

NFPA 251

Standard Methods of Tests of Fire Endurance of Building Construction and Materials

1999 Edition



National Fire Protection Association, 1 Batterymarch Park, PO Box 9101, Quincy, MA 02269-9101
An International Codes and Standards Organization

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NFPA 251

Standard Methods of Tests of Fire Endurance of Building Construction and Materials

1999 Edition

This edition of NFPA 251, *Standard Methods of Tests of Fire Endurance of Building Construction and Materials*, was prepared by the Technical Committee on Fire Tests and acted on by the National Fire Protection Association, Inc., at its May Meeting held May 17–20, 1999, in Baltimore, MD. It was issued by the Standards Council on July 22, 1999, with an effective date of August 13, 1999, and supersedes all previous editions.

This edition of NFPA 251 was approved as an American National Standard on August 13, 1999.

Origin and Development of NFPA 251

NFPA 251 originated in the recommendations of the International Fire Prevention Congress in London in 1903. It was presented to the NFPA by the Committee on Fire-Resistive Construction in 1914. It was adopted officially in a revised form in 1918. Successive editions were published in 1926, 1934, 1941, 1955, 1958, 1959, 1960, 1961, 1963, 1969, 1979, 1985, and 1990. It was overseen, in succession, by the Technical Committee on Fire-Resistive Construction, the Technical Committee on Building Construction, and, for the last three editions, by the Technical Committee on Fire Tests.

The 1995 edition of this document was a reconfirmation of the earlier edition with only a few items being addressed. Substantial investigation and record research was done on the topic of the hose stream application on test specimens. The findings of the committee did not support modification of the provision that permits a test assembly to be tested for one-half the time required for an hourly rating and then to be tested by a hose stream.

The committee also modified the title of this document in response to the research done to convey a truer sense of the standard's proper application.

The 1999 edition is a reconfirmation of the 1995 edition with minor editorial modifications.

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NOTICE: An asterisk (*) following the number or letter designating a paragraph indicates that explanatory material on the paragraph can be found in Appendix A.

Information on referenced publications can be found in Chapter 15, Section G-13, and Appendix H.

Chapter 1 General

1-1* Scope.

1-1.1 These methods of fire tests apply to assemblies of masonry units and to composite assemblies of structural materials for buildings, including bearing and other walls and partitions, columns, girders, beams, slabs, and composite slab and beam assemblies for floors and roofs. They also shall apply to other assemblies and structural units that constitute permanent integral parts of a finished building.

1-1.2* It is the intention of this standard that classifications be based on performance during the period of exposure and shall not be used to determine suitability for use after fire exposure.

1-1.3 The results of these tests are one factor in assessing fire performance of building construction and assemblies. These methods prescribe a standard fire exposure for comparing the performance of building construction assemblies. Application of these test results to predict the performance of actual building construction requires careful evaluation of test conditions.

1-2 Purpose. This standard outlines methods of fire tests for the fire-resistive properties of building members and assemblies.

1-3 Significance.

1-3.1 This standard is intended to evaluate the duration for which the types of assemblies noted in 1-1.1 contain a fire, retain their structural integrity, or exhibit both properties, depending on the type of assembly involved during a predetermined test exposure.

1-3.2 The test exposes a specimen to a standard fire exposure that is controlled to achieve specified temperatures throughout a specific time period. In some instances, the fire exposure is followed by the application of a specified standard fire hose stream. The exposure, however, shall not be considered representative of all fire conditions, which vary with changes in the amount, nature, and distribution of fire loading, ventilation, compartment size and configuration, and heat sink characteristics of the compartment. The test does, however, provide a relative measure of fire performance of comparable assemblies under these specified fire exposure conditions. Any vari-

ation from the construction or conditions (e.g., size, method of assembly, and materials) that are tested substantially varies the performance characteristics of the assembly.

1-3.3 The test standard provides methods to measure the following:

- (1) In walls, partitions, and floor or roof assemblies:
 - a. Transmission of heat
 - b. Transmission of hot gases through the assembly sufficient to ignite cotton waste
 - c. Load-carrying ability of the test specimen during the test exposure where load-bearing elements are included
- (2) For individual load-bearing assemblies such as beams and columns: load-carrying ability under the test exposure with some consideration for the end support conditions (i.e., restrained or unrestrained)

1-3.4 The test standard does not provide the following:

- (1) Full information on the performance of assemblies constructed with components or lengths other than those tested
- (2) Evaluation of the degree to which the assembly contributes to the fire hazard by generation of smoke, toxic gases, or other products of combustion
- (3) Measurement of the degree of control or limitation of the passage of smoke or products of combustion through the assembly
- (4) Simulation of the fire behavior of joints between building elements, such as floor-to-wall or wall-to-wall, connections
- (5) Measurement of flame spread over the surface of the tested element
- (6) Effect on fire endurance of conventional openings in the assembly (e.g., electrical receptacle outlets, plumbing pipe) unless specifically provided for in the construction tested

1-4 Definitions.

Shall. Indicates a mandatory requirement.

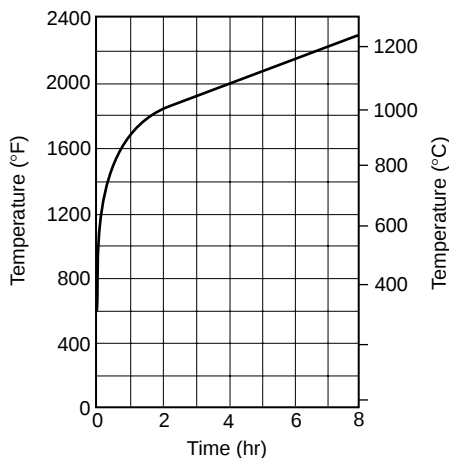
Should. Indicates a recommendation or that which is advised but not required.

Standard. A document, the main text of which contains only mandatory provisions using the word "shall" to indicate requirements and which is in a form generally suitable for mandatory reference by another standard or code or for adoption into law. Nonmandatory provisions shall be located in an appendix, footnote, or fine-print note and are not to be considered a part of the requirements of a standard.

Chapter 2 Control of Fire Tests

2-1 Temperature–Time Curve.

2-1.1* The conduct of fire tests of materials and construction shall be controlled by the standard temperature–time curve shown in Figure 2-1.1.

Figure 2-1.1 Temperature-time curve.

Note: The following are the points that determine the curve.

1000°F (538°C).....	at 5 minutes
1300°F (704°C).....	at 10 minutes
1550°F (843°C).....	at 30 minutes
1700°F (927°C).....	at 1 hour
1850°F (1010°C).....	at 2 hours
2000°F (1093°C).....	at 4 hours
2300°F (1260°C).....	at 8 hours or over

2-1.2 The temperature inside the furnace shall be ambient when the test begins.

2-2* Furnace Temperatures.

2-2.1* The temperature fixed by the curve shall be the average temperature obtained from the readings of not less than nine thermocouples for a floor, roof, wall, or partition and not less than eight thermocouples for a structural column. The thermocouples shall be symmetrically disposed and distributed to show the temperature near all parts of the sample, and shall be enclosed in protection tubes of such materials and dimensions that the time constant of the protected thermocouple assembly lies within the range of 5.0 minutes to 7.2 minutes. The exposed length of the pyrometer tube and thermocouple in the furnace chamber shall be not less than 12 in. (305 mm).

Other types of protecting tubes or pyrometers shall be permitted to be used that, under test conditions, provide the time range of 5.0 minutes to 7.2 minutes within the accuracy requirement that applies for the measurement of furnace temperature. For floors and columns, the junction of the thermocouples shall be placed 12 in. (305 mm) away from the exposed face of the specimen at the beginning of the test and, during the test, shall not touch the sample as a result of its deflection. In the case of walls and partitions, the thermocouples shall be placed 6 in. (152 mm) away from the exposed face of the specimen at the beginning of the test, and shall not touch the specimen during the test in the event of deflection.

2-2.2 The temperatures shall be measured at intervals not exceeding 1 minute during the test period.

2-2.3 The accuracy of the furnace control shall be such that the area under the temperature-time curve, obtained by averaging the results from the pyrometer readings, is within the

following percentages of the corresponding area under the standard temperature-time curve shown in Figure 2-1.1:

- (1) 10 percent for fire tests of 1 hour or less
- (2) 7.5 percent for fire tests over 1 hour and not more than 2 hours
- (3) 5 percent for fire tests exceeding 2 hours

2-3 Temperatures of Unexposed Surfaces of Floors, Roofs, Walls, and Partitions.

2-3.1* Temperatures of unexposed surfaces shall be measured with thermocouples or thermometers placed under thermocouple pads. Thermocouple pads shall meet the following requirements or otherwise shall be demonstrated to be equivalent by comparative NFPA 251 tests:

- (1) Length and width, 6 in. $\pm$ $\frac{1}{8}$ in. (1.52 mm $\pm$ 3.2 mm)
- (2) Thickness, 0.40 in. $\pm$ 0.05 in. (10.2 mm $\pm$ 1.3 mm)
- (3) Thermal conductivity [at 150°F (65°C)], 0.38 $\pm$ 0.027 Btu·in./hr·ft²·°F (0.55 $\pm$ 0.039 W/m·K)

The wire leads of the thermocouple or the stem of the thermometer shall have an immersion under the pad and shall be in contact with the unexposed surface for not less than 3 $\frac{1}{2}$ in. (90 mm). The hot junction of the thermocouple or the bulb of the thermometer shall be placed under the approximate center of the pad. The outside diameter of protecting or insulating tubes and of thermometer stems shall be not more than $\frac{5}{16}$ in. (8 mm). The pad shall be held firmly against the surface and shall fit closely about the thermocouples or thermometer stems. Thermometers shall be of the partial-immersion type, with a length of stem, between the end of the bulb and the immersion mark, of 3 in. (76 mm). The wires for the thermocouple in the length covered by the pad shall be not heavier than No. 18 B & S gauge [0.04 in. (1.02 mm)] and shall be electrically insulated with heat-resistant and moisture-resistant coatings.

2-3.2 Temperature measurements shall be obtained from at least nine points on the surface, as follows:

(a) Five thermocouples shall be symmetrically disposed; one shall be located approximately at the center of the specimen and four shall be located approximately at the center of each quadrant. The other four thermocouples shall be located at the discretion of the testing authority to obtain representative information on the performance of the construction under test.

(b) All of the thermocouples shall be located at a distance of at least 1 $\frac{1}{2}$ times the thickness of the construction or 12 in. (305 mm) from the edges of the test specimen.

Exception: Distance requirements are not applicable where an element of the assembly is located near the edge only.

(c) None of the thermocouples shall be located opposite or on top of beams, girders, pilasters, or other structural members if temperatures at such points are obviously lower than at more representative locations.

(d) None of the thermocouples shall be located opposite or on top of fasteners such as screws, nails, or staples that are obviously higher or lower in temperature than at more representative locations if the aggregate area of any part of such fasteners projected to the unexposed surface is less than 1 percent of the area within any 6-in. (152-mm) diameter circle. Such fasteners shall not be required to extend through the assembly.

2-3.3 Temperature readings shall be measured at intervals not exceeding 1 minute.

2-3.4 Where the conditions of acceptance place a limitation on the rise of the temperature of the unexposed surface, the temperature end point of the fire endurance period shall be determined by the average of the measurements taken at individual points.

Exception: Where a temperature rise of 30 percent in excess of the specified limit occurs at any one of these points, all other points shall be ignored and the fire endurance period shall be judged as ended.

2-4 Furnace Pressure.

2-4.1 The pressure-sensing probes shall be as shown in Figures 2-4.1(a) or 2-4.1(b).

Figure 2-4.1(a) Static pressure-sensing probe dimensions.

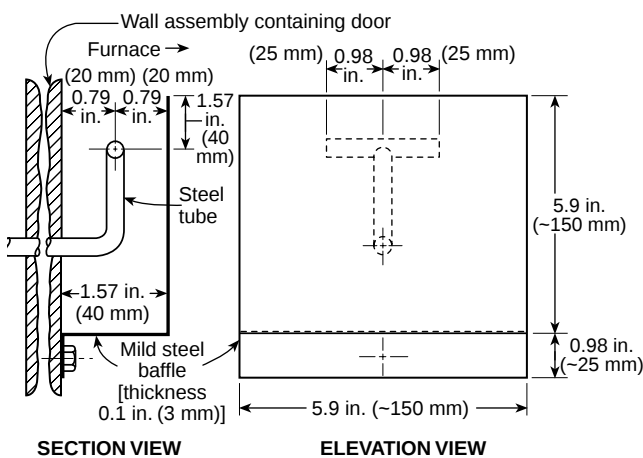
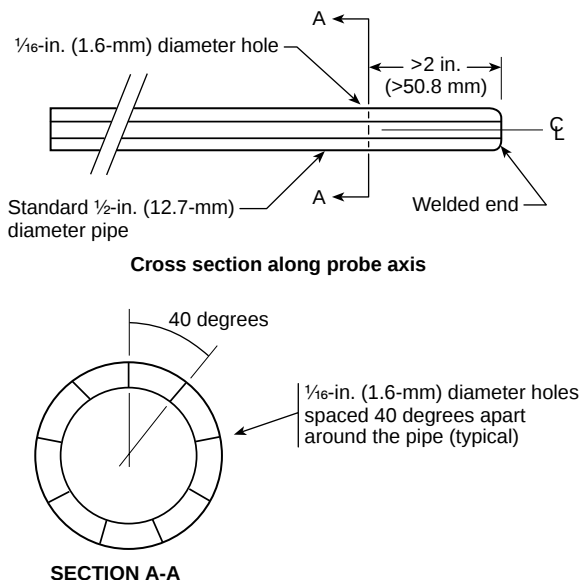


Figure 2-4.1(b) Pressure-sensing probe.



2-4.2 The pressure shall be measured using a differential pressure instrument capable of reading in increments no coarser than 0.01 in. wg (2.5 Pa) with a precision of not less than ± 0.005 in. wg (± 1.25 Pa). The differential pressure measurement instrument(s) shall be located to minimize stack effects caused by vertical runs of pressure tubing between the furnace probe(s) and instrument locations.

2-4.3 The furnace pressure(s) shall be measured and recorded at intervals not exceeding 1 minute throughout the test.

2-4.4 Control of the furnace pressure shall be established no later than 10 minutes after the start of the test and shall be maintained throughout the remainder of the test.

For vertical specimens, the vertical pressure distribution within the furnace shall be measured by at least two probes separated by a vertical distance [minimum of 6 ft (1.8 m)] within the furnace. A calculation of the neutral plane's (zero differential pressure) location shall be made based on the vertical separation of the probes and their pressure differences. The pressure measurements made inside the furnace, along with the calculation showing the position of the neutral plane with respect to the top of the vertical assembly during the test, shall be reported.

For horizontal specimens, the pressure shall be measured at two locations along the centerline of the specimen and 12 in. (305 mm) below the specimen. The pressure (the average of the two readings) during the test shall be reported.

Chapter 3 Test Specimen

3-1 Specimen.

3-1.1 The test specimen shall be a true representation of the construction for which classification is to be determined with respect to materials, workmanship, and details such as dimension of parts. The specimen shall be built under conditions representative of those properties that are practically applied in building construction and operation. The physical properties of the materials and ingredients used in the test specimen shall be determined and recorded.

3-1.2 The size and dimensions of the test specimen described in the standard shall be recognized as intending to apply in rating constructions of dimensions within the usual general range used in buildings.

Exception: Where the conditions of use limit the construction to smaller dimensions, a proportionate reduction shall be permitted to be made in the dimensions of the specimens for a test used to qualify them for such restricted use.

3-1.3 Where it is desired to include a built-up roof covering, the test specimen shall have a roof covering of 3-ply, 15-lb (6.8-kg) type felt not in excess of 120 lb (54.4 kg) per 100 ft² (9.3 m²) of hot mopping asphalt without gravel surfacing. Tests of assemblies with this covering shall not preclude the field use of other built-up roof coverings.

3-2 Protection and Conditioning of Test Specimen. The test specimen shall be protected during and after fabrication to ensure its quality and condition when tested. It shall not be tested until close to its full strength, and, if it contains moisture, it shall not be tested until the excess moisture has been removed to achieve an air-dry condition in accordance with the requirements of 3-2.1 through 3-2.3.

The testing equipment and sample undergoing the fire test shall be protected from any condition of wind or weather that might lead to abnormal results. The ambient air temperature at the beginning of the test shall be within the range of 50°F to 90°F (10°C to 32°C). The velocity of air across the unexposed surface of the sample, measured immediately before the test begins, shall not exceed 4.4 ft/sec (1.3 m/sec) as determined by an anemometer placed at right angles to the unexposed surface. If mechanical ventilation is used during the test, an airstream shall not be directed across the surface of the specimen.

3-2.1* Prior to the fire test, the construction shall be conditioned with the objective of providing, within a reasonable time, a moisture condition within the specimen approximately representative of that likely to exist in similar construction in buildings. For purposes of standardization, this condition shall be considered to be that which would exist at equilibrium as a result of drying in an ambient atmosphere of 50 percent relative humidity at 73°F (23°C); however, with some constructions, it could be difficult or impossible to achieve such uniformity within a reasonable time. Accordingly, where uniformity cannot be achieved, specimens shall be permitted to be tested when the dampest portion of the structure [i.e., the portion at 6 in. (152 mm) depth below the surface of massive constructions] has achieved a moisture content corresponding to drying to equilibrium with air in the range of 50 percent to 75 percent relative humidity at 73°F ± 5°F (23°C ± 3°C). In the event that specimens dried in a heated building fail to meet these requirements after a 12-month conditioning period, or in the event that the nature of the construction is such that it is evident that drying of the specimen interior is prevented by hermetic sealing, these requirements shall be permitted to be waived.

Exception: The requirement for testing of the specimen only after nearing its full strength shall not be permitted to be waived.

3-2.2 If, during the conditioning of the specimen it appears desirable or is necessary to use accelerated drying techniques, it shall be the responsibility of the laboratory conducting the test to avoid procedures that significantly alter the structural or fire endurance characteristics of the specimen, or both, from those produced as the result of drying in accordance with procedures in 3-2.1.

3-2.3* Within 72 hours prior to the fire test, information on the actual moisture content and distribution within the specimen shall be obtained. The information shall be included in the test report.

Chapter 4 Conduct of Fire Tests

4-1 Fire Endurance Test.

4-1.1 A fire endurance test on the specimen, including its applied load, if any, shall be continued until failure occurs, or until the specimen has withstood the test conditions for a period equal to that herein specified in the conditions of acceptance for the given type of construction.

4-1.2 For the purpose of obtaining additional performance data, the test shall be permitted to be continued beyond the time the fire endurance classification is determined.

4-2 Hose Stream Test.

4-2.1 Where required by the conditions of acceptance, a duplicate specimen shall be subjected to a fire exposure test for a period equal to one-half of that indicated as the resistance period in the fire endurance test, but not for more than 1 hour, immediately after which the specimen shall be subjected to the impact, erosion, and cooling effects of a hose stream directed first at the middle and then at all parts of the exposed face, with changes in direction made slowly.

Exception: The hose stream test shall not be required in the case of construction having a resistance period, as specified in the fire endurance test, of less than 1 hour.

4-2.2 The stream shall be delivered through a 2½-in. (64-mm) hose discharging through a national standard play pipe as specified in ANSI/UL 385, *Standard for Safety Play Pipes for Water Supply Testing in Fire Protection Service*. The play pipe shall have an overall length of 30 in. (762 mm) and shall be equipped with a 1⅛-in. (28.4-mm) discharge tip of the standard-taper, smooth bore pattern without shoulder at the orifice. The play pipe shall be fitted with a 2½-in. (64-mm) inside diameter by 6-in. (153-mm) long nipple mounted between the hose and the base of the play pipe.

The pressure tap for measuring the water pressure at the base of the nozzle shall be normal to the surface of the nipple, centered in its length, and shall not protrude into the water stream. The water pressure shall be measured with a suitable pressure gauge [as a minimum 0 to 50 psi (0 to 345 kPa)] graduated in no more than 2-psi (13.8-kPa) increments. The water pressure and duration of application shall be as specified in Table 4-2.2.

Table 4-2.2 Hose Stream Test

Resistance Period	Water Pressure at Base of Nozzle		Duration of Application to Exposed Area	
	psi	kPa	min/100 ft ²	min/9.3 m ²
8 hr and over	45	310	6	0.65
4 hr and over, if less than 8 hr	45	310	5	0.54
2 hr and over, if less than 4 hr	30	207	2½	0.27
1½ hr and over, if less than 2 hr	30	207	1½	0.16
1 hr and over, if less than 1½ hr	30	207	1	0.11
Less than 1 hr, if desired	30	207	1	0.11

4-2.3 The nozzle orifice shall be 20 ft (6 m) from the center of the exposed surface of the test sample if the nozzle is so located that, when directed at the center, its axis is normal to the surface of the test sample. If otherwise located, its distance from the center shall be less than 20 ft (6 m) by a distance equal to 1 ft (0.3 m) for each 10 degrees of deviation from normal.

Chapter 5 Tests of Bearing Walls and Partitions

5-1 Size of Specimen. The area exposed to fire shall be not less than 100 ft² (9.3 m²), with neither dimension less than 9 ft (2.7 m). The test specimen shall not be restrained on its vertical edges.

5-2* Loading. Throughout the fire endurance and fire and hose stream tests, a constant superimposed load shall be applied to simulate a maximum load condition. The applied load shall be, as nearly as practicable, the maximum load permitted by design under nationally recognized structural design criteria. The tests also shall be permitted to be conducted by applying to the specimen a load less than the maximum. Such tests shall be identified in the test report as having been conducted under restricted load conditions. The applied load, and the applied load expressed as a percentage of the maximum permitted design load, shall be included in the report. A double-wall assembly shall be loaded during the test to simulate field use conditions, with either side loaded separately or both sides loaded together. The method used shall be reported.

5-3 Conditions of Acceptance. The test shall be regarded as valid if the following conditions are met.

(a) The wall or partition shall have sustained the applied load during the fire endurance test, without passage of flame or gases hot enough to ignite cotton waste, for a period equal to that required for the classification desired.

(b) The wall or partition shall have sustained the applied load during the fire and hose stream test, as specified in Section 4-2, without passage of flame, gases hot enough to ignite cotton waste, or the hose stream. The assembly shall be considered to have failed the hose stream test if an opening develops that allows a projection of water from the stream beyond the unexposed surface during the hose stream test.

(c) Transmission of heat through the wall or partition during the fire endurance test shall not be sufficient to raise the temperature on the unexposed surface more than 250°F (140°C) above the assembly's initial temperature.

Chapter 6 Tests of Nonbearing Walls and Partitions

6-1 Size of Specimen. The area exposed to fire shall be not less than 100 ft² (9.3 m²), with neither dimension less than 9 ft (2.7 m). The test specimen shall be restrained on all four edges.

6-2 Conditions of Acceptance. The test shall be regarded as valid if the following conditions are met.

(a) The wall or partition shall have withstood the fire endurance test, without passage of flame or gases hot enough to ignite cotton waste, for a period equal to that required for the classification desired.

(b) The wall or partition shall have withstood the fire and hose stream tests, as specified in Section 4-2, without passage of flame, gases hot enough to ignite cotton waste, or the hose stream. The assembly shall be considered to have failed the hose stream test if an opening develops that allows a projection of water from the stream beyond the unexposed surface during the hose stream test.

(c) Transmission of heat through the wall or partition during the fire endurance test shall not be sufficient to raise the temperature on the assembly's unexposed surface more than 250°F (140°C) above the assembly's initial temperature.

Chapter 7 Tests of Columns

7-1 Size of Specimen. The length of the column exposed to fire shall, where practicable, approximate the maximum clear length contemplated by the design and, for building columns, shall be not less than 9 ft (2.7 m). The contemplated details of connections, and their protection, if any, shall be applied according to the methods of acceptable field practice.

7-2 Loading.

7-2.1 Throughout the fire endurance test, the column shall be exposed to fire on all sides and shall be loaded in a manner calculated to develop as nearly as practicable, in theory, the working stresses contemplated by the design. Provision shall be made for transmitting the load to the exposed portion of the column without unduly increasing the effective column length.

7-2.2 If the submitter and the testing body jointly so decide, the column shall be permitted to be subjected to 1³/₄ times its designed working load before the fire endurance test is undertaken. The fact that such a test has been performed shall not be construed as having had a deleterious effect on the fire endurance test performance.

7-3 Conditions of Acceptance. The test shall be regarded as valid if the column sustains the applied load during the fire endurance test for a period equal to that required for the classification desired.

Chapter 8 Alternative Test of Protection for Structural Steel Columns

8-1 Application. This test procedure shall not require column loading at any time and shall be permitted to be used at the discretion of the testing laboratory to evaluate steel column protection that is not required by design to carry any of the column load.

8-2 Size and Character of Specimen.

8-2.1 The size of the steel column used as a specimen shall be a true representation of the design, materials, and workmanship required for the classification desired. The protection shall be applied in accordance with the methods of acceptable field practice. The length of the protected column shall be at least 8 ft (2.4 m). The column shall be vertical during application of the protection and during the fire exposure.

8-2.2 The applied protection shall be restrained against longitudinal temperature expansion greater than that of the steel column by rigid steel plates or reinforced concrete attached to the ends of the steel column before the protection is applied. The size of the plates or amount of concrete shall be adequate to provide direct bearing for the entire transverse area of the protection.

8-2.3 The ends of the specimen, including the means for restraint, shall be provided with sufficient thermal insulation to prevent appreciable direct heat transfer from the furnace.

8-3 Temperature Measurement. The temperature of the steel in the column shall be measured by at least three thermocouples located at each of four levels. The upper and lower levels shall be 2 ft (0.6 m) from the ends of the steel column, and the two intermediate levels shall be spaced equally. The

thermocouples at each level shall be placed to measure significant temperatures of the component elements of the steel section.

8-4 Exposure to Fire. Throughout the fire endurance test, the specimen shall be exposed to fire on all sides for its full length.

8-5 Conditions of Acceptance. The test shall be considered to be valid if the transmission of heat through the protection during the period of fire exposure required for the classification desired does not raise the average (arithmetical) temperature of the steel at any one of the four levels above 1000°F (530°C) or does not raise the temperature above 1200°F (649°C) at any one of the measured points.

Chapter 9 Tests of Floor and Roof Assemblies

9-1 Application.

9-1.1 This test procedure shall apply to floor and roof assemblies with or without attached, furred, or suspended ceilings and the underside of the specimen under test shall be exposed to fire.

9-1.2* Two fire endurance classifications shall be determined for assemblies restrained against thermal expansion:

- (1) A restrained assembly classification based upon the conditions of acceptance specified in Sections 9-5(a) through (e)
- (2) An unrestrained assembly classification based upon the conditions of acceptance specified in Sections 9-6(a) and (b), in addition to Section 9-6(c), (d), (e), or (f)

9-1.3 One fire endurance classification shall be determined from tests of assemblies not restrained against thermal expansion based on the conditions of acceptance specified in Sections 9-6(a) and (b).

9-1.4 Individual unrestrained classifications shall be permitted to be determined for beams tested in accordance with this test method using the conditions of acceptance specified in Section 11-3(a), (b), or (c).

9-2 Size and Characteristics of Specimen.

9-2.1 The area exposed to fire shall be not less than 180 ft² (16.7 m²) with neither dimension less than 12 ft (3.6 m). Structural members, if a part of the construction under test, shall lie within the combustion chamber and shall have a side clearance of not less than 8 in. (203 mm) from the combustion chamber walls.

9-2.2 The specimen shall be installed in accordance with recommended fabrication procedures for the type of construction and shall be representative of the design for which classification is desired. Where a restrained classification is desired, specimens representing forms of construction in which restraint to thermal expansion occurs shall be reasonably restrained in the furnace.

9-3 Loading. Throughout the fire endurance test, a superimposed load shall be applied to the specimen to simulate a maximum load condition. The maximum load condition shall be, as nearly as practicable, the maximum load allowed by the limiting condition of design under nationally recognized structural design criteria. A fire endurance test shall be permitted to be conducted by applying a restricted load condition to the

specimen that shall be identified for a specific load condition other than the maximum permitted load condition.

9-4 Temperature Measurement.

9-4.1 For specimens using structural members (e.g., beams, open-web steel joists) spaced at more than 4 ft (1.2 m) on center, the temperature of the steel in these structural members shall be measured by thermocouples at three or more sections spaced along the length of the members, with one section preferably located at midspan.

Exception: In cases where the cover thickness is not uniform along the specimen length, at least one of the sections at which temperatures are measured shall include the point of minimum cover.

9-4.2 For specimens using structural members (e.g., beams, open-web steel joists) spaced at 4 ft (1.2 m) on center or less, the temperature of the steel in these structural members shall be measured by four thermocouples placed on each member. No more than four members shall be so instrumented. The thermocouples shall be placed at significant locations, such as at midspan, over joints in the ceiling, and over light fixtures.

9-4.3 For reinforced or prestressed concrete structural members, thermocouples shall be located on each of the tension-reinforcing elements unless there are more than eight such elements, in which case thermocouples shall be placed on eight elements selected to obtain representative temperatures of all the elements.

9-4.4* For steel structural members, there shall be four thermocouples located at each section. Where only four thermocouples are required on a member, the thermocouples shall be permitted to be distributed along the member at significant locations as specified in 9-4.2. Two shall be located on the bottom of the bottom flange or chord, one on the web at the center, and one on the top flange or chord.

9-4.5* For steel floor or roof units, four thermocouples shall be located on each section (a section shall equal the width of one unit). One thermocouple shall be located on the bottom plane of the unit at an edge joint, one on the bottom plane of the unit remote from the edge, one on a sidewall of the unit, and one on the top plane of the unit. The thermocouples shall be applied, where practicable, to the surface of the units that are remote from fire and shall be spaced across the width of the unit. Not more than four nor fewer than two sections shall be required to be so instrumented in each representative span. The groups of four thermocouples shall be placed in representative locations.

9-5 Conditions of Acceptance — Restrained Assembly. In obtaining a restrained assembly classification, the following conditions shall be met.

(a) The specimen shall sustain the applied load during the classification period without developing unexposed surface conditions that ignite cotton waste.

(b) The transmission of heat through the specimen during the classification period shall not raise the average temperature on its unexposed surface more than 250°F (140°C) above its initial temperature.

(c) For specimens using steel structural members (e.g., beams, open-web steel joists) spaced more than 4 ft (1.2 m) on center, the beams shall achieve a fire endurance classification on the basis of the temperature criteria specified in Section 9-6(c), (d), (e), or (f) for assembly classifications up to and including 1 hour. For classifications greater than 1 hour,

these temperature criteria shall apply for a period equal to one-half the period for the classification of the assembly or 1 hour, whichever is greater.

(d) For specimens using steel structural members (e.g., beams, open-web steel joists) spaced 4 ft (1.2 m) or less on center, the assembly shall achieve a fire endurance classification on the basis of the temperature criteria specified in Section 9-6(d) for assembly classifications up to and including 1 hour. For classifications greater than 1 hour, these temperature criteria shall apply for a period equal to one-half the period for the classification of the assembly or 1 hour, whichever is greater.

(e) For specimens using conventionally designed concrete beams spaced more than 4 ft (1.2 m) on center, the assembly shall achieve a fire endurance classification on the basis of the temperature criteria specified in Section 9-6(e) for assembly classifications up to and including 1 hour. For classifications greater than 1 hour, these temperature criteria shall apply for a period equal to one-half the period for the classification of the assembly or 1 hour, whichever is greater.

9-6 Conditions of Acceptance — Unrestrained Assembly. In obtaining an unrestrained assembly classification, the following conditions shall be met.

(a) The specimen shall sustain the applied load during the classification period without developing unexposed surface conditions that ignite cotton waste.

(b) The transmission of heat through the specimen during the classification period shall not raise the average temperature on its unexposed surface more than 250°F (140°C) above the specimen's initial temperature.

(c) For specimens using steel structural members (e.g., beams, open-web steel joists) spaced more than 4 ft (1.2 m) on center, the temperature of the steel shall not exceed 1300°F (704°C) at any location during the classification period, nor shall the average temperature recorded by four thermocouples at any section exceed 1100°F (593°C) during the classification period.

(d) For specimens using steel structural members (e.g., beams, open-web steel joists) spaced 4 ft (1.2 m) or less on center, the average temperature recorded by all joist or beam thermocouples shall not exceed 1100°F (593°C) during the classification period.

(e) For specimens using conventionally designed concrete structural members (excluding cast-in-place concrete slabs having spans equal to or less than those tested), the average temperature of the tension steel at any section shall not exceed 800°F (426°C) for cold-drawn prestressing steel or 1100°F (593°C) for reinforcing steel during the classification period.

(f) For specimens using steel floor or roof units intended for use in spans greater than those tested, the average temperature recorded by all thermocouples located on any one span of the floor or roof unit shall not exceed 1100°F (593°C) during the classification period.

Chapter 10 Tests of Loaded Restrained Beams

10-1 Application. An individual classification of a restrained beam shall be permitted to be determined by this test procedure and shall be based on the conditions of acceptance specified in Section 10-4. This fire endurance classification shall

apply to the beam where used with a floor or roof construction that has a comparable or greater capacity for heat dissipation from the beam than the floor or roof with which it is tested. The fire endurance classification determined by this method shall not apply to beams smaller than those tested.

10-2 Size and Characteristics of Specimen. The test specimen shall be installed in accordance with the recommended fabrication procedures for the type of construction and shall be representative of the design for which classification is to be determined. The length of beam exposed to the fire shall be not less than 12 ft (3.7 m), and the member shall be tested in its normal horizontal position. A section of a representative floor or roof construction not more than 7 ft (2.1 m) wide, symmetrically located with reference to the beam, shall be permitted to be included with the test specimen and exposed to the fire from below. The beam, including that part of the floor or roof element forming the complete beam as designed (such as composite steel or concrete construction), shall be restrained against longitudinal thermal expansion in a manner simulating the restraint in the construction represented. The perimeter of the floor or roof element of the specimen shall not be supported or restrained.

Exception: That part of the perimeter of the floor or roof element specimen that forms part of a beam as designed shall be required to be supported or restrained.

10-3 Loading. Throughout the fire endurance test a superimposed load shall be applied to the specimen. This load, together with the weight of the specimen, shall be, as nearly as practicable, the maximum theoretical dead and live loads permitted by nationally recognized design standards.

10-4 Conditions of Acceptance. The following conditions shall be met.

- (1) The specimen shall sustain the applied load during the classification period.
- (2) The specimen shall achieve a fire endurance classification on the basis of the temperature criteria specified in Section 9-6(c), (d), or (e) equal to one-half the period for the classification of the assembly or 1 hour, whichever is greater.

Chapter 11 Alternative Classification Procedure for Loaded Beams

11-1 Application. Individual unrestrained classifications shall be permitted to be determined for beams tested as part of a floor or roof assembly as described in Sections 9-1 through 9-4 (except 9-1.3) or for restrained beams tested in accordance with the procedure described in Sections 10-1 through 10-3. These fire endurance classifications shall apply to beams where used with a floor or roof construction that has a comparable or greater capacity for heat dissipation from the beam than the floor or roof with which it is tested. The fire endurance classification determined by this method shall not apply to beams smaller than those tested.

11-2 Temperature Measurement.

11-2.1 The temperature of the steel in structural members shall be measured by thermocouples at three or more sections spaced along the length of the members, with one section preferably located at midspan.

Exception: In cases where cover thickness is not uniform along the specimen length, at least one of the sections at which temperatures are measured shall include the point of minimum cover.

11-2.2 For steel beams, four thermocouples shall be placed at each section; two shall be located on the bottom of the bottom flange, one on the web at the center, and one on the bottom of the top flange.

11-2.3 For reinforced or prestressed concrete structural members, thermocouples shall be located on each of the tension-reinforcing elements unless there are more than eight such elements, in which case thermocouples shall be placed on eight elements selected to obtain representative temperatures of all the elements.

11-3 Conditions of Acceptance. In obtaining an unrestrained beam classification, the following conditions shall be met.

(a) The specimen shall sustain the applied load during the classification period.

(b) For steel beams, the temperature of the steel shall not exceed 1300°F (704°C) at any location during the classification period nor shall the average temperature recorded by four thermocouples at any section exceed 1100°F (593°C) during this period.

(c) For conventionally designed concrete beams, the average temperature of the tension steel at any section shall not exceed 800°F (426°C) for cold-drawn prestressing steel or 1100°F (593°C) for reinforcing steel during the classification period.

Chapter 12 Alternative Test of Protection for Solid Structural Steel Beams and Girders

12-1 Application. Where the loading required in Section 9-3 is not feasible, this alternative test procedure shall be permitted to be used to evaluate the protection of steel beams and girders without application of design load, provided that the protection is not required by design to function structurally in resisting applied loads. The conditions of acceptance of this alternative test shall not apply to tests performed under design load as provided in tests for floors and roofs in Sections 9-2, 9-5, and 9-6.

12-2 Size and Character of Specimen.

12-2.1 The size of the steel beam or girder shall be a true representation of the design, materials, and workmanship required for the classification desired. The protection shall be applied in accordance with the methods of acceptable field practice, and the projection below the ceiling, if any, shall be representative of the conditions of intended use. The length of the beam or girder exposed to the fire shall be not less than 12 ft (3.7 m), and the member shall be tested in a horizontal position. A section of a representative floor construction not less than 5 ft (1.5 m) wide, symmetrically located with reference to the beam or girder and extending its full length, shall be included in the test assembly and exposed to fire from below. The rating of performance shall not apply to beams or girders smaller than those tested.

12-2.2 The applied protection shall be restrained against longitudinal expansion greater than that of the steel beam or girder by rigid steel plates or reinforced concrete attached to the ends of the specimen before the protection is applied. The ends of the specimen, including the means for restraint, shall be provided with sufficient thermal insulation to prevent

appreciable direct heat transfer from the furnace to the unexposed ends of the specimen or from the ends of the specimen to the outside of the furnace.

12-3 Temperature Measurement. The temperature of the steel in the beam or girder shall be measured with not less than four thermocouples located at each of four sections equally spaced along the length of the beam and symmetrically disposed and not nearer than 2 ft (0.6 m) from the inside face of the furnace. The thermocouples at each section shall be placed symmetrically so as to measure significant temperatures of the component elements of the steel section.

12-4 Conditions of Acceptance. The test shall be accepted as valid if the transmission of heat through the protection during the period of fire exposure required for the classification desired does not raise the average (arithmetical) temperature of the steel at any one of the four sections above 1000°F (538°C) or does not raise the temperature above 1200°F (649°C) at any one of the measured points.

Chapter 13 Performance of Protective Membranes in Wall, Partition, Floor, or Roof Assemblies

13-1 Application. Where determining the thermal protection afforded by membrane elements in wall, partition, floor, or roof assemblies, the nonstructural performance of protective membranes shall be obtained by following the procedure outlined in Sections 13-2 through 13-4. The performance of protective membranes is supplementary information only and shall not be used as a substitute for the fire endurance classification determined by Chapters 5 through 12.

13-2 Characteristics and Size of Sample.

13-2.1 The characteristics of the sample shall conform to 3-1.1.

13-2.2 The size of the sample shall conform to Section 5-1 for bearing walls and partitions, Section 6-1 for nonbearing walls and partitions, or 9-2.1 for floors or roofs.

13-3 Temperature Performance of Protective Membranes.

13-3.1 The temperature performance of protective membranes shall be measured with thermocouples, the measuring junctions of which shall be in intimate contact with the exposed surface of the elements being protected. The diameter of the wires used to form the thermo-junction shall not be greater than the thickness of sheet metal framing or panel members to which they are attached and in no case shall be greater than No. 18 AWG gauge [0.040 in. (1.02 mm)]. The lead shall be electrically insulated with heat-resistant and moisture-resistant coatings.

13-3.2 For each class of elements protected, temperature readings shall be taken at not less than five representative points. None of the thermocouples shall be located nearer to the edges of the test assembly than 12 in. (305 mm). An exception shall be permitted to be made. None of the thermocouples shall be located opposite, on top of, or adjacent to fasteners such as screws, nails, or staples where such locations are excluded for thermocouple placement on the unexposed surface of the test assembly as detailed in 2-3.2.

Exception: In those cases in which there exists an element or feature of the construction that is not otherwise represented in the test assembly, thermocouples shall be permitted to be located closer to the edges of the test assembly than 12 in. (305 mm).

13-3.3 Thermocouples shall be located to obtain representative information on the temperature of the interface between the exposed membrane and the substratum or element being protected.

13-3.4 Temperature readings shall be taken at intervals not exceeding 1 minute for the duration of the test.

13-4 Conditions of Performance. Unless otherwise specified, the performance of protective membranes shall be considered to be the time at which the following conditions occur:

- (1) The average temperature rise of any set of thermocouples for each class of element protected is more than 250°F (140°C) above the initial temperature
- (2) The temperature rise of any one thermocouple of the set for each class of element protected is more than 325°F (180°C) above the initial temperature

Chapter 14 Report of Results

14-1 Classification as Determined by Test.

14-1.1 Results shall be reported in accordance with the performance specifications in the tests prescribed in these methods. The time of resistance shall be expressed as the nearest integral minute.

Reports shall include observations of significant details of the behavior of the material or construction during the test and after the furnace fire is cut off, including information on deformation, spalling, cracking, burning of the specimen or its component parts, continued flaming, and production of smoke.

14-1.2 Reports of tests involving wall, floor, beam, or ceiling constructions in which restraint is provided against expansion, contraction, or rotation of the construction shall describe the method used to provide this restraint.

14-1.3 Reports of tests in which other than maximum load conditions (*see Section 9-3*) are imposed shall fully define the conditions of loading used in the test and shall be designated in the title of the test report as a restricted load condition.

14-1.4* Where the indicated resistance period is $\frac{1}{2}$ hour or more, as determined by the average or maximum temperature rise on the unexposed surface or within the test specimen or by failure under load, an adjustment shall be made for variation of the furnace exposure from that prescribed. In those cases where it will affect the classification, the adjustment shall be made by multiplying the indicated resistance period by two-thirds of the difference in the area between the curve of the average furnace temperature and the standard curve for the first three-fourths of the period, and then dividing the product by the area between the standard curve and a baseline of 68°F (20°C) for the same portion of the indicated period. The latter area shall be increased by 54°F-hr or 30°C-hr (3240°F-min or 1800°C-min) to compensate for the thermal lag of the furnace thermocouples during the first part of the test. For fire exposure that occurs during the test that is higher than standard, the indicated resistance period

shall be increased by the amount of the correction and shall similarly be decreased for fire exposure below standard.

14-1.5 Asymmetrical wall assemblies shall be permitted to be tested with either side exposed to the fire, and the report shall indicate the side so exposed. Both sides shall be permitted to be tested, and the report shall indicate the fire endurance classification applicable to each side.

14-2 Test of Floor and Roof Assemblies.

14-2.1 The fire endurance classification of a restrained assembly shall be reported as that developed by applying the conditions of acceptance specified in Sections 9-5(a) through (e).

14-2.2 The fire endurance classification of an unrestrained assembly shall be reported as that determined by applying the conditions of acceptance to a specimen tested in accordance with this test procedure as specified in Sections 9-6(a) and (b) and, where applicable, Section 9-6(c), (d), (e), or (f).

14-3 Performance of Protective Membranes.

14-3.1 The protective membrane performance for each class of element being protected shall be reported to the nearest integral minute.

14-3.2 The test report shall identify each class of element being protected and shall show the location of each thermocouple.

14-3.3 The test report shall show the temperature-time data recorded for each thermocouple and the average temperature for the set of thermocouples on each element being protected.

14-3.4 The test report shall record any visual observations that are pertinent to the performance of the protective membrane.

14-4 Tests of Load-Bearing Assemblies. Reports of tests in which loading is used shall describe how the applied load was calculated, the design standard used, the governing stress in each structural member (e.g., bending, shear), the details of the system used to apply the load, and the time of load application relative to the start and finish of the test.

Chapter 15 Referenced Publications

15-1 The following documents or portions thereof are referenced within this standard as mandatory requirements and shall be considered part of the requirements of this standard. The edition indicated for each referenced mandatory document is the current edition as of the date of the NFPA issuance of this standard. Some of these mandatory documents might also be referenced in this standard for specific informational purposes and, therefore, are also listed in Appendix H.

15-1.1 UL Publication. Underwriters Laboratories Inc., 333 Pfingsten Road, Northbrook, IL 60062.

ANSI/UL 385, *Standard for Safety Play Pipes for Water Supply Testing in Fire Protection Service*, 1994.

Appendix A Explanatory Material

Appendix A is not a part of the requirements of this NFPA document but is included for informational purposes only. This appendix contains explanatory material, numbered to correspond with the applicable text paragraphs.

A-1-1 The performance of walls, columns, floors, and other building members under fire exposure conditions is an issue of major importance in ensuring construction that is safe and not a menace to neighboring structures or the public. This factor is recognized by the codes of many authorities, municipal and otherwise. It is important to create a balance among the many units in a single building, and in buildings of like character and use in a community, and also to promote uniformity in the requirements of the various authorities throughout the country. Therefore, it is necessary that the fire-resistive properties of materials and assemblies be measured and specified in accordance with a common standard and expressed in terms that are applicable to a wide variety of materials, situations, and conditions of exposure.

These test methods are such a standard. They prescribe a standard exposing fire of controlled extent and severity. Performance is defined as the period of resistance to standard exposure that elapses before the first critical point in behavior is observed. Results are reported in units in which field exposures can be judged and expressed.

The methods are cited as the "Standard Fire Tests," and the performance or exposure is expressed as "2-hr," "6-hr," "1/2-hr," and so forth.

Where a factor of safety exceeding that inherent in the test conditions is desired, a proportional increase should be made in the specified time-classification period.

A-1-1.2 A method of fire hazard classification based on rate of flame spread is covered in NFPA 255, *Standard Method of Test of Surface Burning Characteristics of Building Materials*.

A-2-1.1 For a more precise definition of the temperature-time curve, see Appendix B.

A-2-2 The following provides guidance on the desired characteristics of instrumentation for recording the flow of fuel to the furnace burners. Fuel flow data is useful for a furnace heat balance analysis, for measuring the effect of furnace or control changes, and for comparing the performance of assemblies of different properties in the fire endurance test.

The integrated (cumulative) flow of gas (or other fuel) to the furnace burners should be recorded at 10 minutes, 20 minutes, 30 minutes, and every 30 minutes thereafter or more frequently. The total gas consumed during the test period also should be determined. A recording flow meter has advantages over periodic readings on an instantaneous or totalizing flow meter. A measuring and recording system should be selected to provide flow rate readings accurate to within ± 5 percent.

The type of fuel, its higher (gross) heating value, and the fuel flow [corrected to standard conditions of 60°F (16°C) and 30.0 in. Hg] as a function of time should be reported.

A-2-2.1 A typical thermocouple assembly meeting specified time constant requirements can be fabricated by fusion-welding the twisted ends of No. 18 AWG Chromel-Alumel wires, mounting the leads in porcelain insulators, and inserting the assembly so the thermocouple bead is 1/2 in. (13 mm) from

the sealed end of a standard weight nominal 1/2-in. (13-mm) iron, steel, or Inconel® pipe. The time constant for this and for several other thermocouple assemblies was measured in 1976. The time constant is also calculated from knowledge of the thermocouple assembly's physical and thermal properties.

A-2-3.1 Under certain conditions, it is unsafe or impracticable to use thermometers.

For the purpose of testing roof assemblies, the unexposed surface is defined as the surface exposed to ambient air.

Additional information on refractory pads can be found in Section C-1.

A-3-2.1 A recommended method for determining the relative humidity within a hardened concrete specimen with electric sensing elements is described in Appendix I of "A Method for Determining the Moisture Condition of Hardened Concrete in Terms of Relative Humidity." A similar procedure with electric sensing elements can be used to determine the relative humidity within fire test specimens made with other materials.

With wood constructions, the moisture meter based on the electrical resistance method can be used, where appropriate, as an alternative to the relative humidity method to indicate when wood has attained the proper moisture control. Electrical methods are described on pages 320 and 321 of the 1955 edition of the "Wood Handbook of the Forest Products Laboratory," U.S. Department of Agriculture. The relationships between relative humidity and moisture content are illustrated by the graphs in Figure 23 on p. 327 of this publication. They indicate that wood has a moisture content of 13 percent at a relative humidity of 70 percent for a temperature of 70°F to 80°F (21°C to 27°C).

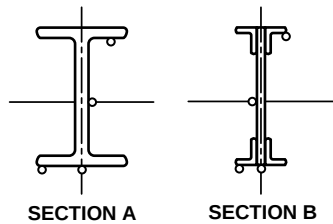
A-3-2.3 If the moisture condition of the fire test assembly is likely to change drastically from the sample taken 72 hours prior to this test, the sample should be taken not later than 24 hours prior to the test.

A-5-2 The choice depends on the intended use and whether the load on the exposed side will be transferred to the unexposed side after the exposed side has failed. If, in the intended use, the load from the structure above is supported by both walls as a unit and would be or is transferred to the unexposed side in the event of collapse of the exposed side, both walls should be loaded for the test by a single unit. If, in the intended use, the load from the structure above each wall is supported by each wall separately, the walls should be loaded separately for the test by separate load sources. If the intended use of the construction system being tested involves situations of both loading conditions described above, the walls should be loaded separately for the test by separate load sources. In tests conducted with the walls loaded separately, the condition of acceptance requiring the walls to maintain the applied load is based on the time at which the first wall fails to sustain the load.

A-9-1.2 Appendix E should be consulted for guidance in determining the conditions of thermal restraint that apply to floor and roof constructions and individual beams in actual building construction.

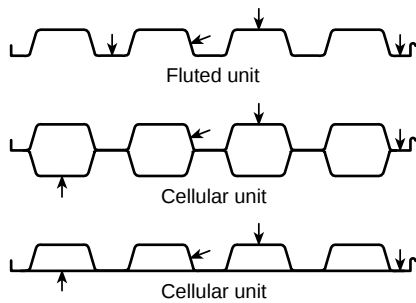
A-9-4.4 Figure A-9-4.4 provides examples of thermocouple distribution at each section.

Figure A-9-4.4 Examples of thermocouple distribution.



A-9-4.5 Figure A-9-4.5 provides examples of typical thermo- couple locations for a unit section.

Figure A-9-4.5 Typical location of thermocouples.



A-14-1.4 The correction can be expressed by the following formula:

$$C = \frac{2I(A - A_s)}{3(A_s + L)}$$

where:

- C = correction in the same units as I
- I = indicated fire resistance period
- A = area under the curve of the indicated average fur- nace temperature for the first three-fourths of the indicated period
- A_s = area under the standard furnace curve for the same part of the indicated period
- L = lag correction in the same units as A and A_s [54°F- hr or 30°C-hr (3240°F-min or 1800°C-min)].

Appendix B Operating Criteria for Fire Tests

This appendix is not a part of the requirements of this NFPA doc- ument but is included for informational purposes only.

B-1 Temperature–Time Curve. Control of fire tests for test- ing of fire-rated assemblies should be in done as demonstrated by the standard temperature–time curve as highlighted in Table B-1.

Table B-1 Standard Temperature–Time Curve for Control of Fire Tests

Time (hr: min)	Temperature °F	Area Above 68°F Base		Temperature °C	Area Above 20°C Base	
		°F-min	°F-hr		°C-min	°C-hr
0:00	68	0	0	20	0	0
0:05	1000	2330	39	538	1290	22
0:10	1300	7740	129	704	4300	72
0:15	1399	14,150	236	760	7860	131
0:20	1462	20,970	350	795	11 650	194
0:25	1510	28,050	468	821	15 590	260
0:30	1550	35,360	589	843	19 650	328
0:35	1584	42,860	714	862	23 810	397
0:40	1613	50,510	842	878	28 060	468
0:45	1638	58,300	971	892	32 390	540
0:50	1661	66,200	1103	905	36 780	613
0:55	1681	74,220	1287	916	41 230	687
1:00	1700	82,330	1372	927	45 740	762
1:05	1718	90,540	1509	937	50 300	838
1:10	1735	98,830	1647	946	54 910	915
1:15	1750	107,200	1787	955	59 560	993
1:20	1765	115,650	1928	963	64 250	1071
1:25	1779	124,180	2070	971	68 990	1150
1:30	1792	132,760	2213	978	73 760	1229
1:35	1804	141,420	2357	985	78 560	1309

Table B-1 Standard Temperature–Time Curve for Control of Fire Tests *(Continued)*

Time (hr: min)	Temperature °F	Area Above 68°F Base		Temperature °C	Area Above 20°C Base	
		°F-min	°F-hr		°C-min	°C-hr
1:40	1815	150,120	2502	991	83 400	1390
1:45	1826	158,890	2648	996	88 280	1471
1:50	1835	167,700	2795	1001	93 170	1553
1:55	1843	176,550	2942	1006	98 080	1635
2:00	1850	185,440	3091	1010	103 020	1717
2:10	1862	203,330	3389	1017	112 960	1882
2:20	1875	221,330	3689	1024	122 960	2049
2:30	1888	239,470	3991	1031	133 040	2217
2:40	1900	257,720	4295	1038	143 180	2386
2:50	1912	276,110	4602	1045	153 390	2556
3:00	1925	294,610	4910	1052	163 670	2728
3:10	1938	313,250	5221	1059	174 030	2900
3:20	1950	332,000	5533	1066	184 450	3074
3:30	1962	350,890	5848	1072	194 940	3249
3:40	1975	369,890	6165	1079	205 500	3425
3:50	1988	389,030	6484	1086	216 130	3602
4:00	2000	408,280	6805	1093	226 820	3780
4:10	2012	427,670	7128	1100	237 590	3960
4:20	2025	447,180	7453	1107	248 430	4140
4:30	2038	466,810	7780	1114	259 340	4322
4:40	2050	486,560	8110	1121	270 310	4505
4:50	2062	506,450	8441	1128	281 360	4689
5:00	2075	526,450	8774	1135	282 470	4874
5:10	2088	546,580	9110	1142	303 660	5061
5:20	2100	566,840	9447	1149	314 910	5248
5:30	2112	587,220	9787	1156	326 240	5437
5:40	2125	607,730	10,129	1163	337 630	5627
5:50	2138	628,360	10,473	1170	349 090	5818
6:00	2150	649,120	10,819	1177	360 620	6010
6:10	2162	670,000	11,167	1184	372 230	6204
6:20	2175	691,010	11,517	1191	383 900	6398
6:30	2188	712,140	11,869	1198	395 640	6594
6:40	2200	733,400	12,223	1204	407 450	6791
6:50	2212	754,780	12,580	1211	419 330	6989
7:00	2225	776,290	12,938	1218	431 270	7188
7:10	2238	797,920	13,299	1225	443 290	7388
7:20	2250	819,680	13,661	1232	455 380	7590
7:30	2262	841,560	14,026	1239	467 540	7792
7:40	2275	863,570	14,393	1246	479 760	7996
7:50	2288	885,700	14,762	1253	492 060	8201
8:00	2300	907,960	15,133	1260	504 420	8407

Appendix C Recommendations for Thermocouple Pads

This appendix is not a part of the requirements of this NFPA document but is included for informational purposes only.

C-1 Refractory Fiber Pads. Specific product information is being provided for informational purposes only and has not been independently verified, certified, or endorsed by NFPA or any of its Technical Committees.

Ceraform 126® is a registered trade name of Manville Specialty Products Group, P.O. Box 5108, Denver, CO 80217.

Comparative fire tests have demonstrated that a refractory fiber material designated Ceraform 126®, placed with the softer surfaces in contact with the thermocouple, can be substituted for the previously specified asbestos pad where the distortion of the unexposed face of the sample is minimal. The pads are relatively rigid and should not be used on surfaces subject to sharp distortions or discontinuities during the test. The properties of Ceraform 126® material are as follows:

- (a) Length and width, 6 in. $\pm$ $\frac{1}{8}$ in. (152 mm $\pm$ 3 mm).
- (b) Thickness, 0.375 in. $\pm$ 0.063 in. (9.5 mm $\pm$ 1.6 mm). The thickness measurement is made under the light load of a $\frac{1}{2}$ -in. (13-mm) diameter pad of a dial micrometer gauge.
- (c) Dry weight, 0.147 lb $\pm$ 0.053 lb (67 g $\pm$ 24 g).
- (d) Thermal conductivity [at 150°F (66°C)], 0.37 Btu-in./hr-ft²·°F $\pm$ 0.03 Btu-in./hr-ft²·°F (0.053 W/m·K $\pm$ 0.004 W/m·K).
- (e) Hardness indentation on soft face should be 0.075 in. $\pm$ 0.025 in. (1.9 mm $\pm$ 0.6 mm). Indentation is determined in accordance with ASTM C 569, *Test for Indentation Hardness of Performed Thermal Insulations*. Modified Brinell values of hardness are obtained from the following equation:

$$\text{Hardness} = 2.24/y$$

where:

y = the measured indentation in inches

- (f) The pads are shaped by wetting, forming, and then drying to constant weight to provide complete contact on sharply contoured surfaces.

Supporting data are available from The American Society for Testing and Materials, 100 Barr Harbor Drive, West Conshohocken, PA 19428-2959. Request RR:E05-1004.

Appendix D Report Information

This appendix is not a part of the requirements of this NFPA document but is included for informational purposes only.

D-1 Sample Report Form. See Figure D-1 for a sample of a report form cover sheet.

Figure D-1 Sample report cover sheet.

NFPA 251
(title page, preferably cover)

Laboratory: _____

Project number: _____

NFPA 251 (edition)
Standard Fire Endurance Test

Fire endurance time: _____

Construction: _____

Date tested: _____

Sponsor: _____

Material: _____

Material: _____

Maximum load condition, or restricted load conditions (as the conditions of the test dictate): _____

(Identify if test is part of a research program)

(Add table of contents)

D-2 Description of Laboratory Test Facility. Describe items such as the furnace, restraining frame, and details of end conditions, including wedges, and bearing.

D-2.1 If construction is to be tested under load, indicate how the load is applied and controlled (provide loading diagram). Indicate whether the load is a maximum load condition or a restricted load condition, and, for either condition, report the specific loads and the basis for limitation, such as bending stress, and shear. A restricted load condition is reported as a percentage of the maximum load condition.

D-2.2 If construction is to be tested as nonload-bearing, indicate whether the frame is rigid or moves during the test, or whether the test is for temperature rise only.

D-3 Description of All Materials. Describe type, size, class, strength, densities, trade name, and any additional data necessary to define materials. The testing laboratory should indicate whether materials meet NFPA standards by markings, by statement of sponsor, or by physical or chemical test by the testing laboratory.

D-4 Description of Test Assembly. The following information should be provided:

- (1) Size of test specimen
- (2) Details of structural design, including safety factors of all structural members in test assembly
- (3) Plan, elevation, principal cross section, and other sections as needed for clarity
- (4) Details of attachment of test panel in frame
- (5) Location of thermocouples, deflection points, and other items for test
- (6) Description of general ambient conditions for all of the following times:
 - a. Time of construction
 - b. During curing (time from construction to test)
 - c. Time of test

D-5 Description of Test. The following information should be reported.

- (1) Temperature at start of test and every 1 minute thereafter. If charts are included in report, clearly indicate time and temperature for all of the following:
 - a. In furnace space
 - b. On unexposed surface
 - c. On protected framing members as stipulated in standard

It is recommended that temperature observations that are not required by the standard, but that are useful, be reported in the appendix to the report. These include temperatures on the face of framing members in back of protection and others that are required by various building codes.
- (2) Furnace pressure at start of test and every 1 minute thereafter
- (3) Deflections every 5 minutes for first 15 minutes of test and during the last hour. In between, report every 10 minutes
- (4) Appearance of exposed face as follows:
 - a. Every 15 minutes
 - b. At any noticeable development, including cracking, buckling, flaming, smoking, loss of material and provide details and time
 - c. At end of test, include items such as amount of drop-out, condition of fasteners, and sag
- (5) Appearance of unexposed face as follows:
 - a. Every 15 minutes
 - b. At any noticeable development, including cracking, smoking, and buckling, provide details and time
 - c. At end of test
- (6) Time of failure caused by the following:
 - a. Temperature rise
 - b. Failure to carry load
 - c. Passage of flame, heat, and smoke

D-6 Hose Stream Test. If a hose stream test is required, repeat appropriate parts of Sections D-2 and D-4. If failure occurs in hose stream test, provide description.

D-7 Official Comments. The following information should be included.

- (a) Statement to the effect that the construction is a true representation of field construction. If the construction does not represent typical field construction, note the deviations.
- (b) If construction is asymmetrical (different details on each face), it should be specified which face is exposed to the fire with comments on fire resistance from opposite side.
- (c) Comment on fire test.

D-8 Summary of Results. A summary of results should include the following:

- (1) Endurance time
- (2) Nature of failure
- (3) Hose stream test results

D-9 List of Official Observers. Provide signatures of responsible persons.

D-10 Appendix. Include all data not specifically required by test standard but useful to better understanding of test results. Special observations for building code approvals should be included in the appendix.

D-11 Photographs. Photographs should be used to show items not covered in a report or to clarify information and should include the following:

- (1) Assembly in construction
- (2) Exposed face prior to fire test
- (3) Unexposed face at start of endurance test; include recording equipment where possible
- (4) Unexposed face at end of fire endurance test
- (5) Exposed face at end of fire endurance test
- (6) Unexposed face at end of fire exposure before hose test
- (7) Exposed face at end of fire exposure before hose test
- (8) Exposed face after hose stream test
- (9) Unexposed face after hose stream test

D-12 Other Pertinent Information. It is essential to include the following:

- (1) Detailed drawing of test assembly
- (2) Photographs [see Sections D-11(1), (4), (8), and (9)] for every test report

Appendix E Guide for Determining Conditions of Restraint for Floor and Roof Assemblies and for Individual Beams

This appendix is not a part of the requirements of this NFPA document but is included for informational purposes only.

E-1 Introduction. The revisions adopted in 1970 introduced, for the first time in the history of the standard, the concept of fire endurance classifications based on two conditions of support: restrained and unrestrained. As a result, most specimens are fire-tested in a manner that seeks to derive these two classifications.

E-1.1 A restrained condition in fire tests, as used in this method, is one in which expansion at the supports of a load-carrying element resulting from the effects of fire is resisted by forces external to the element. An unrestrained condition is one in which the load-carrying element is free to expand and rotate at its supports.

E-1.2 It is recognized that there can be some difficulty in determining the condition of restraint that is anticipated at elevated temperatures in actual structures. Until a more satisfactory method is developed, it is recommended that all construction should be classified temporarily as either restrained or unrestrained. This classification enables the architect, engineer, or building official to correlate the fire endurance classification, based on conditions of restraint, with the construction type under consideration.

E-1.3 For the purpose of this appendix, restraint in buildings is defined as follows: Floor and roof assemblies and individual beams in buildings are considered restrained where the surrounding or supporting structure is capable of resisting substantial thermal expansion throughout the range of anticipated elevated temperatures. Construction not complying with this definition is assumed to be free to rotate and expand and therefore is considered as unrestrained.

E-1.4 This definition of restraint in buildings necessitates the exercise of engineering judgment to determine what constitutes restraint to substantial thermal expansion. Restraint can be provided by the lateral stiffness of supports for floor and roof assemblies and intermediate beams forming part of the assembly. In

order to develop restraint, connections have to adequately transfer thermal thrusts to such supports. The rigidity of adjoining panels or structures should be considered in assessing the capability of a structure to resist thermal expansion. Continuity, such as that occurring in beams acting continuously over more than two supports, induces rotational restraint that usually adds to the fire resistance of structural members.

E-1.5 Table E-1.5 specifies only the common types of constructions. These classifications, as well as the philosophy

expressed in A-1-1, are helpful in determining the less common types of construction.

E-1.6 The foregoing methods of establishing the presence or absence of restraint according to type and detail of construction are considered to be temporary but necessary for the determination of dual fire endurance classifications. It is anticipated that methods for realistically predetermining the degree of restraint applicable to a particular fire endurance classification will be developed soon.

Table E-1.5 Construction Classifications, Restrained and Unrestrained

I. Wall Bearing	
Single span and simply supported end spans of multiple bays: ¹	
1. Open-web steel joists or steel beams, supporting concrete slab, precast units, or metal decking	unrestrained
2. Concrete slabs, precast units, or metal decking	unrestrained
Interior spans of multiple bays:	
1. Open-web steel joists, steel beams or metal decking, supporting continuous concrete slab	restrained
2. Open-web steel joists or steel beams, supporting precast units or metal decking	unrestrained
3. Cast-in-place concrete slab systems	restrained
4. Precast concrete where the potential thermal expansion is resisted by adjacent construction ²	restrained
II. Steel Framing.	
1. Steel beams welded, riveted, or bolted to the framing members	restrained
2. All types of cast-in-place floor and roof systems (such as beams-and-slabs, flat slabs, pan joists, and waffleslabs) in which the floor or roof system is secured to the framing members	restrained
3. All types of prefabricated floor or roof systems in which the structural members are secured to the framing members and the potential thermal expansion of the floor or roof system is resisted by the framing system or the adjoining floor or roof construction ²	restrained
III. Concrete Framing.	
1. Beams securely fastened to the framing members	restrained
2. All types of cast-in-place floor or roof systems (such as beam-and-slabs, flat slabs, pan joists, and waffle slabs) where the floor system is cast with the framing members	restrained
3. Interior and exterior spans of precast systems with cast-in-place joints resulting in restraint equivalent to that which exists in condition III(1)	restrained
4. All types of prefabricated floor or roof systems in which the structural members are secured to such systems and the potential thermal expansion of the floor or roof system is resisted by the framing system or the adjoining floor or roof construction ²	restrained
IV. Wood Construction.	
All types.	unrestrained

¹Floor and roof systems can be considered restrained where they are tied to walls with or without tie beams, the walls being designed and detailed to resist thermal thrust from the floor or roof system.

²Resistance to potential thermal expansion is considered to be achieved where

(a) Continuous structural concrete topping is used.

(b) The space between the ends of precast units or between the ends of the units and the vertical face of supports is filled with concrete or mortar.

(c) The space between the ends of precast units and the vertical faces of supports, or between the ends of solid or hollow core slab units, does not exceed 0.25 percent of the length for normal weight concrete members or 0.1 percent of the length for structural lightweight concrete members.

Appendix F Method of Correcting Fire Endurance for Concrete Slabs Determined by Unexposed Surface Temperature Rise for Nonstandard Moisture Content

This appendix is not a part of the requirements of this NFPA document but is included for informational purposes only.

F-1 Scope.

F-1.1 The standard fire endurance is the time determined by the unexposed surface temperature rise of a test specimen at a standard moisture level.

F-1.2 This appendix provides a procedure for correction of the fire endurance of unprotected vertical or horizontal slabs (solid or hollow) made from essentially inorganic building materials and conditioned on both sides, where moisture content at the time of test is other than at a standard moisture level.

F-1.3 Among the common inorganic building materials, only the hydrated Portland cement products can hold (after due conditioning in accordance with Section 3-2) sufficient amounts of moisture to affect the result of the fire test significantly. Consequently, correcting the experimental fire endurance of constructions containing less than 5 volume percent of Portland cement paste is not necessary.

F-2 Symbols. The symbols used in this appendix are defined as follows:

A	= factor characterizing the drying conditions [see Table F-2(a)]
b	= factor characterizing the permeability of the specimen [see Table F-2(b)]
FE	= fire endurance of specimen (hr)
m	= moisture content in volume fraction (ft ³ /ft ³ or cm ³ /cm ³)
m_a	= average moisture content of test specimen
m_c	= average moisture content of cement paste
m_e	= nominal equilibrium moisture content of cement paste for a given RH [see Table F-2(c)]
m_{es}	= equilibrium moisture content of cement paste at the standard RH level [see Table F-2(c)]
m_s	= average moisture content of a standard conditioned concrete specimen of same concrete and cement paste volume as the test specimen
RH	= relative humidity
v	= volume fraction of cement paste (ft ³ /ft ³ or cm ³ /cm ³)

F-3 Calculation of Moisture Content.

F-3.1 The average moisture content, (m_a) is the volume fraction of moisture [ft³/ft³ (cm³/cm³)] in the material relative to its dry condition, where dry condition is defined as that resulting when the material is heated in an oven at 221°F ± 1°F (105°C ± 0.5°C) until no further weight loss occurs.

F-3.2 The average moisture content of the cement paste can be estimated from the known value of RH at middepth (assuming the material has never been subject to rewetting) by calculating first the moisture content in the cement paste as follows:

$$m_c = A \cdot m_e$$

F-3.3 The average moisture content of the test specimen then is calculated as follows:

$$m_a = v \cdot m_a$$

F-3.4 The average moisture content of a standard conditioned specimen is calculated as follows:

$$m_s = v \cdot m_{es}$$

where m_{es} is the value of m_e in Table F-2(c) pertaining to the standard RH level.

F-4 Correction Procedure. The correction procedure begins with the selection of an empirical factor to reflect the permeability of the material as suggested in Table F-2(b). The known values of m_a and m_s are used to calculate the products bm_a and bm_s . On the nomograph (see Figure F-4), lines are drawn from point R to values of bm_a and bm_s on the right-hand scale. From the point representing the actual fire endurance time (FE) on the left-hand scale, a line is drawn parallel to $R-bm_a$ to intersect the curve. From this point on the curve, a line is drawn parallel to $R-bm_s$ and the corrected fire endurance is determined from the FE scale.

F-5 Example. A wall made from normal weight concrete having 23.2 volume percent of paste is conditioned at 200°F (93°C) and 5 percent RH until the RH at its middepth is reduced to 70 percent. It has a 2.90-hour fire endurance. The adjusted fire endurance is calculated as follows.

(1) Calculate m_a as follows.

For 70 percent RH :

$$m_e = 0.225 \text{ [see Table F-2(c)]}$$

For 200°F (93°C) and 5 percent RH conditioning, for normal weight concrete:

$$A = 0.45 \text{ [see Table F-2(a)]}$$

$$m_c = 0.45 \times 0.225 = 0.101 \text{ (see F-3.2)}$$

For $v = 0.232$:

$$m_a = 0.232 \times 0.101 = 0.0234 \text{ (see F-3.3)}$$

that is, the concrete contains 2.34 volume percent moisture at time of test.

(2) Calculate m_s as follows.

Example: If the standard moisture level is assumed to correspond to a middepth RH of 75 percent, $m_e = 0.24$

$$m_s = 0.232 \times 0.24 = 0.0557 \text{ (see F-3.4)}$$

that is, the standard moisture level is 5.57 volume percent.

(3) Calculate bm as follows.

$$b = 5.5 \text{ [see Table F-2(b)]}$$

$$bm_a = 5.5 \times 0.0234 = 0.129$$

$$bm_s = 5.5 \times 0.0557 = 0.306$$

(4) Draw lines on the nomogram from point R to bm_a and bm_s (see Figure F-5(4)).

(5) Draw a line from the FE ordinate, 2.90, parallel to line $R-bm_a$ to intersect the curve.

(6) Draw a line parallel to $R-bm_s$ from a point on the curve to intersect the FE ordinate scale. The value, 3.19, is the adjusted fire endurance; that is, the fire endurance if the specimen had been tested at the standard moisture level, which is assumed in this example to correspond to 75 percent RH at middepth.

Table F-2(a) Factor Characterizing Drying Conditions

Conditioning Environment	Middepth RH of Test Specimen (%)	Factor A for Portland Cement	
		Normal Weight Concrete	Lightweight Concrete
60°F–80°F (15.6°C–26.7°C) atmospheric conditions	any	1.0	1.0
120°F–160°F (48.9°C–71.1°C), 20–35% RH	70–75	0.7	0.7
190°F–200°F (87.8°C–93.3°C), 0–5% RH	70–75	0.45	0
120°F–200°F (48.9°C–93.3°C), 5–35% RH	less than 70	0	0

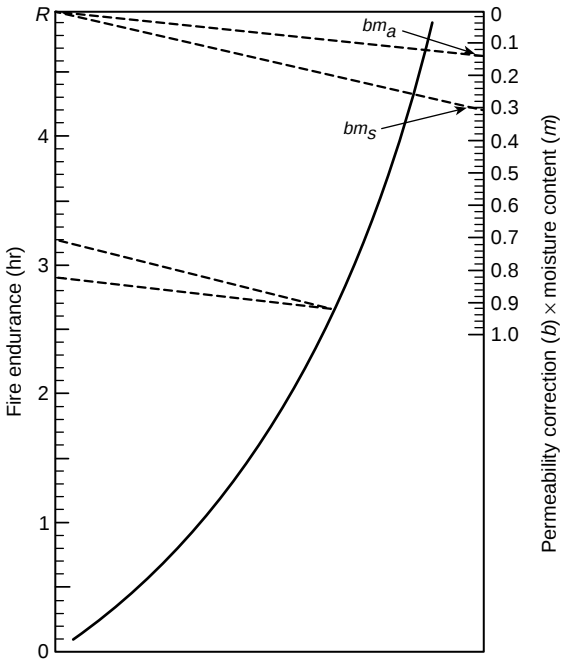
Table F-2(b) Factor Characterizing Permeability of Test Specimen

Material	<i>b</i>
Normal weight and gun-applied concrete [dry unit weight greater than 135 lb/ft ³ (2162 kg/m ³)]	5.5
Lightweight concrete [dry unit weight 85 lb/ft ³ –115 lb/ft ³ (1361 kg/m ³ –1841 kg/m ³)]	8.0
Lightweight insulating concrete [dry unit weight less than 50 lb/ft ³ (801 kg/m ³)]	10.0

Table F-2(c) Equilibrium Moisture Content (Desorption) of Cement Paste at Given Relative Humidity

RH at Middepth (%)	<i>m_e</i>
90	0.30
85	0.274
80	0.255
75	0.24
70	0.225
65	0.21
60	0.195
55	0.185
50	0.175
45	0.16
40	0.15

Figure F-5(4) Nomograph for correcting fire endurance for non-standard moisture content.



Appendix G Commentary

This appendix is not a part of the requirements of this NFPA document but is included for informational purposes only.

G-1 Introduction.

G-1.1 This commentary has been prepared to provide the user of this standard with background information on the development of the standard and its application in the fire protection of buildings. It also provides guidance in the planning and performance of fire tests and in the reporting of results. No attempt has been made to incorporate into this commentary all the available information on fire testing. The serious student of fire testing is strongly urged to consult the referenced documents for a better appreciation of the history of fire-resistant design and the intricate problems associated with testing and with interpretation of test results.[1, 2]

G-1.2 Floors and walls designed as fire separations have been recognized for many years as efficient tools for restricting fires to the area of origin or limiting their spread.[3–11] Prior to 1900, relative fire safety was achieved by mandating use of specific materials. By the year 1900, the appearance of a multitude of new materials and innovative designs and constructions accelerated the demand for performance standards. The British Fire Prevention Committee, established in 1894, was the first to produce tables that provided fire-resistive floors, ceilings, doors, and partitions.[5] Test furnaces in the United States were constructed shortly after 1900 at the Underwriters Laboratories Inc., Columbia University, and the National Bureau of Standards (NBS).[1, 12] These early furnaces eventually led to the development of ASTM E 119, *Standard Test Methods for Fire Tests of Building Construction and Materials*, and its counterpart, NFPA 251.