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FURTHER EXPERIMENTS WITH WOOD BLOCK RADIOMETERS INCLUDING THE RESPONSE TO A SKEWED PULSE OF RADIATION

by

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SUMMARY

Wood blocks of the kind used to make measurements at the Flambeau test fire 760-12-67 have been calibrated using a skewed pulse of radiation approximating to that measured in similar previous fires. The relation between damage sustained by the blocks and peak intensity were broadly similar to those for a constant intensity pulse except that with a skewed pulse having a peak intensity of about 2 W/cm^2 the behaviour of the block was more variable.

The data obtained at the recent Flambeau fire 760-12-67 have been re-examined in the light of these new calibrations. The variation of peak intensity over the fire area was closely similar to that previously obtained when the incident intensity was assumed to be constant for a period of 20 min. Correlations were found, as before, between the peak intensities at various positions in the 'streets' between the fuel piles.

KEY WORDS: Measurement, correlation, damage, radiation, wood, conflagration.

MINISTRY OF TECHNOLOGY AND FIRE OFFICES' COMMITTEE
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1. INTRODUCTION

This report describes the effect of exposing wood blocks to thermal radiation in the form of a skewed pulse similar to that received near a fire of the Flambeau type. Previous experiments[1] in which the intensity of radiation was held constant over the period of exposure of a block showed that the thermal damage sustained by a block or its surface temperature could be related to the incident intensity of radiation and the duration of exposure. Extensive measurements with these blocks were made at the Flambeau test fire 760-12-67, the results[2] being interpreted in terms of an 'equivalent intensity', that constant intensity which incident on a block for a period of 20 min would produce the same damage as was actually measured. However, it is known from thermopile measurements on fires of this kind[3,4] that the radiant intensity varies with time, rising rapidly to a peak and then falling off quite sharply at first and more slowly later to give a skewed pulse. The work described in this report was carried out to explore the behaviour of the wood blocks when exposed to such a pulse of radiation and to establish a relationship between the equivalent constant intensity and the peak intensity in the skewed pulse.

In addition, the calibration for a constant intensity of radiation has been extended to higher intensities.

2. RADIATION PULSE

Figure 1 shows a curve given by Countryman[3] for the intensity of radiation incident on a flat plate radiometer 90 ft from the centre of a fuel pile in test fire 760-1-64, a fire having fuel piles similar to those in 760-12-67 (but spaced much more widely). Also shown in Fig.1 is a plot of the generalised 'intensity' - time curve of Western[4], derived from both radiation and temperature data, and fitted to the radiometer data in Fig.1 by equating peak intensities and times for which half the peak intensity was exceeded. These two curves are reasonably similar and for the calibrations described in this report the step function shown in Fig.1 was taken to represent a pulse of this kind. The relative intensities of radiation and times for the various intervals are shown in Table 1, the overall time of exposure being 60 min. Maximum pulse heights between 0.6 and 6.7 W/cm^2 were taken.

Table 1

Steps used for simulation of radiant pulse

Time (min)	Intensity (fraction of peak intensity)
0 - 3	0.125
3 - 12	1.00
12 - 20	0.75
20 - 32	0.50
32 - 60	0.33

3. EXPERIMENTAL PROCEDURE

The wood blocks were cut from the batch of wood used for the measurements at Flambeau test fire 760-12-67 and were the same size and shape as in the previous experiments[1], i.e. blocks of Baltic Redwood with knot-free surfaces measuring about 96 x 96 x 47 mm and conditioned to approximately 10 per cent moisture content. As before[1], the radiant source was a 30 cm square gas-fired radiant panel in front of which was fitted a sliding platform; the radiation intensity was measured with a thermopile[5].

The initial reflectivity, R_I (measured with a reflectometer as before[1]), and the thickness of the block were first noted. The distances from the panel at which the radiation levels were at the required intensities were marked, the block put into position and slid to the appropriate mark at the given times. After the exposure the final reflectivity, R_F, or the final thickness of uncharred wood at the centre of the block (obtained by cutting the block in half) was measured.

4. RESULTS AND DISCUSSION

Table 2 shows the results obtained for various maximum pulse heights.

Table 2

Damage sustained by blocks exposed to skewed pulses of radiation

Peak intensity W/cm^2	Reflectivity ratio - R_F/R_I	Depth of charring (mm)
6.7	- -	34 36
5.0	- -	26 30
3.35	- -	27 24
2.52	- -	23.5 22
2.1	- - - -	18 13 3 1.5
1.68	0.14 0.13	- -
1.26	0.17	-
0.84	0.73 0.54	- -
0.63	0.89	-

The density of the charcoal layer, measured from a specimen which had a charcoal layer about 1 cm thick, was 0.14 g/cm^3.

Depth of char and R_F/R_I are shown in Figs 2 and 3 as a function of peak intensity. The shape of these curves is similar to that of the curves for constant intensities of radiation (Figs 2 and 5 of reference (1)) except that char depth increased more steeply below a peak intensity of 2 W/cm^2 and less steeply above it.

In order to make a better comparison between the effects of skewed and rectangular pulses of radiation, the calibration for a constant intensity was extended up to 6.7 W/cm^2 (see Fig.4). At the highest intensities the wood blocks sometimes ignited during exposure, however it appears from Fig.4 that this did not noticeably affect the rate of charring.

At an intensity of about 2 W/cm^2 either fast or slow charring could occur, depending on whether or not the charcoal formed by the pyrolysis ignited and burned giving a glowing patch on the surface. The higher rate of charring has been assumed to be applicable for the Flambeau test fire 760-12-67 since surface combustion of charcoal probably occurs most readily in a block exposed in a current of hot gases.

However, in a vitiated atmosphere the rate would probably be the slower one.

For each block, the constant intensity which, applied for 20 min, would have produced the same damage to the block was found using the relationships previously established[1] between rate of charring and intensity, and reflectivity ratio and intensity x $(\text{time})^{\frac{1}{3}}$. Figure 5 shows the relationship between the peak intensity of pulse and the constant intensity which would produce the same damage in the block.

At low intensities constant intensity is nearly proportional to peak intensity, the constant of proportionality being about 0.75, but above 1.7 W/cm^2 constant intensity increases very sharply relative to peak intensity and peak intensities between $2\frac{1}{2}$ and 5 W/cm^2 are between $2\frac{1}{2}$ and $1\frac{1}{2}$ times less than constant intensities producing the same char depth.

5. MEASUREMENTS AT FLAMBEAU TEST FIRE 760-12-67.

The new calibration has been applied to the measurements made at the Flambeau test fire 760-12-67[2], the damage sustained by the blocks being converted to peak intensity of pulse using the conversion values of Table 3. These were derived from Figs 2 and 3 (blocks scorched or charred) and from the rise in surface temperature at various times measured by means of a thermocouple for various incident intensities (temperature sensitive papers changed).

The overall pattern of intensity which emerged is very similar to that obtained using 20 min equivalent intensity[2] although there are differences in some of the numerical constants used to fit the data.

Table 3

Conversion of measured damage to peak intensity of pulse

Initial reflectivity taken as 48 per cent

Damage	Peak intensity W/cm^2	Damage	Peak intensity W/cm^2
U	$<$0.3	1C	1.7
1P	0.3	5C	1.8
2P	0.4		
3P	0.5	10C	1.9
4P 43R	0.6	15C	2.1
5P 38R	0.7	20C	2.3
		25C	3
33R	0.8	30C	5.5
		35C	6.7
26R	0.9	BO	$>$2.7
19R	1.0	(double-sided)	
12R	1.1	BO	$>$9
		(single-sided)	(extrapolated)
8R	1.2		
OR	1.2		

Notes: U denotes no response

nP denotes blackening of n sensitive papers

mR denotes scorching of the surface to a reflectivity of m per cent

pC denotes charring of the surface to a depth of p mm

BO denotes block burnt away completely

OR denotes surface judged by eye to have a very low reflectivity but without any charring.

A quadric regression fitted to the peak intensities registered by the piazza blocks (i.e. blocks placed horizontally on the ground at the centre of intersection of streets) gave elliptical contours of equal peak intensity very similar to those obtained previously for 20 min equivalent intensity (see Fig.5 of Ref.2). The centre of the elliptical contours was just NNW of pile G14; about midway between G14 and F14, and the minor axes were inclined at 44° to the lines of piles of equal number; these values are very close to those derived from 20 min equivalent intensity. The maximum peak intensity was 1.45 W/cm^2, a little higher than that for 20 min equivalent intensity, and the intensity fell to about 0.2 W/cm^2 at the SW corner.

The peak intensities for blocks in the other positions relative to the peak intensity registered by adjacent piazza blocks are shown in Table 4, and

Fig.6 shows the relation between this relative peak intensity and the configuration factor of the fuel pile at the block relative to the configuration factor at the adjacent piazza blocks. There are substantial uncertainties in the relative peak intensities of the most severely damaged blocks. This is because a high proportion of these blocks was burnt out, so that only a lower limit of intensity was obtained, rather than because the charring rate was variable (Section 4).

Figure 6 shows that although the relative peak intensity depends markedly on the relative configuration factor, there is not a 1:1 correspondence between these quantities, so that some other effect such as radiation from the flames, or convection transfer may also affect the response in the blocks.

Table 4

Peak intensities and configuration factors for various positions of wood blocks

Position	Peak intensity relative to that at piazza position	Configuration factor of fuel pile relative to that at piazza position
Piazza	1	1
Horizontal block on ground at street centre	1.5	2
Horizontal blocks on ground-mean across street	2	3.3
Vertical block 1 ft above ground at street centre	1.2 - 3	4.0
Vertical blocks 1 ft above ground - mean across street	1.5 - 5	4.6
Vertical block $3\frac{1}{2}$ ft above ground at street centre	2 - 6	4.3
Vertical block $3\frac{1}{2}$ ft above ground at piazza position	1.3	2.1
Vertical block $3\frac{1}{2}$ ft above ground in plane of edge of piles facing across piazza	1.1	1.5

6. CONCLUSIONS

1. The variation of surface reflectivity and depth of char with peak pulse intensity is given in Figs 2 and 3.

2. At about 2 W/cm^2 the charring rate of the blocks was variable. For the interpretation of the data from Flambeau test fire 760-12-67 the higher charring rate is probably applicable.

3. The peak intensity registered by blocks placed horizontally on the ground at the intersections of streets (piazzas) in test fire 760-12-67 exhibits a pattern of variation over the fire area almost exactly the same as that obtained for the 20 min equivalent intensity, the peak intensity values being slightly higher.

4. Correlations exist between the peak intensity registered by blocks in the other standard positions and those in the piazza positions.

7. REFERENCES

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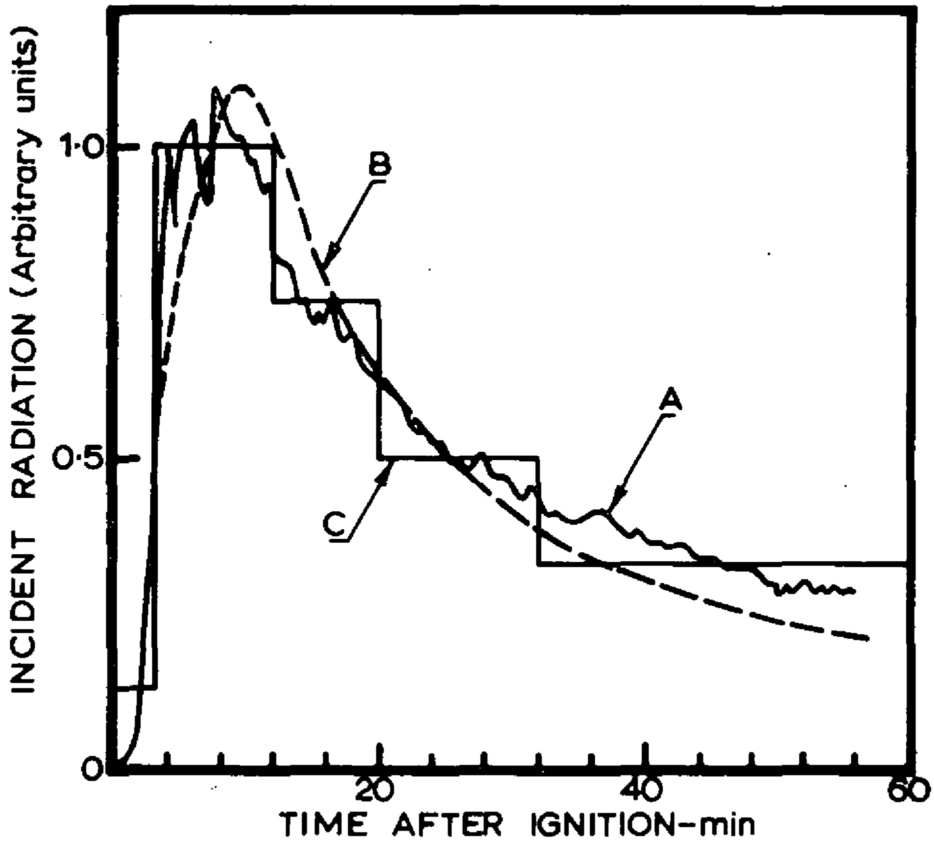


A Intensity incident on a flat plate radiometer[3] (Test fire 760-1-64)

B Generalised intensity/time curve of Western[4]

C Stepped pulse used for calibrations

FIG. 1. STEPPED PULSE SIMULATING OBSERVED RADIATION PULSES

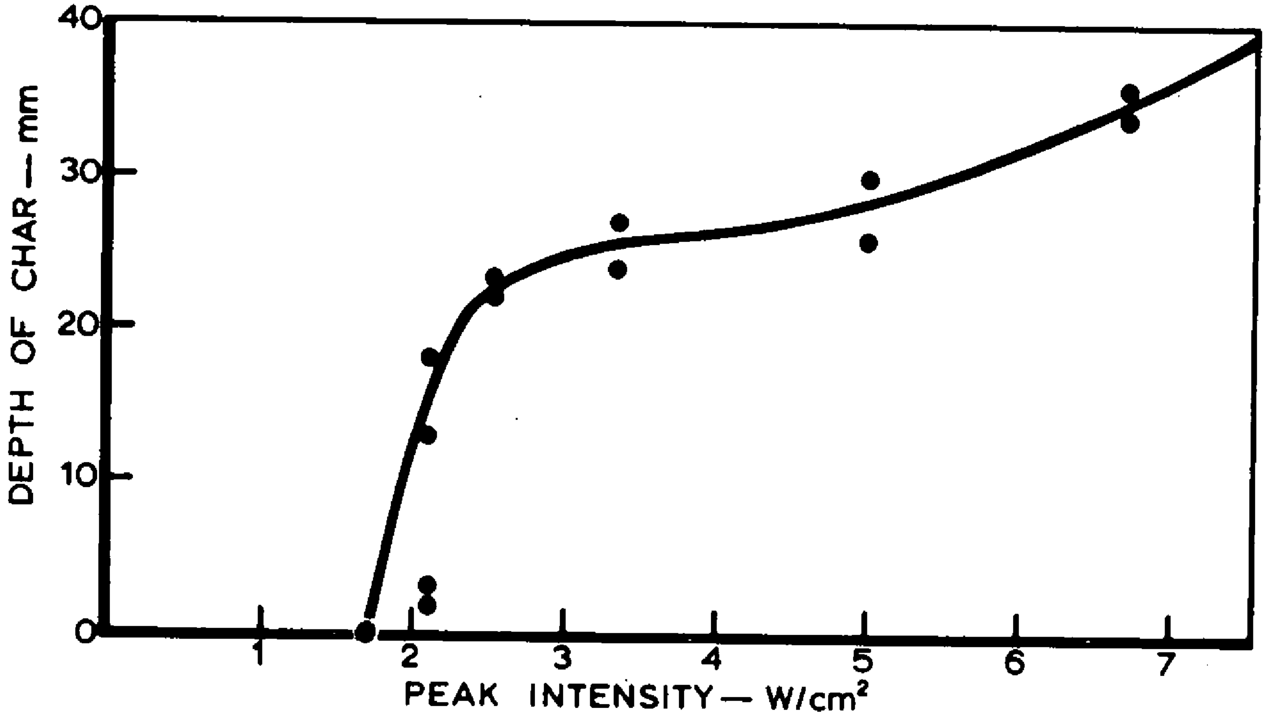


FIG. 2. CHAR PRODUCED BY SKEWED PULSE OF RADIATION

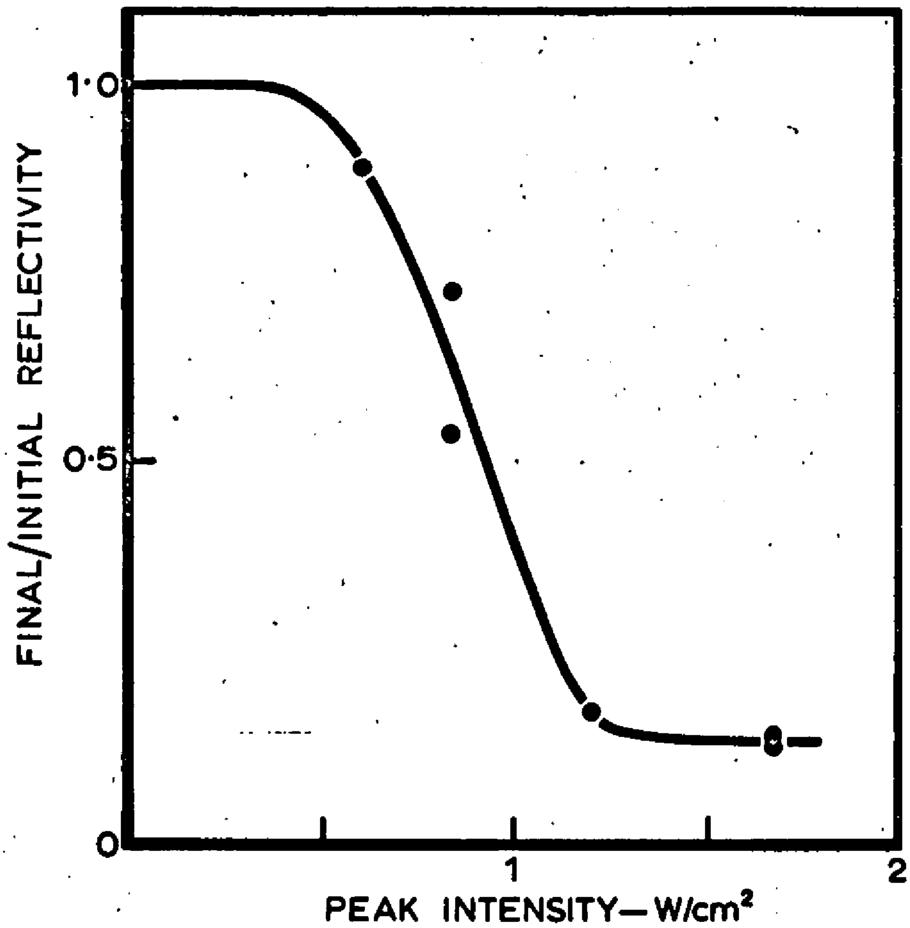


FIG. 3. REFLECTIVITY RATIO AND PEAK INTENSITY

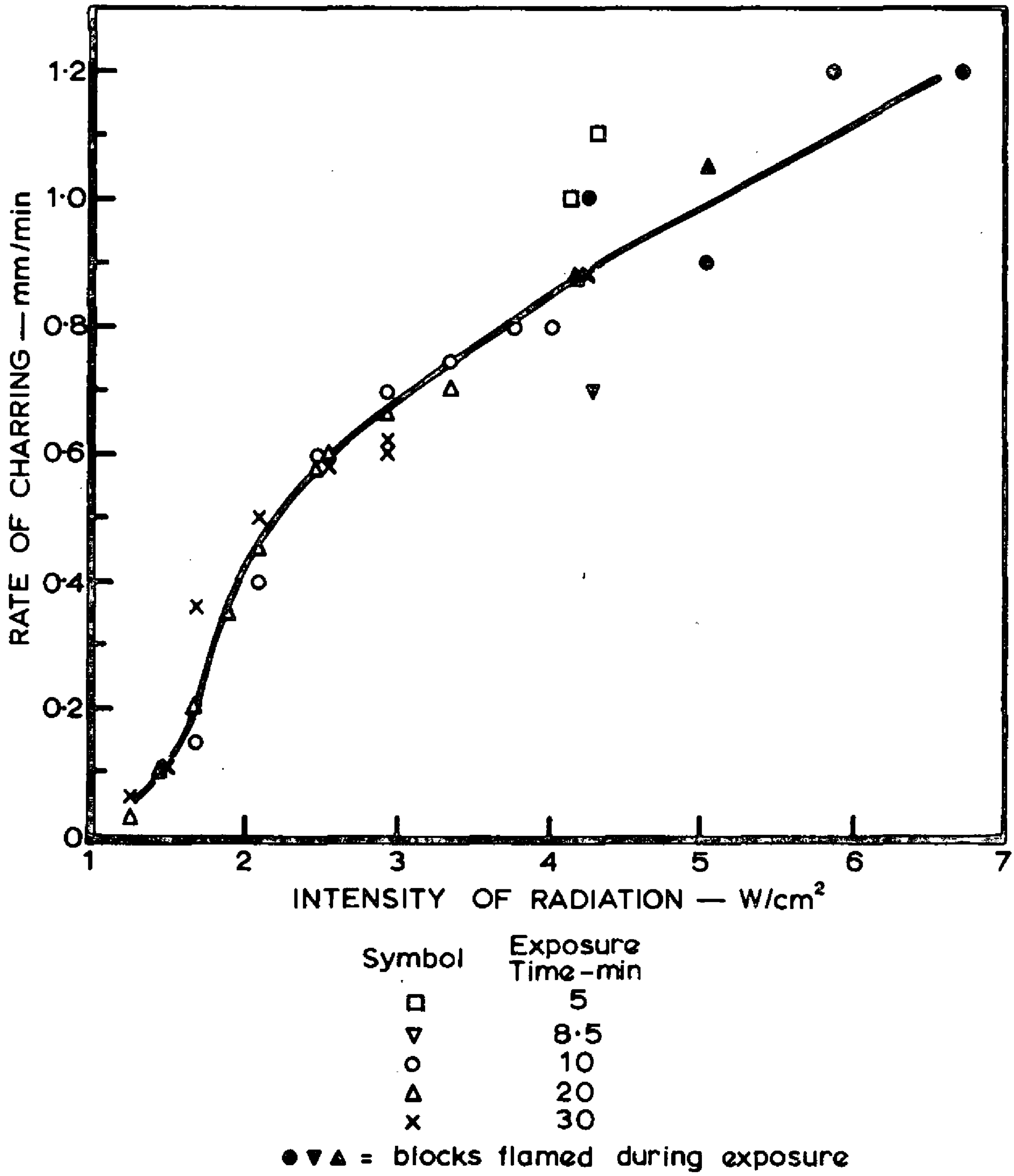
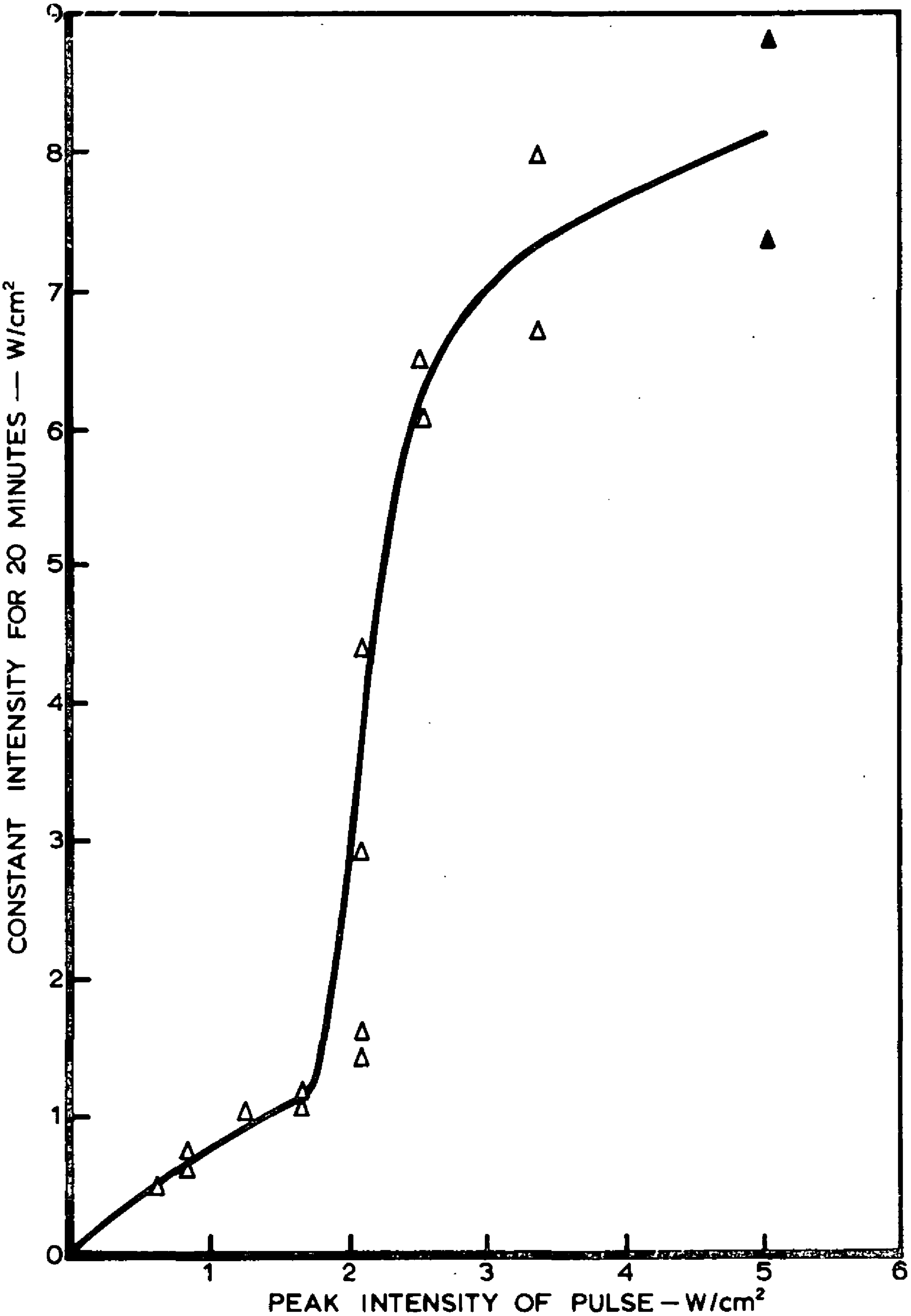


FIG. 4. RATE OF CHARRING AND INTENSITY (RECTANGULAR PULSE)



▲ Points obtained by extrapolation of Fig. 4.

FIG. 5. CONSTANT INTENSITY (20 MINUTE EXPOSURE) AND PEAK INTENSITY OF PULSE GIVING SAME THERMAL DAMAGE IN A WOOD BLOCK

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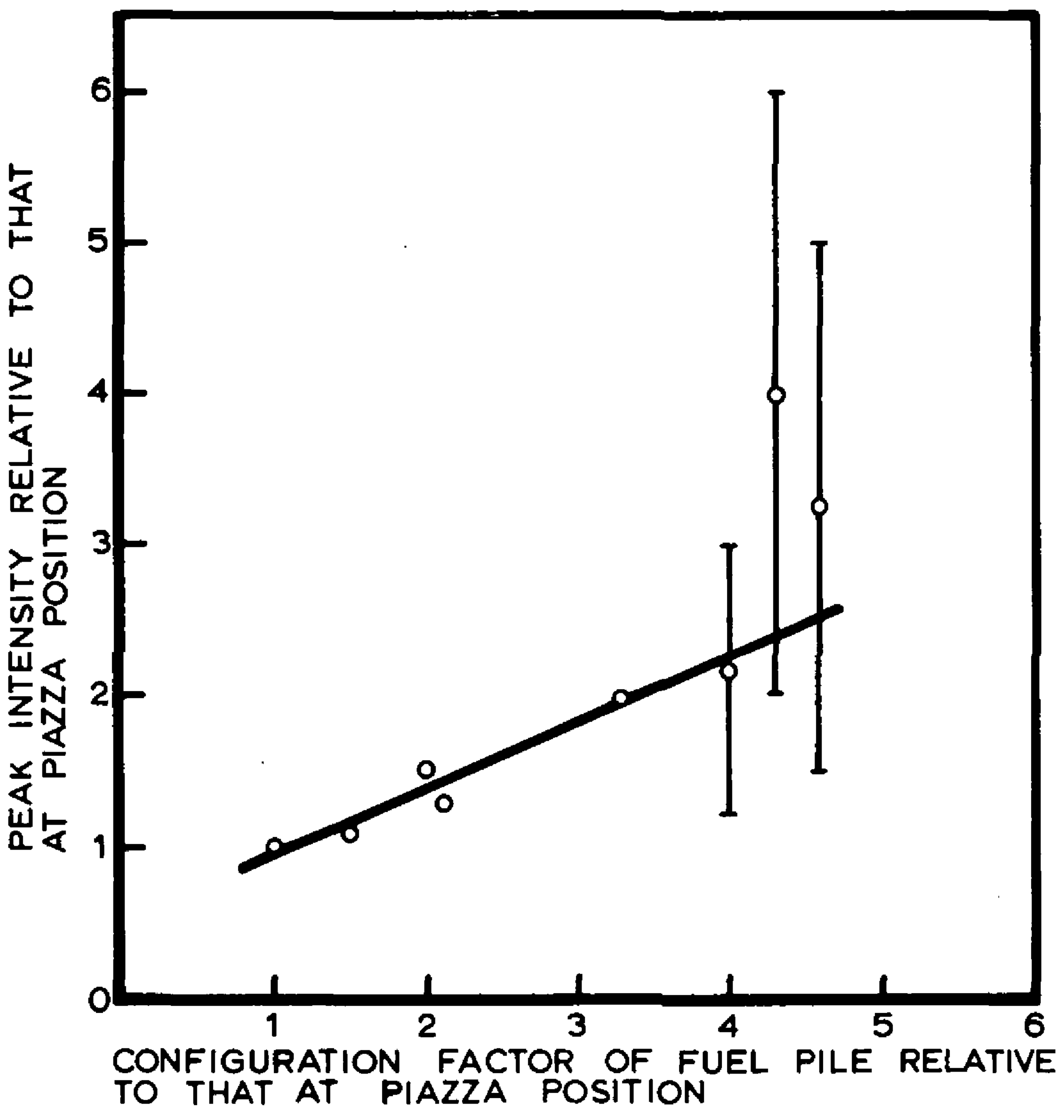

FIG. 6. PEAK INTENSITY AND CONFIGURATION FACTOR OF FUEL PILE