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Trials of Foams on Hydrocarbon Fires in the European Community

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SCIENTIFIC RESEARCH & DEVELOPMENT BRANCH

Publication 8/85 : Trials of Foams on Hydrocarbon Fires in the European Community

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January 1985

SC/84 28/42/1

SUMMARY

A survey is presented of large-scale tests of foam on hydrocarbon liquid fuel fires conducted by five member countries of the European Community Working Group on Fire. The aims and methods of the various trials are compared and discussed. General trends are apparent in the results, but variations in the test conditions adopted make numerical comparisons between trials impossible. In some trials reported, the information given on test conditions is incomplete.

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APPENDICES

1. INTRODUCTION

At the request of the CFBAC Joint Committee on Fire Research, the Home Office Fire Experimental Unit has undertaken a survey of foam trials held on large scale hydrocarbon liquid fuel fires. The study was initiated by the European Community (EC) Working Group on Fire, and was intended to cover the work undertaken in member countries.

A full scale experimental hydrocarbon fuel fire is very expensive to undertake,it was felt in the Working Group that it would be useful to attempt to draw together the results of past tests before any country contemplated any further research work. The purpose of this study was therefore to collate all relevant information from member countries and to present a summary report. It was envisaged that this would prevent needless repetition of tests, and might show general trends in the use and behaviour of foam on liquid fuel fires.

The report summarises contributions from member countries; compares the trials; identifies a number of points which need clarification; and suggests areas for further work.

In the event, problems in correlating the results of the various trials were encountered. These were due to different aims for each series of tests and also to a lack of a standard method for large-scale testing. This is not surprising where the trials take place in five countries and over a period of twenty years.

Nevertheless, general trends as to the effectiveness of different types of foam on hydrocarbon fires have been identified. Attention is drawn in the report (Section 6) to experimental procedures which should be standardised to enable future trials to be more easily correlated. Areas where further work would be beneficial are identified in the same section.

It is outside the compass of this report to produce a detailed analysis of the results of all the European foam trials identified. However, a list of references is given to the work analysed (Appendix A). It is recommended that the original reports be consulted where a detailed analysis of a particular test is required.

2. SUMMARY OF CONTRIBUTIONS ON LARGE SCALE HYDROCARBON LIQUID FUEL FIRE FOAM TRIALS FROM MEMBER COUNTRIES OF THE EUROPEAN COMMUNITY WORKING GROUP ON FIRE.

Table 1 shows responses of the EC Working Group member countries.

Of those countries making a positive return, West Germany enclosed a report on the use of foam for wood or furniture fires which is outside the scope of this report but nevertheless sheds some light on the effectiveness of foam as a fire-fighting agent for dealing with solid fuel fires. West Germany also sent a short report of some tests on an alcohol-resistant foam which is included in the present discussion. The Netherlands contribution was a series of reports concerned with the breakdown of foam when subject to heat radiation. These reports paid particular attention to the sealing properties of foam on hazardous chemicals or on volatile fuels. Obviously such properties contribute to considerations in the effective use of foam on hydrocarbon liquid fuel fires, but it was felt that the extrapolations required when applying these results to a pool fire would be so general and broad that they should not be made here.

Thus, of the EC Working Group member countries, Denmark, France, Italy, the Netherlands, the United Kingdom and to a limited extent West Germany appear to have performed large scale hydrocarbon liquid fuel fires and extinguished them with various types of fire-fighting foams. The aims of the trials were very often different, and these governed details such as the foam types used, the methods of application, the definition of control and extinction times, the methods of assessment of foam quality and the method of reporting the results. A comparison of the various trial programmes is presented in the next section.

3. COMPARISON OF VARIOUS FACTORS INVOLVED IN LARGE SCALE FOAM TRIALS.

Table 2 gives a brief resume of European foam trials.

3.1 Aims.

It was apparent from the various reports produced that the overall aim of trials varied from country to country. France, Italy and the United Kingdom were basically assessing the ability of various types of fire-fighting foam to control and extinguish a hydrocarbon liquid fuel pool fire. These trials were performed with a large tray fire which simulated a fuel spill or any other situation where a large surface area of burning fuel might be present.

The West German trials were performed on a small tray and were actually tests of a manufacturer's particular foam product against a specification. The Danish trials were designed to simulate conditions after an aircraft crash, where burning fuel had been spilt on the ground and persons within the aircraft required rescuing. These trials were therefore concerned with rapid knockdown and control, but not necessarily extinction of the fire. The aim of the work was to assess the best tactical choice and use of fire-fighting media, and consequently foam monitors were often used in conjunction with dry powder and water jets. Thus the aims of these trials and the resulting test methods were very different from those trials performed in France, Italy and the United Kingdom. It is accordingly difficult to correlate the Danish results with those of the other three sets mentioned.

3.2 Fuel type.

Various fuel types were used throughout the European trials. Aviation petrol was used by Italy and Denmark. Italy also performed trials with diesel fuel and toluene. France, for financial reasons, used crude oil for their large scale tests and kerosine for smaller scale tests. The United Kingdom trials were performed with two-star motor petrol.

The essential difference between the various fuels is the variation in the number of light, more volatile fractions. Crude oil does contain substantial light fractions, while heavy oil has few, thus making it difficult to ignite. In any such mixture the lighter fractions will burn off more quickly.

In some French tests the crude oil was left standing in the tray overnight thus allowing the evaporation of some light fractions. For the second test of the day the oil was reignited and therefore the fuel could not be considered to be identical since the percentage of different fractions in the crude oil would have changed. The Italian and United Kingdom trials were each performed with a new, unburnt sample of fuel for each test. The nature of the West German trials dictated that the fuel used was usually methanol (an alcohol, not a hydrocarbon) because the trials were on an alcohol-resistant fire-fighting foam; but to test the effectiveness of this foam on hydrocarbon fuels, aviation petrol was also used for some of the trials.

The volume of fuel used depended on the size of the tray. The depth of the fuel is a parameter which determines the length of time the fire will burn freely. It is approximately independent of the surface area of the tray. Several trials were performed with an unknown depth or volume of fuel, so it is difficult to know whether a fire was extinguished through lack of fuel rather than purely by application of foam. Because the foam being used had poor extinguishing power, the fuel burned itself out in one United

Kingdom trial.

3.3 Foam type.

The different types of foam tested were protein, fluoroprotein, synthetic and aqueous film forming foam (AFFF). The general trend was for all trials to include protein and fluoroprotein foams. In addition, synthetic and AFFF foams were tested in the United Kingdom, Italy and France. Synthetic foam was tested at an expansion ratio between 20 and 30 to 1 in the United Kingdom and at 'medium' expansion ratio[1] in France. United Kingdom trials also used high expansion (greater than 500:1) synthetic foam. All AFFF trials used aspirated foam, i.e. using a foam branch pipe to apply the AFFF, although one of the United Kingdom trials included AFFF in its non-aspirated form, i.e. purely as a water additive without the foaming of the subsequent solution. The expansion ratios for the Danish tests are not known. It is assumed from the report that low expansion protein foam was used. The German trials did not given an expansion ratio either, but it was possible to calculate the expansion ratio from tne measurement of water applied.

3.4 Fire size.

Apart from one set of Italian trials which was performed on a fuel tank, all the other trials were performed on trays of various sizes. All the trays were square or oblong. The largest tray fires were those performed in France, with an area of 2000 square metres (m^2). These were the crude oil tests. The kerosine tests performed in France had an area of $170m^2$, which was also larger than the trays used in the United Kingdom and West Germany, which had surface areas of $84m^2$ and $50m^2$ respectively.

The Italian tests sought to correlate the results from small trays ($9m^2$ and $37m^2$) with those from larger trays ($150m^2$ and $600m^2$) to establish whether large scale trials are necessary. The aim was to determine a minimum tray size above which the results from the trials would be valid for larger-scale spills. This is discussed further in Section 4.

In the Danish trials an aircraft fuselage was placed in a tray of $400m^2$ or $900m^2$ size.

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1. The United Kingdom Manual of Firemanship Book 3 (Ref.1) gives the following definitions of foam by expansion ratio :
   Low expansion. Less than 50:1 (usually 5:1 - 15:1)
   Medium expansion. 50:1 - 500:1 (usually 75:1 - 150:1)
   High expansion. Greater than 500:1 (usually 750:1 - 1000:1)
   The French report did not specify the expansion ratio in numerical terms, but in the film of the trials the appearance of the foam suggested a figure at the high end of the medium expansion range, perhaps about 400:1.

3.5 Pre-burn duration.

Important in any liquid fuel fire is the amount of time that the fuel is burning before the application of the extinguishing medium. The longer the pre-burn, the hotter is the surface of the fuel.

The longest pre-burn times were those in the French crude oil trials, where the pre-burn was usually something over 8 minutes. In Italy in the majority of tests a 5 minutes pre-burn was allowed, although in the smaller scale tests a 1 minute pre-burn was used. The United Kingdom trials used a 1 minute pre-burn. On average the Danish trials had a 45 seconds pre-burn but this was governed by the speed at which the fire-fighting vehicles reached the scene of the fire and commenced extinction. It was not a predefined time.

3.6 Foam application rate and method.

The rate of foam solution application per unit area (in litres per minute per square metre) is a universally significant factor over a range of fire sizes in determining control and extinction times. Only when tests have comparable application rates can control and extinction times be compared. The United Kingdom tests standardised on an application rate of 2.7 litres per minute per square metre of fire. No other country standardised their application rate. The Italians used an application rate which varied between 2.0 and 8.0 litres per minute per square metre, and the application rate was varied even on tests on the same size tray, depending on the type of foam concentrate. The French trials also had variable application rates depending on the foam concentrate used and the method of application. Similarly, in Denmark where various fire-fighting appliances were used, the application rate was again dependent on the equipment and the number of branches or monitors used in any one trial.

In general, the method of application was dependent on the type of foam being used. Only the Italian trials used an indirect method of foam application where the foam was directed at a inclined surface and allowed to flow onto the fire, thus creating a more gentle means of application to the surface of the fuel. The United Kingdom report makes the point that experience of the branchman was a major factor in his ability to put out the fire, particularly with low expansion foams. The Italian tests, whether the foam was directly or indirectly applied, were performed by fixed monitors and branches which meant there was no branchman. This did lead to higher extinction times, because small pockets of flame around the outside of the tray ultimately could not be extinguished by direct impingement of foam, but only by the flowing of the foam blanket into that area. The Danish, French, United Kingdom and West German tests all depended on the skill of local authority or civil aviation authority fire-fighters.

3.7 Sealing properties.

Important factors in the control of a liquid fuel fire are the ability of the foam blanket to prevent a reignition of the fuel after extinction and the ability of the foam to inhibit the growth of a fire once restarted. This latter factor is often called the burn-back property of the foam. Burn-back properties were measured only in the United Kingdom tests and results showed that certain foams did have greater resistance to burn-back than others. The Danish trials did not consider the burn-back properties of foam, although in an aircraft rescue situation it is important that extinguished fuel does not reignite, and perhaps surround the rescuer. In the French trials, the second test of the day used reignited fuel carrying a foam blanket from the previous test, so that some indication of a foam's resistance to burn-back was gained from the time taken to involve the whole tray surface in fire.

Re-ignition tests were performed in West Germany with a 'fire-brand', no details being given.

3.8 Extinction and control measurement.

All countries, with the exception of Italy, measured the time to 100% extinction, i.e. when no fire was left burning. It must be noted that in the Italian tests, what was termed virtual extinction related to the condition where isolated flames were still visible at the corners of the tray. However, fixed branchpipes were used, and this factor would give a longer time than where a branchman could direct a foam jet at isolated pockets of flames (Section 3.6).

In addition to 100% (or near 100%) extinction time, a lower-percentage extinction time was measured in most trials. In the United Kingdom this was a 90% extinction time measured to be when observers estimated that there was only 10% of the fire surface area still burning. The French also measured a 90% extinction time, again from observation of the reduction of the fire area. The Italian measurement was called the 'time to control' the fire, and was judged to be when the flames were brought down to a height of less than sixty centimetres. The Danish and West German trials recorded only the time to 100% extinction.

4. RESULTS AND GENERAL TRENDS.

Appendix B summarises the conclusions reproduced from the various reports studied for this work. Caution must be exercised in using these conclusions without a thorough study of the individual report as a whole.

4.1 Fuel type.

From the Italian and French results it was demonstrated that the heavier hydrocarbons (crude oil and diesel fuel) were extinguished more readily than the more volatile fuels (petrol, kerosine and toluene). In particular the Italian trials demonstrated that, under certain circumstances, a diesel oil fire could be extinguished with protein or synthetic foam, whereas, under the same circumstances, a petrol or toluene fire could not. It is important, therefore, to bear in mind the type of fuel used for a trial when applying the results to a different situation.

4.2 Foam properties.

The United Kingdom trials were the only trials to monitor the foam properties (expansion ratio, shear stress and drainage time) throughout the test programme. Taking the whole group of EC trials, therefore, it is difficult to relate the extinguishing ability of a foam to anything other than the constitution of the concentrate. Having said that, the few results where foam of 'medium' or 'high' expansion was used show improved extinction times over 'low' expansion foams. This was probably due to a more rapid and complete build up of the foam blanket, less dependent on the skill of the branchman to direct the foam onto remaining pockets of fire. It was recorded that, in both the French and United Kingdom trials, the medium and high expansion foam blankets were not stable in windy conditions and had poor burn-back resistance.

4.3 Foam type.

The general trend was that AFFF was the most effective foam for a rapid extinction time. Fluoroprotein foam was also very effective and in the Italian trials performed better than AFFF. Synthetic foam at medium or high expansion was effective as an extinguishing agent (see Section 4.2) but protein foam was only really effective when used on diesel fuel or crude oil fires.

Rapid extinction times need to be balanced against the foam's ability to secure the fire and prevent reignition and burn-back. From the French and United Kingdom tests it was apparent that synthetic foams did not have good securing properties; in the French tests the protein foam also showed poor security. A general result overall was that the film formed by AFFF inhibited reignition but broke down rapidly once a fire was established, thus giving a poor result for burn-back. The foam with the most effective sealing properties was fluoroprotein, which prevented reignition and inhibited fire-spread once the fuel had been ignited.

4.4 Method and rate of foam application.

The French trials sought to examine the effect of increasing the application rate of the foam, and confirmed that a higher rate gave more rapid extinction. It was not established whether each particular foam type had an optimum application rate.

The method of application of the foam does affect the extinction time. Essentially the ability of the branchman to direct the foam onto the remaining pockets of flame reduces the 100% extinction time but has less effect on the 'time to control'. Several tests employed fixed installations to apply the foam (France and Italy in particular) and these resulted in some foam not reaching the tray. Thus, the stated application rate was not necessarily the amount of foam reaching the fire. In the Italian trials, foam applied indirectly, i.e. after sliding down an inclined surface onto the fuel, was more effective than that applied directly. A similar effect was observed in the United Kingdom where experienced branchmen allowed the foam to hit the fuel surface more gently. Thus the method of application should be such that it minimises disturbance of the foam blanket already forming on the fuel surface and avoids loss of the applied foam stream into the fuel layer.

4.5 Fire size.

From the Italian trials it was concluded that the extinction times increased as the size of the tray increased between $150m^2$ and $600m^2$. However, this was accounted for by the decrease in the relative number of foam delivery points for the larger tray even though the application rate per square metre was kept constant. Consequently, to take this effect into account, the Italians concluded that 'small scale test results can be extrapolated to large scale fires with the help of some rational criteria.'. This conclusion is in accord with the French tests which indicated that the relative effectiveness of various types of foam could be established from smaller scale tests.

4.6 Pre-burn duration.

Few deductions concerning the effect of pre-burn time could be made because this was usually a fixed parameter within a group of comparable trials. The Italian results indicated that the longer the pre-burn time, the longer the subsequent time to extinction. This effect makes it difficult to compare tests where the pre-burn time has not been constant, as in the French trials. The Italian tests made use of only two pre-burn times (1 and 5 minutes) and this is insufficient information to enable comparison with the French tests where long pre-burns were used ranging from 2.5 to 15 minutes.

5. POINTS FOR CLARIFICATION.

It seems to have been a tendency in most of the work studied for this report to change several variables in each test to try to obtain maximum data from a short series of fires. In addition, those variables which were not being tested directly (for example, pre-burn time, water temperature and meteorological conditions) were sometimes either not recorded, not standardised or not taken into account, leading to inconclusive results. In many cases results of fire tests would have greater significance if simple tests of foam quality had been made at the test site and other test methods standardised so enabling a more satisfactory comparison to have been made between the trials of different countries.

The high cost of experiments involving large-scale hydrocarbon liquid fuel fires lays particular stress on the need for sound experimental design. Some recommendations and points for clarification are given below.

5.1 Aims.

The aims and objectives of any large-scale liquid-fuel fire trials with foam must be clearly defined and stated in any report. It has become obvious that even with trials which seem similar, the choice of recorded data and reporting method are governed by the original aim of the trial. Thus many conclusions are not comparable because different criteria have been used in the gathering of results. This is highlighted in the Danish trials involving the use of several media. These trials were tactical rather than technical and cannot be compared with trials conducted elsewhere.

5.2 Fuel.

With the stated aims of the work in mind, the fuel must be selected accordingly. It is apparent that trials to test the effective use of foam on, say, aircraft crashes cannot be performed with a cheaper fuel such as crude oil. Similarly the reignition of used and contaminated fuel to perform further extinction tests would appear to be false economy since unknown factors have been introduced into the second test which were not present initially.

To be able to compare results from various trials, it would be advantageous to state that, for all extinction tests, fuel would be used as supplied and without long exposure to the atmosphere which may allow evaporation of volatile fractions. Also fuel should be re-ignited only for a burnback test, not for a new extinction test. If the volume of fuel for each test is standardised, the fuel becomes a controlled variable for the trials series.

5.3 Pre-burn time.

Although the effect of pre-burn time does not appear to have been established conclusively, it is apparent that the duration of the pre-burn has an effect on extinction times. For the purposes of test comparisons a pre-determined pre-burn time should be established and used throughout the trials. Ideally this should reflect a real situation, but in practice a relatively short time will probably be used in order to minimize fuel requirements.

5.4 Foam application rate and method.

In order to compare the extinguishing power of different types of foam effectively they must be applied at the same rate per unit area. Depending on the application rate chosen, some foams may fail to extinguish the fire, but this is valuable information in making the comparison between foams.

From the Italian trials it was apparent that the method of application had a bearing on extinction time. It would be useful to clarify whether tests should be performed with fixed branches (as in Italy) or using branchmen (as in the United Kingdom). There are advantages and disadvantages in both methods. Application by branchmen relates to real firefighting with handheld branches, but may give difficulty in obtaining consistent results if the branchmen's technique varies.

5.5 Foam property measurement.

With many of the trials reported here there was no attempt at foam quality control or assessment. When comparing results it is important to know whether the physical properties of the foams have been consistent. The effect of physical properties (expansion ratio, drainage time, 'shear stress' etc.) on the ability of the foam to extinguish a fire has not been conclusively established but it is important to have a record of these variables for each test. Since ambient conditions and operating factors can affect foam properties it does not seem valid to remove a branchpipe to a laboratory either before or after the tests to perform assessment there. Where several branches are used for a trial they should all be monitored to ensure that their performances are comparable.

5.6 Timing-point determination.

If more reproducible methods of determining timing points such as 'time to control', '90% extinction' and 'virtual extinction', could be established then the recorded times would be more easily compared between trials. As many of the timing points used depended on the judgement of observers, there are possibilities of variations between tests, particularly if performed over a period of time with different observation teams. Even '100% extinction' may be an ambiguous timing point, e.g. the Italian trials took a point where isolated flame was still visible as being the last recorded time for each test.

Measurement of 100% extinction, defined as the point when all the flames have been extinguished, is easy to define and should be noted for every test. Times for 'control' or a percentage extinction are much harder to define or measure. The Italian report gives the most objective criterion for one of these 'intermediate points' where 'time to control' is defined as the time when the flame height is brought down to less than 60 cm. In other reports where a percentage extinction time is given, no exact guidelines as to how this was assessed are reported.

Often in an operational situation it is the 'time to control' which is important rather than the 100% extinction time. Thus a good definition of when a fire is controlled is required. The Italian method of defining a flame height is simple to implement, but its significance depends on several factors, which may also control the maximum flame height achieved in free burn. Possibly the definition of 'intermediate points' could be in terms of the percentage drop in flame height. For example, with a fire in which flames reach, say, 10m , 90% extinction would be defined as the time when flame height had been reduced to 1m. An alternative method would be to measure the reduction in the heat output or radiation of the fire. Although more complicated to implement in a test programme the results thus obtained would be of greater intrinsic value. As the radiation level is reduced, so is the risk to exposed surfaces nearby. This method of assessing the control of a fire has been used on a series of test fires in Sweden (Ref.2) using wide angle radiometers to measure the radiation from the fire. In these tests, visual judgement of 90% extinction time was also recorded. This appeared to give longer times than the radiation method.

It is important that before further large scale tests are performed the method and criteria for determination of timing points must be better defined and consistent within a particular trials series. If a method could be accepted as standard it would enable work from different laboratories to be compared quantitatively rather than qualitatively.

5.7 Sealing Properties.

The extinguishing ability of a foam needs to be supplemented by good sealing properties (see Section 3.7). Given that fuel should not be reignited and used for extinction tests, maximum benefit can be obtained from each trial by performing an ignition test on the fuel with its foam blanket a given length of time (say 10 minutes) after initial extinction. In addition to this the burn-back properties of the foam could be established as part of the same test by letting the fire spread over the full fuel surface, and recording the time taken to 100% involvement.

6. AREAS FOR FURTHER WORK.

There are several areas in which further work would be beneficial for increasing knowledge about the use and behaviour of different foam types on hydrocarbon liquid fuel fires.

6.1 Fuel type.

Categorizing fuels into groups, and from each group selecting a 'standard' fuel would minimize the number of trials required to cover all risks. Although fuels are categorized by flashpoint this property alone does not standardize fuels for foam trials. The important factor is the ease with which a fuel may be extinguished rather than ignited and this is not necessarily related to flashpoint alone. Research, either practical or a literature search, into this topic would be advantageous for the comparison or extrapolation of results.

6.2 Foam type.

From a qualitative viewpoint, the trials undertaken so far have established the effectiveness of various foam concentrates. Work could be performed to assess more exactly the merits or otherwise of using AFFF in its non-aspirated form and to compare further the 'knockdown' capability of AFFF compared with that of fluoroprotein foam.

The relationship between firefighting qualities of a particular foam type and its physical properties (e.g. expansion ratio, drainage time and 'shear stress') has not been fully established. Research in this field would increase the significance of physical tests of foam produced from particular equipment, and reduce the need for expensive fire tests.

6.3 Fire size.

Despite the Italian and French work, there is a need to establish how results from fires of different sizes can be related. Ideally, for foam testing, a fairly small fire should be standardized and the scaling factors calculated. However, it would be necessary to select a larger size for tests of practical fire-fighting equipment.

6.4 Pre-burn duration.

The effect of pre-burn duration on the subsequent fire test for various fuels should be established. By monitoring the radiation from a free burning fire it should be relatively simple to decide on a point at which the fire is thought to be stable. Beyond this point, a further effect occurs due to the heating of the fuel. Both factors should be considered in standardising the pre-burn time.

6.5 Application rate.

For each type of foam there is a critical application rate (Section 3.6) for extinction. At application rates below this the fire will not be extinguished until fuel exhaustion intervenes. Above this, there will also be an optimum application rate which uses the minimum quantity of foam for extinction. There is a definite need for these application rates to be established for the various foam concentrates. This would result in a more cost-effective use of foam and manpower.

Coupled with the application rate is the method by which foam is applied to a fire. The Italian report suggested that several points of attack are more effective than a massive attack at one or two positions. This should be investigated further. An associated requirement is to assess the different tactical methods employed by various firefighters to ensure that foam is applied to a liquid surface by methods which seek to conserve the growing foam blanket and the foam being applied.

6.6 Timing points.

As outlined in Section 5.6 the establishment of preferred timing points would be advantageous. This could probably be done on laboratory scale tests initially and the findings of such tests then applied to full scale trials.

7. CONCLUSION.

It has become apparent that quantitative comparison of foam trials conducted to date is not possible through lack of a standard set of measurements and experimental techniques. However, general trends have been established which are consistent from country to country. AFFF and fluoroprotein gave the shortest extinction times, and synthetic foam at medium or high expansion also gave effective extinction. Except on diesel or crude oil fires, protein foam was less effective, failing to give extinction under some of the test conditions used.

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2. Ryderman, A., 'Testing of foam as a fire extinguishing medium for polar solvent and petroleum fires.', FoU-brand 1981/1982, p.12.

Table 1 E C Working Group—Summary of member countries' contributions.

COUNTRY	FOAM RESEARCH	FIRE TESTS	FUEL	TIME TO TOTAL EXTINCTION	REPORT	COMMENTS
Belgium	X					NIL RETURN
Denmark	✓	✓	AVIATION PETROL	✓	✓	CONCERNED WITH QUICK KNOCKDOWN [CONTROL] AND WATER SAVING FOR USE AT AIRCRAFT FIRES.
France	✓	✓	CRUDE OIL KEROSINE	✓	✓	TRANSLATION OF REPORT AVAILABLE. 16mm FILM OF TRIALS. CODE WORD 'PROSERPINE'
Ireland						ASSUME NO RESEARCH ON FOAM.
Italy	✓	✓	PETROL DIESEL OIL TOLUENE	X	✓	REPORT IN ENGLISH. VIDEO OF TRIALS NOT AVAILABLE MARCH 1984. VIRTUAL NOT COMPLETE EXTINCTION MEASURED.
Luxembourg						ASSUME NO RESEARCH ON FOAM.
Netherlands	✓	X			✓	TESTS ON SEALING PROPERTIES AGAINST FUEL EVAPORATION. FOAM SUBJECTED TO HEAT RADIATION NOT FIRE.
United Kingdom	✓	✓	2 STAR MOTOR PETROL	✓	✓	WELL MONITORED TESTS. VIDEOS AVAILABLE OF THE TRIALS.
West Germany	✓	✓	METHANOL AVIATION PETROL	✓	✓	SOME TRIALS ON WOOD FIRES. OTHER TRIALS OF CONCENTRATE AGAINST A SPECIFICATION.

Table 2 European foam trials – Liquid fuel fires: Summary

Country	Fuel	Stated Volume	Fire Type	Area	Pre-Burn	Protein	Synthetic	Fluoro-Protein	AFFF	Application Rate	Mode of Application	Extinction Time		Burn-Back	Foam Properties Tested
	———	Litres	———	m²	minutes	———	———	———	———	L/min/m²	———	90%	100%	———	———
(1961-62) Denmark	Aviation Petrol	2000	Tray	400	0.75	L				~ 7[1]	Direct	No	Yes	No	None
(1969)	Aviation Petrol		Tray	900											
France (1977)	Crude Oil		Tray	1920	~ 10	L	M	L	L	~ 4	Direct	Yes	Yes	Yes[2]	None
	Kerosine		Tray	170	~ 4	L		L	L	~4 or 12	Direct	Yes	Yes	No	None
Italy (1976)	Petrol, Diesel Oil, Toluene	Varied depending on tray size	Tray	9, 37, 150, 600	1 or 5	L	L	L	L	2, 4, 8	Direct and Indirect	Yes[3]	Yes[4]	No	In Lab
	Toluene		Tank	102	5			L		6	Base Injection	Yes[3]	Yes[4]	No	In Lab
(1976) United Kingdom	Petrol	1370	Tray	84	1	L	M H	L	L[5]	2.7	Direct	Yes	Yes	Yes	In Situ
(1981)	Petrol	1370-1827	Tray	84	1		M H	L		2.7	Direct	Yes	Yes	Yes	In Situ
West Germany	Methanol, Aviation Petrol	1000-1200	Tray	50	1 – 2			L M		~ 4	Direct	No	Yes	Yes[6]	None

Notes

1. Calculated from water application rate
2. Time taken to reignite whole tray for 2nd test
3. 'Time to control' flames < 60cm high
4. 'Virtual extinction', isolated flames at corners
5. Aspirated and non-aspirated AFFF tested
6. Reignition test.

L, M, H denote low, medium and high expansions

APPENDIX A - EUROPEAN COMMUNITY WORKING GROUP MEMBERS' REPORTS SUBMITTED FOR ANALYSIS.

Denmark

1. Statens Brandinspektion, 'Fire tests at the Copenhagen Airport, Kastrup. Reports 1, 2 & 3.', Statens Brandinspektion, (1961,1962,1969).

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France

3. Civil Defence Department, 'Operation Proserpine.', Ministry of the Interior, (1977).

Italy

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The Netherlands

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United Kingdom

6. Parsons, P.L., 'Trials of foam on petrol fires at the Fire Service Technical College.', Home Office SRDB, Report 14/75 (1975).

7. Parsons, P.L., 'Trials of medium and high expansion foams on petrol fires.', Home Office SRDB, Report 48/83 (1981).

West Germany

*8. Fuchs, P., 'Fire and extinguishing tests, full scale, to find suitable extinction agents to reduce water damage in firefighting.', University of Karlsruhe, (1978).

9. Extinguishing tests - Komet Extrakt-AF, Ministry of the Interior permit.

* Papers not relevant to this report but submitted to the EC Working Group.

APPENDIX B - SUMMARIES OF CONCLUSIONS FROM REPORTS SUBMITTED BY EC WORKING GROUP MEMBERS.

Appendix B - Figure B1: Summary of French test results.

TEST No.	FIRE SIZE m^2	PRE-BURN min. s	FOAM TYPE	CONCENTRATION %	APPLICATION RATE l/min/m^2	MODE	50% EXTINCTION min. s	90% EXTINCTION min. s	100% EXTINCTION min. s	BURN-BACK (approx) min. s	COMMENTS
1.1	1920	9.52	PROTEIN	2.35	3.5	FIXED DIRECT	7.00	8.30	10.00	6.00	
1.2	1920	15.00	PROTEIN	5.06	4.7	FIXED DIRECT	2.30	7.10	7.50	——	
1.3	1920	——	NONE	——	——	——	——	——	RAPID	——	NO RECORDED DATA
1.4	170	4.00	PROTEIN	6.21	4.7	PORTABLE DIRECT	4.45	5.55	7.05	——	
2.1	1920	9.00	FLUORO-PROTEIN	4.25	3.1	FIXED DIRECT	3.00	7.00	8.00	DIFFICULT TO REIGNITE	
2.2	1920	——	FLUORO-PROTEIN	——	——	——	——	——	1.30	——	EXTINCTION AIDED BY FOAM RESIDUE
2.3	170	2.30	FLUORO-PROTEIN	5.10	11.8	FIXED DIRECT	0.50	1.00	1.15	——	
3.1	1600	8.30	AFFF	4.60	~ 1.6	PORTABLE DIRECT	3.10	4.15	5.00	~ 12.00	FAIRLY RAPID INITIAL BURN-BACK
3.2			AFFF								QUALITATIVE TESTS
4.1	1920	8.18	MX SYNTHETIC	1.90	~ 1.3	FIXED DIRECT	2.00	3.45	4.50	6.00	
4.3	KEROSINE 170	3.16	PROTEIN	6.00	4.7	PORTABLE DIRECT	6.00	7.00	* 9.00	RAPID	* TOTAL EXTINCTION NOT ACHIEVED
4.4	KEROSINE 170	~ 5.00	AFFF	2.00	12.0	FIXED DIRECT	0.26	0.30	0.35	SPONTANEOUS	
4.5	KEROSINE 170	1.00	AFFF	——	——	PORTABLE DIRECT	——	1.03	1.30	——	

SUMMARY TABLE ON THE EFFECTIVENESS OF VARIOUS FOAMING AGENT TYPES

FOAM APPLICATION METHOD				INDIRECT FLOW TYPE OF SPOUT OR SPRAY								DIRECT SPRAY ON THE BURNING LIQUID							
FOAMING AGENT TYPE				PROTEIN.		SYNTHET.		FL. PROT.		FL. SYNTH.		PROTEIN.		SYNTHET.		FL. PROT.		FL. SYNTH.	
FREE COMBUSTION DURATION				1'	5'	1'	5'	1'	5'	1'	5'	1'	5'	1'	5'	1'	5'	1'	5'
FLAMMABLE LIQUID	GASOLINE-TOLUENE (CAT. A)	SPECIFIC COVERAGE $l/min \cdot m^2$	2	○	○	○	○	◒	◒	◒	○	○	○	○	○	◒	◔	◒	○
			4	◒	◔	◒	◒	●	●	●	◒	○	○	◔	○	●	◒	●	◒
			6	●	◒	●	◒	●	●	●	●	○	○	◒	◔	●	●	●	●
			8	●	●	●	●	●	●	●	●	◔	○	●	◒	●	●	●	●
	GASOIL (CAT. B)		2	◒	◒	●	◒	●	●	●	●	◒	◔	●	◒	●	●	●	●
			4	●	●	●	●	●	●	●	●	●	◒	●	●	●	●	●	●
			6	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●
			8	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●

○ - virtual extinction is not achieved in 5 minutes.

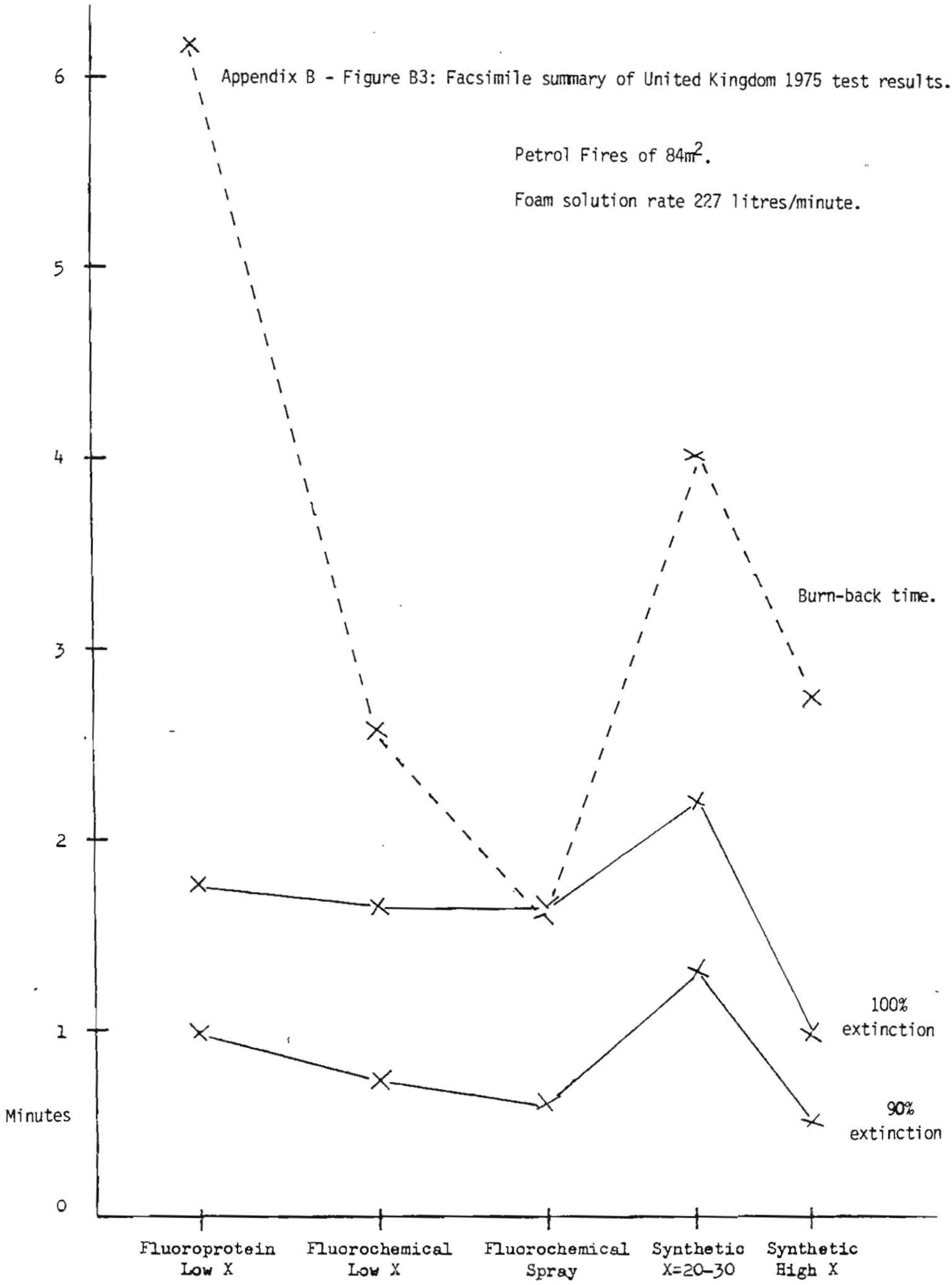
◔ - virtual extinction can be achieved in 5 minutes only if adverse conditions do not occur.

◒ - virtual extinction can be oblained in less than 5 minutes.

● - virtual extinction is achieved in a period of time much shorter than 5 min.

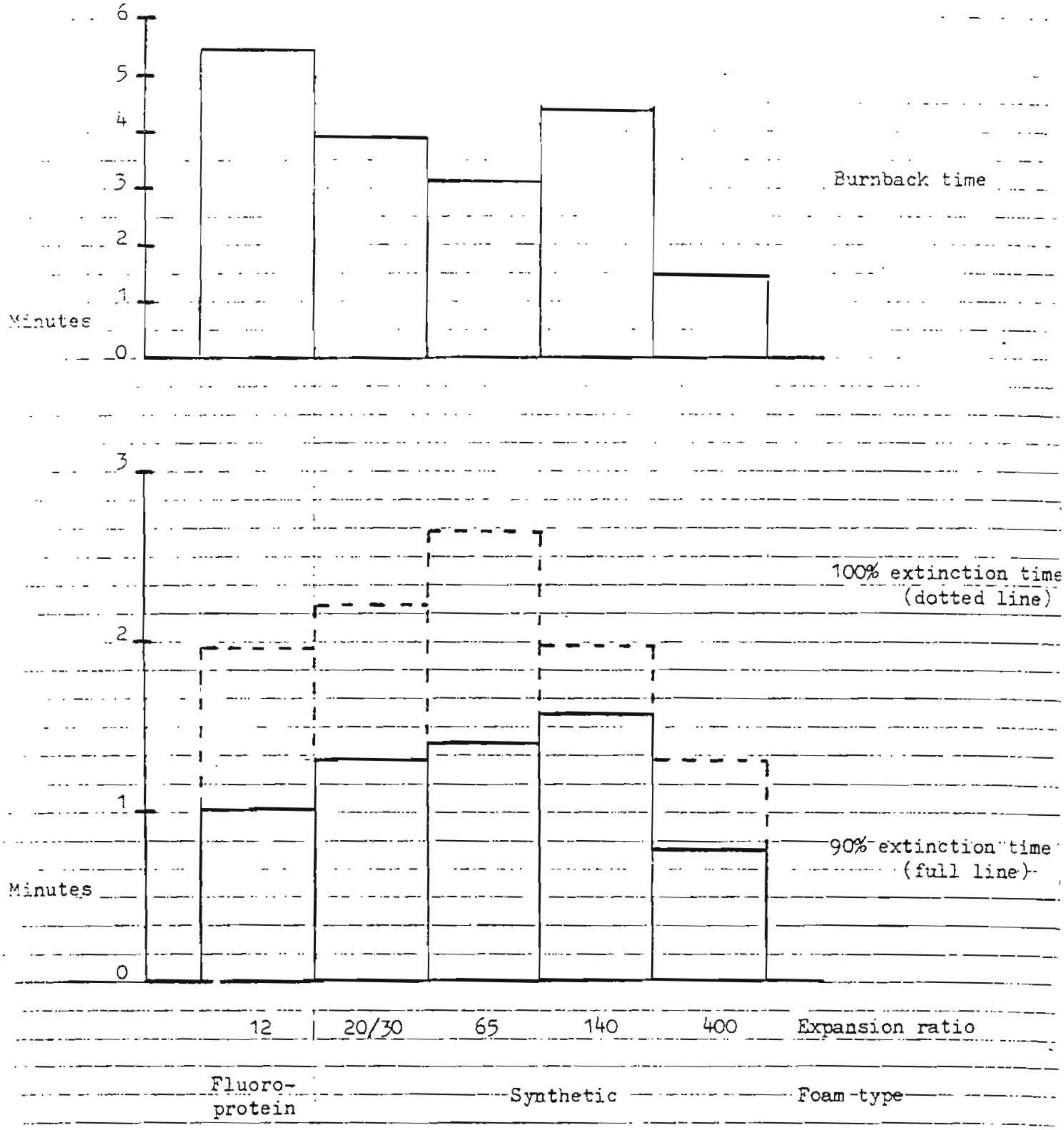
Appendix B - Figure B2: Facsimile summary of Italian test results.

Appendix B - Figure B3: Facsimile summary of United Kingdom 1975 test results.



(X denotes expansion ratio)

Appendix B - Figure B4: Facsimile summary of United Kingdom 1981 test results.



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