Designation: F 1870 – 99

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

[1] This guide is under the jurisdiction of ASTM Committee F-33 on Detention and Correctional Facilities and is the direct responsibility of Subcommittee F33.05 on Furnishings and Equipment.

Current edition approved April 10, 1999. Published June 1999.

[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:*

---

[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