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Upholstered Chair Fire Tests Using a California Technical Bulletin 133 Burner Ignition Source

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Abstract

A series of fire tests were conducted to characterize the potential hazard from ignition of an upholstered chair. The particular chair 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. Two tests were conducted with the chairs placed in the open under large calorimeters. The third test was conducted with the chair located in a room. Peak heat release rates obtained during the tests ranged from approximately 1 MW to 2.5 MW.

Key Words:
chairs; fire data; fire models; fire tests; heat release rate; upholstered furniture

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.

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 from a specific upholstered chair. Figure 1 presents a photograph of the upholstered chair. The front and side views of the chair with approximate dimensions are shown in Figure 2.

Since the fire investigation had not identified a specific ignition scenario, the Bureau of Alcohol, Tobacco and Firearms requested that a "standard" ignition source be used for the tests. The ignition source selected was the burner used for testing upholstered furniture in accordance with California Technical Bulletin 133 Flammability Test Procedure for Seating Furniture Used in Public Occupancies [1]. The burner is shown in Figure 3, and a detailed description of the burner is contained in reference [2]. A series of holes on the underside of the tube allow gas to escape for combustion. When properly adjust, small flames are produced around the entire square of the burner. The CA 133 burner provided a reproducible, well-characterized ignition source for use in each test conducted as part of this study.

Experimental Configuration

The experiments were conducted under the 500 kW hood and the main hood in the NIST Large Fire Research Facility. The 500 kW hood (furniture calorimeter) is a square approximately 3 m (10 ft) on a side and slopes upward at a 45° angle to a 0.5 m (1.6 ft) diameter duct. 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 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 [3].

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 [4, 5] 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 [6] 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 4 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 [7]. Reference 7, page 2 contains details concerning the calculation of heat release rate and its implementation in the Large Fire Research Facility.

The first experiment was conducted with the chair centered under the 500 kW hood. Since the heat release rate of the chair exceeded the capability of the 500 kW hood, the second test was conducted with the chair centered under the main hood. A third test was conducted with the chair located in a corner of a 3.7 m (12 ft) by 3 m (10 ft) room with a 2.4 m (8 ft) high ceiling (Figure 4). The room had three openings in one of the 3.7 m (12 ft) walls. These openings were oriented so combustion products could flow into the main hood for measurement of heat release rate. The opening in the center of the wall was 0.9 m (3 ft) wide by 2.1 m (7 ft) high. The two openings on either side of the center opening both had dimensions of 1 m (3.3 ft) by 1.7 m (5.5 ft) high with an approximately 0.15 m (0.5 ft) high sill.

The square gas burner ignition source is shown in Figure 3. The construction details for this burner are contained in reference [8]. The burner was centered in the middle of the chair approximately 51 mm (2 in) from the chair back and 25 mm (1 in) above the seat cushion. Technical grade methane gas was used to obtain a total heat release rate from the burner of 18 kW.

Experiments

Three upholstered chair fire experiments were conducted on October 19, 1999, in the Large Fire Research Facility at the National Institute of Standards and Technology. Three similar chairs were used for the experiments. Each chair was composed primarily of polyester fiber and polyurethane foam on a wood frame. Two pillows, composed of polyester fiber inside a cotton/polyester fabric, were provided with each chair. The material composition of each chair, as provided by the manufacturer is shown in Table 1.

Table 1. Material Composition of Chair

Frame	Body	Seat Cushion	Pillow
100 % Wood	60 % Polyester Fiber 20 % Resin Treated Defabricated Textile Fibers 15 % Felted Blended Fibers 5 % Urethane Foam	85 % Urethane Foam 15 % Resin Treated Polyester Fiber Pad	100 % Polyester Fill

Each chair and its components were weighed and measured before the test. A typical chair with dimensions is shown in Figure 2. In addition, the weight of the remainder of the chair was determined after the test. This data is presented in Table 2. The standard uncertainty associated with the mass measurements is ±0.2 kg (±0.1 lb), and the uncertainty associated with the length measurements is ±6 mm (±0.25 in). The chairs were conditioned for approximately 3 weeks in a room with a nominal air temperature of 23 °C (73 °F) and a relative humidity of 50 %.

Table 2. Mass of Each Chair and Its Components in kg

Chair Total Mass		Seat Cushion	Pillow No. 1	Pillow No. 2
Before Test	After Test			
42.3	28.6	2.57	0.73	0.71
42.6	33.1	2.57	0.73	0.72
41.4	23.1	2.58	0.71	0.73

For the first test, the chair was placed on 12.7 mm (0.5 in) gypsum board and centered under the 500 kW hood (Figure 1). The burner was placed in the appropriate position in the middle of the chair. Approximately 60 s of background data was recorded then the burner was ignited with a propane torch (Figure 5). The fire was allowed to grow until it appeared to involve the entire chair (Figure 6) at which time the fire was extinguished with water. The chair is shown after the fire in Figure 7.

The second chair fire experiment was conducted under the main hood in the Large Fire Research Facility. The experiment was moved from the 500 kW hood to the main hood because the heat release rate from the chair exceeded the capability of the 500 kW hood. Again, the chair was placed on 12.7 mm (0.5 in) gypsum board and centered under the exhaust hood. The burner was placed on the chair, and the burner was ignited with a propane torch after acquisition of 60 s of background data (Figure 8). The chair was allowed to burn until approximately complete involvement of the chair (Figure 9). The fire was then extinguished with water. The chair is shown after the fire in Figure 10.

The final experiment was conducted with the chair located in a corner of a room enclosure. The chair was placed in the corner such that the backs of the chair arms contacted the room walls (Figure 11). The burner was placed and ignited in the same fashion as the previous two experiments (Figure 12). The fire grew to involve a significant portion of the chair prior to being extinguished with water (Figure 13). The chair is shown after the fire in Figure 14.

Results

The heat release rate curves obtained as a function of time from ignition for each of the three fire tests are shown in Figure 15. For comparison purposes, the three heat release rate curves are shown plotted on the same graph. The test times have been adjusted to show each fire starting at the same time. For the first 60 s of each test, the heat release rate for all three tests appears to increase at the same rate. After this initial period, the heat release rates for the first test and the second test, without room enclosure, appears to almost level off and increase significantly more slowly than during the first 60 s. The third test with the chair inside a room does not exhibit any leveling off of the heat release rate. The peak heat release rate for both the second and third tests is approximately 2.5 MW. The peak heat release rate for the first test is significantly less (approximately 1 MW). This is a direct result of the chair heat release rate exceeding the measurement capability of the 500 kW hood.

References

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Figure 1. Photograph of chair with burner in place for start of test.

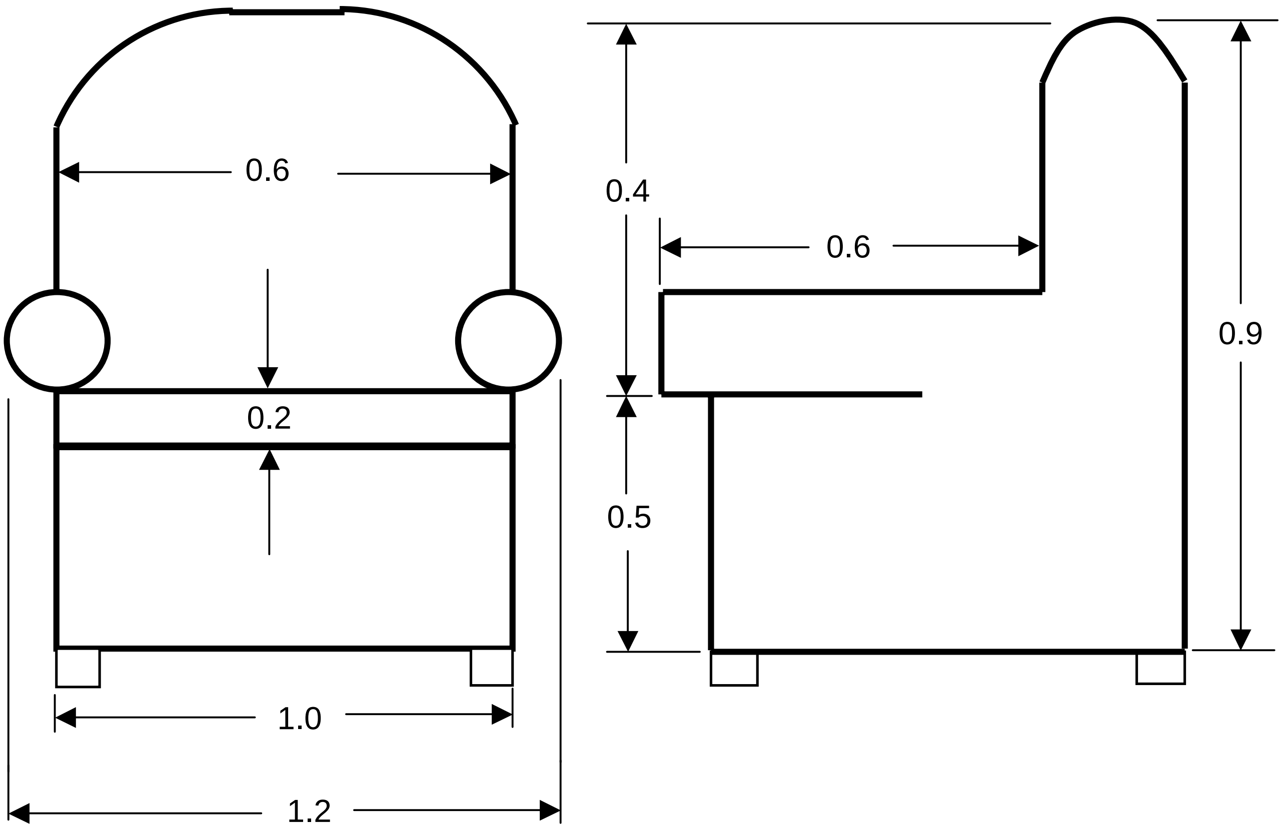

Figure 2. Front and side views of test chair with dimensions in meters.

Figure 3. Photograph of CA 133 burner prior to placement on test chair.

Figure 4. Photograph of a chair with CA 133 burner in placed located in a corner of a 3.7 m by 3 m by 2.4 m high test room enclosure.

Figure 5. Photograph of chair at start of first test with CA 133 burner in place and ignited.

Figure 6. Photograph of chair at peak heat release rate with majority of chair burning during first test.

Figure 7. Photograph of chair at the end of the first test.

Figure 8. Photograph of chair at start of second test with CA 133 burner in place and ignited.

Figure 9. Photograph of chair at peak heat release rate with majority of chair burning during second test.

Figure 10. Photograph of chair at the end of the second test.

Figure 11. Photograph showing chair positioned in test enclosure with CA 133 burner in place for the third test.

Figure 12. Photograph showing chair burning in test enclosure during the third test.

Figure 13. Photograph showing chair fully involved with fire and flames extending from the test enclosure during the third test.

Figure 14. Photograph showing the remains of the chair and a portion of the damaged room at the conclusion of the third test.

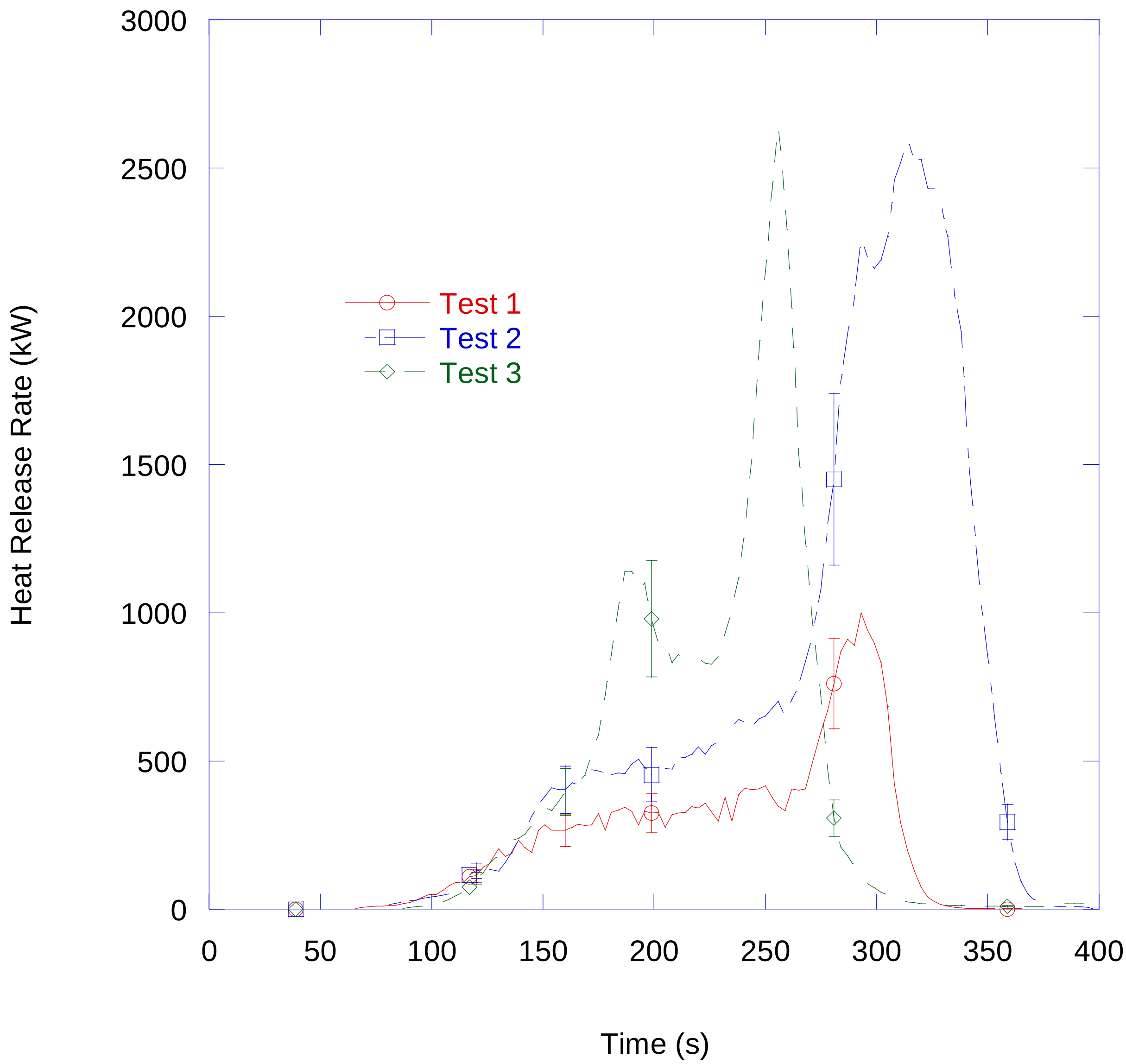

Figure 15. Graph showing heat release rate as a function of time for the three chair tests (Note: Test No. 1 exceeded the capabilities of the 500 kW hood).