



Guidance paper on fluorine-free foam in sprinkler systems

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Introduction

Fluorine-containing organic compounds (compounds which contain carbon) have been shown to be very stable, breaking down very slowly when released to the environment. This is unsurprising since the fluorine-carbon bond is very strong. While there would anyway be concern about the persistence of these compounds in the environment and their potential accumulation in the food chain and in our bodies, some have also been found to be harmful to human health. This has led to pressure to stop their manufacture and use.

These man-made chemicals are collectively known as PFAS (per- and polyfluoroalkyl substances). There are thousands of PFAS, all persistent and some harmful. The first to be studied by regulators was the eight carbon chain PFOS (perfluorooctanesulfonic acid) and its salts, produced by electrochemical fluorination. However, before any regulatory restrictions were introduced 3M, the main manufacturer of these compounds, announced a phaseout of their manufacture in 2000. Their phaseout of the manufacture of PFOS by 3M meant that company, which invented aqueous film-forming foam (AFFF), also stopped selling AFFF. PFOS were subsequently banned in fire-fighting foam by 2010.

Other companies used a different process, telomerisation, to manufacture fluorosurfactants, using PFOA (perfluorooctanoic acid) and precursors. These were also banned. For some time there was a hope that the shorter, six carbon chain fluorosurfactants, PFHxS (perfluorohexanoic acid and perfluorohexanesulfonic acid), could replace the longer carbon chain fluorosurfactants in AFFF. That hope has ended, with these compounds also found to be persistent. In Europe the fire protection market has accepted that AFFF will no longer be sold and foam manufacturers now offer a range of non-fluorinated foam concentrates. However, extensive testing has shown that these new foam concentrates are not drop-in replacements for fixed fire-fighting systems.

The next generation of non-fluorinated foams are often termed synthetic fluorine-free foam (SFFF) or fluorine-free foam (FFF or F3).

This guidance paper addresses the European use of non-fluorinated foam in closed-head sprinkler systems (foam-sprinkler systems). Foam is also used by firefighters, in portable fire extinguishers, and in fixed systems using discharge devices other than closed-head sprinklers (e.g. monitors, foam pourers, sprayers and deluge sprinklers). European standards are being developed and guidance written for these applications. This paper is intended to fill the gap for foam-sprinkler systems.

Applications of foam-sprinkler systems

AFFF has been widely used in certain applications to enhance the performance of sprinkler systems. The film-forming ability of AFFF aids in the protection of ignitable liquids and its reduction of the surface tension of water helps it adhere to solid surfaces and to penetrate solid masses. While in some cases water alone is unable to provide adequate protection, in others a design with AFFF can use a lower application density. Examples of applications are:

- Storage of combustible and flammable liquids
- Waste recycling centres
- Storage of tyres
- Car stackers

International Regulations

Under the United Nations Environment Programme countries came together to agree the Stockholm Convention on Persistent Organic Pollutants (POPs),¹ a global treaty signed by 152 countries, including all EU and EEA countries, Turkey and the UK, although not Japan or the US. The treaty lists various POPs and progress made in their elimination or restriction. PFOA and PFHxS are on the list of substances to be eliminated, while PFOS is currently to be restricted. Most European legislation relating to PFAS (and hence fire-fighting foams) was justified by and in response to the commitment of all EU countries to this international convention. The EU is moving faster and further than the convention by also eliminating PFOS.

EU Regulations

The European Chemicals Agency (ECHA) is responsible for regulating the safe use of chemicals in the European Union. It has coordinated European legislation to restrict and eliminate PFAS in fire-fighting foam. Several European Regulations have been published which affect the manufacture and use of fire-fighting foam.

The European Commission published a Regulation in 2017² which from 4 July 2020 banned the manufacture and placing on the market of PFOA in products at a concentration above 25 ppb. In 2017 such a low concentration could not be measured but this is now possible.

Before the 2020 ban on new sales took effect, in 2019 the European Union published a Regulation on persistent organic pollutants³. It has since been subject to 11 amendments. This Regulation now sets a deadline for the use of PFOA already sold, *'By way of derogation, the use of PFOA, its salts and PFOA-related compounds shall be allowed in fire-fighting foam for liquid fuel vapour suppression and liquid fuel (Class B fires) already installed in systems, including both mobile and fixed systems, until 4 July 2025, subject to the following conditions'*; it then makes clear that the foam cannot be used for training and that all releases must be contained. Point 24 of Article 3 of Regulation (EC) No 1907/2006 defines 'use' as *'any processing, formulation, consumption, storage, keeping, treatment, filling into containers, transfer from one container to another, mixing, production of an article or any other utilisation'*.

In 2024 the European Commission published another Regulation⁴ that affected fire-fighting foam. It concerns the use of PFHxA (undecafluorohexanoic acid), its salts and PFHxA-related (six carbon chain) substances in the European Union. With the banning of the eight carbon chain PFOA and PFOS, the market had switched to six carbon chain fluorosurfactants in AFFF. From 10 April 2026 this Regulation bans the placing on the market of PFHxA and its salts and their use at a concentration above 25 ppb in fire-fighting foams for training and testing, except for functional

¹ Stockholm Convention on Persistent Organic Pollutants, adopted by the Conference of Plenipotentiaries on 22 May 2001

² Commission Regulation (EU) 2017/1000 of 13 June 2017 amending Annex XVII to Regulation (EC) No 1907/2006 of the European Parliament and of the Council concerning the Registration, Evaluation, Authorisation and Restriction of Chemicals (REACH) as regards perfluorooctanoic acid (PFOA), its salts and PFOA-related substances

³ Regulation (EU) 2019/1021 of the European Parliament and of the Council of 20 June 2019 on persistent organic pollutants, Official Journal of the European Union, Brussels. Consolidated 17 October 2024.

⁴ Commission Regulation (EU) 2024/2462 of 19 September 2024 amending Annex VII to Regulation (EC) No 1907/2006 of the European Parliament and of the Council as regards undecafluorohexanoic acid (PFHxA), its salts and PFHxA-related substances

testing of fire-fighting systems where all releases are contained. This is a ban on the use of AFFF by firefighters for training and testing. From the same date the Regulation also bans the use of AFFF by public fire services unless for the control of major accident hazards involving dangerous substances (as described in the Seveso Directive⁵). Moreover, from 10 October 2029 AFFF shall not be placed on the market, or used, for civil aviation. The restrictions in this paragraph have no effect on fixed fire-fighting systems.

We now know by when the use of existing stocks of AFFF will need to be replaced in civil aviation. In practice there is pressure to replace AFFF in all foam systems earlier since if a system is discharged, it may not be possible to refill it with AFFF. The risk would then not be adequately protected and it may be difficult to obtain insurance. Insurers might also not provide cover against liability from leaks of AFFF. Furthermore, in some countries national bans on AFFF are in place or planned. Many foam manufacturers have already stopped selling AFFF in Europe.

The regulatory situation continues to evolve. For example, there is a proposal to extend the deadline to 3 December 2025 for the use of PFOA already installed in systems (another five months) to give end users more time to find replacements and another to raise the limit for PFOA concentration to 10 ppm in existing systems after cleaning them and replacing the foam.

A complete ban on all PFAS substances used in fire-fighting foam is also underway, and, in November 2024, ECHA announced that the document is set for adoption in the second quarter of 2025, which should provide the following transition periods:

- 18 months for its use for training, testing and municipal fire services;
- 5 years for all other uses such as in civil aviation, new ships and air and land-based defense;
- 10 years for its use in establishments covered by Directive 2012/18/EU (Seveso sites), for installations belonging to the offshore oil and gas industry, military ships and civil ships already in service.

Furthermore, a 1 ppm limit for PFAS content in the foam agent as well as a maximum 50 ppm contamination level for the foam system, after cleaning, is proposed.

This last proposal would make it viable to clean pipework and some equipment. Whilst perhaps not cost effective for short sections, and tank bladders will most likely need replacement, this could make transition easier but needs case-by-case evaluation and it is imperative that the compatibility of the new system components and the non-fluorinated foam is attested.

Non-fluorinated foam

Non-fluorinated foam does not work in the same way as AFFF. In particular, it does not spread a film of water on water-immiscible liquids. This feature of AFFF allowed it to spread across a burning liquid and prevent the evaporation of combustible vapour, even if it did not actually form a foam. In this way AFFF was a very forgiving technology and in foam-sprinkler systems the expansion ratio was not critical.

That is very different for non-fluorinated foam, where the expansion ratio is critical and testing has shown that some sprinklers give better foam quality than others. In Europe, although not in

⁵ Directive 2012/18/EU of the European Parliament and of the Council of 4 July 2012 on the control of major-accident hazards involving dangerous substances, amending and subsequently repealing Council Directive 96/82/EC

the US, any differences between one sprinkler and another had been assumed not to be significant when it came to their use in AFFF foam-sprinkler systems. This assumption can no longer be made for non-fluorinated foam, meaning that only tested combinations of foam and sprinkler should be used. Testing has also shown that it is not possible to predict the performance of a non-fluorinated concentrate on one flammable liquid group from its performance on another group. Instead the foam concentrate has to be tested on each liquid group to be protected. This requires careful assessment for systems that are to protect buildings and other facilities where a range of flammable liquids could be present.

Non-fluorinated foam concentrates can have very different physical properties from one manufacturer to another and can be much more viscous than AFFF concentrate. The only way to be sure that they are correctly proportioned (dosed) into the sprinkler system water flow is to use a proportioning system tested for the non-fluorinated concentrate at the range of potential flow rates the system could discharge (first sprinkler up to the design area of operation).

In summary the foam concentrate and discharge device need to be tested together on each combustible liquid group to be protected. Furthermore, the proportioning device should be tested over the range of flow rates for which the sprinkler system is designed.

Hydraulic calculations

Non-fluorinated foam can be much more viscous than AFFF, both in concentrate form and in solution. Higher viscosities may mean that the pipe network of an existing system, or parts of it, is under-dimensioned to flow SFFF and its solution. In some cases pipework may need to be replaced.

SFFF viscosity also varies with shear rate, falling as the shear rate increases (shear-thinning). Alcohol-resistant AFFF concentrate displayed a similar behaviour but it can be more pronounced in SFFF concentrate. Higher viscosity and shear-thinning behaviour of the SFFF premix is a new phenomenon, not observed with AFFF solutions. While this effect may not have much impact on pressure loss for a SFFF solution flowing at high velocity (i.e. high shear rate), it can be significant at low velocity, such as in a sprinkler system riser or main. Therefore, unless the manufacturer can provide flow curves to show that the viscosity of the concentrate and its solution are close to that of water, hydraulic calculations of SFFF and its solutions should not be performed with the Hazen-Williams formula used for sprinkler systems. Hazen-Williams is limited to Newtonian fluids (not shear-thinning) with a viscosity similar to water⁶.

Instead, the Darcy-Weisbach formula should be used. Flow curves from the manufacturer for the concentrate and the solution at its design concentration should be used to determine the viscosity to find the friction factor for the Darcy-Weisbach formula. The other parameter to find the friction factor is the pipe roughness factor. Research by VdS in pipework of existing systems concluded that the pipe roughness factor should be 0.14 mm, instead of the more conservative 0.5 mm in CEA 4001.

⁶ Diskin, M. H. (1960). The Limits of Applicability of the Hazen-Williams Formula. *La Houille Blanche*, 46(6), 720–726

Recent studies⁷ provide information about the accuracy of different fluid models when applied to non-fluorinated foam concentrates and set out how pressure drop calculations can be carried out. There are still some unanswered questions regarding the application in sprinkler systems, such as how the fluids behave in turbulent areas at high Reynolds numbers and whether the k-factors of sprinklers change with the shear rate of the foam solution. The EFSN hopes that with further research these questions will soon be resolved.

Standards and guidance

Europe does not have a test standard for non-fluorinated foam in foam-sprinkler systems, nor does it have a standard for the design of foam-sprinkler systems. The European standard for the design of other foam systems is EN 13565-2⁸. An amendment to EN 13565-2 is being drafted by Working Group 2 (Foam extinguishing systems) of CEN Technical Committee 191. The proposal is to reference UL 162, FM 5130 and VdS 3896 as possible test protocols for all applications of non-fluorinated foam, including in foam-sprinkler systems. For UL 162 the design application density is to be 60% higher than used in the test, in accordance with the design guidance given in UL listings. VdS 3896 was based on UL 162 but does not apply the 60% safety factor and limits the installation of sprinklers to a height of 4.5 m.

The proposed amendment clarifies that retesting of approved products is unnecessary and that the design application density, sprinkler identification number (SIN) and any height restrictions can be taken from the UL, FM and VdS approval listings/certificates, or from the manufacturer's data sheet. EFSN advises that other key design criteria, such as the area of operation and duration can be taken from NFPA 11⁹, the VdS certificate combined with VdS CEA 4001, or FM data sheet 4-12¹⁰. NFPA 11 advises that the design density should be the highest of 6.5 mm/min (as for AFFF), the listing density (UL) or the density for the occupancy specific standard. Certain markets, end users or insurers will have a preference for NFPA/UL, FM or VdS so stakeholders should be consulted.

Meanwhile NFPA 30¹¹ is in its revision cycle and under Annex A.16.4.2.4 to Chapter 16 on storage has proposed the following caution, '*Note that the pool fires used in UL 162 and FM 5130 testing do not mimic what can be encountered in a full-scale containerized liquid fire test. Two- and three-dimensional flowing spills and jet flames are not encountered during UL 162 and FM 5130 testing.*' Full-scale fire testing is therefore needed to determine whether a SFFF can protect such hazards and at what design density.

⁷ David J. Meyer, Luis Herrera Diaz, Bogdan Z. Dlugogorski, Rheological properties of solutions of fluorine-free foams, *Fire Safety Journal*, Volume 141, 2023, 103910, ISSN 0379-7112, <https://doi.org/10.1016/j.firesaf.2023.103910>. (<https://www.sciencedirect.com/science/article/pii/S0379711223001789>)

⁸ EN 13565-2:2018+AC:2019 Fixed firefighting systems – Foam systems – Part 2: Design, construction and maintenance, CEN, Brussels, Belgium, 2019

⁹ NFPA 11 Standard for Low-, Medium-, and High-Expansion Foam, NFPA, Quincy, MA, USA, 2024

¹⁰ FM Property Loss Prevention Data Sheet 4-12, Foam Extinguishing Systems, FM, Johnston, RI, USA, 2023

¹¹ NFPA 30 Flammable and Combustible Liquids Code, NFPA, Quincy, MA, USA, 2024

The European sprinkler system design standard, EN 12845¹², does not offer design guidance for foam-sprinkler systems, nor does its draft revision, prEN 12845-1. Under CEN rules a standard cannot specify design criteria for each manufacturer of foam concentrate with each manufacturer of sprinkler. Yet as explained, performance is unique to each combination. The solution will probably be to adopt an approach similar to water mist, where a CEN fire test protocol is published and a CEN design standard sets out how to use the results from the fire testing to design a foam-sprinkler system. The EFSN has proposed that Working Group 5 (Sprinkler systems and components) of CEN Technical Committee 191 (Fixed firefighting systems) draft a separate part of EN 12845 to address this, e.g. EN 12845-4, but at present WG5 is focussed on the revision to EN 12845 and related documents. Meanwhile designers should refer to criteria from NFPA, UL, FM and VdS.

Existing systems

While the guidance above sets out how to design a new foam-sprinkler system, there are more questions around existing systems, where a conversion to a system using non-fluorinated foam will require more than draining, cleaning and refilling a tank. While the proposed relaxation to 10 ppm of PFOA and 50 ppm for PFAS in reused components may make cleaning possible, this is a specialised cleaning process that requires specialist contractors – it is not simply a matter of repeated flushing, and any flushing solution itself then becomes a controlled waste product which cannot be discharged into wastewater sewers.

Until and unless this relaxation is approved, if AFFF is to be replaced in a foam-sprinkler system that uses an atmospheric tank the tank will probably also need to be replaced. If a bladder tank was used for the AFFF the bladder should be replaced with a new bladder from the bladder tank manufacturer that is compatible with the non-fluorinated concentrate.

All foam concentrate pipework from the tank to the proportioner should be replaced where decontamination is unlikely to be economically or technically viable. As non-fluorinated foam often has a higher viscosity than AFFF, coupled with a need to avoid contamination of the new foam, it is likely that the proportioner will need to be replaced. Recalibration for any change in viscosity will always be necessary.

Often a premix exists in the sprinkler system pipework downstream of the proportioner. This should be drained, retained and processed as waste. This pipework should also be replaced unless testing for PFAS concentration after flushing/cleaning shows decontamination to an acceptable level. Note that the stability of non-fluorinated foam premix has not yet progressed to that for AFFF.

Summary and next steps

The EFSN advises readers to plan now for their transition from fluorinated foam, ahead of a discharge or any deadline. A key point to remember in this process is that non-fluorinated foam is not a drop-in replacement. Systems will need some redesign and probably some components will need to be replaced, as will the foam concentrate itself. It is essential that the sprinklers and

¹² EN 12845:2015 Fixed firefighting systems – Automatic sprinkler systems – Design, installation and maintenance, CEN, Brussels, Belgium, 2015

foam concentrate are tested in combination on the liquid to be protected; testing has thrown up many unexpected results and it is unsafe to make assumptions about performance.

Proportioning devices may need adjustment, and proof that they operate accurately over the flow range of the foam-sprinkler system for the foam concentrate in question.

It may be possible to clean and retain parts of the system but this is specialist work and simple flushing will not suffice. Meanwhile any contaminated water from the system and the cleaning process cannot be disposed of as normal wastewater.

Systems should be configured to deliver foam quickly and make pre-mixes unnecessary. If a pre-mix is required its stability will need verification.