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## THE USE OF HIGH AND LOW PRESSURE WATER SPRAYS AGAINST FULLY

## DEVELOPED ROOM FIRES

by

D. Hird, R. W. Pickard, D. W. Fittes and P. Nash

Summary

Large-scale extinction tests in fully developed room fires have shown that neither the rate of application, within the range from 5 to 25 gallons per min., nor the nozzle pressure within the range 80 - 500 p.s.i., affect appreciably the amount of water used to control or extinguish this type of fire.

It is suggested that the ideal equipment would enable the fire to be controlled with a spray and finally extinguished with a jet.

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# THE USE OF HIGH AND LOW PRESSURE WATER SPRAYS AGAINST FULLY DEVELOPED ROOM FIRES

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## 1. Introduction

The proportion of fires in buildings which are extinguished by hose reel jets has steadily increased since the war until now 75% of the fires in which water is applied by fire brigade equipment are extinguished in this way. This increased use has stimulated interest in obtaining the most efficient application of the limited amount of water which can be carried on the first aid appliance. The following factors might be expected to influence the amount of water used to extinguish fires in buildings.

(a) The rate of application of water. For water as for other extinguishing agents, there is a "critical" rate of application for a given size of fire, below which the fire cannot be extinguished. There is also generally an "optimum" rate of application at which a given fire can be extinguished with the minimum amount of water.

(b) The method of application - by spray or jet. The cooling or smothering action of water in a fire depends on the rate at which heat can be taken up by the water. Since it should be possible to increase the rate of heat transfer by increasing the surface area of the water, there are grounds for supposing that sprays should be superior to jets in some conditions.

(c) The nozzle pressure of sprays. Increasing nozzle pressure can be expected to reduce the droplet size of a spray, although most evidence suggests (1) that there is little reduction for pressures greater than 100 - 150 p.s.i. Nozzle pressure also affects the throw of a spray (3).

Other less easily defined factors, such as the degree of control which can be exercised by the branchman, may also affect the efficiency of extinction.

Operational problems may be associated with variations in any of these factors. For instance, an increase in either pressure or rate of flow increases the reaction at the nozzle, which at some stage will affect the manoeuvrability; an increase in the rate of flow increases the pressure drop in the hose which may have to be offset by an increase in hose diameter or pump pressure.

When all these variables are coupled with the natural variability of fires attended by Fire Brigades, it is not surprising that it is difficult from operational experience to assess the separate effects of pressure, rate of flow and method of application. However, information is required on these separate effects to help in the design of more efficient equipment, and because of this the Joint Fire Research Organization, at the request of Chief Scientific Adviser and H. M. Chief Inspector of Fire Services, Home Office, undertook a series of tests designed to investigate the effects of pressure, rate of flow and method of application on the extinction of fires in buildings.

The extinction tests were made on fully developed fires in rooms of a size chosen to represent approximately the upper limit of the present use of hose reel jets.

## 2. Previous work

Surprisingly few controlled extinction tests have been made on fires in buildings so there is not very much information to draw on. The results of the most important large scale tests are summarised in Table 1.

Table 1. Summary of extinction tests in rooms

Type and size of fire	Rate of application gal/1000cu.ft/min	Jet or spray	Pressure p.s.i	Ventilation ft <sup>2</sup> /ft <sup>3</sup>	Water used to control fire gal/1000ft <sup>3</sup>
National Board of Fire Underwriters <sup>(4)</sup>	60	spray	100	0.1	9.5
	19	spray	100	0.1	9.5
850 cu.ft room lined with fibre insulating board and containing wood and shavings	21	spray	600	0.1	13.0
	15	spray	300	0.1	11.8
	22	spray	600	0.1	10.0
	16	spray	300	0.1	5.4
	116	spray	50	0.1	12.6
	30	spray	200	0.1	4.3
	35	spray			
	61	jet	600	0.1	16
	9	jet	50	0.1	16.4
		jet	600	0.1	6.2
Wartime experimental fires at Building Research Station	2.4 (3 stirrup pumps)			0.015	22.5
1900 cu.ft room furnished with approx. 6 lb/ft <sup>2</sup>	0.8 - 1.6 (1&2 stirrup pumps)			0.015	15
Wartime experimental fires	7.6	jet	100	0.04	15.5
1424 cu.ft room	7.3	spray	100	0.04	14.8
	6.7	spray	100	0.04	not controlled
furnished with approx. 6lb/ft <sup>2</sup>	7.5	spray	100	0.04	14.8
Joint Fire Research Organization <sup>(5)</sup>					
'Birmingham tests'	32	spray	100	0.01	8
	32	spray	100	0.01	8
1250 and 1750 cu.ft furnished with approx. 6 lb/ft <sup>2</sup>	32	jet	100	0.01	8.5
	32	jet	100	0.01	5.8
	32	spray	100	0.01	5.3
	23	jet	100	0.01	8.6
	23	spray	100	0.01	5.7
Joint Fire Research Organization	4.4.	spray	120	0.026	1.8
	3.0	spray	60	0.026	1.2
512 cu.ft room lined with fibre insulating board and containing no furniture	4.4	spray	120	0.026	1.8
	4.8	jet	175	0.026	1.6
	4.8	jet	175	0.034	1.6
	4.8	jet	175	0.034	2.0

The amount and arrangement of furniture, type of nozzle, stage of the fire at which extinction was commenced and the ventilation and rate of application of water, differ widely in these tests. With the exception of the 512 cu.ft room, which was the only one unfurnished, the amount of water used to control the fire does not vary very widely and it is not possible to discern any separate effects of the different factors. More information can be inferred from the results obtained by Thomas and Smart (6) on small scale models of burning rooms. The rooms were unfurnished and were lined with combustible material. The effects of ventilation, rate of flow and method of application were investigated and the results indicated that:-

(a) The amount of water required to extinguish a fully developed room fire is very small if it is applied efficiently, while control was achieved with as little as 2 gall/1000 cu. ft in the experiments, it was thought likely that this would be increased to 5 - 10 gall per 1000 cu. ft under full-scale operational conditions.

(b) The quantity of water required to extinguish the fires in the models increased with increasing ventilation, and also as the rate of application of water increased.

(c) The amount of water used by a spray was the same or less than that used by a jet to control the same fire. The difference became more marked as the rate of application of water was increased. The only published information on the amount of water used to extinguish different types of fire under operational conditions is given by Mobius (7). One brigade reported the performance of two spray nozzles against 211 fires, not including small fires confined to furniture. The nozzles delivered between 25 and 30 gallons per minute at pressures between 60 and 85 p.s.i. The reports contained information on the type of fire, the nature of the combustible materials and the amounts of water used. The minimum amount of water used per fire was about 100 gallons; the amount of water increased with the ventilation and with the amount of "glowing" (fires in straw, textiles and upholstery etc. were defined as "glowing" fires). Mobius concluded that rapid extinction was obtained in rooms when the dimensions of the rooms were less than the throw of the spray. He also suggested that the ideal nozzle would be one in which the branchman could control the spray pattern and the rate of flow.

### 3. Test Programme

In the main test programme, it was required to investigate the effect of pressure on the amount of water, applied as a spray, necessary to control and extinguish a fully developed fire in a room. The range of pressures to be used was 80 - 500 lb/sq.in. for flow rates from 5 to 25 gal/min. During the course of the tests it was decided to include further tests to compare the effectiveness of water applied as a jet. These tests were made over the same range of flow rates at a pressure of 80 lb/sq.in. The main programme thus consisted of 50 tests:-

<u>SPRAY</u>	2 tests at 5, 10, 15, 20, 25 g.p.m. }	40 tests.
	at each of the following pressures:- }	
	80, 125, 225, and 500 p.s.i.	

These tests were randomised.

JET. 2 tests at 80 p.s.i. at 5, 10, 15, 20 and 25 g.p.m. ) 10 tests.

These tests were randomised amongst themselves.

Provision was also made for fourteen preliminary tests with three main objects; first to determine if any measurable property of the fire could be used to obviate a subjective assessment of the condition of the fire during extinction; second to develop a suitable test procedure; third to train the branchman so that he should have reached his maximum efficiency with this type of fire before starting on the main programme. Seven tests were made with a flow rate of 10 g.p.m. at 80 p.s.i. and seven at 25 g.p.m. and 500 p.s.i.

#### 4. Test Fire

The test fires were designed to represent a fully developed room fire. A 1750 cu. ft room with ample ventilation (.035 ft<sup>2</sup>/ft<sup>3</sup>) was used and a plan of the room with details of the furniture is given in Figs. 1, 2 & 3. The fire load was 6½ lb/ft<sup>2</sup> (52,000 B.Th.U/ft<sup>2</sup>) and consisted of a floor of ½ inch timber and simple "mock-up" furniture of 1 inch timber. All the wood was kiln dried but because of the large amounts used it was not possible to maintain the moisture content constant throughout the series of tests, and it varied from 9½% to 15%. The fires were started in the two boxes shown in Fig. 1 by burning a ½ pint of petrol in trays ¼ ft<sup>2</sup> in area. The fires were started in this way so that they would spread to involve the whole room as quickly as possible and in the majority of tests the room was fully involved in fire within 3½ minutes. In some tests, however, the fire took longer to develop and this was generally, although not always, associated with a high moisture content of the furniture. The effects of this on the test results are discussed later. Temperature records for the tests were provided from nine 26 s.w.g. chromel-alumel thermocouples connected in series and mounted within an inch of the ceiling.

Before any extinction tests, a test fire was made to decide the stage at which extinction should be attempted and also to confirm that the fire would last long enough for the extinction tests at the lowest rates of application, when extinction might be expected to take a considerable time. The time-temperature curve of this preliminary fire is shown in Fig. 4.

#### 5. Test Nozzles and Equipment

It was decided to use spray nozzles of the impinging jet type, on which much previous experience existed. In order that any effects of pressure on the droplet size of the sprays would not be masked, the orifice sizes were kept constant at 1/16 inch in all the nozzles. The rate of flow at a given pressure was therefore increased by increasing the number of pairs of impinging jets and not their size. Slight manufacturing differences, as well as the fact that the rate of flow per pair of impinging jets does not increase quite as rapidly with pressure as would be expected, produced some variations from the predicted flow rates. It was decided to keep the flow rates constant at the agreed levels for the test programme and to do this the pressures were adjusted around the four chosen levels. The numbers of pairs of impinging jets used for the different nozzles are given in Table 2 and the actual pressures used to give the desired flow rates are shown in parenthesis. Fig. 5 shows the final form of some of the nozzles.

Table 2. Details of Nozzle Design

No. of pairs of 1/16" impinging jets required				
pressure p.s.i. Rate of flow (g.p.m.)	80	120	225	500
5	5 (78)	4 (128)	3 (232)	2 (490)
10	10 (79)	8 (123)	6 (232)	4 (485)
15	15 (81)	12 (121)	9 (210)	6 (510)
20	20 (73)	16 (130)	12 (213)	8 (495)
25	25 (85)	20 (121)	15 (240)	10 (520)

The angle of impingement of the jets was 60° and the angles of divergence of the two rings of impinging jets (Fig. 6) were chosen to give as uniform a distribution of water as possible in the 30° cone angle of the spray. The cone

angle of a spray is generally taken as the angle of the spray at the nozzle. However, with small numbers of pairs of impinging jets this is not well defined, and it was therefore decided to define the cone angle as that angle subtended at the nozzle by the area wetted by 90 per cent of the water on a plane perpendicular to the axis of the nozzle and at a distance of 8 feet.

The nozzles were fitted to a trigger-operated gun (Fig. 7) which was modified proprietary equipment. The trigger was fitted with a switch connected to a recorder so that the time for which water flowed through the nozzle could be recorded automatically.

## 6. Results of Preliminary Tests

The amount of water required to "control" the fire, that is, to reduce its intensity to a point at which a rapid redevelopment of the fire would not occur if the water application were stopped, had first to be determined. It was also decided to measure the amount of water required to "extinguish" the fire. The two terms "control" and "extinguish" were found to be surprisingly difficult to define for this type of fire. It was found in the preliminary tests that they could not be related to a given room temperature, as this temperature varied with the time taken to achieve control or extinction, presumably due to the cooling of the room. Typical temperature records of fires are shown in Fig. 8 and photographic sequences in Fig. 9. Radiation measurements proved unsatisfactory due to the screening effect of the smoke and steam produced in the early stage of the extinction and the very low values of radiation intensity when the fire neared control. It was necessary therefore to adopt an observer's assessment of "control" and "extinction".

The tests showed that the extinctions generally followed a similar pattern. The intensity of the fire was rapidly reduced when water was first applied, but if the application of water was stopped too early, the fire quickly regained its full intensity. This is indicated in the temperature record of Fig. 10 illustrating one of the preliminary tests in which the application of water was stopped when large volumes of steam were first seen issuing from the windows. The fire was considered to be "controlled" at a later stage when all the main flaming had ceased and only small pockets of flame were left which were unlikely to cause a rapid redevelopment of the fire. The latter stages of the "extinction" consisted in putting out the smaller pockets of flame which remained. The room could be left for at least 10 minutes after "extinction" without any appreciable recurrence of flaming. Whilst the assessment of "extinction" by the observer and the branchman agreed, the branchman's assessment of "control" was generally a little later than the observer's, and it was decided to use both estimates during the main programme. It was evident after the first few preliminary tests that the access of water would have to be improved to two of the boxes or a disproportionate time would probably be spent extinguishing the fire within them, and this might detract from the main objects of the programme. Boards were therefore removed from the rear face of boxes 1 and 2. (Fig. 1.)

Finally it was evident during these tests that extinction was much more difficult if the wind was easterly. With this condition, the branchman's vision was seriously impaired by hot air and smoke blowing out of the doorway. For this reason it was decided not to carry out any tests in the main programme with a wind in this direction.

## 7. Test Procedure

As a result of the preliminary tests the following test procedure was adopted in the main programme.

The rooms were furnished on the morning of the tests and the moisture content of the wood was measured. To obtain a mean value, the number of measurements made on the floor and furniture were proportional to the percentage of the total weight represented. The fire was started in the two boxes indicated in Fig. 1. Two minutes after the whole room had become involved ('flashover') water was applied through the doorway. The observer's assessment of "control" was indicated to the branchman by a bell after which the application of water was stopped when the branchman thought the fire "controlled". When the room had cleared of smoke and steam, water was reapplied, intermittently, at the discretion of the branchman until the fire was considered to be extinguished. A typical record of the water

applied is shown in Fig. 11. No further water was applied for at least ten minutes, in order that any tendency to rekindle could be detected. In the fires which took longer to develop (Section 4) it was sometimes necessary to reduce the period between 'flashover' and the application of water to avoid complete destruction of some sections of the furniture.

The average wind speed and direction were measured during each test. Thickness and weight measurements were made on the furniture before and after the tests to determine the rate of burning.

## 8. Test Results for Sprays

The quantities of water used to "control" and "extinguish" the fires were determined for each test and the results are given in Table 3.

Table 3. Water used to control and extinguish fires

<div>Pressure lb/in<sup>2</sup></div> <div>Flow Rate Gal/Min</div>		Gallons							
		80		125		225		500	
5	Control (O)	8.8	28.8 <sup>*</sup>	2.7	9.1 <sup>*</sup>	12.1 <sup>+</sup>	6.5 <sup>*</sup>	3.7	2.8
	Control (B)	9.4	32.6	3.6	35.6	22.7	7.3	4.0	3.5
	Extinction	15.5	58.6	9.7	45.4	31.3	26.3	21.2	16.7
10	Control (O)	6.7	3.5	3.3	5.0 <sup>*</sup>	5.8	4.2	8.8 <sup>*</sup>	4.3
	Control (B)	7.7	5.3	7.7	6.5	6.3	5.0	10.2	4.8
	Extinction	12.8	14.2	18.5	25.7	6.3	9.9	22.3	16.5
15	Control (O)	4.5	4.5	6.8	4.3	3.5	5.7 <sup>*</sup>	3.3	5.0 <sup>*</sup>
	Control (B)	5.3	7.3	7.5	5.4	4.5	6.6	5.8	5.4
	Extinction	10.2	23.0	17.3	12.5	6.3	28.5	12.9	20.8
20	Control (O)	10.0	5.0	5.7	3.3	4.3	4.7	5.0	4.3
	Control (B)	10.7	5.8	7.7	3.7	6.3	6.7	5.7	6.7
	Extinction	20.7	7.7	17.0	17.7	20.0	12.8	5.7	8.3
25	Control (O)	12.1	5.4	4.2	7.5	7.5	7.9 <sup>*</sup>	6.3	3.3
	Control (B)	14.6	7.3	4.2	9.8	11.3	10.2	7.9	3.5
	Extinction	25.4	12.5	12.1	13.1	15.0	30.0	20.4	7.3

CONTROL (O) - Observer's assessment of 'control'.

CONTROL (B) - Branchman's " " "

+ This test was unsatisfactory and the results have been estimated.

\* In these tests the fire took longer to develop (Section 4) and a considerable amount of the furniture had collapsed before the fire was tackled. This meant that instead of reasonably readily accessible surfaces, there were heaps of burning material which appeared to be more difficult to extinguish.

The variability in the results is high as can be seen from Table 3 and there are no obvious effects of either pressure or rate of application on the amount of water used in the tests. Although this means that any effects there may be on pressure or rate of application are likely to be marginal, it was necessary to analyse the results in detail.

## 8. Analysis of results for sprays

In order to obtain as much information as possible from the tests the results were analysed in a number of ways and the results of all the analyses are given in this Section. The logarithms of the quantities of water were used as being of a more normal distribution than the quantities themselves.

Before doing the analysis it is necessary to decide to what extent the "starred" tests of Table 3 can be included in determining the effects of pressure or rate of application and whether or not they must be considered as tests carried out under different conditions from those of the unstarred tests. There is no apparent reason why the collapse of the furniture should affect the amount of water required to reduce the main flaming, and the results show that in only one of the seven "starred" tests was the observer's estimate of the amount of water required to control (control (O)) appreciably greater than in the unstarred tests. This test, the second at 5 g.p.m. and 80 p.s.i. appears to be an exception. There are two "starred" tests in the branchman's estimate of control (control (B)) in which appreciably more water was used and it is less likely that all the tests can be considered as under similar conditions.

More water was used to extinguish the fire in all the "starred" tests and a comparison of the means of the amounts of water required to extinguish the fire in the "starred" and unstarred tests shows that the difference between them is highly significant. Thus in analysing the results, all the tests might be included in the amount of water required to control the fire, but the "starred" tests should not be included in an analysis of the water used to extinguish the fire.

(1) Observer's estimate of control (control O)

(a) All the results were analysed including the test in which there was an appreciable increase in the amount of water used. This analysis shows the linear effect of pressure and the quadratic effect of rate to be significant at the 5% level. The most probable results are given by

$$\log_{10} W = (0.74 \pm .062) + (.04 \pm .037)(r^2 - 2) + (.028 \pm .028)(2p)$$

where W is the quantity of water used in gallons.

$$r = \frac{R - 15}{5} \text{ and } R \text{ is the rate of application in gallons/min}$$

$$p = \frac{1}{\sqrt{P}} - .078 \text{ and } P \text{ is the nozzle pressure in lb/in}^2$$

The most probable results are shown graphically in Fig. 12.

The maximum effects of the two variables can be determined from the 95% confidence limits, and these are shown in Table 4.

Table 4. Maximum effects of pressure and rate of application on the amount of water used to control the fire

	5 g.p.m.	10 g.p.m.	15 g.p.m.	20 g.p.m.	25 g.p.m.
Varying the pressure from 500 p.s.i. to 80 p.s.i. is likely to vary the amount of water used within the following limits -	0 - 5.3 gal.	0 - 3.9 gal.	0 - 3.6 gal.	0 - 3.9 gal.	0 - 5.3 gal.

i. e. changing the pressure from 500 p.s.i. to 80 p.s.i. at 5 or 25 g.p.m. can either have no effect on the amount of water used to control the fire (about 7 gallons), or can increase it by an amount up to 5.3 gal.



	80 p.s.i.	125 p.s.i.	225 p.s.i.	500 p.s.i.
Varying the rate of application from 15 g.p.m. to 5 g.p.m. or 25 g.p.m. is likely to vary the amount of water used within the following limits.	2 - 5.1	2 - 2.9	1.8 - 2.6	1.3 - 3.5

1. e. changing the rate of application from 15 g.p.m. to 5 g.p.m. is likely to increase the amount of water used (about 7 gallons) by an amount between 2 and 5.1 gallons.

(b) All the results were analysed but the test result of 28.8 gallons for the second test at 5 g.p.m. and 80 p.s.i. was replaced by an estimated value of 6.2 gallons.

When analysed in this way none of the factors were significant to the 5% level.

(c) The analysis was carried out on the results obtained from the first series of 20 tests only, the estimated result for the test at 5 g.p.m. and 225 p.s.i. being based on these results. The thirteen tests in which satisfactory repeats were obtained were used as estimates of error.

This gave no factors significant at the 5% level.

## (2) Branchman's estimate of control (control (B))

(a) All the results were analysed as in 1(a). This showed no significant effects of flow rate or pressure.

(b) The analysis was carried out on the results obtained in the first series of tests only, as in 1(c). Only a high order interaction between pressure and rate was significant at the 5% level.

## (3) Extinction

(a) The analysis of all the results was made, although this is of doubtful validity since there is a highly significant difference between the results for the "starred" and unstarred tests.

This analysis showed no significant effects.

(b) The analysis was made on the results obtained in the first series of tests only as in 1(c), and again neither pressure nor rate of application were significant.

## 9. Test Results for Jets

The test procedure for the tests with jets was exactly similar to that with sprays and the results are given in Table 5.

This may not have been shown in these tests since the branchman had tackled the same fire many times when he came to use the jets and knew exactly where the main centres of burning were.

The total amount of water used to extinguish the fire was about 15½ gallons; thus rather more water was used to subdue the small pockets of flaming and to prevent the fire from re-establishing itself than was used to control the fire. It would appear that the amount of water used in this stage of the fire is more sensitive to the method of application and the type and arrangement of combustibles than is the amount of water used to control the fire. This was emphasised by the tests in which the furniture collapsed, where considerably more water was used for this second phase of extinction with sprays than with jets. This is presumably because the water needs to be applied to a relatively small area and the spray is wasteful. Most fires in practice are likely to have features of this type, upholstered furniture and materials arranged so that supporting radiation would make the final fires more difficult to extinguish. It would seem then that operationally a jet would be better than a spray for the second stage of the extinction.

The effect of both the rate of application and the nozzle pressure on the observers estimate of the amount of water used to control the fire is marginal. This is clearly demonstrated by the fact that if the one doubtful test at 5 g.p.m. and 80 p.s.i. is replaced by an estimated value then no effects are significant. Even including this test neither pressure nor rate of flow are significant in the branchman's estimate of control, which practically is of more importance.

Neither pressure nor rate of flow affect the amount of water used to extinguish the fire.

The foregoing naturally apply within the range of conditions of the tests. There will be a rate of application at which the fire cannot be controlled and previous experience would suggest that for this size of fire the 'critical rate' cannot be much less than 5 g.p.m.

Thus the choice of a suitable rate of application for hose reel equipment will depend on the maximum size of fire which it is intended that the equipment shall deal with. Since pressure of itself has no effect on the fire fighting capabilities at a given rate of application, the choice of a suitable nozzle pressure will be dictated by operational and economic factors.

### 13. Conclusions

(1) Within the range of conditions investigated in these tests, neither the rate of application nor the nozzle pressure affected significantly the amount of water required to 'control' or 'extinguish' the fire.

(2) From the experience gained during 65 large scale tests and the discussions with operational Fire Officers who witnessed many of them, as well as from the information that can be drawn from the results, it appears that the ideal equipment would enable the fire to be controlled with a spray and then finally extinguished with a jet.

### 14. Acknowledgments

These tests were planned in co-operation with the Fire Service Department and the Chief Scientific Adviser's Branch of the Home Office, and many helpful discussions were held with them both during the tests and in the preparation of this report.

Such a series of large-scale tests as is reported here required the co-operation of many people and the authors would like to thank those, including carpenters, electricians, labourers, office and workshop staff, as well as scientific staff, who helped to ensure the smooth running of the test programme.

### 15. References

- (1) Giffen and Miraszew - "The atomization of liquid fuels". Chapman & Hall Ltd. p.184. London 1953.
- (2) Fraser, R. P. and Eisenklam. 'Liquid atomization and the drop size of sprays'. Trans. Inst. Chem. Eng. Vol. 34, No. 4, 1956 p.294 - 319

Table 5

Water used to extinguish fire by jet

	FLOW RATE - GAL/MIN									
	5		10		15		20		25	
Control (O)	7.9	7.7	20.0	5.2	5.0	5.0	6.0	10.0	8.3	5.8
Control (B)	13.2	11.0	28.0	7.0	7.3	6.0	7.7	14.4	10.0	7.5
Extinction	20.2	16.0	39.5	25.7	18.1	11.5	11.9	19.4	24.6	15.6

\* In these tests the time to flashover was delayed and some of the furniture had collapsed before the application of water.

10. Analysis of results for jets

There is no significant difference in the amount of water used either to control or extinguish the fire in the "starred" and unstarred tests and all the results can be used in a comparison of sprays and jets. Such a comparison shows no significant difference between the performance of sprays and jets against the test fire. The rate of application of water as a jet also had little effect on the amount of water used.

In some of the tests (starred results) with both sprays and jets, the fire developed more slowly and as a result, some of the furniture collapsed and was less accessible. This allows a further comparison to be made between sprays and jets, for which there was a significant difference in the amount of water used to extinguish the fire, less water being required with the jets. The mean amount of water used to extinguish the fire in the starred tests with sprays is 33.8 gallons compared with 22.7 gallons using jets.

11. Branchman's Observations

After each test the branchman recorded his impressions of the fire and the efficiency of extinction.

The gun was found difficult to manoeuvre, particularly when closing or opening the water supply at 500 p.s.i. with rates above 15 g.p.m. The protection against radiation afforded by the sprays made fire fighting easier than with jets, though this effect was not noticed with the tests carried out at 80 p.s.i. Further, it appeared to the branchman that 'control' was achieved more rapidly with sprays than with jets under the same conditions though the directional properties of a jet appeared to make the extinction of more deep-seated pockets of fire beneath collapsed furniture easier.

12. Discussion of all results

Despite the considerable care taken to standardise the test conditions and procedure, there was still a large variability in the test results. However, the number of tests carried out was sufficiently large to show any marked effects of the three variables; method of application, rate of application and nozzles pressure.

The mean amount of water used with sprays or jets to 'control' the fire was 7 gallons, equivalent to 4 gallons/1000 ft<sup>2</sup>, a very small amount of water, and just sufficient to fill the room with steam if completely vaporised. This agrees reasonably well with the results obtained in previous work, Table 1. More protection was afforded to the branchman by the spray than by the jet and this is probably the reason why he thought 'control' was achieved more rapidly, although the results do not show this to be so. It is probable, however, that under operational conditions 'control' could be achieved more rapidly with the spray since less manipulation is required.

- (3) Fire Research 1955 London. H.M.S.O.
- (4) "Characteristics of water spray nozzles including those designated as fog nozzles for fire-fighting use". National Board of Fire Underwriters, Chicago 1944.
- (5) Thomas, P. H. and Smart, P.M.T. Fire extinction tests in rooms. F. R. Note No. 121/1954.
- (6) Thomas, P. & H. and Smart, P.M.T. The extinction of fires in enclosed spaces. F. R. Note No. 86/1954.
- (7) Mobius, K. "Experience obtained with the testing of spray nozzles". V. F. D. B. 1956. 2 (2) 33 - 42.

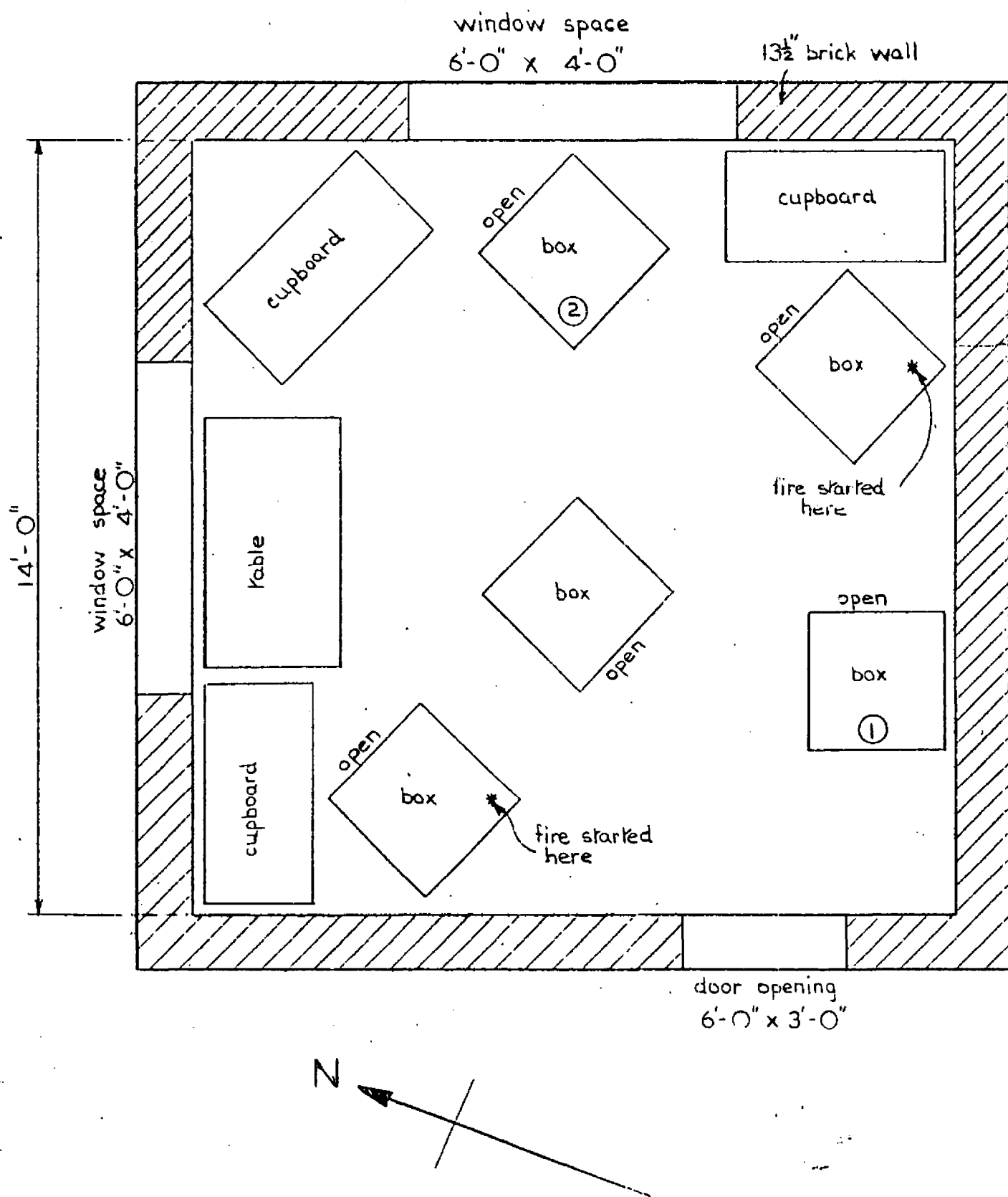


FIG.1. PLAN OF ROOM AND FURNITURE

FURNITURE MADE  
OF 1" TIMBER

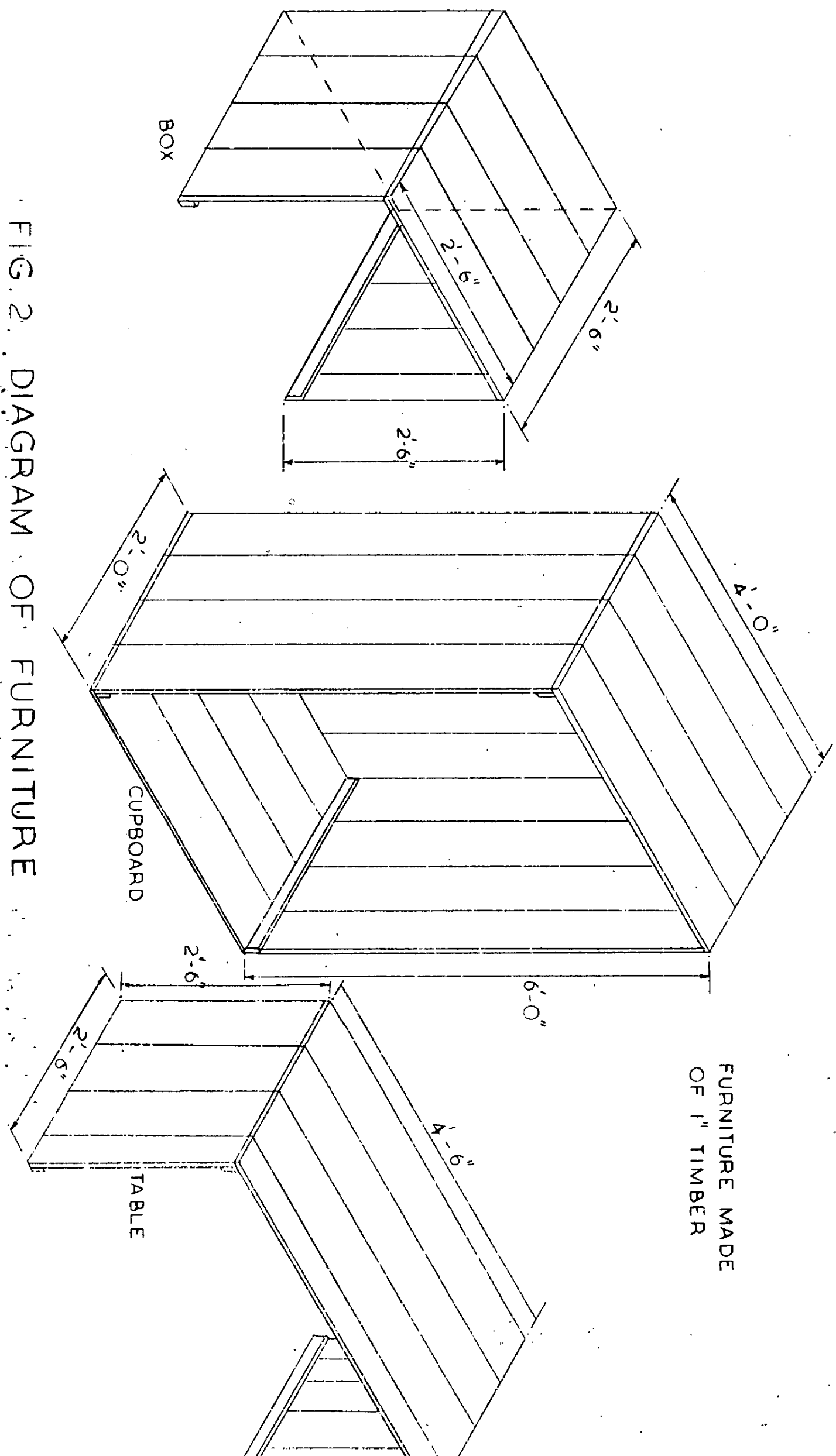


FIG. 2. DIAGRAM OF FURNITURE

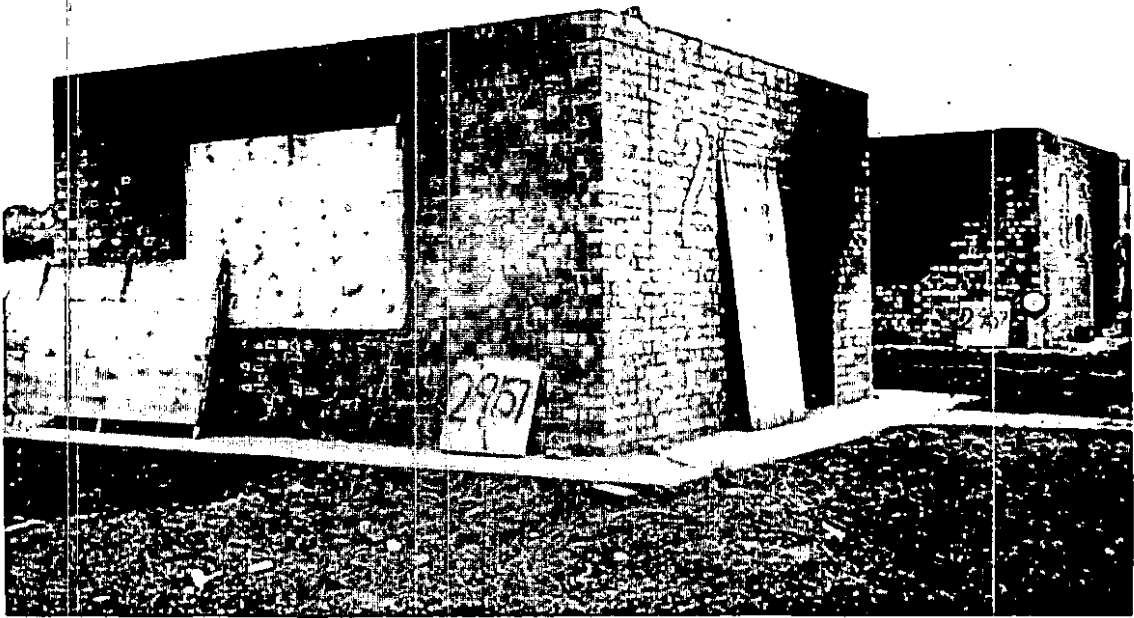


FIG. 3. FIRE TEST ROOMS

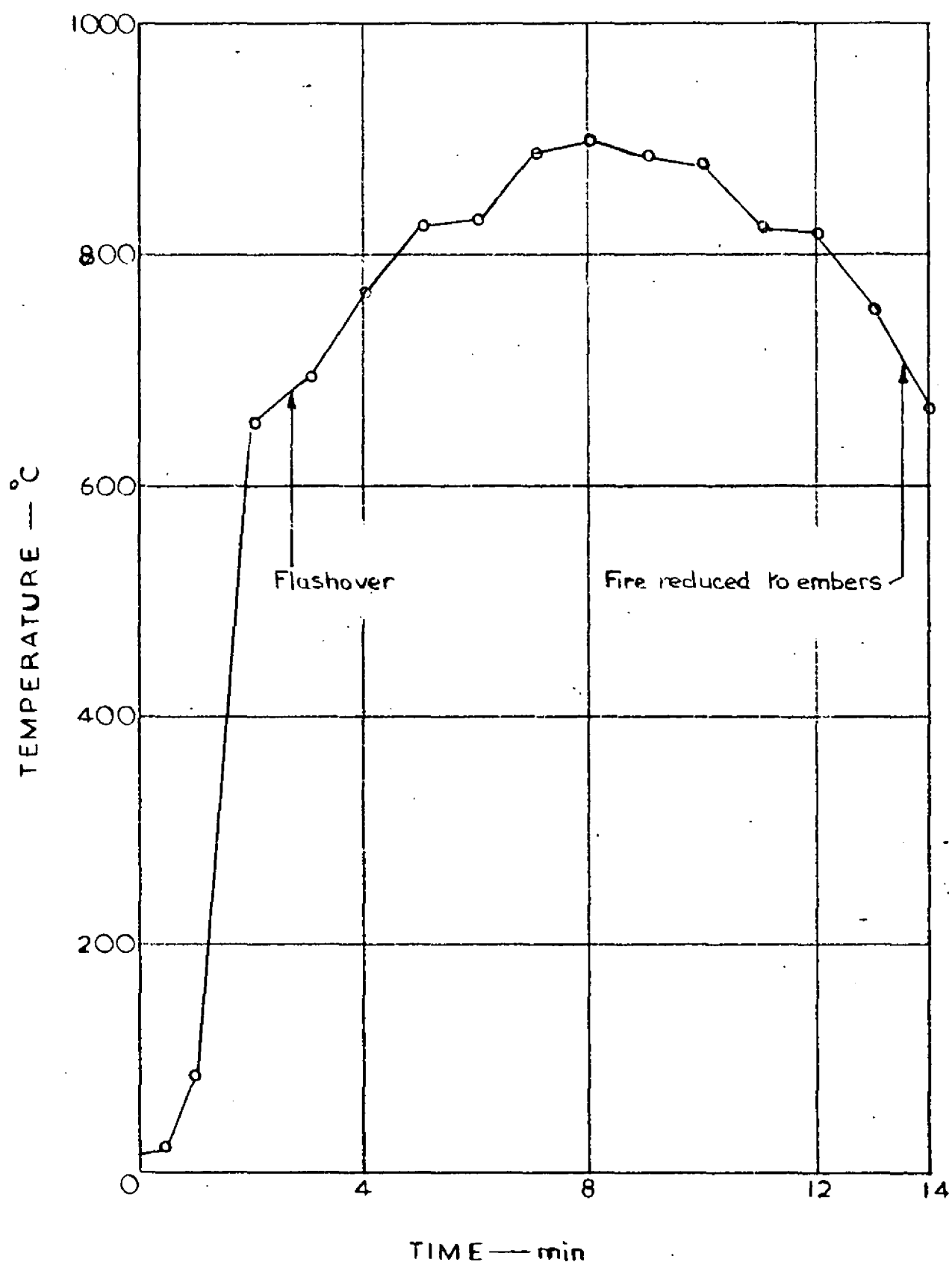
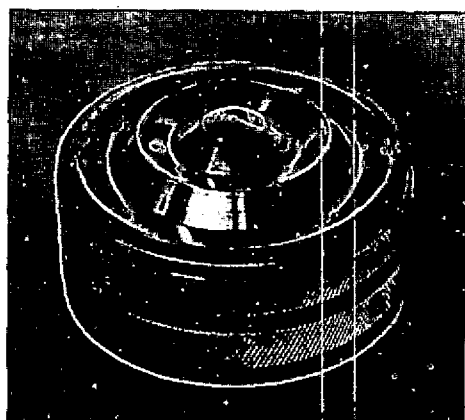
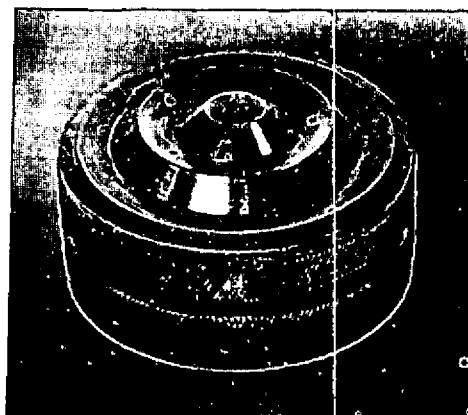


FIG. 4. TIME-TEMPERATURE RECORD OF FIRE TEST

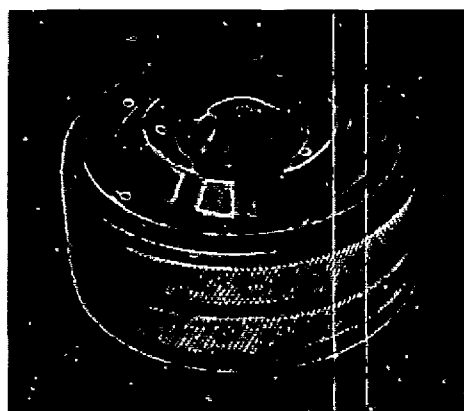




5 g.p.m. at 500 p.s.i.

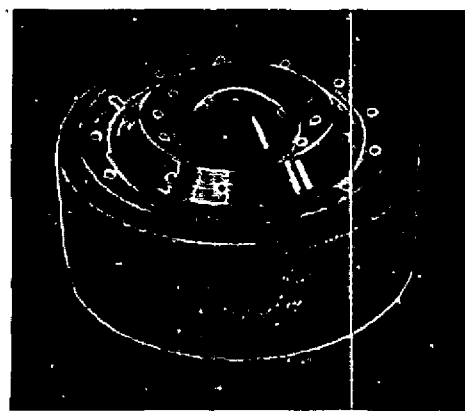


5 g.p.m. at 80 p.s.i.



10 g.p.m. at 80 p.s.i.

25 g.p.m. at 500 p.s.i.



25 g.p.m. at 80 p.s.i.

FIG.5. TEST NOZZLES

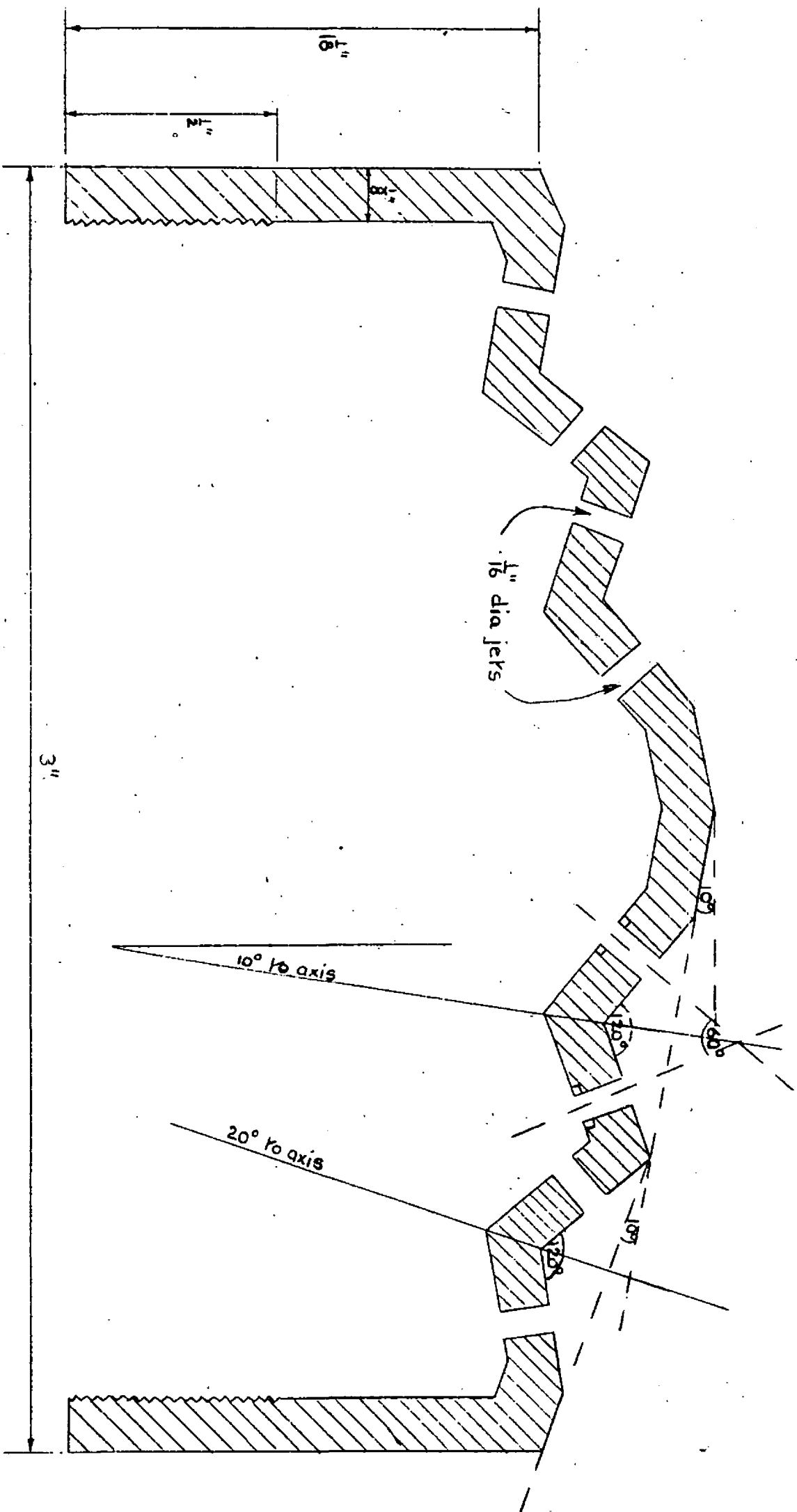


FIG. 6. DIAGRAM OF SPRAY NOZZLE

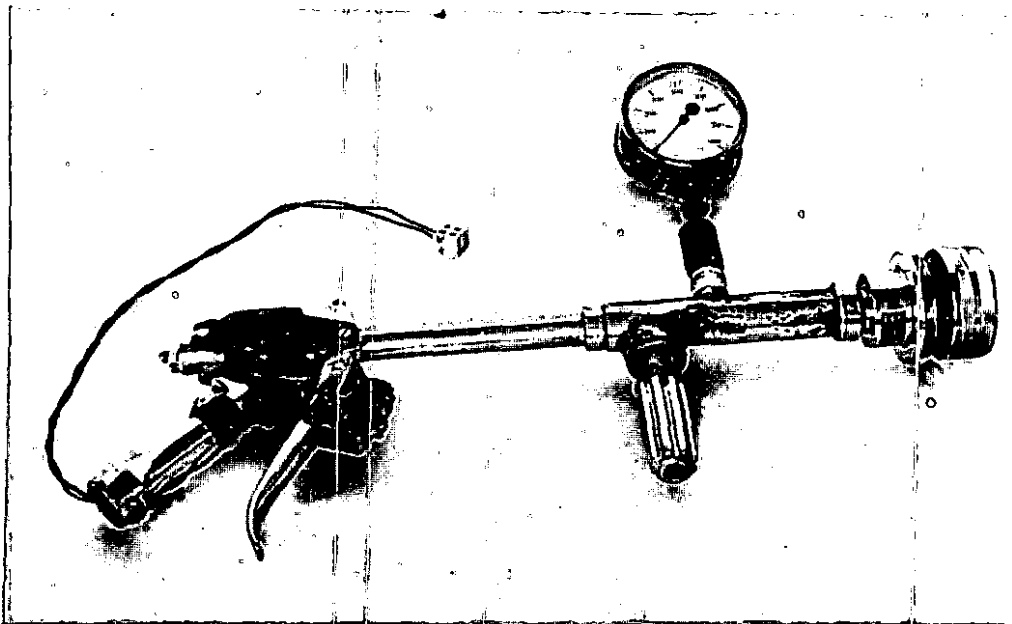


FIG.7. NOZZLE AND GUN ASSEMBLY

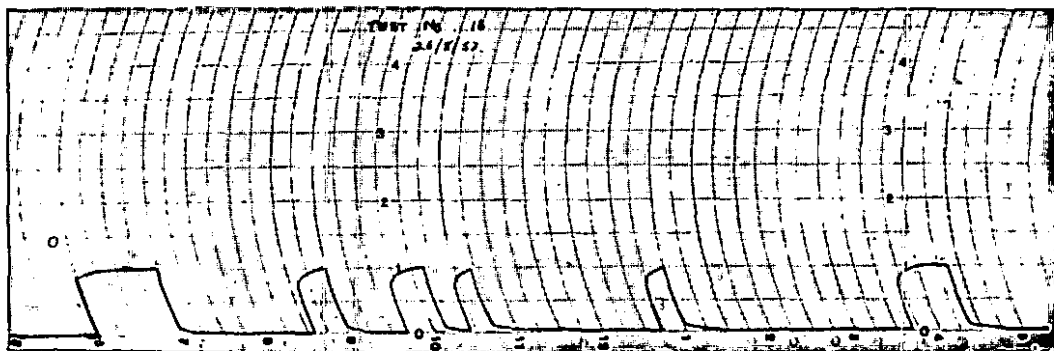


FIG.II. RECORD OF WATER APPLIED

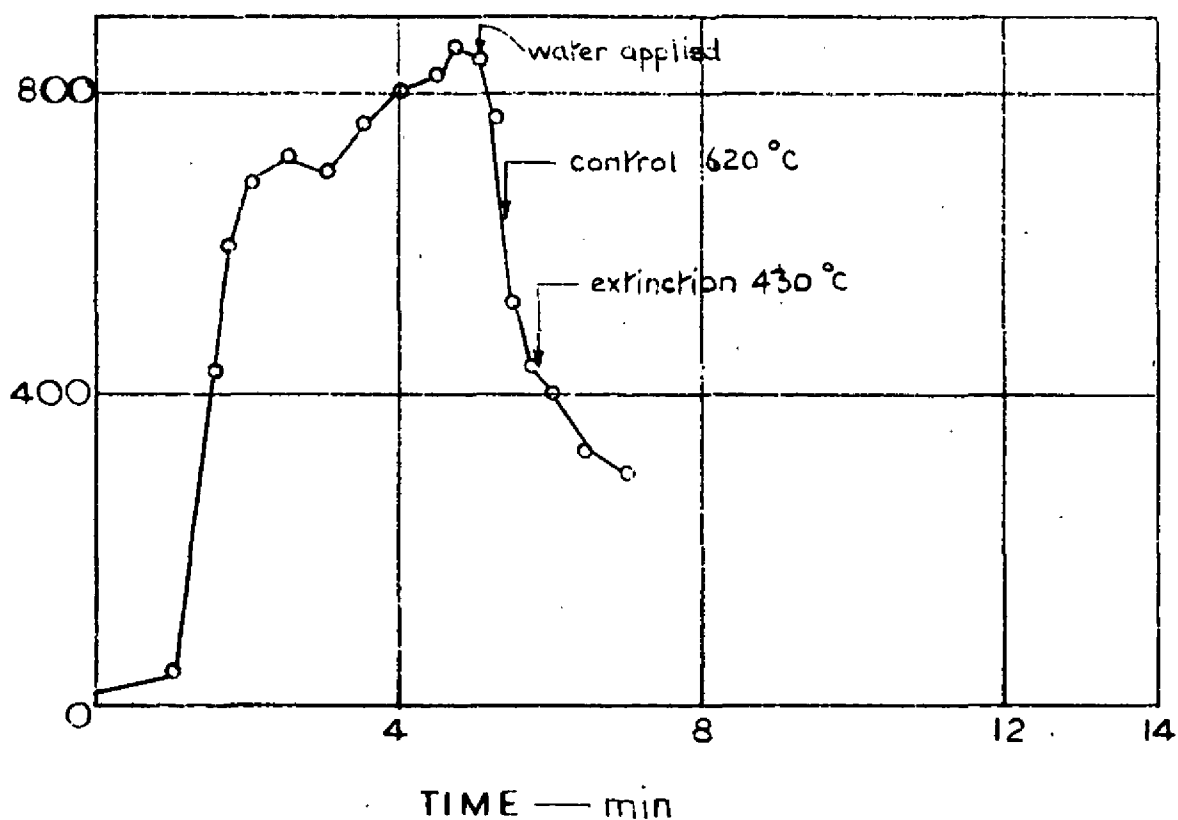
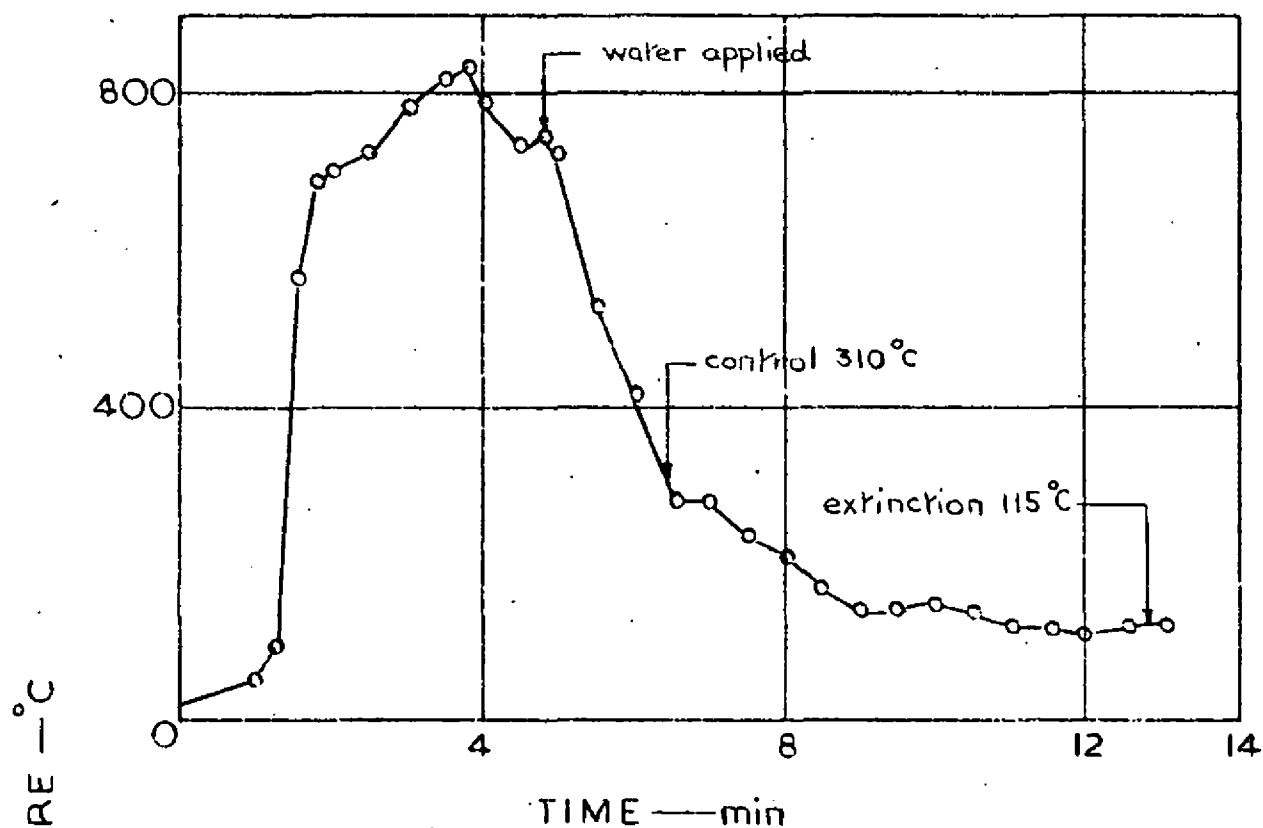
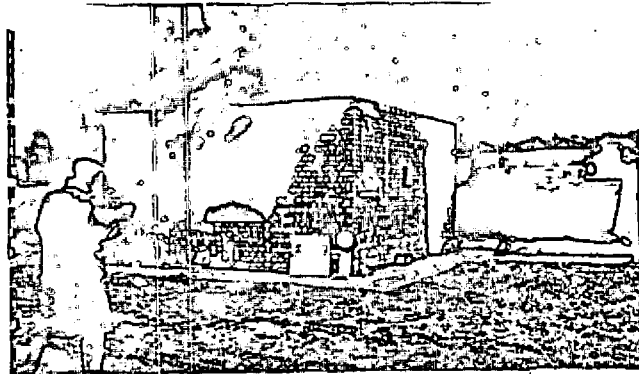
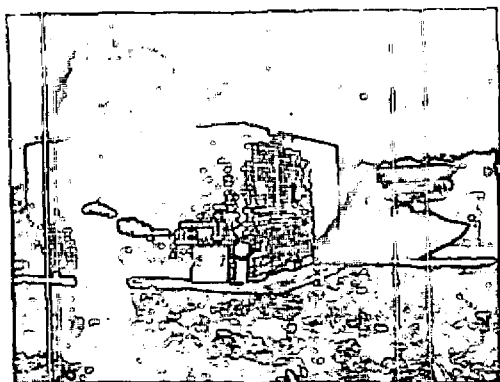


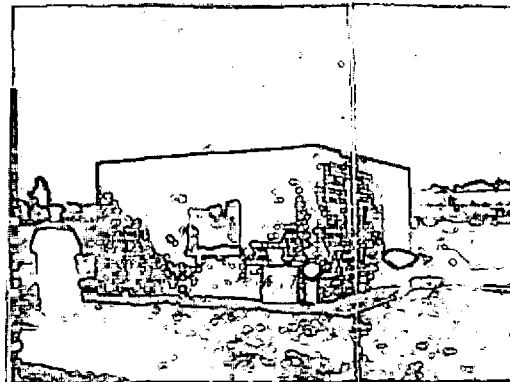
FIG. 8. TYPICAL TIME-TEMPERATURE RECORDS OF EXTINGUISHMENT TESTS



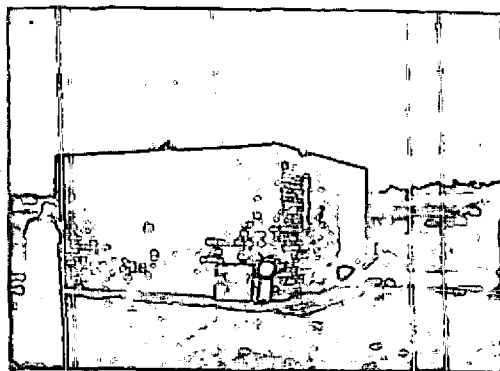
(a) 2 seconds before water application



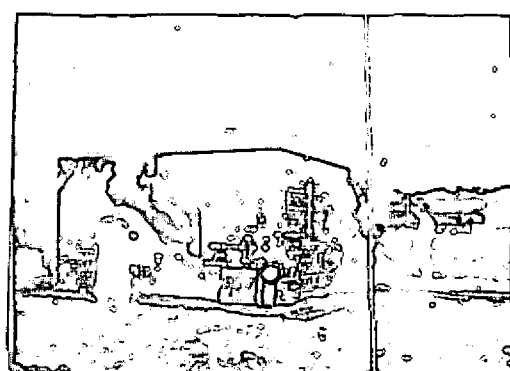
(b) Water applied



(c) Marked reduction in intensity



(d) Control (O)



(e) Control (B)

FIG.9. SEQUENCE OF EXTINCTION

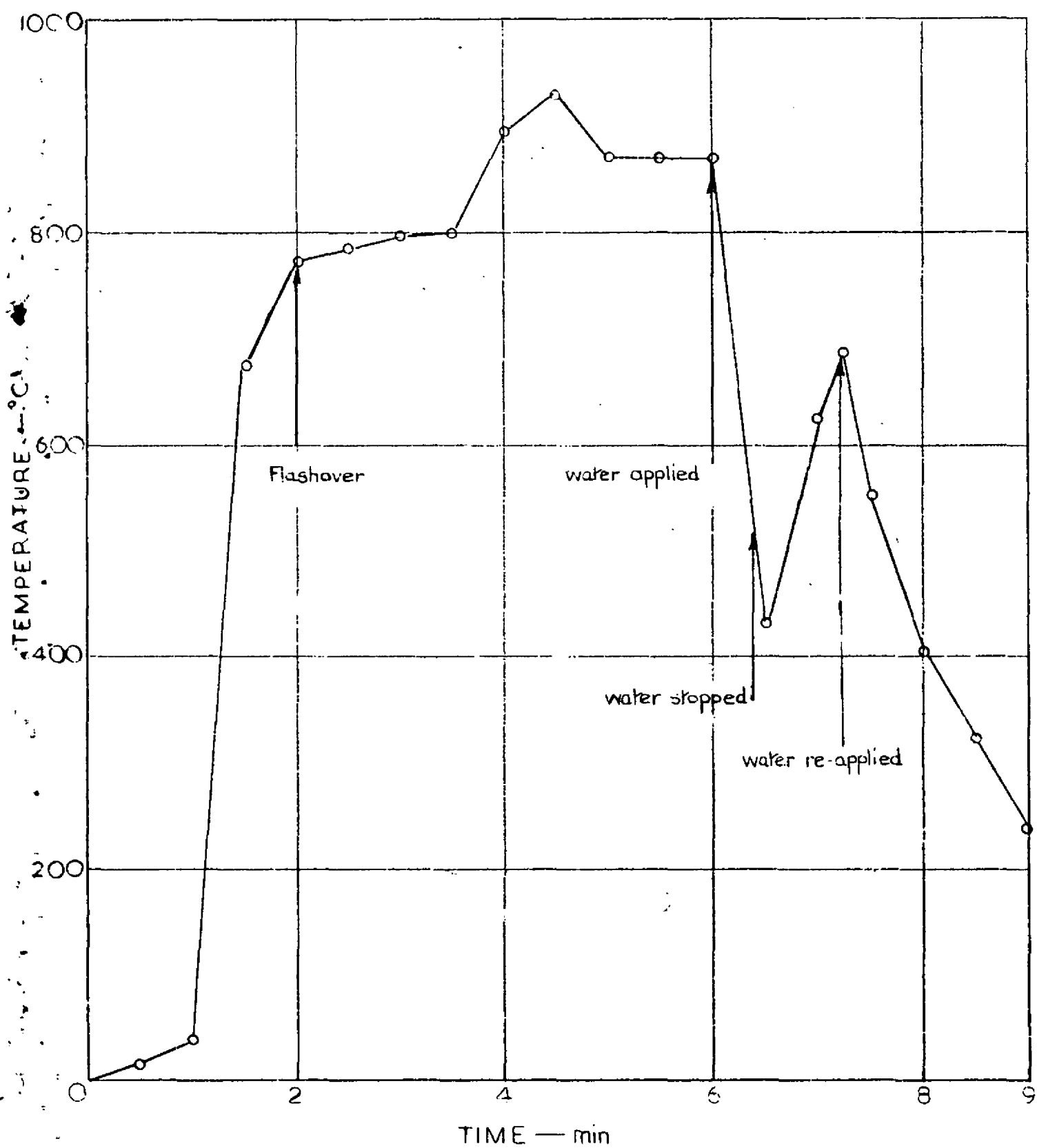


FIG.10. TIME-TEMPERATURE RECORD OF EXTINGUISHMENT TEST IN WHICH FIRE IS RE-ESTABLISHED

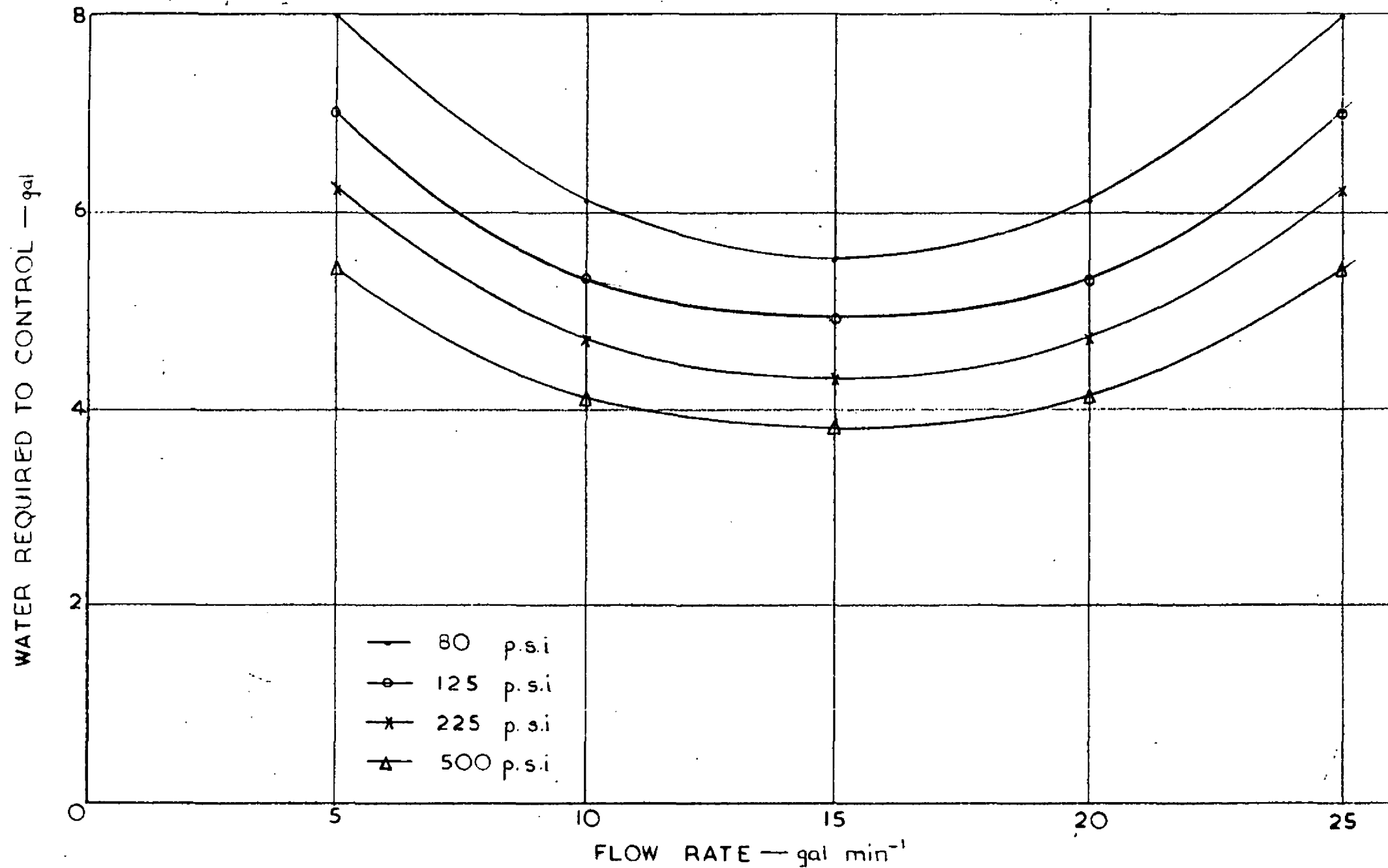


FIG.12. 'MOST PROBABLE' QUANTITY OF WATER REQUIRED TO CONTROL FIRE