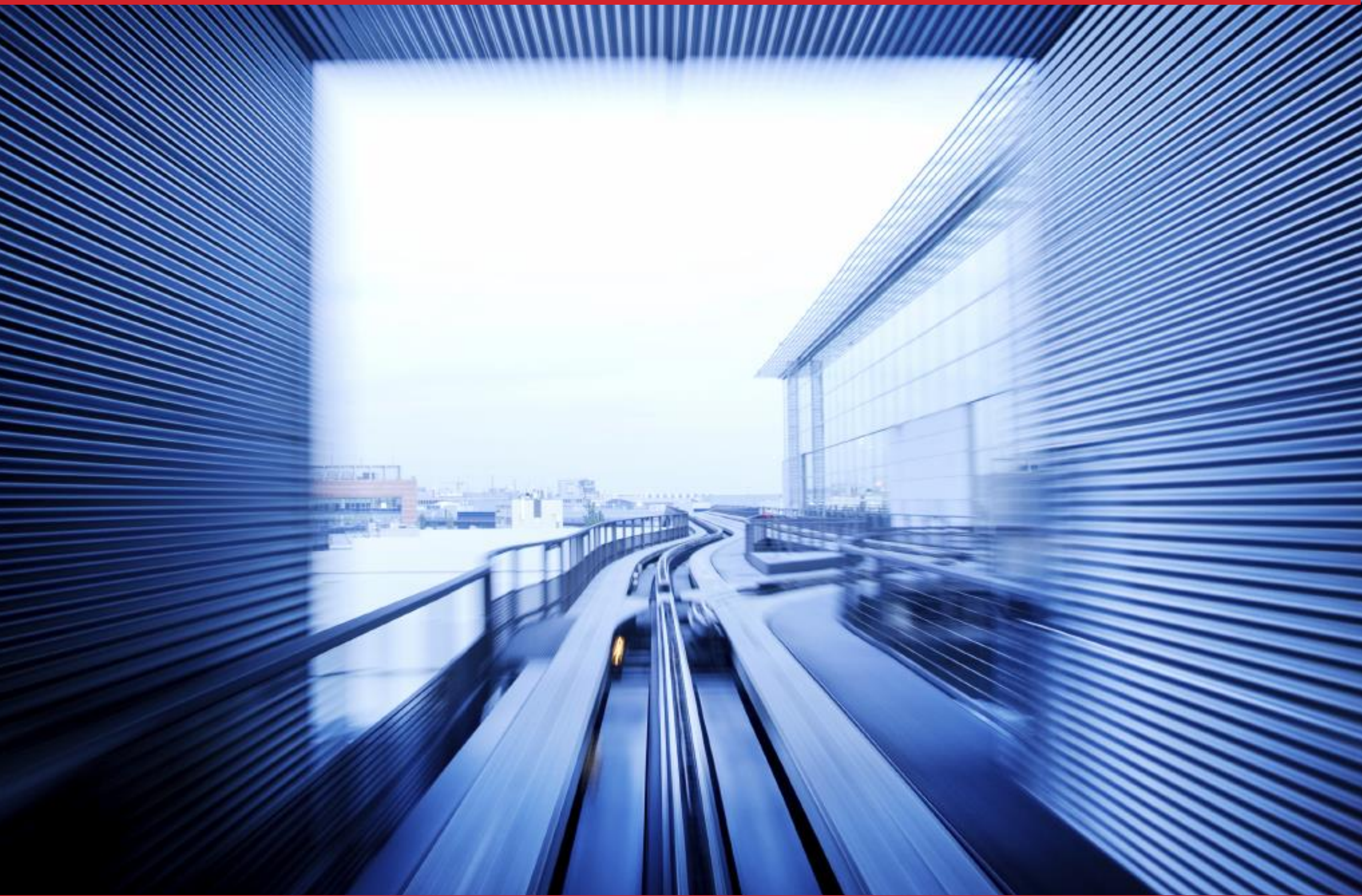
Information Bulletin

IB 06

Selection and use of firefighting foams



FPA AUSTRALIA

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1 Purpose statement

The purpose of this document is to increase awareness of the issues surrounding the selection and use of firefighting foams based on their:

- Firefighting performance;
- Environmental impact; and
- System and equipment compatibility.

This Information Bulletin also provides information on the different types of firefighting foams, suggestions for environmental best practice, as well as general recommendations for the selection and use of firefighting foams.

NOTE: The content of this Information Bulletin is informed by the real world experiences of our members as well as significant local and international research in this area, see Section 11 "References".

2 Audience

This Information Bulletin is intended for:

(i) FPA Australia members;

(ii) Users of firefighting foams, including owners of facilities protected by foam systems and response agencies who use firefighting foam; and

(iii) Other stakeholders involved in the selection and use of firefighting foam, including manufacturers, suppliers, installers and maintainers of fire protection systems and equipment that use firefighting foam.

3 Abbreviations

Abbreviations are used extensively in this Information Bulletin to make the document easier to read.

Refer to Appendix A for a list of these abbreviations.

4 Background

Firefighting foam is an effective suppression agent for preventing, extinguishing or controlling fires involving flammable liquids (Class B fuels). Its use can significantly reduce the risk to life, property, environment and business disruption from such fires. Also, in addition to limiting the growth and impacts of a fire, use of these foams also reduces the amount of noxious and harmful breakdown products—including known carcinogens—released by the fires on which they are used.

Firefighting foam is used in fixed and portable fire extinguishing systems as well as fire brigade apparatus. Firefighting foam is produced by mixing foam concentrate with water to produce foam solution. This solution can either be applied:

- Non-aspirated (through water nozzles, sprinklers or deluge nozzles, provided the foam is suitable for application through these devices); or
- Aspirated (when the foam solution is mixed with air through dedicated foam making devices; such as, a foam branch pipe, top pourer, foam cannon, foam sprinkler or high expansion generator).

The application of firefighting foam to liquid fuel fires suppresses the release of flammable vapours, separates flames from the fuel, blocks the supply of oxygen to the fuel and cools the fuel surface.

The environmental acceptability of different types of firefighting foam has been a topic of increasing global discussion in recent years, with particular focus on the properties of fluorinated versus fluorine free foams (F3 foams). Whilst a vast amount of environmental information is now available in the public domain, FPA Australia is concerned that much of this information focusses on environmental issues in isolation of other key factors such as firefighting performance, firefighter safety and system compatibility.

FPA Australia recognises that fire protection products and practices must be environmentally responsible. In fact, protecting the environment is a fundamental part of the Association's Vision. However, FPA Australia contends that acceptable fire life safety, fire protection and environmental outcomes cannot be achieved by consideration of any single performance characteristic. All the characteristics and properties of a product or system must be considered holistically to reach a well-informed view as to which product or system is best suited for a particular application. FPA Australia contends that the decision to select and use a particular type of foam should only be made after careful consideration of a range of factors, including:

- Firefighting performance;
- Protection of personnel (both firefighters and the community);
- Potential adverse environmental impacts;
- Compatibility with the fixed or portable fire systems in which it is to be used;
- Compatibility with existing foam concentrate in storage;
- Compatibility with materials (e.g. potential tank/pipework corrosion and seal materials);
- Compatibility with existing proportioning equipment; and
- Cost.

This document is intended to provide a balanced overview of the key issues which impact on the selection and use of firefighting foam. Only by careful consideration of all these key criteria can foam users make an informed decision as to which type of foam is most suitable for their current and future needs.

5 Factors impacting on selection and use

Three main factors must be considered when assessing the selection and use of firefighting foam:

- Firefighting performance;
- Environmental impact; and
- System/equipment compatibility.

5.1 Firefighting performance

Firefighting foam is used to prevent, control and extinguish fires. The firefighting effectiveness of a foam must be a prime consideration for its selection and use.

To be effective, a firefighting foam must:

- Rapidly spread over the fuel surface;
- Cool the fuel surface;
- Resist mixing with the fuel;
- In the case of polar solvent (water miscible) fuels, resist attack from or breakdown by the fuel;
- Suppress the release of flammable vapours;
- Resist breakdown due to radiant heat; and
- Provide protection from re-ignition and flash-back.

A high level of firefighting performance is essential to protect life, property and the environment. High level firefighting performance facilitates:

- Rapid fire extinguishment;
- Reduced potential for fire spread;
- Reduced release of toxic products of combustion;
- Reduced usage of water and foam;
- Reduced risk to the life safety of responding firefighters and the community; and
- Reduced volume of firewater effluent (foam and products of combustion).

It is essential that the firefighting performance of any foam being considered for use—irrespective of whether it is a fluorinated or fluorine free foam—is independently tested and certified to relevant and recognised standards.

Poor firefighting performance will result in fires being more difficult to extinguish and burning longer. This, in turn, will result in an increased release of toxic and carcinogenic products of combustion into the environment. Contaminates in firewater runoff have a direct adverse impact on the environment, so minimising the quantity of water used to extinguish a fire is also essential to minimising environmental impacts. Additionally, use of a foam with inferior firefighting performance can adversely affect the safety of firefighters and the wider community.

There are a range of firefighting performance test standards which, depending upon the intended application, can be used to demonstrate the suitability of a foam for a particular application. Some commonly used test standards are listed in Clause 6.2.

Demonstrated evidence of firefighting performance—to the relevant test standard, using representative fuels and operating conditions—is essential in selecting the most suitable firefighting foam for a particular application.

5.2 Environmental impact

FPA Australia supports efforts to reduce the adverse impacts that fire and firefighting activities have on the environment. Appropriate selection and use of firefighting foams is important as some firefighting foams do have a greater environmental impact than others by virtue of their chemical composition.

It must be clearly understood, however, that <u>all</u> firefighting foams and firewater runoff have the potential to pollute the environment. Short-term effects can be expressed in terms of acute toxicity and Biochemical Oxygen Demand (BOD). A comparison of foams published in 2006 by the Fire Fighting Foam Coalition (FFFC) indicated that, in terms of acute effects, F3 foam concentrates fell into the 'Slightly Toxic' category while fluorinated foam concentrates were categorised as 'Relatively Harmless'.

Regardless of the type of firefighting foam used, it is also extremely important to consider the environmental impact from the combustion products of the fire itself. Whilst it is difficult to quantify the environmental impact of an individual fire, it is clear that extinguishing a fire as quickly as possible will reduce adverse environmental effects resulting directly from the fire. Using a foam with superior firefighting performance can minimise the amount of foam and water required and will result in less firewater effluent whilst also reducing the quantity of combustion products released, potentially reducing adverse environmental impacts.

Failure to adequately consider the firefighting performance of a foam may result in selection of a foam that is ineffective for the intended application, increasing the adverse environmental impacts from a fire incident whilst also increasing the risk to life safety of both firefighters and the community.

For more information on environmental impact, see Section 6.

5.3 System and equipment compatibility

Fire testing protocols for firefighting foams evaluate performance under representative conditions for the application in question, including, extremes of ambient temperature, the fuel type and the aspiration ratio available from discharge devices.

Use of a firefighting foam which has not passed the fire testing protocols applicable to the fire protection system or equipment that it is to be used in may increase the risk to life, property and the environment from a fire incident. Its use may also have serious implications for product/system approvals and insurance cover.

It is important to remember that firefighting foams form only one part of a system and a decision to change the type of foam used should not be made without considering the impact of that change on the complete system.

Before making a decision to change the type of firefighting foam used, consultation with key fire protection stakeholders, especially foam system designers and manufacturers, is essential to ensure the performance of the system will not be adversely affected.

Important factors that must be considered include:

- Viscosity of the foam concentrate (Newtonian and thixotropic);
- Suitability for use with existing proportioning hardware;
- Homogeneous mixing of concentrate with water;
- Compatibility with materials in the system (e.g. plastic, rubber seals, metals, etc.);
- Stability of foam concentrate or pre-mix solution (separation, stratification, sedimentation);

- Suitability for use on the flammable liquids in question;
- Suitability of application method (aspirated, non-aspirated, forceful, gentle);
- Extremes of ambient temperature that may be encountered in an incident;
- Suitability of the expansion ratios produced by existing equipment for effective firefighting performance; and
- Suitability of the application rates produced by existing equipment for effective firefighting performance.

6 Environmental and firefighting performance indicators

A range of methods exist to assess the environmental impact and firefighting performance of firefighting foams. Some of these are detailed below.

6.1 Environmental performance indicators

Scientific measures used to assess the impact of chemicals include Biochemical Oxygen Demand (BOD), Chemical Oxygen Demand (COD) and aquatic toxicity. These factors have an influence on the likely short-term impacts of the chemical. Guidance values that can be used to quantify the biodegradation of a chemical's environmental impacts are provided below:

- Short-term: ≤ 40% within 7 days
- Long-term: ≥ 65% within 28 days

BOD/COD profiling identifies the biodegradability and de-oxygenating characteristics of chemicals in the environment. Chemicals that biodegrade rapidly can suffocate organisms by consuming available oxygen, as can larger quantities of high BOD chemicals in the environment.

Other factors, as detailed below, are also used to establish whether a chemical has other environmental or health effects that necessitate high levels of concern and/or control.

6.1.1 UN Stockholm Convention

The Stockholm Convention on Persistent Organic Pollutants (POP), an international treaty signed in 2001 and effective from May 2004, aims to eliminate or restrict the production and use of POPs. Australia is one of 179 parties who are signatories to this convention. Australia ratified the Convention on 20 May 2004 and became a party to it on 18 August 2004.

Perfluorooctanyl Sulfonate (PFOS) was added as a POP to the Convention in 2009 (see Clause B1).

The Persistent Organic Pollutants Review Committee (POPRC) established by the Convention developed a procedure for the consideration of individual substances. To qualify as a POP, a substance must meet all four of the following criteria:

- **(P) Persistence in the environment**
  - (i) Evidence that the half-life of the chemical in water is greater than two months, that its half-life in soil is greater than six months, or that its half-life in sediment is greater than six months; or
  - (ii) Evidence that the chemical is otherwise sufficiently persistent to justify its consideration within the scope of the Convention.
- **(B) Bio-accumulation**
  - (i) Evidence that the bio-concentration factor or bio-accumulation factor in aquatic species for the chemical is greater than 5000 or, in the absence of such data, that the octanol-water coefficient (K_{OW}) is greater than 5; or
  - (ii) Evidence that a chemical presents other reasons for concern, such as high bio-accumulation in other species, high toxicity or eco-toxicity; or
  - (iii) Monitoring data in biota indicating that the bio-accumulation potential of the chemical is sufficient to justify its consideration within the scope of the Convention.

- **(T) Toxicity**
  - (i) Evidence of toxicity or eco-toxicity data that indicates the potential for damage to human health or to the environment.
- **(LRET) Potential for Long-Range Environmental Transport**
  - (i) Measured levels of the chemical in locations distant from the sources of its release that are of potential concern; or
  - (ii) Monitoring data, modelling or environmental fate properties showing that LRET of the chemical, with the potential for transfer to a receiving environment, may have occurred via air, water or a migratory species.

If a substance meets each of the above criteria, risk profiling is used to evaluate whether, as a result of its LRET, a substance is likely to lead to significant adverse human health and/or environmental effects and therefore warrants global action. If global action is warranted, a risk management evaluation is undertaken reflecting socio-economic considerations associated with possible control measures and the substance is listed under the appropriate annex of the convention. Annexes include:

- Annex A – Elimination;
- Annex B – Restriction; and
- Annex C – Unintentional production.

The legacy C8 foam fluorosurfactant PFOS became a listed POP in 2009. Perfluorooctanoic Acid (PFOA) has been accepted for listing as a POP by the Stockholm Convention POPRC and is expected to be added, with Perfluorohexane Sulfonate (PFHxS) likely to follow.

In May 2019, the Conference of the Parties (COP-9) accepted the revision that the Stockholm Convention "*Encourages* Parties and others to use alternatives to PFOA, its salts and PFOA-related compounds, where available, feasible and efficient, while considering that fluorine-based fire-fighting foams could have negative environmental, human health and socioeconomic impacts due to their persistency and mobility."

The Committee recognised that some time may be needed for a transition from long-chain C8 PFAS to alternatives.

6.2 Firefighting performance indicators

As previously highlighted, it is important to consider the firefighting performance and system compatibility of any foam when considering changing to a different foam from that currently used.

There are a number of local and international standards that are used to rate the firefighting performance of foam. These include, but are not limited to the latest versions of:

(i) Australian Standards

- AS/NZS 1850, *Portable fire extinguishers – Classification, rating and performance testing*;
- AS 5062, *Fire protection for mobile and transportable equipment*; and
- DEF(AUST) 5706, *Foam Liquid Fire Extinguishing, 3 percent and 6 percent concentrate*.

(ii) International Standards

- EN 1568, *Fire Extinguishing Media – Foam Concentrates* (Parts 1, 2, 3 & 4);
- EN 13565, *Fixed Firefighting Systems – Foam Systems* (Parts 1 & 2);
- International Civil Aviation Organisation (ICAO) Fire Test Method, Doc 9137 — *Airport Services Manual,* Part 1 — *Rescue and Fire Fighting*;
- NFPA 11, *Standard for Low-, Medium-, and High-Expansion Foam*;
- UL 162, *Standard for Safety for Foam Equipment and Liquid Concentrates*;
- Mil-PRF-24385F(SH) Amendment 2, *Fire Extinguishing Agent, Aqueous Film Forming Foam (AFFF) Liquid Concentrate, for Fresh and Sea Water*; and
- Factory Mutual 5130 (foam enhanced sprinklers).

In addition to these test standards, there are a number of listing or product certification schemes that provide independent evaluation of fire protection products, including firefighting foams. Evidence of suitability from such listing bodies should be sought to confirm the firefighting performance of a foam on the fuels to be protected; with the type of equipment to be used; and, under the conditions likely to be experienced on the site. When considering the use of product that has been listed or certified, it is important to check the basis for listing or certification and that this includes testing to a standard relevant for the intended application.

The performance parameters identified as a result of testing to these standards will typically include:

- Time to achieve extinguishment;
- Burn-back resistance; and
- Speed of knockdown and vapour control.

Recognising that some current international standards do not detail recommended application rates and operational duration for modern fluorine free (F3) foams, NFPA and UL in the USA have both started testing programs to determine effective recommended application rates for F3 foams in comparison to AFFFs.

Recent NFPA research into the effectiveness of fluorine free firefighting foams found that in comparison to the C6 AR-AFFF foam baseline used (and noting some variability in the capability of the 5 F3 foams tested) all F3 foams tested required much higher application rates and density to achieve similar results to C6. The F3 foams also required higher expansion ratios to enhance their performance.

This research also found that heptane, which works as an 'equivalent' to gasoline for C6 foams, does not work as an 'equivalent' to gasoline for F3 foams. The reasons for this were identified in a previous US Naval Research Laboratory (NRL) that identified aromatic components within gasoline as the source of the increased difficulty in gasoline fire suppression compared to heptane fire suppression using F3 foams. This NRL research also recommended a more appropriate test fuel for F3 foams so that, like C6 foams, one fuel can be used in testing and cover multiple fuels/applications.

As such, while the performance of F3 foams has improved, further testing is demonstrating specific factors that need to be considered in standards relating to firefighting foams and in selecting F3 foams.

Also, it is important to note that these factors and more need to be considered in selecting <u>any</u> firefighting foam—whether a C6 or F3 foam—to be used in a new or existing system. In particular, no foam should be considered a "drop-in" replacement in an existing system; its suitability must be confirmed.

Selection needs to consider all of the system and equipment compatibility factors listed in Clause 5.3, above, and evidence of its suitability should be demonstrated by testing to a relevant standard, or listing or certification that includes testing to a relevant standard.

Also, given the ongoing evolution of firefighting foams (particularly F3 foams), consideration should also be given to any new research (like the NFPA and NRL research above) as well as the real-life performance of specific foams in major fire incidents, as valuable additional indicators of potential firefighting performance and environmental behaviour.

7 Environmental Regulations

Regulation and restriction of undesirable legacy C8 PFAS chemicals is increasing around the world in response to legacy site contamination of soils, groundwater, human blood levels, food and drinking water where there was intensive use at specific locations for decades (e.g. airports, defence sites and fire brigade training areas). Specific high profile site contamination has led to a legacy requiring clean up and management, but it is believed to be restricted to legacy C8 PFAS (e.g. PFOS, PFOA, PFHxS).

7.1 NICNAS (National Industrial Chemicals Notification and Assessment Scheme)

NICNAS, a branch of the Australian Government's Department of Health, helps protect the Australian people and the environment by assessing the risks of industrial chemicals and providing information to promote their safe use.

It makes recommendations about chemicals to other government agencies responsible for the regulation of industrial chemicals, collects data on the use of industrial chemicals in Australia and ensures Australia meets its obligations under international agreements about chemicals.

NICNAS advice includes:

- The Inventory Multi-tiered Assessment and Prioritisation (IMAP) Environmental Tier II Risk Assessment for C6 PFAS, which sets its status as Persistent, not Bio-accumulative, not Toxic; and
- The IMAP Human Health Tier II Risk Assessment's occupational and public health risk characterisations for C6 PFAS, which concluded "C6 chemicals are not considered to pose an unreasonable risk to workers health" and "the public risk from direct use of these chemicals is not considered to be unreasonable".

7.2 PFAS National Environmental Management Plan (NEMP) – EPA

The PFAS NEMP was developed by Australian State and Territory Environmental Protection Authorities (EPA) & the New Zealand EPA and was implemented in February 2018. It includes extensive guidance notes designed to help governments, industry and the community identify, monitor and respond to PFAS contamination.

The NEMP includes the following:

- All PFAS (C8 and C6) to be covered;
- Requirements for PFAS monitoring and assessment, plus site evaluation and prioritisation;
- Defined measurement techniques for PFAS and environmental levels indicating a need for action;
- Guidance on how to deal with sites contaminated with PFAS: waste, transport and treatment, with information sharing across Australia;
- Requirements for updating of the NEMP as an evolving document to incorporate emerging new data;
- Requirements for evaluation of the NEMP's effectiveness, and future research towards future revisions;
- Definition of key trigger values for soil investigation, biota guideline values, landfill acceptance and health based drinking/recreational water values; and
- Requirements for collection, separation, treatment, destruction of all PFAS.

7.3 Queensland—Environmental Management of Firefighting Foam – Operational Policy (QLD Foam Policy)

The first PFAS regulation in Australia, this policy was implemented in Queensland by the Department of Environment and Science in July 2016.

The QLD Foam Policy requires:

- Immediate removal of PFOS legacy foams from service;
- Containment and control measures for all PFAS foams so none enters the environment;
- Phase out of fluorinated firefighting foam where primarily the perfluorinated part of the carbon chain is longer than or equal to 7 carbon atoms (C8 foams) within 3 years;
- Preference for F3 foam use wherever possible, but acceptance where this can be demonstrated not possible that C6 foams with a purity of >99.5% could be used providing there is complete collection and containment of all foam solution, firewater runoff and wastes in impervious dikes, with proper and safe disposal. This includes accidental spills and the testing/maintenance of fixed and mobile equipment;
- High temperature (>1,100°C) disposal of all fluorinated organic wastes (including firewater runoff);
- Containment of non-persistent F3 foam wastes, wherever possible, using all reasonable and practical measures to minimise environmental harm;
- A 10 parts per million (ppm or mg/L) limit of PFOS/PFHxS residual contamination in replacement firefighting foam stock;
- A 50 ppm limit of PFOA, precursors and higher homologues (≥ C7) contamination in replacement foam stock; and

- Full compliance required of all foam users implementing F3 foams by July 2019 (extension by negotiation and documented progress, if necessary for major industries).

7.4 South Australia—Environment Protection (Water Quality) Policy 2015 (SA WQ Policy) – Amendment banning PFAS foam use – Implemented January 2018

This policy covers all firefighting foam uses from portable extinguishers to fire trucks and fixed foam systems in South Australia.

The SA WQ Policy includes:

- A ban on the use of all fluorinated firefighting foams for all applications with a timeframe of two years for compliance for all non-handheld applications by January 2020.

  This ban applies to hand-held applications (portable extinguishers) upon re-charge or re-fill or within two years of commencement of the policy, whichever is earlier;
- Provisions to address PFAS contamination in existing equipment;
- Certification of fluorine concentrations in foam to be provided by suppliers;
- That EPA SA may consider an exemption application by demonstrating assessment of actions already taken and proposed to be taken plus a justification why F3 foams cannot currently be used at the site.

7.5 USA

A number of States in the USA are passing or considering legislation to restrict the use of PFAS foams, particularly for training purposes (where most usage occurs), but allowing continued use of PFAS based foams for major hazard facilities (e.g. California, Colorado, New Hampshire, New York, Virginia and Washington).

The National Defense Authorization Act also provides restrictions from 2024.

7.6 Canada

An exemption has been made which allows the use of fluorine free foams at Canadian airport.

8 Different types of firefighting foam

Firefighting foams can be broken into two broad categories:

- Foams that contain fluorinated surfactants; and
- Foams that are fluorine free.

However, there are also individual foam types within these two broad categories.

Commonly used firefighting foam types are better known by the following terms:

- **Fluorinated Foams**
  - AFFF—Aqueous Film Forming Foam
  - AR-AFFF—Alcohol Resistant Aqueous Film Forming Foam
  - FP—Fluoro-Protein Foam
  - FFFP—Film Forming Fluoro-Protein Foam
  - AR-FFFP—Alcohol Resistant Film Forming Fluoro-Protein Foam
- **Fluorine Free Foams**
  - F3—Fluorine Free Foam
  - AR-F3—Alcohol Resistant Fluorine Free Foam

> **Note:** High-expansion, protein, Class A and most training foams are, and always have been, fluorine free.

8.1 Fluorinated firefighting foams (C8 and C6 Foams)

8.1.1 Overview

Historically, fluorinated firefighting foams include small quantities of perfluorinated and polyfluorinated compounds (PFCs) or Per- and Poly-fluoroalkyl Substances (PFAS), as they are more commonly called.

Perfluorooctanyl sulfonate (PFOS) and perfluorooctanoic acid (PFOA) are two of the most common PFAS-based products derived from a range of precursors which were contained in older legacy C8 foams.

C8 foams have good firefighting performance but have Persistent (P), Bio-accumulative (B), Toxic (T) and Long-Range Environmental Transport (LRET) characteristics, all of which are undesirable and have a significant negative environmental effect and a potential to harm human health.

Note: C8 foams—dependant on the specific formulation—may contain substances such as PFOS, PFHxS, PFOA and PFOA precursors.

C6 foams may contain trace levels of PFOA, which are unavoidably produced by the manufacturing process, but these foams are acceptable under the US EPA PFOA Stewardship program and the Registration, Evaluation, Authorisation and Restriction of Chemicals (REACH) Regulation (EU) 2017/1000, see Clauses 8.1.2 and 8.1.3.

C6 foams are persistent but are neither bio-accumulative, nor toxic and are of low concern to human health and the environment.

Further detail on health concerns and the phase out of legacy C8 foams and replacement C6 foams is provided in Appendix B.

8.1.2 US EPA PFOA Stewardship Program

The United States Environmental Protection Agency (US EPA) Voluntary PFOA Stewardship Program (2006-2015) aimed to eliminate PFOA content by 2015 from the surfactants manufacturing processes, products and waste streams by transitioning from C8 surfactants to environmentally more benign C6 surfactants. US EPA reports confirm this was achieved.

Note: For more information on the US EPA PFOA Stewardship Program, see https://www.epa.gov/assessing-and-managing-chemicals-under-tsca/and-polyfluoroalkyl-substances-pfass-under-tsca#tab-3.

8.1.3 REACH Regulation (EU) 2017/1000

Foam manufactured or supplied in Europe must comply with the REACH Regulation (EU) 2017/1000.

This Regulation permits C6 foams to include up to:

- 25 parts per billion (ppb or µg/L) of PFOA including its salts, or
- 1,000 ppb for one or a combination of PFOA-related substances.

Firefighting foams already in use are exempted from this impurity restriction, so C8 foams purchased before July 2020, could still be used until their expiry date and be compliant with this European Union (EU) Regulation. This Regulation has a 3 year transition period, becoming effective from July 2020 (i.e. completed by July 2023).

Note: For more information on the Registration, Evaluation, Authorisation and Restriction of Chemicals (REACH) Regulation (EU) 2017/1000, see https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32017R1000&from=EN.

8.1.4 Summary of fluorinated firefighting foams (C8 and C6 foams)

Fluorinated firefighting foams should not be grouped as a single class in terms of their environmental properties. C6 foams compliant with the US EPA PFOA Stewardship Program and REACH Regulation (EU) 2017/1000 have distinctly different environmental and human health characteristics to C8 foams that contain PFOS or PFOA. As such, US EPA PFOA Stewardship Program and REACH Regulation (EU) 2017/1000 compliant foams should not be subject to the same level of restriction or environmental controls as those imposed on legacy C8 foams.

Further detail on health concerns and the phase out of legacy C8 foams and replacement C6 foams is provided in Appendix B.

8.2 Fluorine-free firefighting foams (F3 foams)

8.2.1 Overview

In response to the environmental concerns with PFOS and PFOA fluorinated foams and as a result of European and US reforms, F3 foam technology has advanced in recent years and modern F3 foams are available in both the Australian and international markets.

F3 foams do not contain persistent fluoro-surfactants and play an important role in fire protection and training. However, as a general rule, they do not provide the same level of firefighting performance as C8 foams or C6 foams. Typically, F3 foams do not provide the same fuel shedding, film forming characteristics, vapour sealing or burnback resistance, which can be vitally important to rapid extinguishment of fires in some applications. These properties are particularly important in industrial and petrochemical applications as well as incidents where the foam is applied forcefully, as is often inevitable in emergency incidents.

However, it must be noted that F3 foams are available which have been certified to test standards including UL 162, ULC, FM, ICAO, EN1568, IMO and LASTFIRE. As is the case with all foams, users should verify that the foam being considered for use has been independently tested and certified to a standard relevant to the intended application and are proven effective when applied on the applicable fuels, at the extremes of ambient temperatures and at the expected expansion ratios and application rates expected from the discharge devices used in the system. Any change in foam type should not compromise the designed fire life safety and critical infrastructure protections required and provided by a foam based fire protection system.

While F3 foams are typically 100% biodegradable, and are therefore not persistent in the environment, it should be noted that the short-term environmental impacts of many F3 foams have been shown to be an order of magnitude higher in short-term aquatic toxicity than C6 foams. Evidence suggests, when unsuited to the application, they are slower to extinguish volatile fuels, so more foam is likely to be used, increasing BOD issues. These factors combined could cause more short-term adverse impacts on fish and other aquatic organisms, particularly in small or isolated water bodies. It is therefore important to remember that all foams pollute regardless of the type of foam being used. As such, their use should be minimised and the used foam solution and firewater runoff collected and managed to reduce environmental impacts.

A huge amount of investment and resources are being directed to improve the performance of F3 foams by organisations such as the FAA, US Research Naval Laboratory, NFPA and UL.

FPA Australia supports the use of more environmentally responsible foam formulations, however, firefighting foams must only be used in applications where they provide acceptable levels of fire life safety and firefighting performance demonstrated through a risk based assessment of realistic worst case incident scenarios.

Historically, there have been a number of important applications for which F3 have not been suitable;

(i) Portable fire extinguishers;

(ii) Non-aspirated pre-engineered foam/water spray systems used to protect large mining machines; and

(iii) Forceful application onto volatile fuels in depth (e.g. storage tanks and associated bunded areas).

> **Note:** F3 foams are now used and approved for use in (i) Portable fire extinguishers and (ii) Non-aspirated pre-engineered foam/water spray systems used to protect large mining machines.

In Australia, the use of foam in application (i) requires the portable fire extinguisher to pass the specific fire test protocols detailed in AS/NZS 1850, *Portable fire* *extinguishers – Classification, rating and performance testing*.

The use of foam in application (ii) above, requires the system to pass specific fire test protocols detailed in AS 5062 *Fire protection for mobile and transportable equipment*.

It is important to note that the 2016 edition of AS 5062 includes a number of new test requirements. These include a 90 day agent (pre-mix) stability test and fire testing using cylinders filled at least 30 days prior to testing. All systems will need to be tested to these new requirements in the future, whether fluorinated or fluorine free, to claim compliance to AS 5062:2016.

FPA Australia is aware of systems using F3 foam that have been tested to these latest requirements.

8.2.2 Summary of fluorine free foams (F3 foams)

As with C8 and C6 foams, F3 foams should not be grouped as a single class in terms of their environmental properties or performance. Some F3 foams have better firefighting and environmental performance than others, and just like C6 foams, evidence of suitability for adequate fire life safety and fire protection of the application in question must be sought before a commitment is made to use a specific F3 foam.

9 Environmental Best Practice

The following outlines FPA Australia's recommended environmental best practice for use of firefighting foams.

9.1 Training and system testing and commissioning

Training of personnel in the use, testing and commissioning of fire protection systems is essential to ensure the fire preparedness of a facility. However, such activities should be undertaken in an environmentally responsible manner.

To minimise the potential for firefighting foam to enter the environment, FPA Australia recommends the following measures be implemented to facilitate training and system testing and commissioning:

- Use training foams or other surrogate liquids that do not contain fluoro-surfactants for training, system testing and commissioning purposes, wherever possible;
- Develop test and commissioning methods for foam proportioning systems which do not discharge foam to the environment;
- Where the discharge of foam cannot be eliminated, ensure it is contained for appropriate collection/treatment/disposal in accordance with the requirements of the local regulatory authorities.

  If containment is not possible, then training, testing and commissioning should only be carried out with a surrogate liquid that is neither persistent, nor bio-accumulative, nor toxic and without known potential human health impacts. Comparative proportioning rates using water only against the specific foam type could be considered, if sufficient reliable comparative data is available; and
- New system designs or system upgrades should incorporate the facilities to allow testing and commissioning of the proportioning system without the need to discharge foam. This may be achieved by comparative flow meters (assuming similar viscosities of foam to water), incorporating a test return line to the bulk foam storage tank or alternatively diverting foam or a surrogate liquid to a dedicated test tank from which it can be recovered for re-use, or disposal in accordance with the requirements of the environmental regulatory authorities.

9.2 Firewater effluent

Firewater effluent or runoff contains many potentially harmful chemicals and will possibly include PFAS; unburnt hydrocarbon or polar solvent fuels; products of combustion (potentially including Volatile Organic Compounds (VOC) and Polycyclic Aromatic Hydrocarbons (PAH), some of which are known carcinogens); particulates; surfactants; water-soluble polymers; hydrolysed proteins; organic matter; suspended and dissolved solids; co-solvents;

anti-freezing agents; biocides; pathogens; and, other compounds.

It is likely to also be contaminated with PFAS from a wide range of consumer sources, including pre-existing contamination of soil, water and other infrastructure, even when F3 foams are used. Pre-existing PFAS contamination is highly likely to exist on many industrial sites.

For these reasons, all firewater effluent is potentially hazardous and it is therefore vitally important that it be contained as far as possible, regardless of whether C8, C6 or F3 foam has been used or not.

This contained firewater effluent/runoff should then be tested for contamination levels before remediation/treatment or disposal in accordance with the requirements of local environmental regulatory authorities.

9.3 Remediation of PFAS contaminated soil and water

Considerable research work has been undertaken recently into effective remediation options for soil and water contaminated with C8 and C6 PFAS, particularly PFOS/PFHxS and PFOA. An increasing number of viable technologies are becoming commercially available.

Some of these technologies for adsorption, separation and concentration of PFAS include:

- Granular activated carbon (GAC) (effective predominantly for C8 PFAS);
- Modified clays & bio-absorbent granules;
- Ion exchange resins (IX);
- Ozone fractionation with catalysed reagent addition (OCRA);
- Membrane filtration including reverse osmosis (RO) and nano-filtration (NF);
- Electrocoagulation; and
- Reed bed filtration.

A number of well-documented commercially available case studies have been completed removing PFAS to non-detect levels.

Effective PFAS breakdown/destruction technologies include:

- Electrochemical oxidation;
- Cement kiln destruction*;
- Plasma arc incineration/thermal destruction*;
- Thermal desorption;
- Sonic destruction;
- Heated persulphate oxidation; and
- Fungal degradation.

*Cement kiln destruction, plasma arc incineration and thermal desorption are available in Australia. The other technologies are yet to be commercially available in Australia. For information on destruction options in your local region, FPA Australia recommends you contact the local environmental regulatory authority.

More recent additional technologies being explored, and which show promise at laboratory and pilot scale, include the following:

- Photocatalysis—uses silicon, carbon and iron catalysts and short wavelengths (<200 nm) of UV light to degrade PFAS.

  Note, it seems to be sensitive to pH and require longer exposure times for shorter chain PFAS substances.
- Carbon nanotubes and filters—increase the surface area for PFAS adsorption, increasing effectiveness of short-chain capture and extending life and efficiency of filters.
- Advanced electrochemical oxidation—creates free radicals and has also been shown to be effective, as has advanced reduction using nano zero-valent iron.
- Colloidal activated carbon—has shown effective results in case studies providing soil barriers to curtail PFAS plume movements.
- Ionic Fluorogels—leverage a synergistic combination of fluorophilic sequestration and targeted ion exchange to generate high performing and selective gels for PFAS remediation.

  It has been shown to be highly effective at adsorbing PFAS substances (both long and short-chains, including C4) from waste water treatment plant effluent.

These gels can also be regenerated to provide increased operational efficiency.

These technologies could also potentially be effective methods of treating firewater runoff and fire training ground effluent if they are proven to perform and become commercially available.

9.4 Cleaning/change out of existing legacy fluorinated foams

FPA Australia recommends the following process when cleaning foam tanks or changing out existing C8 foams:

1. Decant existing C8 foam into suitable storage containers, which are also bunded and clearly marked for incineration/destruction.
2. Thoroughly flush system with water and collect effluent in suitable storage containers/tankers, identifying contents. The use of hot water may facilitate cleaning.

> **Note:** Changing from a foam containing PFOS or PFOA to a US EPA PFOA Stewardship compliant C6 foam, a REACH Regulation (EU) 2017/1000 compliant C6 foam or an F3 foam will require thorough washing of the tank and concentrate sections of pipework (including proportioners) until no frothing is visible. It also requires collection, remediation and safe disposal of all effluent from this washing process.
>
> It is recommended a sample of the "clean" effluent be tested by a NATA accredited laboratory for traces of PFOS/PFHxS/PFOA to determine a baseline level of contamination for future reference and to confirm the storage is essentially "PFOS, PFHxS and PFOA free" down to the levels specified in the Queensland Policy, see Clause 7.3.
>
> To avoid the possibility of contamination, the tank should not be filled with the replacement foam until the results of this testing are available and confirm sufficiently low levels acceptable to the local environmental regulator.

3. Using suitable remediation technologies, flushed foam solution and effluent should be treated to concentrate the PFAS into as small a volume as practical and should be held separately and labelled prior to disposal/destruction.
4. Analyse clean water for residual PFAS levels, before any release for re-use to the sewer/environment to ensure local regulatory requirements are met.

   This is likely to require temporary storage in large clean tanks without any previous PFAS usage or potential pre-existing PFAS contamination.
5. Send concentrated PFAS containing materials for disposal/destruction in accordance with local regulatory requirements.

10 Recommendations

FPA Australia's recommendations on the selection and use of firefighting foam are as follows:

1. The use of foams containing PFOS should be banned;
2. Existing stocks of foams containing PFOS should be removed from service and sent for high temperature incineration or equivalent destruction at an approved facility.
3. All foam manufacturers should reduce and eliminate the production of foams containing PFOA in accordance with the US EPA PFOA Stewardship Program or REACH Regulation (EU) 2017/1000.
4. Foam users should phase-out their use of C8 foams, which contain PFOS or PFOA, and transition to US EPA PFOA Stewardship Program/REACH Regulation (EU) 2017/1000 compliant C6 foams or F3 foams (providing existing safety standards are not compromised) using a holistic risk based assessment approach to select the foam most appropriate for the intended application without compromising fire life safety.
5. Regardless of whether the replacement foam under consideration is a C6 foam or F3 foam, evidence of suitability must be sought to demonstrate its ability to achieve the required firefighting performance for the specific fuel(s) stored/used, at the extremes of ambient temperature that may be encountered on site, with the aspiration level and application rates being provided by the discharge devices and

system design in place or being modified accordingly.

Evidence must also be sought to confirm that the replacement foam is compatible with the systems and equipment with which it is to be used and that the performance of these systems is not being compromised.

6. Whilst important, the environmental performance of a foam should not be used as the sole selection criteria, nor considered in isolation. Effective fire life safety and critical asset protection must also be adequately considered. Choosing the most responsible firefighting foam—the best one to protect life, property and the environment—involves selecting one that provides a combination of firefighting performance, reliability and fire life safety, balanced with minimal toxicological and adverse environmental impacts. Therefore, the following key selection criteria must all be adequately considered to ensure all realistic expectations are being met:
   (a) Firefighting performance;
   (b) Fire life safety;
   (c) Physical properties and suitability for use on known hazards (including forceful application);
   (d) Compatibility with in-depth fuels (i.e. >25 mm), system design, application method, existing delivery equipment, site conditions and approvals; and
   (e) Environmental impact (including whole incident, not just foam in isolation).
7. Any proposal to change the type of foam used in a system requires careful consideration and must take fire safety and engineering factors into account. The type of foam used should not be changed without completing a detailed risk assessment review of the design, performance and operation of the system as a whole. Such design reviews should include consultation with fire system designers, foam and foam hardware suppliers/specialists, and the relevant authority having jurisdiction (AHJ).
8. Where possible, eliminate the discharge of foam during training and system testing and commissioning. Where this is not possible, use surrogate liquids or training foams. Where the discharge of foams containing fluorosurfactants during training, testing or commissioning cannot be avoided, ensure that the discharge is contained, collected, treated and disposed of in accordance with the requirements of the relevant AHJ.
9. All firewater run off/effluent, irrespective of foam type used, should be contained and tested for regulated contaminants (including PFAS*) prior to any discharge, as it is likely to qualify as hazardous waste. It should then be treated and disposed of according to the requirements of the relevant AHJ.

   *Note, significant PFAS levels may occur from non-foam related consumer products in fire incidents, even when F3 foams are being used.

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For more information, please see www.fpaa.com.au or contact FPA Australia on 1300 731 922.

Appendix A – Abbreviations

AFFF	Aqueous Film Forming Foam (Fluorinated)
AHJ	Authority Having Jurisdiction
AR-AFFF	Alcohol Resistant Aqueous Film Forming Foam (Fluorinated)
AR-FFFP	Alcohol Resistant Film Forming Fluoro-Protein Foam (Fluorinated)
AR-F3	Alcohol Resistant Fluorine Free Foam (with no fluorinated content)
AS	Australian Standard
AS/NZS	Australian/New Zealand Standard
BOD	Biochemical Oxygen Demand
C6	Short carbon chain lower or equal to 6 carbon atoms
C6 foam	Fluorinated firefighting foam where the per-fluorinated carbon chains are shorter or equal to 6 carbon atoms
C8	Long carbon chain greater or equal to 7 carbon atoms including >C8s which may breakdown to PFOA, PFOS and PFHxS (PFHxS is defined as C8 under United Nations – OECD, 2015)
C8 foam	Fluorinated firefighting foam where per-fluorinated carbon chains are longer or equal to 7 carbon atoms and may breakdown to PFOS, PFOA, PFHxS.
COD	Chemical Oxygen Demand
ECF	Electrochemical Fluorination
EPA	Environmental Protection Agency/Authority
EU	European Union
FAA	Federal Aviation Administration (USA)
FFFC	Fire Fighting Foam Coalition
FFFP	Film Forming Fluoro-Protein Foam (Fluorinated)
FM	Factory Mutual Insurance Company
FP	Fluoro-Protein Foam (Fluorinated)
FPA Australia	Fire Protection Association Australia
F3 foam	Fluorine Free Foam (with no fluorinated content)
GAC	Granular Activated Carbon
ICAO	International Civil Aviation Organisation
IMAP	Inventory Multi-tiered Assessment and Prioritisation
IX	Ion Exchange Resins
K_{ow}	Octanol-water coefficient
LRET	Long-Range Environmental Transport
NEMP	National Environmental Management Plan (Australia/New Zealand)
NFPA	National Fire Protection Association (USA)
NICNAS	National Industrial Chemicals Notification and Assessment Scheme (Australia)
OECD	Organisation for Economic Cooperation and Development (United Nations)
OCRA	Ozone fractionation Catalysed Reagent Addition
PAHs	Polycyclic Aromatic Hydrocarbons
PBT	Persistent, Bio-accumulative and Toxic
PFAS	Per- and Poly-fluoroalkyl Substances
PFCs	Perfluorinated and Polyfluorinated Compounds (more recently replaced by the term “PFAS”)

PFCA	Perfluorocarboxylic Acid
	PFSA Perfluorosulfonic Acid
PFHxA	Perfluorohexanoic Acid
PFHxS	Perfluorohexane Sulfonate
PFOA	Perfluorooctanoic Acid
PFOS	Perfluorooctanyl Sulfonate
POPRC	Persistent Organic Pollutants Review Committee (UN Stockholm Convention)
POP	Persistent Organic Pollutant (POPs is the plural)
ppm	parts per million (1,000,000) or mg/L
ppb	parts per billion (1,000,000,000) or µg/L
mg/L	1 milligram per litre = 0.000,001 grams/litre or ppm
µg/L	1 microgram per Litre = 0.000,000,001 grams/litre or ppb
NF	Nano-filtration
REACH	Registration, Evaluation, Authorisation and Restriction of Chemicals (EU regulations)
RO	Reverse Osmosis
SA WQ Policy	South Australia Water Quality Policy
UL	Underwriters Laboratories (USA)
ULC	Underwriters Laboratories of Canada
UN	United Nations
US	United States
US EPA	United States Environmental Protection Agency
VOC	Volatile Organic Compounds

Appendix B – Health concerns and phase out of legacy C8 foams and the use of replacement C6 foams

This Appendix discusses the health concerns of particular chemicals in legacy C8 foams, the phase out of these foams and the use of replacement C6 foams.

B1 Perfluorooctanyl Sulfonate (PFOS)

PFOS is a Perfluorosulphonic acid (part of the PFAS family) and derives from the 3M™ developed Electrochemical Fluorination (ECF) process, (no longer used outside China, and perhaps Russia).

The main global manufacturer of PFOS containing foams, 3M™, voluntarily ceased global manufacture of fluorochemicals by end 2002, but in Australia the manufacture of 3M™ Lightwater™ AFFF and ATC™ AR-AFFF concentrates extended into 2003.

In 2004, the first 12 POPs were listed in annexes to the Stockholm Convention. In 2009, PFOS was one of 9 new substances added as an Annex B Restricted substance in accordance with the Stockholm Convention with the expectation that every four years progress on its elimination is reported. It should be noted that Australia's National Implementation Plan – Stockholm Convention on Persistent Organic Pollutants (dated July 2006) was published by the Commonwealth Department of the Environment prior to the addition of PFOS as a POP.

Australia is yet to ratify this addition of PFOS as an Annex B Restricted substance and update the National Implementation Plan to reflect this. Australia is considering ratification of PFOS as a POP but must go through a domestic treaty process for which the Commonwealth Department of the Environment and Energy is responsible. FPA Australia considers that the Australian Government should ratify PFOS as a POP in accordance with the Stockholm Convention urgently to provide clarity for foam users and protection for our environment.

The Stockholm Convention's goal is to reduce and ultimately eliminate production and use of PFOS and encourages:

- Phase out of PFOS use when suitable alternative substances or methods are available;
- Producers or users of PFOS to develop and implement an action plan for elimination; and
- PFOS producers or users, within their capabilities, to promote research on development of safe alternative substances to reduce human health risks and environmental implications.

The European Union (EU) has prohibited the marketing and use of PFOS since 27 June 2008. Subsequently, PFOS was banned from use in 28 European countries in 2011, requiring high temperature incineration (above 1,100°C) to destroy it. New Zealand followed by banning it in 2011 and Canada followed in 2013.

As PFOS is listed as a Persistent Organic Pollutant under the United Nations (UN) Stockholm Convention, FPA Australia recommends that any fluorinated firefighting foam containing PFOS and/or its related chemicals, including PFHxS, should be immediately removed from service and sent to an authorised regulated waste facility for disposal.

B2 Perfluorooctanoic Acid (PFOA)

PFOA is a Perfluorocarboxylic acid (PFCA) (part of the PFAS family) and has been accepted for listing as a POP by the UN Stockholm Convention POPRC.

Concerns about PFOA's persistence, detection in human blood and effects in animal studies has led to further scientific research. This research has shown that C8 fluorochemicals have larger more complex precursor molecules, which are more likely to breakdown to C8 endpoint substances (PFOS, PFOA and PFHxS) that are persistent, toxic, bio-accumulative and remain in mammalian organisms for long periods of time. Research indicates that C8 fluorochemicals have half-lives in humans typically averaging 5.4 years for PFOS, 8.5 years for PFHxS, and 3.5 years for PFOA. In comparison, the main short-chain C6 foam breakdown product PFHxA has an average human half-life of just 32 days.

PFOA was mainly used as a polymerization aid in the manufacture of several types of fluoropolymers. The ECF that produced PFOS from C8 precursors also generated some unavoidable PFOA as a by-product of the manufacturing process (generally at a ppm level), and from C8 precursors. Similarly, trace amounts of PFOA (but not PFOS) can be found from precursors and in C8 fluorotelomers. These fluoropolymers were used in a wide variety of industrial and consumer products, including domestic cookware, but not in firefighting applications.

In 2006, the US EPA and eight global fluorotelomer and fluoropolymer manufacturers launched a voluntary PFOA Stewardship Program working towards elimination of PFOA and its precursor chemicals from their production processes, waste streams and finished products by the end of 2015, which was achieved.

All major fluorotelomer manufacturers who were part of the US EPA PFOA stewardship program have virtually eliminated PFOA (down to ppb levels) from fluorotelomer surfactants as they transitioned to environmentally more benign high purity (≥98.5%) short-chain C6 alternatives which are now being used in firefighting foam concentrates by all main manufacturers (outside China and perhaps Russia). The remaining percentage consists predominantly of C4 fluorosurfactants, improving environmental outcomes and complying with both the US EPA PFOA Stewardship Program and the REACH Regulation (EU) 2017/1000 requirements for PFOA.

It is interesting to note that the French Food Safety Agency and Norwegian Institute of Public Health have evaluated the potential human health risks related to the residual presence of PFOA in non-stick coatings for cookware, concluding that the consumer health risk is negligible.

B3 C6 fluorotelomers

Scientific research has shown that C6 foams are environmentally more benign than those using C8 fluorochemicals, including PFOS and PFOA, and are widely considered safe for continued use.

C6 fluorotelomer surfactants meeting the US EPA PFOA Stewardship Program and the REACH Regulation (EU) 2017/1000 do not have the same adverse environmental profile as PFOS, PFHxS, PFOA or PFOA precursors. Scientific research indicates that they are not bio-accumulative, not carcinogenic, not genotoxic, not endocrine disruptors, not developmental toxins nor mutagenic and they exhibit low toxicity to humans and aquatic environments.

The Australian Department of Health, Expert PFAS health panel concluded in its May 2018 advice that:

> “There is no current evidence that supports a large impact on an individual’s health” from C6 fluorotelomers and “In particular, there is no current evidence that suggests an increase in overall cancer risk” from C6 PFAS use.
>
> This health report confirms "Differences between those with the highest and lowest exposures are generally small, with the highest groups generally still being within the normal ranges for the whole population. There is mostly limited or no evidence for an association with human disease accompanying these observed differences.”
>
> It concludes, “Our advice to the Minister in regards to public health is that the evidence does not support any specific biochemical or disease screening, or health interventions, for highly exposed groups, except for research purposes."

US EPA Stewardship Program and REACH Regulation (EU) 2017/1000 compliant C6 fluorotelomer surfactant-based foams:

- Do not break down to PFOS, PFOA or chemicals currently listed or suspected of being POPs or persistent, bio-accumulative and toxic (PBT) substances;

- Although persistent, are not made with chemicals currently considered to be bio-accumulative, nor toxic by environmental authorities; and
- Are not listed by the Stockholm Convention or European Chemicals Agency (2016) list of substances of high or very high concern (VHC).

Importantly, C6 foams retain fast, effective, reliable and efficient firefighting performance, in most cases equivalent to C8 foams, without increased fluorochemical content. Equivalency has been verified using the MilSpec foam test standard and UL listings.