Central Fire Brigades Advisory Councils
For England and Wales and for Scotland

JOINT COMMITTEE ON FIRE RESEARCH

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PLANNING FOR THE USE OF BULK FOAM STOCKS

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Fire Research

Planning for the of Use of Bulk Foam Stocks

Prepared : by S.Gilbert
Approved : by S.F.J.Butler

SCIENTIFIC ADVISORY BRANCH
Horseferry House
Dean Ryle Street
LONDON SW1P 2AW

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1. INTRODUCTION

Foam is used in dealing with fires involving flammable liquids and certain chemicals. Large quantities of foam will be required very rarely, but brigades must be prepared to deal with a major fire at, for example, an oil refinery or oil storage depot, where very large amounts of foam may be needed. The problems considered here are the planning of the fire brigade arrangements for storing, handling and transporting large quantities of foam concentrate, and how to determine the level of stocks required.

This report describes a study of the planning of bulk foam concentrate stocks in Cheshire Fire Brigade. Although the emphasis in this report is on the requirements in Cheshire, the general principles will be applicable to other brigades faced with similar problems.

In the first part of the report the problem is described and the general principles of providing bulk foam concentrate stocks are discussed. The second part of the report describes the Cheshire study.

2. BACKGROUND

Two important characteristics of incidents requiring the use of large quantities of foam are the seriousness and the rarity of such events. Throughout the country there are very many risks where a fire could potentially become very serious and require massive foam use. However past experience shows that large fires at these risks occur very rarely.

2.1 Potential risks

Foam may be required at fires where oil, petrol or other flammable liquids are stored, processed or transported. While there are very many such premises where a major fire might conceivably occur, the greatest risks occur at oil refineries, oil terminals or docks, oil storage depots or large chemical works. These types of premises are often located quite closely together (the terminals providing crude oil to the refineries which in turn provide feedstocks for the chemical works). It is therefore possible to identify major risk areas where large stocks of foam may be required as those areas surrounding the major oil refineries.

Almost all of the United Kingdom's 150 million tonnes per year refining capacity is concentrated in fewer than 20 such refineries. Figure 1 shows the locations of the major refineries in the United Kingdom and indicates the areas where there is considerable risk of a serious fire requiring the use of foam.

2.2 Past incidents

The record of fires in the chemical and petrochemical industries, and particularly the record of the usage of foam at these incidents, provides an indication of the requirements for bulk foam concentrate.

Detailed information has been obtained on a sample of major fires in the chemical and petrochemical industries. This information has been examined for evidence of foam use; Appendix A summarises the findings.

The analysis of the sample of large fires shows that foam concentrate is almost always available at serious fires in the chemical and petrochemical industries - often as part of the brigade first attendance. However, the analysis also shows that in most cases the foam was not required, and when it was required no

more (and often much less) than 6,000 gallons of foam concentrate were used. In all but one instance the foam concentrate available on site after the arrival of the initial brigade attendance was sufficient to fight the fire. Fires such as the Avonmouth fire in 1951 where 47,000 gallons of concentrate were used appear to be very rare.

In summary, even at major fires foam compound is often not required, and when it is required is very rarely used in quantities exceeding a few thousand gallons. However the consequences of being unprepared for these major incidents may be very serious.

3. PLANNING FOR THE USE OF BULK FOAM CONCENTRATE STOCKS

Although large quantities of foam may be required only rarely, brigades must have contingency plans and be prepared to deal with the major incidents which require large quantities of foam.

In this study the planning for the use of bulk foam concentrate stocks has been considered as a series of four questions:

1. How much foam concentrate should be held?

   No brigade will be able to hold sufficient stocks to meet any eventuality, and each brigade must decide on the level of stocks which they will hold.

2. What alternative arrangements are possible for storing and handling bulk foam concentrate stocks?

   The different arrangements and different types of equipment which can be used for storing and transporting foam concentrate in bulk should be identified. It is useful at this stage to prepare a comprehensive list of possible options rather than to limit consideration to just one or two solutions which at first sight appear to be best.

3. What are the criteria for choosing between alternatives?

   Once the possible options are identified the planners should decide on the criteria which are to be used to assess the options and to make the final choice.

4. What is the best system for the brigade's needs?

   Having identified the range of options and the criteria to be used to assess the alternative options, the evidence can be examined and the final decision can then be made.

Each of these four questions is discussed in general terms and the specific situation in Cheshire is then considered.

3.1 How much foam concentrate should be held?

Each brigade must consider the potential risks in their area and decide how much foam concentrate should be held. There can be no simple rule for this decision. It should be recognised that a brigade will not be able to hold the amount of concentrate which might be required in truly exceptional circumstances, and the decision as to how much foam should be held will depend on their judgement of the risks as well as being a matter of policy.

One way of approaching the problem is to try to visualise the type of incidents - and particularly the worst possible incidents - with which the brigade should be prepared to cope. Some examples of incidents which may require large quantities of foam include a pipetrack fire resulting from a fractured product line; a pipetrack fire occurring when there has been damage to the instrumentation or controls and the line cannot be shut down immediately; a spillage and fire filling a large bund area, storage tank or dock area. For all these incidents an estimate can be made of the area which the fire might cover. The amount of foam concentrate required can then be calculated by assuming that foam will be applied at, say, one gallon per square foot per minute for 20 minutes to achieve extinction, followed by continued application at some lower rate to maintain the blanket of foam. By considering the implications of possible major fires in different circumstances the brigade may be able to build up a picture of the potential foam concentrate requirements.

It may be useful to consider the total foam concentrate stocks in terms of "initial" stocks, "support" stocks and "back-up" stocks.

The initial stocks are the stocks of concentrate which might be sent as part of the predetermined first attendance or on the first call for foam. These stocks should be available rapidly, possibly within 30 minutes of being called. An examination of the past incidents (Appendix A) suggests that the size of the initial stocks might be in the range 500-2,000 gallons.

The support stocks provide the balance of the stocks which the brigade hold. These stocks should be available within a few hours of being called.

The back-up stocks are the stocks which might be required for any incident larger than the brigade had anticipated in their pre-planning. The stocks required for a disaster of this magnitude would be part of a regional or national arrangement.

The amount of foam required for a major incident will not all necessarily have to be provided by the brigade. The brigade may be able to use foam concentrate held by refinery or chemical plant operators, at dockyards or airports, and stocks held by foam manufacturers and other brigades. These other sources of concentrate must be taken into account when the brigade plan their own stockholding requirements. If arrangements are made with other

stockholders it is important to ensure that their stocks are in an operationally useful and compatible form and that suitable transport will be available to deliver these stocks to a major incident. The use of these other stocks should, therefore, be as carefully pre-planned as the use of brigade stocks.

3.2 What alternative arrangements are possible for storing and handling bulk foam concentrate stocks?

Having decided on the level of stocks which the brigade should hold, the alternative means of storing and handling these stocks must be considered. A list should be made of the alternative options. The list should be as comprehensive as possible and might include novel approaches as well as the more obvious alternatives. No attempt should be made at this stage to select the best arrangement.

A list of some possible options is shown in Table 1. In the list the options are grouped according to the general mode of operation - whether the containers are portable, transportable, mobile or fixed. This classification of the equipment may suggest other alternatives.

3.3 What are the criteria for choosing between alternatives?

There will be a number of criteria used in making the final decision. Some of the criteria may be more important than others; some will be quantifiable while others can only be expressed in the most general terms; and there may be a conflict between some of the criteria. However, in a systematic study it is useful to draw up a list of the important criteria. This list will indicate which of the factors can be, and should be, investigated more fully in the assessment, and the list also provides a useful check list or aide memoire in the planning stage.

The list of criteria will include:

1. Cost - the capital cost and maintenance cost of any additional equipment required.
2. Response times - the time required to get the stocks to any site at which they may be required.
3. Manpower requirements - the number of men required to handle the bulk stocks, and any special skills required.

4. Storage requirements - the amount of space and any other facilities which may be required for the storage of the bulk stocks.

5. Reliability - whether the planned arrangements can be relied on to operate satisfactorily any time they may be required.

6. Operational suitability - any operational difficulties which might arise when using the bulk foam at a fire.

The first four of these items can be examined and expressed to some extent in quantitative terms. The remaining two items - reliability and operational suitability - are largely matters of experience and professional judgement.

3.4 What is the best system for the brigade's needs?

The choice of the best arrangements for storing and handling bulk foam concentrate stocks cannot be reduced to a simple formula. However, the evidence collected in answer to the first 3 questions should assist the planners in making a systematic assessment of the alternatives and choosing the system which best meets their own needs. The Cheshire case study provides an illustration of the way in which evidence can be collected and assessed.

In making the final decision the arrangements for the provision of bulk foam concentrate cannot be viewed in isolation from other aspects of the pre-planning for a major incident. In particular the arrangements for the foam concentrate should be compatible with the arrangements for water supplies, pumping the water, generating the foam and the manpower requirements to operate the equipment and deal with the fire. There would of course be no point in bringing large quantities of foam concentrate to the fireground if there was, for example, insufficient foam making equipment to utilise the concentrate.

The expected in-service life of the bulk concentrate stocks should also be considered. Stocks which are required only exceptionally may remain in store for several years before operational use, and experience has shown that in some circumstances foam concentrate deteriorates during prolonged storage.

Small scale experimental studies (1) suggest that most modern types of foam concentrate may be stored for at least two years without significant deterioration in performance. However, to overcome any possible storage problems, bulk stocks of concentrate may be used progressively in training exercises or as

a central reservoir for replenishing stocks held on pumping appliances and replaced with new concentrate to maintain a constant stock holding of relatively fresh concentrate. Nevertheless, in practice periodic testing may also be required and standard methods for small scale testing are available (2).

References

1) Benson S.P., Griffiths D.J., Tucker D.M. & Corrie J.G.

Storage Properties of Four Foam Liquids (Final Report)
Fire Research Note No.980
Fire Research Station, Borehamwood, Herts
August 1973

2) Corrie J.G.

Quality Control Procedures for Fire Fighting Foams
Building Research Establishment Current Paper 15/78
Fire Research Station, Borehamwood, Herts
December 1977

4. THE CASE STUDY - BULK FOAM CONCENTRATE FOR CHESHIRE FIRE BRIGADE

At the time this study was done Cheshire Fire Brigade had already decided on the main details of their future arrangements for bulk foam concentrate stocks and were committed to purchasing new equipment. However this study is not limited only to those arrangements which are still practicable in Cheshire. A wider view has deliberately been taken in order to gain a wider experience of the problem and to provide more general results which may be of use to other brigades.

4.1 The risks in Cheshire

Cheshire Fire Brigade provide protection for a number of major oil and petroleum complexes in the county. The major installations are the Ellesmere Port and Stanlow oil refineries. Ellesmere Port refinery has crude oil refining capacity of $1\frac{1}{2}$ million tonnes per annum and Stanlow a capacity of $18\frac{1}{2}$ million tonnes per annum. These refineries include a variety of processes and provide feedstocks for many chemical works in other parts of the county. There are important oil docks and terminals in the Mersey estuary, some of these in the Cheshire area and some within the Merseyside Fire Brigade area. Other major risks in adjacent counties include an oil storage depot at Haydock in Merseyside and chemical and petrochemical works in the Manchester area.

The River Mersey and the Manchester Ship Canal run from East to West across the Northern part of the county and restrict North-South travel in this area.

A map showing the location of the main risks and the motorways in the county is given in Figure 2.

4.2 How much foam concentrate should be held?

The main risks at which large quantities of foam might be used are in the North of the county at Ellesmere Port/Stanlow, Runcorn, Widnes and Warrington (see Figure 3). There are also a number of smaller risks in chemical works and oil storage sites in other parts of the county.

In the judgement of Cheshire Fire Brigade the major fires which might require foam are fires involving spillages of oil or other flammable liquids, and in these cases provided that the flow of liquid is cut off quickly the total foam concentrate required should not exceed 2000 gallons.

Cheshire Fire Brigade have also considered four particular potential fires which would require larger quantities of foam. These major incidents are:

1. A storage tank fire covering an area of 250 feet diameter.

2. A fire in an oil berth on the Manchester ship canal covering an area of 90 feet by 1 mile.

3. A pipetrack fire covering an area of 20 feet by $\frac{1}{2}$ mile.

4. A fire in the largest bund area in the petrochemical complex, covering an area of 312,500 square feet.

The calculation of the foam requirements for these four incidents is shown in Table 2. Two of the incidents, 1 and 3, might require 8000 to 9000 gallons of foam compound and the remaining two incidents would require very much larger quantities of foam.

By reasoning along these lines and considering other local sources of compound Cheshire Fire Brigade have decided that they should hold about 6000 gallons of foam concentrate, of which up to 2000 gallons should be capable of being mobilised very quickly. The total quantity of foam concentrate available in the region is about 50,000 gallons including stocks available at refineries and stocks available from neighbouring brigades. The stocks available in the Cheshire area are listed in Table 3.

As part of the pre-planning exercise suitable arrangements must be made between Cheshire Fire Brigade and the other authorities who will make foam stocks available if needed for a major incident in Cheshire. This study is principally concerned with the arrangements for the storage and handling of the 6000 gallons of foam concentrate which will be held by Cheshire Fire Brigade.

4.3 What alternative arrangements are possible for storing and handling bulk foam concentrate stocks?

The list of alternative methods of storage and transport are summarised in Table 1.

Portable containers. Portable containers range from the 5 and 45 gallon containers in which foam compound is normally supplied through to 250 gallon containers. Intermediate or larger size containers could also be considered. The smaller containers can be moved by hand and could be loaded into a van,

general purpose lorry, tender or other form of transport. The larger containers will be too heavy to move by hand and will need some mechanical device for loading or unloading. For example, 250 gallon containers might be carried on a flat bed lorry fitted with a hoist or power arm or, if the large containers are held in a central store, a fork-lift truck might be available for loading.

Transportable containers. Transportable containers are ready-filled tanks which have to be towed or carried in some way. A small tanker trailer may be towed by a Landrover or some other vehicle normally available in a brigade. A large tanker trailer may form the articulated trailer to be pulled by a cab unit. The transportable containers may not necessarily be wheeled units. There are at least two types of demountable bodies which come into the category of transportable containers.

There are demountable bodies which can be pulled onto a chassis unit. There are also demountable bodies fitted with hydraulically operated legs; the legs of the body unit can be extended to allow the chassis unit to be driven underneath the body. The legs are then retracted leaving the body unit on the chassis. The demountable tanker bodies would be one of a number of interchangeable bodies (for example, control unit, canteen unit etc) which could be carried on the chassis unit.

Mobile containers. Mobile containers are tanks permanently attached to a motive unit. They may range from basic tankers to tankers fitted with pumps and other equipment, or may be dual purpose vehicles, for example appliances carrying both foam concentrate and water tanks.

Fixed tanks. Fixed tanks of almost any size could be used to store bulk foam concentrate. The bulk tanks would be used to fill or refill tankers or other containers which would transport the foam concentrate to the fireground.

4.4 What are the criteria for choosing between alternatives?

A list of some of the important criteria to be used in assessing the alternatives has been given in Section 3.3. The options will now be examined against these criteria in the next section.

4.5 What is the best system for the brigade's needs?

4.5.1 An assessment of some alternative arrangements

The question to be answered is: How and where should 6000 gallons of fluoroprotein foam concentrate be stored so that up to about 2000 gallons could be mobilised very rapidly and the remaining stocks could be made available, if required, within a few hours?

Possible arrangements can be selected from the list of options (Table 1) and can then be assessed.

There are a very large number of combinations of options which might be considered and some initial selection must be made. Other arrangements can be considered later in the light of the experience of the first series of assessments.

A consideration of the requirements for initial stocks and support stocks provides some guide to the arrangements which might be examined.

Initial stocks. The initial stocks for the predetermined first attendance or the first call for foam must be mobilised rapidly and therefore should be kept ready loaded. Either a tanker or a transportable container (eg articulated trailer or demountable tanker body) could be used. If a transportable container were used for the initial stocks the tank must normally be kept fixed to the cab or chassis, or at least the cab or chassis must normally be kept free and available in the close vicinity.

Only 1500 gallon tankers have been considered in this analysis. Larger tankers have been excluded because of the practical difficulty of ensuring that there is a driver with a Class I or II HGV driving licence available 24 hours a day.

Support stocks. Support stocks may either be kept in portable containers, transportable containers or fixed tanks. Mobile containers (eg tankers) have not been considered as these will be more expensive than non-mobile containers of an equivalent size and, by definition, the support stocks need not be available as rapidly as the initial stocks.

Of the portable containers only 250 gallon containers are considered. Five gallon cans are excluded because of the difficulties of handling large quantities of foam concentrate in such small amounts. These small containers would require much manpower for loading and unloading and could not feed the

foam making equipment at a sufficient rate. For example a Jet Master using compound at a 3 per cent induction rate would require approximately 10 gallons of compound a minute ie two 5 gallon cans each minute. Forty-five gallon drums are excluded because of the difficulty of handling these drums, particularly on the fireground, in the quantities required for bulk use. However there are some specialised applications where 45 gallon drums may be a useful storage medium (for example, in ship fires).

The following arrangements have been selected for examination in this case study.

	Initial stocks	Support stocks
1.	1500 gallon tanker	18 x 250 gallon portable containers to be carried by 2 lorries fitted with hoists, each lorry carrying 2 containers.
2.	2 x 1500 gallon tankers	3000 gallon fixed tank.
3.	2 x 1500 gallon tankers	12 x 250 gallon portable containers to be carried by one lorry fitted with hoist.
4.	2 x 1500 gallon tankers	12 x 250 gallon portable containers to be carried by one large lorry, capable of carrying 4 containers, fitted with hoist.
5.	2 x 1500 gallon tankers	12 x 250 gallon portable containers to be carried by 2 lorries fitted with hoists.
6.	2 x 1500 gallon tankers	2 x 1500 gallon transportable tanker bodies with one chassis unit.
7.	2 x 1500 gallon tankers	2 x 1500 gallon transportable tanker bodies with 2 chassis units.
8.	2 transportable tanker bodies with chassis kept "ready"	2 x 1500 gallon transportable tanker bodies.

An important characteristic of any arrangements for bulk foam concentrate stocks is the time it would take to mobilise and transport these stocks to the fireground. The complete picture of the response times would include the availability of concentrate at all the risks in the area, and the complete schedule of possible

delivery times at each of these risks. In this analysis only a summary of the response times has been considered in order to provide a simpler and more manageable picture. The availability of bulk stocks at only three main areas of risk is considered. (Risk 1 - Ellesmere Port - the priority risk in the area; Risks 2/3 - Runcorn and Widnes; Risk 4 - Warrington); and instead of considering the delivery of all the stocks, three summary measures are considered - the time taken for the first bulk delivery, the amount which can be delivered within two hours and the time taken to complete the delivery of 6000 gallons. A convenient method of calculating the possible response times for the different arrangements is described in Appendix B.

Referring to the assessment shown in Table 4, this evidence could be used to choose a final arrangement or, more likely, to eliminate some of the alternatives from consideration and to suggest other arrangements which might merit a closer look. These decisions will depend on matters of judgement and of policy, and can only be made by the brigade.

It should be noted that the costs shown in Table 4 are approximate estimates only. The costs will depend on the detailed specification of the equipment, for example, what pump or other equipment is to be fitted to the tankers.

Some of the points arising from the assessment, shown in Table 4, are as follows:

Arrangement 1 uses only one tanker for the first bulk delivery. The tanker has to cover the risks in different areas and therefore the first attendance time will be relatively long at some of the risks. A second disadvantage is that this arrangement may not be reliable enough as it depends on the availability of a single vehicle.

Arrangement 2 uses two 1500 gallon tankers. This increases the capital cost by about £25000, but improves the cover provided for the separate risks and also, by holding stocks in two vehicles, improves the reliability of the system. This arrangement offers the advantage on the fireground of being able to take foam concentrate from two separately placed sources.

The use of a 3000 gallon fixed tank for the support stocks requires more complicated arrangements at the fireground. The concentrate held in the tankers could possibly be pumped out into a reservoir to allow the tankers to return and refill as quickly as possible. Alternatively, the concentrate could be used

directly from the tankers and the tankers refilled when empty. However as the return journey for refilling might take an hour or more this might not allow continuity of supply to be maintained at the fireground.

Arrangement 3 uses two 1500 gallon tankers for initial stocks and 12 x 250 gallon portable containers for the support stocks. The containers are carried, 2 at a time, on a 4 ton general purpose lorry fitted with a mechanical hoist. In this particular arrangement the lorry is assumed to be kept at central stores. One possible problem is that the mobilisation of the support stocks depends on the availability of the single modified lorry. However, the availability of more than one tanker makes it possible (or inevitable if the lorry was unavailable) for the second tanker to be used as a shuttle vehicle to bring support stocks to the first.

Arrangement 4 is similar to arrangement three with two 1500 gallon tankers and portable containers but uses a larger lorry capable of carrying four containers at a time. This reduces the time required to deliver all 6000 gallons of compound to any of the three main risks. However the reliability again depends on the availability of a single lorry.

If the brigade do not have a suitably sized flat bed lorry (8 tons), then an additional capital cost would be incurred. There may also be problems in getting a mechanical hoist with a long enough reach to load four containers on to the lorry.

Arrangement 5 is again similar to arrangement three, but uses two lorries fitted with hoists rather than one. This increases the reliability of the support stocks. The use of two modified lorries, while increasing the capital cost, enables the containers to be brought to the fireground more rapidly, and the full 6000 gallons of concentrate can be delivered to the three main risk areas in about 2¼ hours.

Arrangement 6 uses two 1500 gallon tankers for the initial stocks but the support stocks are kept in two 1500 gallon transportable tanker bodies (as articulated trailers or demountable tanker bodies) and there is one chassis unit kept at the central stores. This increases the capital cost but improves the delivery times of the support stock substantially. The chassis unit could also be used to carry other bodies such as control units or canteen units, and the calculated delivery times are based on the assumption that priority is given to the transport of foam

Arrangement 7 is similar to arrangement six, using two 1500 gallon transportable tanker bodies, but has two chassis rather than one. This increases the cost, but also the reliability of the system and enables a very rapid delivery of all the stocks. The delivery times may in fact be more rapid than might be required.

Arrangement 8 is based on a different concept and uses transportable tanker bodies for the initial stocks as well as for the support stocks. This reduces the capital cost, compared to using two tankers, while still maintaining a rapid delivery schedule. There are however operational disadvantages in that the tanks of compound cannot easily be moved once they have been parked and left on the fireground, and the tank units may not have their own power source to operate on-board pumps. There is also a problem of competing requirements for the chassis and if the system is to be flexible and the chassis used to carry other bodies, the chassis may not be available when required for the initial mobilisation of foam stocks.

This assessment of eight selected alternatives illustrates the evidence which can be used in making the final decision, and also shows how the final decision must involve some compromise between the conflicting requirements of low cost, high reliability and prompt response times.

4.5.2 The effect of changing the storage locations

Cheshire Fire Brigade have decided to purchase two 1500 gallon foam tankers and twelve 250 gallon containers for foam compound. The only decisions which must still be made are the choice of locations for these stocks.

In this part of the analysis we have taken this arrangement (arrangement three in the first series of assessments) and considered the effect of changing the locations.

The location of the two tankers can be considered as a separate problem of locating the 250 gallon containers. The two tankers could, provided there were drivers and garage space available, be located at any two of the six stations in the Northern part of the county. As these tankers are intended to provide the initial stocks the most important requirement is a quick attendance time at any of the risks in the area.

The first attendance times of the foam tankers to the four main risks have been estimated for the different possible locations of the tankers, and the results

are shown in Table 4. (Stations B1 and B2 are close together and only the attendance times from station B1 have been estimated). There are 10 different combinations of stations at which tankers might be located and Table 5 shows the attendance times for all possible tanker locations. The average attendance times and the maximum attendance time have also been recorded in the Table. Taking into account the requirement that the primary risks are at Ellesmere Port and that a good first attendance time is essential here, the tanker locations which offer the best attendance times are A2/B5 and A2/B1. If station B1 is used rather than B5 this will provide better cover for risks in Merseyside (Haydock), and in the Manchester area.

The above analysis considers the possible tanker locations from a theoretical viewpoint. In practice there will be constraints on the choice of locations. Garage space for the tankers and staff facilities for the tanker drivers need to be provided, and this may, in the shorter term, limit the choice of locations. An unconstrained analysis ignoring such factors is nevertheless useful, not only as a first stage in making decisions in the short term but also as a way of highlighting possible advantages of longer term changes.

There are many possible combinations of sites for the storage of the 250 gallon containers. In this analysis we have simplified the number of combinations by assuming

- containers would be stored in pairs (as the lorry can carry two containers)
- two containers would be kept at the stores (near station A5)
- stations B1 and B2 are close together and can be treated as a single location.

This leaves 126 possible combinations of locations for the containers. In this analysis we have considered all the 126 possibilities, calculating the attendance times using a computer. Without the use of a computer to do the tedious arithmetic, various storage locations could be selected by examining the map of the area, choosing sites by judgement and assessing these on a trial and error basis.

Table 6 shows those storage locations which offered the lowest average time to complete the delivery of the 12 containers or the best cover (the minimum time taken to complete delivery at the risk which had the longest delivery time). The storage locations which appear to offer good attendance times are six containers

at B4, four at B5; six containers at B4, four at A3; four containers at B4, four at B5, two at A3.

It should be noted that although the storage locations are listed in Table 6 in order of the best attendance times, the times for those locations part way down the list are not significantly worse than for those at the top of the list. The final choice of locations should be made from the upper part of the list, taking into account other operational factors. In Cheshire Fire Brigade's case these factors include the necessity to hold stocks at tanker bases for day-to-day replenishment of compound used in exercises etc, and the priority given to the Ellesmere Port risks.

4.6 The case study - a summary of the results

There are a number of possible arrangements and types of equipment which can be used to store and transport the 6000 gallons of foam compound which Cheshire Fire Brigade plan to hold. An assessment of some of the alternative arrangements is shown in Table 4. Some of these methods can be eliminated on operational grounds - the use of a single tanker may not be reliable enough to provide the first attendance, and the use of a 3000 gallon fixed tank might lead to complex logistical problems on the fireground. The use of demountable tanker bodies is only an advantage if these are used as part of a system of interchangeable bodies including, say, a control unit, canteen unit etc. The use of two 1500 gallon tankers, with the remaining stock held in large portable containers, therefore appears to meet the needs of Cheshire Fire Brigade. The choice is between the use of one lorry fitted with a hoist or two lorries fitted with hoists. The use of a second lorry, which adds about £3500 to the cost (assuming a general purpose lorry is available), will reduce the time taken to deliver the complete 6000 gallons and will increase the reliability of the system.

The best locations for the two tankers, based on the attendance times to the main risks in Cheshire, are A2/B5 or A2/B1. The use of station B5 offers quicker attendance times in Cheshire, but station B1 is closer to the risks in neighbouring counties.

There are a large number of possible storage locations for the twelve 250 gallon containers. A list of some of the better locations, judged by the time taken to complete delivery of these stocks to the main risks, is shown in Table 6.

4.7 Further developments

Following the preparation of this report Cheshire Fire Brigade were of the opinion that the use of a single lorry to transport their support stocks was unsatisfactory. As a result the Brigade have evaluated the use of standard Water Tender appliances as bulk foam concentrate carriers. The results of this evaluation have been very encouraging, and Cheshire Fire Brigade intend to go over to this method in the future.

In the evaluation trials Water Tenders were used to collect stocks from a central store at Frodsham and form a relay to supply the foam tankers at the risk. Each Water Tender carried about 350 gallons of concentrate, and a turnaround time of 15 minutes was achieved at the foam concentrate store. This turnaround time included emptying the water tank and reloading with concentrate from 250 gallon containers. The Brigade estimate that, with the number of Tenders which would be available for a major incident, they could mobilise all their stocks in one hour.

Clearly this method has considerable advantages as regards equipment utilisation and ease of operation. As support stocks are required only infrequently the use of existing transport is in many ways preferable to having specialist vehicles standing idle for long periods. In addition, the use of vehicles available in considerable force within the brigade provides good reliability. Doubts have been expressed in the past as to the corrosive effects of foam compound on untreated tanks and pumps. However, in the trials so far carried out, Cheshire Fire Brigade have found no adverse effects have occurred. In practice the concentrate is only kept in the Water Tenders for, at most, an hour or so and, after thorough flushing with water, the Tenders have shown no signs of deterioration.

The use of Water Tenders therefore appears to have considerable benefits. The use of such standard Brigade equipment could also be of great use to smaller Brigades where the pattern of existing risks may make the purchase of any specialised equipment difficult to justify. For a quite small outlay such Brigades could set up one or more bulk concentrate stores and use existing equipment to transport the stocks to potential risks quickly and efficiently.

5. CONCLUSIONS

There is no single best arrangement for the storage and transport of bulk foam concentrate stocks which suits the needs of all brigades. Neither can there be any rule or mathematical formula which can be used to determine the best solution. The arrangement which best suits a brigade's needs will depend on such factors as the location and type of risks and the organisation of the brigade. The final choice of a best arrangement will depend partly on a quantitative assessment of some of the aspects of performance, particularly the costs and the attendance times, but the decision will also be largely a matter of judgement and of policy.

In this study of the situation in Cheshire we have attempted to assess the alternative arrangements in a systematic way. Although the circumstances in other brigades will be different, the same general approach could be used. The assessment involves the following steps:

1. Identify the level of stocks to be held, taking into account all other stocks available in the area, subdividing the brigade's stocks into initial stocks and backup stocks.

2. Draw up a comprehensive list of the alternative arrangements which could be used.

3. Draw up a check list of the criteria to be used in making the final decision.

4. Assess selected choices of equipment and storage locations against the list of criteria. One of the quantifiable factors which will help in the assessment will be the schedule of delivery times. A convenient method of calculating these times is shown in Appendix B.

5. Where there are a large number of alternative storage locations to assess an initial choice may be made on the basis of average delivery times to all major risks and/or maximum delivery time to any major risk. This "screening" will produce a short-list of options for a final, more detailed assessment.

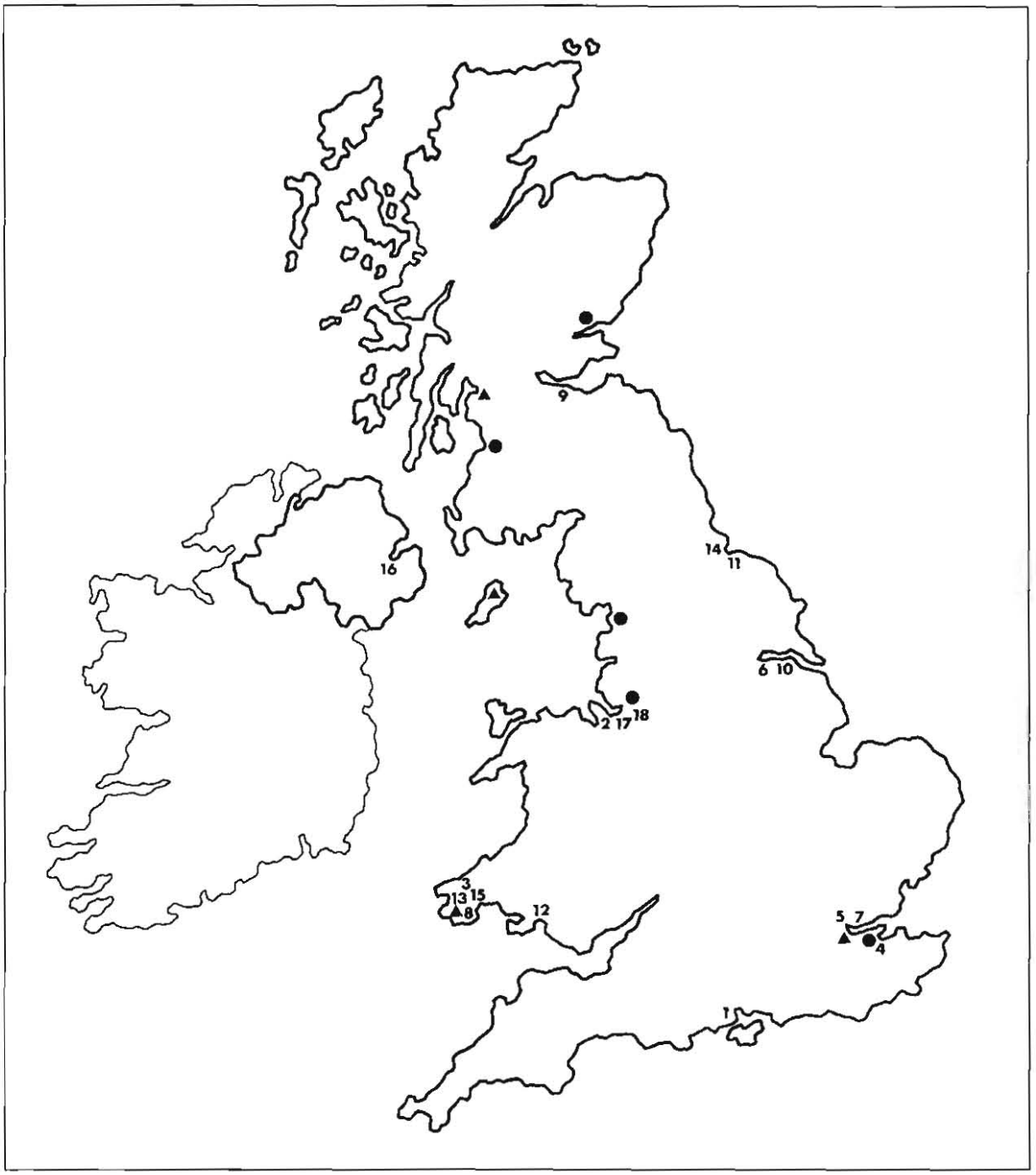
Although, as has already been said, there is no universally best arrangement, each type of equipment has certain performance characteristics, and these are

summarised in Table 7. This Table may provide a guide to the choice of options which are to be evaluated.

Finally, it should be reiterated that although each brigade must make its own arrangements for the provision of bulk foam, there is still a possibility that a major incident may occur for which the brigade stocks are inadequate. Suitable arrangements must therefore be made with other foam stockholders to utilise their stocks if this should be necessary.

ACKNOWLEDGEMENTS

The author wishes to thank the Chief Officer and men of Cheshire Fire Brigade for their invaluable assistance with this project.



Number	Name	Annual Throughput (million tonnes)	Number	Name	Throughput
1	FAWLEY	19·5	10	SOUTH KILLINGHOLME	6·5
2	STANLOW	18·5	11	TEESPORT	5·7
3	MILFORD HAVEN	15·0	12	LLANDARCY	5·4
4	ISLE OF GRAIN	10·5	13	MILFORD HAVEN	5·4
5	SHELL HAVEN	10·0	14	BILLINGHAM	5·0
6	KILLINGHOLME	9·25	15	MILFORD HAVEN	5·0
7	CORYTON	9·0	16	BELFAST	1·5
8	PEMBROKE	9·0	17	ELLESMERE PORT	1·5
9	GRANGEMOUTH	8·6	18	EASTHAM	0·6

● Other smaller Refineries

▲ Proposed Refineries

Fig.1 Major Oil Refineries in the U.K.

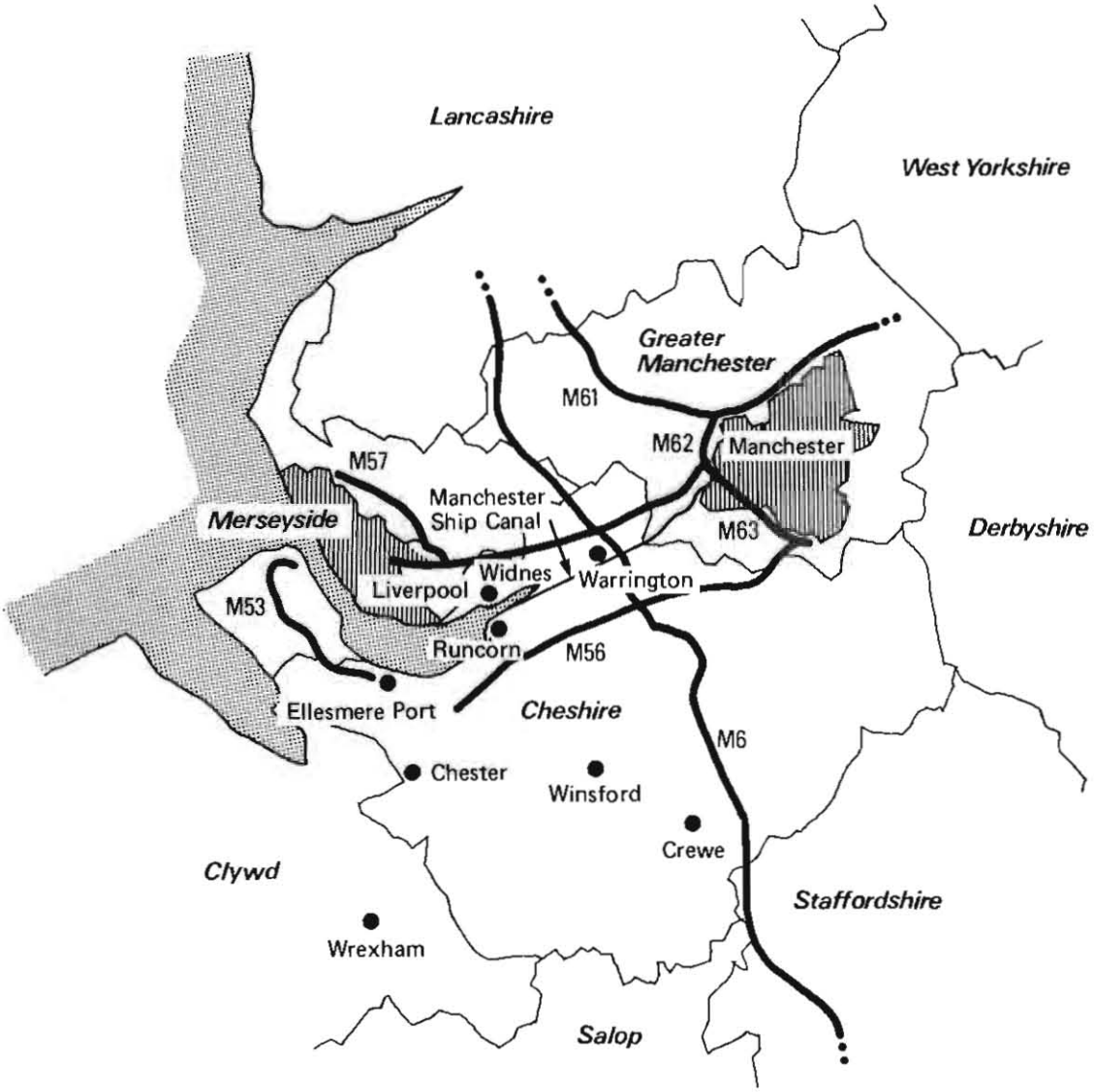


Fig. 2 Cheshire, location and major routes.

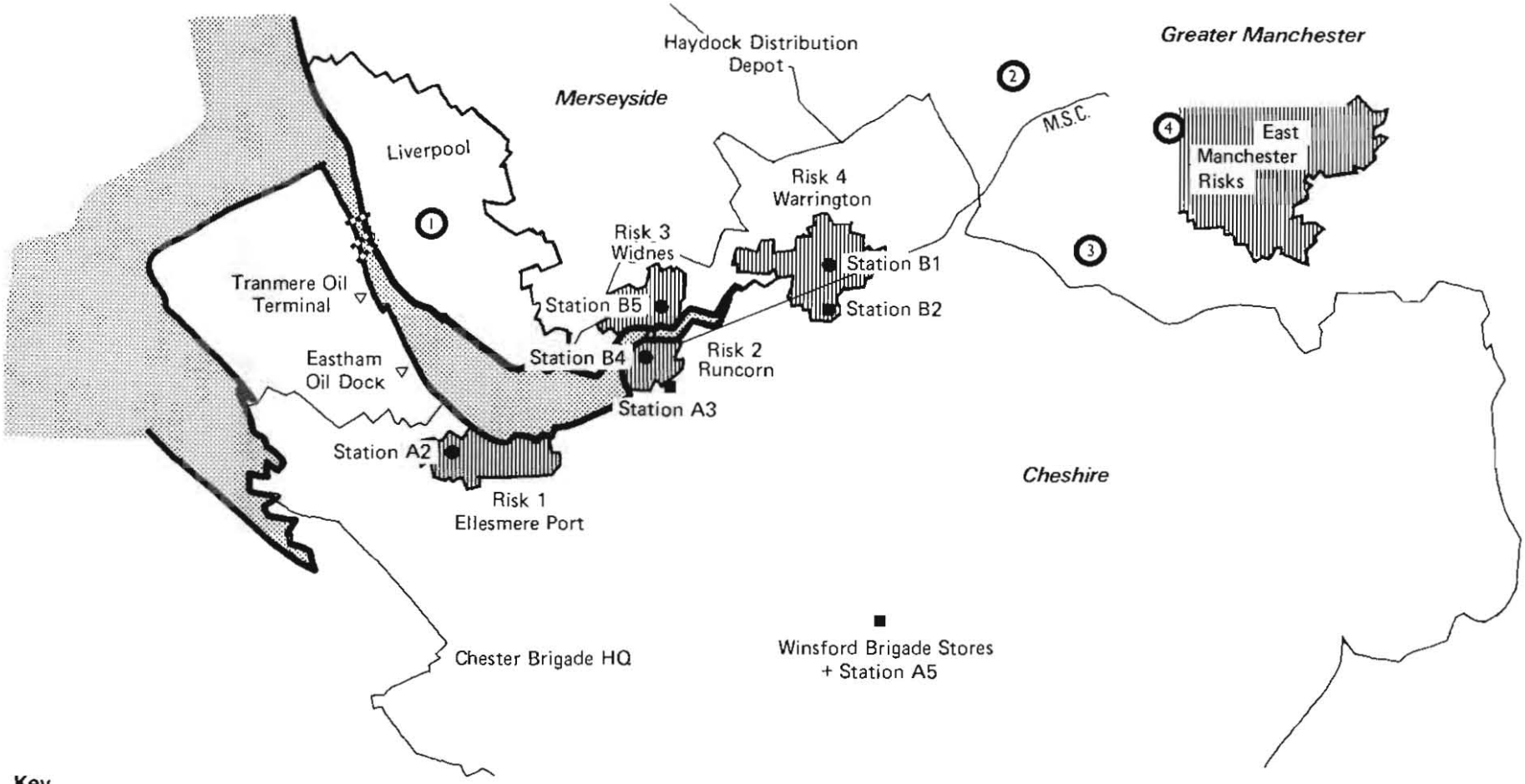
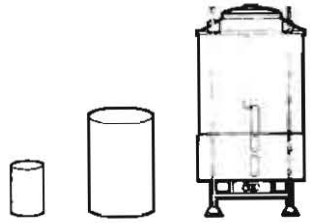
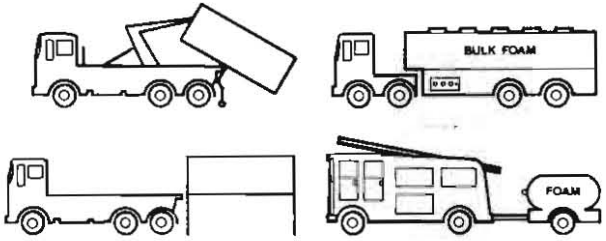


Fig.3 Risks and Fire Stations in the Cheshire area

Table 1 A list of the possible arrangements for storing and handling bulk foam stocks.

Method of Storage	Method of Transport
1. Portable Containers	
– 5 gallon drums	General purpose lorry, tender, van, etc.
– 45 gallon drums	General purpose lorry with or without hoist, trailer etc.
– 250 gallon drums	General purpose lorry with or without hoist
2. Transportable Containers	
– tanker trailer for appliance (250-500 gallons)	Appliance
– articulated tanker trailer (500-3000 gallons)	Cab Unit
– demountable tanker body (500-1500 gallons)	Specially modified chassis unit or flat bed lorry
3. Mobile Containers	
– foam tanker (1500-3000 gallons)	
– foam/water tanker (100 gallons +)	
– pumping appliance with foam tanks (~ 50 gallons)	
4. Fixed Tanks	
– fixed bulk tanks (1000 gallons +)	Tanker or other mobile container





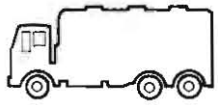


TABLE 2 FOAM USE AT POSSIBLE INCIDENTS IN CHESHIRE

Incident	Area Involved (ft^2)	Foam Application Required (gallons per minute)	Concentrate Required* (gallons per minute)	Total Concentrate Required in 20 minutes (gallons)	Total Concentrate Required if foam blanket maintained for (say) 4 hours using 1/10 standard rate application
1. Shell Storage Tank	49,000	49,000	184	3680	8,100
2. Manchester Ship Canal Oil Berth	475,200	475,200	1780	35,600	78,300
3. Pipetrack	52,800	52,800	198	3960	8,700
4. Bund Area	312,500	312,500	1172	23,440	51,600

* Based on 8 to 1 expansion ratio and 3% induction rate

TABLE 3 THE TOTAL AMOUNT OF FOAM CONCENTRATE AVAILABLE IN THE CHESHIRE AREA

Stockholder	Availability	Amount (gallons)	Notes
Cheshire FB	Within first few hours	6000	Several thousand gallons available within first hour.
Cheshire Refinery Operators			
Shell (UK) Ltd	Rapid availability for fires at these sites	16100	2500 gallons in foam tanker. Other stocks non-mobile; 10000 gallons storedin bulk tanks.
Burmah Castrol Ltd		8100	3900 gallons on foam tenders. Other stocks non-mobile and distributed throughout site.
Associated Octel		415	200 gallons on tanker trailer. Other stocks non-mobile and distributed throughout site.
Neighbouring Brigades			
Merseyside FB	Within first hour	1700	Bulk Tanker sited in Liverpool
Greater Manchester FB	Within first hour	2800	3 Bulk Tenders from Manchester
Merseyside FB	Rapid arrival at fire, but may be delayed by need to unload and decant	800	5 gallon drums stored on lorry.
Greater Manchester FB	Rapid arrival at fire, but may be delayed by need to unload and decant	450	5 gallon drums stored on lorry.
Merseyside FB	May be long loading and unloading delays	2250	5 gallon drums stored as reserves
Greater Manchester FB	May be long loading and unloading delays	6350	5 gallon drums stored as reserves
Clywd FB	May be long loading and unloading delays	1420	5 gallon drums stored as reserves
Other More Distant Brigades			
Lancashire FB	At least 2-4 hours	2950	1450 gallons kept on bulk foam tenders. 2 x 500 gallons stored on lorries in 5 gallon drums. 500 gallons stored in 5 gallon drums as reserves.
Derbyshire FB	At least 2-4 hours	1145	All stocks in 5 gallon drums. 600 gallons kept on foam/salvage tenders.
	C/F	50480	

TABLE 3 (continued)

Stockholder	Availability		Amount (gallons)	Notes
		B/F	50480	
Shropshire FB	At least 2-4 hours		280	All stocks in 5 gallon drums. 80 gallons kept on foam trailer.
Staffordshire FB	At least 2-4 hours		1350	550 gallons kept on foam/salvage tenders. 800 gallons in 5 gallon drums at Divisional Stations.
Foam Manufacturers				
Angus Ltd, Bentham	6 hours or more		1000+	1000 gallons available in drums. Bulk tanker delivery may be possible.
		TOTAL	53110	

TABLE 4 AN ASSESSMENT OF SELECTED ALTERNATIVE ARRANGEMENTS

ARRANGEMENT- METHOD OF HANDLING AND LOCATION OF STOCKS	CAPITAL COST	RESPONSE TIMES**					MANPOWER REQUIREMENTS	STORAGE REQUIREMENTS	RELIABILITY	OPERATIONAL SUITABILITY
		RISK*	FIRST BULK ARRIVAL		AMOUNT IN 2 HOURS (Gallons)	TIME TO COMPLETE DELIVERY				
			QUANTITY (Gallons)	TIME						
1. -1500 gal tanker (at B4) -18 x 250 gal containers (2 at each of A3, B4, B5, 4 at each of A2, A5, B1) -2 lorries fitted with hoists (Kept at A5)	Tanker £25,000 Containers £4,000 Lorry modifications £7,000 = £36,000	1 2/3 4	1,500 1,500 1,500	21 min 8 min 26 min	4,500 4,500 4,500	4hrs 30min 3hrs 30min 4hrs 45min	Tanker driver Lorry drivers	Garaging for tanker	Unreliable if single tanker is engaged or off the run.	On the fireground all the initial stocks come from a single tanker
2. -2x1500 gal tankers (at A2, B1) -3000 gal fixed tank (at B4)	Tankers £50,000 Fixed Tank £5,000 = £55,000	1 2/3 4	1,500 1,500 1,500	6 min 20 min 4 min	Depends on whether foam is pumped into a reservoir or used directly from tankers		Tanker drivers	Garaging for tankers Site and base for storage tank	✓	Complex arrangements required on fireground to allow refilling and maintain continuity of supply
3. -2x1500 gal tankers (at A2, B1) -12x250 gal containers (2 at each of A2, A3, A5, B1, B4, B5) -1 lorry fitted with hoist (kept at A5)	Tankers £50,000 Containers £3,000 Lorry modifications £3,500 = £57,500	1 2/3 4	1,500 1,500 1,500	6 min 20 min 4 min	4,500 4,500 4,500	5hrs 4hrs 5hr 15min	Tanker drivers Lorry drivers	Garaging for tankers Space for containers at stations	Depends on availability of single modified lorry	
4. -2x1500 gal tankers (at A2, B1) -12x250 gal containers (4 at each of A2, A5, B1) -1 large lorry fitted with hoist (kept at A5)	Tankers £50,000 Containers £3,000 Lorry modifications £3,500 = £57,500	1 2/3 4	1,500 1,500 1,500	6 min 20 min 4 min	5,000 5,000 5,000	3 hr 3 hr 3 hr	Tanker drivers Lorry drivers	Garaging for tankers Space for containers at stations	Depends on availability of single modified lorry	
5. -2x1500 gal tankers (at A2, B1) -12x250 gal containers (2 at each of A2, A3, A5, B1, B4, B5) -2 lorries fitted with hoists (kept at A5)	Tankers £50,000 Containers £3,000 Lorry modifications £7,000 = £60,000	1 2/3 4	1,500 1,500 1,500	6 min 20 min 4 min	5,000 5,000 5,000	2hrs 30min 2hrs 15min 2hrs 30min	Tanker drivers Lorry Drivers	Garaging for tankers Space for containers at stations	✓	
6. -2x1500 gal tankers (at A2, B1) -2x1500 gal transportable tanker bodies (at A5, B4) and one chassis unit (at A5)	Tankers £50,000 Tanker Bodies £ 5,000 Chassis Unit £18,000 = £73,000	1 2/3 4	1,500 1,500 1,500	6 min 20 min 4 min	6,000 6,000 6,000	1hr 15 min 50 min 1hr 30 min	Tanker drivers Lorry drivers	Garaging for tankers Space for tanker bodies	Depends on availability of single chassis unit	
7. -2x1500 gal tankers (at A2, B1) -2x1500 gal transportable tanker bodies each with a chassis unit (All at A5)	Tanker £50,000 Tanker Bodies £ 5,000 Chassis £ 36,000 = £ 91,000	1 2/3 4	1,500 1,500 1,500	6 min 20 min 4 min	6,000 6,000 6,000	40 min 35 min 40 min	Tanker drivers Lorry driver	Garaging for tankers Space for tanker bodies	✓	
8. -2x1500 gal transportable tanker bodies with chassis "ready" (at A2, B1) 2x1500 gal transportable tanker bodies (at A2,B1)	Tanker Bodies £ 10,000 Chassis £ 36,000 = £ 46,000	1 2/3 4	1,500 1,500 1,500	7 min 21 min 5 min	6,000 6,000 6,000	1hr 30 min 1hr 15 min 2hr 15 min	Lorry drivers	Space for tanker bodies	Chassis may be in use for other purposes when required for foam tanks.	

* The locations of the stations and the risks are shown in Figure 3

** In addition to Cheshire FB stocks foam concentrate held by other stock holders will also be available - several thousand gallons within the first 2 hours. See Table 3 and Note on Table 5

TABLE 5 THE FIRST ATTENDANCE TIMES WHICH CAN BE ACHIEVED WITH DIFFERENT TANKER LOCATIONS

Tanker Locations	First attendance time of the different risks (minutes)					Maximum 1st Attendance Time
	Risk 1 Ellesmere	Risk 2 Runcorn	Risk 3 Widnes	Risk 4 Warrington	Average 1st Attendance Time	
A2, A3	6½	7½	14½	26½	13¾	26½
A2, B1	6½	21½	16½	3½	12	21½
A2, B5	6½	8½	3½	16½	8¾	16½
A3, B1	18½	7½	14½	3½	11	18½
A3, B5	18½	7½	3½	16½	11½	18½
A3, B4	18½	3½	11½	26½	15	26½
B4, B5	20½	3½	3½	16½	11	20½
A2, B4	6½	3½	11½	26½	12	26½
A3, A2	6½	7½	14½	26½	13¾	26½
B1, B4	20½	3½	11½	3½	9¾	20½

NOTE Bulk tankers from neighbouring brigades may, if mobilised early, arrive at Cheshire risks very soon after Cheshire FB first attendance. The following should be taken into account when final decisions are made.

	Approximate Arrival Times at Risks (minutes)			
	Risk 1 Ellesmere Port	Risk 2 Runcorn	Risk 3 Widnes	Risk 4 Warrington
Greater Manchester Tankers (3 tankers with total capacity 2800 gallons)	65-75	50-60	50-60	30-45
Merseyside Tanker (1700 gallons capacity)	30	40	25	40

NOTE All the above times are calculated using the simple model described in Appendix B. They are not actual attendance times which Cheshire Fire Brigade achieve, but approximate estimates which can be used to compare policy options.

TABLE 6 THE TIMES TAKEN TO COMPLETE DELIVERY OF THE PORTABLE CONTAINERS WITH DIFFERENT CONTAINER LOCATIONS

No of Containers at Stores (2 containers always held at Winsford with lorry) A2	B1	B4	B5	A3	Time to Complete Delivery (hrs) RISK 1 Ellesmere Port	RISK 2 Runcorn	RISK 3 Widnes	RISK 4 Warrington	Average Time to complete delivery (hours)	Maximum Completion Time (hours)
Best Average Times										
0	0	0	10	0	$5\frac{3}{4}$	$2\frac{3}{4}$	2	4	$3\frac{3}{4}$	$5\frac{3}{4}$
0	0	2	8	0	$5\frac{3}{4}$	$2\frac{1}{2}$	$2\frac{1}{4}$	$4\frac{1}{2}$	$3\frac{3}{4}$	$5\frac{3}{4}$
0	0	0	8	2	$5\frac{1}{2}$	$2\frac{3}{4}$	$2\frac{1}{2}$	$4\frac{1}{2}$	$3\frac{3}{4}$	$5\frac{1}{2}$
0	0	4	6	0	$5\frac{1}{2}$	$2\frac{1}{4}$	$2\frac{1}{2}$	$4\frac{3}{4}$	$3\frac{3}{4}$	$5\frac{1}{2}$
0	0	2	6	2	$5\frac{1}{2}$	$2\frac{1}{2}$	$2\frac{3}{4}$	$4\frac{3}{4}$	$3\frac{3}{4}$	$5\frac{1}{2}$
*0	0	6	4	0	$5\frac{1}{4}$	$2\frac{1}{4}$	$2\frac{3}{4}$	5	$3\frac{3}{4}$	$5\frac{1}{4}$*
*0	0	0	6	4	$5\frac{1}{4}$	$2\frac{1}{2}$	$2\frac{3}{4}$	$4\frac{3}{4}$	$3\frac{3}{4}$	$5\frac{1}{4}$*
*0	0	4	4	2	$5\frac{1}{4}$	$2\frac{1}{4}$	3	5	4	$5\frac{1}{4}$*
0	0	8	2	0	5	2	3	$5\frac{1}{2}$	4	$5\frac{1}{2}$
0	2	0	8	0	$6\frac{1}{4}$	3	$2\frac{1}{2}$	$3\frac{3}{4}$	4	$6\frac{1}{4}$
Best Maximum Times										
0	0	0	4	6	5	$2\frac{1}{2}$	3	5	4	5
0	0	2	4	4	5	$2\frac{1}{2}$	3	5	4	5
2	0	0	8	0	$5\frac{1}{4}$	3	3	5	4	$5\frac{1}{4}$
*0	0	6	4	0	$5\frac{1}{4}$	$2\frac{1}{4}$	$2\frac{3}{4}$	5	$3\frac{3}{4}$	$5\frac{1}{4}$*
0	2	0	0	8	$5\frac{1}{4}$	3	4	5	$4\frac{1}{4}$	$5\frac{1}{4}$
*0	0	0	6	4	$5\frac{1}{4}$	$2\frac{1}{2}$	$2\frac{3}{4}$	$4\frac{3}{4}$	$3\frac{3}{4}$	$5\frac{1}{4}$*
0	2	2	0	6	$5\frac{1}{4}$	$2\frac{3}{4}$	4	5	$4\frac{1}{4}$	$5\frac{1}{4}$
*0	0	4	4	2	$5\frac{1}{4}$	$2\frac{1}{4}$	3	5	4	$5\frac{1}{4}$*
0	2	4	0	4	$5\frac{1}{4}$	$2\frac{3}{4}$	$3\frac{3}{4}$	5	$4\frac{1}{4}$	$5\frac{1}{4}$
2	2	0	4	2	$5\frac{1}{4}$	$3\frac{1}{2}$	$3\frac{3}{4}$	5	$4\frac{1}{4}$	$5\frac{1}{4}$

Arrangements marked '*' appear in both the list of best average times and the list of best maximum times.

TABLE 7 A SUMMARY OF THE CHARACTERISTICS OF DIFFERENT TYPES OF EQUIPMENT

Equipment	Cost	Capacity	Other Specifications	Other Characteristics
Containers Cans or Drums	Supplied by foam manufacturer	5 gallons	Size approx 1½ft x 1ft dia Plastic or steel construction weight full: 65lb.	Very small capacity. A large capacity monitor would quickly use up a single can. Many men, and much organisational effort required at the fireground to maintain a continuous bulk supply. Not suited for bulk use.
		45 gallons	Size approx 3ft x 2ft dia Steel construction weight full: 575lb.	More difficult to handle on the fireground than 5 gallon cans and not offering a large enough capacity to be useful. Not suited for bulk use in normal circumstances.
Large Bulk Containers	£240	250 gallons (other sizes available)	Size approx 6ft x 3½ft dia Plastic container with steel lifting pallet Weight: 300lb Weight full: approx 3,300lb.	May be conveniently stored in or out of doors. Must be lifted by mechanical hoist or similar. Size and low cost make these containers appropriate for Support Stocks, but not for Initial Stocks.
Static Bulk Tanks	£800 £1600 £2300	1000 gallons 2000 gallons 3000 gallons and other sizes	Tanks made from lightweight plastic material to various specifications. Costs exclude fixing and any accessories.	May take up considerable space in a station yard etc. Planning permission may be required. The use of bulk tanks to refill tankers etc.at the time of a fire may require quite complex logistical planning.
Modifications to Vehicles Power Arm fitted to GPL	£3400	Depending on model can lift a full 250 gallon container at an extension of 13 to 17ft	Hydraulic Operation. Weight: approx 2100lbs. Extensions available to extend reach to 30ft, with reduced lifting capacity.	Fixes to general purpose lorry behind cab. May be used for purposes other than foam mobilisation. Suitable for mobilising 250 gallon containers as Support Stocks. Mobile lifting equipment allows rapid, reliable unloading at the fireground.

Equipment	Cost	Capacity	Other Specifications	Other Characteristics
Demountable Body Systems Large ground level demountables	16 tonnes GVW £6,000 30 tonnes GVW £10,000 (for vehicle modifications) + cost of tanker body required	Available to fit lorries up to 30 tonnes GVW and for bodies up to 20 ft x 8 ft	Hydraulic Operation. Weight: $1\frac{1}{2}$-$4\frac{1}{2}$ tonnes depending on model. 40 ft or more clear space required for on or off loading.	Chassis conversion available for most lorries. May be used for other purposes when not required for foam mobilisation. To be used efficiently requires a large capital outlay for alternative bodies. May be useful for Initial or Support Stock mobilisations.
Smaller ground level demountables	4 tonnes payload-£3500 10 tonnes payload-£4500 (for modifications) + cost of bodies	4-20 tonnes payload depending on model	Hydraulic Operation	Ditto
'Extendable Leg' demountables		$1\frac{1}{2}$-3 tonnes using light commercial system Larger payloads for bigger lorries.	Mechanical Operation. Electro-hydraulic operation for bigger payloads.	Smaller models require less complicated conversions.
Tanker Trailer	£45,000 - 32 tonne GVW tanker + Cab Unit	Up to approx 3000 gallons for large articulated vehicle.	--------	Articulated system requires specially qualified driver. Cab unit may be used for other purposes.
Tankers Tankers to Cheshire FB Specifications	£25,000 (depends on detailed equipment specified)	1500 gallons	16 tonnes GVW $12\frac{1}{2}$ ft wheelbase, 2 axle, on board foam pump	May be driven by driver qualified for normal appliance. Can pump foam compound to equipment on fireground suitable for Initial Stock Mobilisation
Petrol Tanker Conversion	Variable	2,700 gallons	Large 4 axle rigid chassis vehicle with pump	Requires specially qualified driver
Tanker with monitor	£30,000	no more than 1500 gallons	16 tonnes GVW with rear mounted platform monitor.	Monitor may be used for very fast early attack if tanker arrives very quickly. More suitable for on-site works brigade.

APPENDIX A

FOAM USE AT SOME MAJOR FIRES IN THE PETROLEUM AND CHEMICAL INDUSTRIES

In order to find out how often foam is required at fires, detailed brigade reports of 51 major fires in the petroleum and chemical industries were examined for details of foam use and availability. The fires included in the sample were all serious fires involving direct losses in excess of £100,000 at current prices. The results of this analysis are summarised below:

1. Foam concentrate was available for use at the majority of fires examined. Two-thirds of the reports which included details of overall attendance reported the presence of one or more bulk foam carriers. In many cases the bulk foam carrier was part of the brigade first attendance.

2. Foam was used at only 15 of the 51 major fires examined. The majority of the fires where foam was used were at oil refineries

3. Foam concentrate was very rarely required in amounts exceeding 5000 gallons. In the 15 fires where foam was used the amount of foam concentrate required was as follows:

Foam concentrate Used (gallons)	No. of fires
less than 100	3
100-500	3
1000-2000	4
2000-5000	3
more than 5000	2

In the two fires requiring over 5000 gallons of concentrate the amounts used were 5,500 gallons and 47,000 gallons. The latter fire was an exceptional case; a fire in Avonmouth Docks in 1951.

4. In most cases the local brigade foam attendance, together with works brigade stocks, was sufficient to deal with the fire. Ignoring the Avonmouth fire, the detailed reports only once recorded a call for additional stocks of foam concentrate once the brigade had arrived in strength.

The above results show that, even at incidents where there is potential for massive foam use, foam is used relatively infrequently. This agrees with the experience of senior brigade officers who also emphasised the value of foam in the incidents where it is used.

APPENDIX B

A METHOD OF CALCULATING DELIVERY SCHEDULES FOR DIFFERENT STORAGE AND TRANSPORT ARRANGEMENTS

The assessments made in the case study include an estimation of the times taken to deliver various quantities of foam compound to the different risks. It may be possible to do some of these calculations as simple exercises in mental arithmetic, but some arrangements involve many movements of different vehicles and the calculations become a little more complicated.

In this Appendix a convenient method of calculating delivery schedules is described. The method is based on the use of a map of the country on which cardboard counters are moved to represent the vehicle movements. The movements of the stocks and the associated times are recorded as the moves are made.

The information required

A knowledge of travel times and mobilisation times is essential for the calculation of delivery times.

The travel time is the time taken to travel between any of the stations and the risks in the area. These travel times may already be known or might be estimated from timed appliance runs. Alternatively, an approximation to the travel times for emergency vehicles can be derived by measuring the straight line distance between the two points and assuming a "straight line travel speed" of 35 mph (56 kph) for motorways and other fast roads and 20 mph (32 kph) for roads in towns or narrow, winding or hilly roads in rural areas. Within city centres or where there are barriers such as rivers or coastlines these simple approximations may not be valid.

The time taken to mobilise the vehicles, and to load or unload the foam stocks must be added. This mobilisation time includes the turnout time at the station and, for example, the time taken to haul a demountable tanker body on to the chassis or to load two 250 gallon containers on to a flat bed lorry.

The method of calculation

The steps in the calculation are as follows:

I. Calculate the travel times between the various risks, and the stations from which vehicles may be travelling. If there are only a few routes to be considered the travel times could be marked directly on the map. Alternatively, if there are too many routes to be conveniently marked on the map the times could be summarised in a Table, as is done below.

Table of travel times (minutes)

		Stations						
		A2	A3	B1	B2	B4	B5	Winsford stores (A5)
	R1 Ellesmere	5	17	40	35	19	25	40
	R2 Runcorn	20	6	20	16	2	7	30
Risk	R3 Widnes	28	13	15	20	10	2	40
areas	R4 Warrington	45	25	2	6	25	15	35

II. Estimate the turnout times/loading times/unloading times

In these calculations we have assumed the following times:

Initial turnout time	1½ minutes
Time to load or unload 2 x 250 gallon containers	5 minutes
Time to load or unload a demountable body	1 minute
Time to refill a 1500 gallon tanker from bulk tank	10 minutes

The times shown above are estimates used to illustrate the calculations involved. The longer turnout times at day manned stations and the possible unavailability of a lorry driver have been disregarded. If a more detailed analysis is required these factors would need to be included.

III. Place cardboard counters on the map to represent the initial positions of the stocks and vehicles.

For example for arrangement 3 described in section 4.5.1, place cardboard counters marked "1500 gal tankers" at A2 and B1 counters marked "2 x 250 gal container" at A2, A3, A5, B1, B4 and B5, and counter marked "lorry with hoist" at A5.

IV. Decide which move is to be made next

In order to estimate how quickly the stocks could be brought to the risk it is assumed that a call is made to mobilise all stocks. All the stocks which can be despatched immediately (ie the two tankers and the lorry carrying the first two containers) will then respond. Thereafter the lorry will ferry the remaining containers to the risk, starting with those containers which are at the nearest sites.

In other cases where for example two lorries with hoists are available the scheduling "rules" may be more complicated. The scheduling rules should be designed to complete the delivery of all the stocks as quickly as possible.

V. Move the counters to represent the movement of stocks, and record the moves

The delivery times need to be calculated separately for each risk. Assuming that the maximum amount of stock is required at the risk, move the counters to represent the delivery of the stocks. For example, if the foam was required at risk 1, the tanker at station A2 would deliver the first consignment. This movement would be recorded as follows:-

Start time	Trans-port	Turnout/ Loading time	Journey	Travel time	Unloading time	Finish time	Amount delivered (gallons)
0	Tanker	1½ mins	A2 - R1	5	-	6½ mins	1500

The "finish" time is the time taken to complete the delivery.

The complete delivery schedule is shown in Table A1. All the initial mobilisation is assumed to start at time zero (moves 1, 2 and 3). For the subsequent deliveries made by the lorry the starting time of each journey is equal to the finishing time of the previous journey (ie the lorry is assumed to be unloaded and sent out on its next journey as quickly as possible). The moves noted on the summary sheet include both the outward-return journeys of the lorry when collecting each pair of containers.

This calculation needs to be repeated for each risk, and for each arrangement considered.

In summary, the steps in this calculation procedure are:

I. Calculate the travel times between each risk and each storage location.

II. Estimate the turnout/loading/unloading times.

III. Mark the initial location of the stocks on the map (using cardboard counters).

IV. Decide which move to make first/next.

V. Move the counters and record

" Repeat steps IV to V until all stocks are delivered

" Repeat steps III - V for each risk

Table B1 THE CALCULATION OF THE DELIVERY TIMES

Equipment used	2x1500 gal tankers 1 lorry + hoist 12x250 gal containers
Initial Locations	Tankers - A2,B1 Lorry - stores (A5) Containers - 2 at A5, A2, A3, B1, B4, B5
Mobilisation times	Tanker 1½ minutes turnout Lorry Loading/unloading 5 minutes

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	Start time	Transport	Turnout/ Loading Time	Journey	Travel time	Unloading time	Finish time	Amount Delivered	Cumulative Total
1	0	Tanker 1	1½	A2 R1	5	-	6½	1500	1500
2	0	Tanker 2	1½	B1 R1	40	-	41½	1500	3000
3	0	Lorry 1	1½+ 5	A5 R1	40	5	51½	500	3500
4	51½	"	-	R1 A2	5	-	56½	-	-
5	56½	"	5	A2 R1	5	5	71½	500	4000
6	71½	"	-	R1 A3	17	-	88½	-	-
7	88½	"	5	A3 R1	17	5	115½	500	4500
8	115½	"	-	R1 B4	19	-	134½	-	-
9	134½	"	5	B4 R1	19	5	163½	500	5000
10	163½	"	-	R1 B5	25	-	188½	-	-
11	188½	"	5	B5 R1	25	5	223½	500	5500
12	223½	"	-	R1 B1	40	-	263½	-	-
13	263½	"	5	B1 R1	40	5	313½	500	6000

RISK 2 - RUNCORN