Insight: Fluorinated Foam Concentrates

Recognizing the Risk

Hydrocarbon and polar solvent liquids used in many industries including aviation, transportation, petrochemical, and pharmaceutical can create a severe risk of fire and, complex challenges in fire control. When fires occur with such liquids (classified as Class B fires), water-based fire protection may not be effective and, can actually spread the fire as the burning liquid pool can float on-top of the water. To meet this unique fire control challenge, firefighting foam is frequently used. Unlike water alone, when used properly, these products spread on-top of burning liquids to minimize vapor release to effectively cool and suffocate the fire. Since the invention of firefighting foam more than 70 years ago, there has been global use in many different real-world fire scenarios under varying circumstances and fuels with great success.

The most widely used type of foam today is the low-expansion aqueous film-forming foam (AFFF) and associated alcohol resistant (AFFF-AR) variations. Such products contain fluorinated surfactants and are therefore said to be “fluorinated foams.” The specialized fluorinated surfactants help to create an aqueous film layer that spreads across the burning liquid ahead of the foam, lying between the fuel and the foam blanket. This creates a self-repairing barrier. Unlike other materials, AFFF can be generated without aspiration and therefore can also be easily paired with water-based sprinkler and spray systems for hybrid foam-water fire protection. Relative ease in use, generation equipment, and effectiveness have made AFFF a common choice for many types of global applications.

Legislation and Regulation Affecting Firefighting Foams

Polyfluoroalkyl and perfluoroalkyl chemicals (PFAS) are ingredients in AFFF firefighting foams (and various other materials). PFAS are referred to as long-chain acids and they include perfluorooctane sulfonic acid (PFOS) and perfluorooctanoic acid (PFOA). The use and manufacture of AFFF over many years has resulted in the release of PFAS fluorine chemicals into soil and groundwater (including some underground drinking water sources). New testing technology in the 1990’s began to show that PFAS were environmentally persistent- the high energy bonds between PFAS chemical carbon and fluorine atoms do not easily break down leading to long-term accumulation in both the environment and living organisms including humans. And toxicology studies have now determined the exposure to these chemicals and accumulation in the human body increase the risk of cancer and other diseases.

This information has led to some foam products being phased out with replacement by fluorine-free alternatives. In many cases legislation has required the elimination of older AFFF concentrates with high levels of PFAS in favor of the new generation C6 (Short Chain PFAS) AFFF and fluorine-free alternatives. Concern has primarily focused on long chain PFAS. Firefighting foam concentrates have traditionally been manufactured using fluorosurfactants with carbon chain lengths between 6 (C6) and 12(C12). C6 refers to the length of the fluorosurfactant carbon chain. New AFFF C6 foam formulations (i.e. using fluorosurfactants with 6 or less carbon chains in the formulation) contain only trace amounts of PFAS.

Some PFAS regulations, like those passed in Australia and Washington State in the U.S., do not permit the use of even C6 foams since they still contain some fluorinated ingredients. Other PFAS regulations, such as those in several other U.S. States as well as Canada allow the use of C6 at this time. And the U.S. Environmental Protection Agency negotiated the phase-out of PFOS and PFOA with major manufacturers and issued drinking water health advisories for both substances. Thus, it is foreseeable that additional legislation and/or bans will be adopted in the future as the toxicity of fluorinated substances continue to be researched.

Because of environmental and health risks associated with fluorinated foam and because there are alternatives available that do not have the same level of risk, AIG recommends that fluorine free fire protection options be used wherever possible. This may include the use of other firefighting agents, technology, and mitigating factors. Where the use of foam concentrates is determined to be the most suitable for the application, fluorine free options can include synthetic fluorine-free foam (referred to as FFF or F3), protein foam, or high expansion foam products. Regardless of foam type, installations must follow their UL, FM, or other approval listing, local laws/codes, as well as NFPA 11and/or NFPA 16.

Table 1 Sample of Regulations on Firefighting Foams containing PFAS

Regulation	Territory	Effective Date	Summary
Environmental Protection Water Quality Policy	South Australia	January 2018	Bans fluorinated firefighting foams (new and existing after 2-year grace period) except where exemptions are granted.
ESSB 6413	Washington, U.S.	July 2020	Bans Class B foam discharge for training. Bans manufacture, sale, distribution of PFAS containing foam. Industry exceptions include oil refineries, terminals, chemical plants, and where required by federal law (military aviation, etc.).
SOR/2012-285	Canada	2012	Bans use, manufacture, and sale of multiple types of PFAS including those in firefighting foam and other products and chemicals. An exception is made for foam with trace levels of PFOS. Originally focused on PFOS and has expected to include other PFAS.

Fluorine-Free Firefighting Foams

Protein based fire-fighting foams have been used for decades, but their use was limited due to fuel pick-up or fuel contaminations issues compared to AFFF and other fluorinated foams. High-expansion foams have also been in use for many years but are generally limited to total flooding applications. While both protein and high expansion foams do not contain fluorine, they require specialized foam generating equipment and cannot be added into water-based fire protection systems. These foam concentrates may increase in popularity as the fire protection industry moves away from fluorinated products.

Synthetic, fluorine-free foams (FFF) are relatively new to the firefighting industry. Since the introduction of the first FFF product in the early 2000s, there have been multiple other formulations released, tested, marketed, and also proven through real-world firefighting experience. Ongoing development of fluorine-free products has resulted in some higher quality concentrates providing near equivalent performance to traditional fluorinated foam concentrates. There are currently multiple fluorine-free foam products that meet the performance standards and specifications of most certification standards, including UL 162, FM 5130, EN1568:2008 Parts 3 and 4, ICAO Level B and Level C, LASTFIRE, and IMO – MSC.1/Circ.13.12a.

Like other firefighting foams, there is not one FFF suitable for every application or type of fuel. Research has shown significant variations in performance between manufacturers and fuel types. For example, gasoline and polar solvents create an increased challenge. However, although many can require more water, foam concentrate, and extinguishment time than traditional AFFF products, there are multiple Listed/Approved products for nearly every common foam application.

There are also some known exceptions where FFF cannot meet the performance requirements of a specific design. Such examples include installations where:

- The fuel present falls outside the scope of the listings and certifications of the available FFFs.
- Sub-surface or submerged base injection is required (some storage tank applications.) This limitation is related to the tendency of FFF to “pick-up” or be contaminated with fuel.
- US Military Specification MIL-F-24385F *Fire Extinguishing Agent, Aqueous Film-Forming Foam (AFFF) Liquid Concentrate,For Fresh and Sea Water* is applied. This is due in part to the MIL-Spec requiring the use of fluorinated ingredients to achieve the desired foam properties.

Foam Type Performance Comparisons

A recent study coordinated by the NFPA Fire Protection Research Foundation (NPRF) compared the effectiveness of several commercially available FFF and AR-FFF concentrates to one C6 AR-AFFF concentrate. Results showed significant variation in the performance between different FFF manufacturers with none of them equaling the performance of the AR-AFFF. The performance advantage of the AR-AFFF is attributed to the aqueous film layer that forms over a burning pool in addition to the blanket of foam bubbles that are provided by all foam types. The benefit of this additional extinguishment mechanism is decreased for foams with greater aspiration.

Despite the disadvantage, the NPRF study found that FFF formulations were able to successfully extinguish Class B fires using different types of foam discharge devices, on different fuels, and with different starting temperatures. The tests also showed that the FFF products performed consistently with their UL 162 listings but also highlighted some challenges that prevent it from being a “drop-in” replacement for AFFF:

- FFF’s were found to struggle against some fire scenarios with isopropyl alcohol and gasoline.
- FFF’s required 150-300% of the AR-AFFF application rate to achieve equivalent performance, depending on the manufacturer and level of foam aspiration.
- The FFF application rate to control an isopropyl alcohol and gasoline fires can be significantly greater than for heptane, which is the fuel used for most test standards.

The significant variability in the performance results from the different FFF products highlights the importance that a foam firefighting system be designed and installed in accordance with its specific certification, listing, or approval criteria. This includes using a concentrate, discharge device, proportioner, and other components that are compatible and listed for use in the foam firefighting system. Substitute equipment, mixing of foam concentrates, or other deviations from the requirements could result in reduced reliability and/or limited effectiveness against a fire.

Myths and Marketing

- While there are FFF products that can be used in nearly all applications where AFFF and other fluorinated foam has traditionally been used, there are several prevalent myths that have spread within the fire protection community that have sowed doubt in the technology. In addition, there has been strong marketing of C6 AFFF as the next generation of firefighting foam to replace legacy AFFF products:
- *“Fluorine-free foams are more toxic that AFFF.” MYTH* – All firefighting foam presents some level of toxicity with all types considered either “relatively harmless” or “practically non-toxic.” All firefighting foam also threatens oxygen depletion of waterways to some degree. FFF products present a comparable or lesser hazard that AFFF, on average.
- *“New Pure C6 AFFF formulations are PFAS free.” MYTH* –Trace levels of PFAS continue to be identified by third party laboratory studies on modern C6 foams. More recent research has shown that the fluorine bonds in the C6 formulations may also present an environmental persistence threat and are not as receptive to the same water treatment and clean-up methods as traditional AFFF. While reformulations may have reduced the risk to PFAS, some have required a greater total volume of fluorine containing materials to achieve the same level protection; potentially offsetting any environmental benefit from the reduction of PFAS.
- *“FFF cannot be used with sprinklers.” MYTH* –There are currently FFF concentrates available that are UL Listed and FM Approved for use with select automatic sprinklers.

Resources & Resources

EN 1568 Fire Extinguishing Media – Foam Concentrates – Parts 1-4, (2018)

Environmental Protection (Water Quality) Policy 2015 (South Australia EPA)

Evaluation of the fire protection effectiveness of fluorine free firefighting foams, (Back / Farley, 2020)

Fluorine-Free Firefighting Foams (3F) – Viable Alternatives to Fluorinated Aqueous Film-Forming Foams (AFFF), (IPEN, 2018)

FM 5130 Approval Standard for Foam Extinguishing Systems (2018)

ICAO Doc 9137. Airport Services Manual Part 1 – Rescue and Fire Fighting and ICAO Fire Fighting Foam Testing (ICAO, 2015)

IMO – MSC.1/Circ.13.12a Revised Guidelines for the Performance and Testing Criteria, and Surveys of Foam Concentrates for Fixed Fire-Extinguishing Systems (IMO, 2012)

LASTFIRE Fire Test Specification Revision D (Chisholm, 2015)

NFPA 11, Standard for Low-, Medium-, and High-Expansion Foam

NFPA 16, Standard for the Installation of Foam-Water and Foam-Water Spray Systems

SOR/2012-285 Prohibition of Certain Toxic Substances Regulations, 2012 (Chemicals Management Division, Environment and Climate Change Canada)

Washington State Bill 6413 – 2017-18, Reducing the use of certain toxic chemical in firefighting activities

UL 162 Standard for Foam Equipment and Liquid Concentrates (2018)

*While NFPA documents are the global standard used by AIG, international equivalents may be acceptable.

For more information, contact your local AIG Risk Engineer.