Report Warns Against Misleading Assumptions About Firefighting Foams

July 14, 2020 • by Mike Willson/Willson Consulting

A Type II foam test configuration.

Photo by Anton Riecher

Needed since the 1980s, possibly the most comprehensive, rigorous, and valuable series of fire tests the fire industry has seen has recently been completed. One hundred and sixty-five comparative fire tests involving current commercial formulations of Class B Fluorine Free Foams (F3s) have been examined to evaluate their effectiveness against benchmark C6 AFFF fire performance. Results were reported in a frank, open and fair 77-page report published by the US National Fire Protection Association's Research Foundation in January 2020. This summary brings you the key findings of this important study.

NFPA Research Foundation plans, manages, and communicates research on a broad range of fire safety issues in collaboration with leading scientists and laboratories around the world. This research foundation nominated a nine-member technical panel for this project, including the chair of the NFPA 11 Committee, International Association of Fire Chiefs, Factory Mutual (FM), Lastfire, Building and Safety Risk consultants, all working together. They received support from project sponsors including the American Petroleum Institute, several global energy companies and two leading international firefighting foam manufacturers. The research work was conducted by leaders in this field, Jensen Hughes and the US Naval Research Laboratory, both renowned for thorough, comprehensive, transparent and rigorous scientific research of the highest caliber. The fundamental aim of this research is to provide guidance on system design requirements for Fluorine Free Foams (F3s), although results confirmed that will be significantly more complex than many anticipated.

NFPA Findings Endorse Further Research

F3s are increasingly being encouraged for use in frontline firefighting and system design, due to environmental concerns around legacy C8 fluorinated foam contamination. Many users find F3 performance quite variable and unreliable, preferring the superior performance, efficiency, and reliability of environmentally more benign high purity short-chain C6 AFFFs, which cannot degrade into PFOS, PFOA or PFHxS.

This report delivers some interesting findings which supports recent US Naval Research Laboratory testing and others. It potentially requires us to alter our thinking by highlighting potentially increased dangers many have assumed were not there. This particularly relates to some small-scale fire tests we “take for granted” as reliable indicators of emergency fire performance. Such common “assumptions” are now being exposed as not correct, so extra care is now required to ensure we keep people safe, while protecting critical assets and our environment from unnecessary harm in future.

Speed and Effectiveness Underpins Success

We all rely on fast, effective, reliable, efficient firefighting foams to protect us from the catastrophic consequences that have historically resulted from flammable liquid fire incidents. Fluorinated firefighting foams remain the most effective answer for these incidents. Such fire incidents can occur rapidly at aircraft hangars, airports, flammable liquids fueling facilities, refineries, chemical plants, military facilities, large fuel storage tanks, offshore platforms, helidecks, floating fuel production vessels and other locations. Class B foams need to be able to be used non-aspirated and varyingly aspirated, depending on the situation. They also need to be able to be used effectively in both portable and in fixed system applications to provide effective vapor suppression and extinguishment while also preventing re-involvement of these flammable liquid fires.

Important variables were assessed using the renowned Underwriters Laboratories UL162 fire test protocol. This included gentle pouring (Type II) application for polar solvent (water miscible) fuels, and forceful (Type III) applications with fuels including heptane, regular gasoline (MilSpec) and E10 (a 10% mix of Ethanol in gasoline). Six foam types, all UL listed, were tested -- one C6 AR-AFFF (as baseline), three AR-F3s (AR-FFF-1, AR-FFF-2, AR-FFF-3), and two hydrocarbon listed F3s.

Many Areas of F3 Concerns and Deficiencies Highlighted

Different mechanisms influence performance. Some foams form a film and/or blanket of bubbles on the surface of hydrocarbons preventing the fuel vapors and oxygen from interacting and creating a flammable mixture (eg. AFFFs). Testing was led by an experienced third party engineering company – Jensen Hughes (Jerry Back) and the US Naval Research Laboratory (John Farley), highlighting many areas of concerns and deficiencies when compared with the C6 control.

This NFPA report found that “The baseline C6 AR-AFFF included in this assessment demonstrated superior firefighting capabilities through the entire test program under all test conditions. AR-AFFF was also least affected by the range in variables included in this assessment.”

It continued. “The FFFs [AR-F3s] required between two-four times both the rates and the densities of the AR-AFFF to produce similar results against the IPA fires conducted with the [gentle] Type II test configuration.” During [forceful] Type III tests, FFFs [AR-F3s and F3s] required between three-four times the extinguishment density of the AR-AFFF for tests conducted with MILSPEC [regular] gasoline and between six-seven times the density of the AR-AFFF for tests with E10 gasoline [A mix of 10% Ethanol in gasoline].

“Both grades of gasoline (MILSPEC and E10) were much more difficult to extinguish than heptane for all of the FFFs [F3s and AR-F3s] included in this assessment,” the report states.

This gentle Type II application uses a backplate or backboard at which the foam is projected, delivering the foam gently by sliding it down across the polar solvent fuel (IPA) surface, minimizing any mixing. This is recommended for all AR-foams on polar solvent fuels. In contrast, the hydrocarbon Type III forceful application directs foam into the center of the fuel tray until 90% fire control is achieved, as shown in this comparative testing photograph. The firefighter manually directs foam at the remaining fire in the pan while simultaneously cooling the sides until extinction is achieved. Clearly Type III application is a tough test, and more representative of most emergency fire responses on hydrocarbon fuels.

F3s Mostly Struggled at Low Expansion, Frequently Failing Burnback Tests

While F3s managed to extinguish these forceful Type III application fires, several failed the burn-back tests, often on the second torch test. This indicated a weak seal against the tray edge. While the C6 AR-AFFF proved capable of extinguishing heptane and gasoline at 3-4:1 expansion using a two-gallon minimum application density, only one of the five F3s achieved the burn-back test at 2.25-gallon minimum application density using 3-4:1 on heptane. This same F3 required double this density (4.5-gallon minimum application density) at 7-8:1 expansion to pass the same burn-back test using gasoline. Two of these F3s failed to pass this gasoline burn-back test. None of the five F3s tested were able to pass the burn-back test using E10 at 4.5 gallon minimum application density and 7-8:1, while the C6 AR-AFFF passed this E10 burn-back at 3 gallon minimum application density using 7-8:1 expansion. Overall F3 foams failed 76% of the burn-back tests during these fires.

The expansion ratio of F3s plays an important part in its ability to extinguish volatile fuel fires. “Results clearly demonstrate divergent effects with varying foam quality/aspiration on F3 performance,” the report confirmed. The first series of tests used standard test rates at lower expansions (3-4:1) where AFFFs & AR-AFFFs passed, but F3 products failed. “To compensate for this deficiency a 25% to 50% increase in the flow rate/discharge density of lower aspirated foam was required to match the capabilities of higher aspirated foam [7-8:1],” the report states. During testing observations of the tests conducted with the AR-FFFs [AR-F3s] using lower aspirated foam [3-4:1] suggests the foam blanket was unable to contain the gasoline vapors and/or appeared to react with the foam blanket causing the bubbles to break, making the solution look ‘milky’ rather than ‘foamy.’ As a result of this foam breakdown, flames continued to burn along the top of the blanket, even though the fuel was covered with foam,” as demonstrated in Fig. 9.2-3. Such weaknesses were not found with the C6 AR-AFFF benchmark foam. This may be explained by the lack of fuel shedding ability of F3s, and their poorer vapor sealing ability without the inherent benefits of C6 fluorosurfactant additives. Since field equipment in many applications delivers low or no aspiration (eg. airport crash turrets, refinery monitors, offshore platforms), this deficiency was often understood, but sometimes dismissed or overlooked. This irrefutable validation reenforces that most approval standards use higher expansion nozzles delivering higher quality foam that does not always represent “real life”.

Interestingly F3 performances were generally similar whether fresh or salt water was used for testing, as the report’s Figure 9.3-1 confirms. Although a clear extinguishing advantage by C6 AR-AFFF was evident over all the other F3s.

A third AR-FFF3 was introduced later into the program which did approximately 25% better in terms of extinction in a limited number of tests (gasoline and E10 only) compared to both other AR-F3s shown. This third foam failed burn-back tests on both gasoline and E10.

Report Confirms Fixed System Issues - F3s Not “Drop-in” Replacements for C6 AFFF
We are used to seeing many products within a specific foam class (e.g., AFFFs or FPs) having broadly similar performances, so they can be banded together effectively as a group, clearly distinguished from other classes. Surprisingly this seems not to be the case for modern F3s, including AR-F3s.This NFPA Report found that “In general, the firefighting capabilities of the FFFs [AR-F3s and F3s] vary from manufacturer to manufacturer making it difficult to develop “generic” design requirements.” This alone creates tremendous difficulties for recommending bodies that advise flammable liquid protection requirements such as application rate and duration times. These organizations are predominantly in place to safeguard lives and industries. This point was also made by US Naval Research Laboratory research in June 2019 and independent Spanish testing from 2016, confirming considerably greater consistency amongst C6 AFFFs than F3s.

This NFPA report concluded that *“FFFs [AR-F3s and F3s] are not a ‘drop in’ replacement for AFFFs* [AR-AFFFs and AFFFs]. However, some [F3s] can be made to perform effectively as an AFFF alternative with proper testing and design (i.e., with higher application rates/densities).” This confirms the widely held view that significant costs are frequently incurred by such major system modifications, requiring significantly higher application rates, extended discharge durations and specific expansion ratios, with associated increased size or number of foam systems for a given area to enable F3s to be similarly effective. Discharge distance short-falls and necessary extra containment area extensions may prevent implementation due to space constraints. Major capital expenditure and downtime is likely with alternative fire cover requirements or shutdown while such modification and engineering work during transition is completed. Additional risk considerations of accidental and unintended foam discharges of C8, C6 or F3s, could have negative environmental repercussions, and need to be managed using temporary containment arrangements to deliver a result that may still be inferior.

Such testing has re-confirmed the common difficulty of using F3s in existing fixed systems. Application rates must be increased and because of the individual performance characteristics of specific products, substantial modifications, re-engineering and re-design costs required, plus the potential to easily compromise the safety provisions of the orignial system. It also suggests there are no broad design parameters we can use for F3s when building new F3 systems, since individual designs may “lock in” specific products because each behaves differently from others with varying effectiveness on different fuels. Such complexity verifies previous conclusions that F3s are generally not viable alternatives to C6 foams in many situations, particularly large fires and major hazard facilities (MHFs), which are widely defined as including:

- Refineries and chemical/pharmaceutical plants that handle flammable liquids.
- Storage and distribution facilities, tank farms and terminals for flammable liquids, including jetties/marine terminals.
- Flammable liquids in transit by rail, pipeline or road/ship tankers.
- Airports, helidecks, offshore platforms and major transportation hubs.
- All military applications.
- Fixed foam systems and their re-charging to maintain designed safety protection levels.

These further fluorine free foam failures re-enforce the increased exposure to harm and escalation that could accompany their growing use, particularly on volatile fuels and in fixed foam systems where storage limits duration. We should also be wary of over-reliance on small-scale approval tests using heptane, which do not indicate fire performance on gasoline for F3s, as many previously “assumed”, since “the baseline C6 AR-AFFF included in this assessment demonstrated superior firefighting capabilities through the entire test program under all test conditions. AR-AFFF was also least affected by the range in variables included in this assessment.”

F3s Are Not Viable Alternatives to C6 AFFFs

NFPA's clear recommendation confirms "fuel type is a variable that is not covered in our listing/ approval test protocols, and some foams struggle against other fuels (like gasoline) as compared to heptane. The results demonstrated the need to deploy these new FFFs [AR-F3s and F3s] strictly within the listed parameters and hardware." Concluding that ultimately foam users will need to design and install systems within the specifically listed parameters "in order to ensure a high probability of success during an actual incident." This applies not only to discharge devices but also proportioning systems, due to the highly viscous nature of many FFF [AR-F3 and F3] concentrates, again proving F3s are not viable alternatives to C6 AFFFs.

It seems we do need to alter our thinking. We need to avoid misleading assumptions both about inflated capabilities of F3s and over-precaution about C6 foams where persistence concerns really are not as serious as some make out. Bioaccumulation and toxicity issues are absent. Extra care is needed to ensure we keep people safe, protecting critical assets and our environment from unnecessary harm while avoiding any compromises to the fast, effective, efficient, and reliable fire protection that society expects. We take those advantages for granted, until maybe they are not there anymore. Above all else, the specter of unnecessary loss of life lingers.

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