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

THE SIZE OF FLAMES FROM TWO VERY LARGE FIRES

by

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Summary

A correlation of flame height data for open fires in still air is discussed in the light of data available for two large controlled fires of 4 and 803 acres area.

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INTRODUCTION

Experiments with wood fires on a square base up to 5 ft side have shown that flame height 'L' can be related to the rate of weight loss 'R' and the linear side of the base 'D' by a correlation (1)(2) whose equation is

$$\frac{L}{D} = 4.4\left(\frac{10^6 R^2}{D^5}\right)^{0.305}$$

where D is in cm

and R is in gm/sec

in the range $0.2 < \left(\frac{10^6 R^2}{D^5}\right) < 20$ $gm^2\ cm^{-5} sec^{-2}$

Arguments have been given (2) for believing that this correlation which is a straight line on a bilogarithmic plot is convex upwards. In other words that linear extrapolation in either direction outside the above range of $\frac{10^6 R^2}{D^5}$ overestimates the value of $\frac{L}{D}$. It is desirable to obtain information on fires outside this range of $\frac{10^6 R^2}{D^5}$ but any attempt to reproduce very large fires on small scale is fraught with the following difficulty: For any given type of fuel and arrangement of it, one expects, in fires larger than a few feet in diameter that

$$R \propto D^2$$

the constant of proportionality being a rate of burning per unit area, which, even if a variable tends to be more constant than D^2.

Strictly the "independent" parameter is not $\frac{10^6 R^2}{D^5}$ but $\frac{R^2}{\rho^2 g D^5}$ where ρ is the fuel gas density here taken as a constant and g the acceleration due to gravity.

This parameter is $\frac{V^2}{gD}$ where V is the linear velocity of the gases as they leave the fuel bed. Now, reducing D demands a reduction in V to retain similarity and this leads to a reduction in Reynolds Number VD/ν where ν is the kinematic viscosity. To retain a Reynolds Number high enough for turbulent flow imposes a minimum value of D which is too large for laboratory experiments. Similarity might be achieved by using a liquid, e.g. hot water rising into a salt solution & studying concentration profiles instead of flame boundaries.

Experimental data for large fires

Two large scale tests have been reported in sufficient detail to permit some use to be made of them for correlation purposes. There are the Camp Parks fire (3) in the U.S.A. in 1960 and an experimental fire conducted in France in 1955 (4)(5). In such fires the rate of burning has to be estimated, and some error will be introduced by this. Also in the former, the flame height was of secondary interest, and the reported value is also liable to error.

Details of the two tests are given in Table I.

The values of $\frac{L}{D}$ and $(10^6 R^2/D^5)$ have been plotted in Fig.1 together with the laboratory correlation (1)(2) which has been extrapolated linearly as a dotted line. Despite the errors inherent in the method of evaluating $\frac{L}{D}$ and $10^6 R^2/D^5$ it is unlikely that the correct position of the points is anywhere but below the dotted line, i.e. the extrapolation does over-estimate L/D and a curve can be drawn through them and the laboratory correlation.

Discussion and Conclusions

The points lie near anough to the linear extrapolation to indicate a common correlation. The values of L/D for these two fires, are however, very small. L is only 11 m for a value of D of 1800 m in the French Test so that it is difficult to conceive of a continuous flame envelope above the ground. Any tendency for the flame zone to reach the ground at points within the fire base could be described as "incomplete merging" and would suggest that the flame height is equal to that from a fire of smaller D. Reducing D tends to raise plotted points at 45° in Fig.1 - towards larger values of L/D and larger values of $10^6 R^2/D^5$ thus bringing it nearer the straight line. The extent to which this happens is a feature of the fire dependent presumably on the same basic parameter R^2/D^5 wind turbulence and speed so that it may not be quite correct to regard the curve drawn through the points as universal. But with this one reservation the curve seems a tentative form of the correlation.

$$\frac{L}{D} = f\left(\frac{10^6 R^2}{D^5}\right)$$

holding good over a range of 8 orders of magnitude of R^2/D^5.

References.

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4. ETIENNE, Ct. Rapport de Mission - Incinération de la Lande de Trensacq, 13th April 1955. (Ministère de l'Interieur, Paris).
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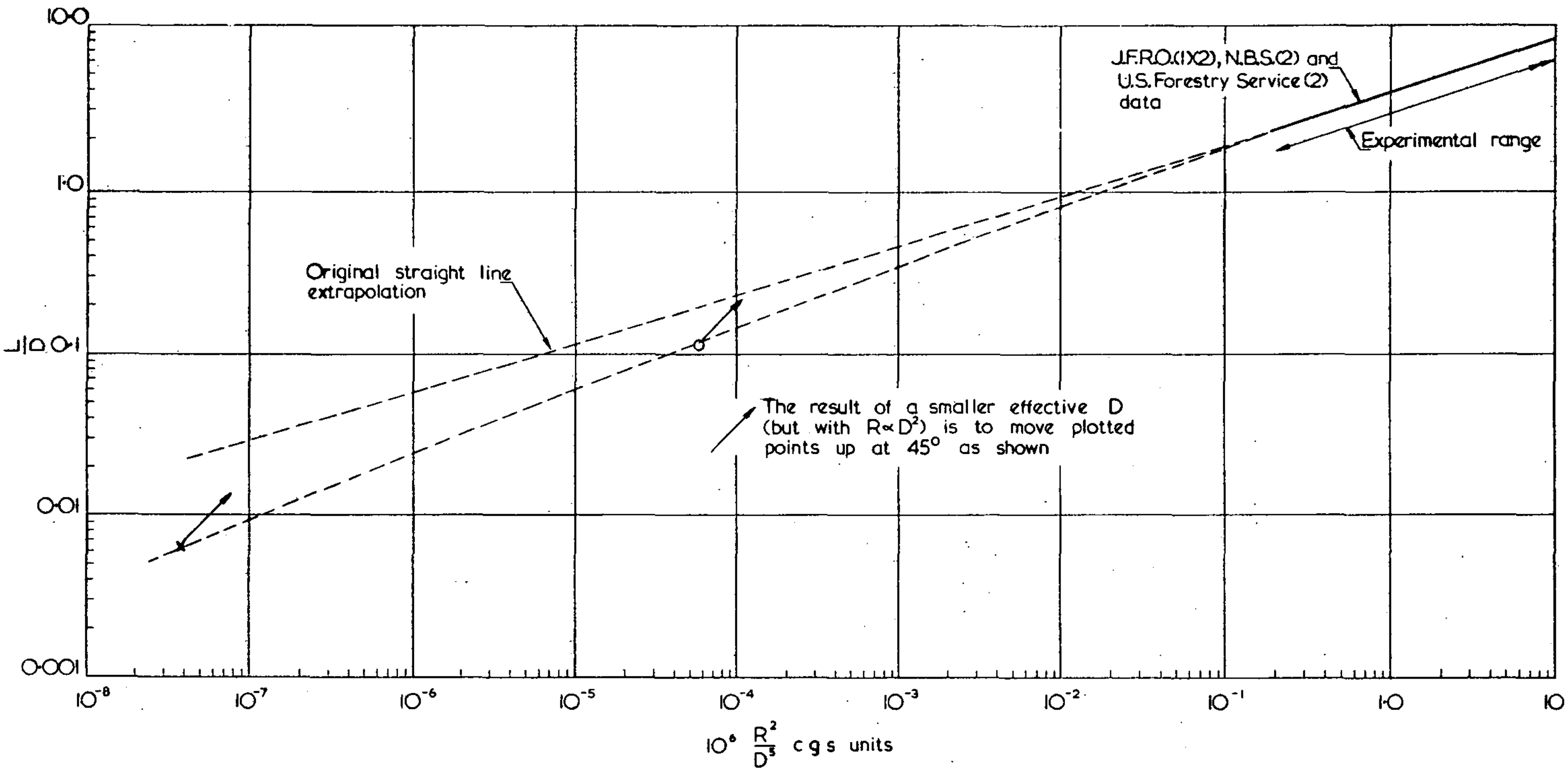
TABLE I

Details of large test fires

Type of information	Details of fire	
Fire & reference for source of details	Camps Park fire (ref 3)	Trensacq fire (ref 5)
Ground area within fire boundary - D^2	4 acres 162×10^6 cm^2	803 acres 325×10^8 cm^2
[illegible] D [illegible]	12.7×10^3 cm [illegible]	18×10^4 cm
Amount of fuel	"About half of 500 tons of assorted scrap timber" "About 2000 (U.S.) gallons of used crankcase oil" Oil assumed equal to 34 000 lb timber. Total: 594 000 lb.	"Small bushes and gorse" 1.7 kg/m^2 i.e. 550×10^4 kg
Arrangement of fuel	Stacks of timber in concentric squares (discontinuous)	Natural vegetation
Combustion time	After 20 mins some of the piles had stopped flaming	"About 35 mins"
How rate of burning 'R' is evaluated here	Assumed that 2/3 of calorific value released in the time of 20 mins	Assumed whole calorific value released in 35 mins because Faure's own calculations were derived this way.
Estimated rate of burning per unit area	$\frac{2}{3} \times \frac{594 \times 10^3 \times 454}{162 \times 10^6 \times 20 \times 60} =$ 0.93×10^{-3} g cm^{-2}sec^{-1}	$\frac{1.7 \times 10^3 \times 10^{-4}}{35 \times 60}$ $= 0.81 \times 10^{-4}$ g cm^{-2}s^{-1}
$\frac{10^6 R^2}{D^5}$	6.82×10^{-5} gm^{2}cm^{-5} sec^{-1}	3.65×10^{-8} g^{2}cm^{-5} sec^{-2}
Observation relating to wind	Because flames were still bent towards centre 7 min after ignition the effect of the wind was disregarded	The smoke plume rose vertically so effect of wind on flames neglected
Flame height	50 ft (15.2 m) Only observation [illegible] recorded. Account implies that there was a period when the flames from the individual stacks merged.	"10 - 12 m" Value taken as 11 m
$\frac{L}{D}$	0.12	0.0061



x — Etienne (1955) (803 acres) o — Broido and McMasters (4 acres)

FIG. 1. CORRELATION OF LABORATORY EXPERIMENTAL DATA AND TWO LARGE FIRES