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

FIRE HAZARDS OF INSECTICIDAL PREPARATIONS USED FOR THE TREATMENT OF WOODWORM

by

P. C. Bowes and G. Skeet

SUMMARY

A laboratory study has been made of the fire hazard associated with the use of flammable preparations for the treatment of woodworm in buildings; where possible the conclusions have been extended to cover the treatment of timber stacks in the open. The hazards comprise, first, the fact that treated surfaces of woodwork may be ignited by a small source and, second, when this is no longer possible due to loss by evaporation, the residue of flammable liquid may still cause a fire to develop more rapidly in a room with treated woodwork than if the woodwork were not treated. Estimates have been made of the time after treatment for which the hazards due to some commonly used flammable liquids may be expected to persist in practice. Depending on the liquid, and subject to provisos concerning mainly the weight of treatment and ventilation conditions, the hazard will disappear within periods of up to one week for the solvents white spirit and kerosine and for ortho dichlorobenzene. The hazard due to a technical white oil is less than for the more volatile liquids, and may even be of little practical importance.

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than 45° to the annual rings. The whole stock was cut up into pieces of the two sizes required for the tests and pieces for tests were taken at random.

The surfaces of the pieces to be treated were planed, and the edges were coated with cellulose lacquer in order to confine absorption of the liquid to the planed surface. It was confirmed by subsidiary tests that absorption of the liquids through the lacquer was negligible.

Before treatment the wood was conditioned to within the limits set for fire tests on building materials and structures (1), i.e. to equilibrium with air at a temperature of 10-21°C and a relative humidity of 55 - 65%. The mean moisture content was 12.5 ± 0.4% * after conditioning and the mean density was 0.62 ± 0.01 g/cm³ (39 lb/ft³).

The liquids used, three solvents covering a wide range of boiling points and an active material, are listed in Table I with their characteristics. The flash point of the Technical white oil was determined by the Cleveland open-cup method (IP 36/55)(2) and that of the other liquids by the Pensky-Martens closed-cup method (IP 34/55)(2). The boiling ranges were determined according to the standard method described under I.P. 123/55(2); the complete distillation results are given in Appendix I.

TABLE I

PROPERTIES OF THE LIQUIDS USED

Liquid	Flash Point °F	Distillation range °C
White Spirit	100	155 - 198
Kerosine	120	155 - 259
Technical white oil	345	-
Ortho dichlorobenzene	162	180 (Boiling point)

2.2. <u>Method of treating the wood</u>

The method of treating the wood specimens with the liquids was standardised as follows. A weighed specimen was supported face downwards with the face 5 mm below the surface of the liquid. After a fixed time of immersion the specimen was allowed to drain for 2 minutes in an atmosphere saturated with the vapour of the liquid used, wiped free of droplets and then weighed.

2.3. <u>Immersion time</u>

In order to select suitable times of immersion for treatment of the wood the absorption of white spirit and ortho dichlorobenzene by blocks, 5 cm square and cut from a single board, was measured. The mean absorption, in mg/cm², for sets of five blocks immersed for times of 2, 8 and 32 min, are given in Table II.

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* Throughout this note ranges of variation are given as 95% confidence limits.

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INTRODUCTION

Insecticidal preparations for the treatment of woodwork in buildings infested with wood boring insects are applied liberally to the surface of the wood with the object of achieving ample penetration. These preparations are often combustible, and the usual hazards associated with the handling of flammable liquids arise during the treatment of wood with preparations having the lower flash points; but for all combustible preparations it is possible that, for a considerable time after treatment, wood that has been treated with them may be capable of supporting flame much more readily than is possible for untreated wood. If this is so the treated wood will be readily ignited by a small accidental source, such as a dropped match, and an extensive fire will be more certain to develop, and may do so far more rapidly, than would have been the case before treatment.

The investigation described in this note was undertaken to assess the extent of this latter hazard for some flammable liquids that are commonly used in insecticidal preparations - either as solvent or active principle. In order to approach conditions of maximum hazard the selected liquids were applied as fairly heavy treatments to a highly absorbent wood. The investigation has, for the time being, been confined to sound wood.

Two small scale tests for assessing the fire hazard have been used, as follows :-

a. Surface Flammability Test. This was a test designed to assess the ability of the treated surface to support flame in the absence of additional supporting radiation. It was considered that this ability would determine the likelihood that a small transient source of ignition would start a continuing fire.

b. Surface Spread of Flame Test. The Preliminary Spread of Flame Test[1], which classifies surfaces according to their ability to support flame in the presence of supporting radiation of standard intensity, was carried out as giving an indication of the behaviour of the surface in fires that have attained appreciable magnitude. The results of this test were, of course, mainly of interest for treated wood that could not be ignited under the conditions of the surface flammability test above, but might prove to be more hazardous than untreated wood if involved in a fire started in some other way, such as in another material.

Flammability tests of both kinds were carried out at different times after treatment of specimens of the wood in order to determine the time that would have to be allowed for any hazard resulting from the treatment to disappear, either by the evaporation of volatile liquids or by the deeper penetration and dispersion of less volatile liquids.

2. EXPERIMENTAL

2.1. Materials used

The wood chosen was the seasoned sapwood of Corsican pine (*Pinus nigra var. calabrica*). The stock used consisted of approximately quarter sawn boards 3/4 in. (1.9 cm) thick; the surfaces were inclined at more

TABLE II

ABSORPTION OF LIQUIDS BY SURFACE OF CORSICAN PINE
(mg/cm^2)

Immersion time, min.	2	8	32
White spirit	11.6	20	25
Ortho dichlorobenzene	29	47	–

The rate of absorption decreased markedly with time of immersion (see further 3.3) and, on the basis of these results, immersion times of 2 minutes and 8 minutes were adopted.

2.4. Comparison of treatment by immersion and treatment by brushing

Tests were carried out to compare the absorption obtained by the immersion procedure described above with the absorption that might be obtained in practice by brushing the liquids on to the surface of the wood.

The liquids used were white spirit and the technical white oil since, of the four liquids, these covered the extremes of volatility and viscosity. The liquids were applied with a 1½ inch paint brush to the planed face of 9.53 cm x 30.5 cm. boards, as used in spread of flame test, which had been lacquered on the sides and backs. Two liberal coats were applied at a 5 minute interval. Two series of tests were carried out; one with the wood in the horizontal position, face upward, and the other with the wood surface vertical.

The mean amounts of liquid absorbed, in mg/cm^2 of surface, for five tests with each liquid applied to surfaces in each position, are given in Table III together with the mean absorption after 2 minutes and 8 minutes immersion respectively obtained in the course of all the flammability and spread of flame tests.

TABLE III

COMPARISON OF TREATMENT BY BRUSHING AND TREATMENT BY IMMERSION

Liquid	Amount absorbed following brushing		Amount absorbed following immersion	
	Vertical tests mg/cm^2	Horizontal tests mg/cm^2	2 min. immersion mg/cm^2	8 min. immersion mg/cm^2
White spirit	21 ± 10	32 ± 16	21 ± 2	42 ± 5
Technical white oil	16 ± 3	27 ± 7	17 ± 3	28 ± 4

It will be seen that the amount of liquid absorbed is similar for brushing on vertical surfaces and 2 min. immersion and, again, for brushing on horizontal surfaces and 8 min. immersion.

2.5. Drying time

After treatment as described in section 2.2. the specimens were allowed to dry for intervals of ¼, 1 and 4 hours and, where necessary, for multiples of one day before being tested for flammability. These intervals were chosen for the reason that drying times of up to half of an eight-hour working day would be of practical interest if the hazard disappeared in this time; but if it did not do so, the drying time should preferably be measured in whole days.

For the drying times of up to 4 hours the specimens were exposed in the laboratory, the temperature of which was maintained within the limits 19° - 22°C; these limits were the closest within which it was practicable to control the temperature of the laboratory. For longer times the specimens were stood in a conditioning room at 22°C and 61% relative humidity.

The specimens were weighed at the end of the drying time in order to determine the amount of residual liquid.

2.6. Surface Flammability Test

The wood specimens used for this test were 15 cm long x 4.5 broad. Treated surfaces were tested in two positions, vertical and horizontal facing upwards; for this purpose the specimens were supported for testing on stands as shown in Figure 1. An igniting source consisting of a fully aerated coal-gas flame, six inches long, from a laboratory bunsen burner (internal diameter of burner tube 5/16 inch) was applied across the surface at one end of the horizontal specimens, as indicated in Fig.1, for 3 seconds and then removed; the spread of any flame that persisted after removal of the bunsen was noted and its duration timed with a stopwatch. For tests in the vertical position the igniting flame was applied across the lower end of the face of the specimen for 2 seconds. The times of application of the igniting flame were just sufficient to scorch the surface of the wood; this was considered to be adequate for the ignition of any residual flammable liquid in the wood capable of burning independently of the wood. Five specimens were tested at each treatment and drying time and in each position. As a protection against draughts the tests were carried out in a 2 ft. cube box with one open side.

2.7. Surface spread of flame test

In this test [1] a board to be tested is supported in a standard way with its face at right angles to a standard radiant panel and a pilot flame is applied for a fixed time to the board at the end nearest the panel. The board is classified, with respect to fire hazard, in terms of certain fixed times and distances for flame spread along its surface.

The test was carried out on the 1/3-scale apparatus with specimens 9.53 cm x 30.5 cm. The classification of the untreated wood was determined from tests on six specimens. For treated wood five specimens were tested for each treatment and standing period, and any special features of the flame spread were noted.

3. RESULTS

3.1. Surface flammability tests

3.1.1. White spirit and kerosine. Depending on the interval between treatment and ignition, the specimens treated with white spirit and kerosine behaved in one of the following ways when tested in the horizontal position:-

(i) a persistent flame spread slowly over the surface after removal of

(iii) a transient flame died out as the igniting flame was removed, but was nevertheless seen to exist separately from the igniting flame;

(iv) no flame at all due to the treatment could be distinguished or, at the most, the igniting flame had a luminous envelope while it was applied to the surface of the specimen.

When white spirit or kerosine were present in specimens tested in the vertical position, at least half, and often the whole, of the surface was enveloped in flame during application of the igniting flame. The persistence of flame after removal of the igniting flame depended on the interval between treatment and testing; ultimately, after long standing (see below), specimens behaved as in (iv) when tested.

Except for some of the most persistent flames, the flames usually died out without charring the face of the specimen; but the edges of the specimens were usually charred and sometimes ignited by the persistent flames.

The results of the test with white spirit and kerosine are summarised in Tables IV and V respectively.

The Tables give the mean weight of liquid absorbed per unit area of surface (mg/cm^2) (the absorption) during treatment, for each group of five test pieces, and also the mean value for the residue of liquid in the test pieces at the end of the drying times, expressed both in the above units and as a fraction per cent of the absorption. The results of the flammability tests are represented in the tables by the maximum and minimum values for the spread and for the duration of the flames in each group of five tests, and also by the number of tests in each group of five in which flames that were independent of the igniting flame were observed. An entry of "zero" in the duration column implies behaviour as in (iv) above, and an entry of "one" implies transient flames having a duration of one second or less.

It will be seen from Table IV that flame spread no longer occurred on specimens tested in the horizontal position 4 hours after a treatment of 2 minutes immersion in white spirit, but flames persisting for up to 4 seconds occurred on two of the five specimens. The mean absorption for the specimens in the horizontal tests at 4 hours happened to be the highest for the whole series of tests with 2 minutes immersion; in the vertical tests at 4 hours the absorption was equal to the mean, i.e. 18 mg/cm^2, for the series, and a transient flame only, of up to 1 second's duration, was obtained on only one specimen. After 24 hours the specimens showed no surface flammability. With the heavier treatments obtained with 8 minutes' immersion, transient flames of up to 1 second's duration occurred in 4 tests in the horizontal position 24 hours after treatment, although specimens tested in the vertical position were non-flammable after this period. 40 hours after an immersion of 8 minutes, for which the absorption was nearly twice that in the test at 24 hours, none of the specimens showed surface flammability, although the residue of white spirit was appreciable.

With specimens immersed for 2 minutes in kerosine (Table V) the tendency for flame to spread on horizontal surfaces was less than for surfaces treated with white spirit, but some spread occurred 4 hours after treatment and transient flames of up to 1 second's duration were obtained on most specimens even after 24 hours. For the specimens tested 48 hours after 2 minutes immersion the absorption was relatively too low for the flammability tests to be comparable with those tested 24 hours after treatment. But, with the heavier treatment obtained by an immersion of 8 minutes, surface flammability disappeared completely after 42 hours.

TABLE IV

RESULTS OF SURFACE FLAMMABILITY TESTS WITH WHITE SPIRIT

Immersion time, min.	Drying time, hours	Amount of liquid absorbed mg/cm²	Residue		HORIZONTAL TESTS					VERTICAL TESTS		
			Amount mg/cm²	Fraction of amount absorbed %	Tests giving independent flame	Spread		Duration		Tests giving independent flame	Duration	
						Min. cm	Max. cm	Min. sec.	Max. sec.		Min. sec.	Max. sec.
2	[illegible]	17 ± 7*	15 ± 7*	91 ± 5*	5	0	Total	4	127ϕ	-	-	-
		20 ± 10	18 ± 10	87 ± 9	-	-	-	-	-	5	2	26
	1	18 ± 4	13 ± 4	78 ± 8	4	0	3	0	24	-	-	-
		16 ± 7	13 ± 15	76 ± 6	-	-	-	-	-	5	1	11
	4	27 ± 9	16 ± 6	59 ± 6	2	0	0	0	4	-	-	-
		18 ± 7	6 ± 2	34 ± 8	-	-	-	-	-	1	0	1
	24	16 ± 5	0.3 ± 0.5	2 ± 3	0	0	0	0	0	-	-	-
		15 ± 2	0.7 ± 1	5 ± 7	-	-	-	-	-	0	0	0
8	4	40 ± 31	26 ± 28	58 ± 16	4	0	Total	0	195ϕ	-	-	-
		41 ± 24	19 ± 4	50 ± 19	-	-	-	-	-	4	0	2
	24	30 ± 19	6 ± 5	19 ± 15	4	0	0	0	1	-	-	-
		36 ± 24	6 ± 5	16 ± 11	-	-	-	-	-	0	0	0
	40	60 ± 19	13 ± 3	23 ± 7	0	0	0	0	0	-	-	-
		58 ± 23	16 ± 6	27 ± 5	-	-	-	-	-	0	0	0

* 95% confidence limits

ϕ Surface of specimen charred

TABLE V

RESULTS OF SURFACE FLAMMABILITY TESTS WITH KEROSINE

Immersion time min.	Drying time hours	Amount of liquid absorbed mg/cm^2	Residue		HORIZONTAL TESTS					VERTICAL TESTS	
			Amount mg/cm^2	Fraction of amount absorbed %	Tests giving independent flame	Spread		Duration		Tests giving independent flame	Du
						Min. cm	Max. cm.	Min. sec.	Max. sec.		Min. sec.
2	1	22 ± 10	20 ± 10	90 ± 5	5	0	4	2	25	-	-
		18 ± 9	17 ± 9	90 ± 7	-	-	-	-	-	5	1
	4	29 ± 8	22 ± 8	74 ± 9	5	0	2	1	57	-	-
		34 ± 21	24 ± 14	70 ± 12	-	-	-	-	-	5	1
	24	27 ± 13	15 ± 11	50 ± 24	4	0	0	0	1	-	-
		37 ± 15	23 ± 15	59 ± 12	-	-	-	-	-	5	1
	48	20 ± 14	13 ± 10	62 ± 13	-	-	-	-	-	0	0
8	42	35 ± 18	13 ± 12	32 ± 17	0	0	0	0	0	-	-
		26 ± 15	12 ± 11	42 ± 21	-	-	-	-	-	0	0

TABLE VI

RESULTS OF SURFACE FLAMMABILITY TESTS WITH o-DICHLOROBENZENE

Immersion time min.	Drying time hours	Amount of liquid absorbed mg/cm²	Residue		Horizontal Tests					Vertical Tests		
			Amount mg/cm²	Fraction of amount absorbed %	Tests giving independent flame	Spread		Duration		Tests giving independent flame	Duration	
						Min. cm	Max. cm	Min. sec.	Max. sec.		Min. sec.	Max. sec.
2	½	39 ± 13	37 ± 13	93 ± 3	5	0	0	1	1	-	-	-
		33 ± 9	31 ± 9	93 ± 3	-	-	-	-	-	5	1	1
	1	77 ± 47	70 ± 43	89 ± 6	5	0	0	1	1	-	-	-
		63 ± 26	56 ± 26	87 ± 8	-	-	-	-	-	5	1	1
	24	61 ± 20	13 ± 6	22 ± 4	-	-	-	-	-	0	0	0
8	½	74 ± 16	72 ± 15	98 ± 1	-	-	-	-	-	2	0	1

In general, the absorption for a given time of immersion of the specimen, and the residue after a given drying time, were too variable for any useful quantitative relationships to be derived. But it will be seen in Table IV that, for specimens tested in the horizontal position at intervals of ¼ hour, 1 hour and 4 hours after 2 minutes immersion in white spirit, the mean residues are similar in absolute amount but they decrease steadily with increasing time when expressed as a fraction of the absorption. This suggests that the decrease in surface flammability that accompanied the increasing drying time was due to a loss of the more volatile fractions of the white spirit. A similar effect is apparent for specimens treated with kerosine and tested at intervals of 1, 4 and 24 hours (Table V).

3.1.2. Ortho dichlorobenzene. The results of tests with this liquid are summarised in Table VI in the same way as above.

When the igniting flame was applied to treated specimens a large smoky flame was produced covering up to about three quarters of the surface of vertical specimens, but it died out almost immediately on removing the igniting flame. Not even with the heavy treatment, obtained by 8 minutes immersion, did the flames persist for more than one second when tested ½ hour after treatment. It was clear that the ortho dichlorobenzene could not be induced to burn with a self-supporting flame under the conditions of test.

3.1.3. Technical white oil. In a total of fifteen tests at ½ hour after treatments that varied between 10 and 30 mg of technical white oil per cm^2 of surface, only transient flames of less than 1 second's duration were obtained on specimens tested in either the horizontal or vertical position. When the igniting flame was applied for a longer period of 5 - 10 seconds to specimens in the vertical position, a larger luminous flame was produced than with the usual 2 seconds' application; but this flame also died out in less than a second when the igniting flame was removed. There was no indication that a self-supporting flame could be initiated under these conditions.

Even when specimens were tested in the vertical position the base of the luminous flame spread for not more than about 2 cm over the surface during the application of the igniting flame for 2 seconds.

3.2. Spread of flame tests

The untreated wood was in Class 4 of the standard spread of flame classification*; i.e. it was classed among surfaces of rapid flame spread.

In general, when treated wood was tested, the wood and vapour from the liquid treatment tended to burn independently. The vapour of the liquid burnt ahead of the flame due to the burning wood, and the character and extent of this advance burning depended on the nature and amount of the liquid present. The flames from the liquid were intermittent flashes over the surface of the wood. On boards containing the larger amounts of liquid the flashes were larger and more frequent. In extreme cases these flashes merged into a continuous flame that persisted for several minutes and ignited the wood for a short distance ahead of the normal flame front of the burning wood, but usually the flames from the liquid did not effect the wood.

Examples of the type of flame spread observed on wood treated with kerosine and the technical white oil respectively are given in Figures 2 and 3.

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* The "effective spread of flame" was 9.4 cm at 1 min. and 22.3 cm. at 3½ min.

TABLE VII

RESULTS OF SURFACE SPREAD OF FLAME TESTS WITH WHITE SPIRIT

Immersion time min.	Drying time hours	Amount of liquid absorbed mg/cm^2	Residue		Behaviour of vapour flame					
			Amount mg/cm^2	Fraction of amount absorbed %	N^o. of occurences	Maximum spread cm	Maximum advance cm	Time to maximum spread min.	sec.	Maximum duration min.
2	4	35 $\pm$ 15	20 $\pm$ 10	54 $\pm$ 8	5	Total	29	0	15	5
	24	27 $\pm$ 11	8 $\pm$ 4	30 $\pm$ 7	0	-	-	-		-
8	24	34 $\pm$ 14	15 $\pm$ 8	42 $\pm$ 14	1	Partial*	-	-		1
	48	38 $\pm$ 8	7 $\pm$ 4	21 $\pm$ 11	0	-	-	-		-

* Actual distance not recorded.

TABLE VIII

RESULTS OF SURFACE SPREAD OF FLAME TESTS WITH KEROSINE

Immersion time min.	Drying time hours	Amount of liquid absorbed mg/cm²	Residue		Behaviour of vapour flame					
			Amount mg/cm²	Fraction of amount absorbed %	N°. of occurences	Maximum spread cm	Maximum advance cm	Time to maximum spread min.	sec.	Maximum duration min.
2	24	25 ± 11	19 ± 9	80 ± 4	5	29	15	1	30	3
	42	27 ± 10	8 ± 6	30 ± 12	3	Total	20	2	1	10
	72	22 ± 13	6 ± 6	26 ± 17	0	-	-	-		-
8	72	58 ± 31	38 ± 19	65 ± 9	4	Total	25*	<1		-
	96	42 ± 37	13 ± 17	25 ± 20	2	Total	15	1	40	5
	168	38 ± 12	6 ± 5	17 ± 10	0	-	-	-		-

* 25 cm at 18 sec.

TABLE IX

RESULTS OF SURFACE SPREAD OF FLAME TEST WITH o-DICHLOROBENZENE

Immersion time min.	Drying time hours	Amount of liquid absorbed mg/cm²	Residue		Behaviour of vapour flame					
			Amount mg/cm²	Fraction of amount absorbed %	N°. of occurences	Maximum spread cm	Maximum advance cm	Time to maximum spread min.	sec.	Maximum duration min.
2	½	80 ± 36	77 ± 35	96 ± 17	5	Total	28	0	30	11
	4	50 ± 26	25 ± 14	50 ± 5	3	23	22	0	30	-
	24	57 ± 17	23 ± 23	38 ± 29	0	-	-	-		-
8	24	99 ± 40	40 ± 29	36 ± 18	3	Total	14	3	50	-
	48	93 ± 33	31 ± 15	33 ± 8	1	18	8	-		10 sec*
	72	80 ± 39	17 ± 13	20 ± 6	0	-	-	-		-

* Brief vapour flames beginning at 1 min. 40 sec. when flame-front on wood reached 10cm.

TABLE X

RESULTS OF SURFACE SPREAD OF FLAME TESTS WITH THE TECHNICAL WHITE OIL

Immersion time min.	Drying time hours	Amount of liquid absorbed mg/cm^2	Residue		Behaviour of vapour flame					
			Amount mg/cm^2	Fraction of amount absorbed %	N^o. of occurences	Maximum spread cm	Maximum advance cm	Time to maximum spread min.	sec.	Maximum duration min.
8	$\frac{1}{4}$	20 ± 4	20 ± 4	100 ± 0	5	13	9	0	33	5
	1	32 ± 22	31 ± 22	97 ± 7	5	15	7	0	49	2
	4	32 ± 7	32 ± 7	100 ± 0	0))see					
	216	30 ± 10	20 ± 13	63 ± 21	0)text					

The technical white oil, which was relatively non-volatile, behaved somewhat differently from the other liquids. Up to 1 hour after treatment flames due to ignition of oil vapour flashed across the surface of the wood ahead of the wood flame, as with the other liquids, although the advance was markedly less and the flames appeared to travel more slowly. At the longer intervals after treatment this type of burning occurred on one board only and lasted for only about 30 seconds; on the rest of the boards, the oil, which had soaked into the wood, was expelled and burnt relatively steadily on the surface of the wood for distances that varied from nothing up to about 5 cm in advance of the wood flame.

The advance burning of the treatments is analogous to that observed by Pickard on boards treated with some nitrocellulose lacquers[3].

The results of the spread of flame tests are summarised in Tables VII - X.

The mean absorption of liquid and the residue after drying are given for each group of five boards as before. Observations on the behaviour of flames due to vapour of the liquid used for treatment are given for each group of five tests as follows:- the number of tests in which vapour flames occurred; the maximum spread, i.e. the maximum distance that vapour flames travelled along the board; the maximum advance, i.e. the maximum distance that vapour flames travelled in advance of the flames due to the burning wood; the time taken for the vapour flames to travel their maximum distance, and the maximum total duration of the vapour flames.

Comparing the behaviour of treated boards in front of the radiation panel with the results of the surface flammability tests, the following may be noted.

One out of five boards treated by 8 minutes immersion in white spirit showed vapour flames in advance of the wood flame for up to 1 minute when tested in front of the panel. The residue of white spirit was such that flames of a few seconds' duration might have occurred on ignition in the absence of supporting radiation. Except perhaps for treatments as high as 60 mg/cm^2 (see Table IV), for which no comparison is available, the tendency for advance burning in the presence of supporting radiation disappeared almost as rapidly as unsupported surface flammability.

With kerosine, on the other hand, the tendency for advance burning persisted appreciably longer than unsupported surface flammability. For example, advance burning occurred on two boards 96 hours after 8 minutes' immersion in kerosine, when the residue was 13 mg/cm^2; but a residue of this magnitude, 48 hours after treatment by 2 minutes' immersion, gave no independent flame whatever under the conditions of the surface flammability tests.

3.3. Summary of the absorption of liquids by Corsican pine

As a check on the relationship between absorption and immersion time determined for a single board (Section 2.3.), the mean absorptions for all tests, for 2 minutes' and 8 minutes' immersion in each of the four liquids, have been calculated and are given in Table XI, together with the ratios of the mean absorptions at the two times.

TABLE XI

ABSORPTION OF LIQUIDS BY CORSICAN PINE
mg/cm^2

Immersion time min.	2	8	ratio
White spirit	21	42	2·0
Kerosine	26	40	1·5
Ortho dichlorobenzene	58	86	1·5
Technical white oil	17	28	1·6

For a four-fold increase in immersion time, from 2 to 8 minutes, the mean absorption increases by a factor that varies between 1·5 and 2·0. It may be noted that if the absorption were due to simple diffusion the amount of liquid absorbed at a given time would be proportional to the square root of the time of immersion, and the amount absorbed in 8 minutes would thus be twice the amount absorbed in 2 minutes. It appears from Tables II and XI, however, that the rate of absorption decreased more rapidly with time than would have been the case for a parabolic law, especially after 8 minutes (Table II).

4. PRACTICAL APPLICATION

4.1. Interpretation of fire tests

4.1.1. Surface flammability of treated wood. The application of the results of the tests to practical conditions is simplest for large exposed surfaces.

Self-supporting flames can be initiated on wood treated with white spirit or kerosine. Surfaces so treated must be regarded as hazardous, in the sense that they may be ignited by an accidental source in the absence of supporting radiation, for at least as long after treatment as it is possible for self-supporting flames to travel over them - even if the flames from the burning liquid do not persist long enough to ignite the wood, they may travel to some more readily ignitable material. The tendency of flames to spread on vertical surfaces could not be measured in tests on the small scale used in this work, but it may be assumed that, on a vertical surface with a reasonably uniform treatment, any flame capable of existing independently of the igniting flame will travel, at least in the vertical direction, for the whole extent of the surface.

The transient flames of up to about 1 second's duration obtained after long standing periods were clearly not self-supporting. But, in view of the large variation in the capacity of the wood for absorbing liquid, it seems advisable to assume that there is a possibility of persistent flames occurring occasionally for as long after treatment as it is possible to obtain transient flames in tests that are fairly small in number, as in the present work. The occurrence of transient flames is therefore adopted as the ultimate criterion for the existence of a hazard.

On this basis it follows from the results in Tables IV and V that, at least for large exposed surfaces of Corsican pine, precautions against accidental ignition must be maintained for at least 24 hours after treatment with either white spirit or kerosine.

Ortho dichlorobenzene and the technical white oil burn locally while an igniting flame is applied to surfaces treated with either of them, but it appears that neither is capable of burning with a self-supporting flame.

Where surfaces meet at an angle of less than 180°, or are separated by relatively short distances, the application of the results of the surface flammability tests are not so straightforward as for large exposed surfaces. Examples of such situations occur in the spaces between the joists and the underside of a floor, or in a stack of timber. In such situations flames can be mutually supporting, and the hazard must accordingly be considered in the light of the tests of spread of flame in the presence of supporting radiation.

4.1.2. Spread of flame with supporting radiation. Cases in which persistent flames from the liquid treatment spread rapidly far in advance of the flame due to the burning wood, and for the whole length of boards tested in front of the radiation panel, clearly represent a dangerous condition. A fire started in an enclosure with treated surfaces capable of behaving in this way would develop much more rapidly than if the surfaces were untreated. It is possible that the surface spread of flame from the liquid would develop quickly into a form of "flash over" in the enclosure; this might result in the enclosure becoming fully involved immediately or, after brief but complete combustion of the liquid, might be followed by a second flash-over characteristic of the solid contents of the enclosure.

Treated surfaces that exhibit advance burning of the liquid for only a few centimeters in front of the wood flame might behave no differently to the untreated wood if involved in a fire. But tests with model enclosures would be required to show whether a small degree of advance burning as exhibited in the spread of flame test could, in fact, be accepted as indicating no increase in hazard. On the basis of the spread of flame test alone, the time after treatment at which the risk of increased rate of development of a fire in an enclosure disappears can only be taken with safety as corresponding with the point at which advance burning no longer occurs in the tests.

Subject to the limitations in section 4.2. below, the results of the spread of flame tests (Tables VII - X) are accordingly interpreted as follows. For well ventilated enclosures treated with white spirit a risk of increased rate of development of fire persists for at least 24 hours after treatment but for less than 48 hours; with kerosine this hazard persists for 96 hours but for less than one week; with ortho dichlorobenzene the hazard persists for 48 hours but for less than 72 hours. With the technical white oil, which is largely non-volatile at ordinary temperatures, any hazard there may be will never be as great as for the other liquids, but it will probably persist indefinitely; while initially, as the oil soaks into the wood, the hazard will diminish with time it will ultimately become a constant depending only on the weight of the treatment.

The conclusions in the above paragraph apply particularly to the treatment of warehouses, roof-spaces etc., when, although the infested area may be only a small fraction of the whole, the whole interior surface is treated. When treatment is confined to infested areas, and when these areas are small compared with the whole, the main hazard will be that of ignitability by a small source. However, it is not known what fraction of the total area of an enclosure can be treated with a flammable liquid without significantly increasing the rate of development of fire, after it is no longer possible to ignite the treated surface with a small source. It therefore seems advisable to base safety precautions on the results of the spread of flame test regardless of the area to be treated, unless this area is obviously quite insignificant.

For the volatile liquids there is a possibility that treated surfaces which enclose relatively small spaces, such as in between joists or in timber stacks, may be ignitable by a small source for at least as long as increased rate of development of fire is possible according to the spread of flame test, i.e. for the periods stated above (subject to the limitations in section 4.2. below).

The behaviour of the technical white oil in the surface flammability tests was such that it is difficult to imagine conditions favourable to ignition of treated surfaces, by a small source in the absence of supporting radiation, short of those favouring ignition of the wood itself. It is felt that the interpretation of the spread of flame tests, as applied to the ignitability of surfaces treated with the volatile liquids, may be too severe on the technical white oil and further tests of a different kind should be applied to it.

4.2. Limitations of results

4.2.1. Weight of treatment. Since the wood was treated by immersion until the rate of absorption was considerably reduced, and since an absorbent wood was used, it is probable that the treatments tested were as heavy as, if not heavier than, any achieved in the normal treatment of sound woodwork by the application of fluids to surfaces parallel to the grain. The comparison of treatment by immersion with treatment by brushing, in so far as the latter was representative of general practice, supports this view.

The use of undiluted ortho dichlorobenzene is uncommon; the treatments, with this material, that have been tested are therefore likely to be heavier than usual for this material.

End-grain surfaces will ABSORB MORE LIQUID THAN surfaces parallel to the grain, and infested wood will absorb more than sound wood. In these cases longer drying times will be required after treatment.

Liquid that penetrates into joints and cracks in wood UNDER AND behind wall plates etc., will require longer to dry out than liquid absorbed by exposed surfaces.

It is not at present possible to estimate what these extended drying times should be be

4.2.2. Ventilation conditions. The drying times for the disappearance of hazard due to the treatments were determined for treated surfaces exposed indoors. Although the area of the treated surfaces was small in relation to the volume of the room, approximate calculations indicated that for the volatile liquids with the lower vapour pressures, i.e. the higher boiling fractions of the kerosine and possibly the ortho dichlorobenzene, the concentration of vapour in the room could have risen to an appreciable fraction of the saturation value, and the rates of evaporation could have been correspondingly reduced towards the end of the drying times. Hence, with a high degree of ventilation the necessary drying times might be somewhat less than the values that have been determined for these liquids; but it is unlikely that the reduction will be sufficient to be of practical value, e.g. sufficient to permit a reduction of 24 hr. in the 72 hr. recommended for ortho dichlorobenzene.

Where the area of wood treated is large in relation to the volume of air enclosed, and ventilation is restricted, longer drying times will be required unless ventilation can be increased artificially. This requirement will usually apply, for example, to the treatment of spaces under floors, to the spraying of timber stacks in situ, and to pretreated timber that is stacked before it is dried. Again it is not possible to specify the extended drying times necessary, but a rough estimate can be made of the minimum ventilation rates for large enclosures in order that the drying times shall be similar to those that have been determined in this work; this will be done in a second report. The drying times were obtained for ambient temperatures in the neighbourhood of 20°C (68°F); for lower temperatures the drying times will be longer.

4.2.3. Composition of insecticidal preparation. The drying times for the disappearance of hazard apply to treatment with preparations in which white spirit, kerosine, or the technical white oil are used alone as solvent for a few parts per cent of active material, and to treatment with undiluted ortho dichlorobenzene.

It may sometimes be possible to make reasonable forecasts of the drying times for some simple mixtures of the liquids tested; but, in general, the drying times for mixtures of these and other liquids will have to be determined as required.

5. CONCLUSIONS

An absorbent wood treated with flammable liquids commonly used in insecticidal preparations for the control of woodworm may have an increased fire hazard in two respects, as follows:-

(a) For an appreciable period after treatment the surface of the wood may be capable of propagating a self supporting flame initiated by a small source.

(b) When the flammable liquid has evaporated sufficiently for the above hazard to disappear there may still be a flammable residue sufficient to support a flame on the surface of the wood in the presence of supporting radiation, this flame appearing before ignition of the wood itself.

For as long as the latter effect persists a fire, started in some other material, must be expected to develop in an enclosure lined with or containing treated woodwork, or in a pile of treated timber, more rapidly than if the wood were not treated. At this stage it may also be possible to initiate a fire by means of a small source of ignition placed between treated surfaces that meet at an angle of less than 180° or face each other close together.

Tests have shown that these hazards may persist for periods within the limits shown in Table XII for two volatile solvents and ortho dichlorobenzene. In view of the wide variation in the amount of liquid absorbed by different specimens of wood, and in the loss during evaporation, it is doubtful whether the limits within which the periods of persistence of hazard lie could with safety be made any narrower than they are in the table.

TABLE XII

PERIODS FOR PERSISTENCE OF ADDITIONAL FIRE HAZARD ON SURFACE-TREATED WOOD

Liquid	Risk of self-supporting flame on surface. Hours.	Risk of increased rate of fire development. Hours.
White spirit	24 - 40	24 - 48
Kerosine	24 - 42	96 - 168
Ortho dichlorobenzene	0	48 - 72

After treatment with preparations containing one of the above liquids as a major component a drying time should be allowed equal to the upper limit of the period for which there is a risk of an increased rate of development of fire. Timber pretreated with any of these liquids should be arranged so as to allow free evaporation for the corresponding period before being stacked. During this drying period extra precautions against fire should be maintained.

The periods given in Table XII were obtained for surfaces of sound, quarter-sawn, wood with weights of treatment that are believed to be typical of those attainable in normal application by brushing or spraying, under conditions of evaporation indoors at temperatures in the neighbourhood of 20°C (68°F). For wood in which the absorption of liquid is greater than in these tests (e.g. infested wood), for situations in which evaporation is retarded through poor ventilation or a low temperature, and for wood with the heavier treatments obtainable by prolonged soaking or by treatment under pressure, longer drying periods will have to be allowed for the hazards to disappear.

Tests on wood treated with a technical white oil indicated that the hazards due to treatments in which this solvent predominates will be less than those due to the other liquids and may even be of little importance, but there is a need for some further investigation. It was found impossible to ignite exposed surfaces, treated with the technical white oil, by a small source in the absence of additional radiation; it is probable that the only arrangement of treated surfaces that would favour ignition of this oil by a small source would be such as to favour ignition of the wood itself. It is possible that the rate of development of a fire in a room would be increased if the woodwork were heavily treated with the technical white oil, but it is on this point that the findings are least clear. Because this oil is relatively non-volatile any effect it may have on the fire hazard will persist almost indefinitely.

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7. REFERENCES

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8. APPENDIX

Distillation of White Spirit and Kerosine

The boiling ranges of the White Spirit and Kerosine were determined according to I.P. 123/55.

		WHITE SPIRIT	KEROSINE
Initial boiling point °C		155	155
Boiling point at distillation of	10 ml	162	183
	20	165	190
	30	167	199
	40	169	207
	50	171·5	215
	60	174	219
	70	177	226
	80	180	234
	90	186	245
	95	191	253
	98	-	259
	98·5	197·5	-
Final boiling point °C		197·5	259
Residue	ml	1 5	1·9
Loss	ml	0	0·1

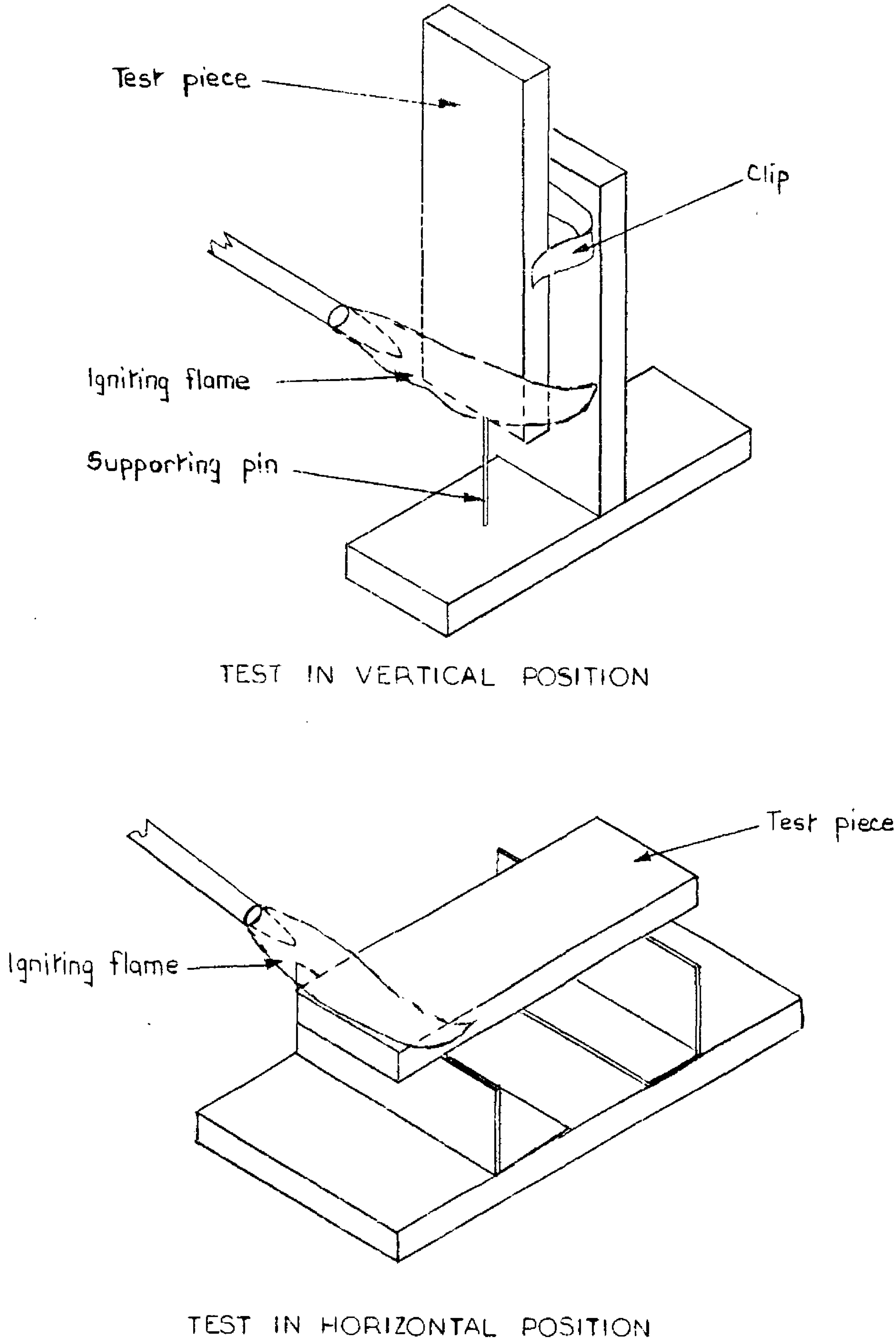

FIG. 1. SURFACE FLAMMABILITY TEST

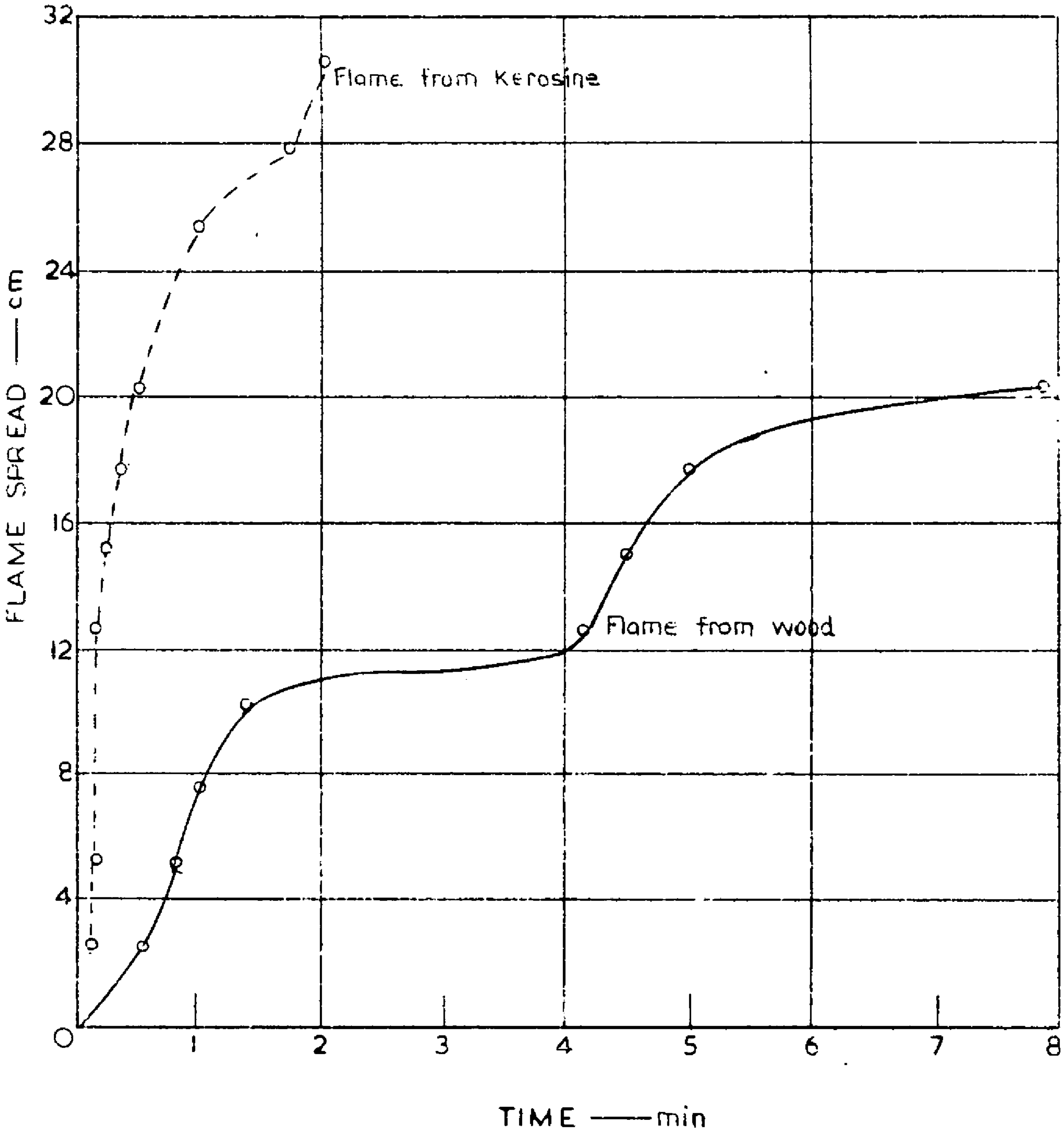

FIG. 2. SPREAD OF FLAME ON CORSICAN PINE TREATED WITH KEROSINE

(TEST 42 HOURS AFTER TREATMENT BY 2 MINUTES IMMERSION)

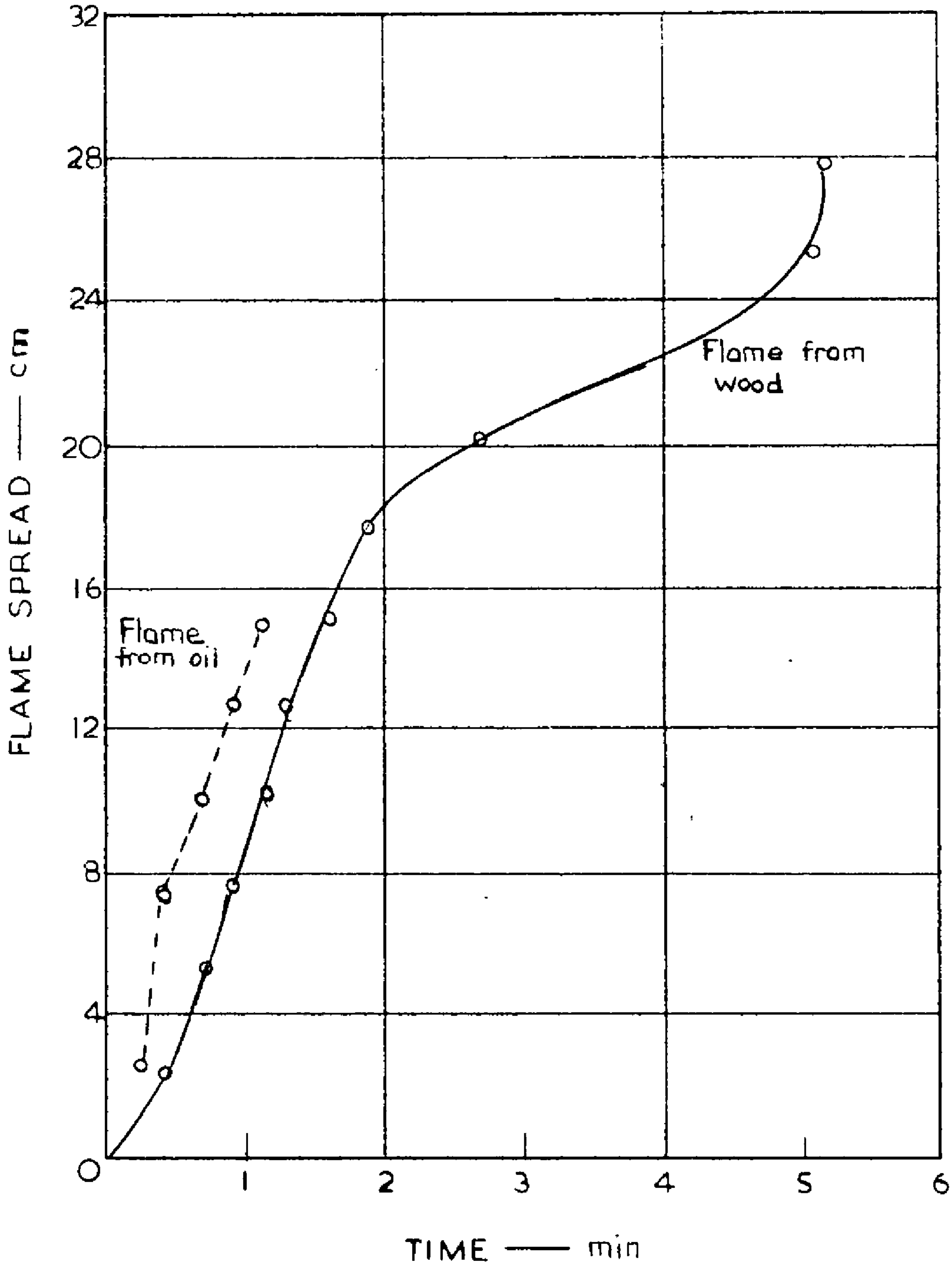

FIG. 3. SPREAD OF FLAME ON CORSICAN PINE TREATED WITH THE TECHNICAL WHITE OIL

(1 HOUR AFTER TREATMENT BY 8 MINUTES IMMERSION)