Demonstration of a PFAS Free Fire Suppression Alternative

WP20-DA-5337

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Project Outbrief

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14. ABSTRACT

A toxicologically low impact alternative to the traditional Aqueous Film Forming Foams for sprayable fire retardants offered by Paradise Environmental Group was tested by DEVCOM Chemical Biological Center. The goal of these alternative agents is similar to foam agents in that they aim to reduce the surface tension of water. However, instead of forming a foam “blanket” on a Class B fuel surface to block the source of oxygen in the air, the solution is vigorously mixed with the fuel to form a non-flammable emulsion. Emulsifiers have limited foaming capabilities. Emulsifiers are mixed with water at a given percentage and forcefully applied onto the entire surface of the burning fuel source. The resulting solution then mixes with the fuel, breaking it into very small droplets. These droplets of fuel are surrounded or encapsulated by the emulsifier/water mixture to extinguish the fire, knocking down the vapor pressure required to ignite and sustain combustion. Solutions of this type material known as ‘Blaze Check’ offered by Paradise Environmental Group [Paradise Pennsylvania] are easily mixed in either fresh or salt water. Laboratory testing to verify the non-corrosive nature of Blaze Check, material properties and lack of PFAS containing compounds was followed up with field testing to verify performance against liquid fuel fires, metal fuel fires and pyrotechnic fires.

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Introduction

- A toxicologically low impact alternative to the traditional Aqueous Film Forming Foams for sprayable fire retardants offered by Paradise Environmental Group was tested by DEVCOM Chemical Biological Center. The goal of these alternative agents is similar to foam agents in that they aim to reduce the surface tension of water. However, instead of forming a foam “blanket” on a Class B fuel surface to block the source of oxygen in the air, the solution is vigorously mixed with the fuel to form a non-flammable emulsion. Emulsifiers have limited foaming capabilities. Emulsifiers are mixed with water at a given percentage and forcefully applied onto the entire surface of the burning fuel source. The resulting solution then mixes with the fuel, breaking it into very small droplets. These droplets of fuel are surrounded or encapsulated by the emulsifier/water mixture to extinguish the fire, knocking down the vapor pressure required to ignite and sustain combustion. Solutions of this type material known as ‘Blaze Check’ offered by Paradise Environmental Group [Paradise Pennsylvania] are easily mixed in either fresh or salt water. Laboratory testing to verify the non-corrosive nature of Blaze Check, material properties and lack of PFAS containing compounds was followed up with field testing to verify performance against liquid fuel fires, metal fuel fires and pyrotechnic fires.

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LAB TESTS (per Table I of Mil-PRF-24385FAM2):
(i) Viscosity (sec 4.7.2)
(ii) pH (4.7.3)
(iii) Corrosion rate (general) (4.7.7)
(iv) PFAS content (3.3.4)
(v) Miscibility/Solubility in H2O

PERFORMANCE TESTS – (per Mil-PRF-24385FAM2 with modifications):

(i) Small scale demos conducted by vendor to demonstrate effectiveness of 'Blaze Check' solution against small pan class B gasoline and diesel fires compared to water only application. Extinction times after re-ignition measured.

(ii) Fire performance tests (sec 3.4) (both 28 sq ft and 50 sq ft fire tests) – based on the AFFF test plan to include measurement of time to extinguish after application of Blaze Check solution and follow-on burnback time measurements. Environmental approvals for collection and processing of neutralized gasoline post-test was been granted by APG environmental office.

(iii) Demonstration against class D type metal (magnesium) shaving fires.

(iv) Demonstration against pyrotechnic fires

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- pH

Test Method: pH meter measurements were conducted on open bench top with an ambient temperature of 25 ° C. (Temperature reading taken from the pH meter.) pH meter was calibrated using standard buffer solutions of pH 4, 7, and10. Once calibration was complete, approx. 10 mL sample was pipetted into three 20 mL glass vials and labeled 1-3. A magnetic stir bar (rice size) was placed in each vial. Starting with Vial 1, the electrode was submerged in the sample sitting on the magnetic stir plate. Stirring was turned on to ensure a uniform sample. Once the pH reading on the meter had stabilized, the number was recorded and the sample removed. The electrode was rinsed with DI water and wiped with a clean Kimwipe. pH measurements were repeated with sample vials 2 and 3.

Sample Vial	pH
1	8.07
2	8.07
3	8.05

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- Viscosity

- Test Method: ASTM D 445 Kinematic Viscosity of Transparent and Opaque Liquids (and the Calculation of Dynamic Viscosity)
- Instrumentation: Cannon-Manning Semi-Micro Viscometer, Cannon CT-1000 Temperature Bath, and Cannon TE-1000 Low Temperature Bath
- Calibration: Manufacturer Calibrated
- Results: Provided below are the viscosity results for the fire-retardant samples run at 25 ° and 5° C. Each value represents the mean of multiple consecutive measurements conducted at the experimental temperatures

Temperature (°C)	**Viscosity (cSt) ± Std. Dev. (σ_{n-1})**
25.0	36.05 ± 0.49
5.0	59.69 ± 0.65

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- Miscibility/Solubility in Water
- Test Method: Optical
- Miscibility of two materials is often determined optically. When the two miscible liquids are combined, the resulting liquid is clear. If the mixture is cloudy the two materials are immiscible. Care must be taken with this determination. If the indices of refraction of the two materials are similar, an immiscible mixture may be clear and give an incorrect determination that the two liquids are miscible.
- Results: One milliliter of Blaze Check was tested for solubility in water. One milliliter of Blaze Check was added to 1 mL of water. When initially added to the water the Blaze Check mixture forms a bilayer with the denser Blaze Check on the bottom (Figure 1 A). If solution is gently shaken the water and Blaze Check is seen to mix completely (Figure 1 B). If the undisturbed bilayer is left at room temperature overnight the Blaze Check mixes completely with the water. Blaze Check was determined to be completely miscible in water.

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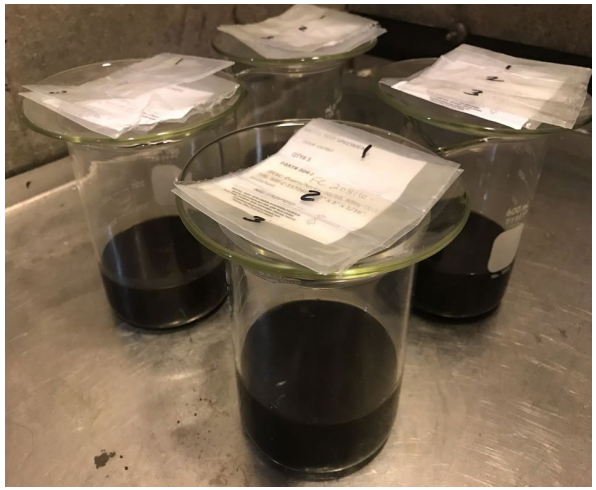
- Corrosion testing per MIL-PRF-24385F w/AM 2 Table I

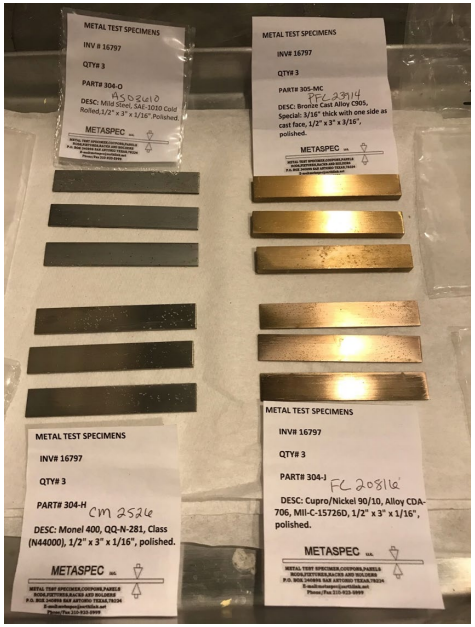
- Three specimens each in the four configurations as:
- Bronze Cast Alloy (C905) 3/16” thick with one side as cast face/other polished ; ½” x 3” x 3/16”
- Cupro/Nickel 90/10 Alloy (304J) CDA-706, Mil-C-15726D; ½ “ x 3” x 1/16”; polished
- Monel 400, (304H); QQ-N-281, Class N4400, ½ x 3 x 1/16; polished
- Mild Steel, (304-O); SAE-1010 Cold Rolled; ½ x 3 x 1/16; polished

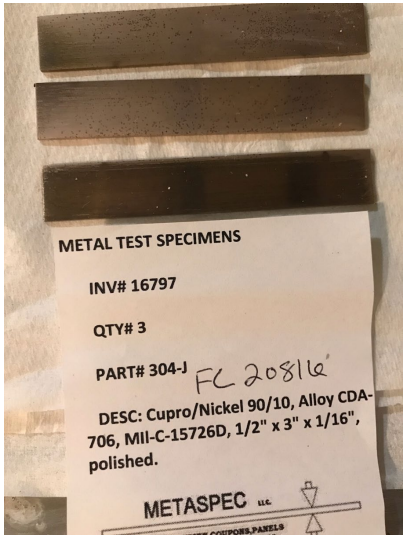
- Except for a couple of outliers, which may have been measured incorrectly before immersion, the mass changes were less than 0.13% by weight. A slight increase in weight for a couple of the specimens could be in part due to deposits observed on some of the samples which were originally assumed to be due to the growth of oxidation products such as copper (I) chloride crystals. Samples of these deposits were scraped off the specimens and submitted for elemental analysis to determine their exact constituency. Elemental analysis was conducted, and it was determined that the deposits were not oxidation species (no Ni or Cu) but rather unrelated species such as Na, Mg, P, K, S, Cl (plus O, C) probably from the sea salt and or the Blaze Check. The only Cu/Ni rich areas are particles that appear to be residue from machining, are very small, and not collocated with the other elements.

- No significant or measurable dimensional (cross sectional) changes were found to have occurred for any of the specimens and hence a corrosion rate could not be calculated.

Corrosion Samples Post Test

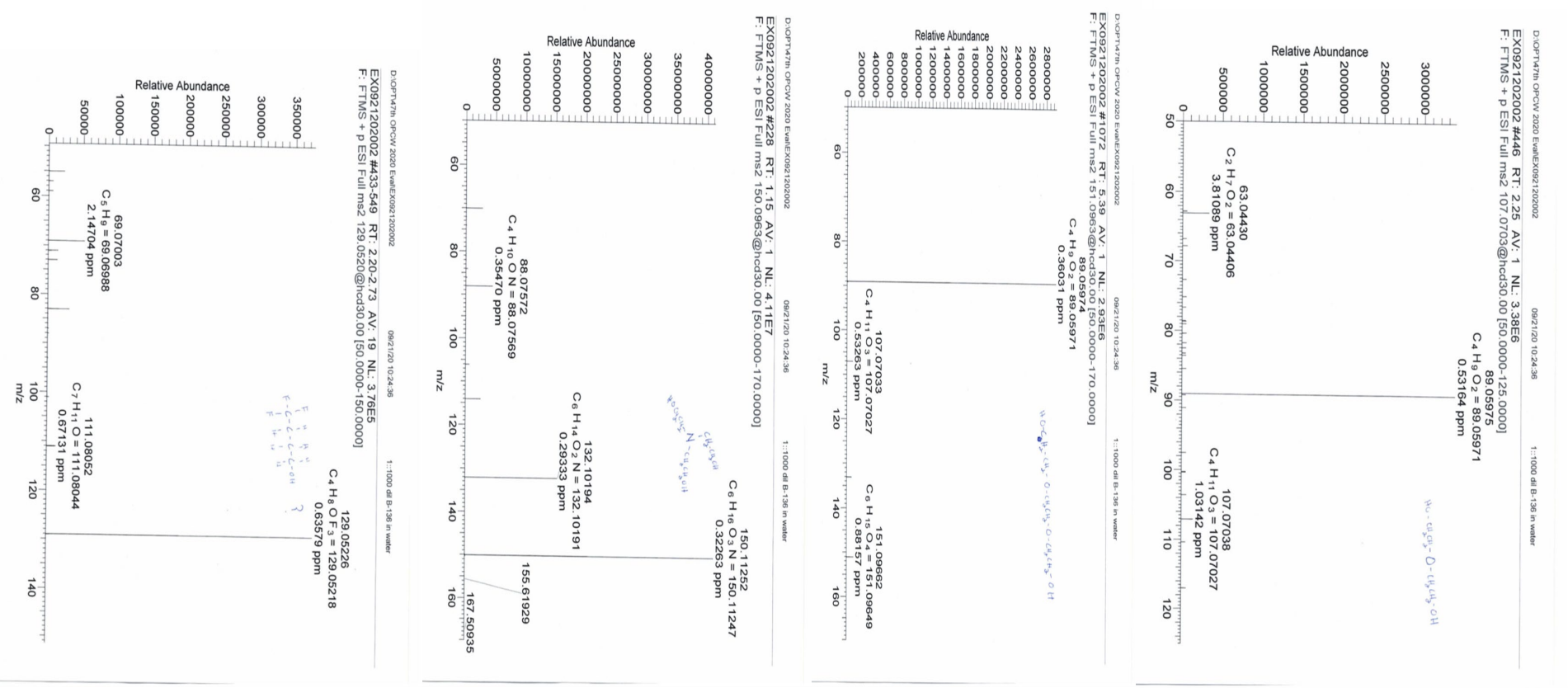






Test for Presence of PFAS

- Mass Spectroscopy sampling for presence of PFAS containing compounds. None detected.
- The following trace (defined as less than 100 ppm) compounds were identified in Blaze Check with none found above the 4 ppm level.



Vendor Small Fire Pan Tests

- Small Class B Fire Pan Tests

For each trial, 800 ml of fuel was placed into a 1 ft square pan, 2.5 in deep. The extinguishing solution (either pure water (0%), 10% Blaze Check in water or 20% Blaze Check in water) was discharged from a 2.5-gallon extinguisher at roughly 216 ml per second. Care was taken to ensure that there was minimal splashing of the burning fuel after the application of the extinguishing solution.

- Extinguishment Time vs Blaze Check Percent Solution

Gasoline	initial extinguishment time	relight extinguishment time
0% BC	No result	No result
10% BC	10 seconds	5 seconds
20% BC	6 seconds	2 seconds

Diesel fuel	initial extinguishment time	relight extinguishment time
0% BC	6 seconds	7 seconds
10% BC	2 seconds	2 seconds
20% BC	2 seconds	1 second

Pyrotechnic Fire Tests

Commercial Pyrotechnic Road Flares from ‘Orion’ were attempted to extinguish with water vs Blaze Check solution. These commercial safety flares were easily extinguished with both water and Blaze Check and are apparently not water-proof. CBC Pyrotechnics team then fabricated special flares using a water-resistant flare mixture reported in Ellern (1). When these flares were sprayed with pure water they would briefly extinguish and then immediately relight. This relight process happened continuously until the flare burned out completely as the pure water was unable to completely extinguish the flame. Blaze Check 10% solution was able to extinguish the flare without relight in one case immediately upon application. These studies are not definitive and need to be tested with a larger sample size and against a range of different pyrotechnics. However, this could potentially be used to improve options for extinguishment of fires in pyrotechnic processing facilities which are currently limited due to the oxygen source availability in the oxidizer portion of the pyrotechnic mixture making them extremely difficult to extinguish via external means.

Blaze Check 10% Solution Application to Magnesium Shavings Fire

T= 0 s

T= 0.5 s

T= 1 s

T= 2 s

T= 4 s

T= 5 s

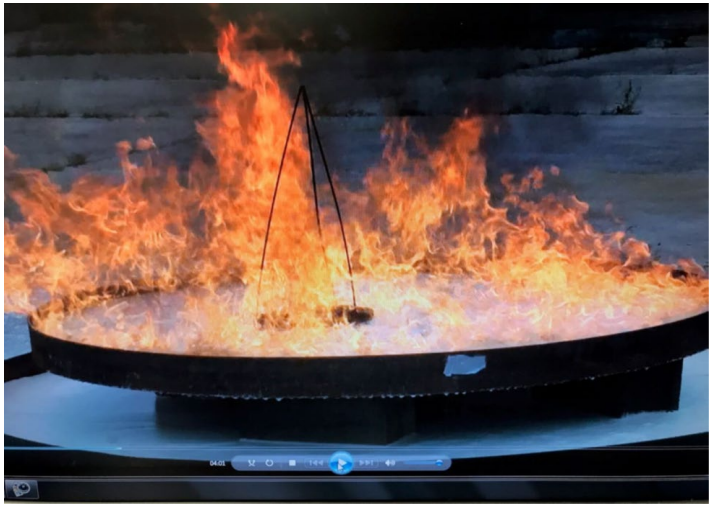
Large Pan Fire Test (28 square Foot Test)

- **Trial 1**: using the 2 gallon per minute discharger with 10% Blaze Check Solution in Fresh Water
  - Result: fire could not be completely extinguished in the 90 second time limit
- **Trial 2**: using a higher discharge rate (15-20 gallons per minute) with a 20% Blaze Check Solution in Fresh Water
  - Result: fire was extinguished in roughly 75 seconds. Burn back test failed to meet the requirement as the entire surface of the pan was reignited once the smaller burnback pan was inserted into the main pan.
  - Clearly a significant amount of fuel was still present in the pan after the first extinguishment.
  - After being allowed to burn for another minute or two, a second attempt to extinguish the burnback fire was conducted using the 2 gallon per minute dispenser required in the test specification and the fire was extinguished in 17 seconds after application of the solution started. After this extinguishment, the fire could not be reignited. The 50 sq ft test was not conducted as no further useful information could be determined.

28 sq foot Fire Pan Test (Trial #2)

Initial extinguishment attempt

Initial extinguishment 75 Seconds



Burn back reignition

Second (final) extinguishment

Conclusions

- Blaze Check was found to be readily miscible in water, have a slightly basic pH, and a kinematic viscosity similar to coconut oil. It was found to be non-corrosive against metal coupons in seawater solution and no trace of Per and Polyfluoroalkyl containing substances was found after analysis with mass spectroscopy.

- Positive indications for Blaze Check performance include the non-corrosive nature of the solution (in fresh or salt water) in contact with metals, the lack of any PFAS detected in the material/non-toxic nature of the material, the relatively cheap cost of the solution, the ability to extinguish Class B fires relatively quickly in small fuel pools (both diesel and gasoline), and some apparent effectiveness in extinguishing metal particle Class D and pyrotechnic fires.

- Further studies for effectiveness against Class A fires are recommended for Blaze Check and other similar types of retardants, although that was not the focus of this study. Further studies for effectiveness against Class D fires are recommended for Blaze Check with safety of use with a water-based solution as part of the evaluation. Study of the heat sink effectiveness of Blaze Check compared to foams would be helpful in determining the ability to cool hot surfaces that contribute to continuation of fires.

Conclusions

- Negative indications for Blaze Check includes the necessity to add and mix significant amounts of the solution with the fuel and the time involved for large Class B fuel pool fires in order to extinguish the flames as seen in the 28 sq ft pan test. Also, with a large fuel pool even if the top layers are passivated, if the fuel below that level is disturbed and brought to the surface by mechanical action the fire can easily restart. This reactivation effect or lack of burn back resistance was demonstrated for large fuel pool fires in the 28 square foot pan burn back tests.

- One source (2) describes the positives and negatives of wetting agent/emulsifiers for firefighting as such: “wetting agents improve the efficiency of water in extinguishing Class A fuel fires. Use on Class B combustibles require higher application rates than those requiring foam agents and is limited to non-water soluble flammable liquids (hydrocarbons only). Little if any burn-back resistance is present on Class B fires extinguished with “emulsifiers or wetting agents.”

- In summary, Blaze Check solution appears to be an effective and safe fire retardant for particular firefighting applications and is deserving of further study.

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- www.blazecheck.net

- (1) Ellern, Herbert ‘Military and Civilian Pyrotechnics’ Chemical Publishing Company; Digital reprint by Rocket Science Institute (2015) edition (December 1, 1968)

- (2) Iffmag.mdmpublishing.com/firefighting-foam-making-water-wetter

- Questions? Contact Mr. Nino Bonavito U.S. Army DEVCOM-CBC (nino.l.bonavito.civ@army.mil) or Mr. Robert Ranck with Paradise Environmental Group at info@blazecheck.net .