Fire Protection Association

RISCAuthority

# MIGRATION OF FOAM-ENHANCED FIXED SPRINKLER AND DRENCHER SYSTEMS TO USE FLUORINE-FREE ALTERNATIVES

This document has been produced by the RISCAuthority Active Suppression & Detection working group to provide information and outline guidance on the application of foam.

## Summary


Fluorine-containing foams that have become synonymous with the protection of high-hazard liquid fuel risks are in the process of being phased out due to their environmental persistence, bio-accumulation potential, and toxicity. The candidate fluorine-free alternatives are currently less efficient, lacking the chemistry that supports the formation of a surfactant aqueous film over the fuel to seal in vapours. As such, they are more reliant upon the creation of a smothering foam layer, which may require a greater level of aspiration at the nozzle than some sprinkler and drencher systems might be able to provide without significant system redesign and component change. This raises some great challenges for the design and certification of sprinkler and drencher systems where, formerly, the augmentation with foam required only the addition of the dosing mechanism when using foam in a non-aspirated form.

This guide and the accompanying questionnaire seek to assist those with foam-enhanced fixed sprinkler and drencher-type systems to adapt, or reduce, their dependency on fluorine-based foam technologies.


## Contents





## 1 Scope

This document and accompanying questionnaire are designed to assist the user in transitioning their dependency on fluorine-containing firefighting foams to alternative chemical compounds, or consider different suppression technologies entirely. **The focus will be on the change to fluorine-free foam agents (F3), rather than making an assessment of whether, and for how long, current C8 and C6 PFC/PFOS/PFOA chemical technologies may continue to be permitted.** It is not the intention of this paper to restate the current laws in place. The latest updates of EU Commission Regulation (EU) 2017/1000 can be sourced from national government websites.

As was the case following the banning of Halon due to its ozone-depleting properties, the candidate alternatives may be less efficient than the current Aqueous Film Forming Foam (AFFF) technologies and are incapable of being considered 'drop-in' replacements for many applications – it is likely that any change made will need to be accompanied by a system design alteration to make up any identified performance shortfall.

This document is limited to considering Class B fire protection of water-miscible and immiscible liquid fuel foams and does not consider Class A (solid fuel) wetting agents and water additives.

The types of applications considered where foam agents are commonly used include:

- chemical plants
- aviation operations
- highway emergency response
- oil refineries, terminals, and bulk fuel storage farms
- military facilities
- municipal services such as fire departments
- flammable liquid storage and processing facilities.

In these instances the foam may be applied from a range of systems, including:

- handheld extinguishers
- fixed monitors
- fixed tank protection systems
- roof-mounted high expansion systems
- bilge pipes
- drenchers/sprayers
- sprinkler systems.

Whilst the impact in many situations and deployment methods might be minor, such as use in firefighting branches and extinguishers, in other areas, such as use in non-aspirated sprinkler and drencher systems, this will be more problematic. Currently, sprinkler systems are designed and certificated to very specific standards. Their augmentation with foam currently demands no material change to the system aside from the attachment of the dosing mechanism and perhaps bunding for the capture of run-off. If F3 foam requires more aeration than current sprinkler heads can provide, then new sprinkler head/F3 foam certification methods will be required to support the change. **The scope of this document has the limited aim of assisting those with foam-enhanced non-aspirated fixed sprinkler and drencher-type systems to adapt, or reduce, their dependency on fluorine-based foam technologies.**

## 2 Technical background

Firefighting foam agents have become essential to the management of significant liquid fuel risks. Mixed with water, the action of the applied solution is to form a stable foam blanket that spreads over the surface of the fire, sealing off vapours leading to extinguishment, cooling the fuel, and replenishing the aqueous interface layer as the foam breaks down. Maintaining the foam blanket post fire security is assured through the continued suppression of flammable vapours and cooling, thus limiting the incident risk through potential re-ignition of the fuel source.

Whilst a simple concept, the physical surface chemistry behind the development of these foams is complex, requiring the manipulation of the various forces of tension at the fuel/water/air interface so as to allow the establishment of a thin aqueous film on top of the burning fuel that will spread at a controlled rate that does not over-thin the protective layer. Perfluorinated chemicals (PFCs) are fundamental to this foam chemistry.

Fluorine-containing foam firefighting agents have been, or are, in the process of being phased out due to the impact they have on the environment. There are three ways whereby foams may pollute the aquatic environment and lower water quality, namely by their persistence, their propensity to bio-accumulate, and their toxicity. Of the latter, toxic effects may result from the inherent toxicity of the foam product being released, or indirectly due to oxygen depletion, as the foam subsequently biodegrades.

The challenge to remove fluorine from firefighting foams is not an easy one. Fluorinated compounds have always been costly to produce, and fluorine-free alternatives have been sought for many years before the environmental issues were identified and restrictions put in place.

Whilst fluorine-free foams might be termed as 'eco' or 'environmentally friendly', this might misrepresent them. Whether man-made or natural, they will have an impact on the environment and there will always be a need to consult the environmental protection authorities regarding their use, especially in areas where groundwater aquifers are the primary source of drinking water.

In general, fluorine-free foams must currently be applied in much greater quantities, and for greater periods of time, to extinguish a fire when compared with AFFFs. While research is still being conducted, the greatest concern with fluorine-free foams (FFF or F3) is that they are not as effective or as fast at fire suppression as AFFF. For now, that means there's no one-to-one alternative solution for many facilities, and those that can switch to fluorine-free firefighting foams will require some system upgrades or changes to accommodate the differing requirements of fluorine-free foams.

## 3 Recent research example (an extract that highlights the issues well)

The Fire Protection Research Foundation (FPRF) facilitated a test programme to evaluate the fire protection performance and effectiveness of the F3 foams on fires involving hydrocarbon and alcohol fuels. The objectives of this study were to compare the firefighting capabilities (i.e., control, extinguishment and burn-back times) of four F3 foams and one short chain legacy C6 AFFF formulation (as a baseline) over a range of test parameters, including fuel type, water type, and fuel temperature.

A total of 162 tests were conducted, utilising four fuel types: heptane, gasoline, E10 gasoline, and isopropyl alcohol (IPA). To very briefly summarise the results, the legacy C6 Alcohol Resistant AFFF (AR-AFFF) demonstrated superior firefighting capabilities through the entire test programme under all test conditions. The AR-AFFF performed well against all test fuels included in this assessment (which included IPA, heptane, gasoline, and E10 gasoline).

The F3 foams did well against heptane but struggled against the other fuels ( which were IPA, gasoline, and E10 gasoline) especially when the foam was discharged with a lower foam quality and/or amount of aspiration. From an application rate perspective, the F3 foams typically required between 1.5 and 3 times the application rates to produce comparable performance as the legacy AFFF.

When comparing the capabilities of the AR-F3 and Hydrocarbon F3 foams (H-F3), the H-F3 foams typically demonstrated better capabilities. In general, the necessary extinguishment densities for the AR-F3 foams were higher than that of the H-F3 foams.

The testing concluded that due to its properties, legacy AFFF has two separate mechanisms that combine to aid in the extinguishment of anignitable liquid fire: a surfactant film that forms on the fuel surface and a foam blanket, which both serve to seal in the flammable vapours that are burning above the fuel surface resulting in extinguishment.

The F3 foams have only the foam blanket to seal in the vapours. As a result, the capabilities of F3 foams are highly dependent on the characteristics of the foam blanket, which depends on the associated discharge devices as well as the foam type itself.

The test results also show that the legacy fuel (heptane) used to test and approve foams may not be a good surrogate for all hydrocarbon-based fuels. In particular, some foams struggled against other fuels (such as gasoline) as compared to heptane. The report recommended that going forward, the F3 foams should be tested and listed for a variety of hydrocarbon fuels (e.g., gasoline, E10, Jet A, etc.), similar to the approach currently used for polar (AR/immiscible AFFF) solvent listings. In addition, the amount of aspiration and foam qualities (i.e., expansion and 25% drainage) should be included on the listing data sheets.

Ultimately, end users will need to design and install F3 foams within the listed parameters in order to ensure a high probability of success during an actual event. This applies not only to the discharge devices but also to the proportioning systems, too (due to the highly viscous nature of some of the F3 concentrates).

## 4 Key comparative foam parameters

An effective foam system requires the selection of:

- the most suitable foam concentrate for the hazard
- the most effective means of delivering foam onto the fuel surface thereby determining the type of foam discharge devices to be used
- the calculation of the quantities of foam concentrate and water, plus the flows and pressures required
- the form of foam proportioning to be used based on the specific system and site conditions, the availability of water supplies, power, and structural considerations
- and, whilst provisions for fire effluent run-off are not within the remit of the fire protection engineer, these need to be factored into the overall project planning.

When considering a change of firefighting foam, the following aspects demand consideration:

- Equipment/method compatibility
- Material and management system compatibility
- Performance equivalency.

Consideration of these three elements will give rise to a GAP analysis where any identified shortfalls in performance can be addressed by measures that might include the following:

- Proportioning changes
- Proportioning equipment changes
- Nozzles/aeration device changes
- Reconfiguration of risk to improve the efficacy of foam performance
- Other non-related risk control measures to reduce the dependency on the foam system.

### 4.1 Equipment, material, and management compatibility

Foam is introduced to suppression systems in the form of a 'premix solution' of water and foam concentrate. The premix solution will be designed for further dilution and assigned a %. Premix solutions of 1%, 3%, and 6% are common where, for instance, the 3% solution would be mixed or dosed with 3 parts of solution to 97 parts of water for application to a fire. This apportionment can be made in advance, such as in a fire extinguisher, or conducted on system activation using a range of proportioning methods including foam venturi inductors, dosing pumps, and pressurised bag systems. Clearly, the choice of a premix solution has a great impact on the volume of held stores. However, key properties for the introduction of foam into a system on activation are the interrelated parameters of viscosity and temperature. It is imperative that the dosing system is accurately calibrated for the viscosity and temperature of the foam used. Any change in foam used, to one of another viscosity, or a significant change in temperature could cause dosing ratios to be severely affected.

Additional parameters to viscosity that must be considered and compared when replacement with an alternative is considered include the following:

- Shelf life (premix solution and premixed solutions)
- Sea water/potable water compatibility
- Toxicity
- Material compatibility and corrosion
- Viscosity
- Expansion ratio:
  - Low expansion ratio between 2:1 and 20:1
  - Medium expansion between 20:1 and 200:1
  - High expansion >200:1

### 4.2 Performance compatibility

The ultimate test of the ability of the foam to perform will be through testing to identified standards. That said, very careful consideration must be given to the detail of the test and its relevance to the replacement ambition.

In an ideal world, the testing of the foam will be made in association with the same equipment that the end application will use, on a representative fuel load. However, this is often not the case, and an alternative method may be adopted that assesses separately each component that contributes to foam performance:

- Annual chemical testing of the foam to show it has not degraded
- Testing of the equipment to show that it will induct foam at the correct proportions
- Testing of equipment to show the correct expansion is achieved
- Testing of the foam on a stylised fire to determine the requirements.

In turning to standards ratings looking for equivalency, it is very likely that the ratings for the candidate replacement foam, and the one it seeks to replace, will have been achieved through the use of differing application rates, expansion ratios, and equipment.

Current standards appropriate to firefighting form standards are listed in Appendix A:

A.1 UL 162 – Foam Equipment and Liquid Concentrates
A.2 ICAO Levels A, B, and C – Onshore Civilian Airports
A.3 EN 1568: 2018 Parts 1–4 – Fire extinguishing media. Foam concentrates
A.4 IMO Maritime Organisation MSC.1/Circ.1312 and MSC Circ.670
A.5 CAP 437 – Offshore helicopter landing areas
A.6 LASTFIRE – Hydrocarbon Storage Tanks
A.7 MIL-F-24385 – Military Specification (US)
A.8 NFPA 11: US Standard for Firefighting Foam
A.9 BS EN 13565: Fixed firefighting systems. Foam systems – Part 1: Requirements and test methods for components and foam systems and Part 2: Design, construction, and maintenance
A.10 NFPA Foam compatibility

## 5 Replacement strategy

The options for a foam replacement strategy are as follows:

- Remove the need for using foam
- Change the risk so that a less efficient unaspirated foam can still do the job required
- Change the protection configuration so that the delivery of the fluorine-free foam may be optimised without major changes to the sprinkler/drencher system
- Change the sprinkler/drencher system design so that fluorine-free foams may be used on an equivalent basis as the ones they replace (unaspirated)
- Change the system to an aspirated foam-water deluge system.

Depending upon the specific circumstances of the installation, the cost benefit of each option may be different.

### 5.1 Designing out the need for the foam augmentation of the sprinkler system

This option will be very dependent upon the specific application but might include options such as the following:

- Management risk reconfiguration – lessen storage quantities by splitting locations or the use of just-in-time store management systems to a point where foam enhancement might be unnecessary
- Address fuĕl spills and fire by another means entirely
- Increase the 'water-only' capability of the system by increasing the delivered density
- In association with other measures, use a different extinguishing technology altogether (such as gaseous, watermist, or hypoxic systems).

### 5.2 Change the risk so that a less effective foam can still do the job required

Liquid fuel fire challenges are characterised by the size of the burning pool area. If the application allows for the alteration of the floor profile to direct spilled fuel to a sump or bilge, then the rate of burning can be controlled extensively to a much smaller area. This benefits fire extinguishment in the form of a reduced fire challenge and a focal point for foam/fuel convergence.

### 5.3 Change the protection configuration so that delivery of the fluorine-free foam may be optimised without major changes to the sprinkler/drencher system

In this option, the requirement for foam delivery is removed altogether from the sprinkler/drencher system and given over to a floor or bilge-mounted secondary system. The advantage of this approach is that the secondary system can be optimised entirely to the requirements of the foam in terms of delivery equipment, aeration, flows, and pressures; foam is delivered directly to where it needs to be, and the sprinkler system remains certificated. NB – there will need to be confirmation that the operation of the overhead system does not prematurely break down the foam introduced at the floor/bilge level.

### 5.4 Change the sprinkler/drencher system design so that fluorine-free foams may be used on an equivalent basis as the ones they replace (unaspirated)

Anyone seeking to replace the foams used within their sprinkler or drencher system will be highly dependent upon the foam supplier to demonstrate the following:

- Equivalency of all foam properties (physical and performance) if a drop-in replacement is proposed
- The revised sprinkler/drencher system design in association with the suggested foam replacement provides equivalent performance.

In terms of sprinkler system design and certification, the second option is currently uncharted territory and will, therefore, need to be supported by significant experimental evidence of being fit for purpose.

Engagement with the insurer of the facility will be essential.

### 5.5 Change the system to an aspirated foam-water deluge system

With the currently accepted shortcomings of using F3 unaspirated, the system could be redesigned as an aspirated deluge system using the listed certificated dosing rates for the candidate replacement foam.

## 6 Questionnaire

Having established the background challenges to the replacement of traditional fluorine foams with fluorine-free alternatives, this questionnaire is designed to assist the user elicit the information required to facilitate the change without compromising the performance of the system.

Table 1 – Replacement strategy

Table 2 – Details of the current foam installation

Table 3 – Details of the candidate foam option

Table 4 – Supplier questions

Table 1 – Replacement strategy

| Replacement Strategy | | |
|---|---|---|
| Is there an opportunity to redesign the risk or management strategy so that foam is no longer required? (See Section 5.1) | Yes ☐ | No ☐ |
| If yes, describe | | |
| Is there an opportunity to redesign the risk so that the use of a less efficient foam might be acceptable? (See Section 5.2) | Yes ☐ | No ☐ |
| If yes, describe | | |
| Is there an opportunity to deliver foam by an alternative means than the sprinkler or drencher system? (See Section 5.3) | Yes ☐ | No ☐ |
| If yes, describe | | |
| Is the only option to redesign the sprinkler system to use the fluorine-free foam and make the engineering adaptations accordingly to give equivalent performance to the fluorine foam that has been replaced? (See Section 5.4) | Yes ☐ | No ☐ |
| If yes, describe foam that has been replaced? | | |
| Can the system be redesigned to be an aspirated foam-water deluge system? (See Section 5.5) | Yes ☐ | No ☐ |
| If yes, describe | | |

Table 2 – Details of the current foam installation

| Current Installation Details | | |
|---|---|---|
| Foam name: | | |
| Foam manufacturer: | | |
| Induction rate: | | % |
| Specific gravity: | | |
| pH @20°C: | | |
| Viscosity at 20°C: | | |
| Max. continuous storage temp: | | °C |
| Max. intermittent storage temp: | | °C |
| Freezing point: | | °C |
| Effect of freeze/thaw: | | |
| Lowest use temperature: | | °C |
| Expansion ratio (nominal): | | >x:y |
| 25% drainage time: | | hours/minutes/seconds |
| Certifications held: | | |
| Application by (select): | | Sprinkler system ☐<br>Deluge system ☐ |
| Dosing system used (select): | Venturi inductor ☐<br>Positive pressure pump ☐ | Foam bag ☐<br>Premixed ☐ |
| Water supply (select): | | Potable ☐<br>Sea water ☐ |
| Aspiration in use (select): | No ☐<br>Medium expansion 20:1 to 200:1 ☐ | Low expansion 2:1 to 20:1 ☐<br>High expansion >200:1 ☐ |
| Fuels protected (select type): | | Immiscible/hydrocarbon ☐<br>Miscible/polar/alcohol resistant ☐ |
| Fuels protected (name): | | |

Table 3 – Details of the candidate foam option

| Details of the Candidate Alternative Foam | | |
|---|---|---|
| Foam name: | | |
| Foam manufacturer: | | |
| Induction rate: | | % |
| Specific gravity: | | |
| pH @20°C: | | |
| Viscosity at 20°C: | | |
| Max. continuous storage temp: | | °C |
| Max. intermittent storage temp: | | °C |
| Freezing point: | | °C |
| Effect of freeze/thaw: | | |
| Lowest use temperature: | | °C |
| Expansion ratio (nominal): | | >x:y |
| 25% drainage time: | | hours/minutes/seconds |
| Certifications held: | | |
| Suitable for use with: | Fresh water ☐<br>Sea water ☐ | |
| Suitable for use on fuels (select): | Immiscible/hydrocarbon ☐<br>Miscible/polar/alcohol resistant ☐ | |
| Suitable for named fuels (list): | | |

Table 4 – Supplier questions (extracted from FIA guidance)

| Supplier questions: Fire performance | | |
|---|---|---|
| What international standards does the foam concentrate comply with? | | |
| What third-party test certificates are available to support the statements on compliance (as above)? | | |
| Is the testing on the specific fuel that the end user has, or is it based on the type of fuel? | Yes ☐ | No ☐ |
| If compliance is on polar solvent fuel fires, is the testing for the specific foam equipment in use or based just on the type of fuel (alcohol, ketone, etc.)? How was the foam applied in these tests and does it equate to the equipment type existing in your facility? If not, request data or conduct additional testing that does. | | |
| If foam concentrate is to be used in a system with non-aspirated sprinkler heads or spray nozzles, what rates of application are being recommended as the minimum rates of application? | | |
| Do these rates of application differ from those recommended with the previously supplied foam concentrate? | | |
| What test data is available to support the rates of application as above? | | |
| Can the supplier confirm that the foam concentrate is compatible with the hardware that it will be used with? | Yes ☐ | No ☐ |
| **Supplier questions: Compatibility and suitability for use with hardware** | | |
| Can the supplier confirm that the foam concentrate is compatible with the hardware that it will be used with? | Yes ☐ | No ☐ |

| Supplier questions: Compatibility and suitability for use with hardware | | |
|---|---|---|
| What test data is available to support the compatibility statements as above? | | |
| | | |

| Supplier questions: Environmental compliance | | |
|---|---|---|
| Is the supplier offering a PFAS (Fluorinated)-based foam concentrate or a Fluorine-Free foam concentrate? | PFAS ☐ | F3 ☐ |
| Can the supplier confirm that the offered foam concentrate is in compliance with the latest Commission Regulation (EU) 2017/1000? | Yes ☐ | No ☐ |
| What data is available to support the compliance statements made? | | |
| | | |

| Supplier questions: Compatibility of foam agents | | |
|---|---|---|
| Is the foam concentrate compatible physically? | Yes ☐ | No ☐ |
| Is the foam concentrate compatible chemically? | Yes ☐ | No ☐ |
| If compatible, what is the impact on the fire performance of the resulting mixture? | | |
| | | |
| If compatible and foam concentrates are mixed, does the resulting mixture comply with the post 4 July 2020 PFOA levels required in Regulation (EU) 2017/1000? | Yes ☐ | No ☐ |

## Appendix A – Standards (draft for completion)

### A.1 UL 162 – Offshore Platforms

UL 162 is an internationally recognised test method carried out by UL Solutions (Underwriters Laboratory), an independent not-for-profit organisation:

- UL 162 requires a 50 sq ft heptane fire with a pre-burn of 60 seconds to be extinguished at an application rate of 1.63L/m$^2$ using a freeze-protected foam with potable (fresh) and sea water.
- This is a pass or fail test.
- UL listed products are monitored with samples being sent to UL every 3 months for conformance testing. This guarantees the foam being supplied is the same formulation as was originally tested – no other test standard requires this monitoring.

### A.2 ICAO Levels A, B, and C – Onshore Civilian Airports

In the UK, the CAA (Civil Aviation Authority) requires a foam concentrate for use in civilian airports to be tested using potable (fresh) water to ICAO (International Civil Aviation Organization) Level A, B, or C:

- ICAO (International Civil Aviation Organization)-approved products are not conformance monitored after accreditation.
- ICAO Level A requires a 2.8m$^2$ fire to be extinguished at an application rate of 4.1L/min/m$^2$.
- ICAO Level B requires a 4.5m$^2$ fire to be extinguished at an application rate of 2.5L/min/m$^2$.
- ICAO Level C requires a 7.32m$^2$ fire to be extinguished at an application rate of 1.75L/min/m$^2$.
- All levels require a heptane fire with a 60-second pre-burn using potable (fresh) water.

### A.3 EN 1568: 2018 Parts 1–4 – European Standard

BS EN 1568: 2018 is a European Standard that critically tests a foam for both extinguishment and burnback in sea and potable (fresh) water.

BS EN 1568-1: 2018:

- This applies to medium-expansion foam for use on water-immiscible liquids.
- This is a pass or fail test.

BS EN 1568-2: 2018:

- This applies to high-expansion foam for use on water-immiscible liquids.
- This is a pass or fail test.

BS EN 1568-3: 2018:

- This applies to low-expansion foam for use on water-immiscible liquids.
- It requires a 4.52m$^2$ heptane fire with a pre-burn of 60 seconds to be extinguished.
- This is not a pass or fail test – concentrates are allocated grades of performance:
  - Extinguishment: Grades I+, I, II, and III
  - Burnback resistance: Grades A, B, C, and D
  - I+A is the highest achievable grade.

BS EN 1568-4: 2018:

- This applies to low-expansion foam for use on water-miscible liquids.
- It requires 1.72m$^2$ acetone and isopropanol fires with a pre-burn of 120 seconds to be extinguished.
- This is not a pass or fail standard – concentrates are allocated grades of performance:
  - Extinguishment: Grades I and II
  - Burnback resistance: Grades A, B, and C
  - 1A is the highest achievable grade.

### A.4 IMO Maritime

The IMO (International Maritime Organization) has two testing standards – IMO MSC.1/Circ.1312 and MSC Circ.670. These standards ensure that the foam used at sea is fit for purpose and takes into consideration performance with sea water induction and temperature conditioning (accelerated ageing):

- The standards are now required by many maritime administrations and classification bodies for foam concentrates to be used on board ships in international waters and have arisen as part of the implementation of the SOLAS Convention (Safety of Life at Sea).
- IMO MSC.1/Circ.1312 sets out the testing protocols and acceptance criteria for the testing of low-expansion foam concentrates. For further information, please visit the IMO website.
- IMO MSC Circ.670 sets out the testing protocols and acceptance criteria for the testing of high-expansion foam concentrates. For further information, please visit the IMO website.

### A.5 CAP 437 – Offshore Helidecks (UK)

For UK offshore helidecks, the standard adopted by the Civil Aviation Authority (CAA) is CAP 437 – Standards for Offshore Helicopter Landing Areas, Chapter 5, paragraph 2.6:

- Unfortunately, CAP 437 requires compliance to at least ICAO Level B using foam tested in sea water and freeze-protected – a standard that does not exist!
- However, CAP 437, paragraph 2.6 does allow the foam manufacturer to advise on performance – Oil Technics (Fire Fighting Products) Ltd recommends UL 162 as the preferred foam concentrate standard for offshore helidecks.
- For further information on CAP 437, please visit the CAA website.
- Information on the UK HSE recommendations for the testing of Offshore helideck foam production systems can be found on the HSE website.

## A.6 LASTFIRE – Hydrocarbon Storage Tanks

On behalf of a consortium of 16 oil companies, a project was initiated in the late 1990s to review the risks associated with large diameter (greater than 40m), open-top floating roof storage tanks. The project was known as the LASTFIRE project (Large Atmospheric Storage Tanks)

- The project was initiated due to the oil and petrochemical industries' recognition that the fire hazards associated with large diameter, open-top floating roof tanks were insufficiently understood to be able to develop fully justified site-specific fire response and risk reduction policies.
- Part of this project was to develop a foam testing protocol in order to assess a foam's capability to achieve the special performance characteristics relevant to large storage tank firefighting.
- The LASTFIRE test was rapidly established as a standard for this severe application and has been included as a requirement in foam concentrate procurement specifications by major international oil companies.
- For further information, visit the LASTFIRE website.

## A.7 MIL-F-24385 – Military Specification (US)

MIL-F-24385 is a US Military Test Specification that critically tests AFFFs for both extinguishment and burnback in sea and potable (fresh) water:

- MIL-F-24385 is a similar test to EN 1568, but the results are highly operator dependent and, more importantly, it is a very expensive test to have done!
- Requires a 4.68m$^2$ heptane fire with a pre-burn of 10 seconds to be extinguished at an application rate of 1.62L/min/m$^2$ using foam with potable and sea water.
- For further information, please visit: https://quicksearch.dla.mil/qsSearch.aspx

## A.8 NFPA 11: US Standard for Firefighting Foam

NFPA 11 is an internationally recognised US Standard for Low-, Medium-, and High-Expansion Firefighting Foam:

- The standard was introduced by the National Fire Protection Agency (NFPA).
- The current revision is NFPA 11: 2021.
- NFPA 11 covers the design, installation, operation, testing, and maintenance of low-, medium-, and high-expansion foam systems for fire protection.
- Criteria apply to fixed, semi-fixed, or portable systems for interior and exterior hazards.
- NFPA 11 stipulates that both foam concentrates and foam proportioning systems should be tested at least annually. For further information on foam testing, please visit www.nfpa.org/codes-and-standards

## A.9 BS EN 13565: Parts 1 and 2

BS EN 13565-1 and BS EN 13565-2 are internationally recognised European Standards regarding Fixed Firefighting Foam Systems.

BS EN 13565 Part 1: 2019:

- The standard was introduced by the European Committee for Standardization (CEN) in 1998.
- The current revision is BS EN 13565-1: 2019.
- BS EN 13565-1: 2019 covers the requirements and test methods for components of fixed firefighting systems that use foam concentrates.
- Section 5 of the standard refers to the accuracy of the foam system's proportioning components and stipulates that produced foam shall be "not less than the rated concentration" and "not more than 30% above the rated concentration or 1 percentage point above the rated concentration (whichever is less)."
- For further information on produced foam testing, please visit: https://www.firefightingfoam.com/foam-testing/produced-foam-testing/

BS EN 13565 Part 2: 2018:

- The standard was introduced by the European Committee for Standardization (CEN) in 2004.
- The current revision is BS EN 13565-2: 2018.
- BS EN 13565-2: 2018 covers the design, construction, and maintenance of fixed firefighting systems that use foam concentrates.
- Section 11 of the standard refers to required annual inspections of foam systems, and it stipulates that "a test of the proportioner and associated fittings" shall be done annually and "the accuracy of the foam proportioning shall be in accordance with the tolerance given in EN 13565-1."
- Section 11 also stipulates that the quality of stored foam concentrates shall be annually checked "by competent and trained foam laboratory personnel."
- For further information on foam concentrate testing, please visit: https://www.firefightingfoam.com/foam-testing/foam-concentrate/

## A.10 NFPA Foam compatibility NFPA 11

NFPA 11: 2021 Edition makes the following recommendations:

- "Different types of foam concentrates shall not be mixed for storage." (Para. 4.4.1.1)
- "Different brands of the same type of concentrate shall not be mixed unless data are provided by the manufacturer ... to prove that they are compatible." (Para. 4.4.1.2)

**Foam compatibility**

In accordance with NFPA 11: 2021, quality foam concentrates of the same type from different suppliers can be mixed, provided that the supplier presents a Certificate of Compatibility (C of C).

Compatibility testing consists of:

- freeze/thaw ageing
- physical property evaluation
- fire tray performance testing.

To be given a C of C, the foam concentrate should show no reportable adverse reactions.

For further information, or to request a copy of any of our Certificates of Compatibility, please visit: https://www.nfpa.org/Codes-and-Standards