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Heat Release Rate Tests of Plastic Trash Containers

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Abstract

Two experiments were conducted to characterize the potential hazard from ignition of nominal 136 L (30 gal) trash containers made from high-density polyethylene (HDPE) and loaded with cellulosic debris. Heat release rate was measured as a function of time from ignition using a furniture–scale oxygen consumption calorimeter. In addition, total heat flux was measured at a location approximately 1 m from the trash container centerline. The two trash containers were observed to burn in a different manner due to the way the containers melted. In the first test, the container opened up from the top down and had a peak heat release rate of approximately 300 kW. In the second case, the trash container melted and opened from the midpoint in the container down. This resulted in a container that tended to close up into itself instead of opening up and thus, yielded a peak heat release rate of approximately 150 kW. Heat release rate and heat flux time histories and photographs are presented for both experiments.

Key Words:
fire data; fire models; fire tests; heat release rate; 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 alarm and suppression system activation time. Heat flux measurements can be used to estimate potential for ignition of adjacent fuel items.

NIST has received requests from state fire marshals and representatives of the Bureau of Alcohol, Tobacco and Firearms (ATF) for estimates on the burning rate of a "typical 30 gallon, plastic trash can filled with construction debris". This report is limited to a single type of trash container with a single fuel load. One replicate experiment was conducted.

Experimental Configuration

The experiments were conducted under the furniture calorimeter hood in the NIST Large Fire Research Facility. This hood is square, 3 m by 3 m and slopes upward at a 45º angle to a 0.5 m diameter duct. During a fire test, data from various sensors is acquired using a computer-based data acquisition system. The fire test data is recorded 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 [4] together with data obtained from instruments in the exhaust hood. The measured heat release rate for the furniture calorimeter in the heat release rate range of the experiments has been shown to be within 20 percent of the actual value [5]. Stroup, et al. [5] contains details concerning the calculation of heat release rate and its implementation in the Large Fire Research Facility.

Experiments

Two experiments were conducted to help characterize the potential hazard from ignition of nominal 136 L (30 gal) trash containers made from high density polyethylene (HDPE) and loaded with cellulosic debris. Each trash container was approximately 515 mm (20.25 in) in diameter and 700 mm (27.5 in) tall. The trash container alone had a mass of 3.6 kg (8 lbs). Each trash container had 10 kg (22 lbs) of debris "typical" of a construction site. The debris consisted of cut pieces of "2 X 4" lumber, sawdust, cardboard, paper, and cups, food wrappers and paper bags from a fast food restaurant. Similar sets of debris were prepared for each trash container. No further details of the fuel load were recorded. A photograph of a trash container loaded for testing is shown in Figure 1. Note the total heat flux gauge located at the back side of the container. The trash containers were placed on a 12 mm thick piece of gypsum board to protect the floor of the test facility.

Each experiment was conducted with the container centered under the exhaust hood. The total heat flux was measured with water-cooled Gardon type transducers. The total heat flux gauge was located 0.81 m above the floor with its face 1.07 m from the trash container centerline. Based on manufacturer's data, the standard uncertainty for the heat flux measurements is estimated at ±3 % [6].

An open flame was applied to the contents of the trash container using a propane torch. The trash was lit approximately half-way down the container and next to a side of the trash container. The torch was held in place for approximately 5 s. Once a small amount of debris was ignited, the torch was removed.

Results

The heat release rate curves obtained as a function of time from ignition for each of the two fire tests are shown in Figure 2. The heat release rate from Trash Container 1 grew to a maximum of approximately 300 kW prior to being suppressed at approximately 800 s. The final spike in heat release rate is due to the disturbance of the fire at the beginning of the suppression process.

The heat release rate from Trash Container 2 tracked the development of the fire in Trash Container 1 for the first three minutes after ignition. Then the heat release rates diverge with Trash Container 2 only reaching a peak of approximately 150 kW.

The total heat flux measurements for each test are given in Figure 3. The trends of the heat release rate curves are similar in the heat flux time histories of each test. Trash Container 1 has a peak heat flux of approximately 5 kW/m^2 while Trash Container 2 peaks at less than 2 kW/m^2.

Photographs of the fire development in Trash Container 1 are shown in Figures 4 through 9. The photographs show the fire growing from a small amount of trash burning in the container (Figure 4) to the fire involving the container (Figure 5). The container melts and opens up allowing more air to reach the fuel and increasing the fire size (Figure 6). The container continues to melt and burn (Figure 7) until the fuel package becomes a debris pile surrounded by a burning pool of molten plastic (Figure 8). Figure 9 shows the remains of the trash container and its contents after suppression at 800 s.

Figures 10 through 15 show photographs representing stages of the fire development for Trash Container 2. The photographs show the fire beginning in a manner similar to Trash Container 1 (Figure 10). Then a hole opens up in the side of Trash Container 2, near the point of ignition (Figure 11). This occurred with only a small portion of the debris burning. As a result, the burning near the opening intensified and caused burning debris to drop lower in the container, prior to a large amount of the debris igniting near the top of the trash can (Figure 12). From Figure 13, it can be seen that Trash Container 2 has closed in on itself, limiting air entrainment to the fuel inside the container and hence reducing the heat release rate. The trash container slowly melts away exposing more fuel surface area to the air, however the flames never grow significantly larger (Figure 14). The last photograph (Figure 15) shows the remains of Trash Container 2 burning just prior to being extinguished just after 900 s.

Summary

The two trash containers were observed to burn in a different manner due to the way the containers melted. In the first test, the container opened up from the top down and had a peak heat release rate of approximately 300 kW. In the second test, the trash container melted and opened from the midpoint in the container down. This resulted in a container that tended to close into itself instead of open up and yielded a peak heat release rate of approximately 150 kW.

While these two experiments provide some insight into the heat release rate and heat flux from the trash containers and debris described above, fire development is dependent on many factors, including: material (fuel) properties, material geometry, containment and ventilation to name a few. In these experiments, a change in how the container melted resulted in a significant difference in heat release rate.

References

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Figure 1. Loaded Trash Container prior to ignition.

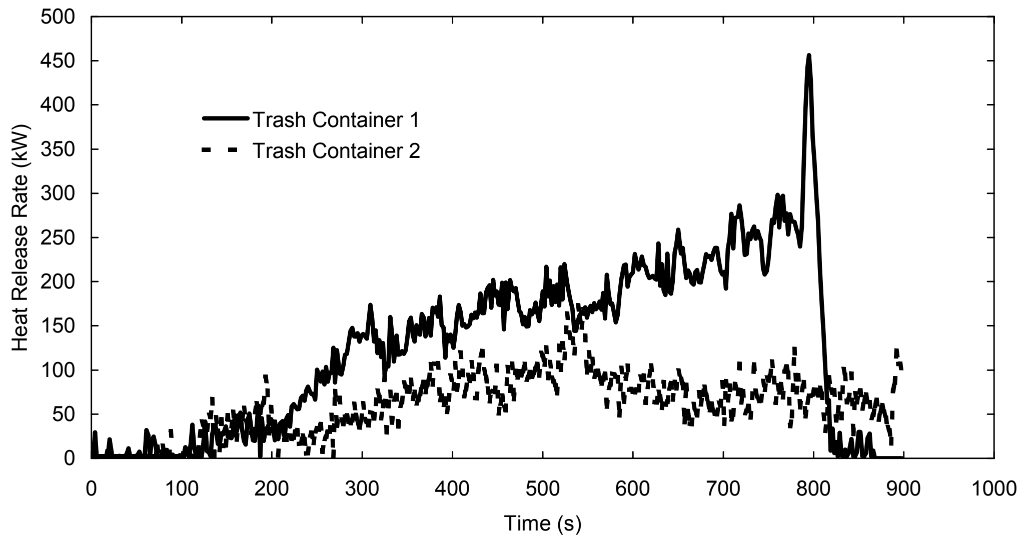

Figure 2. Graph of Heat Release Rate versus Time for Trash Containers 1 and 2.

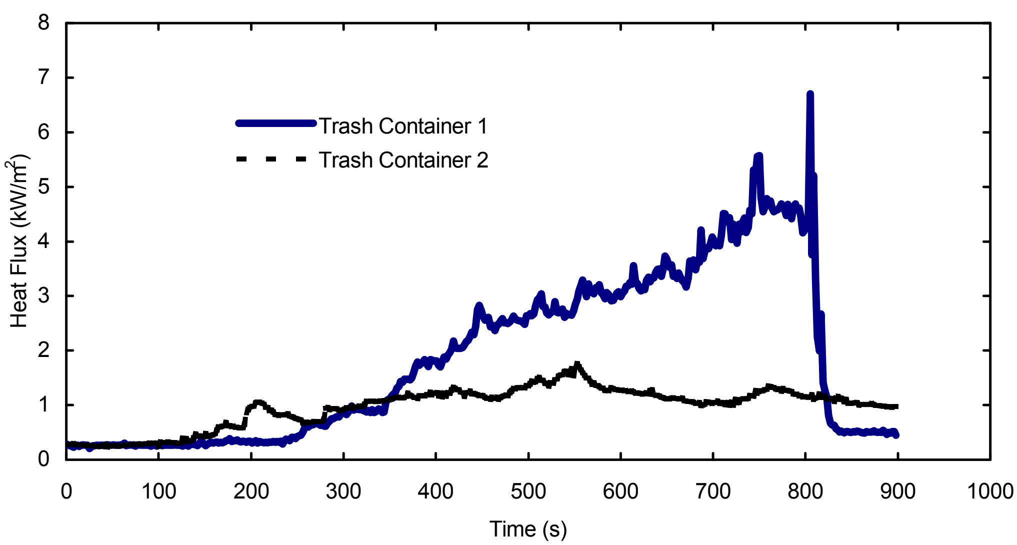

Figure 3. Graph of Total Heat Flux versus Time for Trash Containers 1 and 2.

Figure 4. Fire developing in Trash Container 1.

Figure 5. Trash Container 1 melting and allowing more ventilation for the burning fuel it contains.

Figure 6. Fire continues to grow in Trash Container 1.

Figure 7. Upper portion of container melts and collapses.

Figure 8. Molten plastic burning around debris pile.

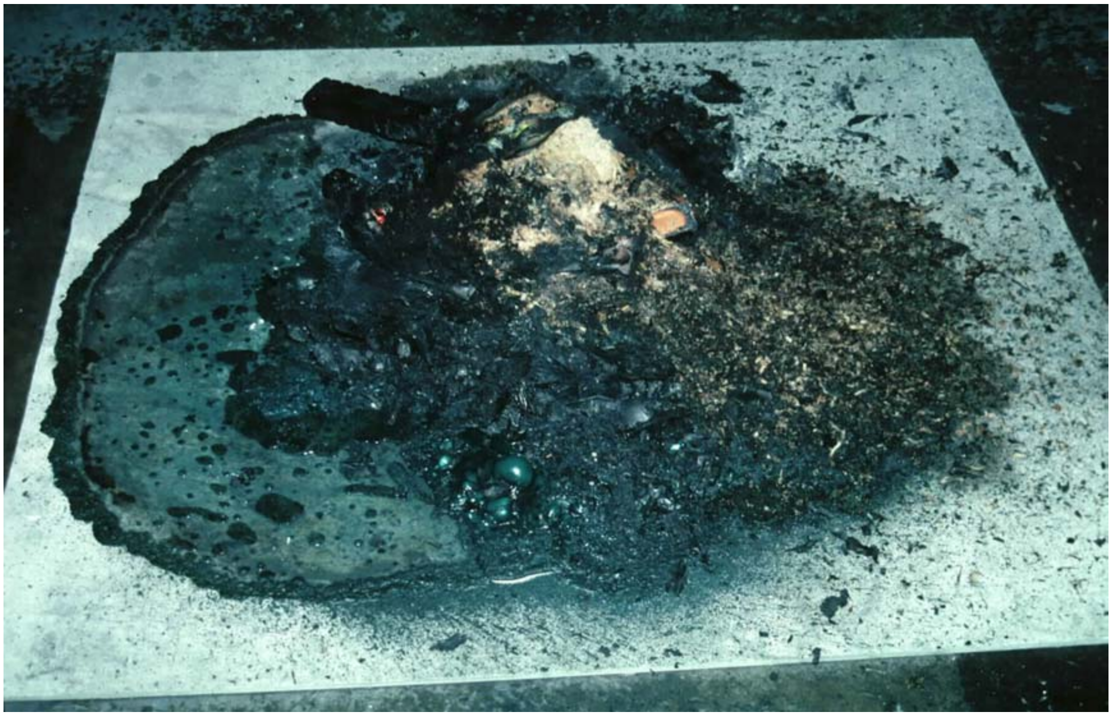

Figure 9. Remains of Trash Container 1 after test.

Figure 10. Trash Container 2 just after ignition.

Figure 11. A hole opens in the side of Trash Container 2 near the point of ignition.

Figure 12. Fire continues to develop in the lower portion of container.

Figure 13. Trash Container 2 collapses in on itself, obstructing ventilation and limiting fire growth.

Figure 14. Trash Container 2 melts and opens exposing burning debris pile.

Figure 15. Remains of Trash Container 2 just prior to suppression at 900 s.