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A PERFORMANCE STANDARD FOR FOAM LIQUIDS

by

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Summary

This note describes the development of a performance standard to form part of the acceptance procedure for foam liquids for use by British Government Departments. Criteria for control of a standard test fire by surface application, and for the stability of the foam blanket during and after extinction, are proposed.

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1. REQUIREMENTS FOR THE PERFORMANCE OF FOAM IN FLAMMABLE LIQUID FIRES

In the application of foam to the surface of burning liquids, there are three main aspects of performance to be considered, namely:

a) the minimum rate of application which will enable the fire to be controlled and extinguished. This rate is termed the "critical rate" and can be measured in terms of gallons of foaming solution applied to each square foot of flammable liquid surface per minute.

b) the ability of the foam to control and extinguish the fire when applied at rates above the critical rate. This can be measured as the time required to reduce the fire to a chosen proportion of its original free-burning intensity, or to extinguish it, when the foam solution is applied at a measured rate above the critical.

c) the ability of the foam to maintain an adequately protective blanket on the flammable liquid surface during and after the extinction of the fire. This can be determined by making a direct measurement of the drainage of liquid from the foam layer during and after extinction of a standard test fire.

The relative importance of each of these three aspects will vary somewhat with the particular circumstances in which the foam is being used, although they are broadly interdependent.

The following note describes an investigation in which the effects of measured foam properties viz, expansion, critical shear stress and drainage, on the performance of fire-fighting foams, have been examined. As a result, a standard test has been devised in which the acceptance criteria are intended to ensure that a satisfactory fire fighting foam will be produced to meet all fire fighting requirements.

This test has been adopted as part of a Standard for fire-fighting Foam Liquids', issued as a Ministry of Defence Specification.

2. PROPERTIES OF FOAMS PRODUCED BY FOAM-MAKING EQUIPMENT

The properties of foam produced by foam-making equipment depend not only upon the foam liquid used, but also upon the design characteristics of the equipment itself. In any study of fire extinction by foam, this must be taken into account, and in this work, a number of typical branchpipes were used to produce foam from several proprietary foam liquids.

A 4 per cent pre-mixed solution was supplied at 100 lb/in^2 to each foam-making branchpipe and the resulting foam was collected in a vessel (Fig 1) placed at 0, 2, 5 or 20 ft from the branchpipe. The expansion, critical shear stress and 25 per cent drainage time* of the foam was measured. In this investigation the

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* Time for a given volume of foam, contained in a duralumin pan, to drain 25 per cent of its calculated liquid content.

the 25 per cent drainage time was measured in addition to the critical shear stress, because the general relationship between these two properties[1] does not necessarily hold for the fluid foams produced in some branchpipes by modern foam liquids.

Table 1 gives the physical characteristics of the foams after collection, the values given being the means of up to 4 measurements.

Examination of Table 1 shows a general increase in the expansion and critical shear stress of foam as the distance between the branchpipe and the collecting vessel is increased. An increase in the collection distance from 0 to 20 feet increases the expansion by 10-20 per cent, dependent upon compound used. In tests with branchpipes (X) and (Y), the critical shear stress of foam made from foam liquid (A) and collected at 20 feet is about twice that collected at the branchpipe. When foam liquid (B) is used the percentage increase is about 10 with branchpipe (X) and about 50 with branchpipes (Y) and (Z). There are two probable reasons for the increase in expansion and critical shearing stress. The foam stream is more widely dispersed further away from the branchpipe, and consequently more air may be entrained in the stream. Second, agitation of the foam may take place in the collecting vessel. With the possible exception of foam made from foam liquid (A) in branchpipe (X) there is no general relationship between the drainage test results and the distance from the branchpipe at which the foam is collected. The foregoing discussion shows the importance of standardization in the method of making and collecting the foam sample. It seems probable that the physical characteristics of a foam sample collected at 20 feet from the branchpipe, will more closely resemble a foam in practical applications than that collected at zero feet. For these reasons, in the latter part of the investigation, foam samples were collected from one make of branchpipe only at 20 feet. This branchpipe, 'Y', was chosen after a study of the variation in drainage with critical shear stress of foams made by different branchpipes, as shown in Fig 2.

After extinction of a flammable liquid fire, a foam may be required to remain as a protective blanket on the fuel surface, to prevent reignition. It follows, therefore, that a foam giving a comparatively high 25 per cent drainage time can be expected to be generally more effective in use than one giving a low 25 per cent drainage time, for a given critical shear stress value. Figure 2 shows that branchpipe (Y) produces a comparatively stable foam. For example, foam having a critical shear stress of 200 dyn/cm^2 would have a 25 per cent drainage time of about 5 minutes from branchpipe (Y), compared with about 1.7, 3.5 and 3.8 from branchpipes (X), (W) and (Z) respectively.

To determine the likely variation between foams produced by different branchpipes of similar manufacture and type, two foam liquids (C) and (E) were used with branchpipes (Y) and (Y^1). The measured physical characteristics of the resulting foams are shown in Table 2. Some results of experiments with different batches of foam liquid are also shown. The results show that there may be some tolerable variation between the physical characteristics of foams produced in different branchpipes of the same make and type. However, serious variation in critical shear stress and 25 per cent drainage time may occur between different batches of the same make of foam liquid, e.g. liquid A. The importance of periodic batch resting is emphasized by these results.

3. NEW SPECIFICATION TEST

A previous investigation of the effects of varying foam properties[2] on the extinction of flammable liquid fires by the gentle application of foam to the surface, has been taken as a basis for the method of test used in the Specification. A range of current proprietary protein foam liquids has been examined by this test method with a view to deciding suitable test criteria.

The foam properties used in the Specification test were those which would be produced when using the foam liquids in a good quality foam-making branchpipe (Branchpipe "Y"). The rate of application of foaming solution (i.e. foam liquid plus water) to the test fire, was chosen to be fairly near the critical rate, so that differences in foam liquids were most discernible, but not so near that an excessive quantity of solution was required for control. In practice, a rate of application of 0.05 gal/ft^2/min (approximately twice the critical rate) was chosen.

3. 1. Test Apparatus

In the test apparatus, Fig. 3, the flammable liquid is contained in a circular tank giving a free liquid surface area of 3 sq. ft. The tank is constructed of 18 S.W.G. brass sheet, the upper section being cylindrical and 4 inches in depth; the lower section is a truncated cone fitted at the bottom with a $2\frac{1}{2}$ in internal diameter x 24 in long glass measuring cylinder, in which the foam solution draining from the foam is collected. The tank is supported on a stand carrying four radial arms on which are mounted four radiometers connected in series for measuring the intensity of the fire.

The foam was applied to the petrol surface through a $\frac{1}{2}$ in B.S.P. tee - piece situated with the outlets just above the petrol surface (gentle application), or through a nozzle (forceful application) which for foams having an expansion of between 7 and 9*, was of 5/32 in diameter. The jet, which directed foam into the centre of the burning petrol, was placed 24 inches from the centre of the fire tank and 15 inches above the fuel surface.

For these experiments, the flammable liquid used was a special petroleum having an initial B.P. of 60°C (min) and a final B.P. of 70°C (max.). The use of this liquid eliminated variation in results due to the liquid itself, but gave results generally similar to those obtained with normal commercial unleaded petrol.

3. 2. Control time of test fire and foam stability

Foam of similar physical characteristics to that produced in the branchpipe (Branchpipe "Y") was made in a laboratory foam generator(3)** and applied to the test fire, after a 30 sec. preburn, at a rate of 0.15 gal min (0.05 gal ft^{-2}min^{-1}) for 4 minutes.

The "two-thirds control times"*** and the liquid drainage from the foam blanket during the the 10 minute period measured from the commencement of foam application, are shown in Table 3. Results are given for both 'gentle' and 'forceful' foam application.

Table 3 shows there is little change in the fire performance of foams made from foam liquids (C and E) due to method of foam application. However, when foam made from foam liquid (B) is applied 'forcefully' to the fire, the two-thirds control time and drainage after 10 minutes increase by about 130 per cent and 17 per cent respectively, when compared with 'gentle' foam application. A similar comparison with foam liquid (A) showed a 28 per cent increase in the two-thirds control time but little change in the drainage value.

* For foams having an expansion outside this range, the nozzle size was adjusted to ensure a similar efflux velocity of the foam.

** Special arrangements may be required with the laboratory foam generator to produce foam having certain critical shear stress and 25 per cent drainage time values. A discussion of the special arrangements required will be included in a note (F.R. Note No. 527) to be produced.

*** The time for which foam had to be applied to reduce the radiant intensity of the fire to $\frac{1}{3}$rd of its initial value.

Some experiments were made in which the foam liquid was fed directly into the improver of the laboratory foam generator. The fire control and drainage results obtained are shown in Table 4, compared with results in which pre-mixed foaming solutions were used. Examination of Table 4 shows that the fire performance of foam liquid B is considerably better when it is not mixed with water until immediately before use; foam liquids C and E show considerably less change in performance in this respect.

Since foam liquids are normally induced into the water line, a similar arrangement was adopted for the acceptance test, both for the branchpipe and for the laboratory foam generator. On the basis of the foregoing results it was also considered that the foam need only be applied gently to the fire to give a satisfactory guide to the fire performance of the foam.

Foam liquids A, B, C and D have been found satisfactory in practical use in the past and it seems reasonable to choose acceptance limits which will pass these foam liquids. A maximum permissible control time of 90 seconds and a maximum drainage under the test conditions of 1400 ml. is therefore suggested.

5. Conclusions

The proposed new test for foam liquids allows the functional requirements of a foam to be assessed independently and is therefore considered to be more satisfactory than the "figure-of-merit" test.

The following criteria for foam liquids on this test are suggested:

(1) Fire control: The time to achieve two-thirds control of the test fire should not be greater than 90 seconds.

(2) Foam stability: The total amount of liquid drained from the foam during the 10 minute period from the commencement of foam application should not be greater than 1400 ml.

Acknowledgments

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References

1. SAVAGE, Nicola. The relation between critical shear stress and "25 per cent drainage time" of air-foam. Department of Scientific and Industrial Research and Fire Offices' Committee, Joint Fire Research Organization, F.R. Note No. 344/1958.

2. FRENCH, R. J. and HIRD, D. Air foam in the control and extinction of petrol fires by surface application. Department of Scientific and Industrial Research and Fire Offices' Committee, Joint Fire Research Organization F.R. Note No. 451/1961

3. FRY, J. F. and FRENCH, R. J. A laboratory method of comparing the efficiencies of fire-fighting air foams. J. Appl. Chem. 1951. I, pp. 429-33.

TABLE 1

Physical characteristics of foams made in different branchpipes

Foam liquid	Branch-pipe	Collection distance (ft)	Expansion	Critical shear stress * (dyn/cm^2)	25 per cent drainage time (min.)
A	X	0	6.3	145	2.4
		2	6.5	260	2.3
		5	7.0	235	2.0
		20	7.6	315	1.8
	Y	0	6.7	145	2.8
		5	6.7	185	3.5
		20	7.2	290	2.6
B	X	0	6.3	110	1.6
		5	6.3	130	1.8
		20	6.7	125	1.8
	Y	0	6.3	105	3.0
		2	6.3	155	2.1
		5	6.7	155	3.0
		20	6.9	155	2.6
	Z	0	5.9	105	1.8
		2	6.0	110	1.8
		5	6.0	105	1.9
		20	6.3	145	1.9
C	Y	20	8.8	400	5.6
D	Y	20	8.5	230	6.3
E	Y	20	6.3	115	2.1

* 60 sec. after collection.

TABLE 2

Variation in foam properties between different batches of foam liquid and between branchpipes of the same manufacture

Foam liquid	Foam liquid batch	Branch-pipe	Collection distance (ft)	Expansion	Critical shear stress (dyn/cm^2)	25 per cent drainage time (min.)
C	Batch 1	Y	20	8.8	400	5.6
		Y^1	20	9.0	410	4.5
E	Batch 1	Y	20	6.3	115	2.1
		Y^1	20	6.3	90	2.6
	Batch 2	Y	20	6.1	130	2.5
A	Batch 1	Y	20	7.2	290	2.6
	Batch 2	Y	20	7.5	190	4.3
B	Batch 1	Y	20	6.9	155	2.6
	Batch 2	Y	20	7.5	150	3.2

TABLE 3

Performance of branchpipe foams in fire tests

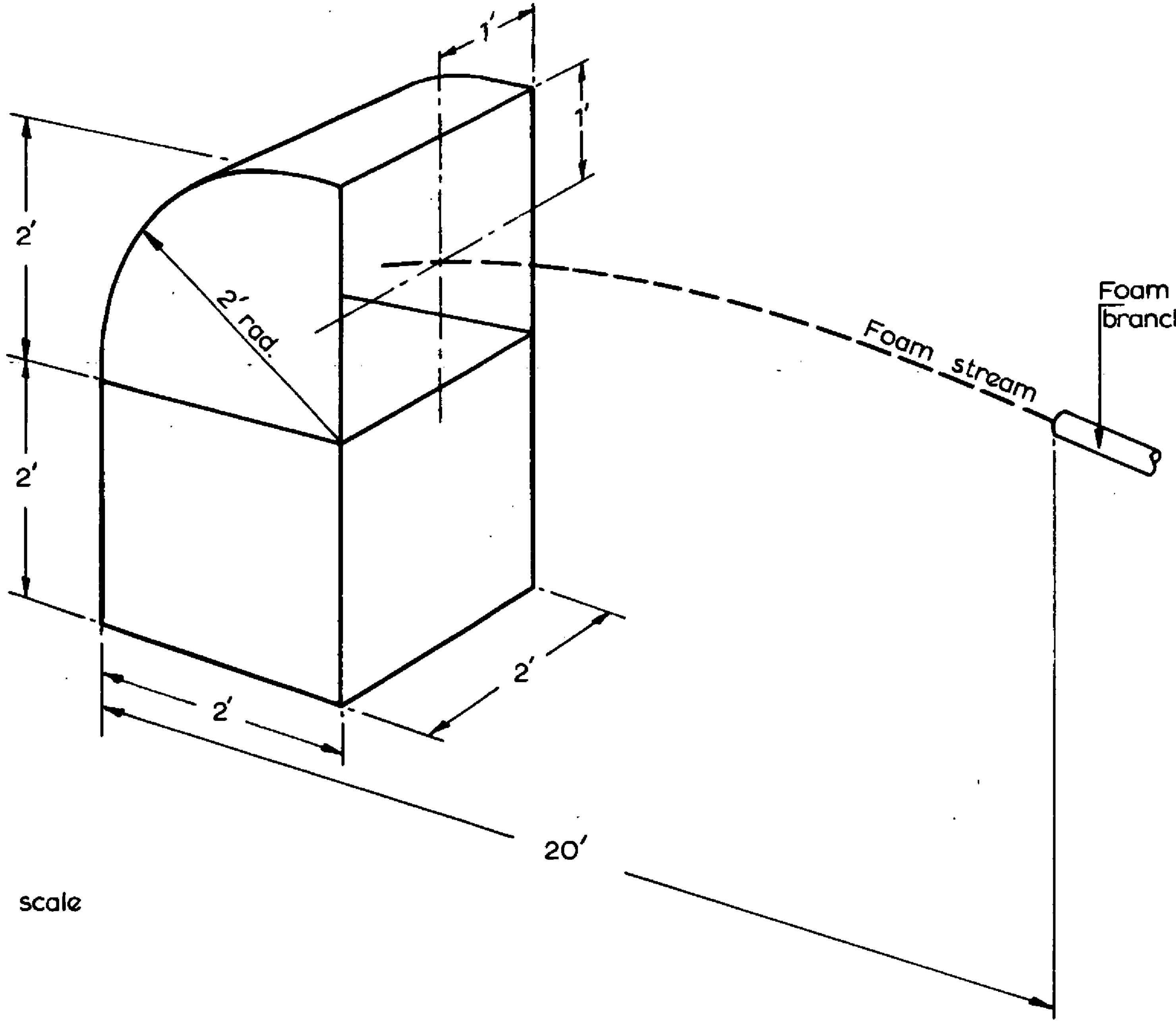
Foam liquid	Expansion	Critical* shear stress (dyn/cm^2)	25 per cent** drainage time (min)	'Gentle' foam application		'Forceful' foam application	
				Two-thirds control time (min)	Drainage after 10 min (ml)	Two-thirds control time (min)	Drainage after 10 min (ml)
A	7.5	190	4.4	65 64 Average 65	1220 1220 Average 1220	80 86 Average 83	1140 1180 Average 1160
B	7.6	140	3.2	43 45 43 Average 44	1500 – 1610 Average 1560	88 120 95 Average 101	1800 1810 1810 Average 1805
C	8.9	430	5.9	81 88 87 92 Average 87	1110 1110 995 935 Average 1040	81 96 Average 89	950 965 Average 960
D	8.5	230	5.8	77 79 Average 78	1090 1140 Average 1120	–	–
E	6.1	130	2.5	72 72 Average 72	1470 1470 Average 1470	67 64 Average 66	1470 1520 Average 1500

* Measured 60 sec. after collection
** Generally within 20 per cent of the values obtained for branchpipe foams

TABLE 4

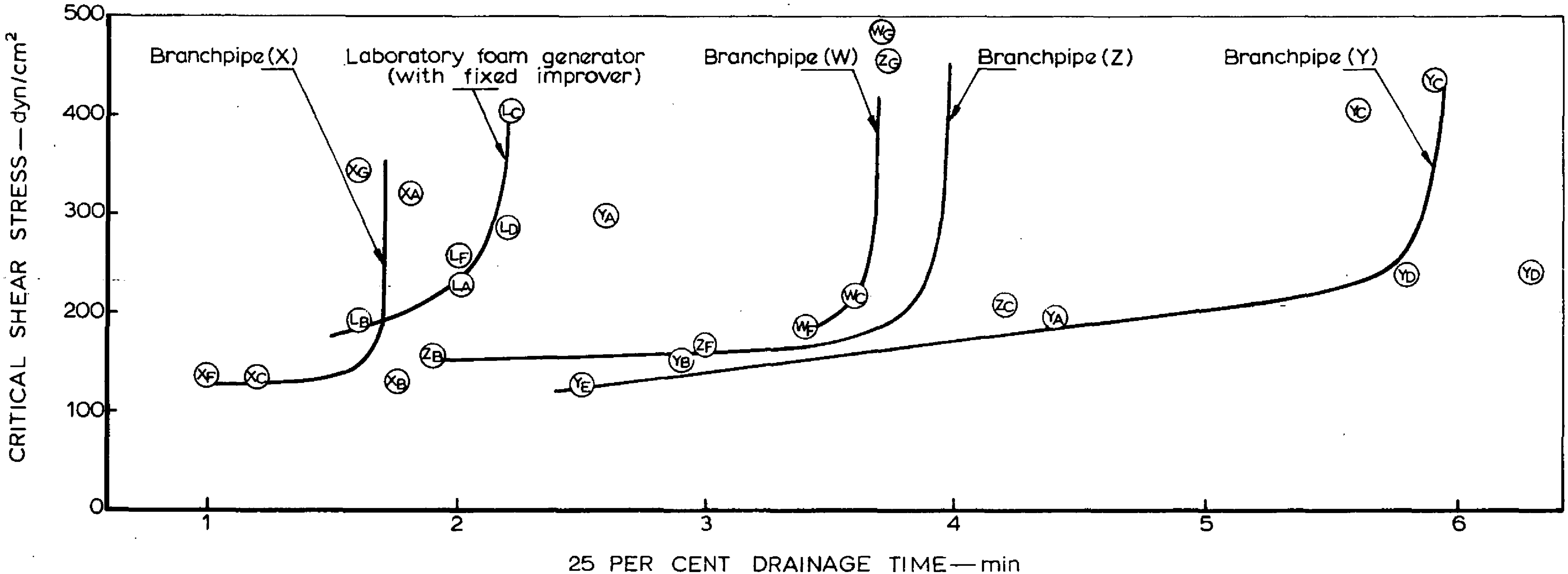
Effect of pre-mixing of foam liquids on fire performance

Foam liquid	Pre-mixed solution				Non pre-mixed solution			
	'Gentle' application		'Forceful' application		'Gentle' application		'Forceful' application	
	Two-thirds control time (sec)	Drainage after 10 min (ml)	Two-thirds control time (sec)	Drainage after 10 min (ml)	Two-thirds control time (sec)	Drainage after 10 min (ml)	Two-thirds control time (sec)	Drainage after 10 min (ml)
B	44	1560	101	1810	51	1320	54	1650
C	87	1040	89	960	96	980	89	1100
E	72	1470	66	1500	61	1350	58	1590



Not to scale

FIG. 1. METHOD OF COLLECTING FOAM



A, B, C, D, E, F, G denotes type of foam liquid
W, X, Y, Z denotes branchpipes
L denotes laboratory foam generator

FIG. 2. RELATIONSHIP BETWEEN DRAINAGE AND FLUIDITY OF FOAM MADE BY DIFFERENT DEVICES

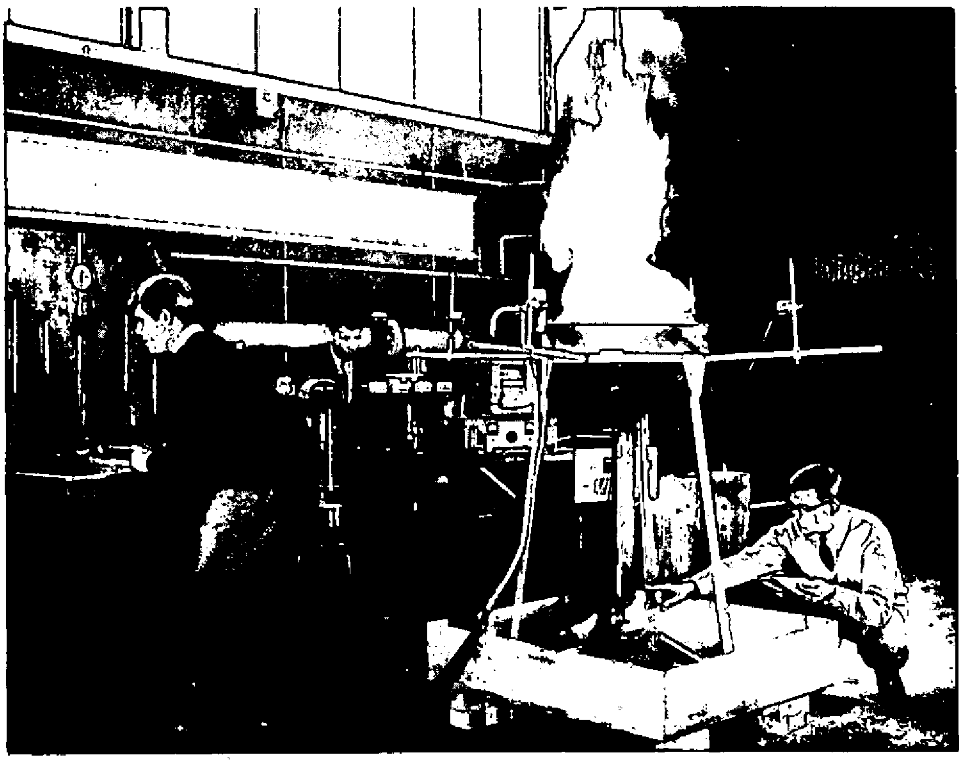


FIG. 3 SPECIFICATION FIRE TEST FOR FOAM LIQUIDS