Flammability tests for regulation of building and construction materials

10

L.E. Hasburgh[a], *K. Sumathipala*[b]

[a] United States Department of Agriculture, United States. [b] American Wood Council, United States

10.1 Introduction

The regulation of building materials and products for flammability is critical to ensure the safety of occupants in buildings and other structures. The involvement of exposed building materials and products in fires resulting in the loss of human life often spurs an increase in regulation and new test methods to address the problem. Flammability tests range from those in which the sample is ground to a powder prior to testing to the full-scale room corner test. Variations in test methods include the specific measurement of flammability parameters being considered, the intensity and characteristics of the fire exposure, the relative scale of the test specimen, and many other factors. As a result of specific details such as specimen orientation and fire exposure intensity, some existing regulatory test methods have been shown not to classify a type of building material or product in a manner consistent with full-scale tests that simulated actual conditions. Such failures have resulted in the development of alternative test methods for specific applications or products. As a result, there are a wide range of tests used to classify building materials and products for flammability or reaction to fire.

Unfortunately, the results of fire and flammability tests are often characteristics of the test procedure, of which there are numerous methods (Lyon and Janssens, 2005). In a 1970s comparison of international test methods for flammability, the ranking of materials by the different regulatory methods was little better than a random number generator (Emmons H, 1974; Karlsson et al., 2002). Therefore, the scope of this chapter is limited to those flammability test standards that are relevant to the regulation of building materials and products. As such, it is only a subset of the many fire tests that have been used or are being used to evaluate building materials (Eickner, 1977; Lyon and Janssens, 2005; Tewarson et al., 2004). This chapter focuses on the compliance criteria used in the regulatory classifications of building materials for flammability in North America, Europe, Japan and China. More details on many of the applicable test methods can be found in other chapters of this book and in the cited references.

Flammability Testing of Materials Used in Construction, Transport and Mining, Second Edition.
DOI: https://doi.org/10.1016/B978-0-08-102801-8.00004-1

10.2 United States flammability requirements

The regulations for building materials and products to address the hazards associated with their flammability and related characteristics are found in the model building codes such as the International Building Code, National Fire Protection Association (NFPA) 101 Life Safety Code, and other similar documents. Acceptance criteria and classifications in this section generally refer to provisions of the International Building Code, which is the dominant model building code in the United States. Two main sets of requirements address the combustibility and the flame spread characteristics of building materials. These two main tests are described in the standards of ASTM International: ASTM E136 for combustibility and ASTM E84 for flame spread. The ASTM E84 test method also addresses the regulation for visible smoke characteristics. To address certain materials or applications, other test methods are also used in the regulation of building materials in North America. ASTM E84 is referenced in the U.S. buildings codes regarding the fire performance of many building materials and products. Given the variety of materials that are required to be tested in accordance with ASTM E84, a series of ASTM standards were developed to prescribe test specimen preparation and mounting for ASTM 84 testing. Separate specimen preparation and mounting guides are available for: pipe and duct insulation, textile, wood products, caulks and sealants, and fibrous insulations.

10.2.1 Combustibility

The classification of a material as a non-combustible material is based on ASTM E136 Standard test method for behavior of materials in a vertical tube furnace at 750 °C. In the test, a dry 38 mm × 38 mm x 51 mm specimen is heated in a small vertical tube furnace. A material is accepted as non-combustible if three of the four specimens pass the criteria of ASTM E136. If the weight loss of the test specimen is 50 percent or less, the criteria are (i) the specimen surface and interior temperatures during the test do not increase more than 30 °C above the temperature measured on the surface of the specimen after initial stabilization and (ii) no flaming from the specimen after the first 30 s. If the weight loss is greater than 50 percent, the criteria are no temperature rise above the stabilized temperature measured prior to the test and no flaming from the specimen at any time during the test. The commentary in ASTM E136 standard discusses the development of the test method and the rationale for the criteria.

As noted by Carpenter and Janssens (Carpenter and Janssens, 2005), one important limitation of ASTM E136 is that the test method does not provide a quantitative measure of heat generation or combustibility, but only a pass/fail result. The ASTM E136 is a severe test in that composite materials with even a small amount of combustible component will often fail to satisfy the criteria. Thus, materials such as mineral wool insulation with combustible binder, cinder concrete, cement and wood chips, and wood-fibered gypsum plaster are all classified as combustible (Institute for Research in Construction (IRC (Institute for Research in Construction) 1995), 1995). The core of gypsum wallboard will satisfy the criteria for non-combustible.

Paper-faced gypsum wallboard does not pass the non-combustible flaming criteria (Canadian Wood (Canadian Wood Council 1991)). As a result, prescriptive provisions to the codes are needed to permit the use of paper-faced gypsum in non-combustible construction. Fire-retardant treatment of a combustible material is not a viable option to satisfy the requirements of ASTM E136 and be classified non-combustible. Although E136 does not measure intrinsic properties, Tewarson et al. (Tewarson et al., 2004) considered E136 to be capable of providing quantitative data such as a material's resistance to ignition and combustion up to 750°C for the assessment of fire hazards associated with the use of products and protection needs.

In 2016, ASTM developed another noncombustible test method ASTM E2652 "Standard Test Method for Assessing Combustibility of Materials Using a Tube Furnace with a Cone-shaped Airflow Stabilizer, at 750 °C," where the test apparatus is identical to that described in ISO 1182. One primary difference between E136 and E2652 is that, in the latter, the use of test specimen center and surface thermocouples is optional.

To accommodate materials that are of low combustibility, alternative test methods have been developed. One such method is the test for potential heat of building materials, NFPA 259. The potential heat is the difference in the gross heat of combustion (obtained from an oxygen bomb calorimeter) of the original material and the material after a two-hour exposure in a furnace at 750 °C. In the NFPA 101 Life Safety Code, the test is used as a criterion for limited-combustible materials. The criterion is a potential heat less than 8,140 kJ/kg. The use of the cone calorimeter as a test for combustibility has also been investigated (Carpenter and Janssens, 2005). The cone calorimeter provides quantitative data such as the heat release rate, time to ignition and mass loss rate that are suitable for the classification of materials and can also be used in performance-based fire design. However, as noted by Carpenter and Janssens (Carpenter and Janssens, 2005), one of the main limitations of the cone calorimeter is that only relatively small samples can be evaluated and, as a result, products with joints or layered materials with a thickness greater than 50 mm cannot be evaluated. The data obtained from the cone calorimeter are also limited to well-ventilated fire scenarios and addresses one-dimensional fire propagation. Additionally, one of the biggest obstacles to the use of the cone calorimeter for combustibility is the implementation of a classification system that does not disrupt the status quo within the building code community.

In 2015, ASTM developed a cone calorimeter test method, ASTM E2965 "Standard Test Method for Determination of Low Levels of Heat Release Rate for Materials and Products Using an Oxygen Consumption Calorimeter." This test method uses a 150 mm square test specimen and an exhaust air flow rate of $0.012m^3/sec$. Traditional cone calorimeter test methods, such as, ASTM E1354 and ISO 5660, use a 100 mm square test specimen and an exhaust air flow rate of $0.024m^3/sec$. As such, E2965 has a larger test specimen and a lower exhaust flow rate and therefore a higher sensitivity to materials that release low amounts of heat. Despite the availability of cone calorimeter-based test methods, E1354 and E2965, use of material heat release rate for building regulation has been sparse. The concept of heat release rate is relatively new, and the cone calorimeter methods rely on oxygen-depletion for calculation of heat released. Oxygen depletion, the difference between exhaust stream oxygen concentration measured at the start of a test and that during a test, is susceptible to drift over time, making reliable measurement of small changes difficult. This is especially applicable for materials that contain or release low amounts of combustibles.

10.2.2 Interior finish flammability

The main test for surface burning characteristics of building materials in North America is the 7.6 m (25-foot) Steiner tunnel test. The applicable standards are ASTM E84 and UL 723. The primary intent of the Steiner tunnel Test is to quantify the wind-aided flame spread propensity of the material tested when compared to cement-fiber board and select grade red oak flooring. Two gas burners at one end of the test chamber provide fire exposure that consists of a 1.35 m (4.5 ft) long test flame with a heat release rate of approximately 88 kW. The test provides comparative measurements of the surface flame propagation and a measure of the optical smoke density. Based on the observations of the flame propagation, a comparative, dimensionless less flame spread index (FSI) is calculated from the areas under the flame spread distance-time plot. Lower FSI correlates to a lower rate of flame spread. The comparative smoke developed index (SDI) is calculated from the area under the smoke density-time plot. Historically, both the flame spread index and the smoke development index were based on red oak flooring being 100 and asbestos board being zero. The times for the flames to reach the end of a red oak flooring specimen is still used to calibrate the equipment but the results for red oak flooring are no longer part of the calculation of the flame spread index. Additionally, 295 g of liquid heptane is now used for the smoke calibration. With the specimen located on the top of the rectangular test furnace, the question of mounting methods has been a controversial aspect of the test method. A non-mandatory appendix of the ASTM E84 standard provides a guide to mounting methods. Tewarson et al. (Tewarson et al., 2004), Endicott and Bowhay (Endicott and Bowhay, 1970), and Resing et al. (Resing et al., 2011) consider the major limitation of E84 to be that the data cannot be applied to other scenarios beyond the heat exposure and product arrangements (size, etc.) specified by the test standard. Additional concerns related to the moisture content and conditioning of specimens and the red oak calibrant have been raised (Hasburgh et al., 2019). For the purpose of research and development of new products, the correlation of other test methods to the ASTM E84 results is an area of ongoing interest (Eickner, 1977; Laymon et al., 2007; Parker, 1983; Stevens M, 1998; White R and Dietenberger M, 2004).

Based on the ASTM E84 FSI, three classes of interior finish are specified in the model building codes. Class A (or I) requires an FSI of 25 or less. For Class B (or II), the FSI must be 26 to 75. Class C (or III) has an FSI range of 76 to 200. Materials not meeting the upper limit of Class III are considered unclassified and not permitted where the flammability of the material is regulated. The requirement for the SDI is 450 or less for all three classes. The primary purpose of the fire-retardant treatment of combustible materials is to reduce the flame spread index classification. Values for flame spread index can be found in American Wood Council (American Wood Council 2017), Appendix

D of the National Building Code of Canada (National Building Code of Canada 2015), and the publications of listing services such as Underwriters' Laboratory, Underwriters' Laboratory Canada, and Intertek. Non-fire-retardant paints and other thin coatings with a thickness less than 0.9 mm (0.036 inches), are typically not required to be tested but can influence the flame spread index. The effect is usually not enough to change the classification unless the classification of the uncoated material is low or marginal. For example, the classification of brick, concrete, aluminium, and gypsum plaster goes from FSI of zero unfinished to 25 with the application of a 1.3 mm alkyd or latex paint or one layer of cellulosic wallpaper (IRC (Institute for Research in Construction) 1995). The FSI classifications of 150 for lumber and various types of plywood and 25 for gypsum wallboard do not change with the application of a 1.3 mm alkyd or latex paint or one layer of cellulosic wallpaper (IRC (Institute for Research in Construction) 1995).

As noted by Belles (Belles D, 2003), materials that may not be adequately evaluated in the tunnel test include foam plastics, textile wall coverings, and expanded vinyl. To test these materials, large-scale room-corner tests such as NFPA 265 or NFPA 286 may be used as an alternative to the tunnel test. These tests, described in further detail below, are similar to the standard ASTM and ISO room-corner tests that use a 2.4 m x 3.6 m x 2.4 m (8 ft x 12 ft x 8 ft) room with a single door opening for ventilation. A single propane burner is placed in a corner of the room.

For non-textile wall and ceiling finishes, the room-corner test of NFPA 286 is an alternative method to achieve Class A classification. In NFPA 286, the burner protocol is 40 kW for five minutes followed by 160 kW for ten minutes. The test materials fully cover the three walls and/or the ceiling depending on the intended application of the material being tested. The acceptance criteria are (i) no flame spread to ceiling during 40 kW exposure, (ii) no flame spread to the outer extremity of sample wall or ceiling, (iii) no flashover during the test, (iv) total smoke released must not exceed 1,000 m^2, and (v) the peak heat release rate may not exceed 800 kW. The criteria for flashover are heat release rate of 1 MW, heat flux at the floor of 20 kW/m^2, average upper air layer temperature of 600 °C, flames exiting the doorway, and ignition of paper targets on floor.

Alternative acceptance criteria for Class A textile and expanded vinyl wall coverings are based on Method B of NFPA 265. In NFPA 265, the burner protocol is 40 kW for five minutes followed by 150 kW for ten minutes. Method B of NFPA 265 is similar to NFPA 286 in that the test material fully covers the three walls. No test material is on the wall with the door in either method. Observations needed for the acceptance criteria of NFPA 265 include absence of flame spread to the outer extremity of the test material, no observation of burning droplets, no observation of flashover, and peak heat release rate of 800 kW or below. Criteria for flashover include a heat release rate that exceeds 1 MW, heat flux at the floor greater than 20 kW/m^2, average upper air temperature of at least 600 °C, flames exit the doorway, and ignition of paper targets on floor.

Besides the slight difference in the burner protocol, a second difference between NFPA 286 and NFPA 265 is that the burner is in direct contact with two walls in NFPA 286 while it is 51 mm (2 in.) from the walls of a corner in NFPA 265. NFPA 265 is considered unsuitable for the testing of ceiling materials since the flame from the burner alone will not touch the ceiling. The involvement of the ceiling in the NFPA 286 test is partially due to the higher energy release rate of the NFPA 286 burner, but primarily due to the NFPA 286 burner being in direct contact with the walls, which increases the overall flame height (Janssens and Douglas, 2004). For decorative materials or other materials in a hanging configuration, one of the two tests described in NFPA 701 is used to determine the acceptance of the materials as flame-resistant materials. Selection of the specific test depends on the type of fabric or film being used.

The critical radiant flux apparatus is used to regulate carpets and other floor covering materials. Floor coverings such as wood, vinyl, linoleum, and other resilient non-fiber floor coverings are exempt from such requirements. The standard designations are ASTM E648 and NFPA 253. Because of the 30° incline of the radiant panel, the radiant heat flux profile on the test specimen ranges from 11 kW/m^2 to 1 kW/m^2 along the length of the specimen. The critical radiant flux is the flux that corresponds to the maximum distance of the flame front. As noted by Blackmore and Delichatsios (Blackmore J and Delichatsios M, 2002), the flooring radiant panel characterizes opposed flow horizontal flame spread and the pyrolysis is induced by both the external heat flux and convection/conduction from the flame at the front. The classes are Class 1 for a critical flux of 4.5 kW/m^2 or greater and Class 2 for a critical flux of 2.2 kW/m^2 or greater. Units of W/cm^2 are used in the U.S. codes and standards. The DOC FF-1 (ASTM D2859) 'pill test' is used as the least restrictive requirement. In the 'pill test' a small methenamine tablet is ignited in the center of a 230 mm square sample of the carpet. The specimen passes the test if the charred portion of the carpet does not extend beyond a 178 mm circle around the center of the sample. Requirements for carpets are also specified by the U.S. Federal Consumer Product Safety Commission (CPSC). The flooring radiant panel test is also part of the European regulations for floor coverings.

As a performance requirement for fire-retardant treated wood, the standard ASTM E84 test is extended from 10 min to 30 min as described in ASTM E2726. Fire-retardant-treated wood is required to have an FSI of 25 or less and show no evidence of significant progressive combustion when the test is continued for the additional 20 min. Additionally, the flame front must not progress more than 3.2 m (10.5 ft) beyond the centerline of the burners at any time during the test. For fire-retardant-treated wood intended to be exposed to weather, damp, or wet locations; the listed FSI must not increase when tested after being exposed to the weathering tests in ASTM D2898.

Due to difficulties in the fire testing of foam plastic insulations that melt, specific requirements beyond those based on ASTM E84 test are specified for all foam plastic insulation. For foam plastic insulation that is part of a classified roof-covering assembly, testing according to FM 4450 or UL 1256 is an option. For exterior walls with foam plastic insulation, test methods include NFPA 268 and NFPA 285. In the NFPA 268 ignitability test, a 1.2 x 2.4 m (4 ft x 8 ft) test specimen is exposed to a 12.5 kW/m^2 heat flux and a piloted ignition source for a 20-minute test period. The NFPA 285 test is an intermediate-scale, multi-storey test apparatus with a minimum 4.6 m (15 ft) height. Large-scale tests such as FM 4880, UL 1040, NFPA 286, or UL 1715 are options to satisfy the provisions for foam plastic via special approval. FM 4880 is a 7.6 m (25 ft) high corner test. For light-transmitting plastics, tests include ASTM D1929 for self-ignition temperature, ASTM D2843 for smoke-development index, and ASTM D635 for combustibility classification (Class CC1 and CC2).

Exposed insulation is also tested using ASTM E84 for flame spread and smoke development. For loose-fill materials that cannot be mounted in the standard ASTM E84 tunnel without a screen or other artificial supports, the Canadian tunnel test for floors (CAN/ULC S102.2) is used to evaluate for flame spread. The Canadian flooring tunnel test addresses the question of testing of loose-fill insulation by placing the test specimen on the floor of the ASTM E84 test furnace and turning the burners down towards the test specimen. Another test for exposed attic floor insulation is the critical radiant flux test described in ASTM E970, which is similar to ASTM E648. Cellulose loose-fill insulation requirements are specified by the US Federal Consumer Products Safety Commission requirements that include the test of ASTM E970.

10.2.3 Exterior finish flammability

The standard test methods for external roof coverings are in ASTM E108 (UL 790). Four separate fire tests for a relative comparison of roof coverings subjected to exterior fire exposure are part of ASTM E108: intermittent flame exposure test, spread of flame test, burning brand test, and flying brand test. The details of the tests are a function of the three classes (A, B, and C). Class A is the most restrictive. While the roof covering tests are primarily considered fire-resistance tests in terms of preventing penetration of the fire to the interior of the structure, there are requirements for surface flammability. The spread of flame test consists of a luminous gas flame burner at the edge of a 1 m wide inclined roof deck and an air current of 5.3 m/s. The length of the deck is 4 m (13 ft) for Class C, 2.7 m (8.8 ft) for Class B and 2.4 m (8 ft) for Class A. The gas flame and air current are applied in the Class A and B tests until any flaming of the test specimen recedes from its point of maximum flame spread, but no longer than ten minutes. If the test is run to obtain the Class C classification, the gas flame and air current is applied for four minutes. In the spread of flame test, the flaming cannot spread beyond 1.8 m (6 ft) for Class A, 2.4 m (8 ft) for Class B and 4.0 m (13 ft) for Class C. No significant lateral spread of flame from the area directly exposed to the test flame is permitted.

10.3 Canadian flammability requirements

The Canadian Commission on Building and Fire Codes is responsible for the National Building Code of Canada. Administrative and technical support for this model code is provided by the Institute for Research and Construction of the National Research Council of Canada. An objective-based code was published in 2005. The fire tests used in the Canadian codes for building materials requirements are similar to those in the United States. The test standard for determination of non-combustibility is CAN4-S114. The tunnel test is CAN/ULC-S102 in the Canadian standards. In addition, there is the tunnel test in which the test specimen is placed on the floor of the tunnel (CAN/ULC-S102.2). It is intended for materials that (i) are intended for horizontal applications in which only the top surface is exposed, (ii) would require supports not representative of those used in actual applications to test the specimen on top of the tunnel (e.g. loose-fill insulation), or (iii) are thermoplastic. Because of melting or dripping, thermoplastics will have lower flame spread index in the ASTM E84 tunnel test with the material on the ceiling of the tunnel than in the Canadian flooring tunnel test (Canadian Wood (Canadian Wood Council 1991)). The Canadian flooring tunnel test addresses the question of testing of loose-fill insulation by placing the test specimen on the floor of the ASTM E 84 test furnace. Except for a few specific applications, the upper limits for the flame-spread rating (FSR) are 25, 75, or 150 (unitless). When regulated, the limits on the smoke developed classification are for values of 50, 100, 300, and 500. The standard for roof covering is CAN/ ULC-S107. More recently, the cone calorimeter was proposed as a standard test method for degree of combustibility (ULC-S135) (Richardson and Brooks, (Carpenter and Janssens, 2005; Richardson L, 1994; Richardson L and Brooks M, 1991).

10.4 European flammability requirements

The national fire regulators of the European Union countries developed a new flammability classification system in 2001. The system replaced the large number of different tests and classification systems used across the European Union. Two classification systems were developed; one for floor coverings (subscript FL) and the other for all other construction products (no subscript). This classification system is published in the standard EN 13,501–1, Fire Classification of Construction Products and Building Elements. This standard applies seven classes of reaction to fire from non-combustible to combustible/easily flammable: A1, A2, B, C, D, E and F. Additionally, there are three classifications for smoke production (s1, s2 and s3) and three classifications for flaming droplet/particles (d0, d1 and d2) both presented in order of absent to high amounts. Depending on the end use application, a combination of the following five test methods may be required with specific pass/fail criteria:

ISO EN 1182 Non-combustibility Test: identifies products that will not contribute significantly to a fire. Used for classification in Class A1, A2, $A1_{FL}$, $A2_{FL}$.

ISO EN 1716 Calorific Value: determines potential heat release by a product under complete combustion. Used for classification in Class A1, A2, $A1_{FL}$, $A2_{FL}$.

EN 13,823 Single Burning Item Test: evaluates the potential contribution to fire growth with a single burning item in a room corner. Used for classification in Class A2, B, C and D.

ISO EN 11,925–2 Ignitability: evaluates the ignitability of a product when subject to a small flame. Used for classification in Class B, C, D, E, B_{FL}, C_{FL}, D_{FL} and EFL

ISO EN 9239–1 Burning behavior of floor coverings exposed to a radiant heat source: evaluates the critical radiant flux at flame extinguishment over a horizontal surface. Used for classification in Class $A2_{FL}$, B_{FL}, C_{FL}, and DFL.

10.5 Japanese flammability requirements

Japan uses the cone calorimeter test results to classify interior finish materials. The test method referenced is ISO 5660–1 at a radiant exposure of 50 kW/m^2. Materials are classified as either non-combustible, quasi-combustible, or fire retardant. Non-combustible materials are classified based either on ISO 1182 with a temperature rise of 20 °C or less or using the cone calorimeter (ISO 5660–1) with a maximum total heat release of 8 MJ and the maximum heat released less than 200 kW/m^2 during the whole 20-minute test period. Quasi-combustible materials are classified either based on ISO 5660–1 or in the box heat test, ISO 17,431. For these materials, the test period is 10 min with the same criteria as non-combustible materials. In the box heat test a total heat release of 30 MJ is allowed with a maximum heat release rate of 140 kW. Additionally, no burn-through is allowed. Flame retardant materials tested in the cone calorimeter have the same classification criteria as non-combustible materials but have a test period of only 5 min.

10.6 Chinese flammability requirements

China has established a non-combustible test and a three-class classification system for combustible wall and ceiling interior finishes. They have also established a two-class classification system for combustible floor coverings. The following test methods are used for the purpose of classification.

GB/T 5464 Non-combustibility test method for building materials.

GB/T 8625 Test method of difficult flammability for building materials.

GB/T 8626 Test method of flammability for building materials.

GB 11,785 Reaction to fire tests for floorings—Determination of the burning behavior using a radiant heat source.

10.7 Future trends

Various drivers will continue to push innovations in fire testing and the adoption of improved test methodologies for flammability of building materials. The first driver is the increased level of engineering involved in the fire protection profession. The increase in demand for tests with suitable and quantifiable results will increase with the use of fire models and will also provide validation data for the models. Tests that provide only a comparative measure of fire performance under specified and limited test conditions will become less acceptable. Belles (Belles D, 2003) noted that future use of fire models may include linking the actual hazards created by the use of a product in a specific situation to regulatory limits.

In synergy with increased fire protection engineering is the international movement toward performance-based building codes. Many of the traditional tests for flammability that have been acceptable in a prescriptive code environment will hinder the potential benefits of the performance-based codes. For harmonization and reliable assessment of fire resistance of materials, Tewarson et al. (Tewarson et al., 2004) noted it is necessary to use quantitative measurements, rather than visual observation. Grayson and Hirschler (1995) noted (i) the recent trend to replace older tests that only rank materials with new standard fire tests that can provide input into mathematical fire models and fire hazard assessment, and (ii) the use of real-scale tests for validation of the small-scale tests and the models. However, as noted by Karlsson et al. (Karlsson et al., 2002), the validity of the models must be demonstrated for a wider range of materials and the models must be made more user friendly and widely available to engineers before there can be widespread performance-based design of interior finish materials. As is happening within the European Union, world globalization of markets will drive the harmonization of regulatory test standards for products. Tewarson et al. (Tewarson et al., 2004) expects further harmonization of test methods as many regulatory agencies are considering augmenting or replacing the prescriptive-based fire codes (currently in use) by performance-based codes. The Forum for International Cooperation on Fire Research (FORUM) (Croce, 2001) supports this movement away from ad hoc approval tests and towards scientifically based tools (accurate data, tests, and models) as a basis for equitable performance levels.

The increased use of heat release rate measurements to quantify the flammability of building materials is likely to continue. Innovation in building materials will continue to be a driver for improvements in the testing of building products for flammability. It is expected that the introduction of new and improved low-hazard materials will increase the pressure to develop and implement methodologies for degrees of combustibility that will not require prescriptive lists of exceptions to the current non-combustibility requirements. Despite significant work, performance-based interior finish regulations have not been widely adopted. This is primarily due to regulators comfort levels with prescriptive requirements.

10.8 Sources of further information

ASTM International, 100 Barr Harbor Drive, West Conshohocken, PA 19,428 2959, USA, www.astm.org.

D 2843 Test for density of smoke from the burning or decomposition of plastics. D 2859 Test method for ignition characteristics of finished textile floor covering materials.

D 2898 Test method for accelerated weathering of fire-retardant-treated wood for fire testing.

E 84 Test methods for surface burning characteristics of building materials.

E 108 Test methods for fire tests of roof coverings.

E 136 Test method for behavior of materials in a vertical tube furnace at 750 °C. E 648 Test method for critical radiant flux of floor-covering systems using a radiant heat energy source.

E 2652 Standard Test Method for Assessing Combustibility of Materials Using a Tube Furnace with a Cone-shaped Airflow Stabilizer, at 750 °C.

E 2965 Standard Test Method for Determination of Low Levels of Heat Release Rate for Materials and Products Using an Oxygen Consumption Calorimeter.

E 970 Test method for critical radiant flux of exposed attic floor insulation using a radiant heat energy source.

Consumer Product Safety Commission, 4330 East West Highway, Bethesda, MD 20,814–4408, USA, www.cpsc.gov.

16 CFR Part 1209 Interim safety standard for cellulose insulation.

16 CFR Part 1630 Standard for the surface flammability of carpets and rugs (FF 1–70).

Factory Mutual Approvals, 1151 Boston-Providence Turnpike, Norwood, MA 02,062, USA, www.fmglobal.com/approvals.

4880 Class 1 Fire Rating of Building Panels or Interior Finish Materials

National Fire Protection Association, 1 Batterymarch Park, Quincy, MA 02,269–9101 USA, www.nfpa.org.

101 Life safety code.

253 Test for critical radiant flux of floor covering systems using a radiant heat energy source.

259 Test method for potential heat of building materials.

265 Standard method of fire tests for evaluating room fire growth contribution of textile wall coverings.

268 Standard test method for determining ignitability of exterior wall assemblies using a radiant heat energy source.

276 Standard Method of Fire Test for Determining the Heat Release Rate of Roofing Assemblies with Combustible Above-Deck Roofing Components.

285 Standard method of test for the evaluation of flammability characteristics of exterior non-load-bearing wall assemblies containing combustible components.

286 Standard method of fire test for evaluating contribution of wall and ceiling interior finish to room fire growth.

701 Standard methods of fire tests for flame-propagation of textiles and films.

Underwriters Laboratories, 333 Pfingsten Road, Northbrook, IL 60,062–2096, USA, www.ul.com.

723 Test for surface burning characteristics of building materials.

790 Standard test method for fire tests of roof coverings.

1040 Fire test of insulated wall construction.

1256 Fire test of roof deck construction.

1715 Fire test of interior finish material.

1975 Fire tests of foamed plastics used for decorative purposes.

Underwriters Laboratories of Canada, 7 Crouse Road, Scarborough, Ontario, M1R 3A9 Canada, www.ulc.ca.

CAN/ULC-S102 Test for surface burning characteristics of building materials and assemblies.

CAN/ULC-S102.2 Test for surface burning characteristics of flooring, floor covering, and miscellaneous materials and assemblies.

CAN/ULC-S107 Fire tests of roof coverings.

CAN/ULC-S134 Standard method of fire test of exterior wall assemblies. CAN/ULC-S114-M80 Test for determination of non-combustibility in building materials.

CAN/ULC-S135 Standard test method for the determination of combustibility parameters of building materials using an oxygen consumption calorimeter (cone calorimeter).

National Research Council Canada, 1200 Montreal Road, Ottawa, Ontario, K1A 0R6 Canada (Institute for Research and Construction of the National Research Council of Canada, http://irc.nrc-cnrc.gc.ca/irccontents.HTML and Canadian Commission on Building and Fire Codes http://www.nationalcodes.ca/).

National Building Code of Canada

International Organization for Standardization http://www.iso.org/.

ISO 1182:2010 Reaction to fire tests for building products Non-combustibility test.

ISO 1716:2018 Reaction to fire tests for building products Determination of the heat of combustion.

ISO 5660–1:2015 Reaction to fire tests Heat release, smoke production and mass loss rate Part 1: Heat release rate (cone calorimeter method).

ISO 9239–1:2010 Reaction to fire tests for floorings Part 1: Determination of the burning behavior using a radiant heat source.

ISO 11,925–2:2020 Reaction to fire tests Ignitability of building products subjected to direct impingement of flame Part 2: Single-flame source test.

European Committee for Standardization: http://www.cen.eu/.

EN 13,501–1 Fire classification of construction products and building elements. Part I: Classification using test data from reaction to fire tests.

EN 13,823 Building products excluding floorings exposed to the thermal attack by a single burning item.

References

American Wood Council, 2017. Flame Spread Performance of Wood Products, Design for Code Acceptance (DCA) No. 1. AWC, Leesburg, VA (Available at www.awc.org.

Belles D, W., 2003. Interior finish', in Fire Protection Handbook, Section 12, Chapter 3. National Fire Protection Association, Quincy, MA 12-43–12-60.

Blackmore J, M., Delichatsios M, A., 2002. Flammability tests for assessing carpet performance. J. Fire Prot. Eng. 12, 45–59.

Canadian Wood Council, 1991. Wood and Fire Safety. Canadian Wood Council, Ottawa, p. 266.

Carpenter, K., Janssens, M., 2005. Using heat release rate to assess combustibility of building products in cone calorimeter. Fire Technol. 41, 79–92.

Croce, P., 2001. The Forum for International Cooperation on Fire Research. Fire Saf. J. 36, 715–717.

Eickner, H.W., 1977. Surface flammability measurements for building materials and related products. Treatise on analytical chemistry. (available at http://www.fpl.fs.fed.us/documnts/pdf1977/eickn77a.pdf.

Emmons H, W., 1974. Fire and fire protection. Sci. Am. 231 (1), 21–27.

Endicott, L.E., Bowhay, R.B., 1970. A statistical evaluation of fire hazard classification furnace (ASTM E84-68). Mater. Res. Stand. 10 (5), 19.

Grayson S, J., Hirschler M, M., 1995. Comparison of ASTM fire standards with international fire standards for building and contents. Grand A Fire standards in the international

marketplace, ASTM STP 1163. American Society for Testing and Materials, Philadelphia, PA, pp. 41–60.
Hasburgh, L.E., Craft, S.T., Van Zeeland, I., Zelinka, S.L., 2019. Relative humidity versus moisture content relationship for several commercial wood species and its potential effect on flame spread. Fire Mater. 43 (4), 365–372.
IRC (Institute for Research in Construction), 1995. National Building Code of Canada 1995. Institute for Research and Construction, Ottawa, National Research Council of Canada, p. 571.
Janssens, M., Douglas, B., 2004. Wood and wood products, Chapter 7. Harper C A, Handbook of Building Materials for Fire Protection. McGraw-Hill, New York 7.1–7.58.
Karlsson, B., North, G., Gojkovic, D., 2002. Using results from performance-based test methods for material flammability in fire safety engineering design. J. Fire Prot. Eng. 12, 93–108.
Laymon, R., Gandhi, P., Liu, X., 2007. Combustibility of Interior Finish and Building Materials Using Small-Scale, Steiner Tunnel and Room-Corner Tests.. Fire and Materials 2007 Fire Conference, Jan, pp. 29–32.
Lyon, R.E., Janssens, M.L., 2005. ‘Polymer Flammability’ (No. DOT/FAA/AR-05/14). Federal Aviation Administration. Office of Aviation Research, United States.
National Building Code of Canada, 2015. Division B, Appendix D, Section D-3. National Research Council of Canada, Ottawa, Ontario.
Parker, W.J. (1983). Assessment of correlations between laboratory and full scale experiments for the FAA Aircraft Fire Safety Program. Part 3: ASTM E 84, No. NIST Interagency/Internal Report (NISTIR)
Resing, J.V., Gandhi, P.D., Sloan, D.E., Laymon, R.K., 2011. Measurement uncertainty and statistical process control for the steiner tunnel (UL 723, ASTM E84). J. Test. Eval. 39 (6), 1097–1102.
Richardson L, R., 1994. Determining degrees of combustibility of building materials-National Building Code of Canada. Fire Mater. 18, 99–106.
Richardson L, R., Brooks M, E., 1991. Combustibility of building materials. Fire Mater. 15, 131–136.
Stevens M, G., 1998. Cone calorimeter as a screening test for ASTM E-84 tunnel test. In: Proc. 5th International conference in Fire and Materials, London, Interscience Communications, pp. 147–151.
Tewarson, A., Chin, W., Shuford, R., 2004. Materials specifications, standards, and testing, Chapter 2. In: Harper, C A (Ed.), Handbook of Building Materials for Fire Protection. McGraw-Hill, New York 2.1–2.54.
White R, H., Dietenberger M, A., 2004. Cone calorimeter evaluation of wood products. In: Proc. 15th Annual BCC Conference on Flame Retardancy, Norwalk, CT. Business Communications Co., Inc., pp. 331–342.

Non-Print Items

Abstract

The regulation of building materials and products for flammability is critical to ensure the safety of occupants in buildings and other structures. The involvement of exposed building materials and products in fires resulting in the loss of human life often spurs an increase in regulation and new test methods to address the problem. Flammability tests range from those in which the sample is ground to a powder prior to testing to the full-scale room corner test. Variations in test methods include the specific measurement of flammability parameters being considered, the intensity and characteristics of the fire exposure, the relative scale of the test specimen, and many other factors. As a result of specific details such as specimen orientation and fire exposure intensity, some existing regulatory test methods have been shown not to classify a type of building material or product in a manner consistent with full-scale tests that simulated actual conditions. Such failures have resulted in the development of alternative test methods for specific applications or products. As a result, there are a wide range of tests used to classify building materials and products for flammability or reaction to fire.

Keywords

Flammability; Regulation; Construction materials; Full-scale tests