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**AVIO^{F3} Green KHC 3% Fluorine Free Foam
Concentrate “Quick Look” Summary
ESTCP WP20-5373 SITREP #1**

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AVIO^{F3} Green KHC 3% Fluorine Free Foam Concentrate

“Quick Look” Summary

ESTCP WP20-5373 SITREP #1

1.0 INTRODUCTION: The purpose of the ESTCP WP20-5373 “Quick Look” summary situational reports (SITREP) are to provide periodic updates on the Naval Research Laboratory’s (NRL) progress while conducting the Phase I Firefighting Performance testing that are being executed in accordance with the approved ESTCP WP20-5373 statement of work [1]. Since this is the first ESTCP WP20-5373 SITREP, also included are some additional insights that should be kept in mind/considered when we move forward with the follow-on ESTCP WP20-5373 Phase II effort to develop a military specification for fluorine free foam (F3) products for shore-based military installations; both mobile (Aviation Rescue Fire Fighting (ARFF) vehicles) and fixed (aviation hangars) F3 technology applications.

2.0 FIREFIGHTING AGENT: The AVIO^{F3} Green KHC 3% agent is fluorine free foam (F3) agent manufactured by National Foam Inc. The AVIO^{F3} Green KHC 3% agent is a low viscosity (Newtonian liquid) concentrate that was specifically designed for ARFF vehicle applications [2]. The agent was also purported to be a fluorine-free aqueous film forming foam (AFFF) product when used with aviation-type fuels.

3.0 FIREFIGHTING PERFORMANCE: Table-1 provides the initial 28ft² fire test results when using the AFFF MILSPEC firefighting nozzle set at 2 GPM (0.071 gpm/ft² application rate) and 3 GPM (0.107 gpm/ft² application rate) flow rates using both ethanol-free gasoline and jet fuel (JP-8).

NOTE: The AFFF MIL-PRF-24385 standard for expansion ratio and drainage time evaluations only applies to full strength agent solution performance testing [3].

Table-1: AVIO^{F3} Green KHC 3% Initial 28 ft² Fire Test Results

Fire Test	Extinction time (sec) ¹	Expansion Ratio ²	Drainage Time ³ (min)	Burnback (sec) ⁴
28 ft² (Ethanol-Free Gasoline)				
2 GPM full strength	59/52/59	8.1	4:57	262
2 GPM ½ strength	62	7.45	4:49	271
2 GPM quintuple strength	65	12.9	4:52	128
3 GPM full strength	50/40	7.3	4:48	244
3 GPM ½ strength	50	6.5	5:48	322
28 ft² (Jet Fuel (JP-8))				
2 GPM full strength	33/30/27	7.2	4:56	365
2 GPM ½ strength	28	7.2	8:42	319
2 GPM quintuple strength	31	12.8	4:48	158
3 GPM full strength	19/20	7.2	5:00	507
3 GPM ½ strength	21	6.1	9:30	421

1. MILSPEC Extinction Times for full strength gasoline is ≤ 30 sec, ½ strength gasoline is ≤ 45 sec, and quintuple strength gasoline is ≤ 55 sec.
2. MILSPEC Expansion Ratio for full strength gasoline is ≥ 5.0.
3. MILSPEC Drainage Time for full strength gasoline is ≥ 2:30 minutes.
4. MILSPEC Burnback Time for full strength gasoline is ≥ 360 sec, ½ strength gasoline is ≥ 300 sec, and quintuple strength gasoline is ≥ 200 sec.

4.0 PRELIMINARY PERFORMANCE ANALYSIS:

4.1 Firefighting Performance: The AVIO^{F3} Green KHC 3% agent performed well when using jet fuel (JP-8) both at the 2 GPM (0.071 gpm/ft² application rate) and the 3 GPM (0.107 gpm/ft² application rate) flow rates. As was expected, the performance when using gasoline was less effective but the performance was slightly better when compared to previously tested commercially available high viscosity (non-Newtonian liquids) fluorine free foam products.

Of particular note, the AVIO^{F3} Green KHC 3% agent, as evident in the Table-1 data, had relatively consistent extinguishing times at the full strength, ½ strength, and quintuple strength foam solution applications. This finding is not what would be expected with AFFF, especially with the ½ strength fresh water foam solutions, which implies that this particular fluorine free foam product may not be susceptible to performance degradation when the product is missed proportioned by the currently fielded foam deliver systems.

4.2 Burnback Performance: The burnback performance with the AVIO^{F3} Green KHC 3% agent when using gasoline was degraded in comparison to its performance with jet fuel (JP-8). This degradation in performance with gasoline is not what has been previously observed with the other highly viscous (persudo solid) fluorine free foam products when tested using full strength foam solutions.

4.3 Film & Seal Performance: Because the AVIO^{F3} Green KHC 3% agent was purported to be a Fluorine-Free Aqueous Film Forming Foam (AFFF) product, two film & seal tests were conducted. The first film & seal test was done with the AFFF MILSPEC test standard using cyclohexane as the base fuel. The AVIO^{F3} Green KHC 3% agent immediately ignited and therefore failed the film & seal test. During this particle film & seal test, it was noted that the foam submerged below the cyclohexane fuel surface. This particular phenomena was also observed when conducting previous UL-162 high viscosity fluorine free foam agents during the 50 ft² fire testing for the NFPA Research Foundation, particularly when using the isopropyl alcohol (IPA) polar solvent fuels (see Figure -1).



Figure -1: NFPA Research Foundation UL-162 High Viscosity Fluorine Free Foam 50 ft² Fire Test

When the film & seal test was performed with jet fuel (JP-8), there was no ignition and therefore the agent passed the film & seal test, implying that the AVIO^{F3} Green KHC 3% agent could be considered a fluorine-free AFFF agent when used with aviation-type fuels.

4.4 Future Military Specification Development Considerations: The following provides some additionally thoughts that should be kept in mind and/or considered when proceeding with the future development of a military specification for a shore-based fluorine free foam product application:

- Normally when evaluating a new firefighting extinguishing agents, the fuel used is based on the expected fuel threat. The genesis for using gasoline for the AFFF military specification was based on the JP-4 fuel threat. Even though the use of JP-4 has been discontinued, the AFFF extinguishing time requirement has remained unchanged, which has resulted in a very high safety factor for AFFF, which may be beyond the requirement for “what is good enough” for shore-based firefighting foam applications.
- For previous transitions of new firefighting extinguishing agents, the application rates (i.e., concentration requirements) were significantly increased to maintain equivalent performance. Two Halon 1301 replacement examples include: (1) The introduction of the Heptafluoropropane (HFC-227 (C₃HF₇)) agent required a factor of “≈ 3” increase in agent concentration to minimize the post-fire Hydrogen Fluoride (HF) generation prior to Fleet introduction, and (2) The introduction for the use of self-contained aerosol generators required an increase by factor of “≈ 2” in agent concentration to account for the presence of polar solvents such as methanol prior to Fleet introduction.
- Table-2 provides a historical review of the AFFF MILSPEC as the AFFF technology improved in capabilities from the 1969-1981 timeframe.

Table-2: Historical Review of the Evolution of the AFFF Military Specification

Specification Version	Specification Date	Fire Area (ft ²)	Flow Rate (GPM)	Extinguishment Time (sec)	Burnback Time (sec)
24385	11/21/69	28	2	84	240
Amendment 3	7/7/71	28	2	65	240
24385A	5/2/77	28	2	45	320
24385B	5/25/78	28	2	30	320
24385C	3/12/81	28	2	30	360

It should be expected that the initial military specification that will be developed for the fluorine free foam shore-based military installation application (in accordance with the FY20 NDAA requirements) will follow the same type of evolution as the fluorine free foam technology continues to improve in capability.

- Very little data is available which quantifies a minimum level of burnback resistance for specific applications. Standards/specifications (i.e., MILSPEC and UL) set requirements essentially on what a foam agent could achieve in small scale testing.

5.0 SUMMARY & CONCLUSIONS:

The main takeaway from this preliminary fire test evaluation is that it may be possible to provide an AFFF alternative that could be compatible with existing foam delivery hardware systems. The true test of this preliminary hypothesis will be to demonstrate adequate scalability (i.e., 50 ft², 400 ft² and 1200 ft² testing) for mobile (aviation rescue and firefighting (ARFF)) vehicle applications and the applicability for fixed foam systems, which may include the use of non-aspirated foam nozzles for shore-based aviation hangar applications.

6.0 REFERENCES:

1. J.P. Farley, "Fluorine-Free Military Specification Development", ESTCP WP20-5373 Statement of Work, March 2020.
2. National Foam Inc., AVIO^{F3} Green KHC 3% "Specification Sheet", NFC515 (Revision A), January 2020.
3. NAVSEA "Fire Extinguishing Agent, Aqueous Film-Forming Foam (AFFF) Liquid Concentrate, Fresh water and Sea Water", MIL-PRF-24385F(SH) wINT Amendment 3, 07 May 2019.

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APPENDIX A

AVIO^{F3} Green KHC 3% Fluorine Free Concentrate Container Photograph

29 May 2020

**AVIO^{F3} Green KHC 3% Fluorine Free Foam
Concentrate “Quick Look” Summary
ESTCP WP20-5373 SITREP #2**

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AVIO^{F3} Green KHC 3% Fluorine Free Foam Concentrate

“Quick Look” Summary

ESTCP WP20-5373 SITREP #2

1.0 INTRODUCTION: The purpose of the ESTCP WP20-5373 “Quick Look” summary situational reports (SITREP) are to provide periodic updates on the Naval Research Laboratory’s (NRL) progress while conducting the Phase I Firefighting Performance testing that are being executed in accordance with the approved ESTCP WP20-5373 statement of work [1]. This ESTCP WP20-5373 SITREP #2 provides an overview of the MILSPEC 50ft² testing, Non-MILSPEC reduced aspiration 28ft² & 50ft² testing, and the PKP compatibility testing using the AVIO^{F3} Green KHC 3% fluorine free foam product using both gasoline and Jet Fuel (JP-8) fueled fires.

2.0 FIREFIGHTING AGENT: The AVIO^{F3} Green KHC 3% agent is fluorine free foam (F3) agent manufactured by National Foam Inc. The AVIO^{F3} Green KHC 3% agent is a low viscosity (Newtonian liquid) concentrate that was specifically designed for Aviation Rescue Firefighting (ARFF) vehicle applications [2]. The agent has also been determined to be a fluorine-free aqueous film forming foam (AFFF) product when used with aviation-type fuels as noted in ESTCP WP20-5373 SITREP #1.

3.0 FIREFIGHTING PERFORMANCE: Table-1 provides the 50ft² fire test results when using the AFFF MILSPEC firefighting nozzle set at 2 GPM (0.071 gpm/ft² application rate) and 3 GPM (0.107 gpm/ft² application rate) flow rates using both ethanol-free gasoline and jet fuel (JP-8).

NOTE: The AFFF MIL-PRF-24385 standard for the 50ft² fires only addresses fully aspirated fire flows and only applies to saltwater firefighting solutions. Expansion and drainage testing is also not required [3].

Table-1: AVIO^{F3} Green KHC 3% 50 ft² Fire Tests Using Fresh Water Solution Test Results

Fire Test	Extinction time (sec) ¹	Expansion Ratio ²	Drainage Time ³ (min)	40 sec ⁴ Summation	Burnback (sec) ⁵
50 ft² (Ethanol-Free Gasoline)					
2 GPM Full Strength	224	N/A	N/A	280	63
3 GPM Full Strength	120	N/A	N/A	340	161
50 ft² (Jet Fuel (JP-8))					
2 GPM Full Strength	54	N/A	N/A	305	206
3 GPM Full Strength	30	N/A	N/A	365	327

1. MILSPEC 50ft² Extinction Time for full strength gasoline using saltwater solutions is ≤ 50 sec

2. MILSPEC Expansion Ratio for 50ft² fire testing is not applicable

3. MILSPEC Drainage Time for 50ft² fire testing is not applicable.

4. MILSPEC 50ft² 40 sec Summation (10/20/30/40) value using saltwater solutions is ≥ 320

5. MILSPEC Burnback Time for the 50ft² fires full strength gasoline saltwater solutions is ≥ 360 seconds

4.0 PRELIMINARY PERFORMANCE ANALYSIS:

4.1 50ft² Firefighting Performance: The AVIO^{F3} Green KHC 3% agent performed well when using jet fuel (JP-8) both at the 2 GPM (0.071 gpm/ft² application rate) and the 3 GPM (0.107 gpm/ft² application rate) flow rates and the test results demonstrate reasonable scalability to the 50ft² level. Beyond fire extinction times, the 40 sec Summation results, which is a measure the foam blanket formation/fire knock at the 10 sec, 20 sec, 30 sec, and 40 sec time intervals, also demonstrated

excellent foam formation and foam flow spreading capabilities over the burning fuel surface. As was expected, the performance when using gasoline was less effective. Although the 40 sec Summation value for the gasoline fueled fires also notes good foam formation and foam flow spreading capabilities, the edge effects of the fuel pan promoted sustained fire burning along the outer perimeter edge of the fuel pan, which resulted in the longer extinction times.

NOTE: It is fully realized that the edge effects of the fuel pan is an artifact of Class B fire testing and it does not truly represent a more realistic unconfined fuel spill scenario. In a more realistic gasoline fuel spill fire scenario, the sustained burning effect along the leading edges of the fire would be less evident, which could lead to more comparative fire extinction results when combatting real-world gasoline-type fires.

4.2 *Non-MILSPEC Reduced Aspiration 28ft² & 50ft² Fire Test Performance:* The intent of the Reduced Aspiration performance fire testing is to evaluate the Fluorine Free Foam product's capabilities when using non-aspirating-type nozzles that are currently being used by various DoD fixed sprinkler applications.

For this preliminary reduced aspiration evaluation, we chose to reduce the MILSPEC firefighting nozzle foam flow expansion ratio to ≈ 5.2 , which is approximately the foam flow expansion ratio delivered from the U.S. Navy non-aspirating Tyco Model SB Flight Deck flush deck sprinkler nozzle that was previously determined by the NRL AFFF Foamability & Dissipation Assessment study [4] (see Figure 1).



Figure-1: Tyco Model SB Flight Deck Flush Deck Nozzle

To achieve the desired expansion ratio, two complete wraps of 1 in. aluminum tape was used to cover the four MILSPEC Firefighting nozzle “air inlet” holes. Once this action was complete, we then used a 0.06 in. (1.52 mm) gauge pin to produce two on-center adjacent holes through the tape to provide the desired expansion ratio that was verified by the MILSPEC expansion & drainage test protocol prior to fire testing. Figure 2 provides a photograph of the modified MILSPEC nozzle assembly.



Figure-2: Modified MILSPEC Firefighting Nozzle Assembly

Tables-2 provide the results of the reduced aspiration fire tests using both Gasoline and Jet Fuel (JP-8) at a 2 GPM (0.071 gpm/ft² application rate) flow rate.

Table-2: AVIO^{F3} Green KHC 3% Non-MILSPEC Reduced Aspiration Fire Test Results

Fire Test	Extinction time (sec) ¹	Expansion Ratio ²	Drainage Time ³ (min)	40 sec ⁴ Summation	Burnback (sec) ⁵
50 ft² Reduced Aspiration					
2 GPM (Ethanol-Free Gasoline)	NC*	5.2	5:00	320	NC*
2 GPM (Jet Fuel (JP-8))	53	5.2	5:00	320	207
28 ft² Reduced Aspiration					
2 GPM (Ethanol-Free Gasoline)	69	5.2	5:00	N/A	190
2 GPM (Jet Fuel (JP-8))	25	5.2	5:00	N/A	310

NC* Due to the limited stream reach of the reduced aspirated foam flow, firefighting action was stopped at the 300 second timeframe to mitigate further burn injury to the firefighter.

Despite the experiences gained with the 2 GPM 50ft² gasoline fire test, the AVIO^{F3} Green KHC 3% fluorine free foam product performed very well during the non-MILSPEC reduced aspiration fire testing. The test results, especially with the Jet Fuel (JP-8) fueled fires actually demonstrated improved performance, which is hypothesized to be due to the thermodynamic cooling effect posed by the wetter foam, which may have helped to reduce the edge effects from the fire test pan. Again, as noted in ESTCP WP20-5373 SITREP #1, this particular fluorine-free AFFF product seems to have other consistency capabilities that are not typically observed with other MILSPEC AFFF products.

NOTE: Additional DoD non-aspirated nozzle testing will be conducted using actually fielded DoD nozzle hardware during the follow-on Jensen Hughes/NRL ESTCP WP20-5374 program.

4.3 PKP Compatibility: The MILSPEC PKP compatibility test repeats the full strength 28ft² fire test with a modified burnback procedure. Once the fire is extinguished and prior to conducting the burnback test, one pound (454 grams) of PKP dry chemical powder is evenly distributed over the foam blanket within a 30 second period using an 8 in. diameter 40-mesh sieve. Once the PKP has been disbursed, the burnback test is executed. The MILSPEC metric for PKP compatibility evaluation testing is to note the difference in burnback time (if any) when 25% of the fuel surface is again burning. Table-3 provides the results for the full strength and ½ strength fresh water foam solution tests using both Gasoline and Jet Fuel (JP-8) at a 2 GPM (0.071 gpm/ft² application rate) flow rate.

Table-3: AVIO^{F3} Green KHC 3% PKP Compatibility Test Results

Fire Test	Extinction time (sec) ¹	Expansion Ratio ²	Drainage Time ³ (min)	Burnback (sec) ⁵
28 ft² (Ethanol-Free Gasoline)				
2 GPM Full Strength	64	8.5	4:21	75
2 GPM Half Strength	84	7.8	7:13	54
28 ft² (Jet Fuel (JP-8))				
2 GPM Full Strength	20	8.5	4:21	283
2 GPM Half Strength	24	7.8	7:13	292

During the PKP compatibility testing there was some level of bubble break down due to the PKP application particularly at the edges of the fuel pan (see Figures 3 and 4).



Figure-3: AVIO^{F3} Green KHC 3% PKP Compatibility 28ft² Gasoline Fire Test

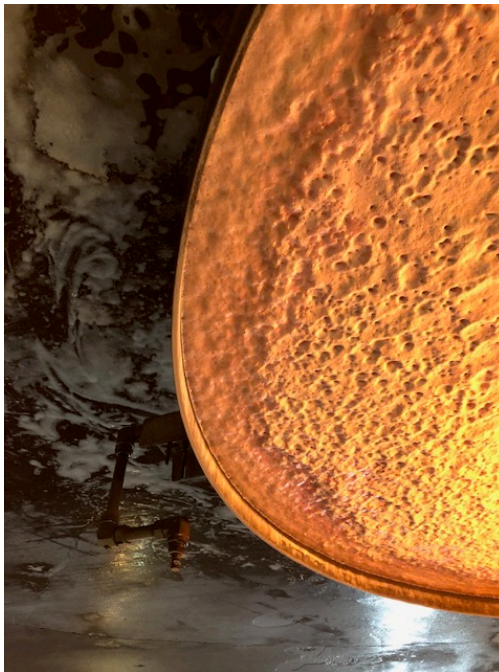


Figure-4: AVIO^{F3} Green KHC 3% PKP Compatibility 28ft² Jet Fuel (JP-8) Fire Test

The AVIO^{F3} Green KHC 3% agent does have PKP resistance capability but does not have the same level of performance as demonstrated with MILSPEC AFFF. We will continue to review this issue with National Foam Inc.

5.0 SUMMARY & CONCLUSIONS:

The AVIO^{F3} Green KHC 3% has demonstrated scalable performance to the 50ft² level and still continues to provide some additional consistency capabilities that are not normally observed with other MILSPEC AFFF products. This testing completes the planned unaged concentrate testing for the AVIO^{F3} Green KHC 3% product. Additional testing will be performed when we are ready to proceed with the aged concentrate/aged solutions and agent compatibility testing portion of the ESTCP WP20-5373 program.

6.0 REFERENCES:

1. Farley J.P., "Fluorine-Free Military Specification Development", ESTCP WP20-5373 Statement of Work, March 2020.
2. National Foam Inc., AVIO^{F3} Green KHC 3% "Specification Sheet", NFC515 (Revision A), January 2020.
3. NAVSEA "Fire Extinguishing Agent, Aqueous Film-Forming Foam (AFFF) Liquid Concentrate, Fresh water and Sea Water", MIL-PRF-24385F(SH) wINT Amendment 3, 07 May 2019.
4. Farley, J.P., Karwoski, S., Whitehurst, C.L., Back, J.G., Tweedie, S.D., Hunstad, M.P., Fletcher, S.G., Berkoski, D.T., "AFFF Foamability and Dissipation Assessment," NRL Ltr Rpt 6180/0039, 24 February 2020.

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APPENDIX A

AVIO^{F3} Green KHC 3% Fluorine Free Concentrate Container Photograph

12 June 2020

**Fomtec ENVIRO USP 2-3% Fluorine Free Foam
Concentrate “Quick Look” Summary
ESTCP WP20-5373 SITREP #3**

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Fomtec ENVIRO USP 2-3% Fluorine Free Foam Concentrate

“Quick Look” Summary

ESTCP WP20-5373 SITREP #3

1.0 INTRODUCTION: The purpose of the ESTCP WP20-5373 “Quick Look” summary situational reports (SITREP) are to provide periodic updates on the Naval Research Laboratory’s (NRL) progress while conducting the Phase I Firefighting Performance testing that are being executed in accordance with the approved ESTCP WP20-5373 statement of work [1]. ESTCP WP20-5373 SITREP #3 reviews the Fomtec ENVIRO USP 3% unaged concentrate 28ft² and 50ft² fire test results.

2.0 FIREFIGHTING AGENT: The Fomtec ENVIRO USP 2-3% agent is fluorine free foam (F3) agent manufactured by Dafo Fomtec AB, Tyreso, Sweden. The agent is a high viscosity (non-Newtonian liquid) concentrate that was specifically designed for fresh water applications only. The Fomtec ENVIRO USP 2-3% formulation currently has two listings (EN1568-1-2-3:2008 & ICAO Level B). Table-1 provides some preliminary chemical and physical property test results.

Table-1: Fomtec ENVIRO USP 2-3% Chemical & Physical Properties

Chemical & Physical Properties	Results
Refractive Index	1.3740
Viscosity Concentrate	16,120 cP
Spreading Coefficient*	0

NOTE*: Spreading Coefficient $S_{a/b} = \gamma_b$ (Surface Tension Cyclohexane) - γ_a (Surface Tension Foam Solution) - γ_i (Interfacial Tension between Liquids) [2].

3.0 FIREFIGHTING PERFORMANCE: Tables-2 provides the initial 28ft² fire test results when using the AFFF MILSPEC firefighting nozzle set at 2 GPM (0.071 gpm/ft² application rate) and 3 GPM (0.107 gpm/ft² application rate) flow rates using both ethanol-free gasoline and jet fuel (JP-8).

Table-2: Fomtec ENVIRO USP 3% Initial 28 ft² Fire Test Results

Fire Test	Extinction time (sec)	Expansion Ratio	Drainage Time (min)	Burnback (sec)
28 ft² (Ethanol-Free Gasoline)				
2 GPM full strength	59	8.2	42:54	434
2 GPM ½ strength	61	7.0*	8:10*	427
2 GPM quintuple strength	105	N/A	N/A	945
3 GPM quintuple strength	112	N/A	N/A	840
3 GPM full strength	37	7.57	45:59	678
3 GPM ½ strength	65	6.8*	9:34*	418
28 ft² (Jet Fuel (JP-8))				
2 GPM full strength	24	8.2	42:54	647
3 GPM full strength	15	7.57	45:59	767

NOTE*: The additional expansion & drainage testing for the ½ strength tests were conducted to provide additional insight into the product’s performance when not proportioned at full strength.

4.0 PRELIMINARY PERFORMANCE ANALYSIS:

4.1 Firefighting Performance: The Fomtec ENVIRO USP 3% agent performed well when using jet fuel (JP-8) both at the 2 GPM (0.071 gpm/ft² application rate) and the 3 GPM (0.107 gpm/ft² application rate) flow rates. As was expected, the performance when using ethanol-free gasoline was less effective due to the lower flash point of the fuel. The performance was less effective when compared to the previously tested low viscosity (Newtonian liquid) fluorine free foam AFFF product.

The Fomtec ENVIRO USP 3% agent, as evident in the Table-2 data, did not demonstrate consistent extinguishing times at the full strength, ½ strength, and quintuple strength foam solution applications, which implies that this particular fluorine free foam product may have varying performance when the product is missed proportioned by the foam delivery system. It is also noted that the drainage time is also significantly affected when the product is not proportioned at full strength. The excessive extinguishment times for the ethanol-free gasoline fueled fires noted in Table-2, were attributed to the difficulties with extinguishing the persistent flaming combustion along the perimeter of the fire test pan. Finally, of particular note, the foam solution properties dramatically changed when the concentrate was pre-mixed at the quintuple strength level as noted in Figure-1.



Figure-1: Fomtec ENVIRO USP 3% Quintuple Strength Burnback Test

When conducting the quintuple strength burnback test following fire extinguishment, there was a significant amount of mucus-like liquid draining from both the sides and bottom of the burnback pan when it was pulled from the generated foam blanket. This type of phenomena is not a normal occurrence when conducting burnback testing with either AFFF or fluorine-free AFFF products.

4.2 Burnback Performance: The burnback resistance performance with the Fomtec ENVIRO USP 3% agent was very good with the 28ft² testing both with the non-ethanol gasoline and the jet fuel (JP-8) fueled fires. The burnback resistance performance with the 50ft² fires and the non-MILSPEC reduce aspiration tests did note reduced burnback resistance capability.

4.3 PKP Compatibility: Table-3 provides the results of the Fomtec ENVIRO USP 3% agent PKP compatibility testing. The Fomtec ENVIRO USP 3% agent PKP compatibility testing did note some level of foam degradation due to the introduction of the PKP dry chemical as evident in the lower burnback times noted in Table-3 in comparison to the original (i.e., no PKP introduction) burnback

times noted in Table-2. This observation is most likely due to the degraded foam bubble structure, which enables more fuel vapor transport through foam blanket.

NOTE: For the high viscosity hydrocarbon-based fluorine free foam products, their performance heavily relies on the integrity of the generated foam blanket since they do not have the desired oleophobic nature/property that is inherent with the fluorosurfactants used in AFFF formulations.

Table-3: Fomtec ENVIRO USP 3% PKP Compatibility Test Results

Fire Test	Extinction time (sec)	Expansion Ratio	Drainage Time (min)	Burnback (sec)
28 ft² (Ethanol-Free Gasoline)				
2 GPM Full Strength	51	8.2	42:54	265
28 ft² (Jet Fuel (JP-8))				
2 GPM Full Strength	24	8.2	42:54	386

4.4 50ft² Firefighting Performance: Table-4 provides the 50ft² fire test results using both ethanol-free gasoline and jet fuel (JP-8) fueled fires at 2 GPM (0.071 gpm/ft² application rate) and 3 GPM (0.107 gpm/ft² application rate) flow rates.

Table-4: Fomtec ENVIRO USP 3% 50ft² Fire Test Results

Fire Test	Extinction time (sec)	Expansion Ratio	Drainage Time (min)	40 sec Summation	Burnback (sec)
50 ft² (Ethanol-Free Gasoline)					
2 GPM Full Strength	119	N/A**	N/A**	357	220
3 GPM Full Strength	N/C*	N/A**	N/A**	340	N/C*
50 ft² (Jet Fuel (JP-8))					
2 GPM Full Strength	32	N/A**	N/A**	360	350
3 GPM Full Strength	50	N/A**	N/A**	330	303

NOTE*: Final fire extinguishment was not achieved at the 210 second timeframe.

NOTE**: Expansion & Drainage testing is not required for the 50ft² MILSPEC fire test protocol [2].

As previously noted with the 28ft² fire performance tests, the Fomtec ENVIRO USP 3% agent continued to have difficulties with the ethanol-free gasoline fueled fires due to the persistent flaming combustion along the perimeter of the fire test pan.

4.5 Non-MILSPEC Reduced Aspiration Performance: Table-5 provides the reduced aspiration fire test results for the Fomtec ENVIRO USP 3% agent. The intent of the reduced aspiration performance testing is to evaluate the fluorine free foam products capabilities when using non-aspirating nozzles that are currently being used by various DoD fixed sprinkler systems.

The reduced aspiration testing followed the same test protocol that was used for the previous AVIO^{F3} Green KHC 3% fluorine-free AFFF product testing [3].

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Table-5: Fomtec ENVIRO USP 3% Non-MILSPEC Reduced Aspiration Test Results

Fire Test	Extinction time (sec)	Expansion Ratio	Drainage Time (min)	40 sec Summation	Burnback (sec)
50 ft² Reduced Aspiration					
2 GPM (Ethanol-Free Gasoline)	138	4.95	22:25	290	282
2 GPM (Jet Fuel (JP-8))	58	4.95	22:25	364	383
28 ft² Reduced Aspiration					
2 GPM Full Strength (Ethanol-Free Gasoline)	95	4.95	22:25	N/A	617
2 GPM Half Strength (Ethanol-Free Gasoline)	86	4.6	10:12	N/A	375
2 GPM Full Strength (Jet Fuel (JP-8))	27	4.95	22:25	N/A	820

As noted in Table-5, the Fomtec Enviro USP 3% formulation did not perform as well as the previously evaluated Fluorine-Free AFFF product and for the most part did not have the same thermodynamic cooling effect capability to help mitigate the persistent flaming combustion along the perimeter of the fire test pan with the exception of the 2 GPM full strength 28ft² test fire using jet fuel (JP-8).

5.0 SUMMARY & CONCLUSIONS:

The Fomtec ENVIRO USP 3% fluorine free foam product was selected for more detailed fire test evaluation since it was previously determined by NRL and Jensen Hughes to be one of the two better performing commercially available fluorine free foam products in the 2018/2019 timeframe when using both ethanol-free gasoline and heptane fueled fires at full strength applications [4]. The other commercially available fluorine free foam product was the Solberg RF3 product, which is another high viscosity (non-Newtonian Liquid) formulation that will be evaluated next in the ESTCP WP20-5373 fire test evaluation program. Table-6 provides some preliminary chemical & physical property test results for the Solberg RF3 product, which will be more fully assessed and documented in ESTCP WP20-5373 SITREP #4.

Table-6: Solberg RF3 Chemical & Physical Property Test Results

Chemical & Physical Properties	Results
Refractive Index	1.3880
Viscosity Concentrate	26,320 cP

Overall, the high viscosity fluorine-free firefighting agents will most likely not be a drop-in AFFF replacement and their transition may incur additional costs due to the need to redesign the foam delivery system hardware (both mobile ARFF and fixed shore-based aviation Hangar) applications. From a firefighter's perspective, these types of agents are somewhat reminiscent of the old Protein Foam agents used in the 1940-1970 timeframe (i.e., they have reduced firefighting performance but exceptional burnback resistance capability when properly proportioned). From a technical standpoint, this may not to be a direction that would be the "best valued" option to meet the FY20 NDAA requirement (remember the *USS Forrestal*, see Figure-2).



**Figure-2: USS Forrestal (CV-59) 29 July 1967
(134 Sailors Killed/161 Injured)**

Since we now know that there are at least two low viscosity commercially fluorine-free AFFF products (i.e., National Foam Inc.'s, AVIO^{F3} Green KHC 3% and Angus's JetFoam) that are readily available, these types of product selection may ultimately provide the best overall direction to fulfill the FY20 NDAA requirements.

6.0 REFERENCES:

1. J.P. Farley, "Fluorine-Free Military Specification Development", ESTCP WP20-5373 Statement of Work, March 2020.
2. NAVSEA "Fire Extinguishing Agent, Aqueous Film-Forming Foam (AFFF) Liquid Concentrate, Fresh water and Sea Water", MIL-PRF-24385F(SH), w/Amendment 4, 07 April 2020.
3. Farley, J.P., Karwoski, S., Whitehurst, C.L., "AVIO^{F3} Green KHC 3% Fluorine Free Foam Concentrate "Quick Look" Summary ESTCP WP20-5373 SITREP #2", 29 May 2020.
4. Back, G.G., Farley, J.P., "Evaluation of the Effectiveness of Fluorine Free Firefighting Foams," NFPA Research Foundation, January 2020.

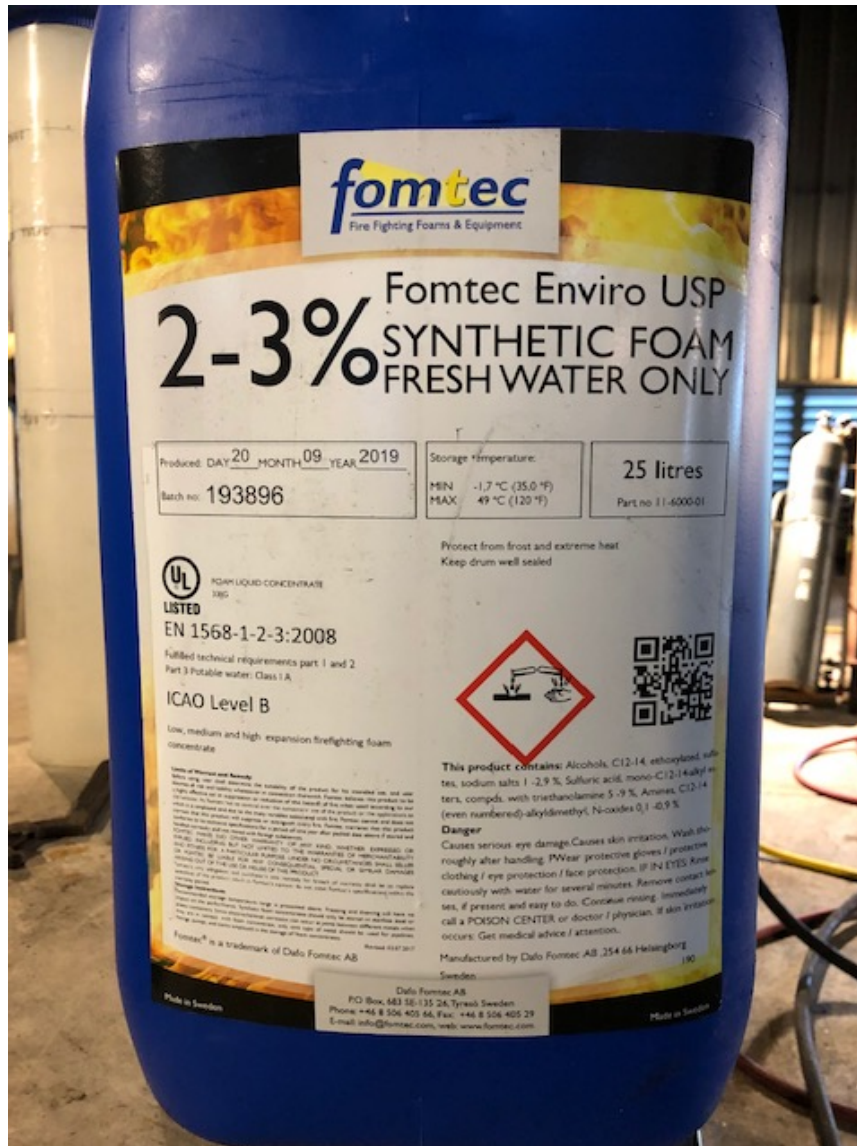


NRL Fire Research Team's Firefighters (John Farley & Stan Karwoski)

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APPENDIX A

Fomtec ENVIRO USP 2-3% Fluorine Free Foam Concentrate Container Photograph



**Fomtec ENVIRO USP 2-3% USP
Fluorine Free Foam Concentrate Container**

28 June 2020

**Solberg Re-Healing RF3 Synthetic Foam
Concentrate “Quick Look” Summary
ESTCP WP20-5373 SITREP #4**

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Solberg Re-Healing RF3 Synthetic Foam Concentrate

“Quick Look” Summary

ESTCP WP20-5373 SITREP #4

1.0 INTRODUCTION: The purpose of the ESTCP WP20-5373 “Quick Look” summary situational reports (SITREP) are to provide periodic updates on the Naval Research Laboratory’s (NRL) progress while conducting the Phase I Firefighting Performance testing that are being executed in accordance with the approved NRL ESTCP WP20-5373 statement of work [1]. This ESTCP WP20-5373 SITREP #4 reviews the Solberg RF3 Synthetic Foam unaged concentrate 28ft² and 50ft² fire test performance results.

2.0 FIREFIGHTING AGENT: The Solberg RF3 Synthetic Foam concentrate agent is fluorine free foam (F3) agent manufactured by Perimeter Solutions LP. The agent is a high viscosity (non-Newtonian liquid) concentrate and has an International Civil Aviation Organization (ICAO) Level C certification [2]. Table-1 provides some preliminary chemical and physical property test results.

Table-1: Solberg RF3 Synthetic Foam Concentrate Chemical & Physical Properties

Chemical & Physical Properties	Results
Refractive Index	1.3880
Viscosity Concentrate	26,320 cP

As noted in Table-1, the Solberg RF3 Synthetic Foam Concentrate is highly viscous and required a two-step process to make the final 3% pre-mixed foam solution used for the fire test evaluations. In step-one, the measured foam concentrate was poured into the foam solution container (see Figure-1).



Figure-1: Step-1; Solberg RF3 Concentrate (Pouring into the Foam Solution Container)

Once the foam concentrate was poured into the pre-mixed foam solution container, an electric powered drill fitted with a double blade paint mixing tool was used to complete the final 3% pre-mixed foam solution (see Figure-2).¹



Figure-2: Step-2; Solberg RF3 Pre-mixed 3% Foam Solution Final Preparation

3.0 FIREFIGHTING PERFORMANCE: Tables-2 provides the initial 28ft² fire test results when using the AFFF MILSPEC firefighting nozzle set at 2 GPM (0.071 gpm/ft² application rate) and at 3 GPM (0.107 gpm/ft² application rate) flow rates using both ethanol-free gasoline and jet fuel (JP-8) fueled fire treats.

Table-2: Solberg RF3 Synthetic Foam Concentrate Initial 28 ft² Fire Test Results

Fire Test	Extinction time (sec)	Expansion Ratio	Drainage Time (min)	Burnback (sec)
28 ft² (Ethanol-Free Gasoline)				
2 GPM full strength	53	8.25	30:31	726
2 GPM ½ strength	49	7.9*	38:56*	510
2 GPM quintuple strength	81	N/A	N/A	1344
3 GPM quintuple strength	50	N/A	N/A	875
3 GPM full strength	45	7.2	36:22	1018
3 GPM ½ strength	57	6.1*	34:55*	691
28 ft² (Jet Fuel (JP-8))				
2 GPM full strength	33	8.25	30:31	690
3 GPM full strength	22	7.2	36:22	1008

NOTE*: The additional expansion & drainage testing for the ½ strength tests were conducted to provide additional insight into the product's performance when not proportioned at full strength.

¹ The same two-step pre-mixed 3% preparation process was used for the Fomtec ENVIRO USP 2-3% Fluorine Free Foam Concentrate fire performance test evaluation [3].

4.0 PRELIMINARY PERFORMANCE ANALYSIS:

4.1 *Firefighting Performance:* The Solberg RF3 Synthetic foam agent performed well when using jet fuel (JP-8) fueled fires at the full strength and ½ strength foam solutions at 2 GPM (0.071 gpm/ft² application rate) and at 3 GPM (0.107 gpm/ft² application rate) flow rates and performed reasonably well when using ethanol-free gasoline fueled fires at full strength and ½ strength foam solutions at 2 GPM (0.071 gpm/ft² application rate) and at 3 GPM (0.107 gpm/ft² application rate) flow rates. The fire extinction performance during the quintuple strength fire test when using ethanol-free gasoline (81 seconds) did note a level of degradation in fire extinguishing performance.

4.2 *Burnback Performance:* The burnback resistance performance with the Solberg RF3 Synthetic foam agent was very good with the 28ft² testing both when using non-ethanol gasoline and jet fuel (JP-8) fueled fires. The burnback resistance performance with the 50ft² fires and the non-MILSPEC reduced aspiration fire tests did note reduced burnback resistance capability by approximately a factor of 2.

4.3 *PKP Compatibility:* Table-3 provides the results of the Solberg RF3 Synthetic foam agent PKP compatibility testing. The Solberg RF3 Synthetic foam agent PKP compatibility testing did note some level of foam degradation due to the introduction of the PKP dry chemical as evident in the lower burnback times noted in Table-3 in comparison to the original (i.e., no PKP introduction) burnback times noted in Table-2. This observation is most likely due to the degraded foam bubble structure, which enables more fuel vapor transport through generated foam blanket (see Figures 3 and 4).

NOTE: For the high viscosity hydrocarbon-based fluorine free foam products, their performance heavily relies on the integrity of the generated foam blanket since they do not have the desired oleophobic nature/property that is inherent with the fluorosurfactants used in AFFF formulations.

Table-3: Solberg RF3 Synthetic Foam Concentrate PKP Compatibility Test Results

Fire Test	Extinction time (sec)	Expansion Ratio	Drainage Time (min)	Burnback (sec)
28 ft² (Ethanol-Free Gasoline)				
2 GPM Full Strength	57	8.25	31:31	412
28 ft² (Jet Fuel (JP-8))				
2 GPM Full Strength	25	8.25	31:31	536



Figure-3: Solberg RF3 Ethanol-Free Gasoline PKP Compatibility Test (Foam Degradation along Fire Test Pan Perimeter)



**Figure-4: Solberg RF3 PKP Jet Fuel (JP-8) Compatibility Test
(Formation of an Unusual Black Substance in the Foam Blanket outside the Burnback Test Pan)**

4.4 50ft² Firefighting Performance: Table-4 provides the 50ft² fire test results using both ethanol-free gasoline and jet fuel (JP-8) fueled fires at 2 GPM (0.071 gpm/ft² application rate) and 3 GPM (0.107 gpm/ft² application rate) flow rates.

Table-4: Solberg RF3 Synthetic Foam Concentrate 50ft² Fire Test Results

Fire Test	Extinction time (sec)	Expansion Ratio	Drainage Time (min)	40 sec Summation	Burnback (sec)
50 ft² (Ethanol-Free Gasoline)					
2 GPM Full Strength	159	N/A*	N/A*	363	320
3 GPM Full Strength	71	N/A*	N/A*	290	319
50 ft² (Jet Fuel (JP-8))					
2 GPM Full Strength	55	N/A*	N/A*	339	376
3 GPM Full Strength	34	N/A*	N/A*	374	671

NOTE*: Expansion & Drainage testing is not required for the 50ft² MILSPEC fire test protocol [4].

The Solberg RF3 Synthetic foam agent did note increased fire extinction times due to the persistent flaming combustion along the perimeter of the fire test pan and also noted reduced scalability performance at the 50ft² fire test level in comparison to the previously tested AVIO^{F3} Green KHC 3% fluorine-free AFFF foam product.

4.5 Non-MILSPEC Reduced Aspiration Performance: Table-5 provides the reduced aspiration fire test results for the Solberg RF3 Synthetic foam agent. The intent of the reduced aspiration performance testing is to evaluate the fluorine free foam products capabilities when using non-aspirating nozzles that are currently being used by various DoD fixed sprinkler systems.

The reduced aspiration testing followed the same test protocol that was used for the previous AVIO^{F3} Green KHC 3% fluorine-free AFFF product testing [5].

**Table-5: Solberg RF3 Synthetic Foam Concentrate Non-MILSPEC
Reduced Aspiration Test Results**

Fire Test	Extinction time (sec)	Expansion Ratio	Drainage Time (min)	40 sec Summation	Burnback (sec)
50 ft² Reduced Aspiration					
2 GPM Full Strength (Ethanol-Free Gasoline)	194	5.4	38:45	280	345
2 GPM Full Strength (Jet Fuel (JP-8))	55	5.4	38:45	333	359
28 ft² Reduced Aspiration					
2 GPM Full Strength (Ethanol-Free Gasoline)	56	5.4	38:45	N/A	858
2 GPM ½ Strength (Ethanol-Free Gasoline)	87	5.4	38:45	N/A	522
2 GPM Full Strength (Jet Fuel (JP-8))	25	5.4	38:45	N/A	841

As noted in Table-5, the Solberg RF3 Synthetic Foam formulation did note increased fire extinction times at the reduced aspiration (i.e., lower expansion ratio) application. For the most part, the Solberg RF3 Synthetic foam agent did not seem to exhibit any thermodynamic cooling effect to the sides of the fire test pan, which would help to mitigate the persistent flaming combustion along the perimeter of the fire test pan with the exception of the full strength 2 GPM (0.071 gpm/ft² application rate) test using the jet fuel (JP-8) fueled fire.

5.0 SUMMARY & CONCLUSIONS:

The Solberg RF3 Synthetic fluorine free foam product was selected for more detailed fire test evaluation since it was previously determined by NRL and Jensen Hughes to be one of the best performing commercially available fluorine free foam products in the 2018/2019 timeframe when using both ethanol-free gasoline and heptane fueled fires at full strength applications [6].

Overall, the high viscosity fluorine-free firefighting agents will most likely not be a drop-in AFFF replacement and their transition will incur additional costs due to the need to redesign the foam delivery system hardware (both mobile ARFF and fixed shore-based Aviation Hangar) applications. The Solberg RF3 Synthetic foam agent has also exhibited stratification issues under the MIL-PRF-24385F aged concentrate test protocol (see Figure-5).



**Figure-5: Solberg RF3 Aged Concentrate
(NRL-CBD Testing, December 2019)**

It is theorized that the aging process for the Solberg RF3 Synthetic foam concentrate resulted in solvation of the constituents of the concentrate (i.e., the hydrocarbon surfactants & thickening agents) and the physical characteristics noted in Figure-5, demonstrates notable striations within the aged concentrate mixture.

NOTE: The noted stratification within the aged concentrate mixture would not meet the current MIL-PRF-24385F standard for aged concentrate stratification testing [4].

Since we now know that the high viscosity commercially available fluorine free foam (F3) products do not offer enhanced fire extinguishing capabilities, the NRL ESTCP WP20-5373 effort will again refocus on evaluating low viscosity (Newtonian liquid) F3 foam products since it is believed that they represent the “Best Valued” option to fulfill the FY20 NDAA requirements. It is anticipated that the next round of unaged F3 concentrate ESTCP WP20-5373 testing will utilize the commercially available BioEx ECOPOL (A&N) F3 formulations.

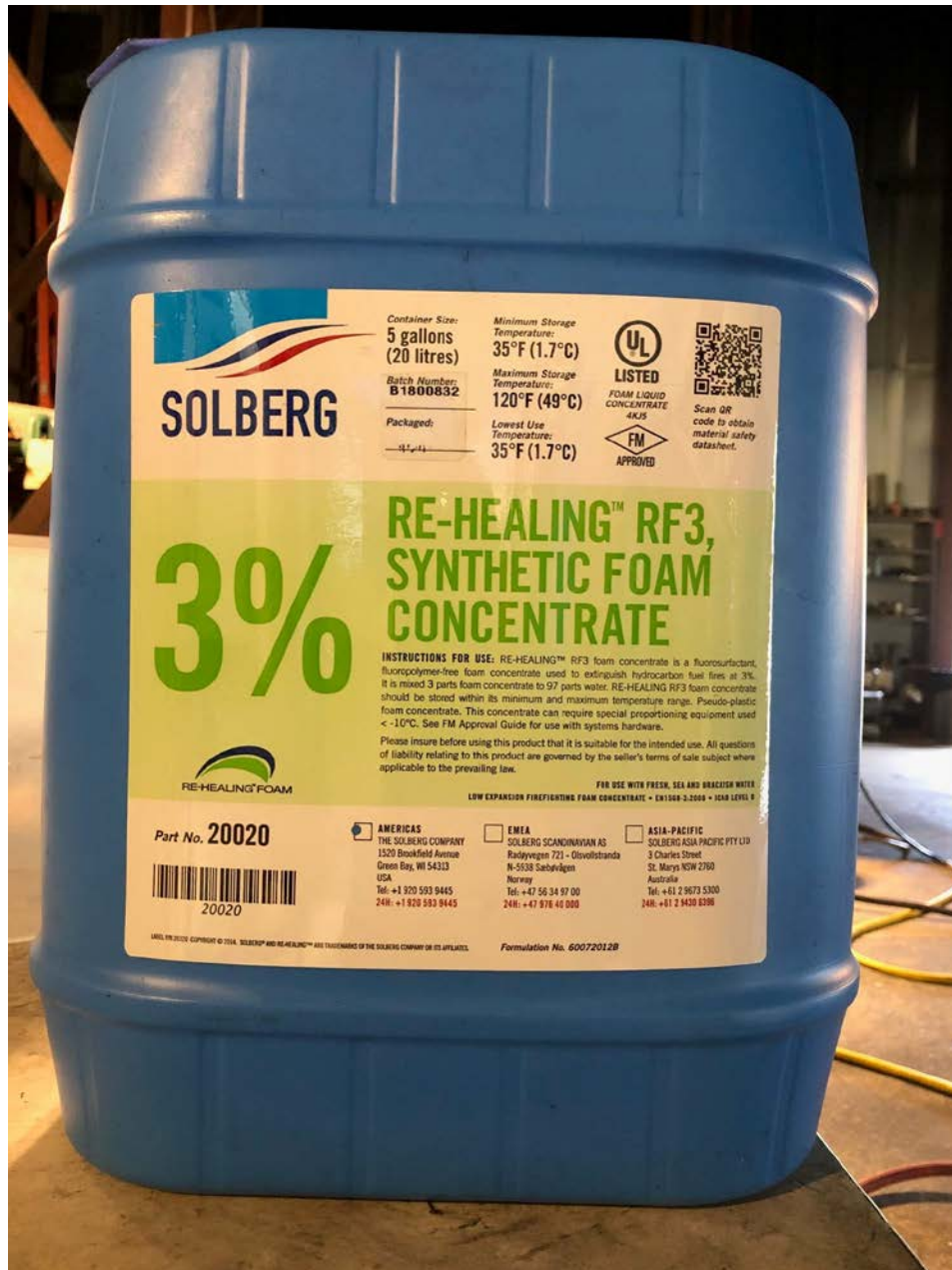
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1. J.P. Farley, “Fluorine-Free Military Specification Development”, ESTCP WP20-5373 Statement of Work, March 2020.
2. Blais, M.S., Huczek, J.P., “Fire Testing of RF3 Synthetic Foam Concentrate, Per International Civil Aviation Organization (ICAO) Fire Test Standard, Airport Services Manual (DOC 9137-AN/898) Part 1 – Rescue and Firefighting (Fourth Edition-2014), Southwest Research Institute, 01 February 2017.
3. Farley, J.P., Karwoski, S., Whitehurst, C.L., “Fomtec EVIRO USP 2-3% Fluorine Free Foam Concentrate “Quick Look” Summary ESTCP WP20-5373 SITREP #3”, 12 June 2020.
4. NAVSEA “Fire Extinguishing Agent, Aqueous Film-Forming Foam (AFFF) Liquid Concentrate, Fresh water and Sea Water”, MIL-PRF-24385F(SH), w/Amendment 4, 07 April 2020.
5. Farley, J.P., Karwoski, S., Whitehurst, C.L., “AVIO^{F3} Green KHC 3% Fluorine Free Foam Concentrate “Quick Look” Summary ESTCP WP20-5373 SITREP #2”, 29 May 2020.
6. Back, G.G., Farley, J.P., “Evaluation of the Effectiveness of Fluorine Free Firefighting Foams,” NFPA Research Foundation, January 2020.

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APPENDIX A

Solberg RF3 Synthetic Foam Concentrate Container Photograph



Solberg RF3 Synthetic Foam Concentrate Container

21 August 2020

BioEx ECOPOL A 3% Concentrate “Quick Look” Summary: ESTCP WP20-5373 SITREP #5

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BioEx ECOPOL A 3% Concentrate “Quick Look” Summary: ESTCP WP20-5373 SITREP #5

1.0 INTRODUCTION: The purpose of the ESTCP WP20-5373 “Quick Look” summary situational reports (SITREP) are to provide periodic updates on the Naval Research Laboratory’s (NRL) progress while conducting the Phase I Firefighting Performance testing that are being executed in accordance with the approved NRL ESTCP WP20-5373 statement of work [1]. This ESTCP WP20-5373 SITREP #5 reviews the BioEx ECOPOL A 3% unaged concentrate 28ft² and 50ft² fire test performance results.

2.0 FIREFIGHTING AGENT: The BioEx ECOPOL A 3% concentrate is a low viscosity (Newtonian Liquid) fluorine free foam (F3) agent that has an International Civil Aviation Organization (ICAO) Level B certification.¹

3.0 FIREFIGHTING PERFORMANCE: Tables-1 provides the initial 28ft² fire test results when using the AFFF MILSPEC firefighting nozzle set at 2 GPM (0.071 gpm/ft² application rate) and at 3 GPM (0.107 gpm/ft² application rate) foam flow rates using both ethanol-free gasoline and jet fuel (JP-8) fueled fire treats.

Table-1: BioEx ECOPOL A 3% Concentrate Initial 28 ft² Fire Test Results

Fire Test	Extinction time (sec)	Expansion Ratio	Drainage Time (min)	Burnback (sec)
28 ft² (Ethanol-Free Gasoline)				
2 GPM full strength	57	7.1	3:12	287
2 GPM ½ strength	106	N/A*	N/A*	124
2 GPM quintuple strength	58	N/A*	N/A*	147
3 GPM quintuple strength	102	N/A*	N/A*	271
3 GPM full strength	52	7.0	3:07	372
3 GPM ½ strength	87	N/A*	N/A*	173
28 ft² (Jet Fuel (JP-8))				
2 GPM full strength	26	7.1	3:12	350
3 GPM full strength	18	7.0	3:07	407

NOTE*: Current MILSPEC expansion & drainage testing requirements only applies to full strength agent testing [2].

4.0 PRELIMINARY PERFORMANCE ANALYSIS:

4.1 Firefighting Performance: The BioEx ECOPOL A 3% agent had marginal performance in comparison to the other top performing fluorine free foam (i.e., National AVIO^{F3} Green KHC 3%, Angus Fire Jetfoam 3% FF, Solberg RF3, and Fomtec ENVIRO USP 3%) agents and the extinction performance was notably degraded when the agent was proportioned at half and quintuple strength foam solutions when combating the gasoline fueled fires. As expected, the firefighting performance did improve when combating the Jet Fuel (JP-8) fueled fires.

¹ ICAO Level B certification includes a single 50ft² heptane fueled fire test using an application rate of 0.06 GPM/ft² and requires total extinguishment within 60 seconds.

4.2 *Burnback Performance:* The burnback resistance performance with the BioEx ECOPOL A 3% foam agent was also considered marginal with the 28ft² and 50ft² testing when using either ethanol-free gasoline or jet fuel (JP-8) fueled fires.

4.3 *PKP Compatibility:* Table-2 provides the results of the BioEx ECOPOL A 3% agent PKP compatibility testing. The BioEx ECOPOL A 3% agent PKP compatibility testing did note foam degradation due to the introduction of the PKP dry chemical as evident in the lower burnback times noted in Table-2 in comparison to the original (i.e., no PKP introduction) burnback times noted in Table-1. This observation is most likely due to the degraded foam bubble structure, which enables more fuel vapor transport through the generated foam blanket (see Figures 1).

Table-2: Concentrate PKP Compatibility Test Results

Fire Test	Extinction time (sec)	Expansion Ratio	Drainage Time (min)	Burnback (sec)
28 ft² (Ethanol-Free Gasoline)				
2 GPM Full Strength	52	7.1	3:12	70
28 ft² (Jet Fuel (JP-8))				
2 GPM Full Strength	22	7.1	3:12	154



**Figure-1: BioEx ECOPOL A 3% PKP Compatibility Test
(Foam Degradation along Fire Test Pan Perimeter)**

4.4 50ft² Firefighting Performance: Table-3 provides the 50ft² fire test results using both ethanol-free gasoline and jet fuel (JP-8) fueled fires at 2 GPM (0.071 gpm/ft² application rate) and 3 GPM (0.107 gpm/ft² application rate) foam flow rates.

Table-3: BioEx ECOPOL A 3% Concentrate 50ft² Fire Test Results

Fire Test	Extinction time (sec)	Expansion Ratio	Drainage Time (min)	40 sec Summation	Burnback (sec)
50 ft² (Ethanol-Free Gasoline)					
2 GPM Full Strength	NE ¹	N/A ²	N/A ²	339	NC ³
3 GPM Full Strength	71	N/A ²	N/A ²	290	319
50 ft² (Jet Fuel (JP-8))					
2 GPM Full Strength	137	N/A ²	N/A ²	333	140
3 GPM Full Strength	57	N/A ²	N/A ²	310	272

NOTE: (1) Not Extinguished (NE), firefighting action stopped at 126 seconds to prevent further burn injury to the firefighter.

(2) Expansion & Drainage testing is not required for the 50ft² MILSPEC fire test protocol [2].

(3) Burnback test not conducted (NC) due to the fire not extinguished with the MILSPEC firefighting nozzle.

The BioEx ECOPOL A 3% agent's reduced firefighting performance is evident by the higher fire extinction times that were principally due to the persistent flaming combustion along the perimeter of the fire test pan and these test findings demonstrated inadequate scalability performance capability to the 50ft² fire test level.

4.5 Non-MILSPEC Reduced Aspiration Performance: Table-4 provides the reduced aspiration fire test results for the BioEx ECOPOL A 3% agent. The intent of the reduced aspiration performance testing is to evaluate the fluorine free foam products capabilities when using reduced aspirating nozzles that are currently being used by various DoD fixed sprinkler systems.

Table-4: BioEx ECOPOL A 3% Concentrate Non-MILSPEC Reduced Aspiration Test Results

Fire Test	Extinction time (sec)	Expansion Ratio	Drainage Time (min)	40 sec Summation	Burnback (sec)
50 ft² Reduced Aspiration					
2 GPM Full Strength (Ethanol-Free Gasoline)	NC ¹	NC ¹	NC ¹	NC ¹	NC ¹
2 GPM Full Strength (Jet Fuel (JP-8))	NC ¹	NC ¹	NC ¹	NC ¹	NC ¹
28 ft² Reduced Aspiration					
2 GPM Full Strength (Ethanol-Free Gasoline)	103	4.7	3:38	N/A	202
2 GPM ½ Strength (Ethanol-Free Gasoline)	NE ²	4.7	3:38	N/A	NC ³
2 GPM Full Strength (Jet Fuel (JP-8))	30	4.7	3:38	N/A	354

NOTE: (1) Due to marginal performance at the 50ft² full aspirated test conditions and the experiences gained with the 28ft² testing, the reduced application testing at the 50ft² test level was not conducted to limit burn injury.

(2) Not extinguished at 137 seconds with the MILSPEC firefighting nozzle and test was terminated.

(3) Burnback testing not conducted due to no extinguishment with the MILSPEC firefighting nozzle.

As noted in Table-4, the BioEx ECOPOL A 3% concentrate formulation noted poor performance with the gasoline fueled fires and marginal performance with the Jet Fuel (JP-8) fueled fires at the reduced aspiration (i.e., lower expansion ratio) application. For the most part, the BioEx ECOPOL A 3% agent did not seem to exhibit any thermodynamic cooling effect to the sides of the fire test pan, which would have helped to mitigate the persistent flaming combustion along the perimeter of the fire test pan.

5.0 SUMMARY & CONCLUSIONS:

The BioEx ECOPOL A 3% fluorine free foam product was selected for more detailed fire test evaluation since it was previously determined by NRL to meet the pre-screening requirement to extinguish a gasoline fueled fire in less than 60 seconds and a Jet Fuel (JP-8) fueled fire in less than 30 seconds when the foam was applied at the 2GPM (0.071 gpm/ft² application rate) foam flow rate. The agent was also certified to be an ICAO Level B agent.

Overall, the BioEx ECOPOL A 3% low viscosity (Newtonian Liquid) agent had relatively poor performance in comparison to the other top performing (National AVIOF3 Green KHC 3%, Angus Fire Jetfoam 3% FF, Solberg RF3, and the Fomtec ENVIRO USP 3%) fluorine free foam agents and is considered not worthy for follow-on evaluation.

NOTE: Time permitting, follow-on aged concentrate (50/50 mixture) compatibility testing may be considered to further investigate the firefighting performance when a relatively poor performing agent is mixed with a good performing agent.

The final WP20-5373 unaged firefighting performance testing will be completed with the Angus Fire Jetfoam 3% FF product. The Angus Fire Jetfoam 3% FF concentrate is a low viscosity (Newtonian Liquid) fluorine free foam product that has an ICAO Level C certification and as noted in Table-5, demonstrated good pre-screening firefighting performance test results.

Table-5: Angus Fire Jetfoam 3% FF Pre-Screening Firefighting Test Results

Fire Test	Extinction time (sec)	Expansion Ratio	Drainage Time (min)	Burnback (sec)
28 ft² (Ethanol-Free Gasoline)				
2 GPM Full Strength	49	8.5	4:13	244
3 GPM Full Strength	42	8.0	4:58	285
28 ft² (Jet Fuel (JP-8))				
2 GPM Full Strength	19	8.5	4:13	357
3 GPM Full Strength	15	8.0	4:58	537



Angus Fire Jetfoam 3% FF Container

6.0 REFERENCES:

1. J.P. Farley, "Fluorine-Free Military Specification Development", ESTCP WP20-5373 Statement of Work, March 2020.
2. NAVSEA "Fire Extinguishing Agent, Aqueous Film-Forming Foam (AFFF) Liquid Concentrate, Fresh water and Sea Water", MIL-PRF-24385F(SH), w/Amendment 4, 07 April 2020.

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APPENDIX A

BioEx ECOPOL A 3% Concentrate Container Photograph



(Manufacturing Date 05/2020/Batch # 20C02EO)

27 October 2020

**Angus Fire Jetfoam 3% Fluorine-Free Concentrate
“Quick Look” Summary: ESTCP WP20-5373
SITREP #6**

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Angus Fire Jetfoam 3% Fluorine-Free Concentrate

“Quick Look” Summary:

ESTCP WP20-5373 SITREP #6

1.0 INTRODUCTION: The purpose of the ESTCP WP20-5373 “Quick Look” summary situational reports (SITREP) are to provide periodic updates on the Naval Research Laboratory’s (NRL) progress while conducting the Phase I Firefighting Performance baseline testing that are being executed in accordance with the approved NRL ESTCP WP20-5373 statement of work [1]. This ESTCP WP20-5373 SITREP #6 reviews the Angus Fire Jetfoam 3% Fluorine-Free unaged concentrate 28ft² and 50ft² fire test performance results.

2.0 FIREFIGHTING AGENT: The Angus Fire Jetfoam 3% Fluorine-Free concentrate is a low viscosity (Newtonian Liquid) fluorine free foam (F3) agent that has an International Civil Aviation Organization (ICAO) Level C certification.¹

3.0 FIREFIGHTING PERFORMANCE: Table-1 provides the initial 28ft² fire test results when using the AFFF MILSPEC firefighting nozzle set at 2 GPM (0.071 gpm/ft² application rate) and at 3 GPM (0.107 gpm/ft² application rate) foam flow rates using both ethanol-free gasoline and Jet A fueled fires.

Table-1: Angus Fire Jetfoam 3% Fluorine-Free Concentrate 28 ft² Initial Fire Test Results

Fire Test	Extinction time (sec)	Expansion Ratio	Drainage Time (min)	Burnback (sec)
28 ft² (Ethanol-Free Gasoline)				
2 GPM full strength	49	8.51	4:08	244
2 GPM ½ strength	57	N/A*	N/A*	305
2 GPM quintuple strength	63	N/A*	N/A*	174
3 GPM quintuple strength	62	N/A*	N/A*	193
3 GPM full strength	42	8.06	4:35	285
3 GPM ½ strength	53	N/A*	N/A*	206
28 ft² (Jet A Fuel)				
2 GPM full strength	19	8.51	4:08	357
3 GPM full strength	15	8.51	4:08	537

NOTE*: Current MILSPEC expansion & drainage testing requirements only applies to full strength agent testing [2].

4.0 PRELIMINARY PERFORMANCE ANALYSIS:

4.1 Firefighting Performance: The Angus Fire Jetfoam 3% Fluorine-Free agent had good performance in comparison to the other top performing Fluorine Free Foam products (National AVIO^{F3} Green KHC 3%, Solberg RF3, and Fomtec ENVIRO USP 3%) and the extinction performance with the Jet A fueled fires is considered comparable to AFFF fire extinction performance.

¹ ICAO Level C certification includes a single 78.8ft² Jet A fueled fire test using an application rate of 0.038 GPM/ft² and requires total extinguishment within 60 seconds. The ICAO Level C test protocol uses a UNI 86 firefighting nozzle fixed at 3.3ft above the pan with the stream directed at the center of the pan and the nozzle is not moved during the fire test.

4.2 *Burnback Performance:* The burnback resistance performance with the Angus Fire Jetfoam 3% Fluorine-Free product when using gasoline was degraded in comparison to its performance with Jet A. fuel. This finding is most likely due to the dramatic difference in the fuel flash points (i.e., Gasoline flash point; -45°F and Jet A flash point; 100°F). Since the primary fire threat for shore-based applications are two-dimensional Jet A pool fires, the demonstrated burnback resistance is considered adequate for mobile ARFF vehicle and fixed Aviation Hangar applications.

4.3 *PKP Compatibility:* Table-2 provides the results of the Angus Fire Jetfoam 3% Fluorine-Free agent PKP compatibility testing. The Angus Fire Jetfoam 3% Fluorine-Free agent PKP compatibility testing did note some foam degradation due to the introduction of the PKP dry chemical as evident in the lower burnback times noted in Table-2 in comparison to the original (i.e., no PKP introduction) burnback times noted in Table-1. This observation is most likely due to the noted degradation of the foam bubble structure along the perimeter of the fire test pan, which enabled more fuel vapor transport through the generated foam blanket.

Table-2: Angus Fire Jetfoam 3% Fluorine-Free Concentrate PKP Compatibility Test Results

Fire Test	Extinction time (sec)	Expansion Ratio	Drainage Time (min)	Burnback (sec)
28 ft² (Ethanol-Free Gasoline)				
2 GPM Full Strength	43	7.3	5:12	110
28 ft² (Jet A Fuel)				
2 GPM Full Strength	30	7.3	5:12	245

4.4 *50ft² Firefighting Performance:* Table-3 provides the 50ft² fire test results using both ethanol-free gasoline and Jet A fueled fires at 2 GPM (0.071 gpm/ft² application rate) and 3 GPM (0.107 gpm/ft² application rate) foam flow rates.

Table-3: Angus Fire Jetfoam 3% Fluorine-Free Concentrate 50ft² Fire Test Results

Fire Test	Extinction time (sec)	Expansion Ratio	Drainage Time (min)	40 sec Summation	Burnback (sec)
50 ft² (Ethanol-Free Gasoline)					
2 GPM Full Strength	150	N/A ¹	N/A ¹	320	124
3 GPM Full Strength	113	N/A ¹	N/A	348	138
50 ft² (Jet A fuel)					
2 GPM Full Strength	63	N/A ¹	N/A ¹	334	201
3 GPM Full Strength	32	N/A ¹	N/A ¹	369	294

NOTE: (1) Expansion & Drainage testing is not required for the 50ft² MILSPEC fire test protocol [2].

The Angus Fire Jetfoam 3% Fluorine-Free agent's fire knock capability was considered adequate as evident by the 40-second summation findings but the fire extinction times were higher in comparison to AFFF due to the persistent flaming combustion along the perimeter of the fire test pan. The fire extinction times may have also been affected by the plunging effect of the foam application using the MILSPEC firefighting nozzle, which may have contributed to increased fuel pickup into the generated foam blanket.

NOTE: The current MIL-PRF-24385 50ft² fire test 40-second summation requirement is 320 [2].

It is also noted that the current AFFF MIL-PRF-24385 qualification test protocol for the 50ft² fire test requires the use of saltwater AFFF solutions [2]. Table-4 provides the 50ft² fire test results when using a qualified MILSPEC AFFF QPL product using fresh water solutions applied at the 2 GPM (0.071 gpm/ft² application rate) foam flow rate on both ethanol-free gasoline and Jet A fueled fires.

Table-4: 50ft² Fire Test Using AFFF Fresh Water Solutions Test Results

Fire Test	Extinction time (sec)	40-Second Summation	Burnback (sec)
50 ft² (Ethanol-Free Gasoline)			
2 GPM Full Strength	62	343	290
50 ft² (Jet A Fuel)			
2 GPM Full Strength	32	379	446

NOTE: The current AFFF MIL-PRF-24385 qualification standard for the 50ft² fire test using a saltwater solution at a 2 GPM (0.071 gpm/ft² application rate) foam flow rate against a gasoline fueled fire includes:

- Fire Extinguishment – 50 seconds
- Burnback – 360 seconds

4.5 *Non-MILSPEC Reduced Aspiration Performance:* Table-4 provides the reduced aspiration fire test results for the Angus Fire Jetfoam 3% Fluorine-Free agent. The intent of the reduced aspiration performance testing is to evaluate the fluorine free foam product capabilities when using reduced aspirating nozzles that are currently being used by various DoD fixed sprinkler systems.

Table-5: Angus Fire Jetfoam 3% Fluorine-Free Concentrate Non-MILSPEC Reduced Aspiration Test Results

Fire Test	Extinction time (sec)	Expansion Ratio	Drainage Time (min)	40 sec Summation	Burnback (sec)
50 ft² Reduced Aspiration					
2 GPM Full Strength (Ethanol-Free Gasoline)	196	5.2	5:10	320	96
2 GPM Full Strength (Jet A Fuel)	81	5.2	5:10	340	180
28 ft² Reduced Aspiration					
2 GPM Full Strength (Ethanol-Free Gasoline)	54	5.2	5:10	N/A	273
2 GPM ½ Strength (Ethanol-Free Gasoline)	67	5.2	5:10	N/A	282
2 GPM Full Strength (Jet A Fuel)	30	5.2	5:10	N/A	341

As noted in Table-5, the Angus Fire Jetfoam 3% Fluorine-Free concentrate formulation firefighting performance was comparable to the 28ft² fully aspirated fire test results but there was reduced performance at the 50ft² level. The reduced performance at the 50ft² level can be directly attributed to the limited foam flow reach provided by the generated MILSPEC firefighting foam nozzle stream.

5.0 SUMMARY & CONCLUSIONS:

The Angus Fire Jetfoam 3% Fluorine-Free foam product was selected for more detailed fire test evaluations since it was previously determined by NRL to meet the pre-screening requirement to extinguish a gasoline fueled fire in less than 60 seconds and a Jet A fueled fire in less than 30 seconds when the foam was applied at the 2GPM (0.071 gpm/ft² application rate) foam flow rate. The agent was also certified to be an ICAO Level C agent.

Overall, the Angus Fire Jetfoam 3% Fluorine-Free low viscosity (Newtonian Liquid) agent had good performance in comparison to the other top performing Fluorine Free Foam products (National AVIO^{F3} Green KHC 3%, Solberg RF3, and Fomtec ENVIRO USP 3%) and the extinction performance with the Jet A fueled fires is considered comparable to AFFF fire extinction performance.

On 15 October 2020 the NRL Fire Research Team conducted a fire test demonstration for the Honorable Jordan Gillis Assistant Secretary of Defense. The VIP delegation included: Hon. Jordan Gillis ASD (Sustainment), Hon. Charles Williams (ASN EIE), Mr. Paul Cramer (Principle Deputy Assistant Secretary), Mr. Bryan Maxwell (Senior Defense Policy Advisor, Senator Shaheen (D-NH)), Ms. Ariel Marshall (Legislative Director, Senator Shaheen (D-NH)), Col Lisa Rennard (Senior Military Assistant (OSD)), Dr. Herb Nelson (Director, SERDP/ESTCP (OSD)), and CAPT Ricardo Vigil (Commanding Officer, U.S. Naval Research Laboratory).



John P. Farley (NRL Director, Fire Test Operations) providing an ESTCP WP20-5373 overview to the Assembled Guests including Hon. Jordan Gillis, Hon. Charles Williams and CAPT Ricardo Vigil

During this ESTCP WP20-5373 program review, two 28ft² demonstration fire tests were conducted using both a MILSPEC QPL AFFF and the Angus Fire Jetfoam 3% Fluorine-Free product. Both of the demonstration fire tests used the MILSPEC firefighting nozzle set at 2 GPM (0.071 gpm/ft² application rate) foam flow rate with a Jet A fueled fire. The extinguishment time for the MILSPEC

AFFF QPL product was 20 seconds and the extinguishment time for the Angus Fire Jetfoam 3% Fluorine-Free product was 27 seconds.

The ESTCP WP20-5373 Phase I unaged baseline testing is now complete and the NRL Fire Research Team will now be shifting to the aged concentrate/aged pre-mixed solution and the agent compatibility ESTCP WP20-5373 portion of the Phase I baseline testing. The results of the Phase I unaged and aged concentrate baseline test results will then be used in the ESTCP WP20-5373 Phase II effort to help develop the new Fluorine Free Foam military specification requirements for all shore-based military installation (both mobile ARFF vehicle and fixed Aviation Hangar) applications .

6.0 REFERENCES:

1. J.P. Farley, “Fluorine-Free Military Specification Development”, ESTCP WP20-5373 Statement of Work, March 2020.
2. NAVSEA “Fire Extinguishing Agent, Aqueous Film-Forming Foam (AFFF) Liquid Concentrate, Fresh water and Sea Water”, MIL-PRF-24385F(SH), w/Amendment 4, 07 April 2020.

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APPENDIX A

Angus Fire Jetfoam 3% Fluorine-Free Concentrate Container Photograph

20 November 2020

**National AVIO^{F3} Green KHC 3% and Angus Fire
Jetfoam 3% Fluorine-Free Concentrate “Quick
Look” Summary: ESTCP WP20-5373 SITREP #7**

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National AVIO^{F3} Green KHC 3% and Angus Fire Jetfoam 3% Fluorine-Free Concentrate “Quick Look” Summary: ESTCP WP20-5373 SITREP #7

1.0 INTRODUCTION: The purpose of the ESTCP WP20-5373 “Quick Look” summary situational reports (SITREP) are to provide periodic updates on the Naval Research Laboratory’s (NRL) progress while conducting the Phase I Firefighting Performance baseline testing that are being executed in accordance with the approved NRL ESTCP WP20-5373 statement of work [1]. This ESTCP WP20-5373 SITREP #7 reviews the National AVIO^{F3} Green KHC 3% and the Angus Fire Jetfoam 3% Fluorine-Free aged concentrate, aged pre-mixed solutions and the National AVIO^{F3} Green KHC 3% & Angus Fire Jetfoam 3% agent compatibility fire test performance results.

2.0 FIREFIGHTING AGENTS: The National AVIO^{F3} Green KHC 3% and the Angus Fire Jetfoam 3% Fluorine-Free concentrates are a low viscosity (Newtonian Liquid) fluorine free foam (F3) agents that have an International Civil Aviation Organization (ICAO) Level C certification.¹

3.0 AGED CONCENTRATE FIREFIGHTING PERFORMANCE: Tables 1 and 2 provides the aged concentrate fire test results when using the AFFF MILSPEC firefighting nozzle set at 2 GPM (0.071 gpm/ft² application rate) and at 3 GPM (0.107 gpm/ft² application rate) foam flow rates using both ethanol-free gasoline and aviation Jet A fueled fires.

Table-1: National AVIO^{F3} Green KHC 3% Aged Concentrate Fire Test Results

Fire Test	Extinction time (sec)	Expansion Ratio	Drainage Time (min)	Burnback (sec)
28 ft² (Ethanol-Free Gasoline)				
2 GPM full strength Fresh Water	49	7.6	4:57	294
2 GPM ½ strength Fresh Water	57	N/A*	N/A*	325
3 GPM full strength Fresh Water	44	7.8	4:55	295
3 GPM ½ strength Fresh Water	40	N/A*	N/A*	337
28 ft² (Jet A Fuel)				
2 GPM full strength Fresh Water	28	7.6	4:57	307
2 GPM ½ strength Fresh Water	36	N/A*	N/A*	290

NOTE*: Current MILSPEC expansion & drainage testing requirements only applies to full strength agent testing [2].

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¹ ICAO Level C certification includes a single 78.8ft² Jet A fueled fire test using an application rate of 0.038 GPM/ft² and requires total extinguishment within 60 seconds. The ICAO Level C test protocol uses a UNI 86 firefighting nozzle fixed at 3.3ft above the pan with the stream directed at the center of the pan and the nozzle is not moved during the fire test.

Table-2: Angus Fire Jetfoam 3% Aged Concentrate Fire Test Results

Fire Test	Extinction time (sec)	Expansion Ratio	Drainage Time (min)	Burnback (sec)
28 ft² (Ethanol-Free Gasoline)				
2 GPM full strength Fresh Water	53	7.6	4:47	289
2 GPM ½ strength Fresh Water	61	N/A*	N/A*	355
3 GPM full strength Fresh Water	35	7.4	4:32	290
3 GPM ½ strength Fresh Water	42	N/A*	N/A*	387
28 ft² (Jet A Fuel)				
2 GPM full strength Fresh Water	27	7.6	4:47	347
2 GPM ½ strength Fresh Water	24	N/A*	N/A*	331

NOTE*: Current MILSPEC expansion & drainage testing requirements only applies to full strength agent testing [2].

4.0 PRELIMINARY AGED CONCENTRATE PERFORMANCE ANALYSIS:

4.1 General Observations for Aged Concentrate Samples: The current MIL-PRF-24385 performance standard stipulates that the samples of agent concentrate shall be prepared in sufficient quantity to perform the required tests. The samples shall be placed in glass containers and be stored in an oven at 65°C ± 2.0°C for a period of ten days [2]. Figures 1 and 2 note photographs of the National AVIO^{F3} Green KHC 3% and the Angus Fire Jetfoam 3% aged concentrate samples once the aging process was complete.

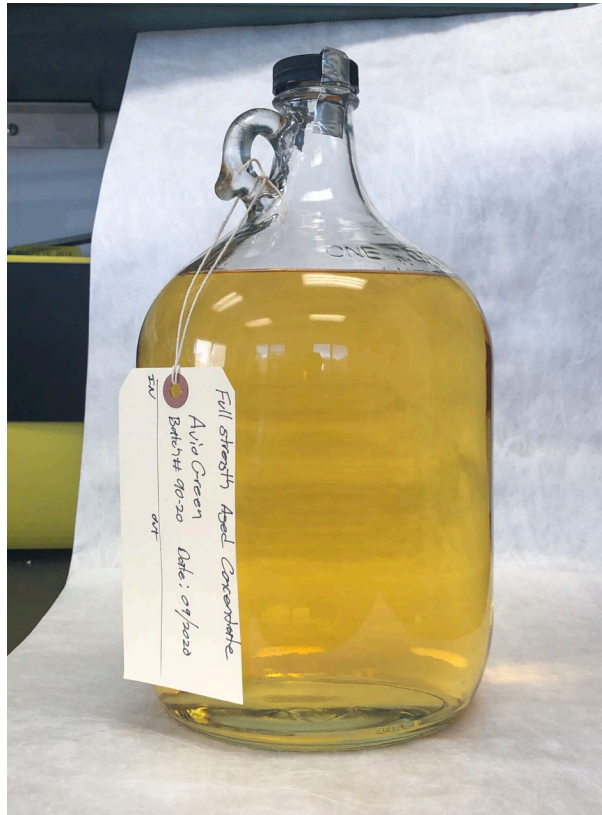


Figure-1: National AVIO^{F3} Green KHC Aged Concentrate Sample



Figure-2: Angus Fire Jetfoam 3% Aged Concentrate Sample

As can be seen in Figures 1 and 2, there was no visible agent stratification or precipitation noted in either of the samples.²

4.2 *Firefighting Performance:* The National AVIO^{F3} Green KHC 3% and the Angus Fire Jetfoam 3% Fluorine-Free aged concentrate test results had similar firefighting performance in comparison to their previous unaged full and half strength fire test results and in many cases the aged concentrate results for both firefighting and burnback resistance capabilities actually noted improved performance [3-5].

5.0 AGED PRE-MIXED SOLUTIONS FIREFIGHTING PERFORMANCE: Tables 3 and 4 provides the aged pre-mixed solutions fire test results when using the AFFF MILSPEC firefighting nozzle set a 2 GPM (0.071 gpm/ft² application rate) and at 3GPM (0.107 gpm/ft² application rate) foam flow rates using both ethanol-free gasoline and aviation Jet A fueled fires.

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² Further Precipitation evaluations using the ASTM D1796 test standard will be performed by NRL-DC when all of the requisite Chemical & Physical property testing is complete.

Table-3: National AVIO^{F3} Green KHC 3% Aged Pre-Mixed Solution Fire Test Results

Fire Test	Extinction time (sec)	Expansion Ratio	Drainage Time (min)	Burnback (sec)
28 ft² (Ethanol-Free Gasoline)				
2 GPM full strength Fresh Water	48	8.3	4:47	312
2 GPM ½ strength Fresh Water	49	N/A*	N/A*	336
3 GPM full strength Fresh Water	37	8.2	5:08	346
3 GPM ½ strength Fresh Water	40	N/A*	N/A*	337
28 ft² (Jet A Fuel)				
2 GPM full strength Fresh Water	24	8.3	4:47	390
2 GPM ½ strength Fresh Water	26	N/A*	N/A*	316

NOTE*: Current MILSPEC expansion & drainage testing requirements only applies to full strength agent testing [2].

Table-4: Angus Fire Jetfoam 3% Aged Pre-Mixed Solution Fire Test Results

Fire Test	Extinction time (sec)	Expansion Ratio	Drainage Time (min)	Burnback (sec)
28 ft² (Ethanol-Free Gasoline)				
2 GPM full strength Fresh Water	42	7.6	6:20	310
2 GPM ½ strength Fresh Water	46	N/A*	N/A*	345
3 GPM full strength Fresh Water	34	8.3	7:30	315
3 GPM ½ strength Fresh Water	42	N/A*	N/A*	343
28 ft² (Jet A Fuel)				
2 GPM full strength Fresh Water	25	7.6	6:20	374
2 GPM ½ strength Fresh Water	26	N/A*	N/A*	300

NOTE*: Current MILSPEC expansion & drainage testing requirements only applies to full strength agent testing [2].

6.0 PRELIMINARY AGED PRE-MIXED SOLUTION PERFORMANCE ANALYSIS:

6.1 General Observations for Aged Pre-Mixed Solution Samples: The aged pre-mixed solutions were prepared in a similar fashion to the aged concentrate samples as noted in Section 4.1. Figures 3 and 4 note photographs of the National AVIO^{F3} Green KHC 3% and the Angus Fire Jetfoam 3% aged pre-mixed solutions once the aging process was complete.

**Figure-3: National AVIO^{F3} Green KHC 3% Aged Pre-mixed Solution Sample**



Figure-4: Angus Fire Jetfoam 3% Aged Pre-mixed Solution Sample

As noted with the aged concentrate samples, the National AVIO^{F3} Green KHC 3% and the Angus Fire Jetfoam 3% aged pre-mixed solutions also did not note any visible agent stratification or precipitation.³

6.2 Firefighting Performance: The National AVIO^{F3} Green KHC 3% and the Angus Fire Jetfoam 3% aged pre-mixed solutions had similar firefighting performance in comparison to their previous unaged full and half strength fire test results and in many cases the results for both firefighting and burnback resistance capabilities actually noted improved performance [3-5].

7.0 AGED CONCENTRATE AND AGED PRE-MIXED SOLUTION NON-MILSPEC REDUCED ASPIRATION PERFORMANCE RESULTS:

Tables 5 and 6 provides the reduced aspiration fire test results for the National AVIO^{F3} Green KHC 3% and the Angus Fire Jetfoam 3% Fluorine-Free agents. The intent of the reduced aspiration performance testing is to evaluate the fluorine free foam product capabilities when using reduced aspirating nozzles that are currently being used by various DoD fixed sprinkler systems.

**Table-5: National AVIO^{F3} Green KHC 3% Non-MILSPEC
Reduced Aspiration Test Results**

Fire Test	Extinction time (sec)	Expansion Ratio	Burnback (sec)
28 ft² (Ethanol-Free Gasoline) AGED CONCENTRATE			
2 GPM full strength Fresh Water	66	4.5	247
2 GPM ½ strength Fresh Water	93	4.4	252
28 ft² (Ethanol-Free Gasoline) AGED PRE-MIXED SOLUTION			
2 GPM full strength Fresh Water	64	4.5	265
2 GPM ½ strength Fresh Water	74	4.6	242

³ Further precipitation evaluations using the ASTM D1796 test standard will be performed by NRL-DC when all of requisite Chemical & Physical property testing is complete.

**Table-6: Angus Fire Jetfoam 3% Non-MILSPEC
Reduced Aspiration Test Results**

Fire Test	Extinction time (sec)	Expansion Ratio	Burnback (sec)
28 ft² (Ethanol-Free Gasoline) AGED CONCENTRATE			
2 GPM full strength Fresh Water	66*	4.6	228
2 GPM ½ strength Fresh Water	79*	4.5	220
28 ft² (Ethanol-Free Gasoline) AGED PRE-MIXED SOLUTION			
2 GPM full strength Fresh Water	55*	4.6	261
2 GPM ½ strength Fresh Water	91*	4.5	237

NOTE*: The increased fire extinction time results can be directly attributed to the limited foam flow reach provided by the generated MILSPEC firefighting foam nozzle stream.

8.0 AGENT COMPATIBILITY PERFORMANCE TEST RESULTS:

The intent of this set of tests was to assess the compatibility of the National AVIO^{F3} Green KHC 3% agent when mixed with a 50/50 mixture of the Angus Fire Jetfoam 3% agent. As is stipulated in the AFFF MIL-PRF-24385 standard, agent compatibility testing is performed with aged concentrate mixtures that are prepared using the same guidance noted in Section 4.1 [2]. Figure 5 is a photograph of the aged 50/50 mixture of the National AVIO^{F3} Green KHC 3% and Angus Fire Jetfoam 3% agents once the aging process was complete.

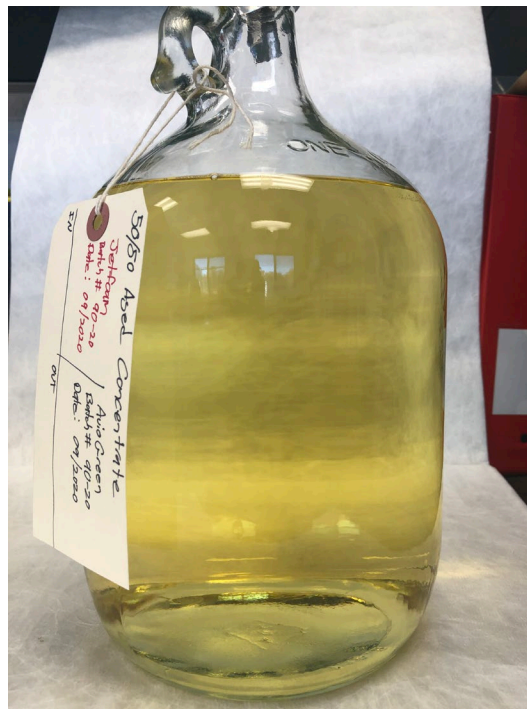


**Figure-5: National AVIO^{F3} Green KHC 3% and Angus Fire Jetfoam 3%
Aged Concentrate 50/50 Mixture Sample**

As can be seen in Figure 5, there was no visible agent stratification or precipitation noted in prepared 50/50 concentrate mixture following the aging process.

Table 7 provides the results of the National AVIO^{F3} Green KHC 3% and the Angus fire Jetfoam 3% agent compatibility test results.

**Table-7: National AVIO^{F3} Green KHC 3% and Angus Fire Jetfoam 3%
50/50 Mixture: Agent Compatibility Fire Test Results**

Fire Test	Extinction time (sec)	Expansion Ratio	Drainage Time (min)	Burnback (sec)
28 ft² (Ethanol-Free Gasoline) AGED CONCENTRATE				
2 GPM full strength Fresh Water	43	7.8	11:38	271
3 GPM full strength Fresh Water	35	7.2	10:11	318
2 GPM full strength Fresh Water (REDUCED ASPIRATION)	66	4.7	9:52	181
28 ft² (Jet A Fuel) AGED CONCENTRATE				
2 GPM full strength Fresh Water	29	7.8	11:38	355

Based on these test results, the National AVIO^{F3} Green KHC 3% and the Angus Fire Jetfoam 3% fluorine-free foam products are deemed compatible for shore-based firefighting operations.

5.0 SUMMARY & CONCLUSIONS:

The ESTCP WP20-5373 “Quick Look” Summary SITREP #7 provides the National AVIO^{F3} Green KHC 3% and the Angus Fire Jetfoam 3% aged concentrate, aged pre-mixed solutions, and the agent compatibility firefighting test results. The firefighting performance test results indicate that there was no degradation in performance due to the aging process and in some respects the agents performance capabilities improved as a result of the aging process. It was also determined that the National AVIO^{F3} Green KHC 3% and the Angus Fire Jetfoam 3% products are deemed compatible for shore-based firefighting applications.

This concludes the ESTCP WP20-5373 baseline testing for the National AVIO^{F3} Green KHC 3% and the Angus Fire Jetfoam 3% fluorine-free foam products. The next series of fire testing will be the aged concentrate, aged pre-mixed solution and agent compatibility testing for the Solberg RF3 and the Fomtec ENVIRO USP fluorine-free foam products. Since the Solberg RF3 and the Fomtec ENVIRO USP 3% products are high viscosity (non-Newtonian Liquids) formulations, we will also further investigate the compatibility of the these high viscosity agents with the National AVIO^{F3} Green KHC 3% and the Angus Fire Jetfoam 3% low viscosity (Newtonian Liquid) agents.

6.0 REFERENCES:

1. J.P. Farley, “Fluorine-Free Military Specification Development”, ESTCP WP20-5373 Statement of Work, March 2020.
2. NAVSEA “Fire Extinguishing Agent, Aqueous Film-Forming Foam (AFFF) Liquid Concentrate, Fresh water and Sea Water”, MIL-PRF-24385F(SH), w/Amendment 4, 07 April 2020.

3. Farley, J.P., Karwoski, S., Whitehurst, C.L., “AVIO^{F3} Green KHC 3% Fluorine Free Foam Concentrate “Quick Look” Summary: ESTCP WP20-5373 SITREP #1, 25 May 2020.
4. Farley, J.P., Karwoski, S., Whitehurst, C.L., “AVIO^{F3} Green KHC 3% Fluorine Free Foam Concentrate “Quick Look” Summary: ESTCP WP20-5373 SITREP #2, 29 May 2020.
5. Farley, J.P., Karwoski, S., Whitehurst, C.L., “Angus Fire Jetfoam 3% Fluorine-Free Concentrate “Quick Look” Summary: ESTCP WP20-5373 SITREP #6, 27 October 2020.

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20 April 2021

**Solberg RF3 and Fomtec ENVIRO USP 3%
Fluorine-Free Concentrate “Quick Look”
Summary: ESTCP WP20-5373 SITREP #8**

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**Solberg RF3 and Fomtec ENVIRO USP 3% Fluorine-Free Concentrate
“Quick Look” Summary:
ESTCP WP20-5373 SITREP #8**

1.0 INTRODUCTION: The purpose of the ESTCP WP20-5373 “Quick Look” summary situational reports (SITREP) are to provide periodic updates on the Naval Research Laboratory’s (NRL) progress while conducting the Phase I Firefighting Performance baseline testing that are being executed in accordance with the approved NRL ESTCP WP20-5373 statement of work [1]. This ESTCP WP20-5373 SITREP #8 reviews the Solberg RF3 and the Fomtec ENVIRO USP 3% fluorine-free aged concentrate, aged pre-mixed solutions, and the Solberg RF3, Fomtec ENVIRO USP 3%, and the National AVIO^{F3} Green KHC 3% agent compatibility fire test performance results.

2.0 FIREFIGHTING AGENTS: The Solberg RF3 and the Fomtec ENVIRO USP 3% fluorine-free concentrates are high viscosity (non-Newtonian Liquids), which have an International Civil Aviation Organization (ICAO) Level C and ICAO Level B certification respectively and the National AVIO^{F3} Green KHC 3% concentrate is a low viscosity (Newtonian Liquid), which has a ICAO level C certification.¹

NOTE: Due to the range of viscosities for the commercially available fluorine-free foam products, it has been determined that it is more appropriate to measure viscosity using an interfacial rheometer, which measures viscosity through an applied shear rate. A rheometer sandwiches the material between two plates, which helps to push any entrapped air bubbles out of the sample that are typically present for the more viscous, gel-like materials. Table-1 provides the agent viscosity test results when using the interfacial rheometer test methodology.

Table-1: Agent Viscosity Test Results

Viscosity Test	Solberg RF3	Fomtec ENVIRO USP 3%	National AVIO ^{F3} Green
Using Interfacial Rheometer			
Concentrate 25°C (over shear rate 1-10 1/s)	12,644	7,659	110
Concentrate 5°C (over shear rate 1-10 1/s)	15,508	9,171	330

3.0 AGED CONCENTRATE FIREFIGHTING PERFORMANCE: Tables 2 and 3 provides the aged concentrate fire test results when using the AFFF MILSPEC firefighting nozzle set at 2 GPM (0.071 gpm/ft² application rate) and at 3 GPM (0.107 gpm/ft² application rate) foam flow rates using both ethanol-free gasoline and aviation Jet A fueled fires.

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¹ The concentrate batch numbers and manufacturing dates used during this testing include: Solberg Re-Healing RF3 (Batch # B1800832/Date 8/18), Fomtec ENVIRO USP 3% (Batch # 1938966/Date 20/02/2019), and National AVIO^{F3} Green KHC 3% (Batch # 90-20/Date 09/2020).

Table-2: Solberg RF3 Aged Concentrate Fire Test Results

Fire Test	Extinction time (sec)	Expansion Ratio	Drainage Time (min)	Burnback (sec)
28 ft² (Ethanol-Free Gasoline)				
2 GPM full strength Fresh Water	46	6.7	29:48	871
2 GPM ½ strength Fresh Water	65	N/A*	N/A*	423
3 GPM full strength Fresh Water	29	7.0	27:24	1022
3 GPM ½ strength Fresh Water	39	N/A*	N/A*	582
28 ft² (Jet A Fuel)				
2 GPM full strength Fresh Water	35	6.7	29:48	823
2 GPM ½ strength Fresh Water	44	N/A*	N/A*	380

NOTE*: Current MILSPEC expansion & drainage testing requirements only applies to full strength agent testing [2].

Table-3: Fomtec ENVIRO USP 3% Aged Concentrate Fire Test Results

Fire Test	Extinction time (sec)	Expansion Ratio	Drainage Time (min)	Burnback (sec)
28 ft² (Ethanol-Free Gasoline)				
2 GPM full strength Fresh Water	57	7.4	58:00	495
2 GPM ½ strength Fresh Water	54	N/A*	N/A*	362
3 GPM full strength Fresh Water	48	6.3	44:44	613
3 GPM ½ strength Fresh Water	47	N/A*	N/A*	437
28 ft² (Jet A Fuel)				
2 GPM full strength Fresh Water	36	7.4	58:00	587
2 GPM ½ strength Fresh Water	33	N/A*	N/A*	449

NOTE*: Current MILSPEC expansion & drainage testing requirements only applies to full strength agent testing [2].

4.0 PRELIMINARY AGED CONCENTRATE PERFORMANCE ANALYSIS:

4.1 General Observations for Aged Concentrate Samples: The current MIL-PRF-24385 performance standard stipulates that the samples of agent concentrate shall be prepared in sufficient quantity to perform the required tests. The samples shall be placed in glass containers and be stored in an oven at 65°C ± 2.0°C for a period of ten days [2]. Figures 1 and 2 provide photographs of the Solberg RF3 and the Fomtec ENVIRO USP 3% aged concentrate samples once the aging process was complete.

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Figure-1: Solberg RF3 Aged Concentrate Sample

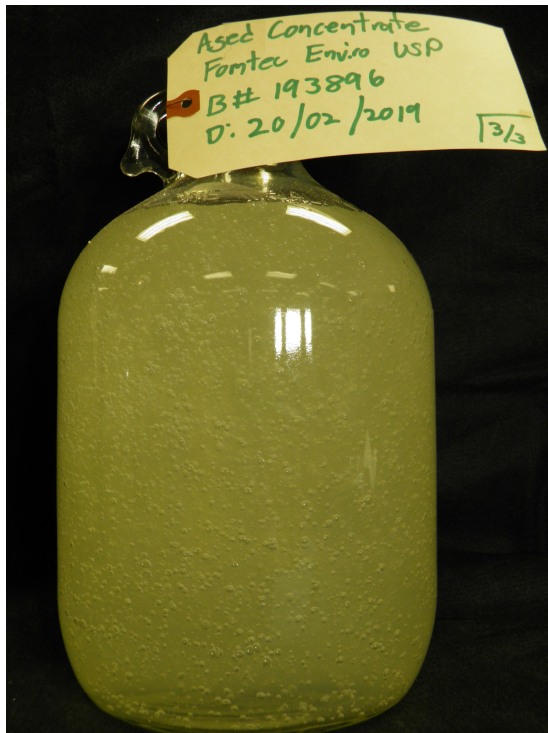


Figure-2: Fomtec ENVIRO USP 3% Aged Concentrate Sample

As noted in Figure 1, the Solberg RF3 product did appear to have some level of stratification, which is theorized to be due to solvation of the constituents in the concentrate (i.e., the hydrocarbon surfactants & thickening agents). As noted in Figure 2, the Fomtec ENVIRO USP 3% product did not appear to have any signs of stratification or precipitation in the aged concentrate sample.

4.2 Firefighting Performance: The Solberg RF3 and the Fomtec ENVIRO USP 3% fluorine-free aged concentrate test results had similar firefighting performance in comparison to their previous unaged full and half strength fire test results and in many cases the aged concentrate test results for both firefighting and burnback resistance capabilities actually noted improved performance [3-4].

5.0 AGED PRE-MIXED SOLUTIONS FIREFIGHTING PERFORMANCE: Tables 4 and 5 provides the aged pre-mixed solutions fire test results when using the AFFF MILSPEC firefighting nozzle set a 2 GPM (0.071 gpm/ft² application rate) and at 3 GPM (0.107 gpm/ft² application rate) foam flow rates using both ethanol-free gasoline and aviation Jet A fueled fires.

Table-4: Solberg RF3 Aged Pre-Mixed Solution Fire Test Results

Fire Test	Extinction time (sec)	Expansion Ratio	Drainage Time (min)	Burnback (sec)
28 ft² (Ethanol-Free Gasoline)				
2 GPM full strength Fresh Water	42	6.9	17:30	789
2 GPM ½ strength Fresh Water	147	N/A*	N/A*	353
3 GPM full strength Fresh Water	28	7.1	12:56	952
3 GPM ½ strength Fresh Water	108	N/A*	N/A*	407
28 ft² (Jet A Fuel)				
2 GPM full strength Fresh Water	30	6.9	17:30	810
2 GPM ½ strength Fresh Water	48	N/A*	N/A*	427

NOTE*: Current MILSPEC expansion & drainage testing requirements only applies to full strength agent testing [2].

Table-5: Fomtec ENVIRO UPS 3% Aged Pre-Mixed Solution Fire Test Results

Fire Test	Extinction time (sec)	Expansion Ratio	Drainage Time (min)	Burnback (sec)
28 ft² (Ethanol-Free Gasoline)				
2 GPM full strength Fresh Water	57	7.3	57:45	496
2 GPM ½ strength Fresh Water	77	N/A*	N/A*	243
3 GPM full strength Fresh Water	42	7.7	51:06	630
3 GPM ½ strength Fresh Water	54	N/A*	N/A*	399
28 ft² (Jet A Fuel)				
2 GPM full strength Fresh Water	33	7.3	57:45	629
2 GPM ½ strength Fresh Water	39	N/A*	N/A*	403

NOTE*: Current MILSPEC expansion & drainage testing requirements only applies to full strength agent testing [2].

6.0 PRELIMINARY AGED PRE-MIXED SOLUTION PERFORMANCE ANALYSIS:

6.1 General Observations for Aged Pre-Mixed Solution Samples: The aged pre-mixed solutions were prepared following the same MIL-PRF-24385 guidance noted in section 4.1. Figures 3-5 provide

photographs of the Solberg RF3 and the Fomtec ENVIRO USP 3% aged pre-mixed solutions once the aging process was complete.



Figure-3: Solberg RF3 Aged Pre-Mixed Solution Sample



Figure-4: Fomtec ENVIRO USP 3% Aged Pre-Mixed Solution Sample



Figure-5: Fomtec ENVIRO USP 3% Aged Pre-Mixed Solution Noting Sediment

As noted in Figure 3, the Solberg RF3 pre-mixed solution did not appear to have any precipitation but as noted in Figures 4 and 5, the Fomtec ENVIRO USP 3% aged pre-mixed solution did note some level of precipitation/sediment at the bottom of the glass container.

6.2 Firefighting Performance: The Solberg RF3 and the Fomtec ENVIRO USP 3% aged pre-mixed solutions had similar firefighting performance in comparison to their previous unaged full and half strength fire test results (with the exception 2 GPM ½ strength tests) and in many cases the results for both firefighting and burnback resistance capabilities actually noted improved performance [3-4]².

NOTE: It generally recognized that the fresh water 2 GPM ½ strength test is the more challenging firefighting performance test when qualifying AFFF products and the required MIL-PRF-24385 extinguishment time is 45 seconds.

7.0 AGED CONCENTRATE NON-MILSPEC REDUCED ASPIRATION PERFORMANCE RESULTS:

Tables 6 and 7 provides the reduced aspiration fire test results for the Solberg RF3 and the Fomtec ENVIRO USP 3% Fluorine-Free agents. The intent of the reduced aspiration performance testing is to evaluate the fluorine-free foam product capabilities when using reduced aspirating nozzles that are currently being used by various DoD shore-based fixed sprinkler systems.

**Table-6: Solberg RF3 Non-MILSPEC
Reduced Aspiration Test Results**

Fire Test	Extinction time (sec)	Expansion Ratio	Burnback (sec)
28 ft² (Ethanol-Free Gasoline) AGED CONCENTRATE			
2 GPM full strength Fresh Water	57	4.3	895
2 GPM ½ strength Fresh Water	80	4.0	438

² The unaged Solberg RF3 2 GPM ½ strength fire extinction time was 49 seconds and the unaged Fomtec ENVIRO USP 3% 2 GPM ½ strength fire extinction time was 61 seconds.

**Table-7: Fomtec ENVIRO USP 3% Non-MILSPEC
Reduced Aspiration Test Results**

Fire Test ²	Extinction time (sec)	Expansion Ratio	Burnback (sec)
28 ft² (Ethanol-Free Gasoline) AGED CONCENTRATE			
2 GPM full strength Fresh Water	77 ¹	5.0	428
2 GPM ½ strength Fresh Water	79 ¹	4.0	280

NOTE: 1. The increased fire extinction time results can be directly attributed to the limited foam flow reach provided by the generated MILSPEC firefighting foam nozzle stream.
2. Reduced aspiration aged pre-mixed solution testing was not conducted since it is deemed not relevant for DoD shore-based fixed sprinkler military installation applications.

8.0 AGED CONCENTRATE 50/50 MIXTURE COMPATIBILITY FIREFIGHTING PERFORMANCE:

The intent of this set of tests was to assess the compatibility of the Solberg RF3 agent when mixed with a 50/50 mixture of the Fomtec ENVIRO UPS 3% agent, which are both high viscosity (non-Newtonian Liquid) concentrates. In addition to assessing the compatibility of the two noted high viscosity (non-Newtonian Liquid) concentrates, we also assessed the compatibility of the two high viscosity (non-Newtonian Liquid) agents with the National AVIO^{F3} Green KHC 3% low viscosity (Newtonian Liquid) concentrate agent. As is stipulated in the AFFF MIL-PRF-24385 standard, agent compatibility testing is performed with aged concentrate mixtures [2].

Tables 8-10 provides the aged concentrate 50/50 mixture fire test results when using the AFFF MILSPEC firefighting nozzle set at 2 GPM (0.071 gpm/ft² application rate) and at 3 GPM (0.107 gpm/ft² application rate) foam flow rates using both ethanol-free gasoline and aviation Jet A fueled fires.

**Table-8: Solberg RF3 and Fomtec ENVIRO USP 3%
50/50 Mixture: Agent Compatibility Fire Test Results**

Fire Test	Extinction time (sec)	Expansion Ratio	Drainage Time (min)	Burnback (sec)
28 ft² (Ethanol-Free Gasoline) AGED CONCENTRATE				
2 GPM full strength Fresh Water	44	6.79	34:50	593
3 GPM full strength Fresh Water	37	7.4	49:55	730
2 GPM full strength Fresh Water (REDUCED ASPIRATION)	58	4.5	44:46	528
28 ft² (Jet A Fuel) AGED CONCENTRATE				
2 GPM full strength Fresh Water	35	6.79	34:50	624

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**Table-9: Solberg RF3 and National AVIO^{F3} Green KHC 3%
50/50 Mixture: Agent Compatibility Fire Test Results**

Fire Test	Extinction time (sec)	Expansion Ratio	Drainage Time (min)	Burnback (sec)
28 ft² (Ethanol-Free Gasoline) AGED CONCENTRATE				
2 GPM full strength Fresh Water	56	6.6	61:00	390
3 GPM full strength Fresh Water	39	6.4	56:00	520
2 GPM full strength Fresh Water (REDUCED ASPIRATION)	83	4.9	43:00	376
28 ft² (Jet A Fuel) AGED CONCENTRATE				
2 GPM full strength Fresh Water	28	6.6	61:00	532

**Table-10: Fomtec ENVIRO USP 3% and National AVIO^{F3} Green KHC 3%
50/50 Mixture: Agent Compatibility Fire Test Results**

Fire Test	Extinction time (sec)	Expansion Ratio	Drainage Time (min)	Burnback (sec)
28 ft² (Ethanol-Free Gasoline) AGED CONCENTRATE				
2 GPM full strength Fresh Water	75	6.8	24:50	300
3 GPM full strength Fresh Water	54	7.3	30:00	427
2 GPM full strength Fresh Water (REDUCED ASPIRATION)	160	4.4	11:40	253
28 ft² (Jet A Fuel) AGED CONCENTRATE				
2 GPM full strength Fresh Water	28	6.8	24:00	437

9.0 PRELIMINARY AGED CONCENTRATE 50/50 MIXTURES PERFORMANCE ANALYSIS:

9.1 General Observations for Aged Concentrate 50/50 Mixture Samples: Figures 6-8 provide photographs of the aged concentrate 50/50 mixtures (i.e., Solberg RF3 & Fomtec ENVIRO USP 3%, Solberg RF3 & National AVIO^{F3} Green KHC 3%, and Fomtec ENVIRO USP 3% & National AVIO^{F3} Green KHC 3%) once the aging process was complete.

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Figure-6: Solberg RF3 and Fomtec ENVIRO USP 3% Aged Concentrate 50/50 Mixture Sample

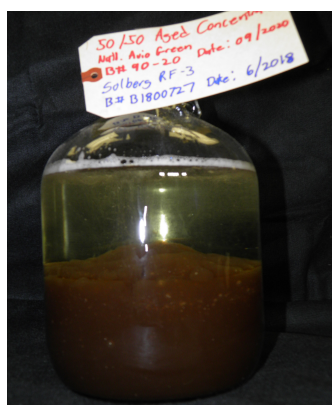


Figure-7: Solberg RF3 and National AVIO^{F3} Green KHC 3% Aged Concentrate 50/50 Mixture Sample



Figure-8: Fomtec ENVIRO USP 3% and National AVIO^{F3} Green KHC 3% Aged Concentrate 50/50 Mixture Sample

As can be seen in Figure 6, there was visible agent stratification noted in the Solberg RF3 and Fomtec ENVIRO USP 3% 50/50 concentrate mixture following the aging process due to the significant differences in the agent concentrate viscosities.

As can be seen in Figures 7 and 8, there was also visible agent stratification noted when the Solberg RF3 and Fomtec ENVIRO USP 3% products when mixed with the National AVIO^{F3} Green KHC 3% agent and there was also a visible mucus/polymeric-type material that had separated from the National AVIO^{F3} Green KHC 3% concentrate formulation.

Based on these noted observations, the Solberg RF3, Fomtec ENVIRO USP 3% and the National AVIO^{F3} Green KHC 3% products would not be considered compatible from a chemical and physical property standpoint.

9.2 Firefighting Performance: Due to the extreme differences in viscosity between the Solberg RF3, Fomtec ENVIRO USP 3% and the National AVIO^{F3} Green KHC 3% agents, all of the aged concentrate 50/50 mixtures required a three-step process to make the final 3% pre-mixed foam solution. In step-one, the two foam concentrate were mixed (i.e., before the introduction of water). In step-two, the two mixed concentrates were then poured into the foam solution container where water was then introduced. Once the mixed foam concentrates and water were poured into the pre-mixed foam container, an electric powered drill fitted with a double blade paint mixing tool was used to complete the final 3% pre-mixed foam solution.

Based on the firefighting performance (pre-mixed 3% solution) test results, the Solberg RF3 and the Fomtec ENVIRO USP 3% aged concentrate 50/50 mixture would be considered compatible when fighting either a gasoline or an aviation Jet A fueled fire. The Solberg RF3 and the National AVIO^{F3} Green KHC 3% 50/50 aged concentrate mixture would also be deemed compatible when they are delivered as a 3% pre-mixed solution when fighting either a gasoline or an aviation Jet A fueled fire. The Fomtec ENVIRO USP 3% and the National AVIO^{F3} Green KHC 3% 50/50 aged concentrate mixture would be considered compatible if they are delivered as a 3% pre-mixed solution when fighting an aviation Jet A fueled fire.

10.0 SUMMARY & CONCLUSIONS:

The ESTCP WP20-5373 “Quick Look” Summary SITREP #8 provides the Solberg RF3 and the Fomtec ENVIRO USP 3% aged concentrate and aged pre-mixed solutions firefighting test results. The firefighting performance test results indicate that there was no significant degradation in performance due to the aging process and in some respects the agents performance capabilities improved as a result of the aging process.

Agent compatibility using aged concentrate 50/50 mixtures was also investigated during this firefighting performance test series. It was determined that due to the extreme differences in viscosity that the Solberg RF3 and the Fomtec ENVIRO USP 3% concentrate formulations are not compatible and they should not be mixed for shore-based military installation applications. It was also determined though, if the Solberg RF3, Fomtec ENVIRO USP or the National AVIO^{F3} Green KHC 3% firefighting agents were applied by different foam delivery sources (i.e., different Aviation Rescue Fire Fighting (ARFF)) vehicles, the resulting generated foam provided by the different foam delivery

sources would not be expected to have any adverse effect on the foam quality/firefighting performance (both firefighting extinguishment or burnback resistance) capabilities.

This concludes the ESTCP WP20-5373 Phase I baseline firefighting performance testing effort and the collected data from the Fluorine-Free Concentrate “Quick Look” Summary: WP20-5373 SITREP #’s 1-8 will now be used in the WP20-5373 Phase II effort, which will help to generate a new fluorine-free military specification for DoD shore-based military installation (both mobile (ARFF vehicle) and fixed (aviation hangar)) applications and will additionally help to fulfill the congressionally mandated FY20 National Defense Authorization Act (NDAA) requirements.

NOTE: The ESTCP WP2-5373 Phase I firefighting performance testing effort will continue to support the on-going SERDP AFFF replacement programs as their formulations continue to be refined and will also be on the lookout for any additional commercially available fluorine-free foam products that may become available in the FY21 timeframe.

10.0 REFERENCES:

1. J.P. Farley, “Fluorine-Free Military Specification Development”, ESTCP WP20-5373 Statement of Work, March 2020.
2. NAVSEA “Fire Extinguishing Agent, Aqueous Film-Forming Foam (AFFF) Liquid Concentrate, Fresh water and Sea Water”, MIL-PRF-24385F(SH), w/Amendment 4, 07 April 2020.
3. Farley, J.P., Karwoski, S., Whitehurst, C.L., “Solberg RF3 Fluorine Free Foam Concentrate “Quick Look” Summary: ESTCP WP20-5373 SITREP #4, 28 June 2020.
4. Farley, J.P., Karwoski, S., Whitehurst, C.L., “Fomtec ENVIRO UPS 3% Fluorine Free Foam Concentrate “Quick Look” Summary: ESTCP WP20-5373 SITREP #3, 12 June 2020.

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