F.R. Note No. 393/1959
Research Objective B1.

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

THE EFFECT OF PROLONGED HEATING ON THE
SUBSEQUENT SPONTANEOUS IGNITION OF OAK

by

D. L. Simms, Valerie E. Roberts and Constance J. Cook.

Summary

There is no significant change in ignition time at a given intensity
of irradiation after prolonged preliminary heating within the range of
temperatures (120-180°C) but the minimum intensity at which ignition was
possible was progressively raised with increasing severity of preliminary
heating. This increase is shown to be related to the loss in volatiles,
during the preliminary heating. Values of the reaction constants are in
good agreement with those found elsewhere.

April 1959

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Boreham Wood,
HERTS.

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1. Introduction

Specimens of oak exposed to different intensities of radiation for the same time and then subjected to a much higher intensity of radiation appeared to ignite at different times [1]. The number of specimens tested was not large enough to warrant firm conclusions and because of the theoretical and practical importance of this problem, further experiments have been performed using an oven which could be kept at a uniform temperature.

2. Experimental method

Oak of density ranging from about $0.6 - 0.8$ g/cm^3 was cut to a nominal size 5 cm x 5 cm x 1.2 cm thick. The pieces were dried in an oven at approximately 95°C for 24 h., and allowed to cool over phosphorus pentoxide. The density was then obtained from the weight and volume when oven-dry. Specimens were then further heated in an oven at a constant temperature. Details of the experimental conditions are given in Table 1 below. Each batch consisted of 12 specimens and each set contained a control batch.

TABLE I

Oven temperature		
180°C	150°C	120°C
	Time of exposure	
2 h	15 h	5 days
8 h	27 h	9 "
32 h	54 h	18 "
128 h	104 h	40 "
12 days	9 days	72 "
	18 "	
	24 "	
	36 "	

After heating the density of selected specimens was determined.

The source was a 1 ft square gas fired radiant panel and the intensity at any point was measured by a water cooled thermopile. The specimen was moved rapidly into place in front of the radiant panel and the ignition time measured. The experiment was repeated over a range of intensities. The results are shown in Figs. 1a - c. The position of the continuous lines is the same on each graph as it refers only to the controls which were not preheated.

3. Discussion of results

The physical appearance of the specimens changed considerably during the heating (Plate I). At 120°C, at 150°C and for short exposures at 180°C (<27 h) the specimens darkened to various shades of brown but for long exposures at 180°C (>27 h) the specimens charred and some became deeply pitted. This may account for the greater variation in the ignition times at this temperature. There was no significant variation in ignition time with prolonged heating (Fig. (1a - c), although there were at least two anomalous results for wood heated at 180°C. All three batches of controls lie on the same curve.

On the other hand, the minimum intensity at which ignition occurred increased with increasing exposure by an amount related to the loss in weight of the specimens (Fig. 2). Here too, there is a good correlation for all the results except for one specimen heated at 180°C.

4. Discussion and conclusions

The volatilising of some of the components of the wood leads to loss in weight of the specimens, and this has been shown by Stamm [2] to follow a first order reaction equation, i.e. the rate of production of volatiles is directly proportional to the amount of volatile present at that time. Thus, if the initial concentration of volatiles has been diminished, then the rate of production of volatiles at any time will also be diminished proportionally. In the range of the present experiments, the ignition time does not vary with the preheating condition and this is consistent with its being insensitive to the rate of production of volatiles [3].

The minimum intensity for ignition does depend upon the preheating conditions and is therefore sensitive to the initial loss in volatile content, as has been suggested elsewhere [3].

These results suggest that volatiles are given off at temperatures as low as 150°C and possibly as low as 120°C. If these volatiles were confined, a flammable mixture could form which could be ignited by a pilot source.

References

1. THOMAS, P. H. The effect of preheating on the ignition of cellulosic materials, Joint Fire Research Organization F.R. Note No. 328/1958.

2. STAMM, A. J., Ind. Eng. Chem., 1956, 48 (3) 413-7

3. THOMAS, P. H. and SIMMS, D. L. The mechanism of ignition of materials by radiation, Joint Fire Research Organization F.R. Note No. (in preparation).

4. BAMFORD, C. H., CRANK, J. and MALAN, D. H. The combustion of wood. Part I. Proc Camb. Pil. Soc. XLII pp 166 - 182, 1946.

5. SAUER, F. M. The charring of wood during exposure to thermal radiation. Division of Fire Research, Forest Service, U.S. Dept. of Agriculture, August, 1956.

Acknowledgments

Appendix I

Values of the Reaction Constants

The rate of loss in weight of the volatiles may be assumed to follow a first order Arrhenius reaction, i.e.

$$\frac{\partial \omega}{\partial t} = \omega \, f \, e^{-E/RT} \tag{1}$$

where ω is the volatile content at time t
f is a frequency factor
E an activation energy
R the gas constant
and T the absolute temperature

For isothermal heating Equation (1) integrates to give

$$\log\left(\frac{\omega_o}{\omega_i}\right) = - f \, e^{-E/RT} \times \tau \tag{2}$$

where ω_o, ω_i are the initial and final concentrations and
τ is the time of heating.

A value for ω_o of 0.62 has been assumed [4] and the results for specimens heated at 150°C and 180°C are shown in Fig. 3; the results for 120°C are too scattered to be used. From the slopes of the straight lines equation (2) may be solved giving values for f of 10^{10}s^{-1} and E of 35,000 cal/g.mole. These values are in good agreement with those given elsewhere [2][5].
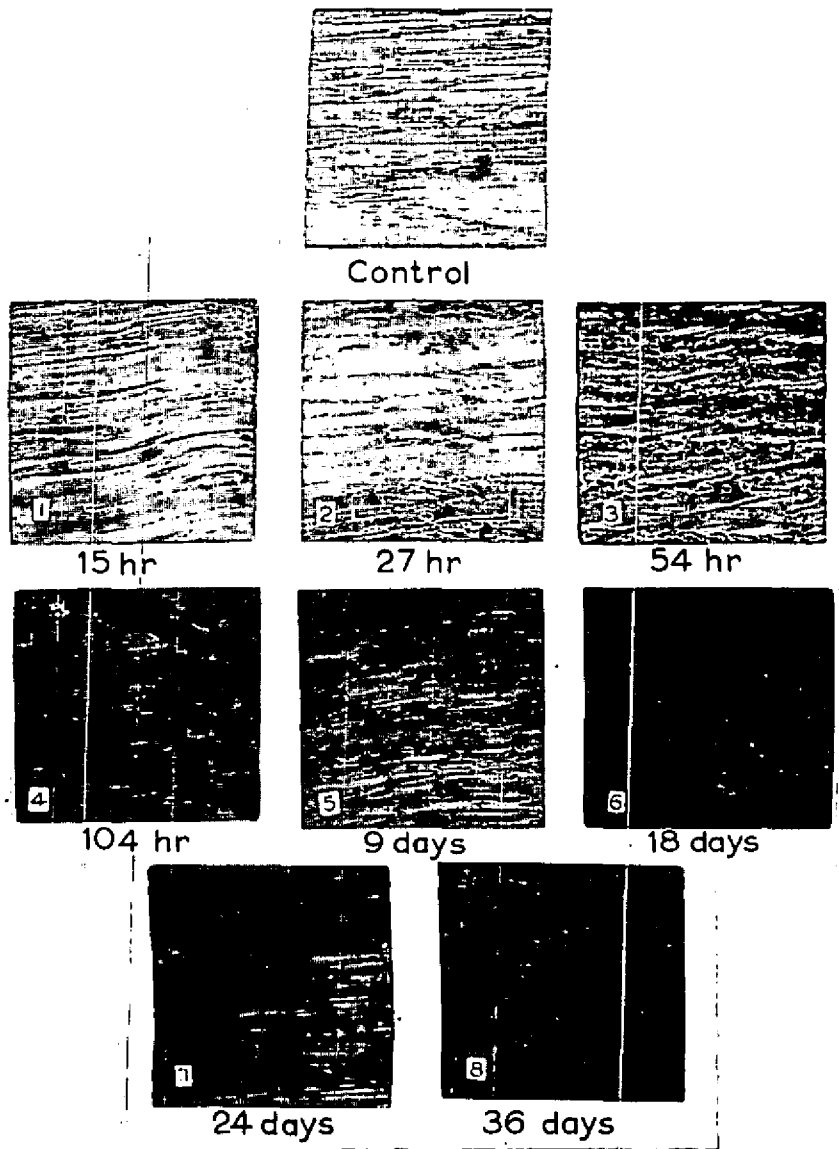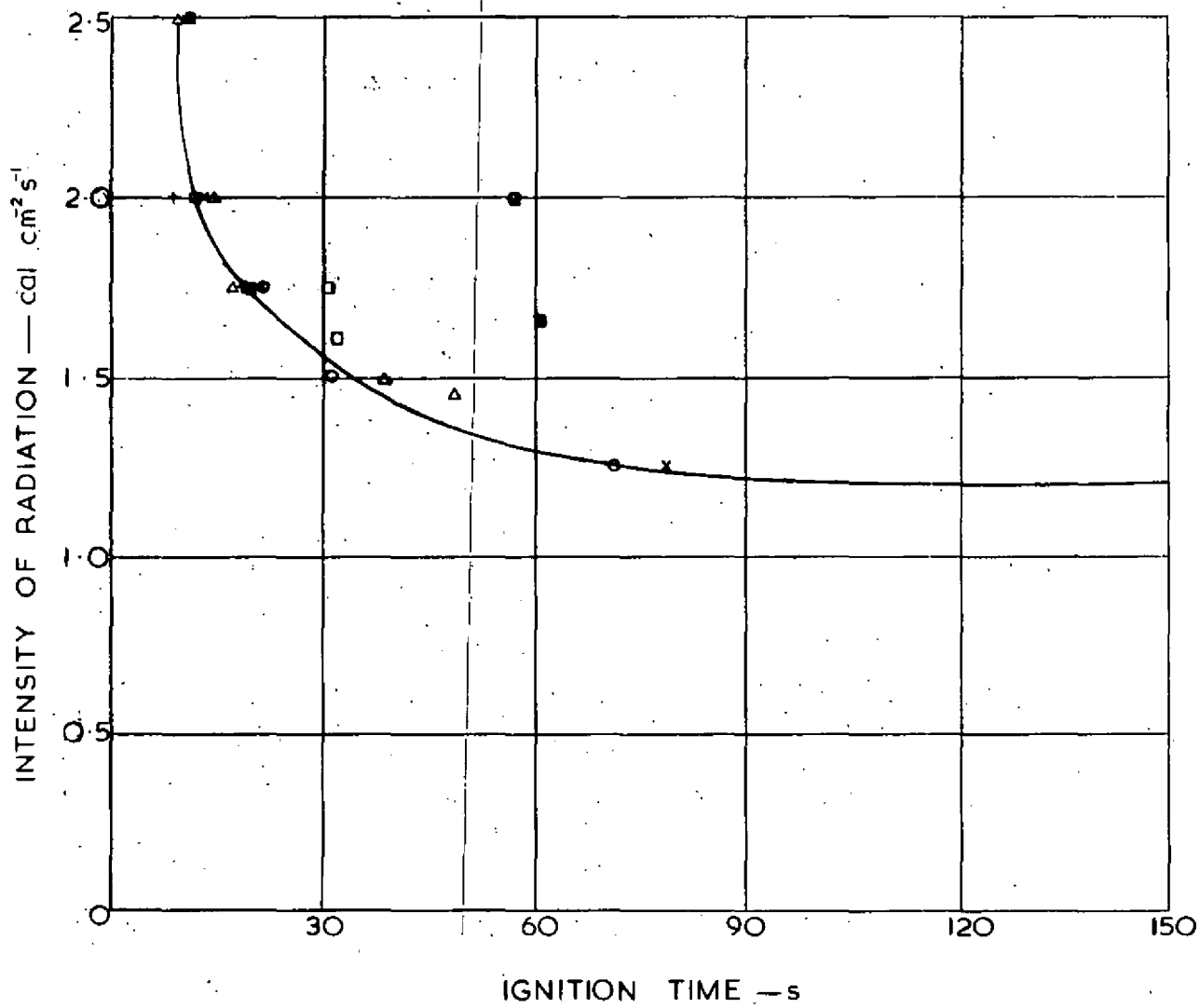
Control

15 hr   27 hr   54 hr

104 hr   9 days   18 days

24 days   36 days

PLATE.I. SURFACE DARKENING OF WOOD
IN OVEN AT 150 °C

FIG. Ia. IGNITION AFTER HEATING — 180 °C
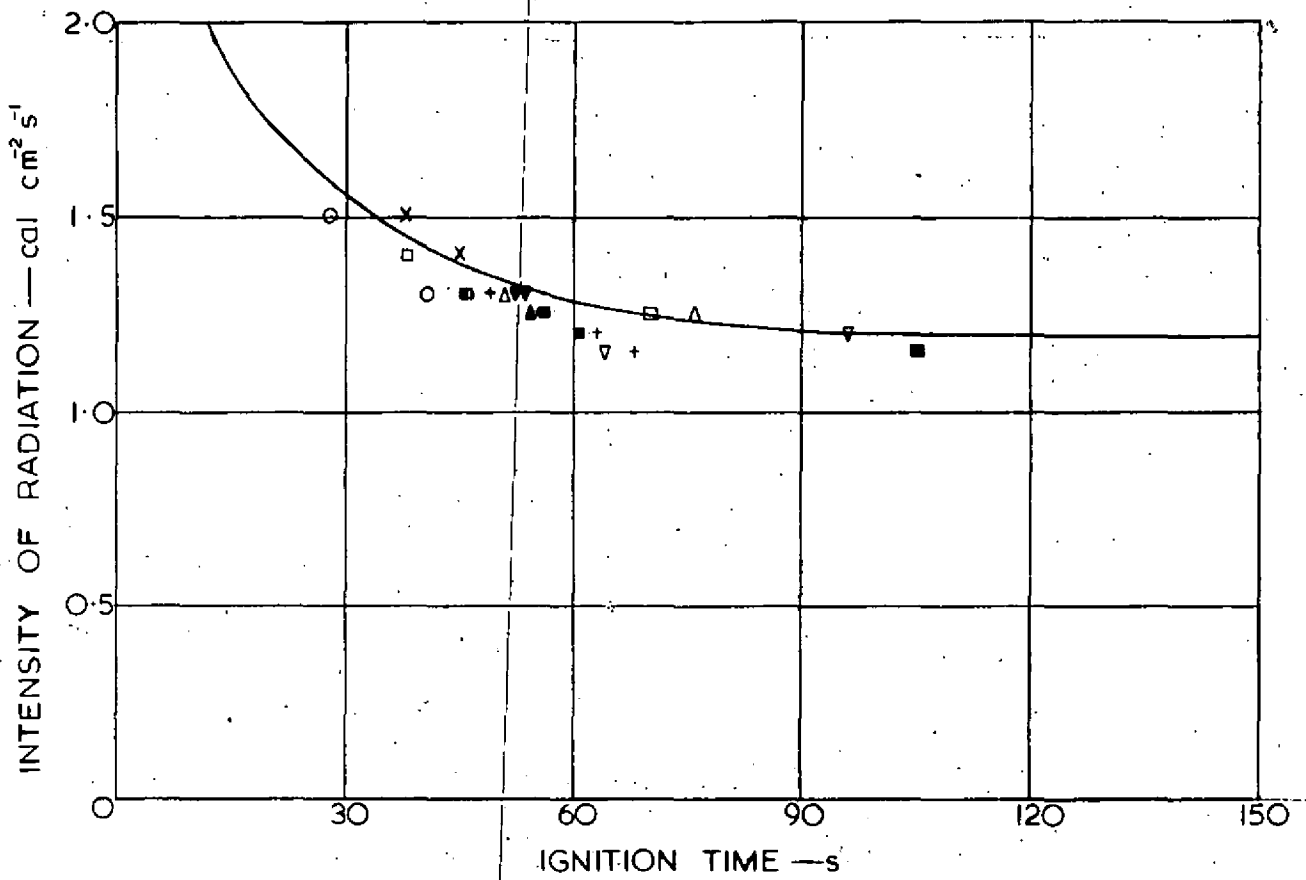
TIME IN OVEN

—△— control   ▲ 15 hours   ■ 27 hours

▽ 54 hours   ▼ 104 hours   + 9 days

□ 18 days   o 24 days   x 36 days

Line drawn through controls (no preheating)

FIG. Ib. IGNITION AFTER HEATING — 150 °C
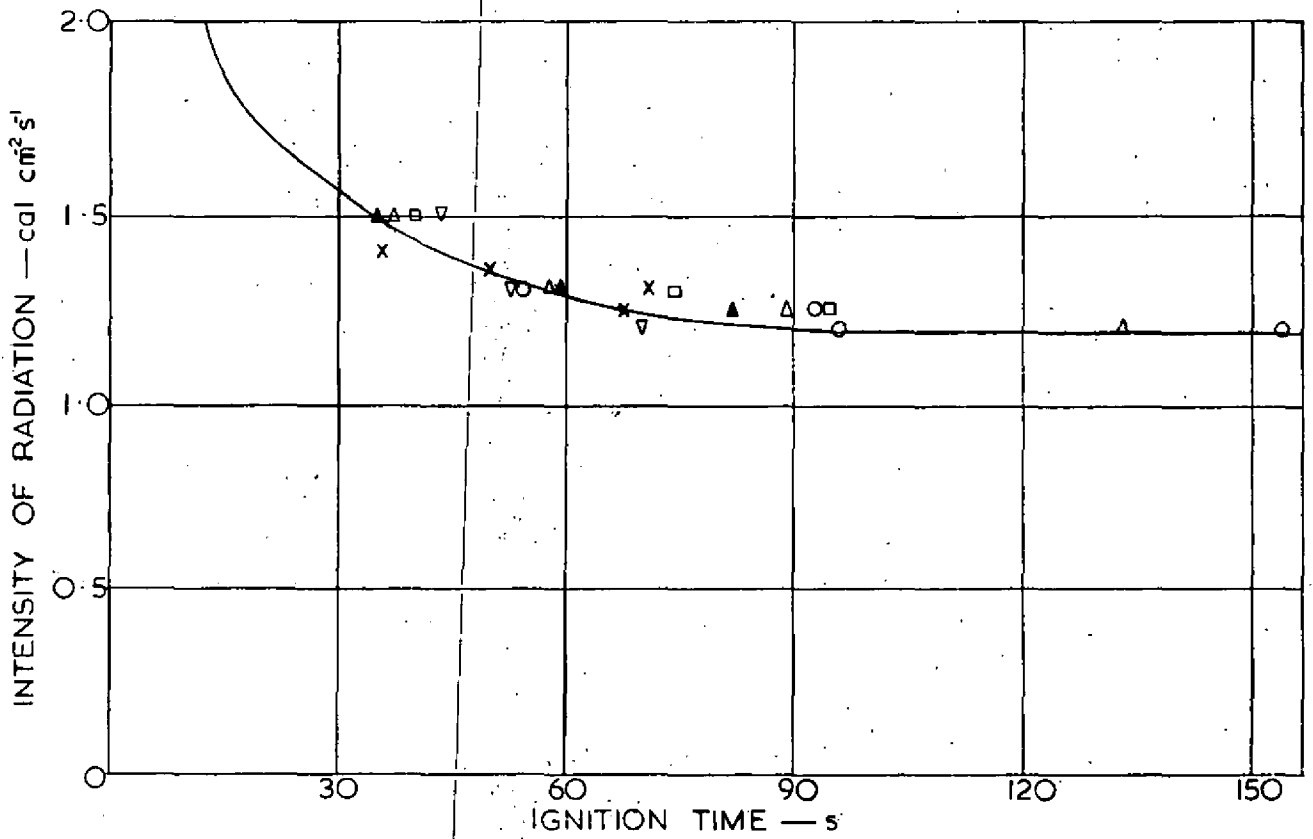
TIME IN OVEN

—△— control   ▽ 5 days   □ 9 days

▲ 18 days   o 36 days   x 54 days

Line drawn through controls (no preheating)
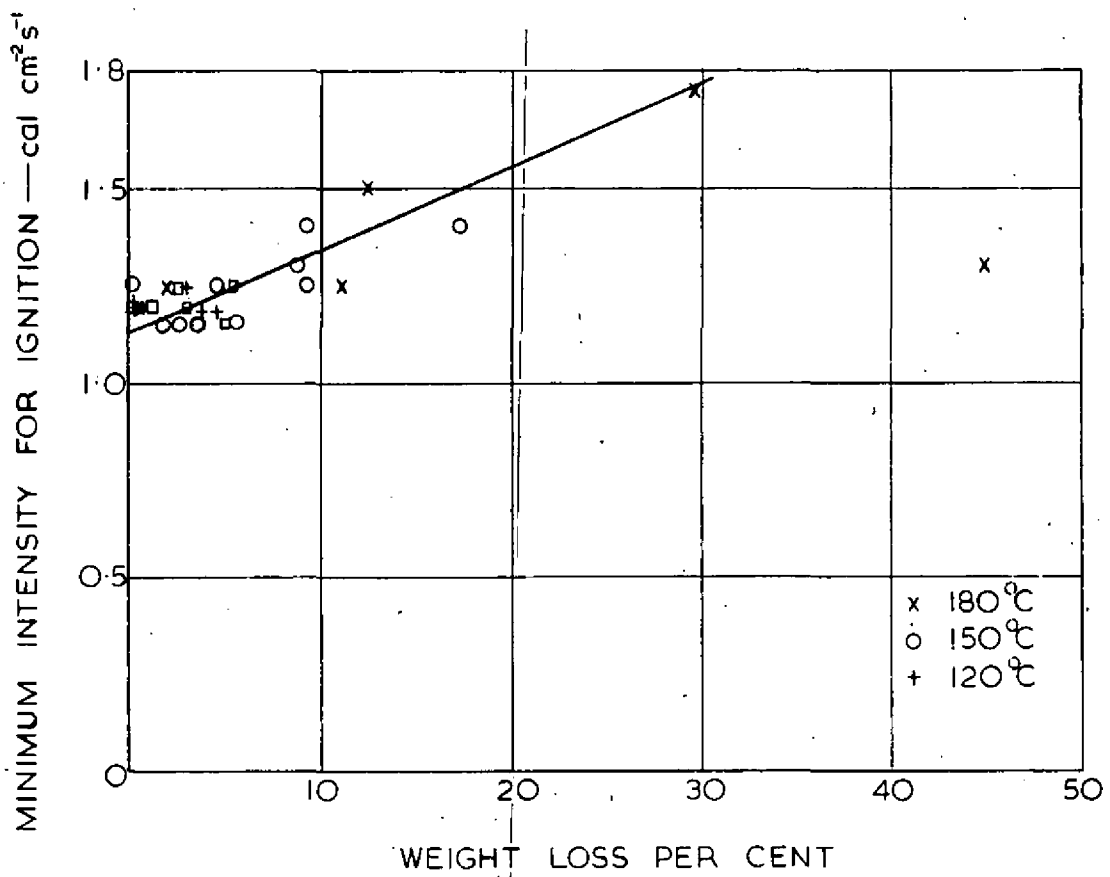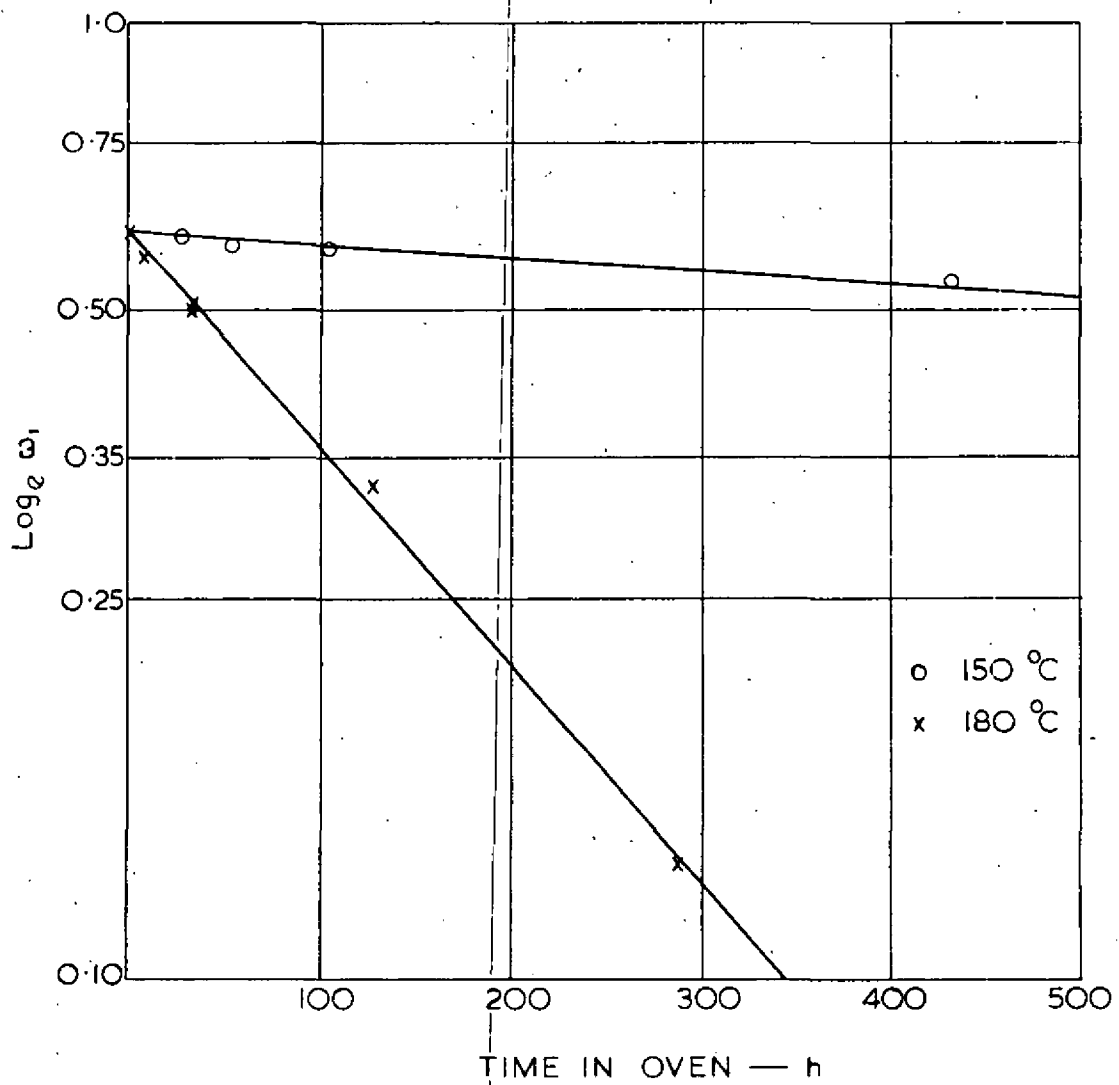
FIG. Ic. IGNITION AFTER HEATING — 120 °C

FIG. 2. THE MINIMUM INTENSITY FOR IGNITION

FIG. 3. LOSS OF VOLATILES