# Fire Research Note No. 736

## THE CRITICAL DISTANCE FOR IGNITION FROM SOME ITEMS OF FURNITURE

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## SUMMARY

As part of a study of the growth of fire in buildings, single items of furniture have been burned in a well-ventilated compartment and the distances found at which these could just ignite nearby wood specimens representing unignited furniture.

Ignition distances found ranged from more than 1.2 m for a tall wardrobe to less than 150mm for an easy chair.

Key words. Fire spread; furniture; flame; size; ignition.



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## INTRODUCTION

A peace-time fire in a compartment usually starts at one point and then spreads to other combustible items. The initial igniting source may be small, as with an electrical fault or large as with an overturned oil heater. In most fires, however, there is a chain of ignitions as the fire spreads to previously unignited items. The likelihood of this chain of ignitions leading eventually to flashover and a fully developed fire depends on the arrangement of combustible items. Some fires are known to burn out before all combustibles are involved; and one can readily envisage this happening in a sparsely-furnished room.

If the fire is initiated by a nuclear flash several pieces of furniture, floor and wall coverings may be ignited but the duration of the flash is short - and only a shallow depth of the material is heated. After the flash, the cold interior of the furniture and the surrounding air will cool the burning surface and the fire will subside and may even go out. If any part of an item remains alight the subsequent development of the fire will be similar to that of a peace-time fire except that more than one article may be burning, the windows may have been broken by blast and there will have been a large amount of thermal energy dissipated into the surrounding air.

The experiments reported in this note were carried out following a request from the Home Office for information concerning minimum separation distances between items of furniture at which fire would not spread from one piece to another, following ignition of one or more items of furniture by an atomic flash.

Single items of furniture were burned in a compartment preheated to simulate the energy entering the room from the flash. The distances at which wood specimens ignited and the size and duration of the fire were then measured.

The results may not apply directly to a peace-time fire because initially the glass of the windows is usually intact for these. Unless there is a substantial leakage of air into the compartment or unless some glass breaks and falls out, a fire in a compartment as small as a room of a house may go out. If it does spread, any restriction in the flow of air into and confinement of the combustion gases in the compartment, caused by the presence of the glass, may lead to higher gas temperatures and the resulting heating of the fuel might enable ignition to occur at larger distances than those quoted here.

## 2. Experimental method

The tests were performed in a compartment measuring 7.7 m wide, 3.7 m deep and 3.0 m high, and having a ventilation area of 6 $m^2$. As it is unlikely that window glass would remain intact after the blast, the window openings were left unglazed.

All the items of furniture were placed in one corner of the compartment except for a few tests performed with chairs in the middle of the floor. The probability of fire spread is greatest when the whole of a piece of furniture is burning at once, and some initial tests were carried out to find a method of ignition that would achieve this. The method finally adopted employed pieces of 80mm wide fibre insulation board, 15 mm thick, placed under the edges of the furniture. In addition, 15 mm x 15 mm strips of fibre insulation board were fixed horizontally at 0.23m spacing to the face of the wardrobe. 600 g of alcohol was then poured over the furniture and fibre insulation board. The compartment was preheated by burning 2 kg of wood wool spread along the back and end walls. This is roughly equivalent to a gross dose of 150 cal/$cm^2$ over the entire window opening. Strict similarity is not possible owing to the difference in time scales; the peak surface temperature depends on the dose and the time scale. The wood wool was ignited at the same time as the furniture but burned out rapidly, usually in less than 60 s. Standardised wooden blocks[1] were mounted on stands at heights of 0.45 and 0.90 m above the floor and at various distances from the furniture. These

served mainly to test whether wood could ignite at a particular distance, but also provided some information on the rate of reception of heat from the furniture by their changes in reflectivity or their depth of char. Specimens of 3 ply wood 4 mm thick and cotton cloth[2] were mounted alongside each of the blocks. The cloth was more readily ignitable than the wood blocks and so provided a more sensitive measure of the heat dose. Throughout each test, visual estimates were made of flame height until the item burned out or collapsed: from these observations an effective duration of burning was taken to be the period during which the item was flaming briskly.

## 3. Results

### 3.1. Burning characteristics of furniture

The test results are given in Table 1.

It was not possible to obtain a self-sustaining fire with a kitchen chair, probably due to the lack of supporting radiation between adjacent surfaces: only about $\frac{1}{4}$ of the chair was burned away, and this fraction of the weight was used in calculating the burning rate.

All the armchairs and easy chairs tested burned up fairly slowly, and usually produced flames up to 0.6 m high as long as the ignition strips continued burning; these generally burned out in about 5 min. Fire then spread over various parts, usually the arms or back, producing large quantities of smoke and flames up to about 0.2 m high until the covering material fell away exposing the timber frame and stuffing. Flaming then increased slightly, but none of the chairs tested seemed to have padding that was seriously flammable perhaps because the stuffing was packed fairly densely and became further compressed in use. None of the chairs was upholstered with foam rubber or plastic padding. Almost all the armchairs burned for about 30 min and collapse occurred generally soon after. The easy chairs usually burned out more quickly.

Because the chairs burned slowly, and the flames produced were not more than about 0.60 m high, there was little tendency for the flames to rise up the wall, and hence there was no detectable difference in the results between chairs placed either in one corner or in the middle of the compartment.

3.1. (cont'd)

The bookcase ignited readily, and flames reached the ceiling in about 3 min. The shelves contained about 24 kg of books, journals and newspapers, and these were also burning well after 3 min. Because of its re-entrant openings, the bookcase burned briskly and efficiently; very little smoke was produced throughout the test. Collapse occurred after about 15 min.

The wardrobe ignited quickly and produced flames to the ceiling at about 3 min, after ignition. Fire spread rapidly over the whole item, and flames reached about 4 m along under the ceiling. This state of burning was only sustained for between 3 to 5 min, the wardrobe collapsing soon afterwards. Very little combustible material remained at the end of the test.

Apart from the bookcase and wardrobe, the furniture showed little tendency to produce large flames or significant heating at distances greater than 150 mm.

3.2. Behaviour of indicator specimens

3.2.1. Wood blocks

With the various kinds of chairs, wood blocks were usually charred but not ignited even at 150 mm and at these small spacings ignition would depend strongly on the geometry of the situation and the movement of the flames over the surfaces.

The bookcase ignited the blocks 0.30 m away but only charred those 0.60 m away. The wardrobe ignited the furthest specimen, at a distance of 1.20 m.

3.2.2. Plywood specimens

These behaved broadly similarly to the wood blocks but ignition occurred at 150 mm with one armchair and one easy chair.

3.2.3. Cotton cloth specimens

A substantial proportion of these were ignited at 150 mm by the armchair and easy chairs. For the bookcase and wardrobe maximum distances for ignition of specimens were 0.45 m and 1.20 m respectively.

Discussion

There are clearly large differences in the maximum distance at which various items of furniture can cause ignition, some items being unable to ignite wood even as close as 150 mm and these differences are related to the way in which the items burn.

Fig. 1 shows the maximum distance at which various effects were produced in the specimens of wood and cloth, as a function of peak total flame height, i.e. the height of the tip of the flames above the floor. Approximate values for the corresponding average intensity of radiation are given, based on previous work[1, 2].

The geometry of the flames from the wardrobe is different from that of the other fires since the flames spread some distance under the ceiling and the total flame height was effectively very much greater than the height which the flames would have attained in the absence of a ceiling[3]: because of this, the wardrobe result has been omitted from Fig. 1. When flames reach the ceiling, the fire enters a critical stage, for any subsequent increase in burning results in a considerable extension in flame length beneath the ceiling, and objects remote from the fire of origin may be ignited. This stage in the development of a fire represents the period when one mechanism of fire spread changes from "short range" radiation to "long range" radiation, "short range" radiation being that emitted from the vertical flames, "long range" radiation emanating from the horizontal flames beneath a ceiling. For a given burning rate, a given level of intensity for "long range" radiation can be at about five times the distance for "short range" radiation. Further exploration is particularly desirable in this region, which may be crucial in the development of a fire in a compartment.

These tests show that fire spread in a compartment is not a function of the lining material alone. Tall items of furniture are present in many compartments, and some of these can produce flames that could quite possibly cover the entire ceiling area of smaller rooms. Armchairs made from conventional materials are apparently a minor factor in fire spread, when only one is burning in isolation from other items.

The parameters of flame height and rate of burning are plotted in the form previously used by Thomas[4] in Fig. 2. The line has a slope of $\frac{2}{3}$ and

resulted from the earlier work: the furniture results lie very close to this line indicating that the behaviour of the burning furniture could be related by the expression

$$\frac{L}{D} = 45 \left\{ \frac{R}{D^2 \rho_o \sqrt{g D}} \right\}^{\frac{2}{3}} \qquad (1)$$

where $L$ = flame height above furniture

$D = \sqrt{A}$

$A$ = floor area covered by furniture

$R$ = rate of burning, gm/s $\doteq \frac{\text{weight of item}}{2 \times \text{duration of burning}}$ *

$\rho_o$ = ambient density of air $\doteq 1.3 \times 10^{-3}$ gm/cm$^3$

$g$ = acceleration due to gravity = 9.81 m/s$^2$

To enable this correlation to be used for unburnt furniture, a rate of burning is required. The duration of burning is shown plotted against weight of furniture in Fig. 3. The resulting line indicates a reasonable trend between burning time and total weight for the limited range of furniture used. The solid line should be used for chairs and items of furniture of the order of one metre in height, but a different and lower value of time and hence, a higher rate of burning, may be more realistic for taller pieces of furniture such as wardrobes; a tentative relation is indicated by the dashed line in Fig. 3. Also shown plotted in Fig. 3 are values of weight divided by surface area against time. This ratio was chosen as it represents a typical thickness of the material in the furniture, and burning time was expected to vary with thickness. However, the resulting graph shows no correlation between these parameters, and it seems that burning time is principally governed by the weight and geometry of the furniture. It would therefore, be advisable for further experiments to be carried out including other types of furniture in order to confirm this.

* An approximate rate of burning based on the assumption that 50 per cent of the total weight is burnt during the period of brisk flaming.

Conclusions

1. Specimens of cloth but not wood were ignited at 0.15 m away from conventional armchairs and easy chairs. No ignition of cloth or wood was recorded at a distance of 0.30 m. Flames were produced which extended about 1.8 m above the floor.

2. The bookcase produced flames which reached the ceiling but did not spread beneath it. Cloth was ignited up to a distance of 0.45 m and wood specimens at a distance of 0.30 m.

3. The wardrobe burned strongly and flames extended for about 4 m beneath the ceiling. Specimens were ignited at least as far away as 1.20 m; but ignition would probably have occurred at greater distances. It is quite possible that in a smaller room, the flames produced would have covered the entire ceiling area.

4. Once flames have reached the ceiling and are travelling under it the distance at which material can be affected by heat; or ignited, increases sharply.

5. Tentative relations have been obtained relating ignition distance via flame height to parameters of the burning furniture.

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TABLE 1a

Test Results

| Type of furniture | Height 'L' -m | Weight 'W' kg | Floor Area 'A' $m^2$ | Surface Area '$A_s$' $m^2$ | Max. Flame Height above furniture m | Effective duration of burning 'T' min | Rate of burning $R = \frac{W}{2T}$ gm/s |
|---|---|---|---|---|---|---|---|
| Kitchen chair | 0.84 | 5.9 | 0.4 | 0.42 | 0.3 | 7 | 1.67 |
| Easy chairs | 0.76 | 13.6 | 0.57 | 2.3 | 0.6 | 17.5 | 6.5 |
| Arm chairs | 0.84 | 28 | 0.82 | 3.8 | 0.9 | 21 | 11.2 |
| Book case | 0.9 | 36 | 0.2 | 7.45 | 2.1 | 19 | 15.8 |
| Ward-robe | 1.75 | 34.5 | 0.48 | 5.6 | 1.2 + 4 beneath ceiling | 12 | 24 |

TABLE 1b

Test Results (cont'd)

| Type of furniture | Maximum distance (m) at which | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Cotton cloth | | Plywood | | | Wood blocks | | |
| | I | S | I | C | S | I | C | S ø |
| Kitchen chair | - | - | - | - | - | < 0.15 | < 0.15 | < 0.15 |
| Easy chairs | < 0.15 | 0.30 | < 0.15 | 0.15 | 0.30 | < 0.15 | < 0.15 | 0.30 |
| | 0.15 | 0.60 | < 0.15 | 0.15 | > 0.15 | 0.15 | 0.15 | 0.60 |
| | < 0.15 | 0.15 | < 0.15 | < 0.15 | < 0.15 | < 0.15 | < 0.15 | 0.30 |
| | 0.15 | 0.30 | < 0.15 | < 0.15 | 0.30 | < 0.15 | < 0.15 | 0.30 |
| | < 0.15 | 0.15 | < 0.15 | < 0.15 | 0.15 | < 0.15 | 0.15 | 0.15 |
| | 0.15 | > 0.15 | < 0.15 | < 0.15 | 0.15 | < 0.15 | 0.15 | 0.30 |
| | 0.15 | > 0.15 | 0.15 | > 0.15 | > 0.15 | < 0.15 | 0.15 | 0.30 |
| | 0.15 | > 0.15 | < 0.15 | 0.15 | > 0.15 | < 0.15 | 0.15 | 0.30 |
| Mean | < 0.15 | > 0.24 | < 0.15 | < 0.15 | > 0.19 | < 0.15 | < 0.15 | 0.32 |
| Arm chairs | < 0.15 | 0.30 | < 0.15 | 0.15 | 0.30 | < 0.15 | 0.15 | 0.30 |
| | < 0.15 | < 0.15 | < 0.15 | < 0.15 | < 0.15 | < 0.15 | < 0.15 | < 0.15 |
| | 0.15 | 0.60 | 0.15 | > 0.15 | > 0.15 | < 0.15 | 0.15 | 0.60 |
| | < 0.15 | 0.30 | < 0.15 | < 0.15 | 0.30 | < 0.15 | < 0.15 | 0.60 |
| | < 0.15 | 0.60 | < 0.15 | < 0.15 | < 0.15 | < 0.15 | < 0.15 | 0.60 |
| | 0.15 | 0.30 | < 0.15 | 0.30 | > 0.30 | < 0.15 | 0.30 | > 0.30 |
| Mean | < 0.15 | < 0.38 | < 0.15 | < 0.18 | 0.23 | < 0.15 | < 0.18 | 0.43 |
| Book case | 0.45 | 0.60 | 0.45 | 0.60 | > 0.60 | 0.30 | 0.60 | > 0.60 |
| Wardrobe | > 1.20+ | > 1.20+ | > 1.20+ | > 1.20+ | > 1.20+ | > 1.20+ | > 1.20+ | > 1.20+ |

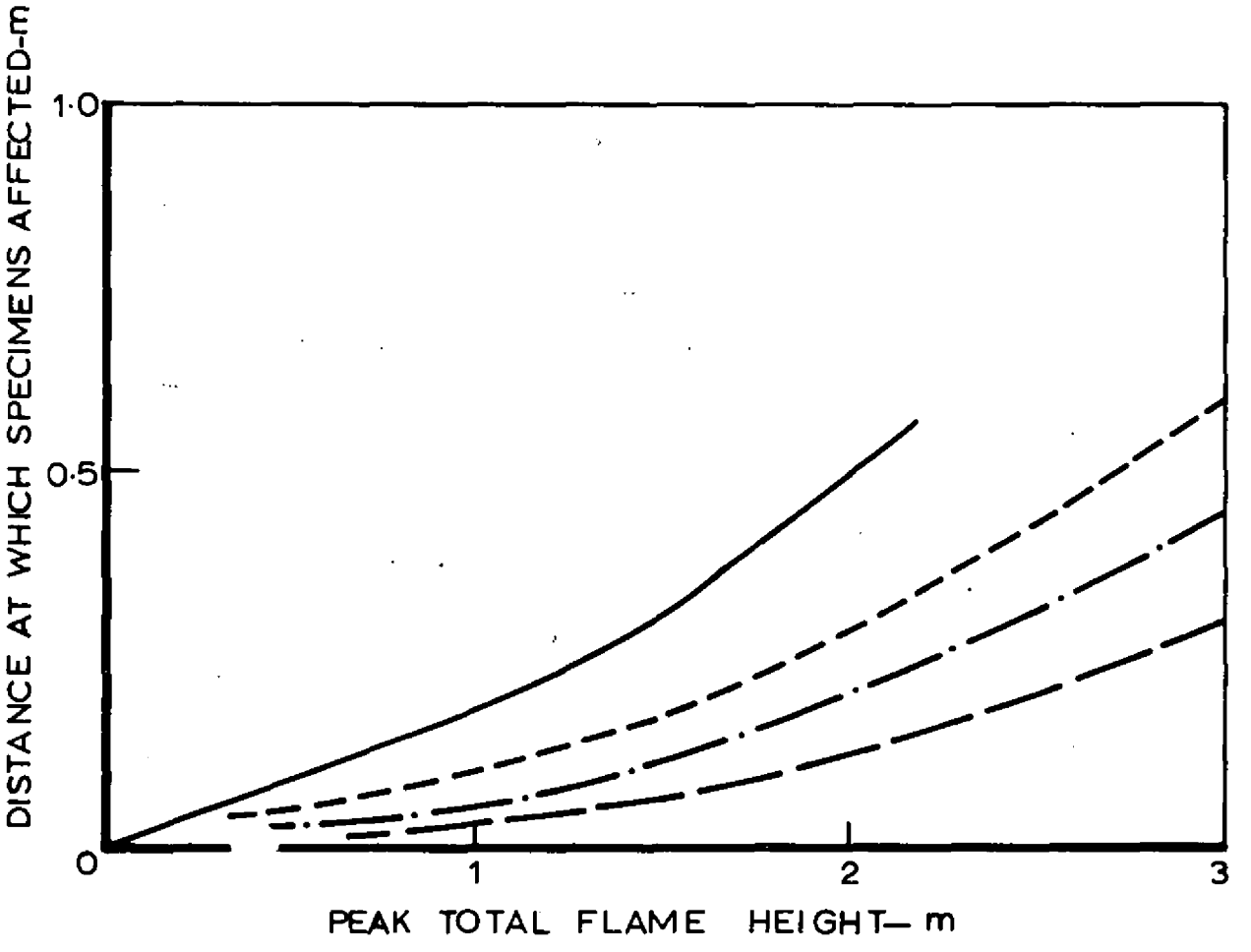
I = ignited

C = charred

S = scorched

ø Difficult to estimate

\+ Furthest specimens 1.20 m from wardrobe




Specimens scorched 0·8–1·2 W/cm²

Blocks and ply charred 1·6 W/cm²

Cloth and ply ignited 3·5 W/cm²

Blocks ignited 4·2 W/cm²

The intensities of radiation indicate the minimum intensity to produce the effect

FIG. 1. PEAK TOTAL FLAME HEIGHT AND DISTANCE AT WHICH SPECIMENS AFFECTED

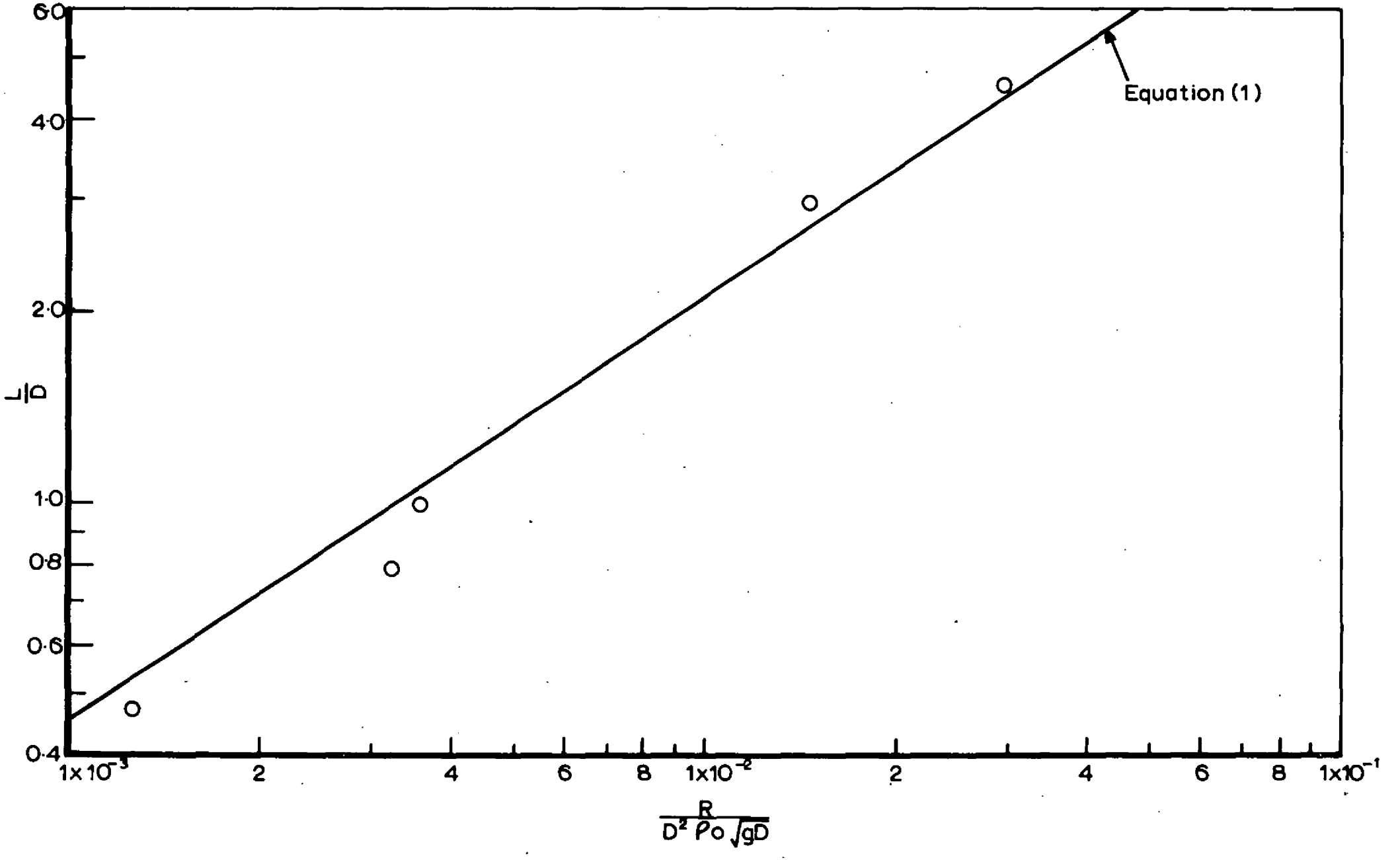



FIG. 2. FLAME HEIGHT CORRELATION

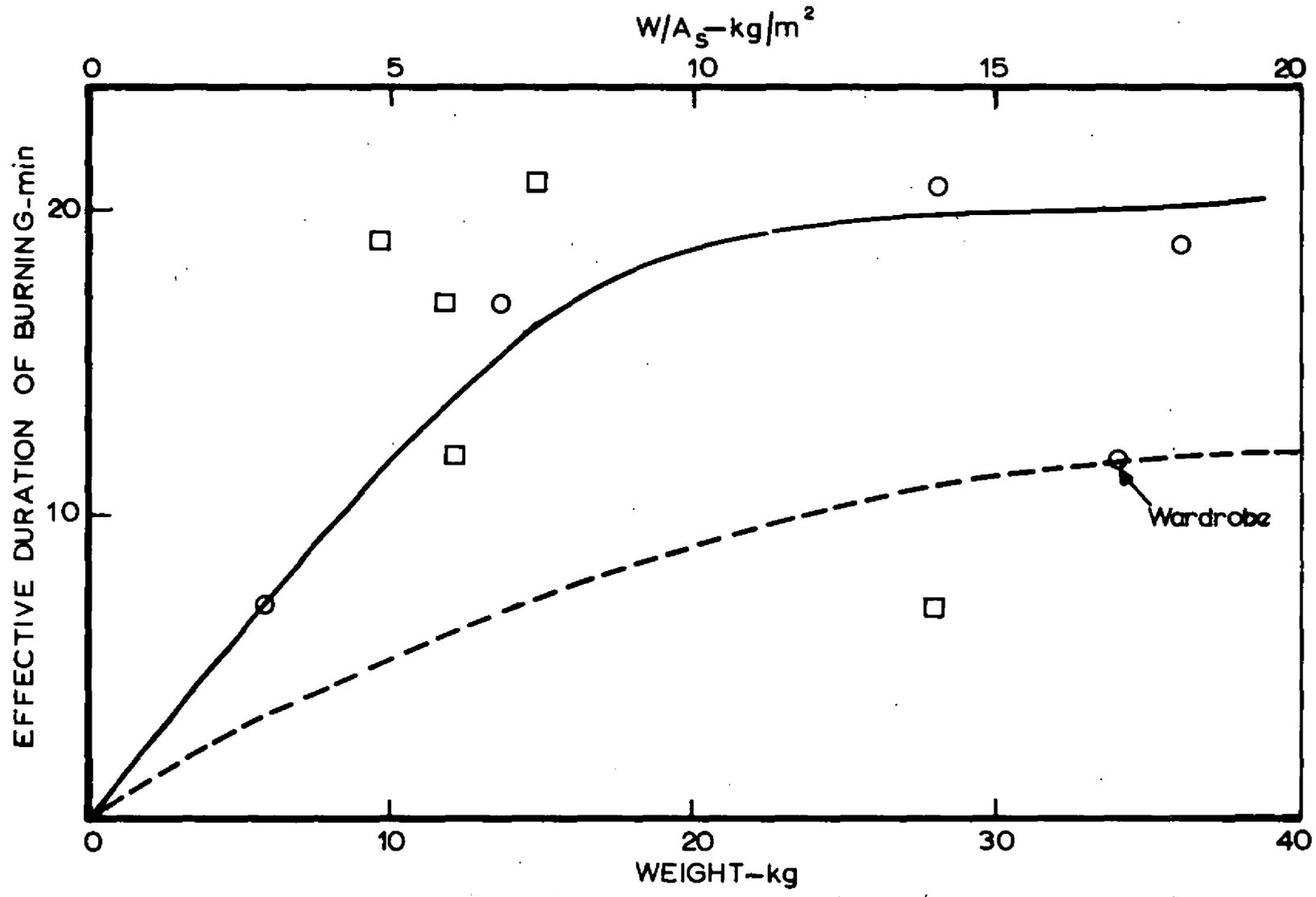



FIG. 3. WEIGHT AND "THICKNESS" OF MATERIAL AGAINST EFFECTIVE DURATION OF BURNING OF FURNITURE