NFPA 272

Standard Method of Test for Heat and Visible Smoke Release Rates for Upholstered Furniture Components or Composites and Mattresses Using an Oxygen Consumption Calorimeter

2003 Edition

This edition of NFPA 272, *Standard Method of Test for Heat and Visible Smoke Release Rates for Upholstered Furniture Components or Composites and Mattresses Using an Oxygen Consumption Calorimeter*, was prepared by the Technical Committee on Fire Tests and acted on by NFPA at its November Association Technical Meeting held November 16–20, 2002, in Atlanta, GA. It was issued by the Standards Council on January 17, 2003, with an effective date of February 6, 2003, and supersedes all previous editions.

This edition of NFPA 272 was approved as an American National Standard on January 17, 2003.

Origin and Development of NFPA 272

In 1998 (F98) NFPA 264A was renumbered as NFPA 272 to coordinate a family of documents that will be relying on NFPA 271 as the base document for specifics on the test apparatus, calibration, and test procedure. The concept is to develop specific documents such as NFPA 272, which provides criteria for the specimen preparation for upholstered furniture components and mattresses.

The original 1990 edition of NFPA 264A was based on the methods of measuring rates of heat release using an oxygen consumption calorimeter developed at the National Bureau of Standards (now the National Institute of Standards and Technology) by V. Babrauskas et al. It addressed only upholstered furniture and mattresses. The 1994 edition of NFPA 264A was a reconfirmation of the original document, with minor editorial changes, because the methods of measuring rates of heat release were still being used within the industry in areas such as product development. In testing of other various materials, a new document, NFPA 264, *Standard Method of Test for Heat and Visible Smoke Release Rates for Materials and Products Using an Oxygen Consumption Calorimeter*, was developed. The NFPA 264

document was closely related to and derived from NFPA 264A.

The 1999 edition of NFPA 272 incorporated updated provisions for specimen preparation as used in current testing practices. Chapter 6 on calculations was updated and revised to include the measurement of smoke obscuration.

The 2003 edition of NFPA 272 incorporates all formatting changes required under the provisions of NFPA's *Manual of Style* and revised requirements for developing the report of results, as described in Chapter 8.

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This list represents the membership at the time the Committee was balloted on the final text of this edition. Since that time, changes in the membership may have occurred. A key to classifications is found at the back of the document.

NOTE: Membership on a committee shall not in and of itself constitute an endorsement of the Association or any document developed by the committee on which the member serves.

NFPA 272
Standard Method of Test for Heat and Visible Smoke Release Rates for Upholstered Furniture Components or Composites and Mattresses Using an Oxygen Consumption Calorimeter
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NOTICE: An asterisk (*) following the number or letter designating a paragraph indicates that explanatory material on the paragraph can be found in Annex A.

A reference in brackets [ ] following a section or paragraph indicates material that has been extracted from another NFPA document. As an aid to the user, Annex C lists the complete title and edition of the source documents for both mandatory and nonmandatory extracts. Editorial changes to extracted material consist of revising references to an appropriate division in this document or the inclusion of the document number with the division number when the reference is to the original document. Requests for interpretations or revisions of extracted text shall be sent to the technical committee responsible for the source document.

Information on referenced publications can be found in Chapter 2 and Annex C.

Chapter 1 Administration

1.1 Scope.

1.1.1 This test method shall be used to determine the ignitability and release rates of heat and visible smoke from components or composite structures of upholstered furniture and mattresses using an oxygen consumption calorimeter.

1.1.2 In this test method, a horizontally oriented specimen shall undergo radiant thermal exposure using an external igniter.

1.1.3 Radiant exposure shall be maintained at a constant rate of 35 kW/m^2 to determine time to sustained flaming, rate of heat release per unit area (kW/m^2), specific extinction area, and effective heat of combustion (MJ/kg).

1.1.4 The rate of heat release shall be determined by measurement of oxygen consumption as determined by the level of oxygen concentration and the flow rate in the combustion product stream.

1.1.5 The effective heat of combustion shall be determined from a concomitant measurement of specimen mass loss rate, in combination with the heat release rate.

1.1.6 The testing shall be done on bench-scale specimens combining the furniture or mattress cover fabrics and padding, but not including frame elements.

1.1.7 Safety.

1.1.7.1 This standard shall not purport to address all safety problems associated with use of the equipment.

1.1.7.2 It shall be the responsibility of the user of this standard to establish appropriate safety and health practices and to determine the applicability of regulatory limitations prior to use.

1.2 Purpose.

1.2.1 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.

1.2.2 Specimens in the test are burned in ambient air conditions while being subjected to a prescribed external heat flux of 35 kW/m^2.

1.2.3 The rate of heat release shall be determined by measurement of the oxygen consumption, as determined by the oxygen concentration and the flow rate in the combustion product stream.

1.2.4 The primary measurements are of oxygen concentration and exhaust gas flow rate, used (together with temperature and pressure measurements) to assess heat release rate.

1.2.4.1 Additional measurements include the mass loss rate of the specimen, the time to sustained flaming, the effective heat of combustion, the specific extinction area, and other measurements as required in the relevant material or performance standard.

1.2.4.2 Ignitability shall be determined as the measure of the time from initial exposure to time of sustained flaming.

1.3 Application.

1.3.1* This test method shall be used to determine fire properties, including the time to ignition and heat release rate (as indicated in 1.2.4.1) of materials and composites exposed to a prescribed heat flux.

1.3.2* Quantitative heat release measurements provide information that is potentially useful in the design of upholstery and mattress products and in product development.

1.4 Test Limitations.

The test data has limited validity in the following situations:

(1) When explosive spalling occurs

(2) When the specimen swells sufficiently, prior to ignition, to cause it to touch the spark plug, or if it swells up to the plane of the heater base during combustion

1.5 Units and Formulas.

1.5.1 SI Units. Metric units of measurement in this standard are in accordance with the modernized metric system known as the International System of Units (SI).

1.5.2 Unless otherwise stated, all dimensions included in the test and figures shall be mandatory and shall be followed within nominal tolerances of 1 mm.

1.5.3 Symbols. The following symbols shall be used in this standard:

A_S = nominal specimen exposed surface area (0.01 m^2)

C = calibration constant for oxygen consumption analysis ($m^{1/2}$ $kg^{1/2}$ $K^{1/2}$)

$\Delta H_c/r_0$ = net heat of combustion (kJ/kg)

$\Delta H_{c,eff}$ = effective heat of combustion (kJ/kg)

I = actual beam intensity

I_0 = beam intensity with no smoke

k = smoke extinction coefficient (m^{-1})

L = extinction beam path length (m)

m = specimen mass (kg)

m_f = final specimen mass (kg)

m_i = initial specimen mass (kg)

$\dot{m}$ = specimen mass loss rate (kg/sec)

ΔP = orifice meter pressure differential (Pa)

q'' = total heat release (kJ/m^2)

$\dot{q}$ = heat release rate (kW)

$\dot{q}''$ = heat release rate per unit area (kW/m^2)

t_0 = stoichiometric oxygen/fuel mass ratio

t = time (sec)

t_d = oxygen analyzer delay time (sec)

Δt = sampling time interval (sec)

T_e = absolute temperature of gas at the orifice meter (K)

v = volume exhaust flow rate measured at the location of the laser photometer (m^3/sec)

X_{O_2}

$X_{O_2}^0$ = initial value of oxygen analyzer reading

$X_{O_2}^1$ = oxygen analyzer reading, before delay time correction

σ_f = average specific extinction area, for smoke (m^2/kg)

Chapter 2 Referenced Publications

2.1 General.

The documents or portions thereof listed in this chapter are referenced within this standard and shall be considered part of the requirements of this document.

2.2 NFPA Publication.

National Fire Protection Association, 1 Batterymarch Park, P.O. Box 9101, Quincy, MA 02269-9101.

NFPA 271, *Standard Method of Test for Heat and Visible Smoke Release Rates for Materials and Products Using an Oxygen Consumption Calorimeter,* 2001 edition.

2.3 Other Publications. (Reserved)

Chapter 3 Definitions

3.1 General.

The definitions contained in this chapter shall apply to the terms used in this standard. Where terms are not included, common usage of the terms shall apply.

3.2 NFPA Official Definitions.

3.2.1 Shall. Indicates a mandatory requirement.

3.2.2 Should. Indicates a recommendation or that which is advised but not required.

3.2.3 Standard. A document, the main text of which contains only mandatory provisions using the word "shall" to indicate requirements and which is in a form generally suitable for mandatory reference by another standard or code or for adoption into law. Nonmandatory provisions shall be located in an annex, footnote, or fine-print note and are not to be considered a part of the requirements of a standard.

3.3 General Definitions.

3.3.1 Heat of Combustion.

3.3.1.1 ***Effective Heat of Combustion.*** The measured heat release divided by the mass loss for a specified time period. [**271:** 3.3.1.1]

3.3.1.2 ***Net Heat of Combustion.*** The oxygen bomb calorimeter value for the heat of combustion, corrected for the gaseous state of water produced. [**271:** 3.3.1.2]

3.3.2 Heat Release Rate. The heat evolved from the specimen, per unit of time. [**271:** 3.3.2]

3.3.3 Heating Flux. The incident radiant heat flux imposed externally from the heater on the specimen at the initiation of the test. [**271:** 3.3.3]

3.3.4 Ignitability. The propensity for ignition, as measured by the time to sustained flaming, in seconds, at a specified heating flux. [**271:** 3.3.4]

3.3.5 Orientation. The plane in which the exposed face of the specimen is located during testing (e.g., horizontally facing the heater). [**271:** 3.3.5]

3.3.6 Oxygen Consumption Principle. The expression of the relationship between the mass of oxygen consumed during combustion and the heat released. [**271:** 3.3.6]

3.3.7 Smoke Obscuration. The reduction of light transmission by smoke, as measured by light attenuation. [**271:** 3.3.7]

3.3.8 Sustained Flaming. The existence of flame on or over the surface of the specimen for periods of at least 4 seconds. [**271:** 3.3.8]

3.3.9 Visible Smoke. The obscuration of transmitted light caused by combustion products released during the test. [**271:** 3.3.9]

Chapter 4 Test Apparatus

4.1 General.

4.1.1 The test apparatus shall consist of the following components:

(1) A conical-shaped radiant electric heater

(2) Specimen holders

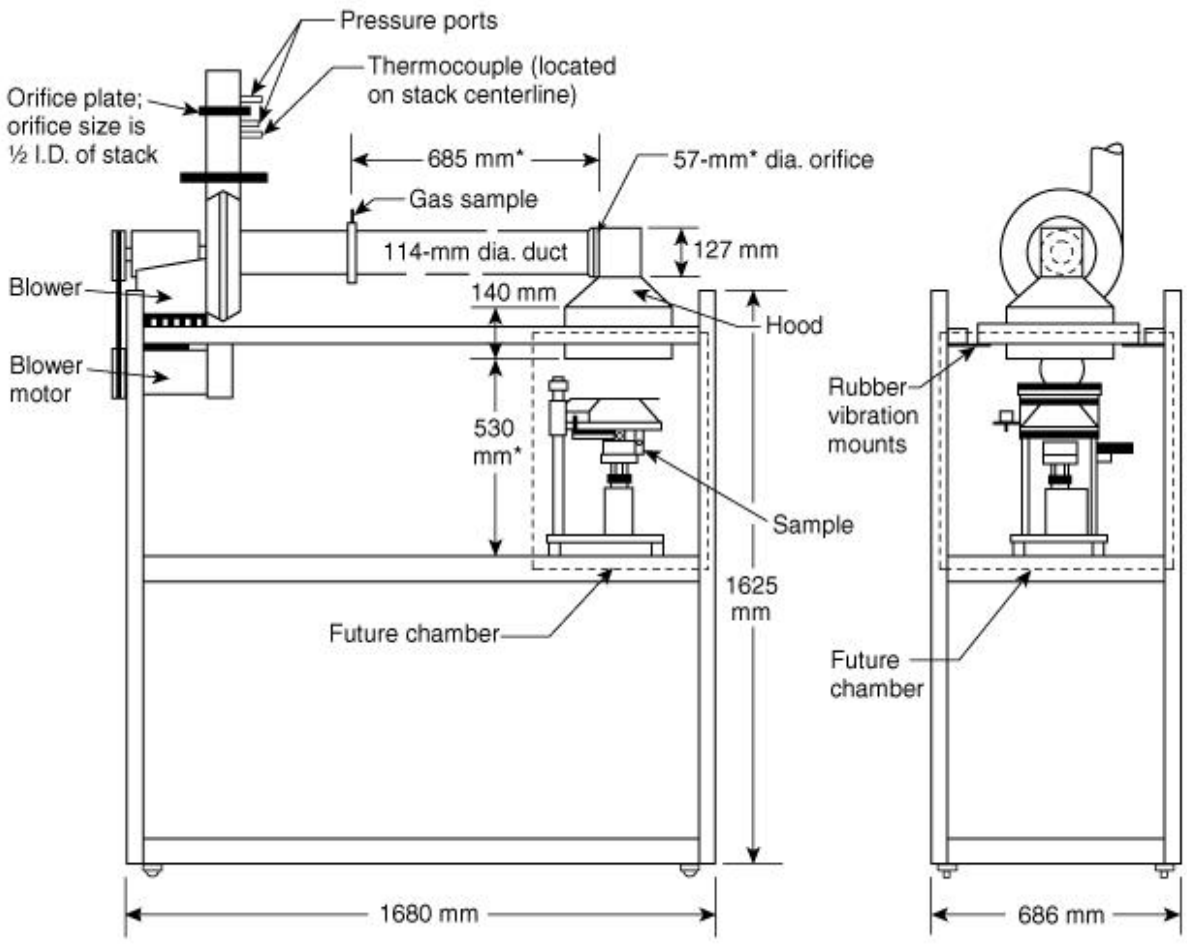
(3) An exhaust-gas system with oxygen-monitoring and flow-measuring instrumentation

(4) An electric ignition spark plug

(5) A data collection and analysis system

(6) A load cell for measuring specimen mass loss

4.1.2 The apparatus shall be configured as shown in Figure 4.1.2.



* Indicates a critical dimension.

FIGURE 4.1.2 Overall View of Test Apparatus.

4.2 Specific.

Test apparatus shall be constructed in accordance with Chapter 4, Test Apparatus, of NFPA 271, *Standard Method of Test for Heat and Visible Smoke Release Rates for Materials and Products Using an Oxygen Consumption Calorimeter*.

4.3 Calibration.

The equipment shall be calibrated in accordance with Chapter 5, Calibration of Equipment, of NFPA 271, *Standard Method of Test for Heat and Visible Smoke Release Rates for Materials and Products Using an Oxygen Consumption Calorimeter*.

Chapter 5 Test Specimens

5.1 Test Specimens.

Test specimens shall be prepared in accordance with Section 5.2, Method A, or Section 5.3, Method B.

5.2* Method A.

Equipment and supplies for test specimen preparation for Method A shall be as specified in 5.2.1 through 5.2.11.

5.2.1 Cutting Equipment. Foams shall be cut with a band saw.

(A) A foam-cutting blade shall be used.

(B) This blade shall have no teeth and shall have a wavy scallop to the edge.

(C) The blade shall be well sharpened.

(D) No silicones or other oils shall be applied to lubricate the blade.

(E) Lubrication shall be solely with graphite or molybdenum compounds.

(F) The band saw blade shall make a straight and true cut of the foam.

(G) The blade guide shall be set no higher than 12 mm above the stock to be cut.

5.2.2* Forming Blocks. Forming blocks shall be made in dimensions of 98 mm × 98 mm × 50 mm.

(A) Each of these dimensions shall be controlled to within 0.5 mm.

(B) A dense wood shall be used as the material for the forming blocks.

(C) Only fully kiln-dried timber shall be used for making the forming blocks.

(D) All surfaces shall be cut straight and true and shall be smooth.

(E) The edges shall not be rounded, but the corners shall be slightly rounded.

(F) Blocks shall be permitted to be lacquered with an acrylic lacquer to ensure a hard,

smooth, stable surface.

(G) A minimum of 12 blocks shall be made to permit a number of specimens to be prepared at the same time.

5.2.3* **Adhesive.** The adhesive shall be low in flammability.

5.2.3.1 The adhesive shall have holding power to permit the insertion of the resilient padding and to stay in place until the testing is performed (i.e., through the required conditioning) and during the flammability test procedure.

5.2.3.2 For the flammability test procedure, the glued portions of the fabric shall neither flame excessively nor retard burning.

5.2.4* **Adhesive Application.** The method of adhesive application shall be in accordance with the particular adhesive selected.

5.2.5 Adhesive Checking.

5.2.5.1 To test the efficiency of an adhesive, a small amount of it shall be applied on two small pieces of the fabric or interliner to be used.

5.2.5.2 The adhesive shall be allowed to dry a minimum of 12 hours, and then an attempt shall be made to tear the fabric pieces from one another.

5.2.5.3 To be acceptable, the glued pieces shall not be able to be separated without tearing the fabric.

5.2.6* **Tape.** Masking tape or other tape with adhesive shall be permitted to be used to assist in assembling the test composites.

5.2.7* **Aluminum Foil.** Aluminum foil that is 0.03 mm to 0.04 mm thick shall be used.

5.2.8 Basic Preparation of Specimens. Basic preparation of specimens shall be as detailed in 5.2.8.1 and 5.2.8.2.

5.2.8.1 These basic instructions shall pertain to specimens that comprise only a single layer of fabric over a single layer of resilient padding.

(A) The same instructions shall apply to specimens where an interliner is laminated onto the back of the fabric.

(B) For specimens referred to in 5.2.8.1(A), the fabric/interliner combination shall simply be treated as a fabric alone.

(C) For specimens that use multiple padding layers, separate interliner layers, and other more specialized constructions, supplemental instructions shall be given in 5.2.11.

5.2.8.2* **Cutting of Resilient Padding Blocks.**

(A) Each resilient padding block shall be cut square, with 90-degree corners and face dimensions of 102.5 mm ± 0.5 mm × 102.5 mm ± 0.5 mm.

(B) The thickness of the resilient padding block shall be 50 mm when a single layer of resilient padding is the only padding material used in the composite.

5.2.8.3* **Forming of Resilient Padding Blocks.** Each batch of resilient padding specimens prepared shall be checked for mass.

(A) A minimum of three replicate tests shall be performed for each specimen type.

(B) Once three blocks of resilient padding have been cut, the mass shall be determined.

(C) No block shall have a mass of more than 105 percent of the mean of the three masses nor a mass of less than 95 percent.

(D) If such a difference occurs, additional blocks shall be cut and the mass determined.

(E) The preparation of composites shall not start until three blocks of resilient padding that conform to the 5 percent deviation limit described in 5.2.8.3(C) have been obtained.

(F) The blocks accepted shall be marked, so as to be traceable.

(G) The mass of each block of resilient padding shall be recorded along with the identification marks of the blocks.

(H) The mass of resilient padding shall be reported in the test report along with other information about this test run.

5.2.8.4* **Fabric Cutting.**

(A) First, a square of 200 mm × 200 mm shall be cut.

(B) Fabrics shall not be cut on the bias.

(C) For cone calorimeter results to be repeatable, fabric for the different replicates shall show uniformity.

(D)* When fabric material is obtained directly from a bolt of cloth, specimens shall not be cut any closer than 10 cm to 12 cm to the selvedge.

5.2.8.5 Checking Mass of Specimens. To assist in verifying that uniform specimens have been cut, each set of fabric specimens that have been cut to the 200 mm × 200 mm size shall be checked for mass.

(A) Once three replicate pieces have been cut, the mass shall be determined.

(B) None of the pieces shall have a mass of more than 105 percent of the mean of the three nor a mass of less than 95 percent.

(C) If such a difference occurs, the pieces shall be checked to see whether any of them has been cut oversized.

(D) The pieces shall be trimmed if oversize is found.

(E) If the cause of variation is not due to oversized pieces, then additional fabric pieces shall be cut and the mass determined.

5.2.8.6 Alternative Procedures. If fabrics cannot be prepared to within the 5 percent deviation limit, then the fabric masses and mass range of the specimen shall be noted.

(A) The fabric for each specimen shall continue to be cut to the shape indicated in Figure

5.2.8.6(A).

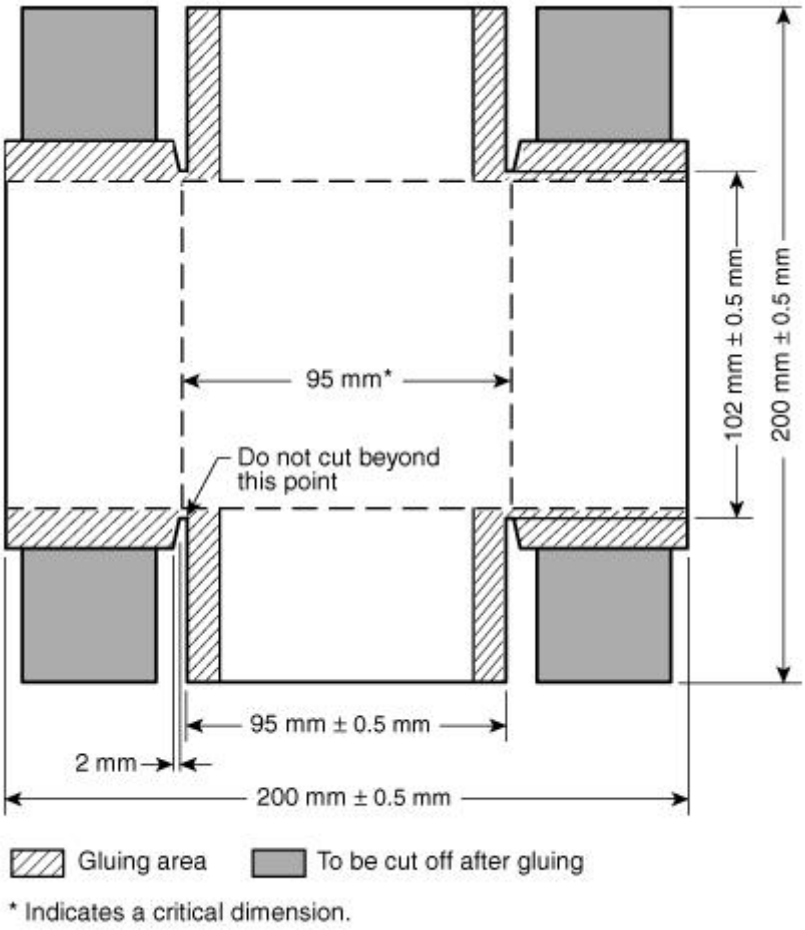


FIGURE 5.2.8.6(A) Fabric Cutting Shape.

(B) All given dimensions shall be controlled according to the tolerances given in Figure 5.2.8.6(A) (±0.5 mm).

(C) The one essential dimension given in Figure 5.2.8.6(A) shall be maintained.

(D) The 95 mm and 102 mm dimensions shall be checked both before and after cutting.

(E) When a fabric having thick yarns is cut, cutting shall stop outside the "102 mm dimension" when a yarn is reached.

(F) The yarn shall not be cut through if the resulting dimension will be smaller than 102 mm.

5.2.9 Preparing the Fabric Shell.

5.2.9.1 The finished shell shall be assembled upside down on a forming block.

(A) The fabric shall be placed topside down on the table.

(B) The block shall be placed on top so that it is well centered.

(C) The two short sides shall be bent up.

(D) Each of the two short sides shall be taped onto the top of the forming block in the center of the top edge.

(E) The long sides shall be bent up and taped to the top of the block.

(F) All four corners of the top face shall be checked to make sure that the fabric does not slip sideways on the block.

(G) The fabric shall be snug but not stretched.

5.2.9.2* For sensitive interliners, when paper strips are used, two strips shall be placed to form a cross under the fabric before the forming block is placed on top of it.

5.2.9.3 The gray area shown in Figure 5.2.8.6(A) shall be used for gripping and stretching the fabric around the corners of the forming block.

(A) After adhesive is applied to the first two corners, the block shall be turned to rest on the side just glued, and the adhesive shall be applied to the other two corners.

(B) If necessary, the fabric shall be taped over the gripping handles and around the corners in order to secure it in the shape of the forming block, or the block shall be wrapped with paper strips prior to sealing with masking tape.

5.2.9.4 The specimen shall be allowed to dry face down for 24 hours.

(A) The specimens shall not be stacked during drying.

(B) The brush or other utensils used to apply the adhesive shall be cleaned.

(C) The solvent and any excess adhesive shall be wiped off the brush with a piece of cloth before the next specimen is glued.

(D) After 24 hours have elapsed, all the pieces of masking tape shall be removed, and the four flaps shall be trimmed down to the indicated offset mark so that only the 10-mm glued-down portion is left.

(E) Any fabric protruding below the bottom edge of the forming block shall be trimmed.

5.2.9.5 Preparing the Aluminum Foil. An oversized piece of aluminum foil shall be cut.

(A) If the foil has a shiny side and a dull side, the shiny side shall be placed facing up.

(B) The actual specimen shall be slightly larger than the forming block, depending on the thicknesses of the fabric and interliner (if present).

(C) The aluminum foil shall be shaped for the final specimen according to either 5.2.9.6 or 5.2.9.7.

5.2.9.6 A fabric-covered forming block shall be used, encased with the fabric shell topside up.

(A) The block shall be placed on the aluminum foil.

(B) The block shall be held firmly in place and each side of the foil shall be pulled up to

create the bottom folds.

(C) The corners shall be formed by holding the foil firmly in contact with the corner of the specimen.

(D) The corner of the foil shall be stretched and a 45-degree fold shall be made at each corner.

(E) Finally, the corners shall be pulled flat against the two sides of the specimen and all sides shall be patted down flat against the specimen.

(F) Folds shall be made as illustrated in Figure 5.2.9.6(F).

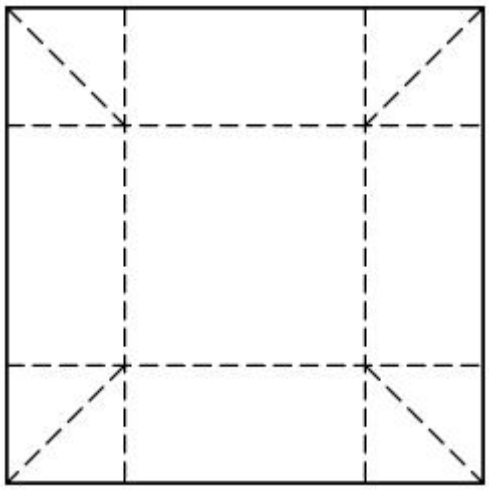


FIGURE 5.2.9.6(F) Folding of Foil.

(G) The bottom edges and the corners shall be crisp, straight, and smooth.

(H) The forming block and its encasing fabric shell shall be removed from the foil cup.

5.2.9.7 One forming block shall be set aside specifically for shaping the aluminum foil containers.

(A) Either another block shall be prepared with dimensions 102 mm × 102 mm (rather than 98 mm × 98 mm), or cardboard shall be glued or taped to the sides of a block to create one that is 102 mm × 102 mm.

(B) This new block shall be used for shaping the aluminum foil as described in 5.2.9.6.

5.2.10 Assembling the Shell of Resilient Padding and Fabric.

5.2.10.1* The forming block shall be removed from the fabric shell.

5.2.10.2 The blocks of resilient padding shall be identified and tracked according to their masses, which have already been recorded. *(See 5.2.8.3.)*

5.2.10.3 The four corners of the selected resilient padding block shall be compressed slightly with the fingers, and the block shall be inserted into the fabric shell.

(A) The resilient padding shall be inserted straight and verified.

(B) Each of the resilient padding block corners shall be checked to see that they line up exactly at the corners of the fabric shell.

(C) The top face shall be checked to ensure that the block of resilient padding is inserted fully into the shell and that there are no gaps.

(D) The bottom of the resilient padding shall be checked to ensure that it is neatly lined up with the bottom edge of the fabric.

(E) If the specimen construction involves additional padding layers or different padding layers, similar steps shall be followed to ensure that a straight, taut assembly is made.

5.2.10.4 The specimen shall be carefully inspected.

(A) There shall be no buckles, warping, twisting, pulling, or similar conditions.

(B) The fabric shall be taut, and there shall not be any air spaces between the fabric and the padding.

(C) If any such problems are discovered and cannot be corrected, the specimen shall be discarded.

(D) Each of the four sides shall be stapled as shown in Figure 5.2.10.4(D).

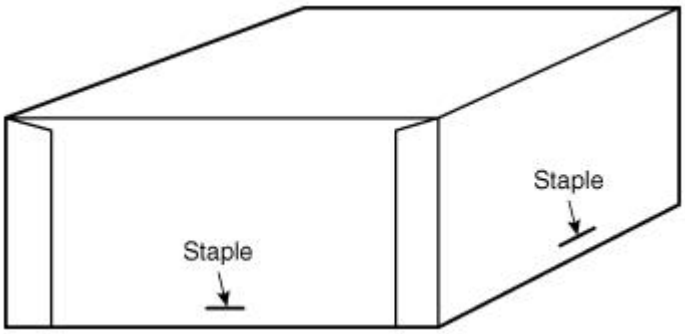


FIGURE 5.2.10.4(D) Assembled Specimen.

(E) The top face of the specimen shall be inspected.

(F) None of the four tabs shall overhang at the top of the specimen.

(G) If there is excess material, it shall be trimmed with scissors.

(H) No holes shall be made in the specimen while doing the trimming.

5.2.10.5* **Assembling the Specimen and the Foil.** The assembled specimen shall be placed in the foil cup.

(A) The aluminum foil sides shall be patted down flush against the specimen.

(B) The top of the foil shall be cut to be flush with the top of the specimen.

(C) The corners of the aluminum foil shall be opened up slightly and the foil top shall be pulled about 20 mm away from the specimen.

5.2.10.6 Conditioning.

(A) The specimen shall be placed in a conditioning chamber for 24 hours.

(B) The specimen shall be conditioned to moisture equilibrium (constant mass) at an ambient temperature of 23°C ± 3°C and a relative humidity of 50 percent ± 5 percent.

5.2.10.7* Final Preparation. The specimen shall be removed from the conditioning chamber.

(A) The specimen shall be checked to ensure that it is wrinkle-free, smooth, and visually completely uniform and symmetrical.

(B) If defects are found, the specimen shall be fixed or rejected.

(C) The specimen mass shall be determined with and without the aluminum foil.

(D) The aluminum foil sides shall be patted down flush against the specimen.

(E) The specimen shall be placed on the sample holder.

(F) The top of the specimen shall be gently pushed down against the ceramic fiber blanket.

5.2.11* Preparation of Specimens with Multiple Layers and Specialized Constructions.

5.2.11.1 Specimens That Use a Separate Interliner Layer. For these composites, the forming block shall be covered twice, first with the interliner, then with the fabric, as detailed in 5.2.11.1.1 and 5.2.11.1.2.

5.2.11.1.1* An alternate tape shall be selected or paper strips shall be used if needed.

(A) The interliner shall be cut using the same method as described for cutting fabrics. *(See 5.2.8.4 to 5.2.8.6.)*

(B) The interliner shall be glued up around the forming block using the same instructions as for fabrics. *(See 5.2.9.1 to 5.2.9.4.)*

(C) The specimen shall be left to dry for 24 hours.

(D) After 24 hours have elapsed, all pieces of masking tape shall be removed.

(E) If there is any interliner protruding below the bottom edge of the forming block, such excess shall be trimmed off with scissors.

5.2.11.1.2 Once the forming block has been covered with interliner, the instructions in 5.2.8.4 and 5.2.9 for cutting and preparing the fabric shall be followed.

(A) To minimize thickness variations along the completed assembly, when the fabric is placed on top of the interliner, its orientation shall be turned by 90 degrees, so that the two sides where the fabric flaps are glued are not lined up with the similar flaps on the interliner.

(B) Two of the sides of the finished specimen shall contain doubled-up areas of fabric flaps, and the two other sides shall contain doubled-up areas of interliner flaps.

5.2.11.2 Specimens That Use a Polyester Fiber Topper Layer on Top of the Foam.

The padding assembly shall be prepared according to 5.2.11.2.1 or 5.2.11.2.2, then 5.2.11.2.3.

5.2.11.2.1 Thickness.

(A) If the uncompressed polyester fiber layer is 20 mm thick or less, it shall be compressed to one-half of that thickness in the final assembly.

(B) The foam block thickness shall then be the difference between 50 mm and one-half of the uncompressed thickness of the polyester fiber layer.

5.2.11.2.2 If the uncompressed polyester fiber layer is greater than 20 mm, the polyester fiber layer shall be cut back to give a 20 mm depth, and the preparation shall be continued as above.

(A) The polyester topper layer shall be placed on top of the foam block.

(B) This composite block shall be used wherever the general instructions refer to actions to be taken on the block of resilient padding.

5.2.11.2.3 During final assembly of the padding inside the fabric, the polyester-plus-foam composite block shall be compressed so as to have a total depth of 50 mm when the assembly is finished.

5.2.11.3 Specimens That Use More Than One Padding Layer (Except Polyester Fiber).

(A) Any padding layers thinner than 8 mm in their natural thickness shall be used.

(B) The thickness of each remaining layer (those greater than or equal to 8 mm in thickness) shall be proportioned so that its relative thickness in the remaining specimen depth (50 mm minus the thin layers) is in the same proportion as is found for those layers in the full-scale furniture article.

(C) Once the appropriate layers are prepared according to this instruction, they shall be used in exactly the same way as is the single forming block in 5.2.11.1.2.

5.2.11.4 Specimens from Furniture Items of Unusually Thin Construction.

5.2.11.4.1* For some furniture items, the total thickness of the entire padding layer is less than 50 mm, and the padding layer shall be tested in a 50-mm depth.

5.2.11.4.2 To comply with 5.2.11.4.1, two or more layers of padding shall be stacked together to achieve the required 50 mm depth.

5.2.11.4.3 When testing specimens that represent known full-scale constructions, the test report shall clearly identify what the maximum thickness of padding found in the full-scale article was, if that thickness was less than 50 mm.

5.2.11.4.4 For specimens in which the padding comprises layers of several different materials, yet with a total thickness of less than 50 mm, each layer shall be laid up in an increased thickness so that the total padding thickness is 50 mm, and the ratios of individual layer thickness shall be maintained in the same proportion as occurs in the full-scale article.

5.2.11.4.5 The layers in the test specimen shall be laid up in the same order as the layers of

the furniture item.

5.2.11.5 Specimens That Use Loose Filling Materials.

5.2.11.5.1 Loose filling materials shall include feathers, down, shredded foam, and any other fillings that are poured into place rather than cut to size.

(A) Cone calorimeter samples for the loose filling materials shall be prepared by the manufacturer rather than by the testing laboratory.

(B) The manufacturer shall prepare a square pillow filled with the product.

(C) The square pillow shall be encased with the same fabric (not normally the outside upholstery fabric) that is used in the full-scale furniture article to hold together the loose filling material.

5.2.11.5.2 Pillow Casing.

(A) The outside dimensions of the square pillow casing shall be 98 mm × 98 mm × 48 mm.

(B) The fabric casing shall be prepared from two pieces.

(C) The top piece shall be cut slightly larger than 200 mm × 200 mm.

(D) The exact dimensions shall depend on the needs of the sewing technique.

(E) The casing top piece shall now be folded in a "waterfall" fold as shown in Figure 5.2.11.5.2(E).

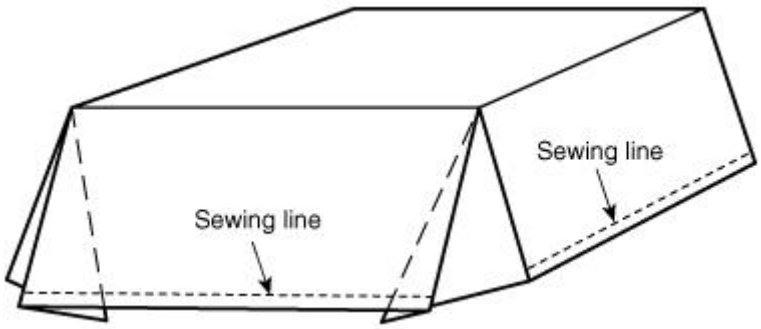


FIGURE 5.2.11.5.2(E) Folding of Fabric for Loose Filling Materials.

(F) The four corners shall be tucked inside.

(G) The blind opening left at each corner shall then be sewn shut.

(H) The second fabric piece [not shown in Figure 5.2.11.5.2(E)] shall be used to form the bottom.

(I) The bottom size shall be slightly larger than 100 mm × 100 mm.

5.2.11.5.3 The bottom piece shall be sewn to the bottom edge of the top piece by sewing around all the four sides.

(A) Before the bottom is completely sewn shut, the inside of the casing shall be filled with the same density of material as will be used in the intended test article.

(B) The corners shall be filled evenly and any bulging of the top shall be minimized.

5.2.11.5.4 It shall be permitted to have multilayer constructions, where the loose fill material does not comprise the entire depth of construction, with the remaining depth comprising foam, battings, or other nonloose materials.

(A) In such cases, the fabric casing shall still be constructed to the dimensions specified in 5.2.11.5.2.

(B) For such multilayer constructions, the casing shall be filled inside with depths of loose fill and nonloose fill material, proportioned to the depths in the full-scale furniture article.

5.3 Method B.

Equipment and supplies for test specimen preparation for Method B shall be as described in 5.3.1.1 through 5.3.1.4 when quality of specimen is not required.

5.3.1 Test Specimens.

5.3.1.1 The construction of the test specimens shall reflect the actual construction used in the upholstered or mattress items.

5.3.1.2 The test specimen shall represent the padding and upholstery fabric materials, but not frame materials, welt cord, decking construction articles, or dust covers.

5.3.1.3 In all cases, the test specimen shall comprise the upholstery or mattress fabric and any intermediate layers found between the upholstery fabric and the padding that are 8 mm or less in thickness.

5.3.1.4 Where there is only one padding material, its thickness shall be such that the total specimen thickness, including fabric and intermediate layers, is 50 mm.

5.3.1.5 When the construction involves several material layers, the specimen shall comprise all the types of layers sampled in 5.3.1.5.1 through 5.3.1.5.3.

5.3.1.5.1 Upholstery fabric or intermediate layers 8 mm thick or less shall be used in full thickness.

5.3.1.5.2 The depths taken up by the full-thickness layers shall be added together and then subtracted from the 50 mm.

5.3.1.5.3 For the remaining depth, the remaining layers shall be proportioned in thickness such that the ratio of their thickness in the test specimen is the same as that in the full-scale furniture article.

5.3.2 Fabric Cutting.

5.3.2.1 The upholstery or mattress fabric and intermediate layers shall be cut to a size of 200 mm × 200 mm with a square 50 mm × 50 mm removed at each corner.

5.3.2.2 The length and the width of the padding layers shall be slightly less than 100 mm, so that the fabric and intermediate layers can be folded over each of the four sides to produce a specimen measuring 100 mm × 100 mm.

5.3.2.3 The sides folded over shall be edge-stapled to the padding near the bottom of the specimen.

5.3.2.4 Care shall be taken to trim the fabric and intermediate layers so that they are even with the bottom of the test specimen.

5.3.3 Aluminum Foil.

5.3.3.1 The four sides and bottom of the finished test specimen shall be covered with aluminum foil 0.04 mm thick (shiny side in).

5.3.3.2 A single sheet of aluminum foil, 200 mm × 200 mm, shall be used.

5.3.3.3 The corners shall be folded at a 45-degree angle, flush against the sides.

5.3.4 Conditioning. The specimen shall be conditioned to a moisture equilibrium (constant mass) at an ambient temperature of 23°C ± 3°C and a relative humidity of 50 percent ± 5 percent.

Chapter 6 Test Procedure

6.1 Preparation.

The test procedure shall be in accordance with Chapter 5, Test Procedure, of NFPA 271, *Standard Method of Test for Heat and Visible Smoke Release Rates for Materials and Products Using an Oxygen Consumption Calorimeter*.

6.2 Procedure.

6.2.1 When the test is ready to be carried out, the empty specimen holder shall be removed.

6.2.2 The radiation shield shall be inserted, and the specimen, within the horizontal holder, shall be positioned in place.

6.2.3 The holder shall initially be at room temperature.

6.2.4 The radiation shield shall remain in place until load cell equilibrium, but for no longer than 10 seconds total if the shield is not water cooled.

6.2.5 Data collection shall be initiated upon removal of the radiation shield, which is the start of the test.

6.2.5.1 The data collection intervals shall be 2 seconds or less.

6.2.6 Ignition Sequence.

6.2.6.1 The ignition shall be conducted in the following sequence:

(1) Start the ignition timer.

(2) Move the spark igniter into place.

(3) Turn on the power to the spark igniter.

6.2.6.2 These steps shall be accomplished within 2 seconds of the removal of the radiation shield.

6.2.7 Flaming.

6.2.7.1 The times at which flashing or transitory flaming occurs shall be recorded.

6.2.7.2 When sustained flaming occurs, the time shall be recorded, the spark igniter shall be turned off, and the spark ignition shall then be removed.

6.2.7.3 If the flame self-extinguishes in fewer than 60 seconds after the spark has been turned off, the spark igniter shall be reinserted and the spark igniter shall be turned on.

6.2.7.4 If flaming reoccurs, the test shall be stopped.

6.2.7.5 The test data shall then be discarded, and the test shall then be repeated without removing the spark igniter until the entire test is completed.

6.2.7.6 The events in 6.2.7.1 through 6.2.7.5 shall be included in the test report.

6.2.8 Data shall be collected until 2 minutes after any flaming or other signs of combustion cease, until the average mass loss over a 1-minute period has dropped below 150 g/m^2, or until 20 minutes have elapsed, whichever occurs first.

6.2.9 The specimen holder shall be removed.

6.2.10 The empty specimen holder shall be replaced.

6.2.11 After the start of the test, if the specimen does not ignite within 15 minutes, it shall be removed and discarded unless the specimen is showing signs of heat evolution.

6.2.12 Unless otherwise specified in the material or performance standard, three determinations shall be made and reported, as specified in Section 8.1 through Section 8.4.

6.2.12.1 The 180-second mean heat release rate readings for the three specimens shall be compared.

6.2.12.2 If any of these mean readings differs by more than 10 percent from the average of the three readings, then an additional set of three specimens shall be tested.

6.2.12.3 In such cases, the average for the set of six readings shall be reported.

6.3* Safety Precautions.

6.3.1 Protective Gloves.

6.3.1.1 The operator shall use protective gloves for insertion and removal of test specimens in recognition of the fact that the test procedures involve high temperatures and combustion processes.

6.3.1.2 Neither the cone heater nor the associated fixtures shall be touched while hot except with the use of protective gloves.

6.3.2 Exhaust.

6.3.2.1 The exhaust shall be checked for operation before testing.

6.3.2.2 The exhaust shall discharge into a building exhaust system with sufficient capacity to handle the exhaust.

6.3.3 Provisions shall be made for collecting and venting any combustion products that are not collected by the exhaust system of the apparatus.

Chapter 7 Calculations

7.1 Calibration Constant Using Methane.

7.1.1 The methane calibration shall be performed prior to the day's testing to check for the operation of the instrument and to compensate for minor changes in mass flow determination.

7.1.2 The calibration constant, C, shall be determined from the following equation:

$$C = \frac{5.0}{1.10\left(12.54 \times 10^{3}\right)}\left(\frac{\sqrt{\Delta P}}{T_e}\right)\left[\frac{X_{O_2}^{0} - X_{O_2}(t)}{1.105 - X_{O_2}(t)}\right]$$

where:

5.0 = quantity of methane supplied (kW)

1.10 = ratio of oxygen to air molecular weight

12.54×10^3 = ratio $\Delta H_c/r_0$ for methane

P = See 1.5.3.

T_e = See 1.5.3.

$X_{O_2}^{0}$ = See 1.5.3.

X_{O_2} = See 1.5.3.

t = See 1.5.3.

7.2 Calculations for Test Specimen.

7.2.1 The calculations in this section shall be used for various applications.

7.2.2 The applicable material or performance standard shall be consulted for additional calculations.

7.2.3 Heat Release.

7.2.3.1 Before other calculations are performed, the oxygen analyzer time shift shall be determined by the following equation:

$$X_{O_2}(t) = X_{O_2}^{1}\left(t + t_d\right)$$

7.2.3.2 The heat release rate then shall be determined by the following equation:

$$\dot{q}(t) = \Delta \frac{H_c}{r_0}(1.10)C\sqrt{\frac{\Delta P}{T_e}}\left[\frac{X_{O_2}^0 - X_{O_2}}{1.105 - 1.5X_{O_2}}\right]$$

7.2.3.3 The value of $\Delta H_c/r_0$ for the test specimen shall be set to equal 13.1×10^3 kJ/kg, unless a more accurate value is known for the test material. The heat release rate per unit area shall be determined as follows:

$$\dot{q}''(t) = \frac{\dot{q}(t)}{A_s}$$

where:

A_S = 0.01 m²

7.2.3.4 The total heat released during combustion, $\dot{q}''$, shall be determined by the following summation, where the summation begins with the first reading after the last negative rate of heat release reading that occurs at the beginning of the test and continues until the final reading recorded for the test:

$$q'' = \sum_i \dot{q}''i(t)\Delta t$$

7.2.4 Mass Loss Rate and Effective Heat of Combustion.

7.2.4.1 The required mass loss rate, $-dm/dt$, shall be computed at each time interval using five-point numerical differentiation.

7.2.4.2 The equations to be used shall be as follows:

(1) For the first scan, ($i = 0$),

$$-\left(\frac{dm}{dt}\right)_{i=0} = \frac{25m_0 - 48m_1 + 36m_2 - 16m_3 + 3m_4}{12\Delta t}$$

(2) For the second scan, ($i = 1$),

$$-\left(\frac{dm}{dt}\right)_{i=1} = \frac{3m_0 + 10m_1 - 18m_2 + 6m_3 - m_4}{12\Delta t}$$

(3) For any scan for which $1 < i < n - 1$ (n = total number of scans),

$$-\left(\frac{dm}{dt}\right)_i = \frac{-m_{i-2} + 8m_{i-1} - 8m_{i+1} + m_{i+2}}{12\Delta t}$$

(4) For the next to the last scan, ($i = n - 1$),

$$-\left(\frac{dm}{dt}\right)_{i=n-1} = \frac{-10m_n - 3m_{n-1} + 18m_{n-2} - 6m_{n-3} + m_{n-4}}{12\Delta t}$$

(5) For the last scan, ($i = n$),

$$-\left(\frac{dm}{dt}\right)_{i=n} = \frac{-25m_n + 48m_{n-1} - 36m_{n-2} + 16m_{n-3} - 3m_{n-4}}{12\Delta t}$$

7.2.4.3 The average effective heat of combustion shall be determined as follows, with the summation taken over the entire test length:

$$\Delta H_{c,eff} = \frac{\sum_i \dot{q}i(t)\Delta t}{m_i - m_f}$$

7.2.4.4 A time-varying value also shall be determined as follows:

$$\Delta H_{c,eff}(t) = \frac{\dot{q}i(t)}{-\left(\frac{dm}{dt}\right)}$$

7.2.5 Smoke Obscuration.

7.2.5.1 The extinction coefficient shall be determined by the smoke meter electronics as follows:

$$k = (1/L)\ln(I_0/I)$$

7.2.5.2 The average specific extinction area obtained during the test shall be as follows:

$$\sigma_{f(avg)} = \sum_i v_i k_i \Delta t_i / (m_i - m_f)$$

7.3 Final Numbers.

7.3.1 The ignition time shall be determined and reported as "time to sustained flaming" in seconds.

7.3.2 Heat release rate, per unit area (kW/m^2) averaged over the first 180 seconds after specimen ignition, shall be calculated and reported.

7.3.3 Effective Heat of Combustion.

7.3.3.1 The effective heat of combustion (MJ/kg) average for the duration of the test period shall be calculated and reported.

7.3.3.2 The effective heat of combustion average shall be determined by dividing total heat released by the total specimen mass lost.

7.3.4 Reported Values. The values reported shall be the average for the three test

replicates.

Chapter 8 Report of Results

8.1 Report.

8.1.1 The test report shall contain the information as given in Section 8.2 through Section 8.4.

8.1.2 The information to be reported shall be divided into data for each specimen tested and summary data for all specimens of a particular material or product tested.

8.2 All Specimens.

The following shall be reported as a summary for all specimens of a particular material or product:

(1) Specimen identification or number

(2) Manufacturer or submitter

(3) Date of test

(4) Operator

(5) Composition or generic identification

(6) Details of preparation

(7) Number of replicate specimens tested (a minimum of three)

8.3 Each Specimen.

The following information shall be included for each specimen:

(1) Specimen thickness

(2) Specimen mass

(3) Heating flux and exhaust system flow rate

(4) Time to sustained flaming (seconds)

(5) Heat release rate (per unit area) curve

(6) Peak heat release rate

(7) Average heat release rate values for the first 180 seconds after ignition

(8) Total heat released by the specimen

(9) Curve of heat release rate versus time for entire test (optional)

(10) Average effective heat of combustion for entire test

(11) Curve of effective heat of combustion versus time for entire test (optional)

(12) Average specific extinction area for entire test

(13) Mass remaining after test

(14) Sample mass loss

(15) Additional observations, if any

(16) Difficulties encountered in testing, if any

8.4 Averaged Values for All Three Specimens.

The following values shall be averaged for all specimens:

(1) Time to sustained flaming (seconds)

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

(3) Average heat release rate value (kW/m^2) for 180 seconds after ignition

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

(5) Average specific extinction area for the entire test

Annex A Explanatory Material

Annex A is not a part of the requirements of this NFPA document but is included for informational purposes only. This annex contains explanatory material, numbered to correspond with the applicable text paragraphs.

A.1.3.1 This test method can also be used to determine various fire properties, including the rate of heat release at different heat flux exposure levels from the prescribed value of 35 kW/m^2 determined using this test method. Such additional fire properties include mass loss and the release of smoke and other combustion products (among them carbon monoxide and carbon dioxide). Any measurement conducted at an incident heat flux other than 35 kW/m^2 is not considered a part of this test method. This test can be used to predict performance of furniture in large scale fires. This concept has been used in NFPA 555, *Guide on Methods for Evaluating Potential for Room Flashover*, and some examples of predictive work are included in Section C.2.

A.1.3.2 Release rate measurements are a source of useful information for product development. They provide a quantitative measure of specific changes in fire performance caused by product modifications.

A.5.2 Additional information can be found in Babrauskas and Wetherlund, *Fire Testing of Furniture in the Cone Calorimeter — The CBUF Test Protocol* .

A.5.2.2 Specimen preparation rests crucially upon the proper use of forming blocks. Maple is an acceptable dense wood. It undergoes minimal dimensional changes when the humidity is changed. Do not use pine.

A.5.2.3 The following product information is provided for informational purposes only and

has not been independently verified, certified, or endorsed by NFPA or any of its technical committees. Adhesives that are based on polychloroprene (Neoprene™), acrylic, or water have been found suitable. Parabond™ A-1535 is a Neoprene, solvent-based adhesive (polychloroprene in methylene chloride solvent) that has been found suitable. An acrylic, water-based adhesive, DAP Weldwood™ Hobby 'n Craft Glue, which is readily available in hardware and craft stores, has also been found suitable. The latter adhesive is often called "white glue" and has been proven adequate for many, but not all, fabrics and interliners tested by a U.S. testing laboratory. Other adhesives are also suitable, provided they meet the stated requirements.

A.5.2.4 Water-soluble adhesives are applied directly from the bottle and therefore do not require a brush. Likewise, any spillage is readily cleanable with water. This type of adhesive does not set as quickly as the solvent-based adhesives, which permits shifting the fabric as necessary to create a neat, tight package. However, the glued specimen has to be left overnight to ensure a good seal. On the other hand, polychloroprene-based adhesives are applied with a brush made of hog bristles or other stiff, coarse material. The brush has to be flat and cut square, with a width of 7 mm to 8 mm. A solvent compatible with the adhesive must be used for cleanup and storage of the brush. The solvent-based glues set up very quickly and do not permit any adjustment around the wood block.

A.5.2.6 Any type of tape that will adequately adhere to all fabrics and be easy to remove after completion of assembly is suitable for this purpose. Some interliners or fabrics will be damaged by direct application of masking tape to their surface, since removal results in tearing or marring the surface. For items susceptible to such damage, prepare strips of paper slightly wider than the width of the masking tape and long enough to reach all the way around the forming block. Then secure the paper strips with tape.

A.5.2.7 No other foil thickness should be used. It is especially important not to substitute a thicker foil. Commercially available heavy-duty foil has the appropriate thickness.

A.5.2.8.2 This size ensures that the resilient padding will be compressed during composite assembly, leading to tight, well-formed specimens. With a typical fabric thickness, this size will result in a total specimen thickness of approximately 50.9 mm, which is acceptable.

Some resilient paddings have a tendency to create high friction against the sawing table and the guide. To make a smooth cut by allowing the resilient padding to slide more easily, put a piece of paper between the resilient padding and the table/guide. Push the assembly of resilient padding and paper forward and allow the blade to cut through both the resilient padding and the paper.

A.5.2.8.3 The cone calorimeter test results will not be repeatable if the density of the resilient padding tested is not very closely controlled.

A.5.2.8.4 If the fabric weave is such that the yarns in the two directions do not lie at 90 degrees to each other, do not cut the sample along yarns in both directions because a skewed specimen will result.

A.5.2.8.4(D) The cutting of the cloth should not be any closer to the selvedge than 10 cm to 12 cm because sometimes weaving or coating variations occur near the selvedge.

A.5.2.9.2 Make the paper strips wider than the tape, but shorter, so that the tape can adhere to the wood block or to itself.

A.5.2.10.1 If bits of adhesive make the fabric stick to the block, use a chemist's spatula or a similar dull, knife-like device to loosen the corners. It is easiest to release the fabric by grabbing along the top edge of the fabric with the thumb and the index finger. Remove any adhesive that remains stuck to the forming block.

A.5.2.10.5 The corners of the aluminum foil should be opened to allow good access of air into the conditioning chamber.

A.5.2.10.7 The top of the specimen should be pushed down to ensure that the bottom conforms smoothly to the same bottom conditions as will be seen during the testing. The specimen is now ready to be tested.

A.5.2.11 These instructions give additional details for preparation of those constructions that involve more than a single layer fabric and a single resilient padding layer. The instructions also provide for some materials that need specialized preparation techniques.

A.5.2.11.1.1 Some interliners are mechanically quite fragile. Avoid tearing them when the masking tape is stripped off. Test the tape to be used to make sure that it can be smoothly pulled off the interliner without damage.

A.5.2.11.4.1 Examples include thinly padded chairs and innerspring mattresses.

A.6.3 The test procedures involve high temperatures and combustion processes. Therefore, hazards exist for burns, ignition of extraneous objects or clothing, and inhalation of combustion products.

Annex B Precision and Bias

This annex is not a part of the requirements of this NFPA document but is included for informational purposes only.

B.1

Precision is defined as a series of interlaboratory tests for test Method A and test Method B that were run. Method A was conducted using seven laboratories and five constructions. Method B was conducted using five laboratories and three constructions.

B.1.1 Table B.1.1(a) through Table B.1.1(e) present the data for repeatability and reproducibility of the individual combinations used to examine precision of test specimen preparation Method A. The analysis was conducted following ISO 5725, *Accuracy (Trueness and Precision) of Measurement Methods and Results*. Stragglers were those entries with a probability of occurring between 1 percent and 5 percent based on their differences from the average, and they were identified and retained in the calculations. Outliers were those entries with a probability of occurring of less than 1 percent based on their differences from the average, and they were removed from the calculations. The abbreviations used for Table B.1.1(a) through Table B.1.1(e) are as follows:

TTI = time to ignition (seconds)

THR = total heat release (MJ/m^2)

RHR_{Av} 60 = average heat release rate for the period of 60 seconds after ignition (kW/m^2)

RHR_{Av} 180 = average heat release rate for the period of 3 minutes after ignition (kW/m^2)

EHC = average effective heat of combustion (MJ/kg)

SEA = average specific extinction area (m^2/kg)

m = average value

r = repeatability

R = reproducibility

Table B.1.1(a) Repeatability and Reproducibility for Combination 1,[a] Method A

Variable	Number of Labs	*m*	*r*	*R*
TTI[b]	7	16	2	4
THR[c,d,e]	7	35	4	4
RHR_{Av} 60	7	159	34	83
RHR_{Av} 180[d]	7	123	27	63
EHC[c,d]	7	18.2	2.0	6.2
SEA[f]	5	399	93	366

[a]Combination 1: Backcoated acrylic pile fabric ($546 g/m^2$) on non–fire-retarded high-resilient polyurethane foam ($21 kg/m^3$).
[b]Lab 7 was removed as an outlier for repeatability.
[c]Lab 3 was removed as an outlier for repeatability.
[d]Lab 4 was removed as an outlier for repeatability.
[e]Lab 7 was identified as a straggler for reproducibility.
[f]Lab 1 was removed as an outlier for repeatability.

Table B.1.1(b) Repeatability and Reproducibility for Combination 2,[a] Method A

Variable	Number of Labs	*m*	*r*	*R*
TTI[b]	7	13	3	4
THR[b,c]	7	40	5	11
RHR_{Av} 60	7	116	16	47
RHR_{Av} 180	7	120	22	49
EHC	7	16.9	1.3	3.6
SEA	5	108	60	76

[a]Combination 2: Fire-retarded cotton fabric ($422 g/m^2$) on combination modified high-resilient foam ($30 kg/m^3$).
[b]Lab 7 was identified as a straggler for repeatability.
[c]Lab 2 was identified as a straggler for repeatability.
[d]Lab 6 was removed as an outlier for repeatability.

Table B.1.1(c) Repeatability and Reproducibility for Combination 3,* Method A

Variable	Number of Labs	*m*	*r*	*R*
TTI	7	7	1	3
THR	7	58	4	8
RHR_{Av} 60	7	320	59	82
RHR_{Av} 180	7	292	43	61
EHC	7	30.5	2.4	5.0
SEA	5	449	91	112

*Combination 3: Polypropylene fabric (264 g/m^2) on non–fire-retarded high-resilient polyurethane foam (21 kg/m^3).

Table B.1.1(d) Repeatability and Reproducibility for Combination 4,* Method A

Variable	Number of Labs	*m*	*r*	*R*
TTI	7	14	3	7
THR	7	57	5	11
RHR_{Av} 60	7	222	25	78
RHR_{Av} 180	7	266	33	56
EHC	7	20.9	1.4	3.7
SEA	5	241	27	56

*Combination 4: Wood fabric (432 g/m^2) on combustion modified high-resilient foam (30 kg/m^3).

Table B.1.1(e) Repeatability and Reproducibility for Combination 5,* Method A

Variable	Number of Labs	*m*	*r*	*R*
TTI	7	15	2	11
THR	7	31	5	24
RHR_{Av} 60	7	137	19	136
RHR_{Av} 180	7	83	20	89
EHC	7	16.3	2.9	12.7
SEA	5	341	93	33

*Combination 5: Backcoated acrylic pile fabric (546 g/m^2) on non–fire-retarded high-resilient polyurethane foam (21 kg/m^3) (like Combination 1), with an added Kevlar interliner (65 g/m^2). Lab 3 was removed as an outlier for repeatability.

B.1.2 Table B.1.2 presents the overall repeatability and reproducibility of the investigation for precision using test specimen preparation Method A. The constants *a*, *b*, *A*, and *B* correspond to the following linear regression equations:

$$r = a + bm$$

$$R = A + Bm$$

Table B.1.2 Overall Repeatability and Reproducibility, Method A

Variable	*a*	*b*	*A*	*B*
TTI	1.22	0.076	0	0.44
THR	4.48	0	11.70	0
RHR_{Av} 60	0	0.164	85.19	0
RHR_{Av} 180	12.75	0.092	63.42	0
EHC	1.66	0.016	6.25	0
SEA	28.83	0.14	15.63	0.56

B.1.3 Figure B.1.3 shows a comparison of the results of an investigation where one of the laboratories (Lab 1) tested three test specimens it had prepared using Method A (labeled "own-prepared" in Figure B.1.3) and three test specimens the lead laboratory (Swedish National Testing and Research Laboratory) had prepared (labeled "SP-prepared" in Figure B.1.3). Figure B.1.3 indicates that there are no systematic deviations, meaning specimen preparation instructions were followed correctly.

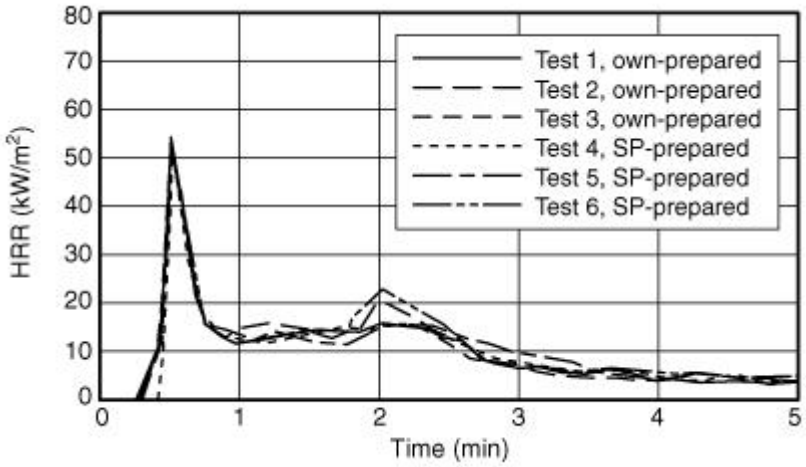


FIGURE B.1.3 Comparison of Results.

B.1.4 Table B.1.4(a) and Table B.1.4(b) present the data for repeatability and reproducibility of the individual combinations used to examine precision of test specimen preparation Method B.

Table B.1.4(a) Within-Laboratory (Repeatability) Precision Data

Parameter	Units	Mean Value	SD[a]	RDS (%)[b]

Table B.1.4(a) Within-Laboratory (Repeatability) Precision Data

Parameter	Units	Mean Value	SD[a]	RDS (%)[b]
Material: nylon fabric on a flame-retardant treated polyurethane foam				
Time to sustained flaming	sec	9	1	11
Average heat release rate at 180 sec[c]	kW/m^2	258	6	2
Peak heat release rate	kW/m^2	364	27	7
Total heat release	MJ/m^2	89	1.5	2
Heat of combustion	MJ/kg	24	0.6	3
Material: polyolefin fabric on a standard polyurethane foam				
Time to sustained flaming	sec	8	0	0
Average heat release rate at 180 sec[c]	kW/m^2	374	11	3
Peak heat release rate	kW/m^2	474	16	3
Total heat release	MJ/m^2	80	1	1
Heat of combustion	MJ/kg	25	1	4
Material: cotton velvet with glass fiber liner on a standard polyurethane foam				
Time to sustained flaming	sec	8	0.5	6
Average heat release rate at 180 sec[c]	kW/m^2	113	8	7
Peak heat release rate	kW/m^2	316	10	3
Total heat release	MJ/m^2	52	0.2	0
Heat of combustion	MJ/kg	16	0.8	5

[a]Standard deviation
[b]Relative standard deviation
[c]After ignition

Table B.1.4(b) Between-Laboratory (Reproducibility) Precision Data

Parameter	Units	Mean Value	SD[a]	RDS (%)[b]
Material: nylon fabric on a flame-retardant treated polyurethane foam				
Time to sustained flaming	sec	12	2.5	21
Average heat release rate at 180 sec[c]	kW/m^2	228	29	13
Peak heat release rate	kW/m^2	309	54	17
Total heat release	MJ/m^2	85	6	7
Heat of combustion	MJ/kg	24	1.6	7
Material: polyolefin fabric on a standard polyurethane foam				
Time to sustained flaming	sec	10	2.3	23
Average heat release rate at 180 sec[c]	kW/m^2	389	19	5
Peak heat release rate	kW/m^2	442	64	14
Total heat release	MJ/m^2	77	2.8	4
Heat of combustion	MJ/kg	27	2.1	8
Material: cotton velvet with glass fiber liner on a standard polyurethane foam				
Time to sustained flaming	sec	12	3	25

Table B.1.4(b) Between-Laboratory (Reproducibility) Precision Data

Parameter	Units	Mean Value	SD[a]	RDS (%)[b]
Average heat release rate at 180 sec[c]	kW/m^2	92	29	32
Peak heat release rate	kW/m^2	262	52	20
Total heat release	MJ/m^2	48	7	15
Heat of combustion	MJ/kg	20	4	20

[a]Standard deviation
[b]Relative standard deviation
[c]After ignition

B.2

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 oxygen consumption standard value of $H_c/r_0 = 13.1 \times 10^3$ kJ/kg oxygen results in an expected error band of ±5 percent compared to true value. For homogeneous materials with only a single pyrolysis mechanism, this uncertainty can be reduced by determining H_c from oxygen bomb measurements and r_0 from ultimate elemental analysis. For most testing, determining H_c is not practical, because specimens can be composite, can be nonhomogenous, and can exhibit several degradation reactions. Therefore, for unknown samples, a ±5 percent accuracy limit is anticipated. For reference materials, however, careful determination of H_c/r_0 can substantially reduce this source of uncertainty.

Annex C Informational References

C.1 Referenced Publications.

The following documents or portions thereof are referenced within this standard for informational purposes only and are thus not considered part of the requirements of this document unless also listed in Chapter 2.

C.1.1 NFPA Publication. National Fire Protection Association, 1 Batterymarch Park, P.O. Box 9101, Quincy, MA 02269-9101.

NFPA 555, *Guide on Methods for Evaluating Potential for Room Flashover*, 2000 edition.

C.1.2 Other Publications.

C.1.2.1 ISO Publication. International Standards Organization, 1 rue de Varembé, Case Postale 56, CH-1211 Geneve 20, Switzerland.

ISO 5725, *Accuracy (Trueness and Precision) of Measurement Methods and Results,* 1994.

C.1.2.2 SP Publication. Swedish National Testing and Research Institute, Fire Technology,

P.O. Box 857, 56.501, 15 Boras, Sweden.

Babrauskas, V. and I. Wetherlund, *Fire Testing of Furniture in the Cone Calorimeter — The CBUF Test Protocol, SP Report,* 1994:32.

C.2 Informational References.

The following documents or portions thereof are listed here as informational resources only. They are not a part of the requirements of this document.

Ames, S.A., V. Babrauskas, and W. J. Parker, "Upholstered Furniture: Prediction by Correlations," in V. Babrauskas and S.J. Grayson (eds.), *Heat Release in Fires*, London: Elsevier, 1992, pp. 519–544.

Hirschler, M.M. "Tools Available to Predict Full-Scale Fire Performance of Furniture," *Fire and Polymers II-Materials and Tests for Hazard Prevention*, ACS Symposium Series 599, American Chemical Society, 1995, pp. 593–608.

Hirschler, M.M. "Use of Heat Release Rate to Predict Whether Individual Furnishings Would Cause Self Propagating Fires," *Fire Safety J.*, 32 (1999), 273–296.

Krasny, J.F., W.J. Parker, and V. Babrauskas, *Fire Behavior of Upholstered Furniture and Mattresses*, Norwich, NY: William Andrew Publishing, 2001.

C.3 References for Extracts.

The following documents are listed here to provide reference information, including title and edition, for extracts given throughout this standard as indicated by a reference in brackets [ ] following a section or paragraph. These documents are not a part of the requirements of this document unless also listed in Chapter 2 for other reasons.

NFPA 271, *Standard Method of Test for Heat and Visible Smoke Release Rates for Materials and Products Using an Oxygen Consumption Calorimeter*, 2001 edition.