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CHEMISTRY AND CHEMICAL ENGINEERING DIVISION
DEPARTMENT OF FIRE TECHNOLOGY
FAX (210) 522-3377

April 2, 2002

Mr. Bruno Belanger
Reichhold
P.O. Box 13582
Research Triangle Park, NC 27709

Re: SwRI Project No.: 01.04913.01.195 **FINAL REPORT**
**(Consisting of 4 pages)**

UL 94 (1998), "Standard for Tests for Flammability of Plastic Materials for Part in Devices and Appliances - Vertical Burning Test for Classifying Materials 94V-0, V-1, and V-2"

Dear Mr. Belanger:

This letter constitutes our final report on a fiberglass reinforced plastic product identified as Dion 31033-02 (Request 01-0470). The samples were received March 19, 2002 and submitted for evaluation by the above referenced test method.

The results apply specifically to the specimens tested, in the manner tested, and not to the entire production of these or similar materials, nor to the performance when used in combination with other materials.

## TEST METHOD AND PROCEDURE

This method is intended for use in determining the flammability of plastic materials used for parts in devices and appliances. It is designated primarily for plastic materials, but may be utilized in other applications as specified in applicable procurement documents. The results of this test do not necessarily indicate whether the material tested will resist the propagation of flame under severe exposure or when used in a manner that differs substantially from the test conditions.

The flammability test was performed on March 28, 2002, at Southwest Research Institute's (SwRI's) Department of Fire Technology, located in San Antonio, Texas. One set of specimens is conditioned in a circulating air oven for 168 hours at 158°F and then cooled at room temperature for a minimum of 4 hours prior to testing. These are the "aged" specimens. Another set of specimens is conditioned for at least 48 hours at 70°F and 50% relative humidity prior to testing ("before aging specimens"). Each specimen is inserted into the cabinet and the 3/4 in. Bunsen burner methane/air blue flame is applied vertically to the bottom end of the specimen, 3/8 in. from the top of the burner tube, for 10 seconds. The flame is then withdrawn at least 6 in. away from the specimen and the duration of flaming of the specimen noted. When the flaming ceases, the flame is applied again for 10 more seconds.

The material undergoing the test is evaluated for afterflame time, afterglow time, flaming drip, and char length. Any unusual behavior of the sample during testing is also reported.

**CLASSIFICATION CRITERIA** (reprinted from UL 94 Standard, Sections 3.2, 3.3, 3.4, 3.5)

A material classed 94V-0 shall:

A. Not have any specimens that burn with flaming combustion for more than 10 seconds after either application of the test flame;
B. Not have a total flaming combustion time exceeding 50 seconds for the 10 flame applications for each set of five specimens;
C. Not have any specimens that burn with flaming or glowing combustion up to the holding clamp;
D. Not have any specimens that drip flaming particles that ignite the dry absorbent surgical cotton located 12 inches below the test specimen;
E. Not have any specimens with glowing combustion that persists for more than 30 seconds after the second removal of the test flame.

A material classed 94V-1 shall:

A. Not have any specimens that burn with flaming combustion for more than 30 seconds after either application of the test flame.
B. Not have a total flaming combustion time exceeding 250 seconds of the 10 flame applications for each set of five specimens.
C. Not have any specimens that burn with flaming or glowing combustion up to the holding clamp.
D. Not have any specimens that drip flaming particles that ignite the dry absorbent surgical cotton located 12 inches (305 mm) below the test specimen.
E. Not have any specimens with glowing combustion that persists for more than 60 seconds after the second removal of the test flame.

A material classed 94V-2 shall:

A. Not have any specimens that burn with flaming combustion for more than 30 seconds after either application of the test flame.
B. Not have a total flaming combustion time exceeding 250 seconds for the 10 flame applications for each set of five specimens.
C. Not have any specimens that burn with flaming or glowing combustion up to the holding clamp.
D. Be permitted to have specimens that drip flaming particles that ignite the dry absorbent surgical cotton placed 12 inches (305 mm) below the test specimen.
E. Not have any specimen with glowing combustion that persists for more than 60 seconds after the second removal of the test flame.

If only one specimen from a set of five specimens does not comply with the requirements, another set of five specimens is to be tested. In the case of the total number of seconds of flaming, an additional set of five specimens is to be tested if the totals are in the range of 51-55 seconds for 94V-0 and 251-255 seconds for 94V-1 and 94V-2. All specimens from this second set shall comply with the appropriate requirements in order for the material in that thickness to be classified 94V-0, 94V-1, or 94V-2.

## MATERIAL DESCRIPTION

| | |
|---|---|
| Material ID:* | Request 01-0470 |
| Trade Name:* | Dion 31033-02 |
| Description:* | Fiberglass reinforced plastic (FRP) composites made by pultrusion process |
| Composition:* | 72% glass and 28% resin by weight |
| Color: | Brown/ mauve |
| Thickness: | 0.25 in. |

* From Client's material description and/or instructions

## PREPARATION AND CONDITIONING

| | |
|---|---|
| Preparation: | None other than conditioning required |
| Conditioning Time: | The "aged" specimens were placed in a circulating air oven for 168 hours at 158°F, and then cooled in a desiccator for 4 hours prior to testing; The "before aging" specimens were conditioned for 15 days at 70°F and 50% relative humidity prior to testing. |

## TEST RESULTS

| | |
|---|---|
| Date of Test: | March 28, 2002 |
| Number of Runs: | 10 (five specimens were tested before aging, and five were tested after aging) |

<u>BEFORE AGING:</u>

| Run No. | Flame Application | Afterflame Time (sec) | Afterglow Time (sec) | Drip with Flame | Ignition of Cotton | Burn to Holding Clamp |
|---|---|---|---|---|---|---|
| 1 | First | 0 | N/A | No | No | No |
| | Second | 0:02 | 0 | No | No | No |
| 2 | First | 0 | N/A | No | No | No |
| | Second | 0 | 0 | No | No | No |
| 3 | First | 0 | N/A | No | No | No |
| | Second | 0 | 0 | No | No | No |
| 4 | First | 0 | N/A | No | No | No |
| | Second | 0 | 0 | No | No | No |
| 5 | First | 0 | N/A | No | No | No |
| | Second | 0 | 0 | No | No | No |
| Totals | | 0:02 | 0 | No | No | No |

AFTER AGING:

| Run No. | Flame Application | Afterflame Time (sec) | Afterglow Time (sec) | Drip with Flame | Ignition of Cotton | Burn to Holding Clamp |
|---|---|---|---|---|---|---|
| 1 | First | 0 | N/A | No | No | No |
| | Second | 0 | 0 | No | No | No |
| 2 | First | 0 | N/A | No | No | No |
| | Second | 0 | 0 | No | No | No |
| 3 | First | 0 | N/A | No | No | No |
| | Second | 0 | 0 | No | No | No |
| 4 | First | 0 | N/A | No | No | No |
| | Second | 0:28 | 0 | No | No | No |
| 5 | First | 0 | N/A | No | No | No |
| | Second | 0 | 0 | No | No | No |
| Totals | | 0:28 | 0 | No | No | No |

**CONCLUSIONS**

On the basis of the test results, the material identified as Dion 31033-02 meets the specified criteria for UL 94V-0.

If there are any questions or if I can be of assistance, please do not hesitate to contact me by telephone at 210/522-3718 or fax at 210/522-3377. I can also be reached by electronic mail at anthony.sauceda@swri.org.

Sincerely,

A. L. Sauceda

Anthony L. Sauceda
Engineering Technologist
Material Flammability Section
ALS/ls
c:\wpdata\reports\archive\04913\r195.doc

Approved:

James R. Griffith for

Alex B. Wenzel
Director
Department of Fire Technology

# Fire resistance of preservative-treated slash pine fence posts

**Technical Note**

**Philip D. Evans**
**Peter Beutel**
**Ross B. Cunningham**
**Christine F. Donnelly**

**Abstract**

Preservative-treated slash pine posts were subjected to a burning test to determine the effects of treatment and fuel load on their fire resistance. Posts treated with chromated copper arsenate (CCA-C), CCA-wax, and CCA-oil smoldered to destruction; however, those treated with CCA-oil were less likely to be destroyed after 2 hours of smoldering. Creosote-treated posts and untreated controls did not smolder to destruction. A high fuel load decreased the fire resistance of posts.

Recently, water-repellent chromated-copper-arsenate (CCA) preservative formulations have been developed (6) to reduce the pronounced tendency of CCA-treated timber to split during natural exposure (4). These modified CCA formulations usually contain a hydrophobic additive such as wax (6) or petroleum oil, and a surfactant to stabilize the resulting emulsion. There is no published information on the fire resistance of fence posts treated with these modified CCA formulations, even though parts of rural North America and Australia are periodically subject to grass fires that may cause the destruction of fence posts made of treated wood. It is estimated that in Queensland and Western Australia, fire is the main cause of destruction in 18 percent of fence post failures (1). Fence posts treated with chromium-containing preservatives, such as CCA-C, are particularly susceptible to destruction by fire because once ignited they smolder until complete failure occurs (1). In contrast, posts treated with creosote are more fire resistant (3) and therefore have been recommended for use, in preference to CCA-treated posts, in fire-prone regions (2). The poor fire resistance of CCA- treated fence posts led to the development of a CCA formulation modified with zinc and phosphorous (CCA 3S) that reduced the problem of smoldering or 'afterglow' (5), but this formulation is no longer available commercially.

In this technical note, the fire resistance of pine fence posts treated with CCA-C, creosote, and two water-repellent CCA formulations (CCA-wax and CCA-oil) is reported. The aim was twofold, to determine whether treatment of fence posts with modified CCA formulations increases their resistance to fire compared to posts treated with unmodified CCA; and to examine the effect of fuel load on the fire resistance of preservative-treated posts.

## Materials and Methods

Posts made of slash pine (*Pinus elliotii* Engelm.), 97 mm in diameter and 1.6 to1.8 m long, were treated separately (nine posts per treatment) with CCA-C (2.1%), CCA-wax (2.1% CCA, 1% wax), and a CCA-oil emulsion (2.1% CCA, 5% petroleum oil) using a Bethel process. The process involved an initial vacuum of −90 kPa for 30 minutes, pressure of 1400 kPa for 62 minutes, and a final vacuum of −90 kPa for 42 minutes. Preservative salt retentions for posts treated with CCA-C, CCA-wax, and CCA-oil were determined by weight gain after treatment and were 12.0, 14.8, and 13.3 kg/m$^3$ respectively. A batch of nine posts was also treated with creosote at 90°C using a Reuping process, which involved initial pressure of 450 kPa for 15 minutes, pressure of 1380 kPa for 90 minutes, and a final vacuum of −80 kPa for 30 minutes. A batch of untreated posts was also retained as controls. Posts were air-dried for 4 weeks after treatment to allow

The authors are, respectively, Senior Lecturer, Senior Technical Officer (Dept. of Forestry), Statistical Consultant, and Data Analyst (Graduate School), The Australian National Univ., Canberra, ACT 0200, Australia. This paper was received for publication in February 1994.

Forest Prod. J. 44(9):37-39.

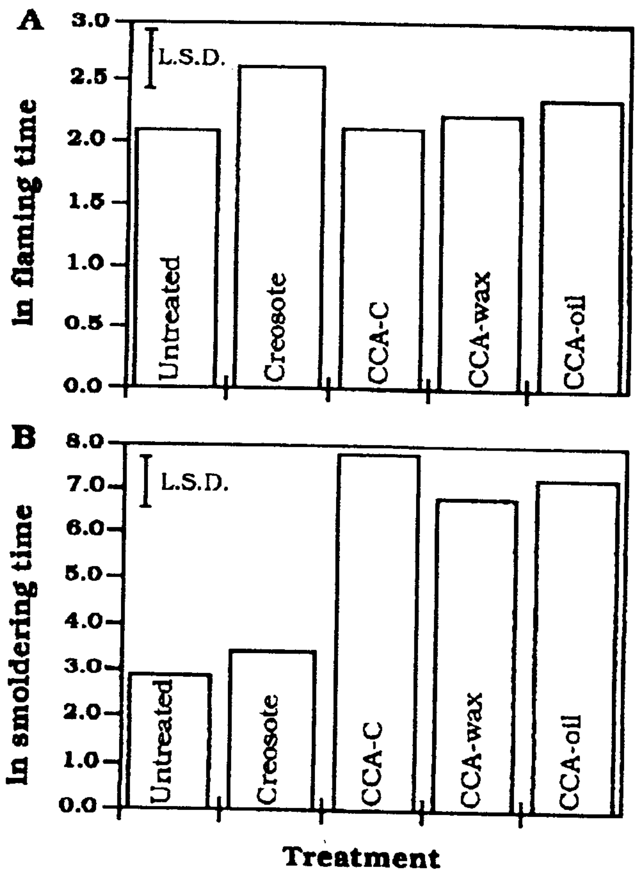


Figure 1. — Effect of preservative treatment on: A) flaming time of treated and untreated posts; and B) smoldering time of treated and untreated posts. ln = natural logarithm of time (min.).

preservative fixation to occur. The posts were then planted in the ground to a depth of approximately 500 mm, 1500 mm apart, in a randomized block design with five replicates, weathered for 6 months, and then subjected to a controlled burning test in the autumn of 1990, as described by McCarthy et al. (5). The average moisture content of untreated posts prior to the burning test, determined using an electrical resistance-type moisture meter, was 26.4 percent. Two fuel loads, 1 and 4 kg of air-dried (oat) straw surrounding and extending up the posts to heights of 767 and 835 mm, respectively, were used to simulate the effect of fires of low and high intensity. The straw was ignited and allowed to burn until it was completely consumed. This took, on average, 5 and 7.5 minutes for the 1- and 4-kg loads, respectively. Observations were then made of the duration of flaming and smoldering of posts and the time taken for destruction of the posts, i.e., until they fell over. Statistical methods involved estimating the treatment, fuel load, and treatment by fuel load interaction effects. This was achieved by analysis of variance for continuous response variables (sometimes transformed), and by logistic regression for discrete response such as whether or not a post was destroyed (fell) before a given time.

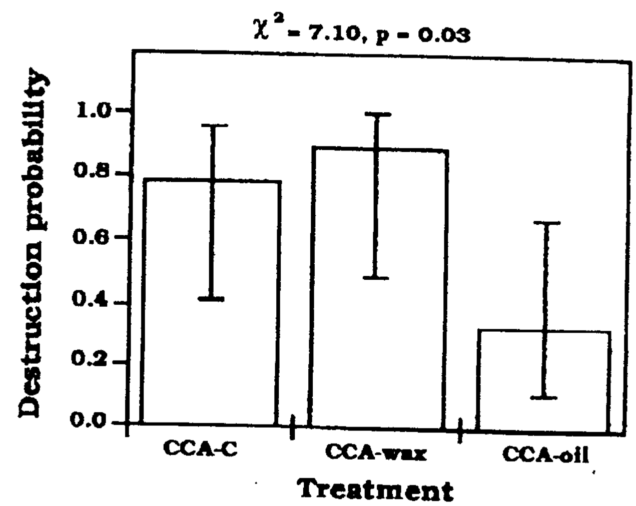


Figure 2. — Effect of preservative treatment on the probability of CCA-treated posts being destroyed 120 minutes after the start of the fire test.

## Results and discussion

### Effect of preservative treatment

Analysis of variance showed that there was no significant ($p > 0.05$) interaction of preservative treatment with fuel load and, therefore, the effect of treatment on flaming and smoldering time was aggregated across fuel load (Fig. 1). There was an insignificant ($p = 0.135$) effect of preservative treatment on the time that posts were alight (flaming time), although comparison of treatments reveals that creosote-treated posts were on average alight for longer than the other treated posts or untreated controls (Fig. 1A). This effect may be due to the volatilization and ignition of creosote rather than due to the combustion of wood. There was a highly significant ($p < 0.001$) effect of preservative treatment on the time that posts smoldered, and in accord with previous observations (1,2), posts treated with CCA-C showed prolonged smoldering (Fig 1B). Posts treated with CCA-wax and CCA-oil showed similar behavior (Fig 1B), but in contrast, untreated posts and those treated with creosote did not show prolonged smoldering. CCA-treated posts smoldered until destruction, but there was a significant ($p = 0.03$) difference between CCA treatments in the time taken for destruction to occur. Thus, the probability of posts being destroyed, 120 minutes after commencement of the burning test, was significantly lower for posts treated with CCA-oil than for posts treated with CCA-C or CCA-wax (Fig. 2), possibly because posts treated with CCA-oil smoldered less intensely. This suggests that fence posts treated with CCA-oil may be preferable to those treated with CCA-C and CCA-wax for use in fire-prone areas because if the smoldering posts could be extinguished shortly after ignition, a greater proportion of CCA-oil-treated posts would remain functional. However, in the absence of fire control, the additional fire resistance conferred by the CCA-oil treatment is likely to be of little value

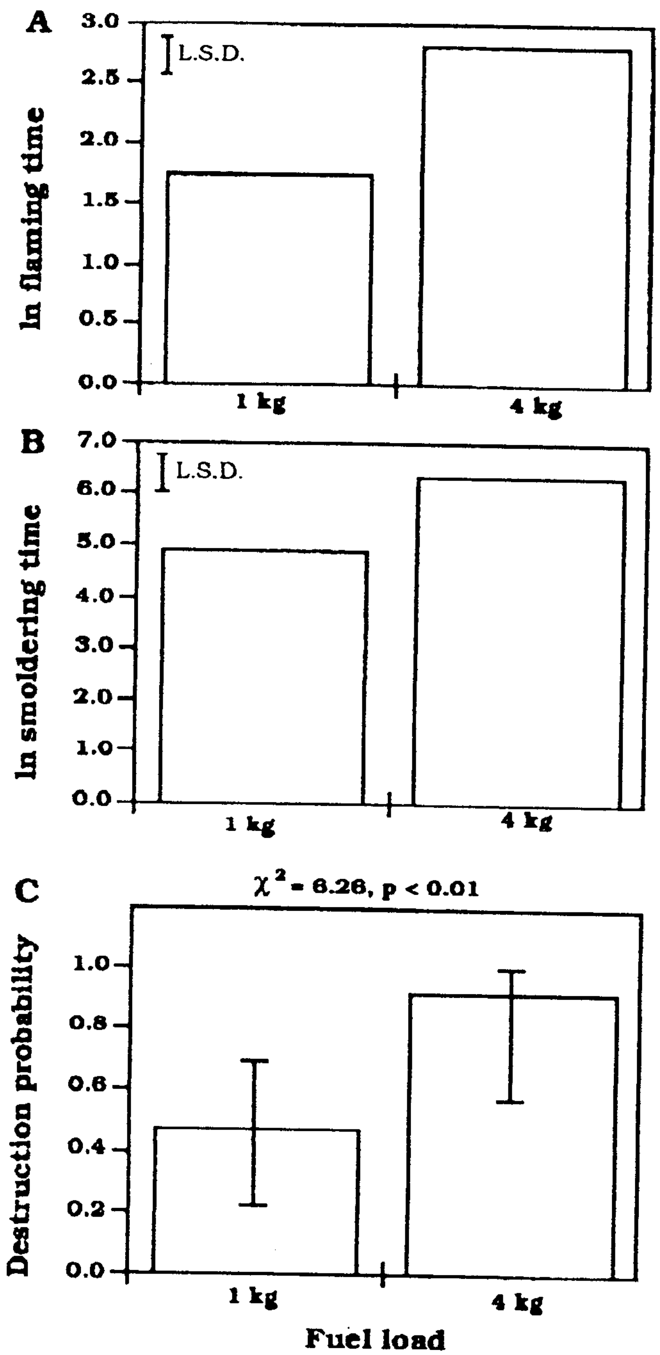


Figure 3. — Effect of fuel load on: A) flaming time of treated and untreated posts; B) smoldering time of treated and untreated posts; and C) probability of CCA-treated posts being destroyed 120 minutes after the start of the fire test. ln = natural logarithm of time (min.).

because ultimately, the majority of CCA-treated posts (including those treated with CCA-oil) failed. Because creosote-treated posts and untreated controls did not show prolonged smoldering, they were not destroyed by the burning test.

## Effect of fuel load

Analysis of variance showed a highly significant ($p < 0.001$) effect of fuel load on flaming and smoldering time. The effect of fuel load on flaming and smoldering time was aggregated across treatments (Fig. 3A,B) as there was no significant ($p > 0.05$) interaction of fuel load with preservative treatment. A high fuel load clearly increased the time that preservative-treated posts and untreated controls were alight and smoldering (Fig. 3A,B) and also significantly ($p < 0.01$) increased the probability of CCA posts being destroyed (Fig. 3C), but it was not sufficient to cause the destruction of creosote-treated posts and untreated controls. There are currently no standard test methods available for testing the fire resistance of preservative-treated fence posts, but the significant effect of fuel load on burning characteristics suggests standard tests, if developed, should consider fire intensity and duration.

## Conclusions

Adding petroleum oil at a level of 5 percent to CCA modified the smoldering characteristics of CCA-treated slash pine fence posts. Posts treated with CCA-oil were less likely than posts treated with CCA-C or CCA-wax to be destroyed after 2 hours of smoldering.

Creosote-treated posts were more resistant to the effects of fire than posts treated with CCA, but concerns in Australia about handling creosote-treated wood probably preclude the recommendation that they be used in preference to CCA-treated posts in fire-prone regions. Instead, there may be merit in examining the fire resistance of posts treated with other preservatives, particularly those that do not contain chromium, to determine whether they show greater fire resistance than CCA-treated posts.

Tests on the fire resistance of preservative-treated posts should take into account the effect of fuel load because a high fuel load increased the time that posts were alight and smoldering, and for CCA-treated posts, decreased their time to destruction.

## Literature cited

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6. Zahora, A.R. 1991. Interactions between water-borne preservatives and emulsion additives that influence the water repellency of wood. Doc. No. IRG/WP/2374. The Inter. Res. Group on Wood Pres. Stockholm, Sweden. 11 pp.

# ASTM E1354 CONE CALORIMETER TESTING OF A FIBER REINFORCED POLYESTER COMPOSITE MATERIAL

Prepared for:

Powertrusion International, Inc.
7845 East Redfield Road
Scottsdale, Arizona 85260-2991
(480) 951-8111

Prepared by:

HUGHES ASSOCIATES, INC.
FIRE SCIENCE & ENGINEERING

3610 Commerce Drive, Suite 817
Baltimore, Maryland 21227
(410) 737-8677
www.haifire.com

January 22, 2002

## ASTM E1354 CONE CALORIMETER TESTING OF A FIBER REINFORCED POLYESTER COMPOSITE MATERIAL

### EXPERIMENTAL

ASTM E1354 "Standard Test Method for Heat and Visible Smoke Release Rates for Materials and Products using an Oxygen Consumption Calorimeter" [1] provides a small-scale test procedure to measure the ignitability, heat release rate, mass loss rate, and combustion product generation rate of a material exposed to a specified irradiance level. During a test, a 100 mm by 100 mm sample is placed beneath a conical shaped heater that provides a uniform irradiance onto the sample surface, see Figure 1. The sample mass is constantly monitored using a load cell and the effluent from the sample is collected in the exhaust hood above the heater. In the duct downstream of the hood, the flow rate, smoke obscuration, and $O_2$, $CO_2$ and CO concentrations are continuously measured.

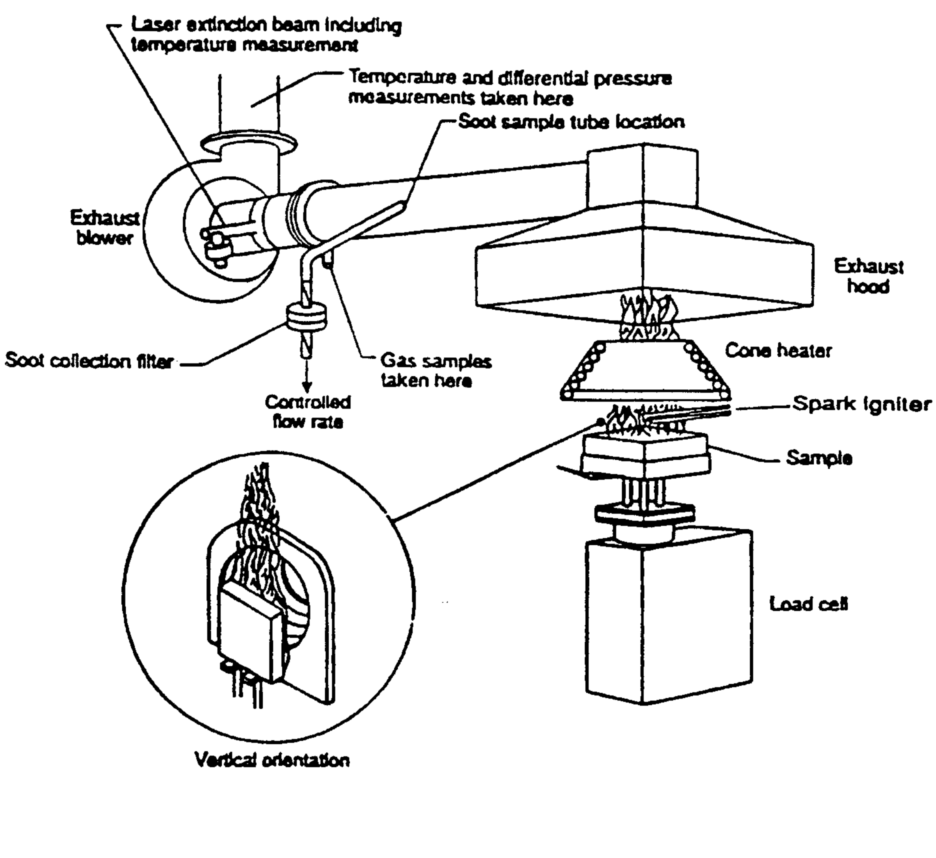



**Figure 1. ASTM E1354 Cone Calorimeter Test Apparatus.**

A spark igniter 12.5 mm above the sample surface is used to initiate the burning of any combustible gas mixture produced by the sample. Once the sample ignites, the burning of the sample causes a reduction in the oxygen concentration within the effluent collected by the hood. This reduction in oxygen concentration has been shown to correlate with the heat release rate of the material, 13.1 MJ per kg of $O_2$ consumed. This is known as the oxygen consumption principle. Using this principle, the heat release rate per unit area of the sample is determined with time using measurements made in the duct.

Material samples were tested at a range of irradiance levels (25, 50, and 75 $kW/m^2$) to evaluate the material performance when exposed to different heat loads. In accordance with the ASTM E1354, each sample was tested three times at each irradiance level for a total of nine tests. The ASTM E1354 standard requires the following data be reported for each material tested :

- Time to ignition (s)
- Peak rate of heat release ($kW/m^2$)
- Rates of heat release averaged over various time periods, starting with the time of ignition ($kW/m^2$)
- Effective heat of combustion (MJ/kg)
- Mass loss rate per unit area ($kg/s\ m^2$)
- Percent specimen mass lost (%)
- Average smoke specific extinction area ($m^2/kg$). Smoke production from a material has the rational units of $m^2$, representing the extinction cross-section of the smoke. This is normalized by the amount of specimen mass loss (kg)
- Average yields of each of the measured gas species (kg/kg)

In addition to the standard data, non-standard measurements were made during the tests to quantify the heat transmission through the sample. This was done by measuring temperature on the surface and unexposed side of the sample continuously throughout the test, as shown in Figure 2. The surface temperature was measured using a optical pyrometer, Wahl HSM 400, with an emissivity setting of 0.95. The temperature on the unexposed side of the sample was measured using a Type K thermocouple that was taped to the back of the sample.

## SAMPLE DESCRIPTION

Samples were supplied to Hughes Associates, Inc. (HAI) by Dr. Shridhar Yarlagadda of the University of Delaware. Samples were 100 mm by 100 mm but the thickness was non-uniform, as shown in Figure 2. A non-uniform thickness was tested because it was representative of the composite construction. Samples were a brownish color and were described as a fiber reinforced polyester composite material. Samples were allowed to condition in the laboratory environment for 24 hours prior to being tested.

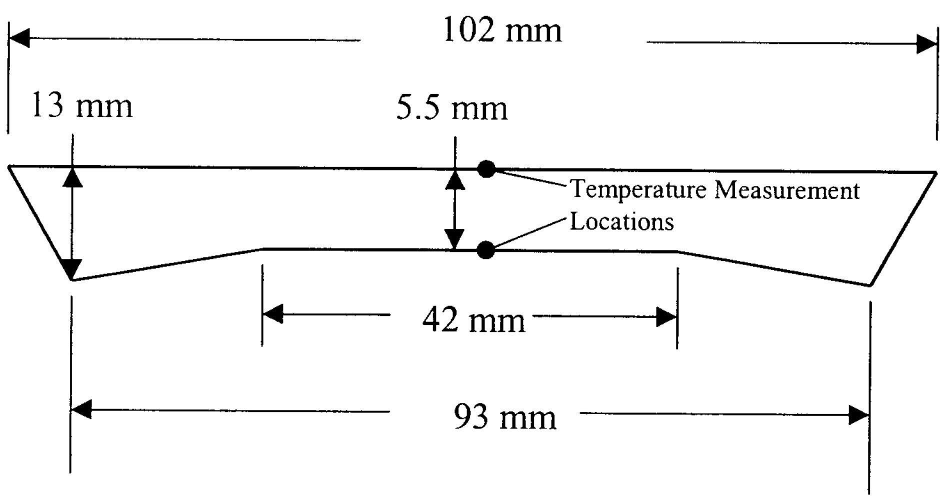



**Figure 2. Cross-section of sample showing dimensions and location of temperature measurements.**

## TEST RESULTS

A summary of the standard cone calorimeter test results is provided in Table 1. A more detailed summary of the results and a heat release rate curve for each test is provided in Appendix A. The average results for the composite material at irradiance levels of 25 and 50 kW/m$^2$ are shown in Table 2 compared with data for untreated wood, 19 mm thick Redwood and 17 mm thick Douglas Fir [2].

The temperature on the surface and the unexposed side of the sample is provided in Figures 3-5 for irradiance levels of 25, 50, and 75 kW/m$^2$, respectively. Figure 6 is a comparison of the temperatures at three different irradiance levels.

**Table 1. Summary of cone calorimeter test results on the fiber reinforced polyester composite.**

| ID # | Irradiance [kW/m$^2$] | Initial Mass [g] | Fraction Burned[%] | Time to Ignition[s] | Burn Duration[s] | Test Avg. MLR [g/(s m$^2$)] | Avg. Eff. HOC [MJ/kg] | Total Heat Release [MJ/m$^2$] | Test Avg. HRR [kW/m$^2$] | Peak Heat Release Rate HRR [kW/m$^2$] | Peak Heat Release Rate Time [s] | Test Avg. SEA [m2/kg] |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| cn01171 | 25 | 143.0 | 26.9 | 225 | 1020 | 4.1 | 22.9 | 88.0 | 85 | 185 | 31 | 619 |
| cn01188 | 25 | 169.4 | 23.5 | 260 | 1255 | 3.1 | 18.2 | 72.4 | 58 | 128 | 30 | 556 |
| cn01189 | 25 | 153.4 | 24.6 | 283 | 962 | 3.6 | 16.2 | 61.2 | 64 | 150 | 27 | 691 |
| **Average** | **25** | **155.3** | **25.0** | **256** | **1079** | **3.6** | **19.1** | **73.9** | **69** | **154** | **29** | **622** |
| | | | | | | | | | | | | |
| cn01173 | 50 | 146.1 | 23.8 | 77 | 851 | 4.1 | 19.8 | 68.9 | 81 | 161 | 16 | 886 |
| cn01186 | 50 | 175.7 | 23.6 | 69 | 1182 | 3.5 | 20.1 | 83.3 | 70 | 167 | 20 | 561 |
| cn01187 | 50 | 153.4 | 23.2 | 75 | 915 | 3.8 | 17.3 | 61.6 | 67 | 144 | 19 | 520 |
| **Average** | **50** | **158.4** | **23.5** | **74** | **983** | **3.8** | **19.1** | **71.3** | **73** | **157** | **18** | **656** |
| | | | | | | | | | | | | |
| cn01182 | 75 | 145.1 | 28.0 | 29 | 771 | 6.2 | 19.7 | 80.0 | 104 | 208 | 17 | 1360 |
| cn01183 | 75 | 154.8 | 24.7 | 27 | 693 | 6.2 | 19.3 | 73.9 | 106 | 212 | 18 | 987 |
| cn01184 | 75 | 140.3 | 27.9 | 27 | 658 | 6.1 | 17.8 | 69.4 | 105 | 216 | 19 | 1282 |
| **Average** | **75** | **146.7** | **26.9** | **28** | **707** | **6.2** | **18.9** | **74.4** | **105** | **212** | **18** | **1210** |
| | | | | | | | | | | | | |
| **Total Avg.** | | **153.5** | **25.1** | | | | **19.0** | **73.2** | | | | **829** |

MLR=Mass Loss Rate per unit area
HOC=Heat of Combustion
HRR=Heat Release Rate per unit area

**Table 2. Comparison of cone calorimeter test data for the fiber reinforced polyester composite with data on two types of untreated wood [2].**

| ID # | Irradiance [kW/m$^2$] | Initial Mass [g] | Fraction Burned[%] | Time to Ignition[s] | Burn Duration[s] | Test Avg. MLR [g/(s m$^2$)] | Avg. Eff. HOC [MJ/kg] | Total Heat Release [MJ/m$^2$] | Test Avg. HRR [kW/m$^2$] | Peak Heat Release Rate HRR [kW/m$^2$] | Peak Heat Release Rate Time [s] | Test Avg. SEA [m2/kg] |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| FRP | 25 | 143.0 | 26.9 | 225 | 1020 | 4.1 | 22.9 | 88.0 | 85 | 185 | 31 | 619 |
| Redwood | 25 | 82.0 | - - | 133 | 1460 | 5.4 | 9.3 | - - | 50 | 129 | - - | 46 |
| Douglas Fir | 25 | 79.0 | - - | 70 | 1056 | 8.2 | 11.6 | - - | 95 | 155 | - - | 15 |
| | | | | | | | | | | | | |
| FRP | 50 | 158.4 | 23.5 | 74 | 983 | 3.8 | 19.1 | 71.3 | 73 | 157 | 18 | 656 |
| Redwood | 50 | 82.0 | - - | 11 | 1061 | 7.4 | 12.7 | - - | 94 | 200 | - - | 27 |
| Douglas Fir | 50 | 79.0 | - - | 11 | 776 | 10.8 | 10.9 | - - | 118 | 207 | - - | 16 |

FRP=Fiber-reinforced plastic supplied by Powertrusion
MLR=Mass Loss Rate per unit area
HOC=Heat of Combustion
HRR=Heat Release Rate per unit area
Data from Janssens (1991), Redwood is 19 mm thick and Douglas Fir is 17 mm thick

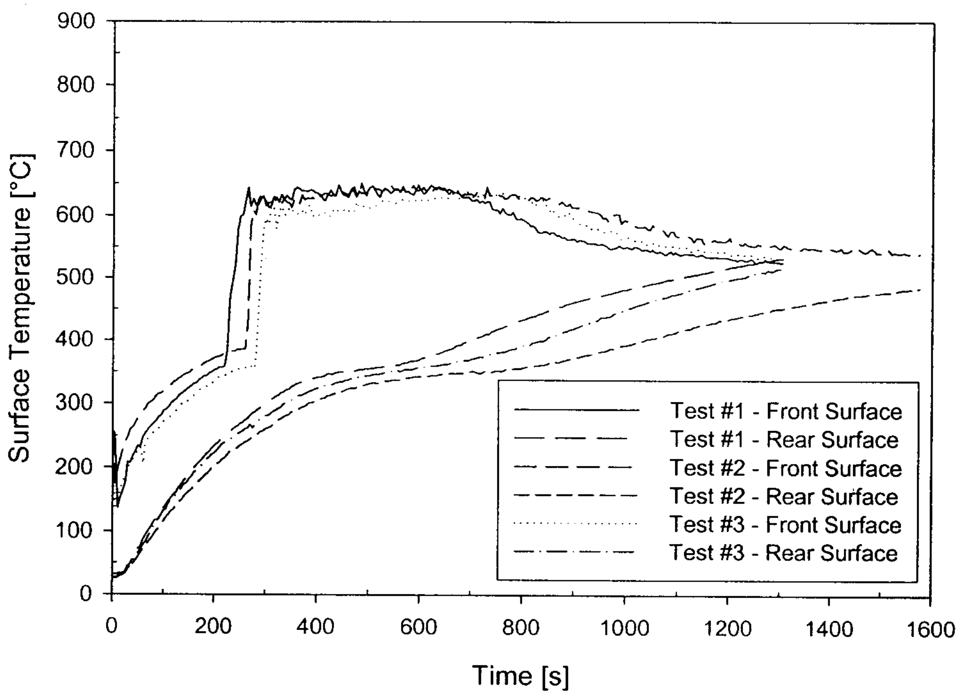



**Figure 3. Surface (front) and unexposed (rear) side temperatures in tests at 25 kW/m$^2$.**

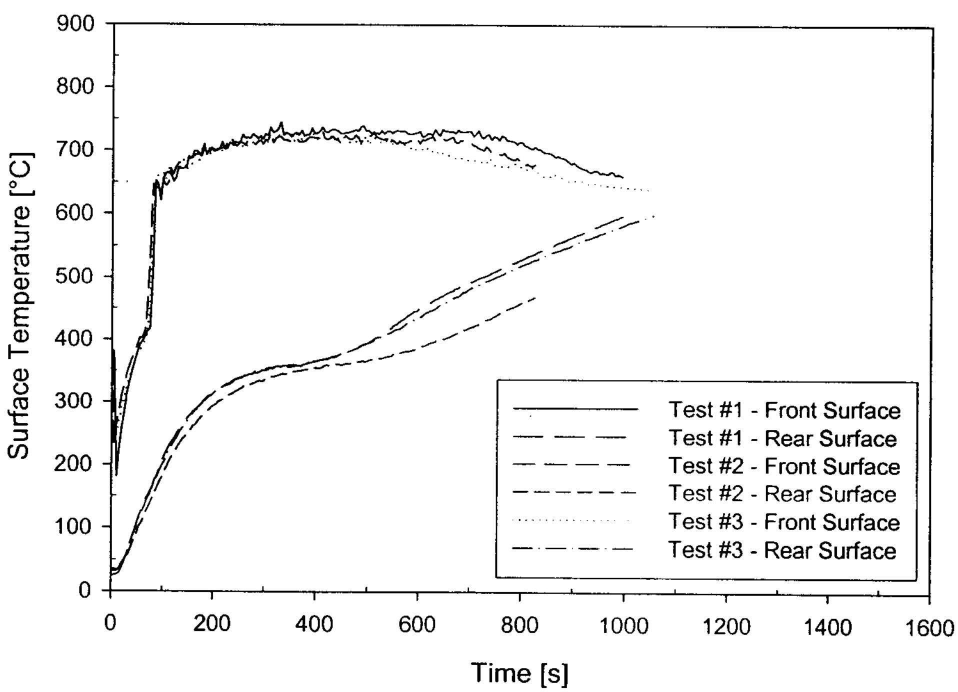



**Figure 4. Surface (front) and unexposed (rear) side temperatures in tests at 50 kW/m$^2$.**

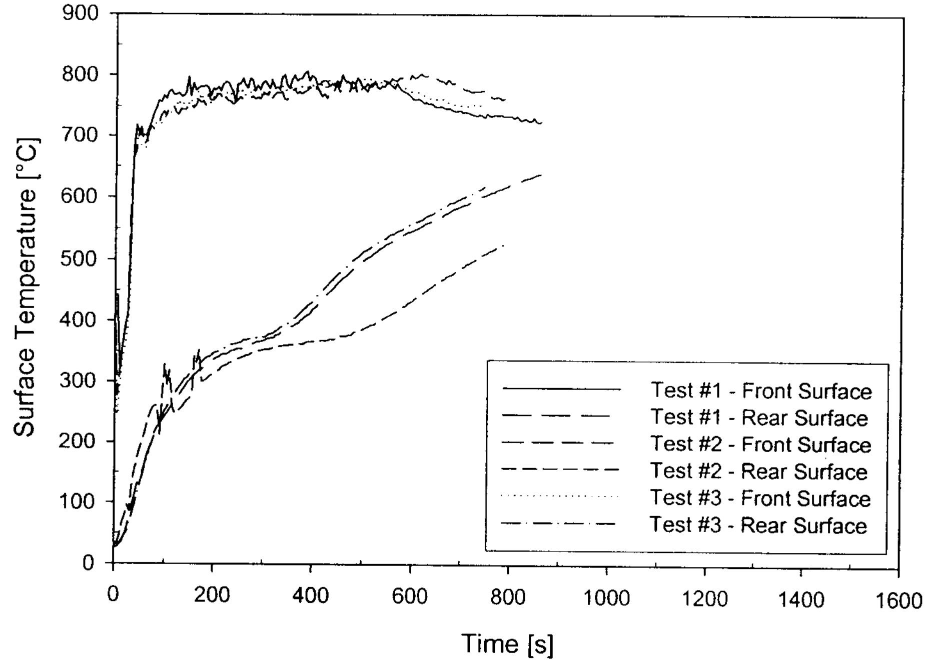



**Figure 5. Surface (front) and unexposed (rear) side temperatures in tests at 75 kW/m$^2$.**

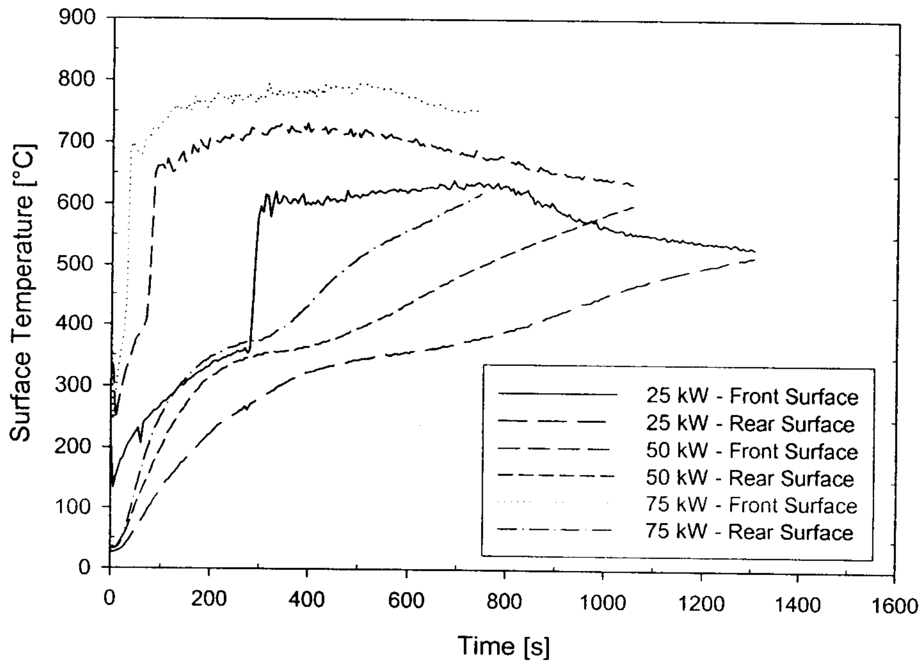



**Figure 6. Surface (front) and unexposed (rear) side temperatures in tests at 25, 50, and 75 kW/m$^2$.**

## REFERENCES


1. ASTM E1354, "Standard Test Method for Heat and Visible Smoke Release Rate for Materials and Products Using an Oxygen Consumption Calorimeter," *1997 Annual Book of ASTM Standards,* Vol. 04.01: Building Seals and Sealants; Fire Standards; Dimension Stone, American Society for Testing and Materials, Philadelphia, PA, pp. 649-666, (1997).
2. Janssens, M.L., "Fundamental Thermophysical Characteristics of Wood and their Role in Enclosure Fire Growth," Ph.D. Dissertation, University of Gent (Belgium), September, (1991).

# APPENDIX A. ASTM E1354 CONE CALORIMETER TEST DATA

# Cone Calorimeter Summary Data Sheet

Test Number and Data File: cn01171
Date: 1/17/2002
Time: 8:48
Test Operator: Ralph Ouellette

Manufacturer/Customer: Powertrusion International Inc.
Point of Contact: Brian Lattimer
HAI Job Number: 2568

Sample ID: 1.1
Sample Description: Composite Telephone Pole Material
Sample Thickness (mm): 13 edge, 5.5 center
Sample # 1 of 9
Conditioning (if any): Cut to size

Sample Orientation: Horizontal
Holder Type: Pan
Spark Used: Yes
Applied Heat Flux($kW/m^2$): 25

Ignition Time (sec): 225
Flame Duration (sec): 1020

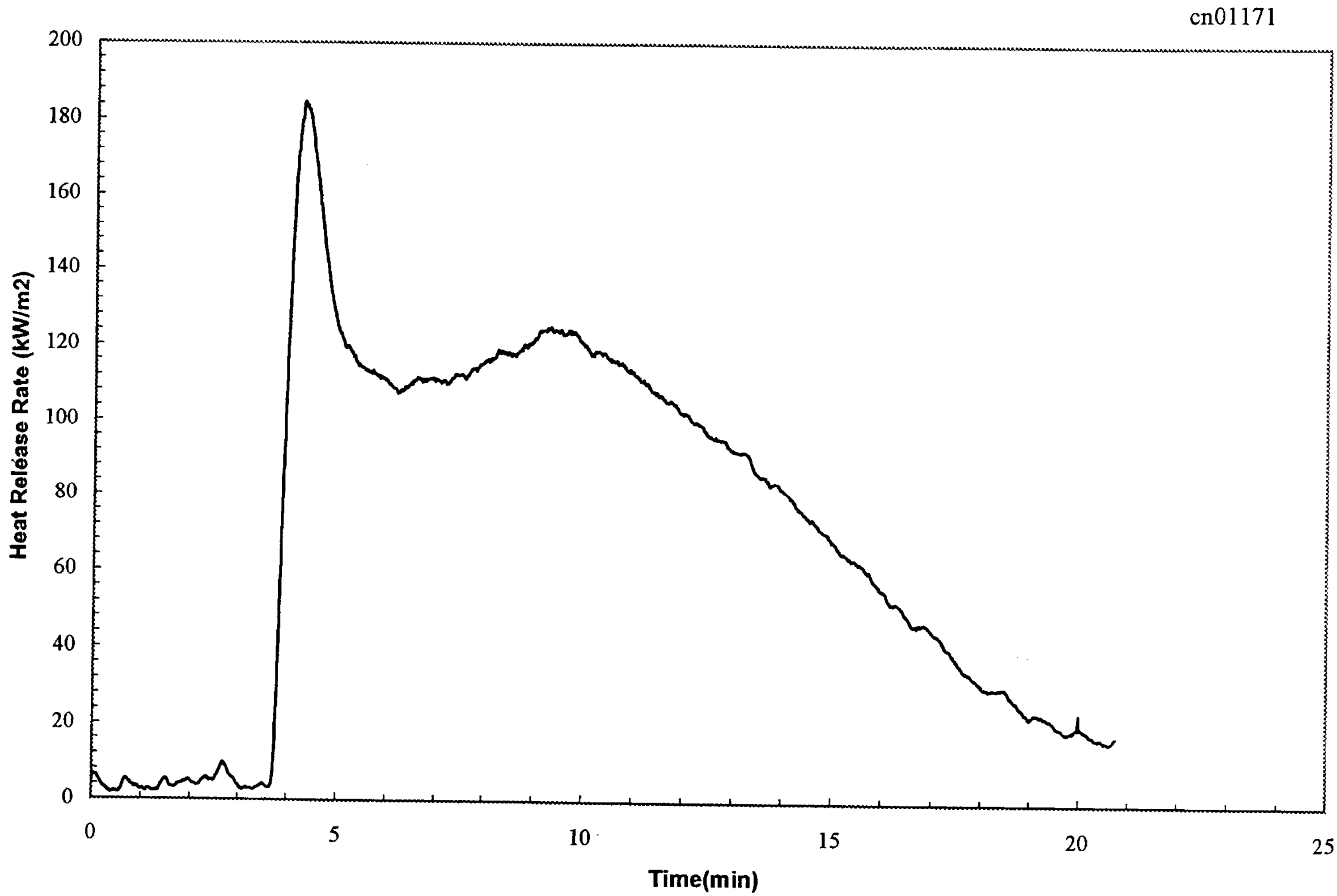
Initial Sample Mass (g): 143
Final Sample Mass (g): 104.5
Total Mass Loss (g): 38.5
Percent Mass Loss: 26.9
Average Mass Loss Rate (g/s): 0.041
Average Specific Extinction Area ($m^2/kg$): 619

Average CO2 Yield (g/g): 8.0128
Average CO Yield (g/g): 0.127
Total Heat Released ($MJ/m^2$): 88
Average Effective Heat of Combustion (MJ/kg): 22.9

| | **60 sec** | **180 sec** | **300 sec** | **Test** |
|---|---|---|---|---|
| Peak HRR ($kW/m^2$) | 184.6 | 184.6 | 184.6 | 184.6 |
| Time of Peak (s) | 31 | 31 | 31 | 31 |
| Average HRR ($kW/m^2$) | 140.9 | 123.8 | 119.9 | 85.3 |

Remarks:

# Heat Release Rate




A.2

# Cone Calorimeter Summary Data Sheet

Test Number and Data File: cn01188
Date: 1/18/2002
Time: 10:36
Test Operator: Ralph Ouellette

Manufacturer/Customer: Powertrusion International Inc.
Point of Contact: Brian Lattimer
HAI Job Number: 2568

Sample ID: 8
Sample Description: Composite Telephone Pole Material
Sample Thickness (mm): 15 edge, 7 center
Sample # 8 of 9
Conditioning (if any):

Sample Orientation: Horizontal
Holder Type: Pan
Spark Used: Yes
Applied Heat Flux($kW/m^2$): 25

Ignition Time (sec): 260
Flame Duration (sec): 1255

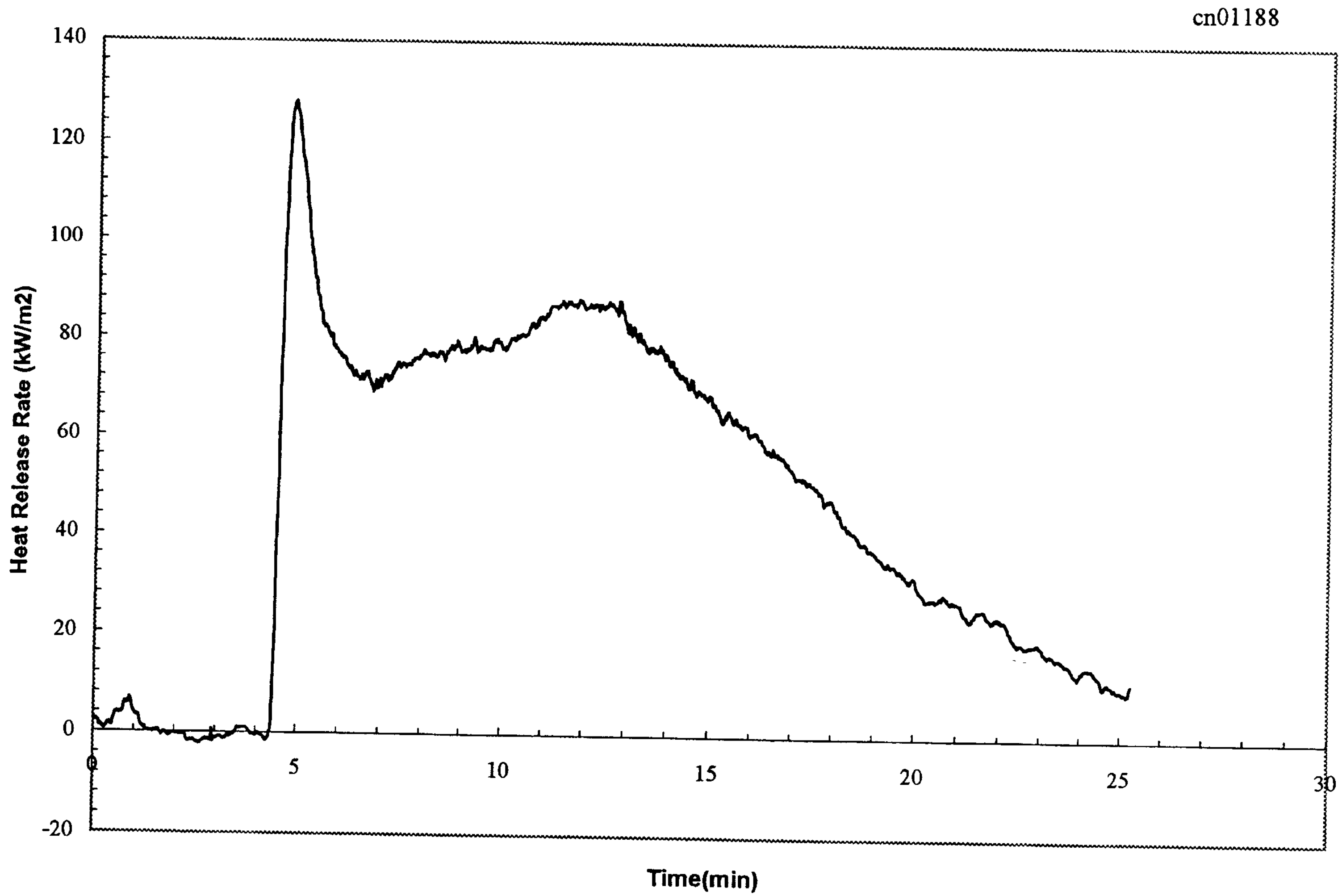
Initial Sample Mass (g): 169.4
Final Sample Mass (g): 129.6
Total Mass Loss (g): 39.8
Percent Mass Loss: 23.5
Average Mass Loss Rate (g/s): 0.031
Average Specific Extinction Area ($m^2/kg$): 556.3

Average CO2 Yield (g/g): 5.176
Average CO Yield (g/g): 0.1813
Total Heat Released ($MJ/m^2$): 72.4
Average Effective Heat of Combustion (MJ/kg): 18.2

| | 60 sec | 180 sec | 300 sec | Test |
|---|---|---|---|---|
| Peak HRR ($kW/m^2$) | 128.1 | 128.1 | 128.1 | 128.1 |
| Time of Peak (s) | 30 | 30 | 30 | 30 |
| Average HRR ($kW/m^2$) | 91.7 | 81.1 | 79.3 | 57.6 |

Remarks:

# Heat Release Rate



# Cone Calorimeter Summary Data Sheet

Test Number and Data File: cn01189
Date: 1/18/2002
Time: 11:03
Test Operator: Ralph Ouellette

Manufacturer/Customer: Powertrusion International Inc.
Point of Contact: Brian Lattimer
HAI Job Number: 2568

Sample ID: 9
Sample Description: Composite Telephone Pole Material
Sample Thickness (mm): 15 edge, 6.0 center
Sample # 9 of 9
Conditioning (if any): Cut to size

Sample Orientation: Horizontal
Holder Type: Pan
Spark Used: Yes
Applied Heat Flux($kW/m^2$): 25

Ignition Time (sec): 283
Flame Duration (sec): 962

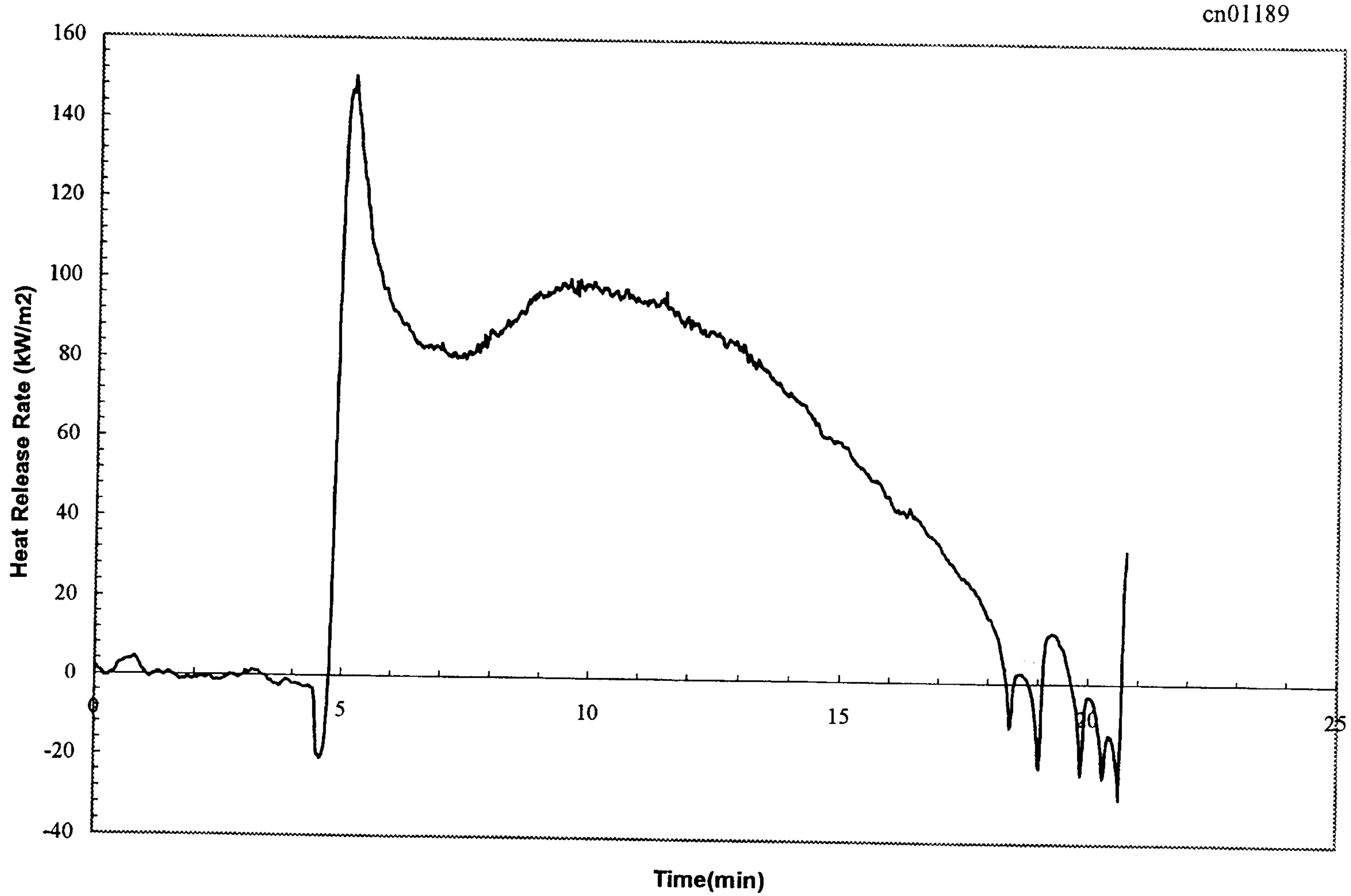
Initial Sample Mass (g): 153.4
Final Sample Mass (g): 115.7
Total Mass Loss (g): 37.7
Percent Mass Loss: 24.6
Average Mass Loss Rate (g/s): 0.036
Average Specific Extinction Area ($m^2/kg$): 690.6

Average CO2 Yield (g/g): 3.5179
Average CO Yield (g/g): 0.063
Total Heat Released ($MJ/m^2$): 61.2
Average Effective Heat of Combustion (MJ/kg): 16.2

| | **60 sec** | **180 sec** | **300 sec** | **Test** |
|---|---|---|---|---|
| Peak HRR ($kW/m^2$) | 150.4 | 150.4 | 150.4 | 150.4 |
| Time of Peak (s) | 27 | 27 | 27 | 27 |
| Average HRR ($kW/m^2$) | 106.5 | 92.5 | 92.5 | 63.9 |

Remarks:

# Heat Release Rate




A.6

# Cone Calorimeter Summary Data Sheet

Test Number and Data File: cn01173
Date: 1/17/2002
Time: 10:58
Test Operator: Ralph Ouellette

Manufacturer/Customer: Powertrusion International Inc.
Point of Contact: Brian Lattimer
HAI Job Number: 2568

Sample ID: 2
Sample Description: Composite Telephone Pole Material
Sample Thickness (mm): 12 edge, 6.0 center
Sample # 2 of 9
Conditioning (if any): Cut to size

Sample Orientation: Horizontal
Holder Type: Pan
Spark Used: Yes
Applied Heat Flux(kW/m²): 50

Ignition Time (sec): 77
Flame Duration (sec): 851

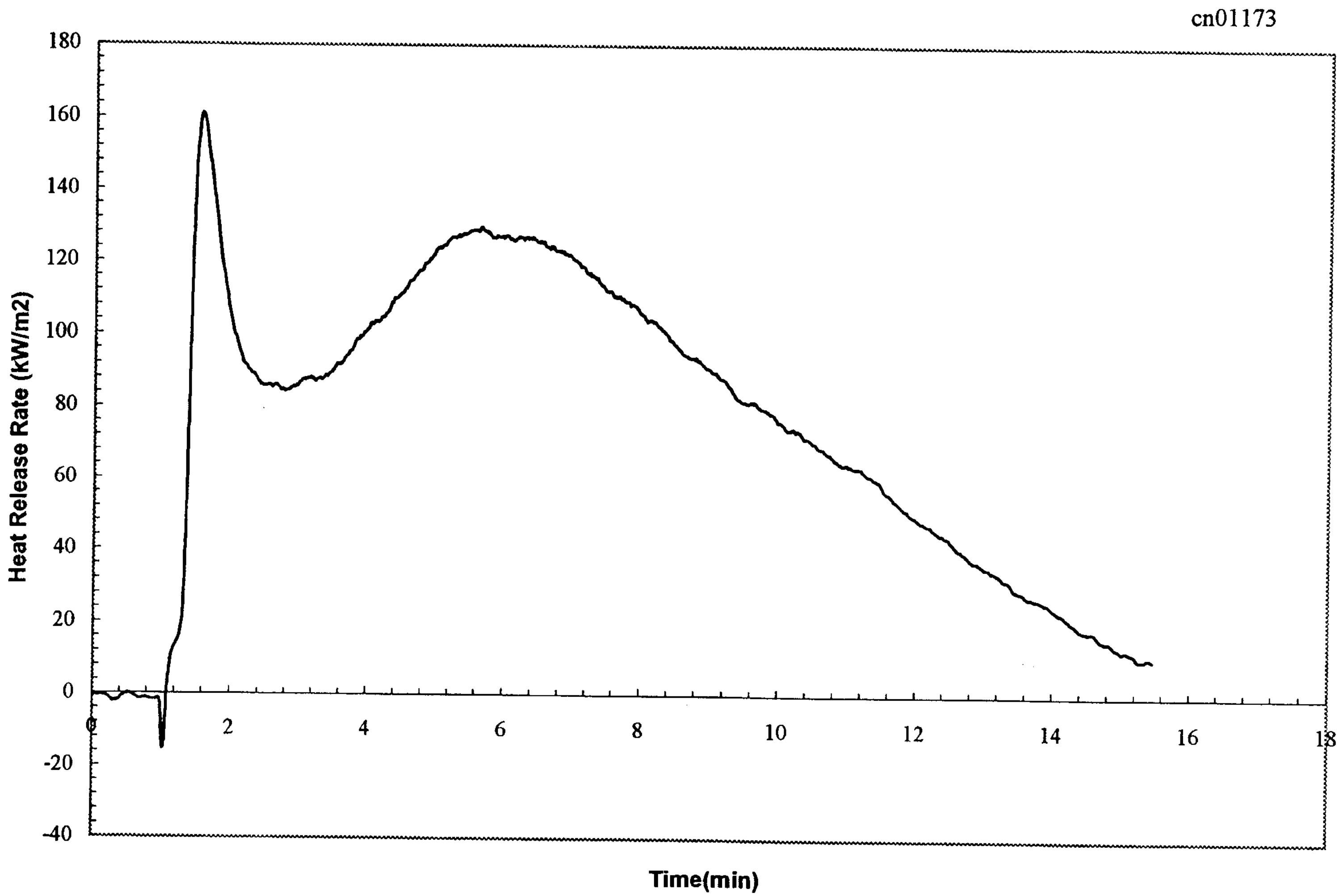
Initial Sample Mass (g): 146.1
Final Sample Mass (g): 111.3
Total Mass Loss (g): 34.8
Percent Mass Loss: 23.8
Average Mass Loss Rate (g/s): 0.041
Average Specific Extinction Area (m²/kg): 886.2

Average CO2 Yield (g/g): 3.0054
Average CO Yield (g/g): 0.0848
Total Heat Released (MJ/m²): 68.9
Average Effective Heat of Combustion (MJ/kg): 19.8

| | **60 sec** | **180 sec** | **300 sec** | **Test** |
|---|---|---|---|---|
| Peak HRR (kW/m²) | 161.2 | 161.2 | 161.2 | 161.2 |
| Time of Peak (s) | 16 | 16 | 16 | 16 |
| Average HRR (kW/m²) | 110.8 | 98.0 | 107.8 | 80.9 |

Remarks:

# Heat Release Rate




A.8

# Cone Calorimeter Summary Data Sheet

Test Number and Data File: cn01186
Date: 1/18/2002
Time: 9:27
Test Operator: Ralph Ouellette

Manufacturer/Customer: Powertrusion International Inc.
Point of Contact: Brian Lattimer
HAI Job Number: 2568

Sample ID: 6
Sample Description: Composite Telephone Pole Material
Sample Thickness (mm): 15 edge, 7 center
Sample # 6 of 9
Conditioning (if any):

Sample Orientation: Horizontal
Holder Type: Pan
Spark Used: Yes
Applied Heat Flux(kW/m²): 50

Ignition Time (sec): 69
Flame Duration (sec): 1182

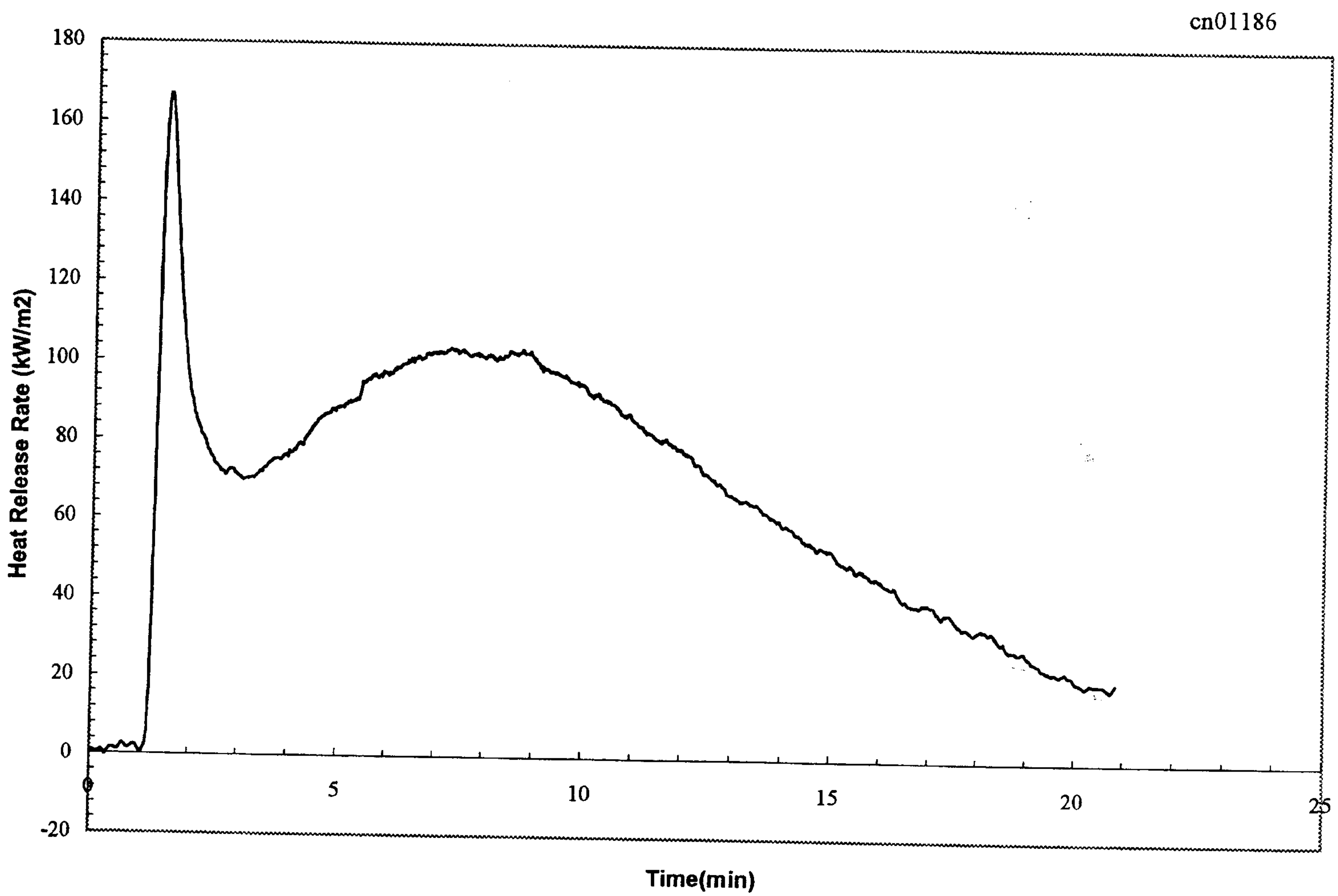
Initial Sample Mass (g): 175.7
Final Sample Mass (g): 134.2
Total Mass Loss (g): 41.5
Percent Mass Loss: 23.6
Average Mass Loss Rate (g/s): 0.035
Average Specific Extinction Area (m²/kg): 561.1

Average CO2 Yield (g/g): 20.0035
Average CO Yield (g/g): 1.8233
Total Heat Released (MJ/m²): 83.3
Average Effective Heat of Combustion (MJ/kg): 20.1

| | **60 sec** | **180 sec** | **300 sec** | **Test** |
|---|---|---|---|---|
| Peak HRR (kW/m²) | 166.9 | 166.9 | 166.9 | 166.9 |
| Time of Peak (s) | 20 | 20 | 20 | 20 |
| Average HRR (kW/m²) | 109.9 | 86.1 | 87.6 | 70.3 |

Remarks:

# Heat Release Rate




A.10

# Cone Calorimeter Summary Data Sheet

Test Number and Data File: cn01187
Date: 1/18/2002
Time: 9:50
Test Operator: Ralph Ouellette

Manufacturer/Customer: Powertrusion International Inc.
Point of Contact: Brian Lattimer
HAI Job Number: 2568

Sample ID: 7
Sample Description: Composite Telephone Pole Material
Sample Thickness (mm): 14.5 edge, 6 center
Sample # 7 of 9
Conditioning (if any):

Sample Orientation: Horizontal
Holder Type: Pan
Spark Used: Yes
Applied Heat Flux($kW/m^2$): 50

Ignition Time (sec): 75
Flame Duration (sec): 915

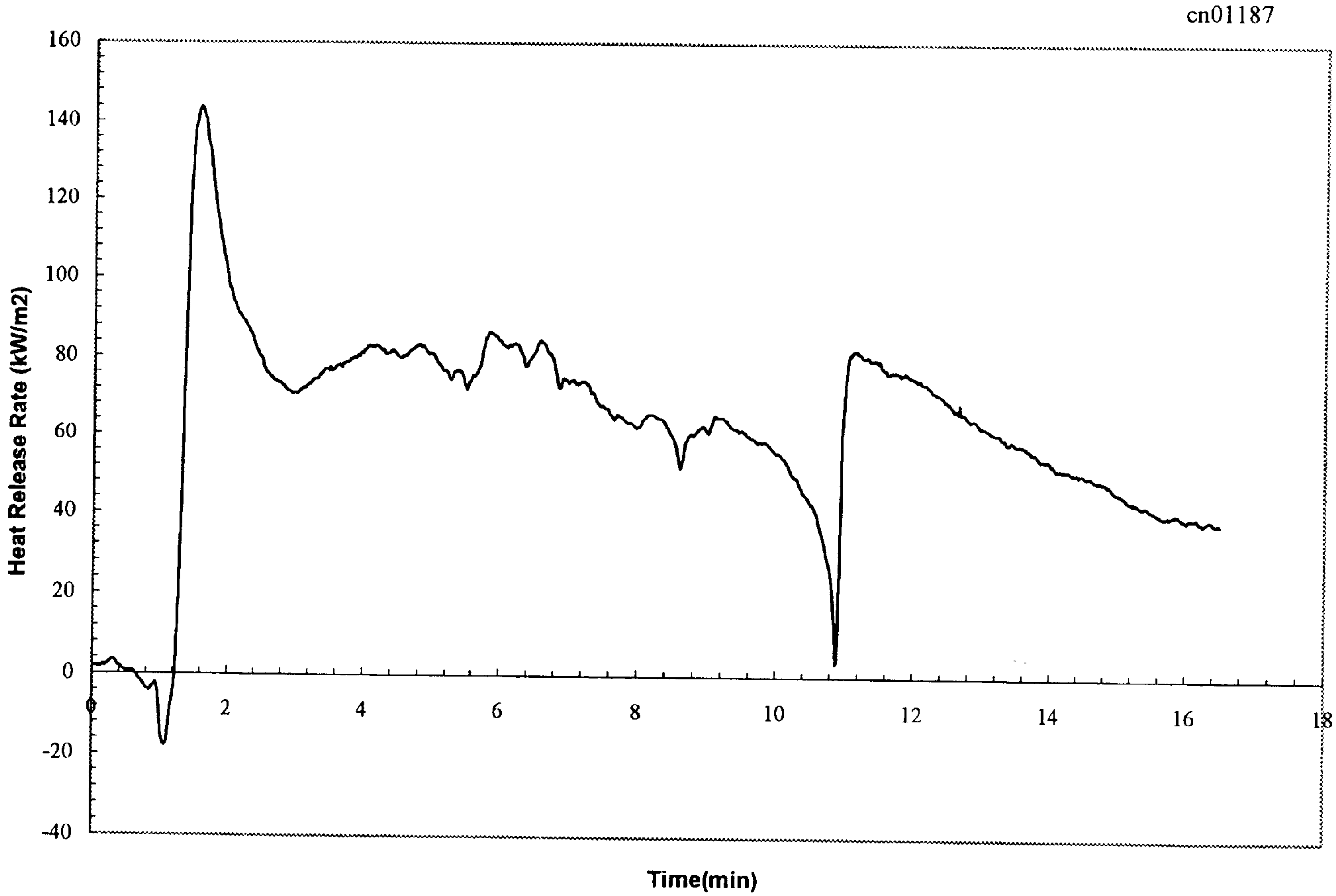
Initial Sample Mass (g): 153.5
Final Sample Mass (g): 117.9
Total Mass Loss (g): 35.6
Percent Mass Loss: 23.2
Average Mass Loss Rate (g/s): 0.038
Average Specific Extinction Area ($m^2/kg$): 520.1

Average CO2 Yield (g/g): 3.386
Average CO Yield (g/g): 0.1286
Total Heat Released ($MJ/m^2$): 61.6
Average Effective Heat of Combustion (MJ/kg): 17.3

| | 60 sec | 180 sec | 300 sec | Test |
|---|---|---|---|---|
| Peak HRR ($kW/m^2$) | 143.7 | 143.7 | 143.7 | 143.7 |
| Time of Peak (s) | 19 | 19 | 19 | 19 |
| Average HRR ($kW/m^2$) | 104.3 | 86.4 | 83.9 | 67.4 |

Remarks:

# Heat Release Rate




A-12

# Cone Calorimeter Summary Data Sheet

Test Number and Data File: cn01182
Date: 1/18/2002
Time: 8:01
Test Operator: Ralph Ouellette

Manufacturer/Customer: Powertrusion International Inc.
Point of Contact: Brian Lattimer
HAI Job Number: 2568

Sample ID: 3
Sample Description: Composite Telephone Pole Material
Sample Thickness (mm): 14 edge, 6 center
Sample # 3 of 9
Conditioning (if any):

Sample Orientation: Horizontal
Holder Type: Pan
Spark Used: Yes
Applied Heat Flux(kW/m²): 75

Ignition Time (sec): 29
Flame Duration (sec): 771

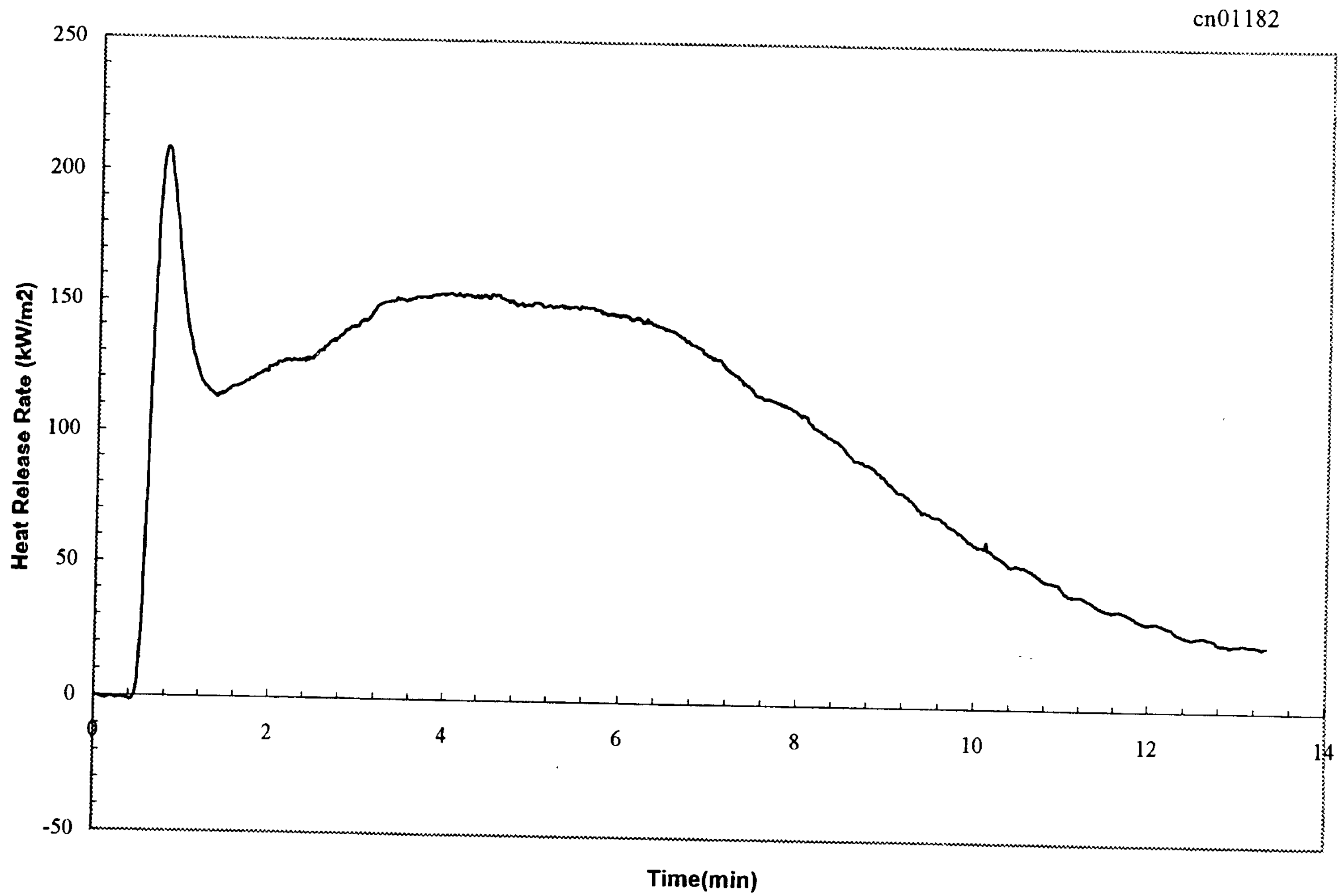
Initial Sample Mass (g): 145.1
Final Sample Mass (g): 104.4
Total Mass Loss (g): 40.7
Percent Mass Loss: 28
Average Mass Loss Rate (g/s): 0.062
Average Specific Extinction Area (m²/kg): 1360.3

Average CO2 Yield (g/g): 1.6711
Average CO Yield (g/g): 0.0387
Total Heat Released (MJ/m²): 80
Average Effective Heat of Combustion (MJ/kg): 19.7

| | **60 sec** | **180 sec** | **300 sec** | **Test** |
|---|---|---|---|---|
| Peak HRR (kW/m²) | 208.3 | 208.3 | 208.3 | 208.3 |
| Time of Peak (s) | 17 | 17 | 17 | 17 |
| Average HRR (kW/m²) | 133.3 | 132.6 | 140.1 | 103.6 |

Remarks:

# Heat Release Rate



# Cone Calorimeter Summary Data Sheet

Test Number and Data File: cn01183
Date: 1/18/2002
Time: 8:25
Test Operator: Ralph Ouellette

Manufacturer/Customer: Powertrusion International Inc.
Point of Contact: Brian Lattimer
HAI Job Number: 2568

Sample ID: 4
Sample Description: Composite Telephone Pole Material
Sample Thickness (mm): 13 edge, 6.5 center
Sample # 4 of 9
Conditioning (if any):

Sample Orientation: Horizontal
Holder Type: Pan
Spark Used: Yes
Applied Heat Flux(kW/m²): 75

Ignition Time (sec): 27
Flame Duration (sec): 693

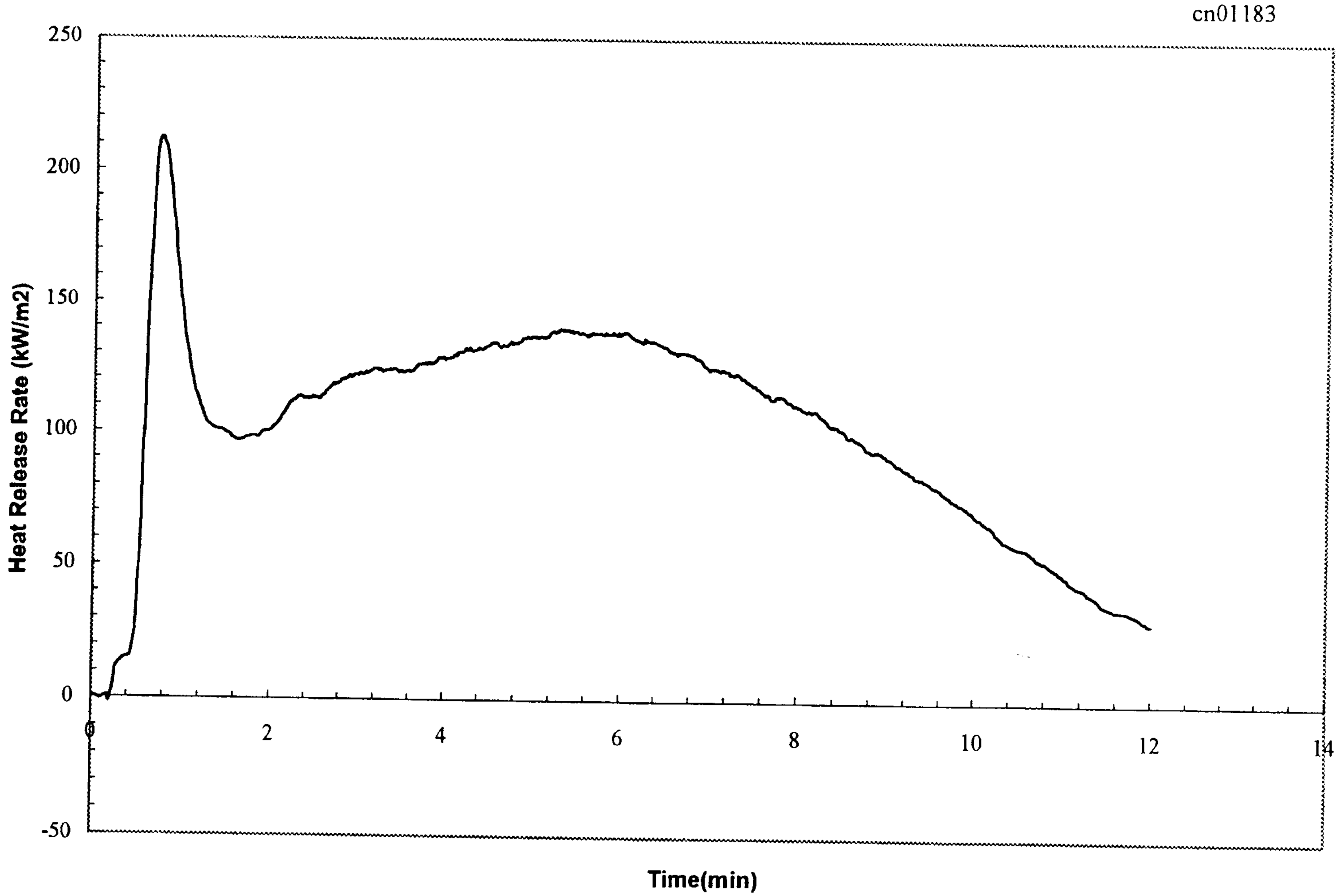
Initial Sample Mass (g): 154.8
Final Sample Mass (g): 116.6
Total Mass Loss (g): 38.2
Percent Mass Loss: 24.7
Average Mass Loss Rate (g/s): 0.062
Average Specific Extinction Area (m²/kg): 986.8

Average CO2 Yield (g/g): 1.7051
Average CO Yield (g/g): 0.0275
Total Heat Released (MJ/m²): 73.9
Average Effective Heat of Combustion (MJ/kg): 19.3

| | **60 sec** | **180 sec** | **300 sec** | **Test** |
|---|---|---|---|---|
| Peak HRR (kW/m²) | 212.3 | 212.3 | 212.3 | 212.3 |
| Time of Peak (s) | 18 | 18 | 18 | 18 |
| Average HRR (kW/m²) | 131.8 | 118.5 | 123.8 | 106.2 |

Remarks:

# Heat Release Rate




A.16

# Cone Calorimeter Summary Data Sheet

Test Number and Data File: cn01184
Date: 1/18/2002
Time: 8:44
Test Operator: Ralph Ouellette

Manufacturer/Customer: Powertrusion International Inc.
Point of Contact: Brian Lattimer
HAI Job Number: 2568

Sample ID: 5
Sample Description: Composite Telephone Pole Material
Sample Thickness (mm): 13 edge, 5.5 center
Sample # 5 of 9
Conditioning (if any):

Sample Orientation: Horizontal
Holder Type: Pan
Spark Used: Yes
Applied Heat Flux($kW/m^2$): 75

Ignition Time (sec): 27
Flame Duration (sec): 658

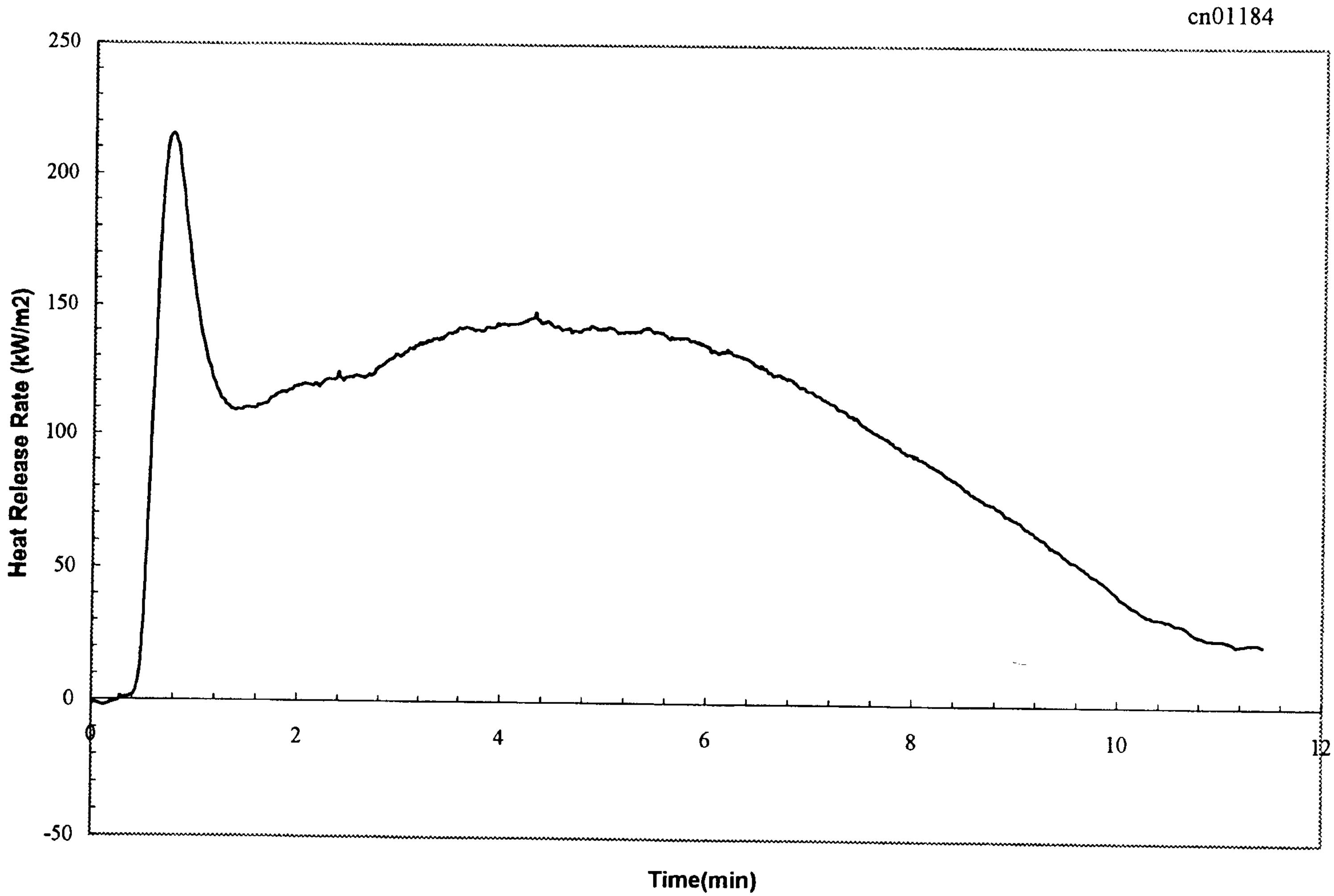
Initial Sample Mass (g): 140.3
Final Sample Mass (g): 101.2
Total Mass Loss (g): 39.1
Percent Mass Loss: 27.9
Average Mass Loss Rate (g/s): 0.061
Average Specific Extinction Area ($m^2/kg$): 1282.3

Average CO2 Yield (g/g): 1.9535
Average CO Yield (g/g): 0.0406
Total Heat Released ($MJ/m^2$): 69.4
Average Effective Heat of Combustion (MJ/kg): 17.8

| | **60 sec** | **180 sec** | **300 sec** | **Test** |
|---|---|---|---|---|
| Peak HRR ($kW/m^2$) | 215.5 | 215.5 | 215.5 | 215.5 |
| Time of Peak (s) | 19 | 19 | 19 | 19 |
| Average HRR ($kW/m^2$) | 135.7 | 127.5 | 133.3 | 105.3 |

Remarks:

# Heat Release Rate




A.18