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NFPA 255
Test Methods Surface Burning— Building Materials
1990 Edition

NFPA

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Policy Adopted by NFPA Board of Directors on December 3, 1982

The Board of Directors reaffirms that the National Fire Protection Association recognizes that the toxicity of the products of combustion is an important factor in the loss of life from fire. NFPA has dealt with that subject in its technical committee documents for many years.

There is a concern that the growing use of synthetic materials may produce more or additional toxic products of combustion in a fire environment. The Board has, therefore, asked all NFPA technical committees to review the documents for which they are responsible to be sure that the documents respond to this current concern. To assist the committees in meeting this request, the Board has appointed an advisory committee to provide specific guidance to the technical committees on questions relating to assessing the hazards of the products of combustion.

Statement on NFPA Procedures

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NFPA 255

Standard Method of Test of

Surface Burning Characteristics of Building Materials

1990 Edition

This edition of NFPA 255, *Standard Method of Test of Surface Burning Characteristics of Building Materials*, was prepared by the Technical Committee on fire Tests and acted on by the National Fire Protection Association, Inc. at its Annual Meeting held May 21-24, 1990 in San Antonio, TX. It was issued by the Standards Council on July 20, 1990, with an effective date of August 17, 1990, and supersedes all previous editions.

The 1990 edition of this document has been approved by the American National Standards Institute.

Changes other than editorial are indicated by a vertical rule in the margin of the pages on which they appear. These lines are included as an aid to the user in identifying changes from the previous edition.

Origin and Development of NFPA 255

The test procedure covered by this standard was originally developed by Underwriters Laboratories Inc., and a descriptive article thereon was published in the NFPA Quarterly for July 1943. Subsequently the test method was considered by Committee E-5 of the American Society for Testing and Materials and adopted by the ASTM as a tentative standard in 1950. Subsequent to NFPA action on this standard, on recommendation of the Committee on Building Construction in 1953, a new NFPA Committee on Fire Tests was created to provide the machinery for NFPA action on fire test standards in cooperation with the American Society for Testing and Materials. At the 1955 Annual Meeting the Committee on Fire Tests, by a divided vote, recommended continuing tentative status, but, in view of the recommendation of the NFPA Committee on Building Construction and also of the NFPA Committee on Safety to Life, which needed this standard for use in connection with interior finish requirements (*see NFPA 101®*), the standard was officially adopted in 1955. Revised editions were released in 1958, 1961, 1966, 1969, 1972, 1979, 1984, and 1990.

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This list represents the membership at the time the Committee was balloted on the text of this edition. Since that time, changes in the membership may have occurred.

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Standard Method of Test of

Surface Burning Characteristics of Building Materials

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Chapter 1 General

1-1 Scope. This method of testing surface burning characteristics of building materials is applicable to any type of building material that, by its own structural quality or the manner in which it is applied, is capable of supporting itself in position or may be supported in the test furnace to a thickness comparable to its recommended use.

1-2 Purpose.

1-2.1 The purpose of the test is to determine the comparative burning characteristics of the material under test by evaluating the flame spread over its surface, when exposed to a test fire, and to thus establish a basis on which surface burning characteristics of different materials may be compared without specific consideration of all end use parameters that might affect the surface burning characteristics.

1-2.2 Smoke density as well as the flame spread rate are recorded in this test. However, there is not necessarily a relationship between these measurements.

1-2.3 It is the intent of this method of test to register performance during the period of exposure and not to determine suitability for use after the test exposure.

NOTE: Reference may be made to NFPA 251, *Standard Methods of Fire Tests of Building Construction and Materials*, for procedures for determining the performance, under fire exposure conditions, of building constructions and materials when incorporated in a test structure and subject to a standard exposing fire of controlled extent and severity.

1-2.4 This method does not establish ratings of standards of performance for specific uses, as these depend upon service requirements.

NOTE: The values stated in U.S. customary units are to be regarded as the standard.

Chapter 2 Test Equipment and Specimens

2-1 Fire Test Chamber.

2-1.1 The fire test chamber, shown in Figures 1 and 2, shall consist of a horizontal duct having an inside width of 17$^3/_4$ ± $^1/_4$ in. (451 ± 6.3 mm) measured at ledge location alongside walls, and 17$^5/_8$ ± $^3/_8$ in. (448 ± 10 mm) at all other points; a depth of 12 ± $^1/_2$ in. (305 ± 13 mm) measured from the bottom of the test chamber to the ledge of the inner walls on which the specimen is supported [including the $^1/_8$ in. (3.2 mm) thickness of woven fiberglass gasketing tape]; and a length of 25 ft (7.62 m). The sides and base of the duct shall be lined with insulating masonry as illustrated by Figure 2, consisting of A. P. Green, G-26 refractory fire brick or equivalent. One side shall be provided with double observation windows with the inside pane flush mounted (*see Figure 2*). Exposed inside glass shall be 2$^3/_4$ ± $^3/_8$ by 11 plus 1, minus 2 in. (7.0 ± 10 by 29.7 plus 25, minus 50 mm). The centerline of the exposed area of the inside glass shall be in the upper half of the furnace wall, with the upper edge not less than 2.5 in. (63 mm) below the furnace ledge. The window shall be located such that not less than 12 in. (305 mm) of the specimen width can be observed. Multiple windows shall be located along the tunnel so that the entire length of the test sample may be observed from outside the fire chamber. The windows shall be pressure tight as described in2-3.2.

NOTE 1: Woven fiberglass tape, 1$^1/_2$ by $^1/_8$ in., No. 8817K35 from McMaster-Carr, P.O. Box 54960, Los Angeles, CA 90054 or an equivalent has been found suitable for this purpose.

NOTE 2: The method of lining the sides and base of the duct with insulating masonry is based upon the use of G-26 fire brick manufactured by A.P. Green Refractories, Green Boulevard, Mexico, MO 65265.

NOTE 3: Double observation windows should be constructed of heat-resistant glass, Vycor, 100 percent silica glass, nominal $^1/_4$ in. thick, has been found suitable for the interior pane; Pyrex glass, nominal $^1/_4$ in. thick, has been found suitable for the exterior pane.

2-1.2 The ledges shall be fabricated of structural materials capable of withstanding the abuse of continuous testing, level with respect to the length and width of the chamber and each other, and maintained in a state of repair commensurate with the frequency, volume, and severity of testing occurring at any time.

NOTE: High temperature furnace refractory. Zircon has been found suitable for this purpose.

2-1.3 To provide air turbulence for proper combustion, turbulence baffling shall be provided by positioning six A. P. Green, G-26 refractory fire bricks or equivalent [long dimension vertical, 4$^1/_2$ in. (114 mm) dimension along the wall] along the side walls of the chamber at distances of 7, 12, and 20 ± $^1/_2$ ft (2.1, 3.7, and 6.1 ± 0.2 m) on the window side and 4$^1/_2$, 9$^1/_2$, and 16 ± $^1/_2$ ft (1.3, 2.9, and 4.9 ± 0.2 m) on the opposite side.

NOTE: This method for turbulence baffling is based upon the use of G-26 fire brick, manufactured by A. P. Green Refractories, Green Boulevard, Mexico, MO 65265.

2-1.4 The top lid shall consist of a removable noncombustible (metal and mineral composite) structure, insulated with nominal 2-in. (51-mm) thick mineral composition material as shown in Figure 2 and shall be of a size necessary to cover completely the fire test chamber and the test samples. The lid shall be maintained in an unwarped and flat condition. The mineral composition material shall have physical characteristics comparable to the following:

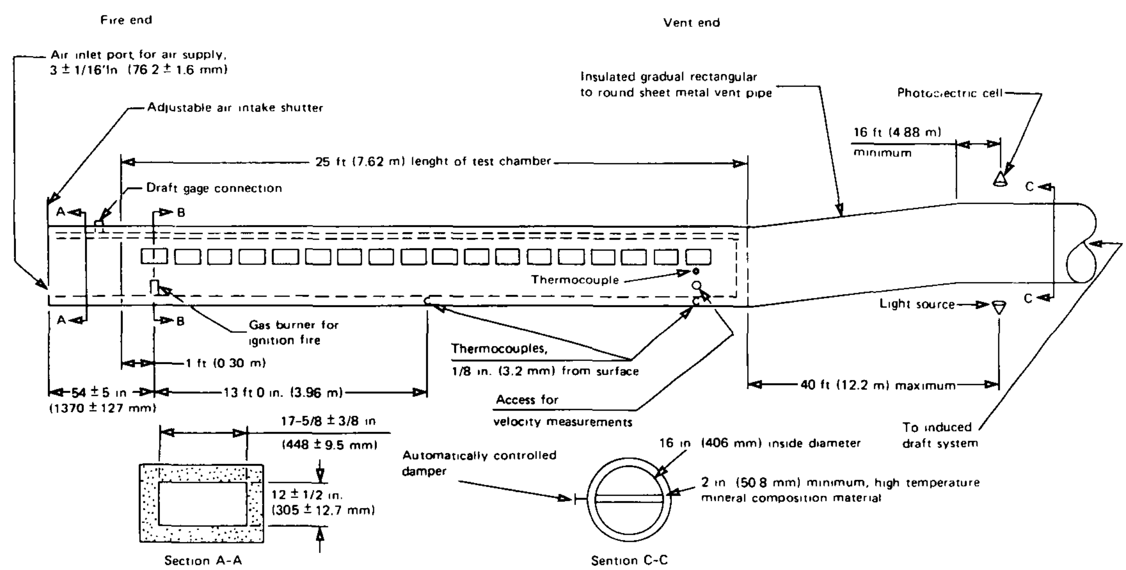

Figure 1

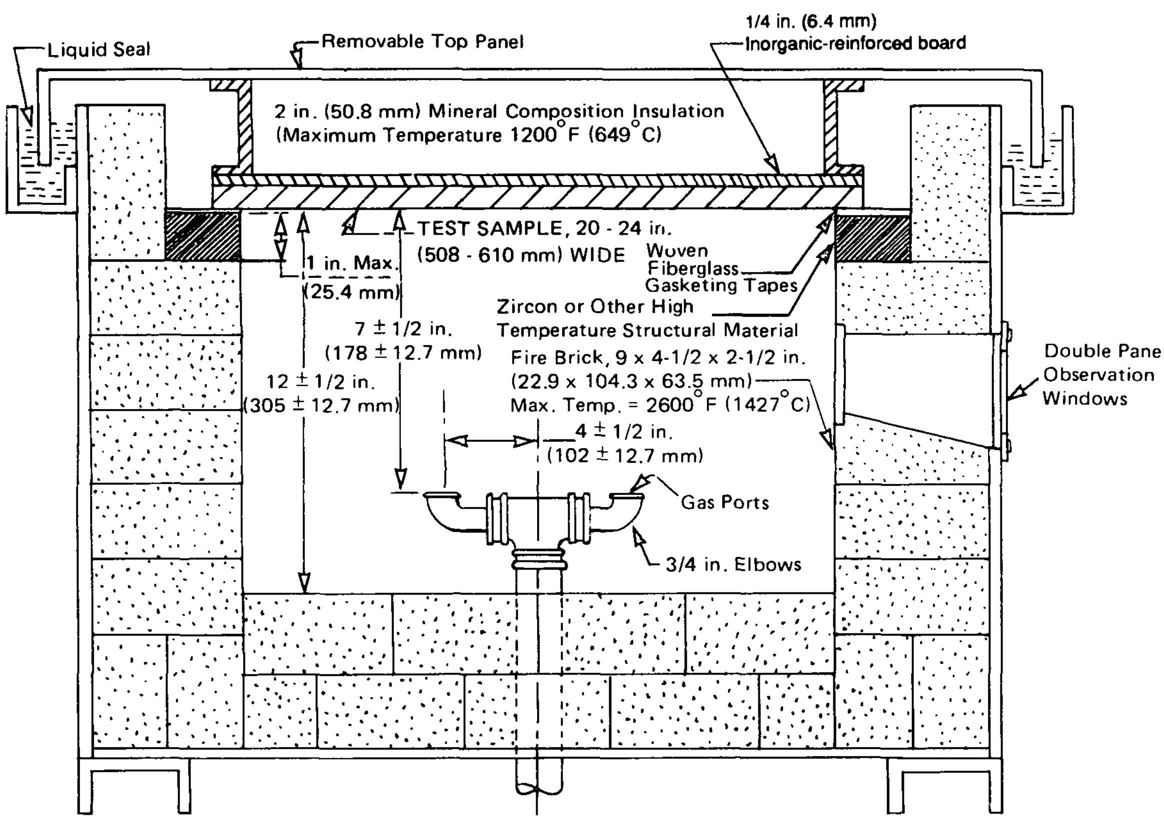

Figure 2

Maximum effective temperature	1200°F (649°C)
Bulk density	21 pcf (336 kg/m^3)
Thermal conductivity at 300 to 700°F (149 to 371°C)	0.50 to 0.71 Btu • in./hr-ft^2 °F (0.072 to 0.102 W/m • /K)
KpC	1 to 4 Btu^2 • /in./ft^5 hr °F^2) (1 × 10^4 to 4 × 10^4 W^2 • /S/m^4 • /K^2)

NOTE: KpC is equal to the thermal conductivity times the density times the specific heat.

The entire lid assembly shall be protected with flat sections of high density (nominal 110 pcf or 1761 kg/m^3) ¼-in. (6.3-mm) inorganic-reinforced cement board, maintained in an unwarped and uncracked condition through continued replacement. This protective board may or may not be secured to the furnace lid. When in place the top shall be completely sealed against the leakage of air into the fire test chamber during the test.

NOTE: For inorganic-reinforced cement board, Manville Building Materials Corporation Flexboard II and Tunnel Building Products Sterling Board have been found to be acceptable materials for this purpose.

2-1.5 One end of the test chamber, designated as the fire end, shall be provided with two gas burners delivering flames upward against the surface of the test sample. The burners shall be spaced 12 in. (305 mm) from the fire end of the test chamber, and 7½ ± ½ in. (190 ± 13 mm) below the under surface of the test sample. The air intake shutter shall be located 54 ± 5 in. (1372 ± 127 mm) upstream of the burner, as measured from the burner centerline to the outside surface of the shutter. Gas to the burners shall be provided through a single inlet pipe, distributed to each port burner through a tee-section. The outlet shall be a ¾-in. (19-mm) elbow. The plane of the port shall be parallel to the furnace floor such that the gas is directed upward toward the specimen. Each port shall be positioned with its centerline 4 ± ½ in. (102 ± 13 mm) on each side of the centerline of the furnace so that the flame is evenly distributed over the width of the exposed specimen surface (*see Figure 2*). The controls used to assure constant flow of gas to the burners during the period of use shall consist of a pressure regulator, a gas meter calibrated to read in increments of not more than 0.1 ft^3 (2.8 L), a manometer to indicate gas pressure in inches of water, a quick-acting gas shutoff valve, a gas metering valve, and an orifice plate in combination with a water manometer to assist in maintaining uniform gas-flow conditions. An air intake fitted with a vertically sliding shutter extending the entire width of the test chamber shall be provided at the fire end. The shutter shall be positioned so as to provide an air inlet port 3 ± 1/16 in. (76 ± 2 mm) high measured from the floor level of the test chamber, at the air intake point.

2-1.6 The other end of the test chamber, designated as the "vent end," shall be fitted with a gradual rectangular-to-round transition piece, not less than 20 in. (508 mm) by 200 sq in. (1290 cm^2) at any point. The transition piece shall, in turn, be fitted to a flue pipe 16 in. (406 mm) in diameter. The movement of air shall be by an induced draft system having a total draft capacity of at least 0.15 in. (3.8 mm) water column with the sample in place, the shutter at the fire end open the normal 3 ± 1/16 in. (76 ± 2 mm), and the damper in the wide open position. A draft gage to indicate static pressure shall be inserted through the top at the midwidth of the tunnel, 1 ± 0.5 in. (25 ± 12 mm) below the ceiling, 15 ± 0.5 in. (381 ± 12 mm) downstream from the inlet shutter.

2-1.7 A photometric system consisting of a light source and photocell shall be mounted on a horizontal section of the 16-in. (406-mm) diameter vent pipe at a point where it will be preceded by a straight run of pipe [at least 12 diameters or 16 ft (4.88 m) and not more than 30 diameters or 40 ft(12.19 m)] from the vent end of the chamber, and with the light beam directed upward along the vertical axis of the vent pipe. The vent pipe shall be insulated with at least 2 in.(51 mm) of high temperature mineral composition material from the vent end of the chamber to the photometer location. A photoelectric cell of which the output is directly proportional to the amount of light received shall be mounted over the light source and connected to a recording device having a minimum operating chart width of 5 in. (127 mm) with an accuracy within ± 1 percent of full scale for indicating changes in the attenuation of incident light by the pas-sing smoke, particulate, and other effluent. The distance between the light source lens and the photocell lens shall be 36 ± 4 in. (914 ± 102 mm). The cylindrical light beam shall pass through 3-in. (76-mm) diameter openings at the top and bottom of the 16-in. (406-mm) diameter openings at the top and bottom of the 16-in. (406-mm) diameter duct, with the resultant light beam centered on the photocell.

NOTE: A Weston Instruments No. 856BB Photronic cell and 12-V sealed beam, clear lens, auto spot lamp with an overall light-to-cell path length of 36 ± 4 in. (914 ± 102 mm) has been found suitable for this purpose.

2-1.8 Linearity of the photometer system shall be verified periodically by interrupting the light beam with calibrated neutral density filters. The filters shall cover the full range of the recording instrument. Transmittance values measured by the photometer, using neutral density filters, shall be within ± 3 percent of the calibrated value for each filter.

2-1.9 An automatically controlled damper to regulate the draft pressure shall be installed in the vent pipe downstream of the smoke-indicating attachment. The damper shall be provided with a manual override.

2-1.10 Other manual and/or automatic draft regulation devices may be incorporated to maintain fan characterization and air-flow control throughout test periods.

2-1.11 A No. 18 AWG (1.02-mm) thermocouple with ⅜ ± ⅛ in. (9.5 ± 3.2 mm) of the junction exposed in the air shall be inserted through the floor of the test chamber so that the tip is 1 ± 1/32 in. (25.4 ± 0.8 mm) below the top surface of the woven fiberglass gasketing tape and 23 ft ± ½ in. (7.0 m ± 13 mm) from the centerline of the burner ports, at the center of its width.

2-1.12 A No. 18 AWG (1.02-mm) thermocouple embedded ⅛ in. (3.2 mm) below the floor surface of the test chamber shall be mounted in refractory or portland cement, carefully dried to avoid cracking, at distances of 13 ft ± ½ in.(3.96 m ± 13 mm) and 23 ¼ ft ± ½ in. (7.09 m ± 13 mm) from the centerline of the burner ports.

2-1.13 The room in which the test chamber is located shall have provision for a free inflow of air during the test to maintain the room at atmospheric pressure during the entire test run.

2-2 Test Specimens.

2-2.1 The test specimen shall be at least 2 in. (51 mm) wider [nominally 20 1/4 ± 3/4 in. (514 ± 19 mm)] than the interior width of the tunnel and a total of 24 ft ± 1/2 in. (7.32 m ± 13 mm) in length. The specimen may consist of a continuous, unbroken length, or of sections joined end-to-end. A 14 ± 1/8-in. (356 ± 3-mm) length of uncoated 16 gage (0.053-to 0.060-in.) steel sheet shall be placed on the specimen mounting ledge in front of and under the specimen in the upstream end of the tunnel. Specimens shall be truly representative of the material for which test results are desired. Properties adequate for identification of the materials or ingredients (or both) of which the test specimen is made shall be recorded.

2-2.2 The test specimen shall be conditioned to a constant weight at a temperature of 73.4 ± 5°F (23 ± 2.8°C) and at a relative humidity of 50 ± 5 percent.

2-3 Calibration of Test Equipment.

2-3.1 Place a 1/4-in. (6.3-mm) inorganic-reinforced cement board on the ledge of the furnace chamber, and then place the removable lid of the test chamber in position.

2-3.2 With the 1/4-in. (6.3-mm) inorganic-reinforced cement board in position on top of the ledge of the furnace chamber and with the removable lid in place, establish a draft to produce a 0.15-in. (3.8-mm) water column reading on the draft manometer, with the fire end shutter open 3 ± 1/16 in. (76 ± 16 mm), by manually setting the damper as a characterization of fan performance. Then close and seal the fire end shutter without changing the damper position. The manometer reading shall increase to at least 0.375 in. (9.53 mm), indicating that no excessive air leakage exists.

2-3.3 In addition, conduct a supplemental leakage test periodically with the fire shutter and exhaust duct beyond the differential manometer tube sealed by placing a smoke bomb in the chamber. The bomb shall be ignited and the chamber pressurized to 0.375- ± 0.135-in. (9.53- ± 3.18-mm) water column. All points of leakage observed in the form of escaping smoke particles are to be sealed. Establish a draft reading within the range of 0.055- to 0.085-in. (1.40- to 2.16-mm) water column. The required draft gage reading shall be maintained throughout the test by the automatically controlled damper.

2-3.4 Record the air velocity at seven points, 23 ft (8.28 m) from the centerline of the burner ports, 6 ± 1/4 in. (168 ± 7 mm) below the plane of the specimen mounting ledge. Determine these seven points by dividing the width of the tunnel into seven equal sections and recording the velocity at the geometrical center of each section. During the measurement of velocity, remove the turbulence bricks (*see 2-1.3*) and exposed 23-ft (7.02-m) thermocouple and place 24-in. (670-mm) long straightening vanes between 16 and 18 ft (4.88 and 5.49 m) from the burner. The straightening vanes shall divide the furnace cross section into nine uniform sections. Determine the velocity with furnace air temperature at 73.4 ± 5°F (23 ± 2.8°C) using a velocity transducer. The velocity, determined as the arithmetic average of the seven readings, shall be 240 ± 5 ft (7.32 ± 1.5 m)/min.

NOTE: A Thermo Systems Inc. Model 1610 velocity transducer (thermal anemometer), using a readout device accurate to 0.001 v, has been found suitable for the purpose.

2-3.5 The air supply shall be maintained at 73.4 ± 5°F (23 ± 2.8°C) and the relative humidity at 50 ± 5 percent.

2-3.6 The fire test chamber shall be supplied with natural (city) or methane (bottled) gas fuel of uniform quality with a heating value of nominally 1000 Btu/ft^3 (37.3 MJ/m^3). Adjust the gas supply initially at approximately 5000 Btu (5.3 MJ)/min. Record the gas pressure, the pressure differential across the orifice plate, and the volume of gas used in each test. Unless otherwise corrected for, when bottled methane is used, a length of coiled copper tubing shall be inserted into the gas line between the supply and metering connection to compensate for possible errors in the flow indicated due to reductions in gas temperature associated with the pressure drop and expansion across the regulator. With the draft and gas supply adjusted as indicated in 2-3.3 and 2-3.6, the test flame shall extend downstream to a distance of 4 1/2 ft (1.37 m) over the specimen surface, with negligible upstream coverage.

2-3.7 Preheat the test chamber with the 1/4-in. (6.3-mm) inorganic-reinforced cement board and the removable lid in place and with the fuel supply adjusted to the required flow. The preheating shall be continued until the temperature indicated by the floor thermocouple at 23 1/4 ft (7.09 m) reaches 150 ± 5°F (66 ± 2.8°C). During the preheat test record the temperatures indicated by the thermocouple at the vent end of the test chamber at intervals not longer than 15 seconds and compare these readings to the preheat temperature shown in the time-temperature curve in Figure 3. The preheating is for the purpose of establishing the conditions that will exist following successive tests and indicating the control of the heat input into the test chamber. If appreciable variation from the temperature shown in the representative preheat curve is observed, suitable adjustments in the fuel supply may be made necessary based on red oak calibration tests.

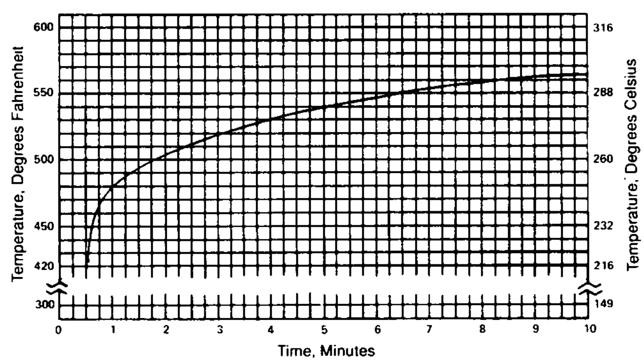

Figure 3 Time-Temperature Chart for Preheat Temperature.

2-3.8 Allow the furnace to cool after each test. When the floor thermocouple at 13 ft (3.96 m) shows a temperature of 105 ± 5°F (40.5 ± 2.8°C), place the next specimen in posi-tion for testing.

2-3.9 With the test equipment adjusted and conditioned as described in 2-3.2 through 2-3.8, make a test or series of tests, using nominal 25⁄32-in. (18.3-mm) select grade red oak flooring as a sample, conditioned to 6 to 8 percent moisture content as determined by the 221°F (105°C) oven dry method described in ASTM D-2016, *Tests for Moisture Content of Wood.* Make observations at distance intervals not in excess of 2 ft (0.6 m) and time intervals not in excess of 30 seconds and record the time when the flame reaches the end of the specimen, that is 19½ ft (5.94 m) from the end of the ignition fire. The end of the ignition fire shall be considered as being 4½ ft (1.37 m) from the burners. The flame shall reach the end point in 5½ min ± 15 seconds. Automatically record the temperatures measured by the thermocouple near the vent end at least every 15 seconds. Automatically record the photoelectric cell output immediately prior to the test and at least every 15 seconds during the test.

NOTE: The flame may be judged to have reached the end point when the vent end thermocouple registers a temperature of 980°F (527°C).

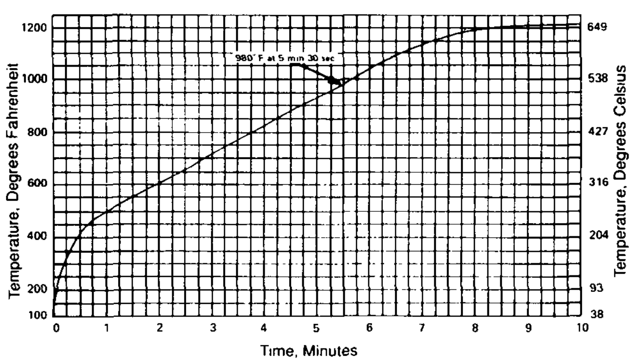

Figure 4 Time-Temperature Chart for Red Oak.

2-3.10 Plot the flame spread distance, temperature, and change in photoelectric cell readings separately on suitable coordinate paper. Figures 5 and 7 are representative curves for red oak smoke density and flame spread distance time-temperature development, respectively. Flame spread shall be determined as the observed distance minus 4½ ft (1.37 m).

2-3.11 Following the calibration tests for red oak, conduct a similar test or tests on samples of ¼-in. (6.3-mm) inorganic-reinforced cement board. The results shall be considered as representing a classification of zero. The temperature readings shall be plotted separately on suitable coordinate paper. Figure 6 is a representative curve for time-temperature development for inorganic-reinforced cement board.

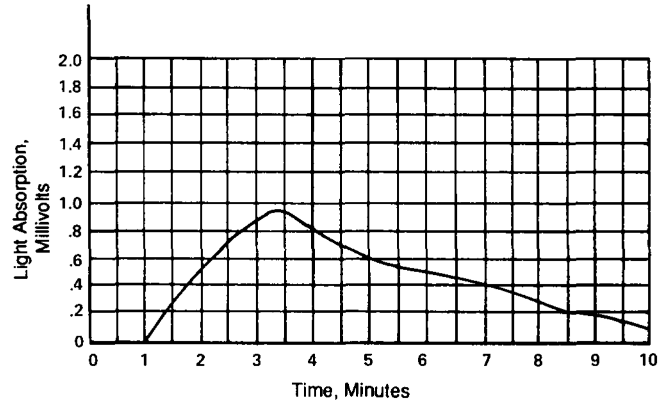

Figure 5 Time-Absorption Curve for Smoke Density of Red Oak.

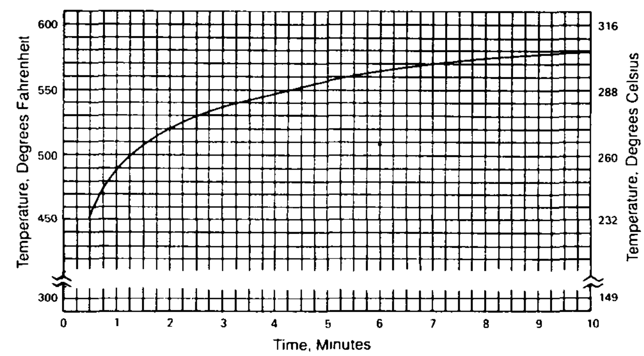

Figure 6 Time-Temperature Chart for Inorganic-Reinforced Cement Board.

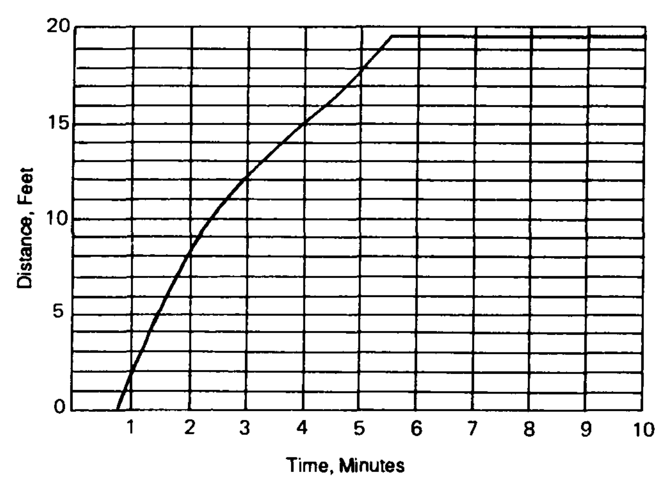

Figure 7 Time-Distance Curve for Flame Spread of Red Oak.

Chapter 3 Conduct of Tests

3-1 Test Procedure.

3-1.1 With the furnace draft operating, place the test specimen on the test chamber ledges that have been completely covered with nominal 1/8-in. (3.2-mm) thick by 1 1/2-in. (38 mm) wide woven fiberglass tape. Place the specimen as quickly as is practical. Place the removable lid in position over the specimen.

3-1.2 The completely mounted specimen shall remain in position in the chamber with the furnace draft operating for 120 ± 15 seconds prior to the application of the test flame.

3-1.3 Ignite the burner gas. Observe and record the distance and time of maximum flame front travel with the room darkened. Continue the test for a 10-minute period. The test may be terminated prior to 10 minutes if the specimen is completely consumed in the fire area and no further progressive burning is evident and the photoelectric cell reading has returned to the base line.

3-1.4 Record the photoelectric cell output immediately prior to the test and at least every 15 seconds during the test.

3-1.5 Record the gas pressure, the pressure differential across the orifice plate, and the volume of gas used for each test.

3-1.6 When the test is ended, shut off the gas supply, observe smoldering and other conditions within the test duct, and remove the specimen for further examination.

3-1.7 Plot the flame spread distance, temperature, and change in photoelectric cell readings separately on the same type of coordinate paper as used in 2-3.10 for use in determining the flame spread and smoke developed classifications as outlined in Section 3-3. The flame spread observations must be recorded at distance intervals not in excess of 2 ft (0.6 m) or time intervals not in excess of 30 seconds. In addition, the peak must be noted with the time of occurrence. Flame spread distance shall be determined as the observed distance minus 4 1/2 ft (1.37 m).

3-2 Analysis of Products of Combustion. Although not required as a part of this method, products of combustion may be drawn from the test duct during the progress of the test for chemical analysis.

3-3 Classification. The flame spread index (FSI) shall be determined as follows:

3-3.1 The total area (A_T) under the flame spread time-distance curve shall be determined by ignoring any flame front recession. For example, in Figure 8, the flame spread was 10 ft (3.05 m) in 2 1/2 minutes and then receded. The area is calculated as if the flame had spread to 10 ft (3.05 m) in 2 1/2 minutes and then remained at 10 ft (3.05 m) for the remainder of the test or until the flame front again passed 10 ft (3.05 m). This is shown by the dashed line in Figure 8. The area (A_T) used for calculating the flame spread classification is the sum of areas A_1 and A_2 in Figure 8.

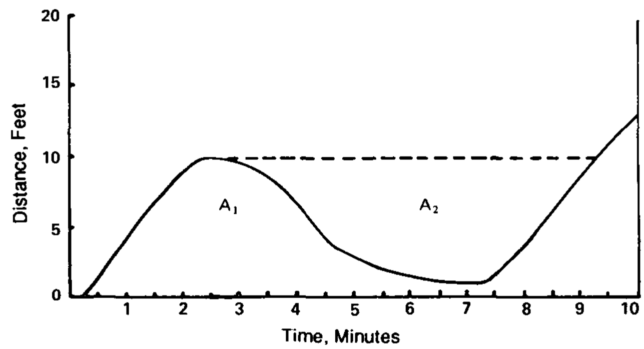

Figure 8 Example of Time-Distance Curve with Flame Front Recession.

3-3.2 If this total area (A_T) is less than or equal to 97.5 min-ft (29.7 min-m), the flame spread index shall be 0.515 times the total area (FSI = 0.515 A_T).

3-3.3 If the total area (A_T) is greater than 97.5 min-ft (29.7 min-m), the flame spread index shall be 4900, divided by the difference of 195 minus the total area (A_T) [FSI = 4900/(195-A_T)].

3-3.4 The test results for smoke shall be plotted using the same coordinates as in 2-3.9. The area under the curve shall be divided by the area under the curve for red oak and multiplied by 100 to establish a numerical index by which the performance of the material may be compared with that of inorganic-reinforced cement board and select grade red oak flooring, which have been arbitrarily established as 0 and 100, respectively.

NOTE: Allowance should be made for accumulation of soot and dust on the photoelectric cell during the test by establishing a revised base line. The revised base line shall be a straight line drawn from the zero point (point on base line where incipient light attenuation occurs) to the point established after the sample has been removed.

3-4 Report. The report shall include the following:

(a) Description of the material being tested

(b) Test results as calculated in Section 3-3

(c) Details of the method used in placing the specimen in the test chamber, and

(d) Observations of the burning characteristics of the specimen during test exposure, such as delamination, sagging, shrinkage, fallout, etc.

Chapter 4 Referenced Publications

4-1 The following documents or portions thereof are referenced within this standard and shall be considered part of the requirements of this standard. The edition indicated for each reference is the current edition as of the date of the NFPA issuance of this document.

4-1.1 The following publication is available from the American Society for Testing and Materials, 1916 Race St., Philadelphia, PA 19103:

ASTM D-2016-74 (Discontinued), *Tests for Moisture Content of Wood.*

Appendix A Guide to Mounting Methods

This Appendix is not a part of the requirements of this NFPA document, but is included for information purposes only.

A-1 Introduction.

A-1.1 This guide has been compiled as an aid in selecting a method for mounting various building materials in the fire test chamber. These mountings are suggested for test method uniformity and convenience; they are not meant to imply restriction in the specific details of field installation.

A-1.2 For some building materials none of the methods described may be applicable. In such cases, other means of support may have to be devised.

A-1.3 These suggested mounting methods are grouped according to building materials to be tested that are broadly described either by usage or by form of the material.

A-1.4 Whenever inorganic-reinforced cement board is specified as a backing in subsequent paragraphs, the material should be nominal 1/4 in. (6.3 mm) thick, high density [110 ± 5 lb/ft^3 (1762 ± 80 kg/m^3)], and uncoated. When metal rods are specified as supports, 1/4-in. (6.3-mm) metal rods spanning the width of the tunnel should be used. Rods should be placed approximately 2 in. (50.8 mm) from each end of each panel and additional rods placed approximately at 2-ft (0.6-m) intervals starting with the first rod at the fire end of each panel.

A-2 Acoustical and Other Similar Panel Products Less than 20 in. (508 mm).

A-2.1 For acoustical materials and other similar panel products with maximum dimension less than 20 in. (508 mm), metal splines or wood furring strips and metal fasteners should be used.

A-2.2 Steel tee splines for mounting kerfed-acoustical tile should be nominal 1/2-in. (13-mm) web by 3/4-in. (19-mm) flange, formed No. 24 MS gage sheet metal.

A-2.3 Wood furring frames for mounting acoustical materials and other similar panel products less than 20 in. (508 mm) should be nominal 1- by 2-in. (20- by 41-mm) wood furring joined with corrugated metal fasteners. Use two frames as shown in Figure A-2.3.

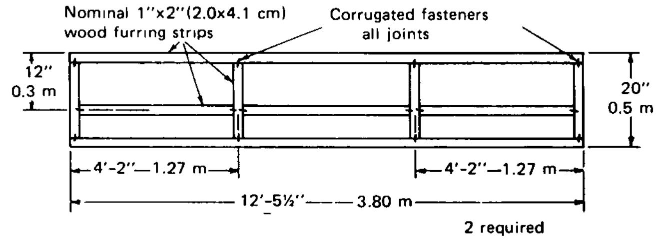

Figure A-2.3 Wood Frame for Acoustical Materials and Other Similar Panel Products Less than 20 in. (508 mm).

A-3 Adhesives. To determine the surface burning characteristics of adhesives, they must be mixed as specified in the manufacturer's instructions and applied to inorganic-reinforced cement board in the thickness or at the coverage rate recommended by the manufacturer. The adhesive application should be cured prior to testing.

A-4 Batt or Blanket-type Insulating Materials. Batt or blanket materials that do not have sufficient rigidity or strength to support themselves should be supported by metal rods inserted through the material and positioned such that the bottom of the rod is approximately 1/4 in. (6.3 mm) from the surface to be exposed to the flame. It is recommended that batt or blanket materials less than 1 in. (25.4 mm) thick not be mounted for testing in this manner.

A-5 Coating Materials, Cementitious Mixtures, and Sprayed Fibers.

A-5.1 Coating materials, cementitious mixtures, and sprayed fibers must be mixed and applied to the substrate as specified in the manufacturer's instructions at the thickness, coverage rate, or density recommended by the manufacturer.

A-5.2 Materials intended for application to wood surfaces should be applied to a substrate made of nominal 25/32 in. (18.3 mm) tongue and groove red oak flooring or to other species for which the surface burning characteristic is to be measured. The pieces are placed side by side and secured with 4 nailing strips spaced approximately 3 1/2 ft (1.07 m) apart to hold the pieces together (*see Figure A-5.2*). Two decks placed end-to-end are to be used.

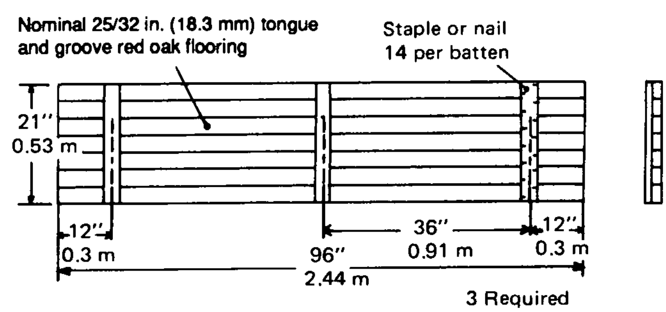

Figure A-5.2 Wood Deck for Coating Material.

A-5.3 Materials intended for application to particular combustible surfaces, but not wood, are applied to the specific surfaces for which they are intended.

A-5.4 Materials intended for only field application to noncombustible surfaces are to be applied to 1/4-in. (6.3-mm) inorganic-reinforced cement board.

A-6 Loose Fill Insulation. Loose fill insulation is placed on galvanized steel screening with approximate $^3/_{64}$-in. (1.2-mm) openings supported on a test frame 20 in. (508 mm) wide by 2 in. (51 mm) deep, made from 2- by 3- by $^3/_{16}$-in. (51- by 76- by 5-mm) steel angles. Three frames are required (*see Figure A-6*). The insulation is packed to the density specified by the manufacturer.

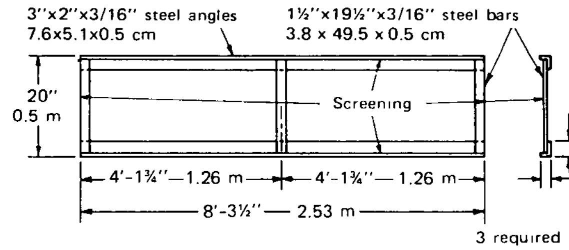

Figure A-6 Steel Frame for Loose Fill Materials.

A-7 Plastics.

A-7.1 The term plastics includes foams, reinforced panels, laminates, grids, and transparent or translucent sheets.

A-7.2 When any plastic will remain in position in the tunnel during a fire test, no additional support will be required. Thermoplastic materials and other plastics that will not remain in place are to be supported by $^1/_4$-in. (6.3-mm) round metal rods, or $^3/_{16}$- by 2-in. (5- by 51-mm) wide steel bars, or 2-in. (50.8-mm) galvanized hexagonal wire mesh supported with metal bars or rods spanning the width of the tunnel.

A-8 Thin Membranes. Single layer membranes of thin laminates consisting of a limited number of similar or dissimilar layers may be supported on poultry netting placed on metal rods as provided in A-4. Netting should be 20 gage (51-mm) hexagonal galvanized steel poultry netting conforming to specification A390. The specimen should be additionally tested, bonded to a substrate representative of a field installation.

A-9 Wall Coverings. Wall coverings of various types are to be mounted to $^1/_4$-in. (6.3-mm) inorganic-reinforced cement board with the adhesive specified by the manufacturer in a manner consistent with field practice.

A-10 When the surface burning characteristics of the material itself are required, specimens should be mounted on inorganic-reinforced cement board with Sairmix #7 High Temperature Bonding Mortar or the equivalent. If the specimen cannot be adhered using Sairmix #7, Kentile #9 epoxy has been found to be a suitable alternative. The application should be determined by a $^3/_{32}$-in. (2.4-mm) notched trowel held at an 80- to 90-degree angle using a random pattern. The adhesive should be applied only to the specimen back. The specimen should then be placed on the smooth side of the inorganic-reinforced cement board and rolled using a 100-lb (54.4-kg) roller [nominal 5-in. (127-mm) long sections placed end-to-end for a total length of 15 in. (381 mm)]. The prepared samples can be dead-stacked overnight but should be transferred to separate storage racks until tested. Each sample should be vacuumed prior to testing.

NOTE 1: Sairmix #7 High Temperature Bonding Mortar: Manufactured by A.P. Green Refractories, Green Boulevard, Mexico, MO 65265.

NOTE 2: Kentile #9 epoxy: Manufactured by Kentile Floors, Inc., Brooklyn, NY 11215.

Appendix B Derivation of Flame Spread Area Formulas Appearing in Section 3-3

This Appendix is not a part of the requirements of this NFPA document, but is included for information purposes only.

B-1 Introduction.

B-1.1 This Appendix contains an abbreviated discussion of the derivations of the flame spread area formulas used to calculate the flame spread value in this test method. This Appendix will show not only the derivations of the formulas, but will illustrate the relationship between this method of flame spread calculation and a previous method.

B-1.2 In these calculations, it is assumed that the flame front never recedes. Hence, in Figure 8 of Chapter 3 there is an imaginary line bounding the upper edge of area A_2.

B-2 Formula 1 Constant. In Figure B-1 an idealized straight-line flame spread distance-time plot is drawn. Lines OA, OA′, and OA″ produce a family of areas ORA having a maximum possible area of 97.5 min-ft ($^1/_2$ by 10 min by 19.5 ft). These represent a steady progression of the flame front to a maximum distance at the end of the 10-min test.

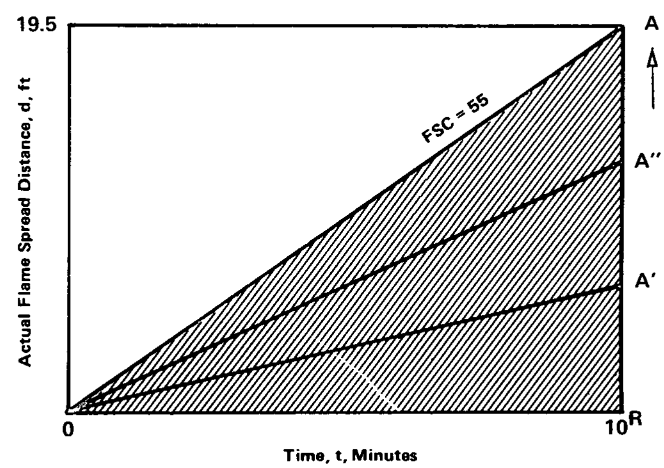

Figure B-1 Idealized Straight-Line Flame Spread Distance-Time Curve for Total Areas Less than or Equal to 97.5 min-ft.

B-2.1 When the flame front spreads its maximum distance (19.5 ft) in 10 minutes, a formula used in Method 255 would yield the following:

$$\text{FSI} = \frac{550}{t} = \frac{550}{10}$$

B-2.2 Also, when the flame front is maximized at 19.5 ft in 10 minutes, the area in Figure B-1 ORA is maximized to 97.5 min-ft.

B-2.3 To relate the current formula, which is of the straight line, origin intercept form, to the previous (Method 255) formula, it is necessary to equate the two as follows:

$$FSI = \frac{550}{t} = KA$$

where:

K = proportionality constant for equations of the current formula's type, and

A_T = total area under area ORA

If A_T = 97.5 min-ft at t = 10 min, then

$$FSC = \frac{550}{10} = K \times 97.5, \text{ and}$$

$$K = \frac{550}{10 \times 97.5} = 0.564$$

B-2.4 Thus, the formula in 3-3.2 for areas (A_T) of 97.5 min-ft or less is as follows:

$$FSI = 0.564\ A_T$$

B-3 Formula 2 Constant. In the idealized straight-line flame spread distance-time curve of Figure B-2, lines 0I, 0I′, and 0I″ produce a family of trapezoidal areas ORBI ranging from 97.5 to 195 min-ft (1/2 by 10 min by 19.5 ft to 10 min by 19.5 ft). This represents a flame front progression to the end of the specimen within the 10 minutes of the test. The area (A_T) of ORBI may be expressed as follows:

(1/2 by 19.5 by OR) + [1/2 by 19.5 by (10 - AI)]

which is equal to: 195 - 9.75 AI since OR is always 10 min.

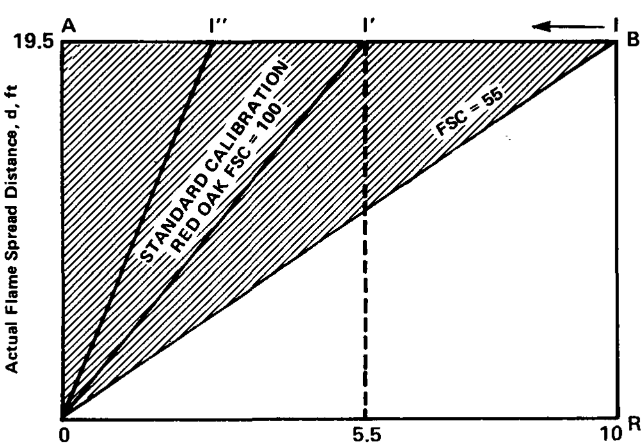

Figure B-2 Idealized Straight-Line Flame Distance-Time Curve for Total Areas Greater than 97.5 min-ft.

B-3.1 The triangular area OIA divided into a proportionality constant K will determine a relationship between flame spread values and the rate and distance of flame propagation. The total area available is 195 min-ft; hence area OIA is equal to 195 - ORBI. Thus, a new flame spread formula may be derived as follows:

$$FSI = \frac{K}{OIA} = \frac{K}{195 - ORBI} = \frac{K}{195 - A_T}$$

B-3.2 To establish K, a relationship between the current and the previous Method 255 formulas will be established at the red oak calibration point of 19.5 ft progression at 5.5 min as follows:

$$FSI = \frac{550}{I} = \frac{K}{195 - A_T}$$

where: A_T = 195 - [9.75 (5.5)] = 141.38 min-ft, and I = 5.5 min.

Thus:

$$FSI = \frac{550}{I} = \frac{K}{195 - 141.38}, \text{ or}$$

$$K = \frac{550 \times (53.63)}{5.5} = 5363$$

B-4 Formulas 1 and 2.

B-4.1 To account for the disproportionate increase that can occur in FSI values at the lower end of the index scale, for K = 0.564 in Formula 1 and 5363 in Formula 2, a further mathematical modification is made.

B-4.2 In order to establish a relationship between the constants (K) in B-2 and B-3, it is necessary to consider the form of the basic formulae, which are as follows:

$$FSI = \frac{K_1}{195 - A_T} \quad (A > K_2)$$

$$FSI = K_3\, A_T\ (A < K_2)$$

where:

K_1 = 100 (195 - R),

R = the area associated under the curve that is to be associated with an index of 100,

K_2 = an arbitrary choice within the limits of 0 and 195, and

K_3 = $K_1/[K_2(195 - K_2)]$.

B-4.3 Choosing K_2 = 195/2 produces a minimum value of K_3, that is, any other K_2 value will result in a higher K_3 value, and choosing R, the area under a red oak calibration plot, as a median value of 146 implies the following:

$$K_1 = 100\ (195 - 146) = 4900$$

B-4.4 Then using 97.5 as the value for K_2, K_3 would be:

$$K_3 = 4900/(97.5 \times 97.5) = 0.515$$

B-4.5 Thus, the formula for flame spread index in 3-3.2 is as follows:

$$FSI = 0.515\ A_T$$

B-4.6 Thus, the formula for flame spread index in 3-3.3 is as follows:

$$FSI = \frac{4900}{195 - A_T}$$

Appendix C Commentary

This Appendix is not a part of the requirements of this NFPA document, but is included for information purposes only.

C-1 Introduction.

C-1.1 This commentary has been prepared to provide the user of NFPA 255 with background information, including literature references, on the development and use of this method. It also provides the reader and user with the basis for the methods that have been used for deriving numerical flame spread indexes; an appreciation of the variability of the test; and comments on its application and limitations for testing selected types of materials.

C-1.2 On November 28, 1942, 490 people died in a fire in the Boston Coconut Grove Nightclub. On June 5, 1946, 61 persons died in the Chicago La Salle Street Hotel fire. On December 7, 1946, a fire in the Winecoff Hotel in Atlanta, Georgia, claimed the lives of 119 persons. These fires had one thing in common. In all 3 fires, rapid flame spread along the surfaces of interior finish was judged to be a major factor in the spread of fire. Two had burlap wall coverings and the other an early type of plywood that seriously delaminated. The fire protection authorities investigated several test methods with the objective of providing one that could be used to regulate interior finish materials and minimize repetition of such fires. These tests included (1)[1]: The Forest Products Laboratory Fire Tube Test (now ASTM Method E 69); Federal Specification SS A118b (acoustical tile/bunsen burner test) (replaced by SS-A-118a-7/63-referencing ASTM E 84); New York City Timber Test and Shavings Test (now obsolete); Crib Test-ASTM Specification C160-41 T (now ASTM Method E 160); and The Swedish Schlyter Test. All of these were relatively small laboratory tests. ASTM E 84/NFPA 255 was developed on the premise that a large test would provide a more realistic and comprehensive test, and it has since been widely adopted for use by the building code authorities to regulate the use of interior finish materials. Subsequently, during this same period, 2 other test methods were developed for use in research and development of new materials: the NBS Radiant Panel (ASTM Method E 162) and the FPL 8 ft tunnel (ASTM Method E 286). These methods have been widely used for research and development purposes.

C-2 History of ASTM E 84/NFPA 255.

C-2.1 The first "tunnel-type" furnace was built at Underwriters Laboratories, Inc., around 1922 when fire-proofing paints and specifically white wash were actively promoted. The equipment consisted of a long bench with a noncombustible top. The sample consisted of a wood trough about 16 ft long, 18 in. wide, and 18 in. deep (5.568 m long, 0.522 m wide, and 0.522 m deep), placed upside down on the bench. The inside of the trough was coated with the paint. A known quantity of wood at one end furnished the ignition source.

C-2.2 In 1927 and 1928, chemically impregnated wood was being developed, and Underwriters Laboratories used a tunnel 36 in. wide, 23 ft long, and 13 in. deep (1.044 m wide, 8 m long, and 0.377 m deep) to evaluate its performance. It was during this time that red oak flooring was selected as a control to calibrate the furnace. The sample formed the top of the tunnel. The fuel and draft were also controlled.

C-2.3 In the early 1940s, a desire to reduce flammability of wood-based products and the introduction of new building materials and combinations of materials brought about the need to further improve the tunnel. The development of the third tunnel furnace is explained fully in Underwriters Laboratories Bulletin of Research No. 32 (2). Subsequent refinements were incorporated, and the first formal test method was published as Standard UL 723 by Underwriters Laboratories in August 1950. Revised editions were published in 1958, 1960, 1971, 1977, and 1979. The National Fire Protection Association adopted the method as NFPA 255 in 1955 with revisions in 1958, 1961, 1966, 1970, 1972, 1979, and 1984. The test was adopted by the American Society for Testing and Materials as a tentative standard in 1950 and formally adopted in 1961 with revisions made in 1967, 1968, 1970, and from 1975 through 1980.

C-2.4 The tunnel has been designated the "Steiner Tunnel" by Underwriters Laboratories in honor of Albert J. Steiner who spent much time developing this and many other fire test methods.

C-2.5 Since 1950 the flame spread properties of materials, as measured by this method, have been reported as ratings, classifications, or indices. The last is considered more indicative of the nature of the results and is the present terminology used in the standard. The original method of determining flame spread index was based on either the ratio of the time at which flames traveled the full tunnel length or the partial flame travel distance relative to that of red oak. In 1968, a change was made in the FSI calculation to account for an anomaly between results for flame spread greater than or less than 13½ ft (4.1 m). In 1976, the flame spread index was changed to an area basis. Here the total area under the distance-time curve, ignoring any flame-front recession, was compared to a prescribed area typical of red oak flooring. The current calculation method (*see Appendix B*) uses a formula that takes the rate of flame travel into account.

C-2.6 The sensitivity study by Endicott and Bowhay (3) in 1970 has led to a concerted effort by the ASTM tunnel operators group to address concerns identified by the report. Since 1975 a series of changes have been specified in the standard. These include defining duration of furnace preheating, and the incorporation of a floor thermocouple, as well as more closely specifying details of furnace construction and standardization.

C-2.7 Particular attention is being paid to the refinement of the apparatus and procedure involved in the measurement of the smoke generated during testing. Round-robin tests that have been conducted to date have indicated large differences in smoke developed values for interlaboratory tests on replicate specimens (4).

C-2.8 Some of these revisions include standardization of the smoke-density measuring equipment, its location in the exhaust duct, and its orientation. The measurement of smoke

[1] The numbers in parentheses refer to the list of references at the end of this Appendix.

density is reported in terms of the area under the light absorption time curve related to a similar curve for red oak. Since the quality of vision obscuring particles in the smoke column is not linearly related to light absorption, this procedure has been criticized by some parties. The method does, however, provide a basis for comparisons.

C-2.9 In 1970, a revision to the scope was adopted to emphasize that there was no direct relationship between the flame spread index (FSI) and the fuel contributed or smoke density index (SDI). This revision was deemed necessary because some enforcement officials were assigning equal significance to the values.

C-2.10 Prior to 1978, the report of tests included an evaluation of the fuel contribution as well as the FSI and SDI. However, it is now recognized that the rise in temperature of the thermocouple located near the end of the tunnel, on which it is based, does not provide a valid measure of fuel contribution. Therefore, although the data are recorded during the test, this information is no longer normally reported.

C-2.11 Appendix A adopted in 1968 is intended as a guide for the mounting of specimens. It is not a mandatory part of the method, since the intent of the method is that the specimen be tested as closely as possible to the manner in which it will be applied in general use. In 1978, revisions were made that dealt with the testing of adhesives, the description of a wood substrate for testing coatings, and the definition of the properties of the inorganic-reinforced cement board used as a standard backing and the metal rods used as supports.

C-3 Fire Exposure Conditions.

C-3.1 The tunnel test fire exposure is provided by a 4½-ft (1.35-m) long test flame, covering approximately 7 ft^2 (0.63 m^2) of the 36 ft^2 (3.25 m^2) of the exposed specimen surface during the 10-min. test period. It releases heat at a rate of approximately 5000/Btu/min (88 kW) and creates gas temperatures near the specimen surface of up to 1600°F (900°C).

C-3.2 The size and heat release rate of the exposing flame, developed after repeated experiment tests, although not optimum fire conditions, were selected to produce a flame spread over the entire length of the calibration material in about 5½ minutes (5). It was found that conditions could be changed so that flames would spread faster, but these conditions caused the flame to spread too fast to make the necessary observations of the flame spread, smoke density, and temperature rise of the thermocouple.

C-4 Furnace Calibration.

C-4.1 Select red oak was chosen as a control material because this term denoted a fairly uniform grade of lumber nationally, whereas many other designations have a purely local significance. It is readily available, usually uniform in thickness and moisture content, and generally gives repetitive results. In recent years experiments have been run using manmade materials, such as particleboard, in the hope of further refining the repeatability; however, red oak is still used as a calibrating material.

C-4.2 The operating conditions of the tunnel are adjusted if necessary to ensure that the flame spreads to the end of the tunnel in 5.5 ± 0.25 min for a specimen of red oak flooring. Tests are run with an inorganic-reinforced cement board (ACB) specimen to establish the distance of the exposing flame at 4.5 ft (1.4 m). The calibration specifies only the time at which the flame passes over the end of the specimen. The FSI depends on the area under the flame spread versus the time curve. Therefore, the FSI of red oak is no longer exactly 100 as originally specified.

C-4.3 Recognition of the importance of turbulence, including the role of fire bricks and of window recesses, resulted in a revision in the method in 1976.

C-5 Repeatability and Reproducibility.

C-5.1 Four round-robin tests have been conducted: the first in 1958 between Underwriters Laboratories and Southwest Research Institute; the second in 1959 sponsored by the former Acoustic Tile Association among 4 laboratories using 4 different tiles (4); the third in 1973 on floor coverings by the National Bureau of Standards with 11 cooperating laboratories (6); the fourth in 1978 on loose-fill cellulosic insulation by the Consumer Product Safety Commission with 6 laboratories. Others are now in progress under the auspices of ASTM Committee E-5. A precision and accuracy statement is being prepared. In the interim, the reader is directed to the round-robin reports if information on precision and accuracy is needed.

C-5.2 An ASTM task group of Subcommittee E05.22, composed of tunnel operators, is now working on comprehensive design and on operational and procedural revisions to improve uniformity among facilities.

C-6 Advantages and Problems.

C-6.1 NFPA 255 results have generally shown performance similar to that observed during accidental building fires for some materials and exposure. It should be emphasized, however, that it is the intent of the method to provide only comparative classifications.

C-6.1.1 It provides a large flaming fire exposure, with specimen thermal exposure and area coverage sufficient to bring about progressive surface burning and combustible volatile generation characteristics of the materials under evaluation, resulting in a moving wind-aided flame front.

C-6.1.2 It involves a large specimen, nominally 36 ft^2 (3.25 m^2) of exposed area, allowing for realistic fire involvement of material surfaces and the development of physical and structural failures (collapse, buckling, large ruptures or cracks, etc.) that may influence flammability performance during the test period.

C-6.1.3 It may be applied to a wide range of materials, including composite constructions of faced or laminated boards, panels, units, or sections in actual field-installed thicknesses.

C-6.1.4 It may be used to measure the effects of density, thickness, surface contour, surface finish, delamination, strength, and joint design on the surface flammability of the specimen.

C-6.1.5 It does characterize most high-flame spread materials identified as having been involved in rapidly developing field fires (for example, highly combustible coatings on wood products, certain cellulosic acoustical materials, insulation facings applied with combustible adhesives, etc.) as well as providing an accurate characterization of the performance of some low flame spread materials in actual fires (for example, gypsum and mineral products).

C-6.1.6 Although this is a test to measure surface burning characteristics, the visual observation of flame travel is based on maximum flame extension anywhere within the tunnel volume, not necessarily directly on the specimen surface that may not be clearly visible. Surface flammability measurements of building materials do not yield a unique material property. Rather, the measurement is influenced by the method of test to a very considerable degree.

C-7 Uses and Limitations.

C-7.1 The orientation of the specimen in this method is in a horizontal ceiling position. This orientation places some limitations on the type of material that can be realistically mounted during testing. Prior to 1960, the tunnel was used primarily for the investigation of the surface burning characteristics of homogeneous compositions of ceiling and wall finishes, such as acoustical tiles, wall coverings, coatings, and various types of decorative panel, all being able to support themselves in the ceiling position throughout the test.

C-7.2 Through adaptation (Appendix A on Guide to Mounting Methods) the procedure was expanded to include the evaluation of composites and assemblies. The guide contains mounting suggestions for a number of individual categories of product classifications including: acoustical and similar panel products; composite building units; adhesive, batt- and blanket-insulating materials; fire-retardant and general-purpose coatings; loose-fill thermal insulations; treated and untreated plywoods; lumber and wood composition boards; foamed, molded, reinforced, and laminated plastics; and sheet-type wall coverings.

C-7.3 The difficulty of defining materials that contribute little or no fuel to a fire has in the past led to the use of ASTM E 84/NFPA 255 to provide information about the combustibility of materials. ASTM Committee E-5 and the NFPA Fire Tests Committee do not and have not ever recommended that the results of these tests be used alone to describe material combustibility.

C-7.4 Composite assemblies or panels using metal or mineral facings and combustible interior cores, and which remain essentially impermeable to flame throughout the test period, may not be completely evaluated for surface burning behavior by this method, since the interior cores are not fully challenged.

C-7.5 Some materials require support to remain in place during the test period, such as loose-fill insulation supported by a metal screen. The supporting screen tends to provide low flame spread indexes (FSI) relative to those obtained for materials that are not so supported. Conversely, materials that are supported on rods, such as batt insulation, may produce higher FSI if retained on the ceiling rather than allowed to burn on the floor.

C-7.6 Some materials, such as composites, may delaminate during the test. This may cause two possible responses: the material may expose two or more surfaces to the flame increasing the FSI; or the material may sag or drop one end into the fire chamber impeding further flame spread.

C-7.7 Some materials, such as cellular plastics and thermoplastic and thermosetting materials, may be difficult to evaluate. Thermoplastic and thermosetting materials not mechanically fastened will often fall to the floor of the tunnel and also usually receive relatively low FSI. If supported on wire screen, rods, or other supports, these materials may be completely engulfed in flame, and a questionable comparison is being made between the surface flame spread of nominal 1-in. (0.039-mm) thick red oak with the burning rate of these materials. Where the entire specimen is consumed, as compared to the surface burning of red oak, much more oxygen is used and higher smoke developed indexes are usually obtained for these materials.

C-7.8 The materials described above, that is, those that drip, melt, delaminate, draw away from the fire, or require artificial support, present unique problems and require careful interpretation of the test results. Some of these materials that are assigned a low FSI based on this method may exhibit an increasing propensity for generating flame-over conditions during room fire test with increasing area of exposure of the material and increasing intensity of the fire exposure. The result, therefore, may not be indicative of their performance if evaluated under large-scale test procedures. Alternative means of testing may be necessary to fully evaluate some of these materials.

C-7.9 In order to provide needed technical data, flammability evaluations of cellular plastics for building construction using the Steiner tunnel began with the testing and classification of a flame-retardant formulation of polystyrene foam board in 1960, with subsequent evaluation of polyurethane-type boards incorporating flame-retardant resin systems (first generation) beginning in 1964, polymerically and chemically modified flame-retardant polyurethane-type formulations (second generation in 1965), polyisocyanurate-type foams initiated in 1968, and, most recently, urea-formaldehyde type, cavity-fill foams. Spray-applied and poured-in-place cellular foam systems were first subjected to the test in 1968 and 1972, respectively.

C-7.10 From 1960 through 1973, over 2000 tunnel tests have been conducted on flame-retardant and general-purpose polystyrene, polyurethane, polyisocyanurate and urea-formaldehyde cellular plastics, in board-stock, spray-applied or poured-in-place forms, yielding flame spread values ranging from less than 5 to over 2000. See Ref. (7) for a full report on one test series.

C-7.11 The flame spread index of some materials may vary depending upon environmental conditions. The prescribed limits on the temperature and relative humidity for specimen conditioning and tunnel air supply (both 73.4 ± 5°F, 50 ± 5% rh) were selected to minimize these effects.

C-8 Correlation with Other Fire Conditions. Several studies have been made to examine the relationship of the FSI test results on materials with their performance in large-scale fire growth experiments and with their performance in other laboratory test methods. Some comparisons with large-scale experiments are given in the references listed below. Comparisons have also been made between ASTM E 84/NFPA 255, ASTM E 162, ASTM E 286, the "2-ft tunnel test," the "corner test," and other tests.

C-9 References.

(1) Steiner, A. J., Building Officials Conference of America Yearbook, 1949-1950, pp. 115-116.

(2) Underwriters Laboratories, Inc., "Fire Hazard Classification of Building Materials," Bulletin of Research, No. 32, Chicago, Ill, September 1947.

(3) Endicott, L. E., and Bowhay, R. B., "A Statistical Evaluation of the Fire Hazard Classification Furnace (ASTM E 84-68)," ASTM Materials Research and Standards, May 1970, pp. 19-21, 50-52.

(4) "Round-Robin Tests on Tunnel Type Flame Spread Furnaces" for ASTM Project No. 1-811-2, Final Report, Southwest Research Institute, San Antonio, Tex., April 16, 1959.

(5) Steiner, A. J., "Burning Characteristics of Building Materials," Fire Engineering, May 2, 1951.

(6) Lee, T. G., and Huggett, C., "Interlaboratory Evaluation of the ASTM E 84-70 Tunnel Test Applied to Floor Coverings," Journal of Testing and Evaluation, Vol. 3, No. 1, ASTM 1975.

(7) Underwriters Laboratories, Inc., Flammability Studies of Cellular Plastics and Other Building Materials Used for Interior Finish, Subject 723, U.L., Inc., Northbrook, Ill., June 13, 1975.

Appendix D Referenced Publications

D-1 The following documents or portions thereof are referenced within this standard for informational purposes only and thus are not considered part of the requirements of this document. The edition indicated for each reference is the current edition as of the date of the NFPA issuance of this document.

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

NFPA 251-1990, *Standard Methods of Fire Tests of Building Construction and Materials.*

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