F.R. Note No. 414
~~Internal Note No. 34~~
Research Programme Objective.

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

FOAM FOR AIRCRAFT CRASH FIRES (2)

by

P. Nash, D. Hird and R.J. French

SUMMARY

This report describes an investigation of the effect of foam properties in the control of a 900 ft^2 mock aircraft crash fire.

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March, 1959.

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1. Introduction

The results of tests on a 100 ft^2 simulated aircraft-crash fire in which foam of different properties was applied and the control time measured, were reported in an earlier paper(1). As a result of this work and the need for further information on fighting aircraft-crash fires, an Inter-Departmental Committee was convened and the Departments most concerned with the problem were represented on it. This Committee recommended that tests of a similar nature should be made on a much larger scale approaching that which might be met under operational conditions. Details of the test programme were worked out by a Sub-Committee on which the following Departments were represented:-

Air Ministry
Ministry of Transport and Civil Aviation
Ministry of Supply
Ministry of Works
Joint Fire Research Organization

The tests were made during September, 1958.

2. Test Programme

The following test programme was drawn up by the Sub-Committee.

(a) Test fire

The test fire was to be made in a 30 ft x 30 ft bunded area with a ½ in. layer of sand on refractory concrete. A mock-aircraft was to be constructed from 40 gallon drums, in a cruciform with each link 20 ft long, and was to be placed in the centre of the bund in which 200 gallons of petrol were to be used for each test.

(b) Foam application

In the main programme the foam was to be applied as a jet from the position of the monitor on the A.M. Mark IV crash tender. Eight duplicated tests were to be made with foam of the following properties.

Expansion	10-12	(E)
	6- 7	(e)
Critical shear stress	800-1000 dynes/cm^2	(S)
	120- 200 dynes/cm^2	(s)
Liquid rate of application	100 gal/min	(R)
	50 gal/min	(r)

Compound concentration - approximately 4 per cent.

(c) Method of foam production

Foam characteristics and rate of application	Method of production	Compound to be used
ESR	Crash Tender	CS
ESr	Crash Tender	CS
EsR	10X Branchpipe	CS
Esr	5X Branchpipe	CS
eSR	Crash Tender	A
eSr	Crash Tender	A
esR	Crash Tender	CS
esr	Crash Tender	CS

(d) Additional tests

In addition to the main programme, tests were also to be made with foam from the Mark VI crash tender applied as both spray and jet, and with foam from a Mark 10X branch-pipe applied as a spray.

3. Modifications to test programme after preliminary tests

After preliminary tests, the following modifications were made to the test programme:

(a) Test fire

To maintain repeatable test-fire conditional it was found necessary to remove all the sand after each test and replace it with dry sand. Because of the adverse weather conditions it was not possible to keep the sand dry, and in practice a free petrol surface became inevitable. It was therefore decided to dispense with the sand entirely, and to apply the petrol directly to the refractory concrete.

(b) Foam properties

A Mark IV crash tender was modified to enable foam of varying properties to be produced, by incorporating a mixing tube after the pump. A varying number of gauzes could be included in the mixing tube, in order to vary the critical shear stress of the foam. However, this did not enable the foam properties to be controlled adequately, and the low and high levels of critical shear stess obtained during the tests were in the ranges 70-350 and 100-1400 dynes/cm^2 respectively. The range of low expansion was 6.4 to 7.5, and of high expansion 8.2 to 11.5.

4. Test Procedure

The tests in the main programme were made in random order and before each test the bund was cleaned and the foam producing equipment was adjusted to give foam properties as near as possible to those planned. The foam was applied after a 1 minute preburn from the monitor position some 20 ft from the edge of the bund (Fig.1). Radiation measurements were taken at the two positions illustrated in Fig.1 and foam application was continued until the radiation from the fire had been reduced to less than 10 per cent of its original intensity. The progress of the fire in one of the tests is shown in Fig.2.

5. Test Results

The results are summarised in Table 1.

The tests were planned as a balanced block of experiments but because of the inadequate control of the variables an analysis of variance is of doubtful validity. However, an analysis of variance was made to give some pointer to the most significant effects. A summary of the results of the analysis is given in Table 2, with the comparable results for the 100 ft^2 fires.(1)

Table 2. Results of analysis of variance of test results

Effect of	100 ft^2 fire		900 ft^2 fire	
	2/3 control time	9/10 control time	2/3 control time	9/10 control time
Rate of application (R)	***	***	***	**
Expansion (E)	**		***	
Critical Shear Stress (S)	***	***		
Interaction R x S	***	***	**	
Interaction E x S	***			

** 1% significance   *** 0.1% significance

Note

Factors significant at 0.1% level are more likely to be real effects than those significant at 1% level.

Table 2 supports that critical shear stress is important for the 100 ft^2 tests, but unimportant for the 900 ft^2 tests. Bearing in mind the doubtful validity of the analysis of variance for the 900 ft^2 fire tests, it was decided to plot the results in the following ways, to clarify the importance of the various foam properties.

(a) Control time against $\frac{\text{Critical shearing stress}}{\text{Rate of application}} = \frac{S}{R}$

For normal top application of foam to petrol fires there is a linear relation between control time and S/R. This indicates that the depth of the foam layer is directly proportional to the expansion and the critical shear stress and that there is little destruction of foam during extinction.

The results of the large scale tests for the 2/3 control time are shown in Fig.3. A similar picture is obtained with the 9/10 control time. The high and low rates of foam application are shown with different symbols as it appears that the control times at the low rates of application are considerably higher than would be expected.

There is no indication from Fig.3. that there is any relationship between the control time and the critical shear stress.

(b) Control time $\dfrac{1}{\text{rate x expansion}} = \dfrac{1}{R \times E}$

The analysis of variance suggest that expansion might be an important variable and the control time is plotted against the reciprocal of the volume rate of flow in Figs.4 and 5, for both 2/3 and 9/10 control times. It can be seen that all the results can be correlated in this way.

6. Discussion of results

The fact that the control time in these tests is not affected by the critical shear stress of the foam might be explained by the fact that foam was applied over the majority of the surface by the operator and was therefore not required to spread, as in normal top application, from one point. This is supported by the results, shown in Fig.4, of tests in which foam was applied to the test fire as a spray. Under these conditions the foam is applied in a dispersed pattern but the control times are comparable with those for jet application. The dependence of control time on the volume flow rate rather than on the liquid flow rate suggests that an almost constant thickness of foam of about 1½ in. is sufficient to prevent vaporization of fuel and to extinguish the fire. Fig.6. shows the quantities of liquid which would be required to control the fire at two expansions (7 and 14) if the results of the tests are generally applicable.

These explanations for the dependence on volume flow rate rather than critical shear stress, would however apply equally to the 100 ft^2 fire tests[1] where the results led to the conclusion that the critical shear stress was the property most affecting control time, and expansion was of little importance. The only important feature in the test procedure which differed between the 100 ft^2 and 900 ft^2 fire tests was that in the smaller fire the operator moved all round the test fire to gain control. This was not possible on the large tests, and may explain the increased control times withe the large tests.

Experiments on a 400 ft^2 fire at the Naval Research Laboratories[2] led to the conclusion that there was an optimum expansion of 10-12 when foam was applied in a dispersed pattern. These tests were made at one rate of application, 0.083/gall/ft^2/min, but other tests[3] in which the fire was matched to the pattern of the foam spray were made at much higher rates of application, up to 0.5 gall/ft^2/min.

The results of the N.R.L. tests have been included with those for the 900 ft^2 and 100 ft^2 fire tests in Fig.7., and it can be seen that there is reasonable agreement with the 900 ft^2 results. The control times of the 100 ft^2 fires are generally lower and are little affected by the volume flow rate.

Conclusions

The results of the large fire tests are not in agreement with those from earlier tests on a smaller scale[1]. They suggest that the volume flow rate, and thus the expansion, is an important property affecting the contol time, and that the critical shear stress has little effect.

These conclusions are based on a small number of tests in which the foam properties were not well controlled. Further large scale tests are necessary to show to what extent these conclusions are valid, and over what range of expansion the improvement in control time could be realised.

Acknowledgments

The investigation described in this report was planned and executed by members of an Aircraft Crash Fire Panel including Air Ministry, Ministry of Transport and Civil Aviation, Ministry of Works, Admiralty, Ministry of Supply and Joint Fire Research Organization.

References

(1) Hird, D., French, R.J., and Nash, P. Foam for aricraft crash fires. F.R. Note No.313/1957.

(2) Tuve, R.L. and Peterson, H.B. Naval Research Laboratory Memorandum Report No.92 Washington 1952.

(3) Tuve, R.L. et alia. Naval Research Laboratory Report No.4558. Washington 1955.

Table 1.

TEST PARTICULARS AND RESULTS

Test No.	Expansion	Critical Shear Stress dynes/cm^2	Rate of application g.p.m.	Wind Speed ft/sec	Wind* direction	Control Time (secs) 2/3	9/10
1	6.7	1416	103	9.1	↖	70	90
2	7.5	350	50	14.1	↖	120	150
3	6.4	850	52	11.6	↖	100	110
4	6.8	1240	99	6.6	↖	51	93
5	10.4	125	50	8.3	←	82	186
6	14	135	100	15.9	↖	43	48
7	7.1	140	103	1.5	↖	46	50
8	8.2	70	50	16.7	↖	80	83
9	16.5	150	100	19.6	↖	30	55
10	7.0	280	46	14.4	↖	108	150
11	11.6	100	58	24.1	↑	76	96
12	8.3	820	97	19.0	↗	77	115
13	7.5	1270	47	13.6	↗	123	147
14	11.1	1200	44	6.1	↗	83	117
15	7.2	250	104	4.7	↑	48	71
16	8.8	1,000	94	5.9	↑	63	68
10X spray	10.2	180	100	9.5	→	48	96
10X spray	10.2	180	100	7.0	↗	51	69
Mk.6 jet	18	530	100	19.0	←	29	39
Mk.6 jet	17.2	940	100	11.7	←	61	67
Mk.6 spray	16.1	1,000	100	13.4	←	20	66
Mk.6 spray		760	100	9.9	←	35	56

*

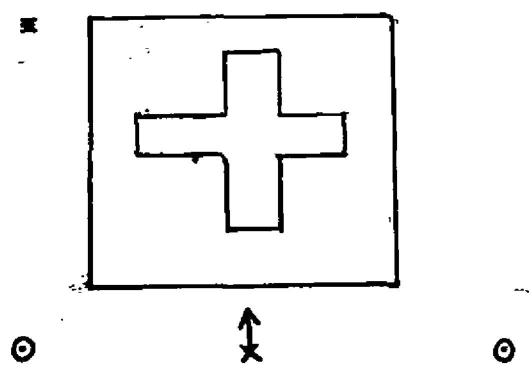

FIG.2. PROGRESS OF TEST FIRE

DS40697/1 331 60 2/59 CL

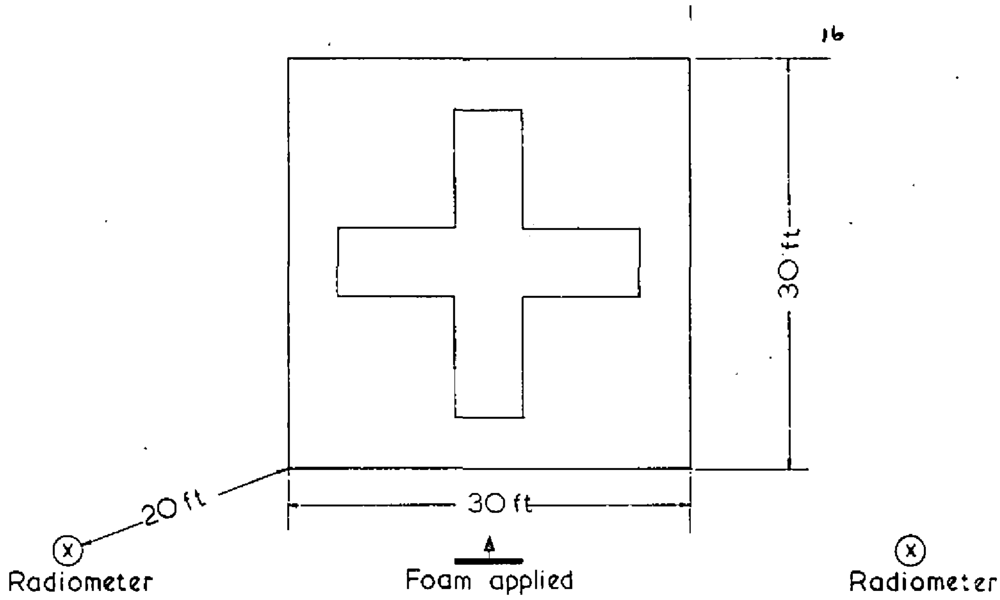

FIG. 1. PLAN OF TEST AREA

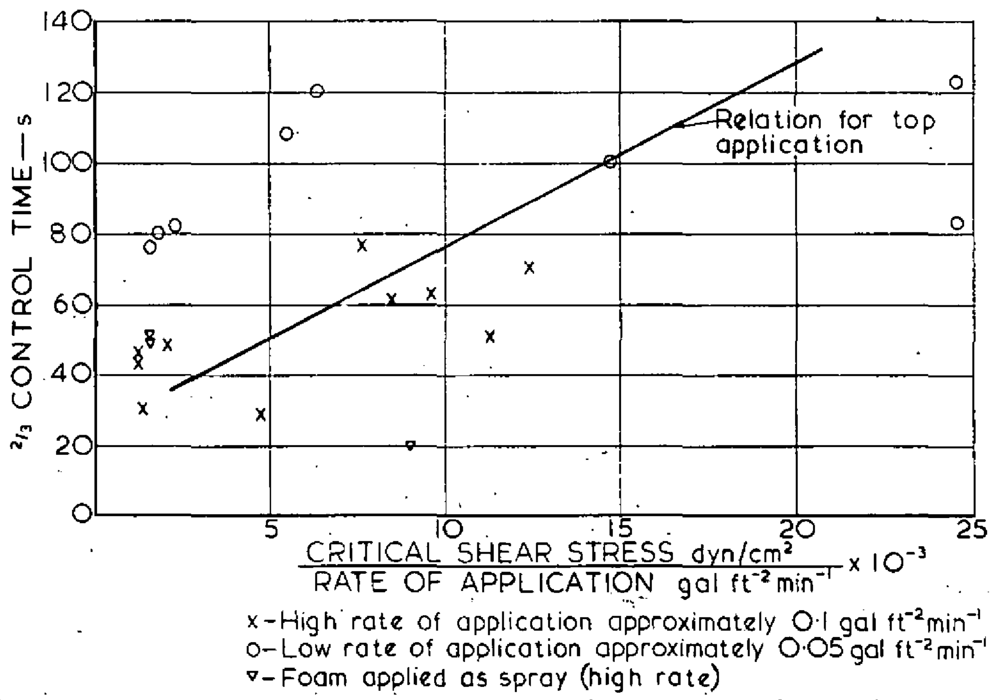

FIG. 3. CONTROL TIME AS A FUNCTION OF CRITICAL SHEAR STRESS AND RATE OF APPLICATION

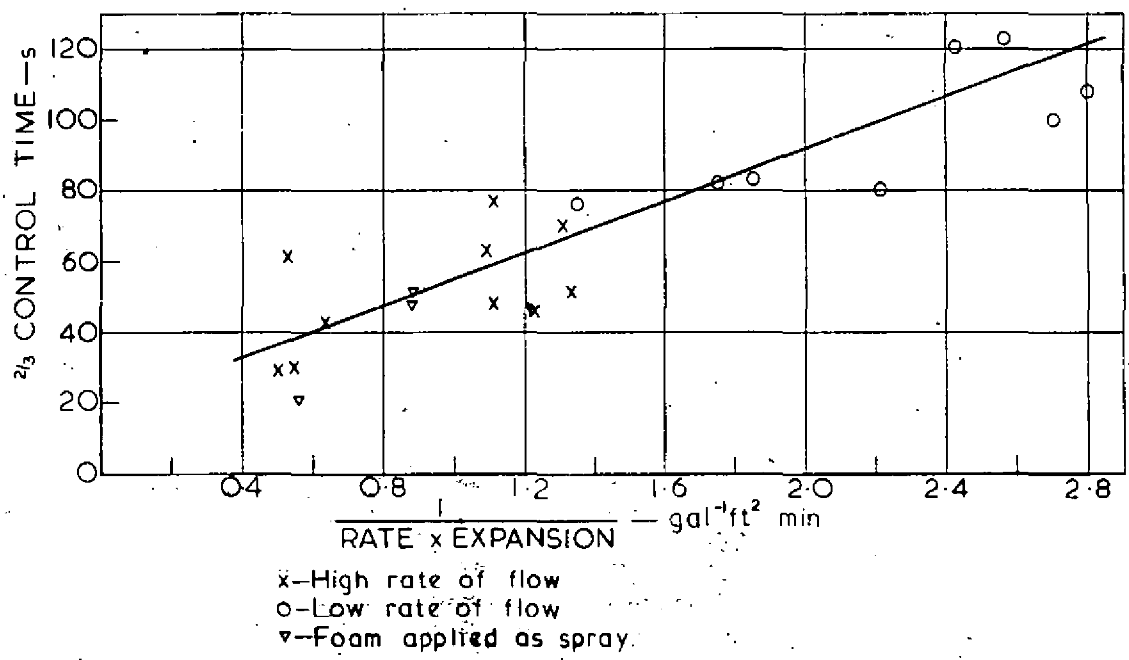

FIG. 4. 2/3 CONTROL TIME AS A FUNCTION OF VOLUME RATE OF FLOW OF FOAM

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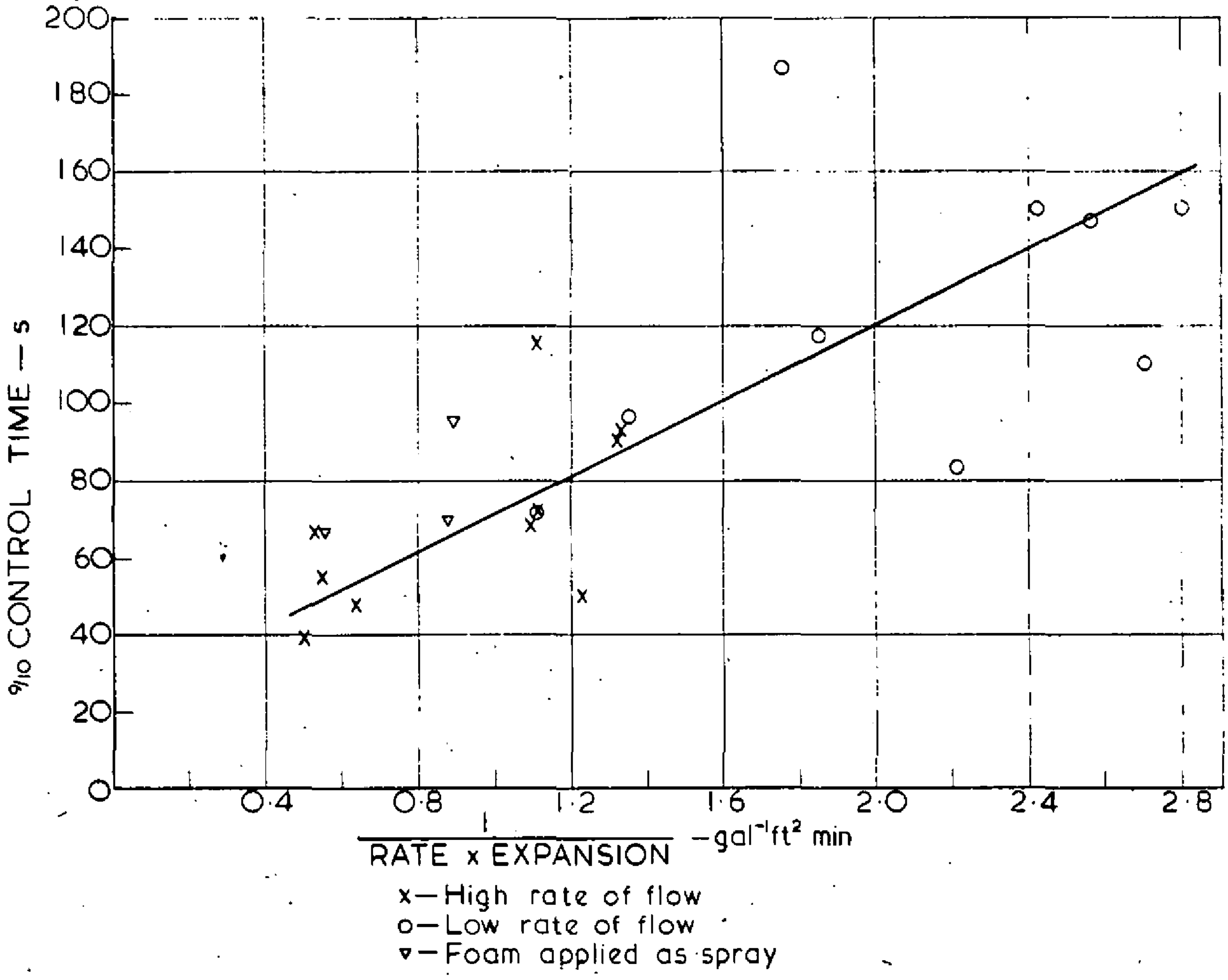

FIG. 5. 9/10 CONTROL TIME AS A FUNCTION OF VOLUME RATE OF FLOW OF FOAM

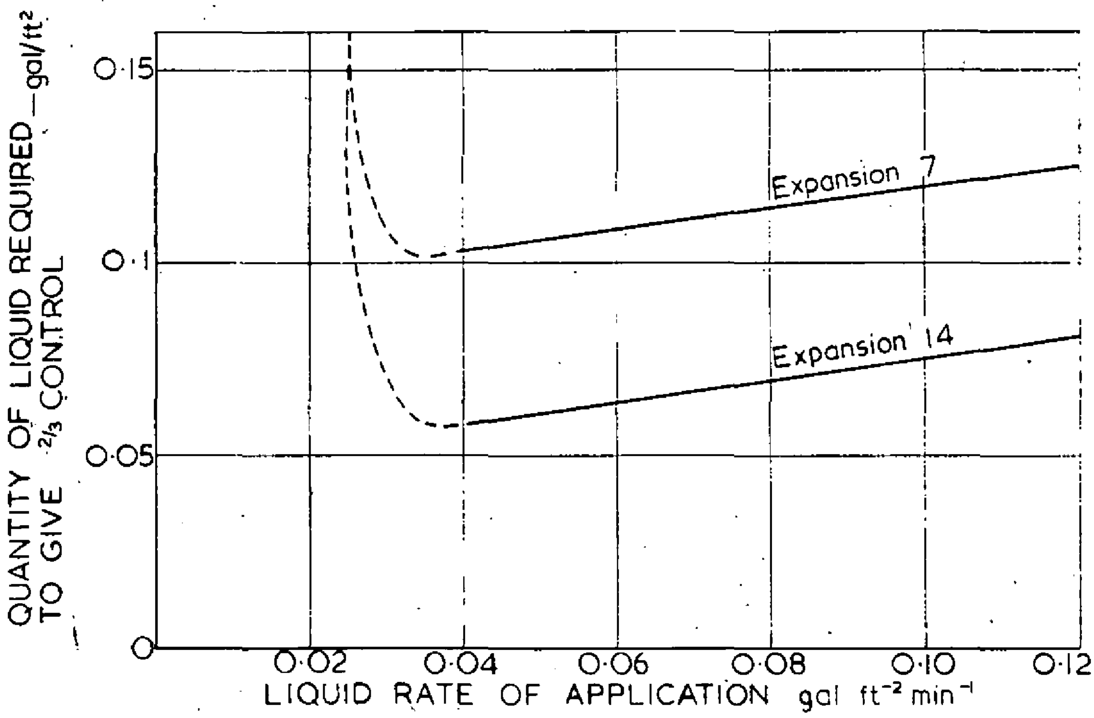

FIG. 6. QUANTITIES OF LIQUID REQUIRED TO CONTROL FIRE IF RESULTS ARE GENERALLY APPLICABLE

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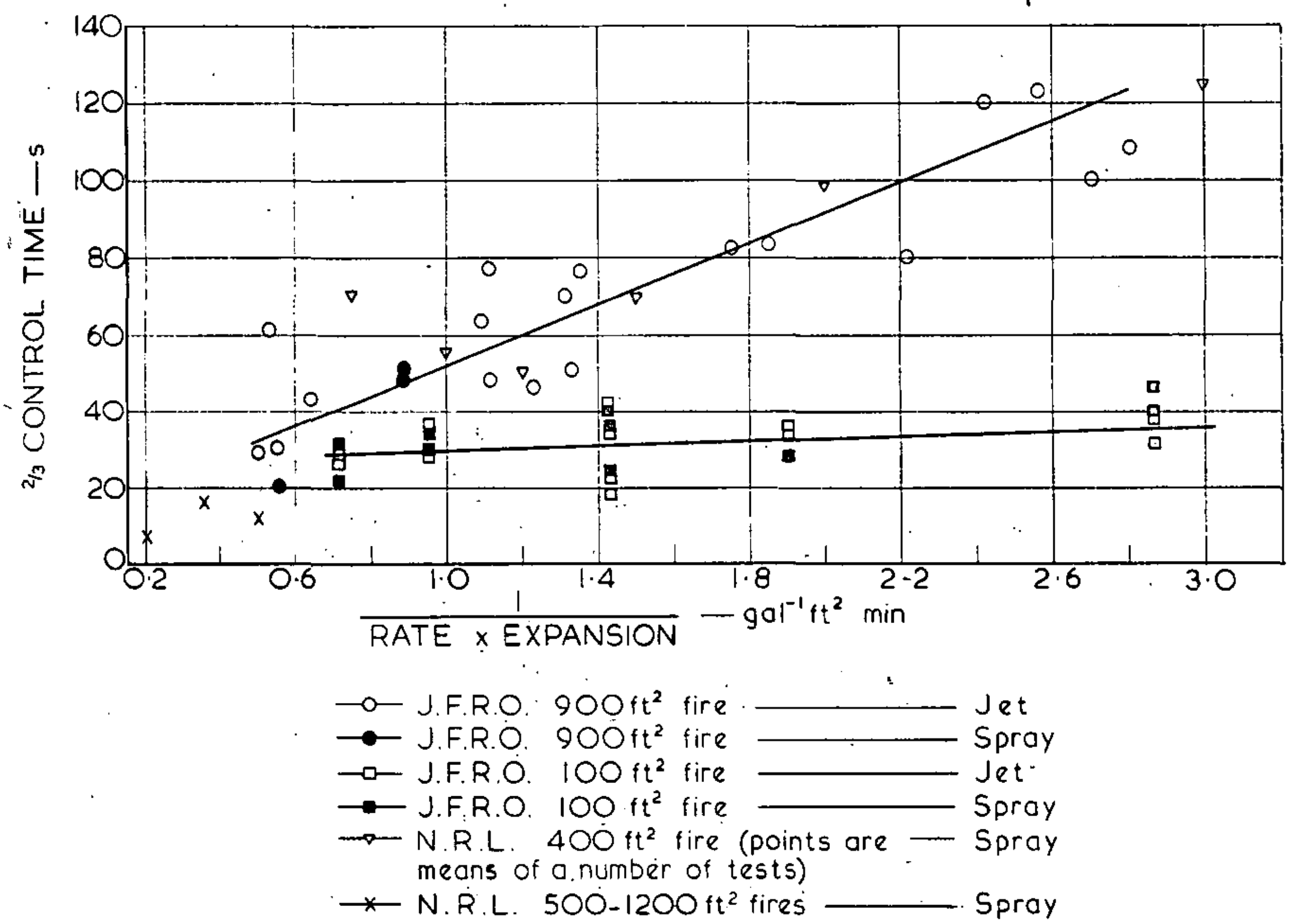

FIG. 7. SUMMARY OF RESULTS OF TESTS ON LARGE FIRES