Designation: E 1740 – 07

An American National Standard

Standard Test Method for Determining the Heat Release Rate and Other Fire-Test-Response Characteristics of Wallcovering Composites Using a Cone Calorimeter[1]

This standard is issued under the fixed designation E 1740; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

INTRODUCTION

This test method provides a means for measuring the fire-test-response characteristics of wallcoverings and wallcovering composites using a bench-scale oxygen consumption calorimeter.

1. Scope

1.1 This fire-test-response test method covers determination of the ignitability and heat release rate of composites consisting of a wallcovering, a substrate, and all laminating adhesives, coatings, and finishes. Heat release information cannot be used alone to evaluate the flammability of wallcoverings. The data are intended to be used for modeling or with other data to evaluate a material.

1.2 This test method provides for measurement of the time to sustained flaming, heat release rate, peak and total heat release, and effective heat of combustion at a constant radiant heat flux of 35 kW/m ^{2}. Heat release data at different heating fluxes are also obtained by this test method. The specimen is oriented horizontally, and a spark ignition source is used.

1.3 The fire-test-response characteristics are determined using the apparatus and procedures described in Test Method E 1354.

1.4 The tests are conducted on bench-scale specimens combining the components used in the actual installation.

1.5 The values stated in SI units are to be regarded as the standard. See IEEE/ASTM SI-10.

1.6 Fire testing of products and materials is inherently hazardous, and adequate safeguards for personnel and property shall be used in conducting these tests. This test method potentially involves hazardous materials, operations, and equipment.

1.7 *This standard is used to measure and describe the response of materials, products, or assemblies to heat and flame under controlled conditions, but does not by itself incorporate all factors required for fire hazard or fire risk assessment of the materials, products, or assemblies under actual fire conditions.*

1.8 *Fire testing of products and materials is inherently hazardous, and adequate safeguards for personnel and property shall be employed in conducting these tests. This test method may involve hazardous materials, operations, and equipment. Specific information about hazard is given in Section 6.*

1.9 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

2. Referenced Documents

2.1 *ASTM Standards:* [2]

C 1186 Specification for Flat Non-Asbestos Fiber-Cement Sheets

D 123 Terminology Relating to Textiles

E 84 Test Method for Surface Burning Characteristics of Building Materials

E 176 Terminology of Fire Standards

E 1354 Test Method for Heat and Visible Smoke Release Rates for Materials and Products Using an Oxygen Consumption Calorimeter

E 1474 Test Method for Determining the Heat Release Rate of Upholstered Furniture and Mattress Components or Composites Using a Bench Scale Oxygen Consumption Calorimeter

[1] This test method is under the jurisdiction of ASTM Committee E05 on Fire Standards and is the direct responsibility of Subcommittee E05.21 on Smoke and Combustion Products.

Current edition approved May 1, 2007. Published May 2007. Originally approved in 1995. Last previous edition approved in 2002 as E 1740 – 02.

[2] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

IEEE/ASTM SI-10 American National Standard for Use of the International System of Units (SI): The Modern Metric System

2.2 *NFPA Standard:*[3]

NFPA 265 Standard Methods of Fire Tests for Evaluating Room Fire Growth Contribution of Textile Wall Covering

2.3 *ISO Standards:*[4]

ISO 4880 Burning Behaviour of Textiles and Textile Products—Vocabulary

ISO 5660 Fire Tests—Reaction to Fire—Part 1: Rate of Heat Release from Building Products (Cone Calorimeter Method)

ISO 13943 Fire Safety—Vocabulary

3. Terminology

3.1 *Definitions*—For definitions of terms used in this test method and associated with fire issues, refer to Terminology E 176 and ISO 13943. The definitions given in Terminology E 176 shall prevail in case of conflict. For definitions of terms used in this test method and associated with textile issues, refer to Terminology D 123 and ISO 4880. The definitions given in Terminology D 123 shall prevail in case of conflict.

3.1.1 *effective heat of combustion*, *n*—the amount of heat generated per unit mass lost by a material, product, or assembly, when exposed to specific fire test conditions (see *gross heat of combustion*).

3.1.1.1 *Discussion*—The effective heat of combustion depends on the test method and is determined by dividing the measured heat release by the mass loss during a specified period of time under the specified test conditions. Typically, the specified fire test conditions are provided by the specifications of the fire test standard that cites effective heat of combustion as a quantity to be measured. For certain fire test conditions, involving very high heat and high oxygen concentrations under high pressure, the effective heat of combustion will approximate the gross heat of combustion. More often, the fire test conditions will represent or approximate certain real fire exposure conditions, and the effective heat of combustion is the appropriate measure. Typical units are kJ/g or MJ/kg.

3.1.2 *oxygen consumption principle*—the expression of the relationship between the mass of oxygen consumed during combustion and the heat released.

3.2 *Definitions of Terms Specific to This Standard:*

3.2.1 *heat release rate*—the heat evolved from the specimen, expressed per unit area of exposed specimen area per unit of time.

3.2.2 *heating flux*—the prescribed incident flux imposed externally from the heater onto the specimen at the initiation of the test.

3.2.2.1 *Discussion*—The specimen, once ignited, also is heated by its own flame. This differs from the generic definition of heat flux in Terminology E 176, because in this test method the heating flux of primary interest is the one imposed at the initiation of the test.

3.2.3 *ignitability*—the propensity for ignition, as measured by the time to sustained flaming at a specified heating flux.

3.2.4 *net heat of combustion*—the oxygen bomb calorimeter value for the heat of combustion, corrected for the gaseous state of product water.

3.2.5 *orientation*—the plane in which the exposed face of the specimen is located during testing, which is horizontal facing up for this test.

3.2.6 *sustained flaming*—the existence of flame on or over the surface of the specimen for periods of 4 s or more.

3.2.7 *wallcovering*—a fabric, vinyl, or paper-based product designed to be attached to a vertical wall surface for decorative or acoustical purposes.

3.2.8 *wallcovering composite*—an assembly of a wallcovering, adhesive (if used), and substrate used as a vertical wall treatment for decorative or acoustical purposes.

4. Summary of Test Method

4.1 This test method is based on the observation that, generally, the net heat of combustion is directly related to the amount of oxygen required for combustion. Approximately 13.1×10^3 kJ of heat are released per 1 kg of oxygen consumed. Specimens in the test are burned in ambient air conditions while subjected to a prescribed external heating flux of 35 kW/m^2.

4.2 The heat release is determined by measurement of the oxygen consumption, as determined by the oxygen concentration and flow rate in the combustion product stream, in accordance with Test Method E 1354.

4.3 The primary measurements are oxygen concentration and exhaust gas flow rate. Additional measurements include the mass loss rate of the specimen, time to sustained flaming (or time to ignition), and effective heat of combustion. Ignitability is determined by measuring the time period from initial exposure to attainment of sustained flaming of the specimen.

5. Significance and Use

5.1 This test method is used to determine the time to sustained flaming and heat release of materials and composites exposed to a prescribed heat flux in the cone calorimeter apparatus.

5.2 Quantitative heat release measurements provide information that can be used to compare wallcoverings and constructions and for input to fire models.

5.3 Heat release measurements provide useful information for product development by giving a quantitative measure of specific changes in fire performance caused by component and composite modifications.

5.4 Heat release data obtained by this test method will be inappropriate if the product will not spread flame over its surface under the fire exposure conditions of interest.

5.5 Variations in substrates, mounting methods, and adhesives used to laminate composite products will potentially affect the test responses. These variables must be controlled during any comparative experiments.

5.6 *Test Limitations*—The test data are invalid if any of the following occur:

5.6.1 Explosive spalling,

[3] Available from National Fire Protection Association, 1 Batterymarch Park, Quincy, MA 02269-9101.

[4] Available from International Standardization Organization, P.O. Box 56, CH-1211, Geneva 20, Switzerland.

5.6.2 The specimen swells sufficiently prior to ignition to touch the spark plug or swells up to the plane of the heater base during combustion, or

5.6.3 The surface laminate rolls or curls when placed under the radiant heater.

5.7 The specimens are subjected to one or more specific sets of laboratory conditions in this procedure. If different test conditions are substituted or the end-use conditions are changed, it is not always possible by or from this test to predict changes in the fire-test-response characteristics measured. The results are therefore valid only for the fire test exposure conditions described in this procedure.

6. Hazards

6.1 The test procedures involve high temperatures and heat fluxes. Hazards therefore exist for burns, ignition of extraneous objects or clothing, and inhalation of combustion products. The operator must use protective gloves for insertion and removal of the test specimens. Do not touch the cone heater or the associated fixtures while hot, except with the use of protective gloves.

7. Test Specimens

7.1 *Size and Preparation*:

7.1.1 All elements of the test specimen shall represent the actual materials used in the final installation. Include the wallcovering, adhesive used for the lamination, and actual substrate. Wallcoverings that are laminated in the field shall be bonded to the actual substrate or to fiber-reinforced cement board (Specification C 1186) if a non-combustible substrate is anticipated. Use the adhesive recommended by the manufacturer. Test wallcovering composites as manufactured for use.

7.1.2 The test specimens shall be cut to an overall size of 100 by 100 mm and tested in the actual thickness, if a composite. The maximum thickness to be tested is 50 mm. If substrates exceed this maximum, the back surface shall be made thinner to reduce the overall thickness of the specimen to 50 mm.

7.2 Specimens shall be cured according to the manufacturer's instructions and conditioned at an ambient temperature of 23 ± 3°C and relative humidity of 50 ± 5 % for a minimum of 48 h.

7.3 *Specimen Holder and Mounting*:

7.3.1 The specimen holder consists of the bottom, edge frame, retaining pins, and wire grid. The bottom is constructed from 2-mm nominal stainless steel and has outside dimensions of 106 by 106 ± 2 mm by 24 ± 2 mm height. The grid is constructed from 2-mm nominal stainless steel rod and has dimensions of 100 ± 2 by 100 ± 2 mm. The grid has 2-mm ribs, and the openings in the center are 18 ± 1 by 18 ± 1 mm. The edge frame is constructed from 1.9-mm nominal stainless steel with outside dimensions of 111 ± 2 by 111 ± 2 by 54 ± 2-mm height. The frame has an 8-mm lip on the top to provide an opening of 94 by 94 mm on the top. There are two 3 ± 0.5-mm diameter by 130 ± 3-mm long retaining pins to lock the test specimen in the edge frame.

7.3.2 The bottom is lined with a layer of a low-density (nominal density 65 kg/m^3) refractory fiber blanket with a thickness of at least 13 mm.[5] If necessary, fill the edge frame below the test specimens with a refractory blanket to the level of the retaining pins. Lock the assembly with retaining pins, and place it on the bottom specimen holder. The distance between the bottom of the radiant heater and the top of the edge frame is adjusted to 25 ± 1 mm by using a sliding height adjustment.

8. Procedure

8.1 *Preparation*:

8.1.1 Calibrate the test apparatus as directed in Test Method E 1354.

8.1.2 Position the cone heater for a horizontal specimen orientation, and set the radiant heating flux level to the required value of 35 ± 1 kW/m^2.

8.1.3 Verify that the distance between the bottom of the cone heater baseplate and the top of the specimen is 25 mm.

8.1.4 Some specimens swell up and contact the heater baseplate or sparker assembly during the test. Contact of the specimen with the sparker or heater baseplate will affect the mass loss readings temporarily. The mass loss readings will resume if the specimen does not remain in contact, and the total mass loss and average heat of combustion can be calculated. If sustained flaming has been achieved, retract the sparker to prevent contact with the swelling specimen. Alternatively, raise the sparker/heater assembly to prevent contact with the specimen.

8.2 *Procedure*:

8.2.1 Prepare the data collection system for testing in accordance with the operating procedures for the system. The heat release curve of some wallcoverings is a narrow peak. Increase the data collection rate to one reading/s for testing wallcoverings.

8.2.2 Assemble the specimen with the edge frame and grid in the appropriate holder. The assembly must initially be at room temperature. A surface area correction must be applied to compensate for the reduction in surface area caused by the edge frame and grid.

8.2.3 Energize the sparker, and move it into place rapidly after the specimen is inserted. The sparker is to remain in place until sustained flaming occurs. If flaming ceases less than 60 s after removal of the sparker, reinsert the sparker and maintain it in place until the end of the test.

8.2.4 Start the timer at the beginning of the test. After flaming is first observed, continue the observation for an additional 4 s. Record the time at that point, and move the spark igniter out of the flame. Determine the time to sustained flaming (or time to ignition). Note that the time to ignition is the time for sustained flaming to start; therefore, if the timer is stopped at the end of the 4 s observation period, the time to be reported is that value minus 4 s.

NOTE 1—If sustained flaming is not observed, report as "no ignition was observed" or "no sustained flaming was observed" and not as "time to ignition equals zero."

[5] A refractory blanket, RT8 ceramic fiber, Cer-Wool, manufactured by Premier Refractories and Chemicals Inc., King of Prussia, PA, is suitable for this application.

8.2.5 Collect data from the start of the test until either of the following occurs: (*1*) flaming or other signs of combustion cease or (*2*) 20 min have elapsed. The test need not be terminated at 20 min if the specimen continues to burn. Move the sparker out of the flame.

8.2.6 Record time-dependent measurements (mass loss, total heat release, and average heat of combustion) at 20 min or at the end of the test.

8.2.7 Observe and record physical changes to the specimen, such as melting, swelling, cracking, or shrinking. Record the final mass of the test specimen. Remove and discard the specimen if it does not ignite within 10 min.

8.2.8 Remove the specimen holder.

8.2.9 Replace with an empty specimen holder or insulated pad to prevent thermal damage to the load cell.

8.2.10 Test a minimum of three specimens of each material or product.

9. Report

9.1 Report the following, as a summary, for all specimens of a particular material or product:

9.1.1 Specimen identification or number;

9.1.2 Manufacturer or submitter;

9.1.3 Date of test;

9.1.4 Composition or generic identification;

9.1.5 Details of preparation; and

9.1.6 Number of replicate specimens tested, which shall be a minimum of three;

9.2 Include the following information for each specimen:

9.2.1 Specimen thickness (mm);

9.2.2 Initial specimen mass measured on the load cell (g);

9.2.3 Heating flux (kW/m^2) and initial exhaust system flow rate;

9.2.4 Time to sustained flaming (s);

9.2.5 Heat release rate curve versus time;

9.2.6 Average heat release rate for the first 60, 120, 180, and 300 s after ignition (kW/m^2);

9.2.7 Peak heat release rate (kW/m^2);

9.2.8 Total heat released by the specimen per unit area (MJ/m^2), including total test time(s);

9.2.9 Average effective heat of combustion for the entire test (MJ/kg), which is obtained by dividing the total heat released by the specimen mass loss;

9.2.10 Mass remaining at test termination (g);

9.2.11 Specimen mass loss (g) and (%);

9.2.12 Additional observations, if any; and

9.2.13 Difficulties encountered in testing, if any.

9.3 The following final values should be averaged for all specimens:

9.3.1 Time to sustained flaming (s);

9.3.2 Average heat release rate value (kW/m^2) over the first 60, 120, 180, and 300 s after ignition;

9.3.3 Average effective heat of combustion (MJ/kg) for the entire test;

9.3.4 Peak heat release rate (kW/m^2); and

9.3.5 Total heat released (MJ/m^2).

10. Precision and Bias

10.1 *Precision*—The precision of this test method has not been determined. The Appendix contains information on repeatability from one laboratory which indicates (see Tables X1.3 and X1.4) the relationship between the standard deviation and the average.

10.2 *Bias*—For solid specimens of unknown chemical composition, as used in building materials, furnishings, and common occupant fuel load, it has been documented that the use of the relationship that approximately 13.1×10^3 kJ of heat are released per 1 kg of oxygen consumed results in an expected error band of ± 5 % compared to true value. For homogeneous materials with only a single pyrolysis mechanism, this uncertainty is reduced by determining the heat evolution from oxygen bomb measurements and oxygen consumption from ultimate elemental analysis. This is not practical for most testing since test specimens are frequently composites and nonhomogeneous. Thus, they often exhibit several degradation reactions. For unknown specimens, a ±5 % accuracy limit is therefore seen. For reference materials, however, careful determination of the heat released per unit of oxygen consumed makes this source of uncertainty substantially less.

11. Keywords

11.1 calorimeter; fire; fire-test response; heat release; ignition; oxygen consumption; small scale; wallcovering

APPENDIX

(Nonmandatory Information)

X1. EFFECT OF SPECIMEN PREPARATION ON TEST RESULTS

X1.1 Introduction

X1.1.1 The cone calorimeter has been standardized in the United States (Test Method E 1354) and internationally (ISO 5660, Part 1). Although widely used as a research tool, applications for product evaluations are developing (such as Test Method E 1474, for upholstered furniture and mattress composites or components). Textile wallcoverings are now regulated in the United States by requirements based on the Test Method E 84 tunnel test and by full-scale room fire tests such as NFPA 265. Reliable bench-scale test methods for composite wall panels could serve as the basis for a predictive method for the full-scale room fire test protocols. The benefits of such predictive methods include reduced testing costs through screening and product classification. Experiments

were conducted to determine the effect of varying parameters on the composite wall panel cone calorimeter results. The following work is the effort of one laboratory.

X1.2 Experiment

X1.2.1 A preliminary study covered as many experimental conditions as possible, based on the time and materials available. The experiment was simplified to more practical conditions after the preliminary study. A limited group of wallcoverings was then evaluated in the cone calorimeter to observe the effects of fabric type (construction and form) and substrate. Additional effects investigated were exposure flux, influence of holders and grids, orientation, and supplemental fastening. The experiments compared the following eight fire-test-response characteristics from the cone calorimeter: peak heat release rate (abbreviated as peak heat), time to peak heat release rate (abbreviated as time peak), heat release rate at 60 s after ignition (abbreviated as heat rate or HRR 60 s), total heat released (abbreviated as total heat), time to sustained flaming (abbreviated as time sust), effective heat of combustion (abbreviated as heat comb or HC (eff)), average mass loss rate (abbreviated as mass loss), and average specific extinction area (abbreviated as avg smoke or smoke). Table X1.1 contains a matrix of the experimental conditions investigated in the first set of experiments.

X1.2.2 Qualitative and quantitative analyses were conducted of the effects of each experimental variable on the fire-test-response characteristics described.

X1.2.3 The qualitative analysis focused particularly on the reactions of the fabrics themselves. Observations are given in Table X1.2.

X1.2.4 The conditions selected for the experiment did not account for the fact that certain fabrics can pull loose, even with staples intended to prevent curling, as indicated in Table X1.1.

X1.2.5 The actual experimental data obtained are presented in Table X1.3 (peak heat release rate, time to peak heat release rate, heat release rate at 60 s after ignition, and total heat released) and Table X1.4 (time to sustained flaming, average effective heat of combustion, average mass loss rate, and average specific extinction area). The tables contain both the mean of the three values determined (avg) and the corresponding standard deviation (STD).

X1.2.6 Some experiments were conducted using a vertical orientation. Table X1.5 indicates that the standard deviation for vertical specimen orientation was higher than that for horizontal specimen orientation in most cases. Moreover, specimens

TABLE X1.1 Experimental Matrix for First Set of Tests

Test Code[A]	Flux	Holder	Preparation
V-MF/50-F-N	50	holder + frame and grid	none
W-FG/35-F-N	35	holder + frame and grid	none
W-FG/50-N-N	50	holder	none
V-MF/35-N-N	35	holder	none
W-FG/50-F-S	50	holder + frame and grid	stapled
V-MF/35-F-S	35	holder + frame and grid	stapled
V-MF/50-N-S	50	holder	stapled
W-FG/35-N-S	35	holder	stapled
W-FG/50-F-N	50	holder + frame and grid	none
V-MF/35-F-N	35	holder + frame and grid	none
V-MF/50-N-N	50	holder	none
W-FG/35-N-N	35	holder	none
V-MF/50-F-S	50	holder + frame and grid	stapled
W-FG/35-F-S	35	holder + frame and grid	stapled
W-FG/50-N-S	50	holder	stapled
V-MF/35-N-S	35	holder	stapled

[A] *Test Code*—Indicates fabric, substrate, flux (kW/m^2), type of holder, and preparation method: (*1*) Fabric: V, Vinyl; W, Woven. (*2*) Substrate: MF, mineral fiber; FG, fiberglass board. (*3*) Holder: F, edge frame; N, none. (*4*) Sample Preparation: N, none; S, fabric stapled to substrate.

TABLE X1.2 Qualitative Experimental Observations

Test Code[A]	Observations
V-MF/50-F-N	flashing before ignition, after glow
W-FG/35-F-N	fabric split and melted under the grid before ignition, after glow
W-FG/50-N-N	fabric shrank to a 50-mm^2 before ignition, after glow
V-MF/35-N-N	flash before ignition, after glow
W-FG/50-F-S	fabric split and melted under the grid before ignition, after glow
V-MF/35-F-S	flashing before ignition, after glow
V-MF/50-N-S	flash before ignition, fabric stayed flat, after glow
W-FG/35-N-S	fabric pulled up staples and shrank, after glow
W-FG/50-F-N	fabric split and melted under the grid, after glow
V-MF/35-F-N	flashing before ignition, after glow
V-MF/50-N-N	flash before ignition, after glow
W-FG/35-N-N	flash before ignition, fabric shrank to 50-mm^2, after glow
V-MF/50-F-S	flash before ignition, after glow
W-FG/35-F-S	fabric split and melted under the grid, flash before ignition, after glow
W-FG/50-N-S	fabric shrank and pulled staples loose, after glow
V-MF/35-N-S	flash before ignition, after glow

[A] *Test Code*—Indicates fabric, substrate, flux (kW/m^2), type of holder, and preparation method. (*1*) Fabric: V, Vinyl; W, Woven. (*2*) Substrate: MF, mineral fiber; FG, fiberglass board. (*3*) Holder: F, edge frame; N, none. (*4*) Sample Preparation: N, none; S, fabric stapled to substrate.

TABLE X1.3 First Set of Experimental Data

Test Code	Peak Heat Release Rate, kW/m^2, AVG—STD	Time to Peak Heat Release Rate, s, Avg—STD	Heat Release Rate at 60 s, kW/m^2, Avg—STD	Total Heat Released, MJ/m^2, Avg—STD
V-MF/50-F-N	104	30	47	3.6
	6	0	3	0.5
W-FG/35-F-N	113	48	47	3.1
	6	3	1	0.1
W-FG/50-N-N	157	27	66	4.4
	24	3	3	0.1
V-MF/35-N-N	109	35	41	3.1
	1	0	3	0.1
W-FG/50-F-S	131	32	53	3.5
	1	3	2	0.1
V-MF/35-F-S	70	52	30	2.2
	6	6	3	0.4
V-MF/50-N-S	142	17	59	5.5
	5	3	7	1.1
W-FG/35-N-S	155	30	58	4.1
	28	5	2	0.1
W-FG/50-F-N	134	32	55	3.7
	2	3	2	0.1
V-MF/35-F-N	79	42	33	2.8
	3	3	4	0.3
V-MF/50-N-N	132	22	54	5.4
	3	3	6	0.6
W-FG/35-N-N	143	33	56	4.5
	31	3	16	0.7
V-MF/50-F-S	107	30	55	4.5
	5	0	2	0.2
W-FG/35-F-S	110	52	45	3.0
	4	3	5	0.3
W-FG/50-N-S	177	22	68	5.0
	12	3	4	0.1
V-MF/35-N-S	103	30	37	3.1
	6	0	6	0.1

TABLE X1.4 Second Set of Experimental Data

Test Code	Time to Sustained Flaming, s, Avg—STD	Average Effective Heat of Combustion, MJ/kg, Avg—STD	Average Mass Loss Rate, kg/m^2-s, Avg—STD	Average Specific Extinction Area, m^2/kg, Avg—STD
V-MF/50-F-N	20.0	9.1	5.37	250
	2.2	0.7	0.19	44
W-FG/35-F-N	25.8	9.0	7.79	786
	1.8	0.4	1.76	21
W-FG/50-N-N	8.9	9.6	9.82	884
	1.3	0.5	0.97	90
V-MF/35-N-N	23.0	8.1	5.61	393
	2.3	0.5	0.16	32
W-FG/50-F-S	15.1	9.1	8.04	810
	1.3	0.4	1.13	13
V-MF/35-F-S	36.0	7.6	4.37	276
	3.3	1.3	0.10	9
V-MF/50-N-S	6.5	8.9	5.17	366
	0.4	0.9	0.30	75
W-FG/35-N-S	16.6	9.0	9.21	924
	1.5	0.2	0.95	18
W-FG/50-F-N	16.0	9.6	8.00	778
	1.4	0.1	0.78	26
V-MF/35-F-N	33.8	9.4	4.23	315
	1.9	0.8	0.08	38
V-MF/50-N-N	13.8	8.6	4.54	236
	0.7	1.1	0.43	97
W-FG/35-N-N	19.6	9.5	8.39	835
	5.6	0.7	2.43	148
V-MF/50-F-S	9.2	10.2	4.42	284
	0.4	0.2	0.18	23
W-FG/35-F-S	31.4	9.2	7.80	787
	4.0	0.9	0.98	47
W-FG/50-N-S	10.7	9.9	10.74	965
	0.2	0.6	1.88	83
V-MF/35-N-S	21.2	8.4	5.30	418
	5.1	0.2	0.35	58

TABLE X1.5 Comparison of Standard Deviations in Horizontal and Vertical Orientations[A]

Test ID	V-MF/35-N-S Horizontal	V-MF/35-FG-N Vertical	NW-FG-35-N-S Horizontal	NW-FG/35-FG-N Vertical	W2-MF-35-N-S Horizontal	W2-MF/35-FG-N Vertical
Peak rate of heat release	6	5	1	8	19	19
Time to peak	0	5	3	3	0	6
Avg HRR 60 s	5	1	3	3	2	18
Total HR	0.1	0.0	0.2	0.2	0.2	1.7
Time sustained flaming	5.1	5.9	0.0	1.6	0.5	2.7
Effective heat of combustion	0.2	0.3	0.2	0.3	0.8	1.6
Mass loss rate	0.35	0.59	2.32	0.46	0.37	0.55
Specific extinction area	58	52	14	35	14	30

[A] The same specimens were used for horizontal and vertical tests. However, a frame and grid were needed for the vertical orientation, while staples were used for the horizontal orientation.

tested in the vertical position tended to have longer periods of intermittent flashing than was ever found in the horizontal orientation. The flame of the specimen burned above the vertical holder in one case. Vertical orientation was therefore not considered to be a satisfactory means of testing.

X1.2.7 The remainder of the factors were reduced to two levels. The levels selected were either the extreme levels or the most practical levels. For example, cutting the fabric to produce an even distribution of melted textile was dropped because of the time required for sample preparation.

X1.2.8 The conditions of holder-with-grid and no-holder-or-grid were chosen as the most useful ones. The grid-only condition did not hold the fabric down in all cases. One fabric could curl up and lift the grid as it formed a ball under the grid.

X1.2.9 Two fabric-substrate combinations were selected to represent the two general specimen reactions to the cone heater: a vinyl fabric and a woven fabric. Charring or melting in place characterizes the reaction of one of the fabrics (the vinyl), and shrinking and curling characterizes that of the other (the woven).

X1.2.10 Two heater flux levels were chosen to demonstrate the effect of heat flux level: 35 and 50 kW/m^2.

X1.3 Test Data

X1.3.1 Cone calorimeter results from the experiment were analyzed using regression analysis. The total of the deviations for each factor are plotted in Fig. X1.1. Each of the significant coefficients of eight responses were converted to a percentage deviation from the mean. This plot shows the possible percentage change in the responses as affected by each factor. In other words, the effects of the four factors on each different response were converted to the same scale by normalization, by changing the effects to fractions of the mean of each response. For example, the effect of the change in holder on the mass loss rate was 0.5475 and the effect of different specimen preparations on the specific extinction area was 22.1. Since the mean mass loss rate was 6.8 and the mean specific extinction area was 581, it is more useful to compare the effect of the holder on mass loss, which is 8.1 %, to the effect of sample preparation on specific extinction area, which is 3.8 %. This analysis demonstrates that, for the products tested in this part of the experiment, specimen preparation (in other words, whether the fabric is stapled or not stapled to the substrate) had no effect on the cone results. Data from tests on other products indicated that specimen preparation can have a significant effect. The corresponding test data are examined below.

X1.3.2 Table X1.6 is an example of the analysis for peak heat release rate. The data reveal the ability of the tests to differentiate between fabrics and the effects of the flux level and of the use (or not) of the frame and grid.

TABLE X1.6 Least Squares Coefficients for Peak Heat Release Rate[A]

Term	Coefficient	Standard Error	T-Value	Significance
Average	123.0	1.81		
Flux, kW/m^2				0.0000
35	−12.5	1.81	−6.91	0.0001
50	12.5	1.81	6.91	0.0001
Holder				0.0000
None	16.8	1.81	9.28	0.0001
Frame and grid	−16.8	1.81	−9.28	0.0001
Fabric				0.0000
Vinyl	−17.1	1.81	−9.47	0.0001
Woven	17.1	1.81	9.47	0.0001

[A] Number of cases, 48; residual degrees of freedom, 44; correlation coefficient, 0.836; adjusted correlation coefficient, 0.824; and root mean square error, 12.55.