D&D Toolbox Project - Technology Demonstration of Fixatives Applied to Hot Cell Facilities via Remote Sprayer Platforms – 9097

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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 at FIU-ARC facilities in Miami, Florida. To meet the technology gap challenge for a technology to remotely apply strippable/fixative coatings, FIU-ARC identified and demonstrated of a remote fixative sprayer platform. During this process, FIU-ARC worked closely with the Oak Ridge National Laboratory in the selection of typical fixatives and in the design of a hot cell mockup facility for demonstrations at FIU-ARC. For this demonstration and for future demonstrations, FIU-ARC built a hot cell mockup facility at the FIU-ARC Technology Demonstration/Evaluation site in Miami, Florida.

FIU-ARC selected the International Climbing Machines' (ICM's) Robotic Climber to perform this technology demonstration. The selected technology was demonstrated at the hot cell mockup facility at FIU-ARC during the week of November 10, 2008. Fixative products typically used inside hot cells were investigated and selected for this remote application [1]. The fixatives tested included Sherwin Williams' Promar 200 and DTM paints and Bartlett's Polymeric Barrier System (PBS). The technology evaluation documented the ability of the remote system to spray fixative products on horizontal and vertical concrete surfaces. The technology performance, cost, and health & safety issues were evaluated during this technology demonstration.

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 hot cell facility normally requires that each of the hot cells 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 usually consists of applying a fixative coating (or similar material) to all hot cell surfaces to hold contamination in place during hot cell 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/fixative coatings. This gap between the identified needs and the available technologies is especially critical for hot cell 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 at FIU facilities.

To meet the technology gap challenge for a technology to remotely apply strippable/fixative coatings, FIU identified and demonstrated a remote fixative sprayer platform. FIU worked with the Oak Ridge National Laboratory and considered recommendations from the Savannah River Site (SRS) ALARA Center in the selection of typical fixatives [1] and designed a hot cell mockup facility for demonstrations at FIU. FIU built the hot cell mockup facility at the FIU technology demonstration/evaluation site in Miami.

The selected technology was demonstrated at the hot cell mockup facility in Miami. Fixative products typically used inside hot cells were investigated for potential remote application [1]. The technology evaluation documented the ability of the remote system to spray fixative product(s) on horizontal and vertical concrete surfaces. The technology performance, cost, and health & safety issues were evaluated during this technology demonstration.

MATERIALS AND METHODS

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, 50-gallon (189-liter) drum, and a mounted electrical box. This work constitutes an experimental, initial phase of method evaluation.

ARC evaluators (Test Engineer and DOE Fellows) were present at all times for the duration of the technology demonstrations to record performance data and take photographs and videos during the technology’s operation. A detailed technology demonstration test plan [3] was developed for this technology evaluation. During the demonstration, ARC evaluators 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 [3] were prepared containing a list of specific data that was collected and evaluated. In addition, a hardcover laboratory notebook was utilized to document the technology demonstration/evaluation along with digital photos and videos.

The technology vendor was responsible for providing operators for the technology equipment. 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 responsible for fuel, maintenance, and operation of the technology equipment.

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 – 50-gallon (189-liter) waste drum, work table, electrical box with ½-inch (1.27-cm) 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 performance was evaluated as per FIU's test plan [3]. The surfaces sprayed included 3 walls (excluding the entry point wall), the ceiling and the floor surface within the hot cell mockup. Table 1 describes the surfaces sprayed.

Table 1. Hot Cell Mockup Surfaces Sprayed With Fixatives

Surface	Description	Dimensions	Number of Fixative Coatings
Wall A	Pre-existing long wall	10' x 20' 3 m x 6 m	2 coats
Wall B	Pre-existing short wall	10' x 10' 3 m x 3 m	2 coats
Wall C	Newly constructed long wall with window	10' x 20 3 m x 6 m	1 coat
Wall D	Newly constructed short wall with entry door	10' x 10' 3 m x 3 m	0 coats (cameras were mounted to this wall)
Floor	Pre-existing floor	10' x 20' 3 m x 6 m	1 coat
Ceiling	Pre-existing ceiling	10' x 20' 3 m x 6 m	1 to 2 coats

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).

    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 hot cell mockup, as designated by the ARC Test Engineer.

c. The decontamination station was set up in the yellow PVC plastic buffer "tent" and 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 Applied Research Center at FIU uses its state-of-the-art facilities to conduct research and development, testing, evaluation, and validation for new and innovative technologies to support DOE and industry. ARC's headquarters, laboratories, and technology demonstration facilities are part of FIU's Engineering Center, a 243,000-square-foot (22,575 m^2) building that occupies 38 acres (0.15 km^2) in Miami, FL. ARC facilities include numerous specialized laboratories and facilities, including the outdoor Technology Assessment Facility were the hot cell was mockup was constructed for this demonstration (Figures 1 and 2). The technology demonstration was conducted under standard non-nuclear conditions.

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

1) Compressed air - 375 CFM (0.177 m^3/sec) at 110 PSI (7.7 kg/cm^2)
2) Electric - 110 volts 20 amp service. Three separate breakers were provided to operate:
    a. Climber and control station
    b. Vacuum
    c. Sprayer
3) Trash disposal of items generated during demonstration
4) Collection and disposal of secondary waste generated by the technology
5) Receiving and shipping assistance of ICM technology and associated equipment (2 pallets)
6) Fixative for the demonstration, an adequate amount to coat the interior walls and floor of the hot cell mockup as delineated in the test plan

A hot cell mockup was built at the ARC's Technology Assessment Facility for this technology demonstration. The hot cell mockup facility is similar in size, construction materials, and points of access to those found around the Complex. The hot cell mockup is 10-ft wide x 20-ft long x 10-ft high (3-m x 6-m x 3-m) and has an entry point at one end as well as a window in the side. Also, the mockup facility was constructed with two round port holes right above the window for future adaptation of a robotic manipulator. The mockup facility was also provided with a 500 cfm (0.236 m^3/sec) air fan providing 15 air exchanges per hour. In addition, two video cameras were installed inside the mockup facility for video collection during the demonstration. The walls were constructed from poured concrete and Plexiglas was subsequently installed over the window. Figure 1 shows the hot cell mockup facility right after construction. A temporary radiological "tent" made of yellow laminated PVC plastic was set up as a buffer area immediately adjacent to the side entry point (Figure 2). This served as the preparation/staging area as well as the division between "clean" and "contaminated" areas.

Figure 1. Hot cell mockup facility at FIU-ARC's outdoor Technology Assessment Facility

Figure 2. Hot cell mockup facility and yellow buffer zone tent

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. International Climbing Machines (ICM) was selected for the initial technology demonstration based on their work experience in nuclear decontamination, technology capabilities, and previous technology demonstrations.

The ICM climbing machines are remotely controlled by an operator with a laptop computer, allowing the machine to access areas unsafe for manual D&D activities. For the purposes of this technology demonstration, ICM developed a coating application via a spray applicator. The following technology description of the climber, the technical specifications shown in Table 2, and Figures 3 were obtained from the ICM website at http://www.icm.cc [4].

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 (13.6 kg) yet have a pull off strength of over 225 pounds (102 kg). 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 locomotes the machine over surface obstacles such as bolt heads, plates, weld seams or virtually any surface irregularity.

Table 2. ICM Climber Specifications [4]

Primary Materials of Construction:	Carbon fiber / advanced composites
Climbing Machine Weight:	30 lbs (13.6 kg)
w/ Abrader Control Assembly:	40 lbs (18 kg)
Width of Climber:	24 inches (61 cm)
Abrader Cleaning Path Width:	6 - 12 inches (15-30 cm)
Length of Climber:	24 inches (61 cm)
w/ Abrader Control Assembly:	36 inches (91 cm)
Height of Climber:	8 inches (20 cm)
w/ Abrader Control Assembly:	15 inches (38 cm)
Rate of travel:	2.5-3 inches/sec (6.3-7.6 cm/sec)
Cleaning/Coating Removal Rate:	40 - 100 sq ft/ hr (3.7-9.3 m^2/hr)
Pull-Off Strength:	225 lbs (102 kg)
Power (Adhesion Vacuum):	24 Volt DC/110 Volt AC/15 amp
Power (Capture Vacuum):	220 Volt / 30 amp

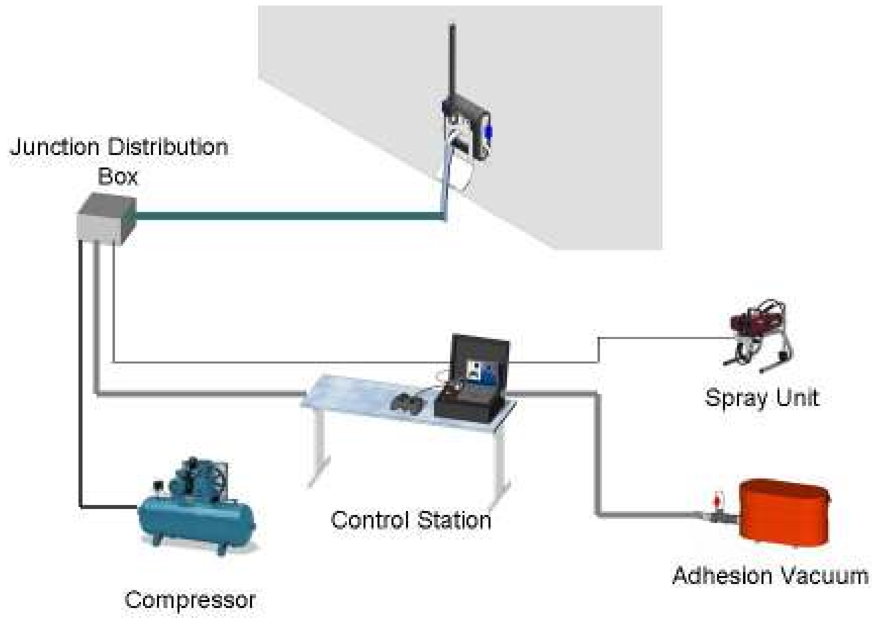

Figure 3. ICM climber set-up [2, 3]

RESULTS AND DISCUSSION

The technology demonstration was performed from November 11 to November 14, 2008. The technology vendor mobilized on November 11, sprayed fixative on November 11-13, and demobilized on November 14. 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: 50-gallon (189-liter) 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 [1]. The technology evaluation demonstrated the ability of the remote system to spray fixative products on horizontal and vertical concrete surfaces. Table 3 lists the fixatives used during the demonstration along with the surfaces and area coated with each. With the climbing machine on the wall surface, the 4-foot (1.2 m) boom attachment to the climbing machine was capable of spraying to the mid-point of the ceiling surfaces [5 feet (1.5 m) from the wall] and the top approximately 4 feet (1.2 m) 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.

Table 3. Fixatives Used During the Technology Demonstration

Product Manufacturer	Name of Product	Type of Product	Surfaces Coated	Surface Area Coated
Sherwin Williams	Promar 200	Latex paint	Ceiling, walls	294 sq ft (27.3 m^2)
Sherwin Williams	Direct to metal (DTM)	100% acrylic coating	Ceiling, walls, floor	627 sq ft (58.2 m^2)
Bartlett Services, Inc.	Polymeric Barrier System (PBS)	Non-toxic water-based solution which forms an impermeable barrier. Specifically for locking down loose contamination.	Ceiling, walls	108 sq ft (10.0 m^2)

Table 4 below compares the fixative product coverage provided by the manufacturer to the actual 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 immobilizing radioactive contamination 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.

The coverage achieved by the Bartlett PBS, 54 sq ft/gal (1.3 m^2/L) was very close to the coverage estimate provided by the manufacturer, 50 sq ft/gal (1.2 m^2/L). A similar actual coverage was achieved with the Sherwin Williams DTM, 57 sq ft/gal (1.4 m^2/L) and a slightly higher actual coverage was achieved with the Sherwin Williams Promar 200, 65 sq ft/gal (1.6 m^2/L). However, the coverage expected by the manufacturer was much higher for these 2 products: 155-250 sq ft/gal (3.8-6.1 m^2/L) and 120-170 (3.0-4.2 m^2/L) sq ft/gal, respectively. The reduction in actual coverage is likely due to the application of the products onto rough-surface concrete, rather than the typical application of DTM on metal and Promar 200 on wallboard.

Table 4. Coverage of Fixatives

Product	Coverage per Manufacturer	Surface Area Coated	Product Consumed	Actual Coverage
Promar 200	120-170 sq ft/gal (3.0-4.2 m^2/L)	294 sq ft (27.3 m^2)	4.5 gal (17 L)	65 sq ft/gal (1.6 m^2/L)
DTM	155-250 sq ft/gal (3.8-6.1 m^2/L)	627 sq ft (58.2 m^2)	11 gal (41.6 L)	57 sq ft/gal (1.4 m^2/L)
PBS	50 sq ft/gal (1.2 m^2/L)	108 sq ft (10.0 m^2)	2 gal (7.6 L)	54 sq ft/gal (1.3 m^2/L)

Table 5 compares of the spraying rate of the 3 fixative 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 began to spray Promar 200 to the hot cell mockup ceiling and Figure 5 shows the climber spraying the wall with PBS.

Table 5. Spraying Production Rate Achieved During Demonstration

Product	Surface Area Coated	Total Spraying Time	Spraying Rate
Promar 200	294 sq ft ($27.3\ m^2$)	87 min	3.4 sq ft/min ($0.32\ m^2/min$)
DTM	627 sq ft ($58.2\ m^2$)	161 min	3.9 sq ft/min ($0.36\ m^2/min$)
PBS	108 sq ft ($10.0\ m^2$)	25 min	4.3 sq ft/min ($0.40\ m^2/min$)

Figure 4. ICM climber beginning to apply fixative (Promar 200) to hot cell mockup ceiling

Figure 5. PBS fixative being sprayed on hot cell mockup wall

At the conclusion of the demonstration and prior to demobilization, 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. In addition, while the tether is protected by a sleeve of plastic, the adhesion vacuum hose would be internally contaminated and would also be disposed. The remaining 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, 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. A good number of digital photos were captured to document the cleaning (decontamination) step.

CONCLUSIONS

Overall, the technology was capable of successfully achieving the objectives of this demonstration. It was able to remotely enter the hot cell mockup from the side entry door, travel across the floor and climbs up the walls unassisted while being controlled remotely by the operator, and spray a coating of 3 different types of fixatives to the wall, floor, and ceiling surfaces.

The technology was evaluated for 16 health and safety categories and a risk rating was applied to each. Fifteen 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. A single category, pressure hazards, received a rating of 2, some level of hazard above background level known to be present.

The challenges encountered during the demonstration included tether management, maintaining line-of-sight between the operator and the technology, and clogging of the sprayer tip. The tether was provided additional slack and retracted by an assistant located in the adjacent radiation buffer tent. Close communication between this assistant and the operator was essential but sometimes difficult due to the distance and noise from the equipment (e.g., compressor, vacuum, and sprayer). One recommendation is to provide radio communication for the assistant and operator.

One window and 2 video cameras were used to allow the operator to view the technology during the demonstration. This worked well for the wall located opposite of the window and for the side wall where the climber and spraying boom could still be seen from the window. The video cameras were fixed on the entry door wall and had a small amount of remote zoom-tilt-pan capabilities. Still, it was more difficult to operate the climber/sprayer from the video images when the climber was out of line-of-sight from the window. Mobile cameras capable of being controlled remotely would be a tremendous benefit to the implementation of this technology.

Finally, the different products used acted differently during the demonstration. The Promar 200 seemed to dry faster and while it sprayed easily for the first hour to hour-and-a-half of use, it then proceeded to clog the sprayer tip repeatedly. No clogging issues were encountered with either the DTM or the PBS. It is recommended that any fixative product be tested thoroughly with the equipment prior to being used in a radioactive environment.

REFERENCES

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