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NATIONAL BUREAU OF STANDARDS REPORT

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NAVAL SHIPBOARD FIRE RISK CRITERIA
4TH PROGRESS REPORT
HEAT RELEASE RATE CALORIMETER

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NBS

U.S. DEPARTMENT OF COMMERCE

NATIONAL BUREAU OF STANDARDS

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The National Bureau of Standards [1] was established by an act of Congress March 3, 1901. Today, in addition to serving as the Nation's central measurement laboratory, the Bureau is a principal focal point in the Federal Government for assuring maximum application of the physical and engineering sciences to the advancement of technology in industry and commerce. To this end the Bureau conducts research and provides central national services in four broad program areas. These are: (1) basic measurements and standards, (2) materials measurements and standards, (3) technological measurements and standards, and (4) transfer of technology.

The Bureau comprises the Institute for Basic Standards, the Institute for Materials Research, the Institute for Applied Technology, the Center for Radiation Research, the Center for Computer Sciences and Technology, and the Office for Information Programs.

THE INSTITUTE FOR BASIC STANDARDS provides the central basis within the United States of a complete and consistent system of physical measurement; coordinates that system with measurement systems of other nations; and furnishes essential services leading to accurate and uniform physical measurements throughout the Nation's scientific community, industry, and commerce. The Institute consists of an Office of Measurement Services and the following technical divisions:

Applied Mathematics—Electricity—Metrology—Mechanics—Heat—Atomic and Molecular Physics—Radio Physics [2]—Radio Engineering [2]—Time and Frequency [2]—Astrophysics [2]—Cryogenics.[2]

THE INSTITUTE FOR MATERIALS RESEARCH conducts materials research leading to improved methods of measurement standards, and data on the properties of well-characterized materials needed by industry, commerce, educational institutions, and Government; develops, produces, and distributes standard reference materials; relates the physical and chemical properties of materials to their behavior and their interaction with their environments; and provides advisory and research services to other Government agencies. The Institute consists of an Office of Standard Reference Materials and the following divisions:

Analytical Chemistry—Polymers—Metallurgy—Inorganic Materials—Physical Chemistry.

THE INSTITUTE FOR APPLIED TECHNOLOGY provides technical services to promote the use of available technology and to facilitate technological innovation in industry and Government; cooperates with public and private organizations in the development of technological standards, and test methodologies; and provides advisory and research services for Federal, state, and local government agencies. The Institute consists of the following technical divisions and offices:

Engineering Standards—Weights and Measures — Invention and Innovation — Vehicle Systems Research—Product Evaluation—Building Research—Instrument Shops—Measurement Engineering—Electronic Technology—Technical Analysis.

THE CENTER FOR RADIATION RESEARCH engages in research, measurement, and application of radiation to the solution of Bureau mission problems and the problems of other agencies and institutions. The Center consists of the following divisions:

Reactor Radiation—Linac Radiation—Nuclear Radiation—Applied Radiation.

THE CENTER FOR COMPUTER SCIENCES AND TECHNOLOGY conducts research and provides technical services designed to aid Government agencies in the selection, acquisition, and effective use of automatic data processing equipment; and serves as the principal focus for the development of Federal standards for automatic data processing equipment, techniques, and computer languages. The Center consists of the following offices and divisions:

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THE OFFICE FOR INFORMATION PROGRAMS promotes optimum dissemination and accessibility of scientific information generated within NBS and other agencies of the Federal government; promotes the development of the National Standard Reference Data System and a system of information analysis centers dealing with the broader aspects of the National Measurement System, and provides appropriate services to ensure that the NBS staff has optimum accessibility to the scientific information of the world. The Office consists of the following organizational units:

Office of Standard Reference Data—Clearinghouse for Federal Scientific and Technical Information [3]—Office of Technical Information and Publications—Library—Office of Public Information—Office of International Relations.

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[1] Headquarters and Laboratories at Gaithersburg, Maryland, unless otherwise noted; mailing address Washington, D.C. 20234.
[2] Located at Boulder, Colorado 80302.
[3] Located at 5285 Port Royal Road, Springfield, Virginia 22151.

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NAVAL SHIPBOARD FIRE RISK CRITERIA
4TH PROGRESS REPORT
HEAT RELEASE RATE CALORIMETER

by
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1.0 BACKGROUND

Two important characteristics of a material that can be used to evaluate its fire hazard are the amount of heat it can contribute to a fire; and the rate at which this heat would be released in a fire. The first property is measured in the standard potential heat test developed at NBS for small specimens.

No standard test has been developed for the rate of heat release of materials. The purpose of this project is to develop such a test. This work involves (1) the building of an apparatus to accurately measure the heat release rate of building materials and combinations of building materials, in various configurations characteristic of their use; and (2) an investigation of the characteristics of the fire environment to determine the best test conditions to employ. This test will be used to set limits on acceptable values of the heat release rate and the potential heat.

The severity of a real fire will depend on some combination of these two properties for all the materials simultaneously involved. A burning rate test which lasts over the entire burning period of the material will also yield a value for the potential heat. Thus these two properties can be measured on the same sample with the same test apparatus.

Our plans call for a test facility which would accommodate 18 by 24 inch specimens. At the present time the effort on this project has been directed toward the building of a prototype of the test apparatus.

A model of a rate of release calorimeter was built at NBS in 1962. It consisted of a combustion chamber in which a 12 by 12 inch test specimen or a noncombustible reference specimen formed one wall. The adjacent sides were porous gas fired panels which served as sources of thermal radiation. A fixed amount of air was added to the hot combustion products and the temperature of the mixture was monitored as it passed up the flue. An attempt was made to determine the heat release rate from the temperature rise when the test specimen replaced a noncombustible reference specimen.

The initial tests showed the time response to be too slow and the heat losses to be too great. There was also a problem of sealing the test specimen to the wall of the chamber.

2.0 DESIGN OF CALORIMETER

Work on the calorimeter was resumed in mid August 1969. The early work on the NBS heat release calorimeter was reviewed and novel approaches were considered. It was decided to build a model capable of measuring the heat release rate on 4-1/2 by 6 inch specimens. A variety of materials would be tested with this device in order to gain information on the performance of the system before designing the full-scale instrument which would be capable of handling test specimens up to 18 by 24 inches in size. The prototype, shown photographically in Figures 1a, b, and c and schematically in Figure 2, is an alteration after the original heat release rate calorimeter with the following refinements:

1. An auxiliary burner is located above the specimen to burn off any of the combustible vapors or smoke which would otherwise pass up the flue without releasing all of their potential heat.

2. The temperature of the flue gases is held constant during the test by controlling the flow to the auxiliary burner. The decrease in the gas flow is used as a measure of the heat release rate of the test specimen. This method overcomes the thermal inertia of the system which made the time response of the original calorimeter intolerably low. This method has the additional advantage of being insensitive to heat losses, provided that they are not too large.

3. The specimen is located in the middle of the chamber instead of forming a part of one of the walls. This eliminates the problem of sealing the specimen to the wall and also releases the hot gases some distance from the walls thereby minimizing the heat losses.

4. The heat losses are further reduced by rerouting the hot gases so that they will be thoroughly mixed and their temperature will be measured before they come in contact with an external wall.

5. The irradiance on the test specimen is made more uniform by utilizing three rather than two gas-fired panels.

6. A pilot flame is introduced near the base of the specimen to induce flaming. The heat fed back to the surface from the flame would increase the heat release rate of the specimen to its highest value for the given irradiance.

7. The calorimeter is calibrated by adding known flow rates of methane to the pilot burner thereby making the system independent of the properties of the city gas so long as they remain constant during the test.

3.0 INITIAL TESTS

Preliminary measurements were made on 3/4 inch plywood specimens. The irradiance on the specimen, determined from the rate of temperature rise of a blackened copper disk located in the plane of the sample, was about 5 watts/cm^2. Enough excess air was mixed with the combustion products to lower the flue gas temperature to 500°C.

As an experiment the burning rate was determined from the rise in temperature of the flue gases after the introduction of a specimen. In order to determine the time constant of the system a steady flow of gas was suddenly introduced at the pilot burner below a noncombustible reference specimen. It required about seven minutes for the flue gas to reach a new temperature plateau. This mode of operation is thus too slow to use for most burning rate determinations.

In the normal mode of operation the flue temperature is held constant by a temperature controller which automatically adjusts the fuel supply to an auxiliary burner. The burning rate of the specimen is then proportional to the reduction in the flow rate to the auxiliary burner. This procedure eliminates the thermal inertia of the system and thus shortens the time constant considerably. Actual measurements of the time response for this mode must await the installation of the automatic control equipment which is now on order.

The heat release rate per unit area was determined for several 3/4 inch plywood specimens by controlling the auxiliary burner flow manually. A typical curve is shown in Figure 3. The peak rate was about 15 watts/cm^2, and the integral of the burning rate over the total burning time, which was about an hour, was roughly in agreement with the heat of combustion of wood.

4.0 FUTURE PLANS

The automatic control equipment and the recording flowmeter, both of which are on order, will be installed. An individual flow meter will be placed in the sample air line so that the burning rate can be determined as a function of air velocity through the lower panel. Burning rate versus irradiance will be measured by adjusting the gas flow to the radiant panels. The completeness of the combustion in the calorimeter will be checked with CO and CO_2 analyzers which will sample the flue gases.

Measurements will be conducted on materials covering a large range of burning rates. Necessary modifications will be made to the equipment to achieve the required sensitivity and time response. When satisfactory performance has been achieved with the model, the design will proceed for the construction of an instrument capable of measuring specimens 18 inches by 24 inches.

Parallel to the work on the instrument, consideration will be given to the design of a full scale test: to relate the burning rate and the potential heat measurements from the calorimeter to the performance of the materials in a real fire.

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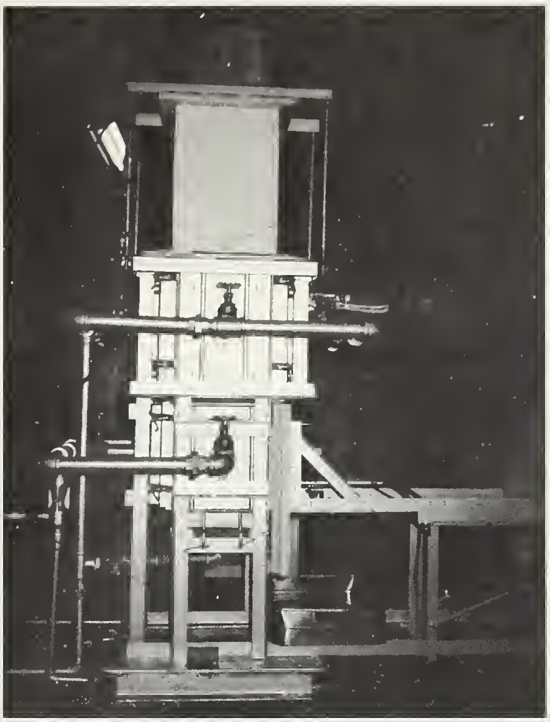


Figure 1(a) - Heat Release Rate Calorimeter in Operation

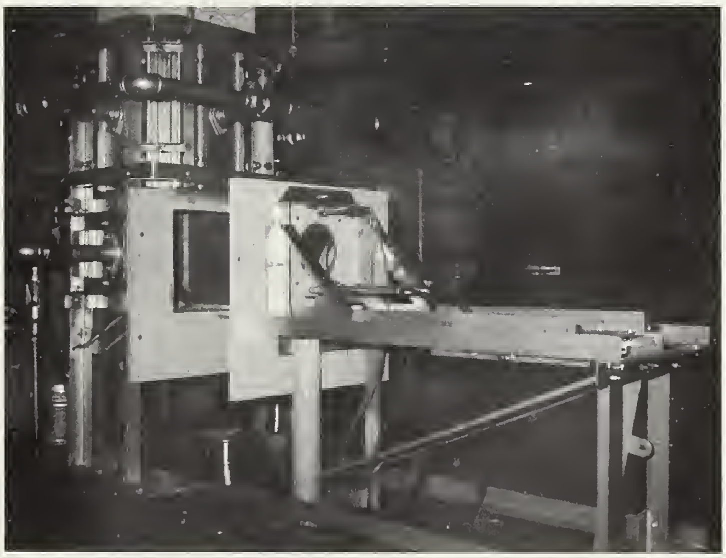


Figure 1(b) - Heat Release Rate Calorimeter with Door Open and Combustion Chamber Exposed

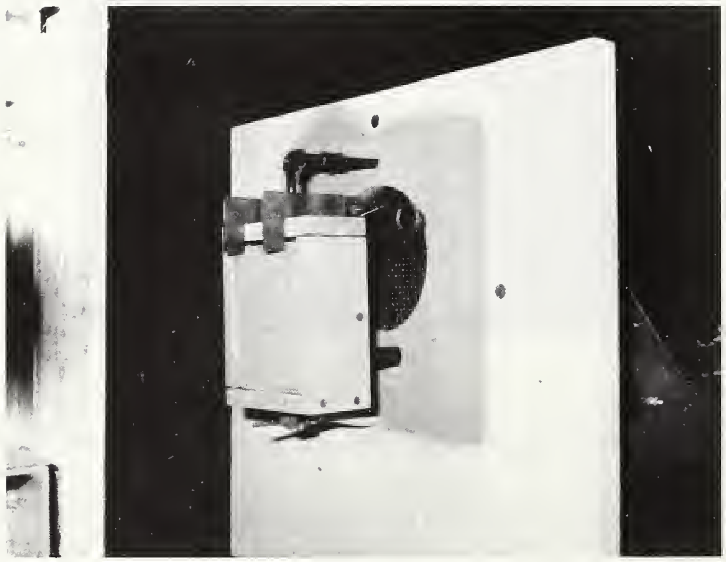
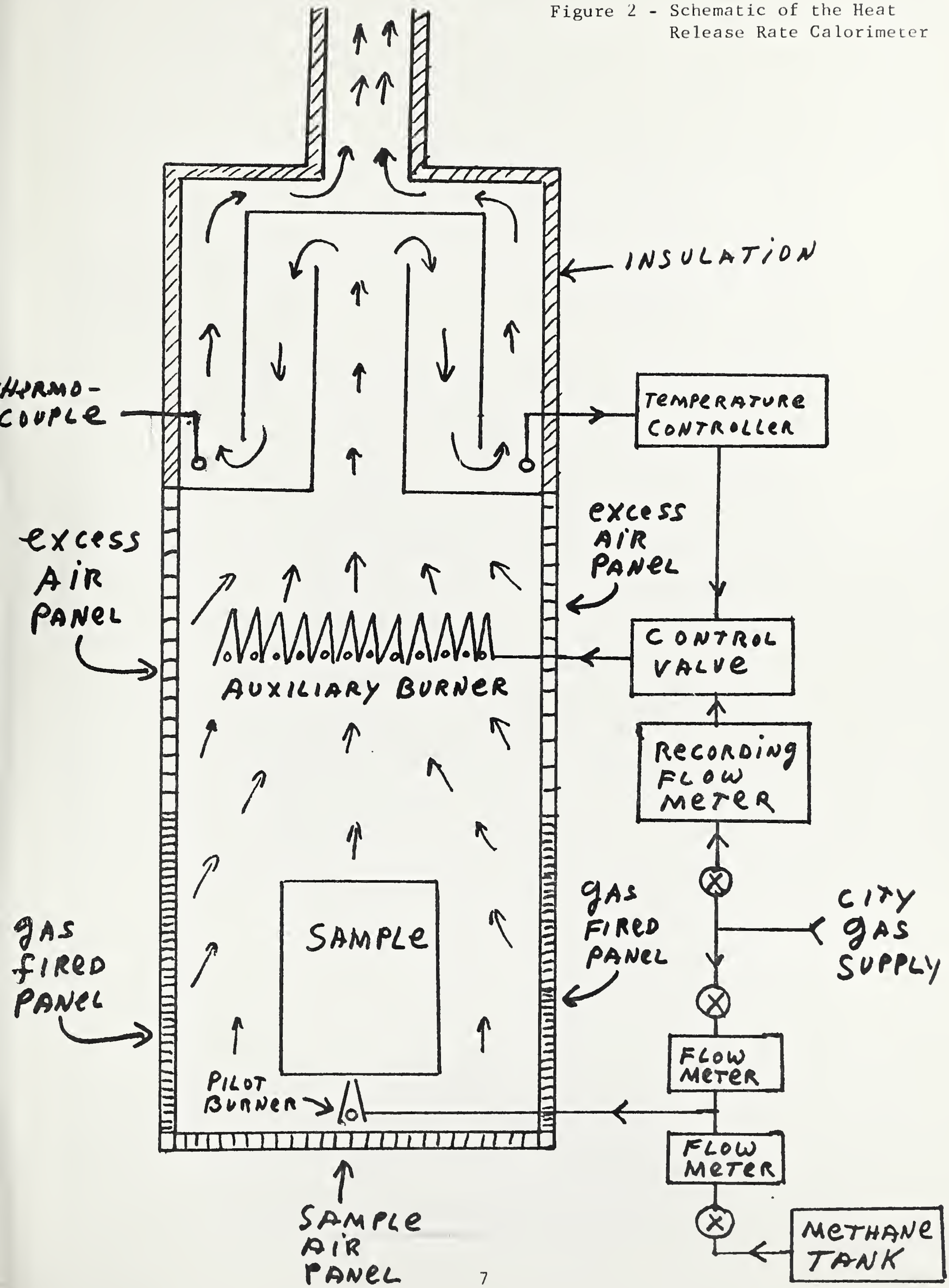


Figure 1(c) - Water Cooled Sample Holder with a Sample in Place

Figure 2 - Schematic of the Heat Release Rate Calorimeter



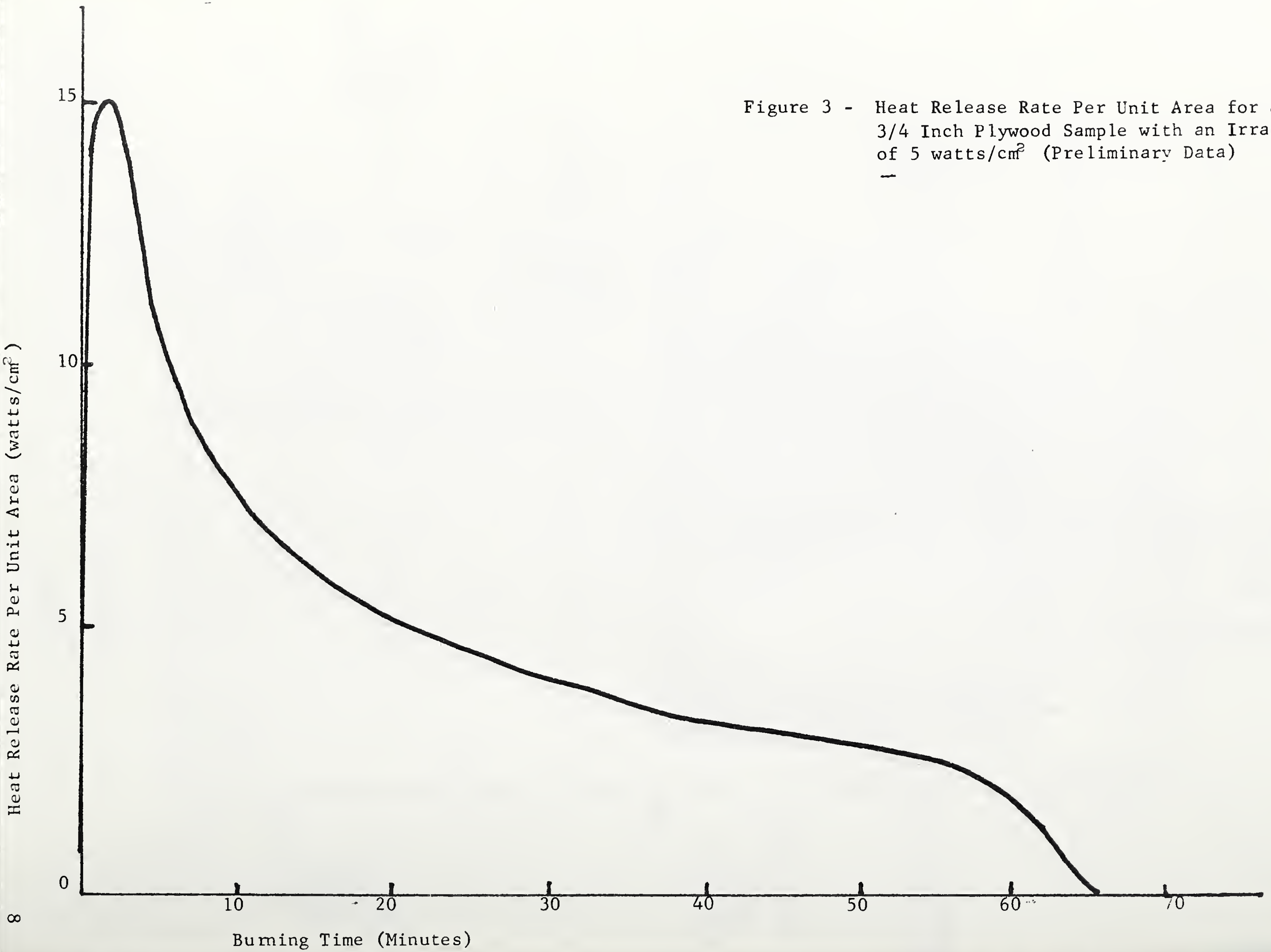


Figure 3 - Heat Release Rate Per Unit Area for a 3/4 Inch Plywood Sample with an Irradiance of 5 watts/cm² (Preliminary Data)