (brushed, rolled, or sprayed), cures to a clear, highly elastic coating which is removed by peeling. Loose contamination is encapsulated in the CC Strip and removed when it is peeled off. CC Strip is water-based, non-toxic, non-hazardous, non-flammable and will not support biological growth [5].

ALARA 1146 is a waterborne vinyl-based strippable decontamination coating. According to the manufacturer, it may be applied to a contaminated surface and the product will attract and bind with surface contaminants. Upon curing, the product mechanically locks the contaminants into a polymer matrix. Removal of the film decontaminates the substrates and produces a solid waste [6].

DeconGel 1121 Spray is a one component, water-based, sprayable, and peelable decontamination hydrogel. It is recommended by the manufacturer for decontamination of radioisotopes as well as particulates, heavy metals, water-soluble and insoluble organic compounds. The hydrogel coating can be applied to most surfaces and when dry, the product locks the contaminants into a polymer matrix. The film containing the encapsulated contamination can then be peeled and disposed [7].

RESULTS AND ANALYSIS

The technology demonstration was performed from June 24 to June 25, 2010. The technology was evaluated on its ability to apply three different strippable coatings to concrete and stainless steel panels. The products sprayed include CC Strip (InstaCote Inc.), ALARA 1146 (Carboline), and DeconGel (CBI Polymers).

The technology evaluation demonstrated the ability of the remote system to spray strippable coatings and decontamination gels on vertical concrete and stainless steel surfaces. Table IV lists the products used during the demonstration along with the surfaces and area coated with each. With the climbing machine positioned on the wall, the 4-foot (1.22m) boom attachment was capable of spraying to a height of 10-feet (3.05m) with no additional fall protection measures. The climbing machine sprayed the top approximately 4 feet (1.22m) of the wall while positioned on the wall. From the floor, the climbing machine was then able to coat the lower 6-feet (1.83m) of wall.

Table IV. Strippable Coatings Used During the Technology Demonstration

Product Brand	Name of Product	Surface Coated	Surface Area Coated (sq ft)/(sq m)
InstaCote	CC Strip	Concrete panel	40/3.72
InstaCote	CC Strip	Stainless steel panel	25/2.325
Carboline	ALARA 1146	Concrete panel	25/2.325
Carboline	ALARA 1146	Stainless steel panel	40/3.72
DeconGel	1121 Spray	Concrete panel	40/3.72
DeconGel	1121 Spray	Stainless steel panel	40/3.72

Table V below provides the product coverage achieved during the technology demonstration. It should be noted that maximizing the coverage per gallon was not an objective of the demonstration. Instead, remotely achieving a coating capable of being readily stripped from the surface once dry and minimizing missed or thinly coated surfaces was an overriding factor. The custom spraying attachment to the remote control climber was successful in achieving this goal.

Table V. Coverage of Strippable Coatings

Product	Total Surface Area Coated	Product Consumed	Wet Film Thickness	Actual Coverage
CC Strip	65 sq ft (6.045 sq m)	1.5 gal (5.67L)	10-30 mil	43 sq ft/gal (1.075 sq m/L)
ALARA 1146	65 sq ft (6.045 sq m)	1.25 gal (4.73L)	10-20 mil	52 sq ft/gal (1.3 sq m/L)
DeconGel	80 sq ft (7.44 sq m)	2 gal (7.57L)	16-35 mil	40 sq ft/gal (1 sq m/L)

Table VI provides a comparison of the spraying rate of the 3 products used during the demonstration. The surface area coated with each product was divided by the total time that product was being sprayed to calculate the spraying rate. These spraying rates do not include

break times and so illustrate the rate during active spraying. The rates do include the time required by the technology to position itself and climb the walls. Figure 4 shows the ICM climber as it sprays each of the three products to the building module walls as well as the products being stripped away from the wall surfaces once dry.

Table VI. Spraying Production Rate Achieved During Demonstration

Product	Surface Area Coated	Total Spraying Time	Spraying Rate
CC Strip	65 sq ft / 6.045 sq m	21 min	3.1 sq ft/min (0.2883 sq m/min)
ALARA 1146	65 sq ft / 6.045 sq m	13 min	5.0 sq ft/min (0.465 sq m/min)
DeconGel	80 sq ft / 7.44 sq m	21 min	3.8 sq ft/min (0.3534 sq m/min)






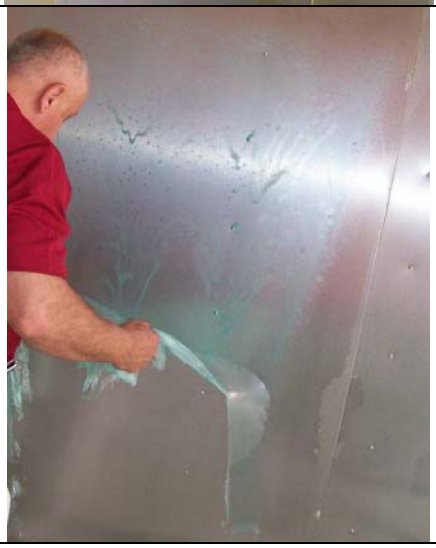

Fig. 4. Wet coatings being applied remotely by sprayer (left) and dry coatings being stripped manually (right): CC Strip on concrete panel (top), ALARA 1146 on steel panel (middle), and DeconGel on steel panel (bottom).

Table VII provides a comparison of the strippable coating/decontamination gel products used during the demonstration. Overall, the three products sprayed well and were relatively easy to strip, once dry, from the stainless steel and sealed concrete panels. In addition, drying time affects the ease with which the products strip away from the surface. Areas of product that were still damp after 24 hours of drying time continued to adhere to the surface, creating holes in the dry product that was stripped away. On the other hand, leaving the product to cure for a week caused the DeconGel to become more brittle and papery, leading to tearing of the coating at thin sections. Finally, for all three products, areas of product overspray were difficult to remove.

Table VII. Comparison of Product Characteristics

Product	Product Description and Consistency (wet)	Result after spraying (wet)	Result after spraying (dry)
CC Strip – HV Green	Yellow, consistency of thin whipped cream	Applied with fair uniformity, ~ 10 mil in thin areas and ~25 mil in thick areas	Peeled very easily in one continuous sheet from the metal panel. Peeled in one mostly continuous sheet from the sealed concrete panel; requires more force to remove from concrete than metal. Some heavy drips were not cured after 24 hours and did not form the film.
ALARA 1146	Orange, consistency of liquid plastic	Very uniform application on metal panel (~20 mil). Good application on concrete panel (mostly ~10-13 mil with some thin areas ~7 mil).	Peeled very easily from the metal panel, even discontinuities and bare spots did not cause the film to rip. Harder to remove off concrete, mostly peeled as a uniform sheet except for thin areas which had some rips.
DeconGel	Blue, consistency of liquid gel	Varying application on metal panel, ~16 to 35 mil. More difficult to judge thickness while spraying due to the clear appearance of the gel. ~20-35 mil thickness on concrete panel.	Removed easily from the metal panel; ripped at thinnest sections. Peeled fairly easily from concrete, harder to remove than from metal, tearing at thin sections.

At the conclusion of the demonstration, the equipment was taken apart to document which parts are removable and what can not be reached for cleaning/decontamination. If used in a

radioactively contaminated environment, the rollers and tracks would be cut off and disposed since the foam material is not conducive to decontamination. The cables and hoses in the tether (e.g., electronic input line, main air hose, and retrieval cable) could be wiped/ decontaminated as an alternative to disposing of the entire tether. The two climbing machine drive chains would be difficult to confirm as clean and would likely be disposed. The main body of the climber consists of a carbon fiber chassis, aluminum or resin drive shafts and spindles, an onboard vacuum, a vacuum chamber, and an internal box for electronics. The body could be wiped/ decontaminated but may be difficult to free-release due to the difficulty in confirming that the contamination did not enter the climber through the openings for the drive shafts and spindles, air hose, etc.

The technology was evaluated for 16 health and safety categories and a risk rating was applied to each, as shown in Table VIII. Twelve of the categories were either not applicable to this technology or received a risk rating of 1, hazard may be present but not expected over background levels. The remaining categories received a rating of 2, some level of hazard above background level known to be present. These categories included pressure hazards, tripping and falling (from the trailing tether), noise (from accessory equipment – air compressor, and airless sprayer), and inhalation (from the product being sprayed).

Table VIII. Health and Safety Risk Ratings for Technology

Health & Safety Category	Health & Safety Rating & Explanation
Electrical	1 - Hazard may be present but not expected over background levels
Fire/Explosion	1 - Hazard may be present but not expected over background levels
Confined Space Entry	0 - Not applicable to this technology
Mechanical Hazards	1 - Hazard may be present but not expected over background levels
Pressure Hazards	2 – Technology uses vacuum pressure to adhere to vertical wall surface, the machine weights approximately 30 lbs/13.6kg and has a pull off strength (when vacuum is being applied) of over 225 lbs/102kg
Tripping and Falling	2 – Technology requires a trailing tether which could pose a tripping hazard
Moving Vehicles	0 - Not applicable to this technology
Protruding Objects	1 - Hazard may be present but not expected over background levels
Overhead Lifts	0 - Not applicable to this technology
Inhalation	2 – Inhalation hazard is not applicable to the climber itself; the inhalation hazard for the climber as used as a coating sprayer platform would depend on the product being sprayed
Skin Absorption	1 - Hazard may be present but not expected over background levels
Heat Stress	0 - Not applicable to this technology
Noise	2 – The climber itself operates with little noise but requires the use of an adhesion vacuum, air compressor, and an airless sprayer (when used as a coating sprayer platform), all of which produce noise above background levels
Cold Stress	0 - Not applicable to this technology
Ergonomic Hazards	1 - Hazard may be present but not expected over background levels
Particulate Emissions	1 - Hazard may be present but not expected over background levels

Approximate cost per gallon for the products used are as follows: $99/gal or $26.16/ liter for CC Strip, $105/gal or $27.74/liter for ALARA 1146, and $170/gal or $44.91/liter for DeconGel. Table IX provides the cost of the strippable coatings and decontamination gel per unit area using

the actual coverage achieved during the demonstration. The ICM climber technology can be purchased for approximately $110K.

Table IX. Cost of Products Per Unit Area

Product	Actual Coverage	Product Cost	Coverage Cost
CC Strip	43 sq ft/gal (1.075 sq m/L)	$99/gal ($26.16/liter)	$2.30/sq ft ($24.73/sq m)
ALARA 1146	52 sq ft/gal (1.3 sq m/L)	$105/gal ($27.74/liter)	$2.02/sq ft ($21.72/sq m)
DeconGel	40 sq ft/gal (1 sq m/L)	$170/gal ($44.91/liter)	$4.25/sq ft ($45.7/sq m)

CONCLUSION

Overall, the technology was capable of successfully achieving the objectives of this demonstration. It was able to travel across the floor and climb-up the walls unassisted while being controlled remotely by the operator. The technology sprayed strippable coatings and a decontamination gel to the vertical wall surfaces of concrete and stainless steel. A sufficient thickness of each product was achieved to promote the ability of the product to be stripped from the surface once dry. While the dry coatings were manually stripped during this demonstration, future research with the technology will address the ability to remotely remove the coatings as well.

Twelve (12) of the 16 health and safety categories were either not applicable to this technology or received a risk rating of 1, indicating that the hazard may be present but not expected over background levels. The remaining categories that received a rating of 2 (some level of hazard above background level known to be present) included pressure hazards, tripping and falling (from the trailing tether), noise (from accessory equipment – air compressor, and airless sprayer), and inhalation (from the product being sprayed).

A few challenges were encountered during the demonstration. The new smooth surfaces of the metal panels had a tendency to allow extra thick coatings to pull away from the surface before it dried. The coating would run down the wall, leaving gaps of coverage on the wall. Aged surfaces exhibiting normal wear is not expected to have this problem. This only occurred where multiple spraying passes were made (overlapping passes with the sprayer).

In addition, line of sight is needed to operate the technology. Where direct line-of-sight by the operator is not possible, at least two cameras spaced apart would be needed to adequately view and operate the technology.

Minimal tether management was needed during the demonstration (providing more tether and removing excess tether) and was achieved from outside the module. In addition, no clogging was encountered during the demonstration although the operator reported that clogging of the spray

tip can occur if there is significant down time with no spraying.

ICM performed preliminary testing using the strippable coating/decontamination gel products with varying nozzles, sprayer models, and sprayer pressures to optimize spraying performance. It is recommended that any new product be tested thoroughly with the equipment prior to being used in a radioactive environment.

The results of this demonstration, including this technology demonstration report and additional photographs and videos taken during the demonstration will be made available to the general D&D community through the FIU/DOE D&D Knowledge Management Information Tool located on the web at www.dndkm.org.

ACKNOWLEDGEMENTS

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