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EXTINCTION OF LABORATORY HYDROCARBON
FIRES WITH A SYNTHETIC FOAM

by

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SUMMARY

The extinction performance of a proprietary synthetic foam liquid, normally used for the production of high expansion foams, has been measured on 0.279 m^2 (3 ft^2) petrol fires, the foam being applied with expansion of about 10 at a rate of 0.04 $1/m^2/s$ (0.05 $gal/ft^2/min$). Control time was found to be a function of expansion as well as of shear stress.

With optimum foam characteristics, control time was equal to that obtained with fluorochemical foam, and superior to all other types of foam which have been tested.

Under the test conditions used, best results were obtained at an expansion of 12 and a shear stress close to 10 N/m^2.

KEY WORDS: Hydrocarbon, fire, foam, fuel liquid, extinguishing, tests.

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INTRODUCTION

Although it is known that synthetic foams are being used as alternatives to protein foams in Scandinavia and Germany for the extinction of flammable liquid fires, no substantial investigation of their performance on hydrocarbon fires could be found in the literature.

It was therefore decided, as an adjunct to another investigation, to examine the performance of a modern synthetic high-expansion foam liquid in some detail, when used at low expansions on petrol fires. The liquid mainly used was proprietary and has been designated 'Synthetic Foam Liquid A'. It is believed to be based on a lauryl ether sulphate/lauryl alcohol mixture, with anti-freeze and other additives, and is known to produce a good high expansion foam. Other similar liquids were also tested and have been found to give comparable results. The fire used was the standard 0.28 m^2 (3 ft^2) petrol fire specified in United Kingdom Defence Standard 42-3/Issue 1.

For comparison, results in similar experiments using protein, fluorochemical, and fluoroprotein foams are given with the results of the purely synthetic foaming liquid.

EXPERIMENTAL PROCEDURE

Laboratory foam production experiments were made in the 800 ml stirred jar[1], using a stirrer speed of 510 r.p.m., and a stirring period of 6 minutes. Drainage rates were measured directly from the 800 ml jar.

Fires in a 0.28 m^2 (3 ft^2) tray were conducted as specified in Defence Standard 42-3[2]. Except where stated, these experiments were with a standard application of 0.04 1/m^2/s (0.05 gal/ft^2/min). Narrow boiling range petrol (60-68°C) was used throughout. The method uses gentle surface application for a period of 4 minutes. Fire drainage was recorded at 5 minutes from the start of foam application, in place of the 10 minutes specified in the Defence Standard, because with the quick-draining experimental foams, the capacity of the graduated drainage cylinder was not sufficient to hold all the drainage occurring in a 10 minute period.

The Defence Standard requires a 10 minute fire drainage not exceeding 48 per cent of the liquid added as foam. It is not possible to give a precise equivalent for the 5 minute drainage value. In cases where both drainage values have been observed, a value of around 28 per cent at 5 minutes was approximately equivalent to the Defence Standard requirement of 48 per cent in 10 minutes.

Branchpipe trials were first made as specified in Defence Standard 42-3[2], in order to determine the foam properties for simulation in the tray fire tests.

EXPERIMENTAL RESULTS (Stirred Jar tests)

Figures 1-4 show the results obtained in the 800 ml stirred jar.

Figures 1, 2, and 3 show that a 2 per cent concentration is sufficient to produce foams of up to 20 expansion and 30 N/m^2 shear, and to ensure that drainage rate is almost independent of concentration.

All the fire tests were therefore made using 2 per cent concentration.

Figure 4 reveals some interesting differences between three liquids tested, as shown in the following table.

Stirred jar tests with various foam liquids

Foam liquid	Expansion necessary to produce a foam which just begins to drain immediately	Time for 16 Exp. foam to start draining
Fluorochemical	5.0	1 min
Synthetic A	8.0	$4\frac{1}{2}$ min
Protein	8.8	$6\frac{1}{2}$ min

Synthetic A and protein produce a fully-foamed liquid with approximately the same readiness, while fluorochemical does so significantly more readily. At higher expansions, protein and synthetic A foams increase rapidly in stability, while fluorochemical foam shows a much lower increase.

EXPERIMENTAL RESULTS - FIRE TESTS

Figure 5 shows the 90 per cent control time against shear stress, at various expansions. The control time depends upon expansion, and this dependency is related to the shear stress. All the curves in Fig. 5 must extend to show infinite control time at low shear stress, but the curves could not be completed beyond the limits shown because of the mechanical limitations of the foam generator. With no gauzes in the improver, using expansion 12, a good foam with a shear stress of 9 N/m^2 was obtained, while with expansion 6.5 and the improver packed full of fine gauzes, the shear stress could not be increased above 17 N/m^2. This limitation of the range of foam properties is not entirely attributable to the mechanical limitations of the generator. Different types of foam liquids each have a range of foam stiffness which is easily produced using that compound, the range depending upon the expansion.

Range of easily produced foams from
different liquids at expansion 8

Protein	$15 - 75$ N/m^2
Fluorochemical	$5 - 7.5$ "
Synthetic A	$5 - 15$ "

This effect has been quantitatively related to the energy used in foam production by Nash[3].

The minimum control time was achieved at expansion 12 and the other observations at this expansion are shown in Fig. 6. It can be seen from Fig. 6 that to obtain the minimum control time the shear must not exceed 11 N/m^2. The fire drainage at 11 N/m^2 is 18.5 per cent and increases markedly as the shear is reduced. At 8 N/m^2 the fire drainage increases to 23.5 per cent. Since however we are concerned with the liquid remaining in the foam rather than that draining from the foam, this is a change from 81.5 per cent to 76.5 per cent which is not a very severe fall.

If the shear rises above 11 N/m^2, the control time increases rapidly. A rise to 15 N/m^2 will increase the control time by almost 25 per cent.

Figure 5 shows that expansion 12 gives the shortest control times, but suggests that even higher expansions may show a further reduction, and it does not indicate the optimum expansion. In Fig. 7 and 8 the drainage data are recorded, and using these figures together with the control time Fig. 5, Fig. 9 was produced, which shows how the various measurements change with expansion when the shear stress is constant within the optimum range at 10 N/m^2. The control time curve indicates that a limiting or minimum value for the control time is approached as the expansion is increased and that although some improvement may be obtainable by increasing above expansion 12, the improvement will be limited.

The 25 per cent drainage time appears to be fairly independent of expansion except at the lowest expansions. This can be related to the stirred jar data which shows (Fig. 4) that it is impossible to make a fully-foamed liquid at expansion less than 8 in the stirred jar - which from Fig. 2 has a shear of 10 N/m^2. When the expansion is reduced below 8, part of the liquid cannot be held in the bubble walls and will drain immediately. This comparison is not strictly true because in the stirred jar data both shear and expansion are changing.

The fire drainage decreases with expansion, presumably as a result of the shorter burning time, but below expansion 8, the fire drainage rises steeply because of the additional drainage of the surplus liquid which cannot be held in the bubble walls.

EXPERIMENTAL RESULTS - BRANCHPIPE

The result of a test with No. 2 branchpipe and 2 per cent solution of Synthetic Liquid A are shown in Table 1, together with stirred jar and laboratory generator foam of the same shear stress.

Table 1

Synthetic Liquid A - 2 per cent concentration
Foam properties from different types of apparatus

Type of apparatus	Shear N/m^2	Expansion	25 per cent drainage time Min
Stirred jar	10.0	7.7	11
Laboratory generator	10.0	8.0	6.45
No. 2 Branch 100 P.S.I.	9.6	17.2	7.3

The branchpipe produced foam of the required shear stress but an expansion which may be too high for optimum control time. The results however give promise that the production of foam of the optimum quantity may not be impractical.

DISCUSSION

The most important result of the investigation is the encouraging result obtained with Synthetic Liquid A.

Table 2 shows comparative test data for other foaming solutions obtained in the same apparatus.

Table 2

Laboratory fires with various foam liquids
0.28 m^2 fires
0.04 $1/m^2/s$
N.B.P. fuel

Foam liquid	Shear N/m^2	25 per cent drain time min s		90 per cent control time s	5 min fire drain per cent
Protein A	19.3	3	24	75	39
Protein B	34.5	3	21	123	33
Fluoroprotein A	21.8	2	57	97	28
Fluoroprotein B	7.7	2	40	54	35
Fluorochemical	5.0	2	37	44	35
Synthetic A 12 expansion	10.0	5	10	42	20

In addition to having minimum control time, Synthetic Liquid A also has a significantly lower fire drainage than the other solutions, and this must favour post-control protection against repropagation. These control times for the various foaming liquids are depicted in Fig. 10. It is interesting to note that the control time for all the different solutions is generally related to the shear stress, indicating that this is the major factor influencing control time.

A second important result is the clear demonstration that with Synthetic Solution A, the control time is dependent upon expansion. Several groups of workers[4,5,6,7] have shown that using surface application and protein foam, the minimum control time is independent of expansion in the range of shear stress values normally used in practice. These two conflicting findings can be reconciled in the following way. Referring to Fig. 5, if a foam of perfect stability is produced, the time to control the fire will be directly proportional to the shear stress - this is the linear section of the expansion 12 curve in Fig. 5.

Alternatively it may be said that to obtain control in a chosen time, foam with a shear stress below a definite value is necessary. For example, Fig. 5 shows that to control in less than 70 seconds, a shear stress of less than 20 N/m^2 is necessary. The time taken to cover the surface is controlling the extinction process - as soon as coverage is obtained extinction is achieved. Thomas[9] gives data to show that coverage rate is a linear function of shear stress.

In practice, it is not possible to produce a foam with perfect stability, and as the shear stress is progressively reduced, a point is reached where extinction can no longer be achieved because the foam falls in stability and disintegrates before it can adequately cover the surface - the stability of the foam is controlling extinction, not the time required for the foam to cover the surface.

Most of the work with protein foams has been at shear stress in the range 15 N/m^2 upwards with test fire sizes and flow rates which fall in the range where the time to cover the surface is controlling and not the foam stability - hence the conclusion that control time is independent of expansion.

As pointed out earlier, protein foams in this range are readily produced, and protein foams with shear stresses of less than 15 N/m^2 are not readily produced.

In a number of reports expansion has been found to effect the control time. Peterson[8] (et al) using dispersed pattern protein foams on 400 ft^2 gasoline fires, found expansions 10-12 gave shorter control times than lower or higher expansions. Fittes and Nash[10], using fluorochemical foam on 0.28 m^2 petrol fires found that increasing the expansion from 4 to 20 reduced the 9/10 control time by 50 per cent. The same authors[11] using fluorochemical foam on 81 m^2 AVTUR fires found expansion 20 marginally better than lower expansions. Clark[12] using protein foam on 6 m^2 petrol fires, found expansion 10 better than 6 or 14. All these reports apply to tests in which the importance of spreading time is reduced by using a dispersed pattern foam, or a moving branchpipe, or utilizing fluorochemical foam which has a low shear stress and high spreading rate.

One possible explanation of the effect of expansion on control time is suggested by the work of French[14], who found that the heat resistance varied with expansion. French was working with protein foams of 40 N/m^2 shear, and his results are shown in Fig. 11. The occurrence of a peak heat resistance at around 14-16 expansion is interesting and this curve could be a mirror image of the control time curve if the latter were extended to high expansions.

These results on 0.28 m^2 laboratory fires are very promising, but they are far from sufficient to prove that Synthetic A foam, used with the preferred foam quality, is superior to protein foam for practical use. A scaling-up factor has been found using protein foam and fluorochemical foam[11,13], and this may be different in magnitude from a factor applying to Synthetic A foam.

Hird[13] has shown that the method of application, either gentle surface or forceful, and the length of preburn, make large differences to the extinction performance of foams. The type of fuel also has large effects and its performance on water-miscible solvents must be determined. Also the critical application rate, which is of practical importance, has not been determined.

In spill fires, the foam is applied as a moving jet, or dispersed pattern. The optimum foam characteristics under such conditions may be different from those found in the small scale fires using gentle surface application.

The solution tested was one which has been developed for producing high expansion foam and improved performance might be obtainable if the formulation is specifically developed for its performance at lower expansions. If a single solution could be used at any expansion between 7 and 1000, this would have great advantages, particularly for municipal fire brigades which have to deal with many varied incidents, the nature of which may not be precisely known when the appliances leave the fire station.

The cost of Synthetic Solution A is approximately the same as protein solution when allowance is made for the use of only 2 per cent concentration in place of the 4-6 per cent of protein liquid. The cost is significantly lower than that of using fluorochemical or fluoroprotein liquid.

Since Synthetic Liquid A can be prepared at a concentration which requires only 2 per cent as compared with 4-5 per cent for protein liquid, this results in a 50 per cent reduction in packaging and carriage costs and facilitates its transport to the fire incident. Packaging and carriage costs can account for about half the total cost.

Synthetic foam would probably be manufactured as a side stream product to a very much larger basic detergent industry. This would greatly favour economic production and would also permit large fluctuations of demand for fire-foam liquid to be absorbed without the need to maintain idle production plant to meet peak demands.

Protein foam production in U.K. is dependent on the supply of a comparatively pure protein as raw material, such as blood, hooves, horn, feathers, etc., and in many instances these materials have to be imported. These raw materials only arise as by-products from the animal production industry and their availability is subject to many vicissitudes both in the natural supply and in the demands for other animal products.

CONCLUSIONS

Laboratory fires have shown that a proprietary high expansion foam liquid, when used on laboratory petrol fires, at 0.04 $1/m^2/s$ and at low expansion, is superior to other types of foam liquids at present in use for the extinction of hydrocarbon fires. A liquid of this type would have valuable production and usage advantages over protein foam. Further studies on a larger scale are necessary for the complete evaluation of synthetic foam liquids before they can be considered as replacements for protein liquids. These studies should include the measurement of the critical application rate, the effects of forceful application and various fuels.

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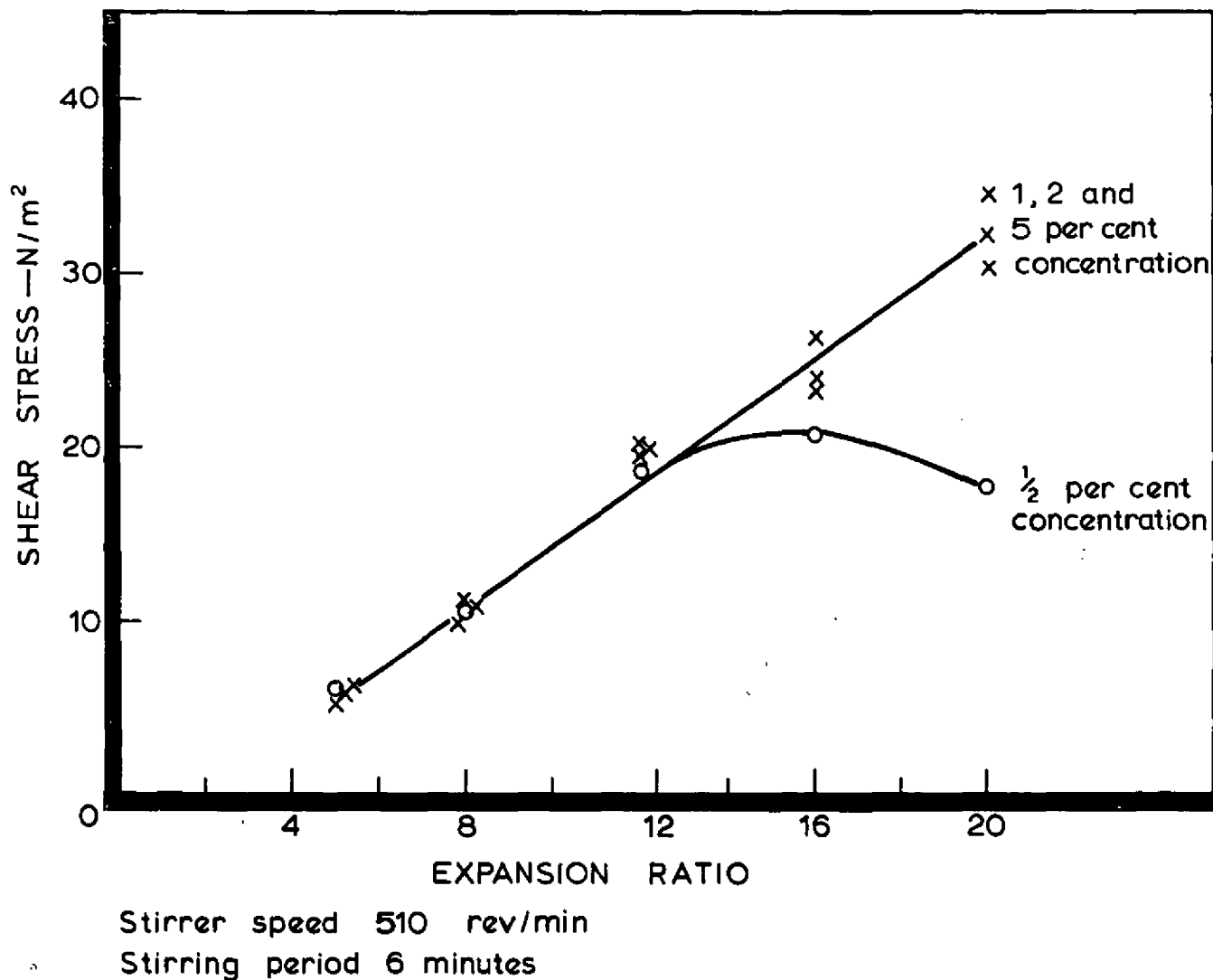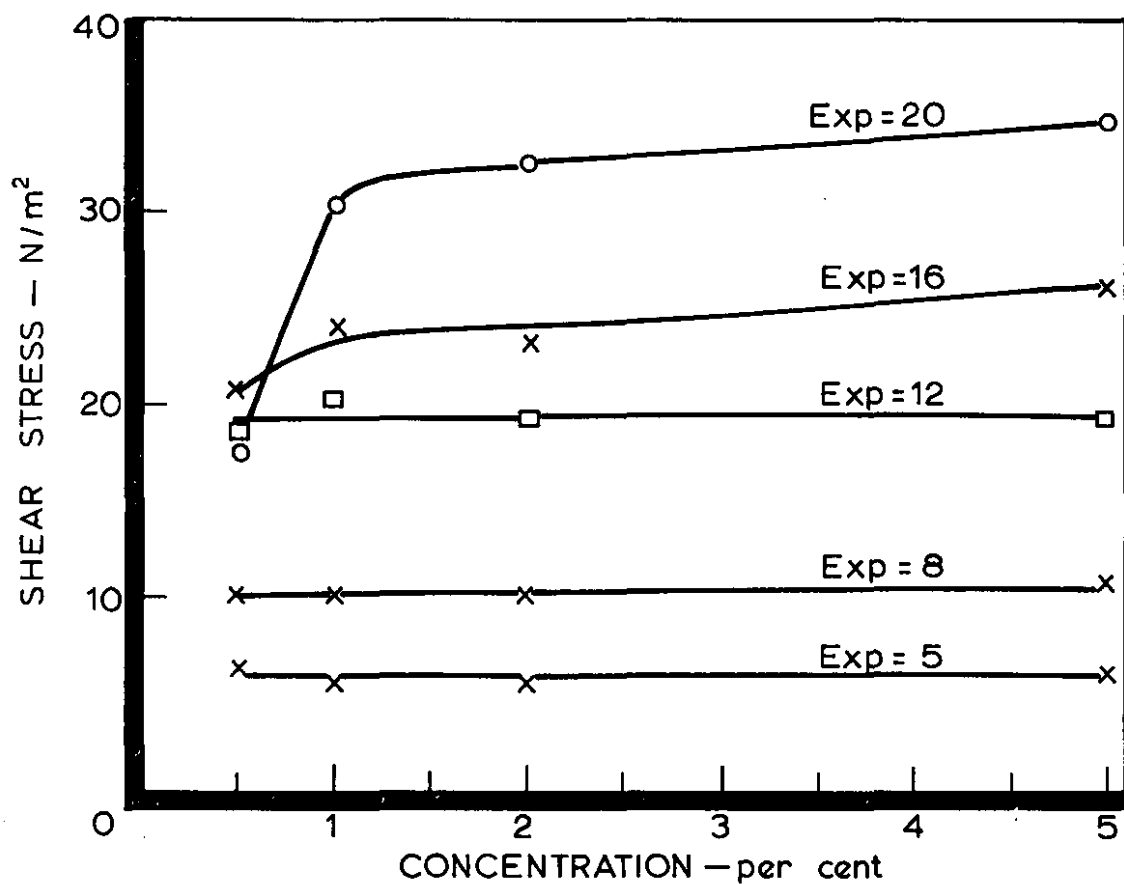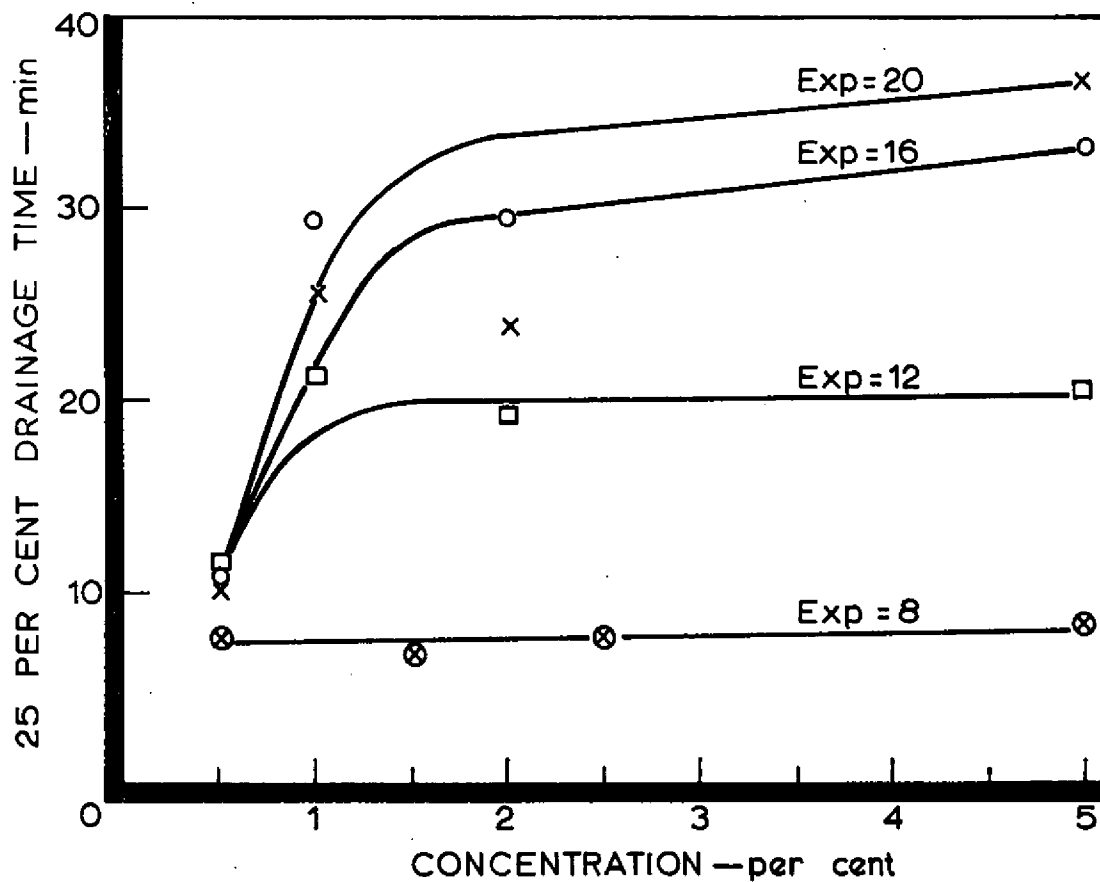
FIG. 1. SYNTHETIC LIQUID A, 800 ml STIRRED JAR
TESTS - VARIOUS CONCENTRATIONS

FIG. 2. SYNTHETIC LIQUID A, 800 ml STIRRED
JAR TESTS - VARIOUS EXPANSIONS

FIG. 3. SYNTHETIC LIQUID A, 800 ml STIRRED JAR TESTS - VARIOUS EXPANSIONS
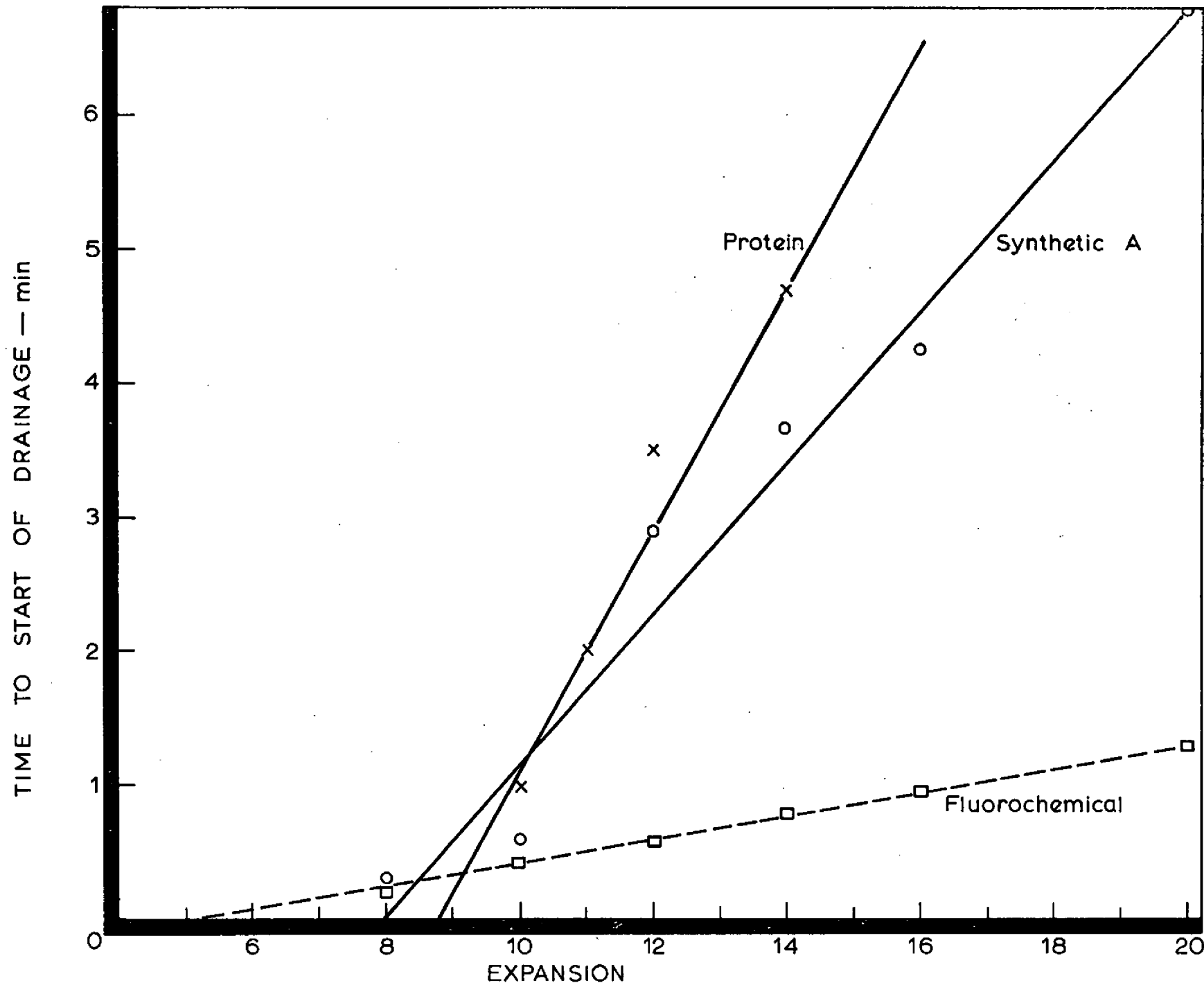
FIG. 4.   VARIOUS   COMPOUNDS   800 ml   STIRRED   JAR   TESTS
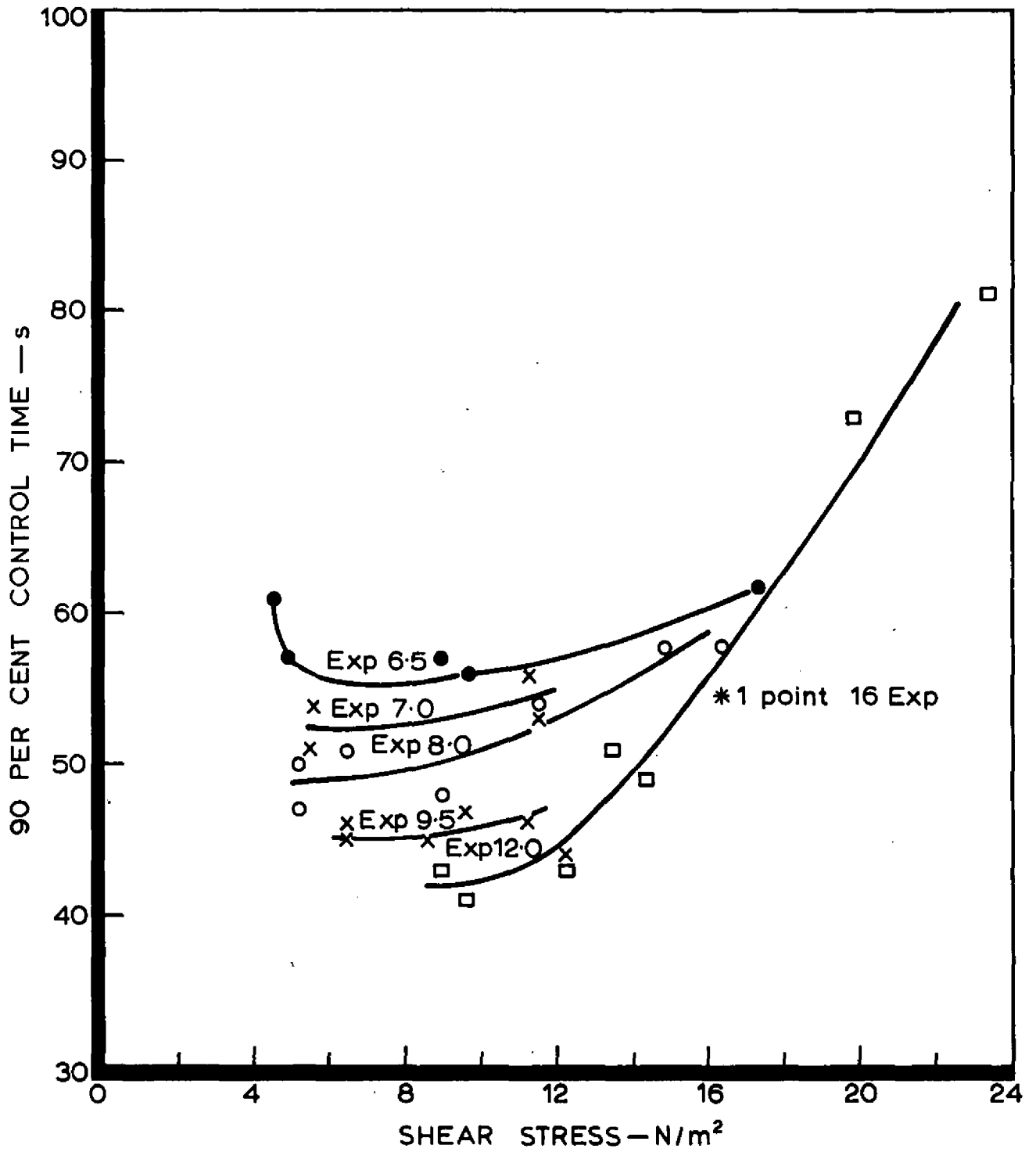
FIG. 5. SYNTHETIC LIQUID A, DEFENCE 42-3 FIRES
- VARIOUS EXPANSIONS
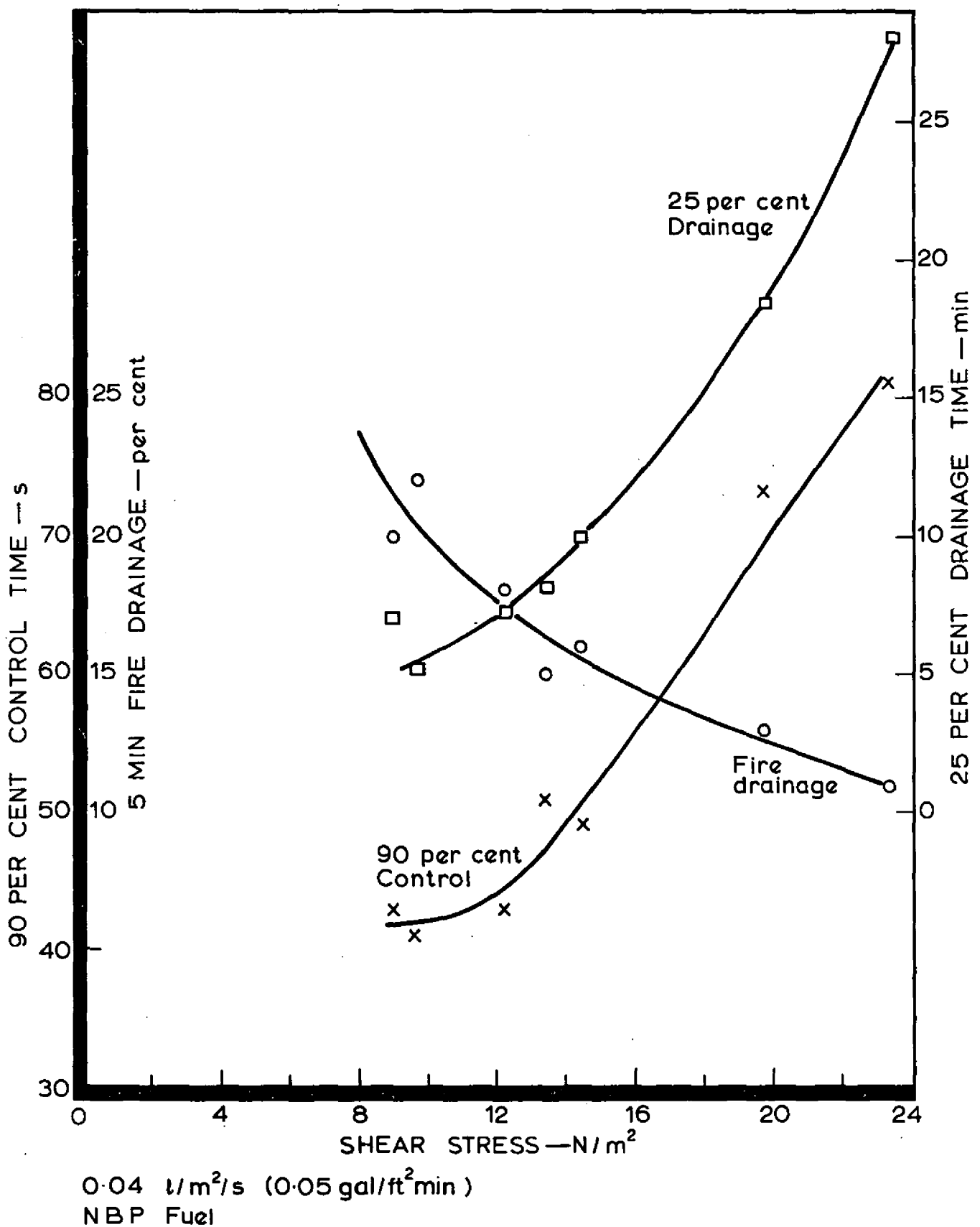
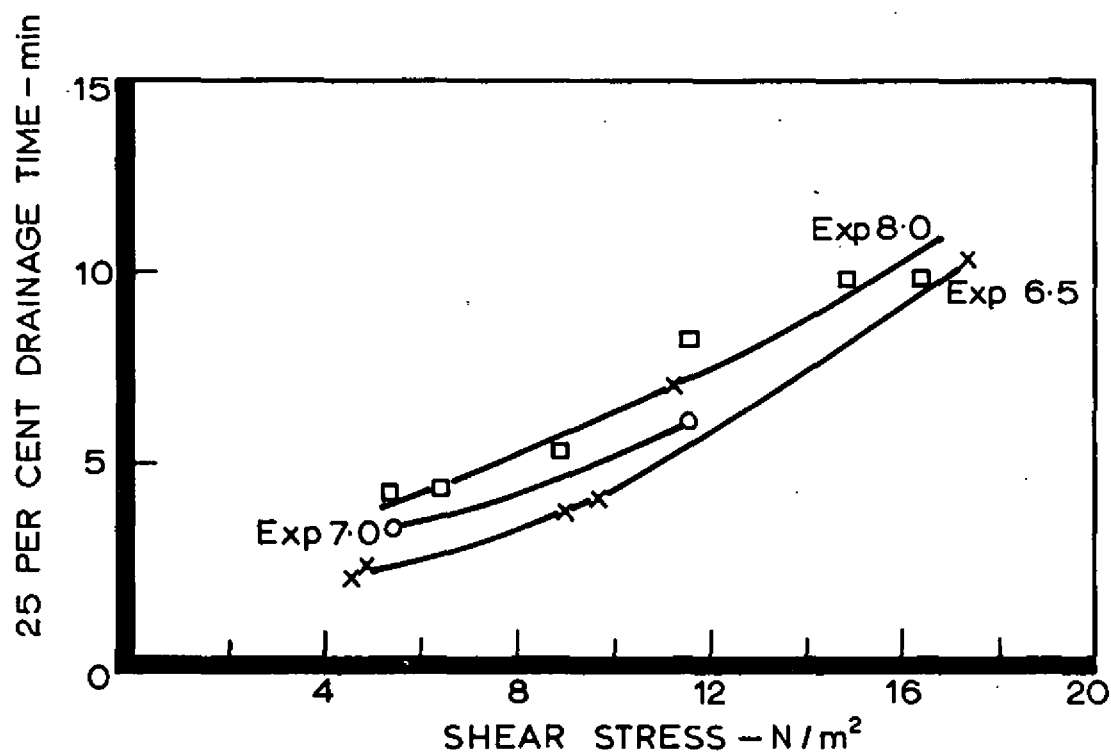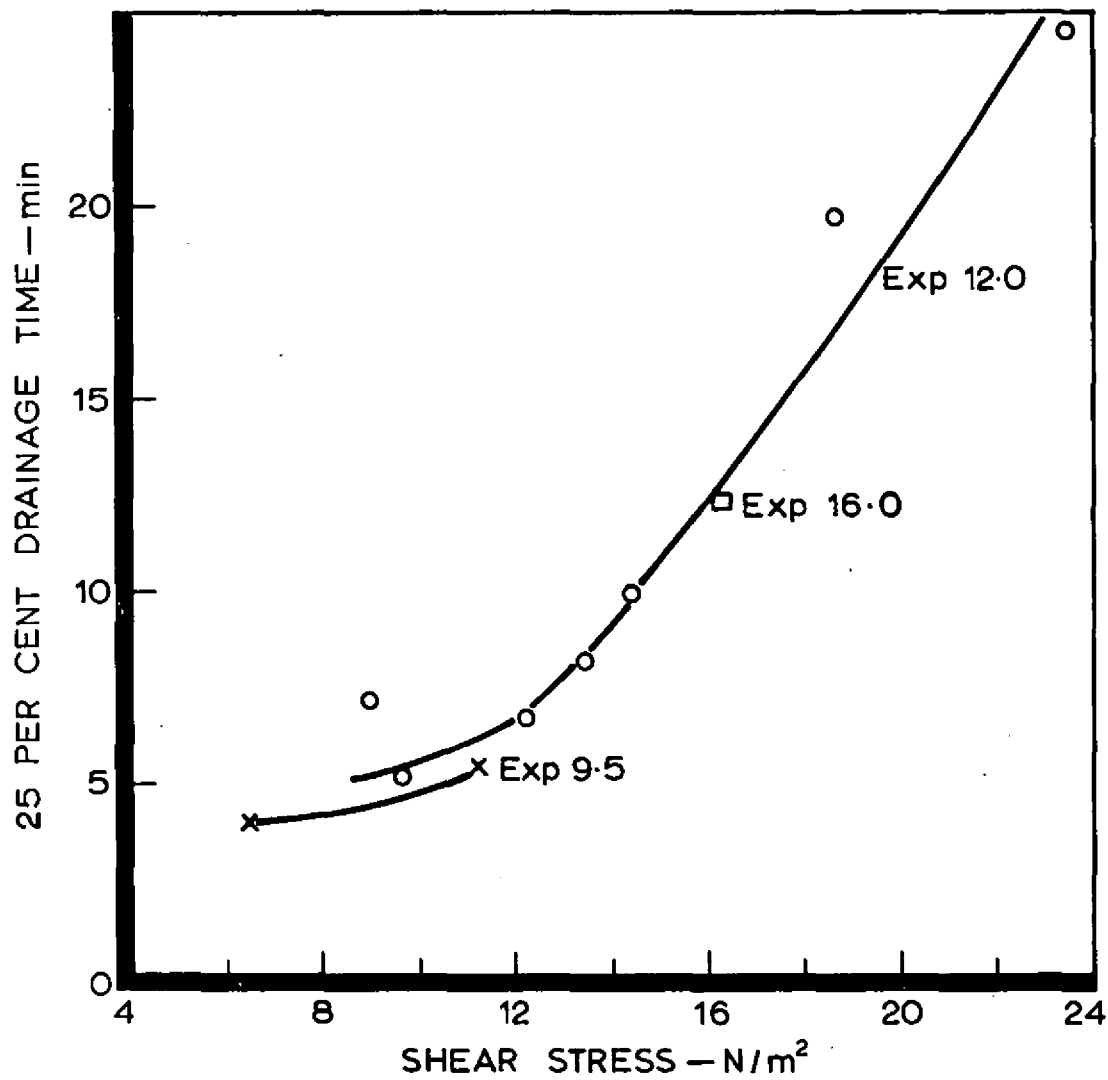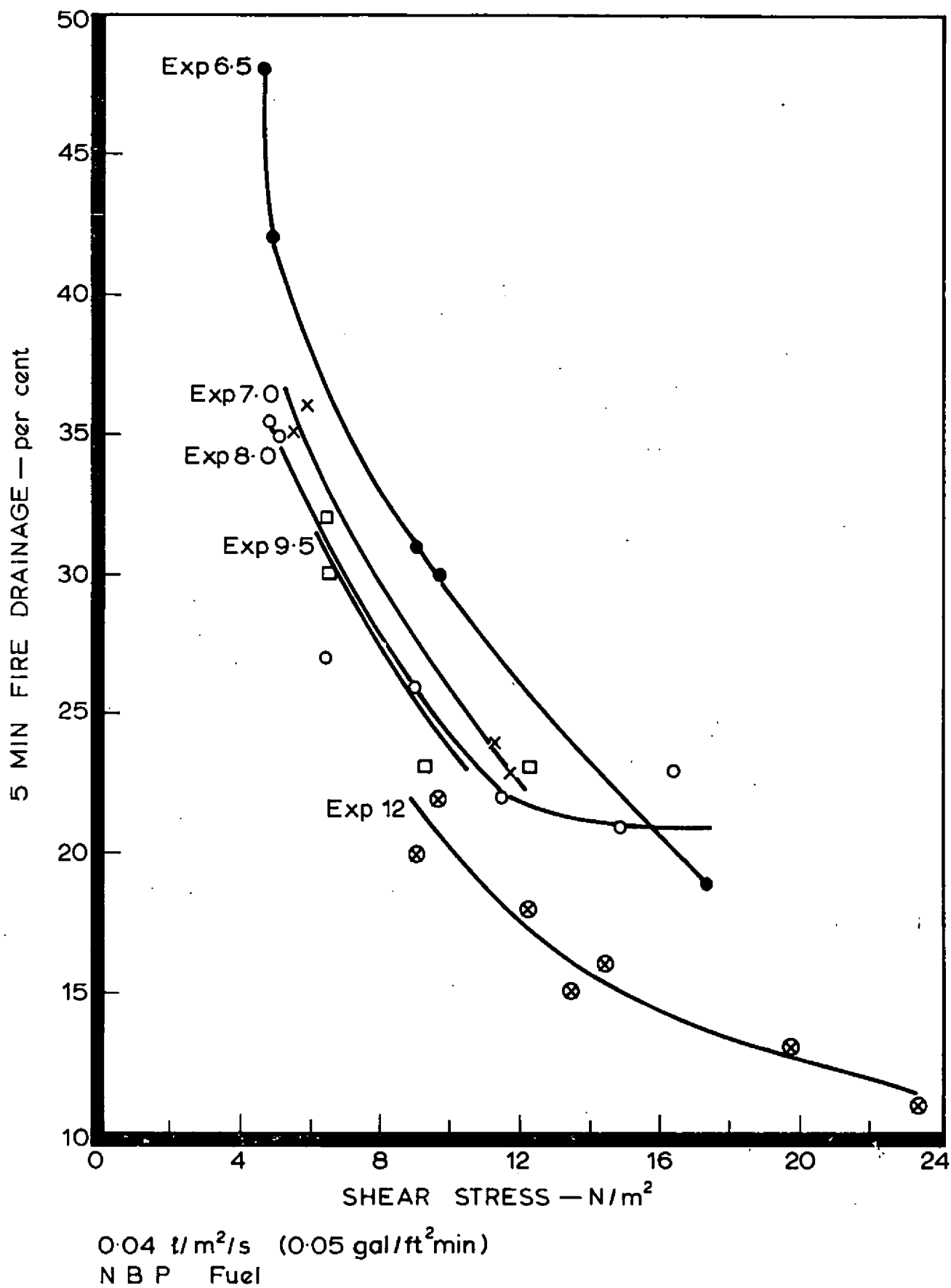FIG. 6. SYNTHETIC LIQUID A, DEFENCE 42·3 FIRES – EXPANSION 12

FIG. 7. SYNTHETIC LIQUID A, FOAM USED ON
DEFENCE 42-3 FIRES - VARIOUS EXPANSIONS

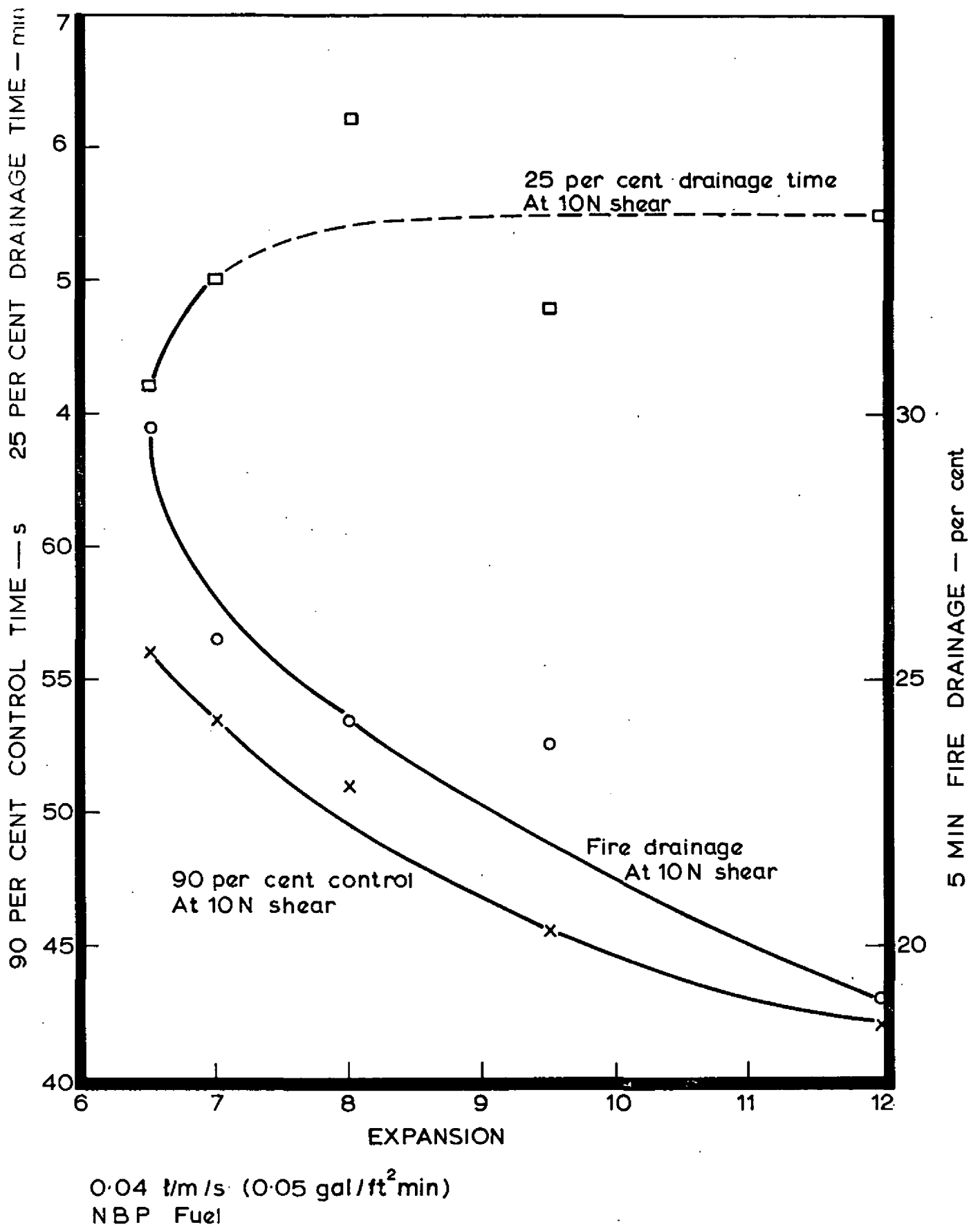FIG. 8. SYNTHETIC LIQUID A, DEFENCE 42-3 FIRES - VARIOUS EXPANSIONS

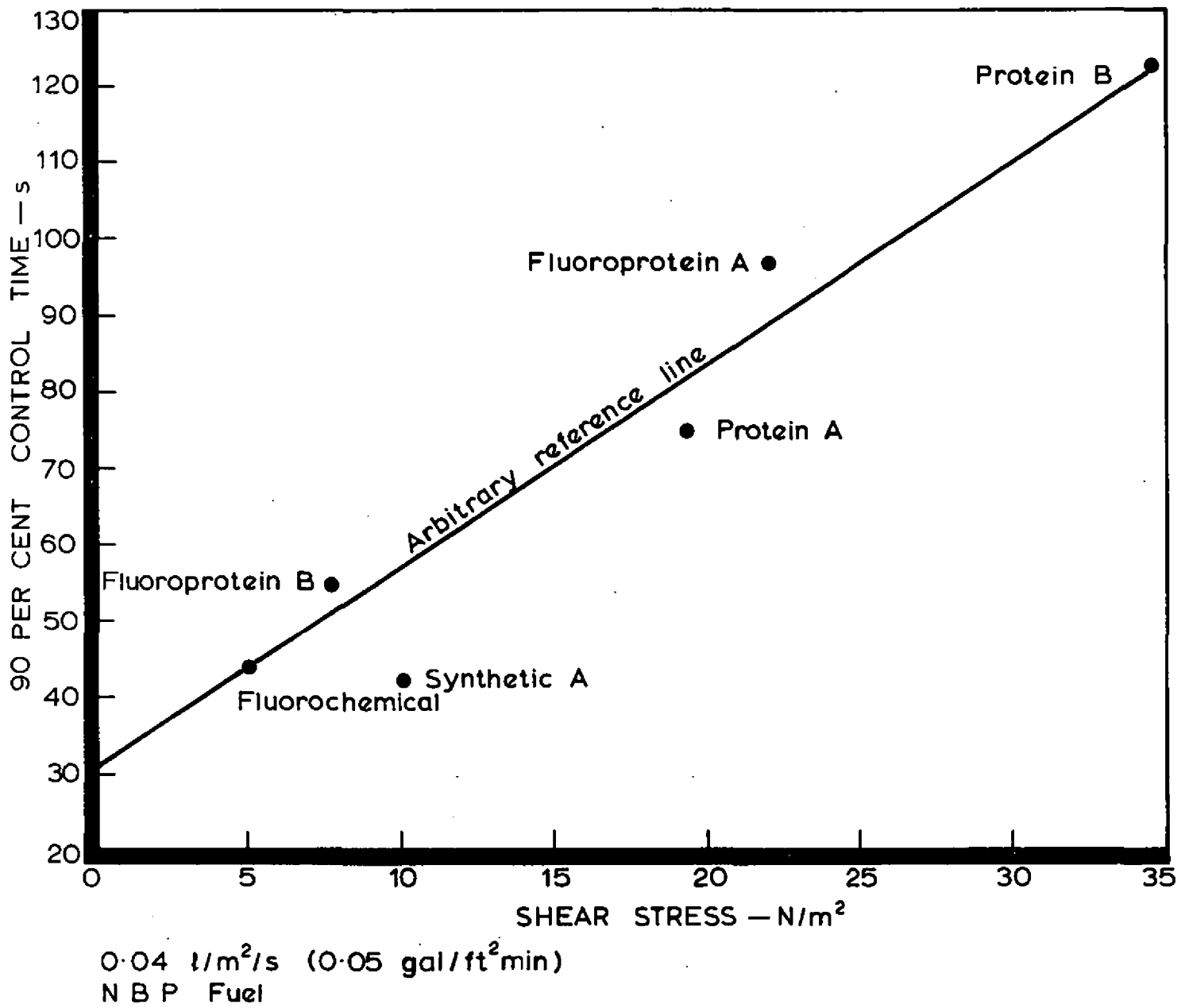FIG. 9. SYNTHETIC LIQUID A, DEFENCE 42-3 FIRES
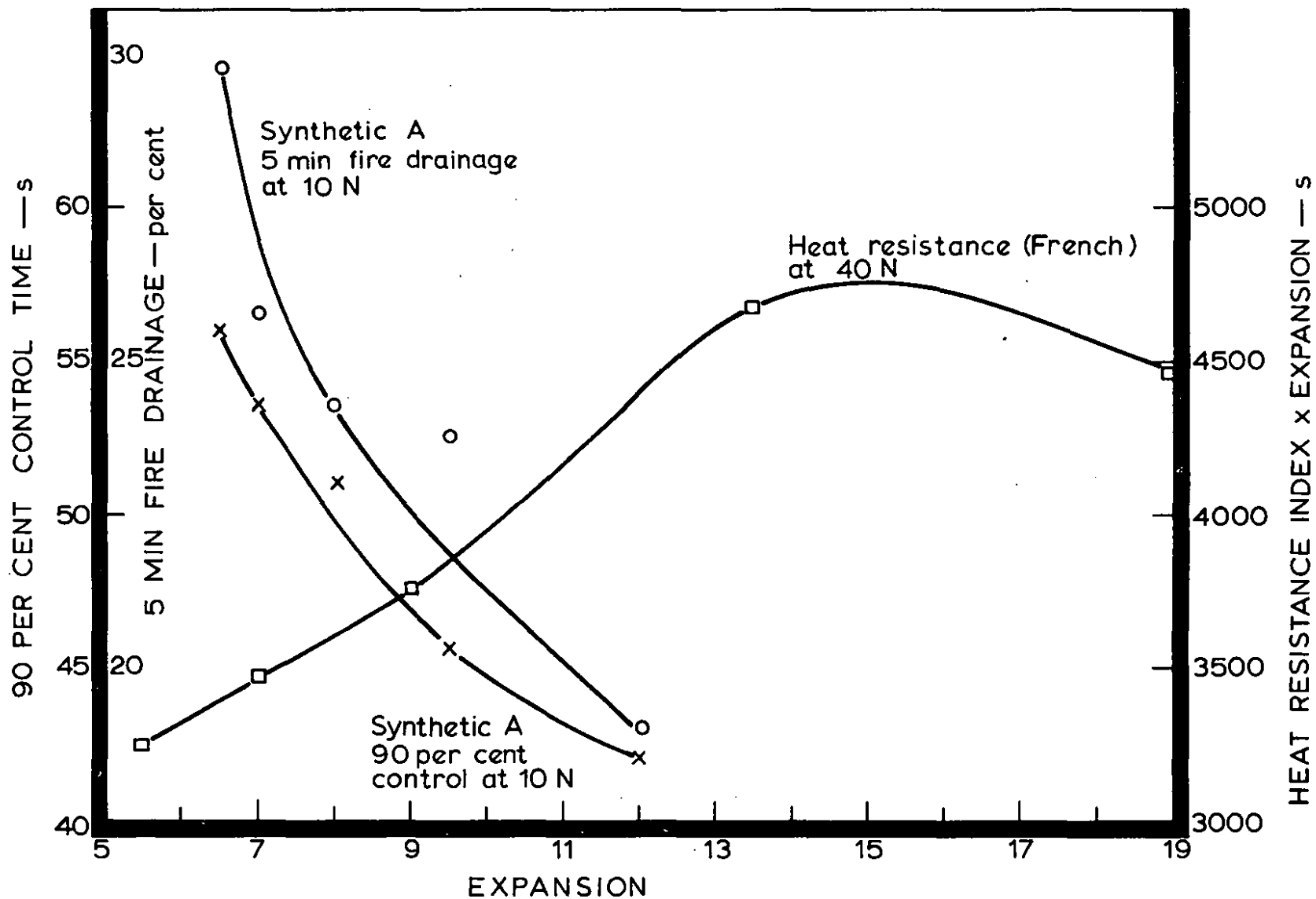
FIG. 10. VARIOUS FOAM LIQUIDS DEFENCE 42-3 FIRES

FIG. 11. SYNTHETIC LIQUID A, DEFENCE 42-3 FIRES AND PROTEIN LIQUID (FRENCH)