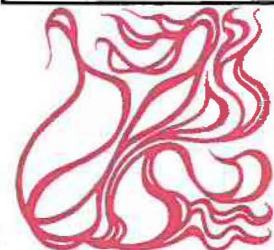


# fire protection planning report



BUILDING CONSTRUCTION INFORMATION FROM THE CONCRETE AND MASONRY INDUSTRIES

NO. 3 OF A SERIES

## Significance of Fire Ratings for Building Construction



The use of fire-resistive floors, roof, walls, beams, and columns will tend to minimize the losses due to fire damage.

### Introduction

Destruction resulting from uncontrolled fires was the primary reason for adopting the first building codes. Because building fires are a major hazard to life and property, building codes require that resistance to fire be considered in building design. Codes provide the means by which structural fire resistance is integrated into the design and construction of buildings.

It is generally presumed that building components will perform satisfactorily for as long as their designated fire ratings indicate under actual fire conditions. However, this is not necessarily true.

How are fire ratings determined? Standard laboratory tests have been developed to provide a means for evaluating the performance of building materials and structural assemblies under fire exposure. Based on the findings from these tests, the fire endurance of the various structural components that make up a building are determined. Beams, columns, floors, roof decks, and wall systems are classified as having fire endurance of

one, two, three, or four hours, or fractions thereof. This provides a comparison between different constructions, but does not necessarily mean that they will perform the same in an actual fire.

Building codes employ this system of hourly fire ratings to specify the minimum requirements for the numerous elements of building construction. The required ratings are dependent upon the intended occupancy, type of construction element, and building size that combine to provide safety factors against potential fire hazards.

Fire-test standards thus form the basis for testing building materials and assemblies in order to determine if they conform to the structural protection requirements for safeguarding lives and property from fire. In order to understand and evaluate the present North American fire-test methods and test results, some important factors should be considered. This publication will review these factors and suggest some of the additional information that is needed for a more complete evaluation.

## Standard Tests

The fire-resistive property of an assembly of building components is determined in compliance with the test methods of the American Society for Testing and Materials known as ASTM E119, Standard Methods of Fire Tests of Building Construction and Materials. Other standards, essentially alike, include the National Fire Protection Association, Standard Method No. 251; Underwriters Laboratories, UL 263; American National Standards Institute, No. A2-1; and Underwriters Laboratories of Canada, ULC—S101.

## ASTM E119

ASTM E119 is a standard for firetesting such construction assemblies as walls, floors, roofs, beams, and columns. The standard provides a common and uniform test method for the comparison of performance of assemblies for specific construction uses.

The standard fire test is based on exposing the test specimen to a fire having a standard relationship between duration and temperature. This relationship is known as the time-temperature curve. The concept was first introduced in the 1918 edition of ASTM Methods of Tests of Material and Construction. At that time 12 curves were plotted indicating all the known temperature schedules in use. The present time-temperature curve was developed from those curves. No major change has taken place in the curve since its adoption in 1918.

The standard time-temperature fire curve represents combustion of about 10 lb of wood (with a heat potential of 8,000 Btu per pound) per square foot of exposure area per hour of test. The actual amount of fuel consumed during a fire test is also

dependent on the furnace design and on the heat capacity of the test assembly.

A standard fire test is conducted by placing the assembly in a test furnace. Floor and roof specimens are exposed to fire from beneath, beams from the bottom and sides, walls from one side, and columns from all sides. The temperature is raised in the furnace over a given period of time in accordance with the ASTM E119 curve shown.

This specified time-temperature relationship provides for a furnace temperature of 1,000°F at five minutes of the test, 1,300°F at 10 minutes, 1,700°F at one hour, and 2,000°F at four hours.

The end point of the test is reached and the fire endurance of the specimen is established when any one of the following occurs:

1. The test assembly structurally fails to sustain the applied loads and physically collapses.
2. Cotton waste placed on the unexposed side of a floor or roof system is ignited through cracks or fissures in the specimen.
3. The temperature of the unexposed surface rises an average of 250°F above its initial temperature or 325°F at any location. In addition, walls must sustain a hose stream test.

In 1970, additional criteria on steel temperatures were added.

Though the complete requirements of E119 and the conditions of acceptance are much too detailed for inclusion in this publication, acceptance criteria for various assemblies are summarized graphically in Table 1.

Design professionals, builders, and building and fire officials recognize the fire-resistance ratings given to building assemblies based on these fire-test criteria.

Although two different assemblies may have the same fire ratings, their performance in a real fire situation can be different. The following considerations will help to explain why this is so.

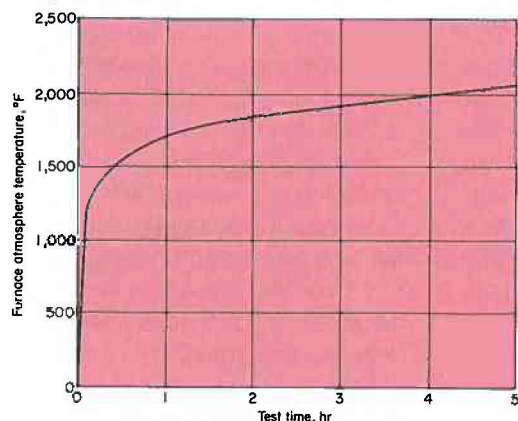
## Separating End-Point Criteria

Some fire-test standards, for example International Standard 834 of the International Organization for Standardization, permit separation of end-point criteria based on three principal conditions of acceptance:

1. Flame or gas passage
2. Heat transmission
3. Load-carrying capacity

Each of these criteria is given equal weight in North America. The first end point reached terminates the test. The fire endurance of the assembly is established from this single result regardless of how long it would take to reach the other end points. The first two criteria relate to the function of

ASTM E119 standard time-temperature curve under which tests are conducted. The curve provides for an exposing fire of controlled extent and severity to be applied to the test specimen.

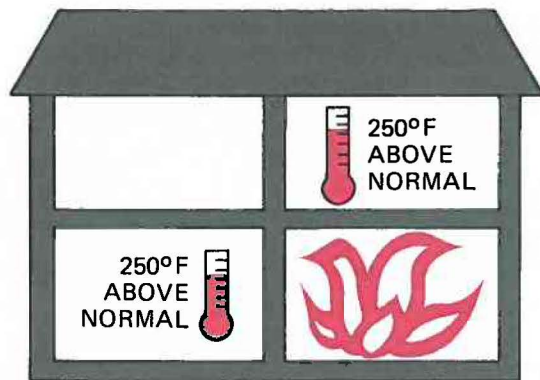


**Table 1. Acceptance Criteria**

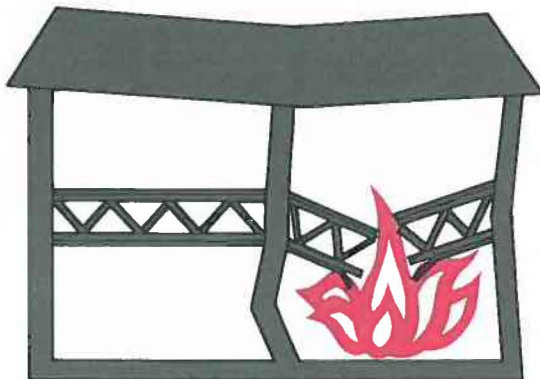
|                  | Sustained load | Flame passage | Hose stream | Reinforcing steel temperature | Heat transmission |
|------------------|----------------|---------------|-------------|-------------------------------|-------------------|
| Floors and Roofs |                |               |             |                               |                   |
| a. Restrained    | •              | •             |             |                               | •                 |
| b. Unrestrained  | •              | •             |             | •                             | •                 |
| Walls            |                |               |             |                               |                   |
| a. Bearing       | •              | •             | •           |                               | •                 |
| b. Nonbearing    |                | •             | •           |                               | •                 |
| Columns          | •              |               |             |                               |                   |
| Beams            |                |               |             |                               |                   |
| a. Restrained    | •              |               |             | •*                            |                   |
| b. Unrestrained  | •              |               |             | •                             |                   |

\* Beams spaced more than 4 ft on centers.

A test can be regarded as successful if the conditions shown above are met. See ASTM E119 for details.



### Heat Transmission versus Load-Carrying Capacity



The collapse of a building is more serious than heat transmission through walls or roofs and the two should be considered separately.

providing a barrier against spread of fire or transmission of excessive heat through the assembly while the third criterion relates to the structural integrity of the assembly to resist fire exposure.



This hotel being constructed of concrete will provide firesafety for guests. The load-carrying capacity of floors and walls is much more than fire rating indicates. Tests of concrete or masonry walls and floors usually terminate because of heat transmission. From firesafety standpoint it is unreasonable to apply same rating to two assemblies when one has collapsed and the other has only failed the heat-transmission criterion.

Failure to meet the heat transmission criterion means that the average temperature on the unexposed side of the assembly has risen only 250°F, a lower heat than is often used for cooking food. Most building construction materials and building contents will not burn at this temperature.

Fire ratings achieved by concrete and masonry assemblies are practically always based on the heat-transmission end point. This means that the structural integrity of the building is maintained during the test well beyond the time indicated by the fire rating. In an actual fire, maintenance of structural integrity affords safety and protection to fire-fighting personnel and equipment. Frequently the concrete and masonry suffer little more than superficial damage in a fire and can readily be restored to use.

Reporting the time required to reach the temperature end point and continuing the test beyond



Masonry walls are ideal for apartment construction. They provide a barrier against the spread of fire while maintaining structural integrity.

that point would make possible the establishment of different, more realistic code requirements based on the need for structural integrity or the control of the spread of a fire.

Codes could maintain high ratings for structural integrity while modifying or waiving the heat-transmission end-point requirement. The 1976 Wisconsin Administrative Code modifies the criterion in *Ind 52.042* with the following general requirements:

(5) The heat transmission requirements of ASTM E119 (25b), with the exception of high hazard areas, penal and health care facilities, and warehouses for combustible materials, may be reduced to one-half of the hourly rating required by this code, but not less than one hour.

(a) The fire-resistive rating for structural integrity required by this code shall be maintained where the heat transmission criteria has been reduced.

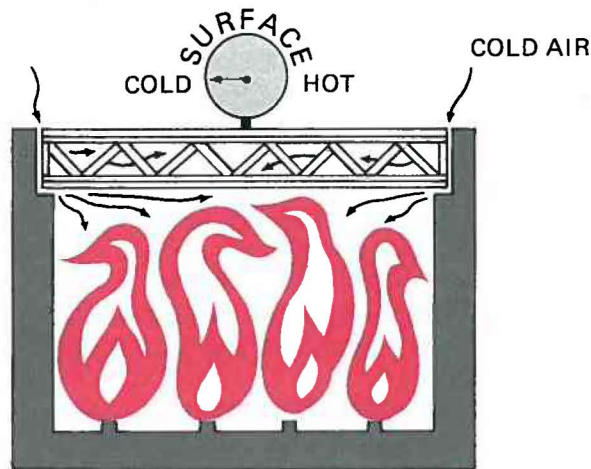
### Effect of Pressure in Fire Test Furnace

The E119 standard does not specify negative or positive furnace pressures, but almost all tests in North America are conducted with negative pressures. One obvious reason for this is to prevent the flow of hazardous fumes and smoke into the laboratory by forcing such emissions out the exhaust flue. In Europe the furnaces are required to operate with positive pressures and adequate safety devices. In actual building fires, positive pressures are developed by gas movements and heat. Positive pressures in the order of 0.5 psf have been observed. Considering all conditions of fire propagation, pressures in a building or compartment can be quite variable, but will be positive in the immediate vicinity of the fire.

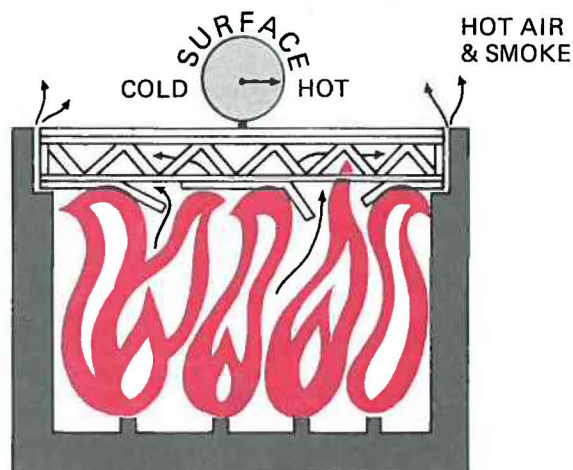
An important factor in the use of negative furnace pressure during a fire test is the tendency for cool air from the laboratory to leak into the furnace through cracks or other openings in the furnace or specimen.

- Floor-ceiling assemblies are examples of types of construction whose ratings could be affected by leakage during furnace tests. If cool air is drawn through the specimen it will result in lower plenum temperatures and higher fire-resistance ratings than would occur without leakage.

- Also, materials that shrink in fires provide openings for air to cool framing materials during the test.



**Negative Furnace Pressures**



**Positive Furnace Pressures**

Negative furnace pressure allows cool air from the laboratory to be drawn into the furnace. This will result in lower specimen temperatures than temperatures that occur under realistic positive pressure.

- Drop-in ceilings are held in place during fire tests by negative pressure, thus giving extra protection that would not exist in an actual fire.
- Studies indicate that the fire-resistance rating obtained by tests conducted with negative furnace pressures may be a poor measure of actual performance in a building. Positive pressure is a more accurate duplication of real fire conditions.

North American fire experts support the maintenance of positive pressure in fire testing as is done in Europe. The International Organization for Standardization requires positive pressure in test furnaces.

When establishing required fire-resistance ratings for building assemblies, code officials should recognize the effect of negative test pressures on the results indicated by the standard North American fire test.

### Fuel Consumed

The furnace temperature is controlled by the standard time-temperature curve. As a result, the amount of fuel required by the exposing fire may depend on the properties of the test specimen. If the specimen itself burns, it contributes to the furnace temperature and reduces the amount of fuel needed to hold the desired time-temperature curve. In a real fire situation, a combustible assembly adds to the fuel load and, therefore, to the intensity of the fire.

If the specimen absorbs heat from the furnace fire as is the case with concrete and masonry, a more intense exposing fire is needed to maintain the required furnace temperature in contrast with a combustible specimen that contributes fuel to the furnace fire.

The amount of fuel consumed during a fire test is a good measure of the actual fire endurance of an assembly. An exposed concrete floor speci-

men is likely to use 10% to 20% more fuel than that used during a test of the same floor with an insulated ceiling protection membrane and considerably more fuel than that used for testing a combustible assembly. This fact is not recognized when assigning or specifying fire-resistance ratings. It should be. The more fuel input it takes to complete a fire test, the more fire endurance a structural assembly has. Since different assemblies require different amounts of fuel to maintain the required time-temperature relationship, standard fire tests expose different specimens to varying energy inputs. Thus, when comparing different assemblies, it would be informative to consider the amount of fuel used in each test and that data should be reported.

### Rational Design

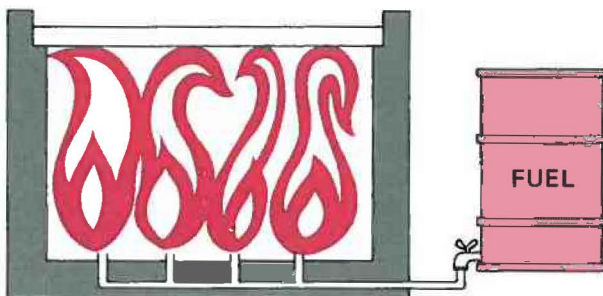
Throughout the history of fire testing, tests on walls, floors, columns, and roofs have demonstrated that concrete and masonry are highly fire-resistant materials. Much information has been developed from these tests about the factors that determine the fire resistance of concrete and masonry assemblies.

In addition, a great deal of research has been conducted on the behavior of concrete structures during fire exposure. Due to the research information and the analytical procedures available, it is now possible to calculate with reasonable accuracy the structural fire endurance of concrete components of a building without laboratory fire-testing. The procedure, known as the rational design or analysis method, eliminates or reduces the need for costly fire tests, and considers the effects on fire endurance of a large number of variables.

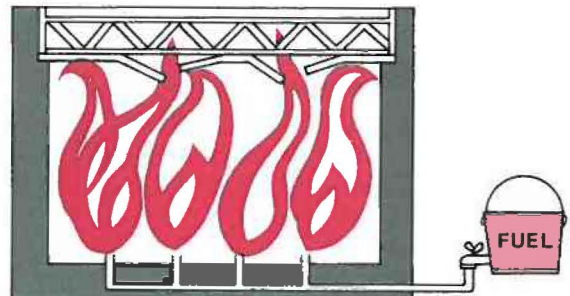
The rational design method is becoming an accepted means of designing for fire protection.

An illustration of the amount of fuel consumed during a fire test. The more fuel it takes, the more severe the fire exposure and the more fire endurance a structural assembly has.

#### Concrete or Masonry Specimen



#### Combustible Materials Specimen



## Conclusions

When evaluating the significance of fire ratings it is important to consider how a specific building assembly might behave if an actual fire were to occur. Users of fire-test reports and fire ratings should be aware that limitations in testing procedures affect their applicability.

Fire ratings do not tell the whole story. Building designers and building officials should—

Take into account any data gathered beyond the initial end point and evaluate whether, from a firesafety standpoint, it is logical to apply the same rating to two assemblies, one of which has collapsed while the other failed only the heat-transmission criterion in the same period of time.

Make allowances for the fact that standard fire tests conducted under negative pressure result in higher fire ratings for some assemblies than would be achieved under positive pressure. Consider this when comparing the fire ratings of various assemblies.

Consider the amount of fuel used in the test and make this a factor in evaluating fire resistance and endurance of various assemblies.

Use rational analytical procedures in determining fire endurance of concrete and masonry components, particularly when precise listings of ratings are not readily available. This eliminates the need for firetesting those components. Rational design is a major step forward in designing for fire protection.

## References

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## Organizations represented on the CONCRETE AND MASONRY INDUSTRY FIRESAFETY COMMITTEE

|        |                                           |
|--------|-------------------------------------------|
| BIA    | Brick Institute of America                |
| CRSI   | Concrete Reinforcing Steel Institute      |
| ESC&SI | Expanded Shale Clay and Slate Institute   |
| NCMA   | National Concrete Masonry Association     |
| NRMCA  | National Ready Mixed Concrete Association |
| PCA    | Portland Cement Association               |
| PCI    | Prestressed Concrete Institute            |

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