# FIREFIGHTING FOAM
## Unveiling the 'big' issues

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### 1.0 Firefighting Foam – effective and versatile!

Like water, which can be used in different forms for different applications, foam too has become a 'must have' agent for municipal and industrial Fire services around the world, as its operational flexibility and efficacy is being proven time and again, with instances of newer applications and uses. The comparative ease of foam operation, whether using vehicles, fixed systems or portable equipment mean a relatively cheaper system compared to other agents (an important factor for developing nations, where funds are a major issue), with the exception of water. The availability of good quality foam concentrates and equipment indigenously can make foam firefighting a financially viable and effective choice. Quite simply, Fire services, manufacturers, statutory bodies and related agencies in the country cannot afford to ignore the issues of proper and optimum utilization of firefighting foam.

### 2.0 Operational shortcomings

It must be appreciated that critical and successful foam operation results from sound knowledge of its properties, equipment, strategies and understanding of related operational factors. Due to the lack of relevant data in the country, it is difficult to provide clear statistics of successful foam operations in the past. However, based on the author's knowledge, and the available information, it can be safely concurred that while most small incidents have been tackled fairly successfully, medium and large size incidents involving flammable liquids have a different story to tell. Major spill fires and storage tank fires are a case in point, and incidents involving them have had a less than happy ending. Even though firefighting foam presents the best chance of successful control and extinction when dealing with major flammable liquid incidents, case histories are a pointer to the fact that the firefighting fraternity in many developing countries have not had the same success rate as those in developed countries.

Developing countries cannot afford to invest much in terms of research and study, and depend on the information available from other developed nations. As there is not much activity in terms of developing operational manuals in the country, there is no source of reliable operational guidance. Due to this, for most Fire service personnel the only source of operational knowledge is the training passed on by seniors/ peers, which by itself may not be fully adequate. Except for a few industrial Fire brigades, most fire service personnel do not have access to recognised international standards/ codes and related information. Whatever little foam equipment standards are available in the country, are very basic and to some extent, ambiguous. Contrary claims and obscure information by manufacturers/ suppliers further add to the confusion.

## 3.0 Major Studies on operational aspects

The fact is that even today, there are aspects of foam operation which are still not very clear, especially those associated with large scale application of foam (eg. those involving large Storage Tanks). A lot of research and study is still going on, though this is mainly privately organized and funded. However, the results of such studies are very important to all users, and efforts have to be made to ensure that the relevant information is made available to concerned users.

Two major studies were carried out on firefighting foam behavior (especially on large fires) in the recent past. One of them was the LASTFIRE ( from LArge Storage Tank FIRE) project, a thorough study of large atmospheric storage tank fires, and whether the prescribed fire preventive and fire protection systems for such tanks were adequate. This was funded by 16 Oil majors of the world, amongst them EXXON, MOBIL, SHELL, BP, Saudi Aramco, etc, and useful information was derived from the sharing of experiences of these oil companies. While many aspects of large tank fires, including causes, prevention, design aspects, etc, were discussed, the study of firefighting foam systems and strategies were also important areas covered, and the conclusions were in turn, brought out in the form a report for dissemination to concerned parties.

The other study conducted was termed FOAMSPEX (for large scale FOAM application – modelling of foam SPread and EXtinguishment), an EC funded independent research project on extinguishing large storage tank fires. Operational tests were carried out to check the behavior of different foams (mainly Fluoroprotein and Alcohol Resisting AFFF) on fairly large (simulated) fires, thus providing accurate feedback on different aspects of firefighting foam performance. Various aspects were studied, such as foam spreading and shearing characteristics of foam blankets, reaction of foam bubbles to fire attack, foam impact onto fuel surfaces and resulting fuel pick up, updraft effects on foam flakes as they arrive into the fire and how the foam stream is affected. While foam application strategies on major tank fires are still a point of debate, useful information was obtained from these two studies, and some pertinent data is discussed later in the paper.

## 4.0 Critical issues for developing nations

With the communication revolution, a lop-sided situation prevails in the Fire services at the present moment with respect to knowledge availability and access. This has been brought about by the sudden availability of information and data, through media such as the Internet. The beneficiaries have been certain sections of the services (mostly industrial and large Metro Fire brigades). However, a large majority of the emergency services, especially the smaller towns and semi-urban areas remain largely unaffected by this, as their access to such avenues of information is limited. This has resulted in a sharp imbalance in terms of knowledge, and differing views on many operational aspects. The other pertinent fact is that while a lot of information is available on the internet (mostly from manufacturers) it is still not complete, in the sense that authoritative and clear guidelines are rarely available. The author wishes to bring out some such issues, associated with foam application on large fires, with the intention of sharing information and initiating healthy discussions. These are areas of concern and need to be taken up seriously by concerned statutory bodies, manufacturers and concerned personnel. At the same time, it is also necessary to disseminate all available information to users for effective, economical use of this agent.

### 4.1. Choice of Foam concentrate

It is important to note that even today, there are several types of foam concentrates available both on the national and international scene. The reason for this is clear - no single concentrate is suitable for all types of fires. While each type of concentrate is best suited for certain type of firefighting situation, it may not be very effective in others. The two broad classes of Foams presently available i.e. Synthetic and Protein based have differing and complementary properties. While synthetic foams (AFFF [Aqueous Film Forming Foam], AR-AFFF [Alcohol Resistant AFFF], and High Expansion Foam) have quick flowing and knockdown properties, their post fire security is poor; on the other hand protein based foams (P [Protein], FP [FluoroProtein], FFFP [Film Forming Fluoro Protein] and FFFP-AR [FFFP–Alcohol Resistant]) produce a heat resistant, longer lasting foam blanket, but flow more slowly as compared to synthetic foams. What this means that the choice of foam concentrate depends to a large extent on the type of risks that are likely to be encountered  (There have been attempts to combine the quick flowing properties of synthetic foams with the heat resisting character of protein based foams by adding chemicals to Fluoroprotein to give it film forming abilities. The resultant foams, FFFP and FFFP-AR combine the advantage of film formation with good thermal resistance, and are now being widely used in many developed countries).

Different situations require different type of foam tactics and foams, for eg. aircraft crashes where shallow spills and spill fires are the most likely scenarios, AFFF with its properties of quick flowability and rapid knockdown would be an ideal choice. But in cases where foam attack may be delayed, or may have to be done more than once (eg. large fires, storage tank fires), it may not be that effective, as it does not have very good heat resisting properties. Instead a foam with good thermal properties such as FP or FFFP would prove more useful. Where water miscible fuels are involved, normal foams are of little use, as the foam blanket gets destroyed on coming in contact with the fuel, and alcohol resisting foams, AR-AFFF or AR-FFFP will have to be used. For high expansion applications like those used in LPG/ LNG spill situations, a high expansion foam is suitable. Therefore, the appropriate choice of foam concentrate should depend specifically on these operational considerations.

#### 4.1.1 Trends and findings

With respect to large tank fires, it is obvious that a foam with good heat resisting properties would be required. At the same time, if the foam would flow quickly across the fuel surface, it would result in fast control and extinguishment, which means a film forming foam would be useful. Unfortunately, it has been established (in tests carried out by the U.S. Navy) that the aqueous film in case of AFFF (which aids quick spread over the fuel surface) does not form above about 70-90° C depending on fuel, so the only mechanism  working to extinguish the fire is the quality and stability of the foam blanket (and not the film which works quickly on shallow spill fires that do not get so hot). Unless foam attack is immediate, AFFF may not prove useful on such fires. Another factor to be considered, especially if foam is being applied from monitors, is the fuel pick-up by the foam. As this is more apparent in synthetic foams (especially AFFF), it is unlikely to be useful in such situations. The trend in most of the developed countries has also been along these lines, and amongst the various types of concentrates, the most commonly preferred for these applications, are AR-AFFF (in USA) and Fluoroprotein foams (in Europe and Canada).

These issues were also taken up during abovementioned studies, and the LASTFIRE study reported that 'the formation of an aqueous film is dependent on the properties and temperatures of both the foam and the fuel, and laboratory film-forming tests do not necessarily imply that a film will form under real fire conditions'. Also that 'thermal resistance, fuel tolerance, foam spreading and post-fire security were the important factors for foams used during such fire incidents'.

FOAMSPEX carried out studies mainly on AR-AFFF and Fluoroprotein as these are two most commonly used concentrates for this application. Certain findings are noteworthy, especially 'that foams with low interfacial tensions pick up more fuel when applied forcefully; i.e. AR-AFFF picks up more fuel than Fluoroprotein'. Another important finding was regarding the foam flow, the study revealed that 'AR-AFFF foams can, in some cases, flow upto 4 times faster than Fluoroprotein foams on cold fuel. However, AR-AFFF can slow up under fire conditions while FP foam flow rate increases, significantly reducing the gap'. Amongst the major conclusions given, was the fact that the best foams for large tank firefighting would be fluid and slow draining (for rapid foam cover), with higher interfacial tension (to reduce fuel pick-up) (quite literally, a mix of AR-AFFF and FP Foam).

### 4.2. Operational strategies / tactics

One of the basic rules of foam operation is gentle application of the agent, resulting in reduced foam breakup and fuel pick-up. A properly designed fixed foam system can achieve this requirement better than any other equipment. This is also the reason why almost agencies worldwide, advocate the provision of proper fixed systems for large storage tanks. NFPA 11 also provides similar guidelines, and strongly advocates the provision of properly designed fixed foam systems for large storage tanks.

However, developments in foam equipment and concentrates have seen large tank fires being successfully tackled with large capacity foam monitors in the past decade or so (about 3 years back, a 80 metres plus Tank fire was successfully put out by a private firefighting company using a large capacity foam monitor). This has had a great impact on firefighters in the country, and there has been a definite trend to have large capacity foam monitors with non-aspirated foam nozzles for tank fire protection. However, the operational worthiness of such monitors depends on a number of factors (some of which are discussed later) and simply installing such monitors may not serve the purpose during the 'real' situation. It may be mentioned here that while NFPA 11 permits the use of foam monitors on larger tanks, it clearly mentions that is shall not be considered as primary means of protection for tanks above 18 metres in diameter.

#### 4.2.1 Trends and findings

The provision of well designed and dependable fixed foam systems provide the best and safest solution (for firefighters) for combating large tank fires. One of the LASTFIRE recommendations was that 'the provision of well designed and maintained fire protection systems (fixed or semi-fixed) is more effective and reduces risk to responding firefighters compared to the use of mobile foam attacks'. For those skeptical about foam's ability to effectively cover the fuel surface of large tanks, FOAMSPEX studies revealed that 'Foams can flow considerable distances, 100 metres for the more fluid AR-AFFF and 90 metres for the stiffer FP foam. This verifies that foam from fixed systems or monitors should be capable of extinguishing colossal 100+ metre diameter tanks'. If fixed systems have been found wanting during past fire incidents, it calls for a critical review of present designs and testing methods, to ensure reliability in 'real' conditions. LASTFIRE reported that 'Firefighters expressed a definite preference for fixed systems provided they could be designed, installed, maintained and tested properly'. The thrust should be therefore, on strengthening these systems and firefighting strategies should focus primarily around these systems. To the author's knowledge, there are number of small design details, which are ignored, but which ultimately affect the performance of the system. The present testing and maintenance methods leave much to be desired.

While foam monitors have been used for tackling such fires, once again it must be emphasised that this is a specialised application, and so far, most of the successful extinguishments have been by private firefighting contractors. Since their tactics are not open knowledge, it would need proper study and operational assessment before these equipment can be confidently deployed. Also the fact that these tactics are learnt from various different experiences, some successful, some not so successful. As a leading firefighting contractor puts it 'We're constantly changing tactics, modifying old equipment, and exploring new technology to battle such large fires. Because we put our lives on the line'. Notably, there are still no standards/ operational manuals available on using such monitors for large tank fire applications and the only information available is from manufacturers of such equipment themselves. The logistics involved in mobilising large quantities of foam concentrate supply, adequate water pumping arrangements, and operational training of personnel are other important aspects to be considered.

There is also a move to opt for non-aspirated (secondary aspirated) foam nozzles, in favour of aspirated (primary aspirated) foam nozzles, the reason being the so-called advantage of better range in case of non-aspirated foam, as it is more dense, and is supposedly able to penetrate the thermal updraft of large flames. While the range of non-aspirated foam streams is definitely more, other related aspects must also be considered, for eg, the FOAMSPEX study had this to say about the range and foam dropout rates of aspirated and non-aspirated foam streams 'typical foam drop out rates for aspirated foam streams (cannons) are only 30% for FP and 40% for AR-AFFF. When non-aspirated foam streams (nozzles) were used AR-AFFF drop out rates increased to 60% of total foam flow against 50% for FP foam, but the remaining foam did travel up to 20% further'. On the notion that the updraft of flames blow away aspirated foam, it was actually found that 'the updraft air movements help to keep the foam stream together and minimise dropout rates. An uplift effect from the hot air also allows the foam to land more gently on the fuel surface and hence pick up less fuel'. Another important fact to be considered is that during some of the operations involving use of non-aspirated nozzles on tank fires, it has been seen that the foam stream is applied in the form of a narrow fog of about 10 to 15 degrees, and not in form of a straight stream (as is perceived by many), due to which its actual operational range would be lesser than claimed.

Presently, some international testing bodies do the testing and certification of foam monitors. These are done keeping in view NFPA 11 specifications, and evaluating the properties of the generated foam as per these guidelines. This certification guarantees the user that the monitor will consistently deliver a foam that lies in the acceptable range specified by NFPA 11 (when used with a matching certified foam concentrate). However, as mentioned above, when being used for large tank fires, a number of other factors also play a part in effective operation, such as the type of foam concentrate used (the concentrate certified for use with the foam monitor may not necessarily be the most appropriate for this specific application), the application rate (this could vary from 6.5 to

13 ltrs/min/m2, depending on the type of liquid and also on the stage of the fire), the discharge pattern, application tactics, etc. Unless all these aspects are fully understood and taken care of, their operational utility for such severe applications would remain debatable.

### 4.3. Environmental considerations

Environmental problems due to firefighting foam are not yet, a major issue in the country, considering that its use is very limited as compared to other chemicals. However, foam is designed to be used with large quantities of water and so may end up in the water or aquatic environment. During large fires, the quantity of foam concentrate used can run into thousands of litres, at the very least, and if carelessly handled, can lead to environmental problems. Therefore, it would be useful to look at some of the issues and present trends in this area of foam manufacture. At the very outset, certain basic information must be understood. Aquatic toxicity tests are usually conducted on a variety of organisms that represent key links in the food chain. These include algae, protozoa, crustacea and fish. The environmental impact of foam is related to two issues – its toxicity and biodegradability. The result of an aquatic toxicity test is usually quoted as an $LC_{50}$ value. This is the lethal concentration in water of foam that would kill 50% of a test batch of animals (eg. fish) within a given period of time. The other issue is biodegradability i.e. how easily the foam can be broken up into simpler and absorbable elements, and how much oxygen is required from aquatic bodies for this. This is measured as a ratio of the $BOD_5$ (Biochemical Oxygen demand) i.e. amount of oxygen consumed by aquatic micro-organisms in a specified number of days (usually 5) to the COD (Chemical Oxygen Demand) i.e. amount of oxygen required to degrade a known quantity of foam.

Certain ingredients in foams have been found to be environmentally damaging, but one of the basic constituents, fluorosurfactant, used both in AFFF and certain FP varieties, is amongst the more damaging of these. While it gives foam desirable properties, like chemical and thermal stability, the ability to form films at the air-water interface, it also results in some undesirable qualities. These chemicals after (firefighting) use, ultimately degrade to highly stable, environmentally persistent constituents. Due to their long life, their accumulation over a period of time (in water bodies and ground water), could affect life adversely and this is a subject of much study and research presently.

#### 4.3.1 Trends and findings

While all foams have been found to be of low toxicity compared to other classes of chemicals, there is variation among the different foam categories. The most toxic foams are Syndets, followed by AFFF; Protein-based foams are much less toxic. They have been found on average to be less toxic to every organism by factors ranging from 9 for fish to 40 for crustacea. Of all the protein-based foams, FFFP is found to be least toxic.

Some information regarding biodegradability - Foams with a $BOD_5$:COD ratio greater than 50% are generally considered to be rapidly biodegraded. In most environmental hazard assessments, high biodegradability is considered desirable as it indicates low persistence. However, foams generally have high BOD values and their rapid biodegradation can deplete dissolved oxygen levels in water bodies which, in turn, may lead to asphyxiation of aquatic organisms. Slower biodegradability may therefore be desirable in certain circumstances. Most foams tested in one independent study demonstrated acceptable biodegradability with the exception of some synthetic foams. Once again, synthetic foams are generally less biodegradable than other foams.

There has been a growing concern amongst the various sections of society in our country, regarding the adverse environmental impact of various chemicals. However, the fire fighting fraternity remains largely unaffected by this, except for the halon replacement programme, to which it responded positively and actively in the recent past. There is now a trend in the developed countries to develop foams which do not affect the environment adversely. Certain firms already offer fluorosurfactant free foams, and many manufacturers have been modifying their manufacturing processes to achieve better levels of acceptability in terms of environmental impact. However, it would be wise not to jump to conclusions at this stage, and infer that presently manufactured foams are going to be replaced in the near future. It is also too early to assess whether the so-called 'environmentally friendly' versions will have the same firefighting performance as their predecessors. Rather a cautious approach and further study of this issue is required. In fact, in many developed countries, the line of thought is to regulate the use of foam, i.e. to use foams only during actual accidents, and use substitutes and/ or 'fluorosurfactant' free foams for training purposes. Once again, trends and developments in developed countries cannot be blindly applied in developing countries like ours, where the situation and problems are vastly different, however, a balanced approach is required, considering the various aspects of this issue, including financial viability.

## 5.0 Conclusion

Firefighting foam is an effective, versatile and economical fire fighting agent, and hence, of much value to developing countries. If we wish to make optimum and effective utilisation of this agent, it is imperative to share and pass on all relevant information, knowledge and training, to the users. In today's scenario, with ever-increasing competitiveness, there is also pressure on the Emergency services to 'do more with less'. The threat of any spillover effects of a large accident, affecting adjoining society and the environment, calls for heightened vigilance, alertness and training. Therefore, a willingness to share information and the resolve to tackle such issues, are required by the Fire service fraternity, educational and training institutes, concerned agencies, and manufacturers, to strengthen the cause of Fire Safety.

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