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From: Commanding Officer, Naval Research Laboratory
To: Commander, Naval Sea Systems Command (Code 05P14 D. Barylski)

Subj: PRELIMINARY RESULTS OF MIL-F-24385F QUALIFICATION TESTING OF
MONSOON FIRE-ADE AFFF TYPE 3/6 CONCENTRATE

Encl: (1) Two copies of subject report

1. Enclosure (1) is forwarded for your information and retention.
2. This report provides preliminary results of qualification testing for the Monsoon Fire-Ade AFFF concentrate, which was evaluated as both a Type 3 and a Type 6 AFFF concentrate against MIL-F-24385F, "Fire Extinguishing Agent, Aqueous Film Forming Foam (AFFF) Liquid Concentrate for Fresh and Seawater". The tested product met all of the fire extinguishment and burnback protection requirements of MIL-F-24385F when used as either a Type 3 or a Type 6 concentrate. There were, however, other properties, particularly foam drainage time and index of refraction, for which the product did not meet all of the requirements of MIL-F-24385F. These discrepancies are detailed in the Executive Summary at the beginning of the enclosed report.
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Preliminary Results of Mil-F-24385F Qualification Testing of Monsoon Fire-Ade AFFF Type 3/6 Concentrate

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EXECUTIVE SUMMARY

This report gives preliminary test results for Fire-Ade Monsoon AFFF Concentrate, which was evaluated against MIL-F-24385F as both a Type 3 and a Type 6 AFFF product.

Note: This product was submitted for testing as both a Type 3 and a Type 6 Concentrate. For the physical properties tests of the undiluted concentrate, the laboratory measurements are identical regardless of which Type AFFF the product is being tested as, although in some instances (for example, maximum viscosity at 5°C), the requirements are different for the two Types. Where MIL-F-24385F specifies the physical properties of diluted mixtures (for example, spreading coefficient), these were measured independently at the two dilutions. Properties specified for the concentrate are indicated with a (C) below; properties indicated for the mixture are marked (M).

The detailed test results are given in the following pages. Although the product met all the fire extinguishment and burn back requirements of MIL-F-24385F, the following test results were at variance with the requirements:

- Index of refraction was 1.3612 ± 0.0010 . This is above the requirement for Type 6 concentrate (1.3580) but slightly below the requirement for Type 3 concentrate (1.3630).
- The "total halides" for the concentrate was reported as 0.03%, equivalent to 300 ppm. The requirement for Type 6 is 250 ppm and for Type 3, 500 ppm. The reported value is higher than the Type 6 requirement, but since the value was only reported to one significant figure, a value of 250 ppm (which would pass) would round to 300 ppm, which would fail. It is worth noting that the concentrate passed the materials compatibility (corrosion) requirements, which are the motivation for the halide requirement.
- Aged concentrate foamability in artificial sea water as a Type 3 product (concentrate subjected to accelerated aging at 60 °C, before dilution): 25% drain times on two runs of 100 seconds (fail) and 109 seconds (fail), compared to a requirement of >150 seconds. This value is substantially below the requirement and it seems unlikely that the 150 seconds requirement would be met on a retest. The fire extinguishment and burn back times for the test with the aged concentrate, however, did meet the performance requirements.
- Aged premix foamability in artificial sea water as a Type 3 product (AFFF solution subjected to accelerated aging at 60 °C): 25% drain times on two runs of 138 seconds (fail) and 144 seconds (fail). These are both slightly below the requirement of 150 seconds, but given the test-to-test variation, it is possible the product might pass on a retest. The fire tests with this aged premixture did meet the extinguishment and burn back requirements.

**Test results--Paragraphs denoted below refer to the applicable section of
MIL-F-24385F**

Paragraph 3.3 Chemical and Physical Requirements for Concentrates

Property	Type 6 Criteria	Type 6 Value	Pass/ Fail	Type 3 Criteria	Type 3 Value	Pass/ Fail
Viscosity @25°C (C) cSt	> 2	2.9	Pass	>2	2.9	Pass
Viscosity @5°C (C) cSt	<10	5.9	Pass	<20	5.9	Pass
Hydrogen Ion (pH) (C)	7-8.5	7.9	Pass	7-8.5	7.9	Pass
Spreading Coefficient on cyclohexane (dynes/cm) (M)	>3.0	5.4	Pass	>3.0	5.4	Pass
Index of refraction	≥1.3580	1.3612	Pass	≥1.3630	1.3612	Fail
Foamability (average of two measurements for each condition):						
Fresh Water Expansion Ratio (M)	>5.0	8.8	Pass	>5.0	7.1	Pass
Fresh Water Drain Time (M) (minutes)	>2:30	5:03	Pass	>2:30	3:10	Pass
Salt Water Expansion Ratio (M)	>5.0	8.0	Pass	>5.0	6.7	Pass
Salt Water Drain Time (M) (minutes)	>2:30	2:53	Pass	>2:30	2:25 ^a	(Pass) (one of two runs)
Corrosion Rate (C)						
steel (10 ⁻³ inches/yr)	<1.5	1.10	Pass	<1.5	1.10	Pass
Cu-Ni (10 ⁻³ inches/yr)	<1.0	0.09	Pass	<1.0	0.09	Pass
Ni-Cu (10 ⁻³ inches/yr)	<1.0	0.05	Pass	<1.0	0.05	Pass
Bronze (mg)	<100	11	Pass	<100	11	Pass
Localized pitting (Corrosion- resistant steel)	No pits	No pits	Pass	No pits	No pits	Pass
Total Halides (C) (ppm)	<250	300	Fail^b	<500	300	Pass
Dry Chemical Compatibility						
Burn Back time (s) (M)	>360	390	Pass	>360	380	Pass
Environmental Impact						
Toxicity (TC ₅₀) mg/L (C)	>1000	>2000	Pass	>500	>2000	Pass
COD (g O ₂ /L) (C)	<500			<1000		
BOD ₂₀ /COD (C)	>0.65			>0.65		

^a On two runs, the 25% drain times were 2:15 (fail), and 2:35 (pass).

^b Result was only reported to one significant figure--a value of 250 (pass) would round to 300 (fail).

Paragraph 3.3.2 Stability

Property	Type 6 Criteria	Type 6 Value	Pass/ Fail	Type 3 Criteria	Type 3 Value	Pass/ Fail
Spreading Coefficient on cyclohexane (dynes/cm) (M)						
using aged concentrate mixed with fresh water	>3.0	5.2	Pass	>3.0	4.7	Pass
using aged premix with fresh water	>3.0	5.7	Pass	>3.0	5.0	Pass
using aged premix with salt water	>3.0	5.3	Pass	>3.0	5.4	Pass
Foamability using aged concentrate(average of two measurements):						
Fresh Water Expansion Ratio (M)	>5.0	9.1	Pass	>5.0	6.5	Pass
Fresh Water Drain Time (M) (minutes)	>2:30	3:42	Pass	>2:30	2:18 ^a	(Pass)
Salt Water Expansion Ratio (M)	>5.0	8.0	Pass	>5.0	5.2 ^b	(Pass)
Salt Water Drain Time (M) (minutes)	>2:30	2:42	Pass	>2:30	1:45 ^c	Fail
Foamability using aged premix (average of two measurements):						
Fresh Water Expansion Ratio (M)	>5.0	10.1	Pass	>5.0	8.8	Pass
Fresh Water Drain Time (M) (minutes)	>2:30	4:25	Pass	>2:30	3:34	Pass
Sea Water Expansion Ratio (M)	>5.0	9.6	Pass	>5.0	6.6	Pass
Sea Water Drain Time (M) (minutes)	>2:30	2:37	Pass	>2:30	2:21 ^d	Fail
Film Formation						
from aged concentrate, full strength, fresh water	no ignition	no ignition	Pass	no ignition	no ignition	Pass
from aged concentrate, full strength, sea water	no ignition	no ignition	Pass	no ignition	no ignition	Pass
from aged premix, full strength, fresh water	no ignition	no ignition	Pass	no ignition	no ignition	Pass
from aged premix, full strength, sea water	no ignition	no ignition	Pass	no ignition	no ignition	Pass
Fire Performance (M)						
Aged Concentrate, 1/2 strength, fresh water						
Extinguishment time (s)	<45	27	Pass	<45	30	Pass
Burn back time (s)	>300	445	Pass	>300	439	Pass
Aged Concentrate, 1/2 strength, sea water						
Extinguishment time (s)	<45	27	Pass	<45	31	Pass
Burn back time (s)	>300	434	Pass	>300	415	Pass
Aged Premix, full strength, fresh water						
Extinguishment time (s)	<30	25	Pass	<30	24	Pass
Burn back time (s)	>360	406	Pass	>360	453	Pass
Aged Premix, full strength, sea water						
Extinguishment time (s)	<30	26	Pass	<30	24	Pass
Burn back time (s)	>360	441	Pass	>360	478	Pass

^a drain times on two runs of 2:07 (fail) and 2:30 (pass)

^b expansion ratios on two runs of 4.8 (fail) and 5.6 (pass)

^c drain times on two runs of 1:40 (fail) and 1:49 (fail)

^d drain times on two runs of 2:18 (fail) and 2:24 (fail)

Paragraph 3.3.2 Stability (cont.)

Property	Type 6 Criteria	Type 6 Value	Pass/Fail	Type 3 Criteria	Type 3 Value	Pass/Fail
Stratification						
using aged concentrate mixed with fresh water	N.O.*	N.O.	Pass	N.O.	N.O.	Pass
using aged premix with fresh water	N.O.	N.O.	Pass	N.O.	N.O.	Pass
using aged premix with salt water	N.O.	N.O.	Pass	N.O.	N.O.	Pass
Precipitation (vol%) (M):						
using aged concentrate mixed with fresh water	<0.05	N.O.	Pass	<0.05	N.O.	Pass
using aged premix with fresh water	<0.05	N.O.	Pass	<0.05	N.O.	Pass
using aged premix with salt water	<0.05	N.O.	Pass	<0.05	N.O.	Pass

*N.O. = None observed.

Paragraph 3.3.3 Compatibility

Mixture: Fire Ade/Buckeye (50/50) (Type 3)

Requirement	Criteria	Value	Pass/Fail
Stratification			
using aged concentrate	N.O.*	N.O.	Pass
Precipitation (vol%):			
using aged concentrate	<0.05	N.O.	Pass
Foamability using aged concentrate(average of two measurements):			
Fresh Water Expansion Ratio (M)	>5.0	8.4	Pass
Fresh Water Drain Time (M) (minutes)	>2:30	4.06	Pass
Salt Water Expansion Ratio (M)	>5.0	7.25	Pass
Salt Water Drain Time (M) (minutes)	>2:30	3:41	Pass
Film Formation (M)			
from aged concentrate, 1/2 strength, fresh water	no ignition	no ign.	Pass
from aged concentrate, 1/2 strength, sea water	no ignition	no ign.	Pass
Fire Performance (M)			
Aged Concentrate, fresh water			
Extinguishment time (s)	<30	26	Pass
Burn back time (s)	>360	603	Pass
Aged Concentrate, sea water			
Extinguishment time (s)	<30	25	Pass
Burn back time (s)	>360	586	Pass

*N.O. = None observed.

Paragraph 3.3.3 Compatibility

Mixture: Fire Ade/National Foam (50/50) (Type 3)

Requirement	Criteria	Value	Pass/ Fail
Stratification			
using aged concentrate	N.O.*	N.O.	Pass
Precipitation (vol%):			
using aged concentrate	<0.05	N.O.	Pass
Foamability using aged concentrate(average of two measurements):			
Fresh Water Expansion Ratio (M)	>5.0	9.7	Pass
Fresh Water Drain Time (M) (minutes)	>2:30	3:51	Pass
Salt Water Expansion Ratio (M)	>5.0	7.08	Pass
Salt Water Drain Time (M) (minutes)	>2:30	2:56	Pass
Film Formation (M)			
from aged concentrate, 1/2 strength, fresh water	no ignition	no ign.	Pass
from aged concentrate, 1/2 strength, sea water	no ignition	no ign.	Pass
Fire Performance (M)			
Aged Concentrate, fresh water			
Extinguishment time (s)	<30	27	Pass
Burn back time (s)	>360	492	Pass
Aged Concentrate, sea water			
Extinguishment time (s)	<30	23	Pass
Burn back time (s)	>360	455	Pass

*N.O. = None observed.

Paragraph 3.3.3 Compatibility

Mixture: Fire Ade/National Foam (50/50) (Type 6)

Requirement	Criteria	Value	Pass/ Fail
Stratification			
using aged concentrate	N.O.*	N.O.	N.O.
Precipitation (vol%):			
using aged concentrate	<0.05	N.O.	Pass
Foamability using aged concentrate(average of two measurements):			
Fresh Water Expansion Ratio (M)	>5.0	9.8	Pass
Fresh Water Drain Time (M) (minutes)	>2:30	4:11	Pass
Salt Water Expansion Ratio (M)	>5.0	9.6	Pass
Salt Water Drain Time (M) (minutes)	>2:30	3:11	Pass
Film Formation (M)			
from aged concentrate, 1/2 strength, fresh water	no ignition	no ign.	Pass
from aged concentrate, 1/2 strength, sea water	no ignition	no ign.	Pass
Fire Performance (M)			
Aged Concentrate, fresh water			
Extinguishment time (s)	<30	27	Pass
Burn back time (s)	>360	483	Pass
Aged Concentrate, sea water			
Extinguishment time (s)	<30	24	Pass
Burn back time (s)	>360	480	Pass

*N.O. = None observed.

Paragraph 3.3.3 Compatibility

Mixture: Fire Ade/Buckeye/National/Chemguard (25/25/25/25) (Type 3)

Requirement	Criteria	Value	Pass/ Fail
Stratification			
using aged concentrate	N.O.*	N.O.	Pass
Precipitation (vol%):			
using aged concentrate	<0.05	N.O.	Pass
Foamability using aged concentrate(average of two measurements):			
Fresh Water Expansion Ratio (M)	>5.0	8.6	Pass
Fresh Water Drain Time (M) (minutes)	>2:30	3:49	Pass
Salt Water Expansion Ratio (M)	>5.0	7.7	Pass
Salt Water Drain Time (M) (minutes)	>2:30	3:05	Pass
Film Formation (M)			
from aged concentrate, 1/2 strength, fresh water	no ignition	no ign.	Pass
from aged concentrate, 1/2 strength, sea water	no ignition	no ign.	Pass
Fire Performance (M)			
Aged Concentrate, fresh water			
Extinguishment time (s)	<30	22	Pass
Burn back time (s)	>360	553	Pass
Aged Concentrate, sea water			
Extinguishment time (s)	<30	24	Pass
Burn back time (s)	>360	567	Pass

*N.O. = None observed.

Paragraph 3.3.3 Compatibility

Mixture: Fire Ade/Ansul/National/Chemguard (25/25/25/25) (Type 6)

Requirement	Criteria	Value	Pass/ Fail
Stratification			
using aged concentrate	N.O.*	N.O.	Pass
Precipitation (vol%):			
using aged concentrate	<0.05	N.O.	Pass
Foamability using aged concentrate(average of two measurements):			
Fresh Water Expansion Ratio (M)	>5.0	8.3	Pass
Fresh Water Drain Time (M) (minutes)	>2:30	3:46	Pass
Salt Water Expansion Ratio (M)	>5.0	8.5	Pass
Salt Water Drain Time (M) (minutes)	>2:30	3:47	Pass
Film Formation (M)			
from aged concentrate, 1/2 strength, fresh water	no ignition	no ign.	Pass
from aged concentrate, 1/2 strength, sea water	no ignition	no ign.	Pass
Fire Performance (M)			
Aged Concentrate, fresh water			
Extinguishment time (s)	<30	29	Pass
Burn back time (s)	>360	486	Pass
Aged Concentrate, sea water			
Extinguishment time (s)	<30	27	Pass
Burn back time (s)	>360	483	Pass

*N.O. = None observed.

Paragraph 3.3.3 Compatibility

Mixture: Fire Ade/Chemguard (50/50) (Type 3)

Requirement	Criteria	Value	Pass/ Fail
Stratification			
using aged concentrate	N.O.*	N.O.	Pass
Precipitation (vol%):			
using aged concentrate	<0.05	N.O.	Pass
Foamability using aged concentrate(average of two measurements):			
Fresh Water Expansion Ratio (M)	>5.0	8.2	Pass
Fresh Water Drain Time (M) (minutes)	>2:30	3:18	Pass
Salt Water Expansion Ratio (M)	>5.0	6.8	Pass
Salt Water Drain Time (M) (minutes)	>2:30	2:58	Pass
Film Formation (M)			
from aged concentrate, 1/2 strength, fresh water	no ignition	no ign.	Pass
from aged concentrate, 1/2 strength, sea water	no ignition	no ign.	Pass
Fire Performance (M)			
Aged Concentrate, fresh water			
Extinguishment time (s)	<30	26	Pass
Burn back time (s)	>360	605	Pass
Aged Concentrate, sea water			
Extinguishment time (s)	<30	22	Pass
Burn back time (s)	>360	510	Pass

*N.O. = None observed.

Paragraph 3.3.3 Compatibility

Mixture: Fire Ade/ Chemguard (50/50) (Type 6)

Requirement	Criteria	Value	Pass/ Fail
Stratification			
using aged concentrate	N.O.*	N.O.	Pass
Precipitation (vol%):			
using aged concentrate	<0.05	0.01	Pass
Foamability using aged concentrate(average of two measurements):			
Fresh Water Expansion Ratio (M)	>5.0	9.1	Pass
Fresh Water Drain Time (M) (minutes)	>2:30	3:55	Pass
Salt Water Expansion Ratio (M)	>5.0	9.3	Pass
Salt Water Drain Time (M) (minutes)	>2:30	4:03	Pass
Film Formation (M)			
from aged concentrate, 1/2 strength, fresh water	no ignition	no ign.	Pass
from aged concentrate, 1/2 strength, sea water	no ignition	no ign.	Pass
Fire Performance (M)			
Aged Concentrate, fresh water			
Extinguishment time (s)	<30	29	Pass
Burn back time (s)	>360	465	Pass
Aged Concentrate, sea water			
Extinguishment time (s)	<30	25	Pass
Burn back time (s)	>360	446	Pass

*N.O. = None observed.

Paragraph 3.3.3 Compatibility

Mixture: Fire Ade/Ansul (50/50) (Type 6)

Requirement	Criteria	Value	Pass/ Fail
Stratification			
using aged concentrate	N.O.*	N.O.	Pass
Precipitation (vol%):			
using aged concentrate	<0.05	None	Pass
Foamability using aged concentrate(average of two measurements):			
Fresh Water Expansion Ratio (M)	>5.0	9.3	Pass
Fresh Water Drain Time (M) (minutes)	>2:30	4:45	Pass
Salt Water Expansion Ratio (M)	>5.0	9.5	Pass
Salt Water Drain Time (M) (minutes)	>2:30	3:30	Pass
Film Formation (M)			
from aged concentrate, 1/2 strength, fresh water	no ignition	no ign.	Pass
from aged concentrate, 1/2 strength, sea water	no ignition	no ign.	Pass
Fire Performance (M)			
Aged Concentrate, fresh water			
Extinguishment time (s)	<30	24	Pass
Burn back time (s)	>360	490	Pass
Aged Concentrate, sea water			
Extinguishment time (s)	<30	25	Pass
Burn back time (s)	>360	432	Pass

*N.O. = None observed.

Paragraph 3.4 Fire Performance

28 ft² fire test

	Type 6 requirement	Type 6 Value	Pass/ Fail	Type 3 requirement	Type 3 Value	Pass/ Fail
Extinguishment time (s)						
Fresh Water 1/2 strength	<45	28	Pass	<45	28	Pass
Fresh Water full strength	<30	24	Pass	<30	28	Pass
Salt Water 1/2 strength	<45	27	Pass	<45	32	Pass
Salt Water full strength	<30	26	Pass	<30	27	Pass
Fresh water Quintuple Strength	<55	33	Pass	<55	32	Pass
Burn back time (s)						
Fresh Water 1/2 strength	>300	433	Pass	>300	458	Pass
Fresh Water full strength	>360	>360	Pass	>360	433	Pass
Salt Water 1/2 strength	>300	388	Pass	>300	345	Pass
Salt Water full strength	>360	401	Pass	>360	388	Pass
Fresh water Quintuple Strength	>200	251	Pass	>200	372	Pass
50 ft ² fire test (Sea water)						
Extinguishment time (s)	<50	49	Pass	<50	45	Pass
Burn back time (s)	>360	363	Pass	>360	>360	Pass
40 second summation	>320	335	Pass	>320	320	Pass

Other properties: Torque to open container (50 inch-pounds max): not tested as final packaging has not yet been specified.

Total fluorine content (no specification).

APPENDIX A

DETAILED INFORMATION ON SELECTED PHYSICAL PROPERTIES

Spreading coefficient on cyclohexane:

Spreading coefficient = $ST(\text{cyclohexane}) - ST(\text{AFFF}) - \text{interfacial tension}$

Requirement: minimum 3 dynes/cm (Type 3 and Type 6)

Cyclohexane surface tension (measured): 24.42 (23°C)

Cyclohexane surface tension (reference value): 24.95 (20°C)

Fire-Ade concentrate @ 3%

Surface tension: 17.59

Interfacial tension against cyclohexane: 1.39

Spreading coefficient: **5.44**

PASS

Fire-Ade concentrate @ 6%

Surface tension: 17.29

Interfacial tension against cyclohexane: 1.70

Spreading coefficient: **5.43**

PASS

Index of Refraction of Concentrate

requirement: minimum 1.3580 @25°C (Type 6); minimum 1.3630 @25°C (Type 3)

substance	observed nD	nominal nD	difference
water	1.3315	1.3330	-0.0015
water	1.3314	1.3330	-0.0016
water	1.3314	1.3330	-0.0016
ethanol (absolute)	1.3595	1.3614	-0.0019
ethanol (absolute)	1.3599	1.3614	-0.0015
70% isopropanol	1.3700	1.3730	-0.003
70% isopropanol	1.3705	1.3730	-0.0025
isopropanol	1.3776	1.3772	0.0004
isopropanol	1.3772	1.3772	0
instrument correction		average	-0.00147
		std dev.	0.00096

fire-Ade concentrate	1.3597
fire-Ade concentrate	1.3595
fire-Ade concentrate	1.3600
average fire-Ade value	1.3597
corrected nD	1.3612
uncertainty	0.0010

The measured refractive index for the Fire-Ade, after applying the instrument correction based on comparison of measured and nominal refractive index values for several liquids having similar indices of refraction, was 1.3612 ± 0.0010 . This is easily above the requirement for Type 6 AFFF concentrate (1.3580) but slightly below the requirement for Type 3 concentrate (1.3630). If one adds one standard deviation of the measurement uncertainty, the value for the Fire-Ade concentrate is 1.3622, still slightly low.

Readings with two other QPL AFFF concentrates were taken with the same refractometer:
Chemguard C301 MS (Type 3 QPL) 1.3645
Chemguard C601 MS (Type 6 QPL) 1.3583
These values meet the MilSpec requirement

Viscosity of Concentrate

Requirement:

Minimum @25°C: 2 cSt (Type 3 and Type 6)

Maximum @5°C: 20 cSt (Type 3); 10 cSt (Type 6)

Test Results:

Temperature = 25°C

Viscosity= 2.89 cSt **PASS**

Temperature = 5°C

Viscosity= 5.91 cSt **PASS** (both Type 3 and Type 6 requirements)

COMPATIBILITY

Precipitation:

The only instance in which a precipitate was observed, including after sample centrifugation, in the mixtures of Fire-Ade with other QPL AFFF's aged for ten days at 65°C was for a 50%:50% FireAde/Chemguard Type 6 AFFF mixture diluted in artificial seawater. Precipitation was *not* observed in the Fire-Ade/Chemguard Type 3 AFFF mixture, or in other mixtures.

We have previously noted the formation of a solid white precipitate from Chemguard Type 6 MilSpec qualified AFFF when mixed with seawater. This formulation appears unique among AFFF formulations in containing significant magnesium sulfate (per the product MSDS). We concluded the additional presence of magnesium and sulfate in seawater together with that in the AFFF causes precipitation of that salt, as it has limited solubility.

Determination of the mass of precipitate was made following centrifuging 30 ml samples of the 50%:50% Fire-Ade/Chemguard Type 6 and 100% Chemguard Type 6 @6% concentration in artificial seawater, followed by drying the precipitate after decanting off the liquid. This was

done by weighing the two centrifuge tubes, scraping off and weighing the residue, and weighed the tubes with residue removed:

	FireAde/Chemguard	Chemguard
Tube	10.0402 gram	10.1006 gram
Tube w/o solid	10.0366	10.0932
Difference = solid	0.0036	0.0074
Solid on paper	0.6296	0.6780
Paper tare	0.6259	0.6702
Difference = solid	0.0037	0.0078

These results show good agreement with the weights of the precipitate weighed directly and by difference. Further, the precipitate from the mixture with 50 per cent Chemguard had slightly less than 50 per cent weight of the precipitate from the full strength Chemguard AFFF.

The quantity of precipitate allowed by the MilSpec criteria is 0.05% by volume. For 30 ml, this is 0.015 gram. The solid density of MgSO_4 is 2.66 gram/cc. This means the maximum volume criteria of 0.05% corresponds to 0.040 gram

CONCLUSIONS:

All the precipitate is from the Chemguard AFFF and not from the FireAde AFFF. In any event, the mass (and volume) of precipitate, both for the pure Chemguard AFFF and the Chemguard/Fire-Ade mixture, is less than 20% of the allowable limit.