

Estimated Inventory
Of
PFOS-based
Aqueous Film Forming Foam (AFFF)

2011 update to the 2004 report entitled
“Estimated Quantities of Aqueous Film Forming Foam (AFFF)
In The United States”

Prepared for the Fire Fighting Foam Coalition, Inc.
Arlington, VA

July 13, 2011

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Introduction

Aqueous film forming foam (AFFF) is the premier fire fighting foam in the United States (US) and many parts of the world. Its ability to rapidly extinguish flammable liquid pool fires is unmatched by any other agent. AFFFs are synthetically formed by combining fluorine-free hydrocarbon foaming agents with highly fluorinated surfactants. When mixed with water, the resulting solution achieves the optimum surface and interfacial tension characteristics needed to produce an aqueous film that spreads across the surface of a hydrocarbon fuel. It is this film formation feature that provides superior fire extinguishment and is the source of the designation – aqueous film forming foam.

In 2004 the Fire Fighting Foam Coalition, Inc. commissioned a report on US inventories of AFFF at the request of the Environmental Protection Agency (EPA). The results were presented separately for AFFF agents manufactured by the 3M Company prior to 2002 with fluorosurfactants that contain perfluorooctyl sulfonate (PFOS), and those manufactured by other companies with telomer-based fluorosurfactants. Telomer-based fluorosurfactants do not contain or break down into PFOS.

The focus of this update is to estimate how much PFOS-based AFFF (AFFF manufactured by 3M prior to 2002) has been consumed in the past seven years, or, stated differently, estimate how much PFOS-based AFFF still remains in the United States in 2011.

Quantities of AFFF in this report are expressed as gallons of concentrate. In the foam industry, concentrates are typically referred to as “3 %” or “6 %” concentrate, depending on the mixture rate with water (a fire fighting foam solution made from “3 %” concentrate will consist of 97 parts water to 3 parts AFFF concentrate). AFFF concentrates contain about 60-90% water and have a fluorine content of about 0.3-1.8%.

Estimated Inventory of PFOS-based AFFF in 2004

The 2004 inventory report [1] concluded that there was 4.6 million gallons of PFOS-based AFFF in the US, broken down roughly as follows:

<u>Use Sector</u>	<u>Gallons of PFOS-based AFFF</u>
Military & Other Federal	2,100,000
Civil Aviation (ARFF)	130,000
Oil Refineries	950,000
Other Petro-Chem	1,000,000
Civil Aviation (Hangars)	190,000
Fire Departments (non-aviation)	120,000
Misc/ Merchant Ship/Offshore	<u>150,000</u>
	4,640,000 gallons

Approach Used in this Up-Date

A two-step approach has been used to develop an estimate of the current inventory of PFOS-based AFFF:

- (1) Consider likely annual consumption or usage rates, both overall and specific to each use sector, and estimate current inventory using the following simplistic formula:

$$3M \text{ Inventory in 2004} - \text{Usage of 3M Past Seven Years} = \text{Current Inventory of 3M}$$

- (2) Solicit input on estimated current 3M inventory from a sampling of major users and knowledgeable experts.

Dozens of inquiries were sent out during the period March – May 2011 to persons known by the undersigned to be knowledgeable and credible. Extrapolation of submitted data in major use sectors yielded educated approximations of current inventory.

The final estimates for each use sector and the overall bottom line number were derived by a reconciliation of both assumed usage rates and extrapolated quantitative input received from the field.

Discussion of Consumption Rates

Annual AFFF concentrate “Consumption” or “Usage” rates, or more specifically usage rates for PFOS-based AFFF, were estimated based on various sources.

Before discussing the assumed rates, a point relative to “usage” or “consumption” should be made for clarification. If the inventory of PFOS-based AFFF has been reduced by “consumption” it of course doesn’t mean that it disappeared. “Consumption” means that AFFF has been discharged or emitted as a result of training evolutions, AFFF system testing, firefighting operations, inadvertent discharge or leakage, or disposal following decommissioning of a firefighting system. The consumed AFFF ends up highly diluted in surface waterways, in subsurface water, absorbed into the ground or partially evaporated. The undersigned was unable to find any evidence of AFFF disposal via incineration in the US. In essence most AFFF that has been used or consumed is technically still “in the US.” However, for this up-date, the term AFFF “inventory in the US” will mean the same as it did in the original 2004 report - AFFF owned by an end user, residing in firefighting system foam tanks or in storage containers supporting such systems.

Also it should be emphasized that there were some end users who were unable to identify precisely the manufacturer of AFFF contained in foam tanks. In some cases documentation had been lost, or in some milspec AFFF applications the end user claimed the foam tank contained a “mixture” of different concentrates. “Mixtures” and reported “unknowns” were not included in calculating estimates of PFOS-based AFFF.

Another point relative to consumption rates should be made. In all use sectors in 2004, AFFF inventories consisted of both telomer-based AFFF and 3M AFFF. If an end user purposely attempted to use up his stock of 3M AFFF then the consumption rate of PFOS-based AFFF would be higher than the overall consumption rate for all AFFF.

Consider the following hypothetical illustration. Suppose an end user had 100,000 gallons of AFFF concentrate equally divided between telomers and 3M (50,000 gallons of each). Suppose that he consumes 10,000 gallons of AFFF per year, which equates to an annual AFFF consumption rate of 10 %. If the consumption occurs equally between telomers and 3M than the annual 3M consumption would be 5,000 gallons. But if this particular end user purposely attempts to consume only his stock of PFOS-based AFFF than the annual consumption rate of 3M could be as high as 10,000 gallons, or 20 % of the original 3M quantity. The point is that for end users who have desired to purge their 3M inventory, the 3M consumption rate can be higher than the overall AFFF consumption rate. This point is significant in that some end users reported to the undersigned that over the years they have made a concerted effort to “use up” their 3M inventories.

Actual data recently compiled by the Navy helps to illustrate some pitfalls in calculating consumption rates and how overall AFFF consumption rates may be different from the consumption rate for PFOS-based AFFF. As discussed later in the military section, the office of the Chief of Naval Installations conducted a survey within the past month of all Naval facilities in the US that have firefighting vehicles carrying AFFF (airfield crash vehicles and structural pumps with foam tanks).

The Navy reportedly has 43,252 gallons of AFFF concentrate on fire vehicles, of which 16,070 gallons is PFOS-based AFFF.

To support those vehicles, the Navy has 58,540 gallons of AFFF as reserve supply, of which 29,060 gallons is PFOS-based AFFF.

The Navy also calculated that their consumption of AFFF for fire vehicles (training, vehicle foam system tests, and actual fire fighting evolutions) was 4,298 gallons in the past year.

The annual AFFF consumption rate for Navy vehicles as a function of all AFFF calculates as follows:

$$\text{Consumption Rate for Vehicle loads} = 4,298/43,252 = 9.9 \%$$

$$\text{Consumption Rate for Reserve Supply} = 4,298/58,540 = 7.3 \%$$

$$\text{Consumption Rate for Vehicle Loads \& Reserve Supply} = 4,298/101,792 = 4.2 \%$$

If however the annual AFFF consumption rate is calculated as a function of remaining 3M, the rates are different:

$$\text{Consumption Rate for Vehicle Loads} = 4,298/16,070 = 26.7 \%$$

$$\text{Consumption Rate for Reserve Supply} = 4,298/29,060 = 14.8 \%$$

$$\text{Consumption Rate for Vehicle Loads \& Reserve Supply} = 4,298/45,130 = 9.5 \%$$

The US Air Force conducted a similar survey in 2004. The Air Force reported an overall AFFF annual consumption rate of only 2.6 %, but that rate appeared to include the large quantity of USAF AFFF in fixed systems (foam sprinklers in hangars, flammable liquid stowage areas, hush houses, etc). The high quantity of AFFF in reserve storage in the Air Force (about 33 % of their total AFFF is in unopened containers) brought the overall consumption rate down as well.

A report prepared in 2004 for the UK Department of the Environment [2] claimed a “15 % per year usage rate” but included all foams, not just AFFF and offered no details as to how the usage rate was defined or calculated.

Similarly, a recent discussion paper on the PFOS issue by Environment Canada [3] stated that in Canada “an average of 10 % of the existing AFFF stock is expended each year,” but failed to provide details as to definition of expenditure rates or calculation methods.

A consumption rate for PFOS-based AFFF in US oil refineries was postulated by an expert knowledgeable in the field as being “about 10 % per year on average,” but this was tempered by another expert who cautioned that consumption of AFFF in oil refineries varies widely each year as a function of serious refinery fires that consume large quantities of AFFF.

Assuming 4.6 million gallons of PFOS-based AFFF in 2004 and seven years of consumption since, the impact of assuming various overall annual consumption rates for PFOS-based AFFF can be illustrated as follows (note- straight line reduction assumed, without compounding):

Assumed Annual 3M Consumption Rate	Reduction in Seven Years	Remaining %	Remaining PFOS-based AFFF in 2011
14 %	98 %	2 %	92,000 gallons
12 %	84 %	16 %	736,000
10 %	70 %	30 %	1,380,000
8 %	56 %	44 %	2,024,000
6 %	42 %	58 %	2,668,000
5 %	35 %	65 %	2,990,000
4 %	28 %	72 %	3,312,000

The above discussion shows that annual consumption rates range from 3 – 15 % depending on use sector, and vary with specifically how consumption rates are defined and calculated. But as an educated guess it may be reasonable to conclude that the PFOS-based AFFF consumption rate in the U.S since 2004 would range from 6 to 10 % per year. Taking the mid-point of that range, 8 %, the above table would indicate that there has been a 56 % reduction in the inventory of PFOS-based AFFF since 2004 and that there would be approximately 2 million gallons remaining.

Lacking any other inventory number as a reasonable starting point, the 2 million gallon figure was adopted as an initial “default number”.

The next step in the analysis was to examine some recent input from some major use sectors to see if the 2 million gallon default number should be modified or if some more precise consumption rates can be applied.

Military and Other Federal

2004 Report

The 2004 report estimated that there were 2.1 million gallons of PFOS-based AFFF in this use sector. The total AFFF for this use sector was 2.87 million and it was estimated that PFOS-based AFFF comprised 70 – 75 % of the total.

This use sector consisted of the Navy, Marine Corps, Military Sealift Command, Army, Air Force, Coast Guard, Defense Logistics Agency, NASA and Department of Energy. By a wide margin the predominant users of AFFF were the Navy and the Air Force, with their total estimated quantity of AFFF in the US being almost 2.4 million gallons. Accordingly, the focus of the analysis of this use sector will be primarily on estimating Navy and Air Force 3M inventories.

Their combined quantity of PFOS-based AFFF in the US was estimated to be almost 1.8 million gallons, broken down as follows (rounded to the nearest 100 gallons):

Estimated Navy and Air Force PFOS-based AFFF in 2004

Navy: 790,000 gallons

Fire Fighting Vehicles: 42,900

Reserve Supply: 60,500

Shore Fixed Systems: 178,600

Ships: 508,000

Air Force: 995,000 gallons

Fire Fighting Vehicles: 141,000

Reserve Supply: 329,700

Fixed Systems: 524,300

2011 Update

Navy Fire Fighting Vehicles & Reserve Supply

The Chief of Naval Installations (CNI) issued a data call in May 2011 to all Navy shore facilities having fire fighting vehicles carrying foam concentrate (airfield crash trucks, foam tenders and structural pumpers). The responses to CNI revealed the following relative to PFOS-based AFFF in US Navy shore facilities:

PFOS-based AFFF in Navy vehicles: 16,070 gallons

PFOS-based AFFF Reserve Supply for Navy Vehicles: 29,060 gallons

The following table illustrates the reduction in PFOS-based AFFF since 2004:

PFOS-based AFFF in Naval Fire Fighting Vehicles

Application	3M in 2004	3M in 2011	3M Reduction	% 3M Reduction	Annual % Reduction
Naval Fire Fighting Vehicles	42,900 gals	16,070 gals	26,830 gals	62.5 %	8.9 %
Vehicles Reserve Supply	60,500	29,060	31,440	52 %	7.4 %
Total Vehicles and Reserve Supply	103,400	45,130	58,270	56.4 %	8.1 %

Navy Shore Fixed Systems

The CNI data call did not include AFFF in fixed systems (sprinklers and fixed spray systems for aircraft hangars, flammable liquid storage areas, engine hush houses, fuel farms, etc). However, an estimate of remaining PFOS-based AFFF in these systems can be derived from the 2004 quantity using an assumed consumption rate for the past seven years.

Maintenance and testing requirements for foam systems in the Navy (and the Air force as well) are specified in a joint-service DOD document (Unified Facilities Criteria – UFC 3-601-02) [4]. This document mandates that a foam concentrate sample be drawn from every system tank annually and tested for quality and that every two years a full flow system discharge test be conducted to verify proper foam proportioning. Calculations would show that on average the bi-annual flow test would consume about 4 % of the foam tank contents annually. Additionally, there might be infrequent foam concentrate consumption due to actual fire discharges, inadvertent or accidental system trips, and replacement of contaminated contents indicated by annual concentrate sample testing. A consumption rate for fixed systems of 5 % per year could reasonably be assumed, which equates to a seven-year reduction of 35 %, or a remaining quantity of 65 % of the 2004 estimate.

Based on the estimate of 178,600 gallons in 2004, the estimated quantity of PFOS-based AFFF in these systems in 2011 is as follows:

$$178,600 \times 65 \% = 116,090 \text{ gallons of PFOS-based AFFF in Navy shore fixed systems in 2011}$$

Navy Ships

There are strict periodic maintenance and test requirements for all shipboard fire fighting systems, including AFFF systems [5]. Every AFFF system must be flow tested with foam solution at least once every three years to confirm proportioner performance and foam distribution. Additionally, AFFF systems on aviation ships must be flow tested following a shipyard availability exceeding six months as part of the flight deck re-certification procedure prior to resuming flight operations. Also, any repair or replacement of AFFF system components may also necessitate a full flow test. The undersigned has

calculated that system testing would consume about 8 % per year of a ship's onboard AFFF inventory. It is also assumed that occasional system use on fires and fuel spills, some training evolutions and infrequent inadvertent or accidental system trips might contribute an additional 2 % per year AFFF consumption. Applying a 10 % annual consumption rate to the 2004 estimated quantity of Navy ship PFOS-based AFFF shows that at present there is slightly over 150,000 gallons of PFOS-based AFFF on navy ships:

Consumption = 10 % per year for 7 years = 70 % reduction (or 30 % remaining in 2011)

508,000 gallons x 30 % = 152,400 gallons of PFOS-based AFFF in Navy ships in 2011

USAF Fire Fighting Vehicles & Reserve Supply

The Air Force did not provide any recent AFFF inventory data. However in 2004 they provided sufficient details concerning PFOS-based AFFF quantities to permit reasonable extrapolation to 2011.

Relative to PFOS-based AFFF carried on Air Force fire fighting vehicles, there is no reason to believe that Air Force 3M consumption rates would differ much from those of the Navy, since both have similar missions, use similar fire fighting vehicles and subscribe to the same vehicle testing and training regimen. Applying the Navy 62.5 % consumption rate for PFOS-based AFFF to the Air Force estimate of 141,000 gallons in 2004 yields the following current estimate for PFOS-based AFFF on Air Force vehicles:

$141,000 - 0.625(141,000) = 52,880$ gallons of PFOS-based AFFF on Air Force vehicles in 2011

On the other hand, the Navy consumption rate of 7.4 % per year for AFFF reserve supply would logically not be applicable to the Air Force because the Air Force has a much higher ratio of reserve AFFF to vehicle AFFF. Looking at the estimates for 2004, the Navy's ratio of reserve supply to vehicle quantities was $60,500 \div 42,900$ or 1.4 gallons of 3M in reserve for every 1 gallon of 3M carried on their vehicles. The 2004 ratio for the Air Force was $329,700 \div 141,000$, which equates to 2.4 gallons of 3M in reserve for every 1 gallon of 3M on their vehicles. Accordingly, a 4 % annual reduction of reserve supply is considered more appropriate for the Air Force reserve supply. Hence, a 28 % overall reduction in the past seven years equates to:

$329,700 \times 28 \% = 92,316 =$ reduction since 2004

$329,700 - 92,316 = 237,380$ gallons of PFOS-based AFFF in Air Force reserve supply in 2011

Air Force Fixed Systems

The Navy 35 % reduction (65 % remaining) calculated under Navy Shore Fixed Systems above is considered also applicable to Air Force fixed systems since both services use similar systems, protect similar hazards, and are governed by the same DOD-wide periodic testing and maintenance requirements (the Unified Facilities Criteria cited previously). Accordingly, the estimated current quantity of PFOS-based AFFF in Air Force fixed systems is:

Quantity in 2004 x 65 % = quantity in 2011

$524,300 \times 65 \% = 340,790$ gallons of PFOS-based AFFF in Air Force fixed systems in 2011

Navy & Air Force Estimated Totals

The estimated Navy and Air Force totals (2004 and 2011) are tabulated below.

Application	3M Gallons in 2004	3M Gallons in 2011
Navy Fire Fighting Vehicles	42,900	16,070
Navy Reserve Supply	60,500	29,060
Navy Shore fixed Systems	178,600	116,090
Navy Ships	508,000	152,400
Air Force Fire Fighting Vehicles	141,000	52,880
Air Force Reserve Supply	329,700	237,380
Air Force Fixed Systems	524,300	340,790
	1,780,000	944,670

This represents a consumption of 835,300 gallons in the past seven years, or average consumption in the range of 6 – 7 % per year.

Other Military and Federal

In 2004 it was estimated that other military and federal had roughly 300,000 gallons combined of PFOS-based AFFF. Assuming a 7 % per year consumption rate (roughly 50 % remaining) yields the following estimate for all other Military and Federal:

$$300,000 \times 50 \% = 150,000 \text{ gallons of PFOS-based AFFF in other military and federal in 2011.}$$

There was one input of anomalous data received from the Department of Energy's Strategic Petroleum Reserve (SPR). The SPR stores over 700 million gallons of petroleum in artificial caverns created in underground salt domes at four different sites on the Gulf of Mexico. In 2004 the SPR claimed to have 25,000 gallons of PFOS-based AFFF at these facilities. This year, based on a query from DOE Headquarters, the SPR reported that they still have 25,000 gallons of 3M. Though the amount is small relative to the total use sector it is mentioned here because it is the only reported case where there was zero consumption of PFOS-based AFFF in the past seven years.

Adding 150,000 gallons to the Navy and Air Force numbers gives a total for this use sector of approximately 1,100,000 gallons.

Assumed Bottom Line for All Military and Federal

1,094,700 gallons of PFOS-based AFFF in 2011

Civil Aviation (Airport ARFF)

2004 Report

This sector covers AFFF in use at commercial airports in support of Aircraft Rescue and Fire Fighting (ARFF). AFFF would be contained in the foam tanks of ARFF vehicles and would include on-site reserve storage to refill those vehicles. In 2004 it was estimated that there were 729,000 gallons of AFFF total at civilian airports supporting ARFF operations, of which 130,000 gallons were made by 3M.

One of the methods used to arrive at the estimate in 2004 was to extrapolate based on answers to questionnaires sent to 34 of the largest airports (classified as Index C, D and E airports by the FAA).

Airports in each index that responded in 2004 are shown below:

Index C Responders to Questionnaire

El Paso, TX	Omaha	Sacramento, CA
Kansas City	Orange County, CA	San Antonio, TX
Little Rock, AR	Oakland, CA	Savannah, GA
Nashville, TN	Portland, ME	Syracuse, NY
Oklahoma City	Richmond, VA	Washington Reagan

Index D Responders to Questionnaire

Baltimore/Washington	Las Vegas	Pittsburgh, PA
Indianapolis, IN	New Orleans	Salt lake City
LaGuardia, NY	Ontario, CA	Tulsa, OK

Index E Responders to Questionnaire

Atlanta, GA	Los Angeles (LAX)
Boston Logan	Miami, FL
Dallas/Fort Worth	Newark, NJ
Denver	Orlando, FL
Kennedy (JFK)	Washington Dulles

In 2004, each of the above airports provided total inventory numbers and also identified their quantities by specific AFFF manufacturer. Though many airports reported verbally that they had “significant quantities of PFOS-based AFFF in the 1990s”, by 2004 the quantity of PFOS-based AFFF had dropped considerably.

Of the 34 airports, only Denver, Los Angeles (LAX), Ontario and Savannah reported still having concentrate made by 3M in 2004.

The total quantity of PFOS-based AFFF reported at those four airports in 2004 was roughly 27,000 gallons, as shown below.

Airports Reporting PFOS-based AFFF in 2004

Airport	3M on Vehicles (gallons)	Spare 3M (gallons)	Total 3M (gallons)
Denver	3,978	6,985	10,963
Los Angeles (LAX)	2,295	3,000	5,295
Ontario	3,375	3,621	6,996
Savannah	1,310	2,260	3,570
			26,824 gals

2011 Update

These four airports were contacted again in April 2011 and queried relative to their remaining quantity of PFOS-based AFFF. As expected, in the past seven years there has been a considerable reduction in the amount of PFOS-based AFFF at those airports:

PFOS-based AFFF in 2011

Airport	3M on Vehicles (gallons)	Spare 3M (gallons)	Total 3M (gallons)
Denver	0	0	0
Los Angeles (LAX)	0	0	0
Ontario	1,687*	0	1,687
Savannah	655*	1,650	2,305
			3,992 gals

* Reported as mixture. 3M assumed at 50% of mix

The reduction in PFOS-based AFFF at these major airports (from 26,824 gallons in 2004 to 3,992 gallons in 2011) represents an 85% reduction, which for seven years equates to 12.2 % per year consumption rate for 3M. This consumption rate is not surprising considering the annual vehicle foam discharges mandated by NFPA and FAA standards. For example, NFPA 403 and 412 [6, 7] require annual discharge of AFFF from all vehicle turrets and nozzles to check foam quality, proportioner accuracy, stream reach and foam pattern distribution. NFPA 403 and 405 [8] mandate frequent training of all ARFF fire fighters, including turret operation and “live fire training evolutions” using the ARFF vehicles.

As additional verification of the reduction of PFOS-based AFFF at major airports, two additional large airports not queried in 2004 were contacted this year (Tampa International on the east coast and SeaTac on the west coast). Both responded that they had no PFOS-based AFFF in 2011.

Applying the seven-year 85 % consumption rate (12.2 % per year) to the estimated total airport PFOS-based AFFF amount in 2004 yields the following:

$$\text{Amount in 2004} - \text{Consumption Past Seven Years} = \text{Remaining Amount in 2011}$$

$$130,000 \text{ gals} - [85 \% \times 130,000 \text{ gals}] = 19,500 \text{ gallons}$$

Assumed Bottom Line for Civil Aviation (ARFF):

20,000 gallons of PFOS-based AFFF in 2011

Oil Refineries

2004 Report

The data on oil refineries in the Fire Fighting Foam Coalition 2004 AFFF Inventory Report was derived primarily from market surveys conducted by three AFFF manufacturers (Ansul, Kidde/National Foam and Buckeye).

The 2004 report estimated that the total inventory of AFFF at US refineries ranged from 1.5 to 2.3 million gallons. Based on US refinery thru-put of 16.8 million oil barrels per day (bpd), the refinery AFFF estimated range varied from one gallon of AFFF concentrate per 11.2 bpd on the low side to one gallon of AFFF concentrate per 7.3 bpd on the high side. This range agreed closely with a prediction by Bill Walton of Williams Fire & Hazard Control that there is probably one gallon of AFFF concentrate per 10 bpd of refinery oil thru-put. The 2004 report used the midpoint of the range in concluding that there were approximately 1.9 million gallons of AFFF concentrate scattered throughout the roughly 150 US oil refineries.

Of the estimated 1.9 million gallons of AFFF concentrate at US refineries, the report further concluded that roughly 950,000 of those gallons were manufactured by 3M. Again this was based on market surveys covering roughly 50 refineries and then extrapolating the data to the entire population of refineries. Input data included specific quantities at specific locations. Understandably there were some differences in the market survey data submitted by the three manufacturers, but overall averages for estimated PFOS-based AFFF fell within a fairly narrow range.

2011 Update

Records of the 2004 market surveys were reviewed to select those refineries having the greatest reported quantities of PFOS-based AFFF. A list was compiled of the top 24 refineries in terms of total reported PFOS-based AFFF in 2004. Each of these 24 refineries had on average 26,500 gallons of PFOS-based AFFF. Collectively they had 475,000 gallons of 3M, exactly 50 % of the entire reported 3M quantities for this use sector in 2004.

Each of these 24 large refineries was queried within the past month as to their current inventory of PFOS-based AFFF. The responses to those inquiries show a dramatic decrease in the inventory of PFOS-based AFFF in US refineries. 17 of the 24 responded. Nine reported that they no longer had any 3M remaining. The other eight reported collectively a total of only 75,000 gallons of 3M.

This decrease, from 475,000 gallons to 75,000 gallons, represents an 84 % reduction, or an average consumption rate of 12 % per year for the past seven years. Two reasons have been offered for this huge decrease in refinery PFOS-based AFFF: (1) there are a discrete number of refineries at known locations, fostering aggressive marketing of telomer alternatives, and (2) much of the 3M inventory has been consumed fighting refinery fires.

According to the US Chemical Safety Board and the US Energy Information Administration there have been as many as 23 refinery fires annually in some recent years. A review of these fires on their web sites reveals that many of these fires have occurred at refineries reporting considerable 3M inventory in 2004. An example is the disastrous fire in 2005 at the BP/Amoco refinery in Texas City, Texas. At the time of

the fire this refinery reportedly had over 100,000 gallons of PFOS-based AFFF. Informed sources have speculated that much of the 3M inventory would have been consumed fighting this fire.

Whatever the reason for the decrease, it is considered appropriate to apply the 12 % consumption rate to the entire population of refinery PFOS-based AFFF since the decrease occurred in such a large proportion of the total AFFF inventory.

7 years at 12 % per year = 84 % reduction (or 16 % remaining).

950,000 gallons of PFOS-based AFFF x 16 % = 152,000 gallons.

Assumed Bottom Line for Oil Refineries

152,000 gallons of PFOS-based AFFF in 2011

Other Petro-Chem Industries

2004 Report

In 2004 it was estimated that there were 2 million gallons of AFFF in this use sector, with 50 % of that total being 3M.

This sector covers the application of AFFF for fire suppression in petroleum storage and operating facilities other than refineries. This includes petroleum blending facilities, fuel farms, fuel tank loading racks, marine fueling terminals, miscellaneous chemical companies and flammable liquid storage and processing areas. Fire protection for these hazardous operations consists of AFFF delivery systems of various designs, including overhead sprinklers, fixed nozzle deluge systems, remote control monitors and manually directed discharge streams.

As pointed out in the 2004 report, development of an estimate of AFFF quantities in this sector was very difficult. Unlike the refinery sector, where there are a fixed number of facilities at known locations, facilities that comprise this sector are scattered throughout the country with no overseeing authority or central database of either the number or location of such facilities or AFFF inventory. Estimates in 2004 were derived essentially from anecdotal information and opinions of persons with varying degrees of knowledge of this sector. Much of the information on this sector in the 2004 report could best be described as “expert guesses.”

The estimate of 1 million gallons of PFOS-based AFFF in 2004 was an average of estimates submitted by three prominent suppliers of AFFF and AFFF systems.

2011 Update

Assuming that the 2004 estimate was reasonable, the essential question for this use sector is how much has been consumed in the past seven years. Consumption would be for the usual reasons – system maintenance and testing, actual fire discharges, system inadvertent or accidental trips, training evolutions, replacement of contaminated agent and some systems decommissioned.

Probably the greatest consumption has been for system testing, as required by national standards and insurance underwriters. Applicable NFPA standards (NFPA 11, 16 and 25) [9, 10, 11] require annual flow tests with foam to verify foam proportioner performance. This is twice the flow frequency required for foam systems within DOD and likely would consume at least 5 % of the concentrate on an annual basis. Adding in the other sources of concentrate losses would reasonably bring the annual consumption rate to 7 % per year (or roughly 50 % remaining after seven years). This would equate to 500,000 gallons of PFOS-based AFFF still in this use sector.

Some insight into the quantity of PFOS-based AFFF in this sector can also be gained by examining the record of 3M samples submitted for foam concentrate quality analysis. The NFPA standards cited above also require that a foam concentrate sample be drawn from every foam system on an annual basis and tested for foam quality. There are four primary companies that offer a foam concentrate testing service. Each of these companies provided data on how many samples of PFOS-based AFFF they had tested. While most of the companies claimed that the number of 3M samples submitted for testing had decreased over the years, the collective total of 3M samples was approximately 1700 in the past 12 months. One testing service estimated that 50 – 60 % of the tested samples came from non-military fixed systems, most of which would probably be systems within this use sector. So if say 55 % of the samples were from fixed systems, that would equal 55 % x 1700 = 935 fixed systems. Several sources in the foam system business estimate that the average foam tank size for a fixed system would fall between 400 to 500 gallons. Using the midpoint of that range, 450 gallons per system, multiplied by 935 systems yields roughly 420,000 gallons of PFOS-based AFFF. This is a highly speculative number but it does add some credence to the 500,000 gallon estimate based on likely consumption rates.

Lacking other definitive data, it is considered that the best estimate of remaining PFOS-based AFFF can be derived by the assumption of a 7% per year consumption rate, or that roughly 50 % remains from seven years ago.

50 % x 1 million gallons = 500,000 gallons.

Assumed Bottom Line for Other Petro-Chem

500,000 gallons of PFOS-based AFFF in 2011

Civil Aviation (Aircraft Hangars)

2004 Report

This use sector covers non-military aircraft hangars protected by AFFF systems, most of which would be at commercial airports. In 2004 it was estimated that there were 190,000 gallons of PFOS-based AFFF in this use sector.

2011 Update

No inquiries were sent out for this sector. However it seems reasonable that the annual PFOS-based AFFF consumption rate for this sector would fall between the annual rate for similar fixed systems (7 %) and the assumed consumption rate for AFFF supporting airport ARFF functions (12 %). Using a 9 % annual consumption rate would equate to 63 % consumption since 2004 (or 37 % of the 2004 estimate still remaining).

$37\% \times 190,000 = 70,300$ gallons.

Assumed Bottom Line for Civil Aviation (Aircraft Hangars)

70,300 gallons of PFOS-based AFFF in 2011

Fire Departments (Non-Aviation)

2004 Report

This use sector includes the inventory of AFFF carried in total by fire departments throughout the country. There are approximately 32,000 individual fire departments (paid and volunteer) and they deploy almost 70,000 pumper trucks. Most trucks carry one or two five gallon foam cans with portable eductors to combat flammable liquid fires they may encounter. Some trucks have built in foam tanks and foam proportioners. Some larger cities also have foam tenders and fireboats equipped with varying quantities of foam concentrate. In 2004 several dozen fire departments around the country were queried relative to their AFFF inventory. Respondents ranged from very large departments (New York City, Los Angeles, Dallas, Boston) to very small departments (Keene, NH and Glen Echo, MD for example). Surprisingly, very few departments reported having PFOS-based AFFF. New York City for example claimed that while they have many thousands of gallons of AFFF, it was all telomer-based milspec concentrate.

The total amount of PFOS-based AFFF estimated for this use sector in 2004 was 120,000 gallons.

2011 Update

The City of Los Angeles had reported in 2004 that they had about 25,000 gallons of AFFF in their fire department inventory (pumpers, tenders, fire boats and reserve supply). Their 2004 response implied that most of it was PFOS-based AFFF. LA was contacted within the past month as to their current status. They reported that “they no longer had any PFOS-based AFFF.”

A 7 % per year consumption rate (or 50% reduction in the past seven years) is assumed for this use sector.

50 % x 120,000 gallons = 60,000 gallons of PFOS-based AFFF in fire departments (non-aviation).

Assumed Bottom Line for Fire Departments

60,000 gallons of PFOS-based AFFF in 2011

Misc/Merchant Ship/Offshore**2004 Report**

This combined use sector includes foam applications that do not fit neatly into other use sectors. This would include AFFF deployed in the following applications:

Helicopter landing sites	Portable extinguishers
Training facilities	Merchant ships
Offshore platforms	Distributors inventory
Unidentified uses	Non-airport ARFF (Boeing and FedEx)

In 2004 it was estimated that there were 150,000 gallons of PFOS-based AFFF in these applications.

2011 Update

In view of the limited scope of this effort and the minimal time allocated for analysis, no queries were sent out for this combined use sector.

As with the fire department uses sector, it is considered reasonable to assume a 7 % per year consumption rate (or 50 % reduction since 2004).

50 % x 150,000 gallons = 75,000 gallons of AFFF in misc/merchant ship/offshore in 2011

Assumed Bottom Line for Misc/Merchant Ship/Offshore

75,000 gallons

Grand Total

The estimates for each use sector are summarized in the following table.

Summarization of Estimates for All Use Sectors

Use Sector	PFOS-based AFFF 2004	PFOS-based AFFF 2011
Military & Other Federal	2,100,000	1,094,700
Civil Aviation (ARFF)	130,000	20,000
Oil Refineries	950,000	152,000
Other Petro-Chem	1,000,000	500,000
Civil Aviation (Hangars)	190,000	70,300
Fire Departments	120,000	60,000
Miscellaneous	150,000	75,000
Totals	4,600,000	1,972,000

Earlier in this paper under Discussion of Consumption Rates it was pointed out that if an assumed overall annual consumption rate of 8 % was applied to the 2004 total of 4,600,00 gallons, the resulting 2011 estimate would be 2,024,000 gallons. It is interesting that the total in the above table, which was derived by adding up estimates for each individual use sector, is only slightly less than the previously mentioned 2 million gallon default number.

As was done in the 2004 report, it is considered appropriate to assign an error margin to the final estimate. The most accurate of the use sector estimates would be the top three (military, ARFF and oil refineries). The error margin for those three would be +/- 10 %. A much higher error margin of +/- 35 % is represented by the 'Other Petro-Chem' sector. The estimate for this sector was also quite speculative in 2004.

A +/- 20 % error margin is considered appropriate for the final overall estimate.

Accordingly, it is the opinion of the undersigned (based on the limited input received and the time allocated for analysis) that the total quantity of PFOS-based AFFF in the United States is currently

2 million gallons, within a range of 1.6 to 2.4 million gallons

Robert L. Darwin, P.E.

July 13, 2011

References

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- (5) "Maintenance Index Page, Shipboard AFFF Systems", Naval Sea Systems Command, Dept of the Navy.
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- (8) NFPA 405, "Standard for the Recurring Proficiency of Airport Fire Fighters", 2010 Edition
- (9) NFPA 11, "Standard for Low, Medium, and High Expansion Foam", 2010 Ed.
- (10) NFPA 16, "Standard for the Installation of Foam Water Sprinkler and Foam Spray Systems", 2011 Edition
- (11) NFPA 25, "Standard for the Inspection, Testing, and Maintenance of Water-Based Fire Protection Systems", 2011 Ed.