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Fire Tests of Men's Suits on Racks

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Abstract

A series of fire tests were conducted to characterize the potential hazard from ignition of men's suits hanging on racks. The fire test scenario was selected as part of a fire investigation being conducted by the U.S. Department of Treasury's Bureau of Alcohol, Tobacco, and Firearms. Heat release rate was determined as a function of time from ignition using the oxygen depletion principle. In addition, the total heat flux from the burning suits and the mass loss were measured. Three tests were conducted with the suits placed in the open under a large calorimeter. The suits were ignited either in the center or at the end of the rack with a propane torch. Peak heat release rates obtained during the tests ranged from approximately 1 MW to 2 MW.

Key Words:
clothing; fire data; fire models; fire tests; heat release rate; heat flux; mass loss

Introduction

Measurement of the rate at which a burning item releases heat is a critical parameter in fire protection engineering. The heat release rate can be used in the characterization of the hazard represented by a given fuel package. Heat release rate can provide information on fire size and fire growth rate. When used as input to a computer fire model, the heat release rate can be used to estimate available egress time and determine detection or suppression system activation time. Heat flux measurements can be used to estimate potential for ignition of adjacent fuel items.

As part of a fire investigation, the U.S. Department of Treasury's Bureau of Alcohol, Tobacco and Firearms (ATF) was interested in determining the rate of heat release and burning characteristics from a rack of men's suits. Photographs of the test arrangement showing the racks of suits are presented as figures 1 and 2. Figure 3 presents front and side views of the test arrangement with dimensions illustrating the location of the heat flux sensors.

Experimental Configuration

The experiments were conducted under the main hood in the NIST Large Fire Research Facility. The main hood is 4 m (13.1 ft) by 5 m (16.4 ft) and slopes upward to a 1.2 m (3.9 ft) square duct. During a fire test, data from various sensors are acquired using a computer-based data acquisition system at a rate of one scan per second. The fire test data are recorded on magnetic media for further data reduction and interpretation after the test. Data acquisition and reduction in the Large Fire Research Facility are accomplished using in-house developed computer software [1].

Using the principle of oxygen consumption, it is possible to calculate the heat release rate of burning materials when the products of combustion are collected in an exhaust hood. Parker [2, 3] presents several sets of equations for calculating heat release rate using oxygen consumption.

The appropriateness of each set of equations depends on the combustion products being measured. A paper by Janssens [4] proposes a form of the equations for calculating heat release rate specifically for full-scale fire test applications.

Heat release rate is determined in the NIST Large Fire Research Facility using the equations from reference 3 together with data obtained from instruments in the exhaust hood. The measured heat release rate has been shown to be within 20 % of the actual value [5]. Reference 5, page 2 contains details concerning the calculation of heat release rate and its implementation in the Large Fire Research Facility.

For each experiment, a rack of suits was placed on a load cell with 454 kg (1000 lb) capacity that was centered under the exhaust hood (Figure 1). The mass values obtained from the load cell are estimated to be within 0.25 kg (½ lb) of the true values. The ends of the racks were constructed of 25.4 mm (1 in) steel box channels crossed and welded at their intersections. Additional box channels were used to form the horizontal members (Figure 2). Each rack was approximately 1.8 m (6 ft) long, 0.8 m (2.5 ft) wide, and 1.8 m (6 ft) high. The suit racks were designed to be similar to those observed in typical suit warehouses. Using plastic hangers with metal hooks, twenty-four suits were hung from each horizontal bar for a total of forty-eight suits per test.

Two water-cooled, Gardon type total heat flux gauges were located 0.9 m (36 in) above the floor with the face of each gauge approximately 0.9 m (36 in) from the outer edges of the suits. The faces of the two gauges were separated by about 0.15 m (6 in). Based on manufacturer's data, the standard uncertainty for the heat flux measurements is estimated at ±3 % [6]. Finally, a Type K thermocouple with a bead diameter of 0.25 mm (0.01 in) was located 5.5 m (18 ft) above the centerline of the clothes rack at the entrance to the hood duct. This thermocouple was installed to provide information concerning the temperature of the fire plume above the burning clothes. Based on work presented in references [7] and [8], the temperature measurements are estimated to be within ±5 % of the actual values.

Experiments

Three fire experiments using men’s suits on metal racks were conducted on October 26, 1999, under the main exhaust hood in the Large Fire Research Facility at the National Institute of Standards and Technology. A total of forty-eight suits, manufactured from a polyester and wool blend, were used for each experiment. Twenty-four suits were hung on either side of a metal rack using plastic hangers with metal hooks. A typical test scenario with dimensions is shown in Figure 3. The standard uncertainty associated with the length measurements is ±6 mm (0.25 in).

For the first test, the rack with the suits was placed on a load cell centered under the exhaust hood (Figure 2). Approximately 60 s of background data was recorded before a propane torch was applied to the sleeve of a suit. The flow of propane was adjusted to provide a 25 mm (1 in) long flame that was held in contact with the suit for 10 s. This scenario placed the ignition location in the center of the rack of suits and immediately in front of the heat flux gauge pair

(Figure 4). The fire was allowed to grow until it involved the entire rack of suits (Figure 5). When all of the suits had fallen from the rack, the fire was extinguished with water (Figure 6). The debris is shown after the fire in Figure 7.

The second experiment was essentially a repeat of the first. The rack with the suits was placed on a load cell centered under the exhaust hood (Figure 8). Approximately 60 s of background data was recorded before a propane torch was applied to the sleeve of a suit located in the center of the rack (Figure 9). The fire was allowed to grow until it involved the entire rack of suits (Figure 10). When all of the suits had fallen from the rack, the fire was extinguished with water (Figure 11). The debris is shown after the fire in Figure 12.

The final experiment was conducted with the suits again placed on a the load cell centered under the exhaust hood (Figure 13). Approximately 60 s of background data was recorded before a propane torch was applied to the sleeve of a suit. (Figure 14). For this test, the ignition location was at the end of the rack of suits immediately in front of the heat flux gauge (Figure 15). Two suits were placed adjacent to the heat flux gauges to provide a visual indication of any damage. The fire was allowed to grow until it involved the entire rack of suits (Figure 16).

Results

The heat release rate curves obtained as a function of time from ignition for the three fire tests is shown in Figure 17. In all three tests, a heat release rate of approximately 1 MW is sustained for about 5 minutes. The peak heat release rate for the first and third tests is about 1 MW while the second test peaks briefly at 2 MW. The temperatures obtained at the entrance to the exhaust hood immediately above the center of the burning clothes is shown in Figure 18. During most of the tests, the temperature above the burning clothes is 150 °C (302 °F). The temperature spikes briefly to 200 °C (392 °F) during the early portion of the second test. The total heat flux data obtained from the two sensors in the three tests are shown in Figures 19 and 20. There is good agreement between the two sensors. Finally, the mass loss rate data for the three tests is presented in Figure 21. The initial mass of suits and racks was 55.8 kg (123 lb), 57.1 kg (126 lb), and 57.6 kg (127 lb) for the first, second, and third tests, respectively. The final mass at the end of the first, second, and third tests was 46.7 kg (103 lb), 48.0 kg (106 lb), and 49.0 kg (108 lb), respectively.

References

[1] Peacock, R.D., J.N. Breese, and C.L. Forney, "A Users Guide for RAPID, Version 2.3," NIST Special Publication 798, National Institute of Standards and Technology, Gaithersburg, MD, January 1991.

[2] Parker, W., "Calculations of the Heat Release Rate by Oxygen Consumption for Various Applications," NBSIR 81-2427, National Bureau of Standards, Gaithersburg, MD, March 1982.

[3] Parker, W., "Calculations of the Heat Release Rate by Oxygen Consumption for Various Applications," *J. of Fire Sciences*, **2**, September/October 1984, pp. 380-395, 1982.

[4] Janssens, M.L., "Measuring Rate of Heat Release by Oxygen Consumption," *Fire Technol.*, **27**, pp. 234-249, 1991.

[5] Stroup, D.W., et. al., "Large Fire Research Facility (Building 205) Heat Release Rate Measurement System," NISTIR 6509, National Institute of Standards and Technology, Gaithersburg, MD, July 2000.

[6] “Design and Manufacture of Medical and Thermal Instrumentation," Medtherm Corporation, Huntsville, AL, July 1996.

[7] Luo, M., “Effects of Radiation on Temperature Measurement in a Fire Environment,” *Journal of Fire Sciences*, **15**, pp. 443-461, 1997.

[8] Blevins, L.G. and Pitts, W.M., “Modeling Bare and Aspirated Thermocouples in Compartment Fires”, NISTIR 6310, National Institute of Standards and Technology, Gaithersburg, MD, April 1999.

Figure 1. Photograph showing arrangement of suits on load cell.

Figure 2. Photograph showing end of suit arrangement with radiometer (wrapped in aluminum foil) visible on right side.

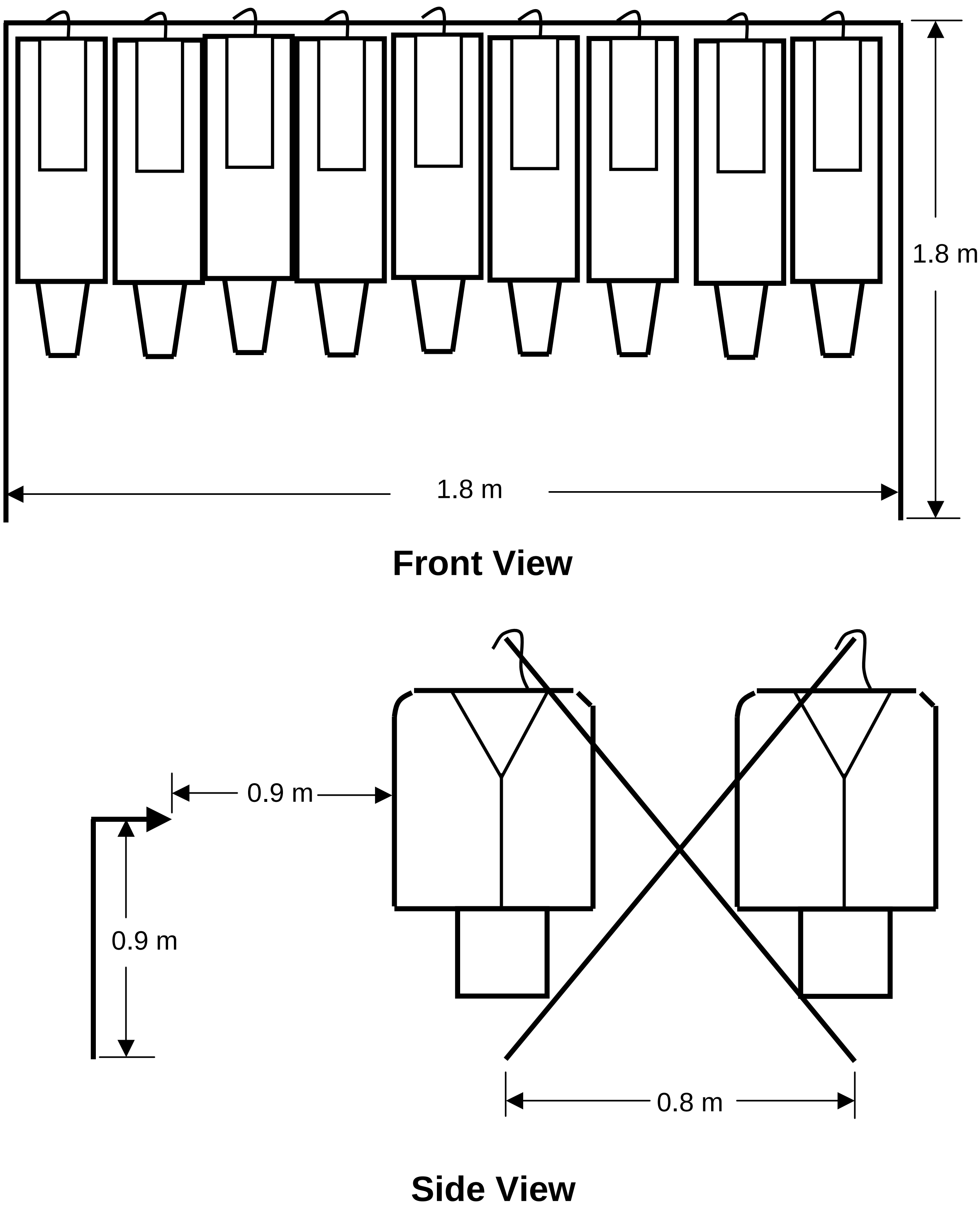

Figure 3. Front and side views of test arrangement.

Figure 4. Photograph of suits immediately after ignition of the front, center suit for the first test.

Figure 5. Photograph showing majority of suits burning during first test.

Figure 6. Photograph of suits at the beginning of extinguishment of the first test.

Figure 7. Photograph showing the debris at the end of the first test.

Figure 8. Photograph of suit arrangement for the second test.

Figure 9. Photograph of suits immediately after ignition of the front, center suit for the second test.

Figure 10. Photograph showing majority of suits burning during second test.

Figure 11. Photograph of suits at the beginning of extinguishment of the second test.

Figure 12. Photograph showing the debris at the end of the second test.

Figure 13. Photograph of suit arrangement for the third test with the addition of two target suits.

Figure 14. Photograph of suits immediately after ignition of the front, right end suit for the third test.

Figure 15. Photograph of suits showing fire spread along sleeve of first suit ignited during the third test.

Figure 16. Photograph showing majority of suits burning during third test.

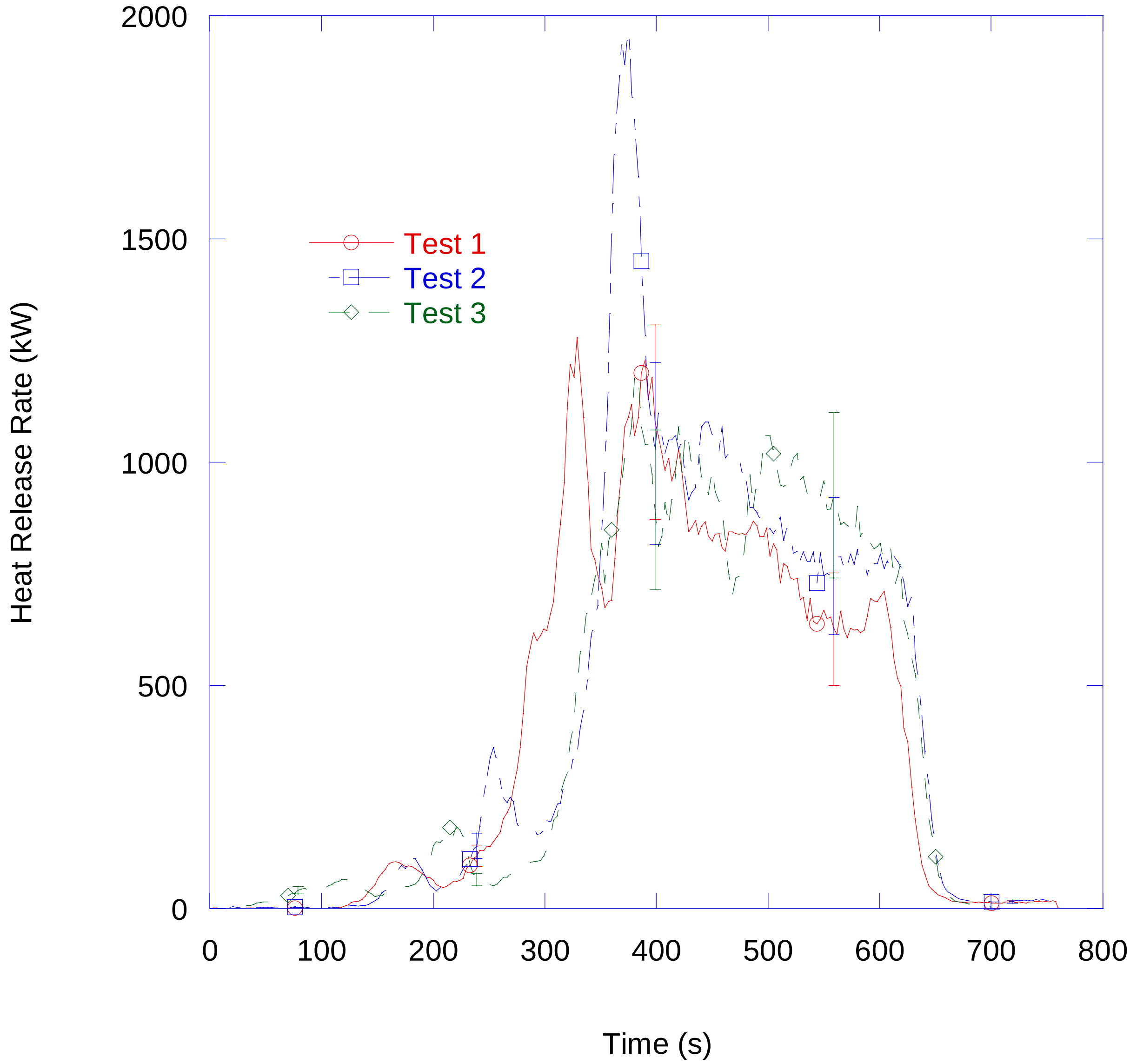

Figure 17. Graph of heat release rate as a function of time for the three tests.

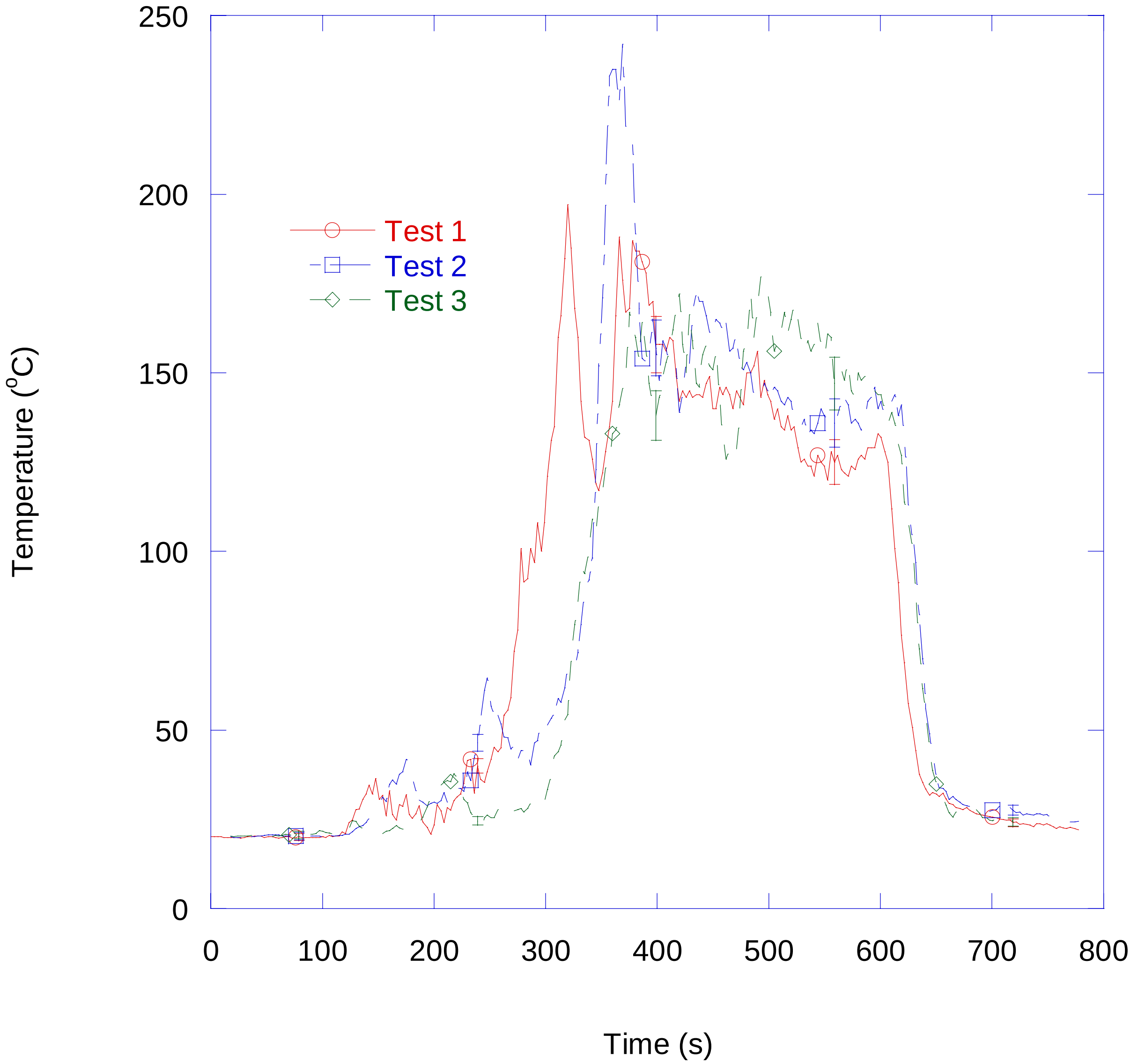

Figure 18. Graph showing temperature at the inlet to the exhaust hood as a function of time for the three tests.

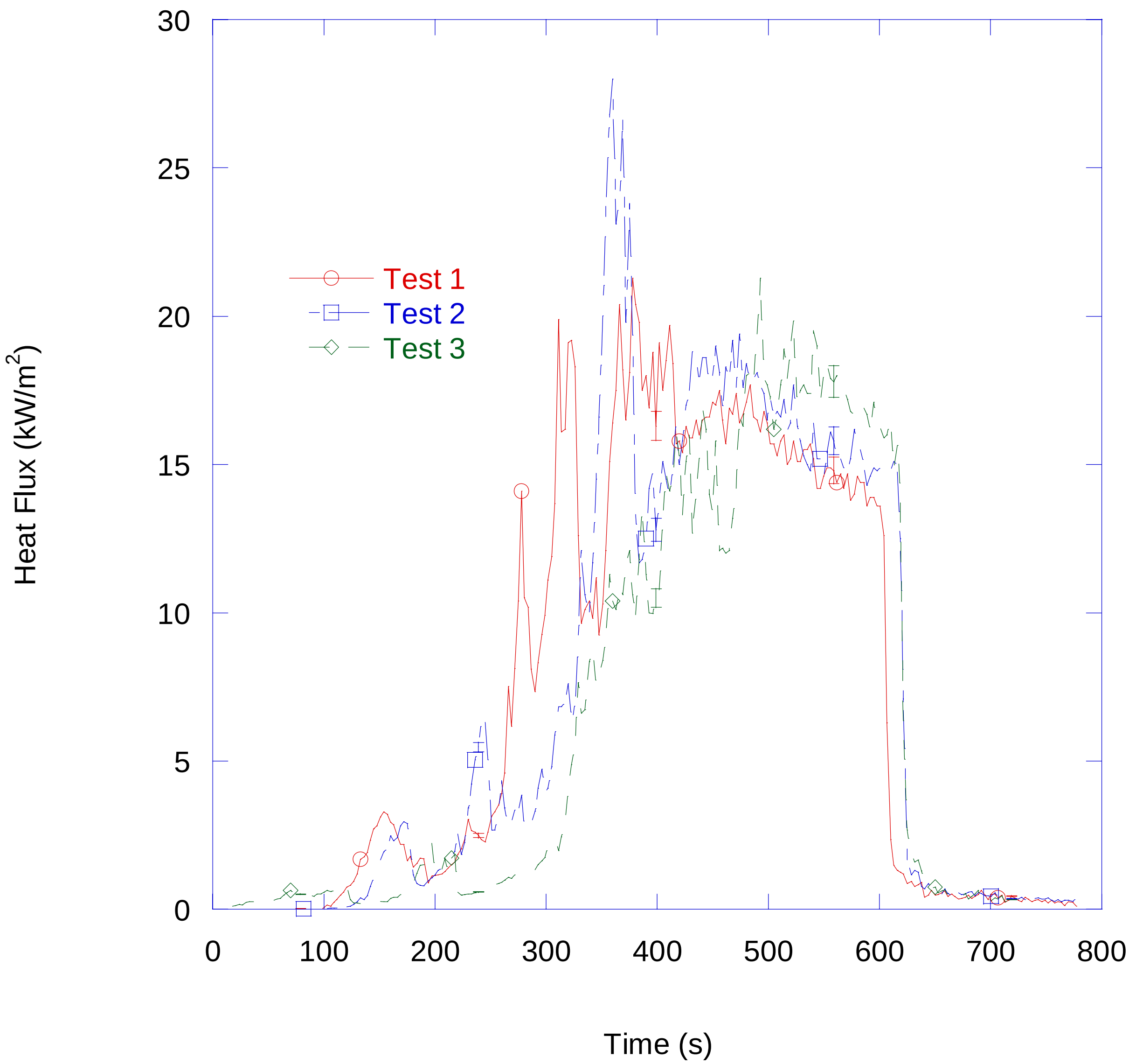

Figure 19. Graph showing total heat flux as a function of time for the first sensor location in each of the three tests.

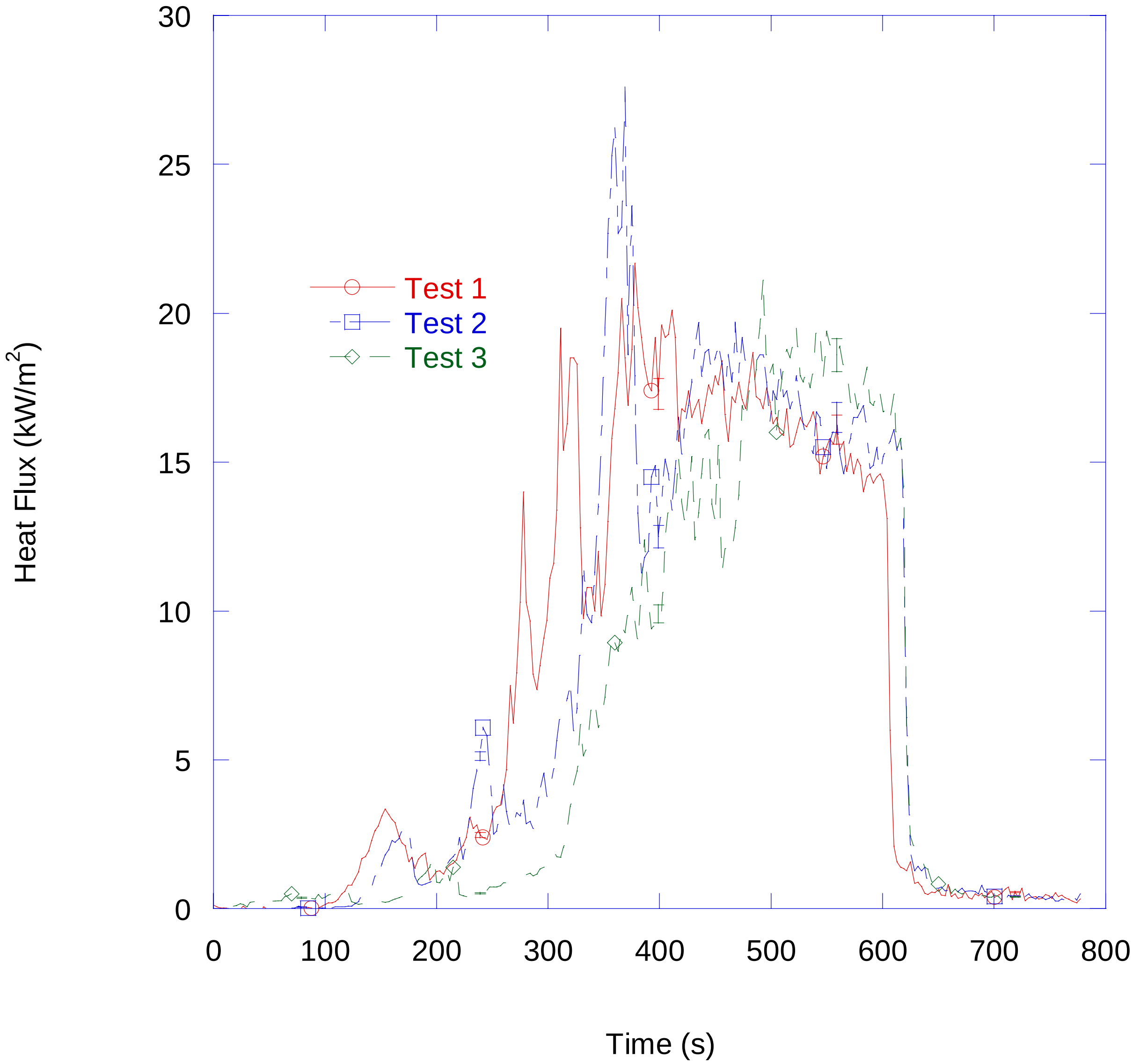

Figure 20. Graph showing total heat flux as a function of time for the second sensor location in each of the three tests.

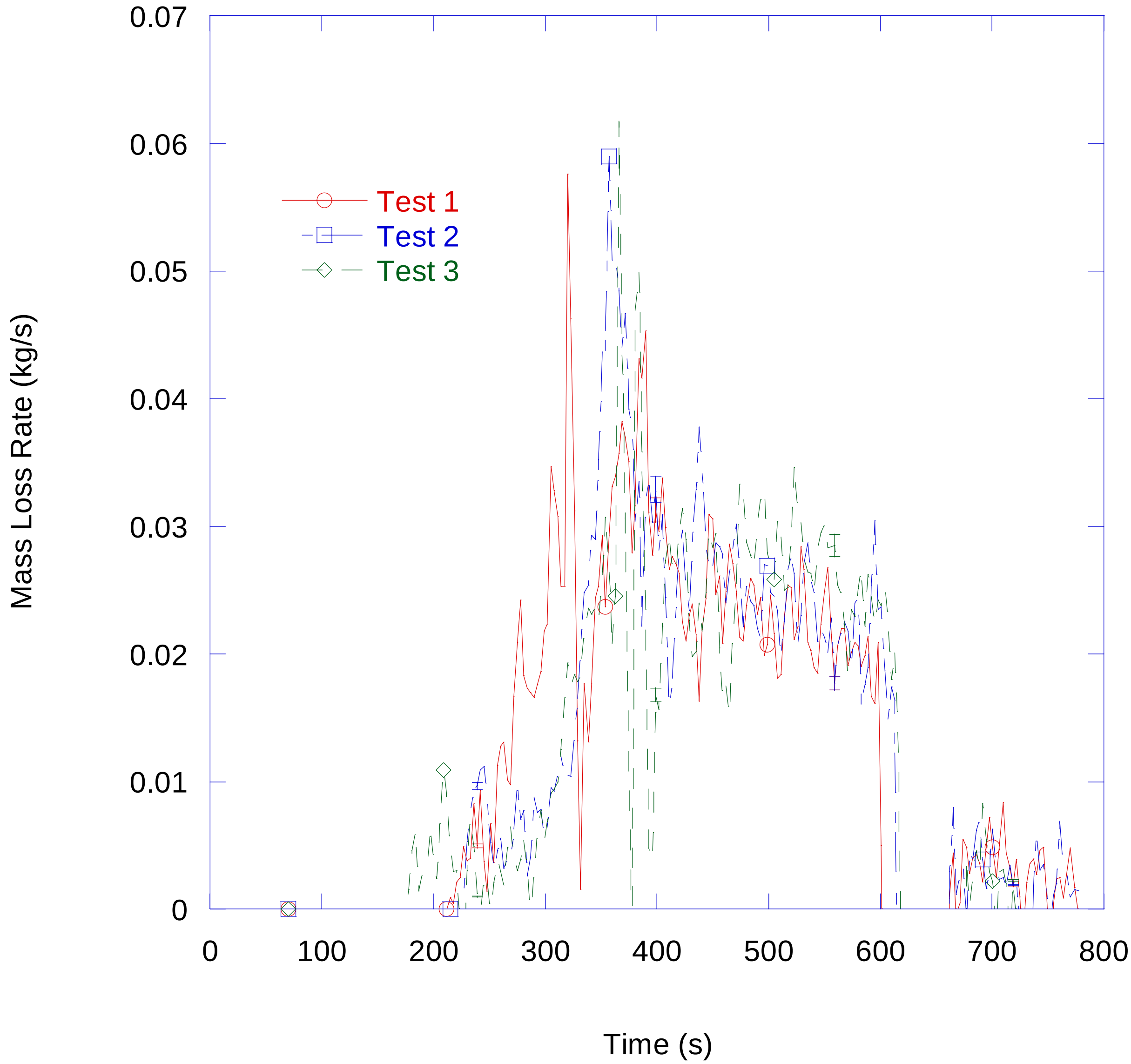

Figure 21. Graph of mass loss rate as a function of time for the three tests.