Application and Removal of Strippable Coatings via Remote Platform – 13133

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ABSTRACT

Florida International University's (FIU's) Applied Research Center is currently supporting the Department of Energy (DOE) Environmental Management Office of D&D and Facility Engineering program. FIU is supporting DOE's initiative to improve safety, reduce technical risks, and limit uncertainty within D&D operations by identifying technologies suitable to meet specific facility D&D requirements, assessing the readiness of those technologies for field deployment, and conducting feasibility studies and technology demonstrations of selected technologies and working with technology vendors to optimize the design of their current technologies to accomplish dangerous and demanding tasks during D&D operations.

To meet one identified technology gap challenge for a technology to remotely apply strippable coatings, fixatives and decontamination gels, FIU identified and performed an initial demonstration of an innovative remote fixative sprayer platform from International Climbing Machines (ICM). The selected technology was demonstrated spraying fixative products at the hot cell mockup facility at the Applied Research Center at FIU in November 2008 under cold (non-radioactive) conditions. The remotely controlled platform was remotely operated and entered the facility and sprayed a fixative onto horizontal and vertical surfaces. Based on the initial FIU demonstration and the specific technical requirements identified at the DOE facilities, a follow-up demonstration was expanded to include strippable coatings and a decontamination gel, which was demonstrated in June 2010 at the ICM facility in Ithaca, NY. This second technology evaluation documented the ability of the remote system to spray the selected products on vertical stainless steel and concrete surfaces to a height of 3 meters (10 feet) and to achieve sufficient coverage and product thickness to promote the ability to peel/remove the strippable coatings and decontamination gel. The next challenge was to determine if a remote platform could be used to remove the strippable coatings and decontamination gels. In 2012, FIU worked with the technology provider, ICM, to conduct feasibility and trade studies to identify the requirements for the remote removal of strippable coatings or decontamination gels using the existing remote controlled platform.

INTRODUCTION

Many facilities slated for D&D across the DOE complex pose hazards (radiological, chemical, and structural) which prevent the use of traditional manual techniques for performing D&D activities. These facilities will require the use of remotely operated technologies to safely and efficiently perform D&D. In addition, the D&D of a radioactive facility often requires that 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 typical step in the D&D process consists of applying a fixative or strippable coating to stabilize or remove loose contamination before demolition.

To meet the technology gap challenge for a technology to remotely apply strippable coatings, fixatives and decontamination gels, FIU identified and performed an initial demonstration of an innovative remote fixative sprayer platform from International Climbing Machines (ICM). The selected technology was demonstrated spraying fixative products at the hot cell mockup facility at the Applied Research Center at Florida International University (FIU) in November 2008 under cold (non-radioactive) conditions. Based on the initial FIU demonstration and the specific technical requirements identified at the DOE facilities, a follow-up demonstration was expanded to include strippable coatings and a decontamination gel, which was demonstrated in June 2010 at the ICM facility in Ithaca, NY. The next challenge was to determine if a remote platform could be used to remove the strippable coatings and decontamination gels.

FIU worked with the technology provider, ICM, to conduct feasibility and trade studies to identify the requirements for the remote removal of strippable coatings or decontamination gels using the existing remote controlled platform. The initial feasibility study entailed analyzing the technical challenges of developing such a device as well as trade studies/bench-scale testing to study and test various potential tools and mechanisms that can be integrated with the remote platform. The preliminary testing served as proof-of-concept that the tools are capable of removing a strippable coating. Since strippable coatings are typically removed by hand, this step was needed to help determine candidate tools that could work via remote control. The tools were further evaluated using factors such as size and weight, motor or electricity usage, and complexity of movement to determine a reasonable mechanism for integrating the tool with the ICM platform.

Remotely operated technologies have proven to be an effective means of protecting workers and minimizing exposure in hostile environments during D&D activities. A technology platform to perform the remote application and removal of decontamination gels and strippable coatings will meet a high-priority need for facilities across the DOE complex.

DESCRIPTION

Technology Description

Potential technologies and technology providers (vendors) were researched via: (1) FIU D&D technology databases, (2) internet search, (3) subject matter experts, and (4) professional conferences and forums. ICM was selected for the technology demonstrations based on their work experience in nuclear decontamination, technology capabilities, and previous technology demonstrations.

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 13.6 kg (30 pounds) yet have a pull off strength of over 102 kg (225 pounds). 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. 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. Table I provides the climber specifications and Figure 1 shows the ICM climber set-up for spraying.

Table I. ICM Climber Specifications

Primary Materials of Construction	Carbon fiber / advanced composites
Climbing Machine Weight	13.6 kg (30 lbs)
Width of Climber	61 cm (24 inches)
Length of Climber	61 cm (24 inches)
Height of Climber	20 cm (8 inches)
Rate of travel	6.3 – 7.6 cm/sec (2.5 - 3 inches/second)
Pull-Off Strength	102 kg (225 lbs)
Power (Adhesion Vacuum)	24 Volt DC/110 Volt AC/15 amp

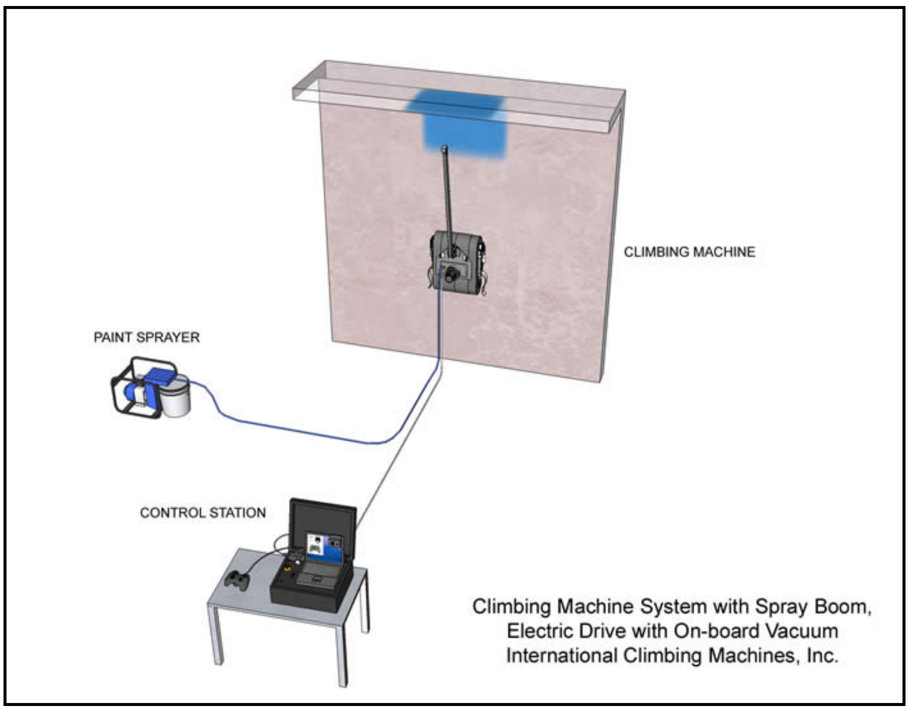

Fig. 1. ICM climber set-up for spraying.

Remote Application of Fixatives

A hot cell mockup was built at the FIU Applied Research Center Technology Assessment Facility for the remote fixative application technology demonstration. The hot cell mockup facility is similar in size, construction materials, and points of access to those found around the DOE complex. The hot cell mockup is 3-m wide x 6-m long x 3-m high (10-ft x 20-ft x 10-ft) and has an entry point at one end as well as a window in the side. In addition, two round port holes were constructed right above the window for future adaptation of a robotic manipulator. The walls were constructed from poured concrete and Plexiglas was subsequently installed over the window. Figure 2 shows the hot cell mockup facility right after construction.

Fig. 2. Hot cell mockup facility at FIU ARC's outdoor Technology Assessment Facility.

Testing of the ICM climber technology with a custom spray applicator was conducted to demonstrate "proof-of-concept" under conditions similar to those actually found in a DOE hot cell facility. Objects commonly found in hot cells were incorporated into the mockup hot cell during the demonstration and included items such as a work table, ladder, conduit, 189-liter (50-gallon) drum, and a mounted electrical box. This work constituted an experimental, initial phase of method evaluation. The technology demonstration was conducted under standard non-nuclear conditions.

The testing protocol included the following:

1. Trial-runs of the ICM climber into and through the hot cell mockup from the side entry point to gain familiarity with the mockup design by the operators, to ascertain that the technology could remotely gain entry into the hot cell mockup, and to determine how much of the hot cell interior was accessible to the technology. This trial run was also used to work out any logistical requirements of the technology (e.g., how to handle

trailing electrical cords, objects inside hot cell – waste drum, work table, electrical box with conduit mounted on one wall). In addition, a setup area was installed by the side entry point. This setup area acted as the buffer zone between "clean" and "contaminated" areas. The buffer area consisted of a radiological tent.

2. Testing of the spraying mechanism outside of the hot cell mockup. The fixative was prepared according to the manufacturer technical data and application instructions.

3. Demonstration of the technology utilizing the custom fixative spraying attachment in the hot cell mockup. This demonstration was performed from the side entry point and the surfaces sprayed included 3 walls (excluding the entry point wall where the cameras were mounted), the ceiling and the floor surface within the hot cell mockup.

4. At the conclusion of the technology demonstration, the equipment was taken apart and "decontaminated" with Simple Green (or equivalent) and disposable wipes. This task was performed to document which parts are removable and what can not be reached for cleaning (decontamination).

Remote Application of Strippable Coatings and Decontamination Gel

Based on the initial FIU demonstration with fixatives and the specific technical requirements identified at the DOE facilities, a follow-up demonstration was expanded to include strippable coatings and a decontamination gel. 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.

The ICM facility is located at 630 Elmira Road in Ithaca, NY. ICM constructed an outdoor building module as shown in Figure 3 and installed panels of concrete and stainless steel on the interior walls. The building module is 3-m wide x 3-m deep x 3.7-4.2 high (10-ft wide x 10-ft deep x 12-14-ft high) and has one side open for observation. The technology demonstration was conducted under standard non-nuclear conditions.

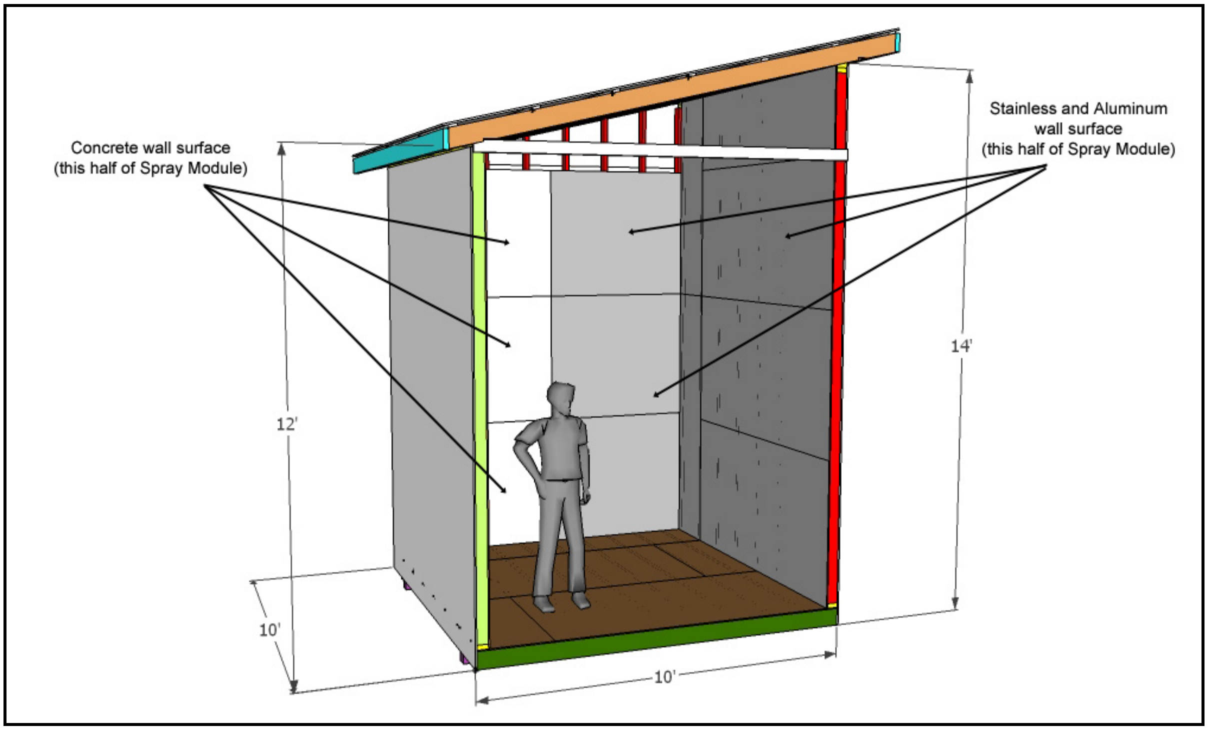

Fig. 3. Diagram of the building module mockup design.

The testing protocol included the 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. Each of the products was applied to both concrete and stainless steel panels up to a height of 3 meters (10 feet). The products sprayed include CC Strip (InstaCote Inc.), ALARA 1146 (Carboline), and DeconGel (CBI Polymers). Table II provides the manufacturer information for each product.

Table II. 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	99
Williams Power Co.	Carboline	ALARA 1146	26 at 25 mils	105
CBI Polymers	DeconGel	1121 Spray	25-75	170

Remote Removal of Strippable Coatings

After successfully demonstrating the ability to remotely apply fixatives and strippable coatings, the next challenge was to determine if a remote platform could be used to remove the strippable coatings and decontamination gels. FIU and ICM partnered to conduct feasibility and trade studies to identify the requirements for the remote removal of strippable coatings using the existing remote controlled platform. The initial feasibility study entailed analyzing the technical challenges of developing such a device as well as trade studies/bench-scale testing to study and test various potential tools and mechanisms that can be integrated with the remote platform. The preliminary testing served as proof-of-concept that the tools are capable of removing a strippable coating. Since strippable coatings are typically removed by hand, this step was needed to help determine candidate tools that could work via remote control. The tools were further evaluated using factors such as size and weight, motor or electricity usage, and complexity of movement to determine a reasonable mechanism for integrating the tool with the ICM platform.

DISCUSSION

Remote Application of Fixatives

The technology demonstration for the remote application of fixatives was performed in November 2008. The selected technology platform was expected to remotely enter a hot cell mockup facility and spray a fixative that would be capable of immobilizing loose/removable radioactive contamination.

Trial-runs of the ICM climber into and through the hot cell mockup from the side entry point were first performed to gain familiarity with the mockup design by the operators, to ascertain that the technology can remotely gain entry into the hot cell mockup, and to determine how much of the hot cell interior is accessible to the technology. This trial run was also used to work out logistical requirements of the technology (e.g., how to handle trailing electrical cords, objects inside hot cell: 180-liter (50-gallon) drum, work table, mock electric box and cable, etc.). The climber had no difficulties in entering the hot cell mockup remotely from the adjacent radiation tent "buffer zone", traveling around the drum and work table on the floor, transitioning onto the concrete walls, and climbing up the walls to the ceiling.

Prior to the demonstration, fixative products typically used inside hot cells were investigated for potential remote application. The technology evaluation demonstrated the ability of the remote system to spray fixative products on horizontal and vertical concrete surfaces. Table III lists the fixatives used during the demonstration along with the surfaces and area coated with each, the actual coverage achieved, and the spraying rate. With the climbing machine on the wall surface, the 1.2-m (4-ft) boom attachment to the climbing machine was capable of spraying to the mid-point of the ceiling surfaces [1.5 m (5 ft) from the wall] and the top approximately 1.2 m (4 ft) of the wall. From the floor, the climbing machine was then able to coat the lower 6-feet (1.8 m) of wall as well as the floor surface. Figure 4 shows the ICM climber as it began to spray Promar 200 to the hot cell mockup ceiling and the climber spraying the wall with PBS.

Table III. Fixatives Used During the Technology Demonstration

Product Manufacturer, Product Name, and Product Type	Surfaces Coated	Surface Area Coated	Product Consumed	Actual Coverage	Spraying Rate
Sherwin Williams Promar 200 (latex paint)	Ceiling, walls	27.3 m^2 (294 sq ft)	17 L (4.5 gal)	1.6 m^2/L (65 sq ft/gal)	0.32 m^2/min (3.4 sq ft/min)
Sherwin Williams Direct to Metal (DTM) (100% acrylic coating)	Ceiling, walls, floor	58.2 m^2 (627 sq ft)	41.6 L (11 gal)	1.4 m^2/L (57 sq ft/gal)	0.36 m^2/min (3.9 sq ft/min)
Bartlett Services, Inc. Polymeric Barrier System (PBS) (non-toxic water-based solution to form an impermeable barrier)	Ceiling, walls	10.0 m^2 (108 sq ft)	7.6 L (2 gal)	1.3 m^2/L (54 sq ft/gal)	0.40 m^2/min (4.3 sq ft/min)

Fig. 4. ICM climber applying Promar 200 to ceiling (left) and PBS to wall (right).

Remote Application of Strippable Coatings and Decontamination Gel

The technology demonstration for the remote application of strippable coatings and decontamination gel was performed in June 2010. The technology was evaluated on its ability to apply three different strippable coatings to concrete and stainless steel panels. With the climbing machine positioned on the wall, the 1.2-m (4-foot) boom attachment was capable of spraying to a height of 3-meters (10-feet) with no additional fall protection measures. The climbing machine sprayed the top approximately 1.2 m (4 feet) of the wall while positioned on the wall. From the floor, the climbing machine was then able to coat the lower 1.8-meters (6-feet) of wall.

Table IV provides the products used, product coverage achieved during the technology demonstration, and spraying rate. Remotely achieving a coating capable of being readily stripped from the surface once dry and minimizing missed or thinly coated surfaces was an overriding objective. The custom spraying attachment to the remote control climber was successful in achieving this goal.

Table IV. Coverage of Strippable Coatings

Product	Total Surface Area Coated	Product Consumed	Wet Film Thickness	Actual Coverage	Spraying Rate
InstaCote CC Strip	6 m^2 (65 sq ft)	5.7 L (1.5 gal)	10-30 mil	1.1 m^2/L (43 sq ft/gal)	0.29 m^2/min (3.1 sq ft/min)
Carboline ALARA 1146	6 m^2 (65 sq ft)	4.7 L (1.25 gal)	10-20 mil	1.3 m^2/L (52 sq ft/gal)	0.46 m^2/min (5.0 sq ft/min)
DeconGel 1121 Spray	7.4 m^2 (80 sq ft)	7.6 L (2 gal)	16-35 mil	1.0 m^2/L (40 sq ft/gal)	0.35 m^2/min (3.8 sq ft/min)

Figure 5 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.

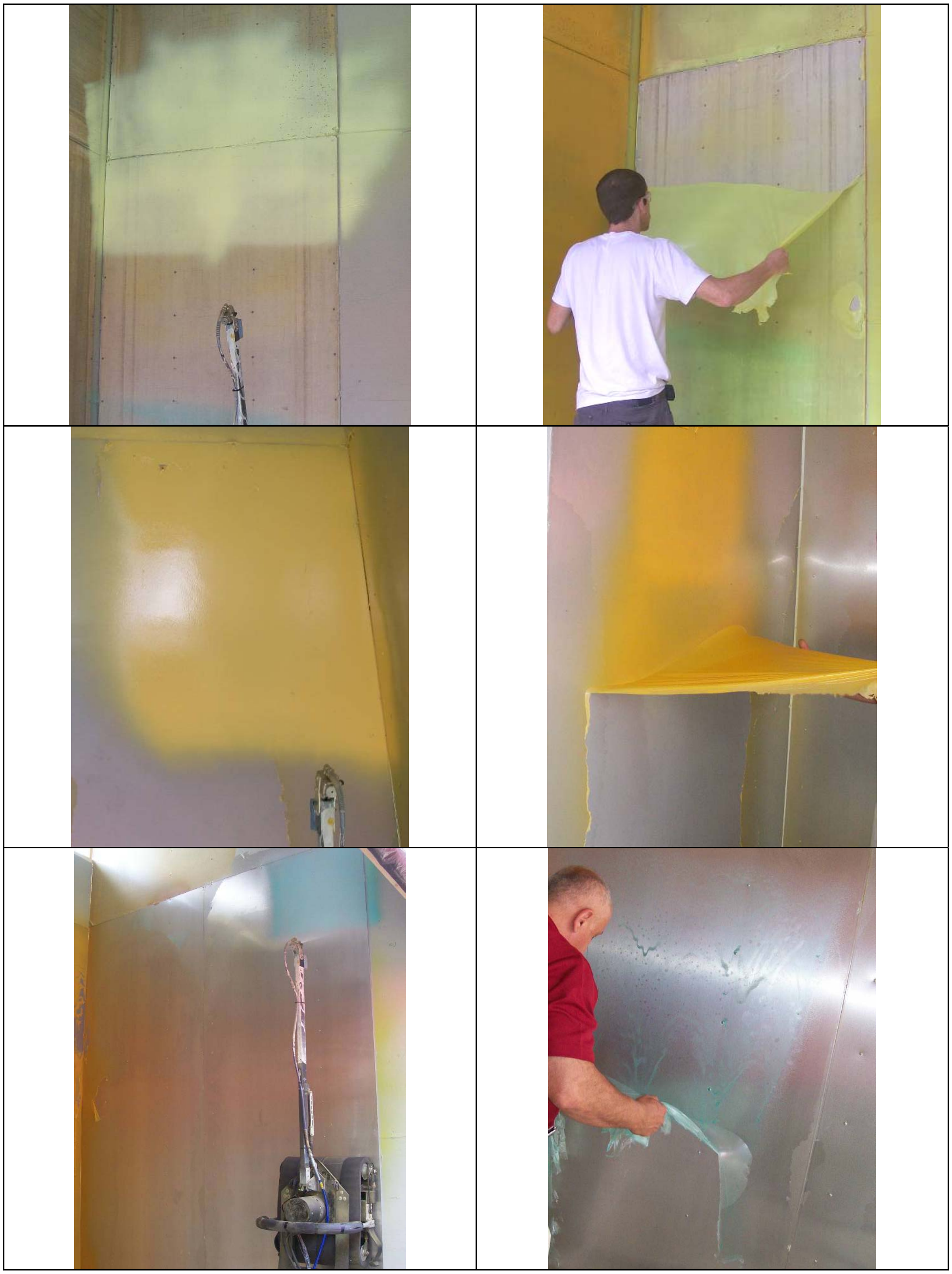

Fig. 5. Coatings being applied remotely by sprayer (left) and dry coatings being stripped manually (right): CC Strip on concrete panel (top), ALARA 1146 on steel panel (middle), and DeconGel on steel panel (bottom).

Table V 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 V. 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.

Remote Removal of Strippable Coatings

To initiate the feasibility study, suitable tools for remote removal of strippable coating were researched and identified. After considerable discussion and fundamental testing with the various strippable coatings, two approaches were identified that merited further investigation: a scraper/gripper combination tool and a stiff-cylindrical-brush/vacuum. Preliminary bench-scale testing of these two tools and approaches were performed.

The scrapper/gripper is a combination tool comprised of a scraper element and a gripper, to get under the coating then grab the coating that has been pulled up by the scrapper element (Figure 6). This approach closely resembles what a human does to manually strip off the coating. A conceptual evaluation determined that a remote-controlled end-effector for this tool could be attached to an ICM Climber to use this approach. Bench testing verified this.

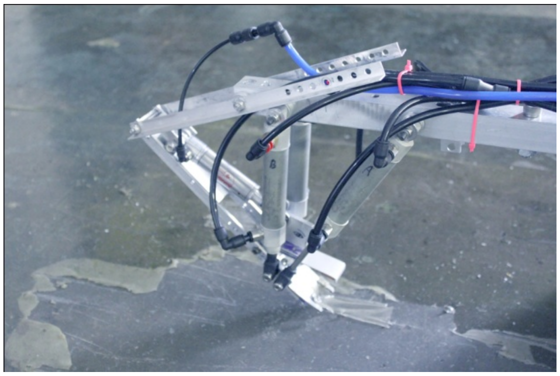

Fig. 6. Scraper/gripper tool.

A stiff bristled cylindrical brush and attached vacuum collection unit was also considered (Figure 7). The stiff bristled cylindrical brush breaks up the cured coating and the attached vacuum collection unit collects the loose particles. The brush is in a shroud and the coating is immediately vacuumed up within the shroud with the attached vacuum collection unit. A small bench scale prototype was developed to establish that this method could be feasible.

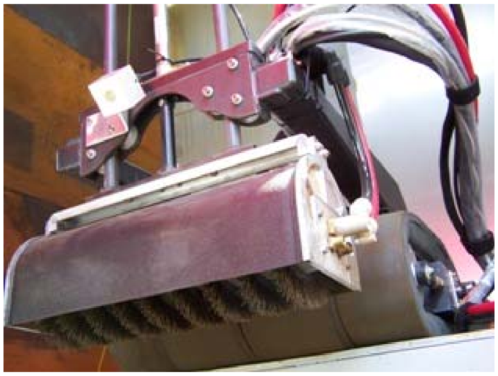

Fig. 7. Cylindrical brush with vacuum shroud.

CONCLUSIONS

Overall, the technology was capable of successfully achieving the objectives of the fixative and strippable coating application demonstrations. It was able to remotely enter the demonstration facilities, travel across the floor and climb the walls unassisted while being controlled remotely by the operator, and spray a coating of a variety of fixatives, strippable coatings, and decontamination gel to the vertical and horizontal surfaces.

One window and 2 video cameras were used to allow the operator to view the technology during the fixative demonstration and direct line-of-sight was used during the strippable coating demonstration. Where direct line-of-sight is limited, two cameras spaced apart or mobile cameras capable of being controlled remotely would be a tremendous benefit to the implementation of this technology.

In addition, preliminary testing using the fixative, strippable coating, or decontamination gel with varying nozzles, sprayer models, and sprayer pressures is recommended 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 preliminary studies of the technology for remote removal of strippable coatings appear promising. Future work on the remote removal of strippable coatings will look at expanding the study to include the design, fabrication, and technology evaluation activities necessary to modify the ICM platform to demonstrate the remote removal of multiple types of strippable coatings and decontamination gels from horizontal and vertical surfaces.

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