FAAN TRAINING CENTRE

#### ARFFS Training Unit

**Fire Extinguishing Media – Foam**

INTRODUCTION

The main risk of fire at any aircraft accident is posed by the involvement of aviation fuel. For this reason our primary extinguishing media is Foam. The amount of foam carried on vehicles is carefully calculated to meet the risks presented by the size of aircraft that operate at the airport. ***Once this amount has been used replenishment can be a slow process so the available foam must be applied correctly***. The effectiveness of the use of foam is determined by the **skill** and **knowledge** of the firefighters.

AIM

The aim of this training note is to introduce students to the aspects of foam and foam production that are relevant to the Airport Fire Service.

OBJECTIVES

After the lesson covering this subject, detailed study of this training note and participating in practical sessions involving the use of foam, firefighters will be able to:

* State the properties of firefighting foam
* State the advantages and disadvantages of foam
* Describe the methods of application
* Describe the areas of application
* State the potential hazards to the firefighter
* Detail the equipment care and maintenance requirements

**GENERAL INFORMATION**

As mentioned in the Introduction to this training note, foam is the primary extinguishing media used by the Airport Fire Service. Foam is a mixture of three basic components:

* Foam concentrate
* Water
* Air

When these three are correctly mixed in the right proportions they produce a substance sometimes referred to as ‘finished foam’. Finished foam is lighter than all fuels and will float on the surface. When foam is used to extinguish fires involving aviation fuels it does so using one or more of the following methods:

* By excluding air (oxygen) from the fuel surface
* By separating the flames from the fuel surface
* By restricting the release of flammable vapor from the surface of the fuel
* By forming a radiant heat barrier which can help to reduce heat absorption by the fuel and hence reduce the production of flammable vapor
* By cooling the fuel surface and any metal surfaces as the foam solution drains out of the foam blanket. This process also produces steam which reduces the amount of oxygen available to the fire.

The type of fuel, method of application and prevailing circumstances will determine the prevalent means of extinguishment.

**GLOSSARY OF TERMS**

Before progressing any further, there are a number of words and terms with which you will need to be familiar if you are to fully understand foam and foam production. They are defined here as an aid to understanding as you read this training note:

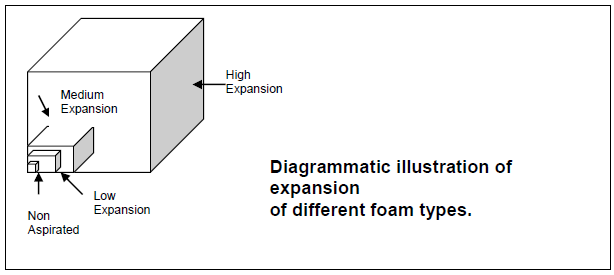
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| **FOAM** | A correctly proportioned mixture of foam concentrate, water and air. |
| **FOAM CONCENTRATE** | A term used to describe the substance supplied by the manufacturer in concentrated liquid form. |
| **FOAM SOLUTION** | A well-mixed solution of foam concentrate and water at the correct concentration |
| **PROTEIN FOAM** | Foam concentrate derived from natural vegetable and animal sources |
| **SYNTHETIC FOAM** | Foam concentrate derived from detergents and other chemicals |
| **PRE-MIX** | A term used to describe correctly mixed foam solution when it is stored ready for use in a tank, etc. |
| **ASPIRATED FOAM** | This is foam solution that has been passed through a purpose made branch. These branches introduce air, agitate the mixture and project it towards the fire. |
| **NON-ASPIRATED FOAM** | This term is used to describe foam solution that is discharged from a branch that does not mix the liquid with air. |
| **INDUCTOR** | An inductor is a device used to introduce foam concentrate into the water stream. It can be fixed or portable. |
| **INDUCTION RATIO** | The percentage of a given sample of foam solution that is foam concentrate. This is expressed as a percentage and, dependent on the type of concentrate in use, will normally be 1%, 3% or 6% |
| **EXPANSION RATIO** | This is the ratio of the volume of aspirated foam to the volume of foam solution used to produce it. For example, if one cubic meter of foam solution, when aspirated, makes ten cubic meters of foam, the expansion ratio would be 10 : 1 |
| **APPLICATION RATE** | The rate at which foam solution is applied to a fire (whether aspirated or not). This is usually expressed as liters of foam solution per square meter of the fire surface area per minute. |

**CLASSIFICATION OF FOAMS BY EXPANSION**

Foam can be classified as being low, medium or high expansion. The expansion, or more strictly the expansion ratio of a foam is the ratio of the volume of the finished foam to the volume of the foam solution used to produce it.

**Typical firefighting foam expansion ratio ranges are:**

* Low Expansion – less than or equal to 20 : 1
* Medium Expansion – greater than 20 : 1 but less than or equal to 200 : 1
* High Expansion – greater than 200 : 1



Non-aspirated foam is the product of a foam solution that has been passed through equipment that has not been specifically designed to produce foam, such as a water branch. However, the use of this type of equipment will often result in some aspiration of a foam solution. This is because air is usually entrained into the jet or spray of foam solution:

* As it leaves the branch
* As it travels through the air due to the turbulence produced by the stream
* When it strikes an object. This causes further turbulence and air mixing.

There is sufficient air entrained by these processes to produce a foam of very low expansion (often with an expansion ratio of less than 5: 1).

**In the Airport Fire Service we normally use low expansion or non-aspirated foam. The reason for this is that medium and high expansion foam contains a lot of air making it difficult to project and is susceptible to wind interference**.

**PROPERTIES OF FOAM IN USE**

There are numerous types of foam available for dealing with a range of fire scenarios. In the Airport Fire Service the main types in use are:

* Fluoro-protein (FP)
* Film forming fluoro protein (FFFP)
* Aqueous film forming foam (AFFF)
* Alcohol resistant foam

NOTE: A description of each type of foam is given later in this note.

The main properties of firefighting foams include:

* **Expansion** – the amount of finished foam produced from a foam solution when it is passed through foam-making equipment.
* **Stability** – the ability of the finished foam to retain its liquid content and to maintain the number, size and shape of its bubbles. In other words, its ability to remain intact.
* **Fluidity** – the ability of the finished foam to be projected on to, and to flow across, the liquid to be extinguished and/or protected.
* **Fuel tolerance** – the ability of the finished foam to resist contamination by the liquid to which it is applied, (this is sometimes referred to as **contamination** **resistance**).
* **Sealing and resealing** – the ability of the foam blanket to reseal should breaks occur and its ability to seal against hot and irregular shaped objects.
* **Knockdown and extinction** – the ability of the finished foam to control and extinguish fires.
* **Burn-back resistance** – the ability of the finished foam, once formed on the fuel, to stay intact when subjected to heat and/or flame.

The performance of firefighting foams can be greatly influenced by:

* The type of foam-making equipment used and the way it is operated and maintained.
* The type of foam concentrate used.
* The type of fire and the fuel involved.
* The tactics of foam application.
* The rate at which the foam is applied.
* The quality of the water used.
* The length of pre-burn.

The most effective and efficient use of firefighting foam can only be achieved after full consideration has been given to all of the above factors.

**TYPES OF FOAM IN USE**

**Fluoroprotein (FP)**

FP foam concentrates basically consist of protein foam concentrates with the addition of fluorinated surface active agents (fluorosurfactants). The addition of fluorosurfactants provides repellent properties and makes the finished foam more fluid. This greatly improves the fire knockdown performance of the finished foam when compared to that of protein foam.

FP foam concentrates are usually available for use at 3% or 6% concentrations and versions are available for use with sea and fresh water.

**Film Forming Fluoroprotein (FFFP)**

FFFP foam concentrates are based on FP foam concentrates with the addition of film-forming fluorinated surface active agents. Under certain conditions, this combination of chemicals can, as well as producing a foam blanket, allow a very thin vapour sealing film of foam solution to spread over the surface of **some** liquid hydrocarbons.

FFFP foam concentrates are usually available for use at 3% or 6% concentrations. They are primarily intended for the production of low expansion foam although they can also be used non-aspirated.

**Aqueous Film Forming Foam (AFFF)**

AFFF foam concentrates are solutions of fluorocarbon surface active agents and synthetic foaming agents. Under certain conditions, this combination of chemicals can, as well as producing a foam blanket, allow a very thin vapour sealing film of foam solution to spread over the surface of some liquid hydrocarbons.

AFFF foam concentrates are usually available for use at 1%, 3% or 6% concentrations and versions are available for use with fresh and seawater. They are primarily intended for the production of low expansion foams although they can also be used non-aspirated.

**Alcohol Resistant Foam Concentrates (AFFF-AR and FFFP-AR)**

Alcohol resistant foam concentrates have been developed to deal with fires involving water-miscible liquids such as alcohols and some aviation de-icing fluids.

Alcohol resistant foams can also usually be used on hydrocarbon fuels and because of this are sometimes known as multi-purpose foams.

Non-alcohol resistant foam concentrates (i.e. FP, FFFP and AFFF) are not suitable for use on water-miscible liquids because their finished foam blankets quickly disintegrate on contact with these liquids. This happens because the water contained in the foam rapidly mixes with, and is extracted by, the water-miscible liquids causing the foam to quickly break down and disappear.

**FOAM CHARACTERISTICS (Advantages & Disadvantages)**

In this section we will highlight the typical characteristics of low expansion foam and their disadvantages. The comparisons made relate mainly to their use on liquid fuel fires. The tests carried out involved the use of petrol. It must be borne in mind that the fuel type and other factors previously mentioned in this note will have an impact on the overall performance of foam.

It should be remembered that there are many companies manufacturing each of the different foam concentrate types. The quality of foam concentrates produced will vary from manufacturer to manufacturer and often different quality versions of the same foam type will be available for the same manufacturer. Consequently the following information represents the typical characteristics of foams produced from each of the foam types.

The table below allows a quick comparison to be made of each main foam type. A more detailed explanation of each follows;

Key: = Poor = Acceptable = Good = Very Good

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| --- | --- | --- | --- | --- | --- |
| **CHARACTERISTIC** | **FOAM TYPE** | | | | |
|  | **FP** | **FFFP** | **FFFP-AR** | **AFFF** | **AFFF-AR** |
| Requires to be well ‘worked’ \* | Yes | No | No | No | No |
| Foam Flow/Fluidity |  |  |  |  |  |
| Film-forming on **some** hydrocarbon liquids? | No | Yes | Yes | Yes | Yes |
| Hydrocarbon fuel tolerance |  |  |  |  |  |
| Flame Knockdown |  |  |  |  |  |
| Edge Sealing |  |  |  |  |  |
| Extinction |  |  |  |  |  |
| Foam Blanket Stability/Drainage Time |  |  |  |  |  |
| Burnback Resistance |  |  |  |  |  |
| Vapour Suppression |  |  |  |  |  |

\* NOTE: Well ‘worked’ means the amount of agitation required to correctly expand the foam solution.

**INDIVIDUAL FOAM CHARACTERISTICS**

**FP**

Low expansion foams produced from FP foam concentrates tend to have the following useful characteristics:

* Flow quicker than protein foams over fuel surfaces, reseal breaks in the foam blanket and seal around obstructions. These properties assist in producing fire knockdown and extinction performances that are quicker than that achieved by protein.
* Good fuel tolerance so they can be applied reasonably forcefully if absolutely necessary
* Produce acceptable fire knockdown and extinction performance although generally slower than film-forming foams
* Good sealing properties against hot metal surfaces
* Form stable foam blankets with slow foam drainage times
* Very good burnback resistance
* Very good vapour suppression

These are the following disadvantages:

* Does not flow as well as film-forming foams. This often results in slower knockdown and extinction performances when compared to those of film-forming foams
* Require to be well ‘worked’ to make acceptable finished foam, they must be used aspirated
* Unsuitable for use with water-miscible fuels (i.e. alcohols) although alcohol resistant FP is available for certain specialised applications.

**FFFP**

FFFPs were designed to exhibit a combination of AFFF and FP characteristics. The intention was to produce a foam concentrate that had the knockdown and extinction performance of AFFF combined with the good burnback resistance characteristics of fluoroprotein. However, fire tests have indicated that although low expansion FFFP gives similar firefighting and burnback performance to AFFF, the burnback performance is greatly inferior to that achieved by fluoroprotein and is generally not much better than AFFF.

Low expansion FFFP finished foams tend to have the following useful characteristics:

* Usable foam can be produced with minimal working, manufacturers suggest that they can be used aspirated or non-aspirated
* Flow quicker than FP foams over liquid fuel surfaces, quickly reseal breaks in the foam blanket and flow around obstructions. This often results in very quick fire knockdown and extinction. On some liquid hydrocarbon fuels, these characteristics may be enhanced by the film-forming capabilities of FFFP
* Moderate resistance to fuel contamination

And the following disadvantages:

* Poor at sealing against hot objects
* Poor foam blanket stability and very quick foam drainage times
* Poor burnback resistance
* Poor vapour suppression
* Unsuitable for use with water-miscible fuels (i.e. alcohols)

**AFFF**

Low expansion AFFF foams tend to have the following useful characteristics;

* Usable foam can be produced with minimal working, manufacturers suggest that they can be used aspirated or non-aspirated
* Flow quicker than FP foams over liquid fuel surfaces, quickly reseal breaks in the foam blanket and flow around obstructions. This often results in very quick fire knockdown and extinction. On some liquid hydrocarbon fuels, these characteristics may be enhanced by the film-forming capabilities of AFFF
* Moderate resistance to fuel contamination

And the following disadvantages;

* Poor at sealing against hot objects
* Poor foam blanket stability and very quick foam drainage times
* Poor burnback resistance
* Poor vapour suppression
* Unsuitable for use with water miscible fuels (i.e. alcohol)

**ALCOHOL RESISTANT FOAM CONCENTRATES (AFFF-AR AND FFFP-AR)**

Low expansion foams produced from AFFF-AR and FFFP-AR alcohol resistant foam concentrates tend to have the following useful characteristics:

* Suitable for use on fires involving water miscible liquids such as alcohols and aviation de-icing fluids
* Suitable for use on hydrocarbon liquid fuel fires
* Usable foam can be produced with minimal working, manufacturers suggest that they can be used aspirated or non-aspirated on aviation fuels. On water-miscible fuels, the foam solutions must not be applied non-aspirated
* Flow quicker than FP foams over liquid fuel surfaces, quickly reseal breaks in the foam blanket and flow around obstructions. This often results in very quick fire knockdown and extinction. On **some** liquid hydrocarbon fuels, these characteristics may be enhanced by the film-forming capabilities of AFFF, film-forming does not occur on water miscible fuels
* Good resistance to contamination from hydrocarbon fuels so can be applied forcefully to these if absolutely necessary. Only gentle application techniques should be used when applying these foams to water-miscible fuels.
* When used on non-water miscible fuels, control and extinction times are similar to those of conventional AFFF and FFFP foams with burnback performance similar to that of FP. Extinction and burnback performance is considerably better when used aspirated (i.e., using a foam-making branch) than when used non-aspirated (i.e., using a water branch)
* Very stable foam blankets with slow foam drainage times
* Good at sealing against hot metal objects
* Good burnback resistance
* Good vapour suppression

These are the following disadvantages;

* Care is required in selecting the correct rate of induction due to the need to use at 3% concentration for hydrocarbon fuels and at 6% for water-miscible fuels. However, some alcohol resistant foams are available that may be used at the same induction rate (normally 3%) for both hydrocarbon and water-miscible fuels.

**FOAM PRODUCTION**

Foam is produced from three main ingredients; foam concentrate, water and air. There are usually two stages in its production. The first stage is to mix foam concentrate with water to produce a foam solution. The foam concentrate must be mixed into the water in the correct proportions (usually expressed as a percentage) in order to ensure optimum foam production and firefighting performance. This proportioning is normally carried out by the use of inductors. This results in the production of a foam solution. In other words, the foam concentrate and water have been mixed together prior to arriving at the foam-making equipment. Occasionally, premix solutions are produced by mixing the correct proportions of water and foam concentrate in a container, such as an appliance tank, prior to pumping to the foam-making equipment.

The second stage is the addition of air to the foam solution to make bubbles (aspiration) to produce the foam. The amount of air added depends on the type of equipment used. Hand-held foam-making branches generally only mix relatively small amounts of air into the foam solution. Consequently, these produce finished foam with low expansion.

**THE TWO STAGES OF FOAM PRODUCTION**



**FOAM APPLICATION**

This section mostly concerns the main fire service operational use of foam, that is on Class B liquid fuels.

When using foam operationally, there are a number of basic, common sense procedures that need to be followed to help to ensure success, these are:

* **Wind Direction-** Obviously, foam can only be effective when it reaches the intended target. Wherever possible, the foam stream should be directed downwind in order to project the foam over the maximum possible distance. In fire situations, this will not only mean that the firefighters will be able to stand as far away from the fire as is possible but also, the wind will cause the fire plume to angle away from them and so further reduce the radiant heat being experienced by them.

* **Correct Operation of Equipment-** The foam-making equipment must be used under the correct operating conditions of flow and pressure. Inductors and foam-making branches must be matched and the correct foam concentrate for the fuel and correct foam induction rate must be chosen. Care should be taken not to cover the air inlet holes of the foam-making branch because this will result in poor quality foam being produced.
* **Gentle Foam Application-** Foam application should be as gentle as possible. Forceful application, which is applying foam directly to the surface of a fuel, will generally result in fuel contamination of the foam, increased breakdown of the foam, and increased flame intensity and radiated heat from the area of application due to vigorous disturbance of the surface of the fuel. The overall effect will be a dramatic reduction in the effectiveness of the foam. In addition, forceful application to an existing foam blanket may cause breaks which reveal the underlying fuel. If complete extinction has not been achieved when this occurs, then a significant amount of burn-back could result.
* **Continuous Foam Application-** Once foam application has commenced, it should continue without interruption until at least the objective of the foam application has been achieved. Interruptions in foam application will result in wasted resources.
* **Edge Fires-** Long after the main bulk of a fire has been extinguished, flames are likely to persist around the edges of the foam blanket where it meets and attempts to seal against objects, such as hot metal. These last flames are likely to require a great deal of time and foam to extinguish. If stocks of foam run out at this stage, the fire may burn back completely. Application should continue to be as gentle as possible. It is often better to reinforce the foam blanket near to persistent flames so that it flows over the area of its own accord. Using water to cool metal around the area of flame can help to reduce the rate of vaporisation of the fuel, and hence the intensity of the flames. In addition, the cooler the metal, the easier it will be for a foam blanket to seal against them, suffocating the remaining flames as it does so.
* **Maintaining the Foam Coverage-** Once a fire has been extinguished or a flammable fuel has been covered with a foam blanket, foam application should continue until a thick foam blanket has been built up. However, the foam blanket will break down and loose its water content with time. Consequently it is important that the foam blanket is regularly replenished in order to ensure continued protection from re-ignition or vapour release. Where possible, the use of water jets or sprays should be avoided in the vicinity of a foam blanket as these can also cause the foam to break down.
* **Maintain Foam-Making Capability-** Even after the fire has been extinguished (or the vapour from flammable material has been suppressed) and a thick foam blanket has been built up, a significant hazard still remains. Consequently, the foam-making capability should be maintained, resources replenished and remain ready for immediate use until all hazards have been removed.

**APPLICATION RATE**

In addition to the previously mentioned considerations, successful extinguishment of fire depends on the rate of foam application. Some terms are used to describe various application rates. They are:

**Critical Application Rate**

The critical application rate is the application rate below which a fire cannot be extinguished. When applied at below this critical rate, the foam will be broken down, by both the fuel and the heat of the fire, to such an extent that a complete foam blanket will not be able to form over the surface of the fuel.

**Optimum Application Rate**

The optimum application rate is sometimes referred to as the most economical rate. It is the rate at which the minimum overall quantity of foam solution is needed to extinguish a fire. Firefighters will probably apply foam at a greater rate than this but the objective should be to keep the actual rate of foam application as close to optimum as possible.

**Overkill Rate**

There is a limit to how quickly a fire can be extinguished when using firefighting foam. Once the application rate has reached a certain level, higher application rates give no improvements in extinction time, they only result in a wastage of resources. These higher application rates are known as overkill rates.

**Non-Aspirated Foam -** Where foam has been applied non-aspirated, the vapour suppression provided is minimal. It is therefore vital that aspirated foam is applied as a back-up as soon as possible after fire extinction.

**APPLICATION AREAS**

As previously mentioned the main risk of fire at an aircraft incident is posed by the fuel. The type, quantity and circumstances in which the fuel may be ignited will be factors that determine the severity of any resulting fire and the method of foam application.

**Spillages (not ignited)**

Spillage fires must be covered in a blanket of aspirated foam to seal in the vapours and reduce the risk of ignition.

**Spill Fires**

Spill fires are fires where the liquid fuel is not contained, therefore it may cover a large area. In this case the application of aspirated foam would give the best results.

**Pool Fires**

Pool fires occur where the liquid fuel is contained. In this case the depth of fuel would be greater leading to longer burn times - again aspirated foam application would give the best results.

**Spreading Fires**

Spreading fires can be spill or pool fires where there is fuel being continually supplied in a spray or stream from ruptured tanks etc. As well as applying aspirated foam to the fuel surface, the fuel flow must be stemmed as soon as possible**.**

**Running Fires**

Running fires are those where burning liquid is running down sloping ground. Non-aspirated foam can be used for quick knockdown on these types of fire. Action should be taken as soon as possible to stop the movement of the fuel and an aspirated foam blanket applied.

**Engines/Undercarriages**

Foam can also be used non-aspirated to deal with fires involving aircraft engines and undercarriages. It can be used as part of the dual application technique where foam spray is used in place of water spray. This has the added benefit of knocking flames down quickly, cooling the areas involved and any turbulence created by the foam spray striking objects, can provide some blanketing for spilled fuel.

**CARE OF EQUIPMENT**

Periodic examination must be made to ensure that all the equipment remains in good working order. Foam concentrates will leave a deposit on the equipment with which they come into contact whether as a concentrate, foam solution, or as foam.

The following points should be checked:

* Washers have not rotted
* Valves operate freely and without leakage
* Metering devices operate correctly
* Flexible connections are free from damage
* Foam concentrate pumps operate without leakage (where fitted)
* Foam tanks and connections for leakage and/or corrosion
* Keep tanks and equipment free from items such as stones etc, as performance is based upon manufacturing to precise tolerances
* Operate equipment in accordance with the manufacturer’s instructions
* Precautions should be taken to avoid the use of non-compatible foam concentrates**.**

**HAZARDS**

Firefighting foam poses only minor health hazards when used correctly. The main areas that firefighters need to be aware of are:

**Slip Hazard**

When foam is applied, particularly to aircraft skin areas, it can cause a major slip hazard. This would not only put firefighters at risk but also escaping passengers who may slip on aircraft wings as they evacuate through overwing exits.

**Reaction with Class D Fires**

If foam is applied to fires involving combustible metals a violent reaction will occur involving molten metal being thrown over a large area and an intensification of burning.

**Personal Contamination**

If any areas of the body are contaminated, thorough washing and good hygiene should be exercised. There is a low risk of nausea and vomiting if protein based foam is ingested. When handling foam concentrates or filling appliance tanks, rubber gloves and goggles should be worn as a precaution.

**Corrosive**

Foam concentrates can, on certain materials, be mildly corrosive. They can also leave deposits on surfaces that can lead to the seizure of moving parts. Thorough flushing of all surfaces and pipework is essential and will minimize the risk of foam system failure at a critical time**.**

**Environmental Hazard**

Foam concentrates, although not acutely toxic, can be harmful to the environment. If foam enters natural water courses it can kill aquatic life by extracting oxygen from the water. If foam does enter water courses, the Officer in Charge must be informed.

**Manual Handling**

In most cases foam is delivered to our airports in 200 liters drums, each weighing around 240kg. A Risk Assessment should have been carried out on the manual handling of these drums. Firefighters should follow any procedures that have been designed to minimize the risk of injury through lifting these drums.

**SUMMARY**

The main risk of fire at an aircraft incident is posed by the involvement of aviation fuel. For this reason foam is the primary media carried by the Airport Fire Service. Knowledge and skill in the characteristics of foam, the use of foam for firefighting either on its own or in conjunction with other extinguishing agents, the methods by which it extinguishes fire and the care and maintenance of foam equipment are essential contributory elements in the overall competence of Airport Firefighters.

NOTE: Handling of all products should follow the Manufacturer’s recommendations and relevant Control of Substances Hazardous to Health (COSHH) Data Sheet to ensure the correct safe working practices.