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# Learning from Past Foam Incidents and Considerations Necessary when Changing Foams - *How Might We Fare Today?*

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# Outline Discussion



- Investigate past & recent major fire incidents - flammable liquids
- Usage of AFFF/FFFP, AR-AFFF/AR-FFFP and Fluorine Free Foams F3/AR-F3
- Assessment of outcomes
- What are our “Realistic Expectations”?
- What necessary considerations? …suitability, compatibility, effectiveness
- What agent options? …change implications, likely outcomes
- Complex inter-relationships examined & **best practice** conclusions drawn

***Dual Aims: reducing environmental impacts***
***+ providing reliable life safety protection***

# 12 Major Flammable Liquid Fire Incidents



29 July 1967: **USS Forrestal Aircraft carrier disaster**

- Major fire involving munitions, aircraft and crews
- **Fluorine Free Foam (F3) used - Protein - like modern F3s** without fuel shedding capabilities & poor vapour sealing
- **Major disaster:** 134 died, 161 injured, 21 planes destroyed, 40 planes damaged
- Accelerated further research & development into AFFFs ***…to ensure such a tragedy never happens again***
- Extensive large scale testing (3,000m2) to verify effective small scale AFFF performance under wide range of "incident" conditions (*not seen with Modern F3s*)
- Mil F 24385F Spec resulted - toughest fire test there is!

**Started the need for AFFFs…**

MilF Spec: 7 different fire tests, fresh & salt water, ½ strength, over-rich, low application rate, corrosion, environmental, high temp (65◦C) use, plus concentrate compatibility & storage tests!

# 1978: Los Angeles Aircrash
# DC-10 severe fire on take-off




DC-10 crash, Los Angeles 1Mar 1978

- Left landing gear collapsed on take-off
- Full left wing fuel tank ruptured at 295kms/hr
- **Intense fire added to severity of incident**
- Left side of aircraft destroyed
- Mil F spec AFFF used, preventing spread
- **198 lives saved out of 200 onboard**
- 28 passengers & 3 crew seriously injured
- 156 passengers & 11 crew suffered minor injuries
- **Initial foam attack protected evacuating passengers escaping on right side**
- **Fire extinguished in 2 mins once fire crews arrived on left side aircraft**

# May 2016: Tokyo Aircrash B777 engine fire



- Engine failure when accelerating for take-off
- Debris ruptured fuel line - caught fire
- Onboard engine fire suppression system activated - did not extinguish
- **Fire crews extinguished using AFFF in few minutes**
- All 319 passengers & crew evacuated safely
- 19 minor injuries sustained
- **Plane undamaged**

B777 engine fire Tokyo - 27May16

# Maximised Life Safety
# Mininimised Infrastructure damage



- Fluorinated Foams provide best fire protection for 50yrs+
- Legitimate public concerns & health fears on legacy issues
- PFOS-PFOA-PFHxS found in people, animals, food, water
- Historic heavy C8 legacy foam usage - poorly managed
- Considered harmless & safe …by manufacturer - Led to extensive usage & problems …**NOW regulated chemicals**

***Seeing a mix:***

- Most transitioning away from C8 AFFF/AR-AFFF/FPs
- F3s use: Training, Brigades, Civil airports
- Environmentally more benign ≤C6 agents: where fuel shedding, vapour sealing, heat resisting, fast capabilities needed for MHFs …incl. airports, military, offshore

- Unintended & unacceptable legacy of community contamination
- A legacy we have to clean up and continue managing …*BUT* management controls dramatically tightened since 2006 - C8s no longer sold
- Less training now, most done with Fluorine Free Foams (F3)
- Less C6 PFAS foam usage ...emergencies only, more care, better collection, better containment ...and effetive **remediation/safe disposal**

**= Preventing such legacy contamination perpetuating**

# What are our “Realistic Expectations”?

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- **No loss of life & minimised injuries**
- **Fast, reliable fire control and extinction**
- **Minimised:** *infrastructure loss*

  *smoke, run-off, resulting damage*

  *risk of closure & job losses*

  *community grief and disruption*

  *foam usage*

  *environmental harm*

  *clean-up & repair costs*

  …Anything ***critical*** missing?

Which foam agents can effectively deliver these expectations …across all fire emergencies?

# Change-out considerations - from Legacy C8 foams

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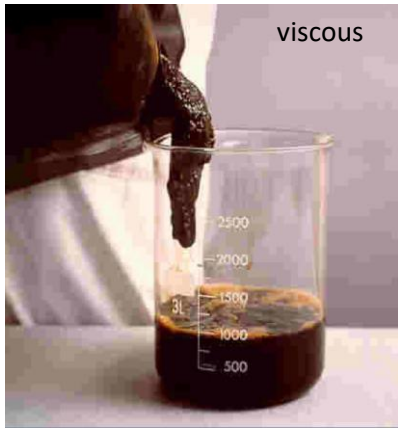
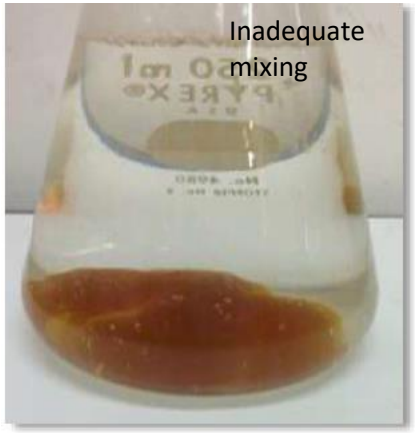
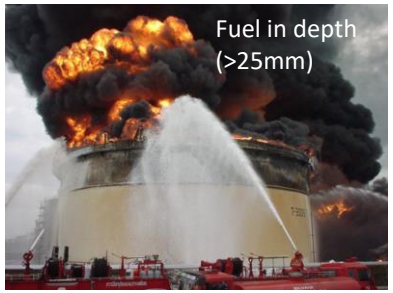
- **Which alternative? - F3s or C6 agents?** (*water alone sinks through fuel spreading it rapidly into other areas*) …depends on fuels, scale hazard, site conditions, existing systems, life safety, escalation potential etc. etc. - do fire tests with site fuels & equipment to verify…
- **Consider** corrosion/seals attack, storage stability, efficiency, compatibility - existing systems & fuels etc …***Is duty of care fulfilled?***
- **Check** suitability/proportioning accuracy with viscosity of ***new*** foam
- **Either way** … tanks, proportioners, pipework needs to be thoroughly cleaned *(or replaced)* to prevent ***new*** foam cross contamination risk -C8
- **Clean** proportioners/pumps/delivery devices/dead ends etc.
- **Record process & residual PFAS level -** use TOP assay lab sample results of final washwater to check - ***before*** filling with ***new*** foam
- **Verify** system design criteria is NOT compromised by changes
- **Ensure** new foam will act swiftly, effectively, reliably, not risk over-flowing containment areas, nor place lives in unnecessary danger






**Remember**: all foams pollute & all firewater/runoff needs containing, collecting, testing for PFAS & potential treatment ...***before*** release to WWTPs

# May 2013: Heathrow, UK
# A319 engine fire on landing



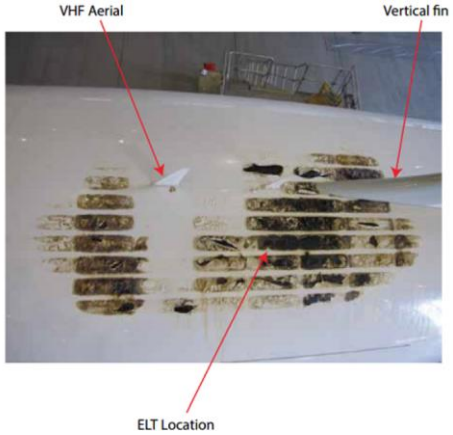
A319 small engine fire, London Heathrow, 24th May2013

- Both engine cowls detached (*left unlatched after maintenance*) damaging airframe on take off
- Fuel leak ignited right engine during landing approach
- Engine immediately shut-down, on-board extinguishing system activated, reduced fire intensity, landed safely
- **F3 used to rapidly extinguish fire**
- All 80 passengers and crew safely evacuated via left side
- No injuries reported

**A further claimed "effective use" of F3 at Heathrow - 12July 2013**

- Ground fire in unpowered, unoccupied B787 aircraft
- Likely cause: crossed wires from lithium battery in rear fuselage created slow burning fire in internal composite materials above cabin
- **F3 used external to the aircraft, but fire extinguished internally with hose-reel water spray**

***Not defined by ICAO Annex 13 as either Accident or Serious Incident***



# Feb.2016: Danish Port Fire
# Fertiliser & Palm Oil Tanks, Fredericia

Fredericia port fire, Denmark Feb.2016

- Silo explosion caused major port fire
- 12,000 tonnes liquid fertiliser (*Ammonium Nitrate*) burst from overfull storage silo, mixed with 2,266 tonnes palm oil catching fire (stored at 70∘C )
- **Firefighters worked all night and into next day to control fire - F3 used** (*palm oil not volatile - high <148∘C flashpoint, cooling watersprays potentially effective to extinguish*)
- **Claimed as F3 "success"** by IPEN …but F3 likely added to BOD problems in harbour
- **Caused an environmental disaster - one of worst in recent Danish history**
- >100 people deployed to "clean up thick layer of palm oil, water and foam"
- **Caused resignation of Danish Environment & Food Minister**

# June 2016: Singapore Aircrash
# B777 engine fire on landing

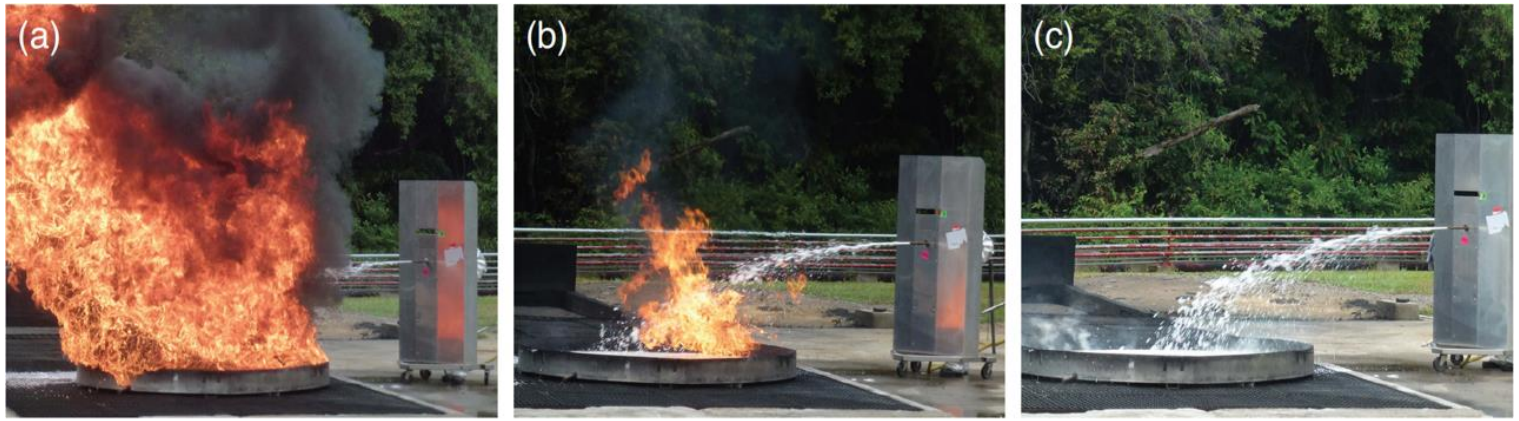


- Cracked fuel pipe in engine heat exchanger leaked fuel into right engine
- Engine and wing caught fire on landing
- Thrust reverser spread fire through core of engine
- **Fire extinguished using AFFF/FFFP in 3 mins**
- Re-involvement in hot engine 3 mins later **extinguished immediately**
- All 241 passengers & crew disembarked via mobile stairs - 15mins ***after*** fire extinguished
- **No injuries were sustained**
- **Minimal disruption resulted**
- **Plane repaired and returned to service**


A safe and well executed “text-book” response

# July 2016: Singapore demo
# F3 replaced …by more robust C6 AFFF






Effective ICAO Level B Fire test demo using C6 AFFF at Singapore Fire Conference, July 2016.

An F3 agent intended as Conference highlight …"showcasing its effectiveness", had to be replaced by ≤C6 AFFF last minute - **because** …***"too many environmental factors were not under our control to do F3"!*** ie it was too hot at 32°C for F3 to be effective (Such ICAO Level B fire tests are usually conducted at around 15 °C).

Twice the day before at 32°C, the same fire demo was unable to be extinguished using F3 agents, …and reportedly caught the training facility's fuel separator alight.

***A demo can be cancelled…REAL EMERGENCIES cannot!***

# Aug. 2016: Dubai Aircrash
# B777 fire - plane burned out




B777 engine fire, Dubai - 3Aug16


- Boeing 777 crashed during “attempted go-around” , 48 °C heat with wind-shear conditions
- Right engine detaching & structural damage on landing caused fuel fire
- All 282 passengers & crew safely evacuated as fuel fire developed
- 4 serious and 26 minor injuries

- **Foam - likely F3** (as Dubai major user) **applied to suppress the fire**
- **9 mins after crash a brave firefighter tragically lost his life when fuel tank exploded**
- Extensive foam application to fuselage continued…
- ***Full control not achieved until 16 hours after impact! ...Plane destroyed - apparently first ever in Emirates fleet.***
- Final investigation - still not yet concluded - *Why?*
- Cause of firefighting failure, ...whether foam or very high ambient temperatures contributed, not yet known - ***remains a possibility...***

***Need to know - Why this fire attack failed?***

# Aug.2018: Footscray Chemical Factory Fire (Melbourne)



- 1.4 ha, est. 100,000 chemical drums - 17 hours fire control & 5 days to extinguish all hot spots *(although some areas potentially shielded from foam attack)*
- **Only F3 used** by MFB during incident (*confirmed by EPA Vic*)
- PFAS chemicals detected at 16x recreational water quality criteria in runoff (*emanating from PFAS materials on site -**not firefighting foam***)
- EPA Vic sampling **confirmed elevated PFAS levels remained for 2 weeks**
- 55million litres contaminated runoff pumped out of creek by 3rd day
- 170million $m^3$ contaminated sediment removed from creek by 24th Sept.
- EPA Vic Chief Env. Scientist confirmed this incident was "…***probably as bad as it could be***, **…the chemicals from the fire have had a '*massive* impact' on the system - *We've had more than 2,000 fish killed*."**
- **Creek remediation is still on-going…**


Footscray Chemical Factory Fire –Aug.2018

**Did slower control situation perhaps deliver worse outcomes?**
**…might faster attack have reduced runoff volumes?**

# Oct.1996: Albright & Wilson Major Chemical Fire, Avonmouth UK



- 6.8ha site - surrounded by another chemical complex, fuel storage depots, major port/docks, industrial units, 2 villages & congested residential area all within 2.5km radius
- Total inventory 220,000L volatile chemicals (incl. Propylene Oxide, phosphorous specialties, petroleum additives etc.)
- 20 tonne tanker delivering Epichlorhydrin at time - explosion caused major fire - explosion heard 8 miles away
- Est. fire area 2,400m$^2$, 100m high black smoke plume (incl. Hydrogen Chloride - acid rain!)
- **Major Fire extinguished after 4 hrs using est. 40,000L AR-FFFP foam concentrate**
- 6 firefighters, hospitalised for smoke inhalation - fully recovered
- 3 appliances monitored site for 10.5 hrs, before handover to UK Health & Safety Executive (HSE) …*think Workplace Health & Safety in Australia*

**Fast reliable efficient control & extinction, protected critical infrastructure & prevented escalation**

# Foam Suitability Considerations

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- **Variety of fuels on site** - volatile hydrocarbons? Polar solvents?
- **Compatibility with existing foam systems equipment**:

  *proportioning* - accuracy? viscosity? flow? mixing?

  *delivery devices* - non-aspirated? aspirated? forceful? gentle? Pouring? monitors? sub-surface?

- **Suitability for spills *and* fuel in depth fires** (>25mm):

  *requires* - fuel shedding, vapour sealing, heat resisting

  *ie.* **no** attack by fuel, **no** edge flickers, **no** burnback or re-ignition, **no** unpredictable flashbacks

  ***= infrequent top-ups, less foam use & reliable fire protection***

- **Minimised environmental harm** - less foam usage reduces aquatic toxicity & biological oxygen demands (reducing fish suffocation)

# Reliable Remediation Options

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Despite some misleading claims to the contrary…

Existing technologies **CAN** commercially concentrate and destroy ≥C8 long-chain & ≤C6 short-chain fluorochemicals …including PFHxA, 6:2 FTS,PFBA, PFOS, PFOA, PFNA, PFHxS etc etc.

Fig 2: OCRA process with airport fire training area in background.

- **Modified clays and bioabsorbent granules** shown to adsorb and collect short-chain C4-C12 fluorochemicals effectively *(ground and firewater runoff).*
- **Some Ion Exchange Resins**
- **Reverse Osmosis/Nano-Filtration**
- **Heated Persulphate Oxidation**
- **Ozone Fractionation (OCRA)**
- **Electrical discharge plasma**
- **Sono-chemical breakdown**
- **Cement kiln or plasma Arc Incineration**

*All can address a wide range of long & short-chain PFAS …including PFOS, PFOA, PFHxS, PFBA, PFHxA, 6:2 FTS etc.*

(**Sources**: Merino 2016, Bruton & Sedlak 2017, Hori 2008, Rodriguez-Friere 2016, Naidu 2015, Dickenson & Higgins 2016, etc.)

# 17-20Mar 2019 ITC Tank Fire, Deer Park Texas USA

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- Huge 107ha site, 242 storage tanks, **15 affected tanks in single bund**!
- Very challenging multi tank fire, congested bund area, strong winds
- Fire started am 17th in 1 tank, spread to 2nd tank (evening) increasing severity, then 5 more tanks alight by early 18th, and 8th tank by daybreak 18th , 2 more tanks alight 10 am 19th + 2 empty tanks collapsed
- Dwight Williams & new C6 1x3 AR-AFFF brought in 7am 19th, chopper tour site & over 4 hrs to set-up equipment - difficulty fighting fires from downwind and crosswind - (not usual upwind)!
- 12 tanks burned over 4 days
- All fires out by 3am 20th - 64 hours to extinguish
- Fuel in 3 tanks salvaged, adjacent tank spread prevented
- Rest 210 tanks on site incl. LPGs unaffected
- No reported injuries


ITC Tank fire , Texas

**How would F3 have fared?**

# 5-9Apr.2019: Campbellfield Chemical Factory Fire (Melbourne)

- Major Chemical Factory Fire (similar size to Footscray-Aug18) - also took 4 days to extinguish (5-9Apr19)
- MFB confirmed "*175 firefighters & 40 firetrucks battled blaze …likely to burn for several days*"
- **MFB only uses F3**
- Est. 300,000L chemicals on site …double EPA's licence allowance
- EPA Victoria working to minimise waterway impacts
- EPA Vic reported ***"very low dissolved oxygen levels on 6 Apr. …low enough to cause fish deaths"***
- Scale of environmental impacts from chemicals and foam used not yet known …*although Footscray fire was widely declared an environmental disaster.*

# 5 May 2019: Moscow Aircrash
# Sukhoi Engine Fire on Landing

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- Russian made Sukhoi Superjet 100 -1st flight 2011
- Technical problems after take-off (possible lightning strike) - returned as emergency
- **Engine ignited during hard emergency landing**
- Trail of burning fuel on runway
- Rear of plane caught & quickly sustained fire
- **Crew evacuated 37 passengers safely in 55secs**
- Firefighters battling blaze took over 1hr to reach tail section passengers - **Foam type unknown**
- **40 passengers & 1 cabin crew tragically died**
- 11 people injured, 6 hospitalised with burns
- Eyewitness said ***"It's a miracle anyone escaped"***
- Aeroflot have 50 such aircraft in current fleet


Sukhoi crash, Moscow May 2019

Pools fuel alight on runway behind aircraft

**How would you respond to a major fire tomorrow?**

# Foam Comparisons: Fire & Environmental Performances

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| Characteristics | C8 legacy foam | Fluorine Free Foam (F3) | High purity ≤C6 foam |
|---|---|---|---|
| Speed control/extinguishment | faster | slower | faster |
| Fuel shedding ability | high | none | high |
| Re-ignition risk *(volatile fuels)* | lower | higher | lower |
| Application flexibility | forceful, gentle, non-asp, asp, in-depth, sub-surface | semi-forceful, gentle, aspirated, shallow (limited applications) | forceful, gentle, non-asp, asp, in-depth, sub-surface |
| Volume foam required *(for given size volatile fuel incident)* | smaller | larger | smaller |
| **Fire Performance ability** | reliable & robust | limited (ability & apps) | reliable & robust |
| Persistence | concerns | no known concerns | concerns |
| Bioaccumulation | major concerns | no known concerns | low concerns |
| Aquatic toxicity | concerns | 10x higher than C8/C6 | low concerns |
| Human health | major concerns | no known concerns | low concerns |

Key: Good, Acceptable, Bad

# How Do We Fare Today?



IF a major fire started in ***your*** facility today…

- **How would *you* Fare? …How would *you* respond?**
- **What is critical to *you*?**
  - *Saving lives, reducing infrastructure damage, responding effectively?*
  - *Meeting your Duty of Care?*

Recent fires discussed, seem to show…

Fast, reliable, effective, efficient fire control and extinction are critical in:

- saving lives,
- reducing injuries,
- minimising escalation,
- reducing infrastructure damage,
- reducing smoke & toxins
- reducing runoff
- preventing escalation/moving off-site
- protecting nearby communities
- collecting & containing ALL runoff
- less contamination problem to deal with
- testing & treatment

***= avoiding environmental disaster***

# What Is "Best Practice" Today?

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**Using best available techniques for fast incident control.**

This requires: effective well trained teams

- best suited equipment/systems for site hazards/conditions
- well maintained & appropriate systems/equipment/foams
- reliable catchment & bunding of ALL runoff
- reliable, proven, effective procedures - acting fast
- protecting lives, infrastructure, communities
- minimising aftermath …"problems to deal with"
- collect & contain ALL runoff - including firewater runoff
- test and treat ALL runoff …***before*** entering WWTPs & environment
- remove & remediate potentially harmful fuel/chemicals

Any Q's or concerns… contact: willsonconsulting26@yahoo.com.au

Fast, effective control minimises escalation

***"The key to preventing worst pollution is have a response plan to clear potential fire hazards …All fire water runoff will be detrimental to the environment if allowed to enter water courses. … best technique is to prevent pollution from entering in the first place."***

*Source: UK Environment Agency, 2017*