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 capital 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 water 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 fire fighters 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 1970’s that concerns focused on the spread of fire at building perimeters. Engineers at the United States Gypsum Company observed that there are three ways for fire to spread from seemingly contained areas:

- **Poke through effect** - this is where flame and hot gases 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 though 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. 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. 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 the six basic design principles for successful perimeter fire containment. These design principles are: 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 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 almost 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 the 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 safining 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 offer 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%.

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**

How do the building codes address life safety in buildings? While ICC-IBC codes address fire containment, they are focused on interior propagation of fire.

IBC 2009, Section 714.4 Exterior Curtain Wall/Floor Intersection specifically states: “Where fire resistance-rated floor or floor/ceiling assemblies are required, voids created at the intersection of the exterior curtain wall assemblies and such floor assemblies shall be sealed with an approved system to prevent the interior spread of fire. Such systems shall be securely installed and tested in accordance with ASTM E 2307 to prevent the passage of flame for the time period at least equal to the fire-resistance rating of the floor assembly and prevent the passage of heat and hot gases sufficient to ignite cotton waste. Height and fire-resistance requirements for curtain wall spandrels shall comply with Section 705.8.5”.

The reference to Section 705.8.5 Vertical Separation of Openings seems to create a lot of confusion when trying to interpret the code and providing the necessary protection at the exterior of the building. Section 705.8.5 states: “Openings in exterior walls in adjacent stories shall be separated vertically to protect against fire spread on the exterior of the buildings where the openings are within 5 feet (1524 mm) of each other horizontally and the opening in the lower story is not a protected opening with a fire protection rating of not less than ¾ hour. Such openings shall be separated vertically at least 3 feet (914 mm) by spandrel girders, exterior walls or other similar assemblies that have a fire-resistance rating of at least 1 hour or by flame barriers that extend horizontally at least 30 inches (762 mm) beyond the exterior wall... There are however, exceptions to this section of the code where if the building meets any of the following three conditions, section 705.8.5 can be ignored completely.

**Exceptions:**

1. This section shall not apply to buildings that are three stories or less above grade plane.
2. *This section shall not apply to buildings equipped throughout with an automatic sprinkler system in accordance with section 903.3.1.1 or 903.3.1.2.*

3. *This section shall not apply to open parking garages.*

Basically Section 705.8.5 refers to the 3’ spandrel height which is sometimes misinterpreted that if a building meets one of the three exceptions then a spandrel height is not needed or only safing is necessary to meet the extension of the rating of the slab. However, this is not true. Testing has demonstrated that a portion of the spandrel wall must be protected in order to maintain the safing insulation’s position so that it provides a barrier to flame and hot gases. In fact there is no reference in Section 705.8.5 or any other section of the code that states that the Exterior Curtain Wall/Floor Intersection (714.4) can be ignored. Therefore, the code strictly enforces the requirement that the fire resistance rating of the floor assembly be maintained and there are no exceptions.

Because Section 705.8.5 caused so much misinterpretation, in order to clear up some of this confusion, Section 714.5 Spandrel Wall was added to the codes. Section 714.5 states: "Height and fire-resistance requirements for curtain wall spandrels shall comply with Section 705.8.5. Where Section 705.8.5 does not require a fire-resistance-rated spandrel wall, the requirements of Section 714.4 shall still apply to the intersection between the spandrel wall and the floor”.

Note that the current code addresses interior spread of fire only and does not address the need for sufficient curtain wall height and curtain wall barrier protection to assure that flames cannot leapfrog to ascending floors. Tested and listed systems by UL and OPL/Intertek require that the spandrel area must be protected in order to meet the building codes.

Codes are actually increasing the requirement for added protection even for non rated floor assemblies. Section 714.4.1 Exterior Curtain Wall/Non Fire-Resistance Rated Floor Assembly Intersections was added in 2009 to address such conditions. This section specifically states that: *Voids created at the intersection of exterior curtain wall assemblies and nonfire-resistance-rated floor or floor/ceiling assemblies shall be sealed with an approved material or system to retard the interior spread of fire and hot gases between stories.*

It can be thought of this way, a small building with a perimeter of 200’ x 200’ and a typical void of 3”, creates 200 square feet of open area that will allow smoke and hot gases to flow freely to the floor above. Multiply this open area times the number of floors and the risk to life safety of the occupants and first responders becomes a magnitude unthinkable to a building owner or community.

Further, it should be noted that while current code calls for the proper installation of approved 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.

Testing has proven that there are six 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 elements areas are:

1. **Back ing 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 and to keep the mineral wool curtain wall insulation from bowing due to the compression...
fit of the safing insulation.

2. Mechanical attachment of the mineral wool curtain wall insulation. The insulation must be mechanically attached, using appropriate fasteners. Adhesive attachments and friction-fit applications do not work. The adhesive service temperature ranges from minus 30° F to plus 250° F. Fire exposure temperatures based on ASTM E 119 very quickly exceed the adhesive service temperatures resulting in failure of the adhesive applied attachment to hold the curtain wall spandrel insulation in place. See Figure 2.

3. Compression-fit and orientation of the safing insulation. Fires produce tremendous air and structural movement that can dislodge safing insulation if not correctly installed. The safing insulation is compression-fit (typically 25% but varies by system) between the slab edge and the inside face of the mineral wool curtain wall insulation. This compression fitting creates a seal that maintains its integrity, preventing flame and hot gases from breaching to the floor above. This material must be compression-fit and installed as required per the tested assembly. Orientation of the safing is also dependent on the system in which it was tested. Listed systems outline which direction to install the safing. See Figure 3.

4. 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. Without the mineral cover protection on the fire exposure side, the aluminum mullions and transoms will soften and melt. The mechanical attachments holding the mineral wool curtain wall insulation will no longer be held in place, allowing the spandrel and safing insulation to fall out resulting in a breach of flame and hot gasses to the floor above. Mullion covers can be mechanically held in place with spiral anchors, such as shown in Figure 4.

5. 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 smoke seal is commonly spray applied to the top of the safing (non-fire exposure side) forming a smoke barrier with a typical L rating or leakage rating of 0. In addition, a 1” over spray as specified, is applied onto the floor slab and spandrel insulation creating a continuous bond that adds to holding the safing material in place during the fire and building movement.

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. When that option doesn’t work, consult with the manufacturer of listed and tested systems for assistance. Manufacturers who have been involved in testing curtain wall systems for many years have extensive files and research on perimeter fire testing of curtain wall designs. Data can be obtained as far back as the early 70’s when the development of perimeter fire containment began. Many of today’s manufacturers offer technical support services that may be able to provide a solution to protect the perimeter void, meet the code requirements, and apply the six basic design principles.

Since every building is unique in design there may be times when a tested system is not remotely close to resembling what was designed. Issues with mullion and transom spacing, multiple transoms, spandrel heights, floor location with respect to the sill height, mounting brackets, etc. all vary and can create a variety of conditions that are not typical to the original tested assembly. Yet, in the final building approval process, perimeter fire containment must provide a system that meets the building code requirements for Section 714.4 of the 2009 International Building Code. The Building Code recognizes that there are issues within a building’s construction that must be resolved in order for the building official to enforce the provisions of the code. Section 104.11- Alternative materials, design and methods of construction and equipment provides the means to resolve those issues. The key is to provide supporting documentation such as tests, research reports, and sufficient evidence that the proposed system meets the basic principles necessary for perimeter fire barrier protection.

What’s more, some manufacturers have now settled on a few systems where they are able to provide virtually all of the necessary components as well as detailed installation instructions. 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.

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.

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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 manufacturers sound attenuation fire blankets, and a variety of specialized insulation products.

James Shriver is Director of Thermafiber’s Technical Services Department. Jim has a BS in Mechanical Engineering and over 34 years experience in the construction industry. Jim is currently Corporate Director of Technical Services for Thermafiber, Inc. (formerly USG Corp.). Jim's related activities include ASTM membership and various ASTM Task Group memberships; most notably as previous Chairman of the Perimeter Fire Barrier Test Standard Task Group E 05.11.20 for including external spread of fire (“leap frog”). Present member of IFC (International Firestop Council) and Former Co-Chair of Inspection Manual. Jim is also a member of the AFSCC (Alliance for Fire and Smoke Containment and Control), and is involved in model building code development (ICC and NFPA), plus the UL and Intertek (OPL) testing coordinator for Thermafiber.

Jim is the author of several published articles pertaining to perimeter fire containment. As the Director of Thermafiber's Technical Services, Jim oversees engineering designs, details and judgments specific to architectural designs for protection at the perimeter. His designs include a patented Thermafiber Impasse System listed in the UL Fire Resistance Directory. His background includes several years in manufacturing including positions as Plant Manager, Quality Manager, and Engineering Manager.
Footnotes:
1. In 1996, United States Gypsum Company (USG) sold its mineral fiber division now known as Thermafiber, Inc.

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