TECHNOLOGY DEMONSTRATION REPORT

FX2 Advanced Fogging Agent

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ABSTRACT

The objective for this technology demonstration was to test and evaluate the FX2 Advanced Fogging Agent, developed at Idaho National Laboratory (INL), for potential implementation at the 235-F facility at Savannah River National Laboratory (SRNL). SRNL has identified a need for an advanced fogging technology to better address the potential airborne contaminants at this facility. Initial testing of the fogging agent at INL has shown the product to be excellent at reducing airborne contamination and fixing particulates in place. The research for this report was conducted at the Applied Research Center (ARC) at Florida International University (FIU) in collaboration with INL and SRNL. This work is also relevant to D&D activities at other DOE sites as well as D&D activities worldwide.

The FX2 Advance Fogging Technology performance and health and safety issues were evaluated during this technology demonstration at FIU. Evaluation included the following:

- Ability to control potential airborne contamination.
  - Capacity to knockdown airborne particulates.
  - Ability to fix loose contamination to different types of surfaces (glass, concrete, steel, plastic, and wood).
  - Ability to cover locations outside of the direct line-of-sight of the fogger.
- Characteristic properties of the product:
  - Burn rate (ASTM E84)
  - Flammability (ASTM D3065)
  - Viscosity (ASTM D2196)
  - Surface Tension (ASTM D1331)
  - Density (ASTM D1475)
- Reactivity to flame and heat sources (during application and after dried/cured).
- Ability to shield against alpha radiation.
- Adhesiveness to surfaces.
- Coverage of surface area, as quantified withImageJ software analysis.
  - Uses contrast analysis to determine coverage of the product.
  - Correlates radiation shielding to the coverage results.

Overall, the technology was capable of successfully achieving the objectives of this demonstration. The FX2 advanced fogging agent was very effective at reaching line-of-sight and non-line-of-sight areas. There did not appear to be any difference in the coverage achieved by the FX2 regardless of placement/location in the test facility. In addition, the advanced fogging agent demonstrated excellent fixing capacity for potential airborne particles such as dust and lint on metal, glass, plastic, concrete, and wood surfaces. The bond appeared slightly less durable on wood, but additional samples may be required before a definitive correlation can be made. The FX2 advanced fogging agent also demonstrated conclusive results in providing shielding against alpha sources as well as its non-flammability during the application phase. Finally, the commercial off-the-shelf Cyclone foggers appeared to do an excellent job of dispersing the FX2.

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LIST OF ACRONYMS

ALARA	As low as reasonably achievable
ARC	Applied Research Center
ASTM	American standard test method
COTS	Commercial-off-the-shelf
CPM	Counts per minute
D&D	Deactivation and decommissioning
DOE	Department of Energy
EMSL	EMSL Analytical, Inc.
FIU	Florida International University
INL	Idaho National Laboratory
MSDS	Material safety data sheet
SRNL	Savannah River National Laboratory
SRS	Savannah River Site
SLS	Sodium lauryl sulfate
SRNL	Savannah River National Laboratory
SRS	Savannah River Site

INTRODUCTION

Many facilities slated for deactivation 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 D&D techniques. 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 common decontamination step is applying a contamination control product (fixative, strippable coating, decontamination gel, or similar material) to all contaminated surfaces to stabilize or remove loose contamination prior to demolition.

The objective of the D&D applied research being performed at FIU is to use an integrated systems approach to develop a suite of D&D technologies that can be readily used across the DOE complex to reduce technical risks, improve safety, and limit uncertainty within D&D operations. The gap between identified needs and 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 Applied Research Center (ARC) at Florida International University (FIU) is identifying and/or developing 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.

The objective for this technology demonstration was to test and evaluate the FX2 Advanced Fogging Agent, developed at Idaho National Laboratory (INL), for potential implementation at the 235-F facility at Savannah River National Laboratory (SRNL). SRNL has identified a need for an advanced fogging technology to better address the potential airborne contaminants in this facility. Initial testing of the fogging agent at INL has shown the product to be excellent at reducing airborne contamination and fixing particulates in place. This technology demonstration was conducted at FIU in collaboration with INL and SRNL. This work is relevant to D&D activities at other DOE sites, as well as D&D activities worldwide.

The selected technology was demonstrated at the ARC Technology Testing & Demonstration Facility in Miami where an existing hot cell mockup facility was modified to meet the objectives of the demonstration. The technology evaluation of the FX2 Advance Fogging Agent included the following: ability to control potential airborne contamination and fix loose contamination to different types of surfaces, physical characteristics of the product, reactivity to flame and heat sources (during application and after drying/curing), ability to shield against an alpha emitting point source, and coverage of surface area. The technology performance and health and safety issues were evaluated during this technology demonstration.

EXPERIMENTAL

ARC evaluators (Test Engineers and DOE Fellows) and the INL collaborator were present at all times for the duration of the technology demonstration to record performance data, take photographs and capture videos during the technology's operation. A detailed technology demonstration test plan was developed for this technology evaluation. During the demonstration, ARC evaluators gathered data concerning the technology's operation, performance, health and safety aspects, benefits, and limitations. Data tables were prepared containing a list of specific data that was collected and evaluated (see Appendix A). In addition, digital photos and videos were utilized to document the technology demonstration/evaluation.

The test site description, technology description, and testing protocols are described in the following subsections.

TEST SITE DESCRIPTION

ARC uses its 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 building that occupies 38 acres in Miami, FL. ARC facilities include numerous specialized laboratories and facilities, including the outdoor Technology Testing & Demonstration Facility where this demonstration occurred. The technology demonstration was conducted under standard non-nuclear conditions. ARC provided all utilities and services, such as water, power, phone, and sanitation services at the work location.

The existing hot cell mockup built at ARC's Technology Testing & Demonstration Facility was modified for this technology demonstration (Figure 1). 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 10' wide × 20' long × 10' high and has an entry point at one end as well as a window in the side. Also, the mockup facility has two round port holes right above the window. The walls are constructed from poured concrete and Plexiglas was installed over the window.

For this technology demonstration, the hot cell mockup was modified to construct smaller spaces: 10' width × 10' length × 10' height for testing scenario 1, and 10' width × 15' length × 10' height for testing scenario 2. The new walls were framed with standard 2×4 lumber and covered with aluminum faced, polyisocyanurate rigid foam insulation boards. All seams were sealed with aluminum foil tape. The two round port holes were covered with acrylic sheets on 2x4 wooden frames and the seams were caulked. An exhaust fan with a filter was connected to an opening in the back upper corner of the facility. A door and window were cut in the entrance wall; the door panel was retained and set back in place during fogging and the window was covered with a clear acrylic sheet for observation purposes. Two small round holes were also cut in this wall to install the fogger dispersal nozzles.

Figure 1. Hot cell mockup at ARC's Technology Testing & Demonstration Facility. Salient features and the interior dimensions of the hot cell mockup are shown.

TECHNOLOGY DESCRIPTION

Fogging Agent

A research initiative started and further developed at Idaho National Laboratory (INL) on a new contamination capture coating and fogging agent, currently dubbed FX2, has been highlighted as having tremendous potential in addressing the airborne contaminant problem at SRS 235-F and throughout the DOE enterprise. The FX2 fogging agent is a proprietary mixture of water, latex paint (LTX), glycerin (GLY), and sodium lauryl sulfate (SLS). It is optimized to penetrate dusty contaminants and bind them into a film (Material Safety Data Sheet included as Appendix C). This fogging fixative behaves like a gas upon dispersion and can be introduced into targeted spaces at low pressure and low velocity to increase its penetration into hard-to-reach areas. It contains a sticky base and surfactant that captures and fixes particulates in place. Recent tests conducted at INL demonstrated that the FX2 agent can be adequately dispersed via commercial-off-the-shelf (COTS) fogging delivery systems, thereby potentially diminishing the requirement for specially designed equipment and reducing implementation costs. The technology improves safety during nuclear facility decommissioning by limiting contamination spread and worker exposure during decontamination activities.

During FY2014, INL built upon earlier findings and refined the fogging agent mixture, resulting in a solution that optimized dispersal and particulate capture characteristics. The initial objective of the solution development was to achieve a fogged capture coating which would allow for easy application, unmanned operation and flow through facilities and equipment. The solution had to "knock down" and fix existing airborne particulates, as well as penetrate through the surface layer of dust and adhere the dusty contaminants to the substrate. This new coating demonstrated better penetration of the lint and dust, and an ability to stabilize potentially respirable particles. All of the additives are common materials, found in paint and shampoo for example, and none are considered harmful (beyond being irritants in higher concentrations). The solutions are aqueous and generally clean up with soap and water. Based on INL laboratory tests that compared, stickiness, dustiness and penetration, several recipes of fogging agents showed improved performance over the conventional fogging technique employing only glycerin.

Stationary Fogging Delivery System

The set of experiments conducted by INL also validated the approach of using an inexpensive, unsophisticated fogger and a portable blower to control the buildup of fog. Previously it was thought that testing the FX2 Fogging Agent would require more sophisticated dispersal equipment; however, a fogger that produced the proper droplet size was commercially available at an inexpensive price.

FIU employed two Cyclone Ultra-Flex Foggers by Curtis Dyna-Fog (Figure 2). The capacity of the tank is one gallon (3.8 liters). The Cyclone Ultra-Flex weighs approximately 10 lbs. and approximately 19 lbs. with a full tank. Table 1 provides the technical specifications for the fogger used during this demonstration/evaluation.

Table 1. Technical Specifications for the Cyclone Ultra-Flex Fogger

Input Power	110/120 V AC, 8.5 amps, 50/60 Hz (models 3000, 3000-1)
Adjustable flow rate	0-5 gal/h. (0-19 L/h.)
Particle Size	5-30 microns.
Tank capacity	1 gal. (3.8 L).
Length	54 in. (137 cm).
Width	8 in. (20.2 cm).
Height	14.5 in. (36.5cm).
Weight empty	10.5 lbs. (4.8 kg.)
Shipping data	L x W x H: 27 in. x 12 in. x 17 in. (68cm x 30 cm x 43 cm)
Weight	16 lbs. (7.26 kg.),
Volume	3.2 cubic feet. (0.09 cubic meter).
Option	36 inch (91 cm) flex hose

Figure 2. Cyclone Ultra-Flex Fogger by Curtis Dyna-Fog.

TESTING PROTOCOLS

Flammability

FIU performed a series of tests using ASTM D3065 for flammability; this standard is generally designed to test the flammability of aerosols during application. FIU implemented both methods described in the standard: the closed drum test and the open flame projection test. All apparatus were constructed in accordance with the standard, and the required procedures were followed.

The closed drum test was conducted in a climate controlled area at 70°F. A small window was cut into the 55-gallon drum (Figure 3). The tests were filmed and photographed. A candle was lit at the designated spot within the drum and then the drum was closed. The fogging agent was dispersed from the Cyclone fogger into the drum through a small hole in the end of the drum.

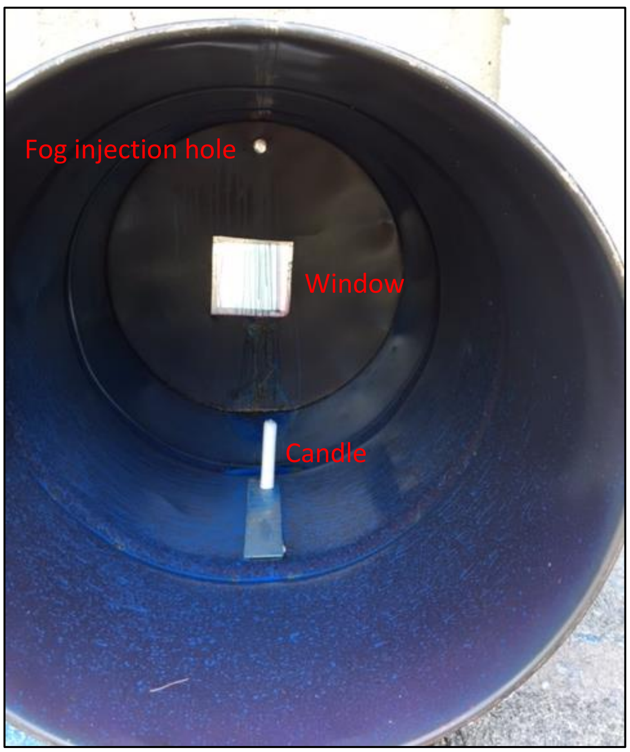

Figure 3. Drum used for flammability test.

Though not part of the ASTM standard, a few control tests were then conducted to confirm the validity of the flammability test as performed. A candle was lit and then the drum closed, to determine if the candle would remain lit without the dispersion of the FX2 agent. The intent was to confirm that other variables could not have been responsible for the flame extinguishing. FIU set the timer for two (2) minutes and videotaped the control run.

FIU then lit the candle and kept the drum open while exposing the candle to a fan producing a wind current, to confirm that the blowing action of the fogger was not a factor in the flammability tests. The fan was placed approximately 3 feet from the candle. The fan's speed was set on low, then increased to medium, and then high.

FIU conducted the open flame projection test inside the hot cell mockup facility. The fogger was located 6" from the candle flame and turned on for the required 4 seconds. All participants observed to see if the flame projected when exposed to the FX2 agent dispersed by the fogger. The test apparatus was marked in inches extending out from the flame to allow an estimation of any flame projection. This test was repeated two (2) more times – a total of three (3) trials.

Analytical Laboratory Testing

FIU outsourced a selection of laboratory tests for the FX2 agent to EMSL Analytical, including:

- Viscosity (ASTM D2196)
- Surface tension (ASTM D1331)
- Density (ASTM D1475)
- Burn rate (ASTM E84)

FIU prepared the samples for viscosity, surface tension, and density testing by thoroughly mixing the bucket of FX2 agent and filling the sample containers provided by the lab (Figure 4). These were shipped to EMSL for analysis on April 2, 2015.

The burn rate samples were prepared by placing 12" × 12" samples of wood and concrete in the hot cell mockup facility on the floor during the fogging tests. The wood and concrete samples were exposed to 30 minutes of fogging and analyzed for surface coverage using ImageJ. An additional wood sample and concrete sample were manually painted with the FX2 agent to ensure 100% surface coverage for comparison purposes. Once completely dry, the samples were shipped to EMSL Analytical for burn rate testing (ASTM E84).

Figure 4. FX2 samples for viscosity, surface tension, and density testing.

Fog Dispersal Testing

Fog dispersal tests were conducted to determine the coverage achieved by the fogging agent throughout the hot cell mockup facility. For Scenario 1 (1000 ft^3), two foggers were activated for 15 minutes and then another 15 minutes. For Scenario 2 (1500 ft^3), two foggers were activated for 30 minutes. A total of twenty-three (23) plastic petri dishes were placed in varying locations within the 10’ wide × 10’ long × 10’ high hot cell mockup, both within and outside of the line-of-sight of the fogger nozzles. The dishes were either empty (for ImageJ analysis) or contained dust (i.e., talcum powder or lint). Open-sided utility shelves were centrally located within the hot cell. Shelves were attached to the hot cell walls 52” (wall shelves 1, 3, and 5) and 100” (wall shelves 2 and 4) from the floor. The samples not in the line-of-sight of the foggers (hidden samples) were placed on the floor, inside containers intended to block a direct application of the fogging agent. One container was a plastic, rectangular, typical office trash can, placed on its side with the opening oriented at 90° from the wall housing the fogger nozzles. The second apparatus was a tent shaped piece of corrugated cardboard, only slightly wider than the petri dishes themselves, placed on the floor and oriented so that the two open ends were perpendicular to the fogging dispersion locations (see Figure 5).

<u>Line-of-Sight Samples</u>

- Wall-shelf 1: Sample 4 (dust) and Sample 16 (ImageJ)
- Wall-shelf 2: Sample 3 (dust) and Sample 17 (ImageJ)
- Wall-shelf 3: Sample 19 (lint) and Sample 18 (ImageJ)
- Wall-shelf 4: Sample 20 (lint) and Sample 21 (ImageJ)
- Wall-shelf 5: Sample 2 (dust) and Sample 13 (ImageJ)
- Utility shelf (bottom): Sample 24 (ImageJ), Sample 25 (dust), Sample 26 (lint)

- Utility shelf (middle): Sample 27 (ImageJ), Sample 28 (dust), Sample 29 (lint)
- Utility shelf (top): Sample 30 (ImageJ), Sample 31 (dust), Sample 32 (lint)

Hidden Samples

- Trashcan: Sample 23 (lint) and Sample 22 (ImageJ)
- Cardboard tent: Sample 33 (dust) and Sample 34 (ImageJ)

Figure 5. Hidden sample locations shown after 30 minutes of fogging: cardboard tent (left) and trashcan (right).

Once the samples were placed, the two foggers (each filled with ~3 liters of yellow-tinted FX2) were activated for 15 minutes. The exhaust fan remained off except for a duration of 30 seconds at the 10 minute mark. Preliminary testing indicated that the fogging agent was able to disperse more evenly without the fan pulling the airflow towards the exhaust. During this first run, the FX2 fog was observed to be extremely thick, making it difficult to even see the utility shelf through the fog (Figure 6). The FX2 fogging agent was allowed to settle undisturbed for 1½ hours, at which point a light fog remained suspended. The exhaust fan was turned on, and the door opened to ventilate the remaining airborne FX2.

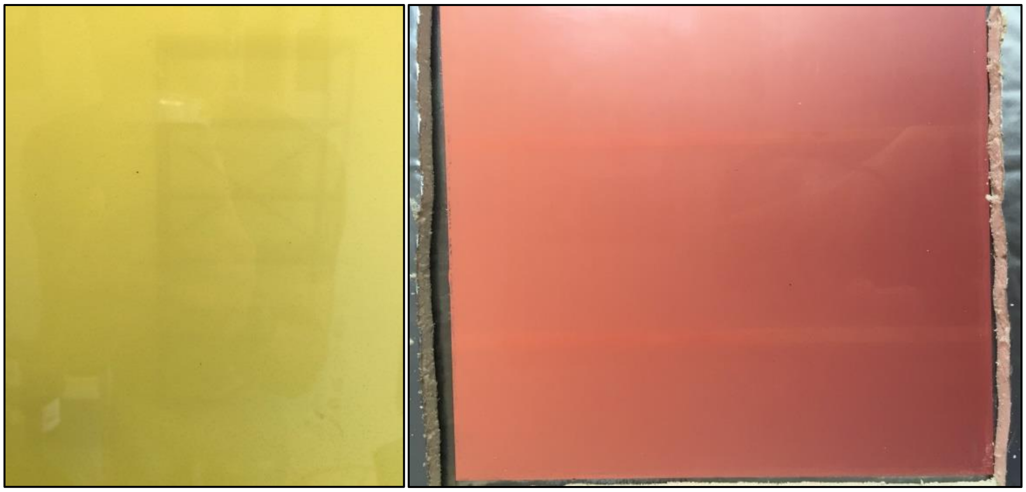

Figure 6. View through hot cell window during fogging: yellow tint (left) and red tint (right).

Sample 13 (ImageJ) from shelf 5 was removed and photographed. The sample was returned to its original location. Samples 27, 28, and 29 on the middle shelf of the utility shelf were removed and replaced with Samples 35 (ImageJ), 36 (dust), and 37 (lint). This exchange was done to provide for a control group to differentiate results between the first and second fogging runs.

A second run of the foggers for 15 minutes was then performed. During this run, the exhaust was turned on for a 30 second duration at the 5 minute, 8 minute, and 11 minute marks. An extremely thick fog throughout the hot cell was observed, obscuring a clear view of the utility shelf. The FX2 fogging agent was allowed to settle for 45 minutes after the foggers were turned off, at which point a light suspension of FX2 fogging agent was still present. All the samples were removed to ARC's climate controlled Environmental Technology Research Lab to dry.

The following day, the hot cell mockup facility was modified to a larger configuration: 10' wide × 15' long × 10' high, for a total of 1500 cubic feet (an increase of 500 cubic feet from the first scenario). Empty plastic petri dishes were again placed at various locations throughout the hot cell to determine the dispersal characteristics of the fogging agent. Given the promising preliminary results observed in the prior test, FIU incorporated a "challenge sample" (sample 60) in an attempt to identify the point at which the FX2 agent would fail to achieve significant coverage. The challenge sample was a plastic petri dish that contained talcum powder, replicating a heavy layer of dust. It was placed inside the rectangular trash can. The trash can was placed on its side with the facing the back wall of the hot cell, opposite the fogging dispersal locations. The opening of the trash can was 4" from the wall. The other samples were placed throughout the room as outlined below:

<u>Line-of-Sight</u>

- Wall-shelf 1: Sample 50 (ImageJ)
- Wall-shelf 2: Sample 51 (ImageJ)
- Wall-shelf 3: Sample 52 (ImageJ)
- Wall-shelf 4: Sample 53 (ImageJ)
- Wall-shelf 5: Sample 54 (ImageJ)
- Utility shelf (bottom): Sample 55 (ImageJ)

- Utility shelf (middle): Sample 56 (ImageJ)
- Utility shelf (top): Sample 57 (ImageJ)
- Top of doorframe (5’ from front wall): Sample 61
- Floor (2’ from front wall): Sample 62
- Floor (4’ from front wall): Sample 63

Non Line-of-Sight

- Trash can set-up: Sample 58 (ImageJ)
- Cardboard tent: Sample 59 (ImageJ)
- Challenge sample: Sample 60 (heavy coating of dust)

Once the samples were placed, the two foggers (each filled with ~3 liters of red tinted FX2) were turned on for 30 minutes. At the 5 min, 8 min, 11 min, and 14 min intervals, the exhaust fan was allowed to run for 30 seconds. At the 17 min, 20 min, 23 min, and 26 min intervals, the exhaust fan was turned on for 60 seconds. The FX2 fog was again observed to be extremely thick, making it difficult to see even the exposed 2” × 4” studs only 5 feet away through the fog. The additional 500 $ft.^3$ of room volume did not appear to impact the density of the fog. At the conclusion of the test, the FX2 fogging agent was allowed to settle for 3 hours, at which point a very light fog could still be observed within the confines of the hot cell mockup. The exhaust fan was then turned on to ventilate the room.

All samples were removed to ARC’s climate controlled Environmental Technology Research Lab to dry.

Surface Coverage Analysis

Surface coverage was assessed using ImageJ software. ImageJ is a public domain image processing and analysis program. It was developed to provide a better means of analysis regarding visual and quantifiable facets of microbiology, such as particle counting in a cell colony. Although developed for use in the life sciences fields, ImageJ is applicable to many other research fields. For purposes of the FX2 testing, ImageJ provided the capacity to evaluate coverage of the FX2 agent on a material’s surface. In order to do so, the following features of the ImageJ software were leveraged: contrast manipulation, edge detection, precision scaling, median filtering, and particle quantification. With the information derived, correlations could be drawn between the coverage of the fixative and its properties.

The following procedure was used to implement ImageJ analysis during the demonstration:

1. After application of the FX2 agent, a photo of the designated coupon, including a ruler / tape measure to annotate scale, is taken with a Canon EOS digital Rebel XTi camera.
2. The images are subsequently uploaded to a laptop, named per the established naming convention, and imported as a new image study.
3. Using the scale shown in the image, a line is drawn across the scale to create a relationship between the number of pixels and the desired distance unit (e.g., cm, inch, etc.).
4. To isolate the desired area, a geometric shape that would serve as the border is created.
5. A duplicate is created and saved as a different file.

6. Excess area is eliminated using the Clear Outside option to trim down the area of analysis within the image.
7. Contrast was enhanced as follows:
    a. Within the Process menu, an option for enhancing contrast can be found. In this setting adjustment, pixels' saturation levels can be manipulated to the desired amount. In other words, the strength of the color, or amount of grey in proportion to the hue, can be modified.
    b. The color balance is then adjusted to highlight the features of interest.
8. The detection threshold is then adjusted as follows:
    a. The user modifies the brightness of the image, the hue filter, and the saturation filter.
    b. The user generates a filtered image that accurately depicts the data in the original.
9. Particle analysis is conducted by quantifying the amount of area the particles occupy, as well as the size of each, and percent coverage of particle area to total area. Using the amount of area the particles occupy and known area of the sample dishes, calculating a ratio of the two to quantify coverage is straightforward.

Figure 7 shows a screenshot of the ImageJ analysis process: the original image, the altered area of focus, the threshold conditions and the end results provided by the particle analysis feature of ImageJ. To set the scale, the known active diameter of 1/4" was used to make the conversion from pixels to inches. A complete description of the use of ImageJ, including the benefits and limitations, is included as Appendix B.

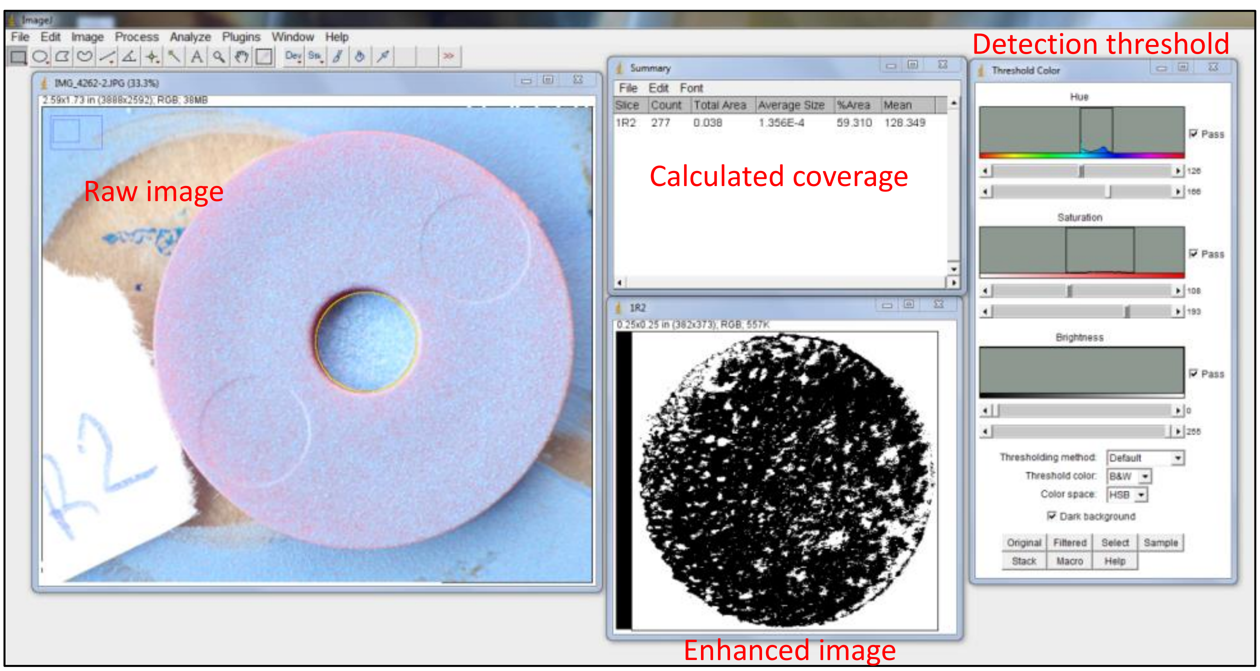

Figure 7. Screenshot of ImageJ analysis process.

Surface Adhesion Testing

Sample coupons were prepared in order to evaluate the FX2 fogging agent's ability to afix particulates (e.g., lint and dust) to a variety of surface types. The surfaces that were selected include metal, glass, wood, plastic, and concrete. Coupons of each surface type were lightly sprinkled with talcum powder to replicate a light coating of dust. The coupons were weighed to document their initial weights prior to fogging (Table 2). A glass petri dish was used for the glass coupon and a plastic petri dish was used as the plastic coupon.

Table 2. Adhesion Samples - Coupon Mass

	Metal Coupon (Sample 1)	**Wood Coupon (Sample 14)**	**Concrete Coupon (Sample 12)**	**Glass Coupon (Sample 15)**	**Plastic Coupon (Sample 11)**
Petri Dish	8.541 g	8.517 g	9.018 g	37.149 g	8.804 g
Coupon and Dust	22.629 g	7.587 g	26.644 g	--	--
Total Combined Mass (before fogging)	31.170 g	16.104 g	35.662 g	37.288 g	9.024 g
Total Combined Mass (after fogging and 24 hour drying period)	31.439 g	16.401 g	35.918 g	37.548 g	9.254 g
Total Combined Mass (after fogging and 5 day drying period	--	--	--	37.541 g	9.248 g

Prior to moving the coupons, the petri dishes were covered with lids to prevent loss of talcum powder mass. The samples were transported to the hot cell mockup facility and placed on the floor in front of the utility shelves, within line-of-sight of the foggers. These samples were in place during Test Scenario 1, which was described previously in the Fog Dispersal section. After fogging, the samples were removed to ARC's climate controlled Environmental Technology Research Lab to dry. After 24 hours of drying, the samples were weighed (Table 2). The addition of the fogging agent added a small but significant amount of mass.

The samples were allowed to dry for a total of 5 days. As shown by the glass and plastic samples in Table 2, the samples lost a very small amount of weight between the 24 hour and 5 day drying periods, indicating that the FX2 was not yet completely cured after 24 hours. After being allowed to dry for a total of 5 days, the following procedure was followed to test the adherence to the sample surfaces of the encapsulated dust (Figures 8 to 10). The “challenge” sample from Test Scenario 2 was also tested per this protocol.

1. Weigh coupon.
2. Vigorously shake side-to-side for 3 seconds followed by turning the coupon upside down and shaking hard 3 times; weigh coupon.
3. Set air compressor to 20 psi; hold nozzle 6” away at a 30° angle to coupon surface, turn on compressor for 3 seconds, weigh coupon.
4. Apply 3 firm brush strokes to the coupon with a 1” semi-hard bristle brush; weigh coupon.
5. Repeat air compressor test (see step 3) at 40 psi.
6. Repeat air compressor test (see step 3) at 100 psi.
7. Vigorously wipe coupon with a paper towel; weigh coupon.

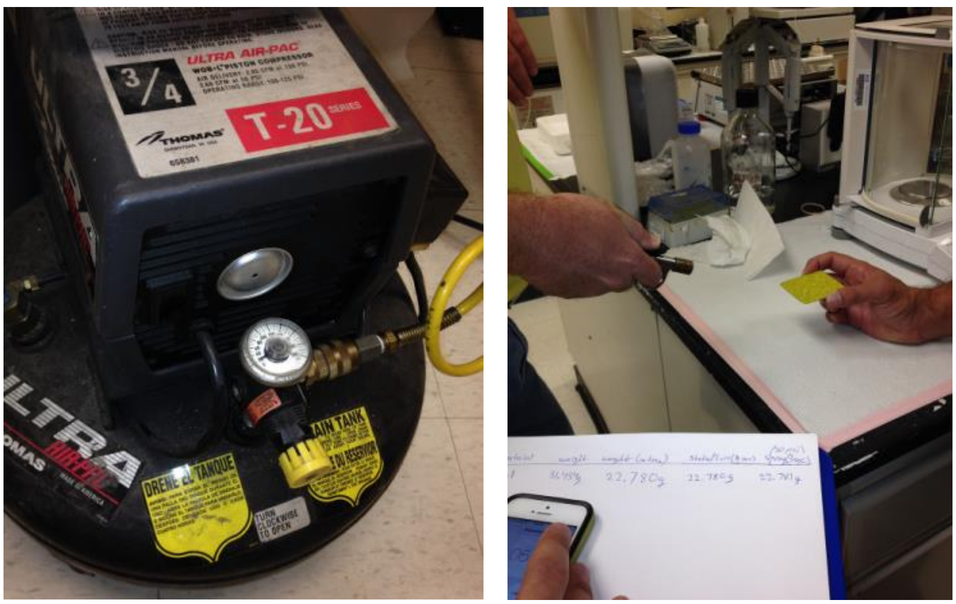

Figure 8. Ultra Air-Pak Compressor (left), applying compressed air to sample (right).

Figure 9. Weighing metal sample (left) and applying brush test (right).

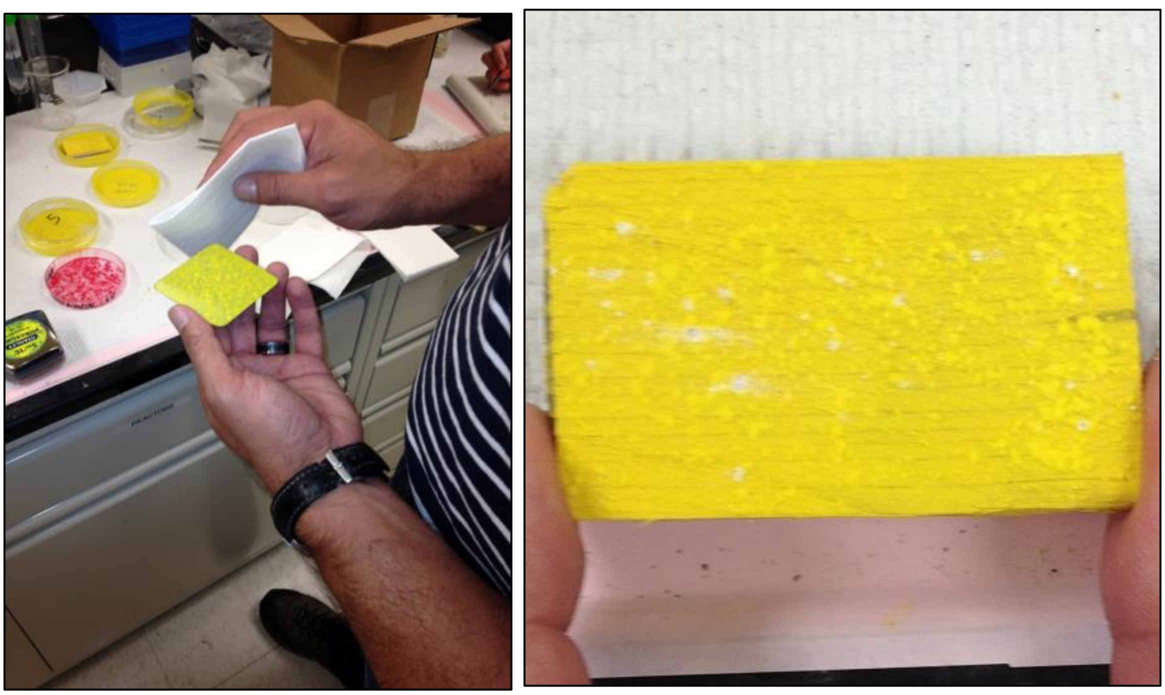

Figure 10. Applying wipe test (left), wood sample after brush test (right).

Airborne Particulate Capture Testing

In order to test the FX2 agent's ability to reduce airborne particulates, the following testing protocol was followed:

1. An empty 55-gallon metal drum was placed in the hot cell mockup facility. The ratio of drum volume to the hot cell mockup volume was used to determine a dispersal time for the fogger (~6.2 seconds) that correlates to the 30 minute dispersal used in the Fog Dispersal tests.
2. A baseline airborne particulate measurement was taken inside the drum for two consecutive days; the drum was sealed after each measurement. The baseline airborne particulates were dust/particles in the environment; no additional particulates were introduced to the drum. The instrument used was a commercial airborne particle counter: HandiLaz Mini from Particle Measuring Systems (Figure 11).
3. After the second baseline airborne particulate measurement was taken, the FX2 agent was dispersed into the drum using the fogger for 7 seconds; the drum was then re-sealed.
4. Four (4) hours later, an airborne particulate measurement was taken inside the drum.
5. Twenty-four (24) hours after fogging, another airborne particulate measurement was taken inside the drum.
6. Ninety-six (96) hours after fogging, a final airborne particulate measurement was taken inside the drum.

Figure 11. HandiLaz Mini airborne particulate counter from Particle Measuring Systems

Shielding Against Alpha Radiation

Although the FX2 agent was not specifically designed to provide radiation shielding, it was believed capable of providing some degree of alpha (α) shielding that could enhance its overall utility in a radioactive environment during D&D activities. An initial radiation background survey was conducted in the hot cell without the sources present, yielding 92 counts per 2 minutes. Two (2) sealed ^{210}Po point sources (activity 0.05 μCi; half-life 134 days) were placed in the center of hot cell mockup facility, approximately 70” from the fogger dispersal points. Each source was labelled and three measurements were taken with a calibrated Geiger-Muller Counter, Pancake-type, Model 2241-3 from Ludlum Measurements in order to obtain a baseline.

The FX2 agent was then applied via the 2 Cylone foggers, running simultaneously for five (5) minutes. After 5 minutes, the foggers were turned off and the exhaust fan was turned on for 10 minutes. At this point, another background radiation measurement was taken, yielding 73 counts/ 2 minutes. Next, three (3) measurements were taken from the alpha point-sources. Photos of the exposed area of each source were also taken, then loaded into the ImageJ software to assess the degree of coverage by the FX2 agent. The fogging process was repeated (an additional 5 minutes of fogging) with subsequent activity measurements and photographs. Once the fogging agent was completely dry, final radioactivity measurements were taken.

RESULTS AND DISCUSSION

The technology demonstration was performed from March 30 to April 3, 2015. The evaluation included the following: ability to control potential airborne contamination and fix loose contamination to different types of surfaces, physical characteristics of the product, reactivity to flame and heat sources, ability to shield against an alpha emitting point source, adhesiveness to surfaces, and coverage of surface area. The field data tables are provided in Appendix A.

FLAMMABILITY

During the closed drum test for flammability (ASTM D3065), a total of three runs were conducted with the following results:

- Run 1 – the flame extinguished in 11 seconds after the fogger was turned on
- Run 2 – the flame extinguished in 8 seconds after the fogger was turned on
- Run 3 – the flame extinguished in 6 seconds after the fogger was turned on

The average time to extinguish the flame was 8.33 seconds after the FX2 agent was dispersed into the closed drum by the Cyclone fogger.

To determine if the candle would remain lit without the dispersion of the FX2 agent, a candle was lit and the drum closed. The candle remained lit the entire 2-minute duration and did not extinguish. In addition, the flame did not extinguish when exposed to an air current from a fan. The fan was placed approximately 3 feet from the candle in the open drum and the speed was set at low, then increased to medium, and then to high. The flame flickered from the air current, with increasing movement for the higher fan speeds, but did not extinguish. These series of control tests confirmed that it was in fact the dispersion of the FX2 agent into the closed drum that caused the flame to extinguish during the flammability test.

During the open flame projection test inside the hot cell mockup facility, the fogger was located 6” from the candle flame and turned on for the required 4 seconds. Three (3) runs were conducted with the following results:

- Run 1 - No flame projection was noted by any of the participants nor upon a review of the videotape; the flame remained lit.
- Run 2 - The flame extinguished at the 4 second point; no flame projection.
- Run 3 - The flame extinguished after 1 second; no flame projection.

The final conclusion for these tests is that the FX2 advanced fogging agent is not flammable during application/dispersion.

ANALYTICAL LABORATORY TESTING

The analytical laboratory testing results are summarized below. The full laboratory reports are included as Appendix D.

Burn rate (ASTM E84)

The burn rate results from the analytical laboratory are shown in Table 3.

Table 3. Burn Rate Results

	Fogged wood sample (100% coverage)	**Fogged concrete sample (95% coverage)**	**Manually coated wood sample (100% coverage)**	**Manually coated concrete sample (100% coverage)**
Flammability with ignition source	Flame spread present	No flame spread present	Flame spread present	No flame spread present
Flammability with ignition source off	Self-extinguished	Not applicable	Self-extinguished	Not applicable
Time between contact and ignition	< 1 second	Not applicable	< 1 second	Not applicable
Smoke point	Not detected	Not detected	Not detected	Not detected
Minimum auto ignition temperature	Greater than 300° C	Not determined	Greater than 300° C	Not determined

While the fogged wood sample exhibited ignition at the point of contact with the ignition source, the flame spread was limited to the ignition source location and the sample self-extinguished upon removal of the ignition source. The analytical laboratory observations indicated that the wood sample appeared to be coated with a flame inhibitor. The fogged concrete sample did not exhibit any evidence of flammability. The results for the manually coated samples were identical to the fogged samples.

Viscosity (ASTM D2196), Surface Tension (ASTM D1331), and Density (ASTM D792)

The analytical laboratory results for two FX2 samples, one red and one white, are shown in Table 4. The density results, just over 1 g/mL, are as expected for a water-based product. The significant different in viscosity between the red and the white sample was unexpected. The laboratory noted that the white sample was less watery than the red sample, which is in line with the viscosity results as well as the observation during the technology testing that the red FX2 seemed to provide better coverage than the white. INL used different bases for the red FX2 and the white FX2.

Table 4. FX2 Viscosity, Surface Tension, and Density

Sample	Surface Tension (mN/m)	Density (g/mL)	Viscosity (cP)
FX2 – Red	33.6	1.050	9.1
FX2 - White	31.7	1.079	16.1

FOG DISPERSAL TESTING

After the foggers had been allowed to run for 15 minutes (yellow tint) with the hot cell mockup modified for the first scenario (10’ width × 10’ length × 10’ height), qualitative visual observations were promising. The FX2 fogging agent had fully infiltrated the non-line-of-sight apparatuses (trashcan and cardboard tent) as well as the floor under the utility shelf. The results showed that the FX2 fogging agent truly acted like a gas/fog and reached all locations within the hot cell, including line-of-sight and non-line-of-sight. The foggers were turned on for an additional 15 minutes, after which all locations (within and outside of the line-of-sight) visually had a more thorough coating of the FX2 agent (Figure 12).

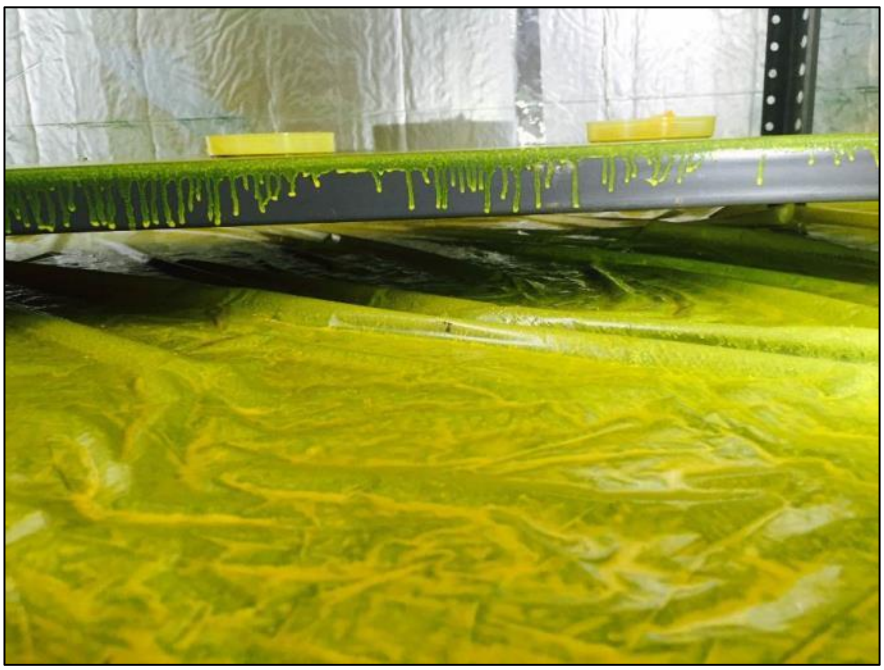

Figure 12. Non-line-of-sight location, under the utility shelves.

The following day, the hot cell mockup was modified for scenario 2 (10’ width × 15’ length × 10’ height). The foggers were filled with red-tinted FX2 agent and allowed to run for 30 minutes. Visual observations after the foggers were turned off were positive. Despite the larger dimensions and greater volume of this scenario, the FX2 fogging agent had fully infiltrated the non-line-of-sight apparatuses (not only the original trash can and cardboard tent, but the “challenge” sample as well). All horizontal surfaces of the hot cell mockup were thoroughly covered in red-tinted FX2 agent (Figure 13).

Figure 13. Red-tinted FX2 agent covers all horizontal surfaces in 10'x15'x10' hot cell mockup. Note the lack of complete coverage of many of the vertical surfaces. Yellow box: The location of the trash can (behind the shelving unit) in which the "challenge" sample was located.

Of particular note was the "challenge" sample, designed to be exceptionally challenging for the FX2 agent to get to, and placed approximately 4-6" inside a trashcan lying on its side. The trashcan was then placed at the maximum distance from the foggers, 15 feet away, behind the utility shelf, with the opening of the trashcan facing towards the back wall, less than 4" away, exactly opposite of the foggers (Figure 14).

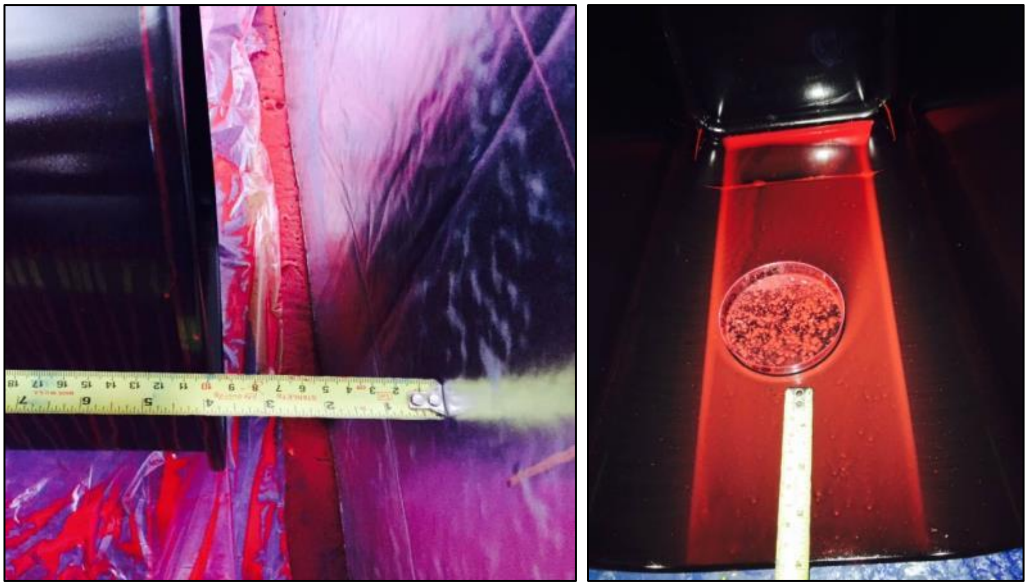

Figure 14. Challenge sample location: distance from wall (left) and inside trashcan (right).

As shown in Figure 15, the FX2 fogging agent not only reached the "challenge" sample but covered the inside of the trashcan so thoroughly that it created a puddle. The majority of the petri dish was covered by the FX2 fogging agent and the FX2 fogging agent also fully penetrated the powder/dust. Figure 15 shows a photo was taken from underneath the petri dish, clearly showing that the FX2 fogging agent penetrated the originally white powder/dust to the bottom of the petri dish. The ImageJ analysis of the challenge sample showed 82.9% coverage.

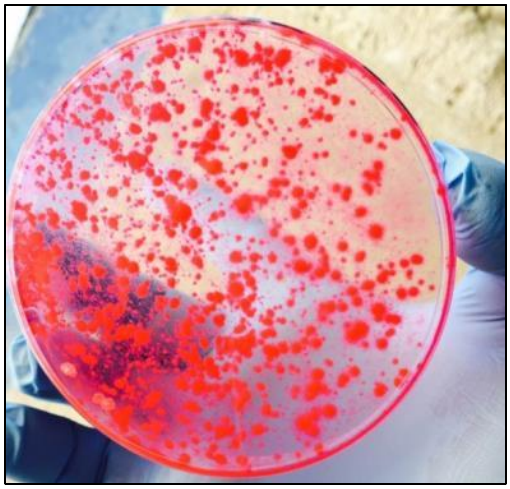

Figure 15. Challenge sample photo taken from bottom of petri dish, showing full penetration of FX2 through powder/dust. The powder was white before the test.

SURFACE COVERAGE ANALYSIS

Figures 16 and 17 shows how the petri dishes were arranged within the hot cell mockup. Table 5 shows the percent coverage of each sample for scenario 1 (10' × 10' × 10') and scenario 2 (10' × 15' × 10') after 30 minutes of fogging with the FX2 agent. Several samples were omitted due to inconclusive ImageJ results: the color contrast was insufficient to produce an acceptable result for samples 17, 22, 27, 30, 35, 52, and 55. Overall, the results indicate that the FX2 agent was well distributed throughout the hot cell mockup. All samples received 75-100% coverage, with the only exception being an out-of-line of sight sample in the cardboard tent. Note that these samples were all placed in a horizontal orientation. The walls of the mockup area were coated very lightly; a residue could be wiped off the walls, but very little tinting (yellow or red) was visible. The wall surfaces were a smooth aluminum material. The fogging agent coated the exposed wood studs to a much greater extent as evident in Figure 13, but only on areas that were in direct line of sight of the fogging nozzles. Special consideration should be given to the relevant factors (e.g., materials of construction, fogging duration) in applications where vertical coverage is a high priority.

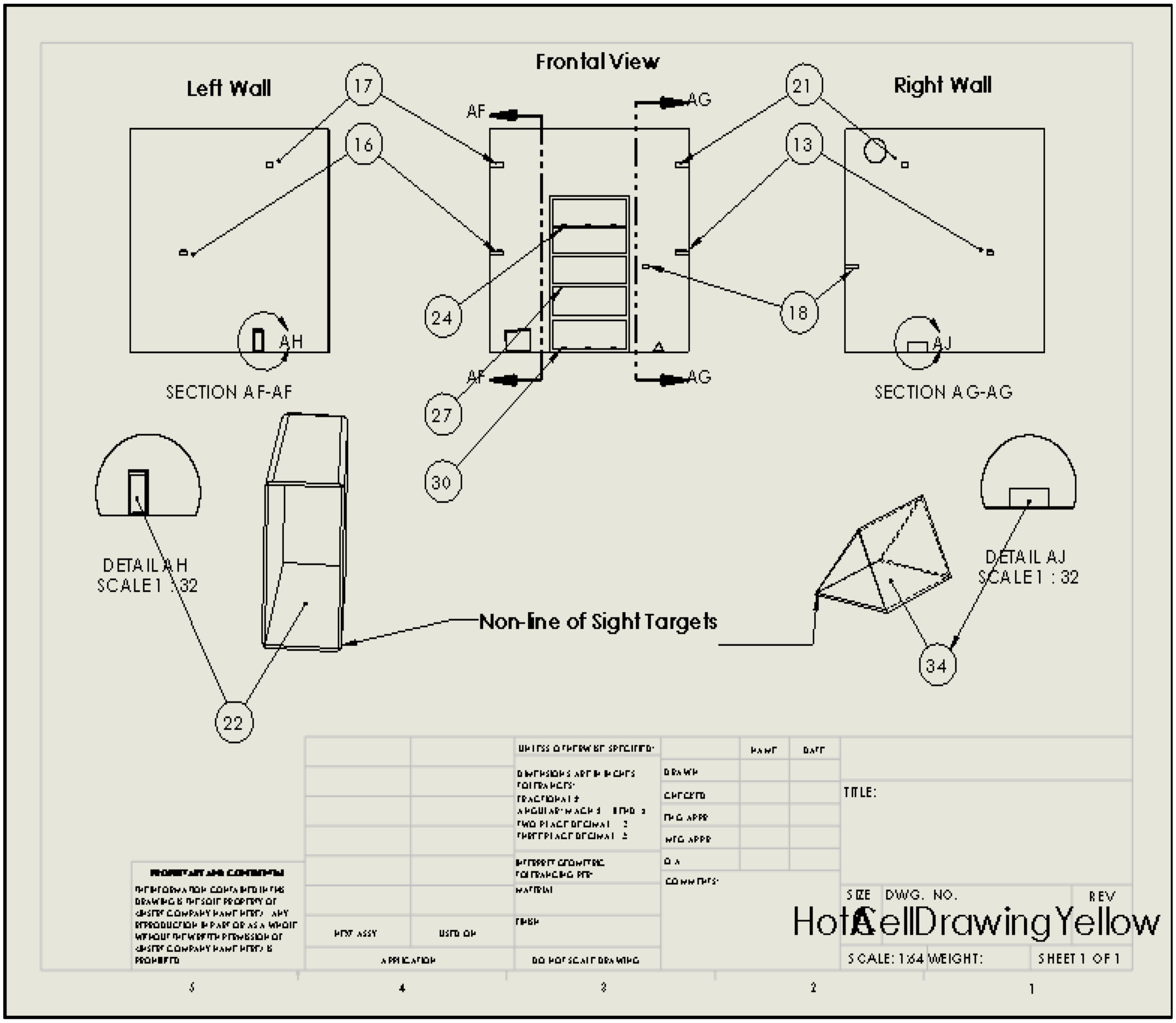

Figure 16. Sample locations within hot cell mockup for scenario 1 (10'×10'×10').

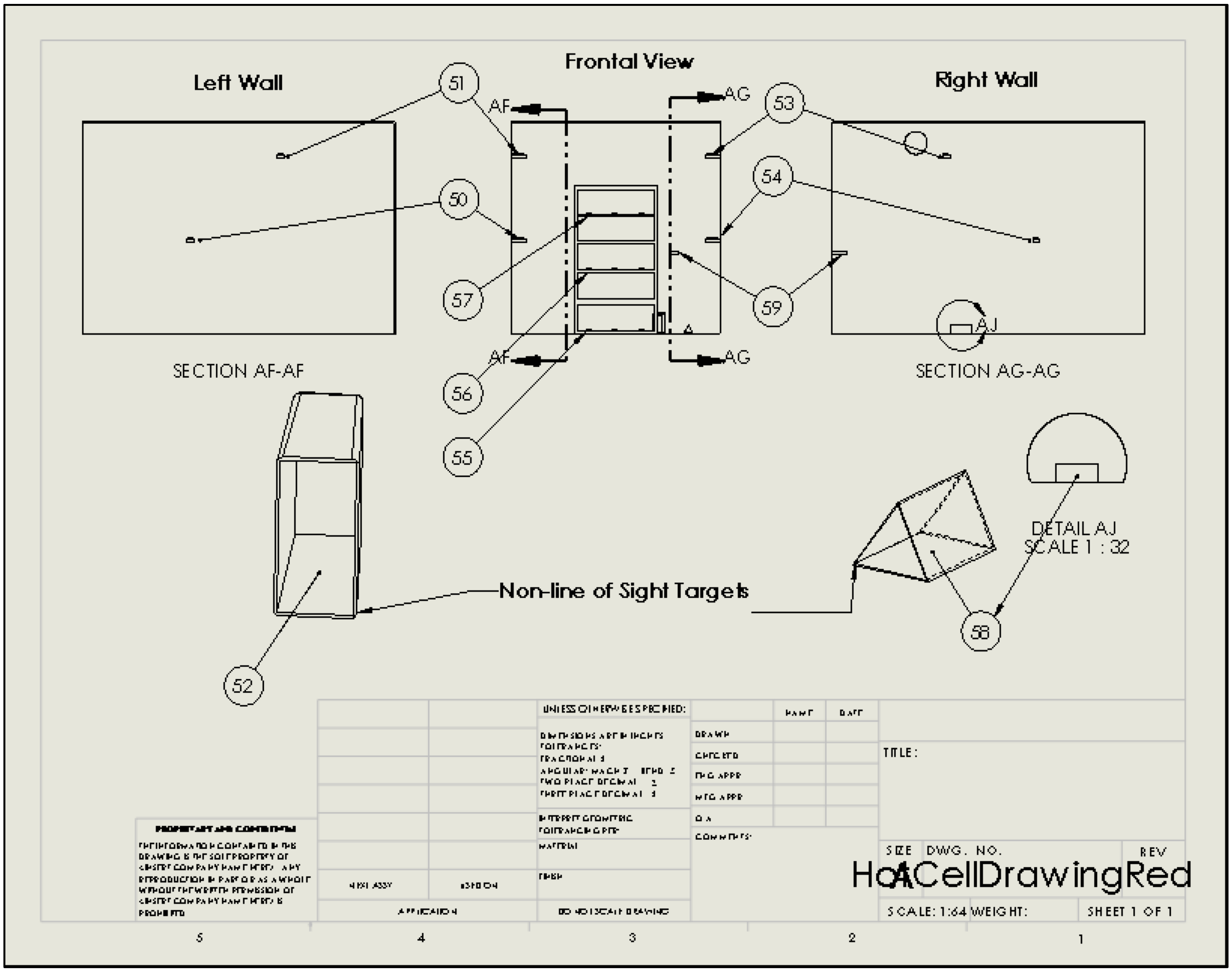

Figure 17. Sample locations within hot cell mockup for scenario 2 (10'×15'×10').

Table 5. ImageJ Results of Percent Coverage

Scenario 1	
Sample	**Percent Coverage**
13	100.0%
16	100.0%
18	88.6%
24	93.1%
Scenario 2	
Sample	**Percent Coverage**
50	80.5%
51	84.6%
53	77.6%
54	78.7%
56	81.1%
57	85.4%
58	53.1%
59	84.2%
61	82.0%
62	76.6%
63	81.9%

SURFACE ADHESION TESTING

The metal, glass, plastic, concrete, and challenge sample showed no signs of losing any mass under the adherence series of tests. However, the wood sample did change in appearance. Note the exposed powder on the wood sample in Figure 10 taken after the brush test. However, the mass loss from the wood sample does not appear to be significant based on the weight results. None of the other materials exhibited this characteristic and the coating of fogging agent remained intact.

In an attempt to find the point of failure, two samples were selected (metal sample and challenge sample) and wiped vigorously with a standard paper towel for 5 seconds. After this more extreme duress, the FX2 agent color was noted to be coming off onto the paper towel and a small loss of mass was noted. These two samples were then further subjected to an additional 100 psi blast from the air compressor for 6 seconds; no additional mass was lost.

The weight of each sample in grams after each adherence test is included in Table 6.

Table 6. Sample Weights During Adherence Tests

Surface type	Starting weight (g)	After shaking (g)	After 20 psi air (g)	After brushing (g)	After 40 psi air (g)	After 100 psi air (g)	After wiping (g)
Plastic	9.248	9.252	9.255	9.254	9.254	9.254	-
Glass	37.541	37.542	37.545	37.545	37.546	37.545	-
Concrete	26.724	26.725	26.725	26.724	26.724	26.724	-
Metal	22.780	22.780	22.781	22.781	22.782	22.782	22.763
Wood	7.773	7.774	7.776	7.773	7.770	7.770	-
Challenge	9.314	9.314	9.315	9.316	9.316	9.316	9.303

AIRBORNE PARTICULATE REDUCTION TESTING

The airborne particulate measurements collected are shown in Table 7 and Figure 18. The results were inconclusive. While the total particle count in the drum soon after moving it to the hot cell mockup facility was almost 248,000 particles/0.1 ft^3, this baseline dropped to almost 80,000 particles/0.1 ft^3after 24-hours. Four hours after the addition of the fogging agent, the total particle count increased to over 510,000 particles/0.1 ft^3. This is most likely due to fogging agent particles still being suspended within the drum and contributing to the particle count. The total particle count in the drum dropped to 361,000 particles/0.1 ft^3after 24 hours and back to near-baseline (88,000 particles/0.1 ft^3) after 96 hours, indicating that a few days are needed for the fogging agent particles to completely settle out of the air.

The development of a different protocol is needed to provide conclusive data on the FX2 ability to reduce airborne particulates. The introduction of a large diameter airborne particulate (i.e., larger than the fog droplet size) into the testing environment prior to fogging would allow for a measurable difference in particulate count before and after fogging.

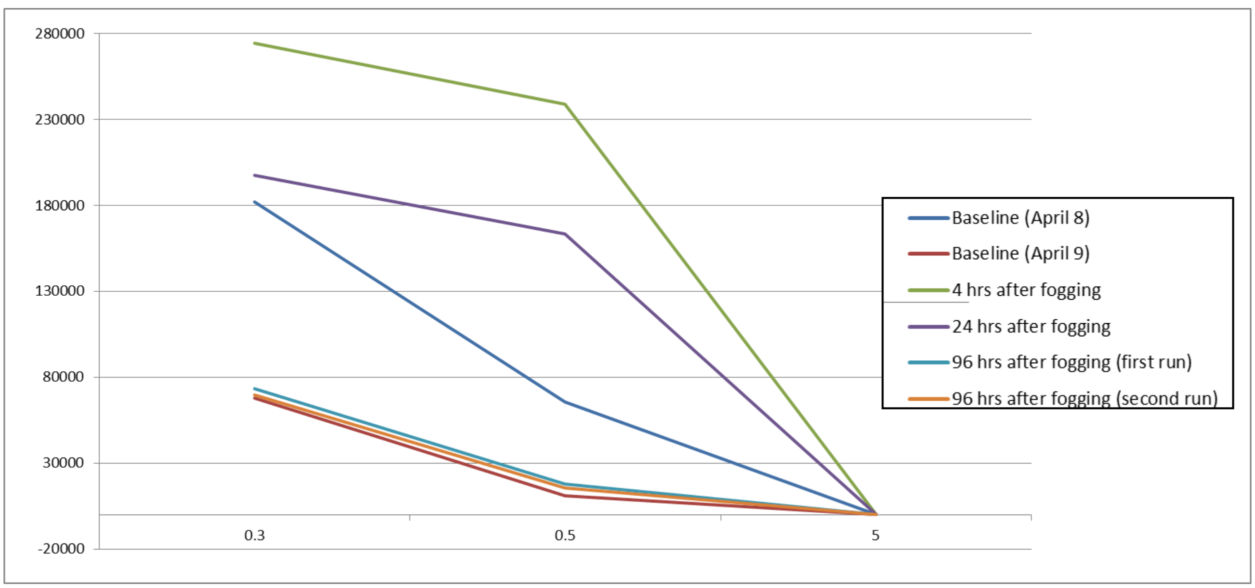

Figure 18. Air particulate measurements – particle count versus particle size.

Table 7. Airborne Particulate Measurements

Location	Particle Size (microns)	Run 1 (particles/0.1 ft^3)	Run 2 (particles/0.1 ft^3)	Run 3 (particles/0.1 ft^3)	Average (particles/0.1 ft^3)
Drum Baseline (April 8)	0.3	178,025	180,772	187,498	182,098
	0.5	63,945	62,354	71,067	65,789
	5	35	29	10	25
	Total	**242,005**	**243,155**	**258,575**	**247,912**
Drum Baseline- (April 9)	0.3	78,481	58,164	67,464	68,036
	0.5	13,918	9,406	10,045	11,123
	5	14	2	21	12
	Total	**92,413**	**67,572**	**77,530**	**79,171**
4 hours after fogging (April 9)	0.3	253,535	280,305	289,819	274,553
	0.5	215,855	240,938	260,337	239,043
	5	476	0	557	344
	Total	**469,866**	**521,243**	**550,713**	**513,940**
24 hours after fogging (April 10)	0.3	198,226	195,577	198,594	197,466
	0.5	159,179	166,137	165,038	163,451
	5	2	0	2	1
	Total	**357,407**	**361,714**	**363,634**	**360,918**
96 hours after fogging (April 13)	0.3	35,893	96,158	87,698	73,250
	0.5	5,208	25,801	23,227	18,079
	5	10	21	16	16
	Total	**41,111**	**121,980**	**110,941**	**91,345**
96 hours after fogging (April 13) – second set of runs	0.3	55,629	67,896	86,106	69,877
	0.5	12,682	16,476	18,341	15,833
	5	8	2	23	11
	Total	**68,319**	**84,374**	**104,470**	**85,731**

SHIELDING AGAINST ALPHA RADIATION

Each source was labelled and three measurements were taken with a calibrated Geiger-Muller Counter, Pancake-type, Model 2241-3 from Ludlum Measurements. Baseline measurements were taken prior to fogging and then additional measurements were taken after 5 minutes of fogging (agent wet), after 10 minutes of fogging (agent wet), and then 7 days later once the fogging agent was completely dry. Table 8 shows the radiation measurement results and Table 9 shows the ImageJ results for percent coverage of the fogging agent for the exposed area of the source.

Table 8. Radiation Measurements from Alpha Point Sources

	Source	Reading 1 (cpm)	Reading 2 (cpm)	Reading 3 (cpm)	Average (cpm)
Baseline and after fogging readings taken in ARC's Hot Cell Mockup Facility. Background reading 92cpm					
Baseline	1	9439	9640	9372	9484
	2	9474	9712	9810	9665
After 5 minutes fogging	1	218	198	214	210
	2	229	202	222	218
After 10 minutes fogging	1	116	121	96	111
	2	99	104	118	107
Dry readings taken in ARC's Environmental Technology Research Lab. Background reading 73cpm					
After fog has dried	1	113	108	110	110
	2	62	97	81	80

Both sealed point sources exhibited significant reductions in measurable alpha radiation immediately following the application of the FX2 agent, while still wet. In order to eliminate the possible effects the high water content may have had on the results, both sources were measured again once dry. The results provide conclusive evidence that the shielding properties of the FX2 fogging agent against alpha emitters are generally consistent when wet or dry.

Table 9. Percent Coverage of Exposed Area of Sources

Source	Percent Coverage (5 minutes fogging)	Percent Coverage (10 minutes fogging)
1	67.2%	75.4%
2	65.2%	77.3%

The window on the sealed Po-210 point sources is very small (1/4" diameter) and recessed (1/8"). The fogging agent successfully accessed this area and provided ~66% coverage after only 5 minutes of fogging and ~76% coverage after an additional 5 minutes of fogging. A comparison of the percent coverage to the radiation measurements was then performed. Figure 19 shows the results.

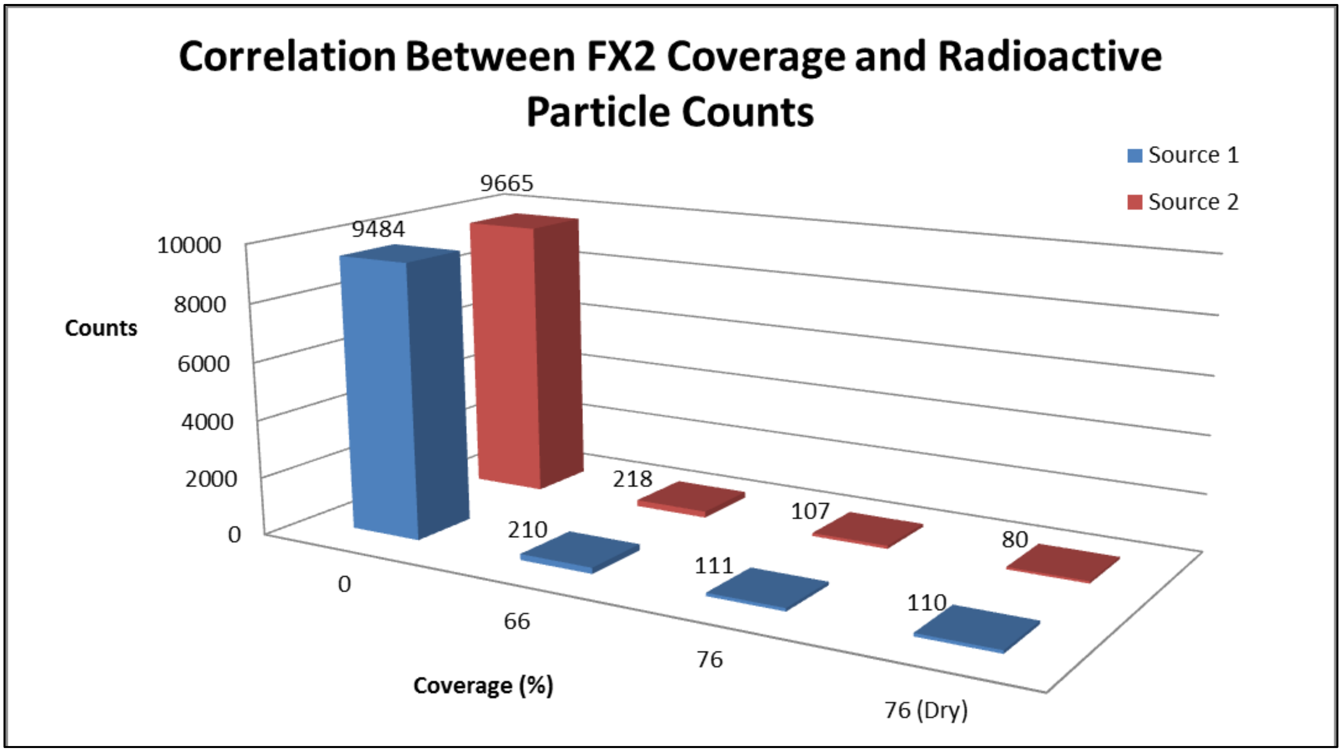

Figure 19. Radiation measurements versus percent coverage.

CONCLUSIONS

Overall, the technology was capable of successfully achieving the objectives of this demonstration. The FX2 advanced fogging agent was very effective at reaching line-of-sight and non-line-of-sight areas in the horizontal plane. Vertical surfaces were less readily coated by the agent. There did not appear to be significant differences in the coverage achieved by the FX2 regardless of placement/location in the test facility. In addition, the advanced fogging agent demonstrated excellent fixing capacity for potential airborne particles such as dust and lint on metal, glass, plastic, concrete, and wood surfaces. The bond appeared slightly less durable on wood, but additional samples may be required before a definitive correlation can be made. The FX2 advanced fogging agent also demonstrated conclusive results in providing shielding against alpha sources as well as its non-flammability during the application phase. Finally, the commercial off-the-shelf Cyclone foggers appeared to do an excellent job at dispersing the FX2 advanced fogging agent in its current composition.

The technology was evaluated for 16 health and safety categories and a risk rating was applied to each (Appendix A). Eleven (11) 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: 1) tripping hazard from the electrical cord to the fogger(s); 2) inhalation irritant of FX2 fogging agent when wet/being dispersed; 3) skin irritant from wet FX2 agent; 4) noise above background produced from the foggers when running; 5) and particulate emissions from the FX2 agent that stay suspended for a period of time after dispersal.

A few challenges were encountered during the demonstration. Initial test runs using a single Cyclone fogger in the hot cell mockup facility failed to achieve a uniform application of the FX2 fogging agent. Since the objectives of the technology demonstration were test the FX2 agent itself and not specifically the delivery device, additional test runs were performed to optimize airflow throughout the entire space in a uniform fashion. The final solution implemented included using two Cyclone foggers at the same height (53”), along the same wall and blowing diagonally across each other’s stream. This set-up manipulated the air flow to move uniformly within the given space.

Another challenge faced was that a comprehensive NIST/ASTM standard for fixatives designed to operate in a radioactive environment does not exit. FIU recommends the development and establishment of standardized testing protocols and performance measures for fixatives and related contamination control products. The testing protocols that FIU implemented during this technology demonstration for the ability of a product to fix loose and potential airborne contamination, ability to effectively cover non-line-of-sight areas, and ability to shield against radioactivity, could be used to begin this process.

While the Cyclone foggers were effective at dispersing the FX2 advanced fogging agent in the hot cell mockup facility, additional research needs to be performed on the potential need for remote application methods, such as a robotic fogger, especially for facilities with significant challenges to the dispersal of a fogging agent from only one or two stationary locations (e.g, large square footage, multiple rooms/areas separated by walls, etc.). Preliminary research indicates that such a robotic fogger technology is not currently available.

One innovative methodology employed by FIU during this technology demonstration was the implementation of ImageJ software to determine the percent of surface coverage by the fogging agent. The software performed well in this regard and provided standardized analyses for documenting the results of the demonstration. The use of ImageJ software is worth further consideration in future testing protocols.

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 and through FIU's dedicated DOE EM research website at doeresearch.fiu.edu.

REFERENCES

Banford, Anthony, Rick Demmer, Jeremy Edwards, Richard Tankin, and Jeremy Hastings, "INL-NNL: An International Technology Collaboration Case Study – Advanced Fogging Technologies for Decommissioning," Paper No. 13463, WM2013 Conference, Phoenix, AZ, February 24-28, 2013.

Florida International University, *FX2 Advanced Fogging Technology: Technology Demonstration Test Plan*, January 16, 2015.

Idaho National Laboratory, *Pilot Scale Advanced Fogging Demonstration*, 2014.

Material Safety Data Sheet (MSDS), *FX2 Fogging Fixative*, Idaho National Laboratory, Reference No. FX-002, February 27, 2015.

APPENDIX A.
FIELD DATA TABLES

FX2 ADVANCED FOGGING AGENT TECHNOLOGY

Field Data Tables

DATA	DESCRIPTION	UNITS
The following sections can be completed prior to the demonstration:		
GENERAL INFORMATION ABOUT TECHNOLOGY **To be supplied by the vendor.**		
Technology Name	The generic name of the technology (i.e., remote climbing machine)	No units
	FX2 Advanced Fogging Agent	
Technology Model Number	Unique identifier for the technology model, where applicable. Typically supplied by the manufacturer.	No units
	FX2	
Technology Model Description	Technical description of the technology including basic principle(s) and operational parameters and conditions. Discuss all pieces of equipment required by the original manufacturer for this technology model. Include dimensions, weight, and schematic of technology model.	No units
	The FX2 fogging agent is a proprietary mixture of water, latex paint (LTX), glycerin (GLY) and sodium lauryl sulfate (SLS). The mixture is thinner than standard latex paint and can be produced in the quantity needed as well as tinted in any color. The FX2 fogging agent was dispersed for this technology demonstration via a commercial off-the-shelf fogger (Cyclone Ultra-Flex Fogger by Curtis Dyna-Fog).	
Maturity of Technology	The maturity of the technology at the time of the demonstration. Choose from: • Commercially available • Prototype	No units
	Prototype	

FX2 ADVANCED FOGGING AGENT TECHNOLOGY

Field Data Tables

DATA	DESCRIPTION	UNITS
Utility Requirements	Energy and material requirements. Includes compressed air and water requirements.	No units
	Power and water are needed for the fogger used to disperse the FX2 fogging agent. Cyclone fogger Power: 110/120 V AC, 8.5 amps Water source needed to clean and flush fogger after each use.	
Technology Model Capital Costs (Rental and Service also)	The vendor's current list price for the entire technology model. Include cost of all pieces that are part of the technology model. Include current prices for rental of equipment or as service provider.	$
	N/A. Technology (FX2) still under development. The Cyclone Ultra-Flex Fogger by Curtis Dyna-Fog used during this demonstration can be purchased for approximately $700.	
Useful Life Expectancy	The number of hours that the technology model can possibly be used for its specified purpose.	Hrs
	The FX2 fogging agent is consumable.	
Applicable Media	List all possible surface types to which the technology model can be applied.	No units
	Any, including wood, metal (ferrous and non-ferrous), plastic, concrete, brick, block, glass, etc.	
Applicable Geometries	List all possible surface geometries to which the technology model can be applied.	No units
	Any room sized or smaller geometry. The FX2 fogging agent covers/coats horizontal surfaces.	
Equipment portability	Select one or more ways that are ways for removing the technology model from the transportation vehicle once it arrives at the facility where the demonstration is to be performed. Options include: • 1 person needed – the technology model is small/light and easily carried by one person • 2 people needed – the technology model is not as small/light and requires two people to carry • Forklift needed – the technology model is large/heavy and requires a forklift to remove it from the	No units

FX2 ADVANCED FOGGING AGENT TECHNOLOGY

Field Data Tables

DATA	DESCRIPTION	UNITS
	vehicle • Truck/trailer mounted – the major pieces of the technology model are not removed from the truck/trailer but instead are operated from this location	
	1 person	
Required Personnel for Operation	Manpower requirements for operation of this technology. Distinguish between number of equipment operators and number of technicians required.	No units
	1 operator and 1 technician/assistant	
Level of training required	The level of training and the skills that are supposed to be provided to the operators of the technology.	No units
	No special operating skills are needed. Day-of training in the use of the FX2 fogging agent and dispersal equipment would suffice.	
Technology Availability	Average expected delay between order placement and vendor delivery.	No units
	N/A. Technology still under development.	
Scale-up Requirements	Provide a description of what enhancements (equipment/personnel/procedures) would be changed or added by the vendor if the size of the job was greater.	No units
	FX2 agent can be produced in any quantity to meet the size of the job. Additional foggers could be added if the job included a large space or multiple spaces.	
Maintenance Requirements	Listing of the maintenance requirements for the technology model. Include time frames to perform maintenance. Examples include: • change filter every 6 months • add oil motor at end of every day	No units
	• FX2 fogging agent should be stored in unopened containers in a cool and dry environment. • Foggers should be cleaned and flushed after each use.	

FX2 ADVANCED FOGGING AGENT TECHNOLOGY

Field Data Tables

DATA	DESCRIPTION	UNITS
Total Maintenance Cost	Include total cost of regular maintenance per hour of use.	$/hr
	Minimal	
Technology Support Equipment and Cost for Each Unit	List any required support equipment (not utilities) that are included in the demonstration. Include description of each and associated capital costs.	
	Cyclone Ultra-Flex Fogger by Curtis Dyna-Fog - $700/unit. One unit required per 500 $ft.^3$. Ventilation fan - ~$150	
Consumables and Cost for Each Unit	List additional expendable items and associated costs for each item, used with the technology that are typically discarded at the end of a job. Examples include vacuum hoses, belts, etc.	
	No items are typically discarded at the end of a job from this technology. The FX2 is consumable. However, expected expendables when the technology is used in a radioactively contaminated environment include the foggers and ventilation fans.	

FX2 ADVANCED FOGGING AGENT TECHNOLOGY

Field Data Tables

MANUFACTURER INFORMATION		
DATA	DESCRIPTION	UNITS
Name and Address	Information to be collected about company that manufactured the technology model.	No units
	Idaho National Laboratory 2525 N. Fremont Ave. P.O. Box 1625 Idaho Falls, ID 83415	
Phone Number(s)	Include area code. Include pager number or second phone number (if applicable).	No units
	(208) 533-7321	
Fax Number	Manufacturer's fax number including area code.	No units
	(208) 526-5337	
Website	Internet web-site location for manufacturer (if applicable).	No units
	www.inl.gov	
E-Mail	E-mail address for the manufacturer where other D&D professionals can request information.	No units
	Rick.demmer@inl.gov	
Services Available	What services the manufacturer provides. Chosen from one of the following: Service provider, Sells technology model*, Rents technology model* (* When these items are chosen, if the manufacturer will train site personnel, include technology model training time.)	No units
	Any service required to perform the work.	
References	Locations where this technology model has been used previously (especially other DOE or commercial nuclear facilities).	No units

	Testing/demonstrations at Idaho National Lab, Florida International University, and the United Kingdom's National Nuclear Laboratory (NNL).	
Publications	List of brochures or publications that provide additional information about the technology model and/or the company. Corporate history or profile.	No units
	INL is part of the U.S. Department of Energy's complex of national laboratories. The laboratory performs work in each of the strategic goal areas of DOE: energy, national security, science and environment. INL is the nation's leading center for nuclear energy research and development. INL is managed by Battelle Energy Alliance for the Department of Energy's Office of Nuclear Energy. Refer to the website for additional information: www.inl.gov	
Photographs/Video	If photographs or video is received from the manufacturer and sent for inclusion in the database, list which and the number of each sent to FIU.	No units
	Photographs and videos taken during demonstration.	
VENDOR INFORMATION		
Name and Address	Information to be collected about the company that was chosen as the vendor for this particular demonstration.	No units
	Idaho National Laboratory 2525 N. Fremont Ave. P.O. Box 1625 Idaho Falls, ID 83415	
Phone Number(s)	Include area code. Include pager number or second phone number (if applicable).	No units
	(208) 533-7321	
Fax Number	Vendor's fax number including area code.	No units
	(208) 526-5337	

Website	Internet web-site location for vendor (if applicable).	No units
	www.inl.gov	
E-Mail	E-mail address for the vendor where other D&D professionals can request information.	No units
	Rick.demmer@inl.gov	
Services Available	What services the vendor provides. Chosen from one of the following: • Service provider Sells technology model * Rents technology model * (* When these items are chosen, if the manufacturer will train site personnel, include technology model training time.)	No units
	Any service required to perform the work.	
References	List of locations where this technology model has been used previously (especially other DOE or commercial nuclear facilities).	No units
	Testing/demonstration at Idaho National Lab, FIU, and UK National Nuclear Laboratory.	
Publications	List of brochures or publications that provide additional information about the technology and/or the company. Corporate history.	No units
	INL is part of the U.S. Department of Energy's complex of national laboratories. The laboratory performs work in each of the strategic goal areas of DOE: energy, national security, science and environment. INL is the nation's leading center for nuclear energy research and development. INL is managed by Battelle Energy Alliance for the Department of Energy's Office of Nuclear Energy. Refer to the website for additional information: www.inl.gov	

<table>
<tr><th colspan="3">GENERAL DEMONSTRATION INFORMATION
(To be completed by evaluation team)</th></tr>
<tr><th>DATA</th><th>DESCRIPTION</th><th>UNITS</th></tr>
<tr><td rowspan="2">Demonstration Site Location and Description</td><td>Location of demonstration including name of facility and city/state and brief site description.</td><td>No units</td></tr>
<tr><td colspan="2">Florida International University, Applied Research Center, Miami, FL

Hot cell mockup facility at ARC’s outdoor Technology Testing & Demonstration Facility was modified for this demonstration, which was conducted under standard non-nuclear conditions. 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 10-ft wide x 20-ft long x 10-ft high and has an entry point at one end as well as a window in the side. The mockup facility has two round port holes right above the window. The walls are constructed from poured concrete and Plexiglas was installed over the window. For this technology demonstration, the hot cell mockup was modified to construct smaller spaces: 10’ width x 10’ length x 10’ height for testing scenario 1 and 10’ width x 15’ length x 10’ height for testing scenario 2. The new walls were framed with standard 2x4 lumber and covered with lightweight panels.</td></tr>
<tr><td rowspan="2">Problem Targeted</td><td>A brief description of the specific problem(s) targeted and its importance or critical nature.</td><td>No units</td></tr>
<tr><td colspan="2">Many facilities slated for D&D across the DOE complex pose hazards (radiological, chemical, and structural) which prevent the use of traditional manual techniques. Efficient and safe D&D of the facilities will require the use of innovative technologies. In addition, the D&D of a radioactive facility requires that it be stabilized to allow demolition to occur while maintaining worker radiation exposure ALARA and without spreading radioactive contamination.

The objective for this technology demonstration was to test and evaluate the FX2 Advanced Fogging Agent, developed at Idaho National Laboratory (INL), for potential implementation at the 235-F facility at Savannah River National Laboratory (SRNL). SRNL has identified a need for an advanced fogging technology to better address the potential airborne contaminants at this facility.</td></tr>
<tr><td rowspan="2">Demonstration Start and End Dates</td><td>Dates from start to finish for this particular demonstration. Example: October 20-24, 2014</td><td>No units</td></tr>
<tr><td colspan="2">March 30-April 3, 2015</td></tr>
</table>

FX2 ADVANCED FOGGING AGENT TECHNOLOGY

Field Data Tables

Major Objectives of the Demonstration	Objectives as they relate to DOE environmental requirements.	No units
	To meet the challenge for a technology to effectively and efficiently address the potential airborne contaminants at the SRS 235-F facility.	
Major Elements of the Demonstration	Specific elements evaluated during the demonstration.	No units
	1. Ability to fix loose contamination to different types of surfaces (glass, concrete, steel, wood, and plastic) and adhesiveness to the surface. 2. Ability to cover locations both within and outside of the direct line-of-sight of the fogger. 3. Capacity to knockdown airborne particulates. 4. Characteristic properties of the product: a. Burn rate (ASTM E84) b. Flammability (ASTM D3065) c. Viscosity (ASTM D2196) d. Surface Tension (ASTM D1331) e. Density (ASTM D792) 5. Reactivity to flame and heat sources. 6. Ability to shield against an alpha emitting point source 7. Ability to effectively cover surfaces throughout hot cell mockup facility	
Boundaries of the Demonstration	Specific goals addressed versus not addressed.	No units
	Demonstration was limited in size of hot cell mockup: scenario 1 was 10’ width x 10’ length x 10’ height and scenario 2 was 10’ width x 15’ length x 10’ height. Larger facilities may require additional foggers and/or additional locations for fogging dispersal to fully cover the entire area.	
Testing Organization, Contact Name, Phone Number, and E-Mail	• The name of the organization responsible for this demonstration and the information on a contact person who can be reached to gather additional information about all of the demonstrations performed by that organization. Example: FIU ARC, Leo Lagos, phone number, email	No units
	FIU ARC, Leo Lagos, 305-348-1810, lagosl@fiu.edu INL, Rick Demmer, (208) 533-7321, rick.demmer@inl.gov	
Test Engineer Name	The name of the person from the test organization in charge of setting up and evaluating this particular demonstration.	No units
	Joseph Sinicrope and Peggy Shoffner (FIU) and Steve Reese (INL)	

Vendor Principal Investigator Name	The name of the vendor personnel that is supervising the demonstration from the demonstration site.	No units
	Steve Reese (INL)	

REGULATORY, PERMITTING, AND SAFETY ISSUES		
DATA	**DESCRIPTION**	**UNITS**
Patent/licensing Issues	Is the technology patented or licensed. If so, by whom. Technology specific.	No units
	FX2 mixture is proprietary, but it is not currently protected by a patent. At this time, the formulation has not been licensed to a private company.	
Site-specific Regulatory/Permitting Issues	List any regulatory/permitting issues specific to the demonstration site or state. Include any OSHA regulations that should be considered for technology operation.	No units
	Standard industrial/jobsite safety practices.	
Secondary Waste Stream Regulatory Considerations	List any regulations that must be considered for the collection and disposal of the secondary waste. Consider RCRA, DOT, and Waste Acceptance Criteria concerns.	No units
	The FX2 fogging agent is consumable. Flushing the foggers with water produces a liquid secondary waste which is a heavily diluted mixture of water and the FX2. Disposal should follow recommendations from the MSDS.	
CERCLA Criteria	Evaluate the technology against the nine CERCLA evaluation criteria. (Even if CERCLA does not apply.) – See page 8 of ITSR Guidance (May 1998)	No units
	1. Overall protection of human health and the environment • Worker risk reduction - protects workers by performing D&D activity remotely. Dose rates within hot cells can range up to hundreds of R/hr, precluding human entry. • Environment risk reduction - fixes loose/removable contamination which will reduce radiation exposure and reduce risk of spread of contamination. 2. Compliance with ARARs 3. Long-term effectiveness and permanence Not applicable. Coating is intended to be a short-term treatment prior to D&D. 4. Reduction of toxicity, mobility, or volume through treatment • Effective reduction of mobility by fixing loose/removable contamination. 5. Short-term effectiveness • Excellent short-term effectiveness 6. Implementability • Technology is not commercially available.	

	7. Cost • Costs relatively low, comparable to other fixative technologies. 8. State acceptance • No hurdles to state acceptance 9. Community acceptance • No hurdles to community acceptance	
Worker Safety Issues	Discuss any safety issues for the workers, include possible exposures or liability risks.	No units
	The technology actually mitigates safety issues for the workers by minimizing exposure to radioactivity by providing a coating to fix loose contamination. FX2 agent is an irritant to eyes, lungs, and skin while wet and being applied.	
Community Safety/Stakeholder Issues	Discuss safety from the perspective of the community and stakeholders. Are there any stakeholder issues that might preclude the use of this technology at the site?	No units
	No community or stakeholder issues.	

DATA	DESCRIPTION	UNITS
The following sections are to be completed during or immediately after demonstration:		
	DEMONSTRATION STATISTICS	
Information to be completed one time during demonstration:		
Mobilization Time	A measured time for how long it takes to mobilize the technology model prior to performing work. This time measures from the time the vendor arrives at the demonstration site to when the technology model is ready to operate.	hr
	Estimated mobilization time during the cold demonstration = 30 minutes. Additional mobilization time would be required at a DOE nuclear facility, depending on site requirements.	
Portability Option Chosen	List of equipment/ personnel used at this particular demonstration to remove the technology model from the vendor vehicle during mobilization/demobilization.	No units
	Equipment and FX2 agent can be moved by 1 to 2 people. No heavy equipment is required.	
Required PPE for Demonstration	List the PPE that was required to operate the technology model during the demonstration. If the equipment operator and technicians wore different levels of PPE, describe the most restrictive.	No units
	Safety glasses, gloves, and breathing protection/particulate trapping masks.	
Demobilization Time	A measured time for how long it takes to demobilize the technology model after demonstration. This time measures from the time the technology model is ready to be decontaminated to when the vendor leaves the demonstration site.	hr
	Estimated demobilization time during the cold demonstration = 1 hr. Additional demobilization time would be required at a DOE nuclear facility, depending on site requirements.	
Supporting equipment installation/setup	A measure of time for setting up/hooking up supporting equipment (generator, air compressor, etc)	hr
	Minimal time required to set up and hook up supporting equipment during the cold demonstration. Significant time could be required at a DOE nuclear facility to connect ventilation filters and fans, depending on site requirements.	

FX2 ADVANCED FOGGING AGENT TECHNOLOGY

Field Data Tables

DATA	DESCRIPTION	UNITS
Information to be completed for each problem set:		
Problem Set	Describe problem set for which data applies.	No units
	Enclosed facility: scenario 1 was 10' width x 10' length x 10' height and scenario 2 was 10' width x 15' length x 10' height.	
Technology Model Maneuverability	Discuss maneuverability of the technology model, including horizontal and vertical surfaces. Include examples of ease or difficulty whenever possible.	No units
	Not applicable. FX2 agent is a consumable product. Foggers can be easily moved manually.	
Consumption Rate	Include measurements on the following: • Fogging rate • Amount consumed Additional information should be collected if relevant.	Various
	• The two scenarios (10' x 10' x 10' and 10' x 15' x 10') resulted in all horizontal surfaces being well coated within 15-30 minutes of fogging from two Cyclone foggers. • Amount of fogging agent consumed: ~3 L consumed total by 2 foggers run for 30 minutes (~3 L/hour per fogger)	
Observation of How Coating is Applied	Description of application	No units

DATA	DESCRIPTION	UNITS
	This demonstration used two Cyclone foggers which dispersed the FX2 fogging agent as a very fine mist. Within just a few minutes of fogging, the color-tinted fog could be seen through the observation window and quickly became thick enough to make it difficult to make out items located in the hot cell mockup.	
Production rate	The measurement of covered surfaces (ft^2) 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 problem set completion, just prior to equipment demobilization. Production time includes breaks taken by operators, equipment adjustments and maintenance, rigging equipment adjustments (when appropriate), 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.	ft^2/hr
	~100 sq ft/hr (10’ x 15’ square footage for scenario 2, 30 minutes to fog and 60 minutes for fog to settle/ventilate)	
Problems encountered	A detailed description of problems encountered during the demonstration.	No units
	Initial test runs using a single Cyclone fogger in the hot cell mockup facility failed to achieve a uniform application of the FX2 fogging agent. Since the objectives of the technology demonstration were test the FX2 agent itself and not specifically the delivery device, additional test runs were performed to optimize airflow throughout the entire space in a uniform fashion. The final solution implemented included using two Cyclone foggers at the same height (53”), along the same wall and blowing diagonally across each other’s stream. This set-up manipulated the air flow to move uniformly within the given space.	
Quality of coated surfaces	Quality refers to the nature of the coated surfaces, whether they are evenly coated, whether there are surfaces the technology was unable to coat, etc.	No units

DATA	DESCRIPTION	UNITS
	Horizontal surfaces were fairly uniformly coated. Vertical surfaces retained little of the FX2 fogging agent. Longer fogging runs resulted in more complete coverage of horizontal surfaces.	
Application rate of coating used	The quantity of coating required per time of operation will be recorded at the test site during the technology demonstration.	(gal/hr)
	3 L/hr per fogger	
Waste Volume	The measured volume of primary/secondary waste generated during this particular demonstration.	No units
	Approximately 45 gallons of loose dry waste was generated during this demonstration, primarily consisting of used PPE (gloves, respirator masks, etc.) and filters from the exhaust fan.	
Waste Characteristics	The description of primary/secondary waste generated during this particular demonstration.	No units
	45 gallons of loose dry trash consisting of used PPE and air filters and miscellaneous loose dry trash (paper towels, water bottles, etc.)	
Technology Model Decontamination Method	The method used to clean and decontaminate the technology model after the demonstration is completed. Examples include: • wiped with damp rags • could not be decontaminated • cleaned using soft media blasting equipment • stainless steel construction makes for easy decontamination by wiping with damp rags.	No units
	Clean tap water was flushed through the foggers.	

FX2 ADVANCED FOGGING AGENT TECHNOLOGY

Field Data Tables

OVERALL RATING OF TECHNOLOGY		
Effectiveness of Overall Technology	Qualitative evaluation of how the technology model, spraying mechanism, and coating combination demonstrated achieved the desired effect. Scale of 1-4, with 4 being the highest. Include reason rating was given including whether final outcome of demonstration met site needs, and if not, what needs were not met.	No units
	4 – demonstration fully met almost all of the test objectives; only the ability to knock down airborne particulates was inconclusive due to the airborne particulate count including suspended fogging agent particles	
Benefits	Technical and economic advantage(s) of the technology over competing technologies (e.g., lower cost, greater degree of cleanup, more stable waste form, increased safety).	No units
	As compared to manual spraying of coating in a radioactive setting, the technology increases worker safety and improves ALARA.	
Limitations	Disadvantages or shortfalls the technologies has (e.g., conditions under which the technology shall not be used at this time). Include any outstanding design issues and/or problems that may have been encountered during the demonstration or post-demonstration. Include needs/recommendations for further development.	No units
	Access points for fogger(s) is a requirement; substantially larger spaces than those tested in this demonstration may need additional foggers and/or dispersion points.	
Potential Markets	Potential markets for the technology (both specific DOE applications/sites and non-DOE applications)	No units
	Radioactive environments at DOE sites.	

Data Sensitivities	Description of items that could affect the quality of the data collected. Examples may include: • Vendor statement that the equipment/personnel used at the demonstration is not what would be used in routine decontamination jobs • Vendor statement that demonstration conditions were unlike what would be seen in normal jobs and adversely effected their performance as seen in the statistics • Information about data that was misplaced or unsure of accuracy.	No units
	• The ImageJ analysis of percent coverage proved very promising but requires additional validation before it can be deemed definitive. • The lack of an existing standardized testing protocol would make it difficult to directly compare the results of this testing and evaluation of FX2 with the testing and evaluation of similar products performed by another organization. FIU highly recommends the development of an industry-wide effort to develop and promulgate uniform standards.	
Recommendations for Improvement	Describe any recommendations that should be made to the vendor to improve the technology to make it more safe, efficient, and/or cost effective.	No units
	The color tint added to the FX2 was very useful in being able to make visual observations of the effectiveness of the fog during and after the fogging operations.	

HEALTH AND SAFETY RATINGS		
A risk rating (from 1 to 4) for each health and safety category and a description of the specific hazards associated with this particular technology and/or demonstration. Use NA if not applicable to this technology. 1 = Hazard may be present but not expected over background levels 2 = Some level of hazard above background level known to be present 3 = High hazard potential 4 = Potential for imminent danger to life and health		
DATA	**DESCRIPTION**	**UNITS**
Electrical	1	No units
Fire/Explosion	1	No units
Confined Space Entry	NA	No units
Mechanical Hazards	1	No units
Pressure Hazards	1	No units
Tripping and Falling	2 – foggers require an electrical cord which could pose a tripping hazard	No units

Moving Vehicles	NA	No units
Protruding Objects	1	No units
Overhead Lifts	NA	No units
Inhalation	2 – FX2 agent is an irritant if inhaled (only applicable when wet/being dispersed)	No units
Skin Absorption	2 – FX2 agent can irritate the skin while wet	No units
Heat Stress	NA	No units
Noise	2 – the FX2 agent itself generates no noise but the foggers used to disperse the agent produce noise above background levels	No units
Cold Stress	NA	No units
Ergonomic Hazards	1	No units
Particulate Emissions	2 – the FX2 agent stays suspended for a period of time after dispersal	No units
Other (list)		No units

APPENDIX B.
IMAGEJ SOFTWARE

Background

ImageJ is a public domain image processing and analysis program scripted in Java and developed at the National Institutes of Health (NIH). Being the primary agency of the United States government in regards to health-related research and the global leader of funding medical research, NIH developed the ImageJ software to provide a better means of analysis regarding visual and quantifiable facets of microbiology, such as particle counting in a cell colony or distribution of parasitic particles and viral agents, to name a few. Due to its extensible plugin infrastructure, ImageJ has the capacity to expand its applicability by allowing the user to download a considerable variety of plugins that will shortcut the process required to perform a specific task. The software is also conducive to the creation of customized plugins via its built-in editor and a Java compiler. The developer of ImageJ has made it readily available for Microsoft Windows, Mac OS, OS X, Linux and Sharp Zaurus PDA.

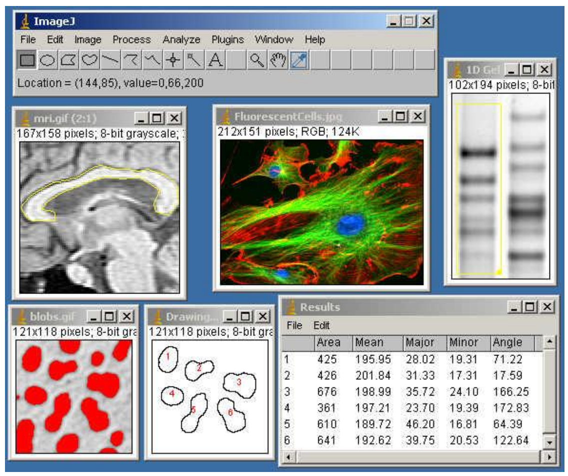

Figure 20. ImageJ software.

Although developed for use in the life sciences fields, ImageJ is applicable to many other research fields. For purposes of the FX2 testing, ImageJ provided the capacity to evaluate coverage of the FX2 agent on a material's surface. In order to do so, the following features of the ImageJ software were leveraged: contrast manipulation, edge detection, precision scaling, median filtering, and particle quantification. With the information derived, correlations could be drawn between the coverage of the fixative and its properties.

Image J Employment during FX2 Testing

To provide the reader with a better understanding of our use of ImageJ during the execution of the FX2 Test Plan, a typical example highlighting the procedure is outlined below.

1. After application of the FX2 agent, a photo of the designated coupon, including a ruler / tape measure to annotate scale, was taken with a Canon EOS digital Rebel XTi camera.
2. The images are subsequently uploaded to a laptop, named per the established naming convention, and imported as a new image study.
3. Using the scale shown in the image, a line is drawn across the scale to create a relationship between the number of pixels and the desired distance unit (e.g., cm, inch, etc.).

4. To isolate the desired area, a geometric shape that would serve as the border is created.
5. A duplicate is created and saved as a different file.
6. Excess area is eliminated using the Clear Outside option to trim down the area of analysis within the image.
7. Contrast was enhanced as follows:
    a. Within the Process menu, an option for enhancing contrast can be found. In this setting adjustment, pixel saturation levels can be manipulated to the desired amount. In other words, the strength of the color, or amount of grey in proportion to the hue, can be modified.
    b. The color balance is then adjusted to highlight the features of interest.
8. The detection threshold is then adjusted as follows:
    a. The user modifies the brightness of the image, the hue filter, and the saturation filter.
    b. The user generates a filtered image that accurately depicts the data in the original.
9. Particle analysis is conducted by quantifying the amount of area the particles occupy, as well as the size of each, and percent coverage of particle area to total area. Using the amount of area the particles occupy and known area of the sample dishes, calculating a ratio of the two to quantify coverage is straightforward.

Benefits

This program proved itself very versatile, having a vast set of options and tools to implement for image processing and analysis. As mentioned earlier, ImageJ has a useful plug-in infrastructure that allows the program to be upgraded with the accessible modifications available on their main website (Figure 21). This enables the user to tackle an issue from several different angles. In our case, we made use of this feature and downloaded several plug-ins that were used in order to maximize contrast, apply filters with the most balanced permeation and to enhance edge detection. Another attribute of the software that should not be overlooked is its simple interface. Since all of its features are neatly organized into seven drop-down menus, it makes ImageJ very user-friendly and conducive to learning. Lastly, a concern that exists with the utilization of any program is the computing time. ImageJ is able to detect particles, size them to scale, calculate the average, the extremes, the area the particles occupy, and the ratio of the areas almost instantaneously in a consistent fashion. This is proof of ImageJ’s capacity to not only edit and process images, but to make computations using numerical analyses and iterative methods similar to other engineering programs.

Filters [top]

Real Convolver
FFT
LoG Filtering
Background Subtraction and Normalization
Contrast Enhancer
Background Correction
Byte Swapper
Discrete Cosine Transform (DCT)
FFT Filter
FFTJ and DeconvolutionJ
Unpack 12-bit Images
De-interlace
2D Gaussian Filter
Kalman Filter
Dual-Energy Algorithm
Anisotropic Diffusion (edge-preserving noise reduction)
Grayscale Morphology Updated
2D Hybrid Median Filter
3D Hybrid Median Filter
Spectral Unmixing
Haar Wavelet Filter and Adaptive Median Filter
'A trous' Wavelet Filter
Kuwahara Filter
Granulometric Filtering
Windowed-Sinc Filter (low pass time series filter)
Anisotropic Diffusion 2D (edge-preserving noise reduction)
Auto Gamma (gamma correction)
Linearize Gel Data
Radon Transform (CT back projection, sinogram)
Correct X Shift of Confocal Images
Multi Otsu Threshold
Spectral Unmixing of Bioluminescence Signals
Lipschitz Filter
Float Morphology (erode, dilate, open, close)
X_Shifter (correct pixel mismatch of confocal images)
Sigma Filter (edge-preserving noise reduction)
Rolling Ball Background Subtraction
Mean Shift Filter (edge-preserving smoothing)
Accurate Gaussian Blur
Add Poisson Noise Updated
CLAHE (Contrast Limited Adaptive Histogram Equalization)
Floyd Steinberg Dithering
Polar Transformer (corrects radial and angular distortions)
Gaussian Blur 3D
Image Rotator (rotates image around ROI center of mass)
Mexican Hat (2D Laplacian of Gaussian) New
Canny Edge Detector New
Plane Brightness Adjustment (enhances CLSM images) New
Polynomial Surface Fit (fits polynomial surface to an image) New

Segmentation [top]

Figure 21. List of filter plug-ins available on ImageJ website.

Limitations

While ImageJ provides reliable and accurate data analysis for the user, there are many user dependent factors which could hinder the validity of the results. The first step in receiving accurate results is to capture a clear image preferably with the presence of natural light. In the case that sunlight is not the light source and the target is slightly reflective, the uniform lighting of the image will be skewed. This will affect the ability of the program to recognize certain areas of the surface due to glare and overexposure. With the use of professional lighting, however, this can mitigated to some extent. To our knowledge, ImageJ does not have a feature to "fill in" these brighter areas or darken them. On the other end of the spectrum, the shot should be taken directly above the subject of interest to generate an image free of any shadows and darker spots. Similarly, modifying these dark ends is not possible and thus must be avoided, along with the potential data that can be extracted in those areas. In addition, a reference length, i.e. ruler, must be present in the image to allow for the proper scaling of the image. This is one of the most important steps in obtaining accurate results. If this is not considered, the primary aforementioned features would not be able to provide the end user with probable data.

Beyond the capturing of the image, issues were often encountered throughout the analysis phase. The first problem at hand was trying to isolate the area we chose to process. When doing so, the program allows you to produce a shape, either preset or freehand, and duplicate that region as a separate image. However, contrary to the end user's intent, it will provide the duplicate as a square each time. A visual aid is provided below (Figure 22).

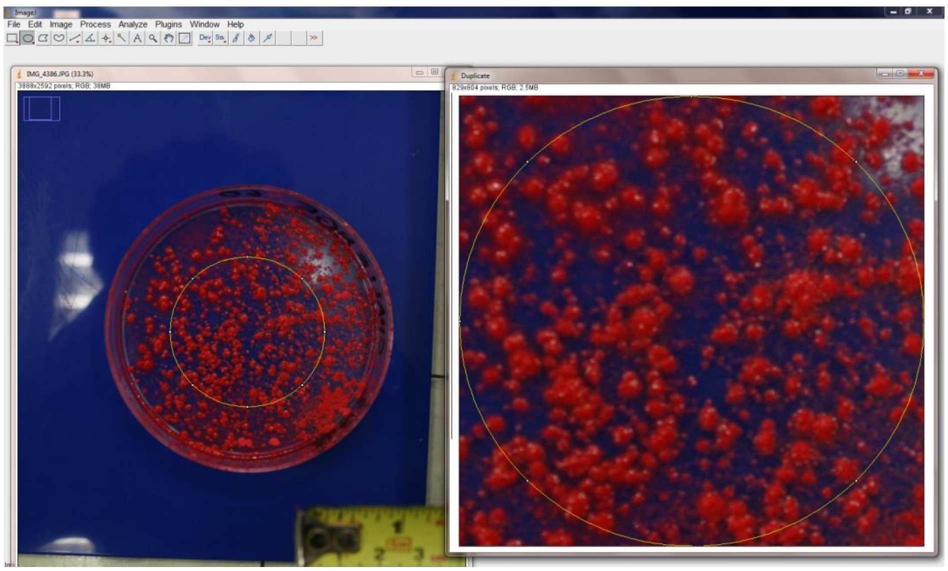

Figure 22. Area desired juxtaposed with area given.

As one can observe, the program will give an excess area, which only makes the image analysis convenient for square areas. There is "Clear Outside" option which will black out the unwanted regions. However, when creating the black and white contrast, it will consider the "cleared" area as part of the white space in the total area, thus creating an inaccurate ratio between covered and uncovered.

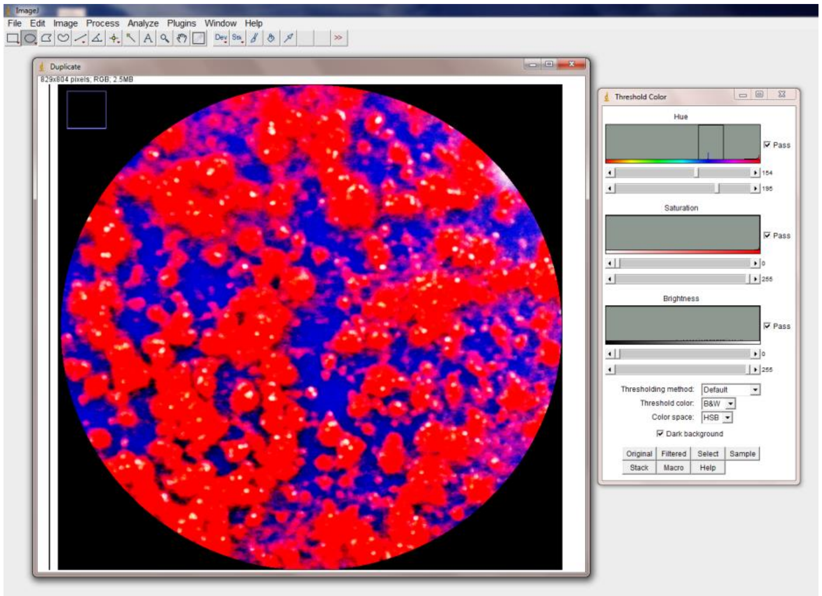

Figure 23. Image with enhanced contrast.

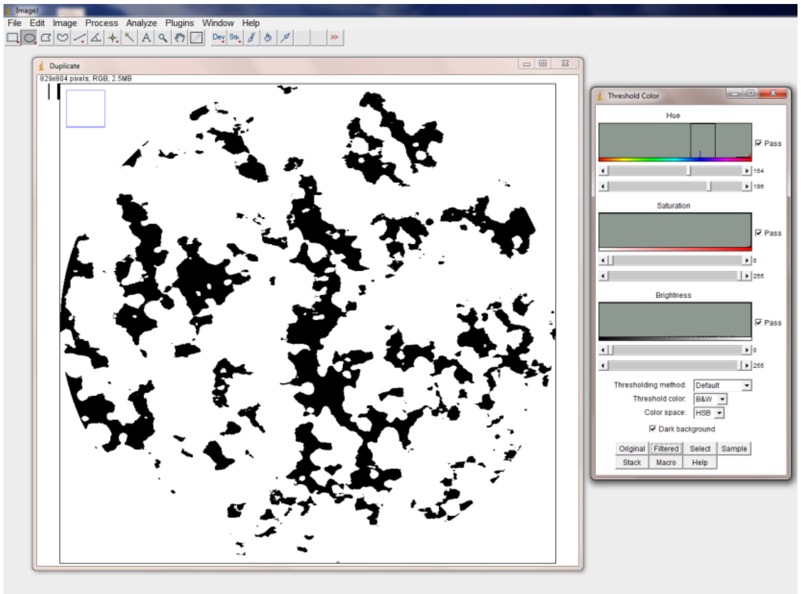

Figure 24. Threshold and filters applied.

This has certainly been the biggest issue we have encountered with the ImageJ software. It was forced us to do simple, yet unnecessarily extraneous, calculations to get an accurate coverage.

Bottom Line Assessment

All in all, ImageJ was of great use and value to the analysis of our testing efforts.

APPENDIX C.
FX2 MATERIAL SAFETY DATA SHEET

MATERIAL SAFETY DATA SHEET

FX2 Fogging Fixative

MSDS Ref. No: FX-002
Date Prepared: 02/27/2015
Date Revised: 02/27/2015

1. PRODUCT AND COMPANY IDENTIFICATION

PRODUCT NAME/USE: FX2 Fogging Fixative -Idaho National Laboratory (INL), Used as a fixative for radioactive contamination on building surfaces.
PRODUCT CODE: FX2
PRODUCT FORMULATION NAME: Latex based fixative
CHEMICAL FAMILY: Surfactants, latex, organic gels
MOLECULAR FORMULA: Not Available
GENERIC NAME: Fogging Fixative

MANUFACTURER

Idaho National Laboratory
2525 N. Fremont Avenue
P.O. Box 1625
Idaho Falls, ID 83415

Emergency Contact: Rick Demmer
Telephone Number: (208) 533-7321
Emergency Telephone (24 hours): (208) 589-4858
CHEMTREC (U.S./Can.): 800-424-9300
CHEMTREC (Int'l): +1 703-527-3887
Transportation: (804) 968-6388

COMMENTS: To the best of our knowledge, this Material Safety Data Sheet conforms to the requirements of US OSHA 29 CFR 1910.1200, 91/155/EEC and Canadian Hazardous Products Act.

2. COMPOSITION / INFORMATION ON INGREDIENTS

INGREDIENT(S)	CAS#	% BY WEIGHT
Latex paint (containing – below)		0-30%
Titanium dioxide	13463-67-7	25%
Kaolin	1332-58-7	10%
Silica, amorphus	7631-86-9	5%
Parraffinic petroleum distillates	64742-65-0	1%
Acetic acid ethenyl ester	108-05-4	0.5%
glyerin	8043-29-6	0-15%
Sodium lauryl sulfate	151-21-3	0-15%
Water (remainder)	7732-18-5	60-80%

COMMENTS: Product composition ranges shown are typical values for health, safety and environmental use and are not intended as specifications.

3. HAZARDS IDENTIFICATION

POTENTIAL HEALTH EFFECTS *(See Section 11 for Toxicological Information)*

PRIMARY ROUTE(s) OF EXPOSURE: X Eye __ Skin Contact __ Skin Absorption

_X_ Inhalation _X_ Ingestion

EFFECTS OF ACUTE EXPOSURE

EYES: Redness and possible itching and/or tearing of the eyes.

SKIN: Redness and/or itching of the skin

INHALATION: Possible coughing, burning, tightness of chest and/or shortness of breath.

INGESTION: Possible nausea and/or vomiting.

ACUTE EFFECTS: No test data is available for acute dermal toxicity.
Not expected to cause significant adverse effects if ingested.
No test data is available for acute inhalation toxicity.

CARCINOGENICITY: This solution does not contain components that are known carcinogens. Titanium dioxide has been classed as "possibly carcinogenic to humans" and exposure should be kept as low as reasonably achievable.

TERATOGENICITY: Not Available

REPRODUCTIVE TOXICITY: Not Available

MUTAGENICITY: Not Available

MEDICAL CONDITIONS AGGRAVATED: None known

TARGET ORGANS: Contains material which may cause gastrointestinal tract and respiratory tract effects based on animal data

SENSITIZATION: Not Available

4. FIRST AID MEASURES

EYES: May cause irritation. Immediately flush eyes with plenty of water for two to three minutes. Remove any contact lenses and continue flushing for 15 minutes. Get medical attention.

SKIN: May cause irritation. Remove contaminated clothing including shoes and immediately wash affected area with plenty of soap and water. Seek medical attention. Wash contaminated clothing and shoes before reuse.

INHALATION: Remove from further exposure. Keep warm and at rest. If cough or other symptoms develop, seek medical attention.

INGESTION: May cause irritation. Wash out mouth with water and keep at rest. Seek immediate medical attention.

5. FIRE FIGHTING MEASURES

FLASH POINT AND METHOD: estimated to be >160 degrees F

FLAMMABLE LIMITS Not Available

AUTOIGNITION TEMPERATURE: > 200°C (392°F)

FLAMMABLE CLASS: Nonflammable, flammability of finely divided spray is unknown (but suspected to be non-flamable); do not use near open flame.

FLAME PROPAGATION OR BURNING RATE OF SOLIDS: Not Available

GENERAL HAZARD: Evacuate personnel downwind of fire to avoid inhalation of irritating and/or harmful fumes and smoke.

EXTINGUISHING MEDIA: Chemical type foam, CO_2 (Carbon Dioxide), Dry Chemical, Water Fog

HAZARDOUS COMBUSTION PRODUCTS: none

FIRE FIGHTING INSTRUCTIONS: This product is a nonflammable substance. However, hazardous combustion products may be formed in a fire situation. Cool exposed containers with water spray to prevent overheating.

FIRE FIGHTING EQUIPMENT: Respiratory and eye protection are required for fire fighting personnel. Full protective equipment (Bunker Gear) and self contained breathing apparatus (SCBA) should be used for all indoor fires and any significant outdoor fires. For small outdoor fires, which may easily be extinguished with a portable fire extinguisher, use of a SCBA may not be required.

SENSITIVE TO STATIC DISCHARGE: Not Available

SENSITIVITY TO IMPACT: Not Available

6. ACCIDENTAL RELEASE MEASURES

SMALL SPILL: Construct temporary dikes of dirt, sand, or any appropriate readily available material to prevent spreading of the material.

Wearing the appropriate personal protective equipment designated in Section 8, close or cap valves and/or block or plug hole in leaking container and transfer to another container.

Absorb spilled material, sweep up absorbant and dispose of at appropriate waste disposal facility according to current applicable laws and regulations. Flush area with water and ensure that the contaminated water is handled according to applicable laws.

LARGE SPILL: Construct temporary dikes of dirt, sand, or any appropriate readily available material to prevent spreading of the material.

Wearing the appropriate personal protective equipment designated in Section 8, close or cap valves and/or block or plug hole in leaking container and transfer to another container.

Contain material as described above and call the local fire or police department for immediate emergency assistance.

ENVIRONMENTAL PRECAUTIONS

WATER SPILL: Use appropriate containment to avoid runoff or release to sewer or waterways.

LAND SPILL: Use appropriate containment to avoid runoff or release to ground.

Remove containers of strong oxidizers from release area.

RELEASE NOTES: If spill could potentially enter any waterway, including intermittent dry creeks, contact the local authorities. If in the U.S., contact the US COAST GUARD NATIONAL RESPONSE CENTER toll free number 800-424-8802.

In case of accident or road spill notify:

- CHEMTREC in USA at 800-424-9300
- CANUTEC in Canada at 613-996-6666
- CHEMTREC, other countries, at (International code)+1 703 527 3887

COMMENTS: See Section 13 for disposal information and Section 15 for regulatory requirements.
Large and small spills may have a broad definition depending on the user's handling system. Therefore, the spill category must be defined at the point of release by technically qualified personnel.

7. HANDLING AND STORAGE

HANDLING: Use appropriate personal protective equipment as specified in Section 8. Handle in a well ventilated area.

Handle and use in a manner consistent with good industrial/manufacturing techniques and practices.

STORAGE: Store in unopened containers under cool and dry conditions.

Do not store with, or close to oxidizers.

8. EXPOSURE CONTROLS / PERSONAL PROTECTION

PERSONAL PROTECTIVE EQUIPMENT (PPE)

EYE: Wear safety glasses with side shields or goggles when handling this material.

SKIN: To prevent any contact, wear impervious protective clothing such as neoprene or butyl rubber gloves, apron, boots or whole bodysuit, as appropriate.

RESPIRATORY: If airborne dust is present, use a NIOSH approved particulate respirator.

ENGINEERING CONTROLS: If dust (or fog) is generated, provide local exhaust ventilation to control airborne levels below the ACGIH TLV-TWA exposure limit for Particulates Not Otherwise Classified of 10 mg/m3 for inhalable particles and 3 mg/m3 for respirable.

WORK HYGIENIC PRACTICES: Facilities storing or using this material should be equipped with an eyewash facility and a safety shower.
Good personal hygiene practices should always be followed.

COMMENTS: This product contains no known OSHA hazardous ingredients per 29 CFR 1910.1200.

EXPOSURE LIMITS:

INGREDIENT(S)	OSHA PEL/STEL	ACGIH TLV/STEL
Heavy Parraffinic Oil	NE	NE
Titanium dioxide	15 mg/m^3	10 mg/m^3
Kaolin	15 mg/m^3	2 mg/m^3
Silica, amorphus	80 mg/m^3	NE
Acetic acid ethenyl ester	NE	10 mg/m^3
glyerin	15 mg/m^3	10 mg/m^3
Sodium lauryl sulfate	NE	NE
Water (remainder)	NE	NE

NA - Not Available

NE – Not Established

9. PHYSICAL AND CHEMICAL PROPERTIES

PHYSICAL STATE: Liquid
ODOR: Odorless
APPEARANCE: Opaque to Purple
COLOR: Cream
pH: ~7 At 20 C.
VAPOR PRESSURE: Not Applicable
VAPOR DENSITY: Not Applicable
BOILING POINT: Not Applicable

FREEZING/MELTING POINT: Not Available
MELTING POINT: 0°C (32°F)
SOLUBILITY IN WATER: Soluble
DENSITY:1 g/ml at (20°F) 68°C
SPECIFIC GRAVITY:1 @ 20°C/4°C
VISCOSITY: Not Applicable
MOLECULAR WEIGHT: Not Available
OCTANOL/WATER PARTITION COEFFICIENT: Not Available

COMMENTS:

DENSITY:

10. STABILITY AND REACTIVITY

STABLE: YES

HAZARDOUS POLYMERIZATION: NO

STABILITY (CONDITIONS TO AVOID): The product is stable under normal ambient conditions of temperature and pressure.

POLYMERIZATION: Will not occur

CONDITIONS TO AVOID: Heat.

HAZARDOUS DECOMPOSITION: Oxides of both Carbon and Nitrogen

INCOMPATIBLE MATERIALS: Strong Oxidizers

11. TOXICOLOGICAL INFORMATION

PRODUCT/INGREDIENT	ORAL LD_{50} (rat)	DERMAL LD_{50} (rabbit)	INHALATION LC_{50} (rat)

EYE EFFECTS: This material may cause irritation to the eyes.

SKIN EFFECTS: This material may cause irritation to the skin.

ACUTE

DERMAL LD_{50}: Not Available

INHALATION LC_{50}: Not Available

SENSITIZATION DATA: Not Available

TARGET ORGANS: Eyes
Skin
Gastrointestinal tract
Respiratory system

CARCINOGENICITY:

IARC: Listed by IARC - No

NTP: Listed by NTP - No

OSHA: Listed by OSHA - No

TERATOGENICITY: Not Available

REPRODUCTIVE/TERATOGENIC DATA: Not Available

CARCINOGENIC/MUTAGENIC DATA: Not Available

12. ECOLOGICAL INFORMATION

ENVIRONMENTAL DATA: May cause adverse environmental impact if material reaches waterways.

ECOTOXICOLOGICAL INFORMATION: Not Available

DISTRIBUTION: Not Available

CHEMICAL FATE INFORMATION: Not Available

13. DISPOSAL CONSIDERATIONS

DISPOSAL METHOD: Dispose of waste at an appropriate waste disposal facility according to current applicable laws and regulations.

FOR LARGE SPILLS: Contain material and call local authorities for emergency assistance. In consultation with the appropriate authorities, determine the disposal method or contact Albright & Wilson Americas.

PRODUCT DISPOSAL: Dispose of at a supervised incineration facility or an appropriate waste disposal facility according to current applicable laws and regulations and product characteristics at time of disposal.

EMPTY CONTAINER: Contaminated bags should be cleaned and disposed of in the same manner as the product in accordance with applicable regulations.

Refer to Section 6, Accidental Release Measures for additional information.

14. TRANSPORT INFORMATION

DOT/TDG HAZARDOUS MATERIAL DESCRIPTION: Not restricted by DOT
DOT/TDG TECHNICAL NAME:
LABEL: Use Product Identifier, "Trade Name", with technical name below.

VESSEL (IMO/IMDG)
PROPER SHIPPING NAME: Not restricted
LABEL: Use Product Identifier, "Trade Name", with technical name below.
ADR/RID HAZARD CLASSIFICATION: Not Regulated

AIR (ICAO/IATA)
PROPER SHIPPING NAME: Not restricted
LABEL: Use Product Identifier, "Trade Name", with technical name below.

U.S. CUSTOMS HARMONIZATION NUMBER: 3402.19.50.00

15. REGULATORY INFORMATION

Not meant to be all-inclusive---selected regulations represented.

EEC SYMBOL ID: Xi

EEC RISK PHRASE CODE(S): R36

UNITED STATES

SARA TITLE III (SUPERFUND AMENDMENTS AND REAUTHORIZATION ACT)

FIRE: NO **PRESSURE GENERATING:** NO **REACTIVITY:** NO **ACUTE:** NO **CHRONIC:** NO

313 REPORTABLE INGREDIENTS: Not Applicable

TITLE III NOTES: Not Applicable

CERCLA (COMPREHENSIVE RESPONSE, COMPENSATION, AND LIABILITY ACT)

CERCLA RQ: Not Applicable

TSCA (TOXIC SUBSTANCE CONTROL ACT)

TSCA REGULATORY: All intentional ingredients are listed on the TSCA Inventory.

NATIONAL RESPONSE CENTER: U.S. Coast Guard National Center telephone # 1-800-424-8802

MASSACHUSETTS, NEW JERSEY, PENNSYLVANIA RIGHT-TO-KNOW:

INGREDIENT(S)	CAS NO.	STATE LISTING
Unknown		

NA - Not Applicable

STATE REGULATIONS: Not Available

CANADA

WHMIS (WORKPLACE HAZARDOUS MATERIALS INFORMATION SYSTEM): This product is WHMIS controlled.

CANADA INGREDIENT DISCLOSURE LIST: This product does not contain any known ingredient(s) on the "Ingredient Disclosure List".

CANADIAN ENVIRONMENTAL PROTECTION ACT: All intentional ingredients are listed on the DSL (Domestic Substance List).

MEXICO

MEXICO: This product is considered to be an irritant according to Mexican Standard, Instruction No. 9, ANNEX 1.

REGULATIONS

INTERNATIONAL REGULATIONS: All intentional ingredients are listed on the European's EINECS Inventory.

LOCAL REGULATIONS: Not Available

16. OTHER INFORMATION

HMIS RATING

HEALTH	1
FLAMMABILITY	1
REACTIVITY	0
PERSONAL PROTECTION	C

NFPA CODES:

0

APPROVED BY: **TITLE:**

REASON FOR ISSUE: New product

INFORMATION CONTACT:

MSDS STATUS

Revision No: 0

APPROVAL DATE:

Information given herein is offered in good faith as accurate, but without guarantee. Conditions of use and suitability of the product for particular uses are beyond our control; all risks of use of the product are *therefore assumed by the user. Nothing is intended as a recommendation for uses which infringe valid patents or as extending license under valid patents. Appropriate warnings and safe handling procedures should be provided to handlers and users.*

APPENDIX D.
ANALYTICAL LABORATORY REPORTS

EMSL Analytical, Inc.

200 Route 130 North, Cinnaminson, NJ 08077
Phone: (856) 858-4800

Attn.: *Jose Rivera*
Applied Research Center at Florida International
10555 West Flagler Street
Miami, FL . 33174

Phone: 305-348-1872 Fax:

EMSL Case No.: 361500694
Sample(s) Received: 4/7/2015
Date of Analysis: 4/21/2015
Date Printed: 4/21/2015
Reported By: J.Newton
Email: Jrivers024@fiu.edu

- Laboratory Report -

Flammability of Solids

Project: FX2 Test

Procurement of Samples and Analytical Overview:

The material for analysis arrived at EMSL Analytical (Cinnaminson, NJ) on 4/7/2015. The package arrived in satisfactory condition with no evidence of damage to the contents. The data reported herein has been obtained using the following equipment and methodologies.

Methods & Equipment: ASTM E84 – Standard Test Method for Surface Burning Characteristics of Building Materials (modified)

Simultaneous Thermal Gravimetric Analysis/ Differential Scanning Calorimetry (SDT), *Thermo Analytics, Q600*

Analyzed by: 21 April 2015

John Newton
Senior Materials Scientist

Date

Reviewed/Approved: 21 April 2015

Eugenia Mirica, Ph.D.
Laboratory Manager

Date

EMSL Analytical, Inc.

200 Route 130 North, Cinnaminson, NJ 08077
Phone: (856) 858-4800

Attn.:	*Jose Rivera*	EMSL Case No.:	361500694
Applied Research Center at Florida International		Sample(s) Received:	4/7/2015
10555 West Flagler Street		Date of Analysis:	4/21/2015
Miami, FL . 33174		Date Printed:	4/21/2015
		Reported By:	J.Newton
Phone: 305-348-1872	Fax:	Email:	Jrivers024@fiu.edu

Summary of Results:

EMSL ID:	361500694-0001	
Sample ID:	1	
Description:	Wood sample #1 for Burn Rate Test (Front Row)	
		Comments
Flammability with Ignition Source:	Flame Spread Present	A
Flammability with Ignition Source Off:	Self-Extinguished	B
Time (sec) between contact and ignition:	<1	
Burn Rate (ft/min):	Not Determined	C
Flame Spread Index (FSI):	<0.1	D
Smoke Density Index (SDI):	Not Determined	D
Moisture Content:	7%	
Loss On Ignition:	98%	E
Onset Temperature:	320°C	F
End Temperature:	800°C	
Energy (j/gm):	10000	G
Smoke Point:	Not Detected	H
Min. Auto Ignition Temperature (MAIT):	Greater than 300°C	I

Comments: The sample exhibited ignition at the point of contact with the ignition source. The flame spread was limited to the location in contact with the ignition source. Flame spread across the surface of the sample was not present during the test cycle indicating the possibility of flame retardants.

A) Flame spread with ignition source in contact with the sample.
B) Flame spread after ignition source is turned off. Smoldering present without re-ignition of flame.
C) Rate of flame propagation with ignition source on.
D) FSI compared to red oak.
E) Total loss of material up to the end temperature.
F) The temperature where sample loss is indicative of smoldering.
G) The energy released by the sample from 110°C to the end temperature.
H) Temperature at which smoke is first visually observed indicating smoldering.
I) The temperature at which the sample auto-ignites as a result of heat without open flame.

EMSL Analytical, Inc.

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Phone: (856) 858-4800

Attn.: *Jose Rivera*
Applied Research Center at Florida International
10555 West Flagler Street
Miami, FL . 33174

Phone: 305-348-1872 Fax:

EMSL Case No.: 361500694
Sample(s) Received: 4/7/2015
Date of Analysis: 4/21/2015
Date Printed: 4/21/2015
Reported By: J.Newton
Email: Jrivers024@fiu.edu

EMSL ID:	361500694-0002	
Sample ID:	2	
Description:	Concrete sample #2 for Burn Rate Test (Back Row)	
		Comments
Flammability with Ignition Source:	No Flame Spread Present	A
Flammability with Ignition Source Off:	Not Applicable	B
Time (sec) between contact and ignition:	Not Applicable	
Burn Rate (ft/min):	Not Determined	C
Flame Spread Index (FSI):	Not Determined	D
Smoke Density Index (SDI):	Not Determined	D
Moisture Content:	8.2%	
Loss On Ignition:	Not Applicable	E
Onset Temperature:	Not Determined	F
End Temperature:	Not Determined	
Energy (j/gm):	Not Determined	G
Smoke Point:	Not Detected	H
Min. Auto Ignition Temperature (MAIT):	Not Determined	I

Comments: The sample did not exhibit any evidence of flammability.

A) Flame spread with ignition source in contact with the sample.
B) Flame spread after ignition source is turned off. Smoldering present without re-ignition of flame.
C) Rate of flame propagation with ignition source on.
D) FSI compared to red oak.
E) Total loss of material up to the end temperature.
F) The temperature where sample loss is indicative of smoldering.
G) The energy released by the sample from 110^{o}C to the end temperature.
H) Temperature at which smoke is first visually observed indicating smoldering.
I) The temperature at which the sample auto-ignites as a result of heat without open flame.

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Phone: 305-348-1872 Fax:

EMSL Case No.: 361500694
Sample(s) Received: 4/7/2015
Date of Analysis: 4/21/2015
Date Printed: 4/21/2015
Reported By: J.Newton
Email: Jrivers024@fiu.edu

Results and Discussion:

Sample 1:

The data obtained during analysis if sample 1, plywood, indicates that the plywood sample may be coated with flame inhibitors. Ignition was present in locations directly in contact with the ignition source. Flame spread was not present during the test cycle and the sample self-extinguished upon removal of the ignition source. Some smoldering was still present. The smoke density index could not be established due to the flame retardant properties of the sample.

Sample 2:

The concrete sample was not flammable.

Method Limitations:

The method was modified due to the size of the sample. The data documented herein is based upon information obtained from a one square foot sample area. Flame spread is calculated based upon the propagation of the flame front across the surface of the sample.

Simultaneous DSC/TGA (SDT) is performed to determine additional sample characteristics including loss on ignition, auto-ignition temperature and energy release during ignition. This data is intended to further characterize the sample and is not intended to replace or alter standard methodologies documented herein.

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Sample(s) Received: 4/7/2015
Date of Analysis: 4/21/2015
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Reported By: J.Newton

Email: Jrivers024@fiu.edu

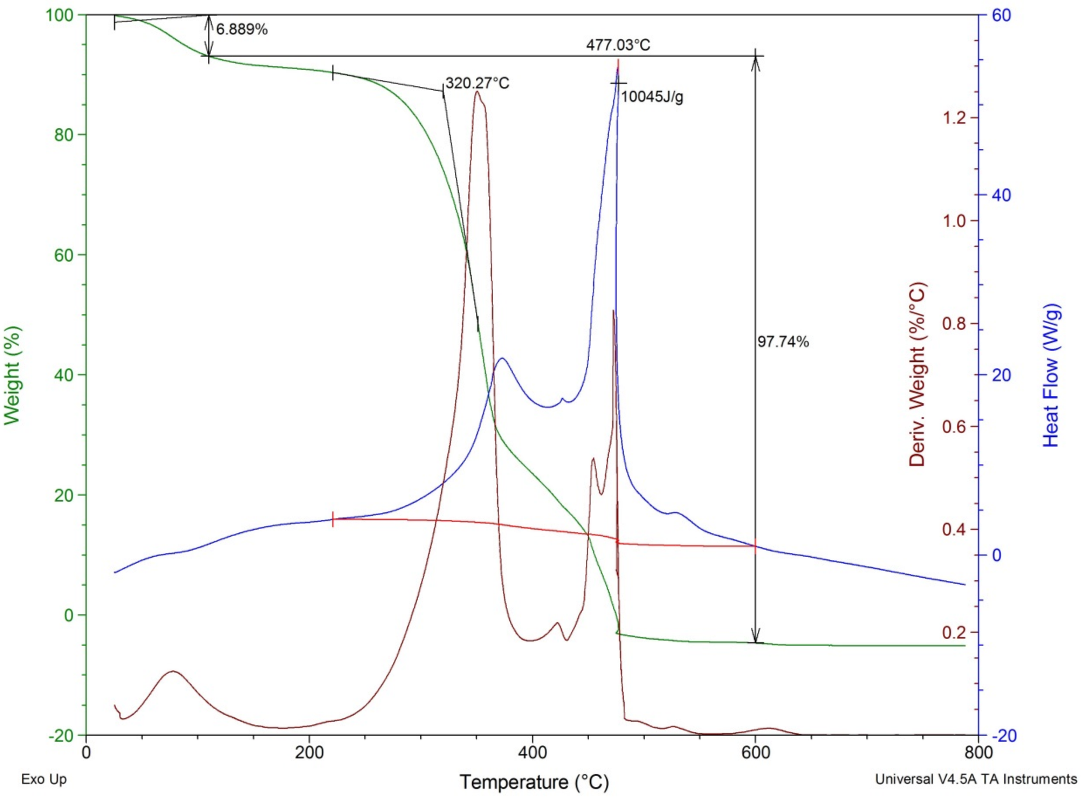

Figure 1: SDT spectra showing the loss on ignition for the Sample 1.

The data indicates that the material is composed mainly of organic matter that decomposes at a moderate rate to near 500^{o}C. The total energy release during the process is near 10,000 J/gm which is consistent with cellulosic material.

Attn.: *Jose Rivera*
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10555 West Flagler Street
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EMSL Case No.:	361500694
Sample(s) Received:	4/7/2015
Date of Analysis:	4/21/2015
Date Printed:	4/21/2015
Reported By:	J.Newton
Email:	Jrivers024@fiu.edu

Descriptions & Definitions:

Limit of Detection (LOD): The minimum concentration that can be theoretically achieved for a given analytical procedure in the absence of matrix or sample processing effects. Particle analysis is limited to a single occurrence of an analyte particle in the sub-sample analyzed.

Limit of Quantitation (LOQ): The minimum concentration of an analyte that can be measured within specified limits of precision and accuracy during routine laboratory operating conditions

Important Terms, Conditions, and Limitations:

Sample Retention: Samples analyzed by EMSL will be retained for 60 days after analysis date. Storage beyond this period is available for a fee with written request prior to the initial 30 day period. Samples containing hazardous/toxic substances which require special handling may be returned to the client immediately. EMSL reserves the right to charge a sample disposal or return shipping fee.

Change Orders and Cancellation: All changes in the scope of work or turnaround time requested by the client after sample acceptance must be made in writing and confirmed in writing by EMSL. If requested changes result in a change in cost the client must accept payment responsibility. In the event work is cancelled by a client, EMSL will complete work in progress and invoice for work completed to the point of cancellation notice. EMSL is not responsible for holding times that are exceeded due to such changes.

Warranty: EMSL warrants to its clients that all services provided hereunder shall be performed in accordance with established and recognized analytical testing procedures and with reasonable care in accordance with applicable federal, state and local laws. The foregoing express warranty is exclusive and is given in lieu of all other warranties, expressed or implied. EMSL disclaims any other warranties, express or implied, including a warranty of fitness for particular purpose and warranty of merchantability.

Limits of Liability: In no event shall EMSL be liable for indirect, special, consequential, or incidental damages, including, but not limited to, damages for loss of profit or goodwill regardless of the negligence (either sole or concurrent) of EMSL and whether EMSL has been informed of the possibility of such damages, arising out of or in connection with EMSL's services thereunder or the delivery, use, reliance upon or interpretation of test results by client or any third party. We accept no legal responsibility for the purposes for which the client uses the test results. EMSL will not be held responsible for the improper selection of sampling devices even if we supply the device to the user. The user of the sampling device has the sole responsibility to select the proper sampler and sampling conditions to insure that a valid sample is taken for analysis. Any resampling performed will be at the sole discretion of EMSL, the cost of which shall be limited to the reasonable value of the original sample delivery group (SDG) samples. In no event shall EMSL be liable to a client or any third party, whether based upon theories of tort, contract or any other legal or equitable theory, in excess of the amount paid to EMSL by client thereunder.

The data and other information contained in this report, as well as any accompanying documents, represent only the samples analyzed. They are reported upon the condition that they are not to be reproduced wholly or in part for advertising or other purposes without the written approval from the laboratory.

EMSL Analytical, Inc.

200 Route 130 North, Cinnaminson, NJ 08077
Phone: (856) 858-4800

Attn.: Jose Rivera		EMSL Case No.:	361500738
Applied Research Center at Florida International		Sample(s) Received:	4/10/2015
10555 West Flagler Street		Date of Analysis:	4/28/2015
Miami, FL . 33174		Date Printed:	4/28/2015rev1
		Reported By:	J.Newton
Phone: 305-348-1872	Fax:	Email:	Jrivers024@fiu.edu

- Laboratory Report -
Flammability of Solids
Project: FX2 Test

Procurement of Samples and Analytical Overview:

The material for analysis (two samples, wood and concrete) arrived at EMSL Analytical (Cinnaminson, NJ) on 4/10/2015. The package arrived in satisfactory condition with no evidence of damage to the contents. The data reported herein has been obtained using the following equipment and methodologies.

Methods & Equipment: ASTM E84 – Standard Test Method for Surface Burning Characteristics of Building Materials (modified)

Simultaneous Thermal Gravimetric Analysis/ Differential Scanning Calorimetry (SDT), *Thermo Analytics, Q600*

4/28/15: Rev1 revises report 361500738 reported on 4/28/15. Reasons for revision: corrected sample identification and description information.

Analyzed by:

John Newton
Senior Materials Scientist

28 April 2015
Date

Reviewed/Approved:

Eugenia Mirica, Ph.D.
Laboratory Manager

28 April 2015
Date

EMSL Analytical, Inc.

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Attn.: *Jose Rivera*
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Phone: 305-348-1872 Fax:

EMSL Case No.: 361500738
Sample(s) Received: 4/10/2015
Date of Analysis: 4/28/2015
Date Printed: 4/28/2015rev1
Reported By: J.Newton
Email: Jrivers024@fiu.edu

Summary of Results:

EMSL ID:	361500738-0001	
Sample ID:	1.1	
Description:	Wood sample #1.1 for Burn Rate Test (Back Row)	
		Comments
Flammability with Ignition Source:	Flame Spread Present	A
Flammability with Ignition Source Off:	Self-Extinguished	B
Time (sec) between contact and ignition:	<1	
Burn Rate (ft/min):	Not Determined	C
Flame Spread Index (FSI):	<0.1	D
Smoke Density Index (SDI):	Not Determined	D
Moisture Content:	7%	
Loss On Ignition:	92.3%	E
Onset Temperature:	321^{o}C	F
End Temperature:	800^{o}C	
Energy (j/gm):	8230	G
Smoke Point:	Not Detected	H
Min. Auto Ignition Temperature (MAIT):	Greater than 300^{0}C	I

Comments: The sample exhibited ignition at the point of contact with the ignition source. The flame spread was limited to the location in contact with the ignition source. Flame spread across the surface of the sample was not present during the test cycle indicating the possibility of flame retardants.

A) Flame spread with ignition source in contact with the sample.
B) Flame spread after ignition source is turned off. Smoldering present without re-ignition of flame.
C) Rate of flame propagation with ignition source on.
D) FSI compared to red oak.
E) Total loss of material up to the end temperature.
F) The temperature where sample loss is indicative of smoldering.
G) The energy released by the sample from 110^{o}C to the end temperature.
H) Temperature at which smoke is first visually observed indicating smoldering.
I) The temperature at which the sample auto-ignites as a result of heat without open flame.

EMSL Analytical, Inc.

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Phone: 305-348-1872 Fax:

EMSL Case No.: 361500738
Sample(s) Received: 4/10/2015
Date of Analysis: 4/28/2015
Date Printed: 4/28/2015rev1
Reported By: J.Newton
Email: Jrivers024@fiu.edu

EMSL ID:	361500738-0002
Sample ID:	2.1
Description:	Concrete sample #2.1 for Burn Rate Test (Front Row)

		Comments
Flammability with Ignition Source:	No Flame Spread Present	A
Flammability with Ignition Source Off:	Not Applicable	B
Time (sec) between contact and ignition:	Not Applicable	
Burn Rate (ft/min):	Not Determined	C
Flame Spread Index (FSI):	Not Determined	D
Smoke Density Index (SDI):	Not Determined	D
Moisture Content:	7.3%	
Loss On Ignition:	Not Applicable	E
Onset Temperature:	Not Determined	F
End Temperature:	Not Determined	
Energy (j/gm):	Not Determined	G
Smoke Point:	Not Detected	H
Min. Auto Ignition Temperature (MAIT):	Not Determined	I

Comments: The sample did not exhibit any evidence of flammability.

A) Flame spread with ignition source in contact with the sample.
B) Flame spread after ignition source is turned off. Smoldering present without re-ignition of flame.
C) Rate of flame propagation with ignition source on.
D) FSI compared to red oak.
E) Total loss of material up to the end temperature.
F) The temperature where sample loss is indicative of smoldering.
G) The energy released by the sample from 110^{o}C to the end temperature.
H) Temperature at which smoke is first visually observed indicating smoldering.
I) The temperature at which the sample auto-ignites as a result of heat without open flame.

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EMSL Case No.: 361500738
Sample(s) Received: 4/10/2015
Date of Analysis: 4/28/2015
Date Printed: 4/28/2015rev1
Reported By: J.Newton
Email: Jrivers024@fiu.edu

Results and Discussion:

Sample 1.1:

The data obtained during analysis if sample 1, plywood, indicates that the plywood sample may be coated with flame inhibitors. Ignition was present in locations directly in contact with the ignition source. Flame spread was not present during the test cycle and the sample self-extinguished upon removal of the ignition source. Some smoldering was still present. The smoke density index could not be established due to the flame retardant properties of the sample.

Sample 2.1:

The concrete sample was not flammable.

Method Limitations:

The method was modified due to the size of the sample. The data documented herein is based upon information obtained from a one square foot sample area. Flame spread is calculated based upon the propagation of the flame front across the surface of the sample.

Simultaneous DSC/TGA (SDT) is performed to determine additional sample characteristics including loss on ignition, auto-ignition temperature and energy release during ignition. This data is intended to further characterize the sample and is not intended to replace or alter standard methodologies documented herein.

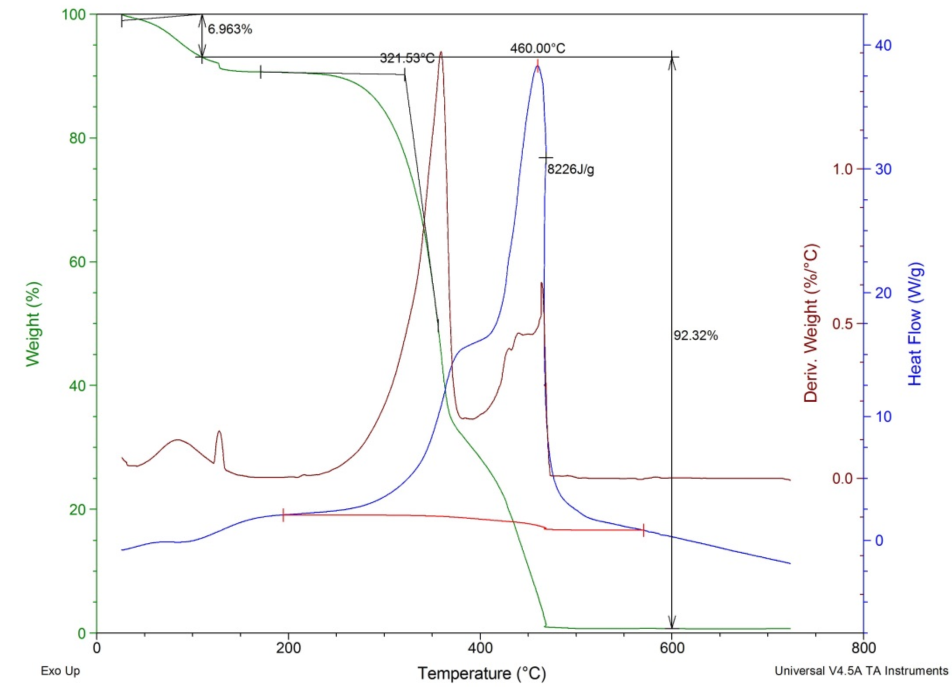

Figure 1: SDT spectra showing the loss on ignition for the Sample 1.1.

The data indicates that the material is composed mainly of organic matter that decomposes at a moderate rate to near 500°C. The total energy release during the process is near 8200 J/gm which is consistent with cellulosic material.

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Phone: 305-348-1872 Fax:

EMSL Case No.: 361500738
Sample(s) Received: 4/10/2015
Date of Analysis: 4/28/2015
Date Printed: 4/28/2015rev1
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Email: Jrivers024@fiu.edu

Descriptions & Definitions:

Limit of Detection (LOD): The minimum concentration that can be theoretically achieved for a given analytical procedure in the absence of matrix or sample processing effects. Particle analysis is limited to a single occurrence of an analyte particle in the sub-sample analyzed.

Limit of Quantitation (LOQ): The minimum concentration of an analyte that can be measured within specified limits of precision and accuracy during routine laboratory operating conditions

Important Terms, Conditions, and Limitations:

Sample Retention: Samples analyzed by EMSL will be retained for 60 days after analysis date. Storage beyond this period is available for a fee with written request prior to the initial 30 day period. Samples containing hazardous/toxic substances which require special handling may be returned to the client immediately. EMSL reserves the right to charge a sample disposal or return shipping fee.

Change Orders and Cancellation: All changes in the scope of work or turnaround time requested by the client after sample acceptance must be made in writing and confirmed in writing by EMSL. If requested changes result in a change in cost the client must accept payment responsibility. In the event work is cancelled by a client, EMSL will complete work in progress and invoice for work completed to the point of cancellation notice. EMSL is not responsible for holding times that are exceeded due to such changes.

Warranty: EMSL warrants to its clients that all services provided hereunder shall be performed in accordance with established and recognized analytical testing procedures, when applicable. The foregoing express warranty is exclusive and is given in lieu of all other warranties, expressed or implied. EMSL disclaims any other warranties, express or implied, including a warranty of fitness for particular purpose and warranty of merchantability.

Limits of Liability: In no event shall EMSL be liable for indirect, special, consequential, or incidental damages, including, but not limited to, damages for loss of profit or goodwill regardless of the negligence (either sole or concurrent) of EMSL and whether EMSL has been informed of the possibility of such damages, arising out of or in connection with EMSL's services thereunder or the delivery, use, reliance upon or interpretation of test results by client or any third party. We accept no legal responsibility for the purposes for which the client uses the test results. EMSL will not be held responsible for the improper selection of sampling devices even if we supply the device to the user. The user of the sampling device has the sole responsibility to select the proper sampler and sampling conditions to insure that a valid sample is taken for analysis. Any resampling performed will be at the sole discretion of EMSL, the cost of which shall be limited to the reasonable value of the original sample delivery group (SDG) samples. In no event shall EMSL be liable to a client or any third party, whether based upon theories of tort, contract or any other legal or equitable theory, in excess of the amount paid to EMSL by client thereunder.

The data and other information contained in this report, as well as any accompanying documents, represent only the samples analyzed. They are reported upon the condition that they are not to be reproduced wholly or in part for advertising or other purposes without the written approval from the laboratory.

EMSL Analytical, Inc.

200 Route 130 North, Cinnaminson, NJ 08077
Phone: (856) 858-4800
Fax: (856) 786-0392

Attn.:	*Jose Rivera*	EMSL Case No.:	361500693
Applied Research Center at Florida International University		Sample(s) Received:	4/6/2015
10555 West Flagler Street		Date of Reporting:	4/24/2015rev1
Miami, FL 33174		Date Printed:	4/24/2015
		Reported By:	D. Macready
Phone:	(305) 348-1872	Email:	Jrive024@fiu.edu

- Laboratory Report -

Project: FX2 Test

Procurement of Samples and Analytical Overview:

The samples for analysis (six, liquids) arrived at EMSL Analytical (Cinnaminson, NJ) on April 6, 2015. The package arrived in satisfactory condition with no evidence of damage to the contents. The samples were submitted for the purpose of surface tension, density and viscosity analysis. The data reported herein has been obtained using the following equipment and methodologies.

Equipment:	Brookfield LVTD Digital Viscometer Pycnometer CSC DuNouy Tensiometer, model 70545

4/24/15: Rev1 revises report 361500693 reported on 4/20/15. Reasons for revision: corrected parameter in table 1 to read “surface tension”

Analyzed by:	*Daniel Macready* *Laboratory Analyst*	*John Newton* *Senior Materials Scientist*	4/20/2015 *Date*
Reviewed/Approved:	*Eugenia Mirica, Ph.D.* *Laboratory Manager*		4/20/2015 *Date*

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Sample(s) Received: 4/6/2015
Date of Reporting: 4/24/2015rev1
Date Printed: 4/24/2015
Reported By: D. Macready

Table 1: Surface Tension Results:

EMSL Sample Number:	361500693-0001		
Customer Sample Number:	FX2 Red sample for surface tension test		
Parameter	Value	Temperature	Units
Surface Tension	33.6	20.0 °C	mN/m

EMSL Sample Number:	361500693-0002		
Customer Sample Number:	FX2 White sample for surface tension test		
Parameter	Value	Temperature	Units
Surface Tension	31.7	20.0 °C	mN/m

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Table 2: Density Results:

EMSL Sample Number:	361500693-0003		
Customer Sample Number:	FX2 Red sample for density test		
Parameter	Value	Temperature	Units
Density	1.050	22.5 °C	g/mL

EMSL Sample Number:	361500693-0004		
Customer Sample Number:	FX2 White sample for density test		
Parameter	Value	Temperature	Units
Density	1.079	22.5 °C	g/mL

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Table 3: Viscosity Results:

EMSL Sample Number:	361500693-0005			
Customer Sample Number:	FX2 Red sample for viscosity test			
Viscosity	Units	Temperature	Spindle	RPM
9.1	cP	22.5 °C	LV-1	60

EMSL Sample Number:	361500693-0005			
Customer Sample Number:	FX2 White sample for viscosity test			
Viscosity	Units	Temperature	Spindle	RPM
16.1	cP	22.5 °C	LV-1	60

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Important Terms, Conditions, and Limitations:

Sample Retention: Non-perishable samples analyzed by EMSL will be retained for 60 days after analysis date at room temperature conditions. Perishable samples will be retained for maximum of 30 days in refrigerated conditions. Storage beyond this period is available for a fee with written request prior to the initial 30 day period. Samples containing hazardous/toxic substances which require special handling may be returned to the client immediately EMSL reserves the right to charge a sample disposal or return shipping fee.

Change Orders and Cancellation: All changes in the scope of work or turnaround time requested by the client after sample acceptance must be made in writing and confirmed in writing by EMSL. If requested changes result in a change in cost the client must accept payment responsibility. In the event work is cancelled by a client, EMSL will complete work in progress and invoice for work completed to the point of cancellation notice. EMSL is not responsible for holding times that are exceeded due to such changes.

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