F. R. Note No. 478

DEPARTMENT OF SCIENTIFIC AND INDUSTRIAL RESEARCH AND FIRE OFFICES' COMMITTEE
JOINT FIRE RESEARCH ORGANIZATION

THE DEVELOPMENT OF A FIRE TEST FOR FOAM LIQUIDS

by

D. Hird, D. W. Fittes and R. J. French

Summary

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

September 1961

Fire Research Station,
Boreham Wood,
HERTS.

THE DEVELOPMENT OF A FIRE TEST FOR FOAM LIQUIDS

by

D. Hird, D. W. Fittes and R. J. French

1. Introduction

In the application of foam to the surface of burning petrol there are three main aspects to be considered. They are:

(a) its ability to control and extinguish the fire when applied at normal liquid rates;

(b) its ability to maintain an adequately protective blanket on the petrol surface after the fire is extinguished;

(c) its critical rate of application, i.e. the minimum rate of application which will enable the fire to be controlled.

The relative importance of each of these three factors will vary with the particular circumstances under which the foam is being used, and in drawing up a specification for a foam liquid, a reasonable balance between the three must be attained. The effect of foam properties on these three criteria have been examined(1), and it has been shown that with a given foam liquid, a wide range of foam properties can be produced depending on the type of foam-making equipment used. The test criteria described in this paper form part of the Defence Specification for foam liquids, and are designed to ensure that a satisfactory fire-fighting foam will be produced, even with relatively inefficient equipment when using foam liquids which meet the specification.

The Figure of Merit test

This test was devised by Clark(2) to assess the fire-fighting properties of a foam and from it a small-scale figure of merit test(3) was developed, and has been used for many years as an approval test for foam liquids. The figure of merit is defined as the ratio of the rate of coverage of the flammable liquid surface to the rate of destruction of the foam by the burning liquid. Since the amount of water in unit area of the foam blanket is proportional to the time taken to cover the surface, the figure of merit is a measure of the rate of destruction of foam per unit water content. The test probably weighs both the critical rate of application and the stability of the foam, but it does not enable the effects of these factors to be separately assessed.

2. New Specification test

The experimental techniques developed in the investigation(1) of the effects of varying foam properties on foam efficiency appeared to provide a basis for a specification test. A range of foam liquids was, therefore, investigated to help in deciding suitable test criteria. It was thought essential that the foam properties to be used in these tests should correspond with those produced by equipment similar in efficiency to operational equipment in current use. It was also felt that foam should be applied to the test fire at a rate fairly near the critical rate of application where differences in foam properties are most discernible; a rate of application of 0.05 gal/ft^2/min (approximately twice the critical rate) was, therefore, chosen.

2.1. Test apparatus

In the test apparatus, which is illustrated in F.R. Note No. 451 (1), 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 2½ inches internal diameter x 24 in. long glass measuring cylinder, in which the foam solution draining from the foam can be measured. 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.

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 any possible variation in results due to the liquid itself, but gave results similar to those obtained with normal commercial unleaded petrol.

2.2. Table 1. Foam liquids tested

Identification	Type	Remarks
A	Hydrolised keratin	Proprietary foam liquid
B	Hydrolised keratin	" " "
C	Hydrolised blood	" " "
E	Wetting agent	Not generally accepted as suitable for fire fighting.
P	Hydrolised keratin	Made as Compound B, but has had stabilizing salt subsequently removed.
Q		Proprietary foam liquid
R		" " "
S		" " "
T	Compound R with 2 per cent wetting agent	

2.3. Experimental

(a) Determination of foam properties in standard branch pipe

A minimum of 4 per cent solution of foam liquid is used by most foam equipment and the main part of the investigation was made using this concentration, but the foam properties produced with 3 per cent solutions were also determined.

A pre-mixed solution was supplied at 100 lb/in^2 to a modified foam-making branchpipe (Figs. 3 and 4), and the expansion and critical shear stress of the resulting foam was measured. The modified branch pipe produced foam of similar physical characteristics to that produced by other types of proprietary branchpipe in common use.

(b) Determination of control time of test fire

Foam of similar physical characteristics to that produced in the branchpipe was made in a laboratory foam generator and applied to the test fire, after a 30 sec preburn, at a rate of 0.15 gl/min (0.05 $gl/ft^2/min$). The foam was applied for 4 minutes to the surface of the petrol through a $\frac{1}{2}$ in B.S.P. tee-piece situated with its outlet just above the petrol surface. The 'control time' was taken as the time to reduce the intensity of the fire to one-third of its initial value. The mean intensity of radiation during the 5 second period immediately prior to the application of foam was taken as the initial intensity. In addition to the tests with foam of branchpipe characteristics, a number of experiments were made with foams having the same expansion as the branchpipe foam, but with a range of critical shear stresses.

(c) Determination of stability of foam blanket

The stability of the foam blanket on the petrol surface was determined by measuring the total amount of liquid drained from the foam during a 10 minute period from the commencement of foam application.

In some tests where the foam was either very unstable or had a relatively high critical shear stress, the fire was not completely extinguished during the 4 minute period of foam application. The small flickers of flame remaining in these tests were extinguished with carbon dioxide.

3. Results

(a) Foam properties in standard branchpipe

In general both the expansions and the critical shear stresses of the foams produced by the branchpipe with a 4 per cent solution were higher than with a 3 per cent solution. The results are shown in Table 2.

Table 2. Physical characteristics of branchpipe foams with two concentrations of compound

Compound identification	3 per cent concentration		4 per cent concentration	
	Critical shear stress ($dyne/cm^2$)	Expansion	Critical shear stress ($dyne/cm^2$)	Expansion
A	280	5.9	380	6.2
B	90	5.4	95	5.9
C	130	5.9	210	6.5
E	70*	11	-	-
P	-	-	35	4.3
Q	75	5.2	70	6.1
R	80	5.0	150	5.8
S	80	5.3	160	6.3
T	-	-	35	4.4

* 3.3 per cent concentration

(b) **Control** time of test fire and foam stability

The effect of varying the critical shear stress of foam on the two-third control time is shown in Fig. 1 for soam made from a 4 per cent concentration of compound. The curves are typical of fire-fighting foams, showing a general linear increase in control time with increasing shear stress at the higher values of shear stress. The deviation from linearity at the lower end of the curve is due to the instability of the foams at low values of shear stress.

The relationship between critical shear stress and the drainage of liquid from the foam for the foam liquids tested in 4 per cent concentration is shown in Fig. 2. Although these curves all show a reduction in drainage with increasing shear stress, foam liquid 'A' shows a considerably lower rate of increase of drainage with decreasing critical shear stress and the drainage from liquid 'E' (wetting agent) is appreciably greater than with any of the protein-based foam liquids.

The results on the proposed specification tests where the foams used had characteristics similar to those obtained in the branchpipe are shown in Table 3.

Table 3. Performance of branchpipe foams in fire tests
(4 per cent concentration of compound)

Compound identification	Critical shear stress (dyne/cm^2)	*Two-thirds control time (sec)	*Liquid drained (ml)	Figure of Merit (with 4 per cent concentration of compound)
A	380	88 F	1,280 P	100 P
B	95	70 P	1,840 F	150 P
C	210	52 P	1,810 F	115 P
+E	70	44 P	2,420 F	35 F
P	35	147 F	1,950 F	90 F
Q	70	58 P	1,910 F	100 P
R	150	61 P	1,780 P	185 P
S	160	52 P	1,730 P	105 P
T	35	153 F	1,930 F	85 F

* Average of three tests.

+ The physical characteristics of the foam made from the wetting agent are similar to those produced in a branchpipe from a 3.3 per cent concentration of wetting agent.

P passes proposed test requirements.

F fails proposed test requirements.

Discussion

In most fire-fighting applications involving foam, the ability of the foam to remain stable on the fuel to prevent possible reignition is perhaps as important as its ability to control the fire quickly. Examination of Fig. 1 and Table 3 shows that when tested to the proposed specification test, a foam can reasonably be expected to control the test fire within 60 seconds. It is felt, however, that the criteria for control of the fire should not limit acceptable foam liquids to those producing foams of low critical shear stress in the branchpipe and exclude those giving somewhat stiffer, more stable foams. A maximum control time of 70 sec. is therefore suggested as a compromise between rapid control and post-extinction stability.

The drainage characteristics of the various foam liquids are shown in Fig. 2 and Table 3. A maximum limit on the drainage under the test conditions of 1,800 ml. (approximately two thirds of the total foaming liquid applied) is suggested.

If these criteria are applied to the foam liquids tested (Table 3) then liquids R and S would meet the requirements and liquid 'C' would be on the borderline. These results can be compared with the performances on the figure of merit test which are given in Table 3. There is no obvious correlation between the results of the two tests although the three foam liquids which would not meet the minimum requirement of a figure of merit of 100 (E, P and T) all fail the suggested requirements of the new test. Liquids A, B and Q would meet the figure of merit requirements, but would fail on the proposed test.

Of these, liquid A has an unacceptably long control time, largely due to its relatively high critical shear stress. Liquid B provides a fluid foam with an unacceptably high drainage rate, although its control time is on the upper limit. Liquid Q provides a very fluid foam of even lower stability than B. This illustrates the advantages of the proposed test in enabling the extinction and drainage properties of a foam to be assessed separately.

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 70 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 1,800 ml.

Acknowledgments

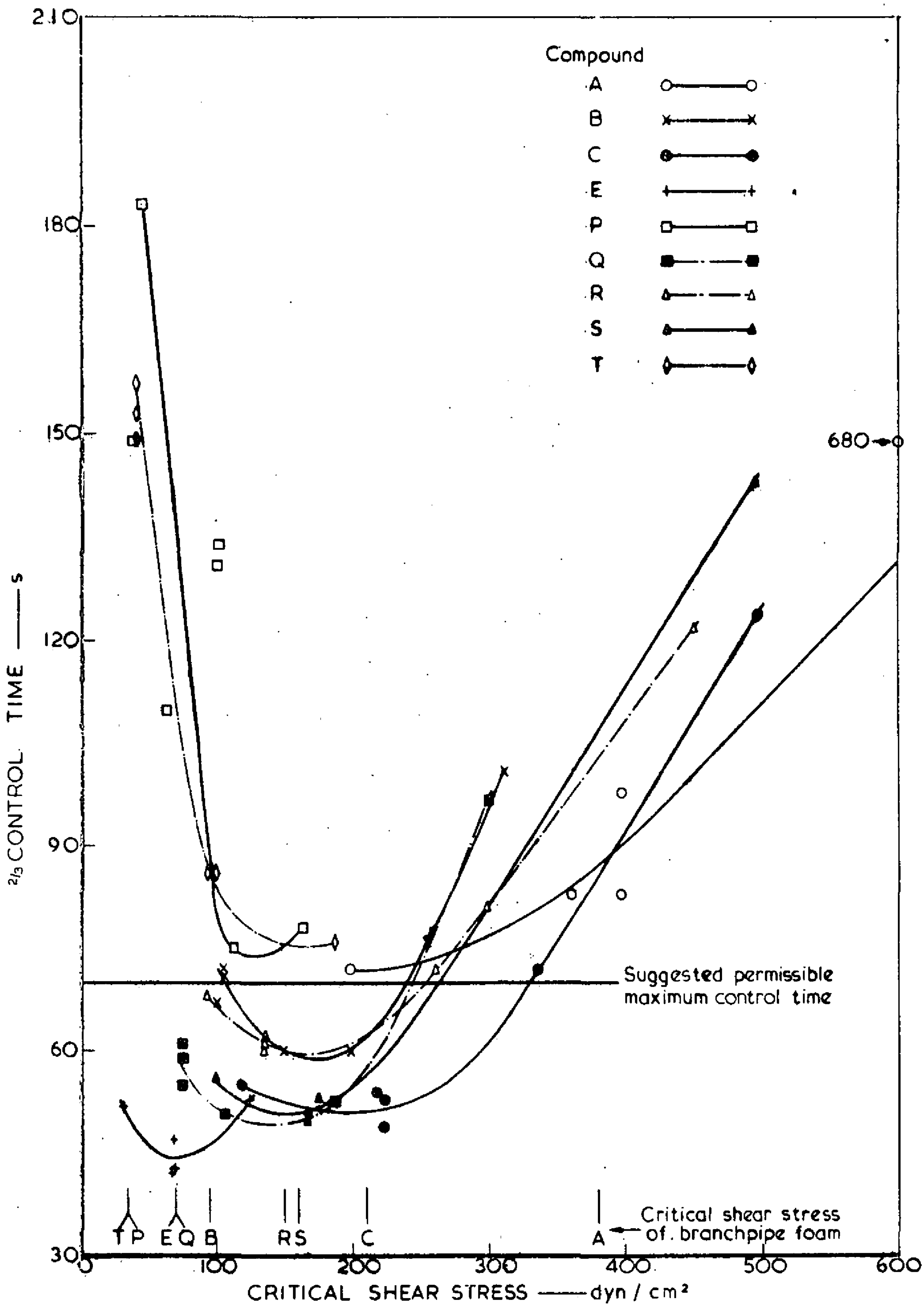
Thanks are due to Mr. D. D. Richardson and Mr. J. Richardson for their assistance with the experimental work.

References

1. 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.

2. CLARK, N. O. A study of mechanically produced foam for combating petrol fires. Department of Scientific and Industrial Research, Chemistry Research Special Report No. 6, London, 1947. H. M. Stationery Office.

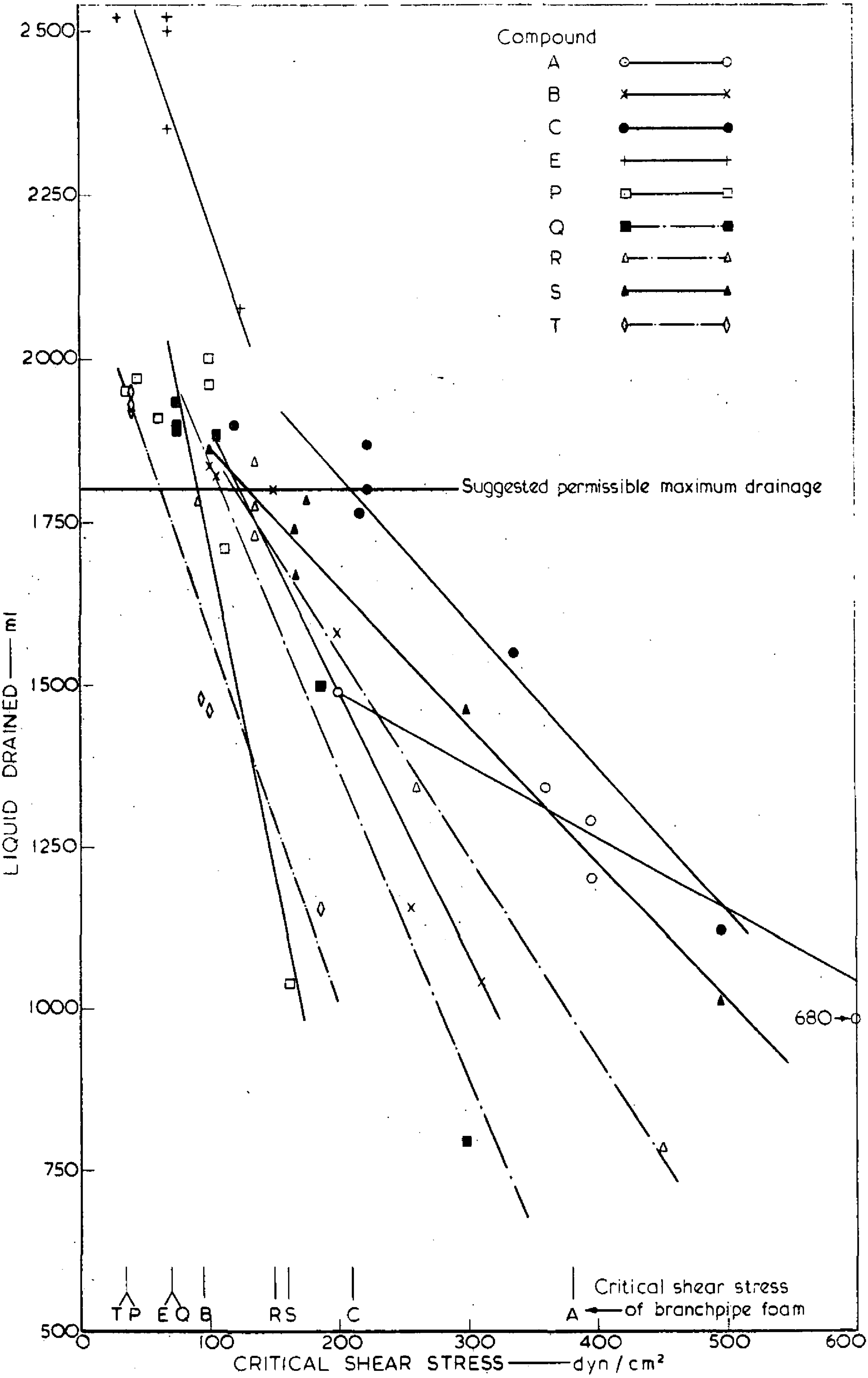
3. FRY, J. F. and FRENCH, R. J. A laboratory method of comparing the efficiencies of fire-fighting air foams. Journal of Applied Chemistry, 1951. I, pp. 429-433.



Compound concentration —— 4 per cent
Rate of application —+— 0·05 gal ft^{-2} min^{-1}
Expansion —— same as branchpipe foam

The critical shear stress value of branchpipe foam is indicated at the bottom of the graph

FIG. 1. RELATIONSHIP BETWEEN $^2/_3$ CONTROL TIME AND CRITICAL SHEAR STRESS



Compound concentration — 4 per cent

Rate of application — 0·05 gal $ft^{-2} min^{-1}$

Expansion — Same as branchpipe foam

The critical shear stress value of branchpipe foam is indicated at the bottom of the graph

FIG. 2. RELATIONSHIP BETWEEN CRITICAL SHEAR STRESS AND FOAM STABILITY

1/4311 F.R. 478

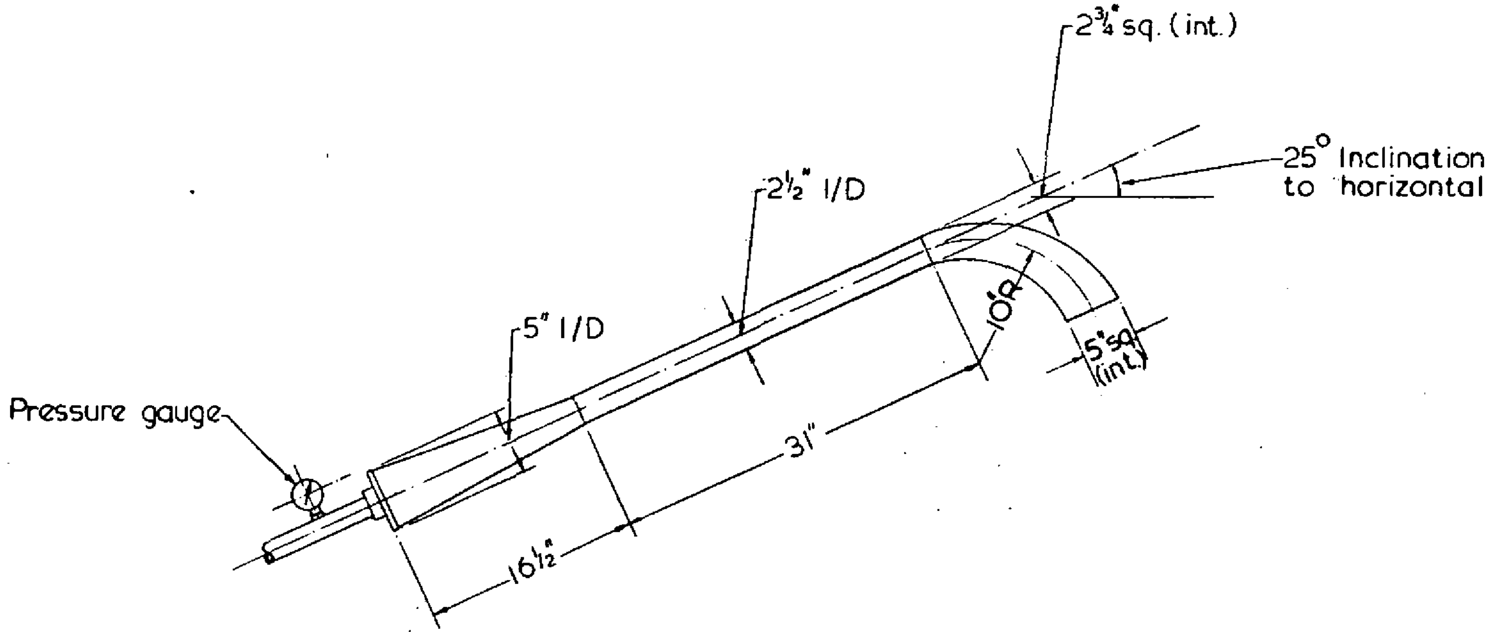


FIG. 3 STANDARD FOAM-MAKING BRANCHPIPE

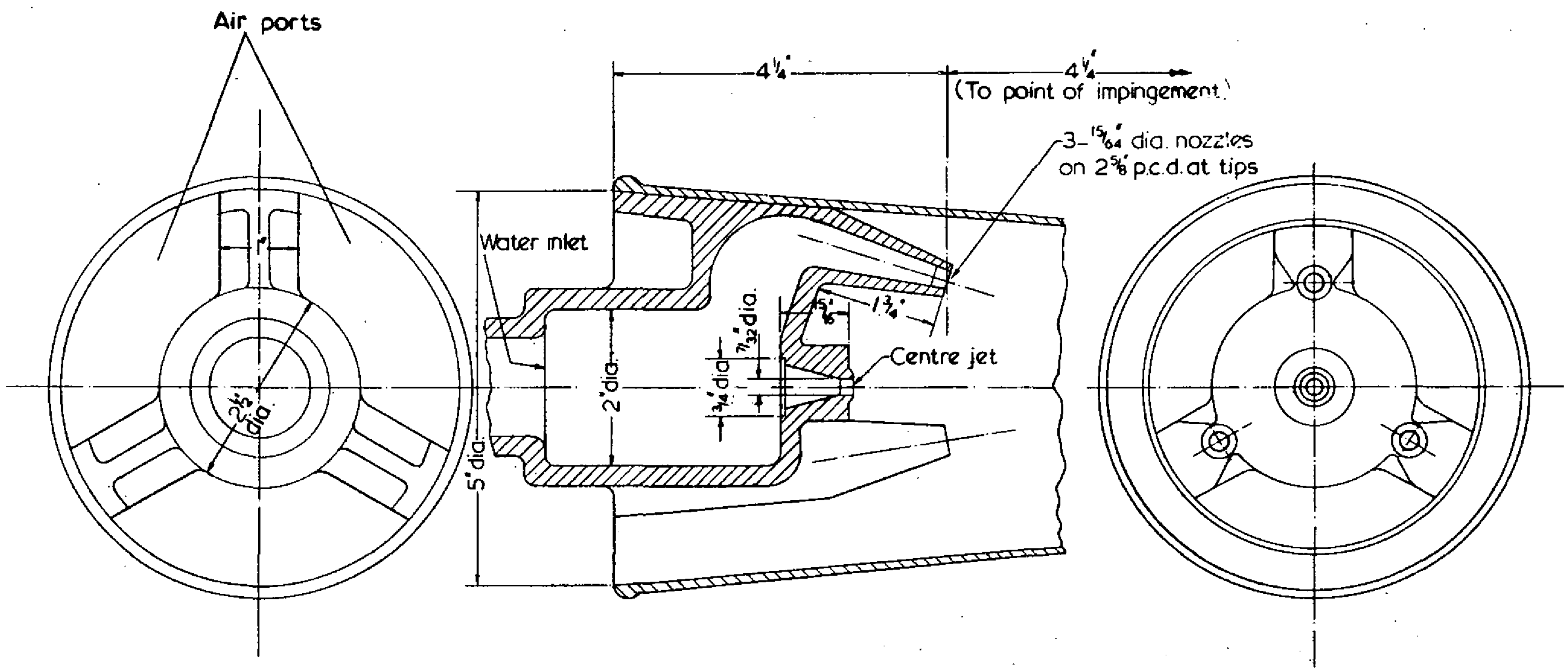


FIG. 4. DETAILS OF WATER HEAD OF STANDARD FOAM-MAKING BRANCHPIPE