# NATIONAL BUREAU OF STANDARDS REPORT

10 557

## STUDY OF THE FIRE SENSITIVITY OF FRAMELESS BUILDINGS

NBS

U.S. DEPARTMENT OF COMMERCE

NATIONAL BUREAU OF STANDARDS

# NATIONAL BUREAU OF STANDARDS

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## STUDY OF THE FIRE SENSITIVITY OF FRAMELESS BUILDINGS

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## ABSTRACT

Preliminary experiments to measure the energy release characteristics of typical small source fires in buildings are summarized. The experimental results of fires in small wastebaskets show that the fuel burning rate is determined by the type and the amount of combustible load; and that, over the range studied, the rate decreases with an increase in fire load density. Plans for further studies of the severity of relatively minor fires in a compartment are outlined.

PRELIMINARY REPORT NO. I

# STUDY OF THE FIRE SENSITIVITY OF FRAMELESS BUILDINGS

## 1.0 Introduction

In view of the growing utilization of buildings constructed from light weight sandwich panels, a study was suggested to determine their sensitivity to small scale fires. This type of structural building panel appears to have little resistance to a moderate fire exposure and may collapse when involved in a fire. It is desirable that such frameless buildings have some resistance to fire so that the occupants can be evacuated safely in the event of an accidental fire. The overall purpose of this program is to evaluate the fire resistance of these panels to a low-level fire.

The immediate objectives of the tests described in this report was to obtain knowledge on the burning behavior of minor fires, such as those which occur in wastebaskets, and to develop a standard "minor fire" exposure for testing frameless building assemblies. The severity of a fire in a building structure depends both upon its intensity and duration. For this exploratory study, the burning rates of the materials involved, the rate of heat transfer to the surrounding enclosure and the temperatures of the flame and the ambient hot gases were measured to determine representative values of the intensity of a minor fire. This report presents some experimental results on the burning characteristics of fires using various amounts of different combustibles inside a metal or a plastic container.

## 2.0 Test Equipment

The tests were carried out in a compartment 8 feet wide by 8 feet deep and 8 1/3 feet high, with a 30 in. wide by 70 in. high door opened to a corridor. Two ventilation openings with adjustable vanes were constructed, in each of the two walls adjacent to the wall containing the door. The vanes provided for an adjustable inlet area up to 14 1/2 in. wide by 6 1/2 in. high. The entire wall surface of the fire compartment had a sprayed coating of vermiculite/gypsum plaster to reduce heat losses and to avoid damage to the masonry structure. A load cell was used for continuously recording the rate of weight loss of the burning combustibles. It was contained in a thermally insulated box maintained at a constant temperature through forced air cooling. A copper pan calorimeter, which had two attached thermocouples to measure its rate of temperature rise, was constructed for determining the rate of heat conducted downward to the floor underneath the wastebasket. Three thermal heat flow meters were installed on the wall surfaces to measure the magnitudes of heat flux through the walls. Radiometers facing the flames were employed to determine either the radiant flux; or the total flux density, a combination of convection and radiation. Temperatures of the gas along the flame centerline above the basket and the hot gases at various locations within the compartment were measured by bare -beaded chromel-alumel thermocouples made from 0.020 in dia. wires. Details of the instrumentation in the fire compartment is shown in Figs. 1 and 2.

## 3.0 Test Procedure

For each test, the wastebasket was prepared by uniformly and loosely filling with the preweighed combustible. The basket was then placed on the copper pan calorimeter. Ignition was started by touching a flaming propane torch to the fuel at the top of the wastebasket, at which time all recording instruments were turned on simultaneously. The development and burning behavior of the experimental fire was recorded during each test.

## 4.0 Experimental Results

Two tests were conducted under the same conditions to check the repeatability of the experiments. Fig. 3 compares the rate of burning for some of the tests and shows that the wastebasket fires had a fairly reproducible rate of burning.

The variables used for each test are summarized in Table 1.

The fire load density for each test is defined as the weight of combustible load per unit bottom area of the wastebasket. For this series of tests the primary interest was the range of severity of the minor fires. Therefore the data presented is generally the maximum or average values rather than the complete range of data.

Several types of combustibles commonly found in an office or a dwelling were utilized to explore the influence of the fuel type on the important parameters involved in the fire development. These fuels included Kraft wrapping paper, paper tissues, packing materials, waxed milk cartons and carbon paper. The fuel consumption rate, duration of burning and the flame and compartment temperatures at the peak of the fire are tabulated and presented in Table 2 for each test.

Fig. 4 shows typical weight loss measurements for several types of fuels. It can be seen from the figure that the weight loss rate increased rapidly at the early stage of the fire and then tended to decrease gradually. The flow of air into the top of burning fuel bed was initially unrestricted allowing combustion to occur readily. As the fire burned lower into the basket the flow of air became more restricted. As shown in the figure the plastic foam cups had the highest rate of burning.

An exploratory study was made to determine the effect of the fire load density on the burning rates of the fuels involved. The results of the series of experiments are shown in Fig. 5. The data indicate that the rate of burning increases with a decrease in fuel load density. This increase is attributed to the more open structure, allowing air to diffuse into the burning zone and permitting radiant heat to be transmitted a further distance to the unburned fuel. Increasing the fuel bed void fraction allows an increase in air supply to the burning zone and produces a higher burning zone temperature and more rapid combustion. This supposition excludes two limiting cases: if the fire load density is too small or the void fraction is too great the unburned fuel may not receive enough heat for ignition; or if the fire load density is too large the sustained burning will not be possible because of the restricted inflow of air.

The results of the maximum measurements on the rates of heat transfer to the surroundings, at various distances from the fire, are presented in Table 3 for each of the tests and in Fig. 6 for a typical test. The radiant flux data shown in the last column of the table were obtained from the radiometer, taking into account the absorptivity of the attached sapphire window.

Fig. 7 shows the spatial distribution of the rate of heat transfer to the environment at the peak of the fire. The data may be used to estimate the rates of energy release from the fire by radiation and convection, and the total heat transfer rates from the flames to building components around the fire. An example of the heat flux distribution at 1 foot from the fire centerline during the test is shown in Fig. 8, where radiative and convective flux densities are plotted against time. The figure illustrates that the radiation comprised approximately 70 per cent of the total energy at this short distance.

Table 2 also summarizes the maximum measured temperatures attained in the hot plume and the average temperature of the hot gas inside the fire compartment during each test. Temperatures measured by means of thermocouples may be inaccurate because of soot formation, radiation errors and flame fluctuations. There has been some difficulty in determining the temperature within the upper region of the flames since the flames occasionally oscillate away from the thermocouples. The measured plume temperature varied from 600° to 900°C for all tests (See Fig. 9). The average air temperature at approximate mid-height in the fire compartment generally increased 20 to 45 degrees C. (See Fig. 10)

Typical curves of the temperature of the copper pan calorimeter versus time for the test fires are shown in Fig. 11. The maximum rates of heat conducted downward to the floor for both cases were calculated from the slopes of these temperature-rise curves taking into account the physical and thermal properties of the copper pan used. These data are presented in the same figure. It can be noted that the heat flux conducted to the floor from a plastic wastebasket fire was significantly higher, by a factor of 3, than that from a fire in a metal container. The rates of heat transferred to the interior walls at several different distances from the fire are shown in Fig. 12. Figures 11 and 12 demonstrate that this type of minor fire releases intense heat in a local area.

Two tests were made to examine the influence of the size of ventilation opening on rate of fuel burning. The experimental results indicate that over the range studied, the burning rate was independent of air supply through the openings. The fire compartment is probably large enough to supply the amount of air required for sustained combustion of a wastebasket filled with combustibles.

## 5.0 Future Tests

Additional studies are planned for investigating the characteristics of fires in various sizes of wastebaskets or trash barrels. Also tests are to be performed in which a variety of typical plastics for containers will be used.

In further tests, it is planned to measure the maximum rates of heat transfer from the flame by using copper disk calorimeters in direct contact with the flame.

Theoretical analyses will be attempted to develop a profile which describes the energy release of the "minor fire."

TABLE 1 Description of Tests

| Test No. | Basket | | Combustible Load | | Fire Load Density ($g/cm^2$) |
|---|---|---|---|---|---|
| | Type | Size (in.) | Type | Weight (g) | |
| 1 | Steel | 10 1/2 X 10 1/2 X 14 1/4 | Kraft Wrapping Paper | 1477 | 2.08 |
| 2 | " | " | " | 574 | 0.809 |
| 3 | " | " | " | 573 | 0.808 |
| 4 | " | " | Kimwipes Paper Tissue | 521 | 0.734 |
| 5 | " | " | Polystyrene Packing Materials | 290 | 0.409 |
| 6 | " | " | Waxed Milk Cartons | 686 | 0.967 |
| 7 | " | " | Carbon Paper with Onion Skin | 490 | 0.691 |
| 8 | " | " | " | 950 | 1.34 |
| 9 | " | " | Waxed Milk Cartons | 657 | 0.926 |
| 10 | " | " | Kraft Wrapping Paper | 883 | 1.24 |
| 11 | " | " | Carbon Paper with Onion Skin | 146 | 0.206 |
| 12 | " | " | Kraft Wrapping Paper | 567 | 0.800 |
| 13 | " | " | Polystyrene Foam Cups | 173 | 0.244 |
| 14 | " | " | Kimwipes Paper Tissue | 335 | 0.472 |
| 15 | Polyethylene | 14 1/4 X 8 1/4 X 15 | Kleenex Paper Tissue | 299 | 1.34 |
| 16 | " | " | " | 150 | 1.16 |
| 17 | " | 12 X 7 1/2 X 13 1/2 | Kimwipes Paper Tissue | 163 | 1.33 |

Table 2 Burning Behavior of Test Fires

| Test Number | Time Duration (min.) | Fuel Burning Rate (g/min) | | Maximum Temperature (°C) | |
|---|---|---|---|---|---|
| | | Average | Maximum | Plume | Average Room |
| 1 | 20.5 | 34.5 | 47.7 | 728 | 37 |
| 2 | 10.0 | 55.7 | 232 | 884 | 54 |
| 3 | 9.0 | 63.7 | 266 | 894 | 54 |
| 4 | 17.2 | 29.5 | 90.5 | 698 | 38 |
| 5 | 10.0 | 19.2 | 57.0 | 576 | 41 |
| 6 | 18.6 | 34.4 | 149 | 774 | 43 |
| 7 | 20.0 | 23.2 | 108 | 793 | 31 |
| 8 | 18.6 | 34.8 | 88.3 | 787 | 30 |
| 9 | 11.8 | 54.1 | 108 | 889 | 47 |
| 10 | 16.2 | 53.1 | 163 | 808 | 44 |
| 11 | 2.6 | 55.4 | 97.5 | 739 | 35 |
| 12 | 13.2 | 42.4 | 162 | 855 | 44 |
| 13 | 5.6 | 30.6 | 51.5 | 529 | 40 |
| 14 | 9.6 | 34.8 | 91.5 | 765 | 37 |
| 15 | 16.0 | 15.3 | 30.0 | 641 | 33 |
| 16 | 15.4 | 50.3 | 80.8 | 653 | 39 |
| 17 | 11.0 | 17.3 | 46.1 | 815 | 33 |

Table 3 Maximum Total and Radiant Heat Fluxes Measured at Various Locations

| Test Number | Time (Min.) | Maximum Total Flux ($w/cm^2$) | | | | Max. Radiant Flux ($w/cm^2$) |
|---|---|---|---|---|---|---|
| | | Distance from the fire centerline | | | | |
| | | 1 ft. | 1 1/2 ft. | 2 ft. | 3 ft. | 1 ft. |
| 1 | 2.9 | 0.28 | - | - | 0.07 | 0.18 |
| 2 | 2.5 | 1.82 | 1.08 | 0.93 | 0.29 | 1.53 |
| 3 | 2.5 | 1.80 | 1.60 | 1.34 | 0.32 | 1.50 |
| 4 | 0.7 | - | 1.17 | 0.21 | 0.12 | 1.56 |
| 5 | 8.6 | - | 2.15 | 0.70 | 0.09 | 1.43 |
| 6 | 2.5 | 0.68 | 0.48 | 0.29 | 0.11 | 0.49 |
| 7 | 0.5 | 0.38 | 0.20 | 0.15 | 0.06 | 0.26 |
| 8 | 1.5 | 0.20 | 0.12 | 0.08 | 0.03 | 0.15 |
| 9 | 1.6 | 0.75 | 0.44 | 0.27 | 0.13 | 0.52 |
| 10 | 1.5 | 0.59 | 0.32 | 0.21 | 0.07 | 0.41 |
| 11 | 0.6 | 0.33 | 0.18 | 0.14 | 0.03 | 0.20 |
| 12 | 1.6 | 0.45 | 0.12 | 0.18 | 0.05 | 0.30 |
| 13 | 2.5 | 0.39 | 0.35 | 0.27 | 0.10 | 0.27 |
| 14 | 0.6 | 0.28 | 0.15 | 0.14 | 0.03 | 0.18 |
| 15 | 0.9 | 0.20 | - | - | 0.08 | 0.11 |
| 16 | 14.5 | 1.47 | 1.00 | 0.53 | 0.42 | 1.27 |
| 17 | 3.5 | 0.33 | 0.10 | 0.08 | 0.01 | 0.23 |

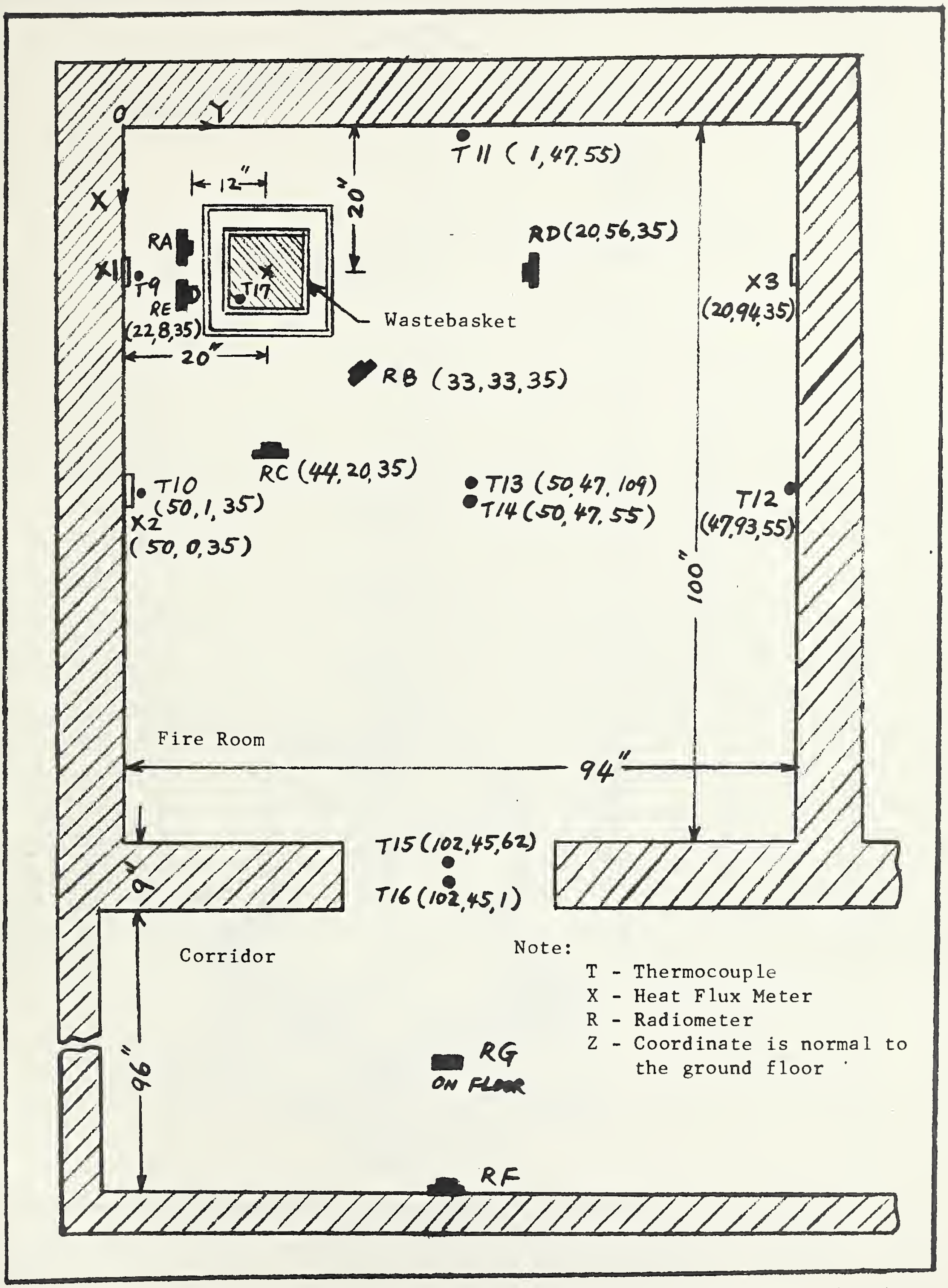


Figure 1 Plan showing the locations of Radiometers, Flux Meters and Thermocouples

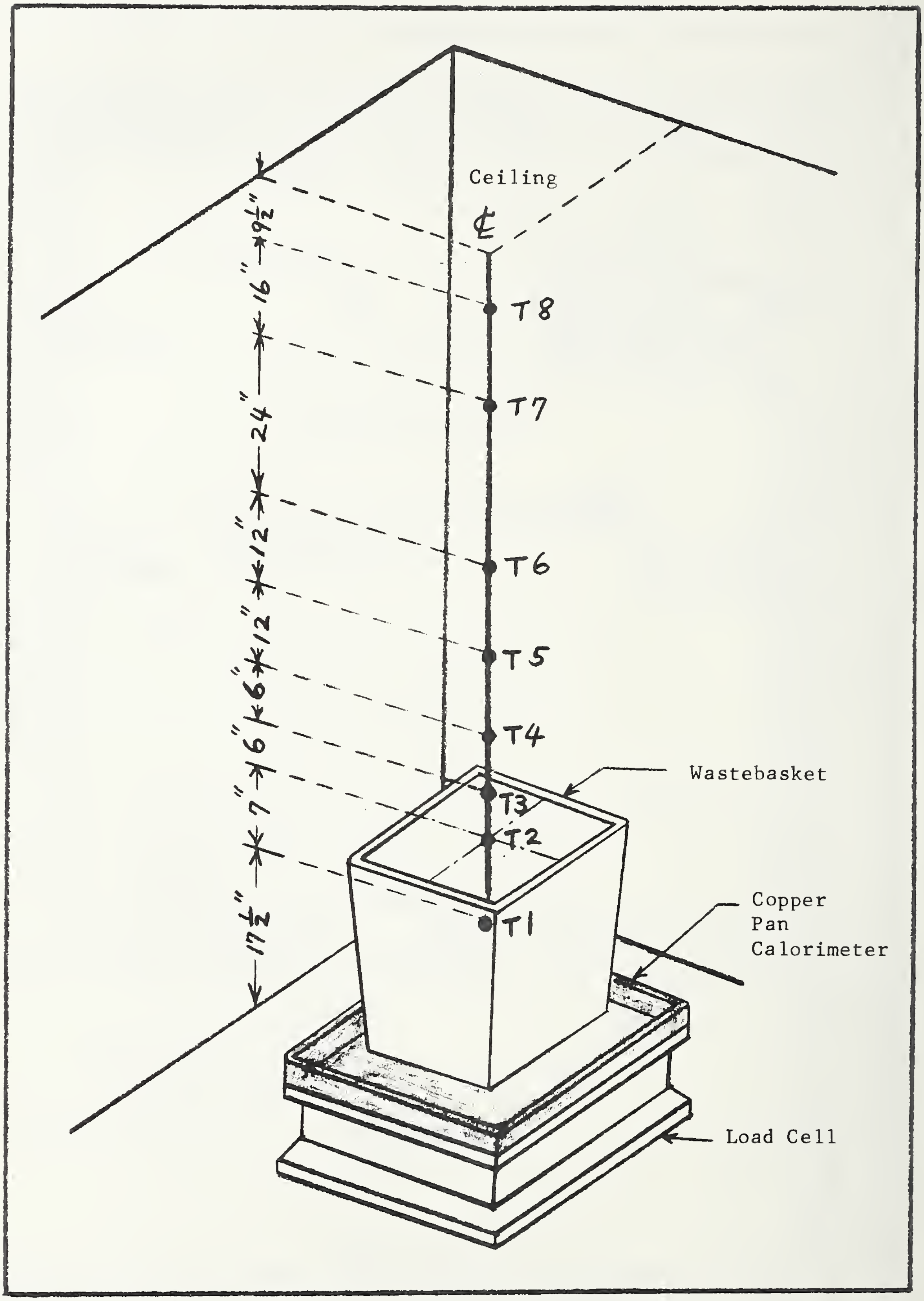


Figure 2 Elevation showing the arrangements of copper pan calorimeter, load cell and thermocouples

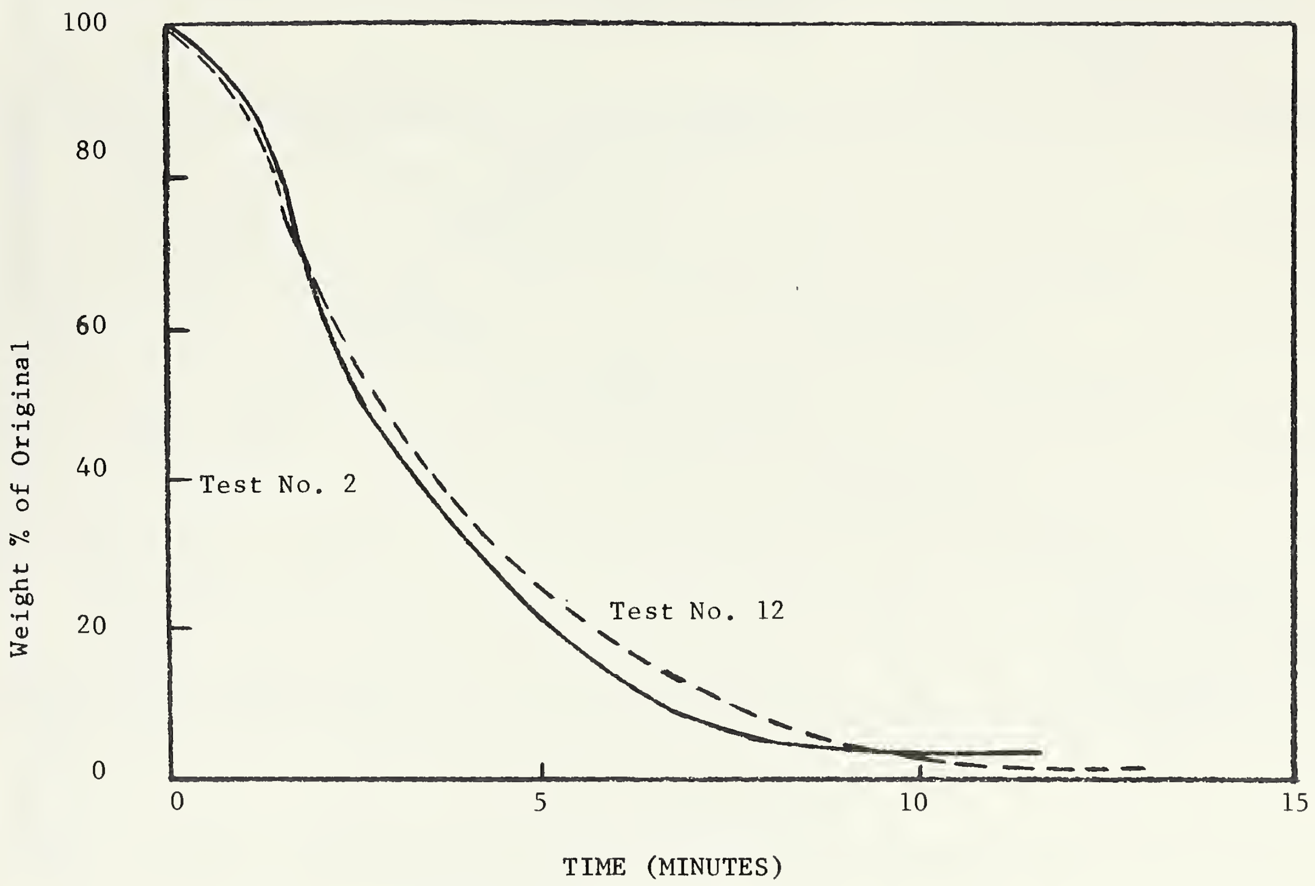


Figure 3 Repeatability of the Resutls

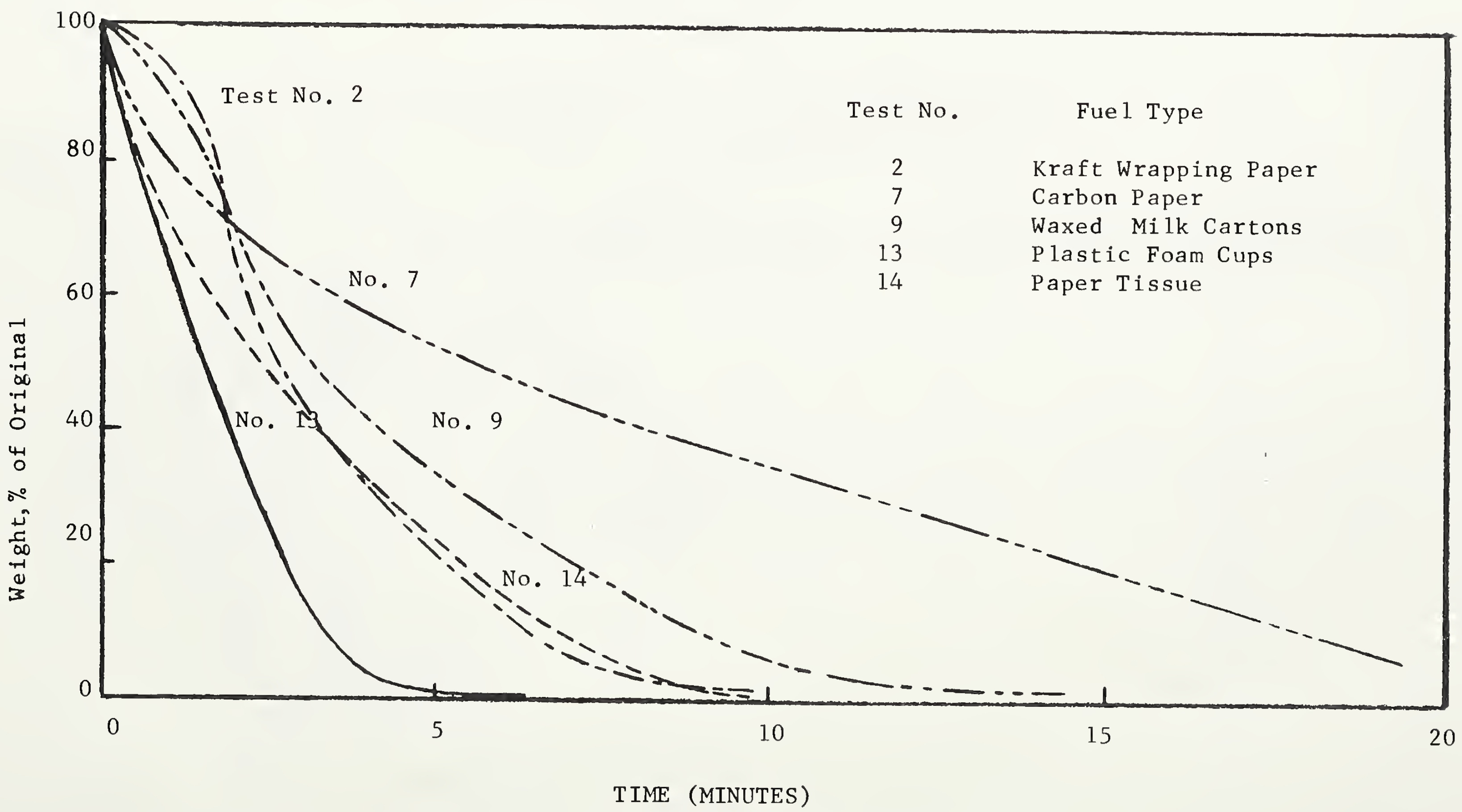


Figure 4 Burning Rates of Various Fuels in Steel Wastebaskets

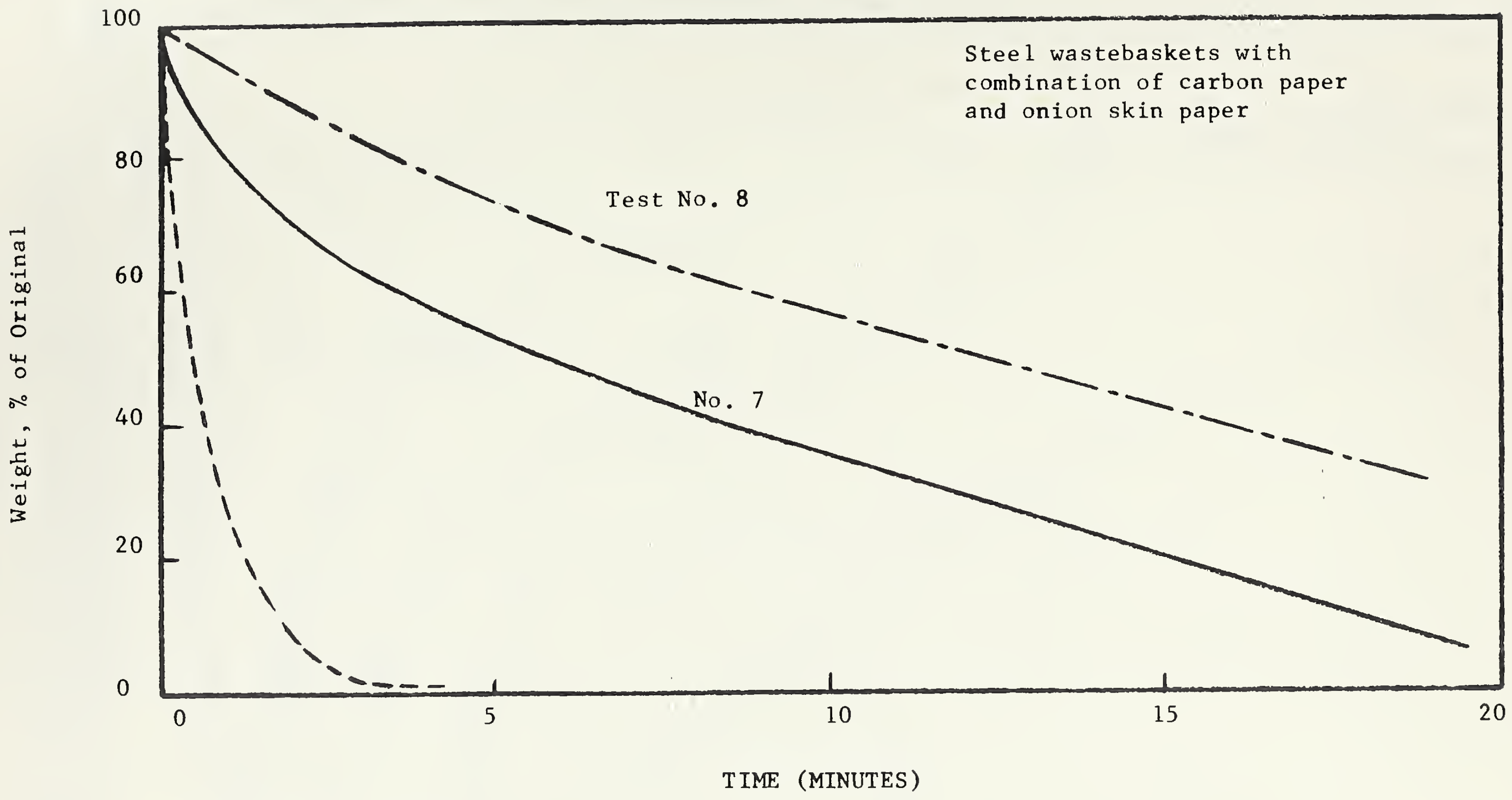


Figure 5 Effect of Fire Load Density on Fuel Burning Rate

| Parameter: | Test No. | Fire Load Density ($g/cm^2$) |
|---|---|---|
| | 8 | 1-34 |
| | 7 | 0-691 |
| | 11 | 0-206 |

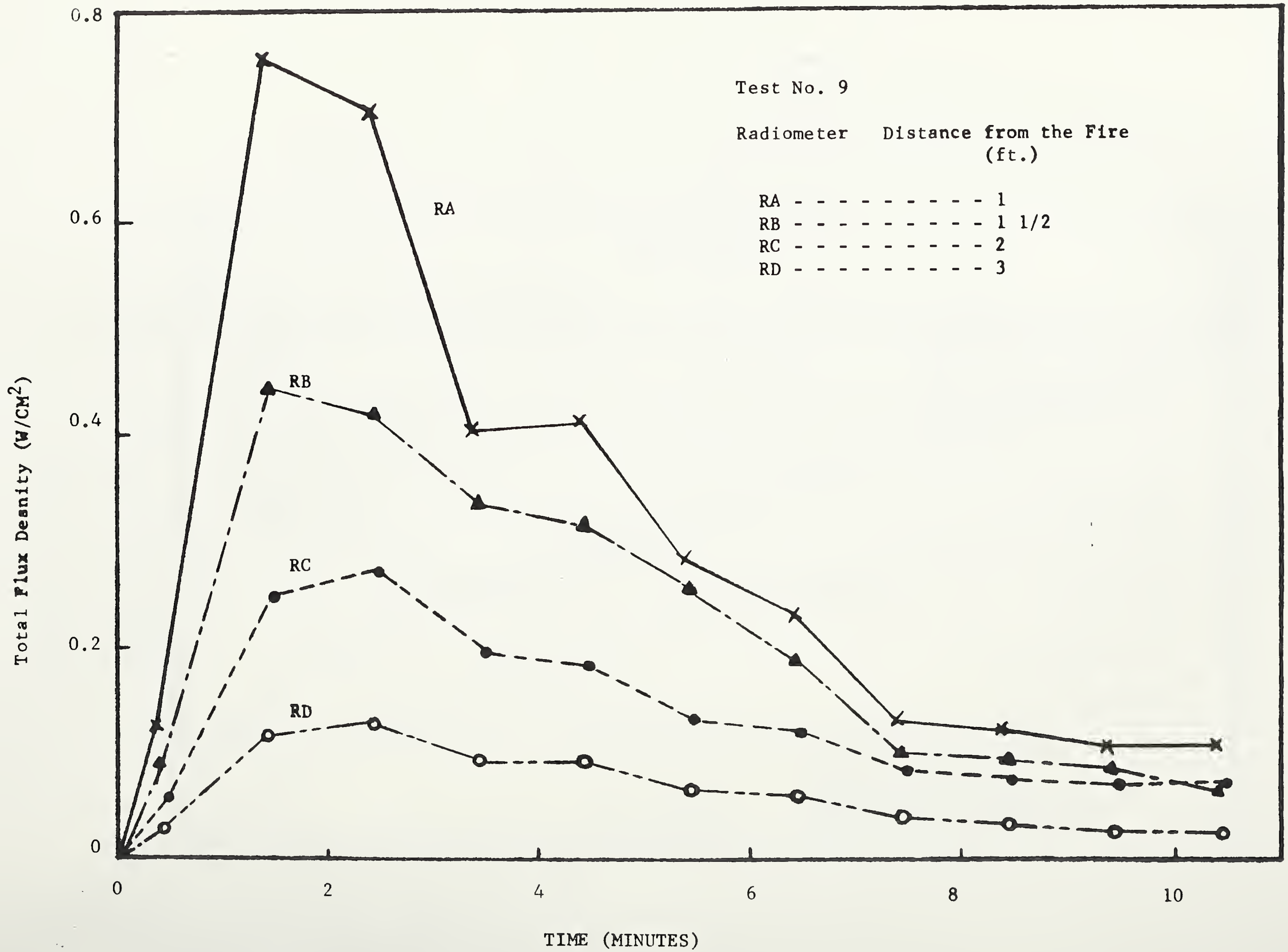


Figure 6 Total Flux Density Versus Time

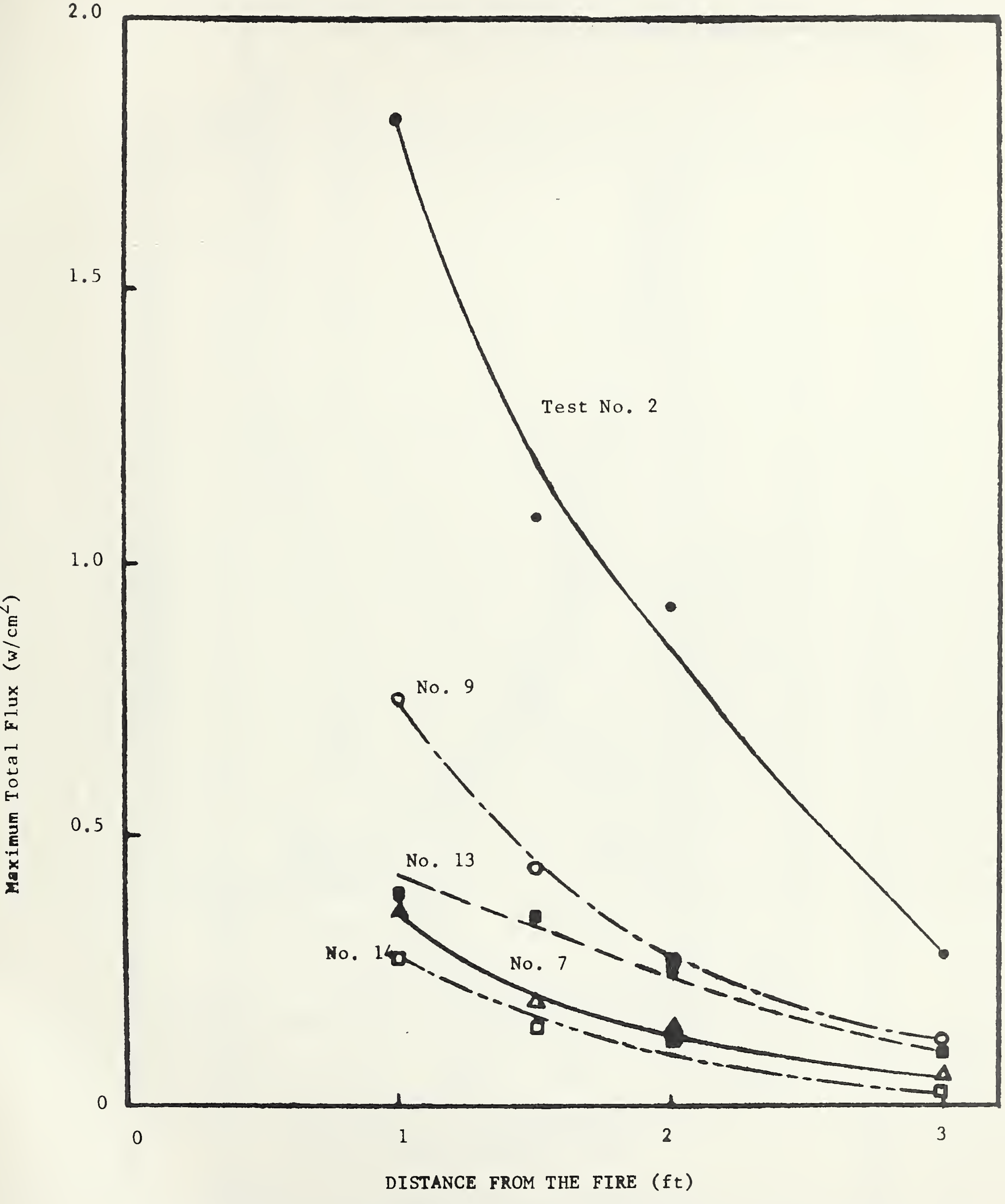


Figure 7 Maximum Total Heat Flux Versus Distance from the Fire Centerling for Various Fuels

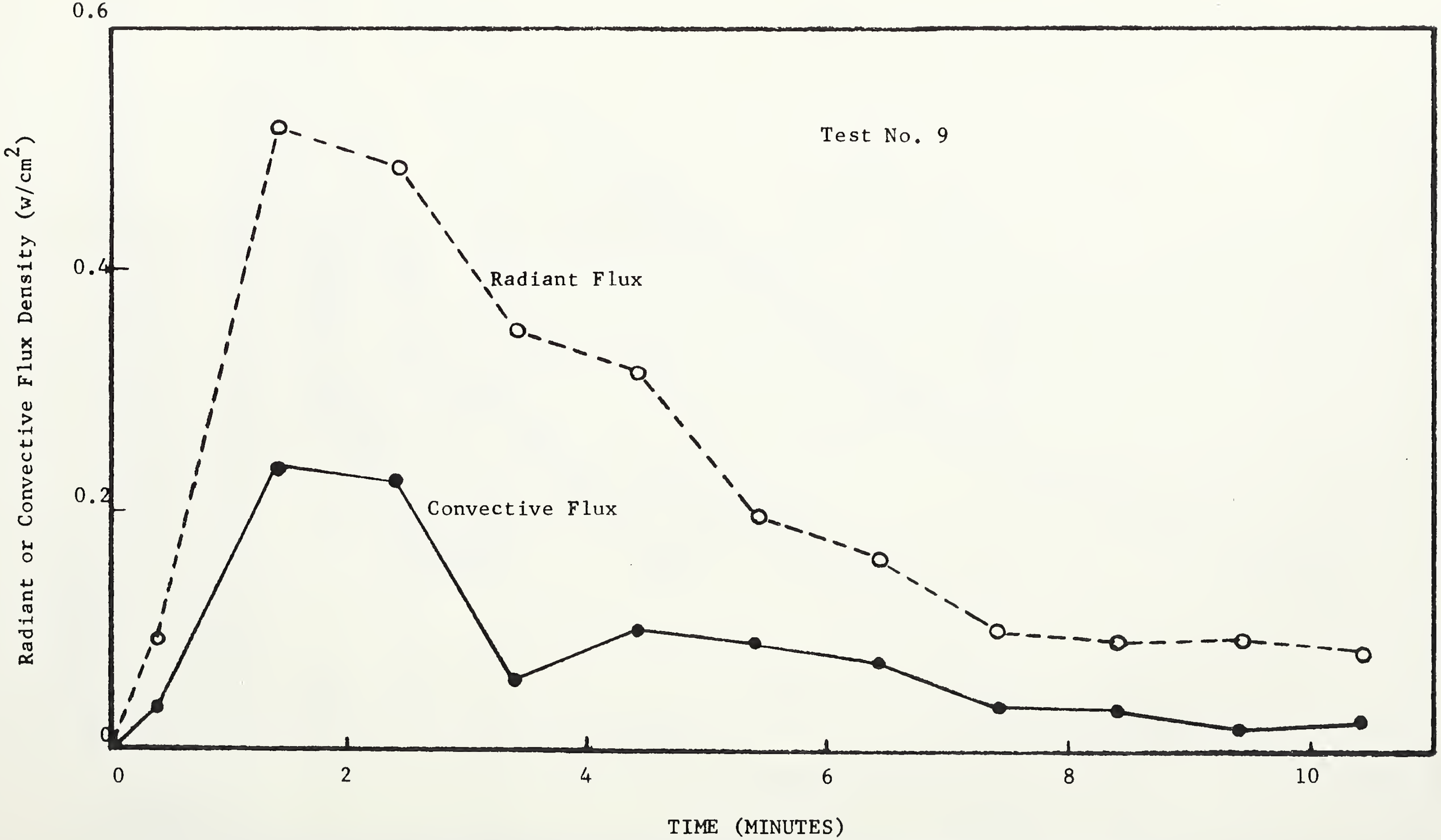

Figure 8 Distributions of Radiation and Convection at 1 ft from the Fire Centerline

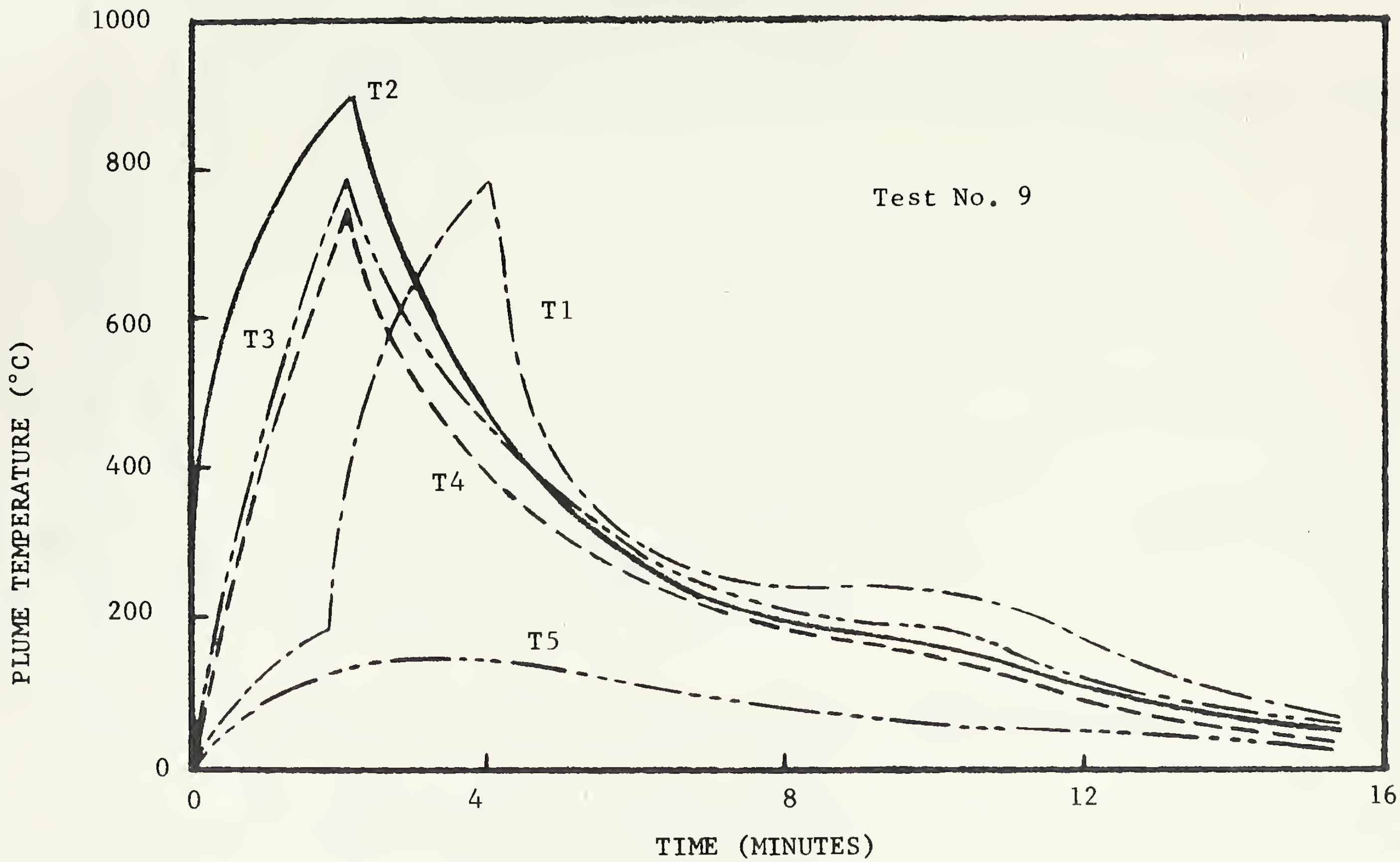


Figure 9 Hot Gas Plume Temperatures along the Fire Centerling Versus Time

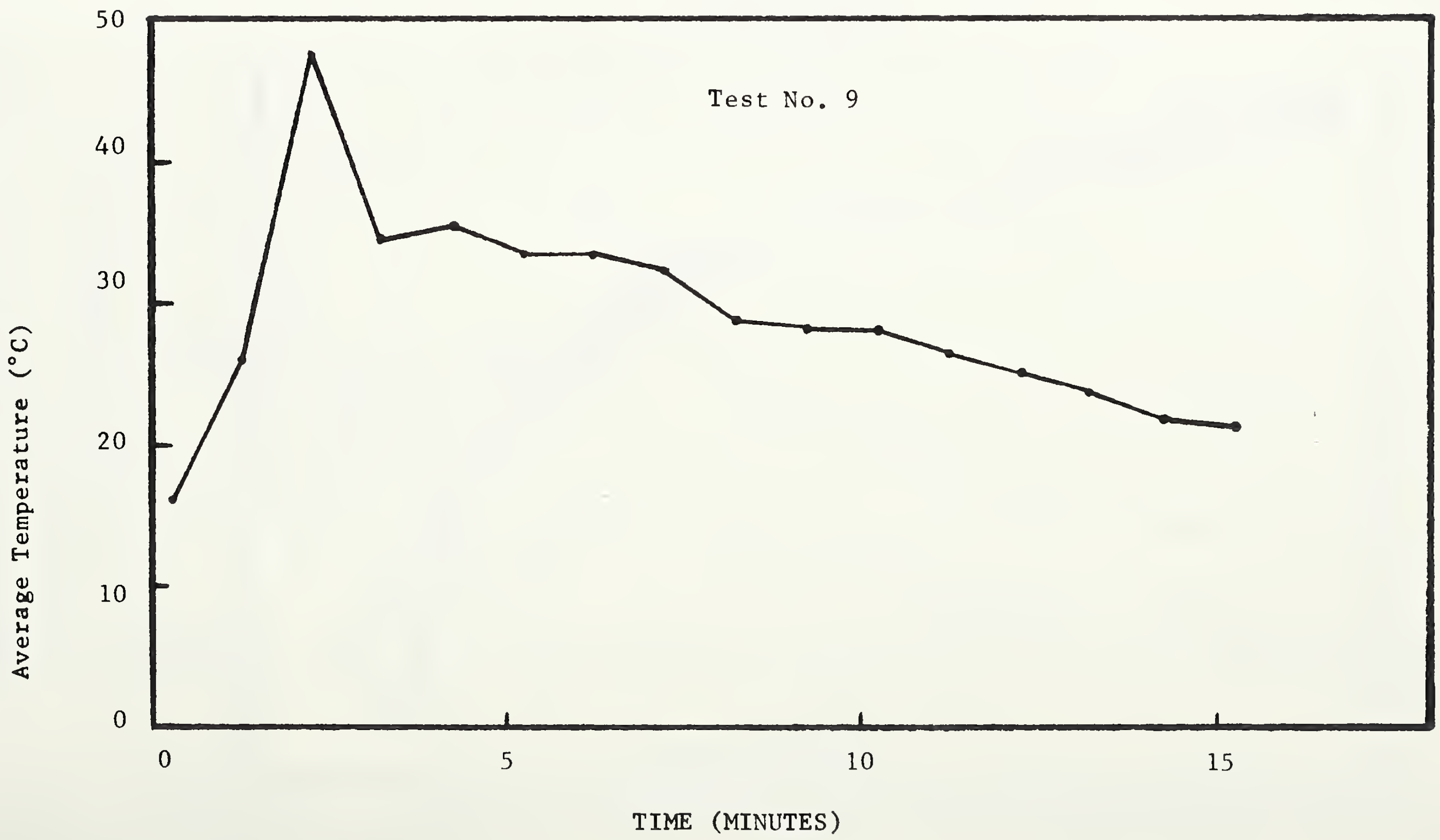


Figure 10 Average Fire Room Temperature (at Mid-Height) Versus Time

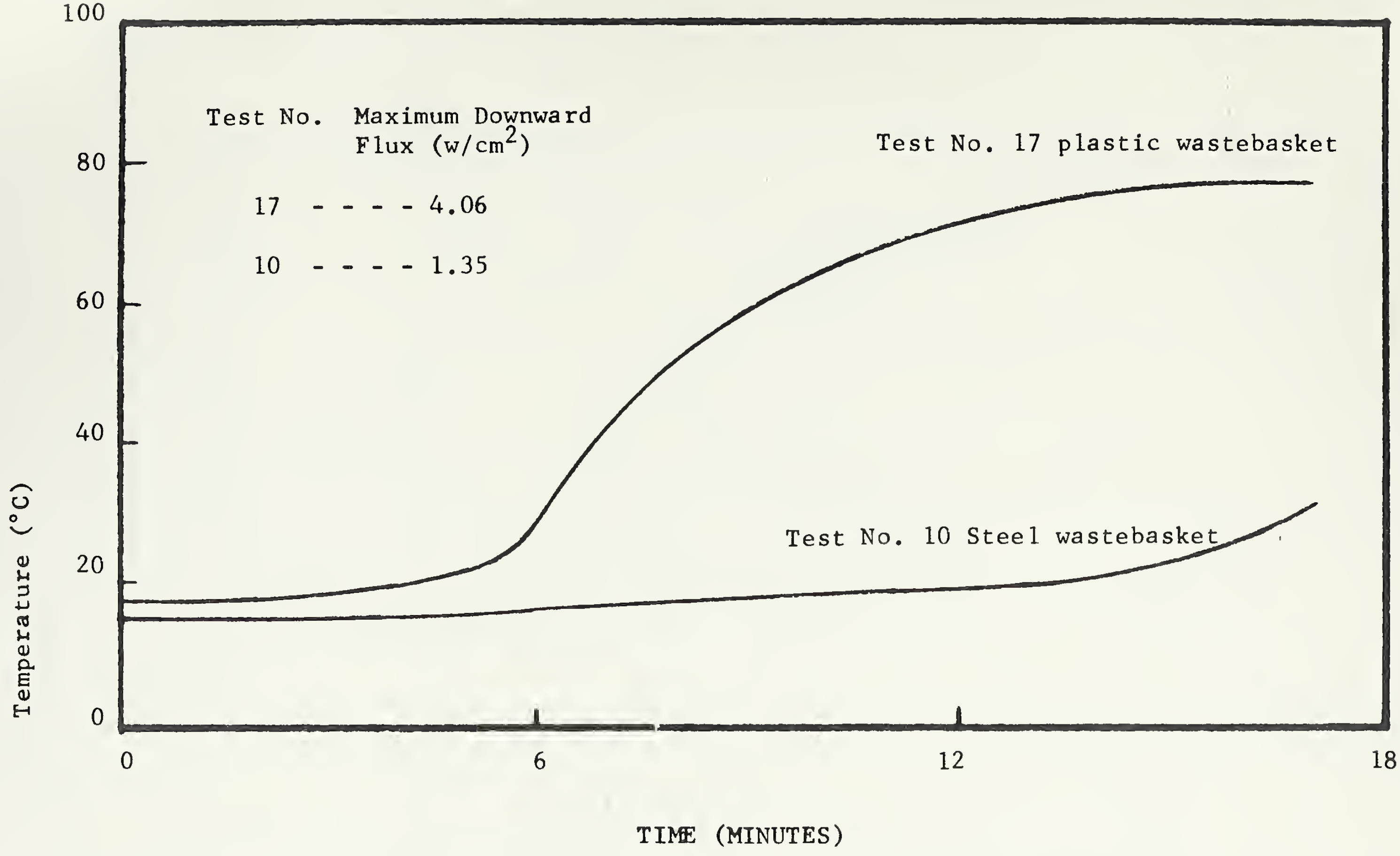


Figure 11 Temperature Rises of the copper pan calorimeter with different types of wastebaskets

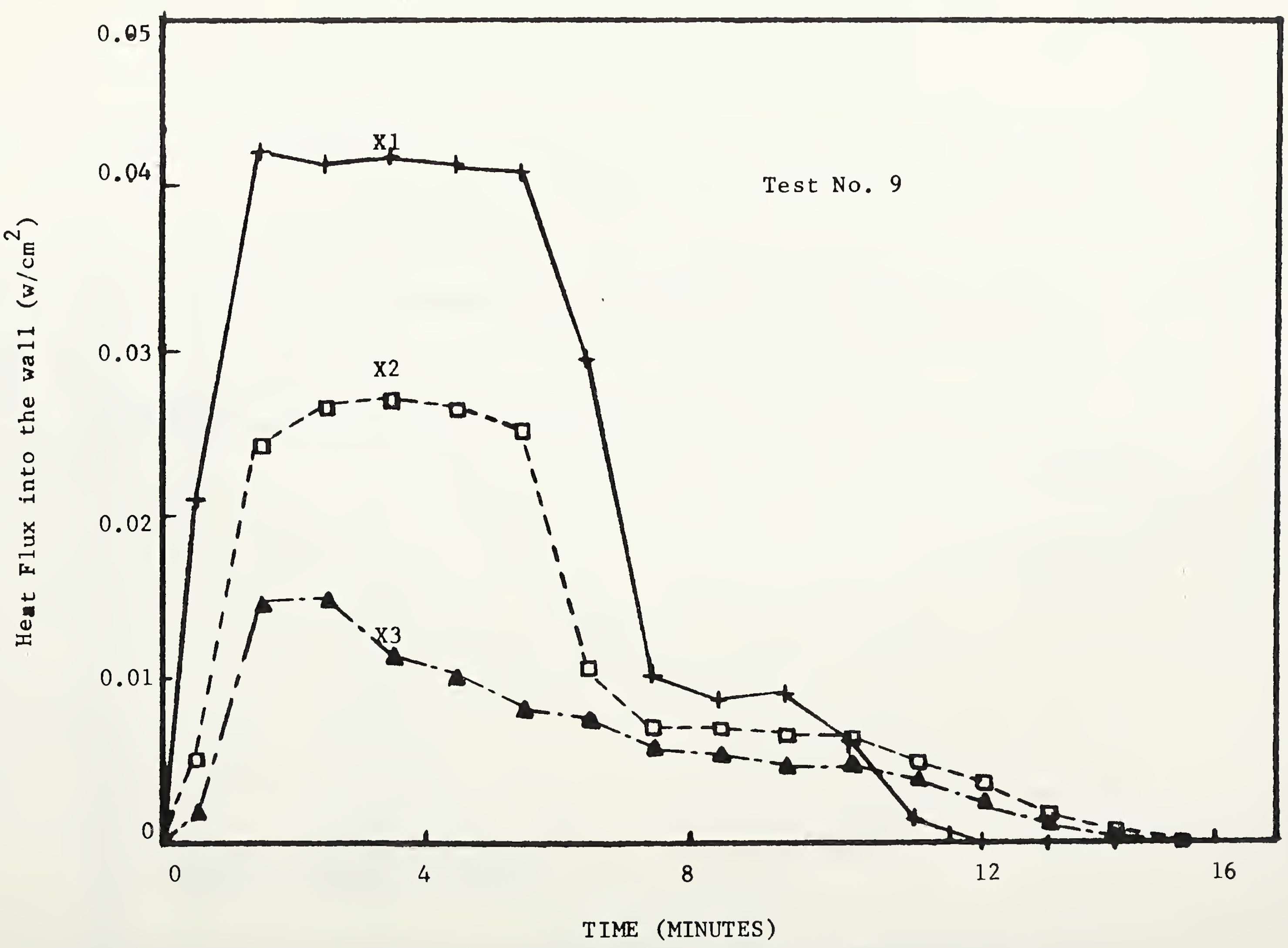


Figure 12 Heat Flux Transferred into the walls Versus Time

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