Building Perimeter Fire Protection

By James C. Shriver
Director, Technical Services
Thermafiber, Inc.
Member FCIA

It was 11 P.M. on Saturday night, February 12, 2005, when an electrical fault on the 21st floor of the Windsor building in Madrid started a small fire. The building was unoccupied and the fire was undetected for quite some time before the city's fire officials were notified. By the time they arrived, the magnificent 32-story structure was essentially lost. All that firefighters could do was to try for the next 18 hours to keep the fire from spreading to adjacent structures.

There was no impact from a jumbo jetliner, and this fire lacked the thousands of gallons of jet fuel that so readily accelerated the World Trade Center fires. It was just a little electrical problem, so how could this fire, spread so uncontrollably that it consumed eleven higher floors and turned the fourth largest structure in Spain's capitol to rubble?

Perhaps a better question is how has the world been so lucky to avoid so many other potential disasters in buildings where the perimeter of the structure is not adequately designed to contain fires to the area of origin? In fact, we haven't avoided all of them:

- On November 21, 1980, fire ripped through the MGM Grand Hotel in Las Vegas. 679 people were injured and 84 died in the fire. Openings in vertical shafts and seismic joints acted as chimneys, spreading smoke and heat all the way through the 26th floor. Guests found out about the fire by actually seeing smoke or because others told them. The hotel's alarm system was destroyed before fire alarms could activate.
- In the late evening of May 4, 1988, a fire broke out on the 9th floor of the 1st Interstate Bank Building in Los Angeles. A shrill coming from a smoke detector caused an employee to try to reset it. By then, nearly 15 minutes had passed before the blaze was reported to the fire department. By the time firefighters arrived, the fire had leapfrogged to the 13th floor and the 14th was being threatened; smoke was filling all 62 floors of the building. A maintenance employee who was investigating the source of the fire died in an elevator at the fire floor. Fire officials reported that the flames had spread up inside the exterior walls, where glass fiber insulation had failed.
- On October 16, 2004, the Parque Central complex in downtown Caracas, Venezuela, saw flames engulfing its 56-story office tower. What started on the 34th floor had spread over 26 floors during the 17-hour blaze. It was reported that although sprinklers were working, there was not enough pressure to suppress the flames on the higher floors. The building was unoccupied at the time of the fire.
- On December 6, 2004, fire raked the 29th floor of the LaSalle Bank Building in downtown Chicago. Fortunately, this historic 75-year old concrete and steel structure was able to contain the fire, and firefighters on an adjacent rooftop were

able to reach much of it with their hose stream. Over the six hours of the fire, the flames had only engaged the 29th and 30th floors. Just one year before, a fire on the 12th floor of the Cook County Administration Building killed six people.

A part of what we have learned from these fires is that the construction systems we specify today have an important role to play in the safety of buildings and their occupants many years from now, and the perimeter of these buildings needs to be the center of our focus.

A Little History

Following the Chicago fire in 1871, architects in that community included non-combustibles such as steel and concrete as the key structural elements in their designs. As they became more adept at using these materials, architects also discovered that they could safely build taller structures. In the 20th century, they found that buildings could be even taller and offer greater eye appeal if weight could be eliminated from the exterior walls. Thus lightweight aluminum curtain wall systems were developed.

It wasn't until the 1970s that concerns focused on the spread of fire at building perimeters. Engineers at the United States Gypsum Company[1] observed that there are three ways for fire to spread from seemingly contained areas:

- Poke through effect – this is where flame and hot gasses penetrate through openings in fire-rated walls and floor/ceilings to ignite combustibles on the other side.
- Chimney effect – is where heated surfaces create thermal zones that include upward air movement, which in turn sucks hot gasses and flames in its direction. This effect is attributed to the spread of fire upward through shafts, and also the spread of fire upward through available openings between the floor slab edge and the curtain wall.
- Leapfrog effect – this effect is apparent in mid- to high-rise building fires where flames blasting out through perimeter windows ultimately reach back in through the windows above and continue to spread vertically to upper floors.

To combat these three identified ways of fire propagation, USG/Thermafiber designed systems to block these passages. The first test of such a system, in 1971, was terminated after 70 minutes, proving that mineral wool could protect an aluminum spandrel panel[2]. Without such a system, under the same conditions, fire would have melted the aluminum panel and the leapfrog effect would take place, breaching the vision glass on the floor above in just a few minutes.

Another test in 1972 proved that mineral wool safing insulation could keep fire from penetrating the area between the floor slab edge and the curtain wall spandrel panel for more than 3 hours[3]. Similar testing with foam and fiberglass showed how quickly those materials would disintegrate. Smoke from the foam was so intense that the test had to be terminated.

During the 1980s, the pioneering phases of multi-story systems were tested. The systems included aluminum curtain wall components with glass, granite, aluminum and glass fiber reinforced concrete (GFRC) spandrel panels. In all cases, the mineral wool curtain wall and safing insulations demonstrated their ability to protect all of these construction components. By the time the decade ended, we also had demonstrated the importance of 1) mineral wool vs. other insulating materials, 2) good mechanical attachments for the mineral wool curtain wall and safing insulation, 3) a backer bar to secure the insulation at the floor slab, 4) compression fitting the safing insulation, 5) protective covers for mullions, and 6) an effective smoke barrier at all connection points.

In the 90s, testing continued, including UL witnessed tests. ASTM began writing a test standard for determining the fire resistance of perimeter fire barrier systems using the intermediate multi-story test apparatus (ASTM E 2307). Multi-story testing has shown that spandrel height has an impact on the leapfrog effect, and can critically enhance the structure's ability to contain a fire to the room of origin. Testing in a controlled environment, using a simulated office setting complete with office furniture, proved the point. In a system without an insulated spandrel panel between the two levels of vision glass, even with safing insulation securely in place between the floor slab and the curtain wall, the fire not only broke through the lower level vision glass, but spread to the floor above in just five minutes. By the time the decade was over, both UL and OPL were testing and listing complete curtain wall systems. Today, ASTM E 2307 (multi-story apparatus) is the test method used by both listing agencies.

We are half way through the decade and significant progress already has been made. We knew from earlier experience that concrete balcony protrusions were instrumental in stopping the leapfrog effect and the spread of fire to floors above the area of origin. More recent tests demonstrate that safing insulation and insulated curtain wall spandrel panels can do the same.

With a 42" mineral-wool insulated spandrel panel, 6" above the top of the slab to 36" below, the fire test lasted 20 minutes. With a 60" spandrel panel, 24" above the top of the slab and 36" below, the test lasted 1-1/2 hours. With a 69" spandrel panel, 33" above the top of the slab and 36" below, the test lasted 2 hours. It is clear that the difference in mineral-wool insulated spandrel height significantly alters the temperature to which the vision glass on the upper floor is subjected, thus the amount of leapfrog protection it provides. It also significantly changes the prospect that firefighters will be able to move above the fire to fight it.

Other Advances to Help Protect Life and Property

During this same 30-year time frame, other advances also were taking place. Smoke detectors were developed to alert building occupants of the danger of fire. Eventually these detection and alert systems also would incorporate emergency lighting to help guide people out of burning buildings, and some alert systems also would be connected to fire stations to reduce emergency response time.

Also active systems, including Halon and other gas products but concentrating especially on water sprinkler systems, were dramatically improved both in terms of performance and reliability. In addition, materials such as vision glass, doors, and other construction products were improved and their ability to withstand fire for a greater period of time has been enhanced.

The Balanced Approach

Improvement in construction materials technology and the advancement of sprinkler systems has resulted in the advocacy of an active sprinkler system *in place of* containment systems such as curtain wall and safing insulation designs. While this alternative can be quickly embraced by those who want to reduce overall construction costs and eliminate apparent redundancy, it also raises questions. What happens if something goes wrong?

No individual life safety system assures performance without failure. But at least protecting the high-rise or mid-rise structure with mineral wool perimeter containment systems offers multiple lines of defense.

Producers of construction materials such as high-heat-resistant vision glass should be applauded for their technological advances. But adding an hour of heat resistance does little to halt a fire that takes firefighters many hours to extinguish.

Active sprinkler systems do a great job of suppressing fires, unless for some reason they don't work as planned. Reports of sprinkler system reliability vary. Reviews show failure rates between 7 and 17%.[4]

Regardless of the reliability projections, the prospect for less-than-optimum sprinkler system performance in a structure without containment systems in place leaves the potential for disaster. Clearly, the best construction design will call for a balance of active sprinkler systems, insulated containment systems and up-to-date detection systems that will alert both building occupants and first responders.

Code Specifications

While ICC-IBC codes address fire containment, they are focused on interior propagation of fire. The code specification requires that the floor slab rating be maintained, but does not address the need for sufficient curtain wall height and curtain wall barrier protection to assure that flames cannot leapfrog to ascending floors. The IBC 2006 code includes a provision that perimeter fire protection be installed as tested in accordance with ASTM E 2307. Language for NFPA 5000 is much the same.

Further, it should be noted that while current code calls for the proper installation of approved materials or systems, it leaves a lot of room for variation and can often lead to improper installation. The disastrous result can be inadequate perimeter protection. In any case, education and further code development can only help to assure better protection for the building and its occupants.

A Case for Better Building Specifications

Over the 30+ years of improved fire protection technology, one thing has become apparent. It is not good enough to simply specify the generic materials to be used in protective assemblies.

Failures in perimeter fire protection assemblies occur for a variety of reasons, including the selection of inappropriate materials (substituting glass fiber insulation in assemblies that call for mineral wool, or using joint compound instead of an approved smoke sealant, for example). More often, however, the failure is a result of installation that does not meet the criteria established for the tested and approved assembly.

There are five design elements that simply must be implemented for curtain wall insulation systems to perform as expected. If these areas of design are not properly addressed and handled, failure can result. Those design element areas are:

- Mechanical attachment of the mineral wool curtain wall insulation. This insulation must be mechanically attached, using appropriate fasteners.
- Mullion protection. The mullions for curtain walls are structural components and are typically made of aluminum. Tests show that aluminum mullions can melt in as little as 9 minutes into the fire. These must be protected with mineral wool insulation covers, mechanically attached to mullions.
- Compression-fit safing insulation. Fires produce tremendous air and structural movement that can dislodge safing insulation if not correctly installed. This material must be compression fit and installed as required per the tested assembly.
- Backing reinforcement at the safing line. Whether this is a specially constructed T-shaped bar or simply a light steel framing member, some kind of backing is required to assure that compression of the safing insulation is constantly maintained.
- Smoke containment. Smoke is a bigger killer than fire, so providing a smoke barrier is essential. A smoke sealant must be applied over the safing and all abutments between the safing insulation and adjacent components.

The biggest contribution specifiers can make to life safety is to be detailed enough in the specification and design drawings for perimeter fire protection to include both components and installation details.

In the past, it might have been difficult for specification writers to come up with completely integrated systems, but that is not true today. Both UL and OPL now publish fire resistance directories and both directories contain curtain wall perimeter fire protection systems. In fact, these two directories combined provide more than 275 tested assemblies to choose from.

What's more, some manufacturers have now settled on a few systems where they are able to provide virtually all of the necessary components, and provide detailed installation instructions to boot. These systems are readily available in either static or dynamic designs.

Conclusion

We have come a long way over the last 30-40 years to detect, contain and control fires at the perimeters of mid- and high-rise buildings. At the same time, however, we recognize that none of the systems we put in place are completely free of the risk of failure. We anticipate that the fire safety systems we incorporate in our building designs will function properly when they are required. We also hope that they will never be required.

Specifiers have a unique role to play in the implementation of these systems, and a special responsibility. The specifications written for these systems must be as specific as possible to assure the performance of these systems when they are required.

The detailed specifications that guide the construction, installation and inspection of perimeter fire protection systems today might not be put to the test by a raging fire during the lifetime of the specifier, the contractor who installed the system or the authority having jurisdiction. But those specifications could well be the instrument that saves the lives of building occupants and first responders in the event of fire.

# # #

Thermafiber Mineral Wool Insulation is manufactured in a variety of formulations to meet specific fire protection and sound control needs. In addition to the Thermafiber FIRESPAN® Curtain Wall Insulation and Thermafiber Safing Insulation required to safeguard high-rise curtain walls and floor slab perimeters, the company also manufactures sound attenuation fire blankets, and a variety of specialized insulation products.

James Shriver is Director of Thermafiber's Technical Services Department.

Footnotes:

1 In 1996, United States Gypsum Company (USG) sold its mineral fiber division now known as Thermafiber, Inc.

2 United States Gypsum Company fire test 1971.

3 United States Gypsum Company fire test 1972.
4 "Reliability of Automatic Sprinkler Systems", White Paper by William E. Koffel and Alliance for Fire Safety.

References:

1. Leavitt, William D., "*Rock Wool Insulations Contain Fire in Aluminum Curtain Walls*", International Conference of Building Officials – Building Standards, Jul./Aug. 1988.
2. USG/Thermafiber, "*Fire Control Test Data and Case Studies*", 1988, USG Interiors, Inc.
3. USG/Thermafiber, "*Explaining the Great Safe-Off Myth*", 1999, Thermafiber, Inc.
4. Loss Prevention Council, *"Fire Spread in Multi-Storey Buildings with Glazed Curtain Wall Facades"*, LPR 11:1999.
5. Licht, Richard, "*White Paper on Balancing Active and Passive Fire Code Protection Systems in the Building Codes*", Southern Building Magazine, Sept./Oct. 2000.
6. Shriver, James C. and Cordts, Brandon, "*Clarifying Curtain Wall Firestop Standards*", Technical White Paper, 2001.
7. American Architectural Manufacturers Association (AAMA), "*FSCOM-1-02 Fire Safety In High-Rise Curtain Walls*", Schaumburg, IL, 2002.
8. Licht, Richard, "*Maintaining Safety Effectiveness in the New Building Codes*", The Construction Specifier, April 2002.
9. Shriver, James C., "*High-rise perimeter protection systems reviewed*", FS-World Magazine, August 2002.
10. Jones, Lee C., "*Making the Case for Balanced Design*", FCIA Article published March 4, 2002.
11. American Society for Testing Materials, "*ASTM E 2307 – Standard Test Method for Determining Fire Resistance of Perimeter Fire Barrier Systems using the Intermediate-Scale Multi-story Test Apparatus*", Volume 04.07, Building Seals and Sealants, Fire Standards: Dimension Stone, 2005.
12. International Code Council, International Building Code, Section 713.4 "*Exterior curtain wall/floor intersection*", IBC 2006.
13. Koffel, William E., "*Reliability of Automatic Sprinkler Systems*", White Paper commissioned by the Alliance for Fire Safety.
14. www.fcia.org, Firestop Contractors International Association, website – 2006.
15. www.firestop.org, International Firestop Council, website – 2006.