Central Fire Brigades Advisory Council

Scottish Central Fire Brigades Advisory Council

JOINT COMMITTEE ON FIRE RESEARCH

RESEARCH REPORT NUMBER 40

SURVEY OF FIRE FIGHTING FOAMS AND ASSOCIATED EQUIPMENT AND TACTICS RELEVANT TO THE UK FIRE SERVICE
PART 3 - LARGE TANK FIRES

1991

Research Report No. 40

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Survey of Fire Fighting Foams and Associated Equipment and Tactics Relevant to the UK Fire Service
Part 3 - Large Tank Fires

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ABSTRACT

This report is one of three constituting a survey of the field of firefighting with foam. It covers the problems associated with large petroleum liquid storage tank fires, showing how existing Fire Service equipment is less suitable than larger specialist equipment, because it poses serious logistical problems.

MANAGEMENT SUMMARY

Statistics are not available regarding the frequency or severity of large petroleum liquid storage tank fires, however, fire brigade experience in the USA, Europe, Middle East and UK indicates a continuing series of incidents. The UK fire service does not have suitable equipment to deal with fires in large storage tanks at present.

As a result of a wide ranging exercise in gathering information associated with this study it has been possible to collect together the various techniques that are being applied in other countries to tackle the problem of large storage tank fires, and to illustrate where there are weaknesses in the approach used in the UK. During the course of the study, information was gathered from foam manufacturing companies, industrial users, testing and research bodies, fire brigades and mutual aid organisations. This particular report is the third in a series of four generated by this study and covers the specific topic of Large Tank Fires.

The other three are:

- Part 1 - Fire Fighting Foam
- Part 2 - Tactics and Equipment
- Part 4 - Management Summary

If large petroleum liquid storage tanks catch fire the consequences to the surrounding environment can be severe. At an average burn rate of 4 mm/min it can take days for a full tank to burn off. The locally intense air pollution may affect crops, natural flora, river and esturary life. Where houses and public roads are close to large storage tanks there can be a risk to people, public property and private property from the effects of a large boilover. It is not considered necessary to list specific areas where these conditions exist, nor to undertake detailed environmental impact studies to be able to draw the conclusion that in the U.K. a general policy of "let-it-burn" would be inappropriate for large storage tank fires.

The report shows how existing fire brigade equipment is far less suitable for tackling such fires than larger, specialist equipment.

A comparison is made between the quantities of standard fire service equipment and the amounts of specialist equipment that would be needed to tackle a large tank fire. The comparison is based on a standardised fire scenario applied to four different sizes of tank; 90m, 75m, 60m and 45m diameters. Many simplifying assumptions have been made about the bund configuaration, hydrant arrangements etc., which mean that in a "real life" fire it is likely that the fire brigades would need considerably more equipment. If tank wall heights are in the region of 20 to 27 m conventional monitors and pumps will probably be unable to project foam over the tank rim. Where water supplies need to be drawn from rivers or lakes the quantities of equipment woud be far greater than those shown.

Even so, the conclusions which can be derived from these comparisons are that the quantities of 70mm hose required become excessive when using standard brigade equipment. Difficulties in deploying equipment can be severe and in the event of a change in wind direction or a boilover, it can be virtually impossible to redeploy equipment within the time available. By contrast the logistic problems are greatly reduced when specialist equipment is used. Only 25% of the number of hoses is required when 125mm diameter hose is employed. Similar logistic improvements can be obtained by use of large monitors, large pumps and specialist foam proportioning equipment without the need to increase the water or foam supplies.

Specialist equipment is also more effective. It is generally agreed that large monitors have increased range over smaller monitors of the same design at the same working pressure; and that foam jets thrown by large monitors will better survive the heat emitted from the tank fire plume. Frictional losses can be designed to be lower in large pumps, hose, headers and monitors than in the equivalent standard brigade equipment.

The report contains three proposals on how it would be possible to introduce specialist foam equipment into the UK to be available for large storage tank fires, viz;

- create specialist teams within the UK Fire Service
- use existing commercial teams
- encourage Mutual Aid organisations to take on this role.

Whilst the advantages of the specialist equipment proposed are clear, there is insufficient field data or research to indicate the largest size of tank fire that could be tackled with foam monitors alone. For this reason it is recommended that all petroleum liquid storage tanks above 45m in diameter should be fitted with fixed base injection foam systems to supplement the foam application over the tank rim. With more research it may be possible to justify a higher threshold for introduction of base injection systems.

CONTENTS

SECTION 1

INTRODUCTION

In September 1987 Ewbank Preece Ltd. was commissioned by the Home Office, Scientific Research and Development Branch to perform a survey of fire fighting foam and associated tactics and equipment relevant to the United Kingdom Fire Service. The survey was conducted between October 1987 and March 1988 inclusive, and this report is the third in a series of four reports which present the findings, analysis and recommendations.

The original scope of the commission is presented in Appendix E, and called for the production of reports on three main areas and a fourth summarising management report. The original three areas for reporting were Foam Types, Tactics and Equipment. Subsequent minuted discussions combined Tactics and Equipment into a single report and created a new third report on Large Tank Fires.

The four reports produced from the study are now:-

Part 1 - Firefighting Foam

Part 2 - Firefighting Foam
- Tactics and Equipment

Part 3 - Firefighting Foam
- Large Tank Fires

Part 4 - Firefighting Foam
- Management Summary

Three main methods were used to gather information; meetings with individuals and organisations who have specialist knowledge of fire fighting foams (a list of such contacts is provided in Appendix C); literature research (a list of references is provided in Appendix B); and a questionnaire to foam concentrate and equipment manufacturers (Appendix D).

This report covers the subject of fires in large flammable liquid storage tanks. The development of this type of fire is described and the particular difficulties that can be experienced in using standard fire service equipment are highlighted. Specialist equipment for this application is reviewed and proposals are made for providing an improved capability in the future.

The generous help received in the course of the study from all of the organisations and individuals contacted is gratefully acknowledged.

SECTION 2

LIMITATIONS OF EXISTING FIRE FIGHTING TECHNIQUES AND EQUIPMENT

2.1 INTRODUCTION

From discussions with those who have had experience in fighting large storage tank fires a consensus exists that there is a limit to the size of fire that can be successfully tackled by conventional equipment and techniques. Opinions vary from 18m to 45m diameter as to where that upper limit should be defined. However, even experienced specialist teams point to the logistical difficulties in conventional deployment for fires of 45m diameter and above.

In this report tank diameters between 45m and 90m have been considered as constituting large storage tanks, although many of the problems and solutions apply equally to smaller tank fires in the range of 18m to 45m.

A limitation of particular importance in the UK is tank height. In this country tanks of up to 27m high are built to minimise the space taken up by tank farms. Standard foam monitors are unable to clear tank walls of this height under normal conditions.

This section describes the development of a large storage tank fire and then examines what would be involved in a typical deployment of conventional equipment. The individual factors which contribute to the difficulty of extinguishing such fires are then discussed in greater detail.

2.2 FIRE DEVELOPMENT

Tanks in the range 45 to 90m diameter tend to be predominantly of the floating roof design, although fixed roof tanks of over 45m diameter do exist.

The first phase of any tank fire is ignition and development to the stage where the tank surface is fully involved in the fire. When considering large storage tank fires it can be assumed that this first phase has already taken place. A description of how ignition and development can proceed is given in Report No. 2 Section 3.2.8 (a).

The fire plume from a fully involved tank fire can be several hundreds of metres in height. The rapidly rising flame and smoke radiate heat to the surroundings and draw fresh air in at the base creating, in some cases, strong artificial winds at ground level. Local wind conditions can incline the angle of the column so that it closely approaches, or even in some cases impinges directly upon, nearby structures which may include other storage tanks. If the tank on fire is partially empty then the exposed freeboard may begin to distort and collapse inwards towards the surface of the burning liquid. The process does not happen suddenly, but rather develops over a period of hours leading to a situation where the wall of the tank can be scrolled over and touch the surface of the burning liquid. The result is a further complication for fire fighters since an annular ring of burning liquid can thus be shielded from direct foam attack. The hydrocarbon liquid itself will be consumed at a burn rate which may vary widely with the fuel and conditions, but a rate of 4mm per minute is often quoted as an average. In the case of single boiling point liquids the surface temperature of the liquid will never rise above the boiling point of the liquid no matter how much heat is generated by the fire. Evaporation from the surface cools the liquid and hence the greater the heat absorbed by the liquid surface the faster liquid vapourises, and the more intense is the fire. With flammable liquid mixtures such as crude oils and partially refined products there may be hot layers of high boiling point residue at or near the surface, or even crusts of coke may form on the burning surface.

Flammable liquid tank fires will eventually burn to extinction which may take many hours or even days. If, however, there is water in the tank either in the form of a stratified layer of moisture or possibly several metres of water in the base or even trapped higher up on a pocket created by a sunken floating roof, then there exists the possibility of sudden violent steam generation. This can result in the phenomenon known variously as slop-over or boilover. Slop-over is the term generally applied to minor eruptions from a burning tank whereas boil-over is a larger event, during which substantial quantities of flammable liquid, possibly even the full contents, are ejected onto the surrounding area. The presence of steam in the ejected oil can increase its volume temporarily by several multiples allowing rapid spread possibly beyond the containment bunds.

There are other reasons why it is desirable to extinguish large tank fires rather than let them burn out. A 500,000 bbl (approximately 80 m diameter by 17 m high) storage tank can hold crude oil to the value of $7,500,000 at an oil price of $10/bbl, or refined products to three times that value. Apart from the losses incurred in the affected tank others around may be damaged or even ignited by the radiant heat if the inter tank spacing is inadequate or if wind conditions are unfavourable. The environmental impact of a major storage tank fire is considerable in terms of air pollution which issue alone could build up public pressure against a policy of "let it burn".

2.3 CONVENTIONAL FIRE ATTACK

2.3.1 Terminology

Both in a small number of UK fire brigades, and in some petrochemical plants and refineries there exists specialist equipment designed purchased or adapted to help tackle large tank fires. This is, however, not the norm. Some brigades maintain a small stock of 4,500 l/min pumping appliances but the predominant size of UK fire appliance pump is 2,270 l/min. Only a few brigades use large diameter hoses of 100mm, 125mm and 150mm. The standard size of 70mm is predominant.

In this section the term "conventional" fire attack has been illustrated by the example of an imaginary brigade equipped with 1,900 l/min monitors, 2,270 l/min pumping appliances, 70mm hose in 25m lengths and venturi - type inline foam concentrate inductors. Based on this equipment a stylised deployment has been worked out as an example to show the logistical difficulties in fighting flammable liquid storage tank fires of 45, 60, 75 and 90m in diameter.

The tables at the end of this section show the quantities of equipment and materials required, but they require some explanation of the assumptions made as well as interpretation of the results.

2.3.2 Assumptions Behind Tables 1 to 11

Tables 1 and 2 are based on NFPA standards for foam application on large tank fires (at 6.5 $l/min/m^2$ foam application).

a. Cooling Water

To estimate the cooling water load there is no directly applicable data and further research is needed to provide satisfactory guidance to brigades. In the tables the cooling water rate of 10.2 $l/min/m^2$ from NFPA 15 is used, but this is intended for fixed water spray systems. This density is based on reducing the heat radiation absorbed by an exposed tank to a safe level of 18, 900W/m^2 where 8.2 $l/min/m^2$ is used to reduce the heat absorbed from 63, 100 W/m^2 to the 18,900 W/m^2 (ie. a reduction of 44,200 W/m^2). The remaining 2.0 $l/min/m^2$ is allowance for windage losses from the spray.

The quantities of water that can be successfully delivered by monitor nozzles will vary with wind speed, wind direction, nozzle type, pressure, distance of throw etc. In addition monitors will deliver water in a less even pattern than spray nozzles. In compensation it is possible to direct monitors more precisely towards the areas worst affected eg. the tank freeboard above liquid level or perhaps the section of tank receiving the incident radiation at right angles. Where tanks are receiving less than 63,100 W/m^2 then proportionally less cooling water can be used.

American practice and the NFPA codes maintain that cooling is not necessary to exposed tanks if the spacing between tanks is equal to the spacing they recommend. In the UK the opinion is strongly held that cooling of exposed tanks is required. Some preliminary calculations indicate that at one diameter spacing the situation is marginal, requiring less efficient burning than normally expected to keep incident radiation levels down to 18,900 W/m^2.

The situation changes considerably when the tank on fire boils over. Radiation rates then rise dramatically, and as reported in the Amoco Milford Haven fire report "cooling of (exposed) tanks was becoming critical". Similarly the wind can incline the angle of the fire plume towards exposed tanks, increasing the incident heat radiation. Pressurised storage tanks will require cooling to maintain their temperatures well below the danger level of 500°C. Where there is insufficient water for both foam attack and cooling concurrently, then if a full scale foam attack could otherwise be mounted the cooling water should be temporarily reduced or ceased to give priority of use to the foam attack. Whilst this may ease the peak demand on firewater it does not normally save on equipment since cooling activities and foam attack will normally be set up in different locations, and redeployment of equipment from cooling activities would take too long.

In the Tables 1 and 2 the cooling water requirement has been taken as 10.2 l/min/m2, which is commonly used as a guide for monitor application as well as for fixed spray application. It is assumed that cooling of only one exposed tank is necessary because of wind direction and speed.

b. Exposed Area

The selection of 1/3 of the exposed tank surface area as a basis for calculating cooling water demand is an assumption for the purposes of this calculation. Estimates of the area which requires cooling vary between 25% and 50% of the tank surface area. On a geometric basis at one diameter spacing a segment of 150° could be considered as exposed. However, the exposed tank is likely to contain some product, and the extreme ends of the 150° segment receive exposure radiation at a low angle of incidence. Bearing these factors in mind the assumption of 1/3 of the tank surface requiring cooling has been made i.e. 80% of the 150° segment. This is an aspect which could benefit from further research.

c. Tank Spacing

Tank spacings of one tank diameter have been assumed in Fig 1. The largest tank spacing in the NFPA Codes is 2/3 of a tank diameter, however various oil company standards opt for one tank diameter spacing, and several published papers call for even greater separation. This is an area where further research and radiation modelling would be of great assistance.

d. Bund, Hydrants and Hose

In order to give an indication of the quantities of hose required it has been necessary to make some assumptions about the tank, bund and mains layout. The arrangement used is show on Fig. 1 (90m diameter tanks), and it must be emphasised that this arrangement is idealised. The bund configuration allows space at the corners of bunds for vehicles and fire appliances to stand during operations, whilst leaving bund roadways clear. Road widths are shown as 10m to permit both hose laying and vehicle passage at the same time. The bund extensions are shown 10m wide and projecting halfway towards the tank.

These extensions would provide a safe vantage point to place monitors during a foam attack and an escape route if necessary. There is a need for improved guidance to brigades on the types of bund which are available and how to assess their likely stability and liquid retaining charateristics at the fire ground. In practice the facilities available would probably fall short of those indicated, and additional fire brigade equipment would be required to compensate. Hydrant spacing is taken as 80m, each hydrant being equipped with four 70mm outlets. For the foam attack, pumping appliances would be located in marshalling areas A and B, and would feed monitors grouped on bund extension E. For the cooling operation, appliances would occupy marshalling areas C and D with monitors deployed along the bund C to D. It has been assumed that one hydrant would be within 25m of the pumps, three within 50m and four within 125m. With a similar arrangement for smaller tanks tables 6 and 7 show the derivation of the lengths of hose required.

e. Further Notes

Tables 3, 4 and 5 are used to derive the pumping rates of water and foam concentrate requirements and give a comparison between the Manual of Firemanship Recommended Minimum Application Rates (RMAR's), the NFPA codes and ESSO as typical of oil company standards. Report No 2 contains similar tables for smaller storage tanks.

It has been assumed that water supplies in the hydrant main are at sufficient pressure. The hydrant main should be capable of providing the full foam and cooling water demand at a residual pressure of not less than 2 bar to ensure a reliable suction supply to the pumps.

One further assumption is that fire fighting depends entirely on "over-the-top" projection of foam by fire brigade monitors. There are cases where fixed systems around the tank rim or for base injection of foam will be available and could be used to advantage, but such provision is by no means certain.

It should be noted that the deployment of equipment shown in the tables is theoretical, based on application rates in the standards and does not represent practical experience. There are few instances of fires in the 45 to 90m range being successfully extinguished. Those claimed have been achieved with the use of specialist equipment (see later in this report). The tables should be used purely as a means of comparing the practicalities of conventional deployment as against use of specialist equipment, rather than as a model for strategic planning.

The tables do not take account of the number of fire fighters required to deploy equipment. For large fire incidents many more personnel may be required than would be provided with the minimum number of appliances shown. Relief crews may be required, and many firefighters may be deployed in establishing a chain of foam concentrate supply, or in setting up hose runs to draw suction from natural water courses. It is recognised that these firefighters will be transported in fire appliances, but these appliances would not necessarily form part of the attack team.

2.4 LIMITATIONS OF CONVENTIONAL FIRE ATTACK

2.4.1 Tank Diameter

The effect of increased tank diameter on the severity of storage tank fires is well recognised in the standards. NFPA 11 gives an upper limit of 18m diameter for tanks which can be protected primarily by portable monitors. The draft BS and ISO standards set an equivalent limit of 20m diameter. All three standards give a limit of 9m diameter for tanks which can be extinguished with the use of hand branch lines as a primary means of protection.

The 18 and 20m limits quoted above are intended to show when fixed protection should be considered to augment fire brigade efforts, and as such they are perfectly valid.

The question of what is the diameter limit at which conventional deployment would become impractical in the absence of fixed protection is a different one, not addressed by the standards. Here there is the reported experience of those who have fought such fires, and this tends to indicate that 45m diameter is the practical upper limit.

Hence there is a grey area in the region of 18/20m diameter up to 45m diameter. Below the 18/20m limit both the standards and those with practical experience agree that conventional equipment is capable of success in "over-the-top" application. Between 18/20m and 45m diameter the standards no longer endorse the technique, but the practitioners maintain that success can be achieved. However, above 45m diameter the experienced firefighters believe conventional equipment cannot be successful. This reflects the increasing difficulty of fighting tank fires in tanks with larger diameters.

Tests have shown that a foam blanket when applied to the surface of a burning hydrocarbon liquid can spread over a distance of at least 30m. Theoretically it should be possible to use "over-the-top" applications for a tank of 60m diameter, but the angle of impingement probably reduces the effective spread that can be achieved back towards the direction of the monitors applying the foam. Tactics can be employed to induce rotational movement into the foam blanket (Report No 2, 3.2.8 (a) "Tricks of the Trade") which reportedly can assist in foam spread. The question of which foam type exhibits the best foam spread characteristics is the subject of debate and Report No 1 proposes improved medium scale tests which could give a comparative guide. In order to obtain absolute results for large storage tank fires it would be necessary to set up a full scale test programme, which would probably not be feasible in terms of cost.

2.4.2 Tank Height

In the UK liquid hydrocarbon storage tanks have been constructed up to 27m high. Generally these are tanks of older design in more congested refineries and depots in traditional industrial areas, for example along the North Thames Estuary. Where space allows tanks are built 15m high, and a variety of sizes exist between these two limits.

The ability of fire brigades to tackle storage tank fires depends to a large extent on the elevation and range of the foam monitors available.

In this area information from manufacturers is scanty, difficult to compare and generally only relates to the reach of the monitor jet, not the elevation obtainable. Results from the survey of equipment manufacturers are disappointing in this respect and allow only generalised conclusions.

Factors which can increase monitor range and trajectory height are; reduced expansion ratio of the foam, increased pump pressure, larger capacity nozzles, minimal obstructions in nozzle waterways, foam induction method, elevation of the monitor (above ground level).

For large storage tank fires expansion ratios in the range of 4 : 1 to 5 :1 are preferred for AFFF and in the region of 6 : 1 to 8 : 1 for fluoroprotein foams. Lower expansion ratios of 2 : 1 to 3 : 1 are used for AFFF but without any support from tests or certification.

Increased pump pressure is obviously useful in this regard. Normal brigade monitors and pumping appliances operate at 6 to 7 bars but can be increased to 10 bars for short periods, although there is resistance to this practice in the belief that it produces additional wear and tear. Increased pumping pressures do not produce a proportional increase in jet range because of air resistance factors. For 15m tank heights 6-7 bars should be adequate, but for 27m heights it is unlikely to be adequate and 10 bar pumping capacity should be available.

There is a significant improvement in range for larger capacity nozzles at constant working pressure. For example one manufacturer quotes a range of 61m for a 2,820 l/min nozzle, 73m for a 3,760 l/min and 79m for a 4,700 l/min nozzle all from the same design of monitor operating at 6.9 bars. This effect is attributed to the stored energy of the stream being related to its mass per unit length whereas frictional drag in air is related to the surface area of the jet. For larger jet sizes stored energy increases to a cube law whereas frictional drag would only follow the square of the jet diameter.

Several nozzles where the design includes significant obstructions exhibit low ranges. Finer and more consistent bubble size may be obtained as a counter balancing virtue.

Report No 2 considers the pressure loss characteristics of the standard type of induction equipment (section 5.2).

Monitor elevation is an obvious aid to reaching over high tank walls. Whilst elevated platforms and cranes achieve the ultimate improvement, significant advantages can be gained by mounting monitors on bunds or bund extensions. A 3m bund can make at least a 10% improvement on the height of the jet trajectory.

To summarise there is need for a formal test programme to compare the jet heights and ranges for various manufacturers combinations of equipment. It is at present difficult for brigades to obtain full impartial information on this subject, which is of particular importance where high sided tanks require protection.

2.4.3 Fuel

Crude Oil, un-refined products and mixtures of flammable liquids can be more difficult to extinguish in storage tank fires compared with single boiling point liquids.

The presence of volatile "light ends" tends to disrupt foam which has already been applied. If the blanket is not sufficiently deep then vapours can permeate the foam and catch fire greatly reducing the resistance to heat and flames. Fluoroprotein foams exhibit good resistance to fuel pick up which can similarly result in break down of the foam blanket by candling effects (See Report No 1).

Fuels which are capable of generating a hot layer, such as heavy crudes, have an inherent boilover risk discussed above, (Section 2.0).

The NFPA recommends higher application rates for water miscible fuel, and this subject is discussed in other reports (Report No 2 Table 7).

There is a difficulty with a fully involved cryogenic storage tank fire of ethylene, LPG or similar liquefied gases. To apply water or low expansion foam to the liquid surface would increase the evaporation rate and intensify the fire. The option of applying high expansion foam does not exist for a tank fire as it would for pool fires in retention bunds because high expansion foam cannot be projected. There is generally little alternative in these cases other than to pump out the tank contents as much as possible, cool the tank to avoid collapse and allow it to burn out under control.

2.4.4 Foam Types

The review of the various types of foam concentrate and the characteristics and properties of finished foams which appears in Report No 1 is relevant to their use on large storage tank fires.

Ideally foams for tank fire application should be used at an expansion ratio of 6 : 1 or more and should give a 25% drainage time in excess of 2 minutes in order to have good heat resistance properties.

Fluoroprotein or FFFP foams exhibit good heat resistance properties, such as edge sealing and burn back resistance but are less effective at lower expansion ratios than AFFF and alcohol resistant AFFF which works well at 4 : 1 or 5 : 1 ratios with 25% drainage times of 3 minutes or more. It is probable that if more attention were paid to foam quality in the course of monitor design then improvements could be made with minimal reduction in monitor range. There may be instances where the projecting range of foam monitors is marginal in which case use of lower expansion ratios would enable the foam to be delivered over the tank rim. As discussed in 2.3.2 above there are, however, many other factors which influence the distance which foam can be projected. Providing the foam can reach its target, use of higher expansion ratios is not itself a disadvantage.

The film forming characteristics of the AFFF group of products is not seen as conveying any inherent superiority, however, the ability to flow more readily and not to from a crust at the flame front may be a significant advantage. Fluoroprotein and FFFP foams do tend to form crusts to varying degrees under heat exposure. Some preliminary test work has been carried out but this is an area that would benefit from further study.

One feature of AFFF type foams is claimed both as an advantage and a disadvantage by the contending manufacturing interests. The ability of AFFF's to continue draining at a higher rate than FFFP and fluoroprotein is said to contribute to their rapid knockdown ability and yet detracts from the integrity of the blanket, necessitating continual replenishment during a fire and more frequent re-application after extinguishment to prevent re-ignition. Again this is a controversial area where independent tests are an unsatisfactory way of assessing foam performance against these larger fires. They over-emphasise the importance of edge sealing, they do not properly test the spreading characteristics of the foam, and the burn back element of the tests is difficult to relate to the practical fire situation. Suggestions for improved tests have been put forward in Report No 1.

2.4.5 Water Supply

Tables 1 and 2 show the large pumping capacities and water storage capacities required for fighting storage tank fires. The total volume of water used for cooling can be far in excess of that required for foam attack because of the longer durations involved. Where there is a need for extended periods of cooling it is usually necessary for fire brigades to set up a further pumping system from an estuary, lake or other natural "unlimited" source to replenish the on site fire water tanks or reservoirs. Several oil companies and specialist fire fighting groups have expressed the opinion that public brigades in both the UK and USA have used excessive amounts of cooling water in previous fire incidents. This is seen as diverting resources of organisational time, equipment and water from a possible foam attack, and contributing to difficult ground conditions in the area surrounding the fire. If tank spacing is adequate cooling can normally be kept to a minimum and resources should certainly be concentrated in making a successful foam attack even if cooling water requirements are cut back during the process. However, cooling of the rim of the tank on fire and of pressurized and exposed atmospheric tanks cannot be neglected, particularly during prolonged pre-burn periods whilst a foam attack is being organised. (See 2.3.2 a. above).

The on site fire pump and mains capacities at UK refineries are in some cases sufficient to meet these high demands and in others not. The most common deficiency seems to be the undersizing of fire mains in storage tank farm areas which are often remote from the fire pumps. The pumping rates shown in the tables reflect favourable conditions in that they assume a successful foam attack within 65 minutes, and on congested sites cooling water requirements can be considerably higher than those indicated. Hydrant mains should be capable of supplying the maximum flow rates required at a residual pressure in excess of 2 bars with a single section of main out of service in the hydraulically least favourable position.

In some areas fire brigade pre-planning exercises have highlighted deficiencies in supply which have been remedied by plant/refinery management. Work in this area should continue and be given priority by both fire brigades and management teams.

Fire hydrants should ideally be of the above ground type with four gated 70mm outlets and a single 100 or 125mm outlet referred to in the USA as a pumper connection.

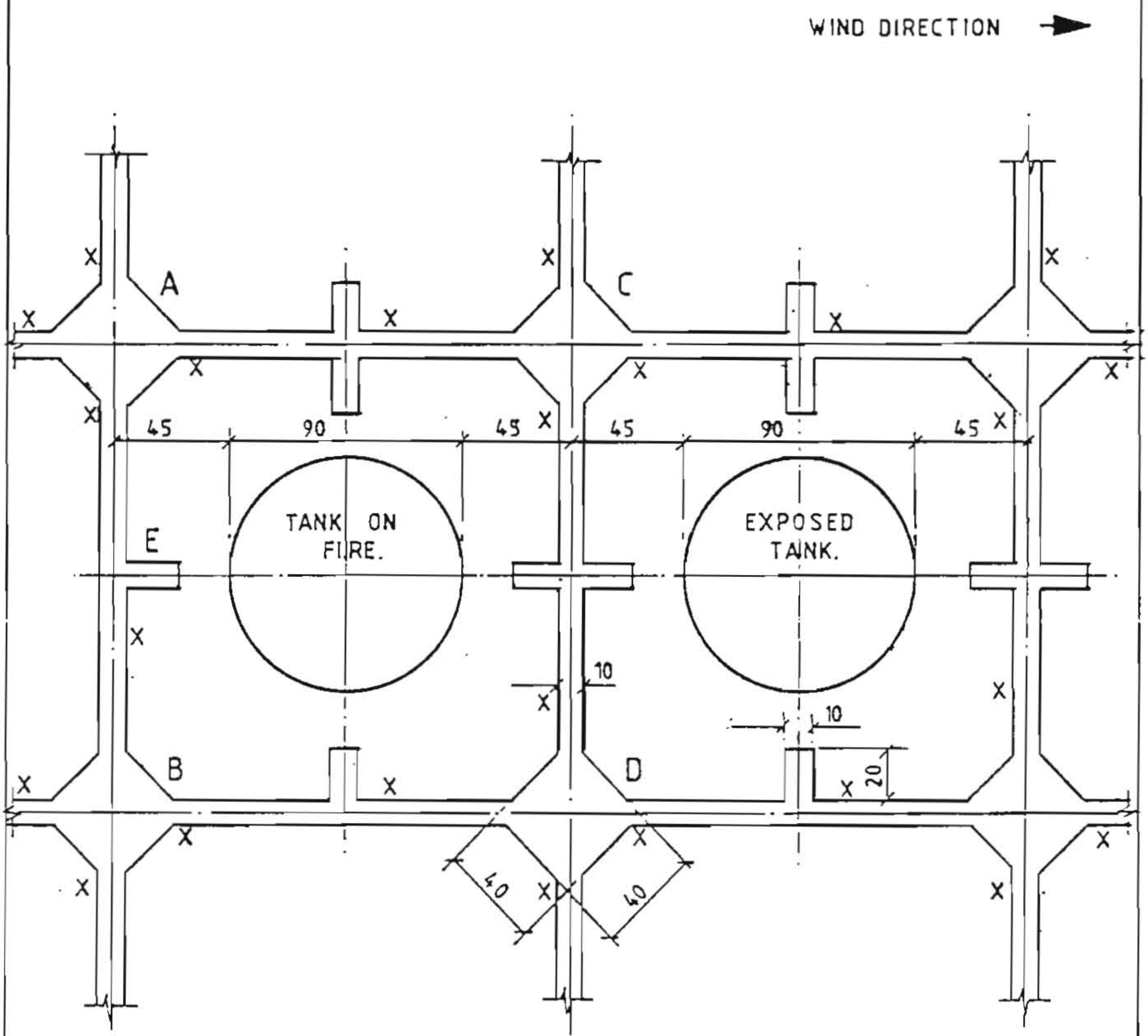
2.4.6 Quantities of Equipment

Tables 1 and 2 show clearly that even under favourable conditions very large quantities of equipment are required. The problems of fire ground organisation can become extreme with insufficient room to lay hose, park appliances, and operate monitors. When the traffic movement requirements of keeping foam dams replenished with concentrate are added and the number of men required is taken into account the logistics can become impractical at tank farms where space is restricted. This situation can itself be dangerous to those involved in that rapid retreat from a boil-over or redeployment of men and equipment due to a change in wind direction may be required. When failure of hoses, pumps, proportioners or monitors occurs space is required to remove the equipment concerned and replace it.

2.4.7 Logistics

The organisation of resources for a major incident of this nature is of itself a complex task. Sources of foam concentrate must be identified and transported to the fire ground, replacement fire crews, messing, first aid, control of the public are a few of the ancillary activities which require organisation.

The conclusion which it is intended should be drawn from this section is that any means that can be found of reducing the quantities of equipment required to tackle large tank fires is well worth while. In fact the logistical problems and lack of flexibility which would occur from the use of conventional fire brigade equipment against large tank fires show that this approach is unlikely to succeed, and could be dangerous to those involved.



X - HYDRANTS SPACED AT APPROX. 80m SEPARATION. FOUR 70 mm OUTLETS, ONE 123mm OUTLET PER HYDRANT.

E - LOCATION OF FOAM ATTACK MONITORS.

C to D - LOCATION OF WATER MONITORS FOR COOLING.

0 10 20 30 40 50 100 200

SCALE IN METRES.

LARGE STORAGE TANK FIRES.
IDEALISED ARRANGEMENT.
(90M DIA TANKS)

Ewbank Preece Limited

A MEMBER OF THE EWBANK PREECE CONSULTING GROUP

FIG. 1

8335-1187

TABLE 1

LARGE STORAGE TANK FIRES
CONVENTIONAL DEPLOYMENT
FOAM ATTACK PLUS COOLING WATER
(1 900 l/min monitors)

	Tank Diameters (15 m High)			
	45 m	**60 m**	**75 m**	**90 m**
Water (pumping rate) l/min	22 649	37 058	54 895	76 417
Total Water usage 65 min attack, 4 hrs cooling (litres)	3 680 000	5 773 000	8 300 000	11 277 000
Monitors (each 1 900 l/min)	13	21	30	41
Pumpers (one per monitor)	13	21	30	41
Hydrant Outlets (2 per pumper)	26	42	60	82
Lengths of 70 mm hose (each 25 m)	96	150	240	366

TABLE 2

LARGE STORAGE TANK FIRES
CONVENTIONAL DEPLOYMENT
DEPLOYMENT - FOAM ATTACK
(1 900 l/min monitors)

	Tank Diameters (15 m High)			
	45 m	**60 m**	**75 m**	**90 m**
Water (pumping rate) l/min	10 032	17 831	27 855	40 119
3% Concentrate (supply rate) l/min	310	551	862	1 241
Total Water Usage (Litres)	652 080	1 159 015	1 810 575	2 607 735
Total Concentrate Usage (Litres)	20 150	35 815	56 030	80 665
Monitors (each 1 900 l/min)	6	10	16	23
Pumpers (one per monitor)	6	10	15	22
Hydrant Outlets (2 per pumper)	12	20	30	44
Hydrants (4 outlets per hydrant)	3	5	8	11
Lengths of 70 mm hose (each 25 m)	44	70	112	204

TABLE 3

LARGE TANK FIRES

REQUIREMENTS FOR SOLUTION AND CONCENTRATE APPLICATION RATES

Tank Diameter	Top Area	Solution RMAR l/min			Concentrate 3% l/min			Concentrate 6% l/min		
		MOF	ESSO	NFPA	MOF	ESSO	NFPA	MOF	ESSO	NFPA
m	m^2	4.5	4.9	6.5						
45	1 591	7 160	7 796	10 342	215	234	310	430	468	621
60	2 828	12 726	13 857	18 382	382	416	551	764	831	1 103
75	4 418	19 881	21 648	28 717	596	649	862	1 193	1 299	1 723
90	6 363	28 634	31 179	41 360	859	935	1 241	1 718	1 871	2 482

MOF - Manual of Firemanship
RMAR - Recommended Minimum Application Rate

N.B. All figures are rounded to the nearest integer.

TABLE 4

LARGE TANK FIRES

TOTAL VOLUME OF CONCENTRATE REQUIRED

Tank Diameter m	**Top Area m^2**	**Litres of 3% Concentrate MOF 30 min**	**ESSO 90 min**	**NFPA 65 min**	**Litres of 6% Concentrate MOF 30 min**	**ESSO 90 min**	**NFPA 65 min**
45	1 591	6 450	21 060	20 150	12 900	42 120	40 365
60	2 828	11 460	37 440	35 815	22 920	74 790	71 695
75	4 418	17 880	58 410	56 030	35 790	116 910	111 995
90	6 363	25 770	84 150	80 665	51 540	168 390	161 330

N.B. All figures are rounded to the nearest integer. This leads to slight discrepancies between 3% and 6% figures, but the differences are not of a significant order of magnitude.

MOF - Manual of Firemanship

TABLE 5

LARGE TANK FIRES

WATER REQUIREMENTS FOR FOAM MAKING
(Pumping Rate and Total Volume)

Tank Diameter m	Top Area m^2	Water Pumping Rate l/min			Total Volume of Water litres		
		MOF	ESSO	NFPA	MOF 30 min	ESSO 90 min	NFPA 65 min
45	1 591	6 945	7 562	10 032	208 350	680 580	652 080
60	2 828	12 344	13 441	17 831	370 320	1 209 690	1 159 015
75	4 418	19 285	20 999	27 855	578 550	1 889 910	1 810 575
90	6 363	27 775	30 244	40 119	833 250	2 721 960	2 607 735

N.B. All figures are rounded to the nearest integer.

Based on use of 3% foam concentrate.

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TABLE 6

LARGE STORAGE TANK FIRES
REQUIREMENTS FOR 70 mm HOSE FOR FOAM ATTACK AT NFPA RATES
Hydrants to Pumps (Inlet)

Tank Diameter	No of. Monitors (1,900 l/min) Needed (Note 1)	No. of Hydrants Needed	No. of Hydrant Outlets Needed (up to 4 per hydrant)	Distance Hydrants to Pumps (see note 2)	No. of Hose Runs for Each Distance	No. of 25 m Lengths Required	Total Inlet Length 25 m Hose
45 m	6	3	12	1 < 25 m	4	4	20
				2 < 50 m	8	16	
60 m	10	5	20	2 < 25 m	8	8	
				3 < 50 m	12	24	30
75 m	15	8	30	2 < 25 m	8	8	
				6 < 50 m	22	44	52
90 m	22	11	44	2 < 25 m	8	2	
				6 < 50 m	24	48	116
				4 < 125 m	12	60	

Note 1 Number of monitors is the NFPA water pumping rate (Table 5) divided by 1 900 l/min.

Note 2 This column should be read as per the following example; 4 < 125 m means four hydrants are located less than 125 m from the pump they supply.

TABLE 7

LARGE STORAGE TANK FIRES
REQUIREMENTS FOR 70 mm HOSE FOR FOAM ATTACK AT NFPA RATES.
Pumps to Monitors (Outlet)
plus Total Requirement (Inlet plus Outlet)

Tank Diameter	No. of Monitors Needed	No. of Hose Runs Needed	Length of Runs (Note 1)	No. of 25 m Lengths Required	Overall Total (Inlet and Outlet)
45 m	6	12	< 50 m	24	44
60 m	10	20	< 50 m	40	70
75 m	15	30	< 50 m	60	112
90 m	22	44	< 50 m	88	204

Note 1 < 50 m - less than 50 m

TABLE 8

LARGE STORAGE TANK FIRES

CONVENTIONAL DEPLOYMENT
- COOLING WATER
(1 900 l/m monitors)

	Tank Diameters m (Height m)					
	45			60	75	90
	(15)	(20)	(25)	(15)	(15)	(15)
Water (pumping rate) l/min	12 617	15 025	17 432	19 227	27 040	36 057
Total Water Storage (4 hrs) litres	3 028 000	3 606 000	4 184 000	4 614 000	6 490 000	8 654 000
Monitors (each 1 900 l/min)	7	9	10	11	15	20
Pumps (one per monitor)	7	9	10	11	15	20
Hydrant Outlets (2 per pumper)	14	18	20	22	30	40
Hydrants (4 outlets per hydrant)	4	5	5	6	8	10
Lengths of 70mm hose (each 25 m)	52	64	72	80	112	176

TABLE 9

LARGE STORAGE TANK FIRES
COOLING WATER REQUIREMENTS

Tank Diameter m	Top Area m^2	Height m	Vertical Area m^2	Total Area m^2	1/3 Total Area m^2	1/3 Area x 10.2 $l/m^2/min$ litres/min	Total Water 65 min litres	Diameter Total Water 4 hrs litres
45	1 591	15	2 121	3 712	1 237	12 617	820 000	3 028 000
45	1 591	20	2 828	4 419	1 473	15 025	977 000	3 606 000
45	1 591	25	3 535	5 126	1 709	17 432	1 133 000	4 184 000
60	2 828	15	2 828	5 656	1 885	19 227	1 250 000	4 614 000
75	4 418	15	3 535	7 953	2 651	27 040	1 758 000	6 490 000
90	6 363	15	4 242	10 605	3 535	36 057	2 344 000	8 654 000

TABLE 10

LARGE STORAGE TANK FIRES
REQUIREMENTS FOR 70mm HOSE FOR COOLING
Hydrants to Pumps (Inlet)

Tank Diameter (Height)	No. of Monitors (1,900 l/min) Needed	No. of Hydrants Needed	No. of Hydrant Outlets Needed (up to four per hydrant)	Distance Hydrants to Pumps	No. of Hose Runs for Each Distance	No. of 25 m Lengths Required	Total Inlet Lengths of 25 m Hose (Inlet)
45 (15)	7	4	14	1 < 25 m 3 < 50 m	4 10	4 20	24
45 (20)	8	4	16	2 < 25 m 2 < 50 m	8 8	8 16	24
45 (25)	10	5	20	2 < 25 m 3 < 50 m	8 12	8 24	32
60 (15)	11	6	22	2 < 25 m 4 < 50 m	8 14	8 28	36
75 (15)	15	8	30	2 < 25 m 6 < 50 m	8 22	8 44	52
90 (15)	19	10	38	2 < 25 m 6 < 50 m 2 < 125 m	8 24 6	8 48 30	86

Note 1 Number of monitors is pumping rate in column 7 Table 9 divided by 1,900 l/min

Note 2 This column should be read as per the following example;
4 < 125 m means four hydrants are located less than 125 m from the pump they supply.

TABLE 11

LARGE STORAGE TANK FIRES
REQUIREMENTS FOR 70 mm HOSE FOR FOAM ATTACK
Pumps to Monitors (Outlet)
plus Total Requirement (Inlet plus Outlet)

Tank Diameter	No. of Monitors	No. of Hose Runs	Length of Runs	No. of 25 m Lengths Required (Outlet)	Overall Total (Inlet and Outlet)
45 (15)	7	14	average 50 m	28	52
45 (20)	8	16	average 50 m	32	56
45 (25)	10	20	average 50 m	40	72
60 (15)	11	22	average 50 m	44	80
75 (15)	15	30	average 50 m	60	112
90 (15)	19	38	average 50 m	76	162

SECTION 3

TECHNICAL OPTIONS

3.1 INTRODUCTION

This section examines some of the specialist equipment and facilities that can be employed in tackling large tank fires and concludes by considering the implications of their use. In all cases there is a need for further assessment of such equipment to quantify the advantages and evaluate performance characteristics. It is considered, however, that it is unnecessary to await the outcome of such an assessment before such equipment is put into service. To do so could be considered over cautious in the light of the shortcomings of existing equipment in tackling large tank fires, and because the advantages of larger equipment are clear, although as yet unquantified.

3.2 LARGE NOZZLES

In recent years large capacity foam monitors have been available from a restricted number of suppliers. More companies are entering this market and a range of products is now available from alternative sources.

Large capacity monitors are at present manufactured in the United States in sizes of 1 000 US gpm (3 800 l/min) 2 000 US gpm (7 600 l/min) and 4 000 US gpm (15 200 l/min). The advantages in their use are;

- larger nozzles have an inherently longer range than their smaller counterparts under the same conditions of water pressure,

- the larger jets are more resilient to the heat effects involved in penetrating the fire plume from a storage tank,

- the localised application rate at impact is higher than with smaller streams making it easier to achieve a "bite" on the fire,

- smaller numbers of monitors are required,

- they can be readily used with large diameter hose,

- success can be claimed in their use against large tank fires.

The disadvantages are;

- they are useful for a limited number of specialist tasks,

- there is a cost penalty both in purchase of specialist equipment and in training fire fighters in its use,

- they are heavier than 1 900 l/min monitors although the 3 800 l/min and 7 600 l/min sizes can still be manoeuvred by hand and deployed as ground monitors,

- some of the large monitor designs have shorter ranges than would be expected, primarily because of internal obstructions in the bore designed to produce improved foam working,

- technical information on some of the monitors is scanty, particularly regarding range, trajectory, footprint, feathering (fallout from the stream) etc., and some equipment is not listed by testing authorities.

Monitors of 3,800 l/min capacity are available for FFFP and fluoroprotein foams but the large monitors currently on the market are specific to AFFF or alcohol resistant AFFF. (ie. 7,600 l/min and 15,200 l/min sizes).

3.3 LARGE PUMPS

Irrespective of whether or not large monitor nozzles are used there is a case for consideration of use of larger sized pumps. These could either take the form of 4 500 l/min pumping appliances, or skid mounted pumps of similar or larger capacity. Pump sizes could be selected so that they match the capacity of the monitors to be supplied (e.g. one pump per monitor, or one pump per 2 monitors). Such pumps would provide the opportunity to use large sizes of suction hose, as well as large delivery hose, and a higher nozzle pressure of 10 bars could be used on a continuous basis. Hose and fittings can be purchased to match the physical requirements of the equipment and the higher pressures.

Disadvantages of cost, specialist use and additional training requirements apply as for large nozzles. The advantage, which is of great benefit, is the reduction in crews needed for the foam attack, space requirements and logistical complexity.

Induction equipment is discussed fully in Report No. 2, and the observations made there apply equally to use with large volume pumps and monitors.

3.4 LARGE HOSE

Use of large diameter hose is considered vital to enable control and flexibility on the fireground. One 125 mm diameter suction hose and one 125 mm diameter discharge hose are sufficient to supply a single 3 800 l/min monitor, compared with four 70 mm hoses. In addition hose laying vehicles should be considered to rapidly deploy and retrieve hose lengths. These are used for specialist applications both in the USA and in Europe, but only a few such vehicles are in service in the U.K. Where long runs of hose are required, as may well be the case with storage tank fires, the time saved in deployment by such a vehicle can be of crucial importance.

Where possible large diameter suction hose should be connected directly, or via a junction coupling, into the large diameter outlet or "pumper connection" of a site hydrant. Where these do not exist 4 to 1 adaptor headers should be fabricated to enable 70mm outlets to be coupled to a 125mm suction hose.

3.5 BUND ARCHITECTURE

Typical storage tank bunds in the UK are 3m high sloping sided earth banks topped with a 3-4m wide roadway. Little or no provision is made for vehicle marshalling or hose runs. The arrangement shown in Fig. 1 incorporates several features of design which should be considered for new constructions or refurbishment of existing facilities viz;

- marshalling points for fire appliances,

- 10m wide roadways to allow hose runs and vehicles to pass,

- bund extension piers. Where it is difficult or impossible to project foam over tank walls from the surrounding bund wall such extensions would provide a suitable platform for monitors reducing the range and increasing the elevation above the bund floor. In addition there is a considerable degree of safety for fire fighters in being able to tend and train monitors outside of the bunded area, in the event of a boilover or slopover their elevation would provide additional time to effect an escape, and they would be on a paved exit route where vehicles could be readily used.

- concrete faced bund walls to prevent erosion by weather and by water from burst hoses etc. Special care should be taken in bund maintenance to ensure no points of weakness develop (for example around pipework penetrating bunds). When a bund is full of liquid any leakage can lead to rapid erosion and loss of containment.

- For liquefied gases lower diversion walls can be provided within the main bund to channel small spills to a catchment pit away from the tank and close to the main bund wall for ease of extinguishment.

- Facilities for drainage of bunds should be provided under control of an isolation valve.

3.6 FIXED EQUIPMENT

The role of fixed fire protection is of great importance in minimising the extent of manual fire fighting required. For floating roof tanks top pourers are usually designed for rim seal protection only and are likely to be damaged in a fully involved tank fire. Similarly with fixed roof tanks, top pourers are often damaged during the ignition phase.

Subsurface injection, on the other hand, overcomes this problem and can be particularly useful for fixed roof tank fires where there is no obstruction in the form of a sunken roof structure. The extent of foam spread from sub-surface injection is limited, probably to less than 30m in any one direction, so for larger tanks "over-the-top" application is still essential to achieve extinguishment.

In determining the requirements of equipment and materials for manual fire fighting no account should be taken of fixed protection, since it can be out of service when required, and is still by no means a common protection feature on storage tanks.

Although fixed fire protection systems are strictly beyond the scope of this report it is worth noting that the use of both base injection systems and "over-the-top" application can be the most effective combination available for large tank fires.

For tanks over 45m diameter, which present a considerable challenge to any manual system of foam application, it is recommended that base injection systems should be provided.

3.7 ELEVATED EQUIPMENT

In Report No. 2 the question of elevating the monitors and nozzles was discussed.

By this method it may be possible to direct the foam to the required point on the fuel surface which could be particularly useful as a method of assisting the foam to flow the whole way across the tank by:-

- Advancing the foam landing zone as the foam front progresses
- Directing the foam stream at the foam blanket near the side of the tank to encourage a circular movement

Foam delivery equipment can be elevated by:-

- Purpose made foam towers
- Mounting the monitor/nozzle on an elevating platform
- Fixing the monitor/nozzle to the jib of a crane

Care must be taken in the case of the elevating platform as the jet reaction may effect the stability of the unit.

In all the methods of elevating equipment some method of remote control would be a distinct advantage.

3.8 IMPLICATIONS OF USE OF SPECIALIST EQUIPMENT

The tables 12 to 16 show the development of the logistics of fire fighting with specialist equipment in direct comparison to the use of conventional equipment.

There is no immediately obvious saving in the quantities of water or concentrate required but the percentage savings in equipment compared with conventional deployment are as follows:-

	3 800 l/min Monitors and Pumps	7 600 l/min Monitors and Pumps
Monitors	48-50%	66-75%
Pumpers	48-50%	66-75%
Hose lengths	73-75%	66-75%

In addition transportation of foam concentrate can be greatly simplified by the use of one, or possibly two foam dams.

The numbers of fire fighters involved directly in the foam attack can be reduced along with the reduction in equipment with a corresponding lower requirement for standby crews and logistic support. It is far more feasible to redeploy the foam attack when needed since less items of equipment would require to be handled. There also is a better chance of extinguishing the fire both because deployment can be achieved earlier, and because large nozzles are more effective in penetrating the fire plume and getting a "bite" on the fire.

Likewise the cooling water application can be simplified by use of large suction hose, large pumps and large delivery hose to distribution headers. However it is envisaged that 1 900 l/min monitors would still be used for cooling because a smaller number of larger monitors would distribute the water less evenly, and there are not the same problems with monitor range when projecting water.

It is considered that use of specialist equipment would increase the range of storage tank fires that could be successfully tackled and extinguished. For fires in tanks of less than 45m it would greatly simplify the process of extinguishment at less risk to all concerned. For larger storage tanks it would be possible to extinguish fires that are beyond the capabilities of present equipment.

TABLE 12

LARGE STORAGE TANK FIRES
SPECIALIST EQUIPMENT DEPLOYMENT

	Tank Diameters (15 m High)			
	45 m	**60 m**	**75 m**	**90 m**
Water (pumping rate) l/min	10 032	17 831	27 855	40 360
3% Concentrate (supply rate) l/min	310	551	862	1 241
Total Water Usage (litres)	652 080	1 159 015	1 810 575	2 607 735
Total Concentrate Usage (litres)	20 150	35 815	56 030	80 665
Monitors (3 800 l/min)	3	5	8	11
Pumps (3 800 l/min)	3	5	8	11
Hydrant Outlets	3	5	8	11
Hydrants	3	5	8	11
Lengths 125 mm hose (each 25 m)	11	18	30	51
Monitors (7 600 l/min)	2	3	4	6
Pumps (7 600 l/min)	2	3	4	6
Hydrant Outlets	4	6	8	12
Hydrants	4	6	8	12
Lengths 125 mm hose (each 25 m)	15	22	30	58

TABLE 13

LARGE STORAGE TANK FIRES
REQUIREMENTS FOR 125 mm HOSE FOR FOAM ATTACK
Hydrants to Pumps (Inlet)

Pumps and Monitors 3 800 l/min

Tank Diameter	No. of Monitors Needed (3 800 l/min) (see Note 1)	No. of Hydrants	No. of Hydrant Outlets Needed (one large outlet per hydrant)	Distance of Hydrants from Pumps (see Note 1)	No. of Hose Runs for Each Distance	No. of 25 m Lengths Required	Total Inlet Lengths of 25 m Hose
45 m	3	3	3	1 < 25 m 2 < 50 m	1 2	1 4	5
60 m	5	5	5	2 < 25 m 3 < 50 m	2 3	2 6	8
75 m	8	8	8	2 < 25 m 6 < 50 m	2 6	2 12	14
90 m	11	11	11	2 < 25 m 6 < 50 m 3 < 125 m	2 6 3	2 12 15	29

Note 1 Number of monitors is the NFPA water pumping rate (Table 5) divided by 3,800 l/min.

Note 2 This column should be read as per the following example; 4 < 125m means four hydrants are located less than 125m from the pump they supply.

TABLE 14

LARGE STORAGE TANK FIRES
REQUIREMENTS FOR 125 mm HOSE FOR FOAM ATTACK
Pumps to Monitors (Outlet)
plus Total Requirement (Inlet plus Outlet)
Pumps and Monitors 3 800 l/min

Tank Diameter	No. of Monitors	No. of Hose Runs	Length of Runs	No. of 25 m Lengths Required	Overall Total (Inlet and Outlet)
45 m	3	3	< 50 m	6	11
60 m	5	5	< 50 m	10	18
75 m	8	8	< 50 m	16	30
90 m	11	11	< 50 m	22	51

TABLE 15

LARGE STORAGE TANK FIRES
REQUIREMENTS FOR 125 mm HOSE FOR FOAM ATTACK
Pumps to Monitors (Outlet)
Pumps and Monitors 7 600 l/min

Tank Diameter	No. of Monitors	No. of Hose Runs	Length of Runs	No. of 25 m Lengths Required	Overall Total (Inlet and Outlet)
45 m	2	4	< 50 m	8	15
60 m	3	6	< 50 m	12	22
75 m	4	8	< 50 m	16	30
90 m	6	12	< 50 m	24	58

TABLE 16

LARGE STORAGE TANK FIRES
REQUIREMENTS FOR 125 mm HOSE FOR FOAM ATTACK
Hydrants to Pumps (Inlet)
Pumps and Monitors 7 600 l/min

Tank Diameter	No. of Monitors Needed (7 600 l/min) See Note 1	No. of Hydrants	No. of Hydrant Outlets Needed (one large outlet per hydrant)	Distance of Hydrants from Pumps (see Note 2)	No. of Hose Runs for Each Distance	No. of 25 m Lengths Required	Total Inlet Lengths of 25 m Hose
45 m	2	4	4	1 < 25 m	1	1	7
				3 < 50 m	3	6	
60 m	3	6	6	2 < 25 m	2	2	10
				4 < 50 m	4	8	
75 m	4	8	8	2 < 25 m	2	2	14
				6 < 50 m	6	12	
90 m	6	12	12	2 < 25 m	2	2	34
				6 < 50 m	6	12	
				4 < 125 m	4	20	

Note 1 Number of monitors is the NFPA water pumping rate (Table 5) divided by 7,600 l/min.

Note 2 This column should be read as per the following example; 4 < 125m means four hydrants are located less than 125m from the pump they supply.

SECTION 4

ORGANISATIONAL ASPECTS

4.1 INTRODUCTION

This section considers the various ways in which a specialist fire fighting capability for large storage tank fires could be achieved in the UK. Other organisational aspects are also addressed.

In the UK some operators adopt the stance that since the fire service has a duty to extinguish fires and the rates sustain the fire service, that money spent on additional men or equipment for an in-house fire team is unnecessary. In other countries where the obligations of the fire service are less wide ranging, operators take more responsibility for their own protection upon themselves by mutual aid systems or their own plant fire brigades. The result is that in the UK plant fire teams and mutual aid systems are less well funded and equipped than in countries of an equivalent standard of development. Equally at present the UK fire service is not equipped or organised to fully fill this gap.

4.2 SPECIALIST TEAMS WITHIN THE UK FIRE SERVICE

If a specialist team were to be established within the UK fire service it would be possible to respond to incidents in most parts of the country within 4 hours.

A possible structure for such a team would be to have a series of four or five stations each equipped with a basic quantity of specialist equipment and a portion of a shared foam stock. The equipment envisaged would be sufficient to mount a foam attack on the largest tank in the sector of the country covered by each specialist team. For all but the largest incidents the teams could operate independently within their local area. For major incidents the local team could be reinforced by the others.

To minimise the cost it is suggested that the teams could be established in premises attached to existing major fire stations in areas with a concentration of chemical or petrochemical risks. Staff could be assigned to team duties for a fixed period after which they could rotate back to normal duties. It would be possible for the officers and fire fighters assigned to these duties to combine them with regular duties, particularly emergency callout. To keep a specialist team in reserve exclusively for a relatively rare event such as a tank fire would be both wasteful and undesirable from a morale standpoint.

In this way the specialist experience and knowledge gained by such a group would, in time, become disseminated throughout the fire service. These units would be well placed to press industrial operators for improvements in water supplies and mains.

4.3 COMMERCIAL TEAMS

There exist in various parts of the world a number of highly skilled and successful commercial organisations that specialise in responding to flammable liquid fires both on and offshore.

These organisations are quite costly to run but can provide a great deal of experience, hardware, foam and manpower.

The advantage of employing this method of dealing with an emergency incident, is that there is less need for the refinery fire team or the fire services to purchase and store large quantities of equipment and volumes of foam which they may never be called upon to use. On the other hand it would be difficult for such an organisation to mobilise equipment to remote areas of this country from overseas within a reasonable time of the fire starting. It is probable that a delay of at least 24 hours would be involved with the continuing air pollution and possibly an increasing risk of boilover.

A further disadvantage is that the expertise in this type of fire fighting would remain outside of the fire service and outside the country.

4.4 MUTUAL AID

Mutual aid organisations are operated in a number of parts of the world where there are large centres of high risk industry. Examples are the Channel Industries Mutual Aid (C.I.M.A.) for the Houston Ship Channel industries in the United States of America, and the Botlek Mutual Aid in the Rotterdam Europoort area in Holland.

The object of these organisations is to bring together the fire fighting and rescue facilities of the industries in the local area for mutual assistance in case of an emergency.

Each member company of a mutual aid scheme must hold a specified reserve manpower, material and equipment for its own protection, but a proportion of which is made available for release to other members of the organisation.

The mutual aid groups operated overseas are well funded and organised. If a company is unable or unwilling to dedicate manpower and material for mutual use in an emergency, it will not be accepted as a member and may therefore not receive mutual aid.

In some areas of the UK where the oil and chemical industry operate in quite large numbers the Fire Brigades and the industrial operators have come to a form of mutual agreement whereby the provision of foam stocks and specialist equipment is divided and as far as is commercially possible the same type of foam concentrate is stored.

4.5 COMMAND AND CONTROL

Whilst preplanning is of great importance in the successful handling of major incidents such as large storage tank fires there are many situations where plans need to be changed at the last moment. This is particularly true when circumstances can change rapidly with a change in wind direction or because of the threat of a boilover.

This can place the Senior Officer in charge of the fire in the difficult position of having to make a large number of decisions and orders at high speed. It can easily occur that the Senior Officer becomes a "bottleneck" in the command and control system when rapid changes are required.

There is also a strong argument for an expert support team drawn from both inside and outside the fire service, to assist the senior officer in charge of a large tank fire. This team could include an engineer charged with assessing heat radiation effects and cooling water requirements, an expert on the tactics of launching the foam attack, and possibly a media spokesman. Equally it is of the utmost importance that all fire officers who could be placed in the position of either being in charge of a major fire incident, or responsible for its preplanning and risk assessment, should have had recent realistic training in all aspects of this specialist work.

For this reason it is proposed that preplanning activities should be extended to include the actions needed for the above alternatives. The objective of rapid changes of tactics could be achieved by the application of an interactive video disc command and control simulator. Such a training aid should assist principal officers to master the details of what is required for the many different circumstances likely to be encountered. Another option would be to preplan the actions required in the form of a decision tree which the senior officer could use as a checklist.

SECTION 5

DISCUSSION OF RESULTS

5.1 INTRODUCTION

The various points for action, discussion or research which have been raised in this report are briefly summarised for reference. There is a certain amount of interrelation between the results derived from this report and from other reports in this series.

5.2 WHEN TANK FIRES SHOULD BE TACKLED

Large storage tank fires should be tackled in all cases with the appropriate foam and water equipment and materials. Foam attack should be delayed until sufficient resources are available for a full 65 minute attack at NFPA RMAR's. The only case where a "let it burn" policy is advised is for liquefied gas storage tanks subject to a fully involved fire. In such cases tank cooling and pumpout of the contents is advised allowing controlled burnout.

5.3 PRIORITY USE OF WATER

Foam attack should be given priority over the use of water for cooling, except that the rim of the tank on fire, exposed pressurised tanks and severely exposed atmospheric tanks may require cooling to be maintained during a foam attack.

5.4 FIXED SYSTEMS

Base injection foam systems are recommended for all tanks (fixed and floating roof) over 45m in diameter. These systems can prove a valuable aid to manual fire fighting methods.

5.5 MONITOR NOZZLES

An independent study is proposed of the range, trajectory, footprint, and feathering or fallout characteristics of foam streams from commercially available monitor nozzles. There is insufficient information available from manufacturers to allow brigades to select the correct equipment for their risks.

5.6 PUMP PRESSURE

Fire pumps for service in large tank fires should be capable of operating at 10 bars pressure for extended periods of time.

5.7 FIRE MAINS

The fire brigades should continue and extend their review of the fire mains capacities at refineries and tank farms within their areas. Where mains capacities are inadequate or have insufficient redundancy built in then brigades should press the facility management for improvements.

5.8 FIRE HYDRANTS

All fire hydrants provided to protect flammable liquid storage tank farms should be of the above ground type with four 70 mm gated outlets and one 100 mm or 125 mm pumper connection.

5.9 SPECIALIST EQUIPMENT

Specialist fire fighting equipment should be acquired for use in the UK. This should include large capacity nozzles, large pumps, large hoses and low pressure loss induction equipment.

5.10 BUND WALL DESIGN

Bund walls around large storage tanks should be upgraded to provide adequate marshalling points, bund extension piers where necessary for projection of foam over the tank side, concrete faced bund walls, wider roads for 2 way traffic use plus provision for hose runs, routine inspection and maintenance to maintain the bund integrity.

Liquefied flammable gas storage tanks should be provided with internal diversion walls around the valve area to direct any small spillage to a catchment pit remote from the tank.

5.11 SPECIALIST FIRE FIGHTING CAPABILITY

A specialist team should be set up to tackle storage tank fires using the specialist equipment now available. The arrangements made should ensure a maximum 4 hour response to tanks throughout the UK and they should also ensure that the expertise is developed within the UK fire service.

5.12 TRAINING IN LARGE INCIDENT COMMAND AND CONTROL

All fire officers who are in a position where they might take charge of a large fire incident should have up to date training in the methods and techniques.

5.13 FURTHER TECHNIQUES IN COMMAND AND CONTROL

Decision trees and use of specialist advisers should be incorporated in the preplanning of major fire incidents.

APPENDIX A

GLOSSARY OF TERMS

This appendix gives a number of definitions referred to in the text of the report.

APPENDIX A

GLOSSARY OF TERMS

The following terms are used throughout the chapters of this report and should be interpreted as illustrated by the definitions that are given.

Accelerated Ageing - Storage of foam concentrate for short periods at high temperatures, to indicate long term storage properties of the foam concentrate at ambient temperatures.

AFFF (Aqueous Film Forming Foam) - A synthetic foam concentrate containing detergents and fluorocarbon surfactants that control the physical properties of water so that it may be able to float and spread across the surface of some liquid hydrocarbon fuels.

Alcohol Resistant Foam Concentrate - A specially formulated foam concentrate for use on alcohol and other water miscible risks.

Application Rate - The rate at which a foam solution is applied to a fire. Usually expressed as litres of foam solution per square metre of fire area exposed per minute.

Aspirated Foam - A general term to indicate expanded foam which has an expansion ratio typically 4:1 or more.

Aspiration - The addition or entrainment of air into the foam solution.

Balanced Pressure Proportioning - A foam concentrate induction system designed to inject automatically the correct quantity of foam concentrate into a water stream over a wide range of variable flows and pressures.

Base Injection - The introduction of expanded finished foam beneath the surface of certain flammable and combustible hydrocarbons, to effect fire extinguishment.

Boiling Liquid Expanding Vapour Explosion (B.L.E.V.E.) - Explosive fire balls caused by the rapid escape of flammable gas, discharging from sealed pressurised containers, which have ruptured/failed due to adverse heat exposure.

Boil Over - Violent ejection of flammable liquid from its container, caused by vaporisation of a water layer beneath the body of the liquid. It will generally only occur after a length burning period, in wide flashpoint range products, such as crude oil.

Branchpipe - A hand-held foam maker and nozzle.

Burn Back Resistance - The ability of a foam blanket to resist direct flame and heat impingement.

Bund Area - A dyked area surrounding a storage tank, which is designed to contain the liquid product in the event of a tank rupture.

Candling - Refers to the thin intermittent flames that can move over the surface of a foam blanket even after the main liquid fuel fire has been extinguished.

Chemical Foam - A foam produced by mixing two or more chemicals. The bubbles are typically caused by carbon dioxide released by the reaction.

Classification of Fire

CEN System (UK and Europe) - Used in this report

Class 'A' Fire - A fire in materials such as wood and paper where the cooling effect of water is of paramount importance in extinguishing the risk.

Class 'B' Fire - A fire involving a flammable liquid or liquefiable solid where a blanket or smothering effect is of major importance in extinguishment.

Class 'C' Fire - A fire involving a flammable gas or gases.

Class 'D' Fire - A fire involving a metal such as magnesium, sodium, lithium and potassium etc.

US Classification (NFPA 10-1984) - Alternative System used in the U.S.A.

Class 'A' Fire - Fires which occur in ordinary combustible materials, i.e. wood, paper, rubber and certain plastics etc.

Class 'B' Fire - Fires which occur in flammable liquids, oils, tars, lacquers etc., and including flammable gases.

Class 'C' Fire - Fires involving energised electrical equipment where the electrical non conductivity of the extinguishing agent is particularly important.

Class 'D' Fire - Fires which occur in metals such as magnesium, zirconium lithium and potassium etc.

Combustible Liquid - Any liquid having a flashpoint at or above 37.8°C (100°F).

Critical Application Rate - The minimum rate at which foam solution can be applied to a given fire in order to achieve extinction.

Drainage Rate - The rate at which water drains from an expanded finished foam.

Dual Agent - See Twin Agent Method.

Eductor - American term for Inductor (q.v.).

Expansion Ratio - The ratio of total foam volume to the volume of foam solution.

Film Forming Foam - A foam that can produce a spreading, vapour securing, thin aqueous film on the surface of certain hydrocarbon fuels.

FFFP (Film Forming Fluoroprotein Foam) - A protein based foam concentrate with film forming characteristics.

Flammable Liquid - Any liquid having a flashpoint below 37.8°C (100°F).

Flashback - Re-ignition of flammable liquid caused by exposure of its vapours to a source of ignition such as a hot metal surface or a spark.

Flashpoint - The lowest temperature at which a flame can propagate in the vapours above a liquid.

Fluoroprotein Foam Concentrate - A foam concentrate based on hydrolised protein with surface active fluorocarbon concentrates added.

Finished Foam - The homogeneous blanket obtained by mixing water, foam concentrate and air.

Foam Generator - See Foam Maker.

Foam Maker - A device designed to introduce air into a pressurised foam solution flow.

Foam Pourer - A device designed to deliver expanded foam gently onto a burning liquid.

Foam Solution - A homogeneous mixture of water and foam concentrate.

Foam Water Sprinkler - An open air aspirating delivery head whose water discharge pattern closely resembles those for standard sprinklers.

Foam Water Spray Nozzle - An open air aspirating delivery head whose discharge pattern is specific to the individual nozzle.

Friction Loss - The loss of pressure in a pipe line resulting from resistance to flow imposed by the inside of the pipe and by changes in flow direction such as elbows and T-pieces. Friction losses are greater with expanded foams than with foam solutions.

GRP - Glass reinforced plastic used for construction of some storage tanks and equipment.

Hazmat - A proprietary trade name used to describe special types of foam which can be used on certain alkaline and acid materials.

High Back Pressure Generator (Forcing Foam Maker) - HBPGs introduce air into the foam solution to produce expanded foam in a base injection system.

High Expansion Foam (HEX) - Foam of expansion ratio between 200-2000:1.

Hydrocarbon Fuel - Fuels based exclusively on chains or rings of linked hydrogen and carbon atoms. Hydrocarbon fuels are not miscible in water.

Inductor (Eductor) - A device used to introduce foam concentrate into a water line. A venturi is fitted to suck foam concentrate into the water stream.

Induction Rate - The percentage of foam concentrate mixed or introduced into the water supply line.

Inline Inductor - An Inductor used in a hose line.

Knockdown - The ability of a foam to quickly control flames. Knockdown does not necessarily mean extinguishment.

Low Expansion Foam - Foam of expansion ratio between 2-20:1.

Mechanical Foam - Foam produced by a physical agitation of a mixture of water, foam concentrate and air.

Medium Expansion Foam - Foam of expansion ratio between 20-200:1.

Monitor - A large throughput branchpipe and nozzle which is normally mounted on a vehicle or on a fixed or portable pedestal.

NFPA - Standards for foam systems published in America by the National Fire Protection Association.

Non-Aspirated Foam - Foam of expansion ratio typically between 0-2:1. Only Film Forming Foam Concentrates are suitable for non aspirating applicators.

Oleophobic - Oil repellent.

pH - Measurement of acidity and alkalinity on a scale of 1-14. Neutral de-ionised water has a pH value of 7.

Polar Solvent - This term is generally used to describe any flammable liquid which destroys standard foams, although it actually refers to liquids whose molecules possess a permanent dielectric charge e.g. alcohols, ketones. Polar solvents are generally miscible with water.

Premix Solution - A mixture in correct proportions of a foam concentrate and water. Use of this term generally implies that the foam is stored in premix form, as in a portable foam fire extinguisher.

Proportioner - A device where foam concentrate and water are mixed to form a foam solution.

Protein Foam Concentrate - Substance containing organic concentrates derived from natural vegetable or animal sources. Hydrolised products of protein provide exceptionally stable and heat resistant properties to foams.

Security - The ability of a foam to seal around hot objects and prevent reignition.

Stability (of Concentrate) - Ability to be stored for long periods without separating out.

Stability (of Finished Foam) - Ability to retain shape and form in the presence of heat, flame and/or other liquids.

Static Pressure - The pressure existing in a line at no flow. This pressure is always considerably higher than under flowing conditions.

Sub Surface Injection - Another term referring to base injection.

Specific Gravity - The specific gravity of a material is a measure of the density of the material in relationship to the density of water. The specific gravity is calculated as:

$$S.G. = \frac{\text{Density of Material}}{\text{Density of Water}}$$

Twin Agent Method - A technique where Dry Chemical Powder is used to knockdown flames quickly, and AFFF is also applied to seal over a fuel spill. Used mainly for rescuing people from crashed aircraft.

Unaspirated Foam - See Non-Aspirated Foam.

Vapour Seal Box - A unit fitted on the outside of a fuel storage tank which will pass expanded foam through it, but will not allow vapours from the fuel in the tank to escape into the atmosphere. Normally fitted with a glass seal which is broken by the foam.

Venturi - A constricted portion of a pipe or tube which will increase water velocity, thus momentarily reducing its pressure. It is in this reduced pressure that foam concentrate is introduced. The pressure difference across the venturi can be used to force foam concentrate into the water.

VFP (Variable Flow Proportioner) - A foam proportioning device that will automatically adjust the pressure of the foam concentrate to match the water mains pressure thus giving the desired induction rate regardless of variation in flow.

APPENDIX B

LIST OF REFERENCES

This is the full list of references. Some of these have been reviewed in abstract form only.

At the end of each section of the report the appropriate references have been listed by number.

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197	BRITTSH STANDARD DRAFT 5306	P.D.O'CONNEL
198	COMPUTER LISTING	UNKNOWN
199	CHIEF INSPECTOR OF FIRE SERVICES REPORTS ON 1986 (ARTICLE)	CHIEF INS.IF FIRE SERVICES
200	PERGAMON INFULINE /ORBIT INFORMATION TECHNOLOGIES	CATALOGUE
201	MI272 DEGRADED & CONTAMINATED FOAM	ARTICLE
202	MI267 FIRE PREVENTION & FIRE FIGHTING IN SHIPS IN PORT	ARTTCLE
203	ONCE MORE INTO THE BREACH	ARTICLE
204	HI-LIFT TWIN STAGE FOAM INDUCTION NOZZLE	CATALOGUE
205	DEBUT OF NEW FOAM NOZZLE SYSTEM	ARTICLE FIRE MAG NOV.87
206	GUIDES FOR FIREFIGHTING IN & AROUND PETROLEUM STORAGE TANKS	API PUB 2021
207	WELDED STEEL TANKS FOR OIL STORAGE	API STANDARD 650
208	A GUIDE TO THE CONTROL OF INDUSTRIAL MAJOR ACCIDENT HAZARD REGULATIONS 1984	UNKNOWN
209	TACOA STORAGE TANK	ARTICLE FTRE ALMANAC 1984
210	STRATEGIC PLAN FOR H.O.FIRE RESEARCH 1987/80-1991/92	UNKNOWN
211	GENERAL RULES FOR FOAM APPLICATION	UNKNOWN
212	OPERATIONAL & TRAINING INSTRUCTIONS PART-1 APPLIANCE & EQUIPMENT	UNKNOWN
213	HOW TO FIGHT HYDROCARBON FIRES	FIRE PROTECTION MANUAL
214	THE PROBLEMS ASSOCIATED WITH VAPOUR SUPPRESSION	ARTICLE
215	DISCUSSION RECORD NOTE -MILFORD HAVEN TANK FIRE	MINUTES OF MEETING
216	FIREFIGHTING-VERY LARGE FLAMMABLE LIQUID STORAGE TANK	D.D.GEORGE
217	BP ENGINEERING CODE OF PRACTICE CP 15-ACTIVE FIRE PREVENTION	
218	FIREFIGHTING SYSTEMS	DEP.80.47.10.11.
219	REQUIREMENTS FOR FIRE PROTECTION IN ON-SHORE OIL & GAS PROCESSING & PETROCHEMICAL INSTALLATIONS	DEP.80.47.10.30
220	PORTABLE & MOBILE EQUIPMENT FOR FIREFIGHTING	[illegible]

RECORD	TITLE	AUTHOR
221	FIREFIGHTING VEHICLES & FIRE STATIONS	DEP.80.47.10.33.
222	CYCLE FIRE TEST & DRAFT STANDARD COMMENTS	
223	ELKHART FIRE FIGHTING EQUIPMENT CATALOGUE	CATALOGUE
224	AKRON CATALOGUE NO.105	CATALOGUE
225	FOAM-MAKING CONCENTRATES :AN ASSESSMENT OF TODAYS PRODUCTS	G.RUSSELL
226	A GUIDE TO THE USE OF FOAM LIQUID CONCENTRATES	UNKNOWN
227	FOAM AND ITS APPLICATION	A.ACKLAND
228	LIGHT WATER AFFF IMPROVES JETTY SAFTEY	ARTICLE
229	THE EXTINGUISHING POWER OF FOAM	DR.STHAMER
230	HOSEREEL SYSTEM ADDITIVES PUT TO THE TEST	H.O.FIRE DEPT
231	FOAM OFFSHORE	ARTICLE
232	FOAM DEMONSTRASTION SPARKED OFF THOUGHTS ON HOW TO TACKLE OIL REFINERY FIRES.	R.CAVANAGH
233	INTRODUCTION TO FOAM	NATIONAL FOAM
234	AT NATIONAL FOAM FLAMMABLE LIQUID FIRE PROTECTION IS A FULL TIME JOB	LEAFLET
235	GETTING THE BEST PROTECTION NOW COSTS LESS WITH OUR NEW REMOTE CONTROL HYDRAULIC MONITOR SYSTEM	LEAFLET
236	FIGHTING FIRE WITH FOAM:BASICS OF EFFECTIVE SYSTEMS	D.N.MELDRUM
237	MODEL HMB-4 REMOTE CONTROL HYDRAULIC MONITOR SYSTEM	LEAFLET
238	MINI-PRO FOAM SYSTEM FOR THE MUNICIPAL FIRE SERVICE	LEAFLET
239	FOAM LIQUIDS AND EQUIPMENT FOR MUNICPAL AND VOLUNTEER FIRE DEPARTMENTS	LEAFLET
240	CONSULTING SERVICES	LEAFLET
241	PER HOUR COST OF FIRE IN PRODUCT LOSS	DATA INFORMATION
242	NOZZLE AND FOAM LIQUID TEST DATA	DATA INFORMATION
243	GASOHOL AND UNLEADED GASOLINE	L.DiMARIO
244	PERFORMANCE AND TESTING OF FOAMS FOR AIRCRAFT CRASH - FIRE FIGHTING PAST,PRESENT AND FUTURE	D.MELDRUM / K.POLLARD
245	THE RIGHT FOAM FOR THE JOB	LEAFLET
246	PROVEN PERFORMANCE...NOT JUST PROMISES	LEAFLET
247	THINK TANKS	LEAFLET
248	INTRODUCING A NEW FOAM SYSTEM FOR FLOATING ROOF TANKS	LEAFLET
249	DAMAGED TANK DRAINED WITHOUT INCIDENT	LEAFLET
250	NATIONAL FOAM HAS THE MOST COMPREHENSIVE SET OF UL LISTINGS OF ANY FOAM FIRE PROTECTION COMPANY	LEAFLET
251	RED ALERT DOES DOUBLE DUTY	LEAFLET
252	ETHANOL - A NEW MARKET FOR FARMERS,A NEW HAZARD TO PROTECT	LEAFLET
253	FOAMSTAT - PREPLANNING AND EMERGENCY SOFTWARE FOR FLAMMABLE LIQUID FIRE PROTECTION	LEAFLET
254	PROTECTING THE PANAMA CANAL	LEAFLET
255	PRODUCING OIL IN THE NORTH SEA	LEAFLET
256	FIRE SCHOOL REPORT	LEAFLET
257	KODAK PARK - INDUSTRIAL FIRE PROTECTION AT ITS FINEST	LEAFLET
258	HAZMAT NF - HAZARDOUS VAPOR MITIGATING FOAMS	LEAFLET
259	"OVER THE TOP DELIVERY" (GASOLINE AND CRUDE OILS)	DATA INFORMATION
260	FIRE PROTECTION EQUIPMENT DIRECTORY	UNDERWRITERS LABORATORIES
261	EVALUATION OF FILM FORMING FLUROPROTEIN FOAM	T.MILLER
262	INFORMATION PACK	UNDERWRITERS LABORATORIES
263	STANDARDS FOR SAFTEY	UNDERWRITERS LABORATORIES
264	REVISED OP 7076 - FOAM SYSTEMS	D.FISHER
265	STORING AND HANDLING ETHANOL AND GASOLINE - ETHANOL BLENDS AT DISTRIBUTION TERMINALS AND SERVICE STATIONS	AMERICAN PETROLEUM INSTITUTE

RECORD	TITLE	AUTHOR
266	COMPUTERS AND INCIDENT SIMULATION	R.F.CAREY
267	CONOCO WORLD	NEWS SHEET
268	FIRE EXTINGUISHANT AND HAZARDOUS SITUATION CONTOL	CATALOGUE
269	MOBIL TRAVEL GUIDE	MOBIL OIL CO-OPERATION
270	PETROLEUM PROPERTIES AND CHEMICAL PLANTS	PHILADELPHIA FIRE DEPT
271	LNG/LPG EMERGENCIES	PHILADELPHIA FIRE DEPT.
272	FIRE EXTINGUISHING AGENT, AQUEOUS FILM-FORMING FOAM (AFFF) LIQUID CONCENTRATE, FOR FRESH SEA AND WATER	MILITARY SPEC.
273	FOAM LIQUID, FIRE EXTINGUISHING, MECHANICAL	FEDERAL SPEC.
274	FIRE PROTECTION ENGINEERING	UNIVERSITY OF MARYLAND
275	TOP POURING FOAM EQUIPMENT FOAM POURER	CATALOGUE
276	FRE-FIRE PLAN FOLLOWED IN SETTING UP PUMPER RELAY FOR SUPERHIGHWAY FIRE	J.D.FEIGE
277	AFFF SPREADING PROPERTIES AT ELEVATED TEMPREATURES	A.WOODMAN/H.RICHTER/A.ADICOFF
278	A TECHNIQUE FOR THE EVALUATION OF AFFF SEALING CHARACTERISTICS	P.NICHLOSON/D.ARTMAN
279	THE USE OF AFFF SPRINKLER SYSTEMS	R.DURFORD
280	HANGAR FIRE PROTECTION WITH AUTOMATIC AFFF SYSTEMS	D.DREEN
281	AUTOMATED SURFACE AND INTERFACIAL MEASURMENTS OF AFFF'S.	D.ELLIOTT/P.CHIESA
282	FIRE TESTS AT ZURICH AIRPORT	ARTICLE
283	LIGHT WATER AFFF IMPROVES JETTY SAFTEY	ARTICLE
284	ENHANCEMENT OF FIRE PROTECTION WITH DIRECTIONAL COOLING SPRAY NOZZLES BY USE OF AFFF	J.PIGNATO
285	CONTROL FLAMMABLE LIQUID FIRES BY 'PREMIXING'	R.GIBSON
286	FIRE-FIGHTING FOAMS FOR LIQUID HYDROCARBON FUELS	ARTICLE
287	TANK FIRE: A CASE STUDY HISTORY	P.FOX
288	ANGUS INTRODUCE PETROSEAL 'FFFP' IN HOLLAND	ARTICLE
289	SELECTION AND USE OF FOAMS TO MEET CHALLANGES OF FLAMMABLE LIQUID FIRES	G.BROWN
290	LIQUEFIED GAS FIRES: WHICH FOAM?	L.BROWN
291	FIRE OUT: MAKING WATER MORE EFFECTIVE	A.SALY
292	TESTING OF FIRE FIGHTING FOAM	W.CAREY
293	MEDIUM AND LIGHT FOAMS FOR FIRE EXTINGUISHING	GERMAN STANDARD DIN 14272
294	PROTEIN BASED FOAMING AGENTS: TECHNICAL CONDITIONS OF SUPPLY	FIRE RESEARCH STATION
295	FOAM BRANCHPIPES: PART 1: PORTABLE FOAM BRANCHPIPES	DIN 14 366:PART 1:DRAFT
296	TEST METHOD FOR FOAM LIQUIDS	H.PERSSON/A.RYDERMAN
297	FOAM AND DRY POWDER SYSTEMS	FIRE PROTECT.ASSN.SOUTH AFRICA
298	FOAM AND DRY POWDER SYSTEMS	AUSTRALIAN FIRE ASSN
299	FOAM FOR AIRCRAFT CRASH FIRES	H.HIRO/R.FRENCH/P.NASH
300	THE RELATION BETWEEN CRITICAL SHEAR STREE AND '25 PER CENT DRAINAGE TIME'OF AIR-FOAM	N.SAVAGE
301	A MECHANICAL FOAM GENERATOR FOR USE IN LABATORIES	J.FRY/R.FRENCH
302	THE ABSORPOTION OF RADIANT HEAT BY FIRE FIGHTING FOAM	P.THOMAS
303	THE APPLICATION OF HIGH EXPANSION AIR FOAM TO 2 TYPES OF FIRE	P.TONKIN/D.TUCKER
304	NOTES ON THE USE OF HIGH EXPANSION AIR FOAM IN FIRE FIGHTING	P.THORNE/D.TUCKER/D.RASBASH
305	AIR FOAM IN THE CONTROL AND EXTINCTION OF PETROL FIRES BY SURFACE APPLICATION	R.FRENCH/D.HIRO
306	THE USE OF FOAM MAKING EQUIPMENT AGAINST BACK PRESSURES	R.FRENCH
307	SUITABLE FOAM COMPOUNDS FOR THE PRODUCTION OF HIGH EXPANSION FOAM FOR FIRE FIGHTING	G.STARK/P.FIELD
308	EXTINCTION OF INDUSTRIAL FIRE BY FOAM	P.NASH/D.FITTES

RECORD	TITLE	AUTHOR
309	A 50 LITRE PER MINUTE STANDARD FOAM BRANCHPIPE	S.BENSON/J.CORRIE
310	EVALUATION OF NOZZLES TO BE USED WITH AFFF AND THE COAST GUARD IN-LINE PROPORTIONER	R.RICHARDS
311	COMPARATIVE EVAULATION OF FIREFIGHTING FOAM AGENTS	G.GEYER/T.NERI/C.URBAN
312	PLANNING FOR THE USE OF BULK FOAM STOCKS	S.GILBERT
313	FIRE EXTINGUISHING EFFECTIVNESS OF A SYNTHETIC SURFACTANT FOAM	D.McDANIEL
314	REVISED DRAFT SPECIFICATION FOR 'HIGH EXPANSION 'FOAM LIQUIDS	P.THORNE
315	A PRELIMINARY EXAMINATION OF A NOVEL FOAM LIQUID	D.TUCKER/D.GRIFFITHS/J.CORRIE
316	FIGHTING FIRES IN OIL STORAGE TANKS USING BASE INJECTION OF FOAM	P.NASH/J.WHITTLE
317	A NEW FOAM RHEOMETER FOR STUDYING FIRE FIREGHTING FOAMS	D.ELLIOTT/P.CHIESA
318	EXTINCTION OF LABORATORY HYDROCARBON FIRES WITH A SYNTHETIC FOAM	J.CORRIE/D.GRIFFITHS
319	TRIALS OF FOAM ON PETROL POOL FIRES	A.WELLS
320	PRELIMINARY REPORT OF FOAM TRIALS ON PETROL POOL FIRES	FIRE MAG
321	THE USE OF FOAM FOR LNG FIRE FIGHTING	Y.LEV
322	INVESTIGATION INTO LIMITATION OF EVAPORATION OF LIQUIDS BY MEANS OF FIRE FIGHTING FOAM.PT3.MEASUREMENT RESULTS	D.NIEVERGELD/W.SULITALU
323	NEW LIQUID FOAM TO FIGHT FOREST FIRES IN FRANCE	S.SZONYI
324	ACTION AND RESULT OF HEAT ON EXTINGUISHING FOAM	S.SZONYI
325	COMBATING FOREST FIRES WITH FOAM REQUIRES A REASSESSMENT OF TACTICS	R.SMITH
326	NEW FOAM EXTINGUISHING AGENTS	R.JAIHESSER
327	BREAKTHROUGH CLAIMED FOR FOAM SOLUTIONS	ARTICLE
328	KWV'S ADVANCES IN FOAM APPLICATION	AARTICLE
329	SIMULTANEOUS APPLICATION OF FOAM AND DRY POWDER ON AIRCRAFT FIRES	F.ANSART
330	THE GODEY WAY TO FIGHT A WAR (FLUROCARBON FOAM)	ARTICLE
331	FOAMS AND FOAM SYSTEMS	P.NASH
332	COULD AFFF'S ACCERLATE THE IGNITION OF AVTUR? A PRELIMINARY INVESTIGATION	A.BRIGGS/C.COUSIN
333	APPLICATION OF FOAM IN THE PETROLEUM INDUSTRY	ARTICLE
334	TEST BURN FOR NEW FIRE FIGHTING FOAM	ARTICLE
335	LIGHT FOAM - LITERATURE COMPLIATION AND RESEARCH REQUIREMENTS	G.HOLMSTEDT
336	A RHEOLOGICAL MODEL FOR A LIQUID GAS FOAM	J.CALVERT/K.NEZHATI
337	OF SEA AND FOAM :OFFSHORE AND MARINE FIRE PROTECTION	S.ROWSELL
338	DEVELOPMENTS IN SHIP FIRE FIGHTING PROCEDURES	T.HAYWARD
339	EXTINCTION TESTS OF FLAMMABLE LIQUIDS	S.NICOLETTI
340	COMPARSION OF FOAMS FOR AIRCRAFT CRASH FIRES	A.RODRIGUEZ
341	FIRE PROTECTION OF SYNFUELS	D.MELDRUM/L.DiMARIO
342	THE EXPERIMENTAL STANDARD AND A4P EXTINGUISHING AGENT	S.SZONYI
343	RIYDAH DISASTER UNDERLINES PROBLEMS OF AIRCRAFT FIRES	J.HORSFALL
344	TESTS FOR PROTECTION FOR THE OPTIMIZATION OF FIRE PROTECTION IN BIG TANK FARMS	R.FIALA
345	TESTS IN LIQUID FUEL FIRES	I.TIEZZI/A.IRACE/G.AMATO
346	AIRCRAFT FIRE PROTECTION CAN START OR FINISH IN A HANGAR	J.MACDONALD
347	FRS INVESTIGATES METHODS OF DEALING WITH GASHOL FIRES	A.BRIGGS
348	OFFSHORE OIL PLATFORM INSTALLATIONS.PT2 FIRE AND EXPLOSION DETECTIONAND FIXED FIRE FIGHTING SYSTEMS	L.HEAVYSIDE
349	THE PROTECTION OF AIRCRAFT HANGARS	J.SIDDLE
350	GASOLINE SPILL - 4000 GALLONS ON THE GROUND	J.BRADSISH
351	GASHOL: GASOLINE OR ALCOHOL ?	R.CANAVAN
352	SEVERE LABORATORY FIRE TEST FOR FIRE FIGHTING FOAMS	P.CHIESA/R.ALGER

RECORD	TITLE	AUTHOR
353	HELICOPTER AND BUCKET TRIALS COULD PROVIDE NEW FOREST FIRE TECHNIQUE	W.SHAND
354	LESSONS FORM THE PAST,NO.3:ONE OF BRITAIN'S WORST OIL FIRES	T.KLETZ
355	A MAJOR FIRE IN A FLOATING ROOF CRUDE OIL STORAGE TANK	C.MUMMFORD
356	THE USE OF A SUSPENSION OF FULLER'S EARTH IN WATER AS A PROTECTION AGAINST THERMAL RADIATION	I.EMSON
357	FIRE PROTECTION AND FIRE FIGHTING IN SHIPS	D.MURRAY SMITH/A.WILLENS
358	A COMPARATIVE TESTING STUDY OF FIRE EXTINGUISHING AGENTS FOR SHIP&U. D MACHINERY SPACES	E.PATTERSON/H.TUVE
359	EXPERIMENTAL METHODS FOR THE STUDY OF FIRE FIGHTING FOAMS	J.CORRIE
360	PROBLEMS WITH THE USE OF FIRE FIGHTING FOAMS	J.CORRIE
361	FIRE OFFICER'S GUIDE TO EXTINGUISHING SYSTEMS	C.EAHME
362	PRINCIPLES OF FIRE PROTECTION CHEMISTRY	R.TUVE
363	TNAKER FIRE CONTAINED	W. WARD
364	'AIRCRAFT ON FIRE.......RUNWAY 6'	P.DITZEL
365	HEXANE TANKER BURNS ON FREEWAY	ARTICLE
366	MUTUAL AID AT TANK FARM FIRE	C.DEKTAR
367	ANALYSIS OF EXPERIENCES COVERING MINERAL OIL FIRES	P.BOHL
368	DRAINAGE TIME AND THE CEILING FIRE TEST	D.TUCKER
369	A REVIEW OF FUTURE TRENDS OF FIRE PROTECTION FOR TANKERS	L.ERRIKSSON
370	DRIANAGE LAWS FOR FIRE FIGHTING FOAMS	P.THORNE
371	TWO NEW TECHNIQUES SUCCESSFUL AT SHIP FIRE IN LONDON DOCKS	J.NILNER
372	THE FIRE PROTECTION OF FLAMMABLE LIQUID RISK BY FOAMS	J.CORRIE
373	ADVANCES IN PROTECTION OF POLAR-TYPE FLAMMABLE LIQUID HAZARDS	L.DiMARIO/P.CHISEA/M.OTT
374	MATHEMATICAL MODEL FOR ANALYZING THE TRADE-OFFS IN AIRCRAFT HANGAR DELUGE SPRINKLER SYSTEMS DESIGN	D.SHPILBERG
375	GASOLINE FIRE AT TANK FARM FOUGHT 7HOURS WITH HELP OF MUTUAL AID COMPANIES	E.VAN DUSEN
376	TO ASPRIATE OR NOT TO ASPIRATE AFFF? TESTS,ADVICE HLEP ANSWER QUESTION	J.BOWEN
377	RUNWAY FOALING - A CONTROVERSIAL FIRE FIGHTING TECHNIQUE	N.ANDERSON
378	GENERATION OF ELECTROSTATIC CHARGE IN FUEL HANDLING SYSTEMS:A LITERATURE SURVEY	J.LEONARD
379	PLANNING PAYS OFF IN TANKER CRASH	H.EISNER
380	FIGHTING FIRES WITH THE RIGHT FOAM	ARTICLE
381	SAFTEY CODES IN DOUBT AFTER BRITAIN'S LARGEST POST WAR REFINERY FIRE(OIL REFINERY MILFORD HAVEN)	ARTICLE
382	PRESSURE CONTROL FOR FIRE FIGHTING SYSTEMS	R.VAUX
383	MOBILE FOAM TOWER	ARTICLE
384	ISSUES RAISED BY FOAM FIRE TESTS	A.A.BRIGGS
385	CAMBRIDGESHIRE IS "COMMITTED TO AFFF" FOR FIRE FIGHTING	D.McCALLUM

APPENDIX C

The attached appendix the people and organisations consulted during the UK and overseas visit which include Brigades, Testing/Standards authorities, Suppliers and Industrial users.

APPENDIX C

LIST OF CONTACTS

The list of contacts below are the people who were consulted during the course of the study, between October 1987 and March 1988. They include:

Officers of the U.K. Fire Service
Equipment and Concentrate Manufacturers
Major oil industry and petrochemical users
Mutual Aid Organisations
Testing Authorities
Research Establishments
Overseas Fire Brigades
Home Office Fire Experimental Unit

Meetings were held in the U.K., Europe and United States of America.

APPENDIX C

Angus Bentham Lancaster	M. Hough D. Ross D. Mulligan
Avon F.B. Bristol	DCFO P. Aris DO B. Townley
Boots & Coots Port Neches Texas	L. Williams D. Williams
BP Petroleum Development Ltd Aberdeen	G. Dalzel
Cambridgeshire F.B. Huntingdon	DCFO A.E. Best
Chubb Fire Security Feltham Middlesex	E. Allen
Cleveland County F.B. Hartlepool Cleveland	CFO B. Cooney ACO J.W. Watson
Conoco Inc. Houston Texas USA	R. Barresi
Cynamid BV Rotterdam Holland	A. Van Bedaf R. Garvelink

Du Pont de Nemours (Netherlands) Dordrecht Netherlands	A. Ciggar
Dyfed Country F.B. Carmarthen	DCFO M.J. Knowles DC R. Oldacres DO M. George
Eau et Feu France	A. Balthazard Y. Lequeux
Essex County FB Brentwood Essex	DCFO J. Sherrington SSO B. Unger DO T. Lilliot
Esso Petroleum Refinery Fawley Southampton	B. Browning
Exxon Florham Park New Jersey USA	R. Murphy
Fire Experimental Unit Moreton-in-Marsh Gloucestershire	Dr M. Thomas DO R. Lock ADO M. Currey DO J. Kitchen
Fire Service Collegew Moreton-in-Marsh Gloucestershire	DO D. Hopkins ADO A. Doig
Gloucesterhsire F.B. Cheltenham	CFO A.R. Currie
Hampshire F.B. Eastleigh Hants	CFO J. R. Pearson ACO D. M. Pain

Houston Fire Dept Houston Texas	DC M. McRae B. Hand
Le Havre F.B. Le Havre France	Lt. Col. J. Bernhaert Comm. Taconet
3M UK PLC Bracknell Berkshire	D. M. Smith
3M Antwerp Belgium	W. Mertens
Mobil Research and Development Paulsboro New Jersey	M. Hicks T. Miller E. Andester
National Foam UK Aylesbury Bucks	N. Ramsden
National Foam USA Lionville USA	B. Robinson D. Cochran B. Schofield W. Woodson
Norfolk County F.B. Norwich	DFCO Smith
Shell International Petroleum Maatschappij BV The Hague Netherlands	R. Kok L. Latter
Shell Oil Co/Shell Chemical Co Deer Park USA	J. Oliphant

Texas A&M University College Station Texas USA	J. Donovan J. Hubaeek Jr B. Paricor
Total Le Havre France	L.P. Le Signor
Underwriters Laboratories Northbrook Illinois USA	E. Misichko D. Nelson
University of Maryland College Park Maryland USA	F. Mowrer Dr H. Hickey

APPENDIX D

QUESTIONNAIRE AND RESPONSE

This questionnaire was sent to the manufacturers and suppliers indicated requesting information regarding their foam concentrate and equipment.

Although the response was disappointing the information that was received was most useful.

APPENDIX D

FOAM STUDY QUESTIONNAIRE RESPONSE

Company	Questionnaire Returned
British Fire Protection Systems Association Ltd., Kingston Upon Thames Surrey	-
Angus Fire Armour Ltd., Morecambe, Lancs	14/12/87
National Foam System UK Aylesbury Bucks	-
Chubb Fire Security Ltd., Sunbury on Thames Middlesex	16/2/88
John Kerr & Co. Ltd., Liverpool	Request declined
Walter Kidde Plc South Ruislip Middlesex	-
Macron Fire Protection Ltd., Aylesbury	-
Gilmat Engineering Ltd., Preston Lancs	-

Company	Questionnaire Returned
Silvani Antincendi S.p.A. Milan Italy	
3M (UK) Plc Bracknell Berks	1/12/87
Wood Group Fire Protection Great Yarmouth	
Angloco Limited Batley West Yorks	
Amendola Engineering Ltd., Birmingham	10/12/87
Symtol Engineering Ltd., Blyth Northumberland	
Sabo Spa Lavate Italy	
Preussag AG West Germany	
Rockwood Systems Corporation South Portland U.S.A.	
Sicli Ltd., Maidstone Kent	

Company	Questionnaire Returned
Dr. Sthamer, Liebigstr. 5 W. Germany	
Hoechst (UK) Ltd., Hounslow	
Ansul Slough	28/1/88

APPENDIX D

FOAM CONCENTRATE DATA

GENERAL

Foam Name/Identification?

Foam Type?

Country of Origin/Manufacture?

Budget Cost per 25 1 drum?

PHYSICAL PROPERTIES

Specific Gravity?

Viscosity at 0 deg C? at 10 deg C? at 20 deg C?

Freezing Point (deg C)?

Undissolved solids before aging,
% by weight?

CHEMICAL PROPERTIES

Constituents and Additives
(N.B. A formulation for the product
is **not** requested)?

pH?

Suitable for mixing with which types of water?
Potable/Fresh/Sea/Brackish

Please comment on suitability or finished
foam for supervision of vapours from
hazardous/toxic materials other than vapours
from 'normal' flammable liquids?

TOXICITY/ENVIRONMENTAL DATA

LD (please supply method of determination)?

Bio-degradability, half-life in soil and water?

Recommendations for dispersal of spilled concentrate and finished foam?

APPROVALS/TESTING

Please quote any approvals or certification issued by national or international bodies?

Please supply reports of testing or certification by other independent bodies?

COMPATIBILITY WITH OTHER MATERIALS

Recommended materials for storage tanks? (Please include any results of tests on materials which have influenced this recommendation)

What known contaminants will substantially decrease the effectiveness of this concentrate, either in contact or in solution (Please supply any relevant test results)?

Which other foam concentrates (of different manufacture or type) will substantially decrease the effectiveness if mixed, up to 50% by volume, either in store concentrate or as finished foam?

STORAGE/ROUTINE TESTING

Recommended materials for bulk storage containers?

Maximum and minimum recommended storage temperature? (deg C)

MAX MIN

Does a repeated freeze/thaw cycle significantly affect foam properties?

YES/NO

Shelf life in original containers at 10 deg C?

Shelf life in bulk storage container of recommended materials at 10 deg C?

Shelf life in lined mild steel tank at 10 deg C? (Please specify lining)

Do original containers identify date of production?

Yes-Directly/Yes-By Code/No

Recommendations for routine testing? (Properties tested and frequency)

USE

Range of Usable expansion rates (numerical values; upper and lower limits)

Recommended proportioning rate (% v/v with fresh water; please quote reasons if more than one rate)

Maximum and minimum proportioning rates which do not cause significant loss of performance?

Please quote application rates (litres/minutes/sq. m) -

Material	Recommended Rate	Minimum Rate
Crude Oil	-	-
Diesel Fuel	-	-
4-Star Petrol	-	-
Hexane	-	-
Heptane	-	-
Methyl Ethyl Ketone (MEK)	-	-
Acetic Acid	-	-

Is non-standard foam making equipment necessary for use of this concentrate?

No/Yes-Please indicate types

QUALITY CONTROL PROCEDURES

Please attach copy of quality schedule and procedures

STRATEGIC STOCKS

Please list locations of depots which can be guaranteed to carry some stock of this form?

Location	Normal Stock	Maximum Stock	Minimum Stock

CASE HISTORIES

Please attach any case histories which show the performance of this foam in real-life situation.

PROPORTIONERS - VENTURI TYPE

Name/Description?

Please provide technical data sheet and quality control procedures

Materials of construction?

Connections (Inlet and Outlet)?

Nominal proportioning rate(s)
(% concentrate/water)? 1%/3%/6%/other _____

Method of achieving variable proportioning?

Accuracy of proportioning rate (guaranteed)?

Water pressure/flow range at inlet?

Water pressure loss across proportioner?

Water back pressure limit?

Limitations on usable foam concentrate
(e.g. S.G., Viscosity)?

Maximum suction lift for concentrate or
required concentrate pressure at concentrate
inlet?

PROPORTIONERS - NOT VENTURI TYPE

Name/Description?

Please provide technical data sheet including schematic diagram of control arrangements, and quality control procedures

Materials of construction of water and foam chemicals?

Materials of construction of housing (if applicable)?

Inlet and outlet connections?

Suitable for portable use or fixed mounting only (including vehicle mounting)?

Nominal proportioning rate(s) (% concentrate/water)? 1%/3%/6%/other ______

Method of ahieving variable proportioning?

Accuracy of proportioning rate (guaranteed)?

Water pressure/flow range at inlet?

Water pressure loss across proportioner?

Water back pressure limit?

Limitations on usage foam concentrate (e.g. S.G., Viscosity)?

Maximum suction lift for concentrate
or required concentrate pressure at
concentrate inlet

Have you identified any concentrates
for which this equipment is
inappropriate (i.e. does not function
or functions significantly poorly)?

Recommendations on maintenance and cleaning?

MONITOR DATA

(N.B. This concerns the fixed waterways leading into a nozzle)

Monitor name/description?

Please attach technical data sheet

For use with which nozzle(s)?

Materials of construction?

Please supply copy of quality control procedures

Method of remote control (if appropriate; please quote water usage if driven by water motor)?

Hydraulic/Pneumatic/Electric/Water Motor

Recommended uses?

Vehicle of Trailer method/Ground Mounted/Portable

Usable Inlet Pressure/Flow Range?

Pressure Drop through monitor?

Connections (inlet and outlet)?

Rotational/Positional Limitations?

Optional Extras?

Recommended Maintenance and Cleaning?

NOZZLE/FOAM GENERATOR DATA

(N.B. This section of question is aimed at a description of nozzles only. Some equipment, e.g. bipod monitors and HI-EX Generators, have integral proportioners and/or monitors. If the equipment described here has such integral parts please also complete the proportioner or monitor questionnaires as appropriate).

Nozzle name/description?

Please attach technical data sheet, and quality control procedures

Materials of construction?

Connection types available?

Suitable for use with -
Monitor/Lay Flat Hose/Hose Reel

Recommended situations for use -

Flammable liquid spill (unconfined)/Tank Fire/Bund Fire/General Purpose

What limitations on types of foam concentrate?

Operating pressure? MAX ______ MIN ______ Recommended ______

Operating flow rates? MAX ______ MIN ______ Recommended ______

Method of aeration?

Range of expansion produced?

Variable expansion method
(other than water flow dependent)?

Nozzle length after aeration?

Nozzle discharge foot print -

Elevation	Flow Rate	Throw	Height	Spread
30				
60				
45				

Are operational additions/extension to the nozzle available, if so what?

Recommendations for maintenance and cleaning?

Budget Price. Ex-works, UK?

APPENDIX E

BRIEF

This brief is a copy of the original document on which the study was structured.

Changes were made to the format as the study progressed and it will be noted that the contents of each report is now different.

APPENDIX E

TERMS OF REFERENCE

SURVEY OF FIREFIGHTING FOAM AND ASSOCIATED TACTICS AND EQUIPMENT RELEVANT TO THE UNITED KINGDOM FIRE SERVICE

1. INTRODUCTION

1.1 The Fire Experimental Unit of the Home Office Scientific Research and Development Branch (FEU) are undertaking research into the use of foam for firefighting in the Fire Service. In the context of these Terms "Fire Service" will be used to describe all United Kingdom Local Government Fire Brigades.

1.2 The Fire Service use a wide variety of foam but as most of their work dues not require the use of foam it is difficult for them to build up expertise in this area. More expertise is available in specialist industries and internationally. The research is directed towards assessing the present state of art, and identifying areas where the Fire Service would benefit from further research.

1.3 As a first step therefore, FEU require a Survey of the advice and expertise which is available. This Survey will then form the basis for an assessment by the FEU of future research areas.

1.4 These Terms of Reference define the scope of the Survey which is to be undertaken by the Contractor.

2. SCOPE OF THE SURVEY

2.1 The Contractor shall address three main areas:-

1. The types of firefighting foam which are or could be made available to the Fire Service; their chemical and physical properties including the effects of high temperatures; the specifications which they are required to satisfy; the suitability of these specifications; possible alternative specifications or quality controls suitable for use by the Fire Service; the advantages and disadvantages of the various types of foam; the information available on the various products on the market.

2. The tactics to be adopted in using foam for fire fighting; foam application rates for different types of fire; the relative merits of non-aspirated and aspirated foam; techniques for delivering the foam to the base of the fire; the logistic problems of fighting large fires.

3. The suitability of existing Fire Service foam delivery equipment; the foam delivery equipment required to deal with fires attended by a small number of Appliances (an "Appliance" is a fire fighting vehicle owned by any fire brigade); the maximum size fire which can be tackled by a single fire brigade; the possiblility of there being fires which a Brigade cannot handle; existing specialist foam delivery equipment required by the Fire Service; the possibility that new specialist equipment is required.

2.2 The Contractor shall obtain his information from as wide a range of sources as possible. These shall include:

1. The FEU, who have access to computer data systems, can provide copies of relevant reports which they hold and will arrange contacts with the Fire Service.

2. The Fire Research Station at Borehamwood, Hertfordshire WD6 2BL.

3. The petro-chemical industry.

4. Overseas fire services.

5. Firefightng foam manufacturers.