NATIONAL BUREAU OF STANDARDS REPORT

7327

PRELIMINARY RESULTS

of

EXPERIMENTAL FIRES IN ENCLOSURES

by

Daniel Gross

U. S. DEPARTMENT OF COMMERCE
NATIONAL BUREAU OF STANDARDS

THE NATIONAL BUREAU OF STANDARDS

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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 characterstics 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:

$$W \propto \frac{C\sqrt{\frac{\Delta T}{T_0}}\; A\sqrt{H}}{G}$$

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 $A\sqrt{H}$ product for the 50 cm box.

*Data for two horizontalwindows 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

[1] Kawagoe, K. Fire Behavior in Rooms, Building Research Institute Report No. 27, Ministry of Construction, Tokyo, Japan, Sept. 1958.

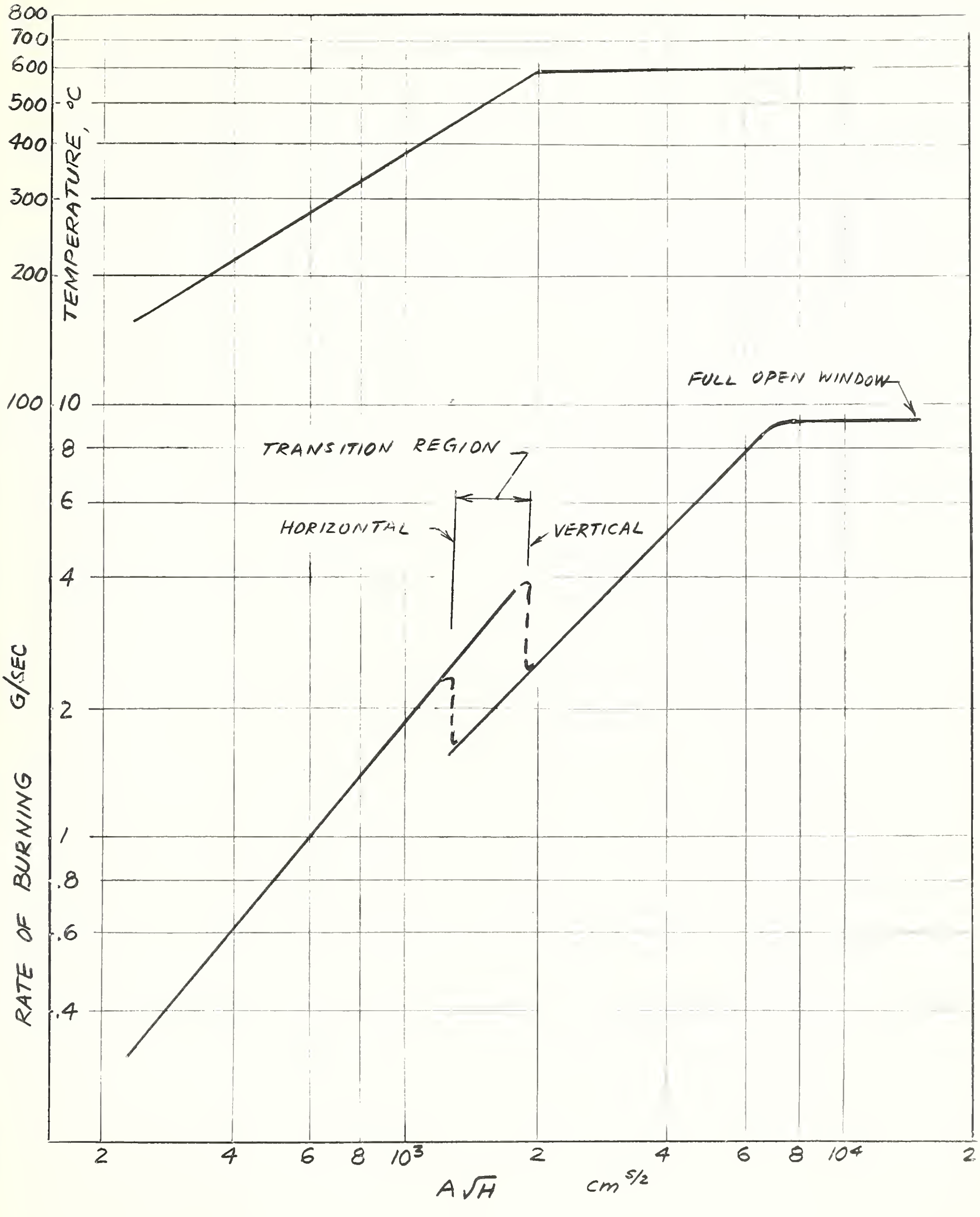

FIG. 1. RATE OF BURNING AND TEMPERATURE, 50 CM BOX
INITIAL CRIB WEIGHT 3180 G

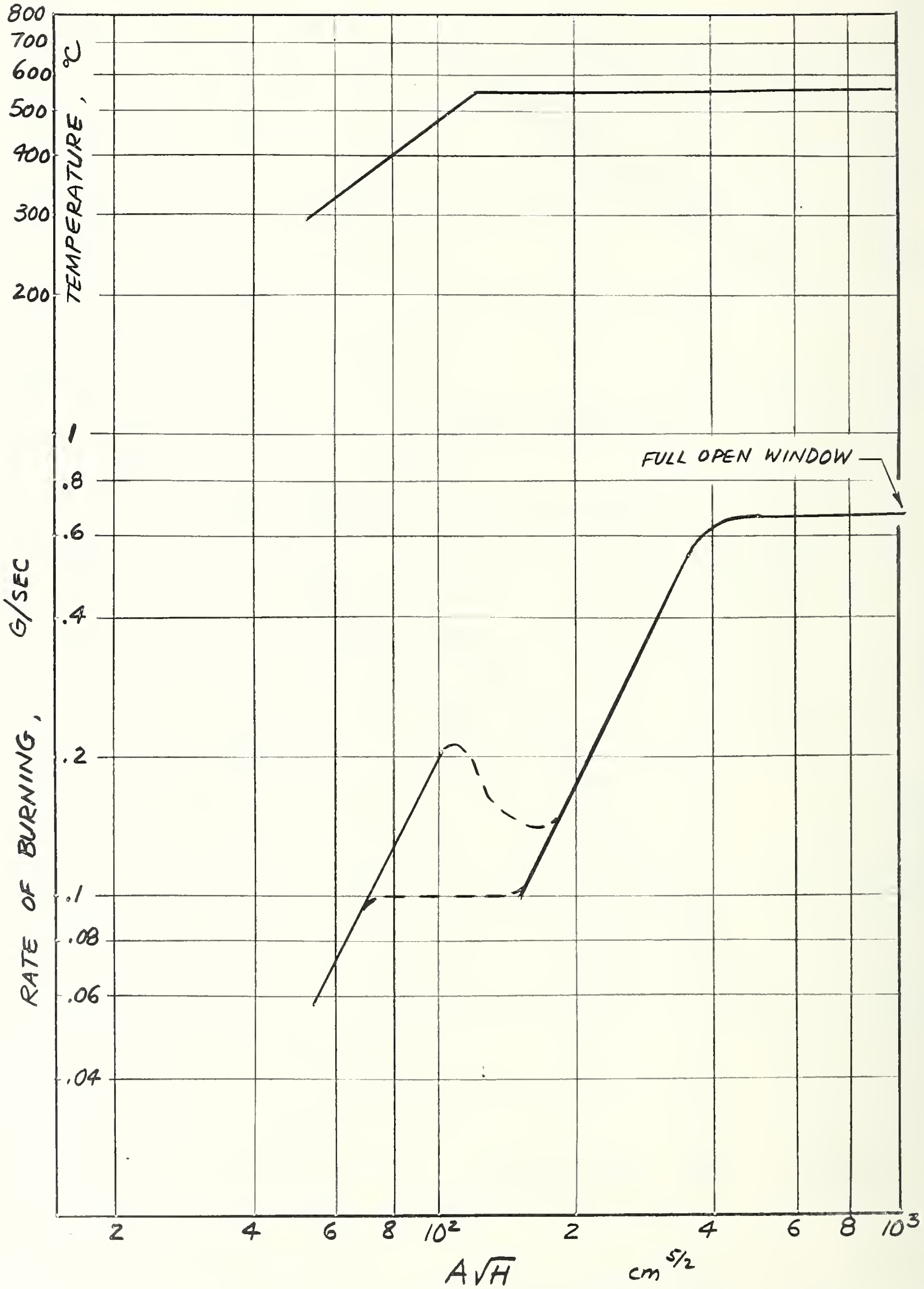

FIG. 2 RATE OF BURNING AND TEMPERATURE, 15 CM BOX
. INITIAL CRIB WEIGHT 265 G

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Metrology. Photometry and Colorimetry. Refractometry. Photographic Research. Length. Engineering Metrology. Mass and Scale. Volumetry and Densimetry.

Heat. Temperature Physics. Heat Measurements. Cryogenic Physics. Equation of State. Statistical Physics.

Radiation Physics. X-ray. Radioactivity. Radiation Theory. High Energy Radiation. Radiological Equipment. Nucleonic Instrumentation. Neutron Physics.

Analytical and Inorganic Chemistry. Pure Substances. Spectrochemistry. Solution Chemistry. Standard Reference Materials. Applied Analytical Research.

Mechanics. Sound. Pressure and Vacuum. Fluid Mechanics. Engineering Mechanics. Rheology. Combustion Controls.

Organic and Fibrous Materials. Rubber. Textiles. Paper. Leather. Testing and Specifications. Polymer Structure. Plastics. Dental Research.

Metallurgy. Thermal Metallurgy. Chemical Metallurgy. Mechanical Metallurgy. Corrosion. Metal Physics. Electrolysis and Metal Deposition.

Mineral Products. Engineering Ceramics. Glass. Refractories. Enameled Metals. Crystal Growth. Physical Properties. Constitution and Microstructure.

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Applied Mathematics. Numerical Analysis. Computation. Statistical Engineering. Mathematical Physics. Operations Research.

Data Processing Systems. Components and Techniques. Digital Circuitry. Digital Systems. Analog Systems. Applications Engineering.

Atomic Physics. Spectroscopy. Infrared Spectroscopy. Solid State Physics. Electron Physics. Atomic Physics.

Instrumentation. Engineering Electronics. Electron Devices. Electronic Instrumentation. Mechanical Instruments. Basic Instrumentation.

Physical Chemistry. Thermochemistry. Surface Chemistry. Organic Chemistry. Molecular Spectroscopy. Molecular Kinetics. Mass Spectrometry.

Office of Weights and Measures.

BOULDER, COLO.

Cryogenic Engineering. Cryogenic Equipment. Cryogenic Processes. Properties of Materials. Cryogenic Technical Services.

Ionosphere Research and Propagation. Low Frequency and Very Low Frequency Research. Ionosphere Research. Prediction Services. Sun-Earth Relationships. Field Engineering. Radio Warning Services.

Radio Propagation Engineering. Data Reduction Instrumentation. Radio Noise. Tropospheric Measurements. Tropospheric Analysis. Propagation-Terrain Effects. Radio-Meteorology. Lower Atmosphere Physics.

Radio Standards. High Frequency Electrical Standards. Radio Broadcast Service. Radio and Microwave Materials. Atomic Frequency and Time Interval Standards. Electronic Calibration Center. Millimeter-Wave Research. Microwave Circuit Standards.

Radio Systems. High Frequency and Very High Frequency Research. Modulation Research. Antenna Research. Navigation Systems.

Upper Atmosphere and Space Physics. Upper Atmosphere and Plasma Physics. Ionosphere and Exosphere Scatter. Airglow and Aurora. Ionospheric Radio Astronomy.

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