# MILITARY SPECIFICATION MIL-F-24385F: FIRE EXTINGUISHING AGENT, AQUEOUS FILM-FORMING FORM (AFFF) LIQUID CONCENTRATE, FOR FRESH AND SEAWATER

Patricia A. Tatem and Clarence Whitehurst
Naval Research Laboratory

Ralph Ouellette and Robert L. Darwin
Hughes Associates, Inc

Douglas Barylski
Naval Sea Systems Command

## SUMMARY OF CURRENT MILITARY SPECIFICATION

Military Specification MIL-F-24385F (SH) [1] is approved for use by all departments and agencies of the Department of Defense. This specification covers the requirements for aqueous film-forming foam (AFFF) liquid concentrate fire extinguishing agents consisting of fluorocarbon surfactants and other compounds, as required, to conform to this specification. Other specifications, standards, and publications (government and non-government) form a part of this military specification to the extent specified in the MILSPEC.

MIL-F-24385F (SH) has specific chemical and physical requirements to which AFFF concentrates and solutions must conform for inclusion on the Qualified Products List QPL-24385-31 (30 October 1998 superseding QPL-24385-30, 30 September 1998). These requirements include conformance to concentration as determined by refractive index and fluorine content: corrosivity (pH, total halides, general and localized corrosion); storage issues related to compatibility with other QPL agents and stability based on aging of the agent (measured by stratification and precipitation); environmental impact as determined by biodegradability factors, specifically, chemical oxygen demand (COD) and biological oxygen demand (BOD) and toxicity (short-term measurement for salt water Killifish); performance as a film-forming agent (dry chemical compatibility, film formation and sealability, viscosity, spreading coefficient, and foamability), and, finally, fire performance on a 28-ft$^2$ and 50-ft$^2$ unleaded gasoline pool fires. Tables 1 through 6 gives the Specification requirements for Type 3 and Type 6 concentrates and also results for a recent 6% candidate submitted for conformance to the Specification.

The refractive index is determined at 25 $\pm$ 0.1 °C, using sodium vapor source lamp illumination. The viscosity is determined at temperatures of 5 $\pm$ 0.1 °C and 25 $\pm$ 0.1 °C in accordance with ASTM D445-74, using capillary viscometers in the appropriate size. The viscosity requirement is based on the mechanics of the current Navy piping system and relates to the pressure loss in pipes as a function of factors such as pipe length and pipe diameter. Viscosity and refractive index requirements, not its fire performance, drive the presence of other compounds in candidate formulation (i.e., diethylene glycol monobutyl ether, ethylene glycol and detergents).

Methodology for determining the fluorine content is not specified in the MILSPEC. The requirement is that the test procedure used for the determination of total fluorine content be furnished as part of the qualification inspection report. Fluorine content is more of a quality control issue rather than pass/fail criteria. If using an optical absorption technique, it is more amenable to laboratory rather than shipboard use.

The pH value is determined potentiometrically, using a pH meter with a glass electrode and a reference electrode, at 25 °C $\pm$ 1.0 °C. This corrosivity requirement is intended to minimize corrosion of metallic plumbing and storage containers. For general and localized corrosion, test coupons are evaluated for weight loss or visible pitting. As seen in Table 1, various types of coupons, in accordance with UNS designations, are evaluated according to ASTM E527 for weight loss (general corrosion) and for visible pitting (localized corrosion). The total halides measurement to evaluate for potential metallic corrosion is determined in accordance with ASTM D1821, with minor modifications. The terminology "total" is misleading because the method is more applicable to determining "free" (inorganic salt) chloride and bromide. Fluoride is not likely determined by this method.

TABLE 1. CHEMICAL AND PHYSICAL REQUIREMENTS FOR CONCENTRATES OR SOLUTIONS.

| Requirement | Pass / Fail criteria* | 6% Candidate results |
|---|---|---|
| Refractive index, minimum | 1.358 (1.3630) | 1.3595 |
| Viscosity (Centistoke) | | |
| Maximum @ 5 °C | 10 (20) | 9.08 |
| Minimum @ 25 °C | 2 | 6.3 |
| Hydrogen Ion Concentration (pH) | 7.0 to 8.5 | 7.6 |
| Spreading Coefficient, dynes/cm, minimum | 3 | 5.4 |
| Film Formation and Sealability | No sustained ignition | No sustained ignition |
| Foamability: | | |
| Foam Expansion Ratio, minimum | 5.0 | |
| Fresh Agent Test: Fresh Water / Sea Water | | 9.0 / 8.2 |
| Stability Test, concentrate: Fresh Water / Sea Water | | 9.1 / 8.8 |
| Stability Test, solution: Fresh Water / Sea Water | | 9.6 / 9.1 |
| Compatibility Tests: Fresh Water / Sea Water | | 5.1 / 7.9 |
| Foam 25% Drainage Time, minutes, minimum | 2.5 | |
| Fresh Agent Test: Fresh Water / Sea Water | | 4.25/ 4.20 |
| Stability Test, concentrate: Fresh Water / Sea Water | | 3.5 / 4.25 |
| Stability Test, solution: Fresh Water / Sea Water | | 4.0 / 4.0 |
| Compatibility Tests: Fresh Water / Sea Water | | 3.15/ 4.0 |
| Corrosion Rate: | | |
| General | | |
| Cold rolled. Low carbon steel (UNS G10100) mili in/yr, maximum | 1.5 | 0.69 |
| Copper-Nickel (90-10) (US C70600) mili in/yr, maximum | 1.0 | 0.02 |
| Nickel-Copper (70-30) (US N04400) mili in/yr, maximum | 1.0 | 0.03 |
| Bronze (UNS C90500), milligrams maximum | 100 | 0.03 |
| Localized, corrosion-resistant (CRES) steel, UNS S30400) | No pits | No pits |
| Total Halides, ppm maximum | 250 (500) | 186 |
| Dry chemical compatibility, burnback resistance time 360 sec minimum | 360 | 427 |
| Environmental impact: | | |
| Toxicity, $LC_{50}$, mg/L, minimum | 1000 (500) | >1000 |
| COD, mg/L, maximum | $5x10^5$ $(1x10^6)$ | 279,000 |
| $BOD_{20}$ minimum | 0.65 | 0.80 |
| COD | | |
| Fluorine content, mg/L | ------ | 5250 mg/L |
| Stratification: Stability Test | None | None |
| Compatibility Test | None | None |
| Precipitation, % by Volume: Stability Test | < 0.05 | < 0.05 |
| Compatibility Test, 1:1 Ratio Mixes | < 0.05 | < 0.05 |
| Compatibility Test, All Agent Mix | < 0.05 | < 0.05 |
| Container cap opening torque (average) | 50 in-lbs max | <50 in-lbs max |

*Numbers in parentheses are for Type 3 if different from Type 6.

TABLE 2. 28 $FT^2$ FIRE PERFORMANCE TEST RESULTS:
6% CANDIDATE FRESH CONCENTRATE.

| Property measured | Extinguish time criteria* (max) | Actual times | Burnback time criteria (min) | Actual times |
|---|---|---|---|---|
| Fresh Water Full Strength | 30 sec | 25 | 360 sec | 551 |
| Fresh Water Half Strength | 45 sec | 43 | 300 sec | 436 |
| Sea Water Full Strength | 30 sec | 30 | 360 sec | 555 |
| Sea Water Half Strength | 45 sec | 41 | 300 sec | 491 |
| Quintuple Strength (15%) Sea Water | 55 sec | 40 | 200 sec | 325 |

*Criteria are the same for Type 3.

TABLE 3. 28 $FT^2$ FIRE PERFORMANCE STABILITY TEST RESULTS:
6% CANDIDATE AGED CONCENTRATE.

| Property measured | Extinguishment time criteria* (max) | Actual times | Burnback time criteria (min) | Actual times |
|---|---|---|---|---|
| Fresh Water Full Strength | 30 sec | 25 | 360 sec | 438 |
| Fresh Water Half Strength | 45 sec | 43 | 300 sec | 345 |
| Sea Water Full Strength | 30 sec | 29 | 360 sec | 472 |
| Sea Water Half Strength | 45 sec | 37 | 300 sec | 485 |

*Criteria are the same for Type 3.

TABLE 4. 28 $FT^2$ FIRE PERFORMANCE STABILITY TEST RESULTS:
6% CANDIDATE AGED SOLUTION.

| Property measured | Extinguishment time criteria* (max) | Actual times | Burnback time criteria (min) | Actual times |
|---|---|---|---|---|
| Fresh Water Full Strength | 30 sec | 27 | 360 sec | 428 |
| Sea Water Full Strength | 30 sec | 23 | 360 sec | 472 |

*Criteria are the same for Type 3.

TABLE 5. 28 $FT^2$ FIRE PERFORMANCE CONCENTRATE COMPATIBILITY TEST RESULTS: 6% AGED CONCENTRATES. (SOLUTIONS FOR FIRE PERFORMANCE TESTS WERE MIXED AT FULL STRENGTH)

| Qualified agent | Property measured | Extinguish time criteria* (max) | Actual times | Burnback time criteria* (min) | Actual times |
|---|---|---|---|---|---|
| QPL#1 | Fresh Water | 30 sec | 24 | 360 sec | 426 |
| QPL#1 | Sea Water | 30 sec | 28 | 360 sec | 428 |
| QPL#2 | Fresh Water | 30 sec | 26 | 360 sec | 399 |
| QPL#2 | Sea Water | 30 sec | 30 | 360 sec | 370 |
| QPL#3 | Fresh Water | 30 sec | 26 | 360 sec | 368 |
| QPL#3 | Sea Water | 30 sec | 27 | 360 sec | 438 |
| QPL#4 | Fresh Water | 30 sec | 24 | 360 sec | 442 |
| QPL#4 | Sea Water | 30 sec | 26 | 360 sec | 457 |
| All of the Above | Fresh Water | 30 sec | 24 | 360 sec | 489 |
| All of the Above | Sea Water | 30 sec | 25 | 360 sec | 427 |

*Criteria are the same for Type 3.

TABLE 6. 50 $FT^2$ FIRE PERFORMANCE TEST RESULTS: 6% CANDIDATE FRESH CONCENTRATE.

| Property measured | Extinguishment time criteria* (max) | Actual times | Burnback time criteria (min) | Actual times | 40 sec summation | Actual total |
|---|---|---|---|---|---|---|
| Sea Water Full Strength | 50 sec | 36 | 360 sec | 406 | 320 (min) | 325 |

*Criteria are the same for Type 3.

The environmental impact of the candidate agent is measured, firstly, in terms of its effect on the Killifish (Fundulus herteroclitus) in accordance with ASTM E729, using dynamic procedures. The minimum acceptable dissolved oxygen content of water used in this procedure shall be 5 ppm. Killifish toxicity is a measure of short-term toxicity for salt water fish. There is a limited season on Killifish, which occasionally presents a problem when attempting to qualify agents. AFFFs are historically considered relatively nontoxic by this short-term measure. The COD is determined in accordance with procedures in *Standard Method for the Examination of Water and Waste Water* (latest applicable edition). Biodegradability is determined by dividing the value expressed in mg/L for the 20-day $BOD_{20}$ determined from 5-day BOD test in accordance with the procedure specified in *Standard Methods for the Examination of Water and Waste Water* (latest applicable edition) by the value expressed in mg/L for COD as expressed previously. This quotient is more applicable where waste runs to small bodies of water in waste water treatment plants and sewage treatment plants.

Storage issues as related to compatibility with other QPL agents and stability based on aging of the agent, as measured by stratification and precipitation, are measured as chemical and physical requirements as well as in fire performance requirements. Samples of concentrate and Type 3 AFFF (if evaluated) and Type 6 AFFF (if evaluated) fresh water and sea water solutions are subjected to the following evaluations after exposure to 65 $\pm$ 2.0 °C for 10 days (stability):

a. Spreading coefficient
b. Foamability
c. Film formation and sealability
d. Fire performance (28 sq ft)
e. Stratification
f. Precipitation

In addition, samples of products on the QPL are mixed with the candidate fresh water and sea water solutions (compatibility) and stored at elevated temperatures as above (stability) before being subjected to the following tests:

a. Foamability
b. Film formation and sealability
c. Fire Performance (28 sq ft)
d. Stratification
e. Precipitation

The spreading coefficient is determined with reference to cyclohexane in accordance with the following relationship:

$$\varsigma_{a/b} = \delta_B - \delta_A - \delta_I,$$

where: $\delta_{a/b}$ = Spreading coefficient

$\delta_b$ = Surface tension of cyclohexane, as determined under "Surface Tension" below,

$\delta_a$ = Surface tension of AFFF solution, as determined under "Surface Tension" below,

$\delta_I$ = Interfacial tension between liquids, as determined under "Interfacial Tension" below.

Surface tension –The surface tension of 3 $\pm$ 0.05% of Type 3 or 6 $\pm$ 0.1% of Type 6 by volume in distilled water, as appropriate, and of reagent grade cyclohexane is determined with a DuNoy tensiometer, or equal, at 23 $\pm$ 2.0 °C in accordance with ASTM D1331.

Interfacial tension – The interfacial tension between 3 $\pm$ 0.05% of Type 3 or 6 $\pm$ 0.1% of Type 6 by volume in distilled water, as appropriate, and reagent grade cyclohexane is determined with a DuNoy tensiometer, or equal, at 23 $\pm$ 2.0 °C until the readings come to equilibrium and are in accordance with ASTM D1331.

Stratification and precipitation measurements are done on all the compatibility solutions and stability solutions. The presence of stratification is determined by visual examination of the candidate sample contained in glass cylinders. The amount of precipitation is determined by centrifuging 100 mL samples after thorough agitation in accordance with the primary method of ASTM D96.

Foamability of the candidate samples is checked by means of a special 2 gal/min test nozzle. The basic nozzle, as made by National Foam System, Inc., Lionville, PA (or equal) is modified and the nozzle inlet pressure and solution temperature maintained as quoted in the MILSPEC. The method and procedure followed are is accordance with NFPA 412. Foamability is run on both fresh and sea water solutions of the candidate concentrate (Type 3 and/or Type 6).

Film formation and sealability are usually conducted on the candidate samples once they have passed the 28-ft$^2$ fire tests. This measurement assures that the films formed over the fuel by the candidate samples are capable of maintaining an effective vapor seal to prevent further vaporization of the fuel during fire fighting. The test is performed on the film-forming liquid without most of the residual foam that can be generating when delivering the agent.

There is a container cap opening torque requirement of 50 in.-lbs max. This requirement assures that a sailor under the duress of fire fighting is able to open an AFFF container with relative ease.

The 28-ft$^2$ fire tests are conducted in a level, circular pan 6 ft in diameter, fabricated from 0.25 in. thick steel with a 4 in. high side. A shallow water layer is used to protect the pan bottom and ensure complete coverage of the area with fuel. The nozzle used for foam application is the 2 gal/min device used for the foamability measurements. The foam from the candidate agent is generated at 23 $\pm$ 5.0 °C from AFFF solutions made with fresh or sea water, as required, at various concentration values given in Tables 2 through 4. Table 2 gives requirements and results for fresh concentrate at full, half and quintuple (sea water only) strengths. Table 3 gives requirements and results for aged concentrates at full and half strengths. Table 4 gives requirements and results for aged solutions at full strength only. Table 5 gives the requirements and results for concentrate compatibility tests for a candidate agent with AFFF agents currently on the QPL. To perform the compatibility fire tests, the candidate agent is mixed individually with each of the QPL products in a 1:1 volume ratio, and with all the QPL products in a 1:1:1:etc. volume ratio. These concentrate mixtures are aged in accordance with the previous "Stability" section and then used to prepare the solutions used for fire performance testing.

Certain procedures must be followed. Ten gallons of unleaded gasoline fuel are used that conform to ASTM D439. The fuel shall be dumped within a 30-sec period, ignited within 30 sec of fueling, and allowed to burn freely for 10 sec. After the preburn period, the fire is attacked and extinguished as expeditiously as possible, continuing foam application for a total of 90 sec even if the fire has extinguished. The actual fire extinguishing time cannot exceed the extinguishment requirement criteria in the tables. Within 60 sec of the completion of foam application, a burning pan (1 ft in diameter with 2 in. side) containing one gallon of unleaded gasoline is placed in the center of the 28-ft$^2$ pan, and a timer starts. When it appears that the fire has spread outside the pan so that burning will continue after pan removal, the pan shall be removed. The burnback time is that time at which it is estimated that 7 ft$^2$ (25%) of the total area is involved in flames.

The 50-ft$^2$ fire test (Table 6) is performed after all the other performance criteria have been satisfied. The fire test is conducted on a level, circular area 8 ft in diameter. The base and surrounding wall shall be suitable for containment of the fuel on a substrate of water. The water depth is the minimum required to ensure complete coverage of the area with the fuel. The nozzle used for foam application is the 2 gal/min device specified previously and operated at a gage pressure of 100 lb/in$^2$

The foam is generated at 23 ± 5.0 °C from full strength, sea water Type 3 and/or Type 6 fresh concentrate. Fifteen gallons of unleaded gasoline fuel is used conforming to ASTMD 439. The fuel is dumped into the area in less than 60 sec, ignited in less than 30 sec after fuel dumping, and allowed a preburn of 10 sec. The fire is attacked and extinguished in an expeditious manner. At 10-sec intervals after the start of foam application, observers estimate the percentage of fire area extinguished. The percentages at 10, 20, 30, and 40 sec are totaled to give the "40-sec summation" value. The exact extinguishing time is recorded at the cessation of all flame, but foam application continues for a total of 90 sec.

Within 60 sec of the completion of foam application, a burnback test shall be conducted as in the 28-ft$^2$ fire tests, except that the burnback area shall be 12.5 ft$^2$ (25%).

## HISTORY AND EVOLUTION OF THE AFFF MILITARY SPECIFICATION

In 1961, researchers at the Naval Research Laboratory (NRL) began an in-depth assessment of the potential firefighting capabilities of a new family of chemicals known as fluorocarbon surfactants. Initial studies showed that foams made from these surfactants rapidly spread over the surface of a hydrocarbon fuel fire, providing much quicker extinguishment times relative to the protein-based foams then in use. The superiority of these new foam agents was attributed to their tendency to form an aqueous film on the fuel surface, which resulted in the adoption of the term "Light Water" or "Aqueous Film Forming Foam (AFFF)." A patent application for this technology was filed in September 1963 [2], and an initial military specification (Mil-F-23905) [3] was issued two months later. The final patent was awarded in June 1966, with rights assigned to the Secretary of the Navy. The AFFF described in the initial specification had limited practical application because it was only compatible with fresh water and required a 25% by volume mixture ratio with water to form an effective foam solution. Within a year, a formulation was developed that reduced the mixture ratio to 6%, which was the same as for conventional foams then in use by the US military. Large-scale tests at NAS Miramar, CA, confirmed a margin of superiority over protein-based foams of approximately 3 to 1 [4]. In early 1968, a joint effort by NRL and the 3M Company produced a formulation that was believed to be compatible with sea water. Testing at NAS Jacksonville, FL, in December of 1968 confirmed the compatibility with sea water [5] and demonstrated the efficacy of deploying the new agent on Navy ships as well as at Naval

Air Stations. The report of the Jacksonville tests [6] contained the initial draft of a proposed specification for sea water compatible AFFF, which was formally issued as Mil-F-24385 a year later.

As indicated in Table 7, numerous revisions and amendments to the original specifications have occurred over the years. Table 8 summarizes the significant changes to AFFF physical and chemical limits that were incorporated in revisions to Mil-F-23905. Similarly, Table 9 summarizes changes in the required physical and chemical properties that have been made to Mil-F-24385 from 1969 to the present version dated January 7, 1992. The most important changes are as follows:

- The conversion from a 25% mixture ratio to a 6% mixture ratio in 1967
- The incorporation of corrosion limits in 1969
- The establishment of maximum chloride limits and the incorporation of a dry chemical compatibility test in 1971
- The 1972 adoption of a minimum pH value of "7"
- The incorporation of a "spreading coefficient" as well as environmental limits in 1977
- The inclusion of a Type 3 concentrate (allowing a 3% mixture ratio) in 1981
- The tightening of the $BOD_{20}/COD$ ratio in 1992

TABLE 7. EVOLUTION OF THE AFFF MILITARY SPECIFICATION.

| | |
|---|---|
| Mil-F-23905 | 11/1/63 |
| 23905A | 3/26/65 |
| Amendment 1 | 8/13/65 |
| Amendment 2 | 9/1/66 |
| 23905B | 4/25/67 |
| Mil-F-24385 (replaced Mil-F-23905) | 11/21/69 |
| Amendment 1 | 5/11/70 |
| Amendment 2 | 6/25/70 |
| Amendment 3 | 7/7/71 |
| Amendment 4 | 1/14/72 |
| Amendment 5 | 2/17/72 |
| Amendment 6 | 6/29/73 |
| Amendment 7 | 7/24/73 |
| Amendment 8 | 6/20/74 |
| 24385A | 5/2/77 |
| 24385B | 5/25/78 |
| Amendment 1 | 5/16/79 |
| 24385C | 3/12/81 |
| Amendment 1 | 6/5/81 |
| Amendment 2 | 12/4/81 |
| Amendment 3 | 4/26/82 |
| Amendment 4 | 3/3/83 |
| 24385D | 10/26/89 |
| 24385E | 11/30/90 |
| 24385F | 1/7/92 |

In addition to changes in specific physical and chemical limits, there have been considerable enhancements to the required level of fire performance. The evolution of stricter fire performance criteria is shown in Table 10. The incorporation of ever-increasing fire performance can be illustrated by the reduction over time in the "maximum allowable extinguishment application density," which is defined as the maximum gallons of AFFF solution required per unit area of fuel surface to achieve total extinguishment. The maximum allowable density dropped from 0.1 gal/ft$^2$ (1963) to 0.08 (1971), to 0.054 (1977), and finally to the current limit of 0.036 for the 28-ft$^2$ fire and 0.033 for the 50-ft$^2$ fire. Similarly, the "minimum 40-sec summation" has increased from 285 to its current level of 320. The 40-sec summation imposes a requirement for very rapid fire knockdown. Finally, there has been a corresponding

TABLE 8. SIGNIFICANT CHANGES TO PHYSICAL AND CHEMICAL LIMITS: MIL-F-23905 (WEP) FIRE EXTINGUISHING AGENT, "LIGHT WATER" LIQUID CONCENTRATE [2].

| | | |
|---|---|---|
| **Original SpecVersion (11/1/63)** | | |
| Mixture Ratio: | 25% (fresh water only) | $R_i$: 1.335 to 1.337 |
| Viscosity: | 22-36 centistokes @ 20 °C<br>57-59 centistokes @ 0 °C | pH: 6.7-7.3 |
| Surface Tension: | 25-30 dynes/cm (1/370 solution) | |
| **"A" Revision (3/26/65)** | | |
| Mixture Ratio: | 25% (fresh water) | pH: 5-6.5 |
| Viscosity: | 14-28 cs @ 25 °C | |
| Surface Tension: | 14-22 dynes/cm (1/370) | |
| Requirement for "fuel vapor sealability" | | |
| **"B" Revision (4/25/67)** | | |
| Mixture Ratio: | 6% (fresh water) | pH: 4.2 min |
| Viscosity: | 50-150 cs @ 25 °C<br>300 cs @ 4.4 °C | |
| Surface Tension: | 20 dynes/cm max (1/370) | |
| Requirement for "film formation and sealability" | | |
| Requirement for "foamability" | (Expansion Ratio =7:1 minimum)<br>(1/4 Drainage Time = 2.5 min) | |

tightening of the allowable "burnback" (the time required for the fire to spread from the burnback pan to involve 25% of the original fire area). The minimum burnback time has been increased from 240 sec in 1969 to the current limit of 360 sec for both the 28 and 50-$ft^2$ fires.

Fire testing is also required to demonstrate adequate performance of "aged" AFFF concentrate and "aged" AFFF solution ("aging"is simulated by storage at 65 °C for 10 days), and also to show that concentrate from one manufacturer can be safely mixed with any other concentrate previously qualified. Dry chemical compatibility must also be demonstrated by successfully passing a burnback test in the presence of potassium bicarbonate powder. An additional fire test requirement was incorporated in the "A" revision to the current specification in 1977 to assure adequate performance for "mis-proportioned" foam solution. At the time, Navy shipboard foam proportioners were very inaccurate and it was considered necessary to assure some level of firefighting capability for both "lean" and "rich" solutions. Tables 11 and 12 summarize the performance required by revision "A" and the change incorporated in revision "C," which still applies in the current version of the specification.

As indicated in Table 12, foam solution at "half strength" (3% of Type 6, or 1.5% of Type 3) must achieve total extinguishments in 45 sec as opposed to only 30 sec for a full strength foam solution. A solution of 5 times full strength (30% of a Type 6, or 15% of a Type 3), made with sea water, must achieve total extinguishments of the same size fire within 55 sec. Maximum allowable burnback times are also shown.

## RATIONALE FOR SPECIFICATION REQUIREMENTS

The establishment of specific limits on AFFF physical and chemical characteristics, as well as the imposition of minimum levels of fire performance, has evolved in an attempt to provide the best flammable liquid firefighting agent for military applications. While some requirements have resulted from the unique nature of Navy shipboard foam systems, most changes that have resulted over the years are beneficial improvements to common shore applications as well [7]. Table 13 provides the underlying rationale for various requirements in the current AFFF specification.

TABLE 9. SIGNIFICANT CHANGES TO PHYSICAL AND CHEMICAL LIMITS: MIL-F-24385 (NAVY) FIRE EXTINGUISHING AGENT, AQUEOUS FILM-FORMING FOAM (AFFF) LIQUID CONCENTRATE, FOR FRESH AND SEA WATER [1].

| | |
|---|---|
| Original Spec Version (11/21/69) | |
| Mixture Ratio: 6% (fresh and sea water) | pH: 4-8 |
| Surface Tension: 18 dynes/cm max | Interfacial Surface Tension: 5 dynes/cm |
| Corrosion Limits (for steel, aluminum alloy, CRES, 90/10 copper/nickel) | |
| Inter-Agent Compatibility Requirements | |
| Stability of Aged Agent | 1/4 Drainage Time Raised to 3 Min |
| Amendment 1 (5/11/70) | |
| Increased the "pour opening" to 1½ inch | |
| Amendment 3 (7/7/71) | |
| Lowered 1/4 Drainage Time to 2.5 min | |
| Added "no visible pitting" of CRES 304 | |
| Limit of 100 ppm max for chlorides | |
| Dry Chemical Compatibility test | |
| Precipitate < 1% by volume for aged concentrate | |
| Amendment 5 (2/17/72) | |
| Changed pH to 7-8.5 | |
| "A" Revision (5/2/77) | |
| Spreading Coefficient limit of 3 minimum | |
| Expansion ratio reduced to 6:1 | |
| Bronze and 70/30 copper nickel added to corrosion requirements | |
| Corrosion expanded to "general" and "localized" limits | |
| Environmental limits ($TL_{50}$ > 1500 ppm, $BOD_{20}$ and COD < 500,000 mg/l) | |
| Cans must be "stackable" and "self supporting" | |
| "B" Revision (5/25/78) | |
| Environmental limits modified (COD < 500,00 mg/l, $BOD_{20}$/COD>.85) | |
| Fluorine content shall not deviate more than 15% | |
| Cap opening torque max of 50 in-lbs | |
| "C" Revision (3/12/81) | |
| Type 3 concentrate added to spec (unique Type 3 limits added to spec) | |
| Total halides limit (250 ppm for Type 6, 500 ppm for Type 3) | |
| Current viscosity and toxicity limits established | |
| Color coding for containers (blue-Type 6, green-Type 3) | |
| "D" Revision (10/26/89) | |
| Revision issued but never implemented ("E" re-invoked "C" version) | |
| "F" Revision (1/7/92) | |
| Environmental limits changed ($BOD_{20}$/COD > .65) | |
| Expansion Ratio reduced to 5:1 | |
| Changes in Fire Performance Requirements | |

TABLE 10. EVOLUTION OF FIRE PERFORMANCE REQUIREMENTS.

| Spec Version | Spec Date | Fire Area ($ft^2$) | Flow Rate (gpm) | Max Control Time (secs) | Max Ext Time (secs) | Max Control Appl Dens ($gal/ft^2$) | Max Ext Appl Dens ($gal/ft^2$) | Min 40 Sec Sum | Min BB Time (secs) |
|---|---|---|---|---|---|---|---|---|---|
| 23905 | 11/1/63 | NR* | NR | NR | NR | NR | NR | NR | NR |
| 24385 | 11/21/69 | 28 | 2 | NR | 84 | NR | .10 | NR | 240 |
| | | 400 | 16 | 30 | NR | .02 | NR | 285 | NR |
| | | 1260 | 50 | 30 | NR | .02 | NR | 285 | NR |
| Amend 3 | 7/7/71 | 28 | 2 | NR | 65 | NR | .08 | NR | 240 |
| Amend 8 | 6/20/74 | 50 | 2 | 40 | NR | .027 | NR | 225 | 240 |
| 24385 A | 5/2/77 | 28 | 2 | NR | 45 | NR | .054 | NR | 320 |
| | | 1260 | 60 | 30 | NR | .024 | NR | 285 | NR |
| 24385 B | 5/25/78 | 28 | 2 | NR | 30 | NR | .036 | NR | 320 |
| | | 50 | 2 | NR | 50 | NR | .033 | 300 | 300 |
| | | 1260 | 60 | 30 | NR | .024 | NR | 300 | NR |
| 24385 C | 3/12/81 | 28 | 2 | NR | 30 | NR | .036 | NR | 360 |
| (To present) | | 50 | 2 | NR | 50 | NR | .033 | 320 | 360 |

*Not required

TABLE 11. TEST OF MIS-PROPORTIONED FOAM SOLUTION: MIL-F-24385A (28-$FT^2$ FIRE).

| | 6% | 3% | 50% (SW) |
|---|---|---|---|
| Max Ext Time | 45 sec | 65 sec | 55 sec |
| Burnback Time | 320 sec (min) | 240 sec (min) | 100 sec (min) |

TABLE 12. TEST OF MIS-PROPORTIONED FOAM SOLUTION: MIL-F-24385C TO PRESENT (28 $FT^2$ FIRE).

| | Full Strength | ½ Strength | 5 x Strength (SW) |
|---|---|---|---|
| Max Ext Time | 30 sec | 45 sec | 55 sec |
| Burnback Time | 360 sec (min) | 300 sec (min) | 200 sec (min) |

## REFERENCES


1. Military Specification, Mil-F-24385 (Navy), "Fire Extinguishing Agent, Aqueous Film-Forming Foam (AFFF) Liquid Concentrate, For Fresh and Sea Water," 21 November, 1969 (and all revision and amendments thereto).

2. United States Patent # 3,258,423," Method Of Extinguishing Liquid Hydrocarbon Fires," Richard L. Tuve and Edwin J. Jablonski, assignors to the United States of America as represented by the Secretary of the Navy, June 28, 1996.

3. Military Specification, Mil-F-23905 (WEP), "Fire Extinguishing Agent, "Light Water" Liquid Concentrate," 1 November 1963 (and all revisions and amendments thereto).

4. Peterson, H.G., Jablonski, E.J., Neil, R.R., Gipe, R.L., and Tuve, R.L., "Full-Scale Fire Modeling Test Studies of Light Water and Protein Type Foams," NRL Report 6573, August 15, 1967.

5. Peterson, H.B., "A Brief Summary of Fire Tests with "Light Water" Concentrates for Use with Sea Water," NRL Letter Report, October 15, 1968.

TABLE 13. RATIONALE FOR MIL-SPEC REQUIREMENTS.

| Spec Requirement | Rationale for Requirement |
|---|---|
| Refractive index | Enables use of refractometer to measure solution concentrations in field (method recommended in NFPA 412) |
| Viscosity | Assures accurate performance through pumps and orifices |
| pH | Assures concentrate is not acidic or excessively basic |
| Corrosivity | Limits corrosion of and deposit build-up on metallic components |
| Total halides | Limits corrosion |
| Environmental limits | Reduces environmental impact |
| Accelerated aging test | Assures a long shelf life |
| Sea water compatibility | Assures satisfactory performance with brackish or sea water |
| Inter-agent compatibility | Allows storage tanks to be topped off with concentrates of different manufacturers |
| Half and 5 x strength | Assures adequate performance for mis-proportioned foam |
| Dry Chem Compatibility | Allows "twin agent" application |
| Torque to remove cap | Able to remove cap by hand in field |
| Packaging | Assures uniformity of containers and ease of handling (strength, stackable, color, size, pour opening, tamper proof seal) |
| Qualification testing | Establish conformance with requirements |
| Quality assurance tests | Assure continued conformance of future lots |
| Spreading coefficient | Provides film formation capability |
| Film formation/sealability | Assures film formation on fuel |
| Fire extinguishments tests | Ultimate measure of effectiveness |
| Burnback tests | Assures foam stability and firefighter safety |


6. Darwin, R. L., and Jablonski, E. J., "Full-Scale Fire Test Studies of Sea Water-Compatible "Light Water" as Related to Shipboard Fire Protection," Naval Ship Engineering Center, August 25, 1969.

7. Scheffey, J.L., Darwin, R.L., Leonard, J.T., Fulper, C.R., Ouellette, R.J., and Siegmann, C.W., "A Comparative Analysis of Film Forming Fluoroprotein Foam (FFFP) and Aqueous Film Forming Foam (AFFF) for Aircraft Rescue and Firefighting Services," Hughes Associates, Inc., Report 2108-A01-90 for the NFPA Aviation Committee, June 1990.

## Headquarters U.S. Air Force

*Integrity - Service - Excellence*

# Aircraft Hangar Fire Suppression Systems (AFFF versus High Expansion Foam)

Mr. Fred Walker

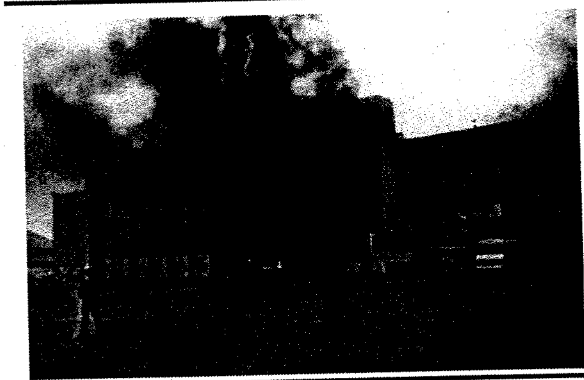
16 Oct 2001

U.S. AIR FORCE

---

## Aircraft Hangar Fire Suppression Systems - AFFF versus Hi-Ex

U.S. AIR FORCE

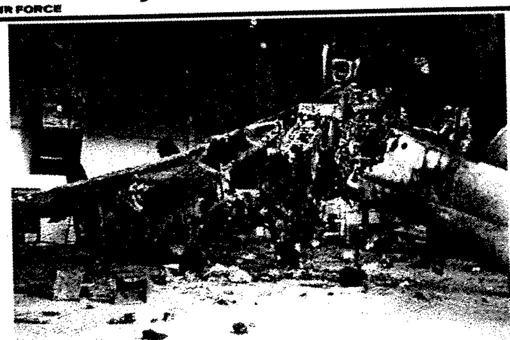


*Integrity - Service - Excellence*

---

## Aircraft Hangar Fire Suppression Systems - AFFF versus Hi-Ex

U.S. AIR FORCE



F-15 in Saudi Maintenance Hangar

*Integrity - Service - Excellence*

## Aircraft Hangar Fire Suppression Systems - AFFF versus Hi-Ex

U.S. AIR FORCE

- 3M announcement caused concern in AF for future of our investment in aircraft hangar fixed systems
  - Primary firefighting chemical in hangars has been AFFF
    - 3M Corporation, the leading manufacturer of AFFF, will cease manufacturing their surfactant because of toxicity concerns
    - Other AFFF manufacturers use different surfactants which are closely related and being evaluated by EPA and industry next two years

*Integrity - Service - Excellence*

## Aircraft Hangar Fire Suppression Systems - AFFF versus Hi-Ex

U.S. AIR FORCE

- Jointly with Navy worked with EPA and manufacturers to develop a possible time line to possible restricted availability
  - Regulatory restrictions would take roughly 10 years to begin to restrict availability
  - Unilateral action by a manufacturer(s) could impact sooner
- The Joint AF/Navy position is we can expect unlimited availability of AFFF until the years 2010
  - Future after that date is open to scientific and political pressures

*Integrity - Service - Excellence*

## Aircraft Hangar Fire Suppression Systems - AFFF versus Hi-Ex

U.S. AIR FORCE

- Current hangars are built for a service life of 50 plus years
  - Current DOD facility replacement rate is over 100 years
- Current hangars suppression systems are built for a service life of 30 to 50 years
- It does not appear prudent to continue investing in new AFFF-based systems given potential for future regulatory controls/limits

*Integrity - Service - Excellence*

## Aircraft Hangar Fire Suppression Systems - AFFF versus Hi-Ex

U.S. AIR FORCE

- Where to go?
- Currently only high- expansion (Hi-Ex) foam approved in the national consensus codes for use in hangars instead of AFFF
- Formally water deluge was approved for hangar applications – but was dropped because there are documented cases where such system were over-whelmed
- Begin research effort to develop new approach to hangars – Navy had just completed a $5 million plus effort which clearly demonstrated you need foam suppression

*Integrity - Service - Excellence*

## Aircraft Hangar Fire Suppression Systems - AFFF versus Hi-Ex

U.S. AIR FORCE

- High- expansion (Hi-Ex) foam chosen and provides these immediate benefits
  - Meets current consensus model code requirements, avoids the use government/military unique criteria
  - Existing commercial technology to support installation in all sizes of hangars from a variety of foam and equipment manufacturers.
  - 25 to 50 reduction in cost over AFFF systems

*Integrity - Service - Excellence*

## Aircraft Hangar Fire Suppression Systems - AFFF versus Hi-Ex

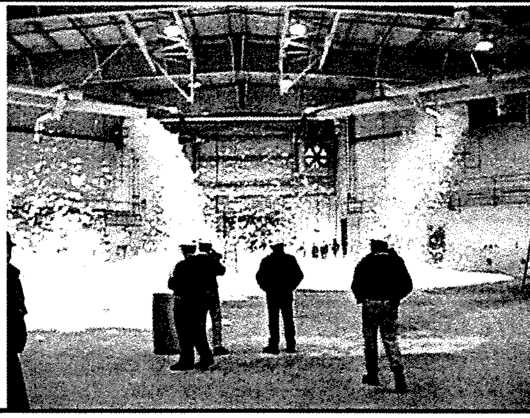
U.S. AIR FORCE

- AF/ILE approved policy with coordination of all MAJCOM/CEs to:
  - Require Hi-Ex in all new aircraft hangars
  - Implement Hi-Ex in all projects under design
  - Evaluate all awarded and under construction projects and implement HEF where cost effective.

*Integrity - Service - Excellence*

U.S. AIR FORCE

## Aircraft Hangar Fire Suppression Systems - AFFF versus Hi-Ex



*Integrity - Service - Excellence*