FOAM + the Environment

DEPARTMENT OF THE NAVY
NAVAL RESEARCH LABORATORY
4555 OVERLOOK AVE SW
WASHINGTON DC 20375-5320

IN REPLY REFER TO

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Ser 6180/0620
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From: Commanding Officer, Naval Research Laboratory
To: Commanding Officer, Naval Facilities Engineering Service Center (Code ESC-421 R. Lee), 560 Center Drive, Port Hueneme CA 93043-4328

Subj: TESTS FOR MECHANICAL SEPARATION OF AFFF IN FIREFIGHTING WASTEWATER

Encl: (1) Two copies of subject report

1. Enclosure (1) is forwarded for your information and retention.

2. The air separation mechanical method for removing AFFF concentrate from the training facility wastewater has proven promising. The amount of surface exposed to air in the separator has a definite impact on its efficiency in separating foam, both in water loss and time to reduce the foam mix. The depth of the solution seems to have an impact on the time to separate the AFFF. Diluting the initial mixture keeps the water loss lower during the separation process. The time gain seems to be minimal, in fact, it seems that diluting the mixture means that a given sample will take longer to reduce than an undiluted sample. The use of the field drain time test appears to be confirmed by the laboratory surface tension measurements. Surface tension appears to be a particularly sensitive laboratory method for measuring low AFFF concentrations, i.e., less than 1000 ppm. The air flow factor did prove to be significant in optimizing the separator performance.

3. The Naval Research Laboratory point of contact is Dr. Frederick W. Williams, Code 6180, (202) 767-2476; email: fwilliams@itd.nrl.navy.mil.

JAMES S. MURDAY
By direction

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Tests for Mechanical Separation of AFFF in Firefighting Wastewater

J.J. Beitel, R.E. Burns, R. Ouellette, D. Szepesi
Hughes Associates, Inc.
Baltimore, MD

J.T. Leonard and F.W. Williams
Navy Technology Center for Safety and Survivability
Chemistry Division
Naval Research Laboratory

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CONTENTS

1.0 INTRODUCTION

Navy firefighter training simulators continue to present a challenge in the effort to reduce the environmental impact of naval facilities. The Navy's special training demands require that large pool fire and airplane crash simulators be used. These large-scale simulations require sizeable amounts of liquid fuel to create a challenging and realistic simulation. Large amounts of Aqueous Film-Forming Foam (AFFF) are also required to extinguish these fires. Although some fuel and AFFF are consumed by the fire, large portions of both remain in the form of a combined residue which must be disposed of in an environmentally-acceptable way. Also, this AFFF/water/fuel run-off can have a considerable negative impact on the surrounding areas. Firefighters on all airfields test their equipment before going on standby alert by flowing foam through the nozzles. This foam, if collected in large tanks to prevent runoff, can cost from $0.50 to $1.50 per gallon to be disposed. The cost can become substantial with amounts of up to 1500 gallons being collected daily.

While the issue of fuel run-off leaking into the surrounding environment is a well-known problem, AFFF has a lesser known but equally negative effect on its surroundings. Once AFFF enters the sewage treatment plants, it causes problems by creating foam in the pipes and pumps. Also, AFFF contains fluoroalkyl surfactants that are non-biodegradable and can destroy bacteria at these treatment plants. A grant has been issued to old Dominion University (reference (1)) to study the acceptable residual AFFF allowed in wastewater entering a modern treatment plant.

In an effort to reduce these problems, the Naval Research Laboratory initiated work in 1987 to investigate the use of ultra-filtration and a reverse osmosis system to recover AFFF chemicals from the test run-off. However, this procedure was eventually deemed unfeasible due to very high set-up and operational costs, as well as the unacceptably high levels of training required to operate the equipment.

In response to a request from the Naval Facilities Engineering Service Center, NRL undertook a study to find an easier, more economically sound way to separate AFFF from the

wastewater coming from firefighter training facilities. This study is focused on separating the AFFF from the wastewater by mechanical means.

It has been observed that agitating the AFFF foam/water solution by bubbling air through it will produce foam on the surface of the solution. It was felt that, if the foam that is generated by the air agitation contains the AFFF fluorosurfactants, then this may result in a viable means of separating the fluorosurfactants. This foam is produced by the viscous solution encapsulating the air bubbles as they rise through the liquid. The foam bubbles stay intact on top of the solution and they eventually form a thick blanket over the top of the solution which can then be removed by mechanical means. If this process is feasible, then the AFFF/water solution can be separated thus potentially allowing for the water solution to go into normal sewage treatment facilities while the foam, now reduced to liquid but at a greatly reduced volume, can be disposed of in the appropriate manner. If the foam blanket contains the AFFF fluorosurfactants, which are believed to be the primary problem to water treatment facilities, then this method of separation can provide a feasible, economic disposal method.

Initially, the focus was on designing some sort of batch or in-line process that would pass the AFFF/water solution through a series of pipes that would induct air into the solution by the venturi effect. The foam would then be allowed to escape the pipe through vents. Other preliminary designs such as cascading systems or spray nozzle agitation were also investigated. These foam-generated methods were discarded in favor of the current system (air agitation) due to their complexity and operational problems.

The best method of aerating the solution was studied, i.e., , either by simple bubbles or by air stone. Tests showed that using pipes with 1 mm (0.04-in.) diameter holes produced foam that was composed of large bubbles while the air stone produced a very dense foam composed mostly of small bubbles. The foam produced by the air stone appeared to be a much wetter foam and, therefore, tests run in this manner showed a greater solution loss which would result in a greater volume of concentrated AFFF fluorosurfactants which translates to more costly disposal Based on these tests, the basic design was narrowed to the pipe/hole method of aeration.

2.0 APPROACH

The basic design concept for this approach is the making of foam. Foam is created when a liquid is able to resist the coalescing of gas bubbles that are within the liquid. Pure water cannot form a foam, but once an impurity is added such as a surface active agent or "surfactant," the resultant decrease in surface tension and increase in the viscosity of the fluid at the surface allow a foam to be formed. This phenomena is similar to making soap bubbles.

AFFF uses a fluorosurfactant to create a low surface tension which not only allows it to make foam when gases are introduced to the liquid, but also makes the water more likely to "wet" solid surfaces rather than to form a bead. This "wetting" phenomenon is a direct result of the reduced surface tension of the foam.

The concept of the separator design therefore, is based upon one of the main functions of AFFF, which is to create a foam blanket. The key ingredient to AFFF that creates the foam blanket is the fluorosurfactant. If the AFFF in solution with water could be aerated to develop a foam blanket, then the foam containing the AFFF could be removed from the surface until the AFFF concentration and in turn, the fluorosurfactant concentration in the solution, were reduced to an acceptable level (the acceptable level is still under debate) by the environmental regulatory agencies. .

Several concerns to be addressed in this work were as follows:

- Will the foam contain the fluorosurfactant and thereby reduce its concentration in the water?

- How much water will be lost while removing the foam? This is important due to the volumes of solutions that will need to be processed.

- The aeration system must be fairly simple to setup and use.

Along with these concerns, several additional limitations to this current work were identified. These are as follows:

- Will other components of AFFF remain in the water and will these be a potential problem in treatment facilities?

- Since the majority of the work reported herein uses water/AFFF solutions, will the technique work with solutions that contain waste fuels?

3.0 EXPERIMENTAL

3.1 Test AFFF/Water Solutions

In this work, AFFF/water solutions were used. The solutions consisted of mixing 3M Brand, 3 percent (MIL-F-24385F) AFFF concentrate with tap water. Appendix A provides a copy of the MSDS data sheet for this product. The solutions were mixed at the desired concentration for each test. A new solution was mixed for each test and water was not reused.

3.2 Preliminary Tests

Initially, scoping tests were conducted using a small-scale test apparatus. These tests were simple tests to evaluate the potential for making foam and determine the air flow characteristics required.

Determining the proper air flow was an iterative process. It was found that too low of an air flow did not sufficiently agitate the solution while too high of an air flow created an unacceptably high water loss by creating dense moist foam.

Visual observations and water loss measurements showed that relatively large bubbles tended to be "dryer" thus reducing water loss while the smaller, dense bubbles tended to be "wetter" thus causing greater water loss.

During these tests, it was determined that uniform spacings of 1 mm (0.04-in.) holes in the tubing provided a consistent foam blanket that could easily be suctioned off the top of the separator.

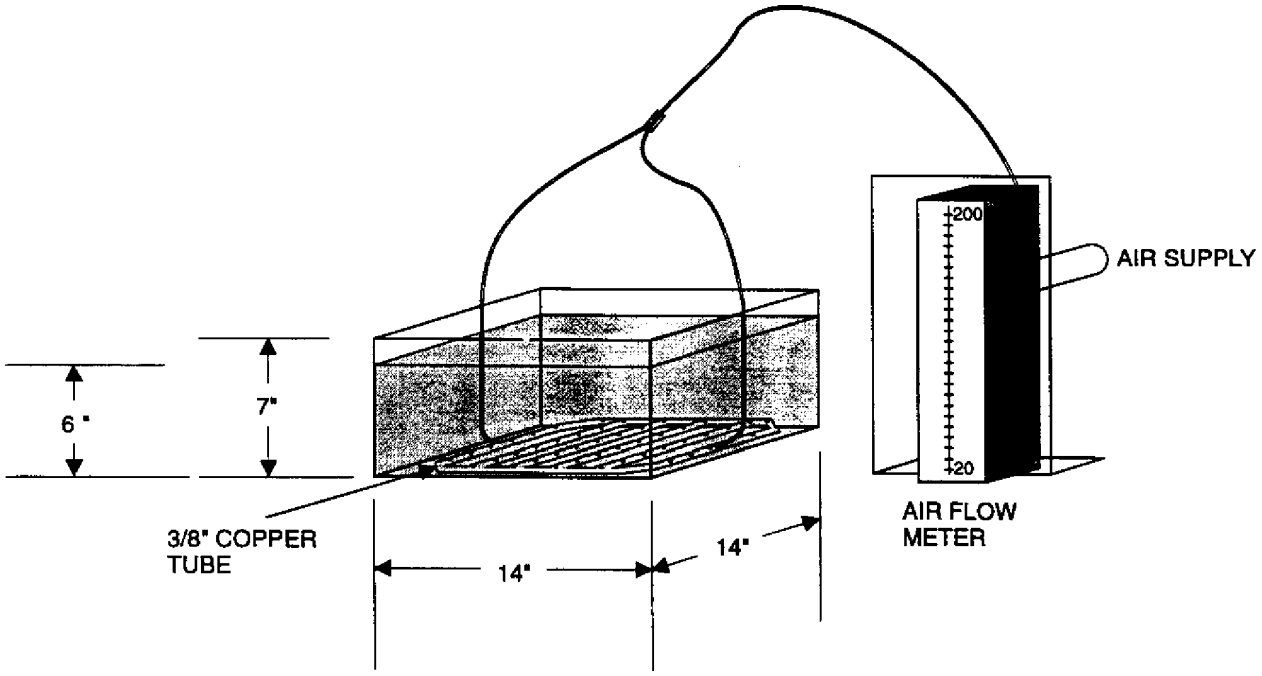
The result of these tests did show the potential feasibility of the separation process.

3.3 Test Apparatus

Four test apparatuses were constructed. They were constructed of plexiglass so that the foam generation could be observed.

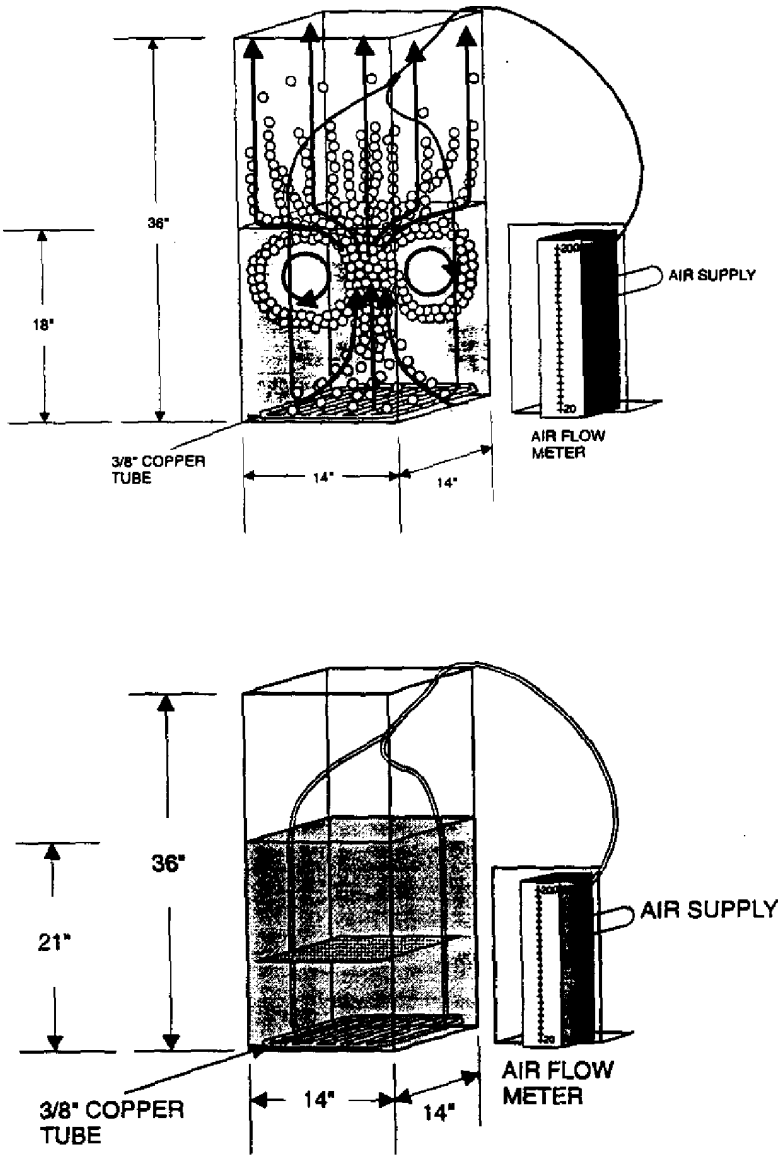
The test apparatuses had the following dimensions:

- Apparatus 1 - 36 cm x 36 cm x 18 cm (14 in. x 14 in. x 7 in.) high. See Fig. 1;
- Apparatus 2 - 34 cm x 36 cm x 91 cm (14 in. x 14 in. x 36 in. high. See Fig. 2 ;
- Apparatus 3 - 18 cm x 72 cm x 91cm (7 in. x 28 in. x 36 in.) high. See Fig. 3; and
- Apparatus 4 - 0.9 m x 2.4m x 0.9 m (3 ft. x 8 ft. x 3 ft.) high. See Fig. 4.



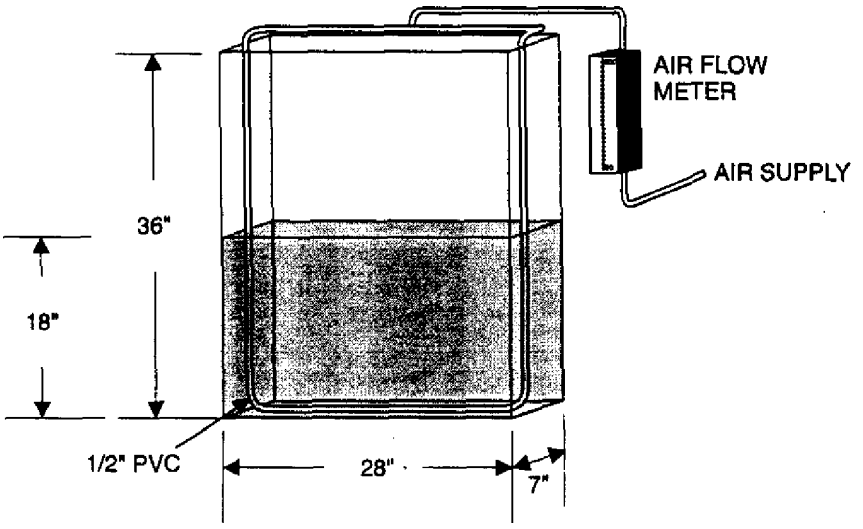
Apparatus 1 – Shallow, square pan: base = 196 in.^{2}

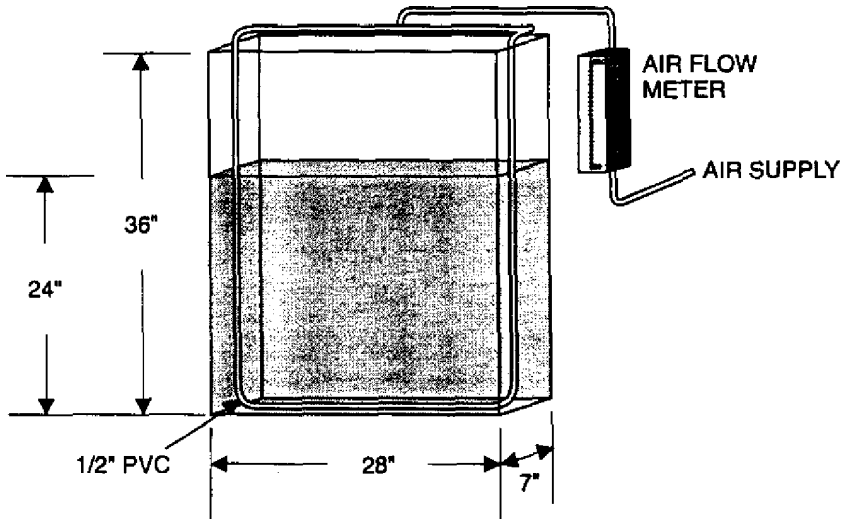
Figure 1.



Apparatus 2 – Tall, square pan: base = 196 in.^{2}

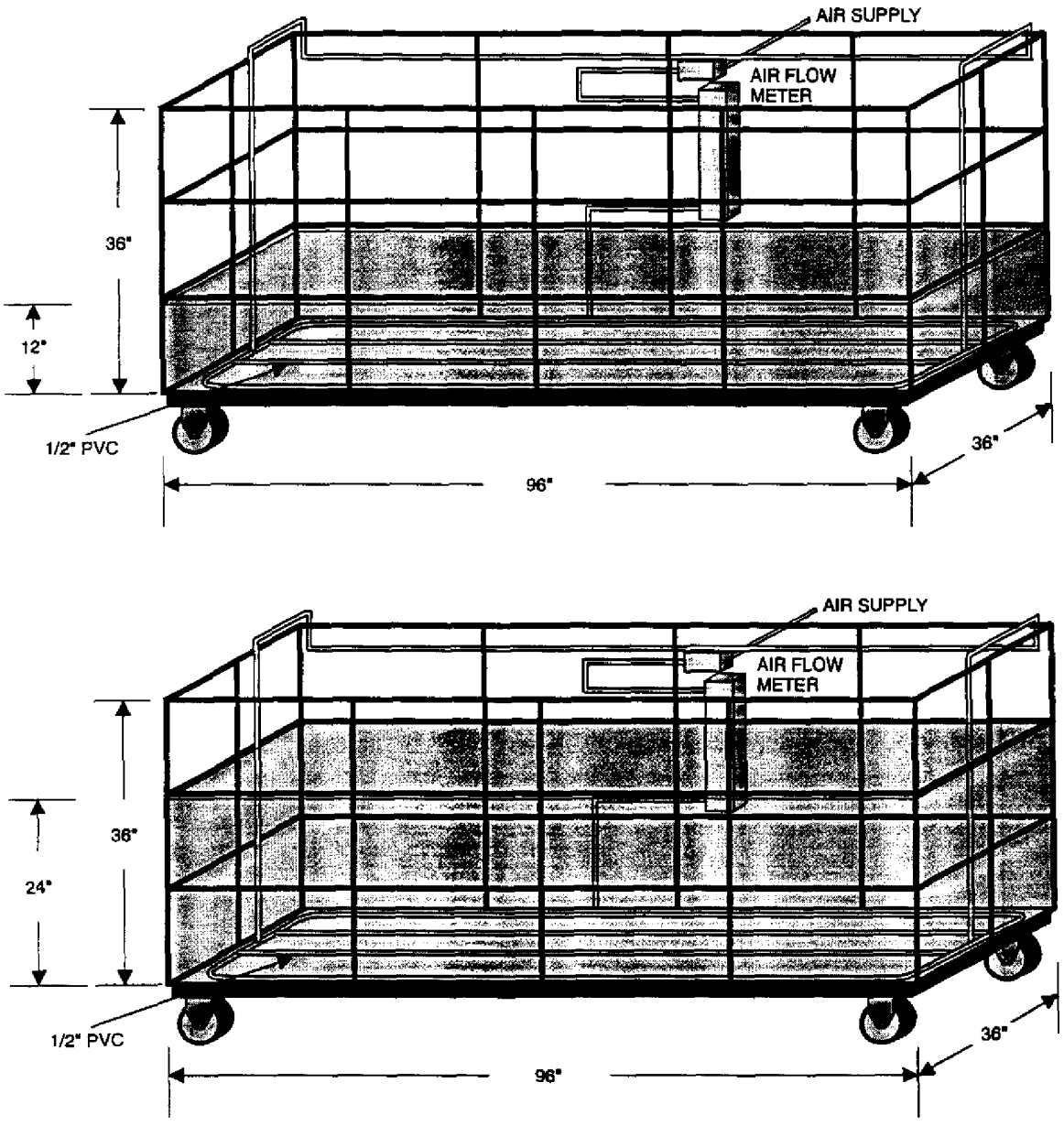
Figure 2.





Apparatus 3 – Tall rectangle pan: base = 196 in.^{2}

Figure 3.



Apparatus 4 – Large-scale tank: base = 3456 in.^{2}

Figure 4.

Test Apparatus Nos. 1, 2, and 3 had the same base area of 1264 cm^2 (196 $in.^2$) Apparatus No. 2 allowed variation of the depth of the solution while keeping the same base area as Apparatus No. 1. Apparatus No. 3 allowed an opportunity to evaluate the change in configuration from square to rectangle while keeping the same base area as Apparatus Nos. 1 and 2. Test Apparatus No. 4 provided the capability to evaluate the impact of scaling to a larger tank and evaluate the comparative times to complete separation.

A screen was used in a few of the tests. For example, in Apparatus No. 2, it was used in an attempt to diffuse the air streams to produce a more consistent foam blanket. This screen, shown in Fig. 2, did not prove beneficial and was only used in a few of the tests. It did diffuse the bubbles in the solution, but in doing so, it created smaller, denser bubbles which are not desirable.

3.4 Air Systems

The air system was supplied by a 16.7 cm (600 CFH) air compressor system and piped into the tanks through an air flow meter as shown in Figs. 1, 2, 3, and 4. Air was then distributed through the 0.95 cm (3/8-in.) copper pipe system for Apparatus 1 and a 1.27 cm (½-in.) PVC pipe system for Apparatus 3 and 4. This pipe system is shown in the Figs. 1, 2, 3, and 4 with air supplied at opposite end of the tank in order to balance the air flow as much as possible.

3.5 Test Procedure

The solution to be used in the test was premixed to the desired strength 1/4, ½, 3/4, or full-strength.

The aerator system was installed in the bottom of the tank and connected to an air compressor, the air flow turned on and the air flow set using a calibrated rotameter. During the test, the air flow was continuously monitored.

The tests were documented via test data sheets. An example of a test data sheet is provided in Fig. 5.

Once foam-making had begun, the foam was periodically suctioned off using a wet vacuum system. Normally, the foam was removed every three minutes, however on some tests it was removed every five minutes.

During the tests, drain times were taken every 30 minutes and recorded on the data sheet for that test. (See Section 3.5.2).

3.6 Measurement of AFFF Concentration

One of the major concerns with this separation technique is the verification of the AFFF concentration remaining in the solution. By visual observations, it was determined that as the solution was aerated, its tendency to create foam was reduced with time as might be expected. These observations lead to the hypothesis that the fluorosurfactants were contained on the foam and that as aeration was continued, the fluorosurfactants were removed from the solution. In order to prove this hypothesis, several methods of evaluating the solution were attempted.

3.6.1 Ion Selective Electrode

Since the fluorosurfactants contain fluorine, an attempt was made to use ion selective electrodes to measure the concentration of fluorine in the solution. It became readily apparent that the ion selective electrode was ineffective at measuring the bound fluorine in the fluorosurfactants. Further, fluorine analysis would require extensive laboratory analyses.

3.6.2 Drain Time

The MIL-SPEC (MIL-F-24385F) requires that the drain time of AFFF solutions be determined. The drain time is defined as the amount of time required for a specific amount of

Figure 5
Test Data Sheet

AFFF Separator Test:_____

Tank Size - 14" x 14" x 7" ☐
14" x 14" x 36" ☐
7" x 28" x 36" ☐
3' x 8' x 3' ☐

Water Depth_____ Gal._____ Temp._____

AFFF MFG._____ ML._____ Temp._____

Air Flow CF/Hour_____

Water Loss_____

Data

Time	Foam Depth Inches	Time	Drain Time
			Min./Sec.

generated foam to return to a specific amount of liquid. the MIL SPEC test requires specific procedures and equipment and is not readily adaptable to this work, buy an adoption of this technique was developed.

An inexpensive, fairly-reliable, small-scale field test to evaluate drain times was developed. Drain time is measured using a 2.54 cm (1-in.) diameter by 10.2 cm (4-in.) high test tube with a screw cap. This tube is filled to a depth of two inches and then shaken 50 times. Drain time was measured as the time required to reduce 90 percent of the foam produced by the agitation back to liquid.

During the performance of these tests, several problems with respect to drain time were identified. It appears that the drain times are potentially sensitive to how vigorously the sample is shaken and the temperature of the liquid.

In order to develop information concerning the accuracy and repeatability of the drain time measurements, a series of drain time tests was performed. In these tests, a group of solutions were made, each with a different concentration of 3M brand, six percent MIL-SPEC AFFF foam concentrate (FC-206 CF). The concentrations of AFFF concentrate to water ranged from 10 ppm to 60,000 ppm. Each concentration was tested in triplicate at room temperature by a single operator. Table 1 provides a summary of the drain times obtained during the tests. Fig. 6 provides a graphical representation of the average drain time versus concentration of AFFF concentrate. Fig. 7 provides a plot of the same data but over the range of 10 ppm to 1000 ppm. The lack of drain times below 200 ppm is indicative of the fact that at this concentration the water/AFFF will not foam.

Several items are of interest; first, the drain time is not a linear function over the ranges that were evaluated. Secondly, the repeatability of the measurement is fairly good using a single operator. It is anticipated that with adequate training, the method's reproducibility will also be good.

Table 1. Drain Times in Minutes Versus the AFFF Concentration

Concentration (ppm)	Drain Time 1	Drain Time 2	Drain Time 3	Avg. Drain Time	Temperature °C
0	0.0	0.0	0.0	0.0	20.5
10	0.0	0.0	0.0	0.0	20.5
100	0.0	0.0	0.0	0.0	20.5
200	0.0	0.0	0.0	0.0	20.5
300	2.0	2.0	2.0	2.0	21.0
400	2.7	2.5	2.3	2.5	21.0
500	3.0	2.8	2.7	2.8	21.0
600	3.8	3.5	3.0	3.4	21.0
700	5.1	5.3	4.1	4.8	21.0
800	6.5	6.6	6.6	6.6	21.0
900	6.8	7.3	7.0	7.0	20.5
1000	7.8	8.1	7.5	7.8	21.0
1100	8.5	8.8	8.4	8.6	21.0
1200	8.6	8.5	7.9	8.3	21.0
1300	9.2	9.3	8.8	9.1	210
1400	13.0	13.6	13.1	13.2	21.0
1500	13.3	14.0	14.0	13.8	21.0
1600	15.9	15.3	15.0	15.4	21.0
1700	16.7	16.1	16.8	16.5	21.0

Concentration (ppm)	Drain Time 1	Drain Time 2	Drain Time 3	Avg. Drain Time	Temperature °C
1800	17.7	16.9	16.8	17.1	21.0
1900	17.6	18.2	18.2	18.0	21.0
2000	20.2	19.8	20.3	20.1	21.0
2500	22.4	22.2	22.1	22.2	21.0
3000	22.3	22.7	22.5	22.5	21.0
3500	30.6	31.1	31.5	31.1	21.0
4000	33.1	34.0	33.1	33.4	21.0
5000	47.6	47.4	48.1	47.7	21.0
6000	54.9	55.9	55.8	55.5	21.0
7000	66.0	66.0	69.0	67.0	21.0
8000	71.0	73.0	74.0	72.7	21.0
9000	78.0	77.0	77.0	77.3	21.0
10000	100.0	99.0	94.0	97.7	21.0
20000	123.0	121.0	123.0	122.3	21.0
40000	140.0	136.0	134.0	136.7	21.0
60000	146.0	146.0	146.0	146.0	21.0

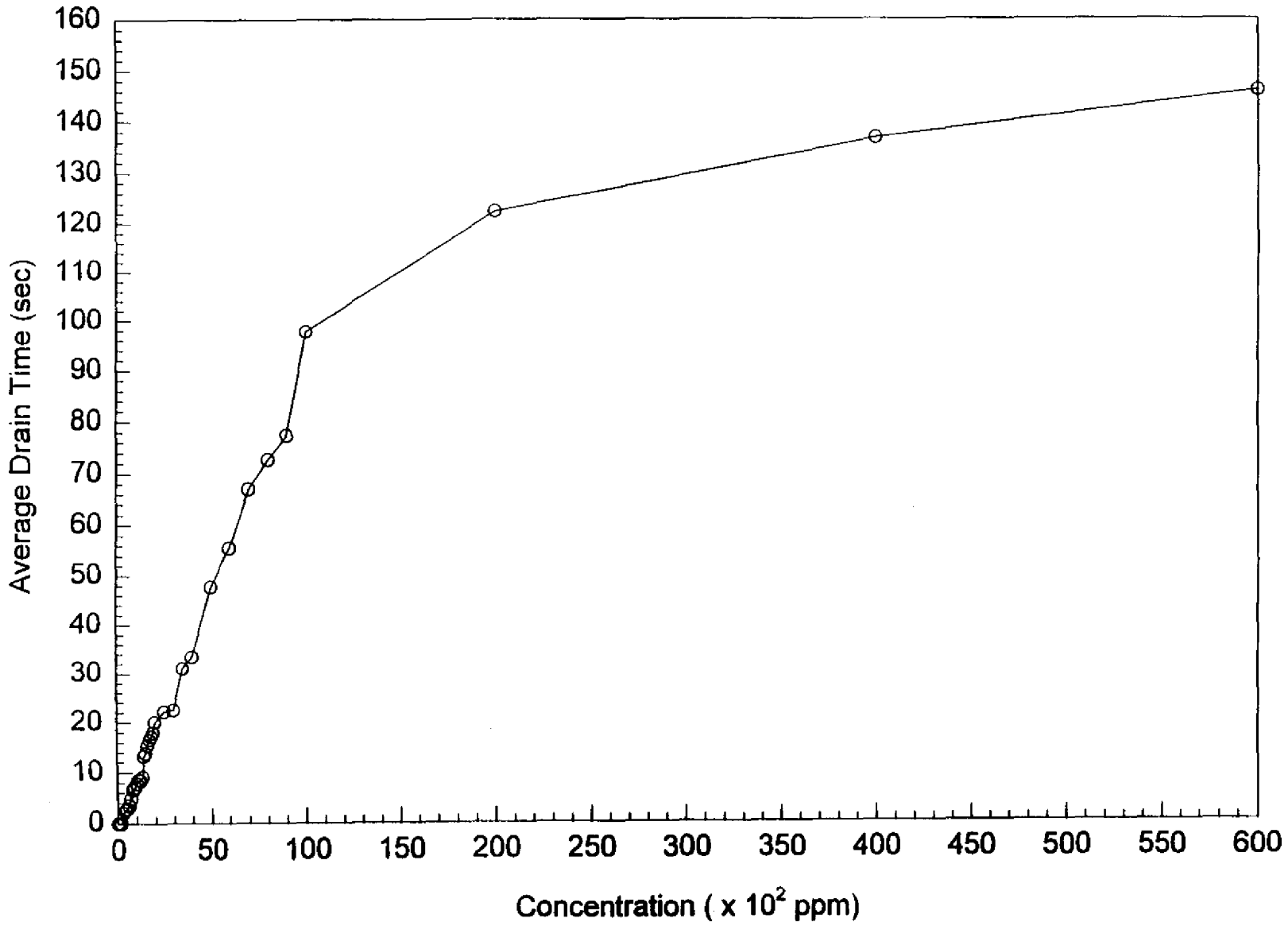

Average Drain Time vs Concentration
for AFFF (6%) Solutions
Average Drain Time (sec)
0
10
20
30
40
50
60
70
80
90
100
110
120
130
140
150
160
0
50
100
150
200
250
300
350
400
450
500
550
600
Concentration (x 10² ppm)

Figure 6

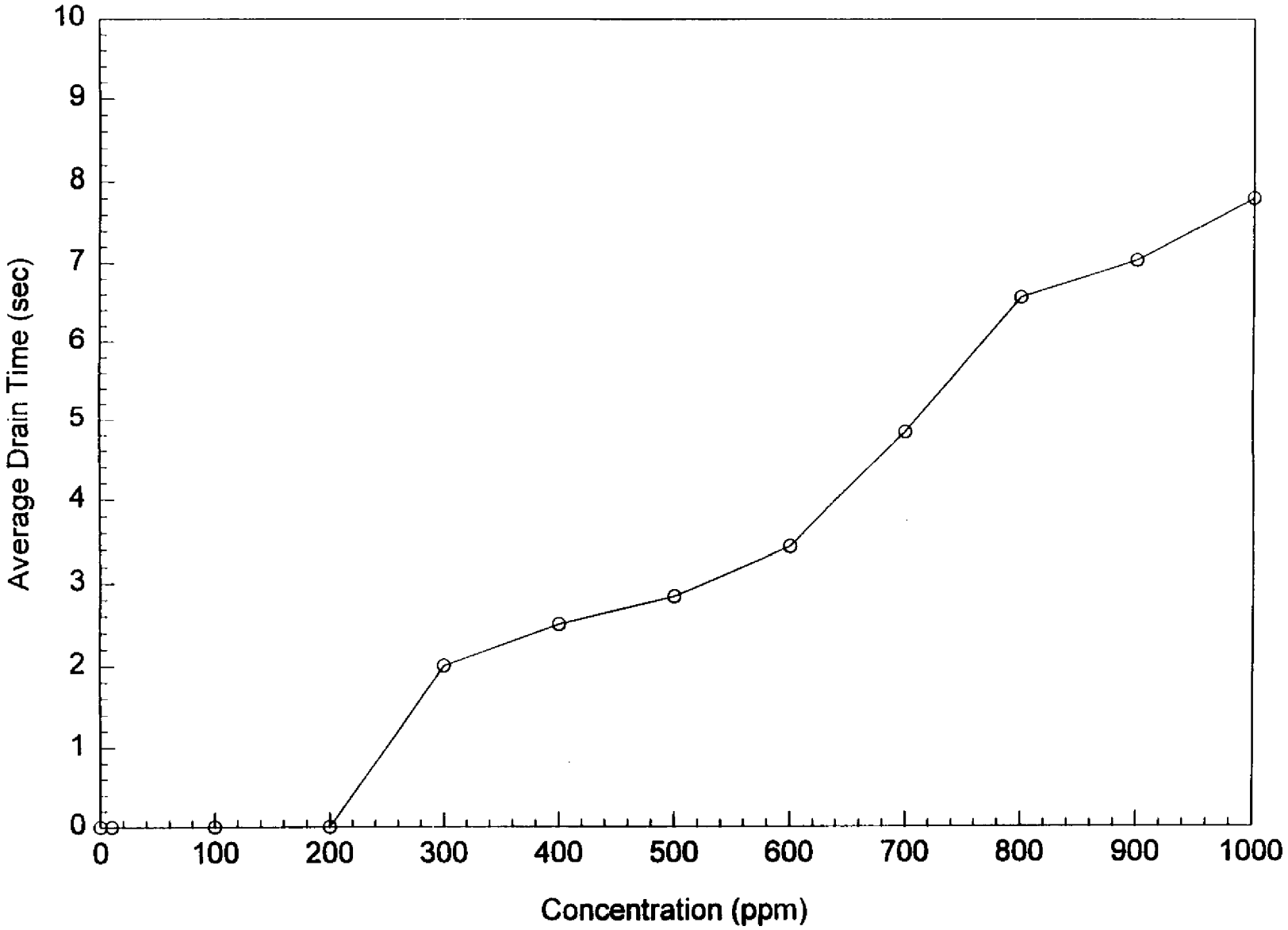


Figure 7

Changing the time period at which the foam was removed did not affect either the difference in water loss or run time, but vacuuming closer to the surface of the solution caused increased water loss.

3.6.3 Surface Tension Measurements

It was apparent that the drain time measurements could potentially provide a measurement of the concentration of the AFFF concentrate in the solution. It was believed that as the drain time decreased, the amount of fluorosurfactant in the solution was also decreasing. In order to verify this, a series of surface tension tests were conducted on the same solutions used in the drain time tests. The objective of these tests was to determine the surface tension of solutions which had varying concentrations of AFFF concentrate. This would also evaluate the concentration of the fluorosurfactant since its concentration is in the same ratio of surfactant to concentrate in all of the solutions and the surfactant is responsible for the decrease in surface tension. These results could then be compared to the drain time measurements to verify their efficacy.

The surface tension tests were conducted according to ASTM D 1331, using the du Nouy tensiometer. Table 2 provides a summary of the surface tension test results. Fig. 8 provides a graph showing the test results. As shown, the AFFF does lower the surface tension of water dramatically. At approximately 1000 ppm of AFFF concentrate, the surface tension curve becomes fairly flat and the concentration is not readily distinguishable above 1000 ppm. At concentrations less than 1000 ppm, the surface tension measurement is sensitive to AFFF concentration.

Fig. 9 provides a graph showing the surface tension versus concentration over the range of 0 to 2000 ppm.

Fig. 10 provides a graph comparing the surface tension measurements with drain times for the various solutions. As shown a good correlation between the two measurements does exist.

This correlation then does provide an assurance that the drain time measurements can provide a reliable measurement for AFFF concentration above 1000 ppm (90 ppm of surfactant; see section 3.6.4).

Table 2. Summary of Surface Tension Tests

Concentration (ppm)	Surface Tension (dynes/cm)	Temperature Before °C (°F)	Temperature After °C (°F)
0	72.8	20.0 (68.0)	20.0 (68.0)
10	69.3	22.2 (72.0)	23.3 (74.0)
100	61.0	22.2 (72.0)	22.2 (72.0)
200	46.4	21.1 (70.0)	23.3 (74.0)
400	35.2	23.3 (74.0)	25.0 (77.0)
600	32.1	22.2 (72.0)	23.3 (74.0)
800	27.7	22.2 (72.0)	22/2 (72.0)
1000	23.0	21.1 (70.0)	21.7 (71.0)
1500	21.0	21.1 (70.0)	21.7 (71.0)
2000	18.7	21.7 (71.0)	22.2 (72.0)
2500	18.4	22.2 (72.0)	23.9 (75.0)
3000	17.6	23.9 (75.0)	23.3 (74.0)
5000	16.7	23.3 (74.0)	23.3 (74.0)
10000	17.0	23.3 (74.0)	23.3 (74.0)
20000	16.7	23.9 (75.0)	23.3 (74.0)

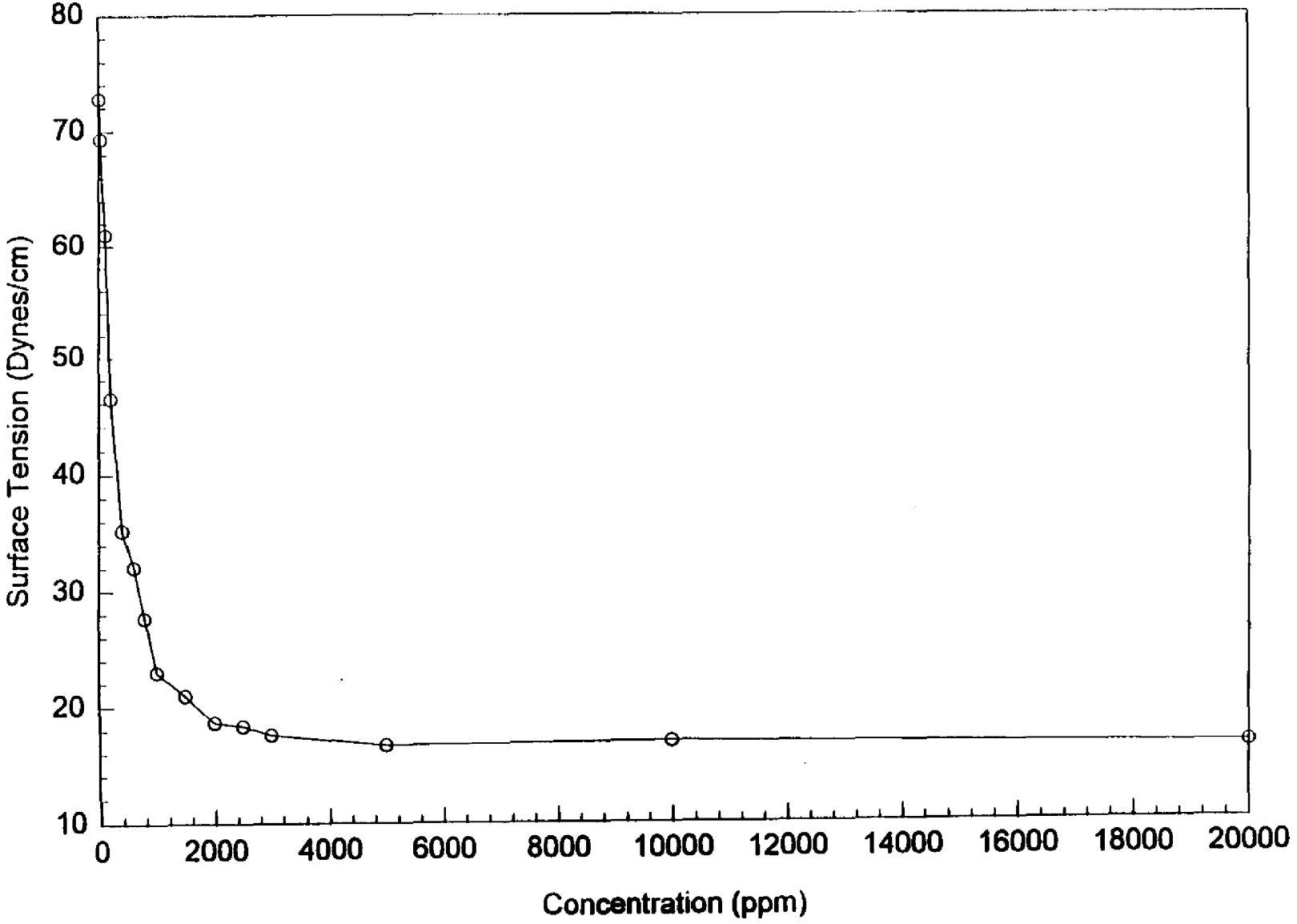


Figure 8

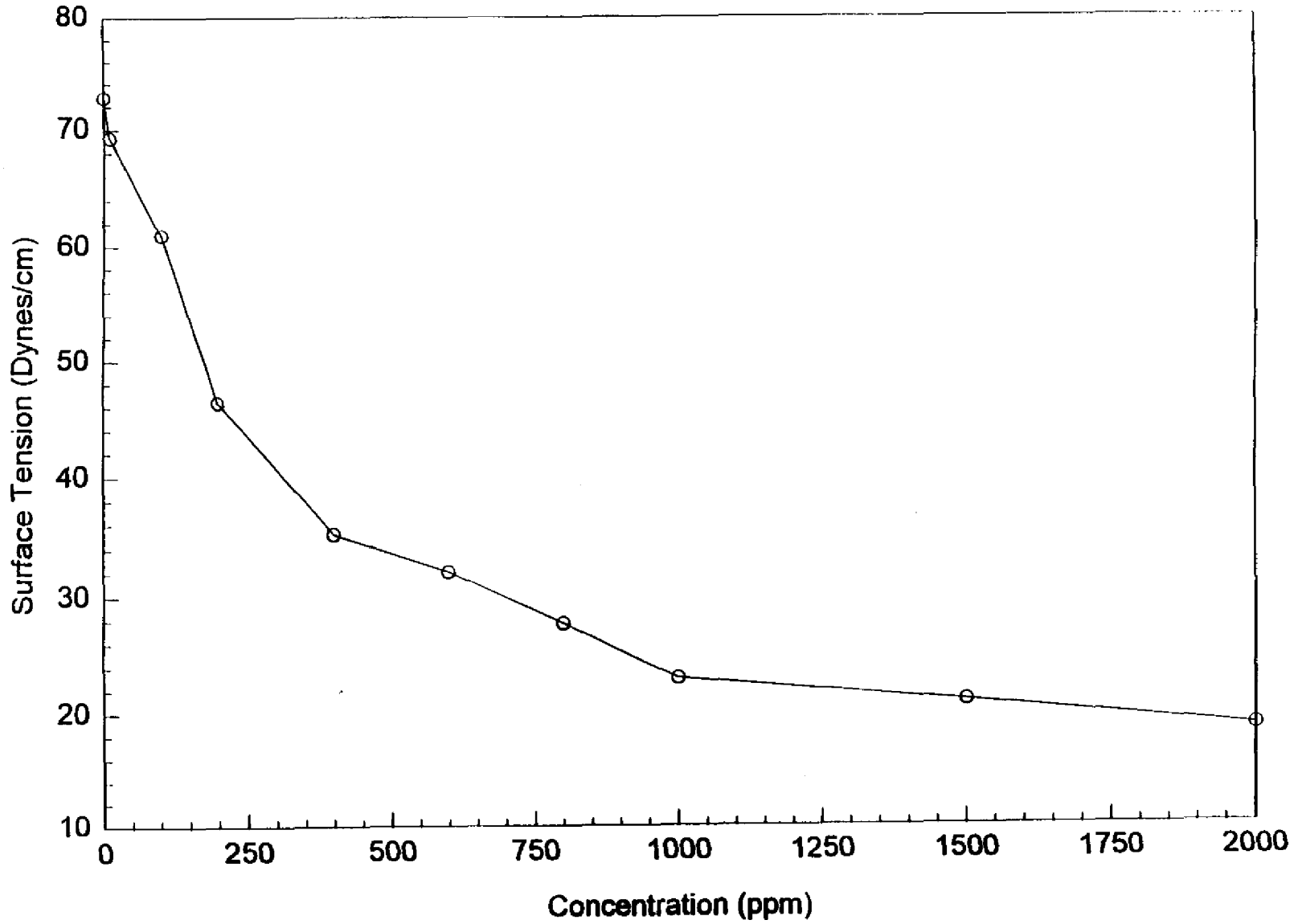


Figure 9.

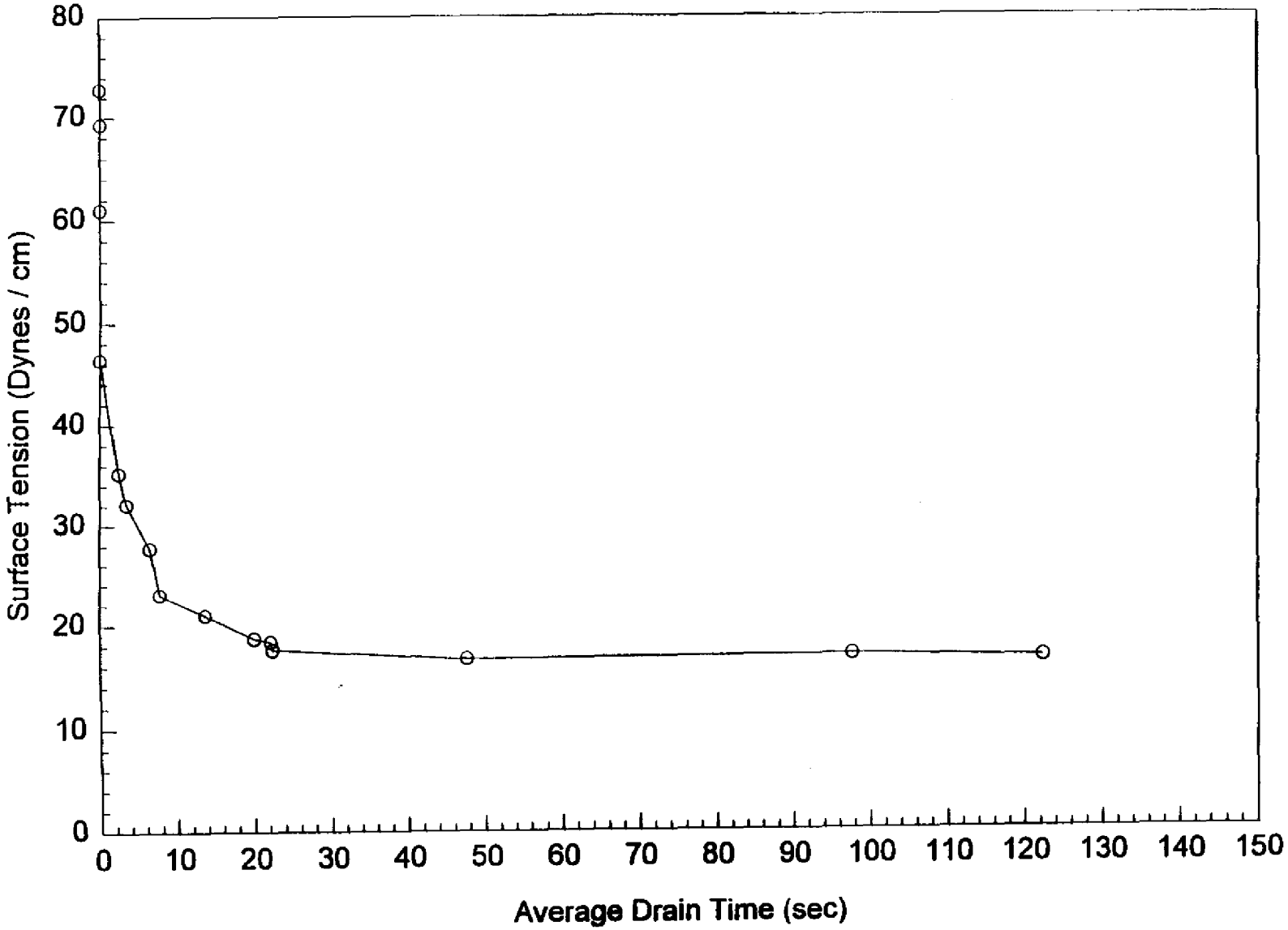


Figure 10.

Below a concentration of 1,000 ppm AFFF in solution, surface tension is a more reliable and highly sensitive indicator of surfactant concentration.

3.6.4 Calculation of Surfactant in Concentrate and Solution

The amount of surfactants in the initial solution can be calculated by using the 3M FC-203FC Material Safety Data Sheet (Appendix B) which provides information on the amount of surfactants in the concentrate. In this case, amphoteric fluoroalkylamide is between four and six percent, triethanolamine is one to five percent, and perfluoroalkyl sulfonate salt is 0.5 to 1.5 percent; the exact concentrations are trade secrets. This gives a range of 5.5 to 12.5 percent, which gives an average of nine percent of the concentrate is surfactants.

To calculate the amount of surfactant in an AFFF/water solution, take three percent of the solution as concentrate and nine percent of the concentrate as surfactants which gives 0.027 percent (2700 ppm) of the solution is surfactant.

If the drain time of an unknown solution is 8 seconds, then the concentration of AFFF is 900 ppm (0.09%) using Fig. 7. Assuming 900 ppm of concentrate contains 9 percent surfactants, then 81 ppm of surfactants remain in the solution. The solution, therefore, contains only 0.03 ppm (3%) of original amount of surfactant by the calculations:

$$\frac{81 ppm}{2700 ppm} \; x \; 100 \; = \; 3\% \; of \; surfactant \; remaining.$$

Even if you assume 12.5 percent of surfactant is in the concentration, then the concentrate contains 3750 ppm, the 8-second drain time solution contains 112.5 ppm and the solution is reduced to 3 percent of the original amount of surfactant.

$$\frac{112.5}{3750} x\ 100\ =\ 3\%$$

These calculations show a removal efficiency of 97 percent surfactant removal based on 8-second drain times.

3.7 Test Matrix

Table 3 provides a summary of the tests conducted.

4.0 DISCUSSION

4.1 Process Parameters

A series of tests were conducted to determine the impact of various air flow rates, air distribution within the test bed, water depth, and tank shape on removal of surfactant.

4.1.1 Air Flow

The air flows in Tests 101, 102, 104, 105, 106, and 107 were varied to evaluate the impact of air flow rate on AFFF separation. The performance of the air flow rates was based on visual observations of the foam and the time required to reduce the rate of foam generation. For these tests, which were conducted in Apparatus 1, it was decided that an air flow factor of 878 $cm^3/hr\text{-}cm^2$ (0.20 ft^3/hr per sq. in. ($CFH/in.^2$)) was the most effective. This air flow factor is based on the rate of air flowing into the apparatus divided by the floor area of the apparatus. Flow rate factors below this value developed smaller bubbles and thus too wet a foam resulting in a greater water loss, while those above this value created too much turbulence and resulted in a longer time to defoam the solution. The hole sizes of 0.1 cm (0.04 in.) diameter were also

. Table 3. Summary of Separator Test Results

Test #	Tank	Solution Depth (in.)	Volume (gal. (l))	Amount of 3% AFFF (ml)	Concentration of 3% AFFF (%)	Air Flow (scfh)	Screen Used (yes/no)	Test Time (hrs)	Drain Time (sec)	Water Loss (l)
101	1	6.0	5.0 (18.9)	20.0	0.1	10.0	No	2.25	—	0.8
102	1	6.0	5.0 (18.9)	10.0	0.05	20.0	No	3.8	—	0.2
103	4	12.0	179.5 (679)	3397.5	0.5	140.0	No	50.0	—	—
104	1	6.0	5.0 (18.9)	190.0	1.0	20.0	No	5.2	—	—
105	1	6.0	5.0 (18.9)	567.0	3.0	40.0	No	0.95	92.0	1.6
106	1	6.0	5.0 (18.9)	76.0	0.4	40.0	No	2.0	15.0	0.2
107	1	6.0	5.0 (18.9)	76.0	0.4	40.0	No	2.0	15.0	0.2
108	4	12.0	179.5 (679)	2710.0	0.4	140.0	No	2.0	48.0	7.1
109	4	12.0	179.5 (679)	2710.0	0.4	280.0	No	2.0 4.0	43.0 16.0	—
110	4	24.0	359.0 (1359)	5436.0	0.4	400.0	No	2.0 5.5	53.0 14.0	—
111	4	24.0	359.0 (1359)	40764.0	3.0	400.0	No	2.0 19.0	120.0 27.0	26.2
112	2	18.0	15.0 (57)	871.0	1.5	40.0	No	2.0 12.5	130.0 8.0	6.8
113	2	18.0	15.0 (57)	435.0	0.76	40.0	No	6.5	8.0	—
114	2	18.0	15.0 (57)	1306.5	2.3	40.0	Yes	13.67	8.0	18.1
115	4	18.0	270.0 (1022)	3398.0	0.3	420.0	No	6.0	8.0	21.2
116	4	18.0	270.0 (1022)	6796.0	0.6	420.0	No	9.0	8.0	21.2
117	2	18.0	15.0 (57)	1733.0	3.0	40.0	Yes	16.0	8.0	11.2
118	3	18.0	15.0 (57)	866.0	1.5	40.0	No	8.0	6.0	6.4
119	2	18.0	15.0 (57)	866.0	1.5	40.0	No	7.0	7.0	3.8
120	4	18.0	270.0 (1022)	22710.0	2.2	420.0	No	29.0	8	70.1
121	2	18.0	15.0 (57)	Waste	Waste	40.0	No	3.0	7.0	1.6
122	3	9.0	7.5(28)	433.0	1.5	40.0	No	7.0	7.5	1.6

selected on an experimental basis. This combination of holes size and flow rate factor was used in all tests involving Apparatuses 1, 2 and 3 after Test 106.

Test 103 was the first test using Apparatus 4, with a water depth of 30.5 (12 in.) and an air flow factor of 176 $cm^3/hr\ cm^2$ (0.04 $CFH/in.^2$). The test required over five hours to reduce the rate of foam generation and this was deemed unacceptable. Two additional tests, Tests 108 and 109, were conducted to confirm these results. Test 108 used an air flow factor of 176 $cm^3/hr\ cm^2$ (0.04 $CFH/in.^2$) and Test 109 used an increased flow rate factor of 35 $cm^3/hr\ cm^2$ (0.08 $CFH/in.^2$). The higher flow rate factor used in Test 109 did show some slight improvement in foam generation. Test 110 used both a increased flow factor of 527 $cm^3/hr\ cm^2$ (0.12 $CFH/in.^2$) and an increased solution depth of 61 cm (24 in.). This test showed significantly better results since the total volume of AFFF was doubled in this test versus Test 109 but the rate of foam generation was greater. Based on the visual observations of the rate of foam generation and the type of foam produced (i.e., dryer foam), along with drain time measurements, the flow rate factor of 0.12 $CFH/in.^2$ was selected for use in subsequent testing involving Apparatus 4.

4.2 Solution Depth

In order to address the issue of solution depth with respect to AFFF removal, two tests were conducted using Apparatus 3. Test 118 used a solution depth of 45.7 cm (18 inches), while Test 122 used a depth of 22.9 cm (9 in.). In Test 118, it appears that the time to reach a drain time of 6 seconds was 8 hours while it took approximately 7 hours to reach a drain time of 7.5 seconds in Test 122. It would appear from these two tests, that removal of AFFF is dependent on the air flow rate and independent of the solution depth.

4.3 AFFF Removal

The capability of the aeration method to remove the fluorosurfactants from the solution, with respect to the initial solution concentration, was evaluated in several of the tests.

In the analysis of drain times and surface tension, it was noted that a drain time of 8 seconds would correspond to a AFFF concentration of approximately 1,000 ppm. If one was to assume that the surfactants were 9% of the AFFF concentration, then a drain time of 8 seconds would correspond to approximately 90 ppm of fluorosurfactant.

It was decided to use this drain time and its corresponding concentrations of AFFF and fluorosurfactent as a bench mark for determining an end point for the experiments.

Fig. 11 provides a plot showing the time to reach the 8 second drain time for solutions with varying concentrations of AFFF, in Apparatus 2 and 4. The solution depth remained constant in all of these tests. Tests 112, 113, 114, 117, and 119 used Apparatus 2. In these tests, the air flow factor, 878 $cm^3/hr\ cm^2$ (0.20 $CFH/in.^2$) remained constant. Tests 112 and 119 were replicates, however, they did show significant differences in the time to reach the 8 second drain time. The plot uses an average of these two tests. As shown, there is a very good correlation between the concentration and the time to attain an 8 second drain time.

The same analysis was performed on solutions in Apparatus 4 using an air flow factor of 527 $cm^3/hr\ cm^2$ (0.12 $CFH/in.^2$), but the same solution depth 45.7 cm (18 in.) as in Apparatus 2. These are Tests 115, 116 120. Again, a correlation between concentration of AFFF and the time to attain an 8 second drain time is shown, but times to reach the 8-second drain time are considerably longer in the larger apparatus. The difference in drain times is attributed to the lower air flow factor in the large apparatus 527 vs 878 $cm^3/hr\ cm^2$ ((0.12 vs 0.20 $CFS/in.^2$) in Apparatus 2)) and the larger volume of solution to be defoamed.

4.4 Reduction Rates

Table 4 provides a summary of the reduction rates for the tests in which an 8 second drain time was determined. This table was created by setting the 8 second drain time to represent a AFFF concentration of 1000 ppm. From this value, it could be determined approximately how much AFFF remained after the separation process. This number was used to

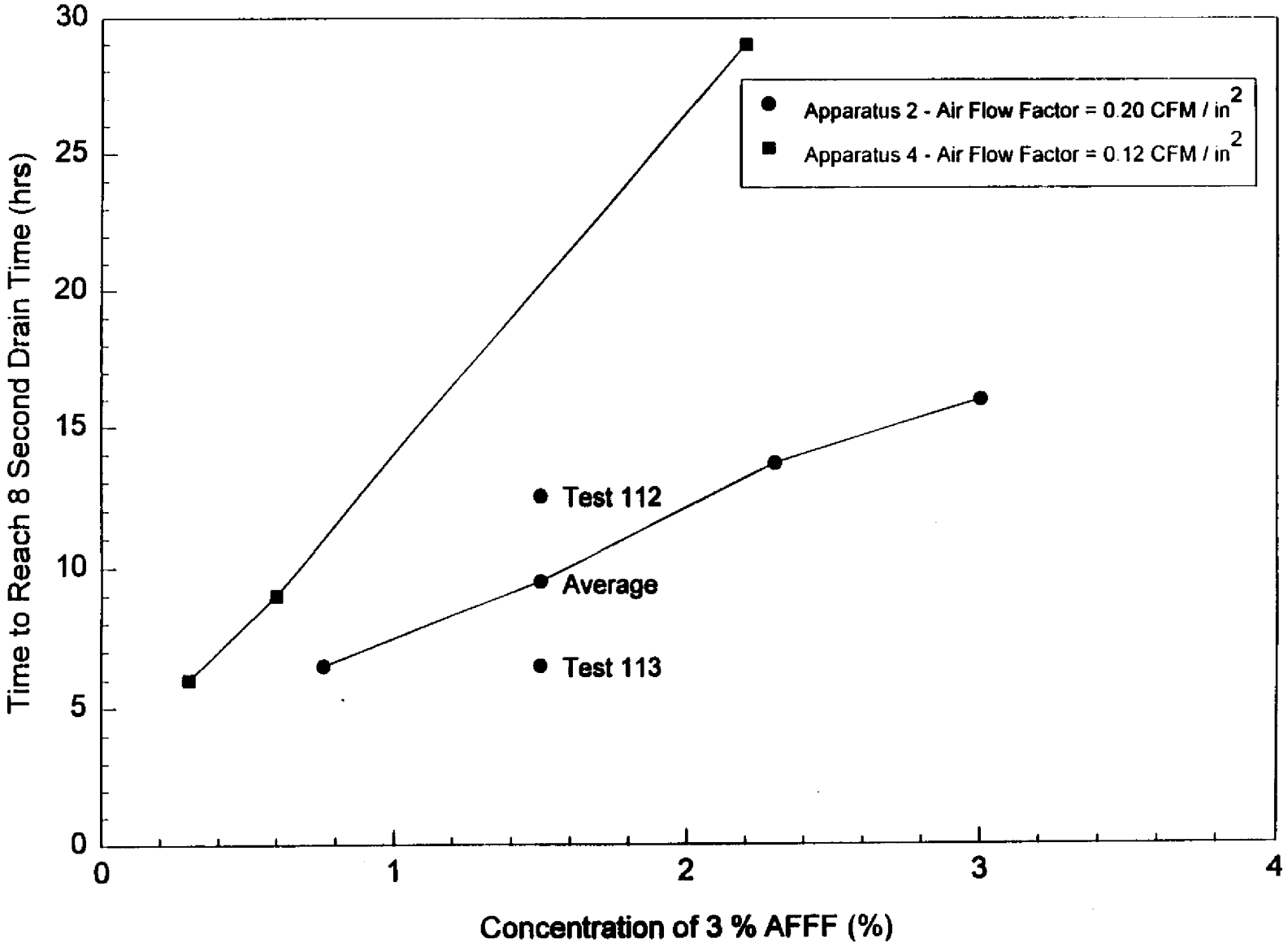


Figure 11

Table 4. Summary of Reduction Rates

Test Number	Test Apparatus	Original Amount of 3% AFFF (ml)	Original Concentration of 3% AFFF (%)	Remaining Concentration of 3% AFFF (ml)	Amount of 3% AFFF Removed (ml)	Time for Removal (hrs)	Reduction Rate (ml/hrs)
112	2	871	1.5	58.07	812.9	12.5	65
113	2	435	0.76	57.24	377.8	6.5	58
114	2	1,306.5	2.3	56.8	1,249.7	13.67	91
115	4	3,398	0.3	1,132.7	2,265.3	6.0	378
116	4	6,796	0.6	1,132.7	5,663.3	9.0	629
117	2	1,733	3.0	57.8	1,675.2	16.0	105
118	3	866	1.5	57.7	808.3	8.0	101
119	2	866	1.5	57.7	808.3	7.0	115
120	4	22,710	2.2	1,032.3	21,677.7	29.0	148
122	3	433	1.5	28.9	404.1	7.0	58

determine total amount of AFFF removed, which when divided by the time taken for the separation, yields a reduction rate.

From these rates, several things can immediately be seen. Tests 115 and 116, both Apparatus 4 tests, have much higher reduction rates than comparable medium scale tests such as 113. This is believed to be due to the much greater surface area of the larger tank allowing more foam to be produced over time than the smaller tanks allow. Also for these tests, a doubling in concentration only resulted in a 50% increase in time needed to reduce the solution to 1000 ppm AFFF. This suggests that the removal rate is not constant. Rather it appears that the removal rate is much faster when the solution is more concentrated and then slows down as the solution becomes more dilute.

Tests 118 and 119 show that changing the shape of the surface area has no impact on the results of the separation, instead, it is the numerical value of the surface area that is important.

By analysis of the reduction rate, it appears that the depth of the solution does not seem to directly affect the separation process. This can be seen by analyzing Tests 122 and 118. The reduction rate for Test 122 is roughly half of that for 118, but it is important to note that since Test 122 had one-half the solution that Test 118 had, it only had to remove half as much foam to reach 1000 ppm. Therefore it is logical that its reduction rate would be reduced.

4.5 Water Loss

In general, water loss is a function of the type of foam formed, the concentration of the solution and the way in which the foam is removed.

The more dilute a solution is, the higher the initial surface tension of the solution. The resultant foam therefore consists of larger, drier bubbles since the smaller bubbles, which are heavier and carry more liquid, have a harder time forming.

This effect is also enhanced by the reduced surface viscosity of the liquid caused by the amount of surfactant per unit volume. This reduced viscosity allows the gases to coalesce easier, causing the large bubbles. Whatever the mechanism, diluting the solution proved efficient because it reduced the water loss suffered by the solution.

During these tests, it was also determined that the removal of the foam should be accomplished such that the dryer, lighter foam should be removed without removing the lower wetter foam. This process will provide for less water loss during the separation process.

Since the end result of this work is to separate AFFF from firefighter training wastewater, a sample from the Naval Research Laboratory's Chesapeake Beach Detachment Fire Test Facilities was obtained and used in Apparatus 2 (Test 121). Within three hours, the drain time had been reduced to below the 8-second limit signifying the end of the test.

The effects of the fuel in the wastewater are still virtually unknown. Samples were taken before and after the test that can be tested at a later date to determine if any of the fuel was removed from the sample by this separation process. The fuel has a tendency to mix in with the water/AFFF emulsion and not separate as cleanly as it does when mixed with only water. This is a concern to address since the fuel has to be removed from the foam as well as the surfactants. It is unknown at this time if the foam separation process is removing fuel from the wastewater.

Testing to date has indicated that it should be possible to separate AFFF from firefighting wastewater down to a concentration of 1000 ppm of AFFF, or lower, using the air separation techniques.

5.0 AFFF SEPARATOR DESIGN

5.1 Data Requirements

The data required to design a working model separator can be addressed as three separate requirements. The first is the amount of AFFF/water solution that needs to be separated, second the concentration of the solution (i.e., full strength versus half-strength), and finally, the time available to process the solution. For example, if the requirement is for 3000 gallons of full strength solution and the time available is 12 hours, then we need to design a system of one size. However, if the requirement is for 1500 gallons of half-strength solution and we have 12 hours available, then it will require a system one-fourth the size.

5.2 System Components

The system will consist of a steel separator compartment (square or rectangular), an air pipe system (removable for cleaning), an air compressor and tank system, a mechanical skimmer, and a suction system to remove the foam.

6.0 CONCLUSION

1. The amount of surface area exposed to air in the separator has a definite impact on its efficiency in separating foam, both in water loss and time to reduce the foam mix. On the scale that we have tried, the more exposed surface area, the better.

2. The depth of the solution seems to have an impact on the time to separate the AFFF. For example, a depth of one foot does not defoam as well as two feet, but no data are available for depths over two feet. It is possible that the limiting

factor is the surface area exposed, and that an optimum ratio can be found between depth of solution and surface area exposed.

3. Diluting the initial mixture keeps the water loss lower during the separation process. The time gain seems to be minimal, in fact, it seems that diluting the mixture means that a given sample will take longer to reduce than an undiluted sample. The wastewater sample obtained from CBD was sufficiently diluted so further dilution was not necessary.

4. The use of the field drain time test appears to be confirmed by the laboratory surface tension measurements. Surface tension appears to be a particularly sensitive laboratory method for measuring low AFFF concentrations, i.e., less than 1000 ppm.

5. The air flow factor did prove to be significant in optimizing the separator performance. Higher air flow factors were found to produce a more turbulent process that created more of the wetter, denser foam which is undesirable.

6. Removing the foam from the top layer of the foam blanket reduces the water loss by allowing the heavier, wetter foam to drain for a longer period of time before it is removed.

7. The effect of the other contaminants present in the firefighter training wastewater, particularly residual fuel, has not yet been determined. The sample tested in the separator reacted well and AFFF was removed but it will require further analysis to determine if it could be discarded as simple wastewater.

8. The air separation mechanical method for removing AFFF concentrate from the training facility wastewater has proven promising. Numerous tests have been run

that show significant reductions in AFFF concentrate without a great loss in water.

7.0 REFERENCES

1. NRL Grant N0014-96-1-G021 awarded to Old Dominion University, September 4, 1996

FREDERICK W. WILLIAMS
Director, Navy Technology Center
for Safety and Survivability

R. E. BURNS, President
Hughes Associates, Inc.
Baltimore MD

JESSE J. BEITEL
Hughes Associates, Inc.
Baltimore MD

RALPH J. OUELLETTE
Hughes Associates, Inc.
Baltimore MD

DANIEL B. SZEPESI
Hughes Assoicates, Inc.
Baltimore MD

Appendix A

3M General Offices

3M Center
St. Paul, MN 55144-1000
612 733 1110

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MATERIAL SAFETY
DATA SHEET

3M

DIVISION: SPECIALTY CHEMICALS DIVISION
TRADE NAME:
FC-203CF LIGHT WATER Brand Aqueous Film Forming Foam

3M ID NUMBER/U.P.C.:

98-0211-5617-3	00-51135-10152-0	98-0211-5618-1	00-51135-10153-7
98-0211-5619-9	00-51135-10154-4	98-0211-5620-7	00-51135-10155-1
98-0211-5621-5	00-51135-10156-8	98-0211-5622-3	00-51135-10157-5
98-0211-5623-1	- - -		

ISSUED: APRIL 14, 1995
SUPERSEDES: FEBRUARY 21, 1995
DOCUMENT: 10-4322-5

1. INGREDIENT

INGREDIENT	C.A.S. NO.	PERCENT
WATER	7732-18-5	69.0 - 71.0
ETHANOL,2-(2-BUTOXYETHOXY)-	112-34-5	19 - 21
ALKYL SULFATE SALTS(2) +(5805P, 5806P)	TradeSecret	~4.0 - ~~6.0~~
AMPHOTERIC FLUOROALKYLAMIDE DERIVATIVE +(5803P)	TradeSecret	~1 - ~5
TRIETHANOLAMINE	102-71-6	0.5 - 1.5
PERFLUOROALKYL SULFONATE SALTS(5) +(5804P)	TradeSecret	~0.5 - ~1.5
1H-BENZOTRIAZOLE,METHYL-	29385-43-1	0 - 0.1

NOTE: New Jersey Trade Secret Registry Number (EIN) 04499600-+
The ingredients of this product are included on TSCA.

THIS PRODUCT CONTAINS THE FOLLOWING TOXIC CHEMICAL OR CHEMICALS SUBJECT TO THE REPORTING REQUIREMENTS OF SECTION 313 OF TITLE III OF THE EMERGENCY PLANNING AND COMMUNITY RIGHT-TO-KNOW ACT OF 1986 AND 40 CFR PART 372:
ETHANOL,2-(2-BUTOXYETHOXY)-

2. PHYSICAL DATA

BOILING POINT:	ca. 100 C
VAPOR PRESSURE:	ca. 29.3 mmHg Calc. @ R.T.
VAPOR DENSITY:	ca. 0.62 Air = 1 Calc. @ R.T.
EVAPORATION RATE:	< 1.0 Butyl Acetate = 1
SOLUBILITY IN WATER:	Miscible
SP. GRAVITY:	ca. 1.0 Water = 1
PERCENT VOLATILE:	ca. 90 %
VOLATILE ORGANICS:	206 gms/liter
VOC LESS H2O & EXEMPT SOLVENT	747 gms/liter
pH:	ca. 8.5
VISCOSITY:	N/D
MELTING POINT	N/A
APPEARANCE AND ODOR:	Clear, amber colored liquid.

Abbreviations: N/D - Not Determined N/A - Not Applicable

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MATERIAL SAFETY
DATA SHEET

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MSDS: FC-203CF LIGHT WATER Brand Aqueous Film Forming Foam
APRIL 14, 1995

3. FIRE AND EXPLOSION HAZARD DATA

FLASH POINT:..... Setaflash
None (Setaflash CC)
FLAMMABLE LIMITS - LEL: ..... N/A
FLAMMABLE LIMITS - UEL: ..... N/A
AUTOIGNITION TEMPERATURE: ... N/A
EXTINGUISHING MEDIA:
Product is a fire-extinguishing agent.
SPECIAL FIRE FIGHTING PROCEDURES:
Not applicable
UNUSUAL FIRE AND EXPLOSION HAZARDS:
See Hazardous Decomposition section for products of combustion.

4. REACTIVITY DATA

STABILITY: Stable
INCOMPATIBILITY - MATERIALS TO AVOID:
Not applicable.
HAZARDOUS POLYMERIZATION: Will Not Occur
HAZARDOUS DECOMPOSITION PRODUCTS:
Carbon Monoxide and Carbon Dioxide, Oxides of Nitrogen, Oxides of Sulfur, Hydrogen Fluoride
Thermal decomposition of usage concentrations does not present a hazard.

5. ENVIRONMENTAL INFORMATION

SPILL RESPONSE:
Observe precautions from other sections. Contain spill. Cover with absorbent material. Collect spilled material. Clean up residue with water. Place in a U.S. DOT approved container and seal.

RECOMMENDED DISPOSAL:
Bleed spent solutions and small product quantities, generally <5 gal., to a wastewater treatment system. Reduce discharge rate if foaming occurs. Incinerate bulk product in an industrial or commercial incinerator. Combustion products will include HF. Disposal alternative: Dispose of completely absorbed waste product in a facility permitted to accept chemical wastes. Since regulations vary, consult applicable regulations or authorities before disposal. U.S. EPA Hazardous Waste No.: None

ENVIRONMENTAL DATA:
A 3M Product Environmental Data Sheet (PED) is available.

EPCRA HAZARD CLASS:
FIRE HAZARD: No **PRESSURE:** No **REACTIVITY:** No **ACUTE:** Yes **CHRONIC:** Yes

6. SUGGESTED FIRST AID

EYE CONTACT:
Immediately flush eyes with large amounts of water for at least 15

Abbreviations: N/D - Not Determined N/A - Not Applicable

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APRIL 14, 1995

6. SUGGESTED FIRST AID (continued)

minutes. Get immediate medical attention.

SKIN CONTACT:
Flush skin with large amounts of water. If irritation persists, get medical attention.

INHALATION:
If signs/symptoms occur, remove person to fresh air. If signs/symptoms continue, call a physician.

IF SWALLOWED:
Drink two glasses of water. Call a physician.

7. PRECAUTIONARY INFORMATION

EYE PROTECTION:
Avoid eye contact with vapor, spray, or mist. Wear vented goggles.

SKIN PROTECTION:
Avoid skin contact. Wear appropriate gloves when handling this material. A pair of gloves made from the following material(s) are recommended: butyl rubber.

VENTILATION PROTECTION:
Use with adequate dilution ventilation.

RESPIRATORY PROTECTION:
Avoid breathing of vapors, mists or spray. Select one of the following NIOSH approved respirators based on airborne concentration of contaminants and in accordance with OSHA regulations: Half-mask organic vapor respirator with dust/mist prefilter.

PREVENTION OF ACCIDENTAL INGESTION:
Do not eat, drink or smoke when using this product. Wash exposed areas thoroughly with soap and water. Wash hands after handling and before eating.

RECOMMENDED STORAGE:
Store in a cool place. Store away from heat. Store out of direct sunlight. Keep container dry. Keep container in well-ventilated area.

FIRE AND EXPLOSION AVOIDANCE:
Keep container tightly closed.

EXPOSURE LIMITS

INGREDIENTS	VALUE	UNIT	TYPE	AUTH	SKIN*
WATER	NONE	NONE	NONE	NONE	

Abbreviations: N/D - Not Determined N/A - Not Applicable

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MSDS: FC-203CF LIGHT WATER Brand Aqueous Film Forming Foam
APRIL 14, 1995

7. PRECAUTIONARY INFORMATION (continued)

EXPOSURE LIMITS

INGREDIENTS	VALUE	UNIT	TYPE	AUTH	SKIN*
ETHANOL,2-(2-BUTOXYETHOXY)-	35	ppm	TWA	CNRG	
ALKYL SULFATE SALTS(2) +(5805P, 5806P)	NONE	NONE	NONE	NONE	
AMPHOTERIC FLUOROALKYLAMIDE DERIVATIVE +(5803P)	NONE	NONE	NONE	NONE	
TRIETHANOLAMINE	5	mg/m3	TWA	ACGIH	
PERFLUOROALKYL SULFONATE SALTS(5) +(5804P)	0.1	mg/m3	TWA	3M	Y
1H-BENZOTRIAZOLE,METHYL-	NONE	NONE	NONE	NONE	

* SKIN NOTATION: Listed substances indicated with "Y" under SKIN refer to the potential contribution to the overall exposure by the cutaneous route including mucous membrane and eye, either by airborne or, more particularly, by direct contact with the substance. Vehicles can alter skin absorption.

SOURCE OF EXPOSURE LIMIT DATA:
- ACGIH: American Conference of Governmental Industrial Hygienists
- AIHA: American Industrial Hygine Assoc. Workplace Environmental Exposure Level
- 3M: 3M Medical Department Guideline
- CNRG: Chemical Manufacture Recommended Guidelines
- NONE: None Established

8. HEALTH HAZARD DATA

EYE CONTACT:
Moderate Eye Irritation: signs/symptoms can include redness, swelling, pain, tearing, and hazy vision.

SKIN CONTACT:
Moderate Skin Irritation (after prolonged or repeated contact): signs/symptoms can include redness, swelling, itching, and dryness.

Prolonged or repeated exposure may cause:

May be absorbed through the skin in harmful amounts.

INHALATION:
Single overexposure, above recommended guidelines, may cause:

Central Nervous System Depression: signs/symptoms can include headache, dizziness, drowsiness, incoordination, slowed reaction time, slurred speech, giddiness and unconsciousness.

Irritation (upper respiratory): signs/symptoms can include soreness of the nose and throat, coughing and sneezing.

Abbreviations: N/D - Not Determined N/A - Not Applicable

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MSDS: FC-203CF LIGHT WATER Brand Aqueous Film Forming Foam
APRIL 14, 1995

8. HEALTH HAZARD DATA (continued)

Prolonged or repeated overexposure, above recommended guidelines, may cause:

Blood disorders: signs/symptoms can include prolonged weakness and fatigue.

Bone Marrow Depression: signs/symptoms can include prolonged weakness and fatigue.

Kidney Effects: signs/symptoms can include reduced urine volume, blood in urine and back pain.

Liver Effects: signs/symptoms can include yellow skin(jaundice) and tenderness of upper abdomen.

Pulmonary Edema: signs/symptoms can include coughing, congestion, difficulty breathing, which can result in respiratory failure and death.

IF SWALLOWED:
Ingestion is not a likely route of exposure to this product.

OTHER HEALTH HAZARD INFORMATION:
A 3M Product Toxicity Summary Sheet is available.

SECTION CHANGE DATES

ENVIRON. DATA **SECTION CHANGED SINCE** FEBRUARY 21, 1995 ISSUE

Abbreviations: N/D - Not Determined N/A - Not Applicable

Appendix B

3M General Offices

3M Center
St. Paul, MN 55144-1000
612 733 1110

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MATERIAL SAFETY
DATA SHEET

3M

DIVISION: SPECIALTY CHEMICALS DIVISION
TRADE NAME:
FC-206CF LIGHT WATER Brand Aqueous Film Forming Foam

3M ID NUMBER/U.P.C.:	ZF-0002-0614-2	-	-	ZF-0002-0621-7	-	-
	ZF-0002-0791-8	-	-	98-0211-5624-9	00-51135-10159-9	
	98-0211-5625-6	00-51135-10160-5		98-0211-5626-4	00-51135-10161-2	
	98-0211-5627-2	00-51135-10162-9		98-0211-5628-0	00-51135-10163-6	
	98-0211-5629-8	00-51135-10164-3		98-0211-5630-6	-	-

ISSUED: APRIL 14, 1995
SUPERSEDES: JUNE 17, 1994
DOCUMENT: 10-4323-1

1. INGREDIENT

INGREDIENT	C.A.S. NO.	PERCENT			
WATER	7732-18-5	78.0	-	81.0	
ETHANOL,2-(2-BUTOXYETHOXY)-	112-34-5	9.5	-	10.5	
UREA	57-13-6	3	-	7	
ALKYL SULFATE SALTS(2) +(5809P, 5810P)	TradeSecret	1.0	-	5.0	
AMPHOTERIC FLUOROALKYLAMIDE DERIVATIVE +(5807P)	TradeSecret	1	-	2	2.5 to 8.0 wt % surfactant
PERFLUOROALKYL SULFONATE SALTS(5) +(5808P)	TradeSecret	0.1	-	1	
TRIETHANOLAMINE	102-71-6	0.1	-	1	
1H-BENZOTRIAZOLE,METHYL-	29385-43-1	0	-	0.1	

NOTE: New Jersey Trade Secret Registry Number (EIN) 04499600-+
The ingredients of this product are included on TSCA.

THIS PRODUCT CONTAINS THE FOLLOWING TOXIC CHEMICAL OR CHEMICALS SUBJECT TO THE REPORTING REQUIREMENTS OF SECTION 313 OF TITLE III OF THE EMERGENCY PLANNING AND COMMUNITY RIGHT-TO-KNOW ACT OF 1986 AND 40 CFR PART 372:
ETHANOL,2-(2-BUTOXYETHOXY)-

2. PHYSICAL DATA

BOILING POINT:	ca. 100.00 C (Initial)
VAPOR PRESSURE:	ca. 30.4000 mmHg Calc. @ R.T.
VAPOR DENSITY:	ca. 0.62 Air = 1 Calc. @ R.T.
EVAPORATION RATE:	< 1.00 Butyl Acetate = 1
SOLUBILITY IN WATER:	Miscible
SP. GRAVITY:	ca. 1.000 Water = 1
PERCENT VOLATILE:	ca. 90.00 %
VOLATILE ORGANICS:	103 gms/liter
VOC LESS H2O & EXEMPT SOLVENT	559 gms/liter
pH:	ca. 8.50
VISCOSITY:	N/D
MELTING POINT:	N/A
APPEARANCE AND ODOR:	Clear, amber colored liquid.

Abbreviations: N/D - Not Determined N/A - Not Applicable

3M General Offices

3M Center
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612 733 1110

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MATERIAL SAFETY
DATA SHEET

3M

3. FIRE AND EXPLOSION HAZARD DATA

FLASH POINT:..... Setaflash
None (Setaflash CC)
FLAMMABLE LIMITS - LEL: ..... N/A
FLAMMABLE LIMITS - UEL: ..... N/A
AUTOIGNITION TEMPERATURE: ... N/A
EXTINGUISHING MEDIA:
Product is a fire-extinguishing agent.
SPECIAL FIRE FIGHTING PROCEDURES:
Not applicable
UNUSUAL FIRE AND EXPLOSION HAZARDS:
See Hazardous Decomposition section for products of combustion.

4. REACTIVITY DATA

STABILITY: Stable
INCOMPATIBILITY - MATERIALS TO AVOID:
Not applicable.
HAZARDOUS POLYMERIZATION: Will Not Occur
HAZARDOUS DECOMPOSITION PRODUCTS:
Carbon Monoxide and Carbon Dioxide, Oxides of Nitrogen, Oxides of Sulfur, Hydrogen Cyanide, Hydrogen Fluoride, Ammonia
Thermal decomposition of usage concentrations does not present a hazard.

6. ENVIRONMENTAL INFORMATION

SPILL RESPONSE:
Observe precautions from other sections. Cover with absorbent material. Collect spilled material. Clean up residue with water. Place in an approved metal container.

RECOMMENDED DISPOSAL:
Slowly discharge spent solutions and small quantities (less than 5 gal.(19 L)) to a wastewater treatment system. Reduce discharge rate if foaming occurs. Incinerate in an industrial or commercial facility in the presence of a combustible material. Combustion products will include HF. Disposal alternative: Dispose of completely absorbed waste product in a facility permitted to accept chemical wastes.

ENVIRONMENTAL DATA:
A 3M Product Environmental Data Sheet (PED) is available.

REGULATORY INFORMATION:
Since regulations vary, consult applicable regulations or authorities before disposal. U.S. EPA Hazardous Waste Number = None (Not U.S. EPA Hazardous).

EPCRA HAZARD CLASS:
FIRE HAZARD: No **PRESSURE:** No **REACTIVITY:** No **ACUTE:** Yes **CHRONIC:** Yes

Abbreviations: N/D - Not Determined N/A - Not Applicable

3M General Offices
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St. Paul, MN 55144-1000
612 733 1110

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MATERIAL SAFETY
DATA SHEET

3M

6. SUGGESTED FIRST AID

EYE CONTACT:
Immediately flush eyes with large amounts of water for at least 15 minutes. Get immediate medical attention.

SKIN CONTACT:
Flush skin with large amounts of water. If irritation persists, get medical attention.

INHALATION:
If signs/symptoms occur, remove person to fresh air. If signs/symptoms continue, call a physician.

IF SWALLOWED:
Drink two glasses of water. Call a physician.

7. PRECAUTIONARY INFORMATION

EYE PROTECTION:
Avoid eye contact with vapor, spray, or mist. Wear vented goggles.

SKIN PROTECTION:
Avoid skin contact. Wear appropriate gloves when handling this material. A pair of gloves made from the following material(s) are recommended: butyl rubber.

VENTILATION PROTECTION:
Use with adequate dilution ventilation.

RESPIRATORY PROTECTION:
Avoid breathing of vapors, mists or spray. Select one of the following NIOSH approved respirators based on airborne concentration of contaminants and in accordance with OSHA regulations: Half-mask organic vapor respirator with dust/mist prefilter.

PREVENTION OF ACCIDENTAL INGESTION:
Do not eat, drink or smoke when using this product. Wash exposed areas thoroughly with soap and water. Wash hands after handling and before eating.

RECOMMENDED STORAGE:
Store in a cool place. Store away from heat. Store out of direct sunlight. Keep container dry. Keep container in well-ventilated area.

FIRE AND EXPLOSION AVOIDANCE:
Keep container tightly closed.

Abbreviations: N/D - Not Determined N/A - Not Applicable

3M General Offices

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MATERIAL SAFETY
DATA SHEET

3M

7. PRECAUTIONARY INFORMATION (CONTINUED)

EXPOSURE LIMITS

INGREDIENTS	VALUE	UNIT	TYPE	AUTH	SKIN*
WATER	NONE	NONE	NONE	NONE	
ETHANOL,2-(2-BUTOXYETHOXY)-	35	ppm	TWA	CMRG	
UREA	10	mg/m3	TWA	AIHA	
ALKYL SULFATE SALTS(2) +(5809P, 5810P)	NONE	NONE	NONE	NONE	
AMPHOTERIC FLUOROALKYLAMIDE DERIVATIVE +(5807P)	NONE	NONE	NONE	NONE	
PERFLUOROALKYL SULFONATE SALTS(5) +(5808P)	0.1	mg/m3	TWA	3M	Y
TRIETHANOLAMINE	5	mg/m3	TWA	ACGIH	
1H-BENZOTRIAZOLE,METHYL-	NONE	NONE	NONE	NONE	

* SKIN NOTATION: Listed substances indicated with "Y" under SKIN refer to the potential contribution to the overall exposure by the cutaneous route including mucous membrane and eye, either by airborne or, more particularly, by direct contact with the substance. Vehicles can alter skin absorption.

SOURCE OF EXPOSURE LIMIT DATA:
- ACGIH: American Conference of Governmental Industrial Hygienists
- AIHA: American Industrial Hygine Assoc. Workplace Environmental Exposure Level G
- 3M: 3M Medical Department Guideline
- CMRG: Chemical Manufacture Recommended Guidelines
- NONE: None Established

8. HEALTH HAZARD DATA

EYE CONTACT:
Moderate Eye Irritation: signs/symptoms can include redness, swelling, pain, tearing, and hazy vision.

SKIN CONTACT:
Mild Skin Irritation: signs/symptoms can include redness, swelling, and itching.

Prolonged or repeated exposure may cause:

May be absorbed through the skin in harmful amounts.

INHALATION:
Single overexposure, above recommended guidelines, may cause:

Central Nervous System Depression: signs/symptoms can include headache, dizziness, drowsiness, incoordination, slowed reaction time, slurred speech, giddiness and unconsciousness.

Irritation (upper respiratory): signs/symptoms can include

Abbreviations: N/D - Not Determined N/A - Not Applicable

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MATERIAL SAFETY
DATA SHEET

3M

MSDS: FC-206CF LIGHT WATER Brand Aqueous Film Forming Foam
APRIL 14, 1995

8. HEALTH HAZARD DATA (continued)

soreness of the nose and throat, coughing and sneezing.

Prolonged or repeated overexposure, above recommended guidelines, may cause:

Blood disorders: signs/symptoms can include prolonged weakness and fatigue.

Bone Marrow Depression: signs/symptoms can include prolonged weakness and fatigue.

Kidney Effects: signs/symptoms can include reduced urine volume, blood in urine and back pain.

Liver Effects: signs/symptoms can include yellow skin(jaundice) and tenderness of upper abdomen.

Pulmonary Edema: signs/symptoms can include coughing, congestion, difficulty breathing, which can result in respiratory failure and death.

IF SWALLOWED:
Ingestion is not a likely route of exposure to this product.

OTHER HEALTH HAZARD INFORMATION:
A 3M Product Toxicity Summary Sheet is available.

SECTION CHANGE DATES

HEADING	SECTION CHANGED SINCE	JUNE 17, 1994 ISSUE
ENVIRON. DATA	SECTION CHANGED SINCE	JUNE 17, 1994 ISSUE

Abbreviations: N/D - Not Determined N/A - Not Applicable

[159] From: 03G2MSGS 4/18/96 7:33AM (3275 bytes: 62 ln)
To mailing list: #03G2
Subject: 171500Z APR 96; R;AQUEOUS FILM FORMING FOAM (AFFF) AND CONCE
---------- Forwarded ----------
From: PWC JACKSONVILLE FL//600// at Intxch 4/17/96 7:10PM (3051 bytes: 62 ln)
To: 03G2MSGS at P-05_01
Subject: 171500Z APR 96; R;AQUEOUS FILM FORMING FOAM (AFFF) AND CONCE
---------- Message Contents ----------

Text item 1: Text Item

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U-UNCLASSIFIED--UNCLASSIFIED-U
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RTTUZYUW RHFJSGG7702 1081500-UUUU--RULSSEA.
ZNR UUUUU
RHBAFXM T USS MCINERNEY
RHBARAR T USS MONTEREY
RHBBHUE T USS HUE CITY
RHBCFGF T USS FAHRION
RHBCSEM T USS SAMUEL ELIOT MORISON
RHPBGWU T USS UNDERWOOD
R 171500Z APR 96 ZYB PSN 169491M30
FM PWC JACKSONVILLE FL//600//
TO ALL SHIPS AND AFLOAT COMMANDS HOMEPORTED MAYPORT
RHFJFFJ/SUPSHIP JACKSONVILLE FL//00//
INFO RUCBCLF/CINCLANTFLT NORFOLK VA//N45/N465//
RHFJJAH/COMNAVBASE JACKSONVILLE FL//00/N3//
RULSSEA/COMNAVSEASYSCOM WASHINGTON DC//SEA 00L6/SEA 00T//
RHFJFGU/COMREGSUPPGRU MAYPORT FL//00//
RULSADK/COMNAVFACENGCOM ALEXANDRIA VA//40/41JG//
RUWFPCN/NFESC PORT HUENEME CA//414KF//
RHFJFMC/SOUTHNAVFACENGCOM CHARLESTON SC//18//
RHFJFFF/NAVSTA MAYPORT FL//N4E//
RHFJFED/COMAFLOATRAGRU MAYPORT FL//00//
BT
UNCLAS //N05090//
MSGID/GENADMIN/PWC JACKSONVILLE FL/600//
SUBJ/AQUEOUS FILM FORMING FOAM (AFFF) AND CONCENTRATED BILGE CLEANER
/REF/A/MSG/111631Z JAN 96//REF/B/DOC/SOPA(ADMIN)MYPTINST/230CT95//
/REF/C/DOC SOPA(ADMIN)MPTINST/22APR94//
NARR/REF/A IS MSG SUBJ/AQUEOUS FILM FORMING FOAM (AFFF) AND
PAGE 02 RHFJSGG7702 UNCLAS
CONCENTRATED BILGE CLEANER REF B IS INST 5090.1C, DISPOSAL OF HAZ
MAT AND HAZ WASTE, REF C IS INST 5090.2, OIL WASTE/WASTE OIL
MANAGEMENT//
POC/TOM RYCZEK/600/PWC JAX/
/ /TEL:DSN 942-2114, X8037.//
RMKS/1. IMPERATIVE THAT SUBJ MATERIAL NOT BE DISPOSED OF IN THE
ASHORE CHT SYSTEM OR THE ASHORE OILY WASTE (BILGE WATER) RISERS PER
REF A. ALTERNATE DISPOSAL PROCEDURES SHOULD BE CONSIDERED INCLUDING
USE OF CONTRACTOR TANKER TRUCK OR COLLECTING INTO DRUMS FOR HAZ WASTE
DISPOSAL THROUGH NAVSTA MAYPORT. REF B AND C APPLY.
2. AN INCIDENT ON 8 APR 96 INVOLVING THE DISCHARGE OF AFFF TO THE
CHT AND OILY WASTE/WATER OIL SYSTEM CAUSED A DISRUPTION IN THE
MAYPORT WASTEWATER TREATMENT PLANT OPERATIONS. THE PLANT
VIOLATED ITS LEGAL PERMIT, STATE, AND FEDERAL REGULATIONS. AFFF

KILLS THE BACTERIA THAT AIDS IN SEWAGE TREATMENT AND RENDERS THE PLANT INEFFECTIVE. AFFF CAN NOT BE TOLERATED IN EITHER THE CHT OR OILY/WASTE OIL SYSTEM, AS BOTH FEED INTO THE WASTEWATER TREATMENT PLANT. AFFF CONTAMINATED LIQUIDS MUST BE DISPOSED OF CORRECTLY.
3. REQUEST COMAFLOATRAGRU PASS TO ALL SHIPS ARRIVING MAYPORT FOR TRAINING.//
PAGE 03 RHFJSGG7702 UNCLAS
BT
#7702
NNNN

00L(1) ....INFO FOR COMNAVSEASYSCOM
00T(1) 03G(1) 03G2(1) 03V(1) 04MS(1) 04PT(1) 071(1)
00(1) 00E(1) 02(1) 3D9MED(1) 04MP(1) 09M(1) PMS325G(1)

Primary Solvent

Butyl Carbitol

(Since this is a glycol ether for a while EPA established a reporting requirement for [illegible]

SARA
Title III
1993

[illegible]

OK

[illegible] Ethylene Glycol [illegible]

US00002519

National Fire Protection Association

1 Batterymarch Park
P.O. Box 9101
Quincy, MA 02269-9101
Telephone (617) 770-3000
Fax (617) 770-0700

Technical Committee on Foam

TO: Committee Members

FROM: Mark T. Conroy, Staff Liaison

DATE: August 8, 1995

SUBJECT: U.S. EPA Reporting Requirements for Glycol Ether

Attached for your information is an update on the U.S. EPA Reporting Requirements for Foam discharges. This update will appear in the NFPA Journal. Please bring a copy of this article with you to the upcoming meeting August 30 in Washington, D.C. as it will be discussed.

MTC/wh

Sept/Oct 95

The May/June 1995 issue of Fire Journal, in the article on "Foam and the Environment: A Delicate Balance" (page 71), discussed the U.S. Environmental Protection Agency (EPA) reporting requirements for foam discharges. The EPA requires reporting of certain releases of chemicals, including some chemicals in broadly defined categories. The glycol ether category of chemicals was placed on the list of Hazardous Air Pollutants under the 1990 Clean Air Act Amendments, section 112. This listing automatically caused it to be designated a hazardous substance under the Comprehensive Environmental Response Compensation & Liability Act (CERCLA), section 101(14). A reportable quantity (RQ) was not defined at the time of the listing of glycol ethers, so it automatically defaulted to a level of one pound.

One of the glycol ethers is diethylene glycol butyl ether (DGBE), which is used in many firefighting foams, including aqueous film forming foams (AFFF). The EPA required that any time AFFF was used resulting in the release to the environment of more then 1 pound of DGBE, approximately 1 gallon of foam concentrate, the National Response Center needed to be notified.

The EPA has now issued a final rule (June 12, 1995, 60 FR 30926) on several broad categories of chemicals, including the glycol ethers. The EPA has assigned no RQ to any of the glycol ethers, at this time. Thus, there is no longer a reporting requirement for the use of AFFF. However, in the future the EPA will evaluate certain substances within the categories to determine whether they should be individually listed and assigned an RQ.

The EPA does state that CERCLA liability continues to apply to releases of all compounds within the glycol ether category, even if reporting is not required. Parties responsible for releases of glycol ethers are liable for the costs associated with cleanup and any natural resource damages resulting from the release.

(j) The ozone nonattainment areas listed in this paragraph (j) are covered areas beginning on January 1, 1995, except that those areas listed in paragraphs (j)(5) (viii) and (ix), (j)(10) (i), (iii), and (v) through (xi) and (j)(11) of this section shall not be covered areas prior to EPA taking final action on the proposal to remove these areas as covered areas.

* * * * *

[FR Doc. 95–16825 Filed 7–7–95; 8:45 am]

BILLING CODE 6560–50–P

40 CFR Part 302

[FRL–5255–5]

Reportable Quantity Adjustments; Correction

AGENCY: Environmental Protection Agency (EPA).

ACTION: Correction to final rule.

SUMMARY: This document corrects errors in the amendatory language of a final rule published on June 12, 1995 (60 FR 30926). The final rule made changes to reportable quantities for hazardous substances under the Comprehensive Environmental Response, Compensation, and Liability Act.

EFFECTIVE DATE: July 10, 1995.

FOR FURTHER INFORMATION CONTACT: The RCRA/UST, Superfund, and EPCRA Hotline at 800/424–9346 (in the Washington, DC metropolitan area, contact 703/412–9810). The Telecommunications Device for the Deaf (TDD) Hotline number is 800/553–7672 (in the Washington, DC metropolitan area, contact 703/486–3323); or Mr. Jack Arthur, Response Standards and Criteria Branch, Emergency Response Division (5202G), U.S. Environmental Protection Agency, 401 M Street SW., Washington, DC 20460, or at 703/603–8760.

Dated: June 30, 1995.

Timothy Fields, Jr.,

Acting Assistant Administrator.

For the reasons set out in the preamble, FR Doc. 95–13787, published at 60 FR 30926 (June 12, 1995) is corrected as follows:

§ 302.4 [Corrected]

1. On page 30938, column 3, amendatory instruction 4 is corrected to read as follows:

4. Table 302.4 in § 302.4 is amended by adding the following new entries in alphabetical order; and by revising the entries for "Benzene, dimethyl", "Phenol, methyl-", and "Xylene (mixed)" and their subentries; and by revising under the heading "Unlisted Hazardous Wastes Characteristics: Characteristic of Toxicity:" the entries for "o-Cresol (D023)", "m-Cresol (D024)", "p-Cresol (D025)", and "Cresol (D026)"; and by revising the entries for "F004", "F025", "F037", "F038", "K088", "K090", and "K091"; and by adding footnote "a" to the entry for "Benzene"; and by removing the entries for "Cresol(s)" and "Cresylic acid" and their subentries, as set forth below:

2. On page 30944, column 1, amendatory instruction 5 is corrected to read as follows:

5. Table 302.4 in § 302.4 is also amended by revising the following entries; and by adding new entries in alphabetical order for "Antimony Compounds", "Aroclors" and its subentries, "Arsenic Compounds (inorganic including arsine)", "Beryllium Compounds", "Cadmium Compounds", "Chlorinated camphene", "1–Chloro-2, 3-epoxypropane", "Chloromethane", "Chromium Compounds", "Cyanide Compounds", "DEHP", "Dibromoethane", "Dichloromethane", "1,4–Diethyleneoxide", "Dimethyl aminoazobenzene", "Ethyl chloride", "Hexone", "Hydrogen phosphide", "Iodomethane", "Lead Compounds", "Lindane (all isomers)", "MEK", "Mercury Compounds", "2–Methyl aziridine", "Nickel Compounds", "PCBs" and its subentries, "PCNB", "Quinone", "Quintobenzene", "Radionuclides (including radon)", "Selenium Compounds", "TCDD", "2,4–Toluene diamine", "2,4–Toluene diisocyanate", and "Urethane", as set forth below:

3. On page 30959, preceding Appendix A to § 302.4, add the following amendatory instruction to read as follows:

5a. Appendix A to § 302.4 is amended by revising the following entries, as set forth below:

[FR Doc. 95–16754 Filed 7–7–95; 8:45 am]

BILLING CODE 6560–50–P

DEPARTMENT OF HEALTH AND HUMAN SERVICES

Health Care Financing Administration

42 CFR Part 414

[BPD–494–F]

RIN 0938–AD65

Medicare Program; Payment for Durable Medical Equipment and Orthotic and Prosthetic Devices

AGENCY: Health Care Financing Administration (HCFA), HHS.

ACTION: Final rule.

SUMMARY: This final rule addresses comments received on an interim final rule with comment period published on December 7, 1992. The interim final rule implemented section 4062(b) of the Omnibus Budget Reconciliation Act of 1987. It specified that payment under the Medicare program for durable medical equipment (DME), prosthetics, and orthotics furnished on or after January 1, 1989 is limited to the lower of the actual charge for the equipment or the fee schedule amount established by the carrier. This final rule describes amendments to the methods for computing fee schedules covering the six classes of DME and how they are updated in subsequent years in accordance with sections 13542 through 13546 of the Omnibus Budget Reconciliation Act of 1993.

DATES: These final regulations are effective August 9, 1995.

FOR FURTHER INFORMATION CONTACT:
Sharon Hippler—(410) 966–4633
(Coverage Issues)
William Long—(410) 966–5655
(Payment Issues)

SUPPLEMENTARY INFORMATION:

I. Background

The provisions of sections 1833 and 1842 of the Social Security Act (the Act) set forth the general payment authority for most physician and other medical and health services furnished under Part B of the Medicare program. Section 1834 sets forth the 6 classes of DME and specifies that payment for these items is limited to 80 percent of the lesser of the actual charge or a fee schedule amount established by each Medicare carrier.

We published an interim final rule on December 7, 1992 (57 FR 57675) that set forth the methods for computing fee schedules for the six classes of DME effective for services furnished on or after January 6, 1993. The interim rule also described how the fee schedules are updated. The December 1992 rule explained in detail the various legislative changes that led to its publication (57 FR 57676).

On August 10, 1993, the Omnibus Budget Reconciliation Act of 1993 (OBRA 93, Public Law 103–66), revised the statutory provisions upon which the DME payment rules that appeared in the December 1992 final rule were based. We are including these provisions in this final rule since the revisions are not discretionary but follow the explicit language contained in sections 13542 through 13546.

A summary of the provisions of these sections of OBRA 93 follows :

- Section 13542 amends sections 1834(a)(2), (a)(3), (a)(8), and (a)(9) of the

National Fire Protection Association

1 Batterymarch Park
P.O. Box 9101
Quincy, MA 02269-9101
Telephone (617) 770-3000
Fax (617) 984-7056
Telex 200250

Technical Committee on Foam

TO: Committee Members

FROM: Mark T. Conroy, Staff Liaison MTC

DATE: April 25, 1995

SUBJECT: 1) Foam Environmental Issues Report Draft
2) Plans for Committee Meeting

Attached for your information is the draft of the Foam Environmental Issues Report that was developed by the Task Group. This report will be discussed at an upcoming meeting.

In order to coordinate dates for an upcoming meeting, the attached calendar is being circulated. Please cross out the dates that you are unavailable and return this form by **May 5, 1995.**

Additionally, please submit any agenda items that you would like Chairman Murphy to consider for the upcoming meeting.

MTC/wh

Attachments

cc: Task Group on Foam Environment Issues

Technical Committee on Foam
Calendar for Planning Upcoming Meeting
June - September, 1995

Please cross-out the dates that you are unavailable for a meeting.

	Monday	Tuesday	Wednesday	Thursday	Friday	Sat/Sun
JUNE				1	2	3 4
	5	6	7	8	9	10 11
	12	13	14 Flag Day	15	16	17 18 Father's Day
	19	20	21	22	23	24 25
	26	27	28	29	30	1 Canada Day 2
JULY	3	4 Independence Day	5	6	7	8 9
	10	11	12	13	14	15 16
	17	18	19	20	21	22 23
	24	25	26	27	28	29 30
	31	1	2	3	4	5 6
AUGUST	7	8	9	10	11	12 13
	14	15	16	17	18	19 20
	21	22	23	24	25	26 27
	28	29	30	31	1	2 3
SEPTEMBER	4 Labor Day	5	6	7	8	9 10
	11	12	13	14	15	16 17
	18	19	20	21	22	23 24 Rosh H. begins
	25 Rosh Hashanah	26	27	28	29	30
	Monday	Tuesday	Wednesday	Thursday	Friday	Sat/Sun

Return by: May 5, 1995

Name:_____

Date: _____

° Foam Environmental Issues °

February 1995

- **Overview**

- **Scope**
  Robert L. Darwin
  US Dept of Navy, NAVSEA, Washington, DC

- **Discharge Scenarios**
- **Fixed Systems and Facility Planning**
  Joseph E. Gott
  US Dept of Navy, NAVFAC, Alexandria, VA

- **Disposal Alternatives**
- **Collection and Pretreatment of Foam Solutions Prior to Disposal**
- **Discharge of Foam Solutions to Wastewater Treatment Facilities**
  Edward C. Norman
  Aqueous Foam Technology, Chester Springs, PA

- **Aqueous Film Forming Foam and Alcohol Resistant Aqueous Film Forming Foam Product Use Reporting**
  Richard E. Ottman
  3M Specialty Chemical Division, St Paul, MN

- **Environmental Properties of Fluorochemical Surfactants**
  Christopher P. Hanauska
  Hughes Associates, Bloomington, MN

Prepared for

The Technical Committee on Foam
National Fire Protection Association
1 Batterymarch Park
Quincy, MA 02269–9101

Foam Environmental Issues

Table of Contents

I. OVERVIEW

Fire fighting foams serve a vital role in fire protection throughout the world. Their use has proven to be essential for the control of flammable liquid fire threats inherent in airport operations, fuel farms and petroleum processing, highway and rail transportation, marine applications, and industrial facilities. The ability of foam to rapidly extinguish flammable liquid spill fires has undoubtedly saved lives, reduced property loss, and helped minimize the global pollution which could result from the uncontrolled burning of flammable fuels, solvents, and industrial liquids.

However, with the ever increasing environmental awareness, recent concern has focused on the potential adverse environmental impact of foam solution discharges. The primary concerns are fish toxicity, biodegradability, treatability in waste water treatment plants, and nutrient loading. All of these are of concern when the end-use foam solutions reach natural or domestic water systems. Additionally, the US Environmental Protection Agency has recently highlighted a potential problem with AFFF by placing glycol ethers, a common solvent constituent in AFFF, on the list of hazardous air pollutants under the 1990 Clean Air Act Amendments.

Recognizing the need for greater public awareness and education, the NFPA Foam Committee established a Task Group of recognized foam experts to draft this informational "white paper" on foam environmental issues. The purpose of this document is to

- Provide foam users with summary information on foam environmental issues,
- Highlight applicable regulatory status,
- Offer guidelines for coping with regulations and provide suggested sources for additional information, and
- Encourage planning for foam discharge scenarios (including prior contact with local waste water treatment plant operators).

It should be emphasized that it is not the intent of this document to limit or restrict the use of fire fighting foams. The Task Group believes that the fire safety advantages of using foam are greater than the risks of potential environmental problems. The ultimate goal of this paper is to foster use of foam in an environmentally responsible manner so as to minimize risk from their use.

II. SCOPE

The information provided in this document covers foams for Class B combustible and flammable liquid fuel fires. Foams for this purpose, as listed in NFPA 11, include protein

foam, fluoroprotein foam, film-forming fluoroprotein foam (FFFP), and synthetic foams such as aqueous film forming foam (AFFF).

While there are some environmental issues common to all foam types, certain foams present unique concerns. For example all types can interfere with the operation of oil/water separators, can contribute to waste water treatment facility "shock loading," and can generate unsightly nuisance foaming. Synthetic foams, such as AFFF, may contain solvents, such as glycol ethers, and are generally less biodegradable. Protein based foams may be more prone to contributing to nutrient loading due to their high ammonia nitrogen content.

This paper is primarily concerned with the discharge of foam solutions to waste water treatment facilities and to the environment. The discharge of foam concentrates, while a related subject, is a much less common occurrence. All manufacturers of foam concentrate deal with clean-up and disposal of spilled concentrate in their MSDS sheets and product literature.

This document is not intended to be a field document, thus no specific strategies or tactics are offered. Information, awareness, and planning are emphasized.

III. DISCHARGE SCENARIOS

A discharge of foam water solution is most likely to be the result of one of four scenarios: manual fire fighting or fuel blanketing operations, training, foam equipment system tests, or fixed system releases. These four scenarios include events occurring at such places as aircraft facilities, firefighter trainers, and special hazards facilities (which include flam/haz warehouses, bulk flammable liquid storage facilities and hazardous waste storage facilities). Each scenario is considered separately below:

1) Fire fighting Operations - Fires occur in many types of locations and under many different circumstances. In some cases it is possible to collect the foam solution used, and in others, such as in marine fire fighting, it is not. These types of incidents would include aircraft rescue and fire fighting operations, vehicular fires (cars, boats, train cars), structural fires with hazardous materials, and flammable liquid fires. Foam water solution which has been used in fire fighting operations will probably be heavily contaminated with the fuel or fuels involved in the fire. It is also likely to have been diluted with water discharged for cooling purposes.

In some cases the foam solution used during fire department operations can be collected. However, it is not always possible to control or contain the foam. This can be a consequence of the location of the incident or the circumstances surrounding it.

Event-initiated manual containment measures are the operations usually executed by the responding fire department to contain the flow of foam water solution when conditions and manpower permit. Those operations include the following measures:

a. Blocking sewer drains - This is a common practice used to prevent contaminated foam water solution from entering the sewer system unchecked. It is then diverted to an area suitable for containment.

b. Portable dikes - These are generally used for land-based operations. They can be set up by the fire department personnel during or after extinguishment to collect run-off.

c. Portable booms - These are used for marine based operations which are set up to contain foam in a defined area. These generally involve the use of floating booms within a natural body of water.

2) Training - Training is normally conducted under circumstances conducive to the collection of spent foam. Some fire training facilities have had elaborate systems designed and constructed to collect foam solution, separate it from the fuel, treat it and, in some cases, reuse the treated water. At a minimum, most fire training facilities collect the foam solution for discharge to a waste water treatment facility.

Training includes simulated airport crash/rescue drills, simulated spill fires, and a variety of simulated interior fires. These may be in the form of flammable liquid fires or propane fires in advanced firefighter trainers.

Such firefighter training can employ the use of artificial foaming agents or minute concentrations of fire fighting foams. Where artificial foaming agents are used, containment and treatment of the foam water solution are not generally issues.

Where actual fire fighting foaming agents are used in training facilities, the facility design should include a containment system. The containment system usually consists of gravity fed drainage piping connected to exterior storage tanks. The foam water solution is collected in the storage tanks. Its pH level is then neutralized before it can be piped to the waste water treatment facility. The waste water treatment facility must first be notified, and give permission for the neutralized agent to be released at a prescribed rate.

3) System Tests -Testing primarily involves engineered, fixed foam fire extinguishing systems. Two types of tests are conducted on foam systems: acceptance tests, conducted pursuant to installation of the system, and maintenance tests, usually conducted annually to ensure the operability of the system. These tests can be arranged to pose no hazard to the environment. It is possible to test some systems using water, salt solution or other non-foaming, environmentally acceptable liquids in the place of foam concentrates if the authority having jurisdiction permits such substitutions.

In the execution of both acceptance and maintenance tests, only a small amount of foam concentrate should be discharged to verify the correct concentration of foam in the foam water solution. Designated foam water test ports can be designed into the piping system so that the discharge of foam water solution can be directed to a controlled location. The controlled location can consist of a portable tank which would be transported to an approved disposal site by a licensed contractor. The remainder of the acceptance test and maintenance test should be conducted using only water.

4) Fixed System Releases - This type of release is generally uncontrolled, whether the result of a fire incident or a malfunction in the system. The foam solution discharge in this type of scenario may be dealt with by event-initiated operations or by engineered containment systems. Event-initiated operations encompass the same temporary measures that would be taken during fire department operations; portable dikes, floating booms, etc. Engineered containment would be based mainly on the location and type of facility, and would consist of holding tanks or areas where the contaminated foam water solution would collected, treated and sent to a waste water treatment facility at a prescribed rate.

IV. FIXED SYSTEMS

Facilities can be divided into those without an engineered containment system and those with an engineered containment system.

1) Facilities Without Engineered Containment - Given the absence of any past requirements to provide containment, many existing facilities simply allow the foam water solution to flow out of the building and evaporate into the atmosphere or percolate into the ground. The choices for containment of foam water solution at such facilities fall into two categories: event-initiated manual containment measures, and installation of engineered containment systems.

Selection of the appropriate choice is dependent on the location of the facility, the risk to the environment, the risk of an automatic system discharge, the frequency of automatic system discharges and any applicable rules or regulations.

"Event-initiated manual containment measures" will be the most likely course of action for existing facilities without engineered containment systems. This will usually fall under the responsibility of the responding fire department and include such measures as blocking storm sewers, constructing temporary dikes, and deploying floating booms. The degree of such measures will primarily be dictated by location as well as available resources and manpower.

The "installation of engineered containment systems" is a possible choice for existing facilities. Retrofitting an engineered containment system is costly, and may adversely affect facility operations. There are special cases, however, which may warrant the design and installation of such systems. Such action is a consideration where an existing facility is immediately adjacent to a natural body of water and has a high frequency of activation.

2) Facilities With Engineered Containment - Any engineered containment system will usually incorporate an oil/water separator. During normal drainage conditions (i.e., no fire flow), the separator functions to remove any fuel particles from drainage water. However, when foam water solution is flowing, the oil/water separator must be bypassed so that the solution is diverted directly to storage tanks. This can be accomplished automatically by the installation of motorized valves set to open the bypass line upon activation of the fixed fire extinguishing systems at the protected property.

The size of the containment system is dependent on the duration of the foam water flow, the flow rate, and the maximum anticipated rainfall in a 24-hour period. Most new containment systems will probably only accommodate individual buildings. However, some containment systems may be designed to accommodate multiple buildings dependent upon the topography of the land and early identification in the overall site planning process.

The specific type of containment system selected will also be dependent upon location, desired capacity and function of facilities in question. They include earthen retention systems, below-ground tanks, open-top in-ground tanks, and sump and pump designs (i.e., lift stations) piped to above-ground or in-ground tanks.

The earthen retention designs consist of open-top earthen berms, which usually rely upon gravity fed drainage piping from the protected building. They may simply allow the foam water solution to percolate into the ground, or may include an impermeable liner. Those containing an impermeable liner may be connected to a waste water treatment facility or may be suction pumped out by a licensed contractor.

Closed-top, below-ground storage tanks may be the least environmentally acceptable design approach. They usually consist of a gravity-fed piping arrangement, and can be suction pumped out or piped to a waste water treatment facility. A potential and often frequent problem associated with this design is the leakage of ground water or unknown liquids into the storage tank.

Open-top, below-ground storage tanks are generally lined concrete tanks which may rely on gravity-fed drainage piping or a sump and pump arrangement. These may accommodate individual or multiple buildings. They must also accommodate the maximum anticipated rainfall in a 24-hour period. These are usually piped to a waste water treatment facility.

Above-ground tanks incorporate a sump and pump arrangement to closed, above-ground tanks. Such designs usually incorporate the use of one or more submersible or vertical shaft, large capacity pumps. These may accommodate individual or multiple buildings.

3) New Facilities - The decision to design and install a fixed foam water solution containment system is dependent on the location of the facility, the risk to the environment, possible impairment of facility operations, the design of the fixed foam system (i.e., automatically or manually activated), the ability of the responding fire department to execute event-initiated containment measures and any pertinent regulations.

New facilities may not warrant the expense and problems associated with containment systems. Where the location of a facility does not endanger ground water or any natural bodies of water, this may be an acceptable choice, provided the fire department has planned emergency manual containment measures.

Where conditions warrant the installation of engineered containment systems, there are a number of considerations. They include size of containment, design and type of containment system, and the capability of the containment system to handle individual or multiple buildings.

Engineered containment systems may be a recommended protective measure where foam extinguishing systems are installed in facilities that are immediately adjacent to a natural body of water. These systems may also be prudent at new facilities where site conditions permit to avoid impairment of facility operations.

V. DISPOSAL ALTERNATIVES

The uncontrolled release of foam solutions to the environment should be avoided. Alternative disposal options are as follows:

- Discharge to a wastewater treatment plant with or without pretreatment,
- Discharge to the environment after pretreatment,
- Solar evaporation, and
- Transportation to a wastewater treatment plant or hazardous waste facility.

Foam users, as part of their planning process, should make provisions to take the actions necessary to utilize whichever of these alternatives is appropriate for their situation. The section below describes the actions which may be taken, depending on the disposal alternative which is chosen.

VI. COLLECTION AND PRETREATMENT OF FOAM SOLUTIONS PRIOR TO DISPOSAL

1) Collection and Containment – The essential first step in employing any of these alternatives is collection of the foam solution. As noted above, facilities that are protected by foam systems normally have systems to collect and hold fuel spills. These systems may also be used to collect and hold foam solution. Training facilities are, in general, designed so that foam solution may be collected and held. Fire fighters responding to fires which are at other locations should attempt, insofar as it is practical, to collect foam solution run–off with temporary dikes or other means.

2) Fuel Separation – Foam solution which has been discharged on a fire and subsequently collected will usually be heavily contaminated with fuel. Since most fuels present their own environmental hazards and will interfere with foam solution pretreatment, an attempt should be made to separate as much fuel as possible from the foam solution. As noted above, the tendency of foam solutions to form emulsions with hydrocarbon fuels will interfere with the operation of conventional fuel–water separators. An alternative is to hold the collected foam solution in a pond or lagoon until the

emulsion breaks and the fuel may be separated by skimming. This may take from several hours to several days. During this time, agitation should be avoided to prevent the emulsion from reforming.

3) Pretreatment Prior to Discharge

a. Dilution – Foam manufacturers and foam users recommend dilution of foam solution before it enters a wastewater treatment plant. There is a range of opinion on the optimum degree of dilution. The consensus is that the concentration of foam solution in the plant influent should not exceed 1700 ppm (588 gallons of plant influent per gallon of foam solution). This degree of dilution is normally sufficient to prevent shock loading and foaming in the plant. However, each wastewater treatment plant must be considered as a special case, and those planning a discharge of foam solution to a wastewater treatment facility should discuss this subject with the operator of the facility in advance.

Diluting waste foam solution 588 to 1 with water is an impractical task for most facilities, especially when large quantities of foam solution are involved. The recommended procedure is to dilute the foam solution to the maximum amount practical and then meter the diluted solution into the sewer at a rate which will, based on the total volume of plant influent, produce a foam solution concentration of 1700 ppm or less.

For example, if the discharge is to be made to a 6 million gal/day treatment plant, foam solution could be discharged at the rate of 7 gpm (6,000,000 gal/day divided by 1440 minutes/day divided by 588 equals 7 gpm). The difficulties of metering such a low rate of discharge can be overcome by first diluting the foam solution by 10 or 20 to 1, permitting discharge rates of 70 or 140 gpm respectively.

Dilution should also be considered if the foam solution is to be discharged to the environment in order to minimize its impact.

b. Defoamers – The use of defoamers will decrease, but not eliminate, foaming of the foam solution during pumping, dilution, treatment, and when exposed to air and agitation simultaneously. The foam manufacturer should be consulted for recommendations as to the choice of effective defoamers for use with a particular foam concentrate.

c. Other Pretreatments – Several chemical and mechanical pretreatments such as precipitation, coagulation, adsorption on activated carbon and ultra–filtration (reverse osmosis) have been studied experimentally. There was no known instance of these processes having been used in the field at the time of the preparation of this document. Foam users should contact the foam manufacturer for up–to–date information on this subject.

VII. DISCHARGE OF FOAM SOLUTION TO WASTEWATER TREATMENT FACILITIES

Biological treatment of foam solution in a wastewater treatment facility is an acceptable method of disposal. However, foam solutions have the potential to cause plant upsets and other problems if not carefully handled. There are several reasons for this:

1) Fuel contamination – Foam solutions have a tendency to emulsify hydrocarbon fuels and some polar fuels which are only slightly soluble in water. Water–soluble polar fuels will mix with foam solutions. The formation of emulsions will upset the operation of fuel/water separators and potentially cause the carryover of fuel into the waste stream. Many fuels are toxic to the bacteria in wastewater treatment plants.

2) Foaming – The surfactants in foam solutions will cause copious foaming in aeration ponds, even at very low concentrations. Aside from the nuisance value of this foaming, the foaming process tends to suspend activated sludge solids in the foam. These solids can be carried over to the outfall of the plant. Loss of activated sludge solids can also reduce the effectiveness of the waste water treatment. This could cause water quality problems such as nutrient loading in the waterway to which the outfall is discharged. Because the fluorochemical surfactants in foam solutions are highly resistant to biodegradation, nuisance foaming may occur in the outfall waterway.

3) BOD (Biological Oxygen Demand) – Foam solutions have high BOD's compared to the normal influent of a wastewater treatment plant. If large quantities of foam solution are discharged to a wastewater treatment plant, "shock loading" can occur, causing a plant upset.

Before discharging foam solutions to a wastewater treatment plant, the plant operator should be contacted. This should be done as part of the emergency planning process. The plant operator will require, at a minimum, a Material Safety Data Sheet on the foam concentrate, an estimate of the BOD content of the foam solution, an estimate of the total volume of foam solution to be discharged, the time period over which it will be discharged and, if the foam concentrate is protein–based, an estimate of the ammonia nitrogen content of the foam solution.

The foam manufacturer will be able to provide BOD and ammonia nitrogen data for the foam concentrate, from which the values for foam solution may be calculated. The other required information is site–specific and must be developed by the operator of the facility from which the discharge will occur.

VIII. AQUEOUS FILM FORMING FOAM AND ALCOHOL RESISTANT AQUEOUS FILM FORMING FOAM PRODUCT USE REPORTING

The US Environmental Protection Agency (EPA) requires the reporting of certain chemical uses and releases, including chemicals contained within categories. The glycol ethers

category is listed and subject to reporting under section 313 of Emergency Planning and Community Right-to-Know Act (EPCRA). Additionally, the glycol ether category was placed on the list of hazardous air pollutants (HAPS) under section 112 of the 1990 Clean Air Act Amendments (CAAA). The HAP's listing automatically caused it to be designated a hazardous substance under the Comprehensive Environmental Response Compensation & Liability Act (CERCLA), section 101(14).

Certain AFFF and Alcohol Resistant AFFF (AR AFFF) products contain diethylene glycol butyl ether (DGBE), CAS#112-34-5. Reporting can depend upon interpretation and therefore, consultation with a regulatory specialist or attorney is recommended for applicability to the regulations described below.

1) US EPA EPCRA Section 313 Reporting Section 313 of EPCRA requires owners or operators of manufacturing facilities that manufacture, process, or otherwise use designated toxic chemicals, in amounts exceeding specified threshold quantities, to report annually their emissions to the environment of such chemicals. Manufacturing facilities that have ten or more full-time employees are subject to Section 313 reporting. A facility is a manufacturing facility under Section 313 if it has a Standard Industrial Classification (SIC) code beginning with 20 through 39. Executive Order 12856 requires all federal facilities that exceed the annual threshold quantities to annually report their releases and comply with the emergency planning and notification requirements.

Annual Form R reporting includes quantitative information for the site on releases and transfers, treatment and waste minimization activities for the covered chemical or category. The specified threshold quantity for total glycol ether usage, of which DGBE is included, is 10,000 lb per year for a facility that otherwise used the listed chemical; it is 25,000 lb per year for a facility that manufactured, imported, or processed the listed chemical.

The amount of DGBE present in AFFF and AR AFFF products depends upon which specific product is used and can be found in the specific product's Material Safety Data Sheet (MSDS). An example for calculating the amount of DGBE used in a spill is outlined below:

A spill of jet fuel is contained by using 10 gallons of AFFF concentrate. The AFFF contains 20% DGBE according to the MSDS. The weight of a gallon of AFFF is 8.3 pounds. The resulting reportable quantity of DGBE is calculated as 10 gallons AFFF concentrate x 20% x 8.3 lb/gallon = 16 pounds of DGBE.

EPCRA also requires emergency planning and release reporting to the State Emergency Response Commission (SERC) and Local Emergency Planning Committee (LEPC) and this is described below in the CERCLA reporting section. Foam manufacturers can assist in identifying reference books and companies that provide assistance on EPCRA compliance.

2) US EPA: CERCLA Sections 102(b) & 103(a) The inclusion of glycol ethers on the HAP's list automatically set a default reportable quantity (RQ) requirement of one pound per day for CERCLA reporting. As a result, CERCLA requires owners or operators of

facilities that use the CERCLA listed substance, DGBE, to report every time one pound or more enters the environment in a 24-hour period.

If reporting is determined necessary, notification must be made immediately after the release to the National Response Center (NCR) at 1-800-424-8802, and to your SERC and the LEPC. Notification will require the following information: chemical name, estimate of quantity released into the environment, time and duration of release, medium into which the release occurred, any known health risks and name and phone number of the person(s) to be contacted for further information.

To obtain these telephone numbers, addresses, current forms, and instructions, call the Emergency Planning & Community Right-to-Know Hotline (1-800-535-0202). An annual Continuous Reporting option for those who can project routine releases may be applicable to some sites. The foam manufacturer can assist in identifying reference books and companies that provide assistance on CERCLA compliance.

3) State Agency - Miscellaneous Some states require reporting to their environmental agency and/or emergency response duty officer in addition to the notification described in Sections (a) and (b). It is recommended that each user of the AFFF and AR AFFF products contact their regulators and establish a plan for product usage reporting.

IX. ENVIRONMENTAL PROPERTIES OF FLUOROCHEMICAL SURFACTANTS

Some fire fighting agents contain surfactants. Two examples are AFFF agents and fluoroprotein foams. Fluorochemicals are organic (carbon-containing) compounds in which a portion of the hydrogen atoms have been replaced by fluorine atoms. Unlike chlorofluorocarbons (CFC's) and some other volatile fluorocarbons, fluorochemical surfactants are not ozone depleting and are not restricted by the Montreal Protocol or related regulations. Fluorochemical surfactants also have no effect on global warming or climate change.

Surfactants or surface active agents are compounds that have both a strongly "water-loving" portion and a strongly "water-avoiding" portion. Soaps and detergents are surfactants commonly used in cleaning products. Surfactants concentrate at the surface or boundary between two phases and they lower the surface tension of liquids in which they are dissolved. The water-avoiding part of fluorochemical surfactants is the fluorocarbon portion.

Fluorochemical surfactants have a property that makes them uniquely suited for use in foams used to prevent or extinguish fires of flammable liquids. They create the lowest surface tension of any known class of surfactant. This low surface tension allows aqueous films or foams containing these surfactants to spread over and seal the surface of hydrocarbon liquids, extinguishing the flames and preventing evaporation of the flammable liquids. No other type of surfactant can do this as effectively. Thus, if all

other factors are equal, fire fighting agents containing fluorochemical surfactants can extinguish flammable liquid fires more quickly and with smaller amounts of extinguishing agent than agents without fluorochemical surfactants. The many environmental advantages of this and the potential benefits to life and property are obvious.

There are environmental concerns with fluorochemical surfactants which must be kept in mind when using these products for extinguishing fires or for fire extinguishment training, such as listed below.

a. Fluorochemical surfactants, like all surfactants, have toxicity.
b. Like other surfactants, they cause foaming.
c. Like some surfactants, they are persistent; in fact, the fluorochemical portions of these surfactants are not known to fully biodegrade.
d. Also like some other surfactants, they are mobile in the environment. They can move with water in aquatic systems and leach through soil.
e. In some cases, fluorochemical surfactants may have some affinity for living systems.

In the following paragraphs, we will explain what each of these properties mean and what this means in terms of how these compounds should be handled.

1) Toxicity of Fluorochemical Surfactants Fire fighting agents, used responsibly and following label and material safety data sheet instructions, pose little toxicity risk to people. However, some toxicity does exist. The toxicity of the surfactants in fire fighting foams, including the fluorochemical surfactants, is a reason to prevent unnecessary exposure to people and to the environment. It is a reason to contain and properly treat AFFF wastes whenever feasible. One should always make plans to contain wastes from training exercises and to treat them following the supplier's disposal recommendations as well as the requirements of local authorities.

Water that foams when shaken due to contamination from fire fighting foam should not be ingested. Even when foaming is not present, it is prudent to evaluate the likelihood of drinking water supply contamination, and to use alternate water sources until one is certain that surfactant concentrations of concern no longer exist. Suppliers of fire fighting foams should be able to assist in evaluating the hazard and recommending laboratories that can do appropriate analysis when necessary.

2) Fluorochemical Surfactants and Foaming Fluorochemical surfactants can cause foaming at very low concentrations. This can cause aesthetic problems in rivers and streams, and both aesthetic and operational problems in sewers and wastewater treatment systems. When too much fire fighting foam is discharged at one time to a wastewater treatment system, serious foaming can occur. The bubbles of foam that form in the treatment system trap and bring flocks of the activated sludge that treat the water in the treatment system to the surface. If the foam blows off the surface of the treatment system, it leaves a black or brown sludge residue where the foam lands and breaks down.

If too much of the activated sludge is physically removed from the treatment system in foam, the operation of the treatment system can be impaired. Other wastes passing through the treatment system will be incompletely treated until the activated sludge concentration again accumulates. For this reason, the rate of fire fighting foam discharge to a treatment system has to be controlled. Somewhat higher fire fighting foam discharge rates may be possible when anti-foaming agents are used. Foam concentrate suppliers should be contracted for guidance on discharge rates and effective anti-foaming agents.

3. Persistence of Fluorochemical Surfactants The fluorochemical portions of fluorochemical surfactants are known to be very resistant to chemical and biochemical degradation. This means that while the non-fluorochemical portion of these surfactants may break down, a persistent fluorochemical portion will remain. The persistent fluorochemical portion is most likely to still be a surfactant. This means that after fluorochemical surfactant containing fire fighting wastes are fully treated, the waste residual could still form some foam when shaken. It could also still have some toxicity to aquatic organisms if it is not sufficiently diluted. Some non-fluorochemical surfactants are resistant to treatment too. The most desirable treatment methods for large volume fire fighting waste streams containing fluorochemical surfactants are physical chemical pre-treatments that remove most of the fluorochemical surfactant prior to discharging the residual wastes to a wastewater treatment system.

4) Mobility of Fluorochemical Surfactants Tests and experience have shown that some fluorochemical surfactants can leach through at least some soil types. The resistance of fluorochemical surfactants to biodegradation makes the mobility of such surfactants a potential concern. While a readily degradable compound is likely to degrade as it leaches through soil, this won't happen to a fluorochemical surfactant. Thus, if allowed to soak into the ground, fluorochemical surfactants that don't become bound to soil components may eventually reach ground water or flow out of the ground into surface water. If adequate dilution has not occurred, they may cause foaming or concerns about toxicity. Therefore, it is inappropriate to allow training wastes to continually seep into soil especially in areas where water resources could be contaminated.

Fluorochemical surfactants that enter aquatic environments may bind to solid materials, but this binding would be reversible and temporary. Fluorochemical surfactants are thus expected to move with the flowing water in aquatic environments until they reach and dilute to extremely low concentrations in the oceans.

5) Fluorochemical Surfactants and Living Systems Fluorochemical surfactants or their persistent degradation products are likely to be anionic or negatively charged compounds. As such, they could form strong ion pairs with positively charged molecules. Since positively charged molecules are frequently found in living organisms this could be a mechanism of affinity for living systems. The release of fluorochemical surfactants back into non-living portions of the environment could be slow because these ionic associations could be strong.