



Protecting the Foundation of Fire-safety

by Robert Berhinig, P.E.

The attack on the World Trade Center (WTC) in New York City has raised concerns among Americans regarding the fire safety of high-rise structures. Until September 11, 2001, few people envisioned the total collapse of a high-rise building except under controlled conditions such as an implosion for demolition purposes. Today, the public's concerns are heightened.

To reduce these concerns, we must first realize that the September 11 attack on the WTC was an extreme act of terrorism. We must also realize that fires in high-rise structures are not unexpected events. Fire testing procedures are in place to determine a building assembly's ability to resist structural collapse when exposed to fire. Structures that consist of fire-resistive building assemblies have functioned well under severe fire conditions. In fact, the Federal Emergency Management Agency (FEMA) report, *World Trade Center Building Performance Study*, states the collapse of these structures is particularly significant in that, prior to these events, no protected steel-frame structure, the most common form of large commercial construction in the United States, had ever experienced a fire-induced collapse. The overall performance of structures during fires is a credit to the entire fire-protection community, which includes product designers, architects, testing organizations, code bodies, inspection agencies and the fire services. Underwriters Laboratories Inc. (UL), a member of the fire-protection community, is confident of the role fire test data plays in providing for fire-safe structures.

How are fire-testing methods used?

The nationally recognized standard used to conduct tests in the United States is the American Society for Testing and Materials standard for *Fire Tests of Building Constructions*, also known as ASTM E119. It is used to generate data to measure the integrity of building assemblies subjected to fire exposure. The first edition of this standard was published in 1918, with the most recent edition published in 2000. Throughout the world, similar fire test methods are published by international organizations such as the International Organization for Standardization (ISO). These basic fire test standards are the foundation for many other test methods that focus upon fire containment within building structures. Technical committees with membership

extending throughout the global fire-protection community develop these test standards, which are consistently reviewed and updated as technology changes. The fire-protection-testing method may appear to have remained unchanged for decades, but the quantity and the accuracy of the data obtained during the tests have advanced greatly. It is important to keep in mind that the testing chamber that is used in the fire test is only a tool—it is used to determine that a fire will be contained by fire-resistance building assemblies within a laboratory environment.

Several published stories have questioned the reliability of the ASTM E119 fire test standard in light of the WTC terrorist attacks. It is implied that because the standard was originally developed 80 years ago and because relatively "low-tech" equipment such as kiln-type furnaces is used for the test, the resulting data may be inadequate. UL, having a 108-year history of fire testing, does not support this conclusion.

At the heart of this debate is the time-temperature curve that controls the temperature conditions within the test chamber. The time-temperature curve is intended to represent an intense, fully developed fire within a building. Does the time-temperature curve perfectly represent every fully developed fire in every location? Probably not. The actual heat and temperature conditions generated from a fire in a particular location is dependent upon many variables such as building contents, materials of construction and ventilation conditions.

The value of the time-temperature curve in ASTM E119 is its reproducibility and its relationship to the



Photo 1. Workers construct sample building assemblies before testing can begin.

previously referenced variables. This standardization enables the building code community to specify a minimum fire-resistive rating for the performance of these building assemblies.

In recent years, some fire conditions have been identified as sufficiently different from those represented by the time-temperature curve in ASTM E119, thus meriting an additional time-temperature curve. As a result, several fire test standards, including UL 1709, *Rapid Rise Fire Tests of Protection Materials for Structural Steel*, specify fire test-chamber temperatures that rise at a quicker rate than those specified in ASTM E119. The time-temperature curve in UL 1709 represents the conditions associated with burning pools of hydrocarbon fuels. At the other end of the spectrum, discussions have cited the need for a time-temperature curve that has a slower rate of rise than specified in ASTM E119.

The ASTM fire test standard is a living document that undergoes constant review by the ASTM technical committee responsible for its content. Discussions regarding the merits of the ASTM standard among fire science professionals are similar to the discussions among professionals in other sciences on topics in their specialized field. It is telling to note that in the FEMA report, an observation on the condition of the structural steel in WTC 5 states that, the structural damage due to the fires closely resembles that commonly observed in test assemblies exposed to the ASTM E119 Standard Fire Test.

Are buildings safe from fire today?

This is an appropriate question to raise as a result of the collapse of the buildings at the WTC site. The FEMA

report has taken the initial step in focusing upon opportunities to enhance high-rise building safety. Items cited in the report include:

- the durability of materials used in passive fire-protection systems,
- the lack of data on the performance of structural connections when exposed to fire, and

- a need for additional data describing the physical characteristics of materials used in passive fire-protection systems. These material characteristics are required for a broad temperature range.

The FEMA report further states that until the attack at the WTC, no protected steel-frame buildings had been known to collapse as a result of a fire. The key word is “protected.” In Chicago, Illinois, the McCormick Place Exhibition Center collapsed as a result of a fire in 1967. In this structure, the steel-frame of the building was unprotected. The reference to McCormick Place is significant because it illustrates the fact that steel-frame buildings can collapse as a result of exposure to fire. This is true for all types of construction materials, not only steel.

Since fires do occur in high-rise buildings, building codes typically require a combination of both active systems (smoke alarms and sprinklers) and passive systems (building assemblies with hourly fire endurance ratings) as a means to protect public buildings. The construction of the WTC and all typical high-rise buildings is based upon requirements in the applicable building codes. The WTC was exposed to conditions far beyond the scope of the building codes. Yet, at the WTC, the FEMA report states that almost everyone below the points of impact was able to safely evacuate the buildings. More than 30,000 people evacuated the WTC.



Photo 2. A glass wall assembly being subjected to 2000 degrees of heat.

Can buildings be safer in the future?

As with any engineering challenge, the resulting solution depends heavily upon the assumptions made during the evaluation process. With respect to the WTC, does one assume the fire origin will be the result of careless housekeeping or the deliberate impact of a highly combustible object such as an airplane? Each scenario requires a different fire protection solution.

The FEMA report focuses upon three passive fire-protection items where action is recommended:

- Develop additional data on the fire resistance of structural connections.
- Improve the durability of fire-resistance materials.
- Develop data describing the characteristics of materials used in passive fire-protection systems.

The fire-resistance of structural connections is not within the current scope of ASTM E119. This does not mean that data on the fire resistance of structural connections could not be obtained using existing test equipment.

With respect to the durability of fire-resistive materials, the ASTM E119 standard test method assumes that the systems tested are located within environmentally controlled areas of a building. By contrast, for more than 20 years, UL has certified fire-resistive materials intended for exterior use. Before a fire test, samples of

the materials intended for exterior applications are subjected to various exposures, which include accelerated aging, wet-freeze-dry cycling, high humidity, salt spray and ultraviolet light. The samples are 6 x 6 x 2 long steel columns.

Furthermore, all intumescent-type materials certified by UL for use in fire-resistive assemblies have been subjected to adverse conditions to measure their durability. These conditions include exposure to accelerated aging and high humidity. These durability tests on intumescent materials are conducted to evaluate the ability of these products to perform as intended after being exposed to harsh environmental conditions.

Similar types of requirements can be developed for all types of fire-resistive materials for which a higher degree of durability is desired. Another consideration could be the expanded use of a hose stream test that is part of the ASTM E119 standard. The hose stream test subjects fire-resistive assemblies to impact and erosion effects. An alternate method of applying the hose stream test, or establishing new acceptance criteria intended for highly durable materials, might be a desirable approach to enhance the level of safety for these products and systems.

As in almost all fields, the growth of computer-related applications have been enormous since the WTC

was constructed. The application of computer models in fire-protection engineering is an example of this growth. Today, computer models are available that will predict temperatures of building materials, such as structural steel, during a fire. Computer models that will predict the per-



Photo 3. UL fire science engineers evaluate a glass wall.

formance of multistory structures under varying temperature conditions are also available. These computer programs are available to the fire-protection engineering community. However the input data required for these programs to function is not readily available for most fire-resistive materials.

As stated in the FEMA report, standardized test methods are needed for fire-resistive materials to determine their physical characteristics such as density, conductivity and specific heat for temperature ranging from 70°F to 2,000°F. The material properties are known for common construction materials such as concrete and steel but not for most proprietary materials. In addition to the need for material properties, the results from computer models require validation. Today's computer models cannot predict the physical performance of fire-resistive materials. This includes items such as the adhesion of coatings to structural steel, the securement of gypsum board and the performance of an acoustical ceiling system with respect to the acoustical panels remaining within the steel suspension system.

Data from ASTM E119 fire tests provide this type of physical performance information. Data from ASTM E119 tests may also be used to validate the accuracy of the computer models for the material properties and fire conditions provided as input to the model. This can be accomplished only because of the reproducibility of the ASTM E119 fire test-chamber conditions.

Summary

High-rise buildings perform very well under fire conditions. The total fire safety package, including active fire-protection systems in combination with passive fire-protection systems and structural design, provides the designed level of safety and performance. The terrorist attack on the WTC is an event that building codes do not consider.

The ASTM E119 fire test method provides a com-

parative benchmark to measure the fire resistance of building assemblies. The fire test-chamber conditions specified by the ASTM E119 test are representative of a fully developed fire within most buildings. This fire condition does not and cannot replicate every fire situation. The hourly fire-resistive ratings

based on an ASTM E119 test do not mean that a specific structure will remain intact for the indicated rating period.

The ratings are benchmarks, with a three-hour fire resistance assembly having a greater endurance than a two-hour rated assembly. Building codes specify the rating duration to obtain the desired level of fire safety.

The application of computer models is expanding greatly within the fire-protection and structural engineering community like all other scientific and engineering disciplines. However, computer models need extensive validation and, for the fire-endurance performance of building assemblies, the ASTM E119 test method is a tool that can be used to provide for computer model validation.

The performance of the WTC has highlighted several focused areas for additional fire research:

- Develop additional data on the fire-resistance of structural connections.
- Improve the durability of fire-resistance materials.
- Develop data describing characteristics of materials used in passive fire-protection systems.

Tens of thousands of lives were saved because the buildings stood as long as they did. We will learn lessons from the WTC that will lead us to improve the fire safety and the structural performance of buildings. However, the fire performance baseline for structures cannot be to survive without damage from any possible attack. For that to occur, unlimited resources would be required and building designers would have to know the unknowable—the magnitude of the next terrorist attack. ✎



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