Firefighting Foam
Legacy, Current & C6 AFFF – Performance vs Environment

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Agenda

- Fire Fighting Foams – Legacy, Current & New Technology
- QLD Fire Fighting Foam Policy
- Fire Fighting Performance vs Environmental Performance
- Impact Existing Hardware & Systems
- Industry's Position

Why do we even bother with Firefighting Foam?

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Why do we have/use Fire Fighting Foam?

- **Ultimately…To protect against threat of fires!**
  - To protect **lives, property & assets**!
- **ALL successful Fire Fighting Foams must:**
  - **Separating fuel from air (oxygen)**
  - **Cool** the fuel surface
  - **Resist mixing** with specific fuels
  - **Resist attack or breakdown** by specific fuels (such as polar solvents)
  - **Suppress** the release of flammable vapors
  - **Control fire spread and provide progressive extinguishment**
  - **Provide protection from re-ignition**

The Fire Triangle

Class B Fuel Types

Hydrocarbons

- Hydrophobic (will not mix with water)
- Float on Water, ie. Gasoline, Kerosene, Fuel Oil
- Typically give off black smoke

Polar Solvents

- Hydrophilic (mix with water)
- ie. Ketone, Acetone, Isopropyl Alcohol
- Usually burn cleaner than hydrocarbons
- Flame is sometimes not visible.

Class B Fuel Types

Environmental Impact of Fire

These combustion products are produced when crude oil burns

- Carbon dioxide (CO_2)
- Carbon monoxide (CO)
- Sulphur dioxide (SO_2)
- Oxides of nitrogen (NO_x),
- Volatile organic compounds (VOCs)
- Ozone (O_3)
- Various polycyclic aromatic hydrocarbons (PAHs)
- Acid aerosols

Crude Oil Tank Fire

Crude Oil Field Fire Kuwait

Environmental Impact of Fire

Calculation on amount of air pollution including soot particles

- Tank size: 60.96 meter diameter (200')
- Burn rate of crude oil: 300-600 mm / hour
- % conversion of crude oil into combustion products: 2-15%
- Specific gravity of combustion products: Assume 1

Sources,
Environmental Exposure Report, Oil Well fires, US Department of Defence.

In situ burning of Oil spills: Smoke production and plume behavior, David D Evans, Large Fire Research Group

Environmental Impact of Fire

Calculation on amount of air pollution including soot particles (cont'd)

- Tank size : 2917 m2
- Amount of crude oil burning (300mm) : 875,100 litres/ hour, at a cost of 330,000 USD / hour (60$/bbl)
- With 2% conversion : 17,500 kg / hour
- With 600mm and 15% conversion : 262,500 kg / hour

Using the lowest burn, and conversion rate this fire event produces 17.5 tonnes of air pollution per hour

Having a Significant Fire + Fighting Foam = Impact on the Environment!

- **Fire Combustible By-Products POLLUTE** every minute the fire is not extinguished.
- Throwing **Long/short chain Fluorinated or Non-Fluorinated Foams ALL POLLUTE**
- The resultant **Firewater Runoff** created the longer the fire is not extinguished **POLLUTE**
- **Fire Performance vs Environment Performance is critical!**

Firefighting Foams – Legacy, Current & New Technology

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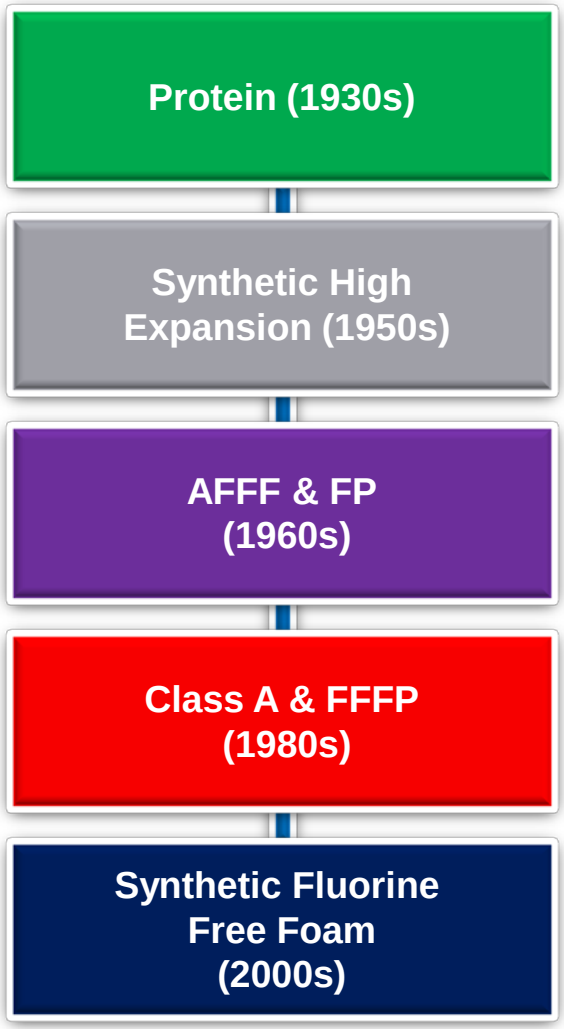
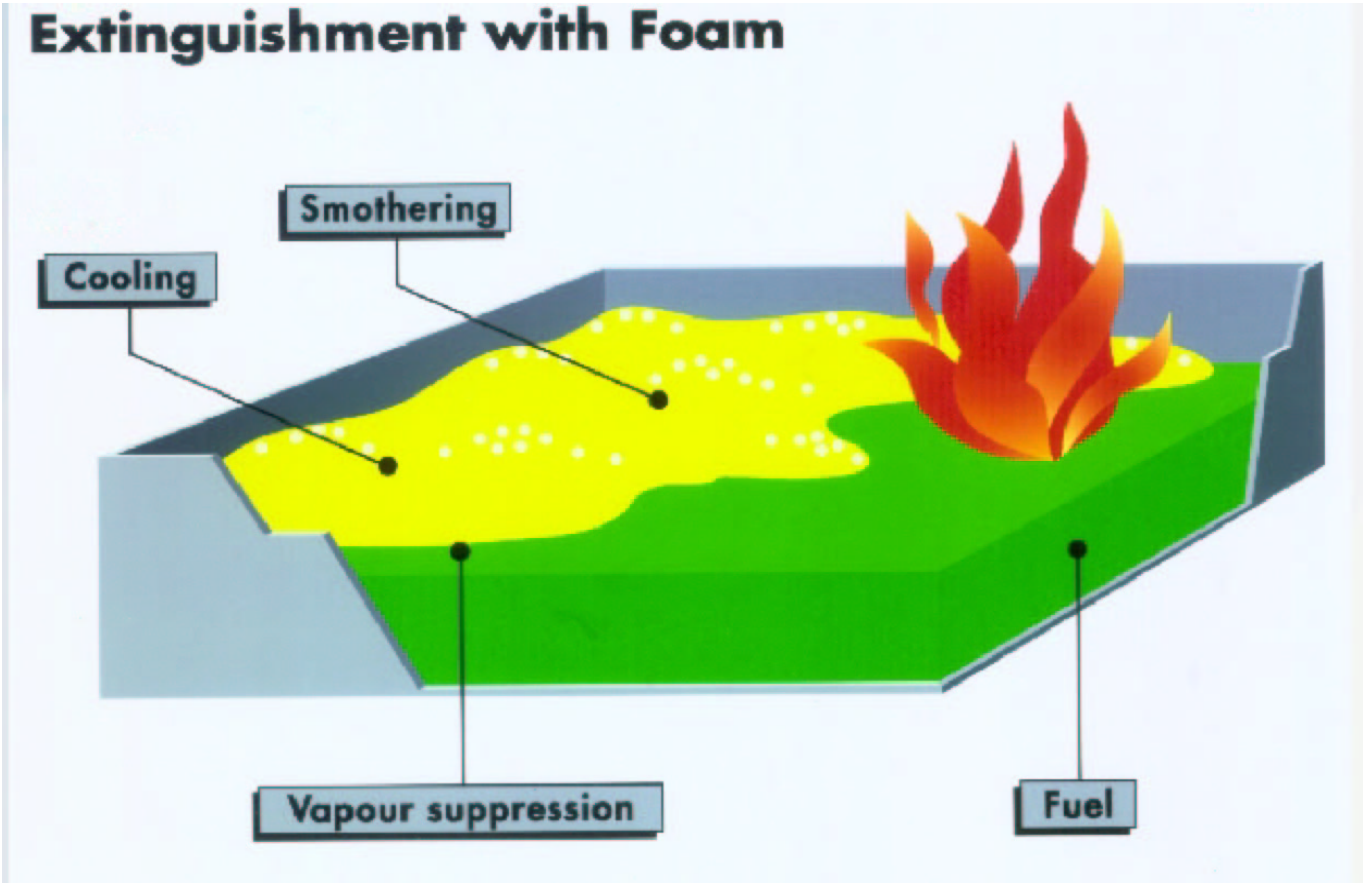
History of Firefighting Foams

- Regular Protein
- Synthetic High Expansion
- Aqueous Film Forming Foam (AFFF)
- Fluoroprotein
- Class A
- Film Forming Fluoroprotein (FFFP)
- Alcohol Resistant - Polar Solvents (AR-AFFF)
- Fluorine-Free Foam

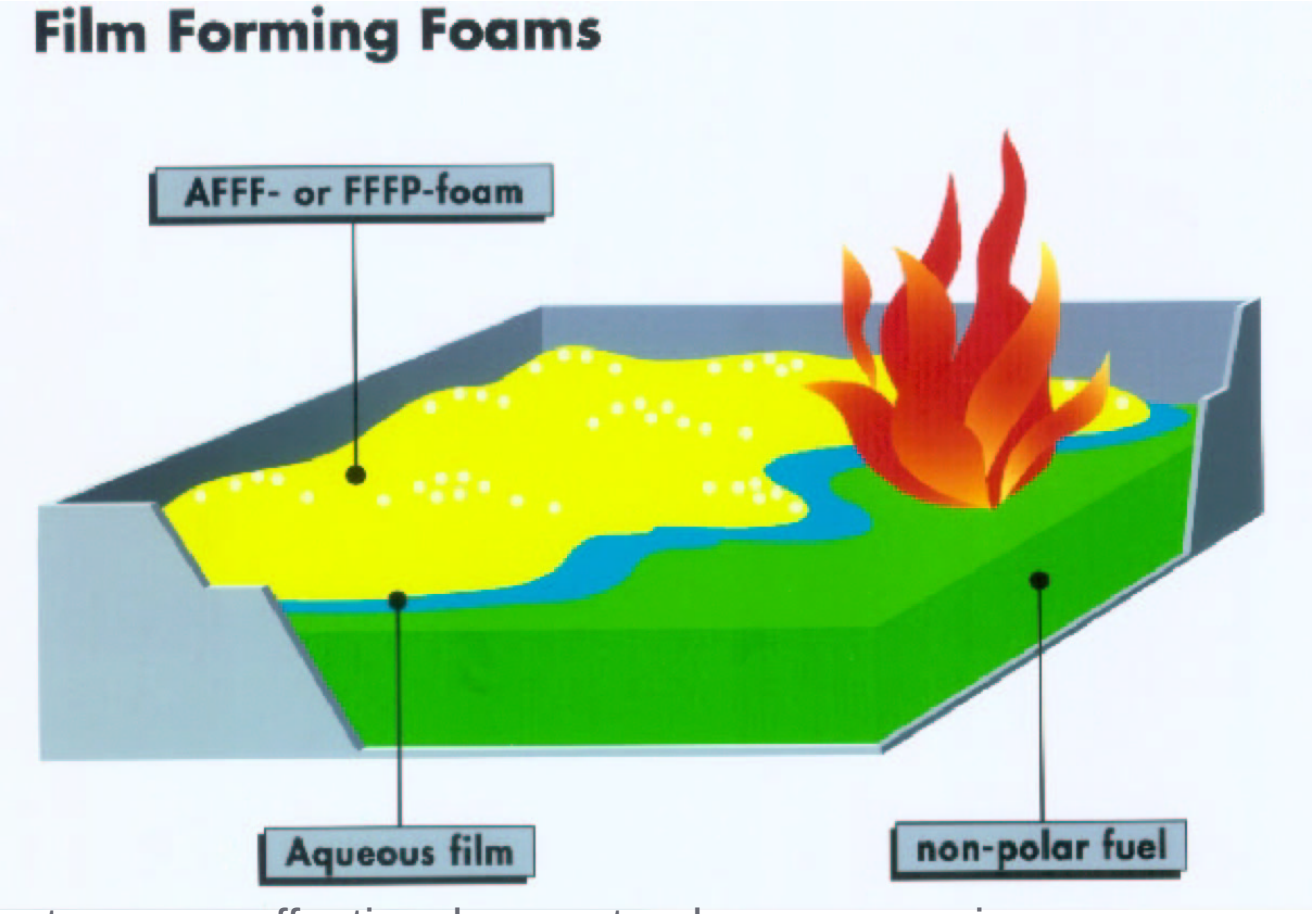


How Fluorine-Free Foam Works



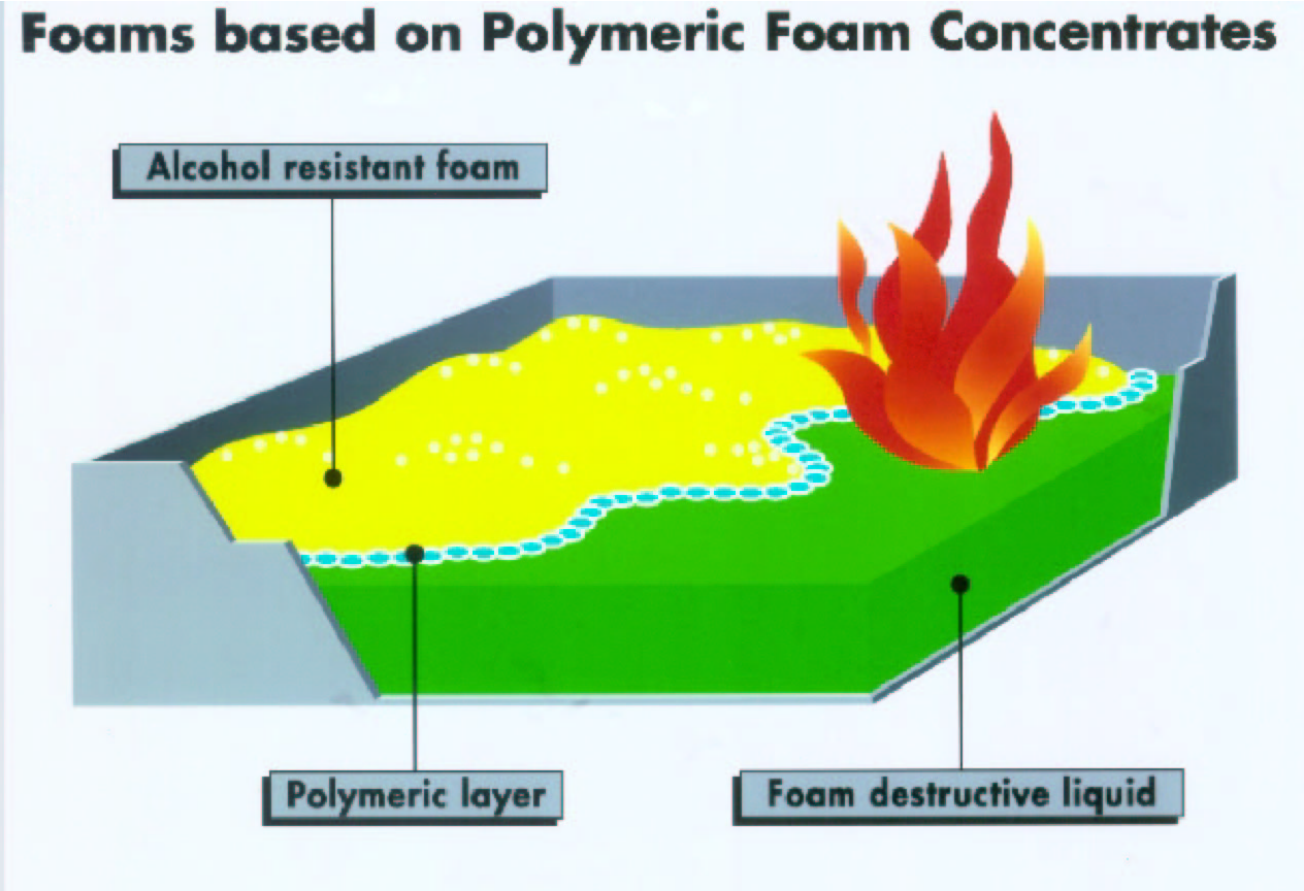
Depends on a Robust Foam Blanket applied gently to the fuel surface.
Non-fluorinated foams – rely solely on the foam blanket to smother & cool
Typically need more water & foam

How Aqueous Film Forming Foam (AFFF) Works



Faster, more effective, less water, lower expansion
Front leading film creates a barrier to help suppress fuel vapour

How Alcohol Resistant Aqueous Film Forming Foam (AR- AFFF) Works



Polymeric film layer forms between foam & polar solvent fuel surface
AR foams are effective for both hydrocarbon & polar solvent fuels

Function of the Primary Ingredients in AFFF

1. Fluorosurfactants

- Oleophobic - provides fuel repellency
- Rapid coverage and extinguishing
- Prevent foam blanket from “burning”

2. Hydrocarbon Surfactants

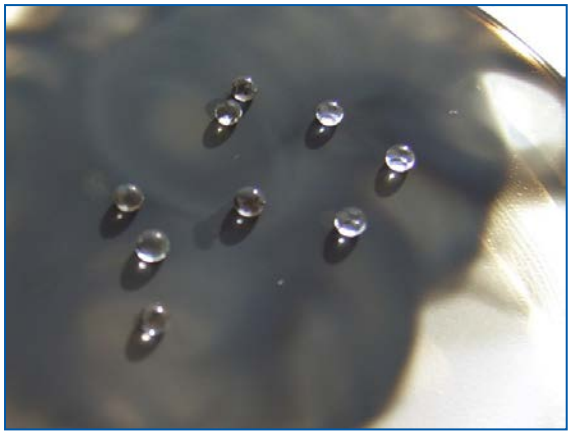
- Foaming agent
- Oleophilic – attracts fuel, leads to easy fuel contamination
- Optimize interfacial tension

3. Solvents

- Keep everything in solution

NOTE: Foam represents around 5% of total fluorochemical usage worldwide

Without surfactant

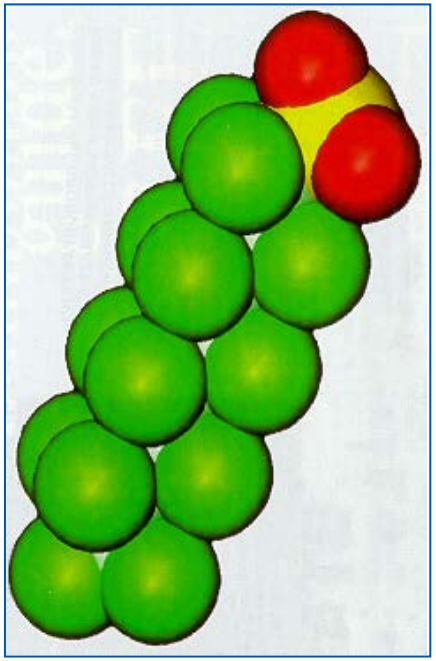


With surfactant

PFOS

PFOS – Per-Fluor-Octanyl Sulfonate

- **Produced in the Electro Chemical Fluorination (ECF) process - ceased 2002, except China**
- Stockholm Convention - **POP listed PFOS 2009**
  - Persistent in environment (P)
  - Bio-accumulates in humans & animals (B)
  - Toxic health concerns (T)
- **3M stopped ECF PFOS production in Lightwater ATC foam, Scotchguard, etc under US EPA Agreement, May 2000**



❑ **PFOS is a Legacy (& old stock) issue**

PFOA

PFOA – Perfluoro Octanoic Acid

- Applications include non-stick cookware, textile stain resistance and waterproofing.
- Can be a breakdown by-product of some fluorinated compounds with 7+ carbon atoms
- Can also be unintended manufacturing by-product in Fluorotelomer process if not quality controlled (ppm levels)
- **Progressively & voluntarily phasing out**

❑ **PFOA is under review & Industry is moving away**

2010/15 US EPA Stewardship Program

- **Voluntary Stewardship Program**
  the eight major fluorochemical companies committed to staged reduction of PFOA .
  - **2010 – removal of 95% PFOA from products & facilities**
  - **2015 – work to elimination the balance of PFOA**

- To comply with the US EPA stewardship program, manufacturers have introduced reformulated products with **only short-chain, C6-based fluorochemicals** - eliminating the potential for breakdown into PFOA compounds.

- **US EPA fully supports the move to C6 – as it doesn't use PFOA ingredients & cannot degrade to PFOA**.

QLD Firefighting Foam Management Policy

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For Fluorinated Firefighting Foams

- **The QLD Policy states …**
  - **Concentration limits for PFOS & PFOA** within AFFF, including C6 formulation
    - **PFOS limited to 10 mg/kg (ppm)**
    - **PFOA limited to 50 mg/kg (ppm)**
  - **C6 purity.** A C6 purity compliant foam product must not have greater than 50 ppm of total impurities
  - **Full Containment & Disposal.** Any potential for spill or release of foam containing fluorotelomers, the end user must fully contain and dispose (as regulated trade waste) the concentrate, foam solution, produced foam, firewater, wastewater, runoff, contaminated soils and other materials.

For Fluorine-Free Firefighting Foams

❑ The QLD Policy states…

- **Direct releases to land of fluorine-free foam is permitted.**

Fully-biodegradable fluorine-free firefighting foam can be released to land, away from Waterways eg. used by Rural Fire Brigades for ignition prevention, fire control, extinguishment, etc.

- **Significant releases directly to, or within 50 metres** of a permanent waterway during rural firefighting ***should*** be avoided ***where possible.***

Firefighting Performance vs Environmental Performance

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Environmental / Hazard Assessment of C6

- Research highlights major differences between PFOS/PFOA and short chain C6 Fluorotelomer surfactants
  - C6 is **NOT Bio-accumulative, NOT Toxic** (Chengalis 2009, Loveless 2009, Iwai 2011, Serex 2008, Hoke 2015).
  - C6 has **LOW persistency**, no evidence to show harm to humans or environment.
  - C6 is **NOT be listed as a POP**, does not fit the POP criteria
  - C6 delivers **significant fire performance benefits**, better than other foam options.
  - C6 main breakdown product is PFHxA. **PFHxA can be fully excreted** through human kidneys/urinary system with half-life of 28-32days (Russell 2013)
  - C6 already **NICNAS APPROVED** for use in Australia

Performance of C6 AFFF

- **Telomer-based AFFF** agent technology is collectively recognized as the **most effective efficient fire-fighting foam available**
  - Rapid extinguishment
  - Aqueous film formation preventing evaporation & re-ignition
    - **Vapor suppression**
  - Foam blanket resealing
    - **Superior burnback resistance**

C6 Product

- C6 are well below QLD Policy limits 10ppm PFOS, 50ppm PFOA
- C6 foams have equal extinguishing performance to C8 foams
- C6 foam concentrates can be used with existing proportioning equipment for C8 of the same type
- If C6 foam concentrate is filled into an existing tank of C8 foam concentrate all will be considered C8
- If C6 based foam concentrates is filled into an existing empty tank previously filled with C8 foam concentrate we recommend a cleaning procedure in line with the manufacturers instructions to avoid contamination. Followed by sample testing.

Aquatic Toxicity

- **Toxicity expressed as 96LC50**
  - 96-hour test
  - LC – Lethal concentration for 50% of the population in the test

LC50 Values Rainbow Trout		LC50 Values Fathead Minnow	
• Non-AFFF Foam	1.06 mg/l	• Non-AFFF Foam	0.8874 mg/l
• 1st Non-Fluorine 3%	65 mg/l	• 1st Non-Fluorine 3%	170.8 mg/l
• 2nd Non-Fluorine 3%	71 mg/l	• 2nd Non-Fluorine 3%	170.8 mg/l
• U.S. Mil-Spec 3%	2,176 mg/l	• U.S. Mil-Spec 3%	883.9 mg/l
• AR-AFFF 3%	3,536 mg/l	• AR-AFFF 3%	1,487 mg/l
• UL 3% AFFF	5,657 mg/l	• UL 3% AFFF	1,726 mg/l

The Lower the Value, The Higher the Toxicity

WWW.FFFC.ORG

Source: Fire & Rescue Suppliers Association (FIRESA), Aquatic Toxicity of Fire Fighting Foams, http://firesa.org.uk/objects_store/fia.pdf

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Characteristics of Fluorine-Free Foam

Issues with Fluorine-free Foams

- No inter-agent compatibility with AFFF agents or with other fluorine-free foams, necessitating a system purge at switchover.
- Potential elevated viscosity, which may compromise product stability and shelf life.

AFFF vs Fluorine-Free Foam Performance

- 2013 Reebok Conference, UK – VS Focum
  - Side-by-side Test conducted at Same Facility and Conditions

Spray Extinction – Fire Out time (minutes)

Foam Type	Heptane	Gasoline	Kerosene Jet A-1
AFFF (1%)	1:03	0:38	0:22
Fluorine-free (1%)	2:14	3:36	3:12
Fluorine-free (1%)	2:21	2:21	3:21
Fluorine-free (3%)	No	No	1:00

Pan Fire – Fire Out time (minutes)

Foam Type	0.25m^2	0.785m^2	4.52m^2	7.06m^2
AFFF (1%)	0:35	1:19	2:16	2:06
Fluorine-free (1%)	0:50	1:55	2:21	No

Source: "Performance Newtonian Fluorine-Free Foam, Manual Acuna, VS Focum, 5th Rebook International Foam Conference, March 2013

Fluorine-Free Foam Fire Performance

- **Incident Caltex Banksmeadow Sydney, 2013**
  - Unleaded gasoline tank 901 - valve leaked into bund
  - 3-4m high fountain, 130,000L unignited fuel in bund
  - F3 blanket suppressed vapours for only 15-20 mins between "top-ups"
  - Kurnell Refinery FP foam used, controlled vapours for 90 mins between "top-ups" = 4.5x longer
  - FP allowed incident to be controlled reliably and effectively with minimal resources used
- Newcastle University research ***"…best F3 provides only 30% durability of AFFF on gasoline"*** (Schaefer, 2008)

Fluorine-Free Foam Performance Considerations

- **Fluorine Free Foam** can suit less aggressive applications where you have greater control eg. Brigades, Training, etc

- **For Major Hazard Facilities** performance concerns for F3 vs AFFF/AR-AFFF (eg. Airports, Petro/Chem Facilities, etc) :
  - **F3 is significantly more aquatically toxic** (upto 10x times more)
  - **F3 needs higher application rates** (upto 3 x for gasoline app)
  - **F3 requires more gentle aspirated application** (to help maintain foam blanket)
  - **Burnback resistance can be poorer** due to fuel pick-up (fire burn longer = more toxic runoff)
  - **No critical fuel shedding, shorter vapour sealing** can reduce performance
  - **Question on repeatability**

Impact on Existing Hardware & Systems

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Hardware & Approvals

Hardware-Foam System Compatibility

- Decision to change the type of foam cannot be made without considering the impact on the complete engineered system.
- Foam compatibility is critical to achieving expected performance.
- Consultation with foam system designers/manufacturers is required prior to taking a decision to change the type of foam.
  Important factors include:
  - Viscosity
  - Proportioning/mixing – recalibrate/redesign, proportioners/inductors
  - Delivery method – non aspirated to aspirated, surface/sub-surface, nozzles, extra outlets
  - Pump type – centrifugal, positive displacement
  - Tank storage – type, size, location
  - Hardware compatibility – component approvals/listing
  - Stability (separation, stratification, sedimentation)

Hardware & Approvals

PROPORTIONING EQUIPMENT SUMMARY

Type of system	Advantages	Disadvantages
Premix	Simple Independent Accurate	Limited amount Not all foams can be used
Inline inductor	Low cost Can refill during operation	Fixed flow and pressure High water pressure required
Around the pump inductor	Simple operation Low cost Can refill during operation	A portion of flow is bypassed. Changes in flow require metering valve adjustment. Auxiliary power required Pump suction inlet pressure must be zero.
Built-in inductor	Low cost Can refill during operation	Energy loss in throw distance
Balanced pressure, bladder tank	Wide flow range Variable pressure Simple operation Water pressure driven	Pressure vessel cost Cannot refill during operation Limited capacity
Balanced pressure, foam pump	Wide flow range Variable pressure Can refill during operation	Auxiliary power required Additional maintenance (pump)

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Hardware & Approvals

❑Foam Fire Extinguishers & Vehicle Fire Suppression Systems

- In Australia, **Foam Fire Extinguishers & Vehicle Fire Suppression Systems** are required to pass specific component & system fire test protocols to Aust Stds (and International Stds) with specific foam types, and be Activefire Listed as a ‘closed system’.
  - AS/NZS 1850, *Portable fire extinguishers – Classification, rating and performance testing*
  - *AS5062-2016, Fire protection for mobile and transportable equipment*

- Changing the foam type will typically void such Aust Std compliance and the product or system listing.

System cleaning, flushing, foam change out & disposal

Cleaning/Change Out of Existing Foams

- Decant foam from the system
- Thoroughly flush system with clean water and collect effluent
- Include thorough washing of the hardware, pipes, valves, pumps, tank and collection of washings until no frothing is visible.
- It is also suggested, that a washwater sample should be laboratory tested for traces of PFOS/PFOA to determine a baseline for that storage tank into the future.
- Refill tanks with new foam. Once filled allow to settle for 24 – 48hrs and inspect for further top up as foam will inherently expand with aeration during the filling. Top up to peak tank volume.
- Treat foam and effluent to reduce volume of PFC containing material
- Send PFC containing material for disposal/destruction

Legacy PFOS Contamination

- **On existing PFOS foam sites – existing contamination??**
  - Recent study found concrete fire training areas at some Airports saturated to 12cm with PFOS
  - Despite thorough clean out PFOS in 2010, change-out to F3
  - PFOS still leaching when F3 used, or just water - even when it rains!
  - Predicted to continue for 25 years
  - So why accept inherent fire performance and toxicity drawbacks of F3?

- **For such sites, using F3 or C6 does not resolve the legacy.**

Source: Baduel et al 2015-Perfluoroalkyl substances in a firefighting training ground, distribution and potential future release

Fire Industry Position

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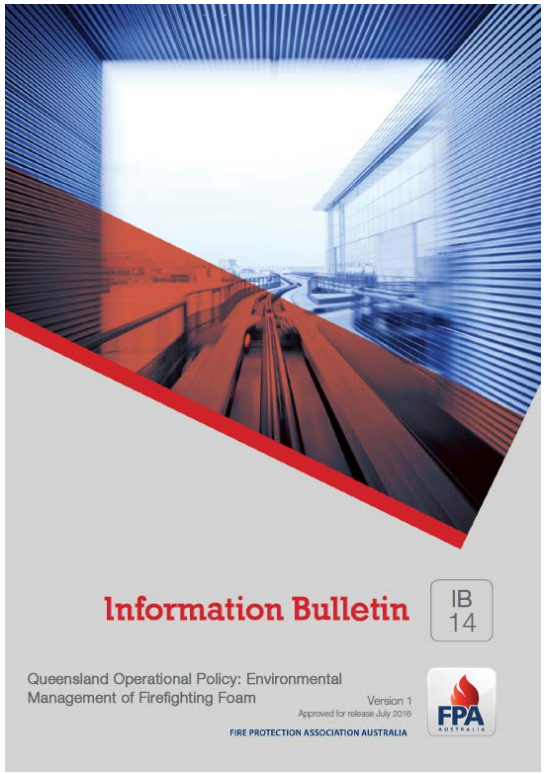
Industry Position on the QLD DEHP Foam Policy

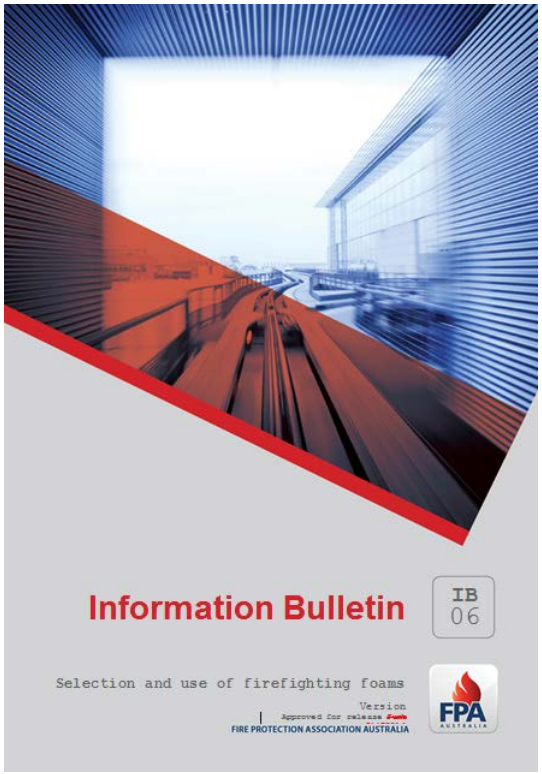
- **FPAA supports improvements in the selection/use of fire fighting foams.**
  - Called for the immediate banning of foams containing PFOS.
  - Elimination of long chain fluorinated foams as per the US EPA Stewardship Program.
- FPAA advocates that the:
  - **Introduction of <u>any</u> fire fighting foams will have an impact on the environment.**
  - **Selection/use of fire fighting foams should be determined via a <u>holistic assessment</u> that includes:**
    - Environmental impact
    - Firefighting performance
    - Life safety
    - Physical properties/suitability of use on known hazards
    - Compatibility with system design and approvals



Industry Position on the QLD DEHP Foam Policy

Fire Protection Association of Australia position on the QLD DEHP Firefighting Foam Policy:

- FPAA have made requests/submissions to QLD Environmental Dept & Minister with **Industry's concerns:**
  - **That the potential environmental impact of the foam alone should not be the sole factor to determine foam selection and use.**
  - **How practically the industry/endusers can implement and** without potentially reduced life safety, as well as significant costs implication.
  - **adhere to the Policy FPAA has been seeking consultation with the QLD DEHP** to have a round table with key industry/enduser stakeholders to develop appropriate & cost effective transitional arrangements



Final Thoughts…

- Only reason why Fire Fighting Foam is use is to protect against Fire!
- Minimising the extent of fire event, minimising the amount of foam released should be the primary aim!
  - Environmentally - all fire pollutes, all foam types pollute - C6, F3, resultant firewater runoff
  - Fire fighting performance matters critically!
- Most agree PFOS, PFOA and PFHxS are undesirable - legacy issue that needs to be managed
- C6 AFFF provides the firefighting performance - no PFOS, PFOA well under thresholds
- F3 has performance concerns

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Final Thoughts…

- The FPAA, the industry are concerned with the QLD Policy's:
  - Using the potential environmental impact of the foam alone to determine foam selection and use
  - One solution does not fit all – Class A fires, Class B (small or large) fires, existing systems, new systems
  - Practical and costs effective implementation of the Policy
- A holistic risk assessment for each individual site will result in most appropriate protection measures – new/existing site, risk of fire, overall environmental impact
- The Industry seeks to work with the QLD DEHP (and other State/Territory Depts) to develop appropriate & cost effective transitional arrangements.

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Thank You