Standard Guide for Extension of Data From Fire Endurance Tests[1]

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ε[1] NOTE—Editorial changes were made throughout in August 2000.

1. Scope

1.1 This guide covers the extension of fire endurance results obtained from fire tests performed in accordance with Test Method E 119 to constructions that have not been tested. Test Method E 119 evaluates the duration for which test specimens will contain a fire, retain their standard integrity, or both during a predetermined test exposure.

1.2 This guide is based on principles involving the extension of test data using simple considerations. The acceptance of these principles and their application is based substantially on an analogous worst case proposition.

1.3 These principles are only applicable to temperature conditions represented by the standard time-temperature curve described in Test Method E 119. Test Method E 119 is a fire-test-response standard.

1.4 The types of building constructions which are the subject of this guide are categorized as follows: beams; floor and roof assemblies; columns; and walls and partitions. Floor and roof assemblies include such assemblies with ceiling protective membranes.

1.5 The extension of test data using numerical calculations based on empirical data or theoretical models is not covered in this guide.

1.6 This guide does not cover the substitution of one proprietary material for another proprietary material, or materials for which fire test data are not presently available.

1.7 This guide does not purport to be comprehensive in its treatment of non-proprietary modifications of tested constructions. Engineering evaluation or tests are recommended for assessing modifications not specifically covered in this guide.

1.8 The values given in SI units are regarded as standard.

1.9 *This guide is used to measure and describe the response of materials, products, or assemblies to heat and flame under controlled conditions, but does not by itself incorporate all factors required for fire hazard or fire risk assessment of the materials, products, or assemblies under actual fire conditions.*

1.10 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

2. Referenced Documents

2.1 *ASTM Standards:*

C 168 Terminology Relating to Thermal Insulating Materials[2]
C 553 Specification for Mineral Fiber Blanket Thermal Insulation for Commercial and Industrial Applications[2]
C 612 Specification for Mineral Fiber Block and Board Thermal Insulation[2]
E 119 Test Methods for Fire Tests of Building Construction and Materials[3]
E 176 Terminology Relating to Fire Standards[3]
E 631 Terminology of Building Constructions[4]
E 1264 Classification for Acoustical Ceiling Products[2]
E 1513 Practice for Application of Sprayed Fire-Resistive Materials (SFRMs)[4]

3. Terminology

3.1 *Definitions:*

3.1.1 For definitions used in this guide, refer to Terminologies E 176, C 168, and E 631.

3.1.2 *fire endurance*, *n*—a measure of the elapsed time during which a material or assemblage continues to exhibit fire resistance

3.1.3 *fire resistance*, *n*—the property of a material or assemblage to withstand fire or give protection from it.

3.1.3.1 *Discussion*—In this guide, it is characterized by the ability to confine a fire and continue to perform a given structural function.

3.1.4 *mineral fiber insulation*, *n*—insulation composed principally of fibers manufactured from rock, slag, or glass processed from molten state into fibrous form to comprise flexible batts or blankets, rigid or semi-rigid blocks and boards, or loose fill insulations, with or without binder.

3.1.4.1 *Discussion*—Mineral fiber blanket thermal insulations and mineral fiber block and board thermal insulations are

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[3] *Annual Book of ASTM Standards*, Vol 04.07.
[4] *Annual Book of ASTM Standards*, Vol 04.11.

classified into various types based upon the maximum use temperature, which can range from 204°C (400°F) to 982°C (1800°F), and the apparent thermal conductivity (See Specifications C 553 and C 612).

3.1.5 *unit weight*, *n*—as applied to concrete, weight per unit volume.

3.2 *Definitions of Terms Specific to This Standard:*

3.2.1 *acoustical ceiling panel*, *n*—a form of a prefabricated sound absorbing ceiling element used with exposed suspension systems (see Specification E 1264).

3.2.2 *acoustical ceiling tile*, *n*—a form of a prefabricated sound absorbing ceiling element used with concealed or semi-exposed suspension systems, stapling, or adhesive bonding (see Specification E 1264).

3.2.3 *beams*, *n*—all horizontally oriented structural members employed in building construction and known variously as beams, joists, or girders.

3.2.4 *ceiling protective membrane*, *n*—a ceiling membrane attached to or suspended from the structural members of the floor or ceiling assembly, usually by hanger wire or threaded rods, consisting of a grid suspension system with lay-in ceiling panels or a grid of steel furring channels to which the ceiling membrane is directly attached, intended to provide fire protection, acoustical and or aesthetic enhancements, or both.

3.2.5 *composite*, *n*—as applied to loadbearing elements, an interaction between structural components which is to be taken into account in the evaluation of load capacity.

3.2.6 *design load*, *n*—the intended maximum design load condition allowed by design under appropriate nationally recognized structural design criteria.

3.2.7 *directly applied fire resistive coating*, *n*—materials that are normally sprayed onto substrates to provide fire-resistive protection of the substrates.

3.2.7.1 *Discussion*—These coatings are called sprayed fire-resistive materials in Standard Practice E 1513 and related standards.

3.2.8 *equivalent thickness*, *n*—the calculated solid thickness of concrete or masonry for purposes of determining fire resistance ratings of barrier elements on the basis of heat transmission end-point criteria.

3.2.9 *insulation*, *n*—a material that is normally added to an assembly to provide resistance to heat flow for purpose of energy conservation.

3.2.9.1 *Discussion*—Insulation materials are also used to improve sound control or improve fire resistance.

3.2.10 *lightweight aggregate concrete*, *n*—concrete made with aggregates of expanded clay, shale, slag, or slate or sintered fly ash, and weighing 1360 to 1840 kg/m^3 (85 to 115 pcf).

3.2.11 *material, generic*, *n*—is one for which a nationally recognized Standard Specification exists.

3.2.12 *material proprietary*, *n*—is one whose fire performance characteristics are determined in consideration of a formulation or process of production that is proprietary.

3.2.13 *non-composite*, *n*—as applied to loadbearing elements, structural interaction between contiguous elements is assumed not to exist in the evaluation of load capacity.

3.2.14 *sand-lightweight concrete*, *n*—concrete made with a combination of expanded clay, shale, slag, or slate or sintered fly ash and natural sand and generally weighing between 1680 and 1920 kg/m^3 (105 to 120 pcf).

3.2.15 *specified load*, *n*—as applied to loadbearing elements, the test load applied to the element in a Test Method E 119 test.

3.2.15.1 *Discussion*—In Test Method E 119 testing, the specified load is generally the design load (see 3.2.6).

3.2.16 *test specimen*, *n*—the specific construction assembly that was tested in accordance with Test Method E 119.

3.2.17 *transfer*, *n*—the process of substituting a loadbearing element from one test specimen for the loadbearing element in another test specimen, or utilizing a loadbearing element from one test specimen for use in another test specimen that does not include a loadbearing element.

3.2.18 *ultimate capacity*, *n*—as applied to loadbearing elements, the actual maximum load carrying capacity of an element based on properties specific to the material constituting the element.

4. Significance and Use

4.1 The methods and procedures set forth in this guide relate to the extension of the fire endurance results obtained from particular fire tested specimens to constructions that have not been tested.

4.2 Users of this guide must have knowledge and understanding of the provisions of Test Method E 119 including those pertaining to conditions of acceptance.

4.3 In order to apply some of the principles described in this guide, reference to the original fire test report will be necessary.

4.4 In Test Method E 119, the specimens are subjected to specific laboratory fire test exposure conditions. Substitution of different test conditions or changes in the end use conditions have the ability to change the measured fire-test-response characteristics. Therefore, the extensions of data are valid only for the fire test exposure conditions described in Test Method E 119,.

5. General Principles

5.1 The same criteria or conditions of acceptance as set out in the Test Method E 119 and followed in the establishment of the fire endurance classification of the original test specimen shall be used in the evaluation of the effect of the modification or substitution of components in a test specimen.

5.1.1 The criteria or conditions of acceptance for the evaluation of modified test specimens shall likewise be in accordance with the appropriate sections of Test Method E 119.

5.2 Statements in this guide only indicate whether a change in the construction either "can reduce" or "does not reduce" fire endurance.

5.3 *Limitations*:

5.3.1 The extension of fire endurance data is valid only for changes to the tested specimen that fall within normal and reasonable limits of standard construction practices.

5.3.2 Statements are valid only if the identified changes are the only changes in the construction or properties of the components.

5.3.3 It is possible that multiple changes have a different cumulative effect than that of individual changes applied separately.

5.3.4 Unless otherwise indicated, statements are only valid if the change identified does not change the specified load.

5.3.4.1 Provisions in this guide involving the ratio of specified load to design load assume that the safety factor (ratio of ultimate capacity to design load) inherent in the design procedure is constant.

5.3.4.2 Increasing the ratio of the maximum applied load (specified load, dead plus live load) to the design load of an element beyond that realized in the test specimen can reduce the fire endurance.

5.3.5 Provisions in this guide pertaining to concrete only apply to concrete with a compressive strength of 55.1 MPa (8000 psi) or less.

5.4 *Restrained/Unrestrained Specimens*:

5.4.1 The fire endurance of a beam, floor, or roof test specimen is related to either a restrained or unrestrained condition, or both. A restrained condition in a fire test is considered to be one in which the displacement or rotation due to fire induced thermal expansion of a load bearing element is resisted by forces external to the element. An unrestrained condition in a fire test is one in which the load bearing element is free to expand and rotate at its supports or is not subject to substantial thermal expansion and its resulting restraining forces.

5.4.2 Ratings of restrained beam, floor, or roof test specimens are intended for application to elements which are considered to be suitable for use in restrained building construction where the surrounding or supporting structure is capable of resisting substantial thermal expansion throughout the range of anticipated elevated fire conditions.

5.4.3 Ratings of unrestrained beam, floor or roof test specimens are intended for application to elements which are considered to be suitable for use in unrestrained and restrained building construction where the surrounding or supporting structure is or is not capable of resisting substantial thermal expansion throughout the range of anticipated elevated fire conditions.

5.4.3.1 The application of unrestrained classified beams, floors or roofs for use in building constructions with end restraint does not reduce the fire endurance.

NOTE 1—See Appendix X3 "Guide for Determining Conditions of Restraint for Floor and Roof Assemblies and for Individual Beams" in Test Method E 119 for assistance in determining the conditions of thermal restraint applicable to floor and roof constructions and individual beams in actual building construction.

5.5 *Composite and Non-Composite Design*:

5.5.1 Fire endurance classifications of beams and floors or roofs tested with composite design between the beam and the floor or roof is not reduced in actual building constructions designed for either composite or non-composite action.

5.5.2 Conversely, fire endurance classifications of beams and floors or roofs tested in non-composite design shall be limited to building constructions designed for non-composite action.

6. Principles Pertaining to Heat Transfer Characteristics of Concrete

6.1 The provisions in this section are applicable only as they affect the transfer of heat through concrete. Considerations involving structural fire endurance are addressed in other sections.

6.2 For concrete test specimens where temperature rise on the unexposed surface of a concrete slab (wall, floor, or roof) is the governing criterion, the following modifications do not reduce the fire endurance of the assembly:

6.2.1 Decrease in concrete unit weight;

6.2.2 Substitution of sanded light-weight aggregate concrete or light-weight aggregate concrete for normal weight concrete; also, substitution of carbonate aggregate for siliceous aggregate for either the coarse or the fine aggregate used in the concrete;

6.2.3 Decrease in the nominal maximum size of coarse aggregate within a given concrete aggregate type;

6.2.4 Increase or decrease in the compressive strength of the concrete;

6.2.5 Change in the type of portland cement, flyash or admixtures used in the concrete;

6.2.6 Changes in the type or amount of reinforcement;

6.2.7 Increase in the equivalent thickness of the slab for a given type of aggregate concrete; and

6.2.8 Change in slab design or restraint conditions, provided the equivalent thickness of slab does not decrease.

6.2.9 In slabs or constructions incorporating joints other than construction joints, changes in joint design provided that the substituted joint design has been tested in a Test Method E 119 test and met the required fire endurance.

6.2.10 For slabs containing hollow cores or air cavities, filling of cores or voids with non-combustible insulation material;

6.3 For temperature rise to be the governing criteria, it is assumed that the structural design requirements of the slab are met and adequate cover protection is provided to the steel reinforcement (prestressing and reinforcing bars).

7. Principles Pertaining to Protective Finish Systems

7.1 *Directly Applied Fire Resistive Coatings*:

7.1.1 The following modifications to directly applied fire resistive coatings can reduce the fire endurance:

7.1.1.1 A decrease in thickness;

7.1.1.2 A change in a critical aspect of the coating such as composition, formulation, density, etc. or system (use of adhesive, sealer or top coat; mechanical retention; etc); and

7.1.1.3 A change in the nature of the substrate (composition, orientation, shape, etc.) or condition (surface texture, surface finish, contamination, etc.).

7.1.2 Except for intumescent coatings, the following modifications to directly applied fire resistive coatings, do not reduce the fire endurance:

7.1.2.1 An increase in thickness;

7.1.2.2 A change in a non-critical aspect of the coating such as color, compatible decorative or protective oversprays, texture, etc; and

7.1.2.3 The use of mechanical retention systems (metal lath, steel studs and disks, etc.) to satisfy concerns about substrate changes.

7.2 *Cover Protection for Steel Columns*:

7.2.1 For steel column protections that are not required by design to carry any of the column load, the alternative test and conditions of acceptance specified under "Alternative Test of Protection for Structural Steel Columns" in Test Method E 119, are applicable (See 11.1.2).

7.2.2 Concrete membrane protection systems- where membrane protection consists of monolithic concrete (column spaces filled), concrete masonry units or precast reinforced concrete units (column spaces not filled), the following modifications do not reduce the fire endurance of the column:

7.2.2.1 Substitution of carbonate aggregate for siliceous aggregate for either the coarse or the fine aggregate used in concrete;

7.2.2.2 Substitution of lightweight concrete for sand-lightweight concrete;

7.2.2.3 Substitution of sand-lightweight concrete or lightweight concrete for normal-weight concrete;

7.2.2.4 Decrease in nominal maximum size of coarse aggregate within a given aggregate type concrete;

7.2.2.5 Change in the type of portland cement, flyash or admixtures used in the concrete;

7.2.2.6 Change in compressive strength of the concrete;

7.2.2.7 Increase in thickness of the membrane protection; and

7.2.2.8 Where column spaces are not filled, increases or decreases in the air space between the column and the column cover.

7.3 *Fire Resistive Protective Membranes*:

7.3.1 Ceiling protective membranes are generally of three types:

7.3.1.1 Lay-in, acoustical or gypsum, panels supported by an exposed steel grid system;

7.3.1.2 Fitted, acoustic, tiles supported by a concealed steel grid system; or

7.3.1.3 Mechanically fastened gypsum boards screw attached to furring channels or screw or nail attached directly to the underside of the structural members.

7.3.2 *Effects of Fasteners*—The following changes relating to fasteners (such as screws, nails, bolts, etc.) can reduce the fire endurance of protective membranes by reducing the stability of the membrane.

7.3.2.1 A decrease in length or a change in shaft diameter of fasteners;

7.3.2.2 An increase in the spacing between fasteners; or

7.3.2.3 A reduction in the distance between the edge of a panel and the location of a peripheral fastener when that distance in the tested specimen is less than 25 mm (1 in.).

7.3.3 The substitution of unbacked joints for joints backed can reduce the fire endurance.

7.3.4 The use of furring channels as a substitute for the direct attachment of the membrane to joists does not reduce the endurance provided that:

7.3.4.1 The joist spacing is not increased and the furring channels are spaced apart a distance no greater than the joist spacing;

7.3.4.2 The spacing of fasteners used to connect the membrane to the furring channels is not increased; and

7.3.4.3 Provisions are made using procedures proven to be effective by prior Test Method E 119 fire tests to reduce furring channel spacing and provide additional furring channel(s) at butt joints between ceiling panels ends to reduce fire induced stresses at these joints.

7.3.5 The substitution of resilient furring channels for "top hat" or "non-resilient" furring channels or vice versa does not reduce the fire endurance.

7.3.6 Increasing the depth of the space between the underside of the floor, beam or roof deck and the protective ceiling membrane does not reduce the fire endurance.

7.3.6.1 A decrease in this depth can reduce the fire endurance.

7.3.7 *Suspended or Lay-In Acoustical Ceiling Panels and Fitted Type Acoustical Ceiling Tiles*:

7.3.7.1 A change in the composition or density of the panels or tiles can reduce the fire endurance.

7.3.7.2 A decrease in the area of individual panels, resulting in an increase in the area of exposed steel, can reduce the fire endurance due to a reduction in insulative performance.

7.3.7.3 An increase in the area of individual panels, resulting in a reduction of the area of exposed steel, does not reduce the fire endurance provided the stability of the larger panel and supporting steel grid system has been validated by a Test Method E 119 test for the duration required and under the anticipated ceiling deflection conditions.

7.3.7.4 An increase in thickness of the panel or tile does not reduce the fire endurance.

7.3.8 *Mechanically Fastened Gypsum Board*—The following changes in dimension or physical characteristic of a gypsum board used in a mechanically fastened ceiling application can reduce the fire endurance:

7.3.8.1 A decrease in length or width due to an increase in the length of joint per unit area of ceiling; or

7.3.8.2 A change in the composition or density.

7.3.9 The following changes in dimension or physical characteristic of a gypsum board used in a mechanically fastened ceiling application do not reduce fire endurance:

7.3.9.1 An increase in thickness;

7.3.9.2 An increase in length or width provided that the spacings between fasteners are not increased and the spacings between fasteners and the edge or ends of the board are not decreased;

7.3.10 *Penetrations of Membranes*:

7.3.10.1 For test specimens employing a membrane penetrated by light fixtures or air-handling services, changes in the area or construction of the penetrating items can reduce the fire endurance.

7.3.10.2 An increase in the individual and aggregate area of light fixtures or air-handling services penetrating the membrane can reduce the fire endurance. A decrease of these areas does not reduce the fire endurance.

7.3.10.3 Substitution of light fixtures that employ casings, framing, screws, or fasteners of materials having a melting point of less than 1000°C (1835°F) can reduce the fire endurance;

7.3.10.4 Substitution of light fixtures that do not permit the ready attachment of the prescribed suspension wires to the perimeter grid without the introduction of rotational stresses in that grid can reduce the fire endurance.

7.3.10.5 For test specimens employing a suspended membrane penetrated by surface mounted air supply or return devices, the use of lay-in air supply or return devices of the same overall area does not reduce the fire endurance, provided that:

7.3.10.6 The lay-in devices are of welded or riveted steel construction;

7.3.10.7 Suspension wires are provided for the steel framing members at each corner of the lay-in device; and

7.3.10.8 Thermal protection is provided to the back of the lay-in device that has demonstrated an equivalent performance to that of the tested system.

8. Principles Pertaining to Thermal Insulation of Walls and Floors

8.1 The addition of thermal insulation in a concealed space within a specimen tested without insulation is regulated by the following:

8.1.1 It is expected that elements of the construction between the insulation and the exposing fire will experience a more rapid temperature rise. Where this effect reduces the stability of the element, the net effect can reduce the fire endurance;

8.1.2 If insulation were incorporated in a concealed space within a test specimen, the substitution of a different type, thickness or density, or the relocation of the insulation can reduce the fire endurance; and

8.1.3 It is expected that elements of the construction between mineral fiber insulation and the unexposed surface will experience a lower rate of temperature rise while the test specimen and the insulation remain intact. This effect does not reduce the fire endurance.

8.2 *Insulation in Floor/Roof Assemblies*:

8.2.1 Where the elements of the construction between the insulation and the exposing fire are required to support the weight of the backloaded insulation, the load imposed on the ceiling protective membrane and its suspension system by excessively high levels of insulation can result in a loss of stability and can reduce the fire endurance.

8.2.2 Except as provided in 8.2.3, the addition of insulation to the top surface of a test specimen supported by structural steel elements can reduce the fire endurance by virtue of heat entrapment causing increased temperatures in the supporting elements. The insulation referred to in this Section is limited to products of the following types: glass fiber, vermiculite, perlite, wood fiber, mineral fiber produced from rock or slag and phenolic foam.

8.2.3 *Steel Deck Roof Construction*:

8.2.3.1 The addition of identical insulation to the top surface of a steel deck roof tested with over 100 mm (4 in.) of insulation does not reduce the fire endurance.

8.2.3.2 In order to increase the thickness of insulation without reducing the fire endurance of a test specimen incorporating 100 mm (4 in.) or less of insulation applied directly on top of a steel deck, it is necessary to include a layer of 12.7 mm (0.5 in.) or thicker type X gypsum board, or equivalent heat sink, between the insulation and the steel deck.

8.3 *Insulation in Wall Assemblies*:

8.3.1 An increase in thickness of the mineral fiber insulation does not reduce the fire endurance.

9. Principles Pertaining to Fire Endurance of Beams

9.1 *Conditions of Acceptance*—Individual fire endurance classifications for beams are determined in accordance with the following:

9.1.1 A restrained beam classification is obtained based on the procedure specified under “Tests of Loaded Restrained Beams” in Test Method E 119 and the conditions of acceptance of that section.

9.1.2 Procedures for obtaining an unrestrained beam classification include:

9.1.2.1 Test as a beam using the procedures specified under “Tests of Loaded Restrained Beams” in Test Method E 119 and the conditions of acceptance in the section entitled “Alternative Classification Procedure for Loaded Beams”, and

9.1.2.2 Test as part of floor or roof assembly using the procedures specified under “Tests of Floors and Roofs” in Test Method E 119 and the conditions of acceptance in the section entitled “Alternative Classification Procedure for Loaded Beams”.

9.1.3 A classification is also obtained for steel beams based on the procedure specified under “Alternative Test of Protection for Solid Steel Beams and Girders” in Test Method E 119 and the conditions of acceptance of that section.

9.1.4 An individual restrained beam classification cannot be obtained from a tested floor or roof specimen.

9.2 *Substitution or Transfer*—The process of substituting a beam from one test specimen for the beam in another test specimen, or transferring a beam from one test specimen for use in another test specimen that does not include a beam shall be regulated by the following:

9.2.1 When tested separately as beams and assigned a classification based on “Tests of Loaded Restrained Beams” of Test Method E 119 (see 9.1.1), it is permitted to transfer provided that:

9.2.1.1 The unrestrained beam classification of the substitute beam is equal to or greater than the unrestrained beam classification of the beam being replaced;

9.2.1.2 The restrained beam classification of the substitute beam is equal to or greater than the restrained assembly classification of the roof into which the beam is to be utilized; and

9.2.1.3 The classification of the substitute beam is at least equal to the classification of the requirement.

9.2.2 When tested as part of a floor and assigned a classification based on “Tests of Floors and Roofs” of Test Method E 119, it is permitted to transfer the beam provided that:

9.2.2.1 The unrestrained beam classification of the substitute beam is equal to or greater than the unrestrained beam classification of the beam being replaced;

9.2.2.2 The restrained assembly classification of the floor or roof in which the substitute beam was tested is equal to or greater than the restrained assembly classification of the floor or roof assembly in which the beam is to be utilized; and

9.2.2.3 The unrestrained classification of the substitute beam is at least equal to the classification of the requirement.

9.2.3 The load deflection (at full specified load of tested specimen) of the construction into which the beam is being substituted or transferred shall be equal to or less than that of the specimen in which it was tested;

9.2.4 The capacity for heat dissipation from the beam in the construction into which it is being substituted or transferred shall be equal to or greater than that of the specimen in which it was tested; and

9.2.5 The capacity for heat transfer to the beam in the construction into which it is being substituted or transferred shall be equal to or less than that in the specimen in which it was tested.

9.2.6 The substitution of steel beams having the same geometric shapes and a greater W/D ratio (ratio of weight to heated perimeter) than that of the tested beam does not reduce the fire endurance. Conversely, the substitution of steel beams having a dissimilar geometric shape or a lesser W/D ratio can reduce the fire endurance.

9.3 It is possible to increase or decrease the span of beams without reducing the fire endurance provided that the structural design requirements arising from the span changes are satisfied and the resulting loading stresses (bending and shear) do not exceed the corresponding stresses of the fire tested design.

9.4 Spacing of beams is governed by provisions of Section 10 and by the following:

9.4.1 Except as noted in Section 10 changes in the spacing of beams tested with spacing greater than 1.2 m (4-ft) on center do not reduce the fire endurance provided that:

9.4.1.1 The structural design requirements arising from the spacing changes are satisfied and that the resulting loading stresses (bending and shear) of both the beam and any deck/slab do not exceed the corresponding stresses of the fire tested design; and

9.4.1.2 Provisions for support of the ceiling membrane are maintained, when the function of that membrane is to provide fire resistance.

9.4.2 Except as noted in Section 10, changes in the spacing of beams from, that of the tested specimen with spacing less than 1.2 m (4 ft) on center up to a maximum of 1.2 m (4 ft) do not reduce the fire endurance provided that:

9.4.2.1 The structural design requirements arising from the spacing changes are satisfied and that the resulting loading stresses (bending and shear) of both the beam and any deck/slab do not exceed the corresponding stresses of the fire tested design; and

9.4.2.2 Provisions for support of the ceiling membrane are maintained, when the function of that membrane is to provide fire resistance.

9.5 *Concrete Beams*:

9.5.1 The following modifications do not reduce the fire endurance:

9.5.1.1 Substitution of carbonate aggregate for siliceous aggregate for either the coarse or the fine aggregate used in concrete;

9.5.1.2 Decrease in the nominal maximum size of coarse aggregate within a given aggregate type concrete;

9.5.1.3 Change in the type of portland cement, flyash or admixtures used in the concrete.

9.5.2 The following modifications do not reduce the fire endurance provided that the modification does not result in a ratio of maximum applied load to design load greater than the tested specimen.

9.5.2.1 Decrease in concrete unit weight;

9.5.2.2 Change in compressive strength of the concrete;

9.5.2.3 Increase in concrete cover to principal steel reinforcement.

10. Principles Pertaining to Fire Endurance of Floor or Roof Assemblies

10.1 *Conditions of acceptance for restrained and unrestrained test specimens*—Individual fire endurance assembly classifications for floors and roofs are based on the procedure specified under "Tests of Floors and Roofs" in Test Method E 119 in accordance the following:

10.1.1 An unrestrained assembly classification based on conditions of acceptance specified in "Conditions of Acceptance-Unrestrained Assembly";

10.1.1.1 There are specific conditions of acceptance for steel structural members spaced more than 1.2 m (4 ft) on center; steel structural members spaced 1.2 (4 ft) or less on center; conventionally designed concrete members; and steel floor or roof units intended for use in spans greater than those tested.

10.1.2 A restrained assembly classification based on conditions of acceptance specified in "Conditions of Acceptance-Restrained Assembly";

10.1.2.1 There are specific conditions of acceptance for steel structural members spaced more than 1.2 m (4 ft) or less; steel structural members spaced 1.2 m (4 ft) or less; and conventionally designed concrete structural beams spaced more than 1.2 m (4 ft) on center.

10.2 *Beams Within a Floor or Roof Assembly*—For guidance on the beams within a floor or roof assembly, see Section 9 on Beams.

10.3 The spans of the beams within floors and roofs can be increased or decreased provided that the structural design requirements arising from the span changes are satisfied and the resulting loading stresses (bending and shear) do not exceed the corresponding stresses of the fire tested design.

10.4 *Concrete Slabs and Assemblies Incorporating Slabs*:

10.4.1 Decreasing the concrete unit weight or increasing the equivalent thickness of the slab will result in higher temperatures in support systems and can reduce the fire endurance.

10.4.1.1 When the heat transmission end point of the ASTM E 119 test is the controlling criterion, the changes specified in 10.4.1 do not reduce the fire endurance.

10.4.2 Where the capacity of the assembly to sustain the applied loading is the governing criterion, the following modifications do not reduce the fire endurance provided that the modification does not result in a ratio of maximum applied load to design load greater than the tested specimen and the structural design requirements of the assembly for ambient conditions are met:

10.4.2.1 For flat slab assemblies without beams, decreasing the concrete unit weight in the slab;

10.4.2.2 For slab assemblies with protected beam supporting systems, increasing the concrete unit weight and/or decreasing the equivalent thickness of the slab within the limitations expressed in 10.4.1 (see 10.4.1.1);

10.4.2.3 Substitution of carbonate aggregate for siliceous aggregate for either the coarse or the fine aggregate in the concrete of the slab or of the assembly;

10.4.2.4 Change in the type of portland cement, flyash or admixtures used in the concrete;

10.4.2.5 An increase in concrete cover to reinforcement in the slab or in the assembly, provided that minimum cover does not exceed 64 mm (2.5 in.);

10.4.2.6 In restrained slabs, changes in restraint conditions provided that effective thermal restraint still exists. See Appendix X5; "Commentary", of Test Method E 119.

10.4.2.7 In substitution cases where restraint is to be provided by structural continuity, it is critical to ensure both: (a) the sufficiency of the compression zones over the supports; and, (b) the negative moment reinforcement, to sustain the redistribution of moment during fire exposures.

10.4.3 For concrete slab assemblies, or concrete assemblies incorporating slabs, where temperature rise on the unexposed surface of a concrete slab is the governing criterion, (that is, The structural design requirements of the slab are met and adequate cover protection is provided to the steel reinforcement [prestressing and reinforcing bars]), the modifications in the concrete materials used, concrete mixture, or slab design described in Section 6 apply and do not reduce the fire endurance.

10.5 *Steel Floor or Form Units*:

10.5.1 For beams in tested specimens with roofs incorporating insulation on steel decks protected by a ceiling protective membrane, increasing the spacing between beams can reduce the fire endurance.

10.5.1.1 If the ceiling is not suspended directly from the steel deck and the tested specimen with roof was tested with spacing between beams less than 1.2 m (4 ft) on center, changes in the spacing up to a maximum spacing of 1.2 m (4 ft) between beams do not reduce the fire endurance.

10.5.2 If the average temperature recorded by all thermocouples located on any one span of the floor or roof units exceeded 593 °C (1100° F) during the classification period, increasing the span of steel floor or roof units beyond that of the tested unrestrained classified assembly can reduce the fire endurance.

10.5.3 A decrease of more than one metal gage thickness of steel roof, floor, or form units can reduce the fire endurance.

10.5.4 A change in design of the joint or composite indentation pattern of a steel roof, floor or form unit can reduce the fire endurance.

10.5.5 A change in profile of steel floor units shall be regulated by the following:

10.5.5.1 A change in profile resulting in a decrease in the total area of contact between the beam and the steel floor or form unit will result in an increase in the temperatures in the top section of the beam. A similar profile change in a test specimen incorporating a directly applied fire resistive coating will result in a decrease in the temperatures in the top section of the beam.

10.5.5.2 A change in profile resulting in an increase in the total area of contact between the beam and the steel floor or form unit does not reduce the fire endurance. A similar profile change in a tested specimen incorporating a directly applied fire resistive coating can reduce the fire endurance.

10.5.6 An increase in metal gage thickness of the steel roof, floor, or form units does not reduce the fire endurance.

11. Principles Pertaining to Fire Endurance of Columns

11.1 *Conditions of Acceptance*—Individual fire endurance classifications for columns are determined in accordance with Test Method E 119 by one of two procedures.

11.1.1 Based on a loaded condition in accordance with the procedure specified under "Tests of Columns" in Test Method E 119 and the conditions of acceptance of that section.

11.1.2 Based on an unloaded condition in accordance with the procedure specified under "Alternative Test of Protection for Structural Steel Columns" in Test Method E 119 and the conditions of acceptance of that section.

11.2 *Reinforced Concrete Columns*:

11.2.1 For reinforced concrete columns (non-prestressed), the following modifications do not reduce the fire endurance provided that: column and conditions and load eccentricities are not changed; that the modification does not result in a ratio of maximum applied load to design load greater than the tested specimen; and the structural design requirements of the column are met.

11.2.1.1 Substitution of carbonate aggregate for siliceous aggregate for either the coarse or the fine aggregate used in concrete;

11.2.1.2 For columns tested with rectangular cross sections, substituting a column of greater cross sectional area provided the minimum dimension of the rectangular column is not decreased;

11.2.1.3 Decrease in nominal maximum size of coarse aggregate within a given aggregate type concrete; and

11.2.1.4 Change in the type of portland cement, flyash or admixtures used in the concrete.

11.2.1.5 For circular sections, increasing the cross sectional area without changing the cross sectional profile;

11.2.1.6 Decrease in concrete unit weight;

11.2.1.7 Change in the compressive strength of the concrete;

11.2.1.8 Increase in the ratio of area of longitudinal reinforcement to concrete cross sectional area; and

11.2.1.9 Substitution of a spirally tied circular section for a tied square section of equal or lesser cross sectional area.

11.2.1.10 Increase in concrete cover to main steel within a range of 47.5 mm (1.9 in.) to 63.5 mm (2.5 in.);

11.3 *Steel Columns*:

11.3.1 The substitution of columns having the same geometric shapes and a greater W/D ratio (ratio of weight to heated perimeter) does not reduce the fire endurance. Conversely, the substitution of steel columns having dissimilar geometric shapes or a lesser W/D ratio can reduce the fire endurance.

12. Principles Pertaining to Fire Endurance of Wall Assemblies

12.1 *Conditions of Acceptance*—Individual fire endurance classifications for walls are determined in accordance with Test Method E 119;

12.1.1 For a bearing wall or partition as based on the conditions of acceptance specified under "Tests of Bearing Walls and Partitions" in Test Method E 119;

12.1.2 For a nonbearing wall or partition as based on the conditions of acceptance specified under "Tests of Nonbearing Walls and Partitions" in Test Method E 119.

12.2 *Load Bearing Walls*—Replacing the load bearing elements with other load bearing elements of the same generic construction materials having greater size (mass per linear length), cross-sectional area or section modulus does not reduce the fire endurance of a wall assembly provided that the modification does not result in a ratio of maximum applied load to design load greater than the tested specimen.

12.3 *Concrete Wall Assemblies*:

12.3.1 For concrete wall assemblies, provided that the structural design requirements are met, the following modifications do not reduce the fire endurance.

12.3.1.1 For monolithic concrete or precast concrete wall panels, substitution of sanded light-weight aggregate concrete or light-weight aggregate concrete for normal weight concrete; also, substitution of carbonate aggregate for siliceous aggregate for either the coarse or the fine aggregate used in the concrete;

12.3.1.2 Decrease in the nominal maximum size of coarse aggregate used;

12.3.1.3 Increase or decrease in the compressive strength of the concrete;

12.3.1.4 Change in the type of portland cement, flyash or admixtures used in the concrete;

12.3.1.5 Increase in the equivalent thickness of the wall within a given aggregate concrete;

12.3.1.6 Increase or decrease in the amount of reinforcement of a given type (pre-stressed or cold-rolled steel)

12.3.1.7 For cavity walls having wythes of unequal thickness, orientation of the wall so that the wythe of greater fire resistance is exposed to the fire;

12.3.1.8 For walls constructed of hollow core concrete slabs, filling of cores with non- combustible insulation material;

12.3.1.9 For ribbed wall panels, decrease in rib spacing;

12.3.1.10 For concrete sandwich wall panels incorporating thermoplastic insulation in thicknesses exceeding 25 m (1 in.) increases or decreases in the thickness of sandwiched insulation Provided that the final thickness is at least 25 m (1 in.);

12.4 *Concrete Masonry Wall Assemblies*:

12.4.1 For concrete masonry wall assemblies, provided that the structural design requirements are met, the following modifications do not reduce the fire endurance.

12.4.1.1 Substitution of light-weight aggregates or sanded light-weight aggregates for normal weight aggregates in the mix design;

12.4.1.2 Increase or decrease in the compressive strength of concrete masonry units, mortar, or grout;

12.4.1.3 Change in the type of portland cement, flyash or admixtures used in the concrete masonry units, mortar or grout;

12.4.1.4 Increase in the equivalent thickness of the wall for the same aggregate type concrete masonry units comprising the wall;

12.4.1.5 Increase or decrease in the amount of reinforcement of a given type (pre-stressed or cold-rolled steel);

12.4.1.6 Changes in the thickness of mortar joints or joint pattern;

12.4.1.7 For cavity walls having wythes of unequal thickness, orientation of the wall so that the wythe of greater fire resistance is exposed to the fire;

12.4.1.8 For walls constructed of hollow masonry units, filling of cores with non- combustible insulation materials;

12.5 *Stud Framed Walls*:

12.5.1 Increase in stud spacing can reduce the fire endurance as a result of impaired membrane stability.

12.5.2 An increase in the depth or material thickness or both of a stud does not reduce the fire endurance.

12.5.3 Closer fastener spacing does not reduce the fire endurance

13. Keywords

13.1 building materials; concrete; fire; fire endurance; fire resistance; steel; wood

APPENDIXES

(Nonmandatory Information)

X1. HARMATHY'S TEN RULES OF FIRE ENDURANCE[5]

X1.1 These ten rules developed by T.Z. Harmathy form the initial basis for the consideration of the extensions of data from fire tests included in this guide. However, there are exceptions to some of these general rules.

X1.1.1 *Rule 1*—The "thermal" fire endurance of a construction consisting of a number of parallel layers is greater than the sum of the "thermal" fire endurance characteristics of the individual layers when exposed separately to fire.

X1.1.2 *Rule 2*—The fire endurance of a construction does not decrease with the addition of further layers.

X1.1.3 *Rule 3*—The fire endurance of constructions containing continuous air gaps or cavities is greater than the fire endurance of similar constructions of the same weight, but containing no air gaps or cavities.

X1.1.4 *Rule 4*—The further an air gap or cavity is located from the exposed surface, the more beneficial is its effect on the fire endurance.

X1.1.5 *Rule 5*—The fire endurance of a construction cannot be increased by increasing the thickness of a completely enclosed air layer.

X1.1.6 *Rule 6*—Layers of materials of low thermal conductivity are better utilized on that side of the construction on which fire is more likely to happen.

X1.1.7 *Rule 7*—The fire endurance of an unsymmetrical construction depends upon the direction of heat flow.

X1.1.8 *Rule 8*—The presence of moisture, if it does not result in explosive spalling, increases fire endurance.

X1.1.9 *Rule 9*—Load-supporting elements, such as beams, girders and joists, yield higher fire endurance when subjected to fire endurance tests as parts of floor, roof or ceiling assemblies than they would when tested separately.

X1.1.10 *Rule 10*—The load-supporting elements (beams, girders, joists, etc.) of a floor, roof or ceiling assembly can be replaced by such other load-supporting elements which, when tested separately, yielded fire endurance not less than that of the assembly.

[5] Harmathy, T. Z., "Ten Rules of Fire Endurance Ratings," Fire Technology, Vol 1, No. 2, May, 1965.

X2. RATIONALE (COMMENTARY)

X2.1 The "fire resistance" requirement is employed in North American building codes to regulate the division of a building into fire compartments by physical barriers (called fire separations) which resist the spread of fire from one compartment to another. It is also employed to regulate building elements which maintain the structural integrity of these fire separations.

X2.2 For many years, building codes have provided for the establishment of fire resistance ratings by subjecting model construction assemblies, representative of the construction to be employed, to a test as presently described by Test Methods E 119. Fire resistance ratings are also developed from information provided in the building codes, using a collection of data concerning generic materials, based upon the performance of these materials in various assemblies when subjected to the requirements of the standard fire endurance test.

X2.3 It has also become the practice to assess the theoretical fire performance of construction assemblies from reasoning based on data obtained from the standard fire endurance test. Such assessment has thus far been confined to assemblies obtained by substituting elements having a different form, mass or dimension. It has entailed an engineering evaluation of the effect of substitution on the results of the fire test.

X2.4 This guide covers various aspects of the design of structures for fire resistance. The purpose of this guide is to elaborate upon the principles involved in the extension of data obtained from fire resistance tests and to enable a potential user to correctly identify whether a proposed design modification will result in a higher, lower, or similar fire endurance compared to that of the original assembly tested.

X2.5 Other documents should be developed or referred to which address procedures for quantified interpolation and extrapolation of data obtained from standard fire resistance tests and procedures for theoretical design of structures for fire resistance based on material properties.

X2.6 This guide was derived from a publication of the Underwriters Laboratories of Canada[6].

X2.7 ISO TC92/SC2/WG2 has prepared the ISO/TR 12470 Fire Resistance Tests - Guidance on the Application and Extension of Results.[7]

[6] Underwriters Laboratories of Canada, *Criteria for Use in Extension of Data from Fire Endurance Tests*, ULC Subject C263 (e) –M1988, 1998.

[7] ISO, International Organization for Standization, Geneva.