F.R. Note No. 365/1958
Research Programme
Objective B2

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

ON THE PILOT IGNITION OF MATERIALS BY RADIATION

by

D. L. Simms and D. Hird

Summary

Woods of different densities have been exposed to radiation and the ignition times with a pilot flame in different positions have been measured.

The question of whether spontaneous and surface ignition may be regarded as special cases of pilot ignition is discussed.

Fire Research Station,
Boreham Wood,
Herts.

July, 1958.

ON THE PILOT IGNITION OF MATERIALS BY RADIATION

by

D. L. Simms and D. Hird

1. Introduction

In an earlier paper[1] pilot ignition was defined as ignition by radiation in the presence of a pilot flame and spontaneous ignition as ignition where there is no pilot flame. Surface ignition was defined[2] as ignition with a pilot flame in contact with the surface. This form of ignition appears to be relevant to the spread of flame over a material; in particular, the least intensity at which this spread of flame is possible, the critical intensity is related to the furthest distance to which the flame spreads across the specimen on the British Standard test[3], and to the furthest distance to which the flame spreads across a wooden floor of a room with furniture but with non-combustible ceiling and walls[4].

The experiments carried out in this paper were intended to measure the effect of the position of the pilot flame on the ignition time at a given intensity of radiation and to find whether it was possible to regard surface ignition and spontaneous ignition as limiting cases of pilot ignition.

2. Experimental procedure and results

Three materials were examined:-

(1) Fibre insulating board, density 0.25 g/cm^3, 0.5 in. thick.

(2) Columbian pine (taxifolia pseudosuga), density 0.5 g/cm^3, 0.75 in. thick.

(3) Oak (quercus sp.) density 0.7 g/cm^3, 0.75 in. thick.

Specimens were cut 2 in. square so that the faces were parallel with the grain and these were dried for 24 hours in an oven at 95°C. After drying, they were allowed to cool over phosphorus pentoxide. The density was obtained from the volume and weight when oven-dry.

Specimens were placed in a holder above which was mounted a pilot gas jet 0.5 in. long, its base level with the top of the specimen. They were exposed to various levels of radiation[5] and the ignition times were measured. Readings were taken with the pilot flames $\frac{1}{4}$ in., $\frac{3}{8}$ in., $\frac{1}{2}$ in., and $\frac{3}{4}$ in. and over from the surface (Fig. 1).

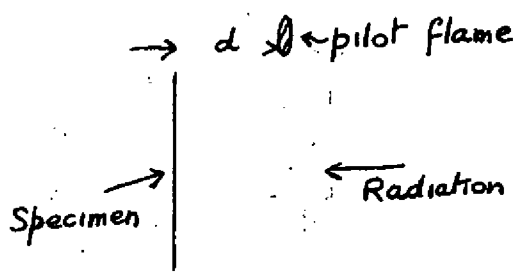


fig 1. POSITION OF PILOT FLAME

The results are shown in Fig. 2a, b, and c. Each point on the graphs is the mean of six observations.

3. Discussion and conclusions

3.1 The position of the flame

Pilot ignition only occurred when the pilot flame was within the visible stream of volatiles issuing from the irradiated specimen; this does not extend beyond 0.8 in. of the surface. Beyond this distance, ignition did not originate at the pilot flame.

The ignition time at a given intensity of radiation increases with increasing distance of the pilot flame from the surface. This increase is large enough to limit the usefulness of pilot ignition as a measure of the ignitability of a material. For the same reason a criterion for pilot ignition cannot be given solely in terms of heat balance in the solid as it can for spontaneous ignition(6).

3.2 Critical intensity for pilot ignition

By plotting I, the intensity of radiation against the function $I/\sqrt{t}$, where t is the ignition time, the critical intensity, I_p, is obtained as the intercept on the intensity axis when $I/\sqrt{t}$ is zero(1). The results for oak are shown in Fig. 3. The value of the critical intensity for ignition appears to be about 0.35 cal cm^{-2} s^{-1} for both oak and columbian pine and independent of the pilot flame. The value for fibreboard is lower, about 0.2 cal cm^{-2} s^{-1}.

The minimum intensity at which ignition actually occurred, however, tended to increase with increasing distance between the pilot flame and the surface (Fig. 2).

3.3 The pilot flame at infinity

In Fig 4a, b and c, the results given in Fig. 2 are plotted as lines of constant intensities of radiation with the ignition time, t, as ordinate and the reciprocal of the distance of the flame, $1/d$, as abscissa. The experimental results for spontaneous ignition have been plotted on the line $1/d$ equal to zero(7). Because the limited thickness of the volatile stream prevents pilot ignition beyond a distance of a little under 0.8 in., the curves should be horizontal in the range, say, $0 < 1/d < 1$, and the results for spontaneous ignition appear consequently to be too high in comparison with those of pilot ignition. However, there is some doubt about this comparison because there is reason to believe that the reduction to be made in the ignition time to convert it to the value for a larger area(8) is probably greater for spontaneous ignition than for pilot ignition on the grounds that ignition occurs much nearer the surface with pilot ignition and the diffusion in the plume of volatiles which appears to be responsible for the area effect is consequently much less.

The critical intensity for the spontaneous ignition of oak is about 0.6 cal cm^{-2} s^{-1} and is much greater than that for pilot ignition, 0.35 cal cm^{-2} s^{-1}. Similar differences are found between the two critical intensities of fibre insulating board and oak.

3.4 Pilot flame at zero distance

In Fig. 5, the results for columbian pine have been plotted with the position of the flame, d, as abcissa; the experimental results for surface ignition are also shown and are consistent with the data for pilot ignition but it is clear that the ignition times for pilot and surface ignition may differ considerably, particularly at low intensities; the critical intensity for surface ignition(2) is about 0.1 cal cm^{-2} s^{-1}, whilst that for pilot ignition is about 0.35 cal cm^{-2} s^{-1}. Similar results have been obtained for oak and fibre insulating board.

In all the observed pilot ignitions the flame jumped from the pilot source to the specimen which is then immediately and entirely involved in flame. With the surface ignition, the flame starts from the pilot source and spreads over the surface at a rate which depends upon the intensity of the heating. Thus, there appears to be an intrinsic difference between these two types of ignition. However, any difference that there may be cannot be detected by the present experiments although it might be detected by employing a smaller flame nearer the surface. Again, there might be an area effect, but no information is available. If this effect is associated with the diffusion of the plume of volatiles it would not be expected to be significantly different for pilot and surface ignition.

4. Conclusions

The time to ignite specimens by radiant heat in the presence of a flame depends markedly on the position of the flame with respect to the surface. There are insufficient experimental results to confirm or disprove the hypotheses that spontaneous ignition is the limiting case of pilot ignition as the flame recedes from the surface and surface ignition the limiting case of pilot ignition as the flame approaches the surface.

5. References

(1) LAWSON, D. I. and SIMMS, D. L., Brit. J. App. Phys. 3, p.288-92 (1952).

(2) PICKARD, R. W., SIMMS, D. L. and WALTERS, J. E. The ignition by radiation of wood protected by some common paints. Department of Scientific and Industrial Research and Fire Offices' Committee Joint Fire Research Organization F.P.E. 61/1951.

(3) B.S. 476. British Standards Institution, London, 1953.

(4) HIRD, D. and FISCHL, C. F., Fires in Model Rooms. Department of Scientific and Industrial Research and Fire Offices' Committee Joint Fire Research Organization F.R. Note No. 12/1952.

(5) SIMMS, D. L. and MILLER, Joan E. Radiation characteristics of a gas-fired radiant panel. Department of Scientific and Industrial Research and Fire Offices' Committee Joint Fire Research Organization F.R. Note No. 217/1955.

(6) SIMMS, D. L. Correlation of ignition times with the physical properties of materials. Department of Scientific and Industrial Research and Fire Offices' Committee Joint Fire Research Organization F.R. Note No. 319/1958.

(7) THOMAS, P. H., SIMMS, D. L. and LAW, Margaret. The effect of moisture content on the spontaneous ignition of wood. Department of Scientific and Industrial Research and Fire Offices' Committee Joint Fire Research Organization F.R. Note No. 280/1956.

(8) SIMMS, D. L., LAW, Margaret, HINKLEY, P. L. and PICKARD, R. W. The effect of area on the spontaneous ignition of materials by radiation. Part I: Effect on time taken to ignite. Department of Scientific and Industrial Research and Fire Offices' Committee Joint Fire Research Organization F.R. Note No. 307/1957.

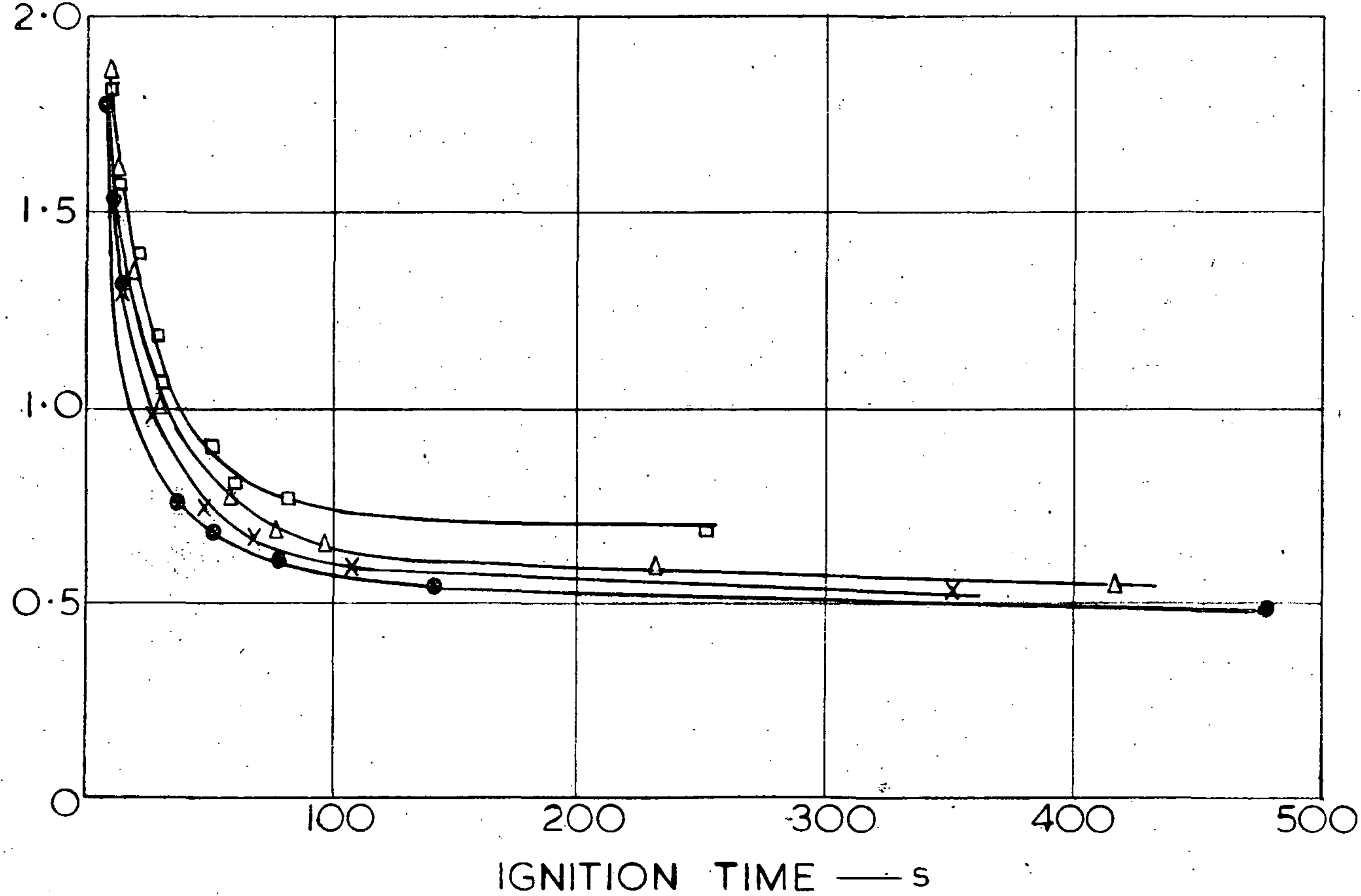


FIG. 2a. PILOT IGNITION OF OAK

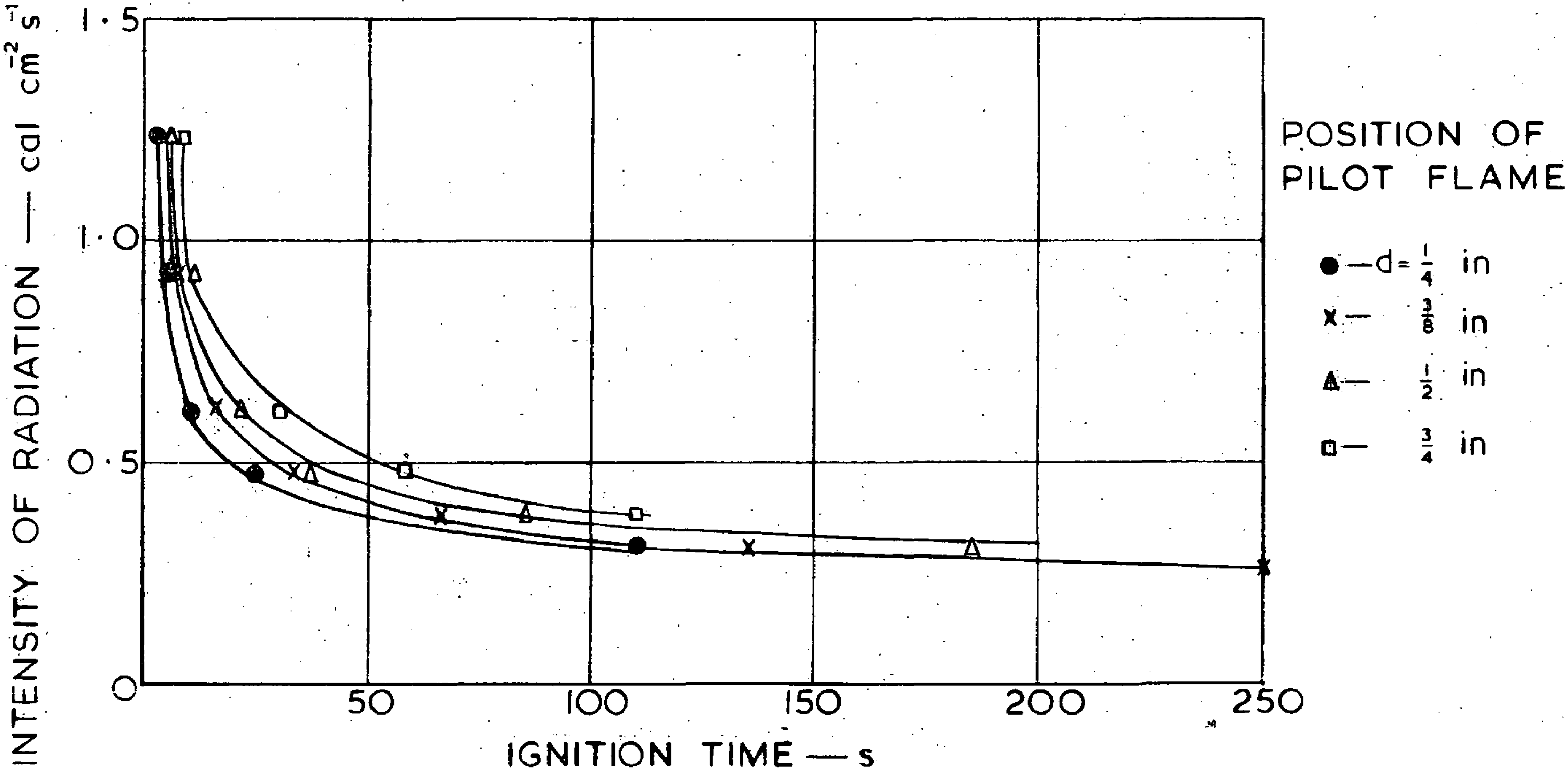


FIG. 2b. PILOT IGNITION OF FIBRE INSULATING BOARD

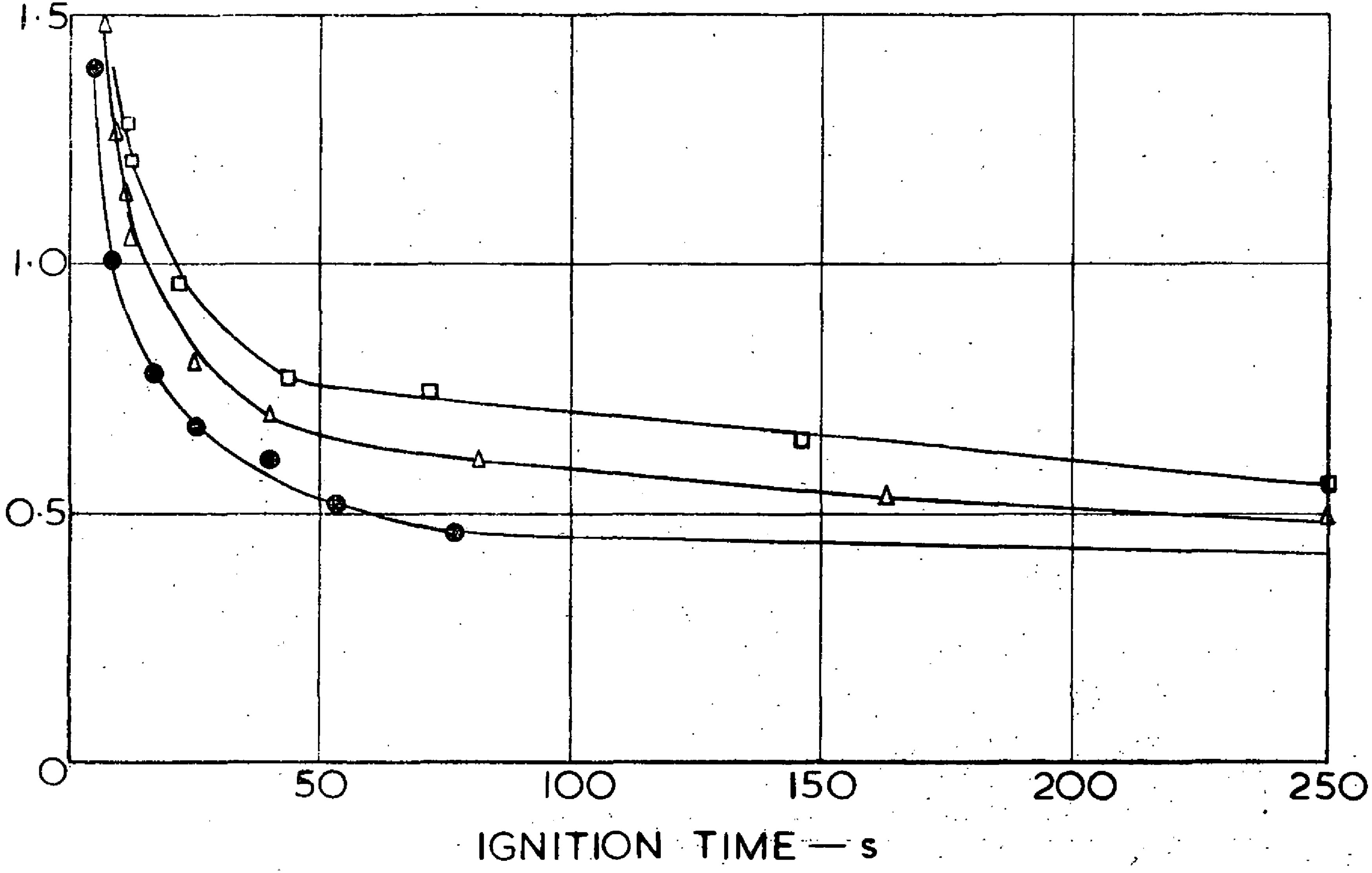


FIG. 2c. PILOT IGNITION OF COLUMBIA PINE

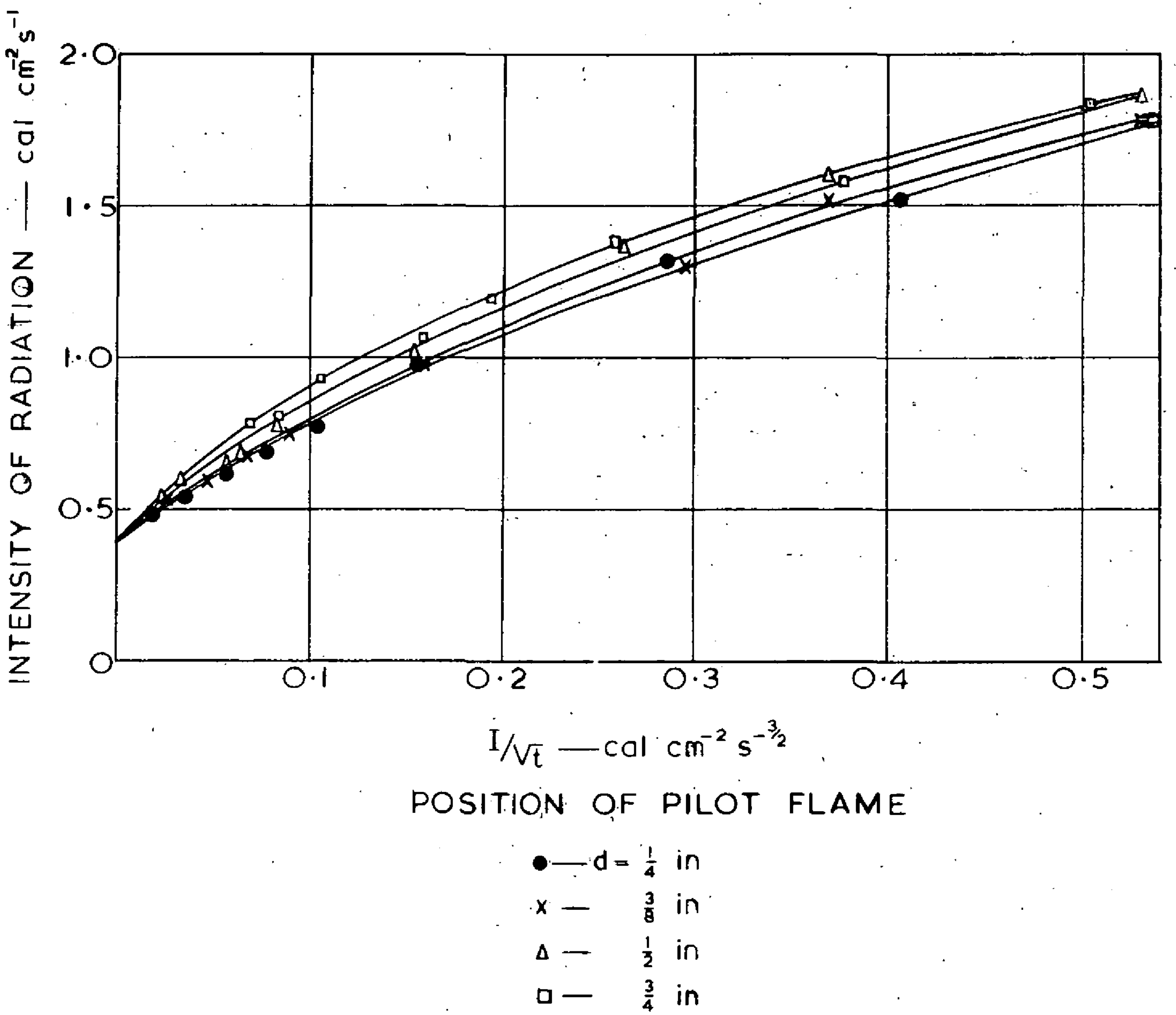
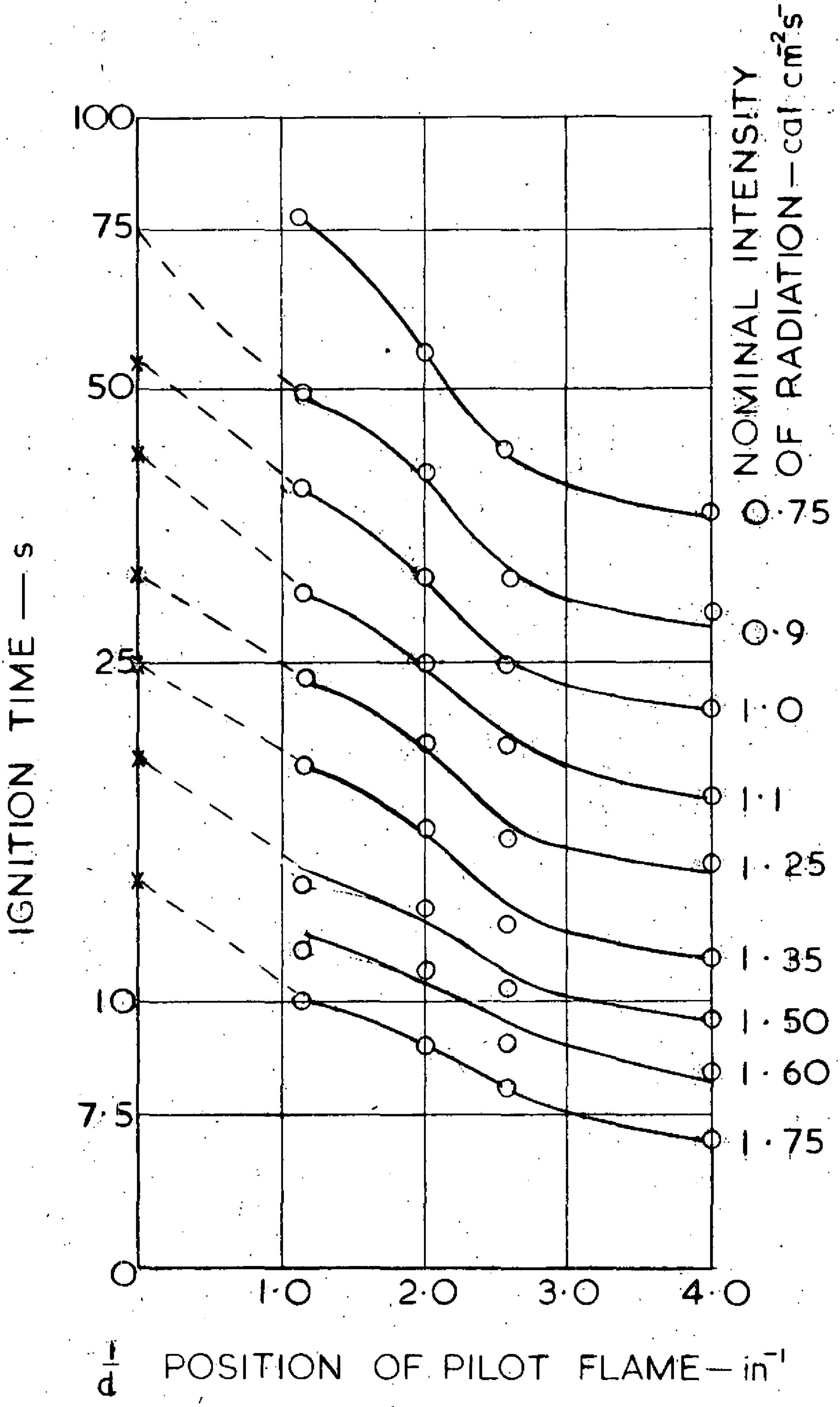


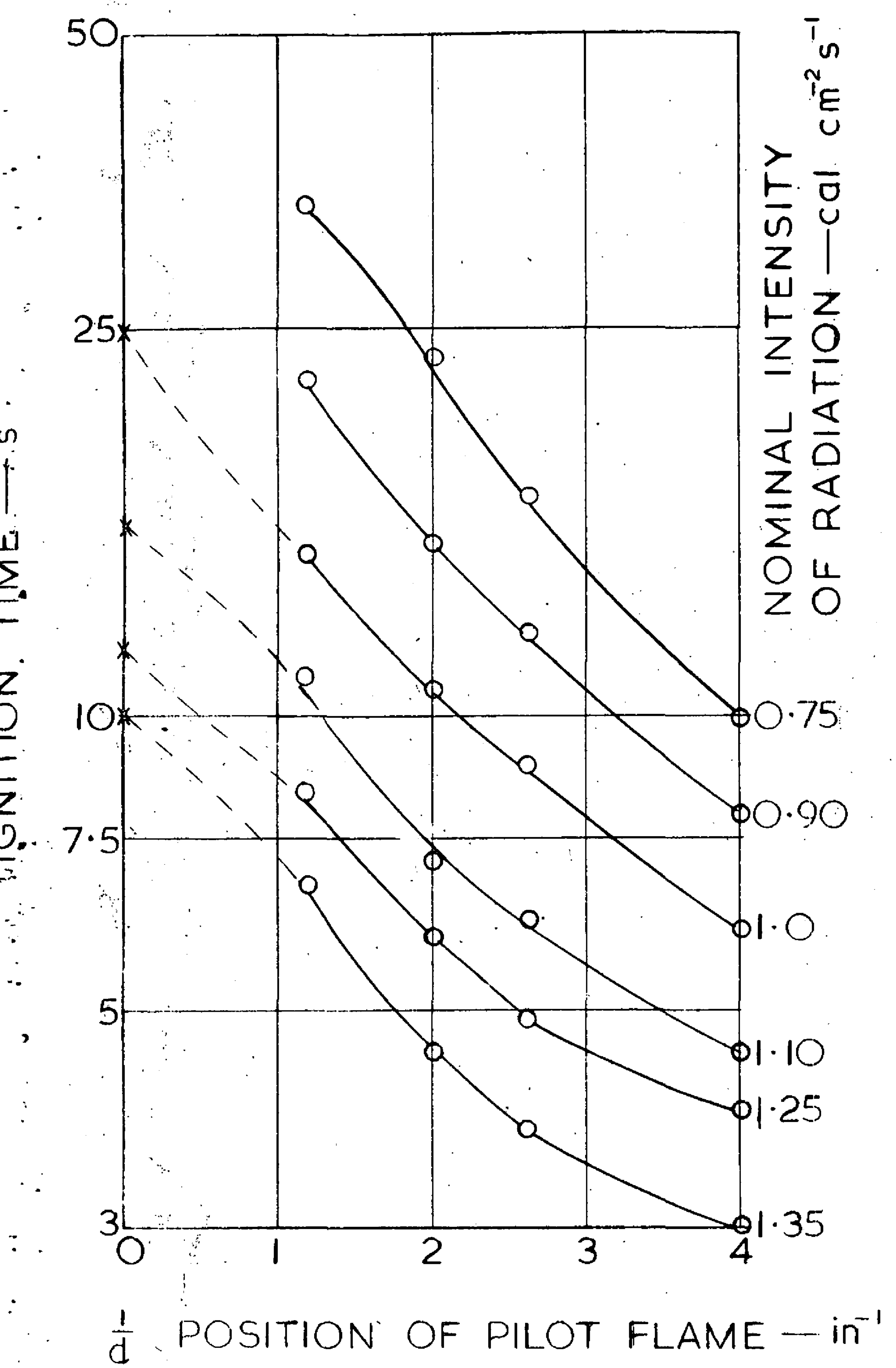
FIG. 3. DETERMINATION OF THE CRITICAL INTENSITY OF PILOT IGNITION



o points obtained by interpolation Fig 2a.

x experimental results spontaneous ignition

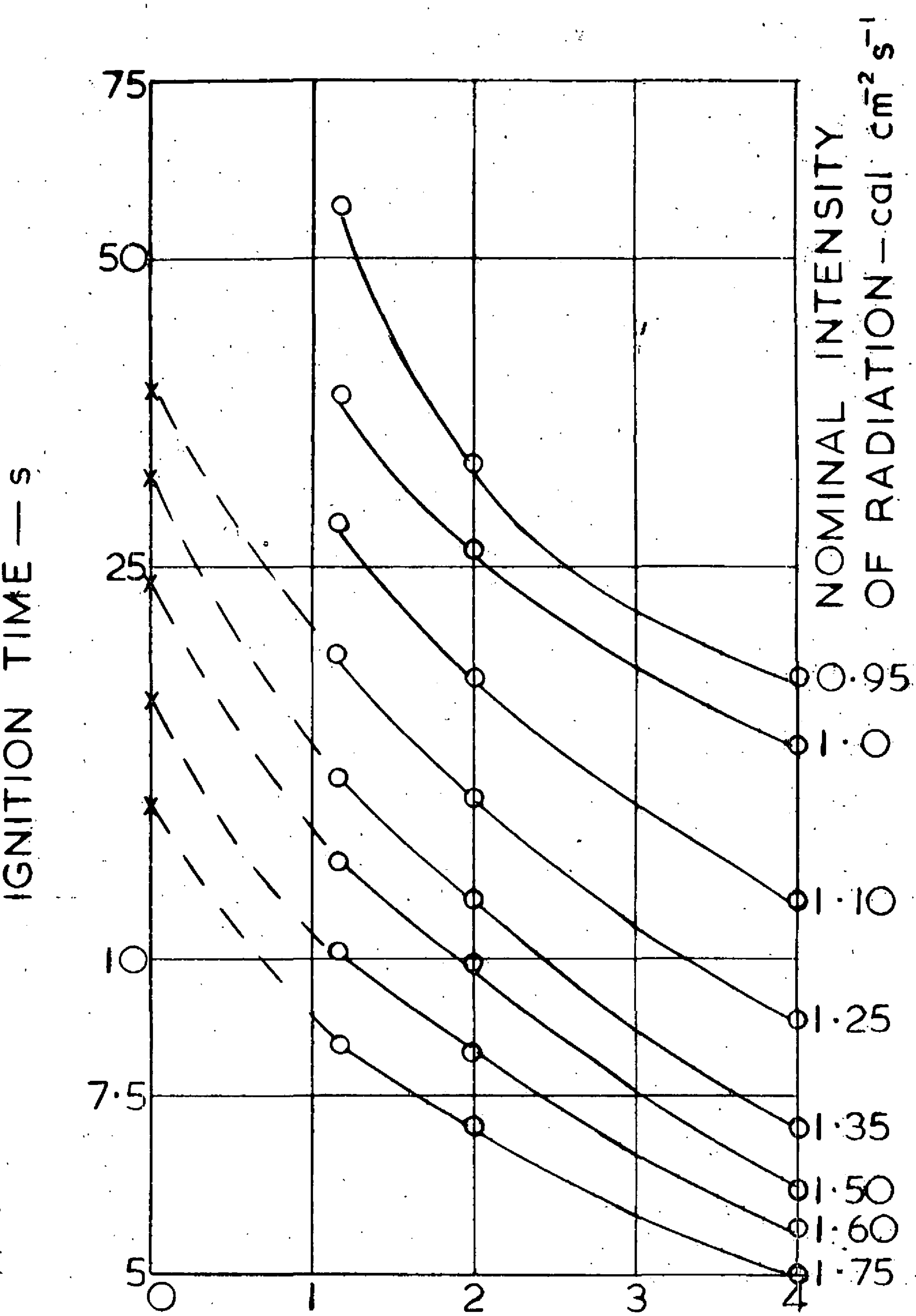
FIG. 4a. PILOT IGNITION OF OAK



o points obtained by interpolation Fig 2b.

x experimental results spontaneous ignition

FIG. 4b. PILOT IGNITION OF FIBRE INSULATING BOARD



$\frac{1}{d}$ POSITION OF PILOT FLAME – in^{-1}

o points obtained by interpolation Fig 2c.

x experimental results spontaneous ignition

FIG. 4c. PILOT IGNITION OF COLUMBIAN PINE

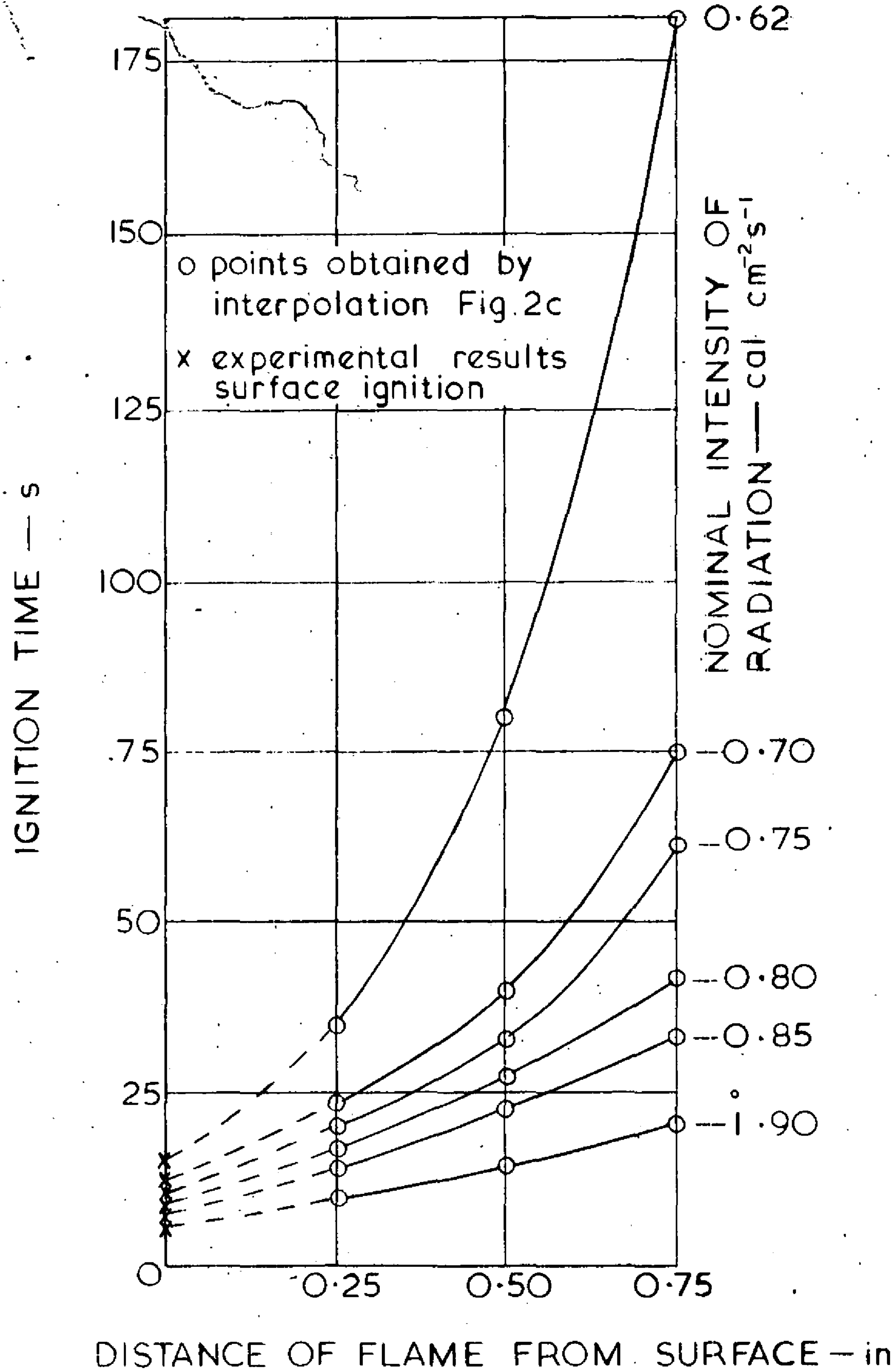


FIG. 5. PILOT IGNITION OF COLUMBIAN PINE