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Scotch Pine Christmas Tree Fire Tests

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Abstract

A series of fire tests were conducted to characterize the potential hazard from ignition of Scotch Pine Christmas trees. Heat release rate was measured as a function of time from ignition using a large calorimeter. In addition, radiative flux and total heat flux were measured at a location 2 m from the tree centerline. Seven of the trees were allowed to dry for approximately three weeks. These trees burned easily when ignited with an electric match. An eighth tree, freshly cut and kept in water until just before testing, could not be ignited.

Key Words:
fire data; fire models; fire tests; heat release rate; radiation heat flux

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 suppression system activation time. Heat flux measurements can be used to estimate potential for ignition of adjacent fuel items.

Christmas trees have been involved in a number of significant fire incidents [1, 2, 3, 4, 5]. Typical ignition scenarios involve shorted electrical lights [1, 2, 3] or open flame exposure [4]. According to the U.S. Consumer Product Safety Commission, Christmas trees account for approximately 400 fires annually, resulting in 10 deaths, 80 injuries and more than $15 million in property damage [6].

There are two primary types of trees used every year as Christmas trees; they are either real or artificial. Real trees vary significantly in species, shape and size. The moisture content of these trees and the dryness of their needles can have a significant impact on ignition and heat release rate. While an effort was made to obtain reasonably similar trees, the trees used in this study did vary somewhat. In order to address this variation, a number of replicate tests were conducted during this study. Differences in the heat release rate and heat flux data can also result from random differences in the spread of the fire. This study focuses primarily on the heat release rate of relatively dry trees. As a point of comparison, one tree used in this study was maintained in accordance with local regulations governing use of real trees in offices [7]. Among other things, these regulations require that the tree be cut in the user's presence, have an additional two inches cut from the bottom of the trunk, and be placed in a stand with at least a 7.6 liter capacity. In addition, the user must maintain the tree's water on a daily basis and keep a record of the maintenance.

Experimental Configuration

The experiments were conducted under the main hood in the NIST Large Fire Research Facility. This hood is 4 m by 5 m and slopes upward to a 1.2 m square duct. During a fire test, data from various sensors is acquired using a computer-based data acquisition system. The fire test data is 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 [8].

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 [9, 10] 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 [11] 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 10 together with data obtained from instruments in the exhaust hood. The measured heat release rate has been shown to be within 20 percent of the actual value [12]. Reference 12, page 8 contains details concerning the calculation of heat release rate and its implementation in the Large Fire Research Facility.

Each experiment was conducted with the tree centered under the exhaust hood (Figure 1). The radiative heat flux and total heat flux were measured with water cooled Gardon type transducers. The total heat flux gauge was located 1.2 m above the floor with its face 2 m from the tree centerline. The face of the radiative heat flux transducer was also located 2 m from the centerline of the tree. However, it was located 50 mm vertically above the total heat flux transducer. Based on manufacturer's data, the standard uncertainty for the heat flux measurements is estimated at ±3 % [13].

Experiments

Eight Scotch pine tree fire experiments were conducted under the main hood in the Large Fire Research Facility. With the exception of the last tree, all of the trees had been allowed to dry for approximately 3 weeks in a room with a nominal air temperature of 23 °C and a relative humidity of 50 %. The last tree was conditioned in the same room, however, it was placed in a 19 liter bucket filled with water. Observation of the water level in the bucket suggested that the tree continued to absorb water until the test. Prior to testing, the moisture content in each tree was measured at several points on the trunk using a moisture meter. The moisture content ranged from 25 % to 35 %. While the moisture content of the tree trunks varied by only 10 percent, the first seven trees differed significantly in apparent dryness from the eighth tree. The needles on the first seven trees were dry needles to the touch and slightly brown in color. The needles broke easily when bent slightly and fell from the tree when the branches were shaken.

An eighth tree was maintained in accordance with local regulations governing use of real trees in offices [7]. Among other things, these regulations require that the tree be cut in the user's presence, have an additional two inches cut from the bottom of the trunk, and be placed in a stand with at least a 7.6 liter capacity. In addition, the user must maintain the tree's water on a daily basis and keep a record of the maintenance. The eighth tree had a much greener color and the needles were very pliable. When a needle was pulled, the tree would bend slightly before needle would separate from the branch.

Each tree was weighed and measured before the test. In addition, the weigh of the remainder of the tree was determined after the test. This data is presented in Table 1. The standard uncertainty associated with the weigh measurements is ±0.2 kg, and the uncertainty associated with the length measurements is ±6 mm.

Table 1. Summary of Tree Parameters

Test No.	Weight (kg)		Height (m)	Width* (m)	Moisture Content (%)
	Before Test	After Test			
1	17.2	6.8	2.6	1.7	30
2	15.9	8.2	2.7	1.3	27
3	20.0	6.8	2.3	1.7	30
4	9.5	5.0	2.5	1.2	30
5	19.1	8.6	2.5	1.7	28
6	12.7	7.7	2.5	1.1	32
7	18.6	7.7	3.1	1.5	25
8	28.1	28.1	2.7	1.4	36

* The width is measured at the widest point of the tree.

Each tree was attached at the bottom of the trunk to a 0.5 m square by 12.7 mm thick plywood board using a 76 mm drywall screw. This board provided the necessary support to keep each tree standing during the tests. An electric match placed in the lower branches of the tree was used as the ignition source for each test. An electric match consists of a typical paper match from a matchbook wrapped with 0.3 mm diameter nichrome alloy wire. When an electric current passes through the wire, the wire generates heat due to resistance heating. This heating causes ignition of the match. If the tree is dry enough, the matches should ignite the tree. An electric match and its placement in a tree are shown in Figures 2 and 3 respectively.

A single match was insufficient to produce ignition of the eighth tree. Ignition was attempted a second time using an electric match composed of an entire matchbook containing 20 paper matches (Figure 2). This second attempt also failed to produce ignition. Finally, an open flame was applied to the tree using a propane torch. The branches ignited briefly, but they self-extinguished upon removal of the torch from the branches.

Results

The heat release rate curves obtained as a function of time from ignition for each of the first seven fire tests are shown in Figures 4 - 10. Since the eighth tree could not be ignited, there is no heat release rate curve available for the eighth test. Peak heat release rates range from about 1.6 MW to 5.2 MW. The total heat flux (solid line) and radiative heat flux (dashed line) measurements for each of the first seven tests are shown in Figures 11 - 17. Again, there is no heat flux measurements for the eighth test since the tree did not ignite. Photographs of the trees prior to testing and at the point of peak heat release rate for the second through seventh tests are shown in Figures 18 - 29. The arrows in the figures indicate the ignition location for each test. Figure 30 depicts the eighth tree prior to testing, and Figure 31 illustrates the results of several attempted ignitions. Due to an equipment failure, photographs of the first tree and test are not available.

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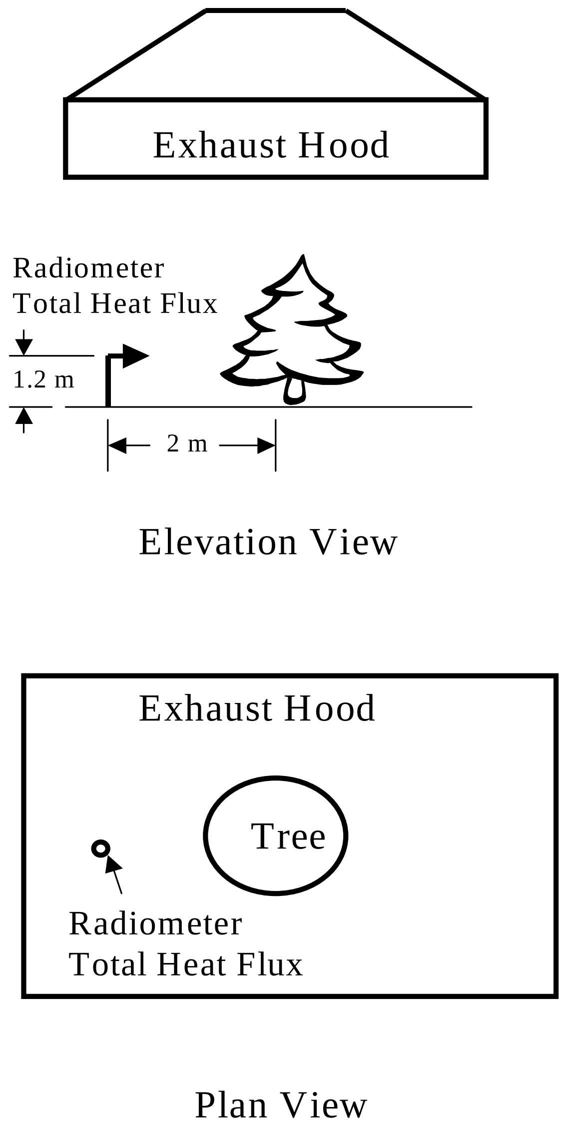

Figure 1. Plan and Elevation Views of Experimental Configuration

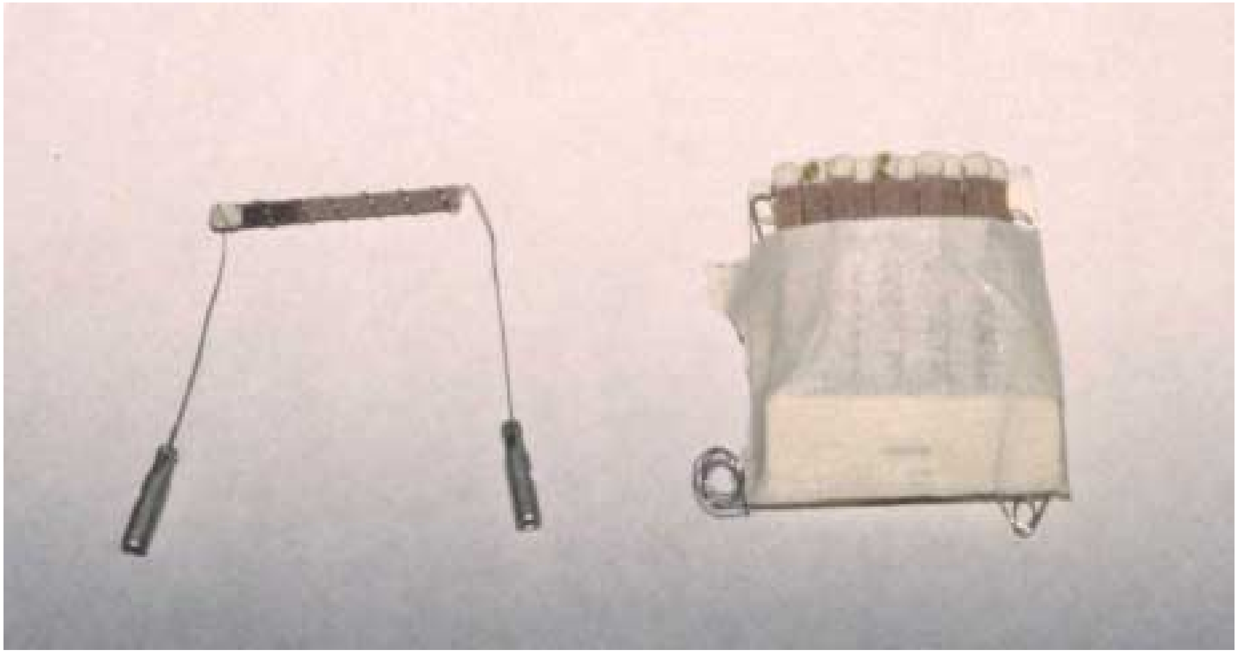

Figure 2. Photograph Showing Two Forms of an Electric Match, One with a Single Match and One with a Matchbook

Figure 3. Photograph Showing Placement of an Electric Match in the Branches of a Tree

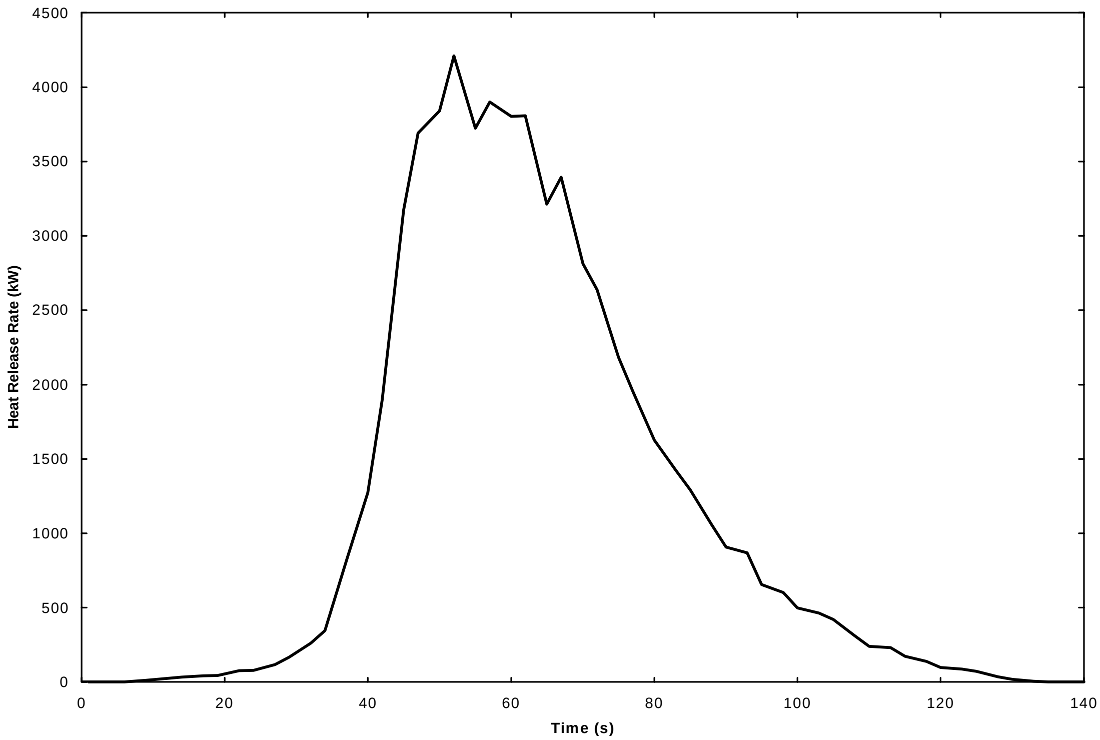

Figure 4. Graph of Heat Release Rate versus Time for Test No. 1

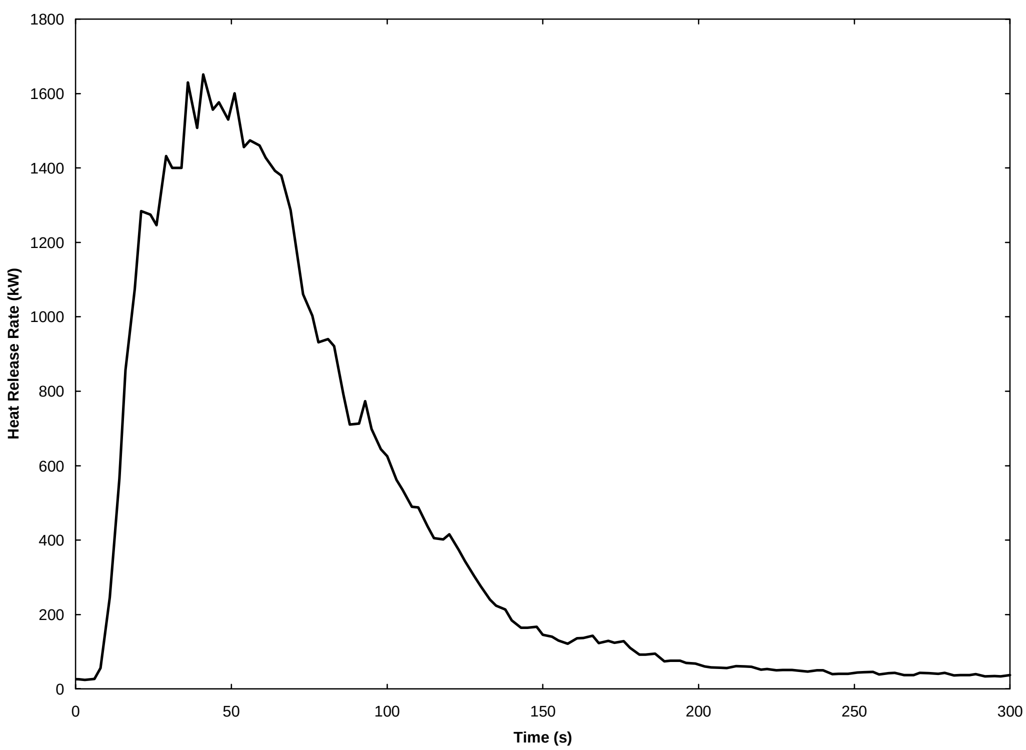

Figure 5. Graph of Heat Release Rate versus Time for Test No. 2

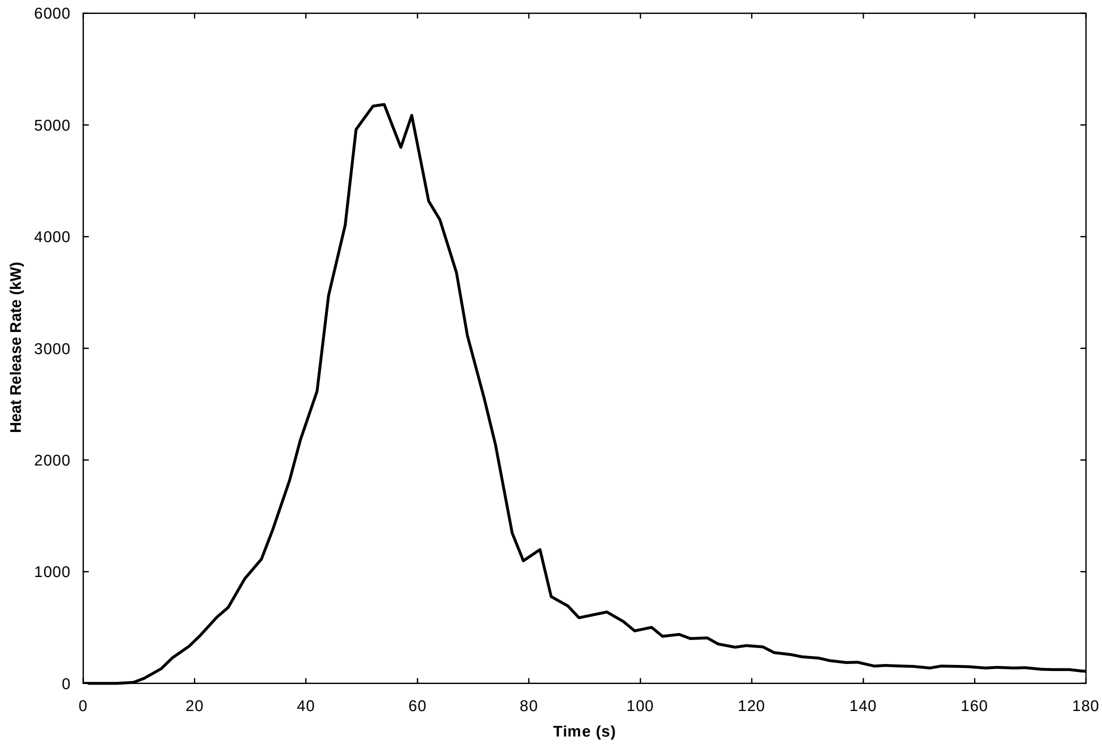

Figure 6. Graph of Heat Release Rate versus Time for Test No. 3

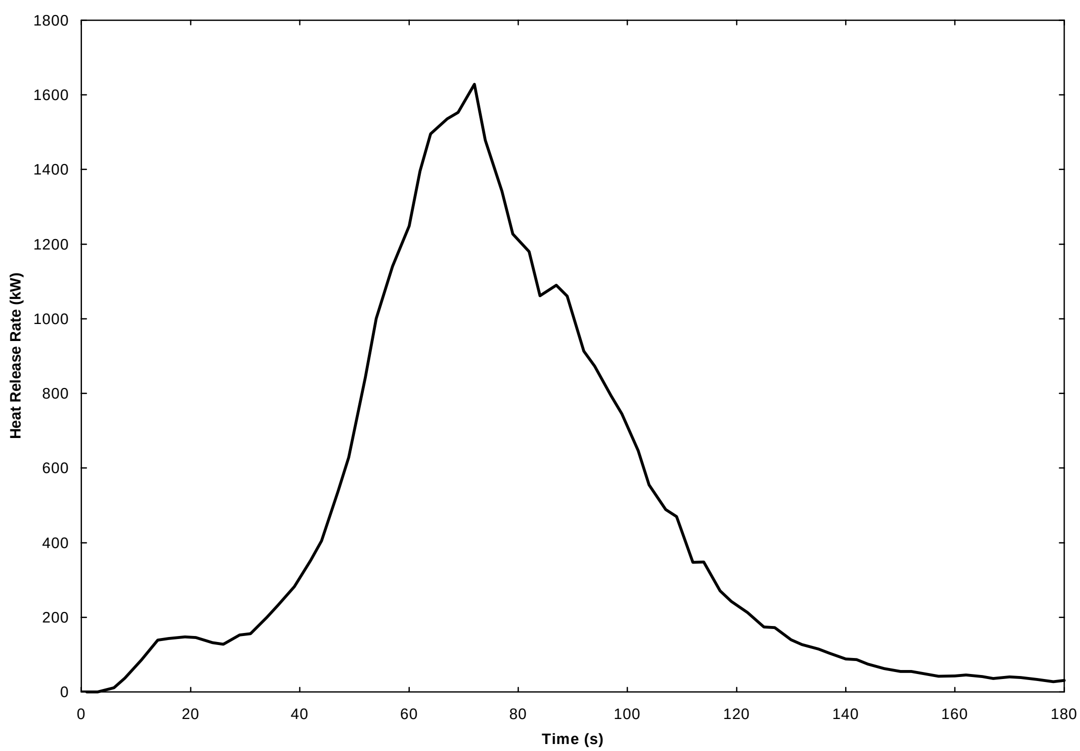

Figure 7. Graph of Heat Release Rate versus Time for Test No. 4

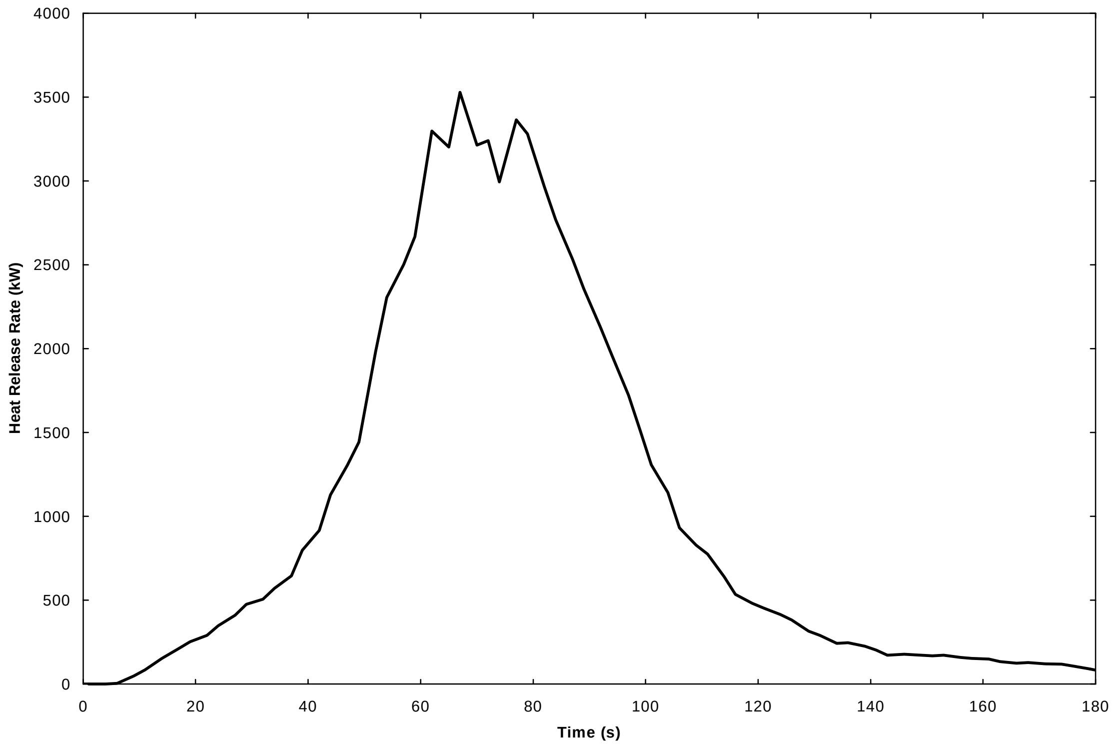

Figure 8. Graph of Heat Release Rate versus Time for Test No. 5

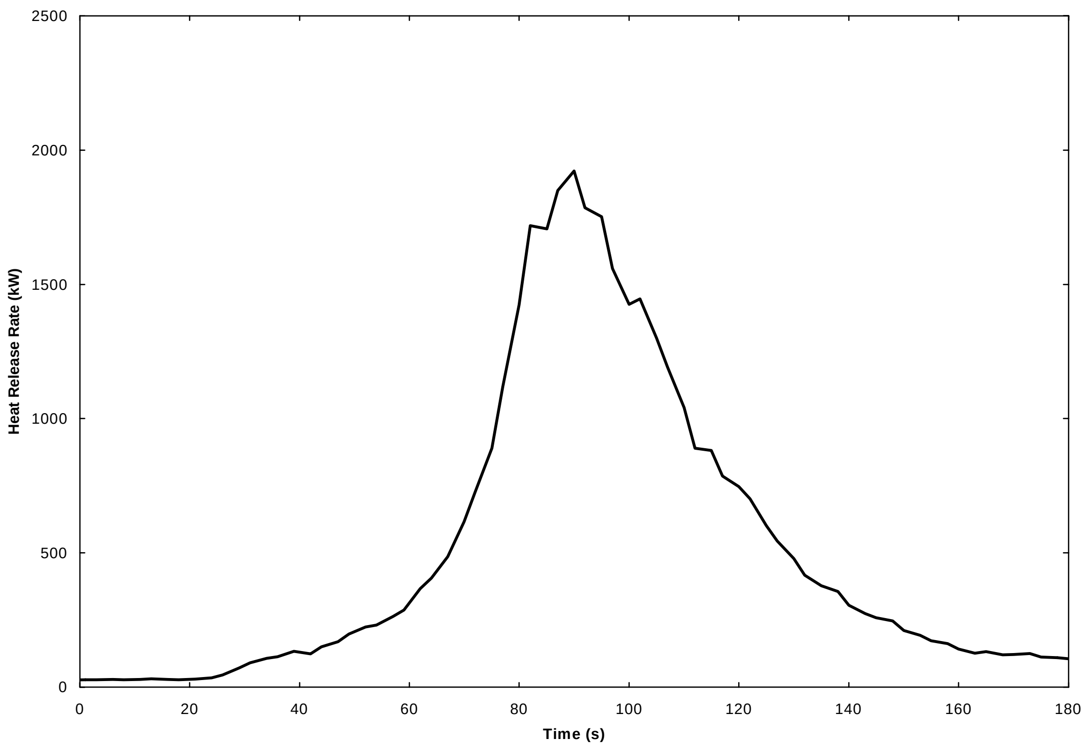

Figure 9. Graph of Heat Release Rate versus Time for Test No. 6

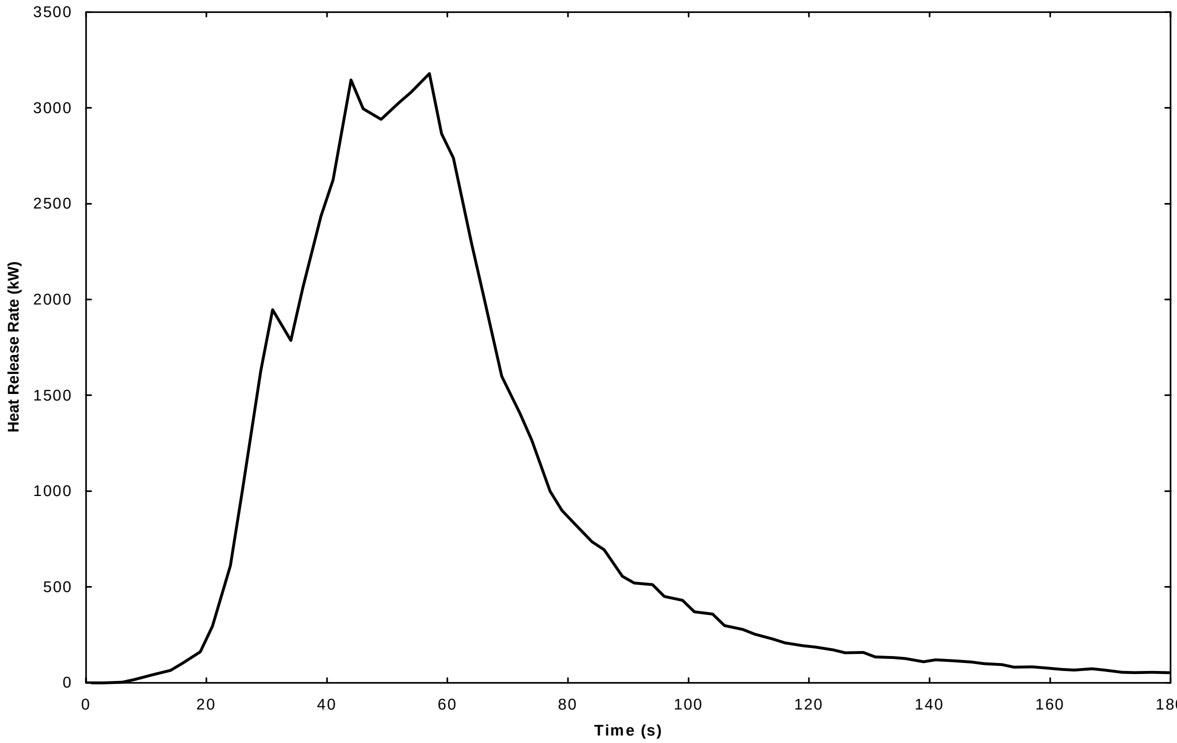

Figure 10. Graph of Heat Release Rate versus Time for Test No. 7

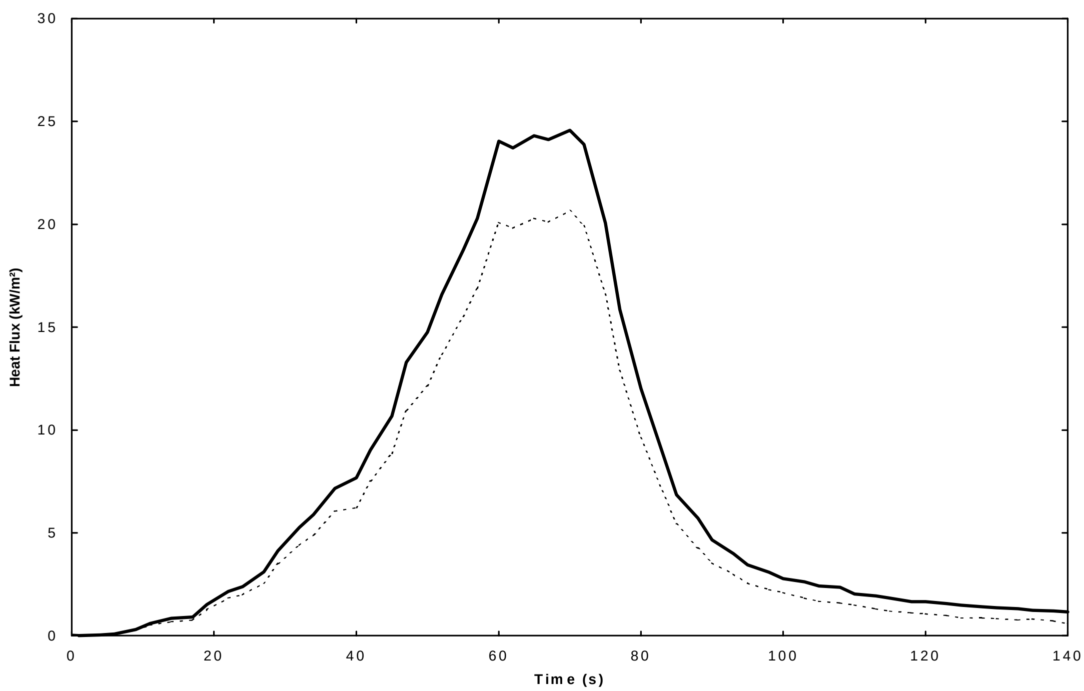

Figure 11. Graph of Total Heat Flux (solid line) and Radiative Heat Flux (dashed line) versus Time for Test No. 1

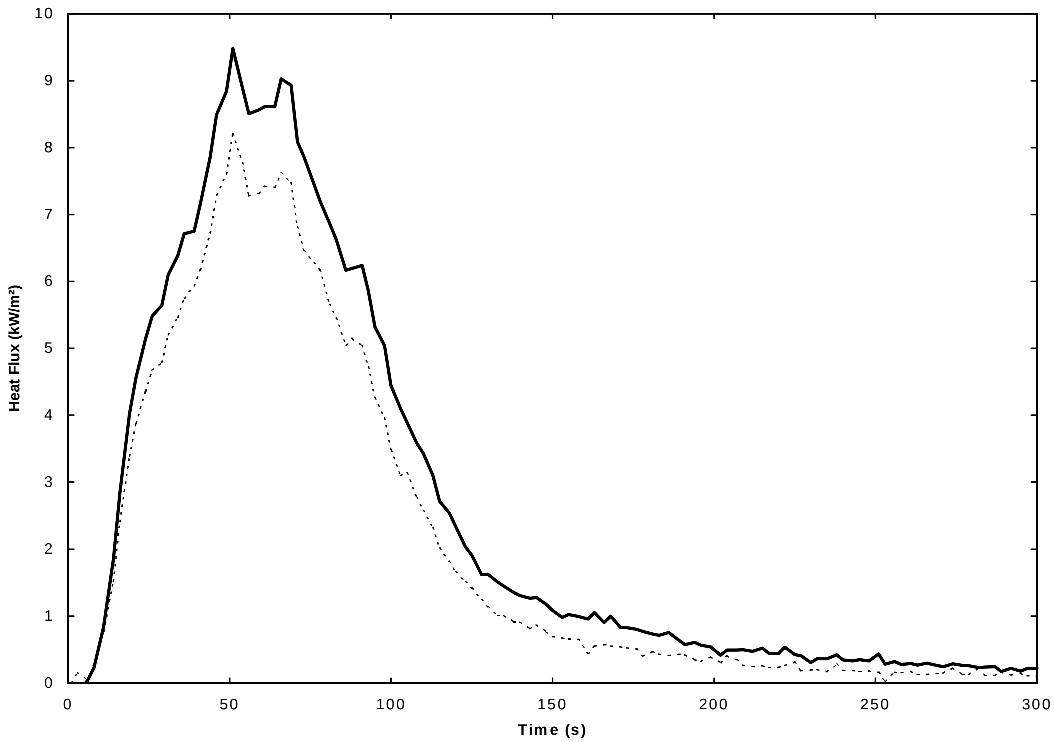

Figure 12. Graph of Total Heat Flux (solid line) and Radiative Heat Flux (dashed line) versus Time for Test No. 2

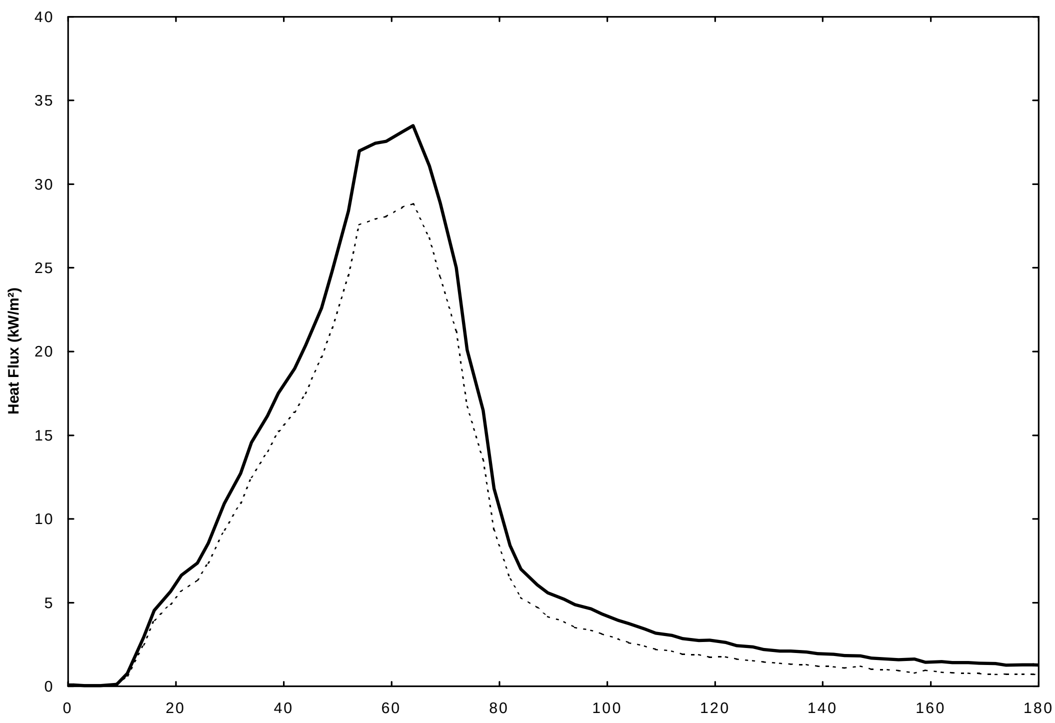

Figure 13. Graph of Total Heat Flux (solid line) and Radiative Heat Flux (dashed line) versus Time for Test No. 3

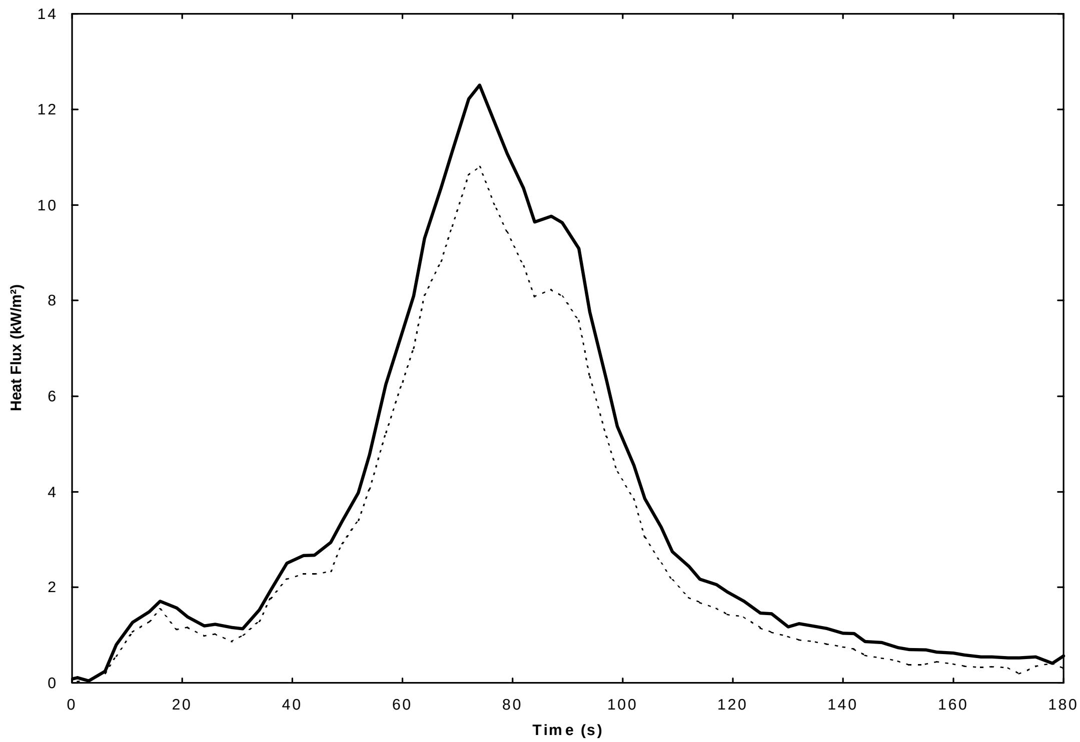

Figure 14. Graph of Total Heat Flux (solid line) and Radiative Heat Flux (dashed line) versus Time for Test No. 4

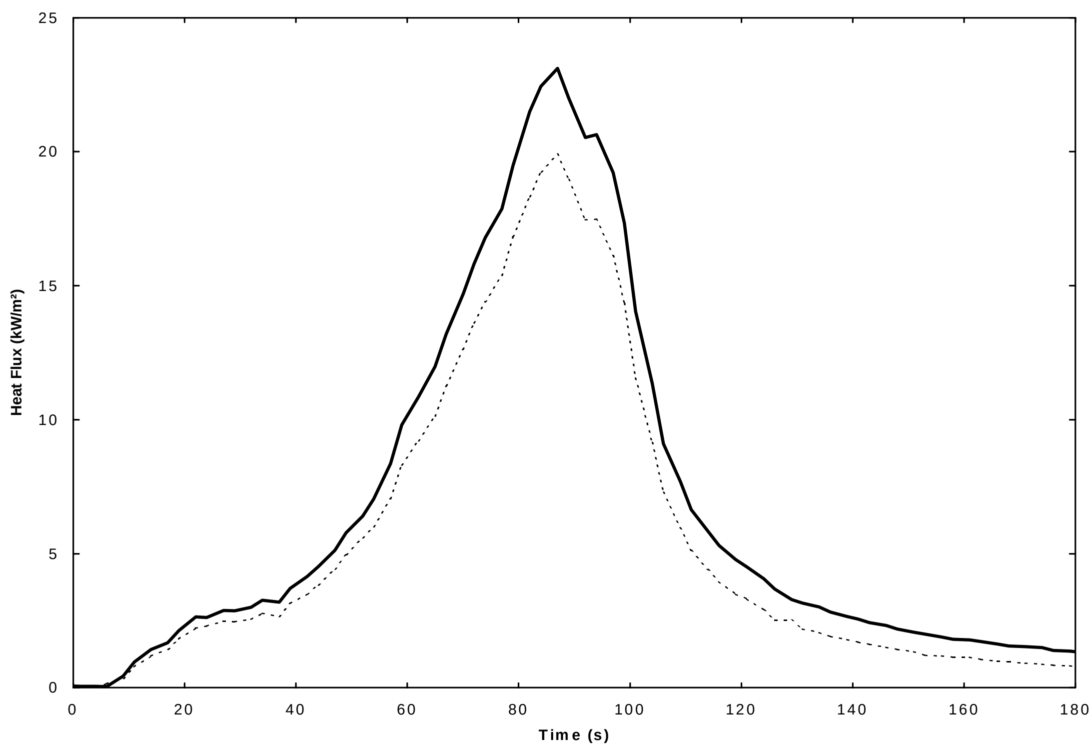

Figure 15. Graph of Total Heat Flux (solid line) and Radiative Heat Flux (dashed line) versus Time for Test No. 5

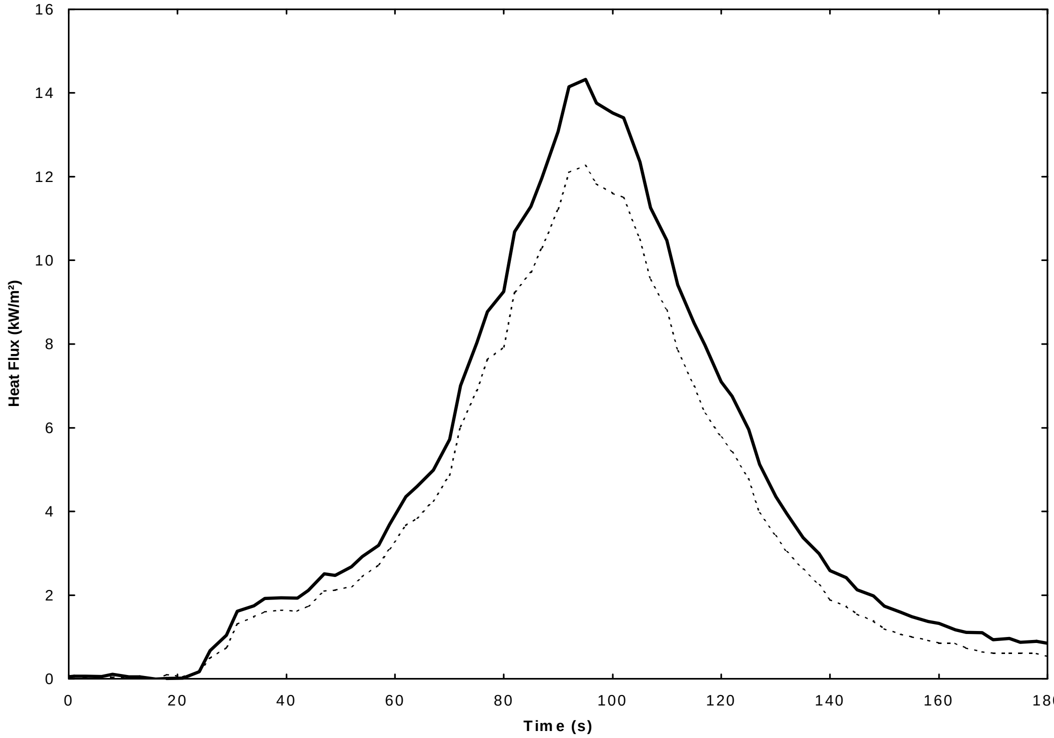

Figure 16. Graph of Total Heat Flux (solid line) and Radiative Heat Flux (dashed line) versus Time for Test No. 6

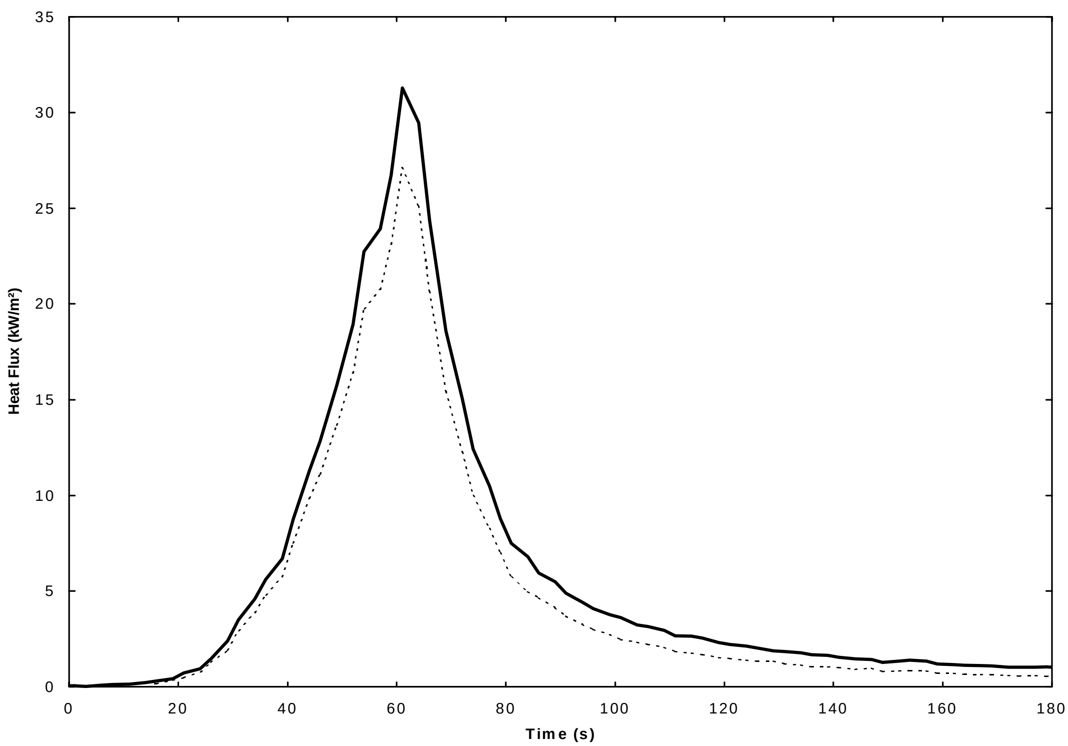

Figure 17. Graph of Total Heat Flux (solid line) and Radiative Heat Flux (dashed line) versus Time for Test No. 7

Figure 18. Photograph of Tree Prior to Start of Test No. 2 with Arrow Indicating Ignition Location

Figure 19. Photograph of Tree at Peak Heat Release Rate During Test No. 2

Figure 20. Photograph of Tree Prior to Start of Test No. 3 with Arrow Indicating Ignition Location

Figure 21. Photograph of Tree at Peak Heat Release Rate During Test No. 3

Figure 22. Photograph of Tree Prior to Start of Test No. 4 with Arrow Indicating Ignition Location

Figure 23. Photograph of Tree at Peak Heat Release Rate During Test No. 4

Figure 24. Photograph of Tree Prior to Start of Test No. 5 with Arrow Indicating Ignition Location

Figure 25. Photograph of Tree at Peak Heat Release Rate During Test No. 5

Figure 26. Photograph of Tree Prior to Start of Test No. 6 with Arrow Indicating Ignition Location

Figure 27. Photograph of Tree at Peak Heat Release Rate During Test No. 6

Figure 28. Photograph of Tree Prior to Start of Test No. 7 with Arrow Indicating Ignition Location

Figure 29. Photograph of Tree at Peak Heat Release Rate During Test No. 7

Figure 30. Photograph of Tree Prior to Start of Test No. 8 with Arrow Indicating Ignition Location

Figure 31. Photograph of Tree After Ignition Attempt During Test No. 8