Standard Guide for Selection of Fire Test Methods for the Assessment of Upholstered Furnishings in Detention and Correctional Facilities[1]

This standard is issued under the fixed designation F 1870; 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.

1. Scope

1.1 This is a fire-test-response standard.

1.2 This guide is intended to provide guidance for the selection of test methods that are applicable to determining fire-test-response characteristics of upholstered furniture items contained within a detention cell.

1.3 This guide is intended for use by those interested in assessing the fire properties of the upholstery products and their component materials or composites, within cells and other areas (such as isolation lounges) of detention and correctional occupancies.

1.4 This guide includes standard test methods promulgated by ASTM, NFPA, Underwriters Laboratories, trade associations and government agencies and other proposed test methods. It does not include industrial materials specification tests. The guide indicates some means by which modifications of standard test methods lead to potential achievement of certain testing goals.

1.5 Use the SI system of units in referee decisions associated with this guide; see Practice E 380. The units given in parentheses are for information only. Some individual standards referenced use inch-pound units for referee decisions.

1.6 This guide contains four types of test methods, namely: (*a*) generic small-scale methods, (*b*) specific applications of small-scale test methods to particular products or composites of products, associated with upholstery items, (*c*) real-scale test methods where actual upholstery products are exposed to heat or flame and (*d*) guides explaining the concepts involved with room-scale testing.

1.7 The main fire-test-response characteristics investigated in this guide are: ignitability, ease of extinction, flame spread, heat release, smoke obscuration and toxic potency of smoke.

1.8 This standard measures and describes 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.

1.9 Fire testing of products and materials is inherently hazardous, and adequate safeguards for personnel and property shall be employed in conducting these tests. This test method may involve hazardous materials, operations, and equipment.

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.*

2. Referenced Documents

2.1 *ASTM Standards:*

D 123 Terminology of Textiles[2]

D 1929 Test Method for Ignition Properties of Plastics[3]

D 2863 Test Method for Measuring the Minimum Oxygen Concentration to Support Candle-Like Combustion of Plastics (Oxygen Index)[4]

D 3675 Test Method for Surface Flammability of Flexible Cellular Materials Using a Radiant Heat Energy Source[4]

E 162 Test Method for Surface Flammability of Materials Using a Radiant Heat Energy Source[5]

E 176 Terminology of Fire Standards[5]

E 380 Practice for Use of the International System of Units (SI) (the Modernized Metric System)[6]

E 603 Guide for Room Fire Experiments[5]

E 662 Test Method for Specific Optical Density of Smoke Generated by Solid Materials[5]

E 906 Test Method for Heat and Visible Smoke Release Rates for Materials and Products[5]

E 1321 Test Method for Determining Material Ignition and Flame Spread Properties[5]

E 1352 Test Method for Cigarette Ignition Resistance of Mock-Up Upholstered Furniture Assemblies[5]

E 1353 Test Methods for Cigarette Ignition Resistance of Components of Upholstered Furniture[5]

E 1354 Test Method for Heat and Visible Smoke Release

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[2] *Annual Book of ASTM Standards*, Vol 07.01.

[3] *Annual Book of ASTM Standards*, Vol 08.01.

[4] *Annual Book of ASTM Standards*, Vol 08.02.

[5] *Annual Book of ASTM Standards*, Vol 04.07.

[6] *Annual Book of ASTM Standards*, Vol 14.02.

Rates for Materials and Products Using an Oxygen Consumption Calorimeter[5]

E 1474 Test Method for Determining the Heat Release Rate of Upholstered Furniture and Mattress Components or Composites Using a Bench Scale Oxygen Consumption Calorimeter[5]

E 1537 Test Method for Testing of Upholstered Seating Furniture[5]

E 1546 Guide for the Development of Fire Hazard Assessment Standards[5]

E 1590 Test Method for Testing of Mattresses[5]

E 1678 Test Method for Measuring Smoke Toxicity for Use in Fire Hazard Analysis[5]

F 1534 Test Method for Determining Changes in Fire-Test-Response Characteristics of Cushioning Materials After Water Leaching[7]

F 1550 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[7]

2.2 *International Organization for Standardization (ISO) Standards:*[8]

ISO Guide 52 Glossary of Fire Terms and Definitions

ISO 3261 Fire Tests - Vocabulary.

ISO 4880 Burning Behaviour of Textiles and Textile Products - Vocabulary.

ISO 5659-2 Determination of Specific Optical Density by a Single-Chamber Test

ISO 9705 Full Scale Room Fire Test for Surface Products

2.3 *National Fire Protection Association (NFPA) Standards:*[9]

NFPA 101 National Life Safety Code

NFPA 258 Research Test Method for Determining Smoke Generation of Solid Materials

NFPA 260 Methods of Test and Classification System for Cigarette Ignition Resistance of Components of Upholstered Furniture

NFPA 261 Method of Test for Determining Resistance of Mock-Up Upholstered Furniture Material Assemblies to Ignition by Smoldering Cigarettes

NFPA 263 Method of Test for Heat and Visible Smoke Release Rates for Materials and Products

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

NFPA 266 Method of Test for Fire Characteristics of Upholstered Furniture Exposed to Flaming Ignition Source

NFPA 269 Test Method for Developing Toxic Potency Data for Use in Fire Hazard Modeling

NFPA 271 Method of Test for Heat and Visible Smoke Release Rates for Materials and Products Using an Oxygen Consumption Calorimeter

NFPA 272 Method of Test for Heat Release Rates for Upholstered Furniture Components or Composites and Mattresses Using an Oxygen Consumption Calorimeter

NFPA 701 Methods of Fire Tests for Flame-Resistant Textiles or Films

2.4 *California Standards:*[10]

California Technical Bulletin 116 (CA TB 116) (January 1980), "Requirements, Test Procedure and Apparatus for Testing the Flame Retardance of Upholstered Furniture"

California Technical Bulletin 117 (CA TB 117) (January 1980), "Requirements, Test Procedure and Apparatus for Testing the Flame Retardance of Resilient Filling Materials Used in Upholstered Furniture"

California Technical Bulletin 121 (CA TB 121) (April 1980), Flammability Test Procedure for Mattresses for Use in Public Occupancies

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

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

2.5 *Consumer Product Safety Commission (CPSC) Standards:*[11]

CFR Part 1610 Standard for the Flammability of Clothing Textiles (General Wearing Apparel)

CFR Part 1632 Standard for the Flammability of Mattresses and Mattress Pads (formerly DOC FF4-72, 40 FR 59940)

2.6 *Federal Standards:*[12]

Americans with Disabilities Act

FED STD 191A Textile Test Method 5830 (July 20, 1978)

2.7 *Model Building Codes:*

National Building Code[13]

Standard Building Code[14]

Uniform Building Code[15]

3. Terminology

3.1 For definitions of terms used in this test method and associated with fire issues refer to the terminology contained in Terminology E 176, ISO Guide 52 and ISO 3261. In case of conflict, the definitions given in Terminology E 176 shall prevail. For definitions of terms used in this guide and associated with textile issues refer to the terminology contained in Terminology D 123 and ISO 4880. In case of conflict, the definitions given in Terminology D 123 shall prevail.

3.2 *Definitions of Terms Specific to This Standard:*

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[7] *Annual Book of ASTM Standards*, Vol 15.07.

[8] Available from International Standardization Organization, P.O. Box 56, CH-1211; Geneva 20, Switzerland or from American National Standards Institute, 11 West 42nd Street, New York, NY, 10046.

[9] Available from National Fire Protection Association (NFPA), 1 Batterymarch Park, Quincy, MA, 02269-9101.

[10] 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.

[11] Available from US Consumer Product Safety Commission, Washington, DC, 20207.

[12] Available from General Services Administration, Specifications Activity, Printed Materials Supply Division, Building 197, Naval Weapons Plant, Washington, DC, 20407.

[13] Available from Building Officials and Code Administrators International, Inc., 4051 West Flossmoor Road, Country Club Hills, IL, 60478-5795.

[14] Available from Southern Building Code Congress International, Inc., 900 Montclair Road, Birmingham, AL, 35213-1206.

[15] Available from International Conference of Building Officials, Inc., 5360 Workman Mill Road, Whittier, CA, 90601.

3.2.1 *fire hazard*, *n*—the potential for harm associated with fire.

3.2.1.1 *Discussion*—A fire may pose one or more types of hazard to people, animals, or property. These hazards are associated with the environment and with a number of fire-test-response characteristics of materials, products, or assemblies including but not limited to ease of ignition, flame spread, rate of heat release, smoke generation and obscuration, toxicity of combustion products and ease of extinguishment.

3.2.2 *fire performance*, *n*—response of a material, product, or assembly in a specific fire, other than in a fire test involving controlled conditions (different from fire-test-response characteristic, q.v.).

3.2.2.1 *Discussion*—The ASTM Policy on Fire Standards distinguishes between the response of materials, products or assemblies to heat and flame, "under controlled conditions," which is fire-test-response characteristic, and "under actual fire conditions," which is fire performance. Fire performance depends on the occasion or environment and may not be measurable. In view of the limited availability of fire-performance data, the response to one or more fire tests, appropriately recognized as representing end-use conditions, is generally used as a predictor of the fire performance of a material, product, or assembly.

3.2.3 *fire scenario*, *n*—a detailed description of conditions, including environmental, of one or more of the stages from before ignition to the completion of combustion in an actual fire at a specific location, or in a full-scale simulation.

3.2.4 *fire-test-response characteristic*, *n*—a response characteristic of a material, product, or assembly, to a prescribed source of heat or flame, under controlled fire conditions; such response characteristics may include but are not limited to ease of ignition, flame spread, heat release, mass loss, smoke generation, fire endurance, and toxic potency of smoke.

3.2.4.1 *Discussion*—A fire-test-response characteristic can be influenced by variables of exposure such as ignition intensity, ventilation, geometry of item or enclosure, humidity, or oxygen concentration. It is not an intrinsic property such as specific heat, thermal conductivity, or heat of combustion, where the value is independent of test variables. A fire-test-response characteristic may be described in one of several terms. Smoke generation, for example, may be described as smoke opacity, change of opacity with time, or smoke weight. No quantitative correlation need exist between values of a response characteristic for two or more materials, products, or assemblies, as measured by two or more approaches, or tested under two or more sets of conditions for a given method.

3.2.5 *flashover*, *n*—the rapid transition to a state of total surface involvement in a fire of combustible materials within an enclosure.

3.2.5.1 *Discussion*—Flashover occurs when the surface temperatures of combustible contents rise, producing pyrolysis gases, and the room heat flux becomes sufficient to heat all such gases to their ignition temperatures. This commonly occurs when the upper layer temperature reaches 600°C or a radiant heat flux at the floor of at least 20 kW/m^2.

3.2.6 *heat release rate*, *n*—the calorific energy released per unit time by the combustion of a material under specified test conditions.

3.2.7 *smoke*, *n*—the airborne solid and liquid particulates and gases evolved when a material undergoes pyrolysis and combustion.

3.2.8 *smoke toxicity*, *n*—the propensity of smoke to produce adverse biochemical or physiological effects.

3.2.9 *toxic potency (as applied to inhalation of smoke or its component gases)*, *n*—a quantitative expression relating concentration and exposure time to a particular degree of adverse physiological response, for example, death, on exposure of humans or animals.

3.2.9.1 *Discussion*—The toxic potency of the smoke from any material, product, or assembly is related to the composition of that smoke which, in turn, is dependent upon the conditions under which the smoke is generated.

3.2.10 *upholstered furniture*, *n*—a unit of interior furnishing that (*a*) contains any surface that is covered, in whole or in part, with a fabric or other upholstery cover material, (*b*) contains upholstery padding or filling materials, and (*c*) is intended for sitting or reclining upon.

3.2.11 *upholstery cover fabric*, *n*—the outermost layer of fabric or other material used to enclose the main support system or upholstery padding, or both, used in the furniture item.

3.2.12 *upholstery padding*, *n*—the padding, stuffing, or filling materials used in a furniture item, which may be either loose or attached, enclosed by an upholstery fabric, or located between the upholstery fabric and support system, if present.

3.2.12.1 *Discussion*—This includes, but is not limited to, materials such as foams, cotton batting, polyester fiberfill, bonded cellulose or down.

4. Summary of Guide

4.1 The test methods identified in this guide can be subdivided in four groups, namely: (*a*) generic small-scale methods; (*b*) specific applications of small-scale test methods applied to particular products or composites of products, associated with upholstery items; (*c*) real-scale test methods where actual upholstery products (or full-scale mock-ups) are exposed to heat or flame and (*d*) guides which explain the concepts required to conduct room-scale testing, or design specific test methods.

4.2 The small-scale test methods relevant to upholstery materials or products for use in detention cells, determine the following fire-test-response characteristics: ignitability, ease of extinction, flame spread, heat release (both amount and rate), smoke obscuration, and toxic potency of smoke.

4.3 Applications small scale test methods are those designed specifically with upholstery products in mind and they assess ignitability and heat release principally. However, of particular interest are the tests designed to assess the effect of vandalism, which is a phenomenon specially prevalent, even if not unique, in detention environments.

4.4 Real-scale fire tests for upholstery products have, most often, not been specifically designed for the detention environment, and are likely to be inappropriate for it.

4.4.1 However, it may be feasible to modify some standard methods to make the procedures more relevant to a very high risk occupancy such as the detention environment.

4.4.2 Such modifications may include alterations to protective layers due to wear, tear, or abuse, characteristic of the environment, which potentially affect the fire-test-response characteristics of the item.

4.4.3 The special advantage of real-scale tests is that their use prevents the problem of trying to understand how fire parameters scale up from smaller scale tests. Moreover, since the specimens used in real-scale tests can be identical to the actual product they are intended to represent (unless mock-ups are used), such specimens incorporate all the peculiarities of actual products, including multiple layers of various thicknesses, non-linear edges or seams.

4.4.4 The major disadvantage of real-scale tests is their higher cost and the inherent inconvenience attached to manufacturing products for testing.

4.5 Guides exist which help for the design of ad-hoc tests, or room tests, in order to assess particular characteristics which cannot be determined with standardized methods. Such guides also explain the potential pitfalls and the advantages inherent in this type of method.

4.6 Ad-hoc tests exist which are peculiar to correction and detention occupancies.

5. Significance and Use

5.1 The information presented provides the user with guidance on identification of test methods, and related documents, which are potentially useful to determine fire-test-response characteristics of upholstery products, and the materials of which they are made, present inside detention cells, in detention and correctional facilities. Some information is given about every standard included, so as to allow a judgment as to the potential usefulness of the original method.

5.2 The detention environment has some unique features which potentially require the use of modifications of standard test methods or the application of particular techniques. Some guidance to that effect is also presented.

6. Small Scale Generic Tests

6.1 *Ignitability*:

6.1.1 Ignitability can be assessed in various ways: ignition temperature, time to ignition and ignition flux. The traditional method involved the ignition temperature, while more modern methods use the other ways.

6.1.2 Four test methods are available for assessing ignitability: Test Methods D 1929, E 906, E 1321 and E 1354 (with Test Methods E 906 and E 1354 having NFPA 263 and NFPA 271 as equivalents).

6.1.3 Test Method D 1929 is used to determine the self ignition temperature or the flash ignition temperature (if a pilot gas flame is lit) of materials. The specimens are small pieces, or pellets, and weigh 3 g; they are exposed, inside a vertical furnace tube, electrically-heated, to a pre-set temperature rise rate, with a slow air flow present. No repeatability or reproducibility statement has been developed for this method in the first 30 years after it was issued, and it has not been shown to be an adequate predictor of real scale fire performance. This apparatus is often referred to as the Setchkin furnace, and results from this test are frequently required in specifications and quoted in data sheets. Test Method D 1929 is mentioned because it was specifically designed for ignition temperature, but it has since been shown to be inappropriate for cellular materials used as padding for cushioning. However, it is referenced in the three model building codes, National Building Code, Standard Building Code and Uniform Building Code as a method for determining the suitability of plastic materials for use in construction.

6.1.4 Test Method E 906 (or NFPA 263) is used to determine time to ignition. The specimen is a plaque 150 by 150 mm (6 by 6 in.) (with a maximum thickness of 45 mm (1.8 in.), which is exposed vertically (although horizontal exposure is also feasible) to a pre-set incident heat flux resulting from a set of four radiant globars, in the absence or presence of a pilot gas flame, under a strong air flow. The primary objective of the test method is to determine heat release rate, but other fire-test-response characteristics are assessed simultaneously, including smoke release rate as well as ignitability. The potential for varying the incident heat flux makes the test method very versatile. Repeatability and reproducibility data suggest that the precision is adequate. It has also been used for predictions of full scale fire performance (see also 6.4.2 and 6.5.3 for other uses of this test method). This apparatus is often referred to as the Ohio State University rate of heat release apparatus (or OSU, for short). It has been shown that the correlation between time to ignition in this test method and in Test Method E 1354 is good, except at very low incident heat fluxes, when the pilot flame in Test Method E 906 causes high localized hot spots **(1-2)**.[16]

6.1.5 Test Method E 1321 is used to determine various ignition parameters, principally surface ignition temperature and critical heat flux for ignition. The specimen for the ignition test is a sheet 155 by 155 mm (6.1 by 6.1 in.) (with a maximum thickness of 50 mm (2 in.), which is exposed vertically to a pre-set incident heat flux resulting from a gas-fired radiant panel, in the absence or presence of a gas burner pilot, in the open. The primary objective of the test method is to determine fundamental thermophysical properties, such as the thermal inertia, as well as critical heat fluxes and surface temperatures for ignitability and flame spread. One major disadvantage of the test method is that materials which melt and drip cannot be easily tested with the apparatus, without making some significant modifications. The potential for varying the incident heat makes the test method somewhat versatile, but its crucial importance is as the provider of material and composite data in a form suitable for input into engineering fire safety or fire hazard assessment models. It has been developed as a result of attempts to improve on some of the shortcomings of the Test Method E 162 apparatus (see 6.3.2). Repeatability and reproducibility have not been developed in the first two years since the test method was approved as a standard. However, preliminary indications suggest that the test method is well suited for materials (or composites) which are non melting and which can

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

be ignited without raising the incident flux to potentially dangerous limits. It has been used for predictions of full scale flame performance (see also 6.3.3 for other uses of this test method). This apparatus is often referred to as the Lateral Ignition and Flame Spread Test (or LIFT, for short).

6.1.6 Test Method E 1354 (or NFPA 271) is also used to determine time to ignition. The specimen is a plaque 100 by 100 mm (4 by 4 in.), with a maximum thickness of 50 mm (2 in.), which is exposed horizontally (although vertical exposure is also feasible) to a pre-set incident heat flux resulting from an electrical heater rod, tightly wound into the shape of a truncated cone, in the absence or presence of a spark igniter pilot, under a relatively strong air flow. The primary objective of the test method is to determine heat release rate, but other fire-test-response characteristics are assessed simultaneously, including smoke release rate and mass loss as well as ignitability. The potential for varying the incident heat flux makes the test method very versatile. It has been developed as a result of attempts to improve on some of the shortcomings of the Test Method E 906 apparatus **(3)**. Repeatability and reproducibility data indicate that the precision is very satisfactory. It has been extensively used for predictions of full scale fire performance and fire hazard (see also 6.4.3 and 6.5.4 for other uses of this test method). This apparatus is often referred to as the cone calorimeter rate of heat release apparatus (or cone, for short), and it is the most recently developed small scale test apparatus mentioned in this guide. It is widely acknowledged as a source of important fire test data in engineering units.

6.2 *Ease of Extinction*:

6.2.1 A single test method exists to assess ease of extinction: Test Method D 2863.

6.2.2 Test Method D 2863 is used to determine the oxygen index, which is the minimum oxygen concentration (in a flowing mixture of oxygen and nitrogen) required to support candle-like downward flaming combustion. It actually serves as a measure of the ease of extinction of the material. The specimen size depends on the application: cellular plastics (such as foams) use specimens 125 mm long, 12.5 mm wide and 12.5 mm thick (5 by 0.5 by 0.5 in.), while films or fabrics require specimens 140 by 52 mm (5.5 by 2.1 in.), and use thickness. The specimen is placed vertically inside a glass column and ignited at the top with a small gas flame. The repeatability and reproducibility of this test method are excellent, and it is capable of generating numerical data covering a very broad range of responses **(4-5)**. This test method is inappropriate as a predictor of real scale fire performance, mainly because of the low heat input and the artificiality of the high oxygen environments used. However, it is widely required in specifications and quoted in data sheets. The method is suitable as a quantitative quality control tool, during manufacturing, and as a semi-qualitative indicator of the effectiveness of additives, during research and development, for low incident energy situations **(6)**.

6.3 *Flame Spread*:

6.3.1 Two test apparatuses are suitable to assess flame spread of materials: the ones in Test Method E 162 (and Test Method D 3675) and in Test Method E 1321.

6.3.2 Test Method E 162 is used to determine a flame spread index. It consists of a gas-fed radiant panel in front of which an inclined (at a 30° angle) specimen (150 by 460 mm (12 by 18 in.) is exposed to a radiant flux equivalent to a black body temperature of 670°C (1238°F), namely approximately 45 kW/m^2, in the presence of a small gas pilot flame. The maximum thickness that can be tested in the normal specimen holder is 25 mm (1 in.), but alternative specimen holders can accommodate thicker specimens. The ignition is forced near the upper edge of the specimen and the flame front progresses downward. The flame spread index is calculated as the product of a flame spread factor, which results from the measurements of flame front position and time, and a heat evolution factor, which is proportional to the maximum temperature measured in the exhaust stack. Thus, this method also procures relative indication of heat release (see also 6.4.4). No repeatability or reproducibility statement has been developed for this method in the first 30 years after it was issued, and it has not been shown to be an adequate predictor of real scale fire performance. If the specimen melts or causes flaming drips, this is likely to affect the flame spread in a way that is uneven; the test method simply requires that such events be reported. Moreover, if flame spread is very rapid, the flame spread is potentially lost unless recording is continuous. This apparatus is often referred to as the radiant panel, and results from this test are frequently required in regulations and detention environment specifications and quoted in data sheets.

6.3.3 Test Method D 3675 uses the same apparatus as Test Method E 162, but is designed specifically for use with flexible cellular materials only, up to a maximum thickness of 25 mm (1 in.). Thus, the method is particularly suitable for padding materials used in upholstery. The major differences with Test Method E 162 are the pilot burner, the times for measurement and the calculation procedure. The repeatability and reproducibility of this test method is such that the test method is able to distinguish between the flame spread of materials which differ by a large amount in their responses, which makes it adequate for identifying poor performers.

6.3.4 Test Method E 1321 was developed as an improvement on the apparatus in Test Method E 162 **(7)**. The apparatus has been described in 6.1.5. The specimen size for flame spread studies is 155 by 800 mm (6.1 by 31.5 in.) by a maximum thickness of 50 mm (2 in.). This test method determines the critical flux for flame spread, the surface temperature needed for flame spread and the thermal inertia or thermal heating property (product of the thermal conductivity, the density and the specific heat) of the material under test. These properties are mainly used for assessment of fire hazard and for input into fire models. A flame spread parameter, ϕ, is also determined, and this can be used as a direct way of comparing the responses of the specimens. Repeatability and reproducibility have not been developed in the first two years since the test method was approved as a standard. However, preliminary indications suggest that the test method is well suited for materials (or composites) which are non melting and which can be ignited without raising the incident flux to potentially dangerous limits. It has been used for predictions of full scale flame performance (see also 6.1.4 for other uses of this test method) **(8)**.

6.4 *Heat Release*:

6.4.1 Two generic small-scale test methods have been designed to assess the heat release of materials: Test Method E 906 and Test Method E 1354 (or their equivalents NFPA 263 and NFPA 271). Test Method E 162 gives relative information associated with heat release.

6.4.2 The apparatus for Test Method E 906 (or NFPA 263) has already been described in 6.1.3. The major purpose of this test method is to determine heat release, and this is done by measuring, with a multiple thermocouple thermopile, the difference in temperature between the combustion products in the exhaust stream and the inlet air, and comparing with a calibration based on a measured flow rate of methane gas. Measurements are made at intervals not exceeding 5 s (this is also referred to as a scan period of 5 s or less). The method is based on the assumption that the system is functionally adiabatic, but this assumption is not fully accurate, so that absolute heat release results determined are somewhat low, although relative rankings of materials are not affected by this **(1-2)**. The heat release magnitudes determined are the heat release rate per unit area (at every scan) and the total heat released per unit area (which is the integrated value of the heat release rate versus time curve). Heat release rate has often been described as one of the most important fire-test-response characteristics, because its maximum value is a quantitative measure of the peak intensity of a fire **(9-11)**. The potential for varying the incident heat flux makes the test method very versatile. Repeatability and reproducibility data suggest that the precision is adequate. It has also been used for predictions of full scale fire performance (see also 6.1.4 and 6.5.3 for other uses of this test method). Some deficiencies associated with this test method are: (*a*) lack of adiabaticity (addressed above), (*b*) lack of homogeneity of the heat flux on the surface of the test specimen, (*c*) the fact that the normal test orientation is vertical, which means that specimens which melt and drip cannot be tested adequately (although specimens can be tested horizontally, by using a specialized specimen holder, and a reflector screen) and (*d*) that continuous mass loss measurements are not available. This test method was proposed **(12)** as a bench-scale mattress test for institutional mattresses, and has been adopted by some hotel chains, and by some correctional facilities. This test method, at an incident heat flux of 35 kW/m^2, is also being used for regulation by the Federal Aviation Administration, for aircraft interiors **(13)**.

6.4.3 Test Method E 1354 (or NFPA 271) is also used to determine heat release; the apparatus has been described in 6.1.6. The primary objective of the test method is to determine heat release. This is done by using the oxygen consumption principle, which shows that heat release rate is proportional to the difference between the oxygen concentration in the exhaust stream of combustion products and in the inlet air **(14-15)**. This is done by using very accurate oxygen analyzers (normally of the paramagnetic type), and alleviates the problem of heat losses associated with lack of adiabaticity of Test Method E 906. The geometrical arrangement also results in homogeneous heat flux distribution on the specimen surface, and the normal specimen orientation is horizontal (although provisions exist for vertical testing). Measurements are made at intervals not exceeding 5 s (this is also referred to as a scan period of 5 s or less), and other fire-test-response characteristics are assessed simultaneously with heat release, including smoke release rate, mass loss and ignitability. The potential for varying the incident heat flux makes the test method very versatile. Repeatability and reproducibility data indicate that the precision is very satisfactory. It has been extensively used for predictions of full scale fire performance and fire hazard (see also 6.1.6 and 6.5.4 for other uses of this test method) and is starting to be adopted for specifications by some correctional facilities. It is widely acknowledged as a source of important fire test data in engineering units.

6.4.4 The heat evolution factor in Test Method E 162 (see also 6.3.2) is a relative measure of heat release. It is calculated as the product of the maximum temperature measured in the stack and some apparatus-dependent constants. However, it is rarely used in detention environments.

6.5 *Smoke Obscuration*:

6.5.1 Smoke obscuration is measured in Test Methods E 662 (or NFPA 258), E 906 (or NFPA 263) and E 1354 (or NFPA 271) and in the international standard ISO 5659 Part 2.

6.5.2 Test Method E 662 (or NFPA 258) consists of a closed chamber, 500 dm^3 in volume, wherein a 76 by 76 mm (3 by 3 in.), up to 25 mm (1 in.) thick is exposed vertically to an incident radiant flux of 25 kW/m^2, in the absence or presence of a small gas pilot flame. The radiant heat source is a small electric furnace. Light obscuration is measured by assessing the transmission of light across a photometric system consisting of a light source (white light) and a photodetector, oriented vertically, to reduce measurement variations due to stratification of smoke. The result obtained from this test method is a specific optical density, characteristic of the instrument, and the value reported is usually either the maximum or the value at a particular time. The test method has no capability for assessing mass loss continuously **(16)**. The fact that the test orientation is vertical means that specimens which melt and drip cannot be tested adequately. Other limitations include: (*a*) the atmosphere inside the chamber becomes oxygen-deficient, for some tests, before the end of the experiment; thus, combustion often ceases when the oxygen concentration decreases and, therefore, for heavy composites, it is possible that the layers furthest away from the radiant source will not undergo combustion; (*b*) the presence of walls causes losses through deposition of combustion particulates; (*c*) there are, frequently, extensive deposits of soot and other combustion particulates on the optical surfaces, resulting in incorrect measurements and (*d*) the test method does not carry out dynamic measurements: smoke simply continues filling a closed chamber: therefore, the smoke obscuration values obtained do not represent conditions of open fires. Moreover, it has been shown that results from this test method do not correlate with those obtained in real fires. The repeatability and reproducibility of the test method have been determined in a round robin conducted by 20 laboratories with 25 materials, and managed by ASTM Subcommittee E05.02 shortly after the initial publication of the test method in 1979. The round robin suggested that the precision of the method is lower than that of some more recent test methods, but some technical improvements have since been made. However, irrespective of its precision, this test method, often known as the NBS smoke density chamber, is extensively referred to in specifications and requirements, and is used in product data sheets.

6.5.3 Test Method E 906 (NFPA 263; 6.1.4 and 6.4.3) is used to assess smoke obscuration dynamically. The transmission of light across a photometric system consisting of a light source (white light) and a photodetector, oriented horizontally in the exhaust stream is used to measure the rate of smoke release at every scan and total smoke released (by integration of the rate of smoke release versus time curve).

6.5.4 Test Method E 1354 (NFPA 271; 6.1.6 and 6.4.4) is also used to assess smoke obscuration dynamically. The transmission of light across a photometric system consisting of a light source (monochromatic light from a laser beam) and a photodetector, oriented horizontally in the exhaust stream is used to measure extinction coefficients. By using a laser as light source the photometer has a smoke purging system which considerably decreases soot deposits on the optics. The fire-test-response characteristic reported is the specific extinction area, which is calculated from the extinction coefficient, the volumetric flow rate and the mass loss rate.

6.5.5 A modification of Test Method E 662 has been standardized internationally (ISO 5660, Part 2), which differs from the original in that the heat source is a conical radiant heater, similar (but not identical) to the one in Test Method E 1354, the pilot ignition is achieved by means of a spark igniter, the specimen is oriented horizontally, and there is an optional capability for a load cell, which assesses mass loss continuously. The incident heat flux can be set at any value, but values of 25 and 50 kW/m^2 are required in the standard. The repeatability and reproducibility of this test method are better than those of Test Method E 662, and it also solves some of the limitations of that procedure.

6.6 *Toxic Potency of Smoke*:

6.6.1 Toxic potency of smoke is measured in Test Method E 1678, NFPA 269 and in NASA CR-152056 **(17)**. Test methods measure toxic potency of smoke, but do not determine the actual smoke toxicity of the resulting fire atmosphere **(18-19)**. Moreover, it has been shown that the smoke toxicity of a fire atmosphere is often controlled by the extent of burning, and consequently by the heat release rate **(9**, **11**, **20)**. A number of comparisons of the advantages and disadvantages of various test methods have been published **(21-22)**, as well as analyses of the implications of smoke toxic potency measurements to fire hazard assessment **(23-26)**.

6.6.2 In Test Method E 1678 (NFPA 269) a test specimen is subjected to ignition while exposed for 15 min to a radiant heat flux of 50 kW/m^2. The smoke produced is collected for 30 min within a 200 L chamber communicating through a connecting chimney with the combustion assembly. Concentrations of the major gaseous toxicants are monitored over the 30 min period, with concentration-time products for each being determined from integration of the areas under the respective concentration–time plots. The concentration-time product data, along with the mass loss of the test specimen during the test, are then used in calculations to predict the preliminary 30 min smoke toxic potency of the test specimen. Six rats are exposed to the combustion products for a period of 30 min, plus a post-exposure period of 14 days, to confirm the preliminary smoke toxic potency obtained. This test method is not suitable for fires that reach flashover, because the carbon monoxide concentration determined is not representative of the values obtained in such fires. The method also incorporates a correction of the carbon monoxide concentration to make it suitable for post-flashover fires. The test method is not presently used for requirements in the correctional industry.

6.6.3 The National Aeronautics and Space Administration, at its Ames Research Center, commissioned a test method from McDonnell Douglas, in the early 1980's: NASA CR - 152056 **(17)**. In this method the test specimen is pyrolyzed by applying a current of 3.5 A for 200 s through a heating coil within which 1 g of the test specimen is placed. The heating coil is made of 24 gage Chromel A wire and is 546 mm (21.5 in.) long. It is inserted inside a Vycor glass pyrolysis tube (13 mm (0.5 in.) diameter and 127 mm 5 in. long), which itself is placed inside a 152 mm by 229 mm by 178 mm (6 in. by 9 in. by 7 in.) exposure chamber, which has a circulating fan and an exercise wheel. A mouse is placed inside the chamber on the exercise wheel. The mouse is examined at 15 min and at 30 min (end of test) to determine whether it has become incapacitated (if he no longer turns the wheel) or has died. Little published information exists about this test method, which has not been adopted by a consensus standards organization. The use of mice as test animals has been shown to be inadequate for materials which can release irritants, because mice are excessively sensitive to irritants **(20-22)**. This test method is required in some correctional facility specifications for mattress cushioning materials.

7. Small Scale Applications Tests

7.1 *Smoldering Ignition*:

7.1.1 Test Methods E 1352 (NFPA 261) and E 1353 (NFPA 260) are procedures designed to assess the ignitability of fabrics, paddings and interliners to smoldering ignition by cigarettes. Mattresses are required by the Consumer Product Safety Commission to comply with CFR Part 1632, Standard for the Flammability of Mattresses and Mattress Pads (formerly DOC FF4-72, 40 FR 59940). Resilient filling materials are also tested in California to assess their ignitability by cigarettes using Technical Bulletin 117 (CA TB 117).

7.1.2 Test Method E 1352 (NFPA 261) contains a mock-up test, designed by the National Bureau of Standards, with a 550 by 680 mm (22 by 25 in.) mock-up of an upholstered furniture material assembly, which is ignited at various positions by lighted cigarettes. The measurement reported is a char length. This test method is of voluntary application, and its traditionally used classification criterion is a char length of 51 mm (2 in.), although this is not spelled out in the standard.

7.1.3 Test Method E 1353 (NFPA 260) was designed by the Upholstered Furniture Action Council (UFAC) and contains six tests for individual components: (*a*) fabric classification; (*b*) welt cord; (*c*) decking material; (*d*) filling/padding; (*e*) barriers and (*f*) interior fabric. The test specimen sizes range from 203 by 203 mm (8 by 8 in.) to 533 by 343 mm (21 by 13.5 in.), is ignited by a lighted cigarette at a specified location, and the results obtained are a function of the char length measured. The test methods classify the materials tested into two classes, as a function of the char length, with the criterion being a length of 44 mm (1.75 in.) for the fabric classification, at 38 mm (1.5 in.) for the interior fabric test, the filling/padding test, the welt cord test and the decking test and at 51 mm (2 in.) for the barrier test. This test is administered by UFAC for voluntary compliance by all manufacturers of upholstered furniture.

7.1.4 CFR Part 1632, Standard for the Flammability of Mattresses and Mattress Pads (formerly DOC FF4-72, 40 FR 59940) requires the testing of each mattress or mattress pads with 18 cigarettes, and none of the char lengths is allowed to exceed 51 mm (2 in.). This is a mandatory federal standard.

7.1.5 California Technical Bulletin 117 contains a section addressing smoldering ignition by cigarettes, for resilient filling materials. A distinction is made between cellular materials (such as foams) and others. The latter are made into specimens 305 by 305 mm (12 by 12 in.), and tested both uncovered and covered with one layer of sheeting material, with a pass/fail criterion of 2 in. Cellular materials are tested using a mock-up test stand, and covered with a standard cellulosic fabric. The pass/fail criterion for the foam (cellular material) is based on the weight loss: not more than one out of six foams may lose 20% or more of the initial weight.

7.1.6 Smoldering ignition tests are designed to assess whether upholstery components or composites are capable of sustaining combustion (and perhaps eventually causing flaming ignition). However, paddings with relatively poor fire performance may pass the smoldering ignition test because they are covered with a fabric that resists smoldering **(27)**. Moreover, resistance to smoldering ignition is no indication at all of the eventual heat released (and thus fire hazard) resulting from a potential flaming fire.

7.2 *Small Scale Flaming Ignition Tests*:

7.2.1 All fabrics intended for wearing apparel must meet CFR 1610, which applies a small butane gas flame, at a 45° angle, to a 51 by 153 mm (2 by 6 in.) specimen for 1 s. The fabric passes the test if it burns for less than 3.5 s (for plain surface textiles) or with more complex criteria for raised surface fiber textiles. It must be stated, however, that almost all available fabrics will meet this test, which is very mild.

7.2.2 California Technical Bulletin 117 also applies a variety of small gas flames to all padding and filling materials, before allowing them for sale in upholstered furniture or mattresses in the state of California. The same test also requires that all upholstery fabrics meet the 45° angle small flame test in CFR 1610.

7.2.3 Fabrics destined for more severe occupancies, and curtains and drapes, are often tested by using NFPA 701. This standard contains two test methods: a “large-scale” version and a “phone-booth” version, both applicable to single or multiple-layered fabrics. The large-scale test involves exposing fabric lengths of 2.1 m (84 in.) vertically to a gas flame 280 mm (11 in.) gas flame for 2 min, and assessing the responses as a function of the maximum char length resulting from upward burning, and the after-flame time. A small-scale version of this test used to yield false “passes” and has been replaced by the “phone booth” test, in which the 150 by 375 mm (6 by 15 in.) specimen is suspended in an open face test chamber and exposed to an 800 W flame for 45 s. The adequacy of the fabric is assessed as a function of the percentage weight loss.

7.2.4 A small scale fabric test was a part of the NFPA 701 standard until the 1989 edition: the specimen was 89 by 254 mm in size, hung vertically, and ignited with a 38 mm long luminous gas flame. The pass/fail criterion was based on the length of fabric destroyed. Experience has shown that the results of using this small-scale test are not predictive of full-scale fire behavior of fabrics, especially in the case of multi-layered fabrics, when one of the materials may shrink away from the flame, melt, ablate or otherwise fail to support upward flames when heated. However, this test is often referenced, even though it no longer is a standard.

7.2.5 It should be pointed out that resistance to ignition by a small flame is no indication at all of the eventual heat released (and thus fire hazard) resulting from a potential flaming fire.

7.3 *Heat Release Tests*:

7.3.1 Test Method E 1474 (or NFPA 272) is an applications standard of the cone calorimeter specifically designed for use with upholstered furniture or mattress composite specimens. It determines the same fire-test-response characteristics as Test Method E 1354, but specifies a particular incident heat flux, namely 35 kW/m^2, and a detailed specimen preparation and mounting procedure **(28-29)**. In fact, the standard allows two specimen preparation procedures, with one of them suggested for screening purposes only. Repeatability and reproducibility information is available for the screening procedure: the relative standard deviations for repeatability ranged between 0 and 11 percent and those for reproducibility ranged between 4 and 32 percent.

7.3.2 Test Method F 1550 is based on Test Method E 1474, for direct applicability to correction and detention facilities. It addresses the testing of upholstered furniture or mattress composite specimens, but in a vandalized fashion, by slashing through the fabric and any potential secondary fabrics present. The objective of this test method is to prevent the use, in correction and detention facilities, of paddings with excessively high fuel loads. Such paddings may be simply protected by a pierceable barrier, so that they do not ignite easily under normal circumstances, but cause severe fire hazard when the barriers are compromised and eventual burning of the padding occurs.

7.4 *Test for Permanence of Fire-Test-Response Characteristics*:

7.4.1 Test Method F 1534 is a procedure to assess whether some fire-test-response characteristics are lost through leaching if exposed to aqueous sources within the detention environment. The procedure is directly applicable to Test Method D 3675 and Test Method E 662, but the principle can be applied to any other test method. In the test method the cushioning materials are subjected to leaching by immersion in flowing softened water for a period of 6 h, while the water is exchanged at a rate of 2 changes per hour, and then dried. The fire-test-response characteristic values obtained after leaching are compared with results obtained from untreated specimens of the same materials, to determine the percentage change in each fire-test-response characteristic.

7.4.2 Similar concepts are applied in FED STD 191-A Textile Test Method 5830, where specimens are submerged in lukewarm water (27-29°C (80-85°F), for 24 hours, while the water is being renewed at a rate of 5 changes per hour.

8. Real-Scale Fire Tests

8.1 *Smoldering Tests*:

8.1.1 California Technical Bulletin 116 is the prime example of a test where a large number of locations in an upholstered furniture item are exposed to smoldering ignition by a cigarette. This test is in place only in the state of California, and is met by the majority of the furniture being sold, even though it is not a mandatory requirement. This is important for residential applications but has little relevance to high risk environments.

8.1.2 As explained above, resistance to smoldering ignition is no indication at all of the eventual heat released (and thus fire hazard) resulting from a potential flaming fire.

8.2 Test Method E 1537 (or NFPA 266) and Test Method E 1590 represent a new generation of fire tests: a real-scale item (either an upholstered furniture piece or a mattress) is placed on a load cell in a furniture calorimeter, or in a room, and ignited by a gas burner, on for a fixed period of time. The release rates of heat, smoke and combustion products are determined by measurements in the exhaust duct. It has been shown that, for peak heat release rates of less than 600 kW, heat release is not affected by the re-radiation from the walls, so that testing in a small room or in an open furniture calorimeter should give similar results **(30)**. More recent work suggests that the limit of interchangeability between room and furniture calorimeters is likely to be somewhat lower, at approximately 450 kW **(31)**.

8.3 Test Method E 1537 involves upholstered furniture, which can be tested under the hood in a furniture calorimeter or inside a small room, either of dimensions 2.4 by 3.7 m (8 by 12 ft) or 3.0 by 3.7 m (10 by 12 ft), with a 2.4 m (8 ft) height and a standard door. The ignition burner is square-shaped, and the flame is turned on for 80 s, at a propane flow rate of 13 L/min. The application for this test method is contract occupancies, of higher than average risk, particularly in the absence of sprinklers. The test is based on the concepts put forward in California Technical Bulletin 133 (CA TB 133), and contains a set of pass/fail criteria, based on heat release: 80 kW peak rate of heat release and 25 MJ total heat released in the first 10 min of test. NFPA 266 is equivalent to ASTM E 1537, except that testing must be conducted in the furniture calorimeter. This test method has been adopted for regulation in some states, and has been incorporated into the generic sections of the National Life Safety Code, NFPA 101, as well as into the specific sections related to detention and correction occupancies. The requirements set are a maximum rate of heat release of 250 kW and a total heat release of no more than 40 MJ in the first 5 min of test. This standard is of some significant severity for contract furniture applications, but is probably insufficient to offer enough protection for a detention cell environment, because furniture can "pass" the test simply by virtue of not igniting. In such cases, however, it is possible for the furniture item to result in a severe fire if it actually ignites.

8.3.1 This test method does not address physical changes to protective layers due to wear, tear or abuse, which potentially affect the resulting fire-test-response characteristics of the upholstery item.

8.4 Test Method E 1590 is the exact equivalent of Test Method E 1537, but for mattresses. The mattresses can be tested under the hood in a furniture calorimeter or inside a small room, either of dimensions 2.4 by 3.7 m (8 by 12 ft) or 3.0 by 3.7 m (10 by 12 ft), with a 2.4 m (8 ft) height and a standard door. The ignition burner is T-shaped, and the flame is turned on for 180 s, at a propane flow rate of 12 L/min. The application for this test method is contract occupancies, of higher than average risk, particularly in the absence of sprinklers. The test is based on the concepts put forward in California Technical Bulletin 129 (CA TB 129). California Technical Bulletin 129, and contains a set of pass/fail criteria, based on heat release: 100 kW peak rate of heat release and 25 MJ total heat released in the first 10 min of test. This test method has been adopted for regulation in some states, and has been incorporated into the generic sections of the National Life Safety Code, NFPA 101, as well as into the specific sections related to detention and correction occupancies. The requirements set are a maximum rate of heat release of 250 kW and a total heat release of no more than 40 MJ in the first 5 min of test. This standard is of significant severity, albeit probably less than Test Method E 1537, but is clearly insufficient to offer enough protection for a detention cell environment, because furniture can "pass" the test simply by virtue of not igniting. In such cases, however, it is possible for the furniture item to result in a severe fire if it actually ignites. It should be noted that typical mattresses used in a detention environment exhibit fire performance far superior to those in the stated requirements of NFPA 101.

8.4.1 This test method does not address physical changes to protective layers due to wear, tear or abuse, which potentially affect the resulting fire-test-response characteristics of the upholstery item.

8.4.2 One of the more severe fire tests for upholstery items in detention or correction occupancies is California Technical Bulletin 121 (CA TB 121), specifically designed for mattresses in such occupancies. It requires a typical institutional mattress be exposed to the flames from a metal container with 10 double sheets of loosely wadded newspaper, and placed underneath the mattress, inside a 3.0 by 3.7 by 2.4 m high room (10 by 12 by 8 ft high). The mattress passes the test if the fire consumes less than 10 % of the original mattress weight, the room hot layer temperature does not exceed 260°C (500°F) and the concentration of carbon monoxide does not exceed 1000 ppm in the room at any time. This test uses antiquated techniques and pass-fail criteria, which should be replaced by more up-to-date technology, but it offers a greater degree of protection than ASTM E 1590 for very high risk occupancies, such as detention and correction facilities. An important difference between the CA TB 121 test method and the detention environment is the type of support on which the mattress is tested, since it does not involve the solid concrete or metal bunks commonly found in detention and correctional facilities. This can lead to a misleading scenario, where thermoplastic materials melt and drip away from the fire source placed underneath the mattress, in a way that would not happen with a solid metal substrate, as used in the metal bunks typical of the detention environment.

8.4.3 This test method does not address physical changes to protective layers due to wear, tear or abuse, which potentially affect the resulting fire-test-response characteristics of the upholstery item.

9. Room Tests and Guidance on Testing Methods

9.1 Guide E 603 explains how to conduct room fire tests, whether in order to design a new standard test or as a means of testing specialized fire scenarios. This is particularly applicable to detention cells, where the basic distribution of furniture is well established, so that a full room test will be a good method for choosing appropriate furnishings.

9.2 In this connection, it would also be appropriate to ensure that the surface finish (wall and ceiling) is adequate enough so that it is not conducive to flashover on its own. This is particularly important when dealing with padded cells. Room corner tests have been standardized both nationally and internationally.

9.2.1 NFPA 265 tests wall lining materials by lining three walls of a small room (all the walls except the one containing the door) of dimensions 2.4 by 3.7 m by 2.4 m high (8 ft by 12 ft by 12 ft high). It utilizes a gas burner, located in a corner at a height of 305 mm (12 in.) from the floor and at a distance 51 mm (2 in.) away from each wall. The burner is set at an incident power of 40 kW for 5 min, followed by a setting of 150 kW for a further 10 min. Measurements are made in the exhaust duct, principally heat release, but also potentially smoke and toxic gas release. However, the principal decision to be made is whether the wall lining is able to prevent the flames from reaching the outer extremities of the test specimen and the room from reaching flashover.

9.2.2 ISO 9705 is another test for wall lining materials in a room environment. The same room and burner as in NFPA 265 is also used, but the burner is placed flush against the wall, in the corner. This test method contains a series of options, of which there are four that are particularly important: (*a*) lining three walls and the ceiling and using a heat setting of 100 kW for 10 min followed by 300 kW for a further 10 min; (*b*) lining three walls and the ceiling and using a heat setting of 40 kW for 5 min followed by 160 kW for a further 10 min; (*c*) lining three walls only but using the 100 kW and 300 kW burner settings and (*d*) lining three walls only but using the 40 kW and 160 kW burner settings. The measurements that are made are similar to those that can be made in NFPA 265.

9.2.3 It has been shown that some information on the probability of flashover in these room corner tests is obtainable from results using the cone calorimeter, Test Method E 1354 **(32)**.

9.2.4 Similarly, test results using Test Method E 1474 (or NFPA 272) are potentially useful in predicting the results of experiments using Test Method E 1537 or Test Method E 1590 **(32-33)**.

9.2.5 No existing standard full scale test method can completely assess the overall fire hazard in a detention cell. Therefore, overall fire hazard assessment can be made by investigating the fire phenomena occurring in a detention cell scenario. Guide E 1546 explains how to write such a fire hazard assessment. This is probably best accomplished by incorporating the results of a combination of validated fire test methods of various types and fire models into the same fire hazard assessment procedure. No fire hazard assessment standards have, as yet, been issued by ASTM, because the complexity of fire hazard typically requires a combination of several test methods and some mathematical procedures for combining the results, typically through computer models.

9.2.6 When mattresses used in detention facilities are evaluated with regard to the potential fire hazard of the environment, the potential for vandalism and excessive wear and tear should be taken into account when evaluating the fire performance of the mattress.

10. Tests and Specifications Designed for Detention and Correction Facilities

10.1 There have been test methods and specifications designed specifically for correctional facility mattresses. However, the majority of them have adopted existing test methods, mostly as described in this guide.

10.2 The best known test procedure designed specifically for detention mattress inserts, or mattresses, is the so-called Michigan "Roll-up" Test **(34)**. It involves rolling up either an actual full-scale detention mattress, or the corresponding mattress cushioning, around a 229 mm (9 in.) diameter stove pipe into a cylinder and holding it in place with poultry wire (to create a "chimney effect". The cylinder is tilted to one side to provide air flow through the base (by placing it on two angle irons or two bricks) and suspended with a metal wire (to avoid it falling during the test). The interior is filled with eight double sheets of newspaper and ignited from the bottom, in the space provided between the two angle irons (or two bricks).

10.2.1 The Michigan "Roll-up" test can be conducted on complete mattresses as well as on mattress cushionings or paddings. However, the most frequent way in which the test has been conducted has been without the cover, for easier evaluation of detention mattress cushionings **(34-40)**.

10.3 In recent work **(41)** a mattress test was designed specifically for detention environments. The method exposes a full scale mattress designed for a detention environment, to a 50 kW source, from a propane gas burner.

10.3.1 Measurements made include rate of heat and smoke release, total amount of heat released, rates and concentrations of carbon oxides released, rates and amounts of mass of mattress lost. The mattress is allowed to burn freely under well-ventilated conditions after ignition. The most important fire property measured in this test method, by the principle of oxygen consumption, is the rate of heat release, which quantifies the fire intensity.

10.3.2 The fire source is a rectangular gas burner (762 mm by 381 mm (30 in. by 15 in.), with the 762 mm (30 in.) length subdivided into three equal sections), used at a heat output of 50 kW (fuel flow rate of 33.7 L/min) for 5 min **(41)**. The burner is placed centrally and 25 mm (1 in.) from the surface of the detention mattress, so that the gas flame faces downwards and penetrates approximately 100 mm (4 in.) into the mattress. The burner is located centrally and approximately 25 mm (1 in.) above the surface of the mattress.

10.3.3 The test specimen is an actual manufactured mattress, in the configuration of its intended use. The size of mattress tested is normally 0.76 m (range 0.7-0.8 m; 25-30 in.) by 1.9 m (75 in.).

10.3.4 The mattress is supported on a solid bad frame, which can be constructed of heavy angle-section iron with all joints welded, and which has a concrete, steel or a rigid non combustible board (to simulate a realistic detention environment and prevent melting or dripping). The top surface of the mattress is ≤ 0.9 m (35.4 in) from the floor. The bed frame is placed on top of a load cell to measure mass loss continuously, separated by a thermal barrier, to protect the load cell, as in Test Method E 1590.

10.3.5 The test room layout is identical to that in the Test Method E 1590. That means that it can be either (*a*) a 2.44 by 3.66 by 2.44 m high (8 by 12 by 8 ft high) room (with a single doorway opening 0.76 by 2.03 m (30 by 80 in), located in the center of the short wall; ASTM room), (*b*) a 3.05 by 3.66 by 2.44 m high (10 by 12 by 8 ft high) room (with a single doorway opening 0.97 by 2.06 m (38 by 81 in), located on one side of the short wall; California room), or (*c*) a furniture calorimeter. The rooms must be made of wooden or metal studs, and lined with fire-rated gypsum wallboard or calcium silicate wallboard, and with a hood outside of the room doorway, such that it collects all the combustion gases. The furniture calorimeter has a hood directly above the test specimen, with symmetrical air flow from all sides.

10.3.6 The bed frame, on the weighing platform, is placed in a corner of the room, at a distance of between 0.10 and 0.25 m (4 and 10 in) from both walls, or centered directly underneath the hood (in the furniture calorimeter).

10.3.7 Tests conducted **(41)** on the heat release of a sleepwear ignition source (1 sweatshirt [50% cotton/50% polyester blend), 1 T-shirt (50% cotton/50% polyester blend), 1 pair of blue denim trousers (100% cotton) and 12 double sheets of newspaper: approximate weight 1 kg) showed that a 50 kW curve, for 5 min, is a good representation of the heat release of the clothing.

10.3.8 Results from this test method, in terms of heat release and other parameters have shown that mattresses which perform very well on Test Method E 1590 can perform quite poorly and generate excessively high heat release, even beyond levels corresponding to flashover. On the other hand, the time to reach a heat release rate of 50 kW (which is a reasonable indicator of actual ignitability **(29, 42)** is fairly similar among most mattresses. This indicates that detention mattresses require a fairly severe fire source in order to be differentiable. Thus, the heat input of the burner, 50 kW, appears to be a more realistic insult for the detention environment than that of the Test Method E 1590, which is less than 20 kW.

10.4 The American Correctional Association has issued a statement informing users and suppliers that, whenever institutional furnishings are made of foamed plastics or foamed rubber, the materials must have known and acceptable fire performance characteristics, and must have been subjected to careful fire evaluation before purchase and use. However, no detailed guidance exists.

10.5 The requirements of the Americans with Disabilities Act should always be considered whenever any redesign is made of detention cell contents or furnishings.

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