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JOINT FIRE RESEARCH ORGANIZATION

SOME GENERAL QUESTIONS IN THE STUDY OF FIRES IN ROOMS

by

P.H. Thomas

Summary

This paper is a series of short notes on some of the basic problems involved in the study of room fires. A description of recent work[1] at the Joint Fire Research Organization has been circulated as C.I.B. papers CIB/CTF/60/10-11(U.K.). Some of the main results are summarised here.

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Ventilation and fireload controlled fires

(1) With relatively large windows there is a rapidly moving flame zone in the fire and there is little or no part of the enclosure where the gases may be regarded as nearly stationary. Hence the pressure differences do not attain the full value corresponding to the buoyancy head. Air is therefore entrained into the flame zone by eddies and the flow is not given by the same formulae as for small windows. The fire burns more nearly as in the open and the rate of burning is generally proportional to the available surface area. If the fuel is in the form of a crib there is a region where the design of the crib is not a controlling factor. Too loosely packed a crib loses heat too readily and too tightly packed a crib may reduce the available surface for burning.

For these fires it seems that the heat from the flames falling on the fuel surface is the controlling factor and it should be possible, once the effect of heat on the decomposition of wood is understood quantitively to predict fuel burning rates.

(2) With relatively small windows the rate of burning in the period after "flashover" is, in general, proportional to the air flow through the windows.

This flow is induced by the pressure differences which arise from the difference in weight between equal heights of the outside air and the hot gases in the room. The greater the fire load the longer the fire lasts.

(3) The fire with restricted ventilation is less well understood despite certain apparent simplicities in the results. It is reasonable to assume the overall fuel/air ratio is approximately constant but in theory the air flow through the window is not the only air involved in combustion. Any flame outside the window entrains additional air and there is no immediately obvious basic reason to explain the observation that these flames are not large.

One possible factor which prevents the gross burning rate increasing in proportion to the fuel surface is that any tendency to increase this rate may tend to reduce the heat transfer to unit area of fuel and hence the rate of loss in weight per unit fuel surface. The maximum velocity head of air is proportional to the height H of the windows and the maximum velocity head of the fuel gases is proportional to $(R/A_W)^2$ where R is the gross rate of burning and A_W the windows area. If the latter were large compared with the air velocity head combustion could not occur within the enclosure and there would be insufficient heat received by the fuel. Hence considerations of mixing place an upper limit on the ratio $R/A_W\sqrt{H}$.

It is therefore possible that the observed burning behaviour $R \propto A_W\sqrt{H}$ arises from mixing considerations.

Flames

The size of flames is important in the study of models because (a) their size determines the radiation on to the fuel and hence the rate of burning and (b) the flame radiation is a hazard to nearly combustible material.

It is possible to derive theoretically a law for any one fuel.

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

where H is flame height
D a characteristic linear dimension
R is rate of burning involved in the flame

Mean flame temperatures, gas densities and composition are assumed constant here.

The height of flames from open cribs are being studied and appear to follow this relation. Flames from cubes with one side open follow an approximate power law

$$\frac{H}{D} \propto \left(\frac{R^2}{D^5}\right)^{\frac{1}{3}}$$

where D is the cube dimension

If R is proportional to the width then for a rectangular window we should expect

$$\frac{H}{D} \quad \left(\frac{R'^2}{D^3}\right)^{\frac{1}{3}}$$

where R' is rate of burning per unit length of window, i.e. $H \propto R'^{\frac{2}{3}}$ independently of D. This law can be derived directly assuming the flame from a line source has a triangular cross section and that air is entrained into the flame with a mean velocity proportional to $\sqrt{H}$. The flame surface per unit length is proportional to H. The air flow per unit length proportional to $H^3/2$ and since this must, for a given fuel, be proportional to R we have the above law.

Reference

(1) THOMAS P.H. Studies of Fires in Buildings using Models. <u>Research</u> 1960 <u>13</u> Part 1 69-77, Part 2 87-93.