PRELIMINARY RESULTS

of

EXPERIMENTAL FIRES IN ENCLOSURES

by

Daniel Gross
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A complete listing of the Bureau's publications can be found in National Bureau of Standards Circular 460, Publications of the National Bureau of Standards, 1901 to June 1947 ($1.25), and the Supplement to National Bureau of Standards Circular 460, July 1947 to June 1957 ($1.50), and Miscellaneous Publication 240, July 1957 to June 1960 (Includes Titles of Papers Published in Outside Journals 1950 to 1959) ($2.25); available from the Superintendent of Documents, Government Printing Office, Washington 25, D.C.
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ABSTRACT

Preliminary results are presented of experimental studies of the burning of fuel within small enclosure models. It was found that on decreasing the size of the ventilation opening in the wall of such an enclosure, not only is the burning rate varied, but on reaching a critical opening size, the character of the combustion reaction appears to be abruptly modified in such a manner as to discontinuously increase the rate of combustion. Further reductions of opening size result in further orderly reductions of combustion rate.

Tests have been conducted in which cribs of fiberboard have been burned in enclosures and the effect on the rate of burning of the size, shape and position of windows studied. The majority of tests were performed using a single full width (horizontal) or full height (vertical) centrally located window in an insulated steel box. Several tests with off-center and dual-opening windows were also made. Fiberboard was used because of its rapid flaming characteristics and the crib was constructed so that the spacing between sticks was three times the stick width. The test was started by igniting kerosene-soaked wicks placed in the openings of the bottom row of sticks. The crib was supported about 3 stick widths above the enclosure floor and was located between the center and rear of the box. Weight-time data was obtained by use of a platform balance scale on which the entire assembly was mounted at least 1/2 meter above the floor level. The rate of burning was taken as the mean rate of weight loss from 80 to 30% of the original crib weight. Temperatures were measured at several locations within the box by means of bare, unshielded No. 24 gage (0.020 in.) chromel-alumel thermocouples.
The results are summarized in Fig. 1 for a box 50 by 50 by 100 cm and in Fig. 2 for a box approximately 15 by 15 by 30 cm. Tests are planned for an enclosure approximately 150 by 150 by 300 cm.* It may be observed that for each enclosure, a limiting value of \( A \sqrt{H} \) was reached beyond which the window no longer limited and the rate of burning had a constant value equal (very nearly) to the rate of burning of the crib in the open. This point corresponded for the 50 cm box to about 50% of the box width for a central vertical window and 60% for a central horizontal window.

A characteristic transition region was found for each enclosure in which the data line for small window openings was shifted upward. The data for this line has been extended to include extremely small openings where an essentially pyrolytic reaction was occurring with the absence of visible flaming. In such cases, repeated and prolonged ignition was required to elevate the enclosure temperature to that required for sustaining the pyrolysis.

It is possible to interpret the results in terms of a simple analysis of wood-burning such as that presented by Kawagoe [1]. From the basic chemistry of cellulose burning and consideration of fluid flow through an opening, the fuel combustion rate \( W \) was shown to be a function of the coefficient of discharge \( C \), the opening area \( A \), the effective height of the opening \( H \), the temperature difference between the enclosure and the surroundings, and the volume of exhaust gas per unit weight of fuel \( G \), as follows:

\[
W \propto C \sqrt{\frac{\Delta T}{T_0}} \frac{A \sqrt{H}}{G}
\]

\( G \) is a function of the temperature in the box \( T \), the fraction of complete combustion \( x \) and the amount of excess air \( n \). The location of the neutral zone determines the effective height of the opening.

For window openings greater than that at the transition point, the temperature was practically constant (see Figs. 1 and 2) and there was apparently sufficient (excess) air for complete combustion. However, for window openings at or below the transition point, the pattern of burning changed and the mean temperature within the enclosure decreased with the window opening. The slope of the line encompassing data below the transition point adjusted to unity when the temperature difference correction was applied to the \( A/H \) product for the 50 cm box.

*Data for two horizontal windows located at top and bottom are also included, using for \( H \) the full height of the box.
Changes observed during the tests with small window openings could bring about a considerably lower exhaust gas volume $G$ compared to those tests with greater window openings. Below the transition point, the deficiency of air prevented the maintenance of complete combustion within the crib and flaming was shifted from within the crib to predominantly in front of or behind the crib. The flames were also observed to oscillate or to pulsate strongly between the window and the crib, sometimes burning exclusively at the window opening. The imperfect combustion also changed the composition of the exhaust products. These changes, which were observed at and below the transition point, serve to reduce the value of $G$ significantly. Actual measurements of the velocity at the opening and the changes in exhaust gas composition are planned.

References

FIG. 1. RATE OF BURNING AND TEMPERATURE, 50 CM BOX
INITIAL CRIB WEIGHT 3180 G
FIG. 2  RATE OF BURNING AND TEMPERATURE, 15 CM BOX

INITIAL CRIB WEIGHT 265 G
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