STUDENT SUMMER INTERNSHIP TECHNICAL REPORT

# Testing of Radiation Resistant High Density Polyurethane Foam

## DOE-FIU SCIENCE & TECHNOLOGY WORKFORCE DEVELOPMENT PROGRAM

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# EXECUTIVE SUMMARY

This research work has been supported by the DOE-FIU Science & Technology Workforce Development Initiative, an innovative program developed by the U.S. Department of Energy's Office of Environmental Management (DOE-EM) and Florida International University's Applied Research Center (FIU-ARC). During the summer of 2023, a DOE Fellow intern, Bryan Torres, spent 10 weeks doing a summer internship at the Savannah River National Laboratory (SRNL) under the supervision and guidance of Dr. Jennifer Wohlwend ((Manager, Glass, Cement, and Ceramics Sciences). The intern's project was initiated on June 5, 2023, and continued through August 10th 2023, intending to quantify the curing time of FoamBag™, an off-the-shelf commercially available two-part polyurethane resin that has been down-selected by Florida International University as a possible engineering control for the removal of contaminated pipes at Savannah River Site. Temperature and humidity conditions were set in an environmental chamber, and it was observed that the samples' curing time was between 4 to 16 minutes in conditions resembling the South Carolina climate. No significant water uptake was observed as samples did not gain mass.

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# 1. INTRODUCTION

By 2027, the F/H Laboratory Deactivation Project Team at the Savannah River Site plans to remove buried piping in the courtyard between 772-F and 772-1F that carries residual radioactive contaminants. The driver for removal is to prevent future release to the environment from the buried, highly contaminated piping. The piping system is buried to a depth of 3-5 feet and is approximately 250 feet in length. To facilitate the removal and disposal of the pipes, they will be cut into 5 feet sections, which means 50 cut pipe sections and 100 open channels with the potential of contaminants flowing out and polluting the ground or harming workers.

Before the technology is implemented in the field, it needs to be validated and pass a series of tests to ensure that it will indeed contain contaminants as expected, it is compatible with the hot tap procedures and routine of the F/H Laboratory Deactivation Project Team and will not introduce new hazards.

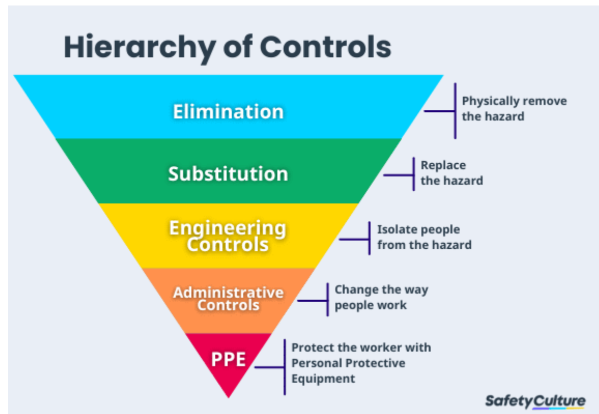


**Figure 1. Hierarchy of controls. FoamBag™ will be an engineering control, the most effective and feasible control for this task.**

During the summer of 2023, SRNL tested the curing time and water uptake of FoamBag™ under different temperatures and relative humidity conditions using an environmental chamber to meet the customer's need of verifying that the resin's curing time is compatible with their hot tap procedure. To ensure workers' safety, off-gas associated with the curing process was to be analyzed identified and quantified through gas chromatography, but due to equipment failure and the brevity of 10 weeks this testing objective was not met during the span of the DOE Fellow's summer internship at the national lab.

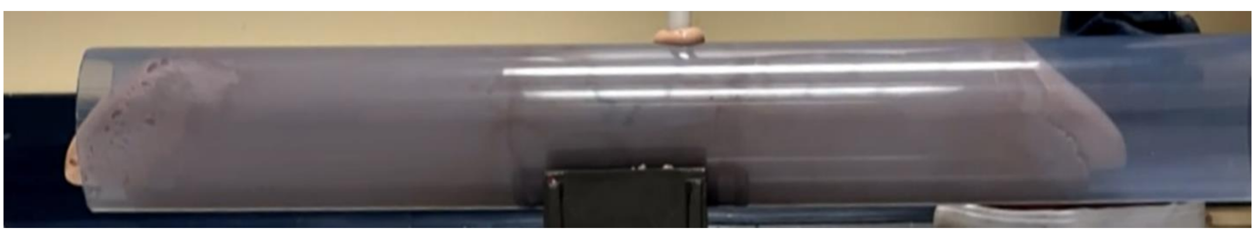

**Figure 2. Cured FoamBag™ extruded in a 3" clear PVC pipe.**

# 2. RESEARCH DESCRIPTION

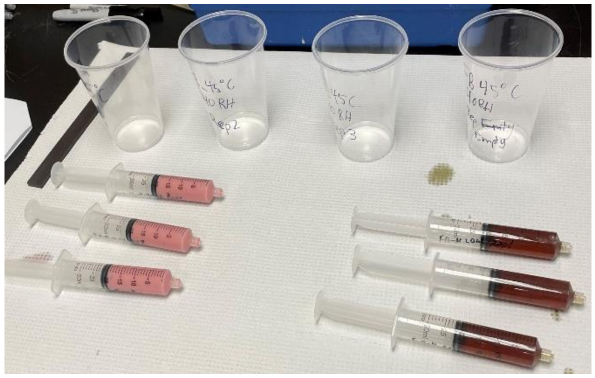

**Figure 3. Drawn syringes with 20 mL of resin or hardener. Syringes with resin are placed on the right and syringes with hardener are placed on the left. The cups with samples are mixed are placed in the back.**

The summer internship research aimed to quantify curing time and water uptake under various environmental conditions. Therefore, all the experiments were conducted on a laboratory scale. Each unit of FoamBag™, as shipped by the vendor, is intended to be deployed in one pipe, but for our experiments such large volumes were not required. Instead, to save funds and decrease waste, samples were prepared by mixing 20 mL of resin and 20 mL of hardener using syringes in a plastic cup (Figure 4), maintaining the 1:1 ratio indicated on the label of the product. The cups were then placed in the environmental chamber where temperature and relative humidity were controlled.


**Figure 4. Mixed samples (20 mL of resin and 20 mL of hardener) placed in the environmental chamber (left), and after mixing and curing (right).**

The environmental chamber conditions were chosen based on the typical South Carolina climate (the place where pipe removal will take place). Temperatures ranged from 15°C to 45°C and relative humidity ranged from 25% to 90%. The syringes were weighed after resin or hardener was drawn and after it was extruded to know the mass of FoamBag™ in the cup.

Sample preparation was the same for curing tests and for water uptake tests. For the curing tests, the samples were taken out of the environmental chamber 5 minutes after curing, and set-to-touch, dry-to-touch, and dust-free tests were performed according to the American Society for Testing and Material's D1640 [2]. For the set-to-touch test, the sample is touched with the finger wearing a nitrile glove and if the resin does not move it passes the test. For dry-to-touch tests, a nitrile glove is slid through the top of the curing foam and net on a glass slide; if the glass slide is clean and there is no residue then the sample passes the test. For the dust-free test, a cotton swab is placed on the cup with the curing foam and blown; if the cotton blows out of the sample, then the sample passes the test. If the samples do not pass all the tests when first taken out of the chamber 5 minutes after mixing, then they are placed back into the chamber and the tests are repeated in 2-minute intervals until the samples pass all the tests. For every environmental condition, 3 repetitions were performed.

For the water uptake tests the samples were mixed in the same way, but the cups were weighted before the FoamBag™ was poured. The samples were placed in the environmental chamber and their mass recorded 5 minutes, 15 minutes, 2 hours, and 24 hours after mixing.

# 3. RESULTS AND ANALYSIS

All the samples passed the set-touch test, dry-to-touch test, and dust-free test in a 4-minute to 16-minute range, as shown in Figure 5. Samples at higher temperatures cured considerably faster than samples at lower temperatures, but since only 8 conditions were tested and temperature and humidity were not tested independently, it cannot be determined whether temperature or humidity is the main determinant of curing time. However, it should be noted that the only samples to pass the dry-touch and set-to-touch tests were those subjected to a temperature of 45°C. Most samples passed the set-to-touch test last.

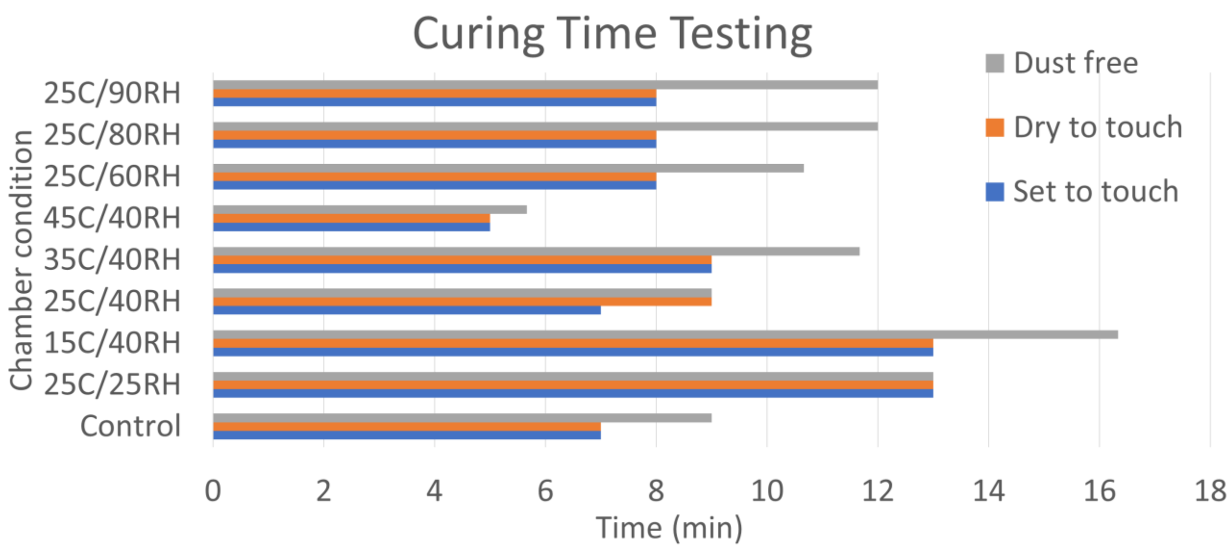


**Figure 5. Graph showing the time for samples to pass the dust-free, dry-to-touch, and set-to-touch tests after mixing resin and hardener. All three tests were performed with all samples. The y-axis shows the environmental chamber's conditions in °C and relative humidity percentage, while the x-axis shows minutes after mixing.**

Mass change of different samples in similar conditions was recorded to evaluate the effect of environmental conditions on water uptake. An increase in mass due to water uptake would not be desirable because it could hinder the mechanical properties and adhesion of the FoamBag™ plug to the pipe. However, as seen in Figure 6, there is no significant increase in mass. In fact, a 1 to 2.5 % mass decrease is observed in the first 5 minutes due to the release of off-gases typical of the curing process. After the first 5 minutes, there is no significant change in mass.

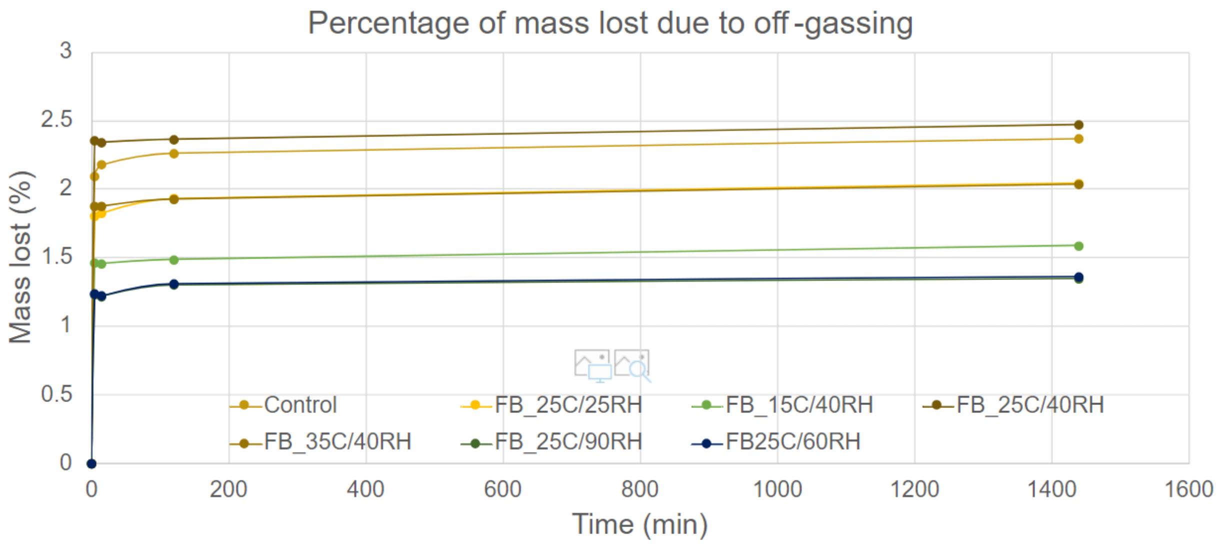


**Figure 6. Line graph showing the percentage of mass lost due to off-gassing. The sample names in the legend indicate the temperature and humidity in which the samples cured in the environmental chamber. Mass was recorded for all samples 5 minutes, 15 minutes, 2 hours and 24 hours after mixing.**

# 4. CONCLUSION

FoamBag™ passed both the environmental chamber curing test and the water uptake test. The F/H Laboratory Deactivation Project Team at Savannah River Site was concerned that FoamBag™ would cure too soon, not allowing sufficient time for the field workers to extrude all the fixatives inside the pipes. As shown in the previous section, the minimum curing time was 4 minutes, which is sufficient time for the workers to perform this task. As a result, FoamBag™ is compatible with the hot tap procedure and routine of the F/H Laboratory Deactivation Project Team. Furthermore, the only sample that cured at 4 minutes was subjected to a temperature of 45°C. According to the South Carolina Department of Natural Resources, the maximum recorded temperature in Aiken SC, the closest county to the job site, was 109°F (42.8°C) on Aug. 22, 1983 [3]. Furthermore, the deactivation and decommissioning efforts are not likely to be performed on the hottest days of the year, therefore lower temperatures and a longer curing time are to be expected on the job site.

It was also determined that water uptake will not likely be a concern, as the samples did not gain mass in the span of 24 hours. FoamBag™ is not hydroscopic, which eliminates the potential for a decrease in the adhesion of the plug to the pipe walls. However, the samples did lose mass due to off-gassing. Off-gassing is to be expected in the curing process of any polyurethane resin, but it would be of interest to identify and quantify these gases to ensure they do not present a hazard for the workers present. This task was intended to be carried out during DOE Fellow Bryan Torres's summer internship, but equipment failure prevented the researchers from running gas chromatography of the samples.

Despite this setback, the internship still proved to be very valuable to the project as it served to further validate the potential use of FoamBag™ in the removal of contaminated pipes. Along with the previous tests carried out at Florida International University and the tests to be carried out in the future, it will serve to justify the usage of an off-the-shelf, commercially available technology to isolate workers from contaminants and mitigate the hazards associated with pipe removal.

Besides the contributions to the project, the summer internship has proven to be an incredibly valuable experience for the intern. Throughout the duration of the internship, he had the privilege of working alongside dedicated scientists and researchers who generously shared their knowledge and expertise. Through hands-on experimentation and data analysis, the intern has developed crucial laboratory skills and safety protocol awareness that will undoubtedly serve as a solid foundation for his future endeavors.

# 5. REFERENCES


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