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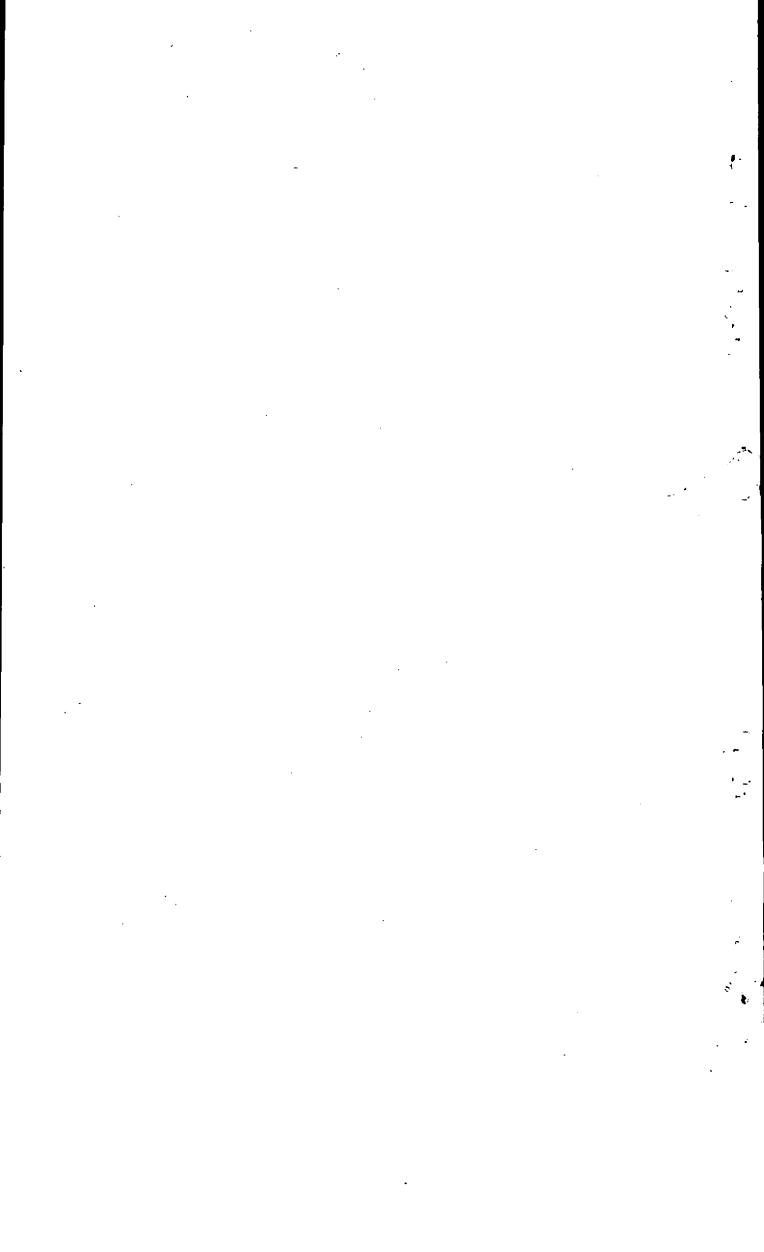
FIRE EXTINCTION TESTS IN ROOLS

by

P. H. Thomas and P. M. T. Smart

July, 1954.

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Introduction

During the past few years, laboratory experiments have been made to examine and compare the extinguishing properties of water agrays and water jets when applied to fully-developed fires in model rooms. This work, and a review of certain full-scale tests, is described in the report (1).

While these model experiments have provided useful information on the amount of water required to extinguish such fires, and on the minimum rate of application at which extinction is possible, they have suffered from the disadvantage that no suitable full-scale tests have been made by which their findings may be systematically compared with those of practical fire-fighting. Experiments of the National Board of Fire Underwriters for example, consisted of twelve tests, each with different conditions of application of water; nine tests were with sprays and three were with jets, and five different pressures were employed, ranging from 50 to 600 lb/in.² Comparisons of particular small-scale tests with their full-scale counterparts, (1) where these existed, showed the results to be reasonably consistent, however, and gave promise of the general extension of information to full-scale.

In these circumstances, an offer by the Home Office to arrange for facilities for the performance of full-scale tests was most velcome, and the ready agreement of the City of Birmingham Fire Service to co-operate in performing a trial sequence of twelve tests permitted the work to proceed. Reports of members of the Service appended to this paper, show, among other things that the joint experiment was appreciated by them also, and their advice and observations, based on their long experience, were invaluable to the Joint Fire Research Organization.

This report describes the sequence of twelve tests, the objects of which were to obtain an estimate of the repeatability of full-scale tests, to measure the amount of water required to control a fully-developed fire in a full-scale room, and to compare control by a spray and a jet at one chosen condition.

2. Experimental design

In considering the objects of the tests, it was decided that all twelve fires should be made under conditions as nearly identical as possible. There were, however, some unavoidable differences which had to be taken into account in the experimental design. The size of and access to the upstairs and downstairs rooms were different (see Section 3 (a)). There was the possibility that the extinction time would be reduced as the operators gained experience of this particular fire, a factor of unknown extent. In order to minimize the chance of fire damage from the first fire in each house affecting the second fire, the upstairs fire was performed first. The two firemen "A" and "B" (see Section 3(f)) took turns to handle the nozzle, the other being in support immediately behind. The twelve tests were performed on three successive days, each fireman using the spray and jet once each day.

The experimental arrangement eventually chosen, after consultation with Mr. D. W. Millar of the Joint Fire Research Organization, is shown in Table 1.

TABLE 1
Arrangement of Tests 1-12

Fireman at nozale		1st	Day	2nd	Day	3rd	Day
		A	В	A	В	A	В
Upstairs	Spray	1.			7	9	
	Jet		3	5			11
	Spray		4	6			1.2
Downstairs	Jet	2	!	!	8	10	

3. Experimental arrangements

(a) Site of Tests

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The property used for the tests was part of a terrace of back-to-back dwelling houses. Six houses alike in size and construction had been selected, each having one ground floor room with a stone floor, and two smaller rooms on the upper floor. The dividing wall between the two upper rooms in each house was removed, making a total of twelve rooms of comparable size available for the tests. Figure 1 is photograph of part of the site. Approximate dimensions of the rooms were:-

Ground floor: 12 ft. x 13 ft. x 8 ft. high. Window area 1 x 17 g sq.ft.

Upper floor: 16 ft. x 13 ft. x $8\frac{1}{2}$ ft. high. Window area 2 x 12 sq.ft.

The Building Surveyor of the City of Birmingham arranged to make good the damage done to the property while it had been standing vacant and to re-cover the floors and ceilings where necessary.

(b) Combustible content of rooms

Sets of furniture consisting of a cupboard, table, four ordinary, and two larger chairs were made to the design shown in Figure 4 and were arranged in each room as shown in Figure 5. This furniture was similar in design to that used in earlier tests on the spread of fire. (3) Some wood wool and paper stuffed under the armchair, and between it and the cupboard provided the initial fire. As additional combustible material some 4 ft. x 4 ft. sheets of 5/16 in. thick fibreboard were put under the table in the downstairs rooms which had stone floors. As the object of the tests was concerned with the extinction, and not the development, of the fires, it was possible to put waste rage, cardboard and wood wool into some of the rooms where the furniture was found to be damp, so that "flash-over" would occur before the ceiling or floor were penetrated. In addition, the furniture was wetted with a petrol-oil mixture. because of this failure of the ceiling or floor that the first three tests were unsuccessful. In Test 4 and subsequent tests ignition produced a large fire for a short time after which it died away, and almost went out. The fire spread, however, from the cupboard and chair, flames spreading across the ceiling and igniting the table. In this respectively. In this respect the fire spread was then normal.

(c) Ventilation

Ventilation to the downstairs room was provided by one window, both the door leading to the stairs and the front door giving access to the street being kept closed. Upstairs fires were ventilated by one window and the stairway, the door to which was kept partly open. During the development of the fire, heat was conserved by boarding which had been placed over half the window. Host of the boards had either fallen or been pushed in by the time the water was applied.

(d) Design of nozzles

In the extinction of fires of this type it is desirable that the fire should be controlled with the minimum of water damage, but that the water should not be cut off so soon that there is unnecessary hazard to the firemen. Both the time of control and the amount of water necessary were shown to depend, in the small-scale experiments, on the rate of application of water, and for this series of experiments this was chosen to be about 40 gallons per minute. This rate is about ten times greater than the minimum capable of extinguishing a fire of this size, and was chosen because any difference between sprays and jets was likely to show up at the higher rates of flow.

The nozzles for the experiments are shown in Figures 2 and 3 and were made to be screwed onto a branch fitted with a stop-cock. The spray nozzle consisted of six pairs of $\frac{1}{6}$ in. diameter orrifices to produce six pairs of jets impinging at 90°, the bisector of the angle between each pair of jets being inclined outwards at 15° to the axis of the nozzle. The jet nozzle had a single orifice of 0.400 in. diameter. On calibration at 100 lb/in. it was found that while the spray gave 40 gal/rán. the flow through the jet was slightly more and the pressure at the nozzle was appropriately reduced to give equal flow. The quantity of water used in each test was determined by measuring the change in water level in the 400 gallon tank from which the nozzle was supplied by hose reel. A check was also made by calculation.

(e) Experimental measurements

Thermocouples were placed 2 in. below the ceiling, one above the cupboard in the corner, one above the table in the centre of the room, and a third in the corner above the second large chair. The temperatures of the couples were recorded at 3 second intervals. Photographs of the fire were taken through the open window. The time of any marked change in the state of the fire was noted.

(f) Method of attacking fire

The fire was ignited in the combustibles between the first armchair and the cupboard, and was allowed to develop until it "flashed over" the whole room. During the development of the fire in the downstairs room, the front door was kept closed to conserve heat. At a suitable moment after flashover, when it was observed that the thermocouple readings had reached a maximum, a signal was given to the firemen to enter the room (see Figures 14 and 15) and fight the fire in accordance with their experience, the time for shutting-off the water being decided by the fireman at the nozzle.

Results

In Figure 16 a series of photographs taken during the course of Test 10, shows that, in a successful test, there was a clearly defined point at which steam was emitted in large quantities at the windows of the room. Visibility was reduced with sprays much more than with jets, and it may not always have been possible to see the fire. During the course of the tests it was found that the time of shutting-off the water could be reduced almost to correspond with the time of emission of steam, with the certainty that the fire was in a controlled state and

8.

only small pockets of fire remained to be extinguished by hand pump. Table 2 and Figure 13 illustrate this point.

Temperature records of the successful tests are shown in Figures 6-12. The minimum times for the appearance of steam correspond to a quantity of water of approximately 6 gallons per 1000 cu.ft. of room volume, and the minimum times of shutting off the water correspond to approximately 9 gallons per 1000 cu.ft. of room volume. Peak temperatures were about 800°C, and in all tests after test 5 the temperature over the table exceeded 600°C for between 1 and 5 minutes before applying water. Flashover did not occur as rapidly in some tests as it did in others and in some instances water was applied sooner than experimentally desirable because of the imminence of the collapse or burning through of the ceiling. This therefore added to the variation in the development and extinction of the fires. The amounts of water used, as measured by the tank of the Fire Brigade Tender, are given in Appendix I. The reports of a Fire Officer observer and one of the two firemen concerned are given in Appendices II and III.

TABLE 2
Time data of tests

Test No.				Water off-sec	Remarks
1 2 3 4 5 6 7 8 9 10 11 12	a,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,	B A A B A A B B A A B B	- - - 15 20-25 15 15 16 - 10-12	38 60 35 65 25 16 -	FAILED-NO FLASH OVER Fire appeared out in 40 secs. FAILED-COLLAPSE OF CEILING Fire appeared out in 13 secs. FAILED-COLLAPSE OF CEILING Fire appeared out in 13-15 secs.

Discussion

There is no evidence of any differences between the performance of the firemen or between the fires in the upstairs and downstairs rooms; it is valid, therefore, to use all the successful experiments in an examination of the main factors.

An apparent slight superiority of the jet in terms of amount of water used may be due, if it is a real difference, to the application of experience gained primarily using jets to the use of a spray.

In the extinction of a fire there are generally two times of importance, the control time and the extinction time. Control time is relevant because it represents a time at which, say, the fire spreads no further or after which the fire does not re-establish itself at once if the application of extinguishing agent is stopped. In practice, if the meaning of 'control time' is in the latter sense, some convenient feature of the fire is chosen by which it may fairly be represented. While this choice is to some extent arbitrary, it has the advantage of reducing the variability of human judgement.

For example the time at which the radiation from a liquid fuel fire has fallen to a certain fraction of its initial value has been taken as the control time in experiments in the use of foam on petrol fires. Values of control time may be expected to be less variable than those of extinction time, if only because variation of the latter generally includes, and therefore exceeds that of, control time.

In the light of the above discussion it is interesting to note that in the results in Table 2 and Figure 13, the time of shutting-off the water was able to be decreased by a factor of two to three, while the time at which steam was observed to appear at the windows was practically Since in Test 8 the water was shut off practically simultaneously with the appearance of steam and there was no sudden re-growth in the fire, it seems reasonable to take this time as a measure of the control time. It is seen from Figure 13 that it is less dependent on the experience of the fireman than is the moment at which it was thought safe to turn off the water. These shut-off times are of course characteristic of the previous experience and training of the fireman in the first test only and for this reason a series of repeated tests in which the same men take part cannot be regarded as giving results necessarily applicable in Although where the test is repeated in nominally identical conditions the fireman's performance would be expected to improve, this does not imply that he was in the first place inadequately trained: that could only be said if he were expected always to fight fires identical with the test fires. Even so, it is pertinent to ask how much, if any, of this improvement in the course of a few repeated tests can be regarded as additional experience which can be transferred to future performance in other fires, and how much is of transitory worth only. This question can only be answered experimentally. All that can be said is that it is possible for some permanent improvement to be retained when it is realized that the water used may be reduced by a factor of two to three with a consequent reduction in water damage but since the firemen were trained men and experienced in the use of jets any transference of experience from one fire to another is much less than in repeated tests and may be insufficient to markedly reduce the amounts of water used with present techniques.

So far as a comparison of sprays and jets is in these experiments concerned, any differences between them were overshadowed by the decrease in the amount of water used from the first to the last tests. Since the fire was not so readily observed when using the spray, it is probable that the firemen had to fall back on their experience with jets, which was greater than that with sprays, in deciding the time at which to shut off the water. The time at which it is safe to stop applying the water was shown to be very soon after the emission of steam from the windows, and it is clear that a question of technique is involved.

The dispersal of water by a spray is much greater than by a jet and in consequence it is not nearly so important that it be moved about. It is probable, therefore, that the same or greater efficiency in controlling a fully-developed fire can be achieved by a spray than by a jet, with less skill on the part of the operator.

Conclusions

Fully-developed fires in domestic rooms can be controlled by jet or by spray with about 6 gallons of water per 1000 cu.ft. of room volume. This figure agrees well with other full-scale tests and represents a volume of steam nearly twice the room volume. It is three to four times larger than the amount of water used to extinguish fires in smaller experimental rooms in which there was no furniture but which were lined throughout with fibre insulating board.

A very significant thing was, that even though the tests were carried out by trained firemen the amount of water used was able to be reduced by a factor of 2-3 from the first to the last tests. This suggests that

as far as jets are concerned training does not automatically result in the minimum quantity of water being used and this means that experience in using jets is not able to be carried over completely from one type of fire to another.

When using sprays it is not so important for the nezzle to be moved about as it is with jets, and it is probable that there is a simpler criterion for the assessment of the time of control of the fire. It may therefore be found that experience with spray equipment is sufficiently transferable to produce a marked economy in the use of water. It is worth while carrying out experiments to investigate this.

Acknowledgement

Thanks are due to Chief Officer H. Coleman, Divisional Officer A. G. Field and all the other officers and men of the City of Birmingham Fire Brigade and other bodies, who assisted so readily and enthusiastically in the preparation and performance of these tests. The efforts of Leading Firemen Partridge and Beeby at the nozzles, were particularly appreciated, and thanks are also due to Mr. T. Gibes and his staff in the preparation of the buildings and furniture.

References

- 1) "The extinction of fires in enclosed spaces". P. H. Thomas and P. M. T. Smart. Department of Scientific and Industrial Research and Fire Offices' Committee Joint Fire Research Organization. F.R. Note 86/1953.
- 2) "Characteristics of water spray nozzles including those designated as fog nozzles for fire fighting use". National Board of Fire Underwriters, Chicago. 1944.
- 3) Fire Research Annual Report 1949. Her Majesty's Stationery Office.

APPENDIX I

<u> </u>				andres describeration and a destruction of
Nozzle		Pumping time	Gals	Remarks
Test No. 1	Spray	_	50	· }
2	Jet	70	25	Branch open and
	066	70	20	shut at
3	Jet	52	36	intervals.
4	Spray	72	50	
5	Jet	39	.30	
6	Spray	69	45	
7	Spray	28	20	<u>.</u>
8	Jet	17	11	
9	Spray ^M	12 1 /2	10 រ ្គ	!
10	Jet	12	17½ I	
11	Jet	13 ¹ / ₂	$12\frac{1}{2}$	<u> </u>
12	Spray	$16\frac{1}{2}$	14	; ;
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From report of Chief Engineer Hole.

- In original report these appeared incorrectly in the reverse order.
- I This figure appears to be too large in relation to time involved. In all these tests efforts were made to make all readings with the hose fully charged and to take the quantity reading before re-opening the nozzle.

APPENDIX II

(COPY)

FROM: Divisional Officer Beeby

TO: Chief Fire Officer.

As you requested at the termination of the experimental fires in Grosvenor Street West and Essington Street last week, I submit herewith my own observations on the tests carried out.

I gathered from the start that the prime purpose of the tests was to ascertain whether a jet of water or a spray jet was the most economical and efficient for extinguishing fires. Over and above this prime factor, it was intended to time the effects of fire spread but due to the difficulty of igniting the material employed, this preved somewhat difficult but by using inflammable liquids as the ignition material, the graph of heat built up, after the initial flare-up did resemble to some extent what would happen to normal materials which could ignite in a small way.

The tests were extremely interesting and were thoroughly enjoyed by all who took part.

From my own views, the most reassuring point was how much fire could be put out with so little water. As far as I could gather not one of the fires required fifty or more gallons of water to extinguish it.

From discussions with the branchmen at different times, I gathered that they were inclined to the jet of water rather than the spray although their observations changed from time to time dependent on the heat intensity of the fire. The main point is that where a jet properly used can cover a large area and a far area, the spray covered a wider area but does not have the reach. Consequently the spray causes more punishment to the branchman due to him having to penetrate into the heat-laden atmosphere further than with a jet.

Further of course, the minute particles of water absorb the heat more rapidly and change to steam more quickly with a result that there is far more steam produced with a spray nozzle than with a jet. My own views on the use of spray, its cause of steam, and steam extinction are still open. I did not think that the extra experiment carried out proved that the steam had any serious dealings in limiting the fire. It may be that I am old-fashioned and brought up on the jet, so to speak, but my confidence in tackling a fire remains in the use of a solid jet. There is of course the likely possibility of a jet/spray branch having all the good points combined but this remains to be seen.

Dr. Thomas was, I think, entirely satisfied with the arrangements made although he may not have gained all the information he sought.

I would like to say that I think the branchmen did an excellent job of work and I think sttod out as a good example of the men we have in this Brigade.

From: Leading Fireman Partridge. To: Chief Fire Officer.

I have to report that on Wednesday, Thursday and Friday, the 11th, 12th and 13th November 1953, twelve fires were started and extinguished in six houses of the 'back-to-back' type in Grosvenor Street West and Essington Street, Ladywood, Birmingham 16.

The fires were extinguished by water from either a spray or a jet connected to $2\frac{1}{2}$ in. rubber lined hose and supplied from the pump unit of a Pump Water appliance using the water contained in the 400 gallon hose reel tank.

The water from the spray covered an area equivalent to the average sized room of a dwelling house, i.e. twelve feet to fifteen feet square.

As one of the two branchmen who extinguished these fires I made the following observations.

- 1. The time taken to extinguish each of these fires varied in each case according to the temperature of the fire, the amount of material burning, and the location of the most severe parts of the fire.
- 2. The difference in the times taken to extinguish the fires also varied when using either the spray or the jet; when the fire was most severe in the centre of the room (involving table and chairs) the spray extinguished it more quickly than the jet, whereas, if the main fire was in the far corner of the room the jet was more expedient.
- 5. After the fire had been brought under control and the branch was shut off, the amount of water lying on the floor was slightly higher in the case of the jet than the spray, this of course being due to the fact that the fire had been mainly "!mocked out" with the jet as against the cooling and smothering effect of the spray.
- 4. When using the spray the rapid generation of steam made it extremely uncomfortable for the branchmen and prevented them from advancing into the room to extinguish any remaining pockets of fire. It must be noted here, however, that in each case the windows had been mainly removed for the purpose of observation and photography, and the ceiling above had been rapidly vented by the fire due to either the deteriorating of the structure or damage from the previous experimental fires in the upper rooms. There is no doubt that if the only openings in the room had been the doorway through which the branch was taken the fire would have been more completely extinguished when the spray was used.
- 5. When using the jet the atmosphere in the room was clearer but not cooler and the main centres of fire were quickly observed and extinguished.
- 6. This type of spray could be used to extinguish fires of this type without endangering the branchmen as it does not require the same degree of accuracy or technique in directing the branch, the branch could be pushed into the room and would eventually extinguish the fire without the necessity of waving it about.

Summing up:

When using the spray it appears that the following conditions can be anticipated:-

- (a) The residual heat is reduced to an extent that will allow personnel to enter and operate within the room.
- (b) The atmosphere will be hot and humid, causing physical discomfort, but this appears to be due to high humidity rather than excessive heat.
- (c) Small pockets of fire and deep seated smouldering may be present.

(d) When the volume of condensing steam has decreased to a noticeable extent, indirect application has ceased and the cooling action of the water is restricted to the area of direct application.

In addition to these twelve fires another fire was started and allowed to spread to the upper room and roof structure. When the spray was applied through the doorway on the ground floor the steam generated penetrated the upper floor and roof space and the fire was brought under control. A jet was finally used to extinguish the remaining pockets of fire.

From these experiments it would appear that the ideal branch for this type of fire would be a combination of the spray and jet, supplied through the $2\frac{1}{2}$ in. hose - the hose reel tubing would not pass sufficient water.

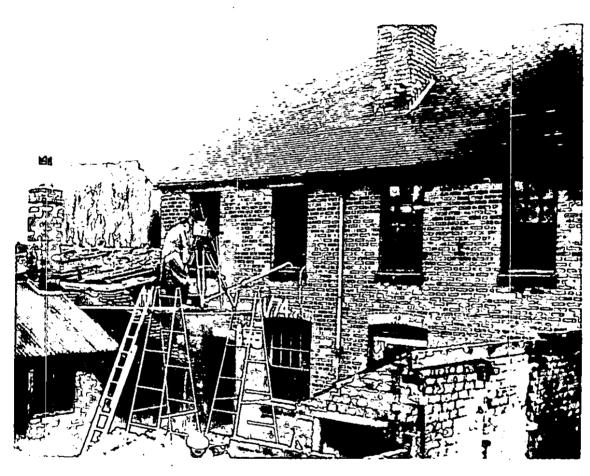


FIG.I. GENERAL VIEW OF SITE

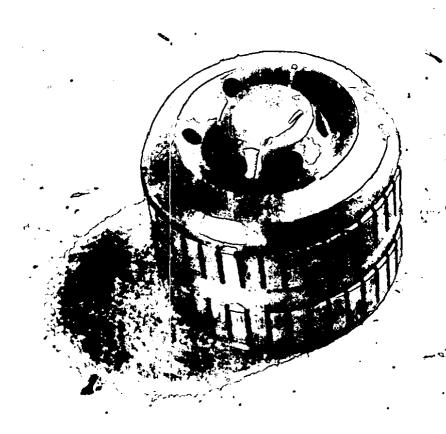


FIG. 2. SPRAY NOZZLE

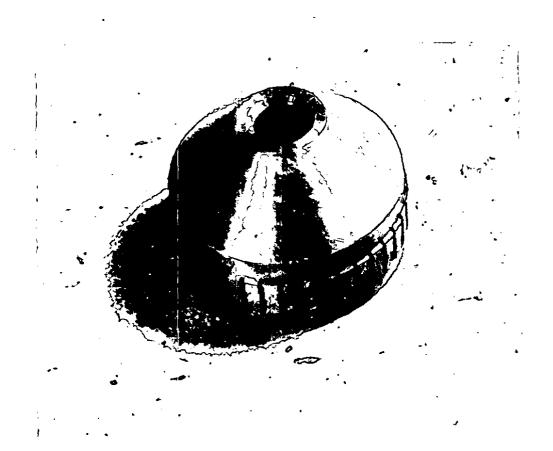
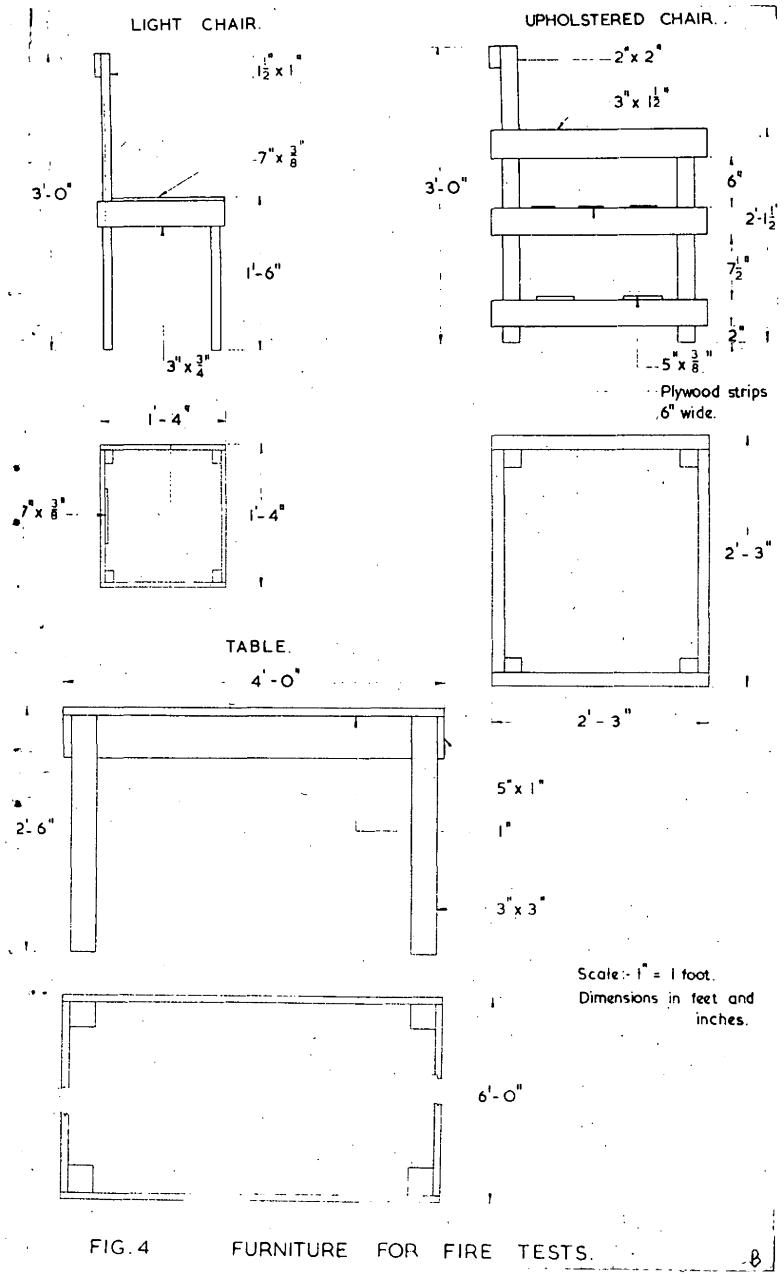
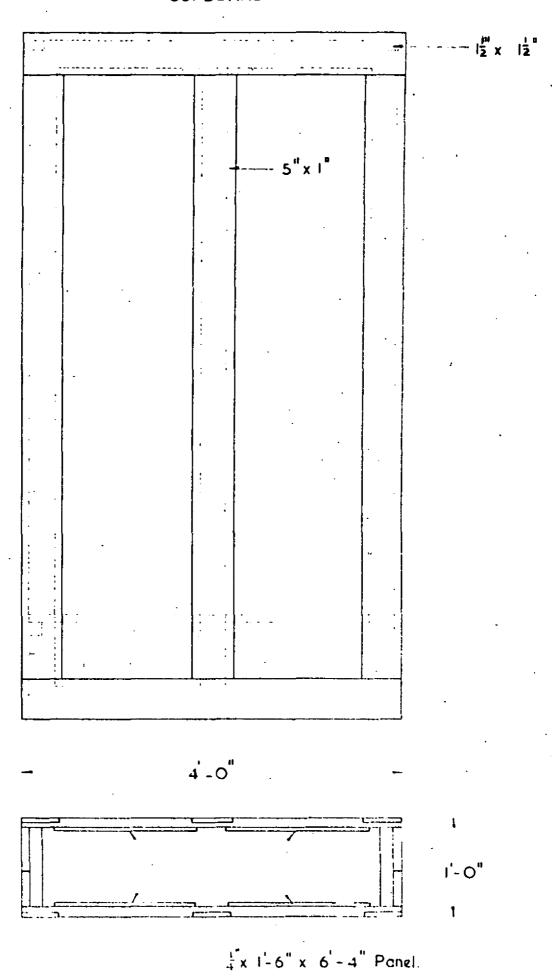


FIG. 3. JET NOZZLE





Scale: I'' = I foot Dimensions in feet and inches

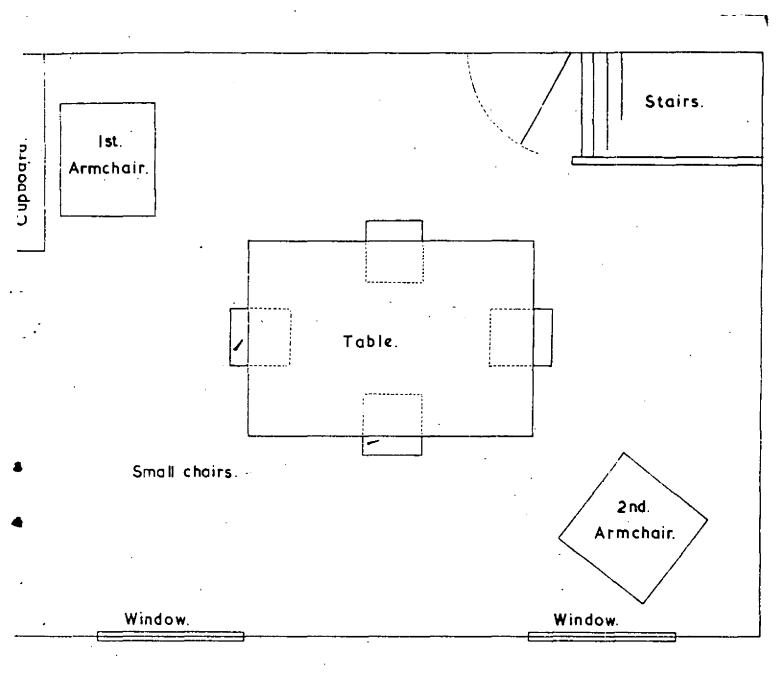


FIG. 5. ARRANGEMENT OF FURNITURE IN UPSTAIRS ROOMS.

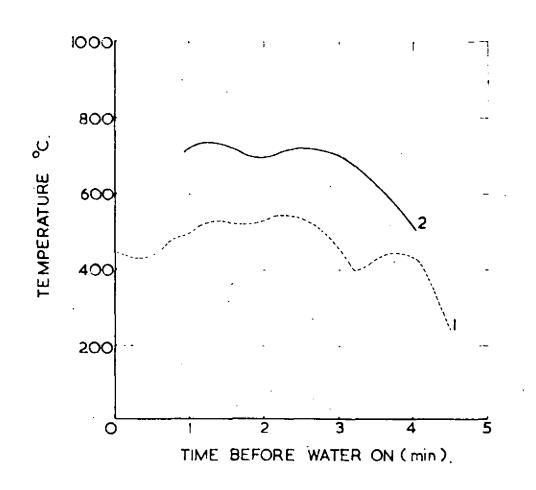


FIG. 6. TIME - TEMPERATURE RECORD. (TEST No. 4.)

В

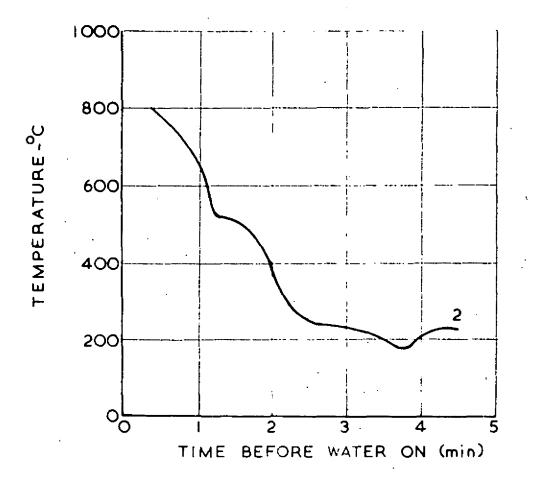


FIG.7. TIME-TEMPERATURE RECORD (TEST No. 5)

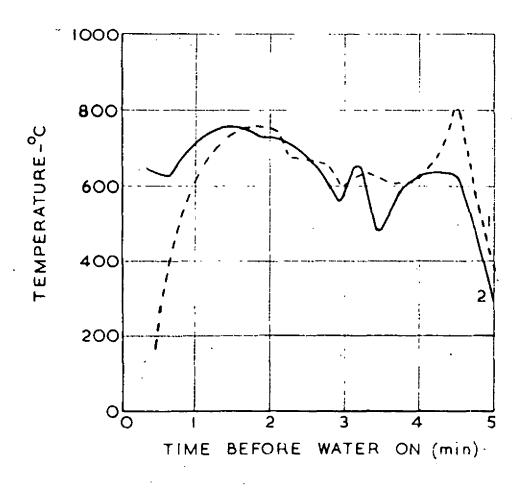


FIG.8. TIME - TEMPERATURE RECORD (TEST No.6)

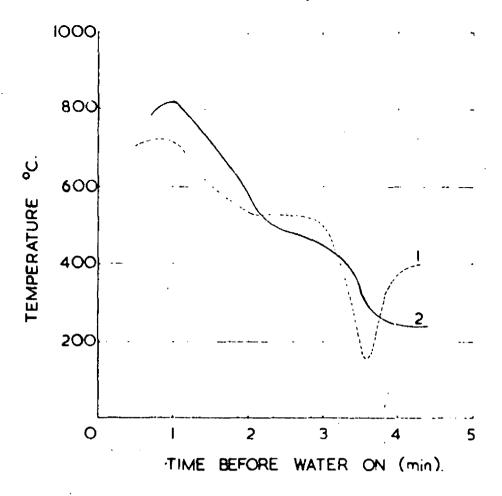


FIG. 9. TIME - TEMPERATURE RECORD (TEST No. 7).

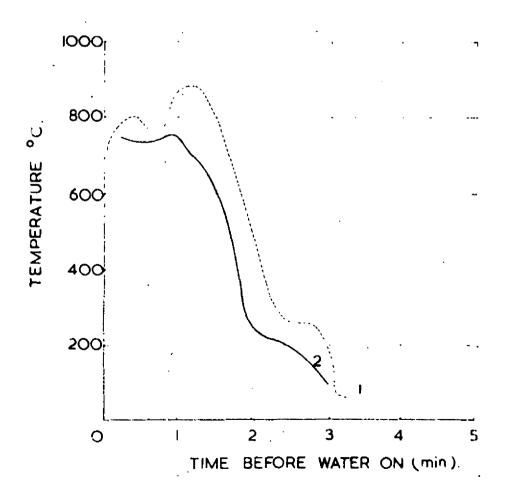


FIG. 10. TIME - TEMPERATURE RECORDS (TEST No. 8).

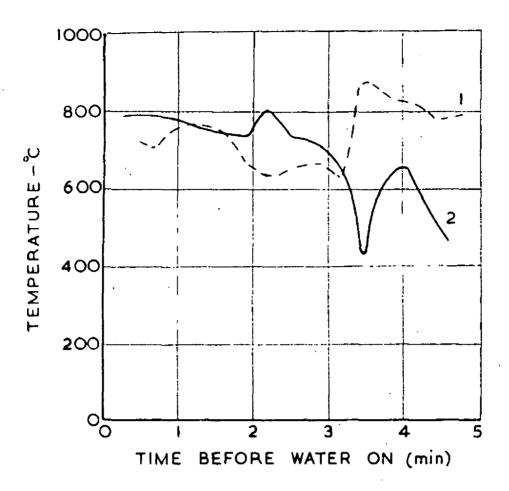


FIG.II TIME - TEMPERATURE RECORD (TEST No. 10)

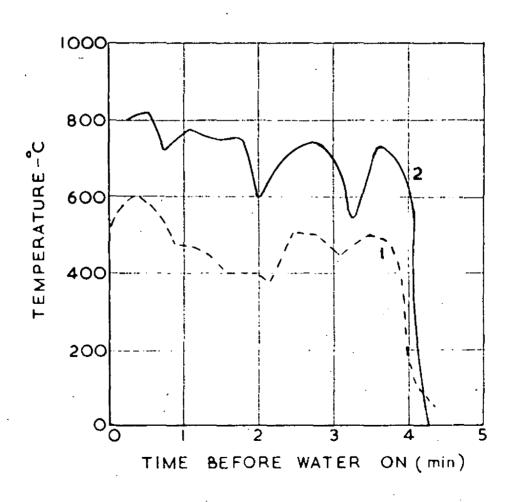


FIG.12. TIME-TEMPERATURE RECORD (TEST No.12)



FIG.14. JUST BEFORE ENTRY IN TEST 12



FIG.15. ENTRY BEING MADE IN TEST 8



isec before water on



Water on



2 sec after water on



4 sec after water on



6 sec after water on



8 sec arter water on



10 sec after water on



12 sec after water on

FIG.16. THE PROGRESS OF EXTINCTION

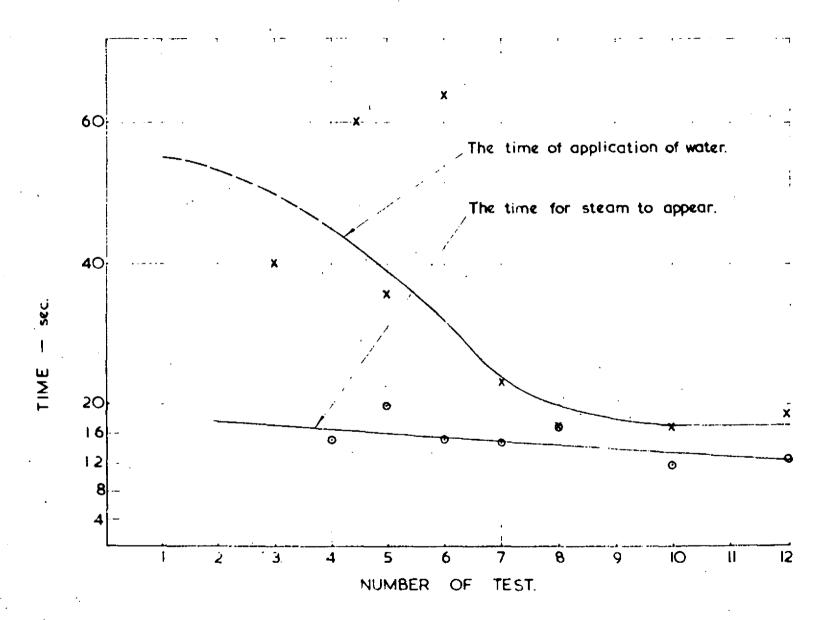


FIG. 13. TIME OF SHUTTING OFF WATER AND APPEARANCE OF STEAM IN SUCCESSIVE TESTS.

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