Designation: F1550 – 16

Standard Test Method for Determination of Fire-Test-Response Characteristics of Components or Composites of Mattresses or Furniture for Use in Correctional Facilities after Exposure to Vandalism, by Employing a Bench Scale Oxygen Consumption Calorimeter[1]

This standard is issued under the fixed designation F1550; 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

In correctional occupancies, vandalism of mattresses or furniture occurs with significant frequency. After such vandalism, it is possible that the filling material (foam or other padding) of the mattress or furniture becomes exposed. If the mattress or furniture filling material is exposed, it is possible for a product which meets prescribed fire-test-response characteristics in its intact state to perform in a decidedly less satisfactory manner. This standard test method provides a means for measuring, in bench scale, fire-test-response characteristics of composite upholstered components of mattresses or furniture, for use in correctional facilities, after having been vandalized in a prescribed manner so as to expose the filling material, using an oxygen consumption calorimeter.

1. Scope

1.1 This fire-test-response test method is designed for use to determine various fire-test-response characteristics, including ignitability and heat release rate, from composites of mattresses or furniture, or correctional facilities, which have been vandalized in a prescribed manner to expose the filling material, by using a bench scale oxygen consumption calorimeter.

1.2 This test method provides for measurements of the time to sustained flaming, heat release rate, peak and total heat release, and effective heat of combustion at a constant radiant initial test heat flux of 35 kW/m^2. See 5.7 for limitations.

1.3 The apparatus used in this test method is also capable of determining heat release data at different initial test heat fluxes.

1.4 The specimen is oriented horizontally and a spark ignition source is used.

1.5 All fire-test-response characteristics are determined using the apparatus and the procedures described in Test Method E1354.

1.6 The tests are done on bench-scale specimens combining the mattress or furniture outer layer components. Frame elements are not included.

1.7 The vandalism is simulated by causing a prescribed cut on the outer layer of the composite, deep enough to expose the filling material to the incident radiation.

1.8 The values stated in SI units are to be regarded as standard. No other units of measurement are included in this standard.

1.9 *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.*

1.10 *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.* For specific safety precautions, see Section 7.

1.11 Fire testing is inherently hazardous. Adequate safeguards for personnel and property shall be employed in conducting these tests.

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[1] This test method is under the jurisdiction of ASTM Committee F33 on Detention and Correctional Facilitiesand is the direct responsibility of Subcommittee F33.05 on Furnishings and Equipment.

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2. Referenced Documents

2.1 *ASTM Standards:*[2]

D123 Terminology Relating to Textiles

E176 Terminology of Fire Standards

E1354 Test Method for Heat and Visible Smoke Release Rates for Materials and Products Using an Oxygen Consumption Calorimeter

E1474 Test Method for Determining the Heat Release Rate of Upholstered Furniture and Mattress Components or Composites Using a Bench Scale Oxygen Consumption Calorimeter

E1537 Test Method for Fire Testing of Upholstered Furniture

E1590 Test Method for Fire Testing of Mattresses

2.2 *ISO Standards:*[3]

ISO 13943 Fire Safety–Vocabulary

ISO 4880 Burning Behavior of Textiles and Textile Products—Vocabulary

2.3 *California Bureau of Home Furnishings and Thermal Insulation Standards:*[4]

CA Technical Bulletin 129 (October 1992), Flammability Test Procedure for Mattresses for Use in Public Buildings

CA Technical Bulletin 133 (January 1991). Flammability Test Procedure for Seating Furniture for Use in Public Occupancies

3. Terminology

3.1 *Definitions:*

3.1.1 For definitions of terms used in this test method and associated with fire issues, refer to the terminology contained in Terminology E176 and in ISO 13943. In case of conflict, the terminology in Terminology E176 shall prevail.

3.1.2 For definitions of terms used in this test method and associated with textile issues, refer to the terminology contained in Terminology D123 and in ISO 4880. In case of conflict, the terminology in Terminology D123 shall prevail.

3.2 *Definitions of Terms Specific to This Standard:*

3.2.1 *effective heat of combustion, n*—measured heat release divided by the mass loss for a specified time period.

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

3.2.3 *heat flux, n*—heat transfer to a surface per unit area, per unit time (see also *initial test heat flux*).

3.2.3.1 *Discussion*—The heat flux from an energy source, such as a radiant heater, can be measured at the initiation of a test (such as Test Method E1354) and then reported as the initial test heat flux, with the understanding that the burning of the test specimen can generate additional heat flux to the specimen surface. The heat flux can also be measured at any time during a fire test, on any surface, and with measurement devices responding to radiative and convective fluxes. Typical units are kW/m^2, W/cm^2, or $BTU/(s\ ft^2)$.

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

3.2.5 *initial test heat flux, n*—the heat flux set on the test apparatus at the initiation of the test (see also *heat flux*).

3.2.6 *mattress, n*—mattress is a ticking (outermost layer of fabric or related material) filled with a resilient material used alone or in combination with other products intended or promoted for sleeping upon.

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

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

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

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

3.2.11 *upholstered, n*—covered with material (as fabric or padding) to provide a soft surface.

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 **(1)**.[5] Approximately 13.1×10^3 kJ of energy are released as heat for each kg of oxygen consumed. Specimens in the test are burned in ambient air conditions, while being subjected to a prescribed external initial test heat flux of 35 kW/m^2.

4.2 The heat release is determined by the measurement of the oxygen consumption, as determined by the oxygen concentration and the flow rate in the combustion product stream, as described in Test Method E1354.

4.3 The primary measurements are oxygen concentration and exhaust gas flow rate, used to calculate heat release. Additional measurements include the mass loss rate of the specimen, the time to sustained flaming, and the effective heat of combustion. Ignitability is determined by measuring the time for initial exposure to time of sustained flaming of the specimen.

4.4 In order to simulate vandalism, the outer layers of the composite to be tested are cut across the surface, in the form of an X, to expose the interior filling material.

4.5 The procedure in this test method is identical to that in Test Method E1474, except for the slashing of the surface of the specimen prior to testing.

[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.

[3] Available from International Organization for Standardization (ISO), 1 rue de Varembé, Case postale 56, CH-1211, Geneva 20, Switzerland.

[4] Available from California Bureau of Home Furnishings and Thermal Insulation, State of California, Department of Consumer Affairs, 3485 Orange Grove Avenue, North Highlands, CA 95660-5595.

[5] The boldface numbers in parentheses refer to the list of references at the end of this standard.

5. Significance and Use

5.1 This test method provides a means to determine various fire-test-response characteristics, including the time to sustained flaming and the heat release rate, of composites exposed to a prescribed initial test heat flux in the cone calorimeter apparatus, after they have been vandalized in a prescribed manner, to expose the filling material.

5.2 It is clearly impossible to predict the manner in which a mattress or furniture will be vandalized. The objective of this test method is to develop data indicating the effect of violating the integrity of the fabric (or fabric-interliner) protection and exposing the padding to the source of heat (see Appendix X3).

5.3 Quantitative heat release measurements provide information which is useful for product design and product development, for mattresses or furniture destined for correctional occupancies.

5.4 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. Heat release data from this method will not be predictive of product behavior if the product will not spread flame over its surface under the fire exposure conditions of interest.

5.5 The use of test specimens simulating vandalism allows the investigation of the variation in response between the system as designed by the manufacturer and the way the system is occasionally present in actual use, with the filling material exposed to the incident energy.

5.6 This test method allows alternative strategies to be employed for producing a product (mattress or upholstered furniture) with the required fire-test-response characteristics for the scenario under consideration.

5.7 *Limitations:*

5.7.1 The test data are invalid if any of the events in 5.7.1.1 or 5.7.1.2 occur.

5.7.1.1 Explosive spalling.

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

5.7.2 This test method is not applicable to ignition by cigarettes, or by any other smoldering source.

5.7.3 The ignition source in this test method is a radiant energy source of relatively high intensity (35 kW/m^2 initial test heat flux). It has been shown that this source models well, for furniture composites, a full scale source equivalent to five sheets of newspaper (**2**). It has also been shown that upholstered furniture and mattresses, particularly in public occupancies, are, on occasion, involved in fires after exposure to flaming ignition sources, However, it is not known what fraction of actual flaming mattress or furniture fires occur with ignitions more or less intense than the one modeled here.

5.7.4 It is not known whether the results of this test method will be equally valid when it is carried out under conditions different from the specified ones. In particular, it is unclear whether the use of a different ignition source, or the same ignition source but at a different initial test heat flux, will change relative results.

5.7.5 The value of heat release rate corresponding to the critical limit between propagating mattress fires and non-propagating mattress fires is not known.

5.7.6 It is not known what fraction of the vandalism that occurs is represented by the prescribed model used in this standard. However, the method described here is adequate to address one of the major objectives of the standard, namely investigate the effect of the exposed filling material on the fire-test-response characteristics of the composite.

6. Apparatus

6.1 Use the apparatus described in Test Method E1354, also known as the cone calorimeter, for this test.

7. Safety Precautions

7.1 These test procedures involve high temperatures and combustion processes. Therefore, there is a potential hazard for burns, ignition of extraneous objects or clothing, and for inhalation of combustion products.

7.2 The operator must use protective gloves for insertion and removal of the test specimens. The operator must refrain from touching either the cone heater or the associated fixtures while hot, except with the use of protective gloves.

8. Test Specimen Preparation (Method A)

8.1 *Equipment and Supplies for Specimen Preparation* (**3**)*:*

8.1.1 *Cutting Equipment*—Cut foams with a band saw. Use a foam-cutting blade. This blade has no teeth. Instead, it has a wavy scallop to the edge. Ensure that the blade is well sharpened, and make certain that no silicones or other oils are applied to lubricate the blade. Lubrication must be solely with graphite or molybdenum compounds. The band saw blade must make a straight and true cut of the foam; therefore, set the blade guide no higher than 12 mm above the stock to be cut.

8.1.2 *Forming Blocks*—The specimen preparation rests crucially upon the proper use of forming blocks. These blocks are made in dimensions of $98 \times 98 \times 50$ mm. Each of these dimensions must be controlled to ±0.5 mm. As the material for the forming blocks, use a dense wood, such as maple, which is minimally subject to dimensional changes when the humidity is changed. Do not use pine. Use only fully kiln-dried timber for making the forming blocks. Ensure that all surfaces are cut straight and true and are smooth. Do not round the edges but slightly round the corners. It is preferable to lacquer the blocks with an acrylic lacquer to ensure a hard, smooth, stable surface. Make up a minimum of 12 blocks to allow a reasonable number of specimens to be prepared at the same time.

8.1.3 *Adhesive*—Several adhesives have been found suitable for securing the fabrics. The adhesive must be low in flammability and must have suitable holding power to permit inserting the resilient padding, stay in place until the testing is performed (that is, through the required conditioning) and during the flammability test procedure. For the latter, the glued portions of the fabric must neither flame excessively nor retard burning. Adhesives that are based on polychloroprene (neoprene), acrylic or water have been found suitable.

8.1.3.1 *Adhesive Application—*The method of adhesive application depends on the particular adhesive selected. 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. The glued specimen must be left overnight, however, to ensure a good seal. On the other hand, polychloroprene-based adhesives are applied with a brush made of hog bristles or other stiff, course material. The brush must be flat and square cut with a width of 7 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.

8.1.3.2 *Adhesive Checking—*To test the efficiency of an adhesive, apply a small amount on two small pieces of the fabric or interliner to be used. Allow the adhesive to dry (at least overnight), and then attempt to tear the fabric pieces from one another. To be acceptable, the glued pieces must not be able to be separated without tearing the fabric.

8.1.4 *Tape—*Masking tape or other tape with adhesive is used to assist in assembling the test composites. Any type of tape that will adhere adequately 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.

8.1.5 *Aluminum Foil—*Use aluminum foil that is 0.03 to 0.04 mm thick.[6] No other foil thickness shall be used. It is especially important not to substitute a thicker foil.

8.2 *Basic Preparation of Specimens:*

8.2.1 The basic instructions here pertain to specimens that comprise only a single layer of fabric over a single layer of resilient padding. The same instructions apply to specimens where an interliner is laminated onto the back of the fabric. In the latter case, the fabric/interliner combination is treated simply as a fabric alone. For specimens that use multiple padding layers, separate interliner layers, and other more specialized constructions. Supplemental instructions are given in 8.3.

8.2.2 *Cutting of Resilient Padding Blocks—*The thickness of the resilient padding block will normally be 50 mm when a single layer of resilient padding is the only padding material used in the composite. With a typical fabric thickness, this will result in a total specimen thickness of approximately 50.9 mm, which is acceptable. Cut square each resilient padding block with 90° corners and face dimensions of 102.5 ± 0.5 mm by 102.5 ± 0.5 mm. This size ensures that the resilient padding will be compressed during composite assembly, leading to tight, well-formed specimens.

[6] Commercially available "heavy duty foil" has the appropriate thickness.

8.2.2.1 Some resilient paddings have a tendency for high friction against the sawing table and the guide. To make a smooth cut by allowing the resilient padding to slide easier, 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.

8.2.3 *Forming Resilient Padding Blocks—*The cone calorimeter test results will not be repeatable if the density of the resilient padding tested is not controlled very closely. For this purpose, each batch of resilient padding specimens prepared must be checked for mass. It is assumed here that three replicate tests will be performed for each specimen type. Once three blocks of resilient padding have been cut, the mass must be determined. No block shall have a mass of more than 105 % of the mean of the three masses nor a mass of less than 95 %. If such a difference occurs, additional blocks must be cut and the mass determined. The preparation of composites cannot start until three blocks of resilient padding, which conform to the above 5 % deviation limit, have been obtained. Mark the accepted blocks so as to be traceable. Note the mass of each block of resilient padding along with the identification marks of the blocks. Report the mass of resilient padding in the test report along with other information about this test run.

8.2.4 *Fabric Cutting:*

8.2.4.1 First, cut a square of 200 mm by 200 mm.

NOTE 1—Do not cut fabrics on the bias. If the fabric weave is such that the yarns in the two directions do not lie at 90° to each other, do not cut the sample along yarns in both directions, since a skew specimen would result.

8.2.4.2 For cone calorimeter results to be repeatable, fabric for the different replicates must show uniformity. When fabric material is obtained directly from a bolt of cloth, do not cut specimens using closer than 10 to 12 cm to the selvedge (that is, the finished edge).

NOTE 2—This is because sometimes there are weaving or coating variations that occur closer to the selvedge.

8.2.4.3 To assist in verifying that uniform specimens have been cut, check each set of fabric specimens that has been cut to the 200 mm × 200 mm size for mass. Determine the mass once three replicate pieces have been cut. None of the pieces shall have a mass of more than 105 % of the mean of the three, nor a mass of less than 95 %. If such a difference occurs, check to see if any of the pieces have been cut oversized. Trim them if this is found to be the case. If the cause of variation was not due to oversized pieces, then cut additional fabric pieces and determine the mass.

8.2.4.4 If fabrics cannot be prepared to within the 5 % deviation limit, then note the fabric masses and mass range of the specimen. Continue cutting the fabric for each specimen by cutting it to the shape indicated in Fig. 1. Control all given dimensions according to the tolerances given in the figure (±0.5 mm). Only essential dimensions are given in this figure. The 95- and 102-mm dimensions must be checked both before and after cutting. When a fabric having thick yarns is cut, stop cutting outside the 102-mm dimension when a yarn is reached. Do not cut through the yarn if this will make the dimension smaller than 102 mm.

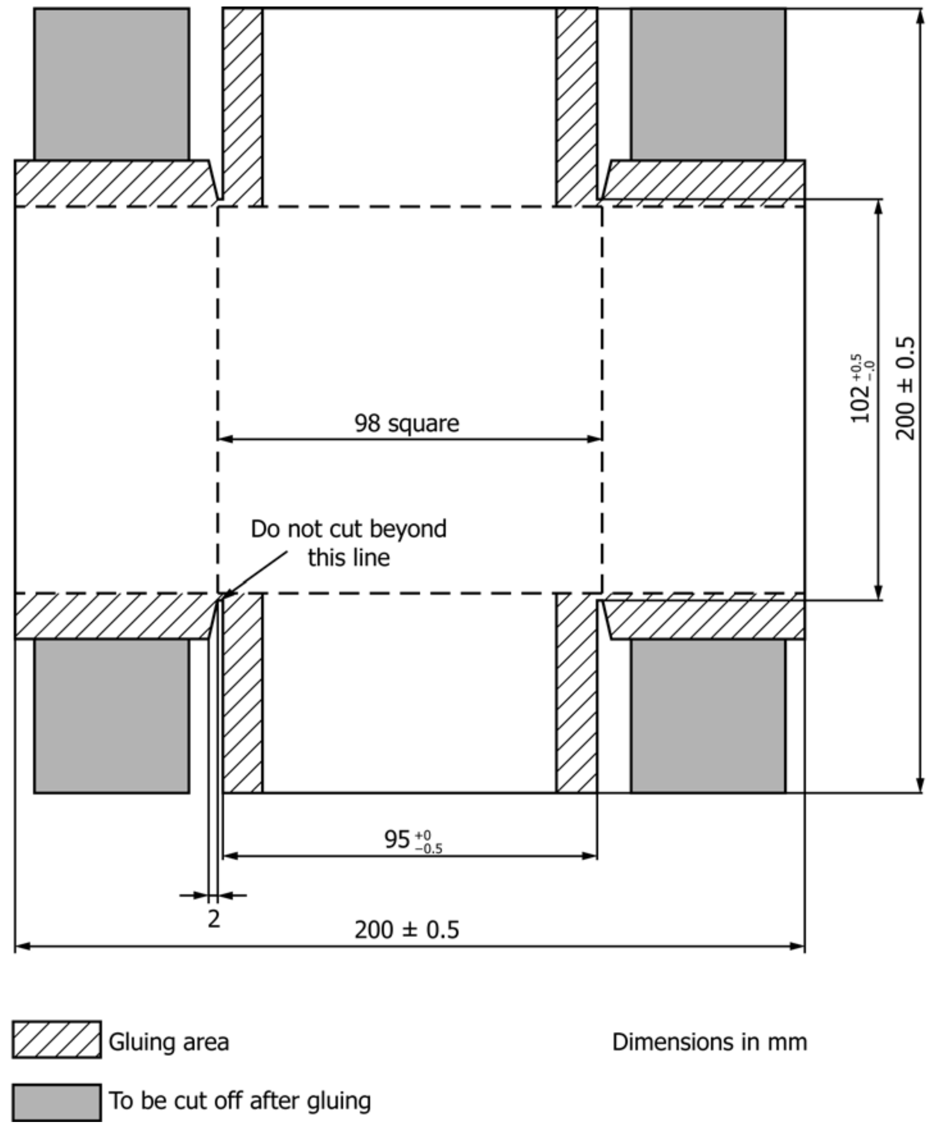

FIG. 1 Fabric Cutting Shape

8.2.5 *Preparing the Fabric Shell:*

8.2.5.1 Assemble the finished shell upside-down upon a forming block. Place the fabric, top-side down, on the table. Place the block on top, making sure that it is well-centered. Bend up the two short sides. Tape each of these sides on to the top of the forming block in the center of the top edge. Bend up the long sides and also tape them to the top of the block. Make sure that the fabric does not slip sideways on the block by checking all four corners of the top face. Ensure that the fabric is snug but not stretched.

8.2.5.2 For sensitive interliners, when paper strips are used, put two strips, forming a cross, under the fabric before placing the forming block on top of it.

NOTE 3—Make the paper strips wider than the tape, but shorter, so that the tape can adhere to the wood block or to itself.

When the fabric is bent up, allow the strips to follow. Secure the paper strip with masking tape to hold it on. Turn the block to stand on one of its short side faces. Using the suitable adhesive, glue down the 10-mm gluing area marked with stripes in Fig. 1 on each corner flap (the area which corresponding to the long side) onto its mating short-side surface. Apply adhesive both to the underneath surface of the flap and to the surface against which it will mate. Use of a 7 to 8-mm wide brush (for solvent based adhesives) will ensure that the glued area is approximately 10 mm wide. Press down immediately after applying the adhesive or after waiting to dry, as appropriate, according to the instructions of the adhesive manufacturer.

8.2.5.3 The grey area shown in Fig. 1 is used for gripping and stretching the fabric around the corners of the forming block. After applying adhesive to the first two corners, turn the block to rest on the side just-glued and apply adhesive to the other two corners. If necessary, tape over the gripping handles and around the corners in order to secure the fabric in the shape of the forming block (see above), or wrap the block with paper strips prior to sealing with masking tape.

8.2.5.4 Allow the specimen to dry face down for 24 h (do not stack specimens during drying). Be certain to clean up the brush or other utensils used to apply the adhesive. Wipe the solvent and any excess adhesive off the brush with a piece of cloth before gluing the next specimen. After 24 h have elapsed, remove all the pieces of masking tape, and trim off the four flaps down to the indicated offset mark so that only the 10-mm glued-down portion is left. Trim any fabric protruding below the bottom edge of the forming block.

8.2.6 *Preparing the Aluminum Foil*—Cut an over-sized piece of aluminum foil. If the foil has a shiny and a dull side, place the shiny side facing up. The actual specimen is slightly larger than the forming block, depending on the thicknesses of the fabric and interliner (if present). Shape the aluminum foil for the final specimen according to either 8.2.6.1 or 8.2.6.2.

8.2.6.1 Use a fabric-covered forming block, encased with the fabric shell top side up. Place the block on the aluminum foil. Hold the block firmly in place and pull each side of the foil up to create the bottom folds. Form the corners by holding the foil firmly in contact with the corner of the specimen. Stretch the corner of the foil and make a 45° fold at each corner. Finally, pull the corners flat against the two sides of the specimen and pat all sides down flat against the specimen. Fig. 2 illustrates the folds to be made. Make sure that the bottom edges and the corners are crisp, straight, and smooth. Remove the forming block and its encasing fabric shell from the foil cup.

8.2.6.2 Set aside one forming block specifically for shaping the aluminum foil containers. Either prepare another block with dimensions 102 × 102 mm (rather than 98 × 98 mm), or glue or tape cardboard to the sides of a block to create one that is 102 × 102 mm. Then use this new block for shaping the aluminum foil as described in 8.2.6.1.

8.2.7 *Assembling the Shell of Resilient Padding and Fabric:*

8.2.7.1 Remove the forming block from the fabric shell. 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 between the thumb and the index finger. Remove any adhesive which remains stuck to the forming block. Make certain that the blocks of resilient padding are identified and tracked according to their masses, which already have been recorded.

8.2.7.2 Compress the four corners of the selected resilient padding block slightly with the fingers and insert the block into the fabric shell. Make sure that the resilient padding is inserted straight. Check each of the resilient padding block corners to see that they line up exactly at the corners of the fabric shell. Check the top face to see that the block of resilient padding is inserted fully into the shell and that there are no gaps. Also check that the bottom of the resilient padding is neatly lined up with the bottom edge of the fabric. If the specimen construction involves additional padding layers or different padding layers, follow similar steps to ensure that a straight, taut assembly is made.

8.2.7.3 Carefully inspect the specimen. Ensure that there are no buckles, warping, twisting, pulling, etc. The fabric must be taut and there must not be any air spaces between the fabric and the padding. If any such problems are discovered and cannot be corrected, discard the specimen. Staple each of the four sides as shown in Fig. 3. Inspect the top face of the specimen. None of the four tabs are to overhang at the top of the specimen. If there is excess material there, trim it with scissors. Be certain that no holes are made in the specimen while doing the trimming.

8.2.8 Assemble the specimen and the foil. Put the assembled specimen in the foil cup. Pat the aluminum foil sides down flush against the specimen. Cut the top of the foil to the flush with the top of the specimen. Open up slightly the corners of the aluminum foil and pull the foil top about 20 mm away from the specimen. This will allow good access of air in the conditioning chamber.

8.2.9 *Conditioning*—Place the specimen in the conditioning chamber for 24 h. Condition to moisture equilibrium (constant mass) at an ambient temperature of 23 ± 3°C and a relative humidity of 50 ± 5 %.

8.2.10 *Final Preparation*—Remove the specimen from the conditioning chamber. Check that the specimen is wrinkle-free, smooth and visually completely uniform and symmetrical. Fix or reject if defects are found. Determine the specimen mass with and without the aluminum foil. Pat the aluminum foil

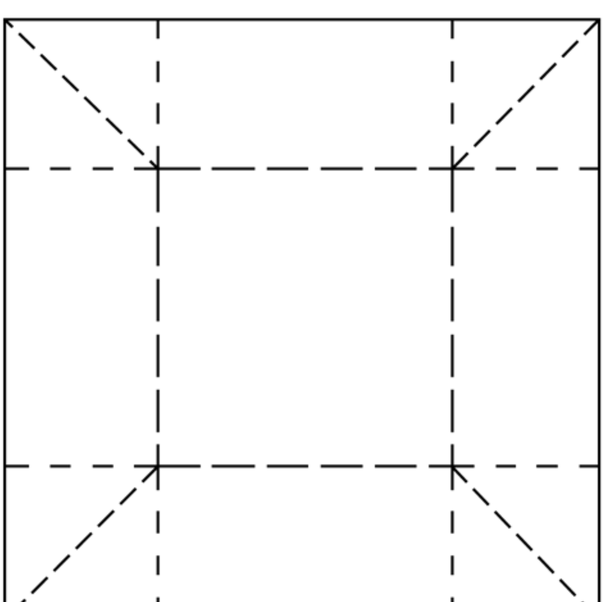

FIG. 2 Folding of Foil

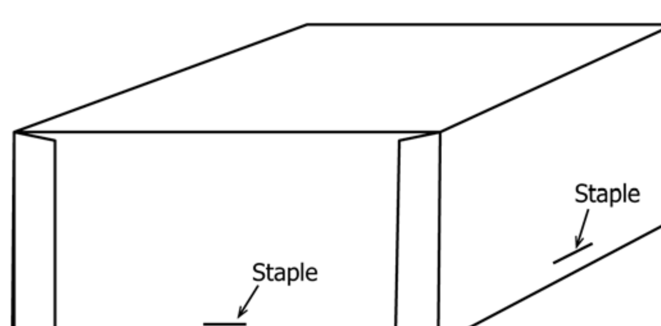

FIG. 3 Assembled Specimen

sides again down flush against the specimen. Place the specimen on the sample holder. Gently push down on the top of the specimen, pushing against the ceramic fibre blanket. This ensures that the bottom conforms smoothly to the same bottom conditions as well be seen during the testing. The specimen is now ready to be tested.

8.3 *Preparation of Specimens with Multiple Layers and Specialized Constructions:*

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

8.3.2 *Specimens that Use a Separate Interliner Layer:*

8.3.2.1 Specimens that use a separate interliner layer are prepared according to the instructions above but with the following special provisions. For these composites, the forming block is covered twice, first with the interliner then with the fabric, using the following steps. Some interliners are mechanically quite fragile. Avoid tearing them when the masking tape is stripped off. Test the tape to be used first to make sure that it can be smoothly pulled off the interliner without damage.

8.3.2.2 Select an alternate tape or use paper strips if needed. Cut the interliner using the same method as described for cutting fabrics (in 8.2.4). Glue up the interliner around the forming block using the same instructions as for fabrics (8.2.5). Leave the specimen to dry for 24 h. After 24 h have elapsed, remove all the pieces of masking tape. If there is any interliner protruding below the bottom edge of the forming block, trim such excess off with scissors. The forming block is now covered with a layer of interliner.

8.3.2.3 Once this is done, follow the instructions above for cutting and preparing the fabric. To minimize thickness variations along the completed assembly, when placing the fabric on top of the interlined turn its orientation by 90°. This will make the two sides where fabric flaps are glued not to be lined up with the similar flaps on the interlined but rather so that two of the sides of the finished specimen will contain doubled-up areas of fabric flaps and the two other sides will contain doubled-up areas of interliner flaps and continue on to 8.2.6.

8.3.3 Specimens that use a polyester fiber topper layer on top of the foam.

8.3.3.1 If a polyester fiber batting layer is present over the top of the foam, the padding assembly is prepared according to 8.3.3.2 or 8.3.3.3.

8.3.3.2 If the uncompressed polyester fiber layer is 20-mm thick or less, compress it to one half of that thickness in the final assembly. The foam block thickness then is to be the difference between 50 mm and one half of the uncompressed thickness of the polyester fiber layer.

8.3.3.3 If the uncompressed polyester fiber layer is greater than 20 mm, cut back the polyester fiber layer to give a 20 mm depth and the preparation continued as above. Place the polyester topper layer on top of the foam block. Use this composite block wherever the general instructions refer to actions to be taken on the "block of resilient padding."

8.3.3.4 During final assembly of the padding inside the fabric, compress the polyester plus foam composite block so as to have a total depth of 50 mm when the assembly is finished.

8.3.4 *Specimens that Use More Than One Padding Layer (except polyester fiber)*—Use any padding layers thinner than 8 mm in their natural thickness. Proportion the thickness of each remaining layer (those ≥8 mm in thickness) 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. Once the appropriate layers are prepared according to this instruction, they are used in exactly the same way as is the single foam block that forms the basis of the general instructions above.

8.3.5 *Specimens from Furniture Items of Unusually Thin Construction:*

8.3.5.1 For some furniture items, the total thickness of the entire padding layer is less than 50 mm. Examples include thinly padded chairs and innerspring mattresses. For such items, the padding layer is still tested in a 50-mm depth.

8.3.5.2 To do this requires that two or more layers of padding be stacked together to achieve the required 50-mm depth. When testing cone calorimeter samples that represent known full-scale constructions, clearly identify in the test report what the maximum thickness of padding found in the full-scale article was, when that thickness was less than 50 mm.

8.3.5.3 For specimens where the padding comprises layers of several different materials yet with a total thickness of less than 50 mm, each layer will be laid-up in an increased thickness so that the total padding thickness is 50 mm and maintaining the ratios of individual layer thickness in the same proportion as occurs in the full-scale article. The layers in the test specimen are to be laid-up in the same order as the layers of the furniture item.

8.3.6 *Specimens that Use Loose Filling Materials:*

8.3.6.1 Loose filling materials include feathers, down, shredded foam, and any other fillings that are poured into place rather than cut to size. Cone calorimeter samples for these shall be prepared by the manufacturer rather than by the testing laboratory. The manufacturer shall prepare a "square pillow" filled with the product. This will involve a fabric casing made from that fabric (not normally the outside upholstery fabric) that is used in the full-scale furniture article to hold together the loose filling material.

8.3.6.2 The outside dimensions of this casing is to be 98 mm × 98 mm × 48 mm. The fabric casing must be prepared from two pieces. The top piece is to be cut slightly larger than 200 mm × 200 mm. The exact dimensions will depend on the needs of the sewing technique. The thread to be used to sew the casings must replicate the material used in the end product. The casing top piece is now folded in a waterfall fold; see Fig. 4. The four corners are tucked inside. The blind opening left at each corner is then sewn shut. The second fabric piece (not shown in this figure) is used to form the bottom. Its size is slightly larger than 100 mm × 100 mm.

8.3.6.3 The bottom piece is to be sewn to the bottom edge of the top piece by sewing around all the four sides. Before the bottom is sewn shut, completely fill the inside of the casing with the same density of material as will be used in the

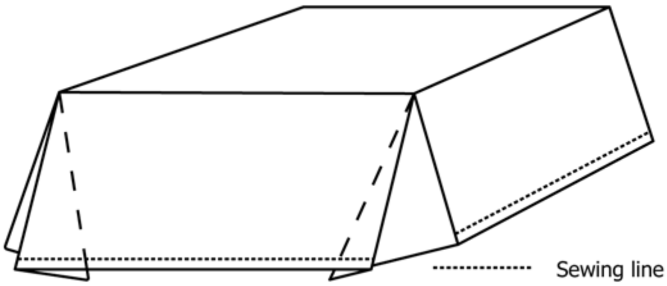

FIG. 4 Folding of Fabric for Loose Filling Materials

intended test article. Make sure that the corners are filled evenly and that any bulging of the top is minimized. Also, it is possible to have multi-layer constructions, where the loose fill material does not comprise the entire depth of construction, with the remaining depth comprising foam, battings, or other non-loose materials. In such cases, construct the fabric casing to the dimensions specified above. For such multi-layer constructions, fill the casing inside with proportionate depths of loose-fill and non-loose fill material, proportioned to the depths in the full-scale furniture article.

8.4 *Simulated Vandalism:*

8.4.1 Once the specimen has been mounted on the holder, cut the outer layer(s) of the composite with a sharp implement.

8.4.2 Make a cut in the shape of an X, starting 10 ± 2 mm from each corner of the surface of the mounted specimen. This means that the length of each of the two cuts will be approximately 120 mm and that they will meet in the center of the specimen.

8.4.3 Ensure that the cuts are deep enough to expose the deepest layer.

9. Calibration

9.1 Calibrate the test apparatus as directed in Test Method E1354. Position the cone heater for a horizontal specimen orientation and set the radiant source to the required initial test heat flux level of 35 $kW/m^2 \pm 1 kW/m^2$.

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

9.3 Position the spark igniter (sparker) as high as possible, without hitting the cone heater assembly.

9.4 Some padding materials swell up. If the swelling of the specimen causes the specimen to come into contact with the sparker or the heater base plate, discard the mass loss and the heat of combustion value measured in the test.

10. Conditioning

10.1 Condition the specimens to moisture equilibrium (constant weight) at an ambient temperature of 23 ± 3°C and a relative humidity of 50 ± 5 %.

11. Procedure

11.1 Maintain the holder at room temperature until the test.

11.2 Prepare the data collection system for testing according to the operating procedures for the system. Place the specimen, in the appropriate holder, on the load cell. The edge frame is not required.

11.3 Energize the sparker and move it into place as rapidly as possible after specimen insertion.

11.4 Record the time to flaming ignition. Move the sparker out of the flame. Note that the ignition time is the time for sustained flaming to start. Therefore, when the timer is stopped at the end of the 10 s observation period, the time to be reported is the value on timer, minus 10 s.

11.5 Collect data until flaming or other signs of combustion cease or until 20 min have elapsed. Observe and record physical changes to the specimen, such as melting, swelling, and cracking.

11.6 Remove the specimen holder.

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

11.8 If the specimen did not ignite within 10 min, remove and discard.

11.9 Test a minimum of three specimens of each sample.

12. Calculations

12.1 Calculate time to sustained flaming, heat release rate, total heat release, mass loss, and effective heat combustion as indicated in Test Method E1354.

12.2 The theoretical background for the understanding of the equations used is found in work by Janssens (**4**).

13. Report

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

13.1.1 Specimen identification or number,

13.1.2 Manufacturer or submitter,

13.1.3 Date of test,

13.1.4 Composition or generic identification,

13.1.5 Details of preparation, and

13.1.6 Number of replicate specimens tested. (The minimum is three.)

13.2 Include the following information for each specimen:

13.2.1 Specimen thickness (mm),

13.2.2 Initial specimen mass, measured on the load cell (g),

13.2.3 Initial test heat flux and exhaust system flow rate,

13.2.4 Time to sustained flaming (s),

13.2.5 Curve of heat release rate versus time,

13.2.6 Average heat release rate for the first 180 s after ignition (kW/m^2),

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

13.2.8 Total heat released by the specimen (MJ/m^2),

13.2.9 Average effective heat of combustion for entire test (MJ/kg),

13.2.10 Mass remaining at termination of test (g),

13.2.11 Specimen mass loss (g),

13.2.12 Curve of effective heat of combustion versus time (optional),

13.2.13 Additional observations, if any, and

13.2.14 Difficulties encountered in testing, if any.

13.3 Average the following final values for all specimens:

13.3.1 Time to sustained flaming (s),

13.3.2 Average heat release rate value (kW/m^2) over the first 180 s after ignition,

13.3.3 Average effective heat of combustion (MJ/kg) for the entire 20 min test,

13.3.4 Peak heat release rate (kW/m^2), and

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

14. Precision and Bias

14.1 *Precision*—The precision of this test method has not been determined. Results of a planned interlaboratory test series will be included when available.

14.2 *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 approximate 13.1 MJ 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, the uncertainty is reduced by determining the net heat of combustion from oxygen bomb measurements at the stoichiometric oxygen/fuel mass ratio from ultimate elemental analysis. For most testing, this is not practical, since specimens are composites, most of which are non-homogeneous and capable of exhibiting degradation reactions. Therefore, for unknown samples, a ±5 % accuracy limit is seen. For reference materials, however, careful determination of the net heat released per unit of oxygen consumed will make this source of uncertainty substantially less.

15. Keywords

15.1 calorimeter; cone calorimeter; correction facility; fire; fire-test-response; heat release; ignition; mattress; oxygen consumption; small scale; upholstered furniture; vandalism

ANNEX

(Mandatory Information)

A1. TEST SPECIMEN PREPARATION (METHOD B)

A1.1 In instances where the highest quality of specimen preparation is not needed, such as in screening tests, an alternate test specimen method is available. The construction of the test specimens is to reflect the actual construction used in the upholstered or mattress items. The test specimens are intended to represent the padding and upholstery fabric materials, but not frame materials, welt cord, decking construction articles, or dust covers. In all cases, the test specimen should 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. If there is only one padding material, its thickness should be such that the total specimen thickness, including fabric and any intermediate layers, is 50 mm. If the construction involves several material layers, the specimen should comprise all of the types of layers sampled in the following manner. Upholstery fabric or intermediate layers 8-mm thick or less should be used in full thickness. The depth taken up by the full thickness layers should be added up and subtracted from 50 mm. For the remaining depth, the remaining layers should be sectioned in thickness such that the ratio of their thicknesses in the test specimen is the same as that in the upholstered item.

A1.2 The upholstery or mattress fabric and intermediate layers (if any) should be cut to a size of approximately 200 × 200 mm, with a square 50 × 50 mm removed at each corner. The length and width of the padding layers should be slightly less than 100 mm so that the fabric and intermediate layers can be folded over each of the four sides and produce a specimen measuring 100-mm long × 100-mm wide. The folded over sides should be edge stapled to the padding near the bottom of the specimen.

A1.3 Take care to trim the fabric and intermediate layers so that they are even with the bottom of the test specimen. Otherwise, the specimen will not rest firmly and evenly on the specimen holder.

A1.4 Cover the four sides and bottom of the finished test specimen with aluminum foil (shiny side in) approximately 0.04-mm thick. A single sheet of aluminum foil, approximately 200 × 200 mm, should be used. The corners should be folded at a 45° angle flush against the sides.

A1.5 Condition the specimens to moisture equilibrium (constant mass) at an ambient temperature of 23 ± 3°C and a relative humidity of 50 ± 5 %.

APPENDIXES

(Nonmandatory Information)

X1. COMMENTARY

X1.1 *Introduction*—This appendix provides a discussion of the prediction of the heat release rate of full-scale upholstered items. Predictive methods are discussed and references for further reading are given.

X1.2 Fire behavior of full-scale upholstered furniture or mattresses can be predicted by using a fire model and appropriate experimental data. Such a procedure has been described (**5**); it is, however, highly complex and not easy to use. For most purposes, estimation of the fire behavior of upholstered furniture or mattresses can be done on the basis of simple predictive correlations. The full-scale fire hazard variable which is to be predicted is the full scale peak heat release rate (Pk $\dot{Q}_{(full\ scale)}$). The bench-scale measurement available is the 180 s average heat release rate per exposed specimen face (Avg $\dot{Q}''_{(bench\ scale)}$). The predictive method to be used depends on the application intended. For residential furniture, a predictive method was developed at the National Institute of Standards and Technology and published in a 1985 monograph (**6**). This reference also discusses many of the engineering principles of upholstered furniture flammability and is an adequate source for a general overview.

X1.3 Cone calorimeter tests of upholstered furniture have also been made at an initial test heat flux of 25 kW/m^2 (**7, 8**). Such work has shown that this lower initial text heat flux is also adequate to obtain heat release data, but only when applied to furniture in residential occupancies.

X1.4 Heat release rate of seating furniture for institutional and other high-risk occupancies is measured in Test Method E1537 and in California Technical Bulletin 133 (TB 133). Corresponding data for mattresses is measured in Test Method E1590 and in California Technical Bulletin 129 (TB 129). TB 129 is not actually used for correctional facilities. Additional data for fire testing of mattresses using heat release equipment has also recently been published (**9**).

X1.5 A joint investigation by the National Institute of Standards and Technology (NIST) and the California Bureau of Home Furnishings (CBHF) showed that a correlation exists between temperature increase in and heat release rate in the duct (**10**). The investigation also showed that heat release rates measured in the "California room" (with dimensions 3.7 by 3.0 by 2.4 m high), in the "ASTM room" (with dimensions 2.4 by 3.7 by 2.4 m high) and in a "furniture calorimeter" are substantially equal, provided they are not higher than 600 kW.

X1.6 Test Methods E1537 and E1590 tests can be conducted in the "California room," the "ASTM room," or in a "furniture calorimeter," with equally acceptable results if the rooms are lined with fire rated gypsum board. The furniture is located on a weighing platform in the rear corner farthest from the doorway. The ignition source is a gas burner placed at the back of the seat. Temperature in the room or heat release, by oxygen consumption in the duct, are the primary measurements in this test. Other measurements include concentration of carbon monoxide, smoke opacity and mass loss.

X1.7 For the series of tests described in (**10**), small-scale experiments were also conducted, following the protocol set out in Test Method E1474. Ten sets of full-scale chairs were tested at NIST and at CBHF. These were chosen to provide a large range of fire performance.

X1.8 For a chair to pass the full scale TB 133 test, it must show a heat release rate of 80 kW, or less. The test data developed during the study showed that a heat release rate of 80 kW in the full scale test corresponds to a bench scale heat release rate measurement (180 s average value) of 107 kW/m^2.

X1.9 The general predictive relationship proposed by NIST (**10**) is:

$$\text{If: Avg } \dot{Q}''_{\text{(bench scale)}} < 100 \text{ kW/m}^2\text{, then:} \qquad (X1.1)$$

$$\text{Pk } \dot{Q}_{\text{(full scale)}} = 0.75 \times \text{Avg } \dot{Q}''_{\text{(bench scale)}}$$

where $\dot{Q}_{(full\ scale)}$ stands for the peak heat release rate in the full scale and Avg $\dot{Q}''_{(bench\ scale)}$ stands for the 180 s average heat release rate per exposed specimen face, in the bench scale. This is the non self-propagating fires region.

X1.10 For chairs with a 180 s average heat release rate larger than 100 kW/m^2, another relationship is obeyed. The latter is given in TB 133, but is of limited importance to institutional mattresses or furniture since the predicted full scale values are well in excess of 80 kW. It must also be noted that the predictive relationship established by Eq X1.1 is applicable only to the type of ignition source used in the CA TB 133 test. It is likely that changing the ignition source will alter the relationship somewhat, although generally not to a major extent.

X2. TEST SPECIMEN PREPARATION

X2.1 A series of experiments was performed to determine the effect of the fabric and liner cutting and mounting procedure used for specimen preparation on selected responses of the cone calorimeter test in Test Method E1474. Two levels of each factor affecting the cone calorimeter responses were used. The levels were chosen to provide a wide range of effects.

X2.2 Non-flame retarded polyurethane foam and flame-retarded melamine-filled polyurethane foam were used as the two foam levels. The levels of fabric were cotton and polypropylene. Cotton fabric is observed to char and polypropylene fabric is observed to melt. No liner and a polymide liner provided the two levels in liners.

X2.3 The largest difference in the effect of the fabric treatment was expected to be the amount of fabric on the test specimen. A 200 by 200 mm piece of fabric folded over the foam, identified as the folded fabric treatment, was the sample tested with the largest amount of material and a 100 by 100 mm piece of fabric stapled to the top of the specimen, identified as the top-only fabric treatment, was the one with the least. Although it is possible that the liner contributes a certain amount of heat itself and the amount of liner is pertinent, the containment or suppression of products of pyrolysis was considered most critical. The folded and the cut-liner treatments were chosen because with the folded treatment the corners are closed and with the cut treatment the corners are open. The folded liner treatment consisted of a 200 by 200 mm piece of liner folded over the foam block. The cut-liner treatment is a 200 by 200 mm piece of liner with 50 mm squares cut from the corners folded over the foam.

X2.4 The results of an analysis of this series of experiments identified the variables of importance. Details are given in the Appendix of Test Method E1474.

X3. RATIONALE FOR USING THIS METHOD

X3.1 This test method differs from Test Method E1474 only in the fact that the surface of the specimen has been cut to expose the filling material.

X3.2 A common strategy employed to produce mattress or furniture products which perform well in the appropriate fire-test-response standard (TB 129 or TB 133) is the use of barriers or interliners, between the cover fabric and the filling.

X3.3 Such barriers or interliners, when adequately upholstered, have shown effectiveness in preventing accidental ignition of the item, when exposed to a number of ignition sources. However, they are not always equally adequate to address the problem of purposeful ignition, preceded by the direct exposure of the filling material to the energy source.

X3.4 The present test method provides a means for addressing this specific problem if a product manufacturer or a specifier wishes; this can be compared to the results of Test Method E1474.

X3.5 It has been shown that vandalism is a relatively frequent occurrence in correctional facilities. It is impossible to predict in which way a particular mattress or furniture will be vandalized in each case. However, the important consideration is that vandalism generally leads to a breach in the protection of the padding material offered by the fabric or fabric/interliner system. The present test method offers an arbitrary, but standardized, means of producing such a breach of protection. In this way, the test method offers a realistic representation of vandalism.

X4. SMOKE OBSCURATION

X4.1 The test equipment is also capable of measuring smoke obscuration, as described in Test Method E1354.

X5. IMPLICATIONS FOR FIRE HAZARD ASSESSMENT

X5.1 The heat release rate is one of the most important variables, and perhaps even the single most important variable, in determining the hazard from a fire (**11-15**). In particular, the heat release rate is a measure of the intensity of the fire. The heat release rate and the amount of heat released will determine the extent to which other materials, products, or assemblies in the fire compartment will be ignited and spread the fire further. Thus, an item which releases heat very rapidly (that is, has a high rate of heat release) is more likely to ignite a nearby article than one which has a low rate of heat release. The amount of smoke generated is usually a direct function of the heat release rate.

X5.2 It is important to point out that it is often not possible to predict the heat released by a product made up of more than one material from the separate heats released by the individual components. Some recent literature describes heat release by materials (**16 and 17**) and the entire issue of heat release rate (**18**).

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