NFPA No.

251

FIRE TESTS— BUILDING CONSTRUCTION & MATERIALS 1972

$1.00

NATIONAL FIRE PROTECTION ASSOCIATION
International
60 Batterymarch Street, Boston, Mass. 02110

5M-6-72-FP
Printed in U.S.A.

Official NFPA Definitions

Adopted Jan. 23, 1964; Revised Dec. 9, 1969. Where variances to these definitions are found, efforts to eliminate such conflicts are in process.

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SHOULD is intended to indicate recommendations or that which is advised but not required.

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Statement on NFPA Procedures

This material has been developed in the interest of safety to life and property under the published procedures of the National Fire Protection Association. These procedures are designed to assure the appointment of technically competent Committees having balanced representation from those vitally interested and active in the areas with which the Committees are concerned. These procedures provide that all Committee recommendations shall be published prior to action on them by the Association itself and that following this publication these recommendations shall be presented for adoption to the Annual Meeting of the Association where anyone in attendance, member or not, may present his views. 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.

Standard Methods of Fire Tests of Building Construction and Materials

NFPA No. 251 — 1972

1972 Edition of No. 251

The 1972 edition of Standard Methods of Fire Tests of Building Construction and Materials incorporates changes proposed by the Committee on Fire Tests and adopted by the National Fire Protection Association at its Annual Meeting on May 17, 1972.

The changes to the 1969 edition incorporated in this 1972 edition are the replacement of Sections 23, 24 and 25 with new sections 23 through 36 (renumbering 26 through 36 as 37 through 47) and the addition of Appendices C and D.

Origin and Development of No. 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 as a result of cooperative activity by the NFPA and other organizations in 1918, 1926, 1934, 1942, 1955, 1958, 1959, 1960, 1961, 1963 and 1969. It was handled in the NFPA successively by the Committee on Fire-Resistive Construction, the Committee on Building Construction, and now by the Committee on Fire Tests. The present Committee on Fire Tests has interlocking membership with the ASTM committee.

The text is similar to that published by the American Society for Testing and Materials, ASTM designation E-119, recommended by the ASTM Committee on Fire Tests. Previous editions of this standard have been adopted and published by Underwriters' Laboratories, Inc., as U.L. 263.

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SCOPE: To develop standards for fire testing procedures when such standards are not available; review existing fire test standards and recommend appropriate action to NFPA; recommend the application of and advise on the interpretation of acceptable test standards for fire problems of concern to NFPA Technical Committees and members; act in a liaison capacity between NFPA and the committees of other organizations writing fire test standards.

Contents

Standard Methods of Fire Tests of Building Construction and Materials

NFPA No. 251 — 1972

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 in 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 follow. 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.

Scope.

1 (a) 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.

(b) 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.

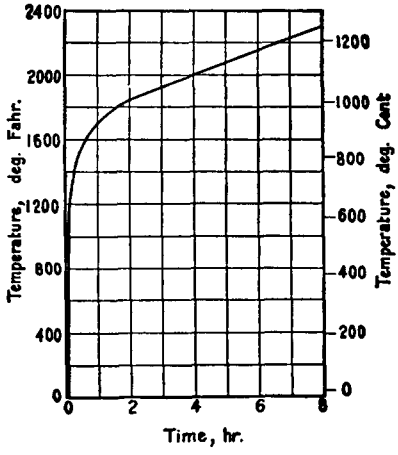
NOTE: A method of fire hazard classification based on rate of flame spread is covered in NFPA Standard No. 255, Method of Test of Surface Burning Characteristics of Building Materials.

CONTROL OF FIRE TESTS.

Time-Temperature Curve.

2. The conduct of fire tests of materials and construction shall be controlled by the standard time-temperature curve shown in Fig. 1. The points on the curve that determine its character are:

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



Time Temperature Curve Fig. 1.

For a closer definition of the time-temperature curve, see Appendix A.

Furnace Temperatures.

3. (a) 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 sealed porcelain tubes ¾ in. in outside diameter and ⅛ inch in wall thickness, or, as an alternative in the case of base metal thermocouples, enclosed in sealed, standard-weight ½-in. black wrought steel or black wrought iron pipe. The exposed length of the pyrometer tube and thermocouple in the furnace chamber shall be not less than 12 in. 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. 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. 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.

(b) The temperatures shall be read at intervals not exceeding 5 min. during the first two hours, and thereafter the intervals may be increased to not more than 10 minutes.

(c) 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 per cent of the corresponding area under the standard time-temperature curve shown in Fig. 1 for fire tests of 1 hr. or less duration, within 7.5 per cent for those over 1 hr. and not more than 2 hr., and within 5 per cent for tests exceeding 2 hr. in duration.

Temperatures of Unexposed Surfaces of Floors, Roofs, Walls, and Partitions.

4. (a). Temperatures of unexposed surfaces shall be measured with thermocouples or thermometers* placed

*Under certain conditions it may be unsafe or impracticable to use thermometers.

under flexible, dry, felted asbestos pads. The properties of these pads shall meet the requirements listed in Appendix B. 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. 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. 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. 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.) and shall be electrically insulated with heat-resistant and moisture-resistant coatings.

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

(b) 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 1½ times the thickness of the construction or 12 in. An exception can be made in those cases where there is an element of the construction which 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.

(c) Temperature readings shall be taken at intervals not exceeding 15 min. 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 min.

(d) Where the conditions of acceptance place a limita-

tion 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 per cent 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.

CLASSIFICATION AS DETERMINED BY TEST.

Report of Results.

5. **(a)** 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.

(b) Reports of tests involving wall, floor, beam or ceiling constructions in which restraint is provided against expansion, contraction and/or rotation of construction shall describe the method used to provide this restraint.

(c) When the indicated resistance period is ½ hr. 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° Fahr.-hr. or 30° Cent.-hr. (3240° Fahr.-min. or 1800° Cent.-min.), 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 (Note).

NOTE: 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.)).

(d) Unless all of the materials used in the assembly classify as "noncombustible" as defined in NFPA No. 220, Standard Types of Building Construction, the term "combustible" shall be used after the assigned hourly classification, except that the roof covering in roof and ceiling assemblies shall not be considered in making this evaluation. No material shall be classed as noncombustible which, as used in the assembly, will be subject to a significant increase in combustibility or flame spread rating beyond the limits established by the definition of "noncombustibility" in NFPA No. 220 through the effects of age, moisture or other atmospheric conditions. Flame spread rating refers to the ratings obtained according to the Method of Test of Surface Burning Characteristics of Building Materials, NFPA No. 255.

TEST SPECIMEN.

Test Specimen.

6. (a) The test specimen shall be truly representative of the construction for which classification is desired, as to materials, workmanship, and details such as dimensions of parts, and shall be built under conditions representative of those obtaining 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.

(b) 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.

(c) 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. per square (100 sq. ft.) 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.

CONDUCT OF FIRE TESTS.

Fire Endurance Test.

7. 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.

Hose Stream Test.

8. **(a)** 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 hr., 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.

(b) Exemption: 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 hr.

(c) Optional Program: 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.

(d) Stream Equipment and Details: The stream shall be delivered through 2½-in. hose discharging through a National Standard Playpipe of corresponding size equipped with a 1⅛-in. 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 I.

TABLE I.

Resistance Period	Water Pressure at Base of Nozzle, psi.	Duration of Application, min. per 100 sq. ft. exposed area.
8 hr. and over	45	6
4 hr. and over if less than 8 hr.	45	5
2 hr. and over if less than 4 hr.	30	2½
1½ hr. and over if less than 2 hr.	30	1½
1 hr. and over if less than 1½ hr.	30	1
Less than 1 hr., if desired	30	1

(e) Nozzle Distance: The nozzle orifice shall be 20 ft. 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. by an amount equal to 1 ft. for each 10 deg. of deviation from the normal.

Protection and Conditioning of Test Specimen.

9. 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 Paragraphs (a) through (c). 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 sec., 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.

(a) 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 per cent relative humidity at 73°F.[1] 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. depth below the surface of massive constructions, has achieved a moisture content corresponding to drying to equilibrium with air in the range of 50 to 75 per cent relative humidity at 73°±5°F. 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.

(b) 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 Paragraph (a).

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[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 alternate to the relative humidity method to indicate when wood has attained the proper moisture content. 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 per cent at a relative

humidity of 70 per cent for a temperature of 70° to 80°F (21° to 27°C).

(c) Within 72 hrs. prior to the fire test[2] information on the actual moisture content and distribution within the specimen shall be obtained. The information should be included in the test report.

[2]If the moisture condition of the fire test assembly is likely to change drastically from the 72 hr. sampling time prior to test, the sampling should be made not later than 24 hrs. prior to the test.

TESTS OF BEARING WALLS AND PARTITIONS.

Size of Specimen.

10. The area exposed to fire shall be not less than 100 sq. ft., with neither dimension less than 9 ft. The test specimen shall not be restrained on its vertical edges.

Loading.

11. During the fire endurance and fire and hose stream tests a superimposed load shall be applied to the construction in a manner calculated to develop theoretically, as nearly as practicable, the working stresses contemplated by the design.

Conditions of Acceptance.

12. 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 8, without passage of flame, of gases hot enough to ignite cotton waste, or of the hose stream, and after cooling but within 72 hr. after its completion shall sustain the dead load of the test construction plus twice the superimposed load specified above.

(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 (139°C) above its initial temperature.

TESTS OF NONBEARING WALLS AND PARTITIONS.

Size of Specimen.

13. The area exposed to fire shall be not less than 100 sq. ft., with neither dimension less than 9 ft. The test specimen shall be restrained on all four edges.

Conditions of Acceptance.

14. 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 test as specified in Section 8, without passage of flame, of gases hot enough to ignite cotton waste, or of the hose stream.

(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 (139°C) above its initial temperature.

TESTS OF COLUMNS.

Size of Specimen.

15. 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. The contemplated details of connections, and their protection if any, shall be applied according to the methods of acceptable field practice.

Loading.

16. (a) During 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.

(b) 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.

Condition of Acceptance.

17. 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.

ALTERNATE TEST OF PROTECTION FOR STRUCTURAL STEEL COLUMNS.

Application.

18. 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.

Size and Character of Specimen.

19. (a) 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. The column shall be vertical during application of the protection and during the fire exposure.

(b) 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.

(c) 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.

Temperature Measurement.

20. 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. 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.

Exposure to Fire.

21. During the fire endurance test the specimen shall be exposed to fire on all sides for its full length.

Conditions of Acceptance.

22. 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, or does not raise the temperature above 1200°F at any one of the measured points.

TESTS OF FLOOR AND ROOF ASSEMBLIES

Application.

23. (a) 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.

(b) 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 Sections 27(a), (b), and (c) and an unrestrained assembly classification based upon the conditions of acceptance specified in Sections 28 (a) and (b) in addition to Section 28(c), (d), or (e).

Note: See Appendix D, 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.

(c) One fire endurance classification shall be developed from tests of assemblies not restrained against

thermal expansion based upon the conditions of acceptance specified in Sections 28(a) and (b).

(d) Individual unrestrained classifications may be developed for beams tested in accordance with this test method using the conditions of acceptance specified in Sections 36(a), (b), or (c).

Size and Characteristics of Specimen

24. (a) The area exposed to fire shall be not less than 180 sq. ft. with neither dimension less than 12 ft. 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. from its walls.

(b) 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.

Loading

25. 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.

Temperature Measurement

26. (a) 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 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.

(b) 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 edge and one on the center of this flange), one on the web at the center, and one on the bottom of the top flange.

(c) 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.

(d) For open-web steel joists, four thermocouples shall be placed on each joist, one on the top chord, one at the middle of the web, and two on the bottom chord, except that no more than four joists need be so instrumented. The groups of four thermocouples shall be placed in representative locations such as at midspan, over joints in the ceiling, and over light fixtures, etc.

Conditions of Acceptance — Restrained Assembly

27. 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 (139°C) above its initial temperature.

(c) For specimens employing beams spaced more than 4 ft. on centers, the beams shall achieve a fire endurance classification on the basis of the temperature criteria specified in Section 28(c) or (d) for assembly classifications of up to and including 1 hr. For classifications greater than 1 hr., the above temperature criteria shall apply for a period of one half of the classification of the assembly or 1 hr., whichever is greater.

Conditions of Acceptance — Unrestrained Assembly

28. 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 (139°C) above its initial temperature.

(c) For specimens employing steel structural members (excluding steel floor units having spans equal to or less than those tested), the temperature of the steel shall not

have exceeded 1300°F at any location during the classification period nor shall the average temperature recorded by four thermocouples at any section have exceeded 1100°F during this period.

(d) 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 for cold-drawn prestressing steel or 1100°F for reinforcing steel during the classification period.

(e) For specimens employing multiple (five or more) open-web steel joists, the average temperature recorded by all joist thermocouples shall not have exceeded 1100°F during the classification period.

Report of Results

29. (a) The fire endurance classification of a restrained assembly shall be reported as that developed by applying the conditions of acceptance specified in Section 27(a), (b), and (c).

(b) The fire endurance classification of an unrestrained assembly shall be reported as that developed by applying the conditions of acceptance specified in Section 28(a) and (b) and, where applicable, Section 28(c), (d), or (e) to a specimen tested in accordance with this test procedure.

TESTS OF LOADED RESTRAINED BEAMS

30. An individual classification of a restrained beam may be obtained by this test procedure and based upon the conditions of acceptance specified in Section 33. 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.

Size and Characteristics of Specimen

31. 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. 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. 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.

Loading

32. 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.

Conditions of Acceptance

33. 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 28(c) or (d) of one half the classification of the assembly or 1 hr., whichever is the greater.

ALTERNATIVE CLASSIFICATION PROCEDURE FOR LOADED BEAMS

Application

34. Individual unrestrained classifications may be developed for beams tested as part of a floor or roof assembly as described in Sections 23 through 26 (except Section 23(c)) or for restrained beams tested in accordance with the procedure described in Sections 30 through 32. 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.

Temperature Measurement

35. (a) 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.

(b) 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.

(c) 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.

Conditions of Acceptance

36. 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 at any location during the classification period nor shall the average temperature recorded by four thermocouples at any section have exceeded 1100°F 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 for cold-drawn prestressing steel or 1100°F for reinforcing steel during the classification period.

ALTERNATE TEST OF PROTECTION FOR SOLID STRUCTURAL STEEL BEAMS AND GIRDERS.

Application.

37. Where the loading required in Section 25 is not feasible this alternate 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 alternate test are not applicable to tests made under design loads as provided under tests for Floors and Roofs in Sections 23 to 29.

Size and Character of Specimen.

38. **(a)** 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. and the member shall be tested in a horizontal position. A section of a representative floor construction not less than 5 ft. 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.

(b) 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 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 or from the ends of the member to the outside of the furnace.

Temperature Measurement.

39. 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. 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.

Conditions of Acceptance.

40. 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, or does not raise the temperature above 1200° F at any one of the measured points.

TESTS OF CEILING CONSTRUCTIONS.

Application.

41. This test procedure is to be used for classification of ceilings that are not an integral part of a floor construction and where thirty-six inches or more of space is provided above the top of the joists or beams supporting and protected by the ceiling.

Size of Specimen.

42. The area exposed to fire shall be not less than 180 sq. ft., with neither dimension less than 12 ft., and the ceiling surface at its edges shall be in contact with the test furnace structure.

Test Construction and Enclosure.

43. The test ceiling construction shall include all structural members and details including hangers, if any, but not walkways. Above the ceiling during the test, there shall be provided a tight flat-topped enclosure, the underside of the covering material of which shall be 36 in. above the top of the joists or beams supporting and protected by the ceiling. The top of the enclosure shall be made of cement-asbestos board ¼ in. in thickness under asbestos millboard ½ in. in thickness, and the side walls of 8-in. common brick, or it shall be of a construction having equivalent heat conductiv-

ity and heat capacity. Where use of the ceiling under a combustible construction is contemplated, at least five 15-in. square panels of 1-in. pine board shall be attached to the underside of the top of the enclosure. The temperatures on the bottom surface of these panels shall be measured.

Conditions of Acceptance.

44. The test shall be regarded as successful if the following conditions are met:

(a) The ceiling shall have withstood the fire endurance test without the passage of flame or ignition of combustible members or materials forming part of the construction above the ceiling as evidenced by glow or flame.

(b) Transmission of heat through the ceiling during the fire endurance test shall not have been such as to raise the average temperature above the test ceiling more than indicated in the following Items (1), (2), and (3). The limiting temperatures shall be the average of those taken at not less than five points, one of which shall be approximately at the center, and four at approximately the centers of the quarter sections.

(1) With combustible supports or other combustible material in contact with the ceiling, the temperature increase at the points of contact shall not exceed 250°F.

(2) With combustible supports or other combustible material not in contact with the ceiling, the temperature increase on the surface of any combustible members, pine panels, or combustible material adjacent to the ceiling shall not exceed 250°F. The temperature on the exposed surface of combustible members not in contact with the ceiling shall be measured under a sheet of mica approximately 0.002 in. in thickness.

(3) With no combustible material above the ceiling construction, the average temperature measured on the lower surface of the main structural supporting members (beams or slabs) shall not exceed 1200°F and the average temperature of the top and bottom of the beams, when used, shall not exceed 1000°F.

TESTS OF PROTECTION FOR COMBUSTIBLE FRAMING, OR FOR COMBUSTIBLE FACINGS ON THE UNEXPOSED SIDE OF WALLS, PARTITIONS, AND FLOORS.

Character of Specimen.

45. Test panels carrying wall, partition, or floor protection shall be finished with the protections which are the subject of the test, except that where the finish on the unexposed side is not the subject of the test and not specifically indicated, the testing authority shall apply a finish judged suitable for the purpose. In case a floor construction, as installed for actual use, is to have no finish on the unexposed side, it shall be so tested.

Size of Specimen.

46. The area exposed to fire shall be, for tests of wall and partition protection, not less than 100 sq. ft. with neither dimension less than 9 ft.; for tests of floor protection, not less than 180 sq. ft. with neither dimension less than 12 ft.

Conditions of Acceptance.

47. The test shall be regarded as successful if the following conditions are met:

(a) The protection shall have withstood the fire endurance test, without ignition of the materials protected, for a period equal to that for which classification is desired.

(b) Transmission of heat through the protection during the fire endurance test shall not have been such as to raise the temperatures at its contact with the protected structural members or facings of the test panel more than 250°F. (139°C) above the initial temperatures at these points, except that for members closely embedded on three sides in masonry, concrete, or other noncombustible materials the permissible temperature rise may be 325°F (181°C).

Appendix A

TABLE II.—STANDARD TIME-TEMPERATURE CURVE FOR CONTROL OF FIRE TESTS.

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	1 800	7 740	129	704	4 300	72
0:15	1 899	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	1 237	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	12 988	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 B

REQUIREMENTS FOR ASBESTOS PADS

B. 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:

(1) Length and width, 6 ± ⅛ in.,
(2) Thickness,* 0.40 ± 0.05 in.,
(3) Dry weight, 0.260 ± 0.026 lb.,
(4) Thermal conductivity (at 150°F.), 0.38 ± 0.027 Btu in. per hr. sq. ft. deg. Fahr., and
(5) Hardness,** 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.

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*The thickness measurement shall be made under the light load of a ½-in. diameter pad of a dial micrometer gage.

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

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

where y = the difference in indentation in inches.