NISTIR 4375

FURNITURE FLAMMABILITY: AN INVESTIGATION OF THE CALIFORNIA TECHNICAL BULLETIN 133 TEST. PART III: FULL SCALE CHAIR BURNS

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ABSTRACT

Ten sets of upholstered chairs were obtained. One chair out of each set was tested in the ASTM room, two chairs out of each set were tested in the furniture calorimeter, and four chairs from each of six sets in the California Technical Bulletin 133 (TB133) room. The chairs in the different sets varied only in the type of fabric, type of foam, and whether or not there was a fiberglass interliner present. The size, frame and style remained constant. Some of the chairs were ignited with the standard TB133 newspaper ignition source. The others were ignited by a gas burner designed to simulate the newspaper ignition source. The rooms were instrumented to measure the total heat release rate of the chairs by oxygen consumption. It was found that (1) similar results were obtained in the TB133 and ASTM rooms, (2) a total heat release rate of 65 Kw in either of the rooms or in the furniture calorimeter was equivalent to the failure criterion of a 111°C (200°F) temperature rise 25 mm below the ceiling and directly above the burning chair in the TB133 test and (3) below 600 kW the heat release rates of the chairs measured in the rooms were the same as those in the furniture calorimeter. The combinations of fabric, fiberglass interliner and foam were also tested in the Cone calorimeter. Correlations are presented between the full scale and bench scale results. Calculations of the room temperatures, using Hazard I and the measured heat release rates, are also shown.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF FIGURES (continued)

1. INTRODUCTION:

The California Bulletin Technical 133 test (TB133) [1], developed at the California Bureau of Home Furnishings (CBHF) in Sacramento, is a flammability test procedure for seating furniture for use in public occupancies (hotels, prisons, nursing homes, etc). The Center for Fire Research (CFR) at the National Institute of Standards and Technology (NIST), in collaboration with CBHF, recently undertook a study of this test and its procedures with a view toward possible improvements, if the test is to be adopted more broadly. This report describes part 3 of a 3 part investigation of this test. Part 1 discusses the fire hazard of upholstered furniture [2]. Part 2 characterizes the newspaper ignition source used in TB133 and develops a gas burner to simulate it [3]. In part 3 an equivalence is sought between full scale furniture fire tests run in the TB133 room, in the proposed ASTM room, and in the furniture calorimeter. These three parts constitute a status report on the furniture project.

2. MATERIALS

Furniture manufacturers, suppliers to the furniture industry, and representative associations of the furniture industry were surveyed prior to the selection of the materials. This was done in order to determine representative material combinations. This study however, does not include blends of fabrics (i.e., wool 60%, nylon 40%) which represent a large percentage of the fabrics utilized in the contract furnishings market. The flammability characteristics of blended fibers and fabrics are much more complex and not within the scope of this work. The intent of this study was to assess the technical merits of TB133, not to evaluate the state of the art in flame retardant upholstered materials.

The material combinations tested in the full-scale upholstered furniture tests were based upon the use of two foam types, a fiberglass interliner, and four fabrics. The foams investigated were melamine-treated polyurethane foam and a polyurethane foam that had passed the California Bulletin 117 test. The four fabrics were nylon, polyolefin, a fire retardant polyvinylchloride, and wool.

Descriptions of the material combinations used are listed in Table 1. A, B, C, D, E, F represent six of the seven material combinations tested in the mock-up cushion tests in Part 2 of this series [3].

The design of the upholstered chairs is seen in Figure 1. The size, frame and style remained constant for all ten sets. The geometry was selected to provide a worst case scenario, in as much as the side arms, if they ignite, would irradiate the seat and chair back, helping to sustain flaming. Experience has shown that chairs with upholstered or closed arms exhibit a greater probability of failing the TB 133. A single manufacturer was selected to construct the chairs to assure that they were all identical in so far as possible. The chair dimensions were as follows; 915 mm wide, 880 mm deep, 775 mm high, with seat height of 460 mm. The top edge of the back cushion was approximately 127 mm above the side arm cushions, while the top surface of the side arms was 178 mm above the seat cushion. Each chair consisted of a solid hardwood frame, with foam padded arms. No cotton or polyester batting wraps were utilized in the construction of these chairs (batting wraps are normally used to achieve a soft and smooth edge finish to the cushions). The support system consisted of a custom coil foundation. The two support cushions can be physically removed from the chair. The back cushion was 570 x 360 x 120 mm and the seat bottom cushion was 570 x 660 x 120 mm.

The combinations utilizing the fiberglass interliner required special assembling. The interliners of the back and seat bottom cushions were sewn with fiberglass thread to assure that the thread would not melt during exposure to the ignition source. The sewing of the liners with the fiberglass thread was done at CFR and at CBHF with approximately 280 stitches per meter. The chair assembly consisted of a foam sheet placed directly onto the chair frame and stapled into place. If a fire barrier was utilized, the fiberglass interliner was placed on top of the foam and attached to the chair frame with the use of a staple gun. Last, the selected fabric was secured to the chair frame.

3. TEST METHODS

3.1 Technical Bulletin 133 Room Fire Test

The TB133 test [1] is conducted in a 10 by 12 ft. (3.0 by 3.7 m) room with a ceiling height of 8 ft. (2.4 m) and a 38 by 81 inch (0.97 by 2.1 m) open doorway in one corner as seen in figure 2. The walls and ceiling are lined with gypsum board. The furniture is located on a weighing platform in the rear corner farthest from the doorway. The ignition source is five double sheets of loosely wadded newspaper placed at the back of the seat and confined by a chicken wire cage. Temperatures, CO concentration, smoke opacity, and mass loss are measured during the test. The ceiling thermocouple is located directly over the ignition source 25 mm down from the ceiling. The 4-foot thermocouple is located 3 ft (0.9 m) in front of the ignition source and 4 ft (1.2 m) above the floor. The gas sampling probe for measuring the CO is 6.5 in. (163 mm) down from the ceiling and 6.5 in. (163 mm) out from the corner. The smoke meters are located 4 ft. (1.2 m) above the floor and 4 in (100 mm) above the floor. A seating furniture fails to meet the requirements of TB133 if any of the following criteria are exceeded:

A. A temperature increase of 200°F (111°C) at the ceiling thermocouple over the chair.

B. A temperature increase of 50°F(28°C) or greater at the 4-foot (1.2 m) thermocouple.

C. Greater than 75% opacity at the 4-foot (1.2 m) smoke opacity monitor.

D. Greater than 50% opacity at the floor smoke opacity monitor.

E. Carbon monoxide concentration shall not continuously exceed 1000 p.p.m. for one minute.

F. Greater than 10% weight loss in the first 10 minutes of the test.

G. Greater than 90% weight loss of the readily combustible materials at the end of the test.

For the purpose of this investigation, instrumentation was added to the exhaust duct to measure the rate of heat release by oxygen consumption and the rates of carbon monoxide and smoke production. The tests were run in accordance with TB133 with some additional instrumentation inside the room. Three 5 mil type K thermocouples were added 100 mm down from the ceiling equally spaced between the doorway and the corner where the chairs were burned. There was also a thermocouple 100 mm down from the top of the doorway. The purpose of these additional thermocouples was to better characterize the temperature of the hot upper layer at locations away from the chair. The smaller thermocouples had improved accuracy since they reduced the radiation losses from the junction. A heat flux gauge was located in the middle of the floor to monitor the radiant heat reaching the lower part of the room from the hot upper layer. Another heat flux gauge was placed 0.76 m from the edge of the chair to monitor the radiant exposure that might be received by a second combustible item. This gauge was located at the same place as the one in the furniture calorimeter at NIST for comparison purposes. In addition to the instrumentation recommended by NIST, CBHF has installed a smoke meter in the upper part of the room and a thermocouple in one of the walls. The propane diffusion burner described by Ohlemiller and Villa [2] was used as an alternate ignition source to the newspaper on some of the tests for comparison purposes.

3.2. ASTM Room

The ASTM room refers to the proposed ASTM room fire test for interior finish materials [4]. This room is 8 by 12 ft. (2.4 by 3.7 m) with a 8 ft. (2.4 m) ceiling and a 30 by 80 in. (0.76 by 2 m) doorway at the center of one of the 8 ft. (2.4 m) walls. The walls and ceiling were lined with calcium silicate board for these tests. The chair to be tested was located in one of the rear corners and was ignited with the standard TB133 newspaper ignition source. For purposes of this project the ASTM room which was located at NIST was instrumented identically to that of the TB133 room at CBHF.

3.3. Furniture Calorimeter

The furniture calorimeter [5] has a hood and exhaust system capable of collecting all of the combustion products from a burning full scale chair and measuring the rates of heat, carbon monoxide and smoke production. The chair sits on a weighing platform to record the mass during the test. There is a heat flux gauge located 0.76 m from the front center edge of the chair to monitor the thermal radiation flux.

3.4. Cone calorimeter

The Cone calorimeter [6] measures the heat release rate per unit area on 100 mm by 100 mm specimens exposed to a uniform and constant thermal radiation field. The source of the thermal radiation is an electrical heating rod wound into the shape of truncated cone. It can deliver a radiant heating flux up to 100 kW/m^2 at the specimen surface which can be either vertical or horizontal. The specimen is ignited by an electric spark. The heat release rate is measured by oxygen consumption and the mass loss rate is measured with a load cell. The heat of combustion is determined by dividing the measured heat release rate by the measured mass loss rate.

4. TEST PROGRAM

The ten sets of upholstered chairs were obtained. One chair out of each set was tested in the ASTM room at NIST, two chairs out of each set were tested in the furniture calorimeter at NIST, and four chairs from each of six sets were tested in the TB133 room at CBHF. In the furniture calorimeter, one was burned with the newspaper ignition source and one with the gas burner designed to simulate it [3]. In the TB133 room two chairs were burned with the newspaper ignition source and two with the gas burner. Both rooms were instrumented to measure the total heat release rate of the chairs by oxygen consumption. Calculations were made of the upper layer temperature in the room, using HAZARD I and the measured heat release rates.

The combinations of fabric, fiberglass interliner and foam were also tested in the Cone calorimeter [6] to examine the correlation between full scale and bench scale results. The tests were run in the horizontal orientation at an external radiant heat flux of 35 kW/m^2. This is the heat flux specified in the proposed NFPA 246A standard for the use of the Cone calorimeter for upholstered furniture [7]. The three minute average heat release rate and heat of combustion were measured for all of the chairs tested on the project. The averaging period began at the time of ignition.

5. RESULTS

Due to delays in the installation of a new collection hood and exhaust duct and its instrumentation, the heat release rate was not measured directly in the TB133 room for the first five chairs tested. Rather it was inferred from the measured mass loss rate multiplied by the heat of combustion obtained from the Cone calorimeter as described below. These tests were run at CBHF in accordance with TB133 including the newspaper ignition source and the standard measurements. Table 2a lists the measured temperature rises, CO concentrations, smoke opacities and mass losses during these five tests. Table 2b indicates the pass/fail status for each of the TB133 criteria for each chair. The chairs are identified with the letters defined in Table 1. Chair B passed all of the criteria. Chair D passed all of the criteria except the temperature rise at four feet. Chair H failed both temperature criteria but passed all of the others. Chair I failed all of the criteria. However none of these four chairs by themselves posed any flashover threat. On the other hand, Chair E which exceeded the temperature criteria by a much greater margin had a sufficient energy output to cause flashover in the TB133 room. Chairs F and G, tested later in the program, also failed all of the criteria. Chairs A, C and J were not tested in TB133 because the fire would have exceeded the capabilities of the exhaust system as was the case for Chair E.

The three minute average heat release rate and the heat of combustion of the fabric, interliner and foam combinations for all of the chairs in the test series were measured with the Cone calorimeter [6] in the horizontal orientation at an external radiant flux of 35 kW/m^2. The averaging period began with the time of ignition. These values are listed in Table 3. There was no direct heat release rate measurement made for the first five chairs tested at CBHF. However, the residual mass measured with the weighing platform was recorded as a function of time and then differentiated to get the rate of mass loss. The peak heat release rate of each of the five chairs was determined by multiplying the peak mass loss rate by the average heat of combustion for the appropriate combination listed in Table 3.

The heats of combustion along with the mass loss rate curves were used as input to HAZARD I [8] to calculate the temperature history in the TB133 room for each of the five tests. The calculated peak temperatures are compared with the measured ones above the chair, 25 mm down from the ceiling, in Table 4. Except for chair B, where the heat release rate was based on a very small mass loss, the agreement is quite good even though, strictly speaking, the calculation should apply to the average temperature of the upper layer rather than the temperature in the corner directly above the burning chair. There is also some uncertainty with regard to the mass measurement during the peak burning period for chair E when the supporting frame for the weighing platform came into contact with the floor. Chair I was prematurely extinguished before the peak burning rate was attained so that the peak heat release rate and the calculated peak temperature were determined at the point of extinguishment.

All ten chair combinations were tested in the ASTM room using the standard newspaper ignition source. None of the chair fires were extinguished until after their peak burning rate had been achieved. These tests were run to see if a correlation could be found between the results obtained in the two different rooms. The carbon monoxide concentration, the maximum temperature rise above the chair and the peak heat release rate are compared between the TB133 and the ASTM room in Table 5. The smoke and mass loss data from the ASTM room test are not available at this time. However, the available data suggests that the test could be conducted in either room with similar results.

The peak carbon monoxide concentration in the corner above the chair, 165 mm down from the ceiling, is plotted as a function of the peak heat release rate in figure 3 for both the TB133 and the ASTM rooms. The data are quite scattered but tend to show a large increase in CO around 1.7 MW which is beyond the point of flashover. This is an expected increase due to the fuel-rich state that exists after flashover.

The peak temperatures measured near the ceiling above the chair in all of the tests conducted in the TB133 and ASTM rooms are plotted against the peak heat release rate in figure 4. The depression of the temperature at 2.8 MW in figure 4 is probably real. The fire has become ventilation limited so that any increase in the rate of pyrolysis simply leads to more burning outside the room without contributing to any increase in the interior temperature. Indeed the unburned pyrolysis products in the room actually lowers the room temperature slightly due to dilution. This curve would make it possible to predict the temperature rise in either the TB133 room or the ASTM room from the heat release rate measured in the furniture calorimeter provided that the interaction with the room does not have a significant impact on the total heat release rate of the chair. This interaction would be due to heat feed back and ventilation restrictions.

Measurements were also made in the NIST furniture calorimeter for all ten chairs using the same newspaper ignition source for comparison with the ASTM room. In order to examine the impact of the room on the burning rate of the chair, the peak heat release rates measured in the TB133 and ASTM rooms are plotted against the peak heat release rate in the furniture calorimeter in figure 5. The data on the plot is taken only from the tests using the newspaper ignition source. The lower solid line in the plot is the equality line. Except for one outlier, chair F, the peak heat release rate in the room is similar to that in the furniture calorimeter for heat release rates under 600 kW. Beyond that point the heat feedback from the hot upper air and room surfaces enhances the burning rate significantly as seen from the upper line in figure 5.

One of the complexities in the burning of these upholstered chairs is the transition from smoldering to flaming combustion. This phenomenon was demonstrated by chairs I, F and G which had California 117 foam. Chair I had a polyolefin fabric and an interliner. Chair F had a Nylon fabric with an interliner and Chair G had a PVC vinyl with no interliner. The total heat release rate curves for these chairs, measured in the furniture calorimeter with the newspaper ignition source, are shown in figures 6, 7 and 8. In each case there is a significant heat release rate at some time during the first five minutes associated with the burning of the fabric. Then the flame dies out and suddenly, in the case of these tests, there is a transition to flaming in about a half hour with a much larger heat release rate. These same phenomena occurred in the ASTM room as well as in the calorimeter for all three chairs as seen in figures 9, 10 and 11. However, the times of the transition to flaming was of the order of half the time in the rooms and the shape of the second heat release rate pulse was different in the room for Chair F even though the total energy release was similar. Transition to flaming must be included in any detailed studies of the hazard of upholstered furniture.

In order to establish a peak heat release rate equivalent to the 111°C (200°F) temperature rise criterion, all of the heat release rate and temperature rise data taken in the TB133 room after the heat release rate instrumentation had been installed is plotted in Figure 12. These data are a subset of the data shown in Figure 4. The heat release rates deduced from the mass loss rates for the first five chairs were not included in the plot because they were considered to be less reliable. The letters refer to the chair type described in Table 1. The peak heat release rate due the foam burning in chairs I, F and G were in most cases considerably higher and the fires were usually extinguished before this peak was reached. The subscript, "1", refers to the first peak, associated with the fabric burning. These data on chairs I, F and G were included to increase the data base for defining the equivalent heat release rate. The solid curve is the best fit of a third degree polynomial to the data. The vertical line at 111°C (200°F) represents the pass fail boundary for the upper thermocouple in TB133. The horizontal line through the intersection represents an equivalent heat release rate criterion of 65 kW. The first quadrant represents the domain where the chair fails both the temperature and the suggested heat release rate criteria. Likewise, the third quadrant represents the domain where the char passes both criteria. Only two points fell outside of these domains. One of the chairs labeled H passed the heat release rate criteria but failed on temperature. One of the chairs labeled F_1 passed the temperature criterion by a small amount but failed the heat release rate criterion by a similar amount. Neither of these discrepancies would be expected to cause a problem. The peak heat release rates for Chairs B, D and H, obtained in the ASTM room, are also included even though they were not used in the calculation of the curve. They lie in quadrants 1 and 3 and fall within the scatter of points from the TB133 room.

The heat release rates measured as a function of time in the ASTM room were used in HAZARD I to calculate the temperature histories of the upper layer for all ten chairs. The peak calculated values are compared with the peak measured values in figure 13. The temperatures were measured with a 5 mil thermocouple located 100 mm below the ceiling at the center of the room. Except for Chair E, the points fall close to the equality line. Chair E had a considerably higher heat release rate than any of the other chairs but a significant fraction of the burning took place outside of the room. The calculations performed with HAZARD I assumed all of the heat was released inside of the room. The impact of the increased rate of pyrolysis was to decrease the temperature due to dilution as discussed in connection with figure 4. Thus the measured temperature for Chair E fell into the range of temperatures measured for Chairs A, C and J which had significantly lower heat release rates. This figure demonstrates once again the strong relationship between the heat release rate of the chair and the temperature of the hot upper layer near the ceiling of the room.

In figure 14, the temperature of the thermocouple 25 mm below the ceiling directly above the chair is plotted against the temperature of the thermocouple 100 mm below the center of the ceiling in the ASTM room. The first thermocouple is the one used for the pass fail criteria in TB133. The second thermocouple gives a reasonable estimate of the upper layer temperature. At the lower temperatures where the flames do not impact the thermocouple above the chair directly for a significant portion of the time there is fairly close agreement between the two thermocouples. However, at higher temperatures the differences become significant.

It has been suggested by Babrauskas [9] that the Cone calorimeter could be used in conjunction with the furniture calorimeter to evaluate the fire hazard of upholstered furniture. Once a particular model with a specified style and frame has been tested in the furniture calorimeter, the effect of changes in fabric, interliner and foam could conceivably be evaluated with the cone calorimeter using composite specimens. The set of ten chairs with identical styles and frames used on this project provided a good data base to begin this investigation.

The peak heat release rate in the furniture calorimeter is plotted against the three minute average heat release rate per unit area in the Cone calorimeter in figure 15. The primes associated with chairs I, F and G denote the height of the first peak. With the exception of chair I which exhibited a transition to flaming, there is a reasonable correlation up to 180 kW/m^2. After a discontinuity, the correlation continues with a much higher slope.

The correlation of the heat release rate per unit area in the Cone calorimeter with the total heat release rate in the ASTM room is shown in figure 16. It is noted that again there is a large transition at a heat release rate per unit area of 180 kW/m^2. However, due to radiation reinforcement in the room the slope above 180 is twice as great. The slope below 180 kW/m^2 is essentially unchanged between the furniture calorimeter and the rooms. The chairs that pass the TB133 test are confined to this regime. In fact it can be seen from the curves in figures 15 and 16 that the total heat release rate restriction of 65 kW derived from the 111°C temperature rise criterion of TB133, is equivalent to a three minute average heat release rate in the Cone calorimeter of 87 kW/m^2. Only Chairs B and D, which passed the upper temperature criterion in TB133, have heat release rates in the Cone calorimeter below 87 kW/m^2. It is important to recognize that this particular correlation can be assumed to be valid only for this particular style and size of chair. More work needs to be done to generalize the application of such a correlation.

In order to fully understand and predict the burning rate of upholstered chairs and the impact of changing the fabric, interliner and foam it will be necessary to develop a model for the burning of such an assembly of materials.

The heat flux incident on the center of the floor for the ASTM room is plotted as a function of the total heat release rate in figure 17. Since a heat flux of 20 kW/m^2 at this location is sometimes taken as the definition of flashover, this plot suggests that a peak heat release rate of 1.7 MW was required for flashover in the case of these chairs. This is consistent with the concentration of CO which increased abruptly at 1.7 MW as seen in figure 3. This high heat release rate requirement for flashover is probably due to the rather sharp peaks associated with the burning of the furniture.

In figure 18 the radiant heat flux measured 0.76 m from the edge of the chair is plotted as a function of the peak heat release rate of the chairs in the furniture calorimeter using the newspaper ignition source. Both the fabric and foam peaks are plotted for Chairs I, F and G. The flux is seen to increase linearly with the total heat release rate according to the formula: $q'' = 11Q$ where q'' is the heat flux in kW/m^2 and Q is the total heat release rate in MW. Assuming a minimum heat flux for ignition of 10 kW/m^2, radiant ignition of a second item at that distance would require that the initial burning chair release heat at a rate of at least 900 kW.

6. CONCLUSIONS

The following conclusions apply to the burning of upholstered chairs:

(1) The TB133 test could be conducted in an ASTM room with similar results.

(2) A heat release rate of 65 kW in the furniture calorimeter is equivalent to a temperature rise of 111°C (200°C) in the TB133 room test.

(3) Below a peak heat release rate of 600 kW there is no significant interaction between the chair and the room so that the heat release rates in the room would be the same as those in the furniture calorimeter. This is true for the ASTM and TB133 rooms and rooms of larger size. However, for rooms with low thermal conductivity lining materials or rooms of smaller size the interaction would be expected to occur at lower peak heat release rates.

(4) Given the heat release rate in the room the temperature of the upper layer can be calculated using HAZARD I. The upper layer temperature is defined here as the temperature measured 100 mm down from the center of the ceiling. After flashover a significant portion of the burning usually takes place outside of the room so that the total measured heat release rate will be higher than the actual heat release rate in the room.

(5) For chairs with sufficiently low heat release rates to pass the TB133 test, the upper layer temperature defined above is equivalent to the temperature above the chair as specified in TB133.

(6) A correlation was obtained between the total heat release rate of the full scale chairs tested on this project and the three minute average heat release rates of the material combinations measured in the Cone calorimeter at an external radiant flux of 35 kW/m^2. For these chairs the total heat release rate of 65 kW is equivalent to a 3 minute average heat release rate of 87 kW/m^2 in the Cone calorimeter. A generalized correlation would hold out the prospect of an effective economical means to test numerous fabric-cushion combinations for a given chair style.

(7) TB133 test can effectively rule out products which are clearly poor performers from a fire hazard point of view. The failure criteria are quite conservative. Products which "pass" this test would not on their own create a "flashover" hazard in realistic-sized compartments.

(8) There are commercially available materials and products which do pass the TB133 test.

7. ACKNOWLEDGMENTS

Kay Villa selected and ordered the furniture used on this project. Dick Zile, Roy McLane and Gary Roadarmel operated the furniture calorimeter, built and instrumented the ASTM room and ran 10 full scale fire tests. Bill Twilley assisted in the construction and instrumentation of the room. Kay Villa, Tom Ohlemiller, John Krasny, Vyto Babrauskas and Jim Quintiere were consulted on various phases of this project.

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Table 1. Combinations of Materials Used in the Full Scale Tests			
Chair Code	Material Description	Chair Code	Material Description
A	Wool Fabric TB117 Foam	B	Wool Fabric Interliner TB117 Foam
C	Nylon Fabric Melamine Foam	D	Nylon Fabric Interliner Melamine Foam
E	Nylon Fabric TB117 Foam	F	Nylon Fabric Interliner TB117 Foam
G	PVC Vinyl Fabric TB117 Foam	H	PVC Vinyl Fabric Melamine Foam
I	Polyolefin Fabric Interliner TB117 Foam	J	Polyolefin Fabric TB117 Foam

Table 2a. Data for First Five Tests at CBHF								
	Temperature Rise °C		Carbon Monoxide		Smoke Opacity %		Mass Loss %	
Chair	4 ft.	ceiling	Peak ppm	Time s over 1000 ppm	4 in.	4 ft.	10 min.	Test
B	14	49	371	0	0.6	0.6	0.3	0.4
D	42	109	165	0	5.9	50	1.8	3.3
H	46	141	2500	55	33	72	1.1	6.1
I	181	356	1900	>240	>89	>99	>13	>13
E	778	997	2800	>130	>75	>99	>57	>57

Table 2b. Pass/Fail Results of First Five Fire Tests at CBHF							
	Temperature Rise °C		Carbon Monoxide	Smoke Opacity %		Mass Loss %	
Chair	4 ft.	ceiling	Time s over 1000 ppm	4 in.	4 ft.	10 min.	Test
B	P	P	P	P	P	P	P
D	F	P	P	P	P	P	P
H	F	F	P	P	P	P	P
I	F	F	F	F	F	F	F
E	F	F	F	F	F	F	F

Table 3. Cone Calorimeter Data		
Chair	Heat Release Rate kW/m^2	Heat of Combustion MJ/kg
A	231	19.3
B	46	10.7
C	264	21.7
D	80	19.8
E	328	24.9
F	181	22.6
G	185	14.5
H	154	14.4
I	105	20.1
J	352	27.4

Table 4. Comparison of Calculated and Measured Peak Temperature Rises in the TB133 Test		
	Temperature Rise (°C)	
Chair	Calculated	Measured
B	81	48
D	107	109
H	161	141
I	351	356*
E	976**	994

* Measured at the time of extinguishment.

** Some uncertainty in the peak mass loss rate upon which this calculation was based.

Table 5. Comparison of TB133 and ASTM Room Data						
	Peak CO Concentration (%)		Peak Temperature Rise (°C)		Peak Heat Release Rate (kW)	
Chair	TB133	ASTM	TB133	ASTM	TB133	ASTM
B	0.06	0.11	48	54	31	25
D	0.08	0.04	109	107	70	64
H	0.36	0.32	141	120	130	80
I	0.22	0.21	356*	522	393*	502
E	6.3	5.1	994	980	>1700**	2760

* Extinguished before peak burning rate was acheived.

** Based on a mass measurement which became defective after a heat release rate of 1700 kW was acheived.

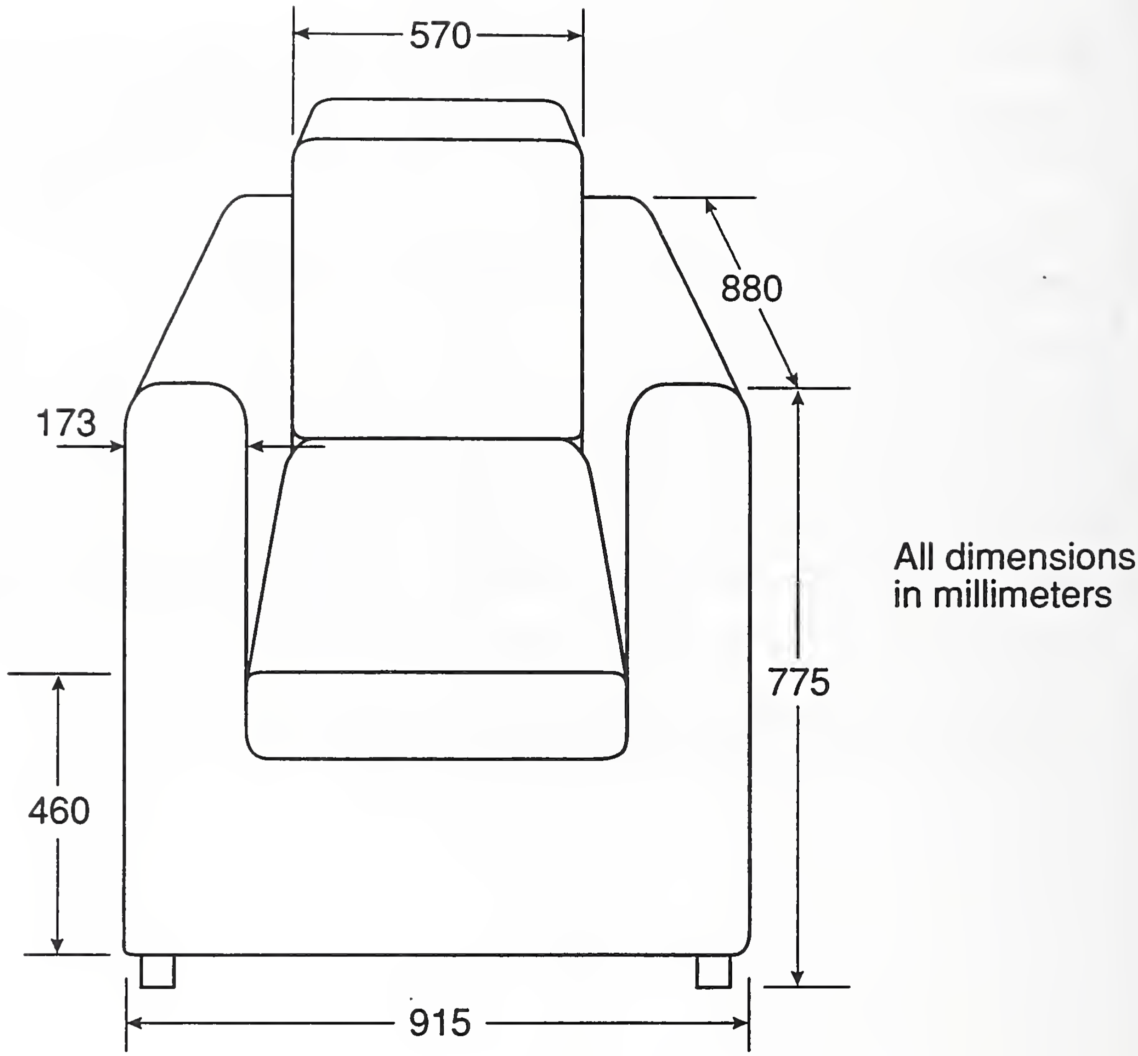

Figure 1. Design of Chairs.

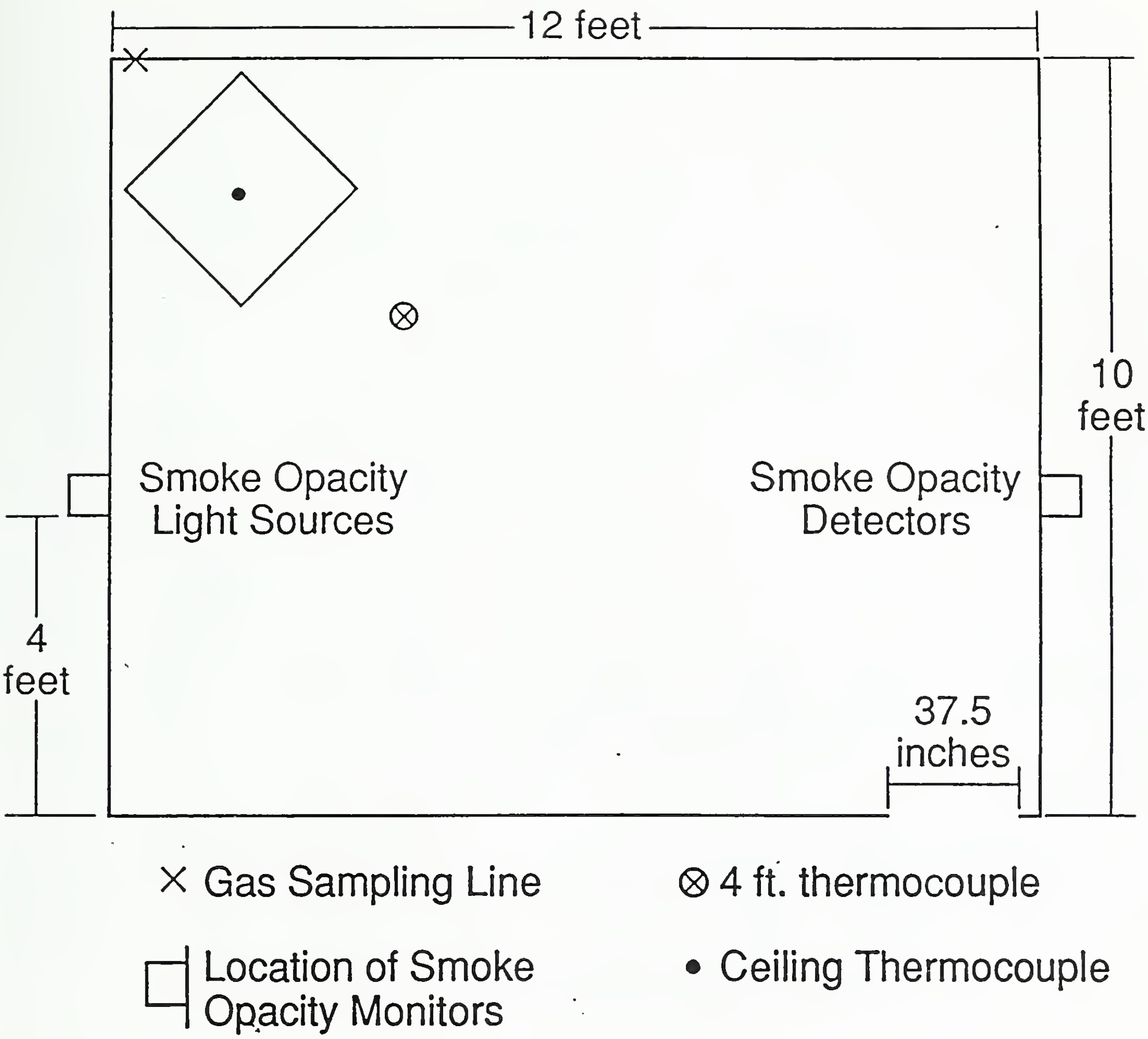

Figure 2. Layout of TB133 Test Room

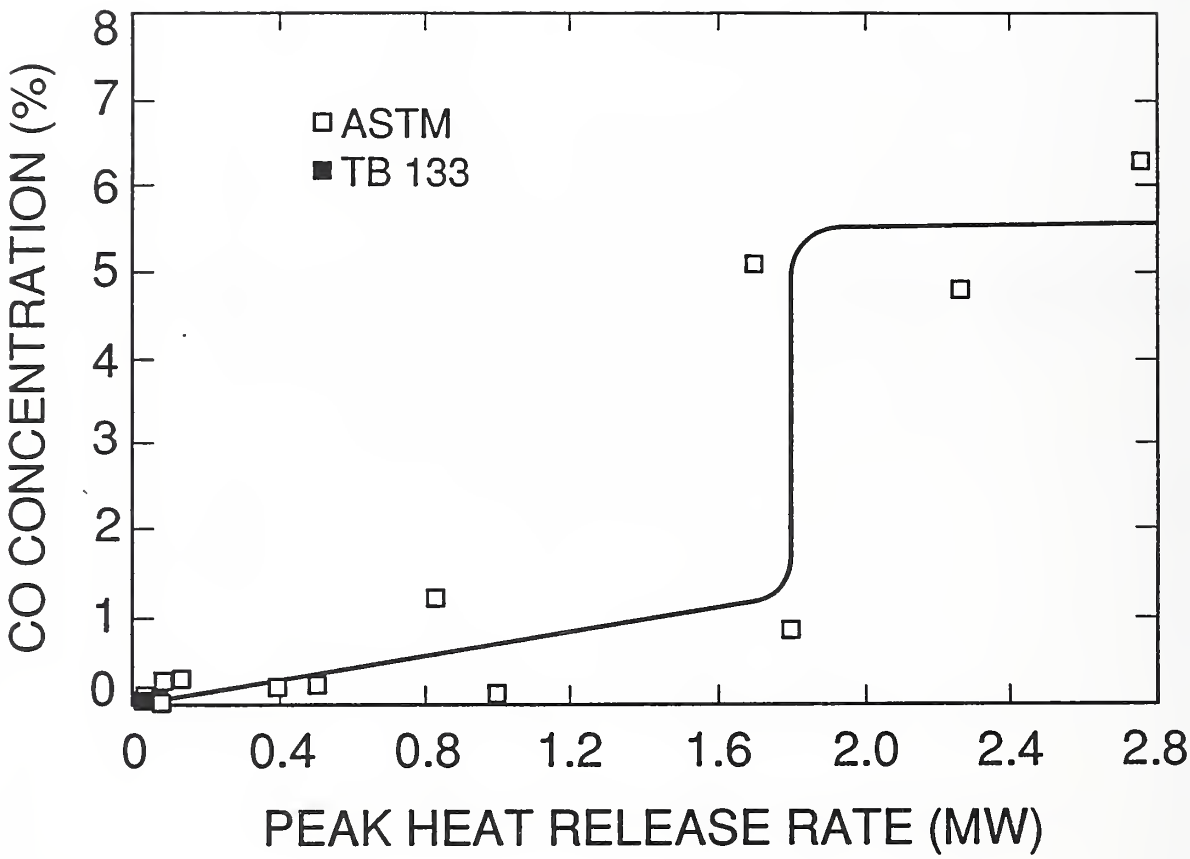

Figure 3. CO Volume Fraction vs. Heat Release Rate for TB133 and ASTM Rooms.

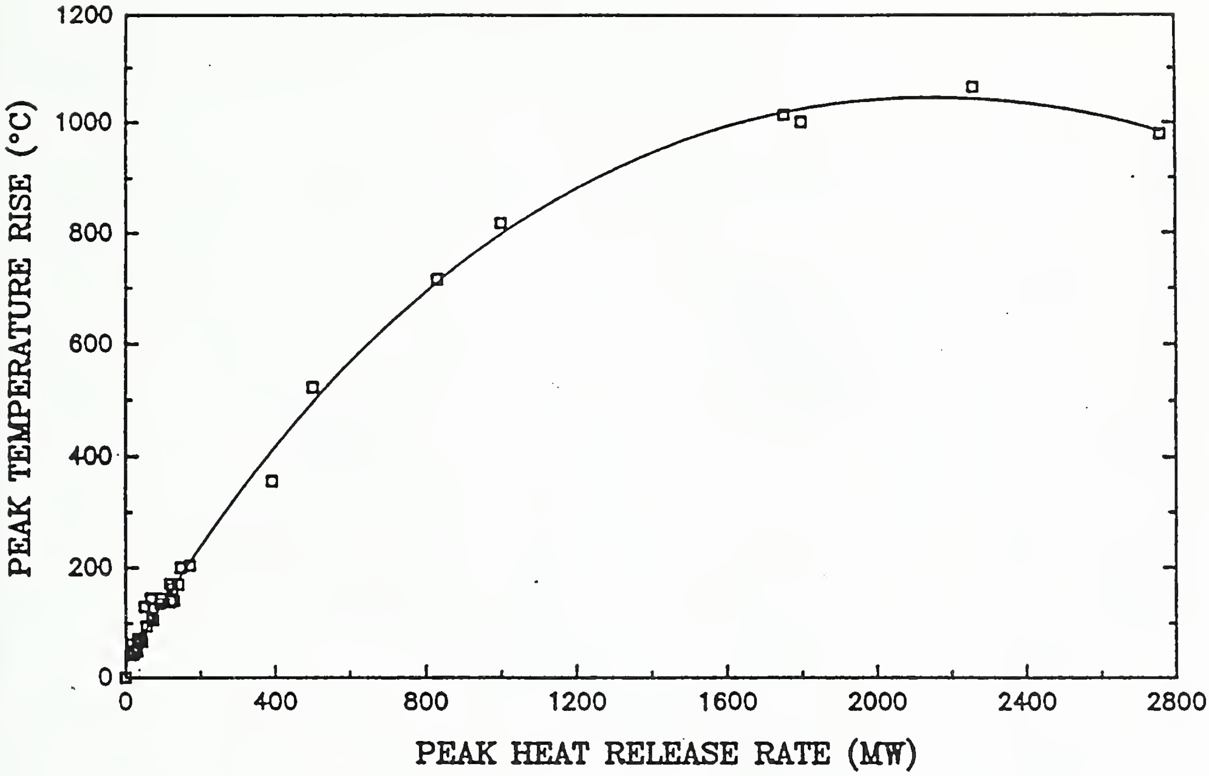

Figure 4. Temperature Rise vs. Heat Release Rate for TB133 and ASTM Rooms.

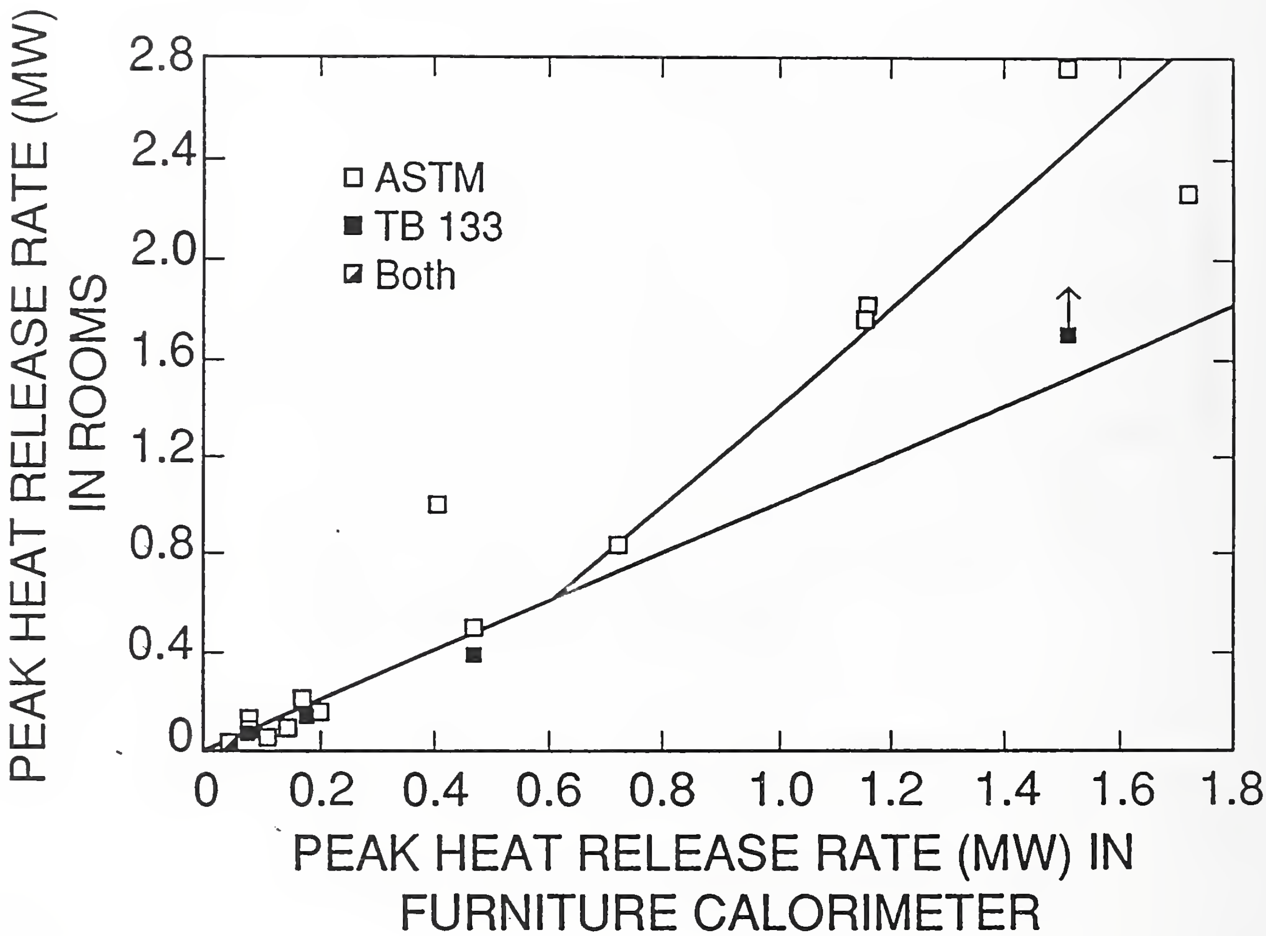

Figure 5. Heat Release Rate in Rooms vs. Heat Release Rate in Furniture Calorimeter.

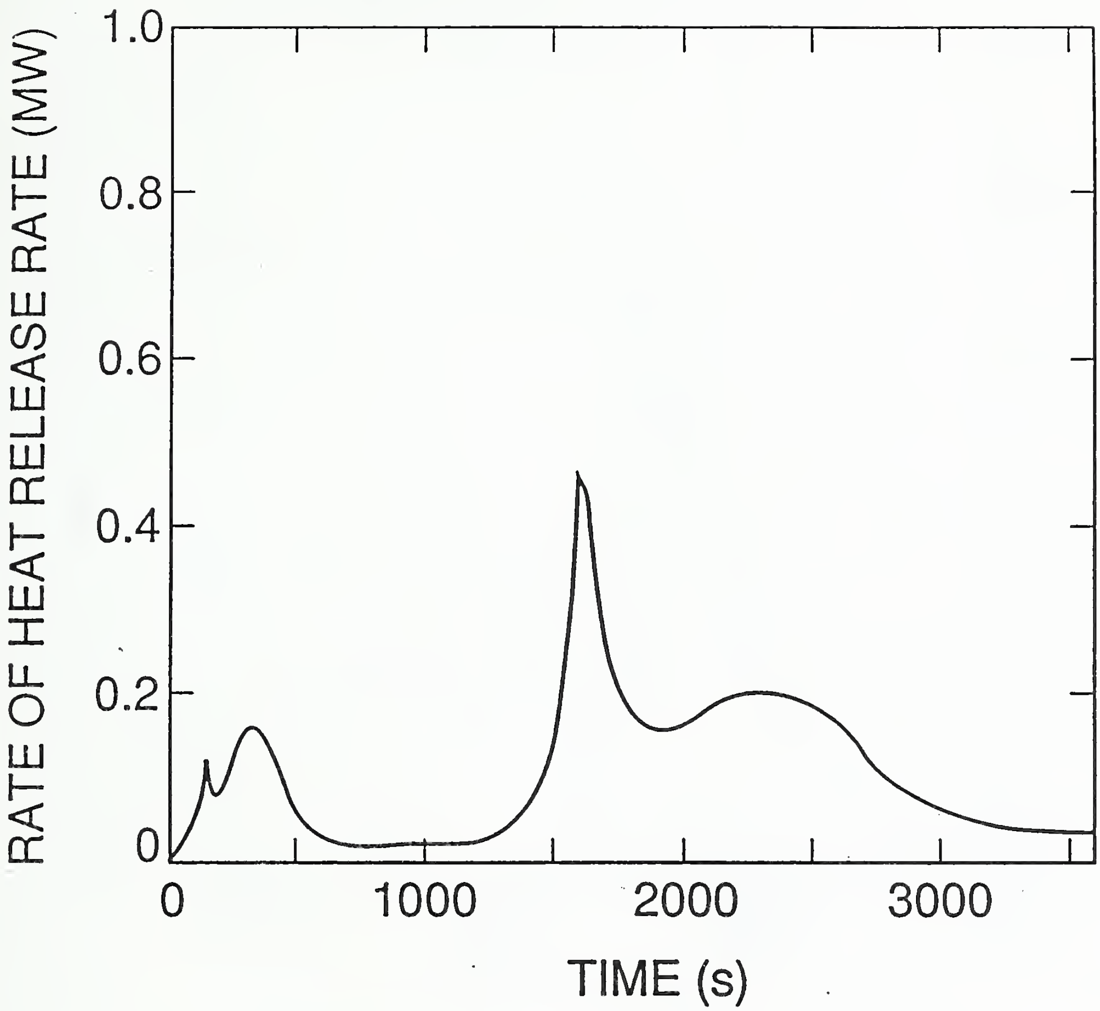

Figure 6. Heat Release Rate of Chair I in the Furniture Calorimeter.

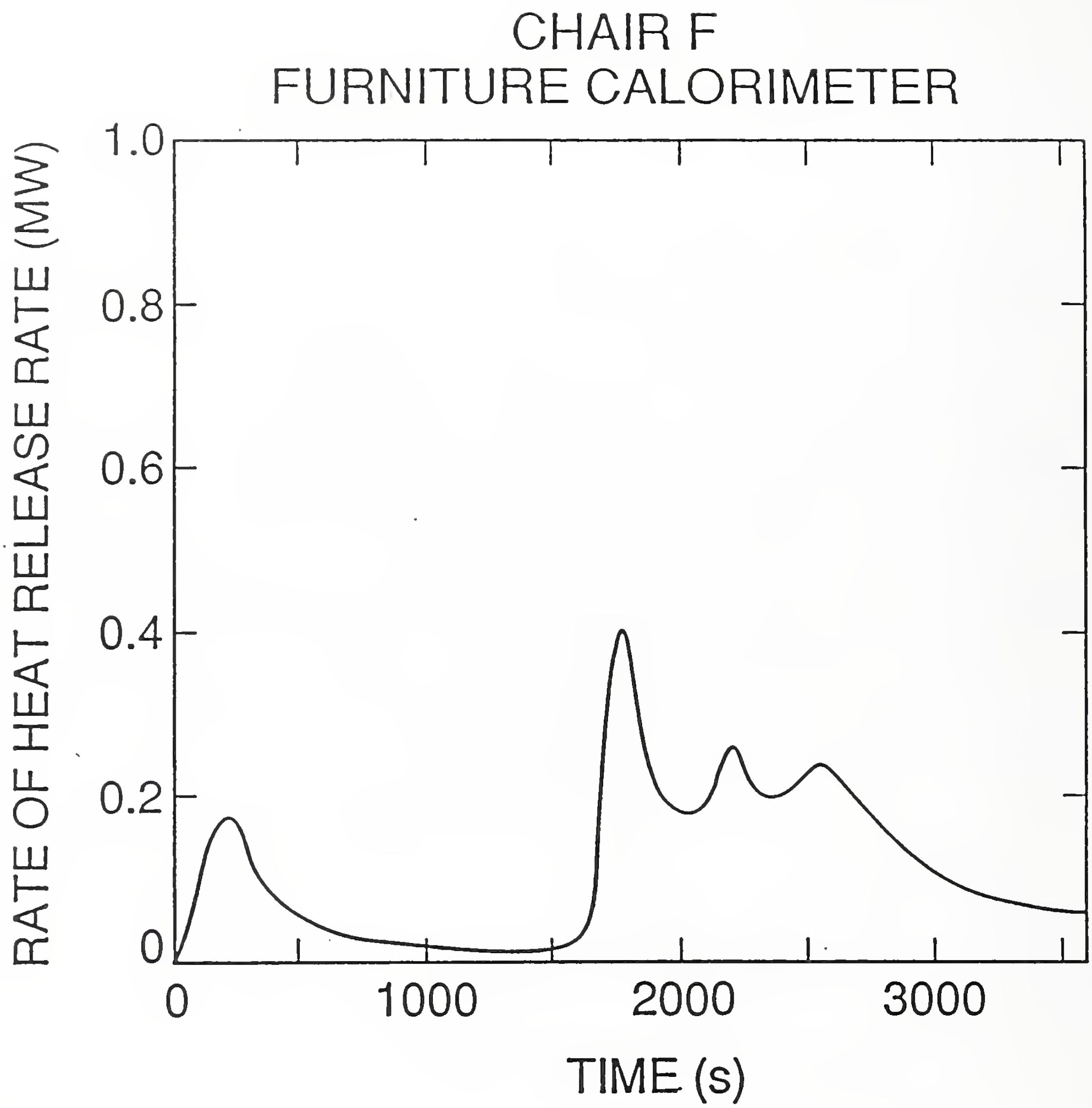

Figure 7. Heat Release Rate of Chair F in the Furniture Calorimeter.

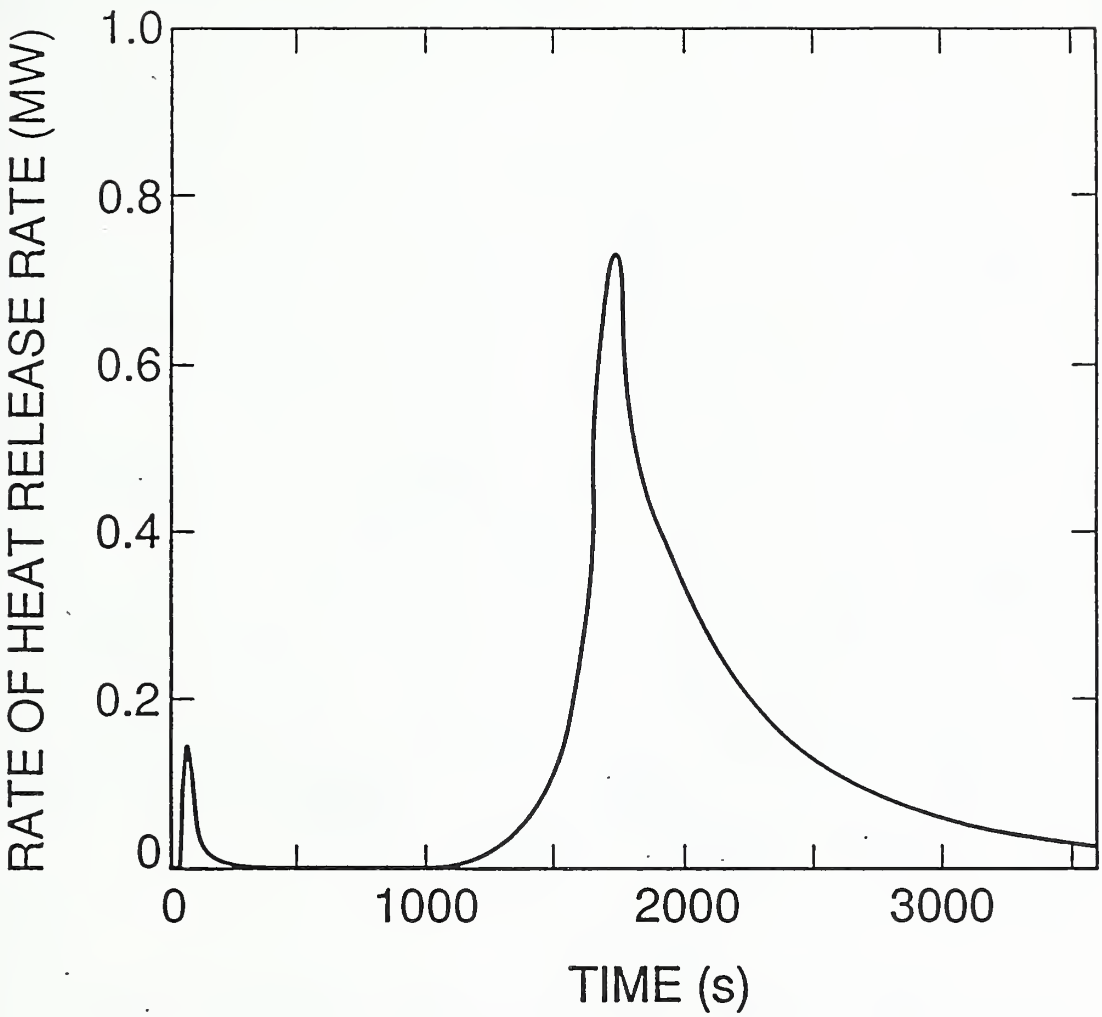

Figure 8. Heat Release Rate of Chair G in the Furniture Calorimeter.

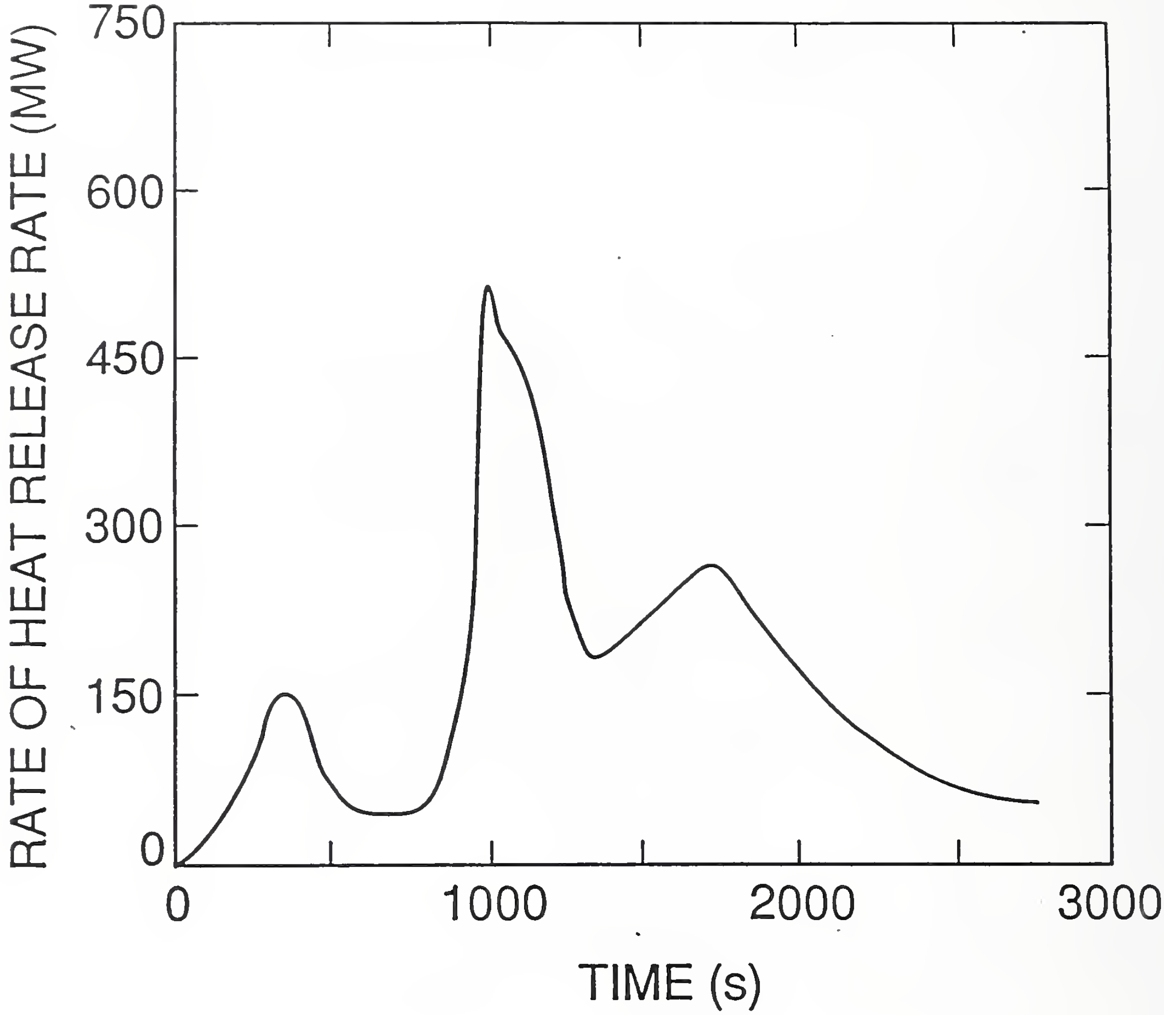

Figure 9. Heat Release Rate of Chair I in the ASTM Room.

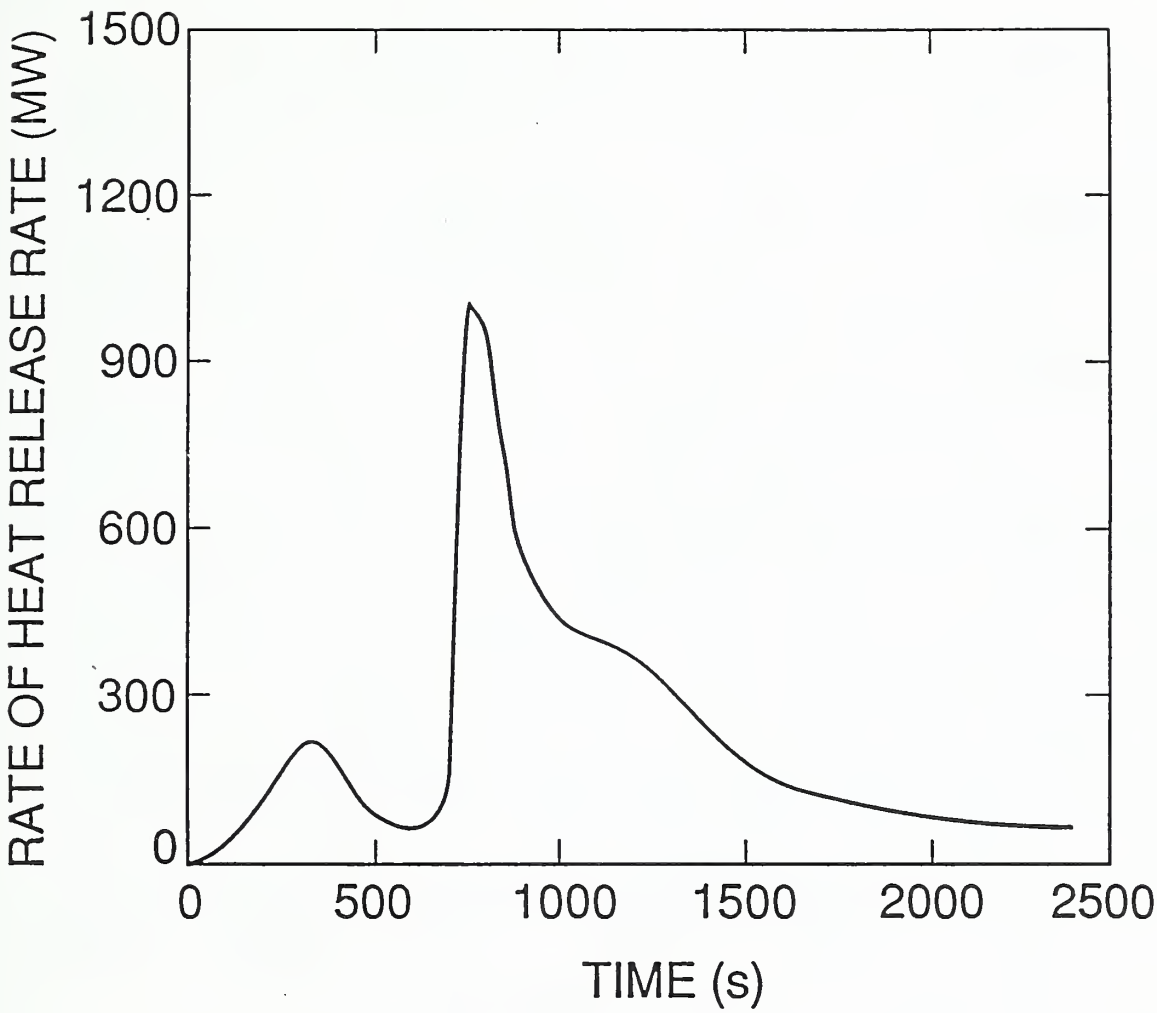

Figure 10. Heat Release Rate of Chair F in the ASTM Room.

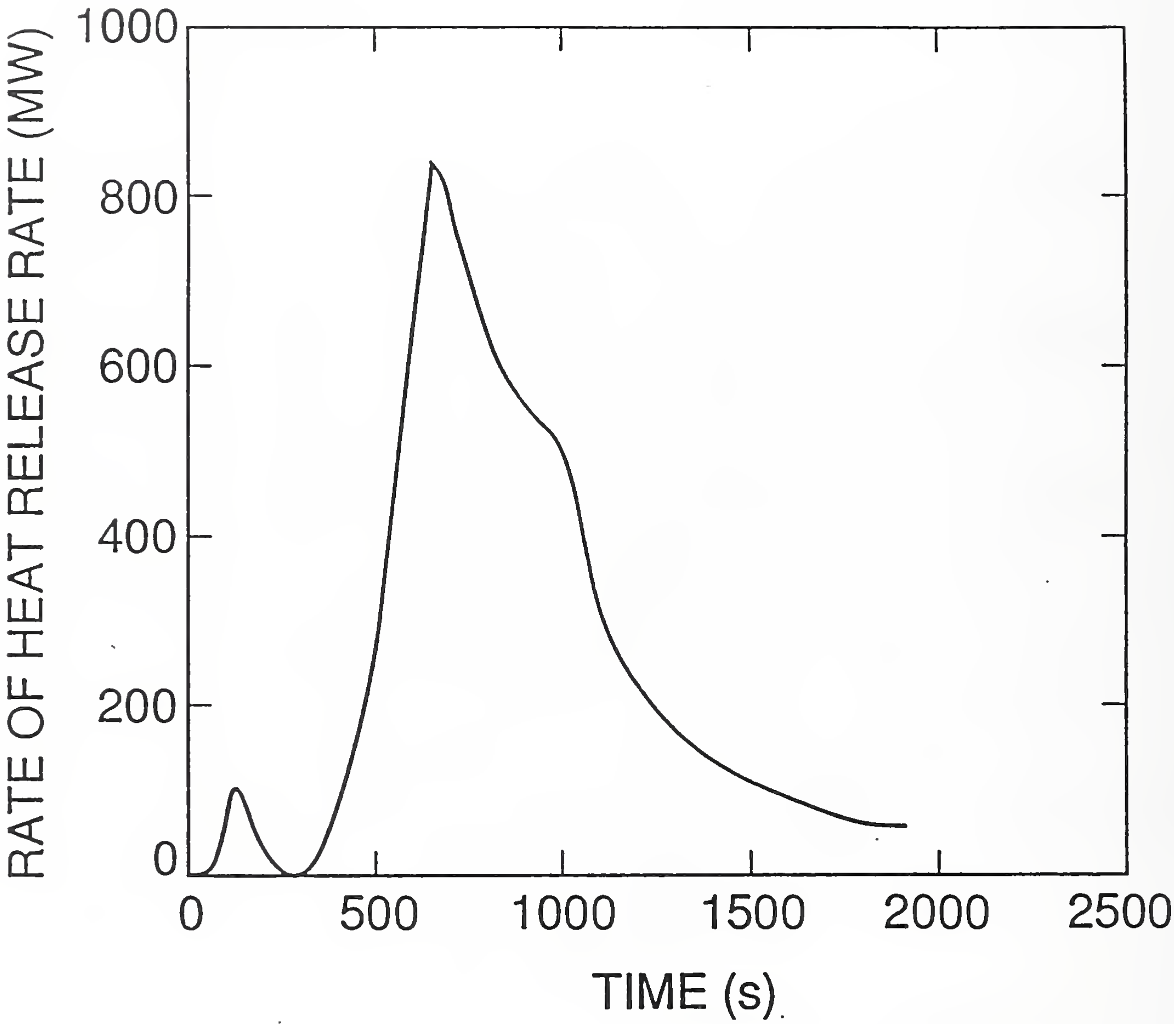

Figure 11. Heat Release Rate of Chair G in the ASTM Room.

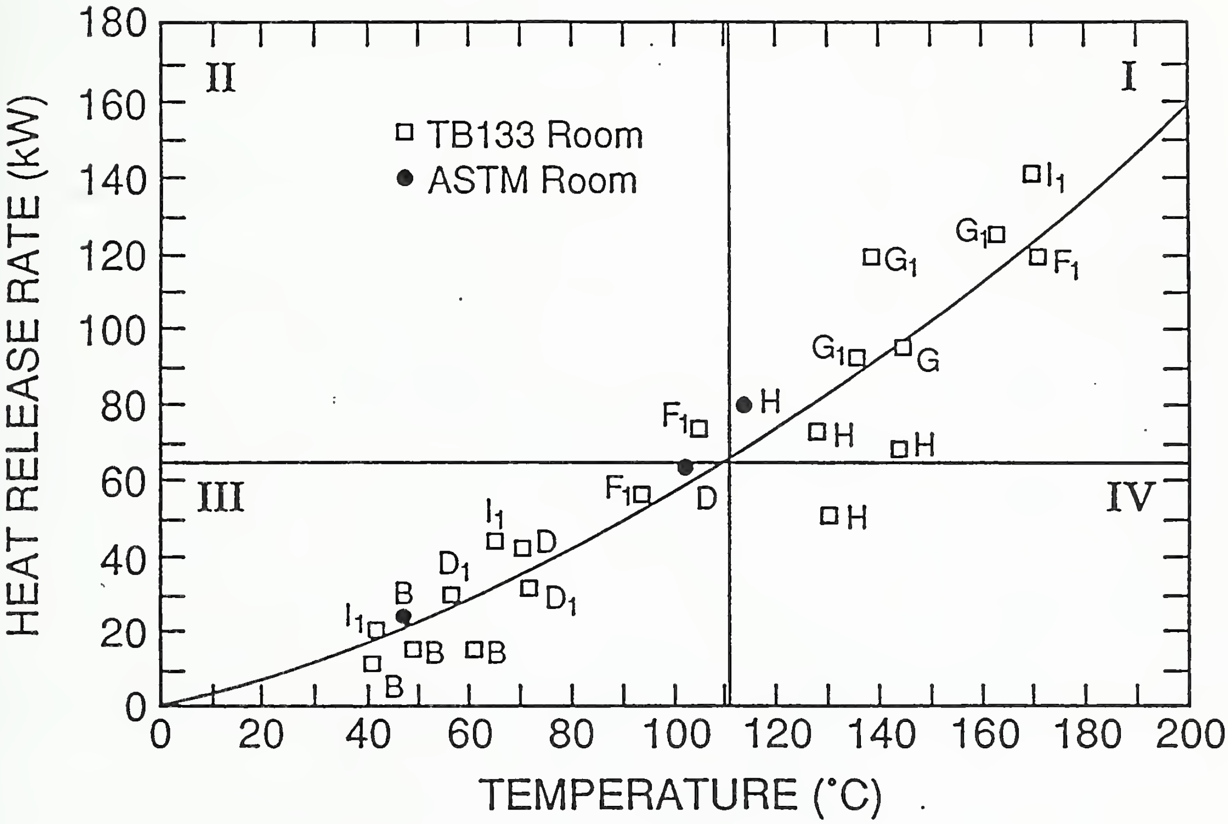

Figure 12. Heat Release Rate of Chairs vs. Temperature in TB133 Room.

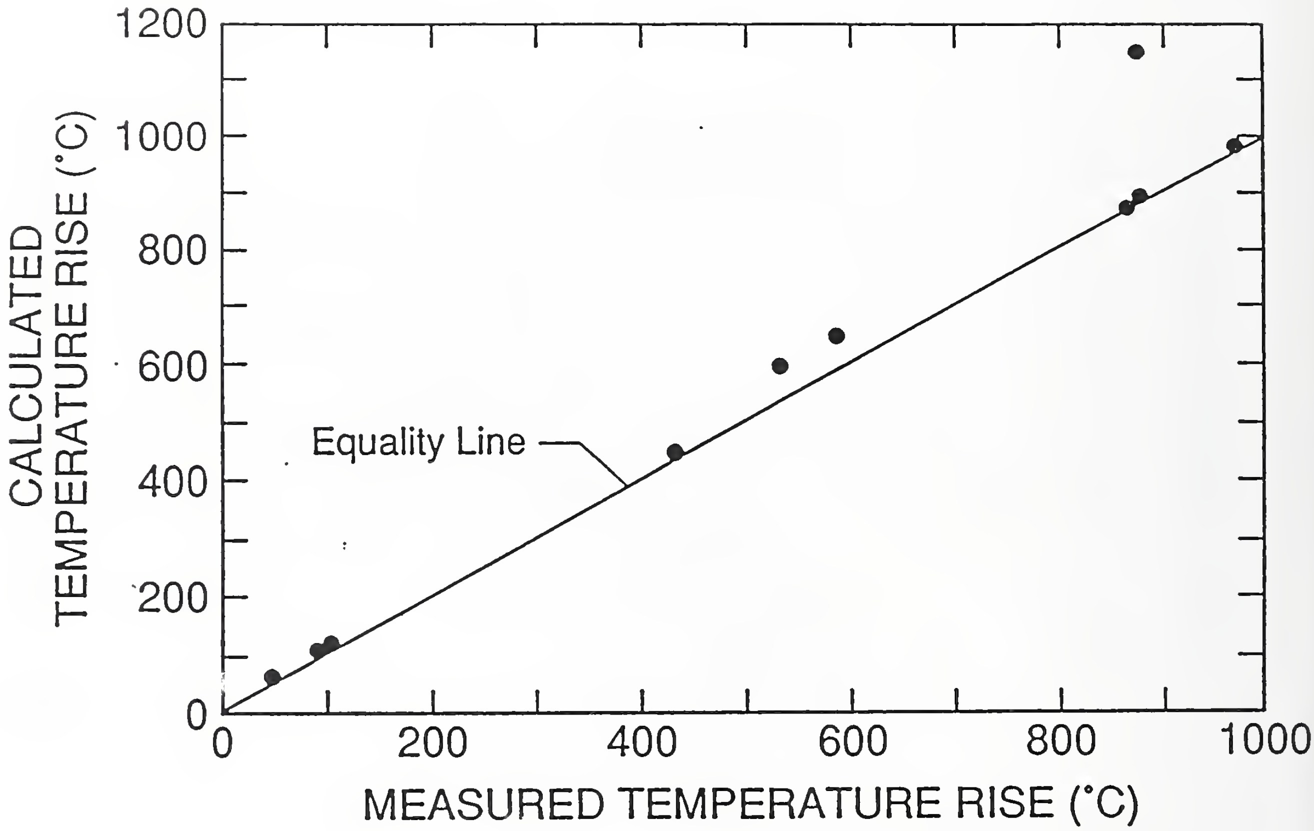

Figure 13. Calculated Temperature Rise Using Hazard I.

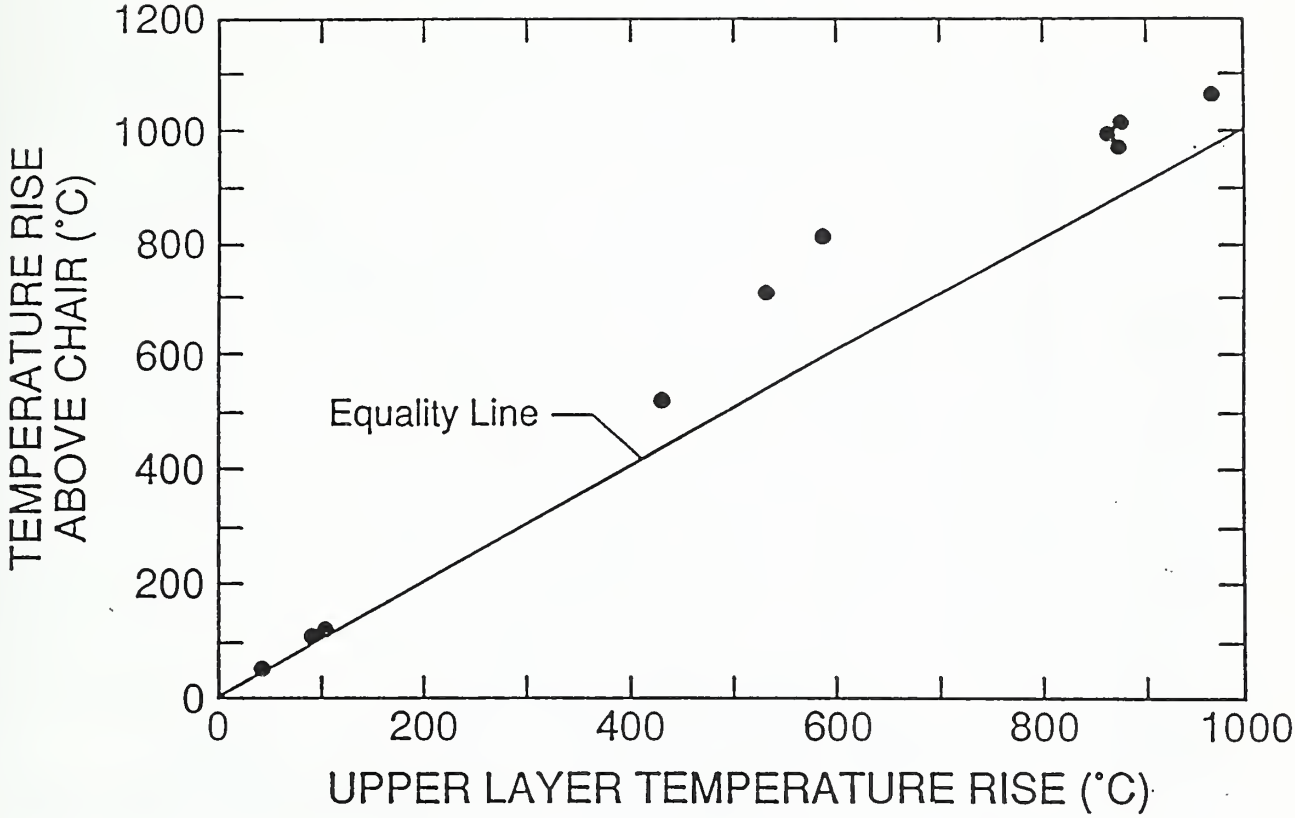

Figure 14. Temperature above Chair vs. Temperature at Center of Room.

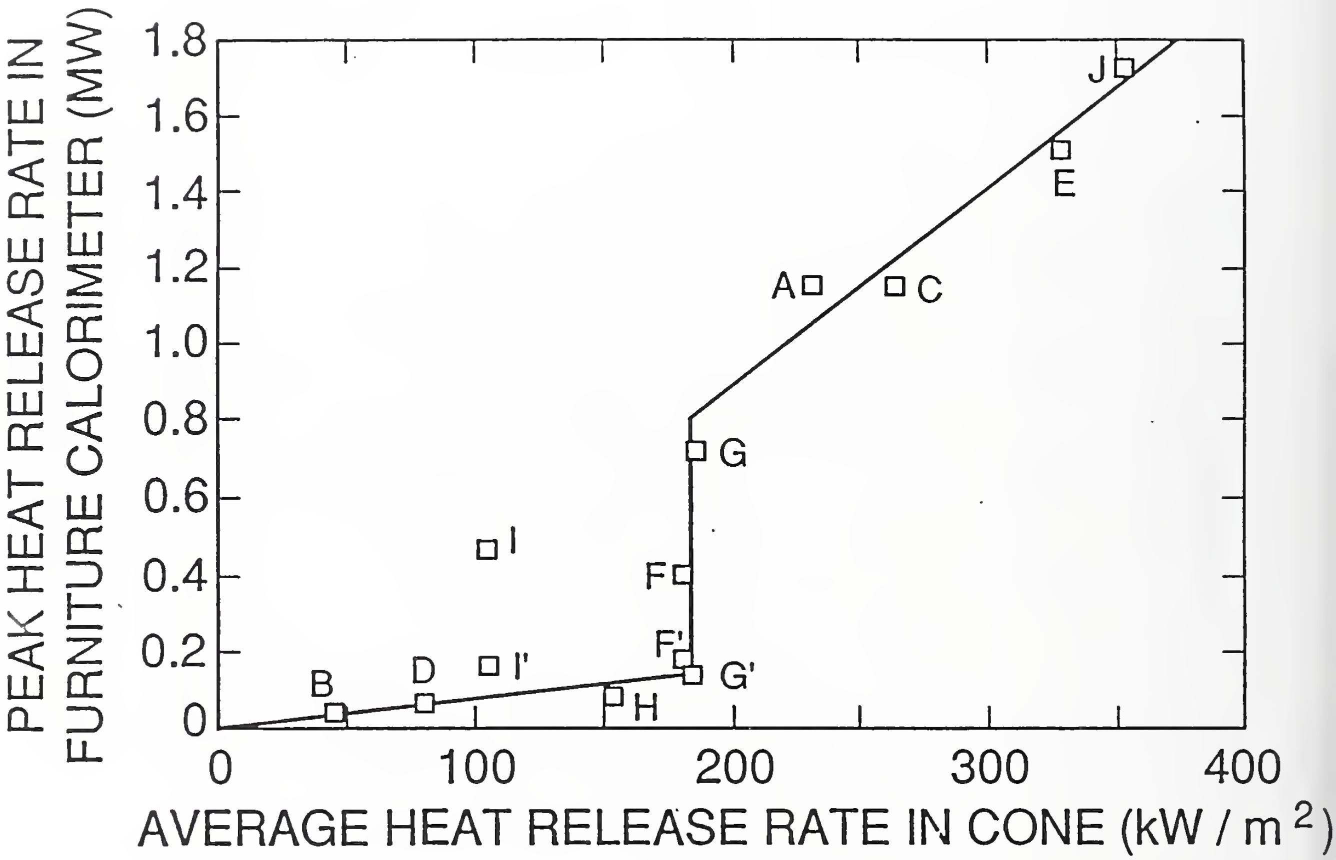

Figure 15. Correlation between Cone and Furniture Calorimeter.

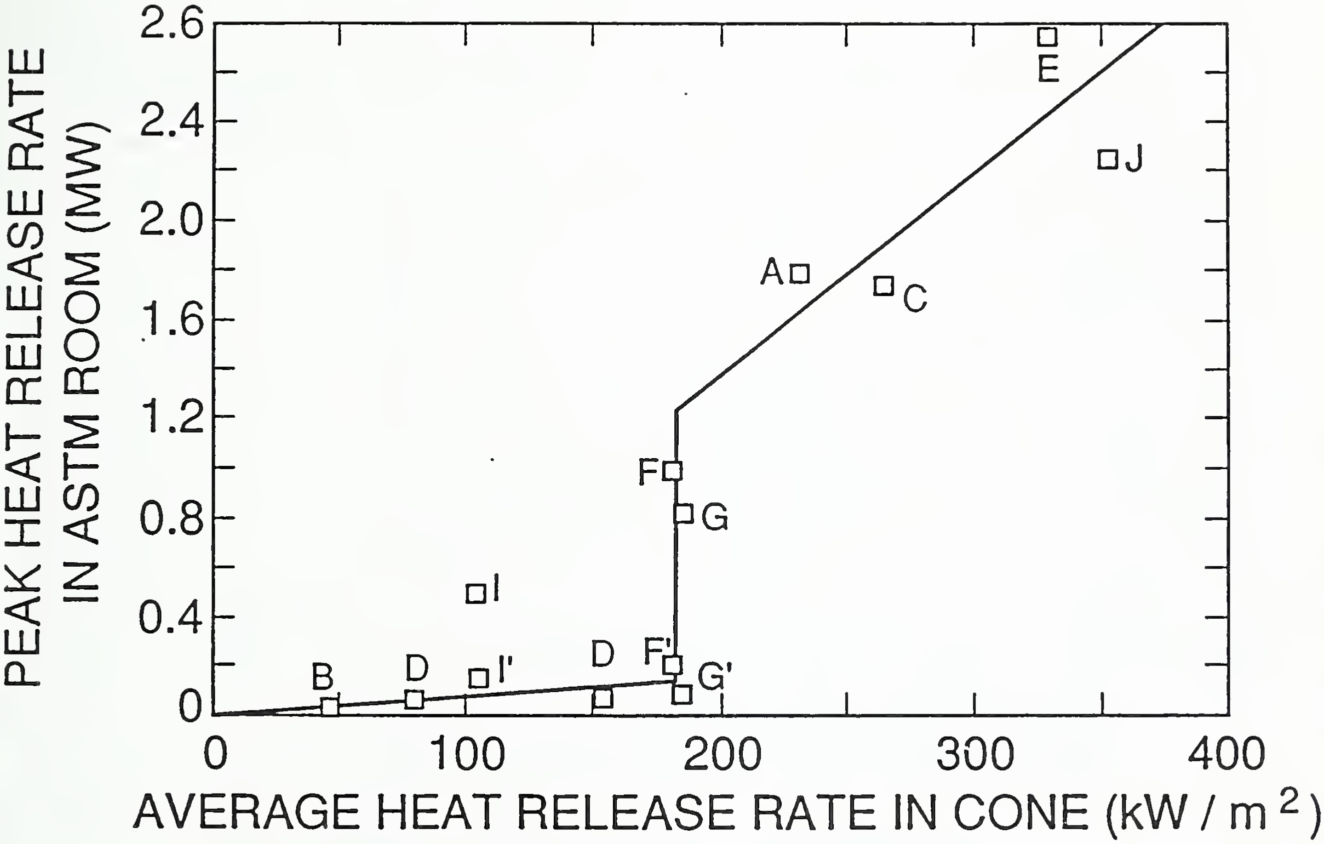

Figure 16. Correlation between Cone and Rooms.

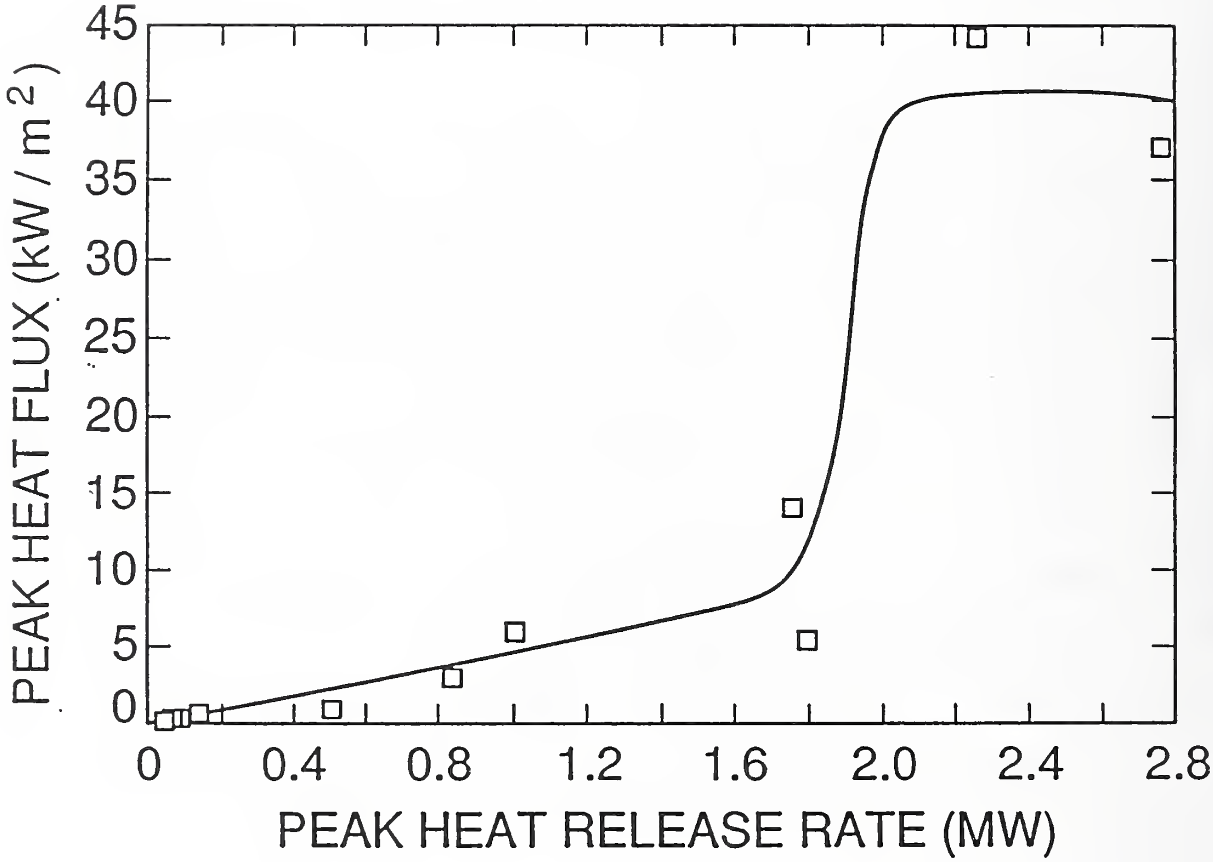

Figure 17. Radiant Heat Flux at Floor Level.

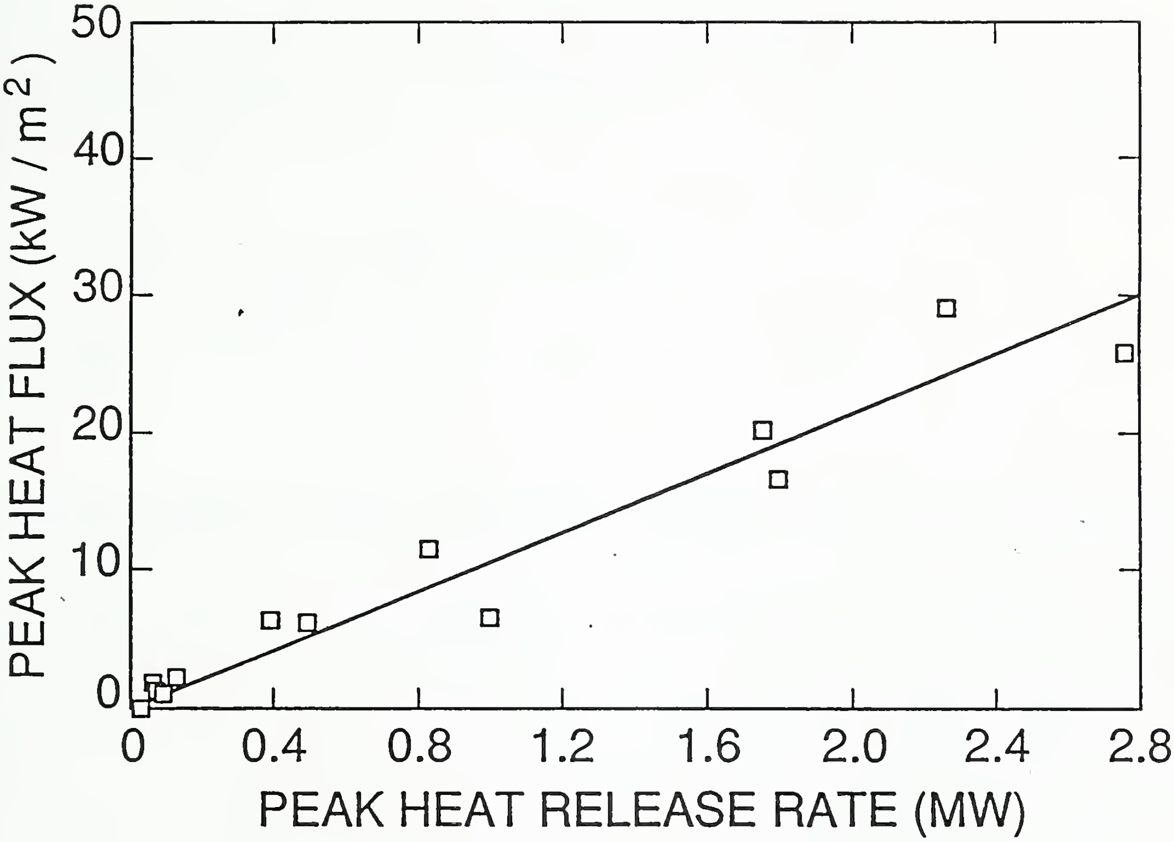

Figure 18. Radiant Flux 0.76 Meters from Chair.

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11. ABSTRACT (A 200-WORD OR LESS FACTUAL SUMMARY OF MOST SIGNIFICANT INFORMATION. IF DOCUMENT INCLUDES A SIGNIFICANT BIBLIOGRAPHY OR LITERATURE SURVEY, MENTION IT HERE.)

Ten sets of upholstered chairs were obtained. One chair out of each set was tested in the ASTM room, two chairs out of each set were tested in the furniture calorimeter, and four chairs from each of six sets in the California Technical Bulletin 133 (TB133) room. The chairs in the different sets varied only in the type of fabric, type of foam, and whether or not there was a fiberglass interliner present. The size, frame and style remained constant. Some of the chairs were ignited with the standard TB133 newspaper ignition source. The others were ignited by a gas burner designed to simulate the newspaper ignition source. The rooms were instrumented to measure the total heat release rate of the chairs by oxygen consumption. It was found that (1) similar results were obtained in the TB133 and ASTM rooms, (2) a total heat release rate of 65 Kw in either of the rooms or in the furniture calorimeter was equivalent to the failure criterion of a 111°C (200°F) temperature rise 25 mm below the ceiling and directly above the burning chair in the TB133 test and (3) below 600 kW the heat release rates of the chairs measured in the rooms were the same as those in the furniture calorimeter. The combinations of fabric, fiberglass interliner and foam were also tested in the Cone calorimeter. Correlations are presented between the full scale and bench scale results. Calculations of the room temperatures, using Hazard I and the measured heat release rates, are also shown.

12. KEY WORDS (6 TO 12 ENTRIES; ALPHABETICAL ORDER; CAPITALIZE ONLY PROPER NAMES; AND SEPARATE KEY WORDS BY SEMICOLONS)
California Technical Bulletin 133; carbon monoxide; cone calorimeters; furniture calorimeters; heat release; large scale fire tests; room fire

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