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A HISTORICAL REVIEW OF FLUORINATED FOAM FIREFIGHTING AGENTS, PERFORMANCE REQUIREMENTS/ ENVIRONMENTAL SAFEGUARDS REVIEW

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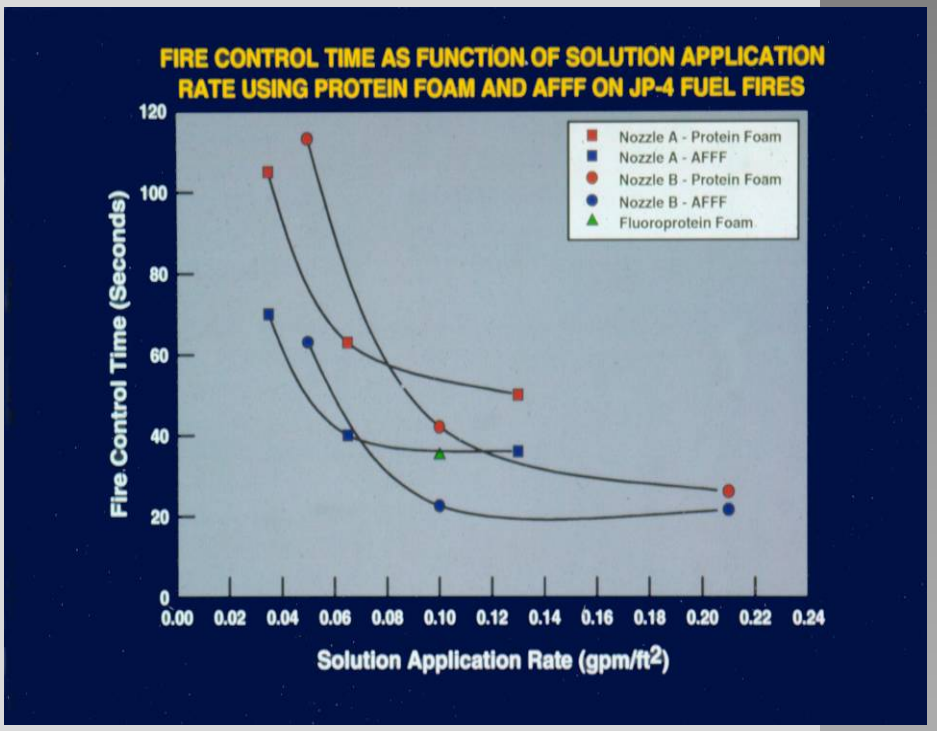
Overview

- Brief history of foam and the AFFF MIL SPEC
- Fire extinguishing performance – why it matters
- Environmental concerns/restrictions
- Mitigation and challenges – approach going forward

Foam History

Originally developed for liquid fuels suppression

- Protein Foam (PF)
- Fluoroprotein (FPF)
- AFFF
- Other variants – FFFP, FFF



Application (mass flow) rate – nozzle flow rate, gallons/minute-ft^2 (gpm/ft^2)

Extinguishment density – mass of foam per unit area required for fire extinguishment, gal/ft^2

AFFF Development

- Naval Research Laboratory
  - 1961 – Synthetic surfactant formulated
  - 1963 – Patent application, initial spec
  - 1966 – Patent award assigned to US Secretary of the Navy
- 1968 – NRL and 3M 6% seawater formulation
- 1969 – Jacksonville, FLA, large and moderate scale test results, Mil-F-24385
- “Light Water” characterized by spreading surface tension/spreading coefficient
  - AFFF solution forms film layer on top of fuel

$$S_{a/b} = \gamma_b - \gamma_a - \gamma_l$$

Where, in (dynes/cm):

$S_{a/b}$ = Spreading coefficient

γ_b = Surface tension of the lower hydrocarbon fuel

γ_a = Surface tension of the upper layer AFFF solution

γ_l = Interfacial tension between liquids a and b

Minimum spreading coefficient of 3 Ignition resistance test (film formation)

AFFF MIL SPEC Extinguishing Performance

- Based on MIL-F-24385F
  - 28 ft^2 fire test
    - Application rate – 0.071 gpm/ft^2
    - Maximum extinguishment time – 30s
    - Maximum extinguishment density – 0.036 gal/ft^2
  - 50 ft^2 fire test
    - Application rate – 0.04 gpm/ft^2
    - Minimum 40 s summation – 320s
    - Maximum extinguishment time – 50s
    - Maximum extinguishment density – 0.033 gal/ft^2
- Burnback resistance
- Field applicability fire tests
  - One-half and quadruple strength
  - Aged concentrate
  - Inter-agent compatibility
- Foam expansion and drainage

Examples of Extinguishment Application Densities of Various Test Standards

	Fuel	Application Rate gpm/ft^2	Nozzle Movement Permitted	Maximum Allowable Time to Extinguishment	Extinguishment Application Density gal/ft^2
MIL-SPEC 28 ft^2	Motor gasoline	0.071	Yes	30	0.036
MIL-SPEC 50 ft^2	Motor gasoline	0.04	Yes	50	0.033
UL 162	Heptane	0.04	Yes	180	0.12
ICAO B 50 ft^2	Kerosene	0.06	Yes (horizontal plane)	60	0.061
ICAO C 80 ft^2	Kerosene	0.04	No?	60 (flickering flame permitted)	0.038
ISO Forceful	Heptane	0.06	No	180	0.18

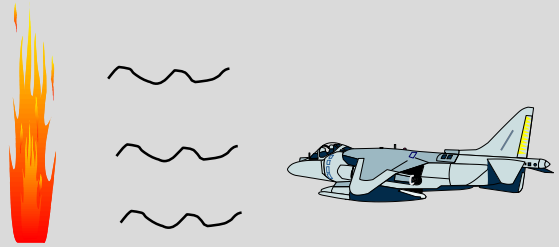
NFPA Standards

- NFPA 11 Foam
  - Basic foam protection, commercial petrochem, marine & industry
  - 0.16 gpm/ft^2 AFFF application rate, commercial UL 162 spec
- NFPA 16 Foam Sprinklers – 0.16 gpm/ft^2, UL 162 spec
- NFPA 403 Aircraft Rescue & Firefighting
  - Commercial aviation, 2 min response,1 min exting
    - AFFF 0.13 gpm/ft^2 High Performance
    - FPF (FFF) 0.18 gpm/ft^2 Medium Performance
    - PF 0.20 gpm/ft^2 General Use
  - Have adopted performance approach
- NFPA 409 Hangar Protection
  - Structural sprinkler option – 0.16 gpm/ft^2
  - Low level AFFF to protect aircraft – 0.10 gpm/ft^2
- NFPA 30 – commercial and industrial flammable liquid storage and operations
  0.30 – 0.60 gpm/ft^2 AFFF

Note – all recognize performance advantage of AFFF vs alternatives

Scenario Comparison

- Aircraft carrier flight deck – <60 seconds
- Commercial Aviation – 60 seconds
- Aircraft Hangar
  - Military Aircraft – 1 min (damageability assessment)
  - Commercial aircraft – 2 min
  - Structure – several minutes
- Shipboard spaces
  - Military – 1 min desirable
  - 2-5 minutes acceptable in some situations
  - Commercial – allow commercial foam spec
- Gasoline Fueling Facility, Sprinklered Liquid Warehouse – 1-5 minutes (UL 162 spec)
- Large Fuel Storage tank – minutes to hours
  - Fixed protection not always provided
  - Critical application rate needed



Chemical/Physical/Quality Parameters in the MIL SPEC

Requirement	Rationale
Refractive index	Refractive index enables use of refractometer to measure solution concentrations in field; this is most common method recommended in NFPA 412[a]
Viscosity	Viscosity Ensures accurate proportioning when proportioning pumps are used; for example, balance pressure proportioner or positive displacement injection pumps
pH	pH Ensures concentrate will be neither excessively basic or acidic; intention is to prevent corrosion in plumbing systems
Corrosivity	Limits corrosion of, and deposit buildup on, metallic components (various metals for 28 days)
Total halides/chlorides	Limits corrosion of, and deposit buildup on, metallic components
Environmental impact	Biodegradability, fish kill, BOD/COD[b]
Accelerated aging	Film formation capabilities, fire performance, foam quality; ensures a long shelf life
Seawater compatibility	Ensures satisfactory fire performance when mixed with brackish or saltwater
Interagent compatibility	Allows premixed or storage tanks to be topped off with different manufacturers' agents, without affecting fire performance
Reduced- and over-concentration fire test	Ensures satisfactory fire performance when agents are proportioned inaccurately
Compatibility with dry chemical (PKP) agents	Ensures satisfactory fire performance when used in conjunction with supplementary agents
Torque to remove cap	Able to remove without wrench
Packaging requirements	Strength, color, size, stackable, minimum pour, and vent-opening tamperproof seal; ensures uniformity of containers and ease of handling
Initial qualification inspection	Establishes initial conformance with requirements
Quality conformance inspection (each lot)	Ensures continued conformance with requirements

[a]NFPA 412, Standard for Evaluating Aircraft Rescue and Fire-Fighting Foam Equipment, 2003 edition
[b]BOD/COD: Biological oxygen demand/chemical oxygen demand

AFFF Environmental Impact

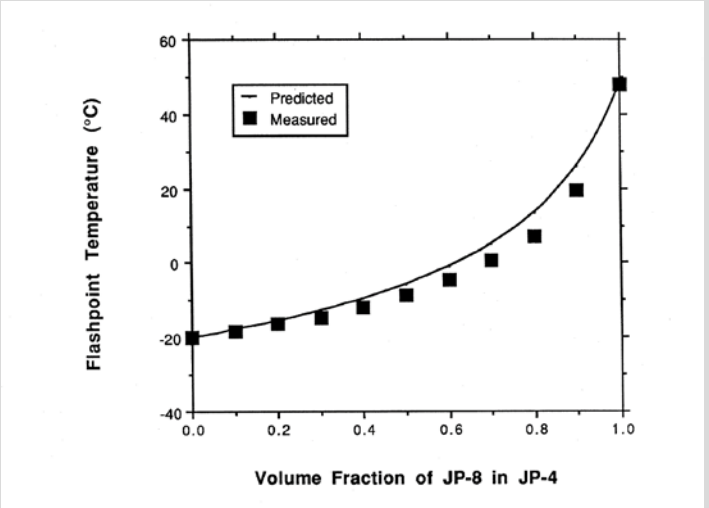
- Environmental Impact
  - Foaming
  - Oil Emulsification
  - Aquatic Toxicity
  - Oxygen Demand and Biodegradation
  - Persistence / Bioaccumulation
- Fluorosurfactants
  - Persistent, Bioaccmulative, Toxic (PBT)
  - Voluntary chemical restrictions in US
    - PFOS foam
      - » Electrochemical fluorination process
      - » No longer produced in US
    - PFOA foam
      - » Telomerization process
      - » Long chain perfluorocarbons (C8 and greater)
      - » A number of reformulations have been qualified
- Glycol ethers
  - Required for refractive index

Mitigation and Improvement Strategies

- Limit “routine” discharges
  - System testing, training
  - Simulants or water (NFPA 11)
- Impoundment for large anticipated discharges
- Anticipate, plan, monitor key water paths
  - Wastewater treatment plants
- Defoamers
- See NFPA 11 for guidance

Reduce the hazard – use of JP-8

Chemical Reformulation
- Fluorine Free Foam
- Conductivity meter in lieu of refractometer
  - Not useful for seawater



SUMMARY

Rapid Fire Extinguishment is Required for Many Scenarios

Elimination of Fluorosurfactants is Desirable Due To Regulatory Pressure

- Extinguishing effectiveness of current FFFs ≠ AFFF

All Foaming Agents Have an Environmental Impact

Both Fire Extinguishment and Environmental Impact Should Be Performance Based – How Good is Good Enough?

QUESTIONS?

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