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NFPA 251 Fire Tests of Building Construction and Materials 1985

National Fire Protection Association Batterymarch Park, Quincy, MA 02269

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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

This material has been developed under the published procedures of the National Fire Protection Association, which are designed to assure the appointment of technically competent Committees having balanced representation. While these procedures assure the highest degree of care, neither the National Fire Protection Association, its members, nor those participating in its activities accepts any liability resulting from compliance or noncompliance with the provisions given herein, for any restrictions imposed on materials or processes, or for the completeness of the text.

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NFPA 251

Standard Methods of Fire Tests of

Building Construction and Materials

1985 Edition

This edition of NFPA 251, *Standard Methods of Fire Tests 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 Fall Meeting held November 12-15, 1984, in San Diego, California. It was issued by the Standards Council on December 7, 1984, with an effective date of December 27, 1984, and supersedes all previous editions.

The 1985 edition of this standard 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 251

This standard had its origin in recommendations of the International Fire Prevention Congress, London, 1903. It was presented to the NFPA by the Committee on Fire-Resistive Construction in 1914. It was officially adopted in a revised form in 1918. Successive editions were published in 1918, 1926, 1934, 1941, 1955, 1958, 1959, 1960, 1961, 1963, 1969 and 1979. It was handled in the NFPA successively by the Committee on Fire-Resistive Construction, the Committee on Building Construction, and for the last two editions by the Committee on Fire Tests.

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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.

NOTE: Membership on a Committee shall not in and of itself constitute an endorsement of the Association or any document developed by the Committee on which the member serves.

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Standard Methods of Fire Tests of

Building Construction and Materials

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

Information on referenced publications can be found in Appendix H.

Chapter 1 General

1-1* Scope.

1-1.1 These methods of fire tests are applicable 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 are also applicable to other assemblies and structural units that constitute permanent integral parts of a finished building.

1-1.2* It is the intent that classifications shall register performance during the period of exposure and shall not be construed as having determined suitability for use after fire exposure.

1-1.3 This standard shall be used to measure and describe the properties of materials, products, or assemblies in response to heat and flame under controlled laboratory conditions and shall not be used to describe or appraise the fire hazard or fire risk of materials, products, or assemblies under actual fire conditions. However, results of these tests may be used as elements of a fire risk assessment which takes into account all of the factors which are pertinent to an assessment of the fire hazard of a particular material's, product's or assembly's intended use.

1-1.4 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 test 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 Section 1-1 will contain a fire, or retain their structural integrity or exhibit both properties dependent upon the type of assembly involved during a predetermined test exposure.

1-3.2 The test exposes a specimen to a standard fire exposure controlled to achieve specified temperatures throughout a specified time period. In some instances, the fire exposure may be followed by the application of a specified standard fire hose stream. The exposure, however, may not be representative of all fire conditions which may vary with changes in the amount, nature and distribution of fire loading, ventilation, compartment size and configuration, and heat sink characteristics of the compartment. It does, however, provide a relative measure of fire performance of comparable assemblies under these specified fire exposure conditions. Any variation from the construction or conditions (that is, size, method of assembly, and materials) that are tested may substantially change the performance characteristics of the assembly.

1-3.3 The test standard provides for the following:

(a) In walls, partitions, and floor or roof assemblies:

1. Measurement of the transmission of heat.

2. Measurement of the transmission of hot gases through the assembly, sufficient to ignite cotton waste.

3. For load-bearing elements, measurement of the load-carrying ability of the test specimen during the test exposure.

(b) For individual load-bearing assemblies such as beams and columns: Measurement of the load-carrying ability under the test exposure with some consideration for the end support conditions (that is, restrained or not restrained).

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

(a) Full information as to performance of assemblies constructed with components or lengths other than those tested.

(b) Evaluation of the degree by which the assembly contributes to the fire hazard by generation of smoke, toxic gases, or other products of combustion.

(c) Measurement of the degree of control or limitation of the passage of smoke or products of combustion through the assembly.

(d) Simulation of the fire behavior of joints between building elements such as floor-wall or wall-wall, etc., connections.

(e) Measurement of flame spread over surface of tested element.

(f) The effect on fire endurance of conventional openings in the assembly, that is, electrical receptacle outlets, plumbing pipe, etc., 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.

Chapter 2 Control of Fire Tests

2-1 Time-Temperature Curve.

2-1.1 The conduct of fire tests of materials and construction shall be controlled by the standard time-temperature curve shown in Figure 2-1.1. The points on the curve that determine its character are:

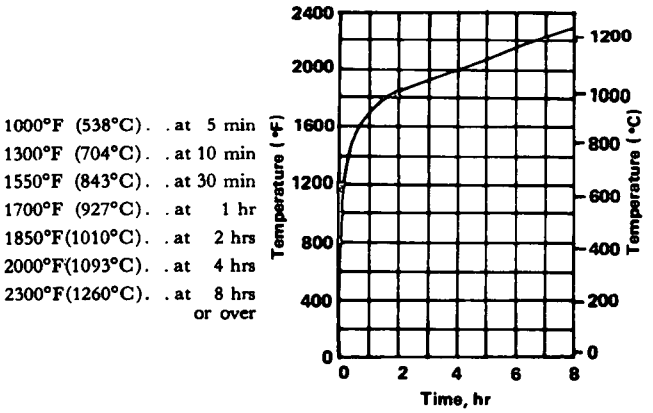


Figure 2-1.1 Time-Temperature Curve.

2-1.2 For a closer definition of the time-temperature curve, see Appendix B.

2-2* Furnace Temperatures.

2-2.1* The temperature fixed by the curve shall be deemed to 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, symmetrically disposed and distributed to show the temperature near all parts of the sample, the thermocouples being enclosed in protection tubes of such materials and dimensions that the time constant of the protected thermocouple assembly lies within the range from 5.0 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 may be used that, under test conditions, give the same indications as the above standard within the limit of accuracy that applies for furnace-temperature measurements. 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 read at intervals not exceeding 5 minutes during the first 2 hours, and thereafter the intervals may be increased to not more than 10 minutes.

2-2.3 The accuracy of the furnace control shall be such that the area under the time-temperature curve, obtained by averaging the results from the pyrometer readings, is within 10 percent of the corresponding area under the standard time-temperature curve shown in Figure 2-1.1 for fire tests of 1 hour or less duration, within 7.5 percent for those over 1 hour and not more than 2 hours, and within 5 percent for tests exceeding 2 hours in duration.

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 dry, felted pads. The properties of these pads shall meet the requirements listed in Appendix C. The wire leads of the thermocouple or the stem of the thermometer shall have an immersion under the pad and be in contact with the unexposed surface for not less than 3½ in. (90 mm). The hot junction of the thermocouple or the bulb of the thermometer shall be placed approximately under the center of the pad. The outside diameter of protecting or insulating tubes and of thermometer stems shall be not more than 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 gage [0.04 in. (1.02 mm)] and shall be electrically insulated with heat-resistant and moisture-resistant coatings.

2-3.2 Temperature readings shall be taken at not less than nine points on the surface. Five of these shall be symmetrically disposed, one to be approximately at the center of the specimen, and four at approximately the center of its quarter sections. The other four shall be located at the discretion of the testing authority to obtain representative information on the performance of the construction under test. None of the thermocouples shall be located nearer to the edges of the test specimen than one and one-half times the thickness of the construction, or 12 in. (305 mm). An exception can be made in those cases where there is an element of the construction that is not otherwise represented in the remainder of the test specimen. None of the thermocouples shall be located opposite or on top of beams, girders, pilasters, or other structural members if temperatures at such points will obviously be lower than at more representative locations. None of the thermocouples shall be located opposite or on top of fasteners such as screws, nails, or staples that will be 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 0.8 percent of the area within any 5-in. (127-mm) square. Such fasteners shall not extend through the assembly.

2-3.3 Temperature readings shall be taken at intervals not exceeding 15 minutes until a reading exceeding 212°F (100°C) has been obtained at any one point. Thereafter the readings may be taken more frequently at the discretion of the testing body, but the intervals need not be less than 5 minutes.

2-3.4 Where the conditions of acceptance place a limitation on the rise of 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; except that if a temperature rise 30 percent in excess of the specified limit occurs at any one of these points, the remainder shall be ignored and the fire endurance period judged as ended.

Chapter 3 Classification as Determined by Test

3-1 Report of Results.

3-1.1 Results shall be reported in accordance with the performance in the tests prescribed in these methods. They shall be expressed in time periods of resistance, to 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, continuance of flaming, and production of smoke.

3-1.2 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.

3-1.3 Reports of tests in which other than maximum load conditions (*see Section 10-3*) are imposed shall fully define the conditions of loading used in the test and shall be designated in the title of the report of the test as a restricted load condition.

3-1.4* When the indicated resistance period is ½ hour or over, determined by the average or maximum temperature rise on the unexposed surface or within the test specimen, or by failure under load, a correction shall be applied for variation of the furnace exposure from that prescribed, where it will affect the classification, by multiplying the indicated period by two-thirds of the difference in area between the curve of average furnace temperature and the standard curve for the first three-fourths of the period and dividing the product by the area between the standard curve and a base line of 68°F (20°C) for the same part of the indicated period, the latter area increased by 54° Fahrenheit-hour or 30° Centigrade-hour (3240° Fahrenheit-minute or 1800° Centigrade-minute), to compensate for the thermal lag of the furnace thermocouples during the first part of the test. For fire exposure in the test higher than standard, the indicated resistance period shall be increased by the amount of the correction and be similarly decreased for fire exposure below standard.

3-1.5 Unsymmetrical wall assemblies may be tested with either side exposed to the fire, and the report shall indicate the side so exposed. Both sides may be tested, and the report then shall so indicate the fire endurance classification applicable to each side.

Chapter 4 Test Specimen

4-1 Specimen.

4-1.1 The test specimen shall be truly representative of the construction for which classification is desired, as to materials, workmanship, and details such as dimension of parts, and shall be built under conditions representative of those properties as 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.

4-1.2 The size and dimensions of the test specimen specified herein are intended to apply for rating constructions of dimensions within the usual general range employed in buildings. If the conditions of use limit the construction to smaller dimensions, a proportionate reduction may be made in the dimensions of the specimens for a test qualifying them for such restricted use.

4-1.3 When it is desired to include a built-up roof covering, the test specimen shall have a roof covering of 3-ply, 15-lb-type felt and not in excess of 120 lbs (54.4 kg) per square [100 sq ft (9.3 sq m)] of hot mopping asphalt without gravel surfacing. Tests of assemblies with this covering do not preclude the field use of other built-up roof coverings.

4-2 Protection and Conditioning of Test Specimen.

4-2.1 The test specimen shall be protected during and after fabrication to assure normality of its quality and condition at the time of test. It shall not be tested until a large portion of its final strength has been attained, and, if it contains moisture, until the excess has been removed to achieve an air-dry condition in accordance with the requirements given in 4-2.1.1 through 4-2.1.3. 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° to 90°F (10° to 32°C). The velocity of air across the unexposed surface of the sample, measured just before the test begins, shall not exceed 4.4 ft per second (1.3 m/second) as determined by an anemometer placed at right angles to the unexposed surface. If mechanical ventilation is employed during the test, an air stream shall not be directed across the surface of the specimen.

4-2.1.1* Prior to fire test, constructions 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 is to be considered as that which would be established at equilibrium resulting from drying in an ambient atmosphere of 50 percent relative humidity at 73°F (23°C). However, with some constructions, it may be difficult or impossible to achieve such uniformity within a reasonable period of time. Accordingly, where this is the case, specimens may be tested when the dampest portion of the structure, the portion at 6-in. (152-mm) depth below the surface of massive con-

structions, has achieved a moisture content corresponding to drying to equilibrium with air in the range of 50 to 75 percent relative humidity at 73° ± 5°F (23° ± 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 will be prevented by hermetic sealing, these requirements may be waived, except as to attainment of a large portion of final strength, and the specimen tested in the condition in which it then exists.

4-2.1.2 If, during the conditioning of the specimen it appears desirable or is necessary to use accelerated drying techniques, it is the responsibility of the laboratory conducting the test to avoid procedures which will 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 given in 4-2.1.1.

4-2.1.3* 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 5 Conduct of Fire Tests

5-1 Fire Endurance Test.

5-1.1 The fire endurance test on the specimen with 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.

5-1.2 For the purpose of obtaining additional performance data, the test may be continued beyond the time the fire endurance classification is determined.

5-2 Hose Stream Test.

5-2.1 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, changes in direction being made slowly.

Exception No. 1: The hose stream test shall not be required in the case of constructions having a resistance period, indicated in the fire endurance test, of less than 1 hour.

Exception No. 2: The submitter may elect, with the advice and consent of the testing body, to have the hose stream test made on the specimen subjected to the fire endurance test and immediately following the expiration of the fire endurance test.

5-2.2 Stream Equipment and Details. The stream shall be delivered through a 2½-in. (65-mm) hose discharging through a National Standard Playpipe of corresponding size equipped with a 1⅛-in. (29-mm) discharge tip of the standard-taper smooth-bore pattern without shoulder at the orifice. The water pressure and duration of application shall be as prescribed in Table 5-2.2.

Table 5-2.2

Resistance Period	Water Pressure at Base of Nozzle, psi.	Duration of Application, min per 100 sq ft exposed area.
8 hrs and over	45 (310 kPa)	6 (0.65 min/m²)
4 hrs and over if less than 8 hrs	45 (310 kPa)	5 (0.54 min/m²)
2 hrs and over if less than 4 hrs	30 (207 kPa)	2½ (0.27 min/m²)
1½ hrs and over if less than 2 hrs	30 (207 kPa)	1½ (0.16 min/m²)
1 hr and over if less than 1½ hrs	30 (207 kPa)	1 (0.11 min/m²)
Less than 1 hr, if desired	30 (207 kPa)	1 (0.11 min/m²)

5-2.3 Nozzle Distance. 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 an amount equal to 1 ft (0.3 m) for each 10 degrees of deviation from the normal.

Chapter 6 Tests of Bearing Walls and Partitions

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

6-2* Loading. Throughout the fire endurance and fire and hose stream tests, apply a constant superimposed load to simulate a maximum load condition. The applied load shall be as nearly as practicable the maximum load allowed by design under nationally recognized structural design criteria. The tests may also 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 allowable 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 together. The method used shall be reported.

6-3 Conditions of Acceptance. The test shall be regarded as successful 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 for which classification is desired.

(b) The wall or partition shall have sustained the applied load during the fire and hose stream test as specified in Section 5-2, without passage of flame, of gases hot enough to ignite cotton waste, or of the hose stream. The

assembly shall be considered to have failed the hose stream test if an opening develops that permits a projection of water from the stream beyond the unexposed surface during the time of the hose stream test.

(c) Transmission of heat through the wall or partition during the fire endurance test shall not have been such as to raise the temperature on its unexposed surface more than 250°F (121°C) above its initial temperature.

Chapter 7 Tests of Nonbearing Walls and Partitions

7-1 Size of Specimen. The area exposed to fire shall be not less than 100 sq ft (9.3 sq m), with neither dimension less than 9 ft (2.7 m). The test specimen shall be restrained on all four edges.

7-2 Conditions of Acceptance. The test shall be regarded as successful 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 for which classification is desired.

(b) The wall or partition shall have withstood the fire and hose stream tests as specified in Section 5-2, without passage of flame, of gases hot enough to ignite cotton waste, or of the hose stream. The assembly shall be considered to have failed the hose stream test if an opening develops that permits a projection of water from the stream beyond the unexposed surface during the time of the hose stream test.

(c) Transmission of heat through the wall or partition during the fire endurance test shall not have been such as to raise the temperature on its unexposed surface more than 250°F (121°C) above its initial temperature.

Chapter 8 Tests of Columns

8-1 Size of Specimen. The length of the column exposed to fire shall, when 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.

8-2 Loading.

8-2.1 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 theoretically, as nearly as practicable, 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.

8-2.2 If the submitter and the testing body jointly so decide, the column may be subjected to 1¾ times its designed working load before the fire endurance test is undertaken. The fact that such a test has been made shall not be construed as having had a deleterious effect on the fire endurance test performance.

8-3 Conditions of Acceptance. The test shall be regarded as successful if the column sustains the applied load during the fire endurance test for a period equal to that for which classification is desired.

Chapter 9 Alternate Test of Protection for Structural Steel Columns

9-1 Application. This test procedure does not require column loading at any time and may be used at the discretion of the testing laboratory to evaluate steel column protections that are not required by design to carry any of the column load.

9-2 Size and Character of Specimen.

9-2.1 The size of the steel column used shall be such as to provide a test specimen that is truly representative of the design, materials, and workmanship for which classification is desired. The protection shall be applied according to 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.

9-2.2 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.

9-2.3 The ends of the specimen, including the means for restraint, shall be given sufficient thermal insulation to prevent appreciable direct heat transfer from the furnace.

9-3 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 equally spaced. The thermocouples at each level shall be so placed as to measure significant temperatures of the component elements of the steel section.

9-4 Exposure to Fire. Throughout the fire endurance test the specimen shall be exposed to fire on all sides for its full length.

9-5 Conditions of Acceptance. The test shall be regarded as successful if the transmission of heat through the protection during the period of fire exposure for which classification is 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 10 Tests of Floor and Roof Assemblies

10-1 Application.

10-1.1 This test procedure is applicable to floor and roof assemblies with or without attached, furred, or suspended ceilings and requires application of fire exposure to the underside of the specimen under test.

10-1.2* Two fire endurance classifications shall be developed for assemblies restrained against thermal expansion: a restrained assembly classification based upon the conditions of acceptance specified in Section 10-5(a), (b), (c), (d), and (e) and an unrestrained assembly classification based upon the conditions of acceptance specified in Section 10-6(a) and (b) in addition to Section 10-6(c), (d), (e) or (f).

10-1.3 One fire endurance classification shall be developed from tests of assemblies not restrained against thermal expansion based upon the conditions of acceptance specified in Section 10-6(a) and (b).

10-1.4 Individual unrestrained classifications may be developed for beams tested in accordance with this test method using the conditions of acceptance specified in Section 12-3(a), (b), or (c).

10-2 Size and Characteristics of Specimen.

10-2.1 The area exposed to fire shall be not less than 180 sq ft (16.7 sq m) 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 have a side clearance of not less than 8 in. (203 mm) from its walls.

10-2.2 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.

10-3 Loading. Throughout the fire endurance test apply a superimposed load 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 may be conducted applying a restricted load condition to the specimen which shall be identified for a specific load condition other than the maximum allowed load condition.

10-4 Temperature Measurement.

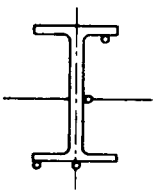
10-4.1 For specimens employing structural members (beams, open-web steel joists, etc.) spaced at more than 4 ft (1.2 m) on center, measure the temperature of the steel in these structural members by thermocouples at three or more sections spaced along the length of the members with one section preferably located at midspan except that 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.

10-4.2 For specimens employing structural members (beams, open-web steel joists, etc.) spaced at 4 ft (1.2 m) on center or less, measure the temperature of the steel in these structural members by four thermocouples placed on each member. No more than four members shall be so instrumented. Place the thermocouples at significant locations, such as at midspan, over joints in the ceiling, and over light fixtures, etc.

10-4.3 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 in such a manner as to obtain representative temperatures of all the elements.

10-4.4 For steel structural members there shall be four thermocouples at each section except that where only four thermocouples are required on a member, the thermocouples may be distributed along the member at significant locations as provided for in 10-4.2. Locate two on the bottom of the bottom flange or chord, one on the web at the center, and one on the top flange or chord. The recommended thermocouple distribution at each section is shown in Figure 10-4.4.

10-4.5 For steel floor or roof units locate four thermocouples on each section (a section to comprise the width of one unit): one 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 side wall of the unit, and one on the top plane of the unit. The thermocouples should be applied, where practicable, to the surface of the units remote from fire and spaced across the width of the unit. No more than four nor less than two sections need be so instrumented in each representative span. Locate the groups of four thermocouples in representative locations. Typical thermocouple locations for a unit section are shown in Figure 10-4.5.



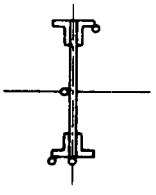


Figure 10-4.4 Recommended Thermocouple Distribution.

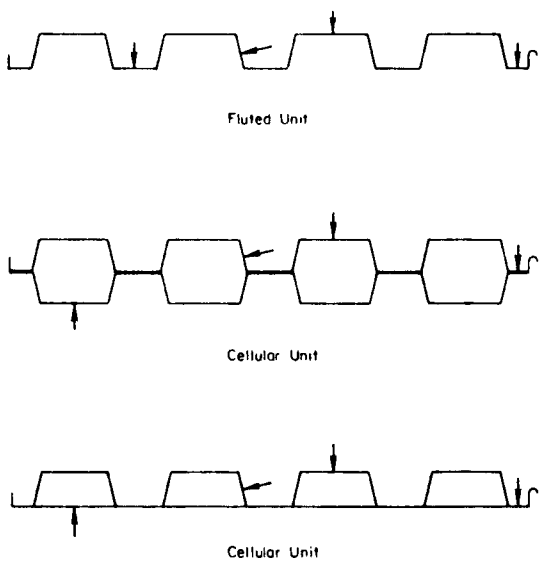


Figure 10-4.5 Typical Location of Thermocouples.

10-5 Conditions of Acceptance — Restrained Assembly. In obtaining a restrained assembly classification, the following conditions shall be met:

(a) The specimen shall have sustained the applied load during the classification period without developing unexposed surface conditions which will ignite cotton waste.

(b) Transmission of heat through the specimen during the classification period shall not have been such as to raise the average temperature on its unexposed surface more than 250°F (121°C) above its initial temperature.

(c) For specimens employing steel structural members (beams, open-web steel joists, etc.) 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 10-6(c), (d), (e) or (f) for assembly classifications up to and including 1 hour. For classifications greater than 1 hour, the above temperature criteria shall apply for a period of one-half the classification of the assembly or 1 hour, whichever is the greater.

(d) For specimens employing steel structural members (beam, open-web steel joists, etc.) 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 10-6(d) for assembly classifications up to and including 1 hour. For classifications greater than 1 hour, the above temperature criteria shall apply for a period of one-half the classification of the assembly or 1 hour, whichever is the greater.

(e) For specimens employing 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 10-6(e) for assembly classifications up to and including 1 hour. For classifications greater than 1 hour, the above temperature criteria shall apply for a period of one-half the classification of the assembly or 1 hour, whichever is the greater.

10-6 Conditions of Acceptance — Unrestrained Assembly. In obtaining an unrestrained assembly classification, the following conditions shall be met:

(a) The specimen shall have sustained the applied load during the classification period without developing unexposed surface conditions which will ignite cotton waste.

(b) The transmission of heat through the specimen during the classification period shall not have been such as to raise the average temperature on its unexposed surface more than 250°F (121°C) above its initial temperature.

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

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

(e) For specimens employing 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 have exceeded 800°F (426°C) for cold-drawn prestressing steel or 1100°F (593°C) for reinforcing steel during the classification period.

(f) For specimens employing 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 have exceeded 1100°F (593°C) during the classification period.

10-7 Report of Results.

10-7.1 The fire endurance classification of a restrained assembly shall be reported as that developed by applying the conditions of acceptance specified in Section 10-5(a), (b), (c), (d), and (e).

10-7.2 The fire endurance classification of an unrestrained assembly shall be reported as that developed by applying the conditions of acceptance specified in Section 10-6(a) and (b) and, where applicable, Section 10-6(c), (d), (e) or (f) to a specimen tested in accordance with this test procedure.

Chapter 11 Tests of Loaded Restrained Beams

11-1 Application. An individual classification of a restrained beam may be obtained by this test procedure and based upon the conditions of acceptance specified in Section 11-4. The fire endurance classification so derived shall be applicable to the beam when used with a floor or roof construction which has a comparable, or greater

capacity for heat dissipation from the beam than the floor or roof with which it was tested. The fire endurance classification developed by this method shall not be applicable to sizes of beams smaller than those tested.

11-2 Size and Characteristics of Specimen. The test 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. 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, may 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, except that part which forms part of a beam as designed, shall not be supported or restrained.

11-3 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.

11-4 Conditions of Acceptance. The following conditions shall be met:

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

(b) The specimen shall have achieved a fire endurance classification on the basis of the temperature criteria specified in Section 10-6(c), (d) or (e) of one-half the classification of the assembly or 1 hour, whichever is the greater.

Chapter 12 Alternative Classification Procedure for Loaded Beams

12-1 Application. Individual unrestrained classifications may be developed for beams tested as part of a floor or roof assembly as described in Sections 10-1 through 10-4 (except 10-1.3) or for restrained beams tested in accordance with the procedure described in Sections 11-1 through 11-3. The fire endurance classification so derived shall be applicable to beams when used with a floor or roof construction which has a comparable or greater capacity for heat dissipation from the beam than the floor or roof with which it was tested. The fire endurance classification developed by this method shall not be applicable to sizes of beams smaller than those tested.

12-2 Temperature Measurement.

12-2.1 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, except that 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.

12-2.2 For steel beams, there shall be four thermocouples 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.

12-2.3 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 in such a manner as to obtain representative temperatures of all the elements.

12-3 Conditions of Acceptance. In obtaining an unrestrained beam classification the following conditions shall be met:

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

(b) For steel beams the temperature of the steel shall not have exceeded 1300°F (704°C) at any location during the classification period nor shall the average temperature recorded by four thermocouples at any section have exceeded 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 have exceeded 800°F (426°C) for cold-drawn prestressing steel or 1100°F (593°C) for reinforcing steel during the classification period.

Chapter 13 Alternate Test of Protection for Solid Structural Steel Beams and Girders

13-1 Application. Where the loading required in Section 10-3 is not feasible, this alternative test procedure may 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 are not applicable to tests made under design load as provided under tests for floors and roofs in Sections 10-2, 10-5, and 10-6.

13-2 Size and Character of Specimen.

13-2.1 The size of the steel beam or girder shall be such as to provide a test specimen that is truly representative of the design, materials, and workmanship for which classification is desired. The protection shall be applied according to 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 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 be applicable to sizes smaller than those tested.

13-2.2 Restrain the applied protection 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 member before the protection is applied. The ends of the member, including the means for restraint, shall be given sufficient thermal insulation to prevent appreciable direct heat transfer from the furnace to the unexposed ends of the member or from the ends of the member to the outside of the furnace.

13-3 Temperature Measurement. The temperature of the steel in the beam or girder shall be measured with not less than four thermocouples 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 symmetrically placed so as to measure significant temperatures of the component elements of the steel section.

13-4 Conditions of Acceptance. The test shall be regarded as successful if the transmission of heat through the protection during the period of fire exposure for which classification is 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 14 Performance of Protective Membranes in Wall, Partition, Floor or Roof Assemblies

14-1 Application. When it is desired to determine 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 14-2 through 14-5. The performance of protective membranes is supplementary information only and is not a substitute for the fire endurance classification determined by Chapters 6 through 13 of this standard.

14-2 Characteristics and Size of Sample.

14-2.1 The characteristics of the sample shall conform to 4-1.1.

14-2.2 The size of the sample shall conform to Section 6-1 for bearing walls and partitions, Section 7-1 for nonbearing walls and partitions, or 10-2.1 for floors or roofs.

14-3 Temperature Performance of Protective Membranes.

14-3.1 The temperature performance of protective membranes shall be measured with thermocouples, the measuring junctions of which are 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 greater than No. 18 B & S gage [0.040 in. (1.02 mm)]. The lead shall be electrically insulated with heat-resistant and moisture-resistant coatings.

14-3.2 For each class of elements being 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. (30.5 cm). An exception can be made in those cases where there is an element or feature of the construction that is not otherwise represented in the test assembly. None of the thermocouples shall be located opposite, on top of, or adjacent to fasteners such as screws, nails, or staples when such locations are excluded for thermocouple placement on the unexposed surface of the test assembly in 2-3.2.

14-3.3 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.

14-3.4 Temperature readings shall be taken at intervals not exceeding 5 minutes, but the intervals need not be less than 2 minutes.

14-4 Conditions of Performance.

14-4.1 Unless otherwise specified, the performance of protective membranes shall be determined as the time at which the following conditions occur:

(a) The average temperature rise of any set of thermocouples for each class of element being protected is more than 250°F (121°C) above the initial temperature, or

(b) The temperature rise of any one thermocouple of the set for each class of element being protected is more than 325°F (163°C) above the initial temperature.

14-5 Report of Results.

14-5.1 The protective membrane performance for each class of element being protected shall be reported to the nearest integral minute.

14-5.2 The test report shall identify each class of elements being protected and shall show the location of each thermocouple.

14-5.3 The test report shall show the time-temperature data recorded for each thermocouple and the average temperature for the set of thermocouples on each element being protected.

14-5.4 The test report shall record any visual observations that are pertinent to the performance of the protective membrane.

Appendix A

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

A-1-1 The performance of walls, columns, floors, and other building members under fire exposure conditions is an item of major importance in securing constructions that are safe, and that are not a menace to neighboring structures nor to the public. Recognition of this is registered on the codes of many authorities, municipal and other. It is important to secure balance of the many units in a single building, and of buildings of like character and use in a community, and also to promote uniformity in requirements of various authorities throughout the country. To do this it is necessary that the fire-resistive properties of materials and assemblies be measured and specified according to a common standard expressed in terms that are applicable alike to a wide variety of materials, situations, and conditions of exposure.

Such a standard is found in the methods that are contained in this test method. They prescribe a standard exposing fire of controlled extent and severity. Performance is defined as the period of resistance to standard exposure elapsing 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 may be cited as the "Standard Fire Tests," and the performance or exposure shall be expressed as "2-hr," "6-hr," "½-hr," etc.

When 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-2-2 Recommendations for Recording Fuel Flow to Furnace Burners. The following provides guidance on the desired characteristics of instrumentation for recording the flow of fuel to the furnace burners. Fuel flow data may be 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.

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

Report 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.

A-2-2.1 A typical thermocouple assembly meeting specified time constant requirements may be fabricated by fusion-welding the twisted ends of No. 18 gage Chromel-Alumel wires, mounting the leads in porcelain insulators and inserting the assembly so the thermocouple bead is ½ in. (13 mm) from the sealed end of a standard weight nominal ½-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 may also be calculated from knowledge of the thermocouple assembly's physical and thermal properties.

A-2-3.1 Under certain conditions it may be unsafe or impracticable to use thermometers.

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

A-3-1.4 The correction can be expressed by the following formula:

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

where:

C = correction in the same units as I

I = indicated fire resistance period

A = area under the curve of indicated average furnace temperature for the first three-fourths of the indicated period

As = area under the standard furnace curve for the same part of the indicated period, and

L = lag correction in the same units as A and As [54° Fahr-hr or 30° Cent-hr (3240° Fahr-min or 1800° Cent-min)].

A-4-2.1.1 A recommended method for determining the relative humidity within a hardened concrete specimen with electric sensing elements is described in Appendix I of a paper by Carl A. Menzel, "A Method for Determining the Moisture Condition of Hardened Concrete in Terms of Relative Humidity," Proceedings, American Society for Testing and Materials, Vol. 55, p. 1085 (1955). 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, when 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 given by the graphs in Fig. 23 on p. 327. They indicate that wood has a moisture content of 13 percent at a relative humidity of 70 percent for a temperature of 70° to 80°F (21° to 27°C).

A-4-2.1.3 If the moisture condition of the fire test assembly is likely to change drastically from the 72-hour sampling time prior to test, the sampling should be made not later than 24 hours prior to the test.

A-6-2 The choice depends on the intended use, and whether the load on the exposed side, after it has failed, will be transferred to the unexposed side. 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 case of collapse of the exposed side, both walls should be loaded in 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 in 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 in 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 shall be based on the time at which the first of either of the walls failed to sustain the load.

A-10-1.2 See Appendix E, which is intended as a guide for assisting the user of this method in determining the conditions of thermal restraint applicable to floor and roof constructions and individual beams in actual building construction.

Appendix B Standard Time-Temperature Curve for Control of Fire Tests

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

Time	Temperature	Area Above 68°F Base		Temperature	Area Above 20°C Base	
hr:min	deg Fahr	deg Fahr-min	deg Fahr-hr	deg Cent	deg Cent-min	deg Cent-hr
0:00	68	00	0	20	00	0
0:05	1 000	2 330	39	538	1 290	22
0:10	1 300	7 740	129	704	4 300	72
0:15	1 399	14 150	236	760	7 860	131
0:20	1 462	20 970	350	795	11 650	194
0:25	1 510	28 050	468	821	15 590	260
0:30	1 550	35 360	589	843	19 650	328
0:35	1 584	42 860	714	862	23 810	397
0:40	1 613	50 510	842	878	28 060	468
0:45	1 638	58 300	971	892	32 390	540
0:50	1 661	66 200	1 103	905	36 780	613
0:55	1 681	74 220	1 287	916	41 230	687
1:00	1 700	82 330	1 372	927	45 740	762
1:05	1 718	90 540	1 509	937	50 300	838
1:10	1 735	98 830	1 647	946	54 910	915
1:15	1 750	107 200	1 787	955	59 560	993
1:20	1 765	115 650	1 928	963	64 250	1 071
1:25	1 779	124 180	2 070	971	68 990	1 150
1:30	1 792	132 760	2 213	978	73 760	1 229
1:35	1 804	141 420	2 357	985	78 560	1 309
1:40	1 815	150 120	2 502	991	83 400	1 390
1:45	1 826	158 890	2 648	996	88 280	1 471
1:50	1 835	167 700	2 795	1 001	93 170	1 553
1:55	1 843	176 550	2 942	1 006	98 080	1 635
2:00	1 850	185 440	3 091	1 010	103 020	1 717
2:10	1 862	203 330	3 389	1 017	112 960	1 882
2:20	1 875	221 330	3 689	1 024	122 960	2 049
2:30	1 888	239 470	3 991	1 031	133 040	2 217
2:40	1 900	257 720	4 295	1 038	143 180	2 386
2:50	1 912	276 110	4 602	1 045	153 390	2 556
3:00	1 925	294 610	4 910	1 052	163 670	2 728
3:10	1 938	313 250	5 221	1 059	174 030	2 900
3:20	1 950	332 000	5 533	1 066	184 450	3 074
3:30	1 962	350 890	5 848	1 072	194 940	3 249
3:40	1 975	369 890	6 165	1 079	205 500	3 425
3:50	1 988	389 030	6 484	1 086	216 130	3 602
4:00	2 000	408 280	6 805	1 093	226 820	3 780
4:10	2 012	427 670	7 128	1 100	237 590	3 960
4:20	2 025	447 180	7 453	1 107	248 430	4 140
4:30	2 038	466 810	7 780	1 114	259 340	4 322
4:40	2 050	486 560	8 110	1 121	270 310	4 505
4:50	2 062	506 450	8 441	1 128	281 360	4 689
5:00	2 075	526 450	8 774	1 135	292 470	4 874
5:10	2 088	546 580	9 110	1 142	303 660	5 061
5:20	2 100	566 840	9 447	1 149	314 910	5 248
5:30	2 112	587 220	9 787	1 156	326 240	5 437
5:40	2 125	607 730	10 129	1 163	337 630	5 627
5:50	2 138	628 360	10 473	1 170	349 090	5 818
6:00	2 150	649 120	10 819	1 177	360 620	6 010
6:10	2 162	670 000	11 167	1 184	372 230	6 204
6:20	2 175	691 010	11 517	1 191	383 900	6 398
6:30	2 188	712 140	11 869	1 198	395 640	6 594
6:40	2 200	733 400	12 223	1 204	407 450	6 791
6:50	2 212	754 780	12 580	1 211	419 330	6 989
7:00	2 225	776 290	12 938	1 218	431 270	7 188
7:10	2 238	797 920	13 299	1 225	443 290	7 388
7:20	2 250	819 680	13 661	1 232	455 380	7 590
7:30	2 262	841 560	14 026	1 239	467 540	7 792
7:40	2 275	863 570	14 393	1 246	479 760	7 996
7:50	2 288	885 700	14 762	1 253	492 060	8 201
8:00	2 300	907 960	15 133	1 260	504 420	8 407

Appendix C Requirements for Thermocouple Pads

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

C-1 The asbestos pads used in measurements of temperature of unexposed surfaces of specimens shall be of felted amosite asbestos free of organic additives and shall exhibit the following properties:

(a) Length and width, 6 ± 1/8 in. (152 ± 3.2 mm)

(b) Thickness,[1] 0.40 ± 0.05 in. (10.2 ± 1.3 mm)

(c) Dry weight, 0.260 ± 0.026 lb (0.118 ± 0.012 kg)

(d) Thermal conductivity [at 150°F (65°C)], 0.38 ± 0.027 Btu in. per hr sq ft deg Fahr (0.55 ± 0.039 w/m-k), and

(e) Hardness,[2] 10-25 (modified Brinell).

The pads shall be sufficiently soft so that, without breaking, they may be shaped to contact over the whole surface against which they are placed.

Appendix D Suggested Report Form

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

NFPA 251

Title Page

(Preferably Cover)

Laboratory _____

Project Number _____

NFPA 251 (Year)

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-1 Description of Laboratory Test Facility. Furnace, restraining frame, details of end conditions, including wedges, bearing, etc.

(a) If construction is to be tested under load indicate how the load is applied and controlled. (Give 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, shear, etc. A restricted load condition shall be reported as a percentage of the maximum load condition.

(b) If construction is to be tested as nonload-bearing indicate whether frame is rigid or moves in test, or whether test is of temperature rise only.

D-2 Description of All Materials. 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, or by statement of sponsor, or by physical or chemical test by the testing laboratory.

D-3 Description of Test Assembly.

(a) Give size of test specimen.

(b) Give details of structural design, including safety factors of all structural members in test assembly.

(c) Include plan, elevation, principal cross section, plus other sections as needed for clarity.

(d) Give details of attachment of test panel in frame.

(e) Location of thermocouples, deflection points, and other items for test.

(f) Describe general ambient conditions at:

1. Time of construction,
2. During curing (time from construction to test), and
3. Time of test.

D-4 Description of Test.

(a) Report temperature at beginning and every 5 minutes. If charts are included in report, clearly indicate time and temperature.

1. In furnace space,
2. On unexposed surface, and
3. On protected framing members as stipulated in standard.

NOTE: It is recommended that temperature observations not required by the standard, but 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 may be required by various building codes.

(b) Report deflections every 5 minutes for first 15 minutes of test and last hour. In between, every 10 minutes.

(c) Report appearance of exposed face:

1. Every 15 minutes,
2. At any noticeable development, give details and time, i.e., cracks, buckling, flaming, smoke, loss of material, etc., and

[1] The thickness measurement shall be made under the light load of a ½-in. (13-mm) diameter pad of a dial micrometer gage.

[2] The hardness measurement shall be made by pressing a 1-in. (25.4-mm) diameter steel ball against the sample and measuring the indentation obtained between a minor load of 2 lb (0.91 kg) and an additional major load of 10 lb (4.5 kg) [12 lb (5.4 kg) total]. The hardness is obtained by the relationship

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

where y = the difference in indentation in inches.

3. At end of test include amount of dropout, condition of fasteners, sag, etc.

(d) Report appearance of unexposed face:

1. Every 15 minutes,

2. At any noticeable development including cracking, smoking, buckling, give details and time, and

3. At end of test.

(e) Report time of failure by:

1. Temperature rise,

2. Failure to carry load, and

3. Passage of flame-heat-smoke.

(f) If a hose stream test is required repeat necessary parts of D-1 and D-3. If failure occurs in hose stream test — describe.

D-5 Official Comments On.

(a) Included shall be a statement to the effect that the construction truly represents field construction. If the construction does not represent typical field construction, then the deviations shall be noted.

(b) If construction is unsymmetrical (has different details on each face), be sure to indicate face exposed to fire with comments on fire resistance from opposite side.

(c) Fire test.

D-6 Summarize Results, Include.

(a) Endurance time.

(b) Nature of failure.

(c) Hose stream test results.

D-7 List Official Observers. Signatures of responsible persons.

D-8 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 in Appendix.

D-9 Pictures. All taken to show what cannot be covered in report or to clarify.

(a) Assembly in construction.

(b) Exposed face prior to fire test.

(c) Unexposed face at start of endurance test; include recording equipment when possible.

(d) Unexposed face at end of fire endurance test.

(e) Exposed face at end of fire endurance test.

(f) Unexposed face at end of fire exposure before hose test.

(g) Exposed face at end of fire exposure before hose test.

(h) Exposed face after hose stream test.

(i) Unexposed face after hose stream test.

D-10 It is essential to have the following:

(a) Detailed drawing of test assembly.

(b) Pictures [(a), (d), (h), and (i) of D-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 information purposes only.

E-1 The revisions adopted in 1970 have 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 will be fire tested in such a manner as to derive these two classifications.

E-2 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 the 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-3 Some difficulty is recognized in determining the condition of restraint that may be anticipated at elevated temperatures in actual structures. Until a more satisfactory method is developed, this guide recommends that all construction be temporarily classified as either restrained or unrestrained. This classification will enable the architect, engineer, or building official to correlate the fire endurance classification, based on conditions of restraint, with the construction type under consideration.

E-4 For the purpose of this guide, restraint in buildings is defined as follows: "Floor and roof assemblies and individual beams in buildings shall be considered restrained when 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 shall therefore be considered as unrestrained."

E-5 This definition requires the exercise of engineering judgment to determine what constitutes restraint to "substantial thermal expansion." Restraint may 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 must 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, will induce rotational restraint which will usually add to the fire resistance of structural members.

E-6 In the following table, only the common types of constructions are listed. Having these examples in mind as well as the philosophy expressed in the Section A-1-1, the user should be able to rationalize the less common types of construction.

E-7 The foregoing methods of establishing the presence or absence of restraint according to type and detail of construction is considered to be a temporary expedient,

necessary to the initiation 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 in the near future.

Table E-1 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 waffle slabs) where the floor or roof system is secured to the framing members	restrained
(3) All types of prefabricated floor or roof systems where 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 would exist in condition III(1)	restrained
(4) All types of prefabricated floor or roof systems where the structural members are secured to such systems and the potential thermal expansion of the floor or roof systems is resisted by the framing system or the adjoining floor or roof construction[2]	restrained
IV. Wood Construction.	
All types	unrestrained

Notes to Table E-1

[1]Floor and roof systems can be considered restrained when 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.

[2]For example, resistance to potential thermal expansion is considered to be achieved when:

(1) Continuous structural concrete topping is used.

(2) 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.

(3) 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 information purposes only.

F-1 Scope.

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

(b) This Appendix gives a procedure to correct the fire endurance of unprotected vertical or horizontal slabs (solid or hollow), made from essentially inorganic building materials and conditioned on both sides, when moisture content at the time of test is other than at a standard moisture level.

(c) From among the common inorganic building materials, only the hydrated Portland cement products can hold (after due conditioning in accordance with Section 4-2) sufficient amounts of moisture to affect noticeably the result of the fire test. Consequently, correcting the experimental fire endurance of constructions containing less than 5 volume percent of Portland cement paste is not necessary.

F-2 Symbols.

(a) The symbols used in this Appendix are defined as follows:

A = factor characterizing the drying conditions (*see Table F-2*)

b = factor characterizing the permeability of the specimen (*see Table F-3*)

FE = fire endurance of specimen, h

RH = relative humidity

m = moisture content, 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-1*)

m_{es} = equilibrium moisture content of cement paste at the standard RH level (*see Table F-1*)

m_s = average moisture content of a standard conditioned concrete specimen of same concrete and cement paste volume as the test specimen, and

v = volume fraction of cement paste, ft^3/ft^3 or cm^3/cm^3.

F-3 Calculation of Moisture Content.

(a) The average moisture content, m_a, is the volume fraction of moisture [ft^3/ft^3 (or cm^3/cm^3)] 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° ± 1°F (105° ± 0.5°C) until no further weight loss occurs.

(b) 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:

$$m_c = A \cdot m_c$$

(c) The average moisture content of the test specimen is then calculated as follows:

$$m_a = v \cdot m_c$$

(d) Calculate the average moisture content of a standard conditioned specimen as follows:

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

where m_{es} is the value of m_e in Table F-1 pertaining to the standard RH level.

F-4 Correction Procedure.

(a) The correction procedure starts with the selection of an empirical factor to reflect the permeability of the material as suggested in Table F-3. With known values of m_a and m_s calculate the products bm_a and bm_s. On the nomograph (Figure F-1) draw lines 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 draw a line parallel to R-bm_a to intersect the curve. From this point on the curve draw a line parallel to R-bm_s and find the corrected fire endurance on the FE scale.

F-5 Illustrative Example.

A wall made from normal weight concrete having 23.2 volume percent of paste was conditioned at 200°F (93°C) and 5 percent RH until the RH at its middepth was reduced to 70 percent. It had a 2.90-h fire endurance. Determine the adjusted fire endurance.

1. Step 1. Calculate m_a as follows:

For 70 percent RH,

$$m_e = 0.225 \qquad (see\ Table\ F\text{-}1)$$

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

$$A = 0.45 \qquad (see\ Table\ F\text{-}2)$$

$$m_c = 0.45 \times 0.225 = 0.101 \quad [see\ F\text{-}3(b)]$$

For $v = 0.232$

$$m_a = 0.232 \times 0.101 = 0.0234 \quad [see\ F\text{-}3(c)]$$

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

2. Step 2. Calculate m_s as follows:

As an example, if the standard moisture level is assumed to correspond to a middepth RH of 75 percent, then $m_e = 0.24$

$$m_s = 0.232 \times 0.24 = 0.0557 \quad [see\ F\text{-}3(d)]$$

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

3. Step 3. Calculate b_m as follows:

$$b = 5.5 \ (see\ Table\ F\text{-}3)$$

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

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

4. Step 4. Draw lines on the nomogram from point R to bm_a and bm_s (*see Figure F-1*).

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

6. Step 6. Draw a line parallel to R-bm_s from a point on the curve, to intersect the FE ordinate scale. The value of FE = 3.19 is the adjusted fire endurance; that is, the fire endurance that would have resulted if the specimen had been tested at the standard moisture level, here assumed to correspond to 75 percent RH at middepth.

Table F-1 Equilibrium Moisture Content (Desorption) of Cement Paste at Given Relative Humidity

RH at Middepth, Percent	m_e
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

Table F-2 Factor Characterizing Drying Conditions

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

Table F-3 Factor Characterizing Permeability of Test Specimen

Material	*b*
Normal weight and gun-applied concrete [dry unit weight greater than 135 lb/ft³ (2162 kgm/m³)]	5.5
Lightweight concrete [dry unit weight between 85 and 115 lb/ft³ (1361 and 1841 kgm/m³)]	8.0
Lightweight insulating concrete [dry unit weight less than 50 lb/ft³ (801 kgm/m³)]	10.0

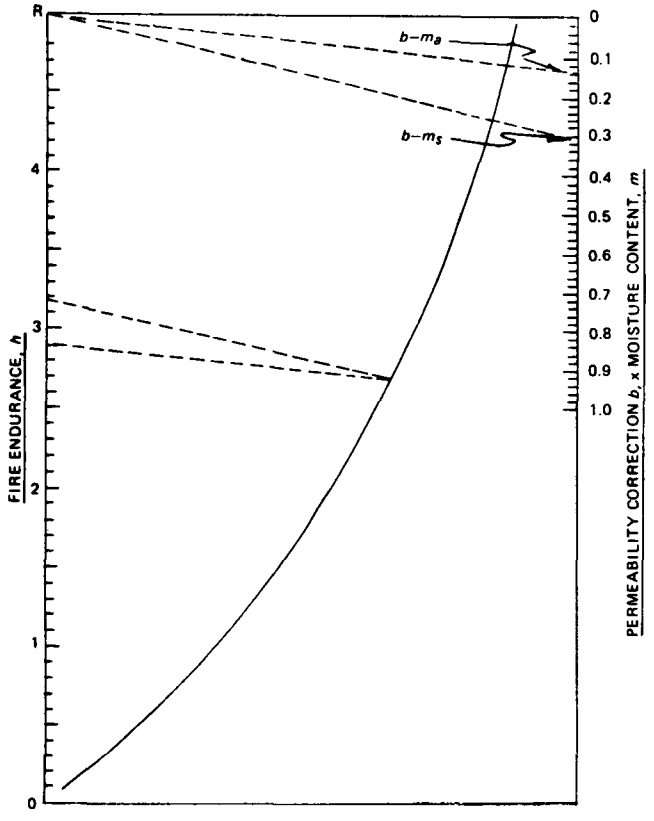


Figure F-1 Nomograph for Correcting Fire Endurance for Nonstandard Moisture Content.

Appendix G Commentary

This Appendix is not a part of the requirements of this NFPA document, but is included for information 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 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 all the available information on fire testing in this commentary. The serious student of fire testing is strongly urged to peruse the referenced documents for a better appreciation of the history of fire-resistant design (1, 2)* and the intricate problems associated with testing and with interpretation of test results.

G-1.2 Floors and walls designed as fire separations have been recognized for many years as efficient tools in restricting fires to the area of origin, or limiting their spread (3, 4, 5, 6, 7, 8, 9, 10, 11). Prior to 1900, relative firesafety was achieved by mandating 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 listing fire resisting 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 E119, *Standard Methods of Fire Tests of Building Construction and Materials*, and its counterpart, NFPA 251.

G-2 Historical Aspects. ASTM E119, *Standard Methods of Fire Tests of Building Construction and Materials*, was first published by ASTM as C19 in 1918. A number of refinements have been made in the standard since that time. However, several provisions, including the temperature-time curve, the major apparatus, and the acceptance criteria remain essentially unchanged. The roots of fire testing as defined today can be traced back to about 1800. A comprehensive review of early fire testing has been published (1).

G-3 Fire-Load Concept.

G-3.1 Specifications for fire resistance in regulatory documents continue to be based largely on the fire load concept developed by NBS in the 1920s and reported in the 1928 NFPA *Quarterly* by S. H. Ingberg. The concept incorporates the premise that the duration of a fire is proportional to the fire loading, that is, the mass of combustible materials per unit floor area. The relationship between the mass of combustible materials and fire duration was established on the basis of burnout tests in structures incorporating materials having calorific or potential heat values equivalent to wood and paper, that is, 7000 to

*The numbers in parentheses refer to the list of references at the end of this Appendix.