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EVALUATION OF ENVIRONMENTAL CONDITIONS ON THE CURING OF COMMERCIAL FIXATIVE AND INTUMESCENT COATINGS

1.0 Executive Summary

Performance metrics for evaluating commercial fixatives are often not readily available for important parameters that must be considered per the facility safety basis and the facility Basis for Interim Operations (BIO). One such parameter is the behavior of such materials in varied, “non-ideal” conditions where ideal is defined as 75 °F, 40% RH. Coupled with the inherent flammable nature of the fixative materials that can act to propagate flame along surfaces that are otherwise fireproof (concrete, sheet metal), much is left unknown when considering the safety basis implications for introducing these materials into nuclear facilities. Through SRNL’s efforts, three (3) fixatives, one (1) decontamination gel, and six (6) intumescent coatings were examined for their responses to environmental conditions to determine whether these materials were impervious to non-nominal temperatures and humidities that may be found in nuclear facilities. Characteristics that were examined included set-to-touch time, dust free time, and adhesion testing of the fully cured compounds. Of these ten materials, three were two-part epoxy materials while the other seven consisted of only one constituent. The results show that the epoxies tested are unable to cure in sub-freezing temperatures, with the low temperatures inhibiting crosslinking to a very significant degree. These efforts show significant inhibiting of performance for non-nominal environmental conditions, something that must be addressed both in the decision process for a fixative material to apply and per the safety basis to ensure the accurate flammability and material at risk is calculated.

2.0 Introduction

Nuclear facilities that are moving towards final disposition face enormous challenges to ensure no release of holdup material is released to the environment between the time the facility is no longer active until the final disposition is achieved. Workers actively seek to remove as much of the radioactive holdup; however decontamination can only remove so much of the material before further efforts become time/cost prohibitive. As such, for contaminated areas, there is often residual contamination remaining after material removal and decontamination operations are completed. To overcome free standing contamination, it is sometimes favorable to place a fixating layer over the spot to ensure no residual contamination can be released should any be left behind. These fixating layers are often in the form of polymer layers labeled "fixatives" by the manufacturer. There is little to no data for these materials pertaining to their response to environmental conditions outside of manufacturer specified "ideal conditions" (~75 ºF, 40% RH).[1-9] In many cases too, the material will not be applied at these static conditions and held for the full cure time of 24 hours, presenting the question of whether these materials are functioning as intended when applied in a non-ideal environment. Further, per safety basis personnel, for an ASTM (or any other internationally standardized method of testing) qualified material, for the qualification to hold meaning, the material must be applied per the MSDS, else it cannot contribute to the safety basis calculation as the materials behavior is unknown at these conditions. Coupled with the finding by FIU that every commercially claimed "fixative" material is highly flammable and promotes flame propagation along the surface while also having a high smoke index, a systematic examination of these materials in varied conditions must be performed.

One means of overcoming the flammability/smoke hazards of commercial fixatives is to use an inherently fire proof material such as an intumescent coating which are used widely for fireproofing of joints in buildings as a fixating material[10-11]. To address these issues, SRNL in collaboration with Florida International University (FIU) Applied Research Center (ARC) examined three (3) commercial fixative materials (Asbestos Binding Compounds [ABC], CC Epoxy SP [CC], and Polymeric Barrier System [PBS]), one (1) decontamination gel (DeconGel 1101 [DG]), and six (6) intumescent coating, four standard single constituent coatings and three epoxies, (FireDam [FD], InterChar [IC], FireFree 88 [FF], and FireGuard [FG] are the single constituent coatings, FireX [FX] and Intumax [IM] are the epoxy based intumescent coatings). These materials were examined for their stability in varied environmental and radiological conditions to test whether the external environmental conditions present during application affected the set-to-touch time (the time it takes for the FCG to be considered functional without full curing), dust-free time (the time it takes for the FCG to no longer collect and/or attract ambient material on the external surface), dry-to-touch time (the time it takes for the FCG to be considered fully cured), and the adhesion (how well the material sticks to the substrate after full curing) of these materials. The goal of this testing was to determine whether the off-normal environmental conditions would affect the curing time of these materials. These materials will be collectively described as fixatives, coatings, and decontamination gels (FCGs) throughout this report.

3.0 Goals and Objectives

A test plan was prepared by SRNL personnel entitled "Incombustible Fixative Test Plan – Environmental Curing Testing" to structure the testing efforts and ensure the objectives necessary were met by the end of the research period[12]. The goal and objectives of this work are described below.

3.1 Goal

The purpose of this test is to quantify environmental effects on the curing process of FCGs to better understand the environmental impact should these materials need to be applied in a facility under non-ideal conditions.

3.2 Objectives

Environmental testing is being performed to characterize the effects on the curing process. Specifically, testing will address the following material characteristics:

- Set-to-touch time – the time it takes for the FCG to be considered functional without full curing
- Dust-free time – the time it takes for the FCG to no longer collect and/or attract ambient material on the external surface
- Dry-to-touch – the time it takes for the FCG to be considered fully cured
- Adhesion – how well the material sticks to the substrate after full curing

Each test will result in a given data set at varied conditions for a select FCG, allowing for characterization of that material in a chosen environment. Resultant data will enable better advisement of the safety personnel with respect to utilizing this material within a facility. Ten (10) different compounds will be tested for the varied parameters and are listed below in Table 1 along with their respective abbreviations for the lifecycle of this study.

Table 1: List of FCGs to be Tested and Associated Abbreviations

FCG Commercial Name	Abbreviation
Asbestos Binding Compound	ABC
CC Epoxy	CC
DeconGel	DG
FireDam	FD
FireFree 88	FF
Fireguard E-84	FG
FireX	FX
Interchar I	IC
Intumax EP 102	IM
Polymeric Barrier System	PBS

4.0 Experimental Procedure

4.1 Sample Preparation

Samples preparation was performed via a paintbrush method as suggested by manufacturer application means for each material. FCGs were applied to 3″ x 3″ squares of stainless steel. The seven (7) single constituent FCGs (ABC, DG, FD, PBS, FF, FG, and IC) where directly applied to the surfaces while the three (3) epoxy FCGs (CC, IM, and FX) where mixed per manufacturer specifications then applied to the surface. Samples were prepared with only a single layer to ensure no thickness compatibility issues with ASTM D3359 adhesion characterization[13]. After preparation of each sample was complete, it was promptly placed in an environmental chamber that was set to the selected parameters for testing.

4.2 Environmental Testing

Environmental testing was performed using a Russell's Technical Products #GD-64-5-5 environmental chamber. Multiple environmental conditions were chosen to simulate conditions that might be found in a nuclear facility after it has been moved to open air exposure. To ensure variables could be isolated, two exposure profiles were tested: variable temperature at a static 40% RH, and variable humidity at a static 75 ºF. The temperatures chosen for this experiment were: 20, 40, 60, 75, 90, and 110 ºF. The humidities chosen for this experiment were: 10, 20, 40, 60, 80, and 95%RH. 10 and 95% were chosen as the bounds as these were the limits of the environmental chamber used. Samples were placed in the environmental chamber as shown in Figure 1 and monitored for set-to-touch, dust-free, and dry to touch times per ASTM D1640[13]. For the single constituent materials, cure times were usually within 2 hrs while the epoxy based materials cured over a longer timescale, often taking more than 4 hours to cure. After dry-to-touch was achieved for each sample, the FCG was then tested for adhesion per ASTM D3359[13].

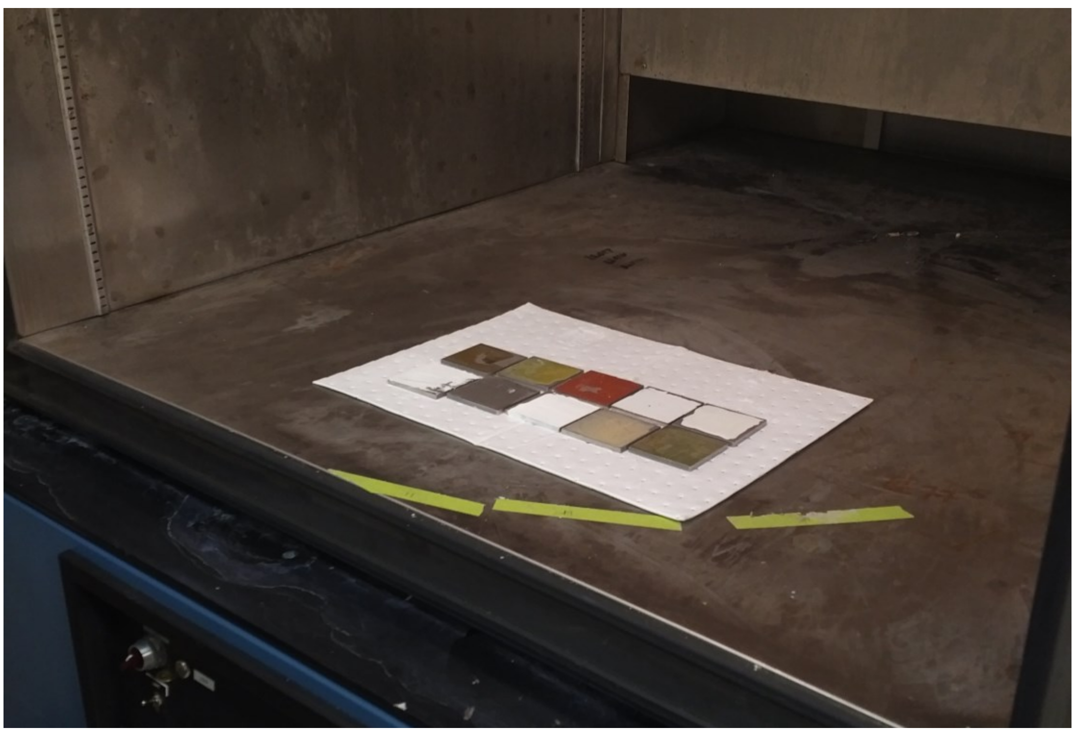


Figure 1: FCGs placed to cure in the environmental chamber.

4.3 Set-to-Touch, Dust-Free, and Dry-to-Touch Times

FCGs were allowed to cure in the selected environmental conditions until the functional dry time as specified by the manufacturer. These times are typically on the order of 1±1 hours for the single constituent materials, and 4 or more hours for the epoxies. Once this time was achieved, the environmental chamber was opened and the samples were tested for set-to-touch per ASTM D1640 [14]. For this test, the researcher touched the material then rolled their finger on a clean piece of glass (Figure 2). The FCG was deemed set-to-touch when it was still tacky to touch, but none of the material adhered to the finger and was subsequently transferred to the glass. If the sample was deemed not to pass D1640, it was placed back into the environmental chamber for another 30 minutes of curing. The sample continued this process until it was deemed set-to-touch or 8 hours has passed. This 8 hour stipulation is set for high humidity/low temperature environments that may not allow the sample to cure at all, and to constrain resources necessary for this testing.

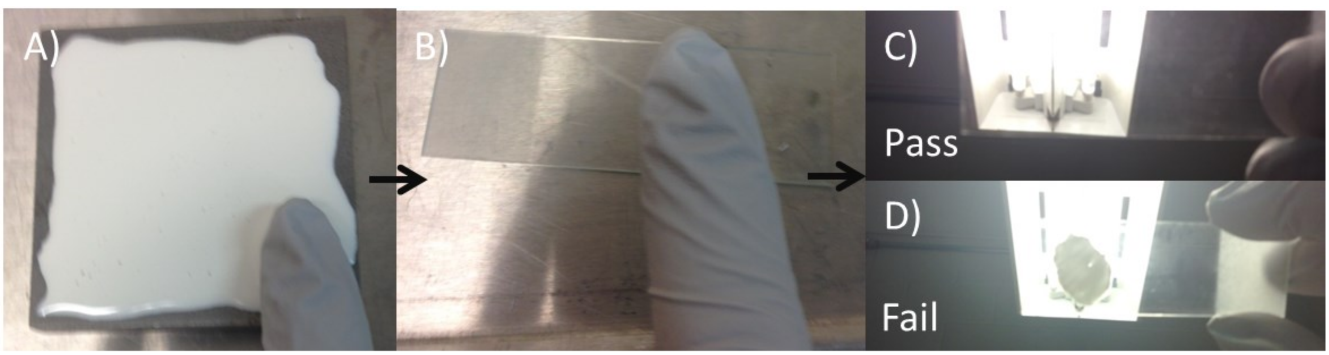


Figure 2. ASTM D1640 image flowchart: A) Sample has a gloved finger gently rolled onto the surface where B) the sample is rolled off onto a glass slide and is then inspected where either a clear view is seen through the glass and passes the inspection at C) or vision is obscured through the slide and fails the D1640 test as shown in D).

Once set-to-touch was achieved, dust-free times were examined. For this test, cotton fibers were dropped on a portion of the sample (Figure 3). The FCG was deemed dust-free once the fibers were capable of being removed from the surface via light blowing. Samples remained in the environmental chamber once set-to-touch has been achieved and removed every 30 minutes to test set-to-touch time.

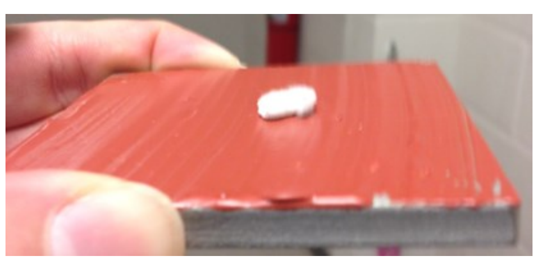


Figure 3. Example dust-free setup on a FD Sample

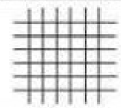
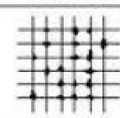
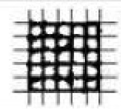
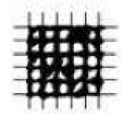
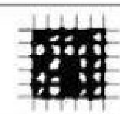
Dry-to-touch was performed once dust-free times were achieved. The testing for this proceeded similar to set-to-touch: dry-to-touch was achieved once the FCG no longer adhered to the finger and did not rub up appreciably when the finger is lightly rubbed across the surface. Outside of the samples tested below the freezing point of water (i.e. 20F testing), there was a 1:1 correlation to the dust free test performed.

4.4 Adhesion Testing

Once the material achieved dry-to-touch, adhesion testing was performed per ASTM D3359[13]. A certified cross-hatch tool (Figure 4) was utilized with certified pressure tape for this adhesion testing. After the material was deemed dry-to-touch, the material was removed from the environmental chamber and promptly processed for adhesion testing. A cut in the shape of an "X" was made through the use of the cross-hatch tool. After this was done, the tape was applied and allowed to sit for 90±30 seconds and then removed rapidly through peeling it back upon itself. The resulting residue was assessed per the Table 2 that is provided via ASTM D3359[13]:

Figure 4: Cross-hatch Tool for Adhesion Testing

Table 2: Cross-hatch Scale with Details [12]

Classification	Description	Appearance of surface of cross-cut area from which flaking has occurred[a] (Example for six parallel cuts)
0	The edges of the cuts are completely smooth; none of the squares of the lattice is detached.	
1	Detachment of small flakes of the coating at the inter-sections of the cuts. A cross-cut area not greater than 5 % is affected.	
2	The coating has flaked along the edges and/or at the intersections of the cuts. A cross-cut area greater than 5 %, but not greater than 15 %, is affected.	
3	The coating has flaked along the edges of the cuts partly or wholly in large ribbons, and/or it has flaked partly or wholly on different parts of the squares. A cross-cut area greater than 15 %, but not greater than 35 %, is affected.	
4	The coating has flaked along the edges of the cuts in large ribbons and/or some squares have detached partly or wholly. A cross-cut area greater than 35 %, but not greater than 65 %, is affected.	
5	Any degree of flaking that cannot even be classified by classification 4.	—

[a] The figures are examples for a cross-cut within each step of the classification. The percentages stated are based on the visual impression given by the pictures and the same percentages will not necessarily be reproduced with digital imaging.

Once all these tests were performed, five thickness measurements were taken using calipers to estimate the thickness of the samples upon the stainless steel substrates.

5.0 Results and Discussion

Summary tables for each of the materials are given below, with highlights on significant differences from the baseline test at 75 °F and 40% relative humidity. Other comments on the FCGs are given on a sample-by-sample basis with the charts. Overall, greater variation in cure times was assigned more to the humidity for the non-epoxy FCGs, with epoxy FCGs showing sensitivity to both humidity and temperature. Samples that were unable to cure at a given temperature/humidity range are denoted with an "X" in the column for tests that were never passed in the 24 hour span. Samples that experienced significant increases in threshold times (≥30 minutes) are shaded red and those that experienced significant decreases in threshold times (≥30 minutes) are shaded blue.

Table 3: Summary Data for Interchar I

Interchar I	**75 °F/ 40% RH**	**20 °F/ 0% RH**	**40 °F/ 40% RH**	**60 °F/ 40% RH**	**90 °F/ 40% RH**	**110 °F/ 40% RH**	**75 °F/ 10% RH**	**75 °F/ 20% RH**	**75 °F/ 60% RH**	**75 °F/ 80% RH**	**75 °F/ 95% RH**
Set to Touch (hr)	1:00	1:00	1:00	1:00	1:00	1:00	1:00	1:00	1:00	1:00	1:00
Dust Free (hr)	1:30	1:30	1:30	1:30	1:30	1:30	1:30	1:30	1:30	1:30	1:30
Dry to Touch (hr)	1:30	1:30	1:30	1:30	1:30	1:30	1:30	1:30	1:30	1:30	1:30
D3359	Class 1	Class 1	Class 0	Class 1	Class 2	Class 1	Class 1	Class 0	Class 1	Class 0	Class 1
Average thickness (mm)	0.852	0.53	0.623	0.434	0.409	0.528	0.325	0.450	0.405	0.308	0.486

Comments: Performed consistently across all testing environments.

Table 4: Summary data for Asbestos Binding Compound

Asbestos Binding Compound	**75 °F / 40% RH**	**20 °F / 0% RH**	**40 °F / 40% RH**	**60 °F / 40% RH**	**90 °F / 40% RH**	**110 ° F/ 40% RH**	**75 °F / 10% RH**	**75 °F/ 20% RH**	**75 °F/ 60% RH**	**75 °F/ 80% RH**	**75 °F/ 95% RH**
Set to Touch (hr)	1:00	1:00	1:00	1:00	1:00	1:00	1:00	1:00	1:00	2:00	3:30
Dust Free (hr)	1:30	2:00	1:30	1:30	1:30	1:30	1:30	1:30	1:30	2:30	4:00
Dry to Touch (hr)	1:30	2:00	1:30	1:30	1:30	1:30	1:30	1:30	1:30	2:30	4:00
D3359	Class 0	Class 0	Class 5	Class 1	Class 5	Class 2	Class 1	Class 5	Class 5	Class 2	Class 5
Average thickness (mm)	0.531	0.341	0.529	0.496	0.105	0.559	0.685	0.508	0.144	0.589	0.216

Comments: High humidity (≥80% RH) caused significant changes in cure times, minor changes at low (20 °F) temperatures. Variation in D3359 tests are due to chips that occasionally delaminate during testing.

Table 5: Summary Data for DeconGel

Decon Gel 1101	**75 °F / 40% RH**	**20 °F / 0% RH**	**40 °F / 40% RH**	**60 °F / 40% RH**	**90 °F / 40% RH**	**110 ° F/ 40% RH**	**75 °F / 10% RH**	**75 °F/ 20% RH**	**75 °F/ 60% RH**	**75 °F/ 80% RH**	**75 °F/ 95% RH**
Set to Touch (hr)	1:00	1:00	1:00	1:00	1:00	1:00	1:00	1:00	1:00	2:00	2:30
Dust Free (hr)	1:30	1:30	1:30	1:30	1:30	1:30	1:30	1:30	1:30	2:30	3:00
Dry to Touch (hr)	1:30	1:30	1:30	1:30	1:30	1:30	1:30	1:30	1:30	2:30	3:00
D3359	Class 0	Class 0	Class 5	Class 0	Class 5	Class 0	Class 0	Class 5	Class 5	Class 5	Class 5
Average thickness (mm)	0.269	0.142	0.114	0.080	0.063	0.173	0.171	0.092	0.135	0.087	0.109

Comments: High humidity (≥80% RH) causes moderate changes in cure times, D3359 testing either caused significant delamination of the thin film from the substrate or had no effect with no correlation between temperature or relative humidity.

Table 6: Summary Data for FireDam

FireDam	**75 °F/ 40% RH**	**20 °F/ 0% RH**	**40 °F/ 40% RH**	**60 °F/ 40% RH**	**90 °F/ 40% RH**	**110 °F/ 40% RH**	**75 °F/ 10% RH**	**75 °F/ 20% RH**	**75 °F/ 60% RH**	**75 °F/ 80% RH**	**75 °F/ 95% RH**
Set to Touch (hr)	1:00	1:00	1:00	1:00	1:00	1:00	1:00	1:00	1:00	2:00	3:30
Dust Free (hr)	1:30	2:00	2:30	2:30	2:00	1:30	1:30	1:30	3:30	3:00	4:00
Dry to Touch (hr)	1:30	2:00	2:30	2:30	2:00	1:30	1:30	1:30	3:30	3:00	4:00
D3359	Class 5	Class 1	Class 0	Class 3	Class 0	Class 5	Class 2	Class 0	Class 5	Class 2	Class 1
Average thickness (mm)	1.112	0.401	0.693	0.584	0.629	0.418	0.431	0.687	0.471	0.752	0.365

Comments: High humidity (≥60% RH) causes significant changes to the curing time, with moderate changes from temperature variations. D3359 testing gives highly varying data with no discernable pattern. This is attributed to being an artifact of the test method rather than the material; D3359 is intended for firm polymer layers rather than clay like materials such as FD. This is to be a discussion topic at the ASTM meeting in January 2017.

Table 7: Summary data for FireGuard E-84

Fire Guard E-84	**75 °F/ 40% RH**	**20 °F/ 0% RH**	**40 °F/ 40% RH**	**60 °F/ 40% RH**	**90 °F/ 40% RH**	**110 °F/ 40% RH**	**75 °F/ 10% RH**	**75 °F/ 20% RH**	**75 °F/ 60% RH**	**75 °F/ 80% RH**	**75 °F/ 95% RH**
Set to Touch (hr)	1:00	1:00	1:00	1:00	1:00	1:00	1:00	1:00	1:00	1:30	1:00
Dust Free (hr)	1:30	1:30	1:30	1:30	1:30	1:30	1:30	1:30	1:30	2:00	1:30
Dry to Touch (hr)	1:30	1:30	1:30	1:30	1:30	1:30	1:30	1:30	1:30	2:00	1:30
D3359	Class 1	Class 2	Class 5	Class 1	Class 2	Class 2	Class 0	Class 2	Class 1	Class 1	Class 1
Average thickness (mm)	0.500	0.68	0.832	0.841	0.952	0.713	0.995	0.859	0.450	0.576	0.214

Comments: High humidity had some effect on the curing time of the material, though less than other FCGs.

Table 8: Summary data for Polymer Barrier System

Polymeric Barrier System	**75 °F/ 40% RH**	**20 °F/ 0% RH**	**40 °F/ 40% RH**	**60 °F/ 40% RH**	**90 °F/ 40% RH**	**110 °F/ 40% RH**	**75 °F/ 10% RH**	**75 °F/ 20% RH**	**75 °F/ 60% RH**	**75 °F/ 80% RH**	**75 °F/ 95% RH**
Set to Touch (hr)	1:00	1:00	1:00	1:00	1:00	1:00	1:00	1:00	1:00	1:00	3:30
Dust Free (hr)	1:30	1:30	1:30	1:30	1:30	1:30	1:30	1:30	1:30	1:30	4:00
Dry to Touch (hr)	1:30	1:30	1:30	1:30	1:30	1:30	1:30	1:30	1:30	1:30	4:00
D3359	Class 0	Class 4	Class 0	Class 1	Class 0	Class 0	Class 0	Class 0	Class 1	Class 1	Class 0
Average thickness (mm)	1.04	0.553	0.341	0.408	0.322	0.446	0.581	0.432	0.413	0.320	0.297

Comments: Changes to the curing time were notable at the extreme ends of humidity. ASTM D3359 tests showed a significant difference during the low temperature cure test signifying an impact on adhesion.

Table 9: Summary data for FireFree 88

FireFree 88	**75 °F/ 40% RH**	**20 °F/ 0% RH**	**40 °F/ 40% RH**	**60 °F/ 40% RH**	**90 °F/ 40% RH**	**110 °F/ 40% RH**	**75 °F/ 10% RH**	**75 °F/ 20% RH**	**75 °F/ 60% RH**	**75 °F/ 80% RH**	**75 °F/ 95% RH**
Set to Touch (hr)	1:00	1:00	1:00	1:00	1:00	1:00	1:00	1:00	1:00	1:30	4:00
Dust Free (hr)	1:30	1:30	1:30	1:30	2:00	1:30	1:30	1:00	1:30	2:00	4:30
Dry to Touch (hr)	1:30	1:30	1:30	1:30	2:00	1:30	1:30	1:30	1:30	2:00	4:30
D3359	Class 0	Class 1	Class 1	Class 1	Class 1	Class 1	Class 1	Class 1	Class 3	Class 1	Class 1
Average thickness (mm)	0.256	0.651	0.424	0.553	0.402	0.434	0.525	0.683	0.292	0.442	0.724

Comments: High humidity (≥80% RH) leads to a noticeable increase in curing time.

Table 10: Summary Data for FireX

FireX	**75 °F/ 40% RH**	**20 °F/ 0% RH**	**40 °F/ 40% RH**	**60 °F/ 40% RH**	**90 °F/ 40% RH**	**110 °F/ 40% RH**	**75 °F/ 10% RH**	**75 °F/ 20% RH**	**75 °F/ 60% RH**	**75 °F/ 80% RH**	**75 °F/ 95% RH**
Set to Touch (hr)	4:00	X	8+	4:00	2:00	1:30	5:30	8+	7:00	8+	4:00
Dust Free (hr)	4:30	X	8+	6:30	3:00	2:30	6:00	>24 hr	8:00	8+	5:30
Dry to Touch (hr)	4:30	X	8+	6:30	3:00	2:30	6:00	>24 hr	8:00	8+	5:30
D3359	Class 0	X	Class 0	Class 0	Class 0	Class 0	Class 0	Class 1	Class 0	Class 0	Class 0
Average thickness (mm)	0.5942	X	0.933	1.353	0.977	0.587	0.816	0.947	0.857	0.951	0.586

Comments: High temperatures shorten the cure time of FX significantly while low temperatures force longer curing times, to the point where FX does not cure at 20F. At 40F, it is overnight until the sample would cure. Variations in humidity also increase cure time to the point where it can take more than 24 hours to cure, however there is no consistency to that data as the 95% relative humidity takes less time to cure than the 80% RH.

Table 11: Summary data for Intumax EP 102

Intumax EP 102	**75 °F/ 40% RH**	**20 °F/ 0% RH**	**40 °F/ 40% RH**	**60 °F/ 40% RH**	**90 °F/ 40% RH**	**110 °F/ 40% RH**	**75 °F/ 10% RH**	**75 °F/ 20% RH**	**75 °F/ 60% RH**	**75 °F/ 80% RH**	**75 °F/ 95% RH**
Set to Touch (hr)	3:30	X	6:00	3:00	1:30	1:00	3:30	2:00	2:00	3:00	3:30
Dust Free (hr)	3:30	X	8+	3:30	2:00	2:00	4:00	3:00	4:30	3:30	5:30
Dry to Touch (hr)	5:00	X	8+	3:30	2:00	2:00	4:00	3:00	4:30	3:30	5:30
D3359	Class 0	X	Class 0	Class 0	Class 0	Class 0	Class 0	Class 0	Class 0	Class 0	Class 0
Average thickness (mm)	0.852	X	1.408	1.116	0.912	0.959	0.931	1.501	1.221	1.114	0.839

Comments: Similar to FX, it is impossible to cure Intumax EP 102 at 20F. Temperature played a significant role in the curing time of the material, with a lesser dependency on the humidity of the sample.

Table 12: Summary data for CC Epoxy

CC Epoxy	**75 °F/ 40% RH**	**20 °F/ 0% RH**	**40 °F/ 40% RH**	**60 °F/ 40% RH**	**90 °F/ 40% RH**	**110 °F/ 40% RH**	**75 °F/ 10% RH**	**75 °F/ 20% RH**	**75 °F/ 60% RH**	**75 °F/ 80% RH**	**75 °F/ 95% RH**
Set to Touch (hr)	3:00	X	8+	4:00	1:30	1:00	4:30	2:30	2:00	2:30	3:30
Dust Free (hr)	3:00	X	8+	7:00	2:00	1:30	5:00	4:00	4:30	3:00	4:00
Dry to Touch (hr)	3:30	X	8+	7:00	2:00	1:30	5:00	4:00	4:30	3:00	4:00
D3359	Class 1	X	Class 0	Class 0	Class 0	Class 0	Class 0	Class 0	Class 0	Class 0	Class 0
Average thickness	1.015	X	1.074	0.790	0.487	0.853	0.705	0.450	0.553	1.001	0.605

Comments: CC epoxy demonstrates dependence on the curing temperature over that of relative humidity. Along with the other two epoxies (IM, FX) it is impossible for the material to cure at 20 °F.

6.0 Conclusions and Path Forward

Through the process of this experiment, multiple FCGs were characterized and found to be impacted during non-ideal environmental conditions. The greatest correlation to the non-epoxy FCGs were found in the humidity of the environment, while the epoxy materials showed strong dependence on both temperature and humidity. For epoxy materials, this dependence was so great that it became impossible to cure them in some of the tested environments. Only one material, InterChar, was found to not be significantly affected by environmental conditions ranging from 20-110 °F and humidities ranging from 10-95% RH.

This data will be discussed with safety basis workers located at SRNS who support the Plutonium Fuel Fabrication (PuFF) decommissioning project. Discussion results will guide ASTM standard development at the January 2017 meeting of the ASTM Subcommittee E10.03 (Radiological Protection for Decontamination and Decommissioning of Nuclear Facilities and Components) with FIU personnel. Previous efforts have resulted in two draft standards to date for codifying the metrics against which "fixative" materials should operate, both for strippable and permanent coatings, and are expected for final vote at the January 2017 meeting. Further ASTM efforts will seek to identify better adhesion characterization methods for non-D3359 compatible materials such as FireDam, standardized environmental characterization for FCGs, and other efforts identified by safety basis assessments, 235-F PuFF Project, and DOE personnel as direct gaps in material(s) characterizations.

The next phase of this project will be characterization into off-gassed compounds from these materials as they cure, as well as the introduction of down-selected FCGs into SRNL 235-F PuFF/F-Area Labs with input from PuFF and safety basis personnel guiding introduction methods and efforts. Off-gas analysis will provide information regarding potentially flammable compounds and their concentrations that may be of concern during the application process. Direct introduction of FCGs in well characterized radiological areas will allow data to be collected over how FCGs interact with Pu-238, something that has not been previously characterized for FCGs. This will allow a better understanding of FCGs in-situ where they will eventually be utilized for contamination fixture should results prove promising for compatibility in these high-alpha radiological environments. Once these results are obtained, final discussions regarding the safety basis policy directives will be discussed for what remaining metrics must be addressed before final approval of use within the facilities as well as how these materials are able to reduce the material at risk within facilities undergoing D&D operations.

7.0 References

1. *Asbestos Binding Compound*; MSDS No. 6421, Fiberlock Technologies, Inc.: Andover, MA, April, 2015. http://www.fiberlock.com/sds/ABC-(6421,%206422,%206423)-SDS.pdf (accessed 9/13/16).

2. *CC Epoxy SP*; MSDS No. N/A, Instacote: Erie, MI. http://instacote.com/msds/CCEpoxySP.pdf (accessed 9/13/16).

3. *FireDam*: 3M DIVISION: Industrial Adhesives and Tapes Division ADDRESS: 3M Center, St. Paul, MN 55144-1000, USA http://multimedia.3m.com/mws/mediawebserver?mwsId=SSSSSuUn_zu8l00xM82vn8tUOv70k17zHvu9lxtD7SSSSSS-- (accessed 12/12/16)

4. *FireFree 88:* Firefree Coatings,Inc. 580 Irwin Street No. 1 San Rafael,CA94901 *http://www.firefree.com/docs/SDSFF8801-15-16.pdf (accessed 12/12/16)*

5. *Intumax EP 102:* Broadview Technologies, Inc. *http://www.broadview-tech.com/LinkClick.aspx?fileticket=WOLaiPp5zE0%3D& (accessed 12/12/16*

6. *Polymeric Barrier System: BHI Energy/Power Services* 60 Industrial Park Road Plymouth, MA 02360 *http://www.bhienergy.com/assets/PBS-MSDS-2015Revised-3-15.pdf*

7. *DeconGel*; MSDS No. 1101, CBI Polymers: Richardson, TX, February 2013. http://decongel.com/the-product/decongel1101/ (accessed 9/13/16).

8. *Polymeric Barrier System*; MSDS No. N/A, BHI Energy: Weymouth, MA, February 2016. http://www.bhienergy.com/assets/DOWNLOAD.pdf (accessed 9/13/16).

9. *FireGuard*; MSDS No. N/A, Shield Industries, Inc.: Woodstock, GA, April 2002. http://shieldindustries.com/fireguard_wp/fireguard/fireguard-e-84/ (accessed 9/13/16)

10. "Intumescent Paint, Fireproofing, and Firestopping." *Archtoolbox*. Arch Media Group LLC, n.d. Web. 13 Sept. 2016. https://www.archtoolbox.com/materials-systems/thermal-moisture-protection/intumescent-paint-fireproofing-and-firestopping.html.

11. "Association for Specialist Fire Protection Technical Guidance Documents (11-17)." *Association for Specialist Fire Protection*. ASFP Kingsley House, n.d. Web. 13 Sept. 2016. http://asfp.associationhouse.org.uk/default.php?cmd=210&doc_category=16.

12. J. C. Nicholson, "Incombustible Fixative Test Plan – Environmental Curing Testing," Savannah River National Laboratory. SRNL-TR-2016-00286 (2016).

13. ASTM Standard D3359, 2009, "Standard Test Methods for Measuring Adhesion by Tape Test," ASTM International, West Conshohocken, PA, 2003, DOI: 10.1520/3359-09e02, www.astm.org.

14. ASTM Standard D1640, 2003, "Standard Test Methods for Drying, Curing, or Film Formation of Organic Coatings at Room Temperature," ASTM International, West Conshohocken, PA, 2003, DOI: 10.1520/D1640_D1640M-14, www.astm.org.