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THE IGNITION OF CORRUGATED FIBREBOARD ('CARDBOARD')
BY THERMAL RADIATION

by

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SUMMARY

The ignition characteristics of corrugated fibreboard (commonly called corrugated cardboard) are of considerable interest in view of its widespread use for packing cases in high stack storage warehouses. Samples of this material have therefore been tested to determine their ease of ignition by thermal radiation.

The results have been tabulated and displayed for three thicknesses of material for both spontaneous and pilot ignition and compared with corresponding results for common softwood.

The minimum irradiance for pilot ignition was 1.5 W/cm^2 – only slightly below that for European whitewood, but the minimum intensity for spontaneous ignition was about 1.7 W/cm^2, about $\frac{1}{3}$ of that for European whitewood.

KEYWORDS: Ignition, radiation.

DEPARTMENT OF THE ENVIRONMENT AND FIRE OFFICES' COMMITTEE
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INTRODUCTION

Composite cardboard sheeting consisting of a 'sandwich' construction with flat cardboard facings enclosing a corrugated interior layer is very widely used for packaging goods and known in the trade as corrugated fibreboard. In many warehouses there is a considerable area of this type of material exposed to view in high stack storage, and other combustible materials will often only be exposed in relatively small areas. In any assessment of fire risk in warehouse occupancies it is clearly important to know how easy it is to ignite this form of cardboard either by radiation from a fire already established or by a small igniting source.

Earlier work[1] on ignition of materials by thermal radiation carried out at the Fire Research Station did not include any investigations with this material. This note describes experiments done to determine the times of exposure to radiation of various intensities necessary for ignition, and in particular to get a value for the highest irradiance at which ignition would not occur. It does not investigate the ignition of this material by a small ignition source such as a glowing cigarette or lighted match.

EXPERIMENTAL EQUIPMENT

The radiation source used was a 300 mm square gas-fired radiant panel[2] mounted vertically at which is burnt a mixture of air and simulated town gas.

The individual samples were held vertically, facing the panel, by slotting them into a steel holder which covered up the edges at both sides. A 100 mm square area of the specimen was exposed to radiation and a strip about 7 mm wide at each side was covered by the holder, while the lower edge of the sample merely rested on the solid steel base of the holder.

For carrying out tests for pilot ignition a tube of 0.5 mm bore and 2 mm external diameter was mounted above the sample and at its open end simulated town gas was burnt in a bluish flame of controlled length.

DESCRIPTION OF SAMPLES

Three thicknesses of material were used, the two thinner types consisting of a layer of corrugated card sandwiched between two flat outer layers and secured by a very small quantity of adhesive. The thickest type was similar except that two layers of corrugated card (with corrugations parallel) were sandwiched between three layers of flat card, one being in the centre and the other two forming the outer facings. Figure 1 shows a section of these two types of construction. The two outer faces differed slightly in appearance and it was obvious when the material was received which face was intended to be the outside of a fully formed packing case. Only this outside face was used for the irradiation experiments.

The corrugated fibreboard was cut into pieces approximately 115 mm square and stored in a room at controlled temperature and humidity before being weighed to determine its density and then tested. One specimen was taken for moisture content determination by an oven drying method.

Information on thetypes of fibreboard is summarised in Table 1.

TABLE 1. DATA FOR CORRUGATED FIBREBOARD

Type of fibreboard	Thin (Double wall)	Medium (Double wall)	Thick (Triple wall)
Mean overall thickness - mm	2.8	4.6	7.5
Density - kg/m^3	160	160	130
Moisture content	7% and 9%	8%	8%
Number of corrugated layers	1	1	2
Number of flat layers	2	2	3

TEST PROCEDURE

In general for each irradiance four identical samples of each of the three types of fibreboard were exposed to radiation until they ignited ('spontaneous ignition'), a further four samples were similarly exposed but with a small pilot flame just above, to obtain pilot ignition. Each sample was inserted in the holder and the top 15 mm or so folded over backwards so as to avoid exposing any part of the interior construction to radiation.

The position of the pilot flame for some of the tests with the thin fibreboard was with the nozzle pointing downward at 13 mm above the top of the sample and 13 mm in front of it so that the flame was in the rising stream of gaseous decomposition products. The length of the flame was adjusted as closely as possible to 13 mm. This arrangement of pilot flame was used earlier in tests on ignition of motor tyre samples[3].

For the remaining tests with the thin fibreboard and for all the tests with the medium and thick fibreboard the pilot flame position was such that its length, after adjusting to about 30 mm, was horizontal and in a direction at right angles to the plane of the sample and also 15 mm above the mid-point of its upper turned over edge. Also the flame was located so that the plane of the sample continued upwards would intersect it halfway along its 30 mm length.

These two pilot flame locations are shown in Fig.2.

For the tests with the medium and thick fibreboard two of the samples in each set of four were tested with the interior corrugations vertical and two with them horizontal.

Each test was carried out by moving the mounted sample quickly to a position (facing the radiant panel) where the irradiance had just previously been determined using a thermopile[4] and simultaneously starting a timer to record the time to ignition. Some samples failed to ignite at the lower irradiances used and were removed either when they were completely charred or after 10 minutes exposure.

TEST RESULTS

The ignition times have been tabulated in Tables 2, 3 and 4 for a range of irradiances both with and without the presence of a nearby pilot flame. There appeared to be no significant difference in times between samples tested with the interior corrugations vertical and those tested with them horizontal.

Generally, all samples charred over most of their exposed surface and then glowed in places mainly nearer their top edge before ignition occurred, except at high irradiances, corresponding to short ignition times, when charring and glowing were much less marked.

The mean ignition times for each set of four samples are plotted against irradiance in Figs 3–5 and from the curves drawn, with some extrapolation at the lower end, an estimate may be made of the minimum irradiance likely to cause ignition. These values are given in Table 5 together with corresponding values for European whitewood[5] for comparison.

In Figs 6-7 the irradiance-ignition time values are replotted with results for all three types of corrugated fibreboard together.

TABLE 2. IGNITION RESULTS FOR THIN CORRUGATED FIBREBOARD

Irradiance W/cm^2	Ignition times - s		Irradiance W/cm^2	Ignition times - s	
	Individual values	Mean		Individual values	Mean
Pilot ignition - vertical flame*			Pilot ignition - horizontal flame*		
8.2	3.8, 4.8, 3.9, 4.6	4.3	3.76	12.1, 12.3, 12.5, 12.0	12.2
7.1	5.2, 5.5, 4.7, 4.5	5.0	2.91	20, 23, 21, 21	21
6.1	7.1, 6.1, 6.7, 5.9	6.5	2.60	24, 28, 26, 26	26
5.09	8.4, 8.5, 8.8, 7.8	8.4	2.28	38, 38, 34, 36	37
4.36	10, 12, 13, 10	11.0	1.99	56, 72, 66, 62	64
3.51	15.6, 16.4, 16.8, 16.9	16.4	1.68	168, 147, 115, 156	147
2.92	22, 23, 26, 29	25	Spontaneous ignition		
2.32	63, 50, 50, 47, 41	50	c.8.0	8.0, 8.6, 8.1, 6.5	7.8
2.14	57, 59, 52, 54	56	6.1	11.5, 13.2, 12.8, 11.9	12.4
1.99	68, 65, 70, 69	68	4.22	24.7, 15.5, 16.3, 18.3	18.7
1.85	91, 106, 97, 85	95	2.56	40, 63, 50, 42	49
1.66	137, 121, 205, 207	168	1.96	80, 90, 79, 79	82
1.60	NI, 211, 180, 197, NI, 202	198	1.84	112 111, 123, 100	112
1.50	NI at 600, removed	NI	1.68	159, 159, 155, 157	158
1.40	NI at 600, removed	NI	1.62	NI at 900, removed	NI

NI = No ignition occurred. *See Fig.2.

TABLE 3. IGNITION RESULTS FOR MEDIUM CORRUGATED FIBREBOARD

Spontaneous ignition			Pilot ignition		
Irradiance W/cm^2	Ignition times - s		Irradiance W/cm^2	Ignition times - s	
	Individual values	Mean		Individual values	Mean
c. 7.1	9.9, 7.9, 9.6, 9.0	9.1	7.00	5.9, 6.2, 5.9, 6.0	6.0
5.43	16.6, 16.3, 17.9, 16.5	16.8	3.76	13.4, 14.1, 14.6, 13.9	14.0
4.29	24, 21, 22, 22	22	2.28	37, 37, 39, 36	37
3.34	31, 31, 33, 30	31	1.93	61, 62, 61, 58	61
2.66	45, 44, 51, 44	46	1.78	76, 81, 82, 80	80
2.08	75, 71, 73, 75	74	1.62	111, 107, 107, 104	107

TABLE 4. IGNITION RESULTS FOR THICK CORRUGATED FIBREBOARD

Spontaneous ignition			Pilot ignition		
Irradiance W/cm^2	Ignition times - s		Irradiance W/cm^2	Ignition times - s	
	Individual values	Mean		Individual values	Mean
6.30	12.3, 12.0, 10.8, 12.5	11.9	7.00	6.2, 6.1, 5.9, 5.8	6.0
5.43	15.7, 15.6, 15.6, 14.8	15.4	4.96	9.3, 9.6, 9.4, 8.9	9.3
4.26	23.8, 24.4, 22.5, 24.2	23.7	3.51	16.7, 15.7, 15.2, 16.6	16.1
3.27	32, 40, 34, 33	35	2.44	34, 32, 32, 35	33
1.99	85, 86, 83, 79	83	1.80	74, 68, 70, 70	71
1.72	116, 120, 119, 120	119	1.63	113, 106, 110, 108	109

TABLE 5. APPROXIMATE MINIMUM IRRADIANCE FOR IGNITION - W/cm^2

Type of ignition	Corrugated fibreboard			European Whitewood
	Thin	Medium	Thick	
Spontaneous	1.65	1.75	1.65	5.2
Pilot	1.55	1.50	1.50	1.6

Too much significance cannot be attached to the slight differences in irradiance necessary to cause ignition of the three different types of corrugated fibreboard, ie a value of 1.65 might be better expressed as 1.6–1.7.

DISCUSSION

Figure 3 shows that there is a tendency for pilot ignition times to be a little longer with the vertical flame, Fig.2a, than with the horizontal flame, Fig.2b. This may be because the horizontal flame is more likely to intercept the gaseous decomposition products rising from the irradiated fibreboard – the samples sometimes warped as they heated up, and this was why the horizontal pilot flame was finally adopted. Figures 3 and 7 show that this effect of pilot flame position is not likely to be very significant.

Figures 6 and 7 show no appreciable differences in ignition times for the three thicknesses of material. The only major difference, see Figs 3–5, is between the spontaneous and pilot ignition times, the latter being shorter as expected.

The minimum intensity for ignition is lower for pilot ignition as one would expect and similar to, or a little less than, the value of 1.6 W/cm^2 given[5] for a common type of softwood. However there is a considerable difference for spontaneous ignition, the wood requiring about three times the irradiance before ignition can occur. The reason for this difference is uncertain but may be due to the corrugated fibreboard starting to glow in one or two spots due to its thin construction, when subject to irradiation. The glowing will provide a 'pilot' source for ignition. With a sample of solid wood glowing is less likely to occur unless the irradiance is higher.

An attempt was made to see if these results for corrugated fibreboard could be correlated on the same basis as those for other cellulosic materials[5], but this was not successful presumably due to the construction of the fibreboard with its interior air passages, which also make it almost impossible to give meaningful values for thermal constants for this type of composite material as compared with more homogenous materials like timber, chipboard or fibre insulation board.

During irradiation flammable gases accumulate between the corrugations and cannot escape very easily until the front wall is almost charred through, when it was observed that the gases rush out in a 'puff' and ignite.

CONCLUSIONS

1. For the type of corrugated fibreboard ('Cardboard') examined in this investigation the minimum irradiance for pilot ignition is marginally below the level of 1.6 W/cm^2 quoted for a common softwood, but the latter requires about three times the irradiance that the fibreboard does in order to ignite spontaneously.

2. The thickness of the material does not affect ignition times.

3. Ignition times are appreciably shorter for pilot ignition, the position of the pilot flame is probably not critical so long as it intercepts the gaseous decomposition products leaving the material.

4. The orientation of the interior corrugations does not significantly affect ignition times.

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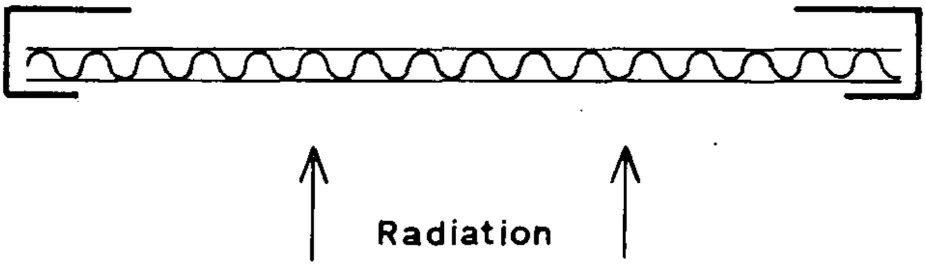
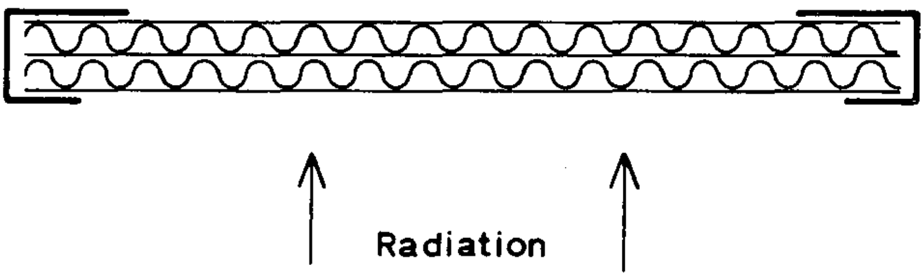


(a) Medium corrugated fibreboard (Double wall)



(b) Thick corrugated fibreboard (Triple wall)

Figure 1 Horizontal section through sample mounted in holder (Full scale)

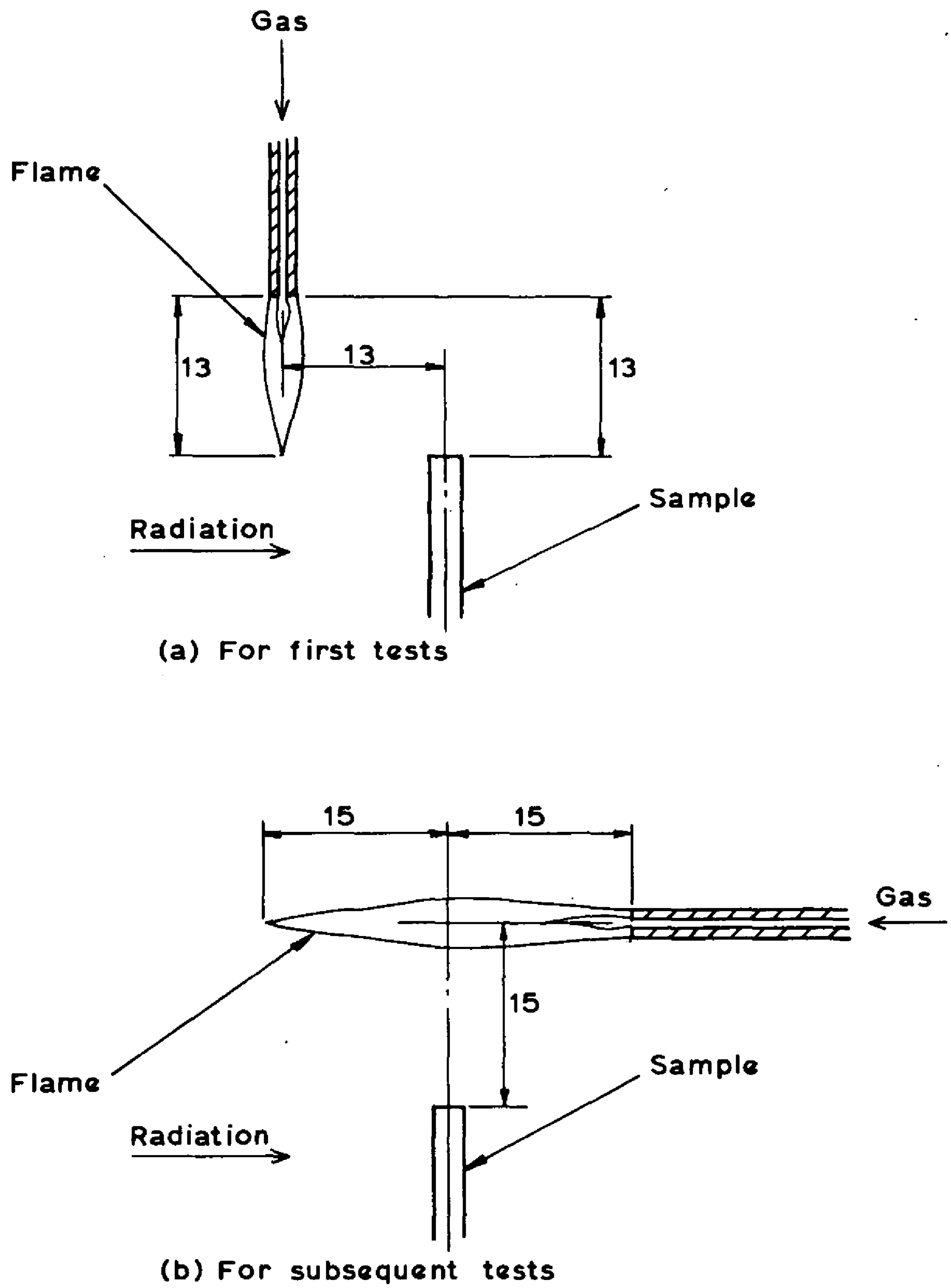


Figure 2 Pilot flame diagrams – vertical sections
(All dimensions in mm)

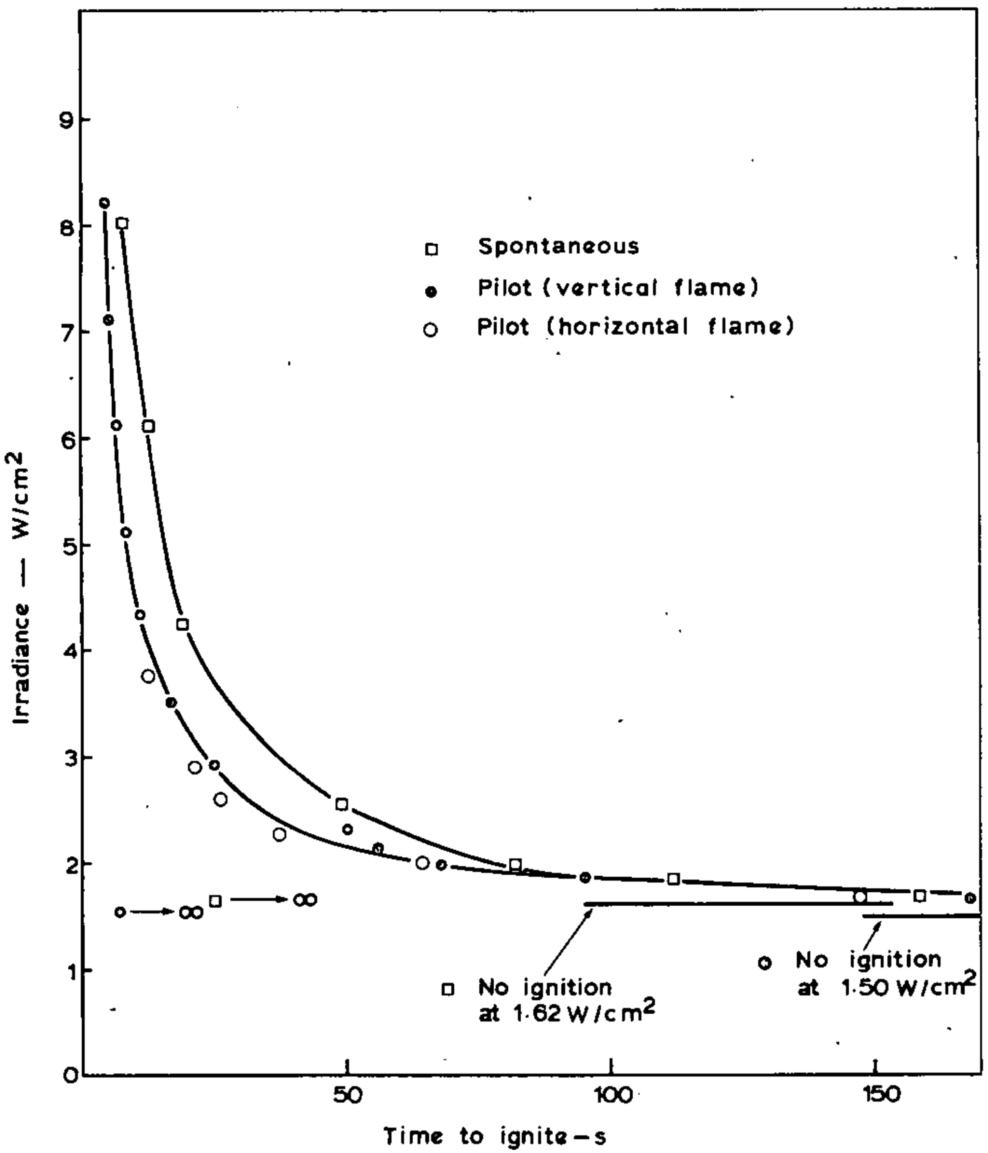


Figure 3 Ignition of thin corrugated fibreboard

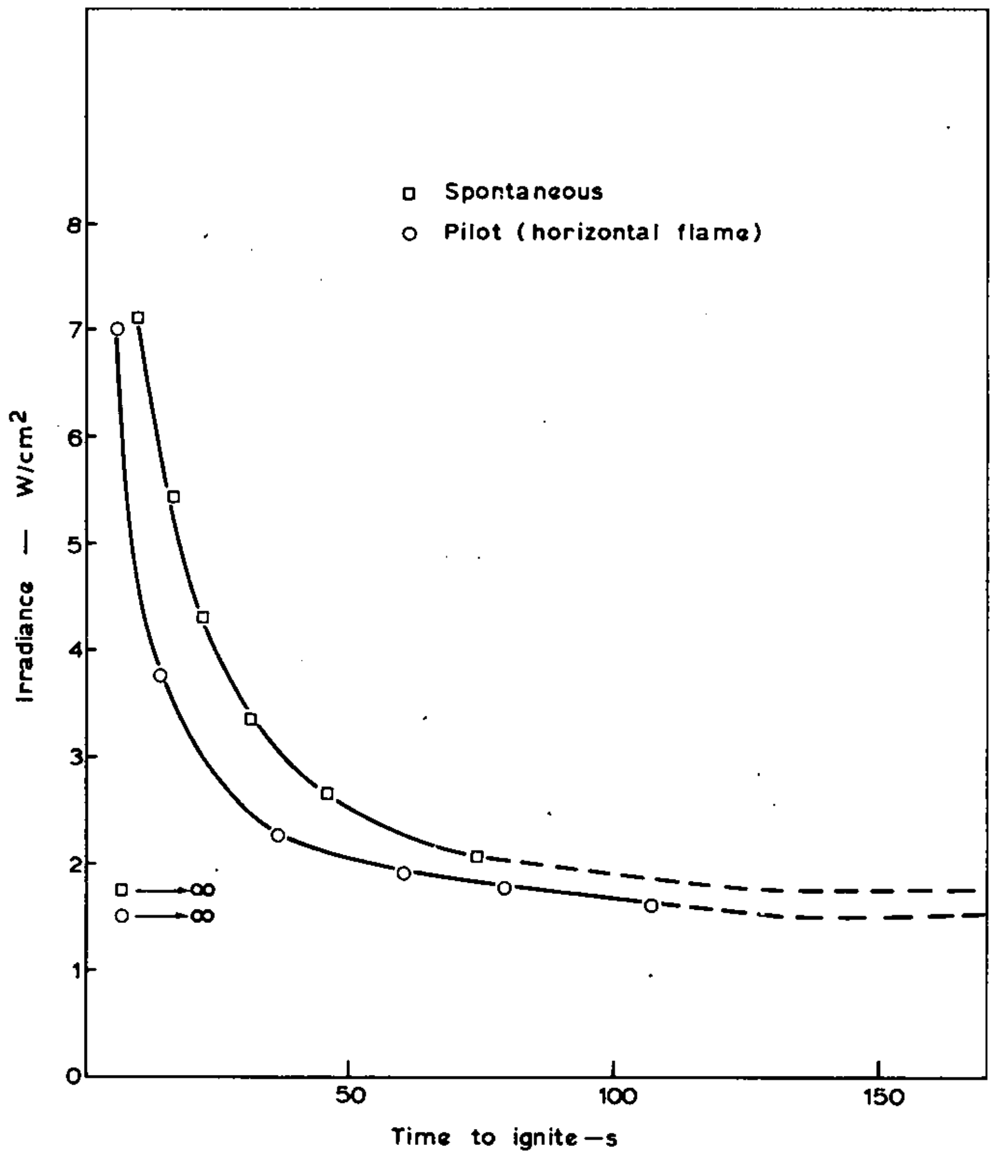


Figure 4 Ignition of medium corrugated fibreboard

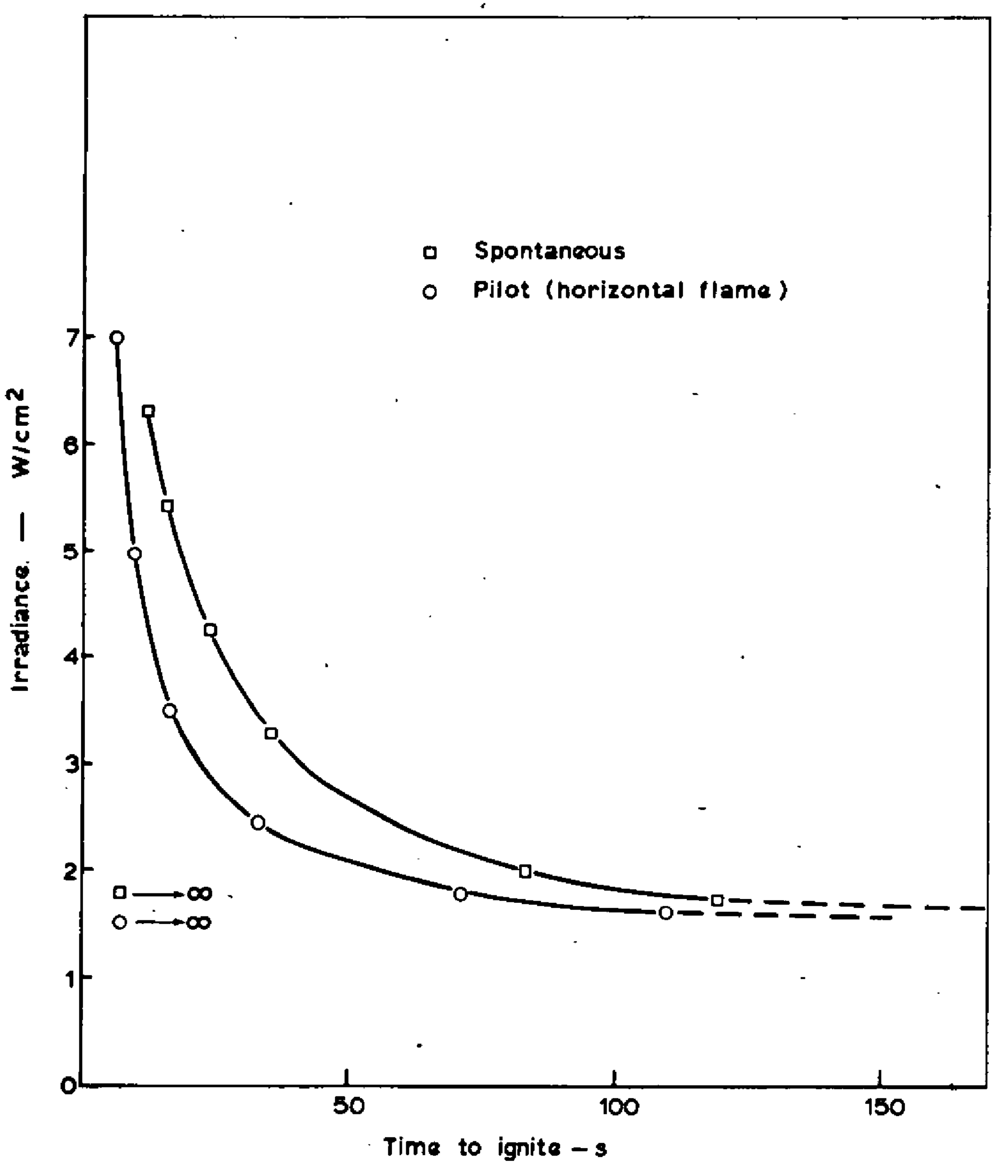


Figure 5 Ignition of thick corrugated fibreboard

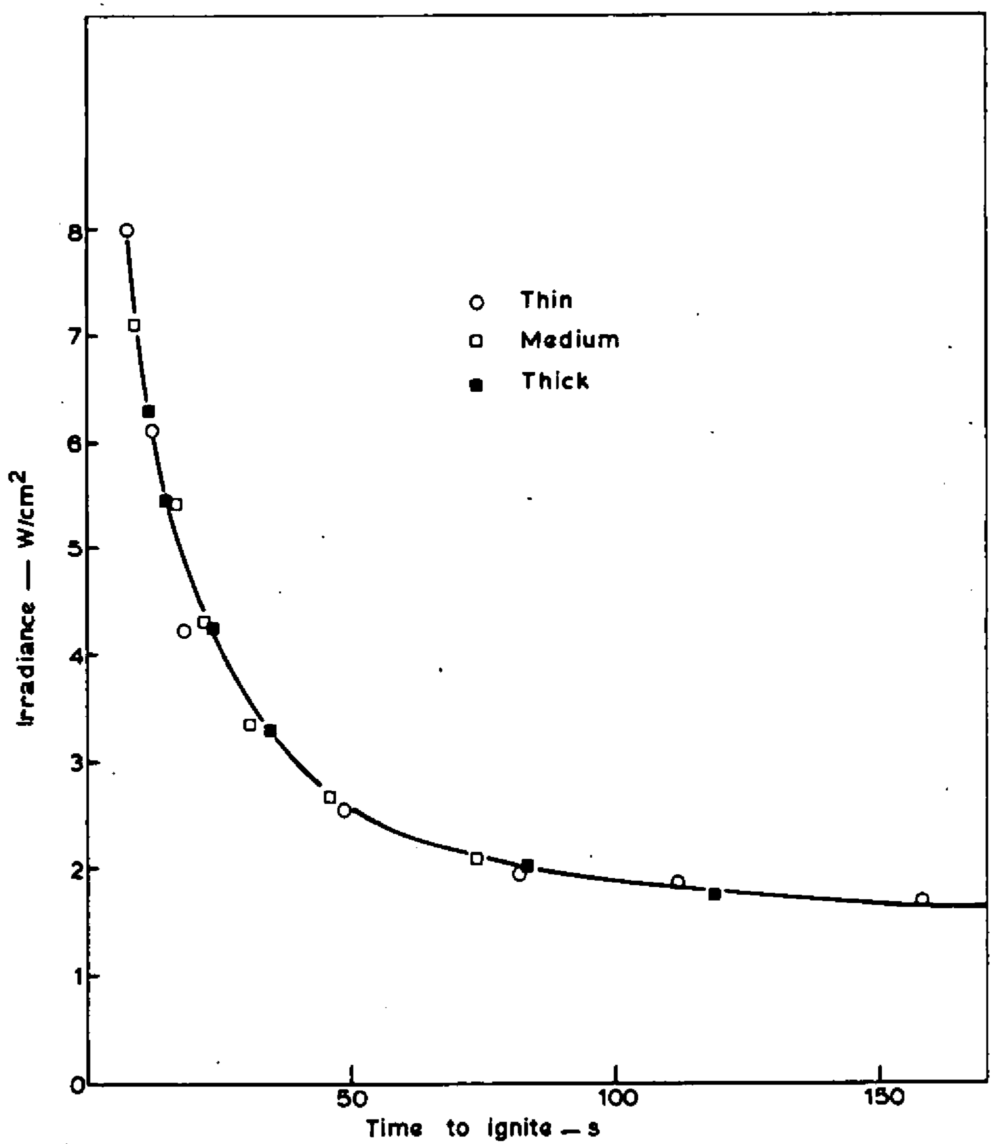


Figure 6 Spontaneous ignition

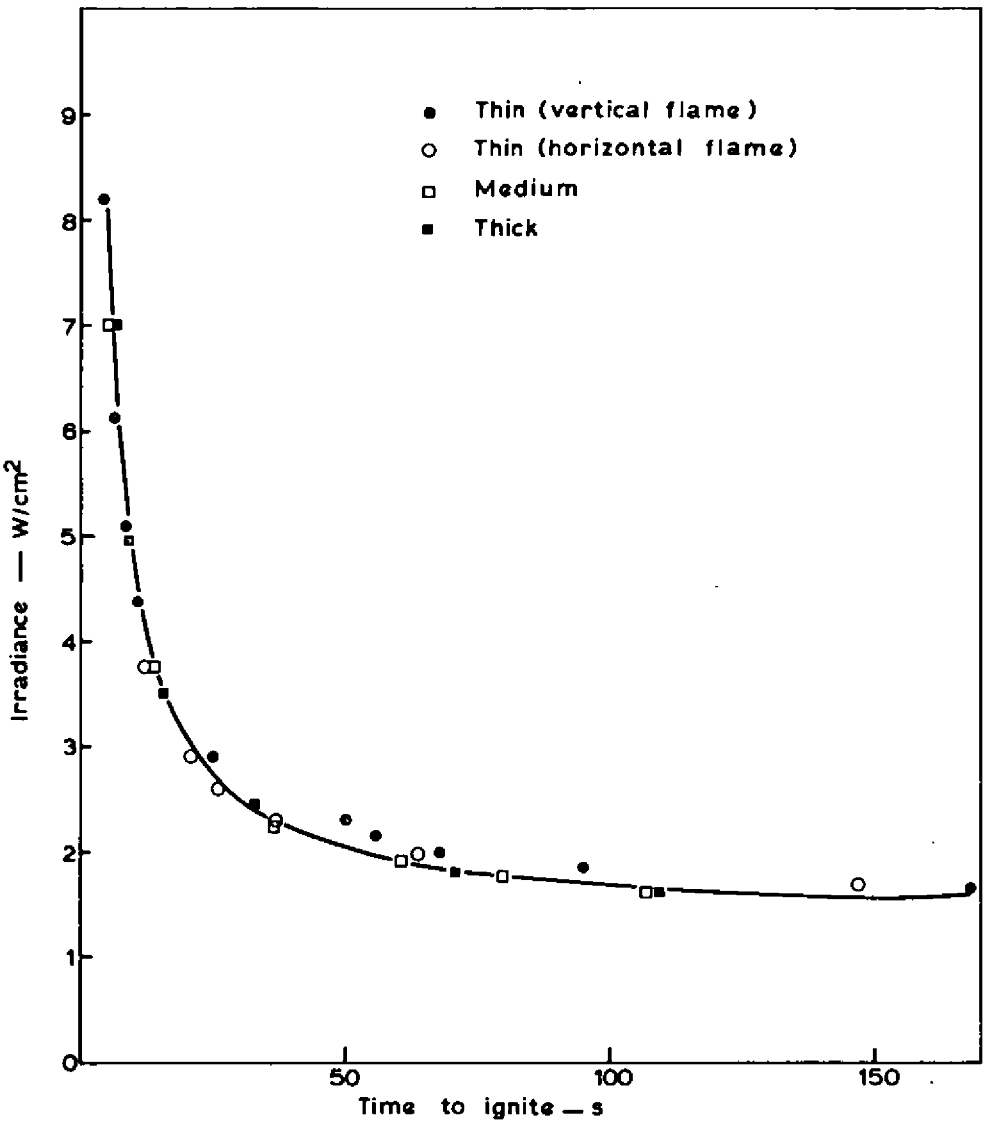


Figure 7 Pilot ignition