ADAPTING INTUMESCENT COATINGS AS FIRE RESILIENT FIXATIVES ISO SRS 235-F D&D ACTIVITIES
PHASE II: CONSTRUCTION OF SRS 235-F HOT CELL TEST BED AND APPLICATION DEMONSTRATION

TEST PLAN

Approval Page

FLORIDA INTERNATIONAL UNIVERSITY – APPLIED RESEARCH CENTER (FIU – ARC)

Test Engineer (Prepared by) — Date 2/1/2017

Principal Investigator — Date 02/01/17

SAVANNAH RIVER NATIONAL LABORATORY

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Principal Investigator:

Leonel Lagos, Ph.D., PMP®

Florida International University Collaborators:

Joseph Sinicrope, M.S., MBA
Peggy Shoffner, M.S., CHMM, PMP®
Jesse Viera, DOE Fellow
Alexander Piedra, DOE Fellow

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1.0 INTRODUCTION

This test plan is in support of the DOE-FIU Cooperative Agreement under Project 3 (Waste and D&D Engineering and Technology Development), Task 2 (D&D Support for Technology Innovation, Development, Evaluation and Deployment). The test objectives outlined here have been developed through extensive coordination with SRS 235-F site personnel (i.e.; project managers, safety and fire representatives, etc.) and Savannah River National Laboratory (SRNL) research scientists, and are specifically designed to advance the testing, evaluation, and possible deployment of intumescent coating (IC) technologies as fire resilient fixatives to mitigate the potential release of radioisotopes during postulated fire scenarios highlighted in the Basis for Interim Operations (BIO) and contingency planning documents in support of D&D activities at SRS 235-F, with a particular emphasis on the 235-F PuFF Facility Cells 6-9.

From September 2015 – August 2016, the FIU Applied Research Center (ARC), in close collaboration with SRNL, embarked on a series of proof of concept experiments to test and evaluate the potential of integrating intumescent coatings into D&D processes to enhance the fire resiliency of facilities and industry fixatives. The results were promising, and the initial findings were presented at various stages to DOE EM HQ, SRS 235-F site personnel, international collaborators, other national labs, and D&D private contractors and professionals. The potential application to several of the most pressing challenges was evident, specifically improving the overall fire protection posture and decreasing the nuclear load within the safety basis of the facility, and continued research and development to adapt the technology to the radioactive environment encountered at SRS 235-F was requested.

This test plan addresses Phase II of the overall research effort, with the first main objective centered on constructing a to-scale SRS 235-F Hot Cell Test Bed on site at ARC that mirrors the operating environment encountered in an adjoining corner and middle hot cell configuration at the SRS 235-F facility. The second main objective involves an evaluation on the mechanics and processes associated with applying the selected intumescent coatings in the hot cell configurations using: 1) the approved tools as identified in the 235-F Risk Reduction Tooling List, Rev 0, dated 26 January 2015; and 2) alternative application methods, such as airless sprayers, recommended by the IC manufacturer. Based on discussions with site personnel, if the alternative application methods prove optimal, then it is possible to have them added to the next revision of the 235-F Risk Reduction Tooling List. All findings from this test plan will be published as an ARC technical report, and a technology fact sheet will also be developed for DOE EM. ARC will continue close collaboration with all stakeholders throughout the execution of this test plan.

2.0 TECHNOLOGY AND TOOL DESCRIPTION

2.1 Intumescent Coatings and Potential Application to D&D

Since 9/11, there have been extensive developments in the area of intumescent coatings as a viable technology to protect and insulate various substrates from extreme heat and fire conditions in order to maintain their structural integrity. Intumescent coatings swell between 50 to 100 times their original thickness into a robust, insulating char / foam upon exposure to heat, protecting the underlying material from fire by providing a physical barrier to heat and mass transfer. Flame spread is also inhibited through mechanisms common to other charring materials. The closed foam / char structure that forms inhibits the transport of volatiles to the environment and the transport of oxygen to unburned regions beneath the char, and the retention of mass in the char limits further involvement of the underlying materials in the fire. Furthermore, many intumescent coatings are exceptionally cost effective (as low as 0.75 cents per square foot) and can be easily applied via brush, roller, or sprayer to a wide variety of substrates (stainless steel, wood, sheetrock, sheet metal, etc.). Lastly, depending on the substrate and specific requirement, as little as two coats (10-30 mils) meet or exceed fire protection regulatory ratings as measured by ASTM E119, ASTM E84, etc.

ARC research scientists had firsthand knowledge and experience in the use of intumescent coatings to harden facilities and improve fire protection in support of the U.S. military, and postulated that the coating technology could be adapted to address the critical concern presented in the accident scenarios outlined in the SRS 235-F BIO. ARC, in close collaboration with SRNL, designed a series of proof of concept experiments and conclusively validated: 1) selected intumescent coatings had the capacity to permanently fix simulated contaminants to a variety of substrates; 2) the selected intumescent coatings mitigated the transport / release of those contaminants at temperatures up to 2000°F for periods up to 2 hours. These results far surpassed the current state of fixatives used across the DOE EM complex, which degrade (mass losses average 70-90%) and release contamination within minutes of exposure to temperatures as low as 300°-400° F. Several of the intumescent coatings tested to date have received similarly positive results during adhesion testing on a variety of substrates under differing environmental conditions (high humidity, etc.), and during irradiation to high levels of cobalt-60 by SRNL.

Over the course of the proof of concept experiments conducted by ARC and SRNL, two of the intumescent coatings tested displayed characteristics expected of and desirable in a standalone fixative for D&D activities. Specifically, when exposed to fire / extreme heat conditions, these intumescent coatings baked into a thick, hard char that maintained exceptional adhesion to the substrate, requiring significant force through chiseling to remove (see Figure 1). Based on these qualities, as well as their performance during SRNL's environmental and irradiation testing protocols, they were identified as the frontrunners of those evaluated to date for mitigating the risks highlighted in the SRS 235-F accident scenarios, and as such, will be used in the conduct of this test plan.

Figure 1. Example of FD adhesion to stainless steel substrate after exposure to 800º F.

2.1.1 Selected Intumescent Coatings

It is important to emphasize that this is a completely novel approach to enhancing the fire resiliency of fixative technologies used to support D&D activities and, therefore, the majority of the testing to date has been purposefully oriented towards basic proof-of-concept experiments to confirm whether the approach has merit. For this reason, as well as in the interest of protecting future intellectual property rights, a naming convention has been established for the selected intumescent coatings to be evaluated in this test plan. The two intumescent coatings to be tested are as follows:

1. Product FD is a sprayable, water-based intumescent material that dries to form a durable, elastomeric firestop coating. This material, when used as part of an assembly, will firestop building joints, perimeter joints (curtain wall), and through penetration seals. It is advertised to provide up to 4-hour fire protection in construction joints.

2. Product FX is a two-part epoxy resin that forms non-toxic cooling gases above 350ºF and an insulating char that advertises protection to temperatures up to 5000ºF. It complies with stringent military and defense fire standards, and is

optimized to provide high levels of performance in rapid temperature rise fires, retaining strength with excellent adhesion even in the harshest of environments such as cellulosic and hydrocarbon fires.

2.2 Application Tools

Pending available funding and resources, application of the two selected intumescent coatings highlighted above will be conducted using the following methods / tools: 1) those already approved in the 235-F Risk Reduction Tooling List, Rev 0, dated 26 January 2015, for fixative application; and 2) self-contained airless sprayers. A description of each is included below.

2.2.1 235-F Risk Reduction Tooling List

In support of the deactivation project, the 235-F Deactivation Project Team identified various tools to remove and/or immobilize the residual radiological material within the PuFF Facility Cells 6-9. Currently, in order to ensure compliance with facility regulations, any tool used in the 235-F PuFF Facility Cells 6-9, and for subsequent management of waste/material from intrusive activities, must be on the 235-F Risk Reduction Tooling List, Rev 0, dated 26 January 2015.

SRNS site personnel approved SDD-2015-00002, 235-F Risk Reduction Tooling List, Rev 0, dated 26 January 2015, for release to FIU ARC on 23 February 2016, and Figure 2 below is a direct extract from that document. It highlights those tools that are currently approved for use in the 235-F PuFF Facility Cells 6-9 for the application of decontamination agents and fixatives. It is ARC's intention to utilize these same tools in the application of the selected intumescent coatings identified above in the FIU ARC SRS 235-F Hot Cell Test Bed during the execution of this test plan.

TOOL	APPROVED USAGE	PHOTO	REF. DRAWING OR PART NO.	COMBUSTIBLE COMPONENT SUBJECT TO REFERENCE 4	APPLICABLE FAI (per Reference 7)
Roller	Apply decontamination agents and fixatives.		SRNL Drawing No. R-R4-F-00153	Yes	SDD-2015-00002
EXTENSION COMPONENTS					
Extension, End	Use in combination with various tools (e.g., Extension Rake) and the Middle Extension. Allows the various tools to be used at distance.		SRNL Drawing No. R-R1-F-00145	Yes	SDD-2015-00002
Extension, Middle	To be used in combination with various tools (e.g., Extension Rake) and the End Extension. Allows various tools to be used at distance.		Fabricated by SRNS Construction or SRNL Drawing No. R-R1-F-00151	No	SDD-2015-00002
Paint Brush, various sizes (No wood, plastic handle only)	For brushing off items and components in the vicinity of the gloveports, and for transferring sweepings to a dust pan.		Various manufacturers and models	Yes	SDD-2015-00002

Figure 2. Approved tools for fixative application per the 235-F Risk Reduction Tooling List.

2.2.2 Alternative Tools Recommended by Manufacturer

Based on conversations with the SRS 235-F project manager and SRNL research scientists, there is the possibility to add tools to the approved tooling list if there is an operational requirement to do so and they are ultimately approved by Industrial Safety, Industrial Hygiene, Radiological Protection, and F-area Engineering, at a minimum. ARC was encouraged to identify new tools and methods that may facilitate the application of the intumescent coatings under the constrained environment encountered in the SRS 235-F hot cells. Some general limiting factors highlighted by SRS site personnel were that the tools / application methods to support D&D activities for hot cells 6-9 should be: 1) self-contained; 2) have no requirement for a tether extending outside the cell; and 3) be able to be introduced through the bag out port (~18" diameter).

In consult with the manufacturer of FD, the tool described below was recommended as a possible application method that is both compatible with the intumescent coating and complies with the above parameters (though its potential impacts on the HEPA filter system will need to be assessed as well via a separate test plan). ARC intends on evaluating it during the conduct of this test plan.

GRACO TrueCoat Pro II Cordless Paint Sprayer: The TrueCoat® Pro II is a cordless airless sprayer with a ProControl™ Pressure Control System that allows the user to adjust the pressure to spray a wider variety of applications. It is provides a full motion of spraying with the new Tilt-N-Spray pendulum suction tube design, and is powered by a new, lighter weight G20 lithium-ion battery. Product dimensions are 10.75"x5" and weighs 6.86 lbs.

Figure 3. GRACO TrueCoat Pro II cordless paint sprayer.

A viable, alternative delivery mechanism for the epoxy-based intumescent coating, FX, that satisfies all the various constraints outlined above, has not yet been identified. The primary obstacle is the requirement to mix the epoxy in accordance with the exact ratios at the time of application. That said, it may be feasible to mix beforehand and then use the GRACO TrueCoat Pro II Cordless Paint Sprayer for application. This same mixing process will need to be followed regardless of the tools used for application.

3.0 SRS 235-F HOT CELL TEST BED CONSTRUCTION

A major component of this test plan is the construction of a SRS 235-F Hot Cell Test Bed on site at FIU ARC in Miami, FL. Extensive coordination on the design has occurred among ARC, SRNL, and SRS 235-F site officials via site visits, emails, and phone conversations, and on or about 28 October 2016, a final design was agreed upon by the respective stakeholders. SRS 235-F site personnel had approved for release to FIU ARC the schematics for a typical cell scheduled for D&D at the facility (see Figure 4), and based on projected funding and available space, ARC developed a to-scale, combined corner-middle cell configuration that mirrors the operating conditions (dimensions, glove ports, surface materials, obstacles/obstructions, etc.) encountered in cells 6-9 at the facility (see Figures 5-7).

Based on the 28 October approval, and a follow on site visit and phone conversation on 15 November with SRS 235-F site personnel and SRNL research scientists, the SRS 235-F Hot Cell Test Bed design at FIU ARC was reaffirmed and construction began on or about 27 December 2016. The construction of the Test Bed is being conducted at FIU ARC's outdoor test facility, and as of 6 Jan 2017, the 3' raised floors for both the middle and corner cells are complete and framing of the walls has commenced (see Figure 8). Pending funding and available resources, construction is expected to be completed no later than 28 April 2017.

Note: It is currently intended to line the inside of the walls and ceilings with 304 stainless steel (1/16" – 1/8" in thickness) to represent the materials and substrates found in the cells. This will be done to the maximum extent possible given available funding and resources. Though the final design has been approved by all stakeholders and construction has commenced, modification requests can be made and will be reviewed on a case-by-case basis and implemented depending on funding, safety reviews, etc.

U-BIO-F-00003
Rev. 1

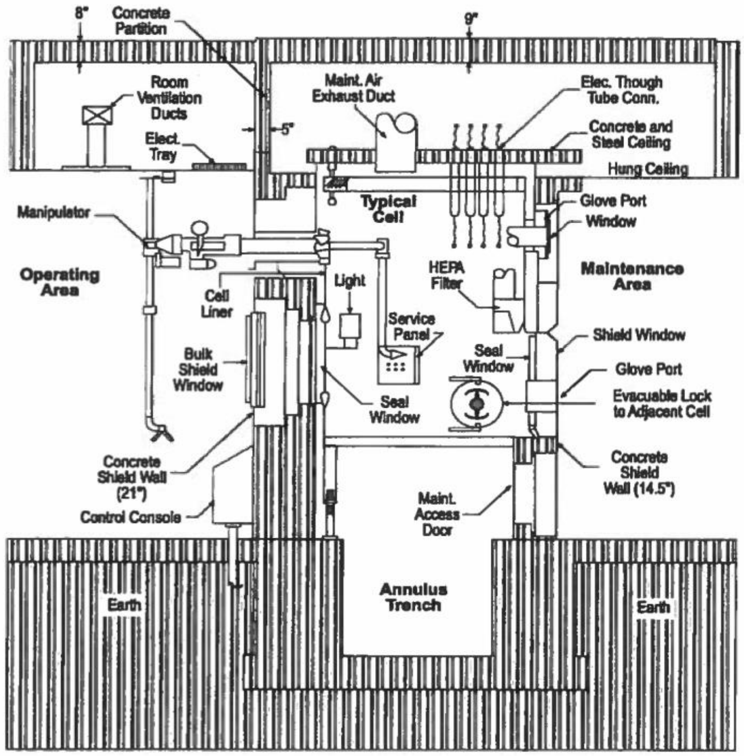

Figure 2-7 Cross-Section of Typical PuFF Processing Cell

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Figure 4. Typical processing cell at SRS 235-F PuFF Facility.

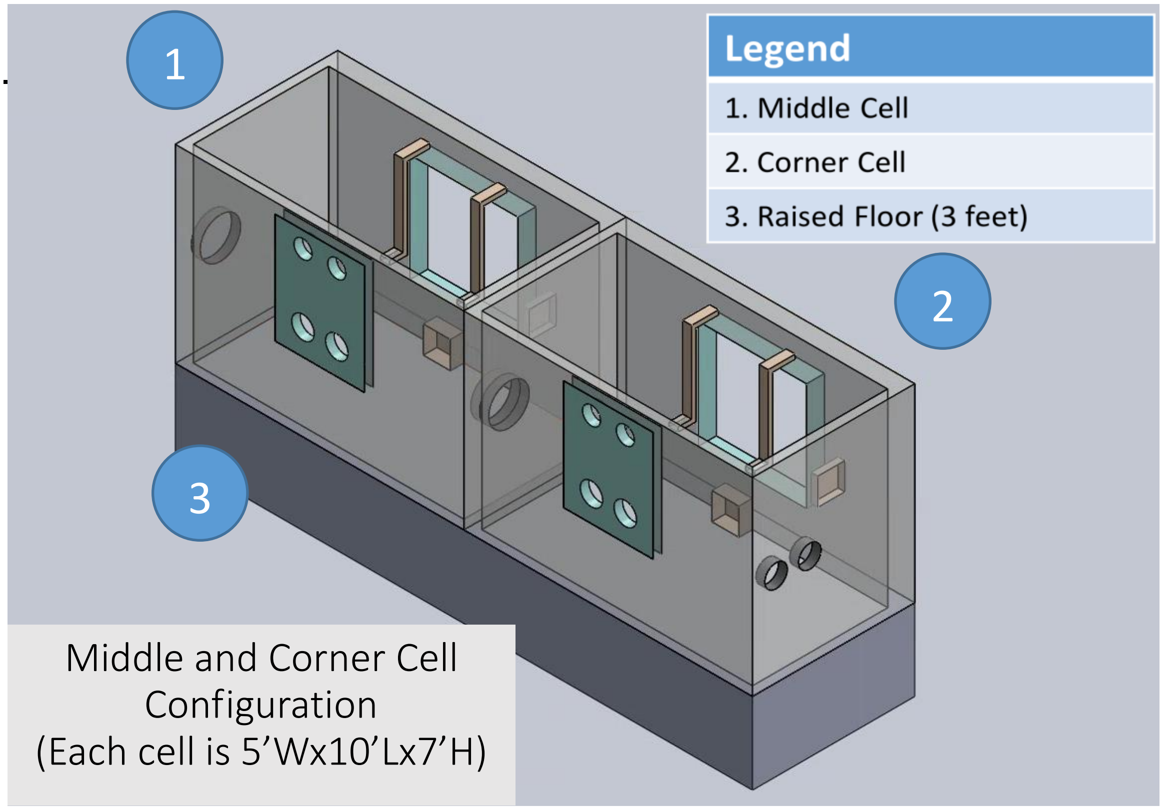

Figure 5. FIU ARC middle and corner cell configuration design.

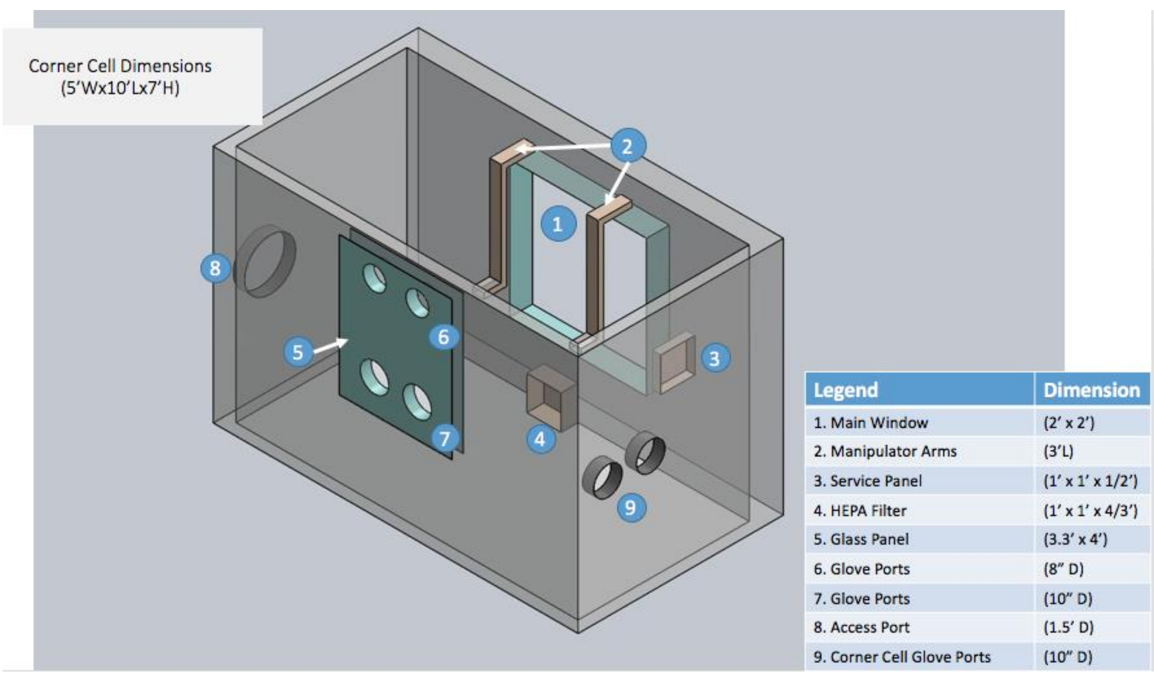

Figure 6. FIU ARC corner cell dimensions.

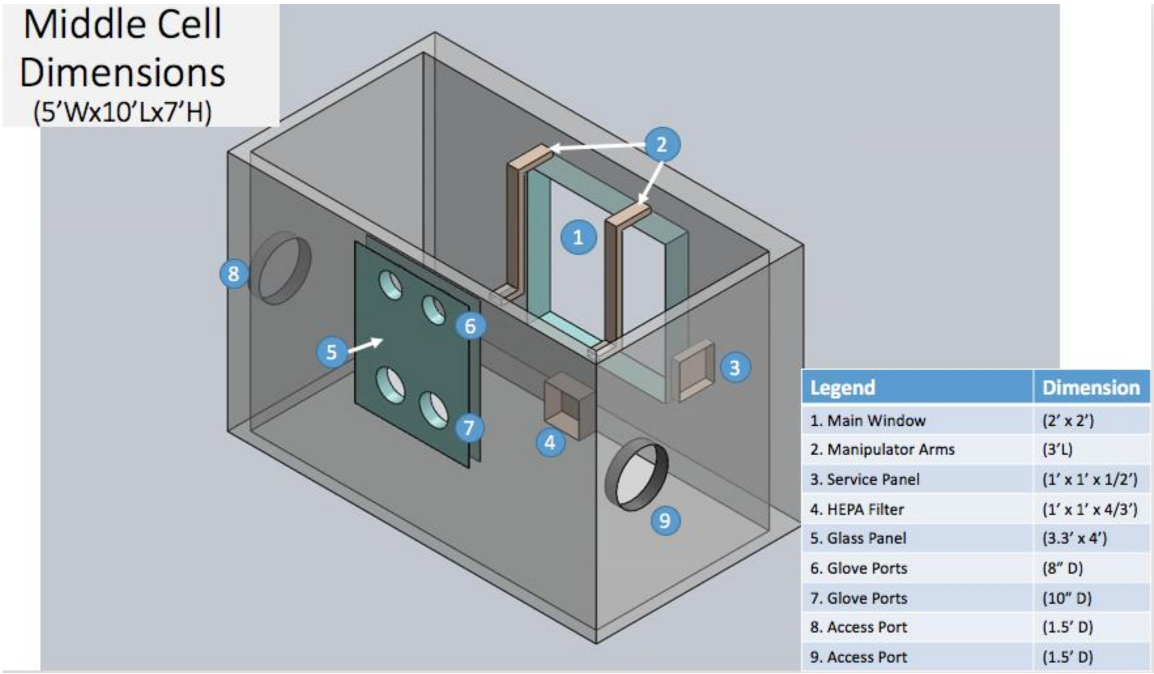

Figure 7. FIU ARC middle cell dimensions.

Figure 8. Construction of SRS 235-F Hot Cell Test Bed at FIU ARC.

4.0 APPLICATION OF INTUMESCENT COATINGS

Upon completion of the construction of the SRS 235-F Hot Cell Test Bed at FIU ARC, it is intended to use the facility to fully support the second objective of this Test Plan - an evaluation on the mechanics and processes associated with applying the selected intumescent coatings in the hot cell configurations encountered at the SRS 235-F PuFF facility. The primary focus will be on leveraging the approved tools as identified in the 235-F Risk Reduction Tooling List, Rev 0, dated 26 January 2015, to apply the selected intumescent coatings (FD and FX) throughout the processing / hot cells. However, as highlighted in Section 2 of this document, alternative application methods, such as the GRACO TrueCoat Pro II cordless paint sprayer, will be investigated as well. Any tools, supplemental items (e.g.; paint roller trays, wet film thickness gauge, etc.), and intumescent coatings will only be introduced into the hot cell environment if they meet the space constraints and can be passed through an 18” diameter bag out port.

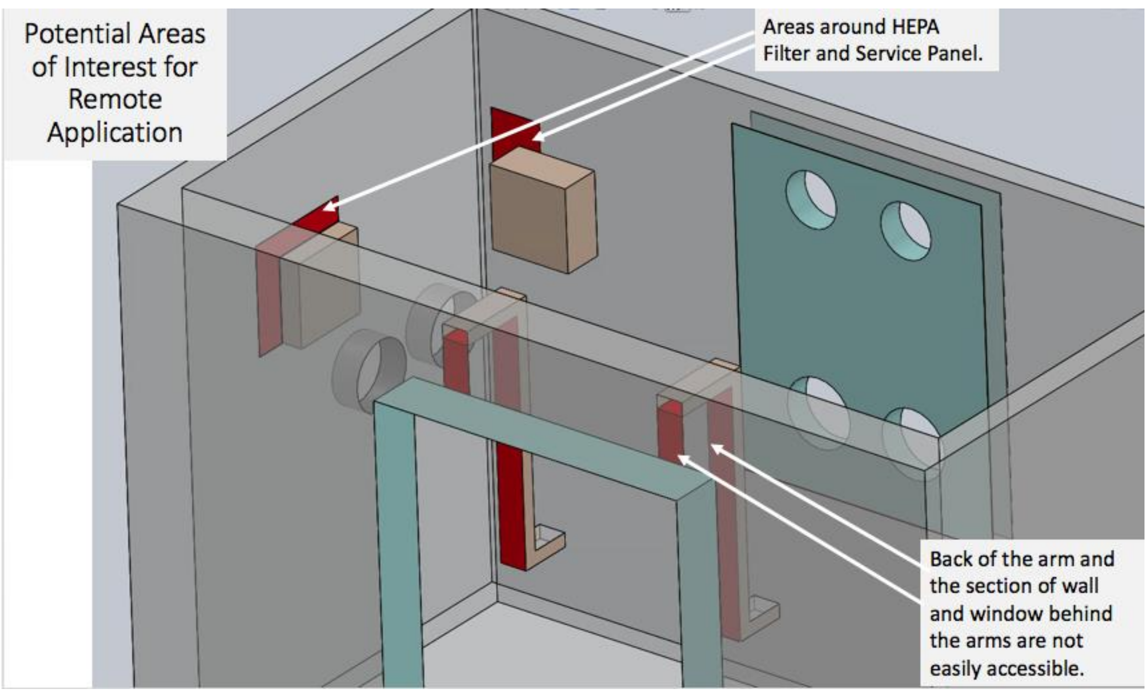

Figure 9. Suspected challenge areas for application.

The emphasis during this component includes: 1) Determining whether the selected intumescent coatings can be applied to the requisite thickness throughout the hot cell given the various operational constraints using the approved tools outlined in the 235-F Risk Reduction Tooling List; 2) Thoroughly documenting the process (i.e.; combination of approved tools, steps developed and utilized, etc.) that optimizes the application of the intumescent coatings in both the corner and middle cells; 3) Identifying / confirming specific challenge areas within the hot cells where difficulties in application are encountered (see Figure 9); 4) Identifying potential efficiencies that can be gained by employing a self-contained airless sprayer like the TrueCoat Pro II; and 5) Recommending other cross-cutting technologies that may facilitate remote application of the intumescent coatings.

A significant benefit of this effort, aside from advancing the testing, evaluation, and possible deployment of intumescent coating technologies as fire resilient fixatives to mitigate the potential release of radioisotopes during postulated fire scenarios highlighted in the Basis for Interim Operations, is the potential for identifying additional tools that could be recommended for inclusion on the tool list. Over the coming months, FIU ARC will work closely with SRS 235-F representatives from Industrial Safety, Industrial Hygiene, Radiological Protection, and F-area Engineering, as well as SRNL research scientists, towards this end.

Note: There is no intent to integrate a climate control capability into the SRS 235-F Hot Cell Test Bed for purposes of this Test Plan, though this may occur at a later date to support other research and development initiatives. It has been agreed that this effort will remain centered on testing and evaluating application methods and processes. However, careful attention will be paid to annotating environmental conditions such as temperature, relative humidity, etc. and documented to support other analysis such as curing, etc..

5.0 ROLES AND RESPONSIBILITIES

Execution of this test plan, as written, is completely dependent on available funding and resources, and may be modified by the Principal Investigator, in consultation with the FIU ARC Task Lead and SRNL research scientists, as required. The following outlines FIU's role and responsibilities:

1) Construct the SRS 235-F Hot Cell Test Bed on site at FIU ARC as prescribed in Section 3.0.

2) Provide all personnel, materials, supplies, and equipment required to support construction of the SRS 235-F Hot Cell Test Bed and execution of the activities outlined in Section 4.0, Test and Evaluation Procedures.

3) Proper trash and hazardous waste disposal of items generated during the construction and test and evaluation.

4) Conduct coordination with the vendors to obtain the designated intumescent materials. ARC will fund the purchasing of these samples from the vendors.

5) Supply all equipment and additional materials outlined in this Test Plan necessary to successfully conduct the outlined research and experiments.

6) Conduct all data collection and analysis for experiments to be conducted at FIU.

7) Develop necessary documents (fact sheet, technical reports, presentation material, etc.).

8) Publish/co-Author with SRNL results in technical reports, peer-reviewed publications, and/or conference proceedings.

9) Provide all equipment needed to support data collection. All data collection equipment will be calibrated as per manufacturer's standards and guidance.

The following outlines SRNL's roles and responsibilities:

1) Review and approve the Test Plan.

2) Review draft and final versions of the technology report document.

3) Review and approve the DOE Tech Fact Sheet.

6.0 TEST PLAN SCHEDULE

Execution of this test plan schedule, as written, is completely dependent on available funding and resources, and may be modified by the Principal Investigator, in consultation with the FIU ARC Task Lead and SRNL research scientists, as required. This test plan will be conducted in two phases. Phase I is the design and construction phase for the SRS 235-F Hot Cell Test Bed on site at FIU ARC in Miami, FL (o/a September 2016 – April 2017), and Phase II is the test and evaluation on the mechanics and processes associated with applying the selected intumescent coatings in the hot cell configurations using approved tools / alternative application methods (o/a 22-26 May 2017). The final results will be documented in a Technology Demonstration Evaluation Report in June / July 2017.

Major events associated with the phases of this test plan are contained below:

5 Sep 2016: SRNS / SRNL provides SRS 235-F hot cell schematics **(Completed)**

21 Oct: FIU ARC completes design of SRS 235-F Hot Cell Test Bed based on schematics and projected funding and resources **(Completed)**

28 Oct: FIU ARC provides Decision Brief on design to SRS 235-F site personnel and SRNL research scientists **(Completed)**

18 Nov: SRNS / SRNL provides approved tool list **(Completed)**

6 Jan 2017: FIU ARC disseminates DRAFT Test Plan to SRNS / SRNL for review and comment **(Completed)**

20 Jan: SRNL completes review of Test Plan and returns to FIU ARC

27 Jan: FINAL Test Plan disseminated for final approval and signature

28 Apr: Construction of SRS 235-F Hot Cell Test Bed complete

5 May: All materials, application tools, intumescent coatings, etc. on hand and staged for test and evaluation

22-26 May: Test and evaluation on the mechanics and processes associated with applying the selected intumescent coatings in the hot cell configurations (Phase II) executed

14 Jul: Draft Technology Demonstration Evaluation Report and Tech Fact Sheet submitted for review

28 Jul: Final Technology Demonstration Evaluation Report and Tech Fact Sheet submitted

7.0 DOCUMENTATION

The data generated by the research as well as the information on the planning and conducting of the experiments will be assembled and documented in a Technology Demonstration Evaluation Report. The report will summarize the experiments, experimental results, and lessons learned. It will also provide recommendations for further research and development. Any changes to the test plan will require approval from the project manager and will be clearly documented and included in the Technology Demonstration Evaluation Report. In addition to the Technology Demonstration Evaluation Report, FIU will also develop a DOE Tech Fact Sheet. Lastly, the scientific results and knowledge obtained during these efforts will be published in a peer-reviewed journal publication.

All documents, technology information, and photographs/videos collected during the execution of this test plan will be made available to the general D&D community through the FIU-DOE D&D Knowledge Management Information Tool (KM-IT) located on the web at www.dndkm.org and through FIU's dedicated DOE EM research website at http://doeresearch.fiu.edu.

8.0 HEALTH AND SAFETY

All activities will be subject to general health and safety procedures established by FIU and ARC. Researchers will perform all tasks in compliance with OSHA guidelines, obeying all personal protective equipment requirements. Appropriate precautions will be taken to protect the health and safety of everyone involved in the research. Any safety concerns that arise will be corrected in a timely manner. Access to the test area will be administratively controlled and briefings will be conducted with all site visitors to ensure that health and safety issues are understood and that safe practices will be followed during the course of the demonstration.

9.0 WASTE DISPOSITION

Based on the Test Plan, the only anticipated waste streams from the Test Objective 1 and Test Objective 2, Stage A, activities are non-regulated, non-hazardous solid wastes. All solid waste generated in conjunction with this research shall be disposed of in a manner that complies with local ordinances and environmental law. The management of any unanticipated solid waste will be in accordance with FIU waste management procedures.

10.0 REFERENCES

1. SDD-2015-00002, 235-F Risk Reduction Tooling List, Rev 0, dated 26 January 2015, F-area Engineering

2. U-BIO-F-00003-1, SRS 235-F Basis for Interim Operations, Rev 1, Cross section of cells found in the SRS 235-F PuFF Facility

3. N-NCS-F-00129, Rev 2, Nuclear Criticality Safety Evaluation: Criticality Potential During Decontamination and Decommissioning of F-area Material Storage (FAMS) (U)