SEE-THROUGH AND SAFE

The east and west wings at the University of Wisconsin School of Business Grainger Hall in Madison are linked via a new Learning Commons. The centerpiece of the new space is a glass stairwell which utilizes fire-resistive glazed walls, doors, and framing to meet code requirements, while maximizing transparency and connection between the spaces.

OLIVIA NASS, COURTESY SAFTI FIRST

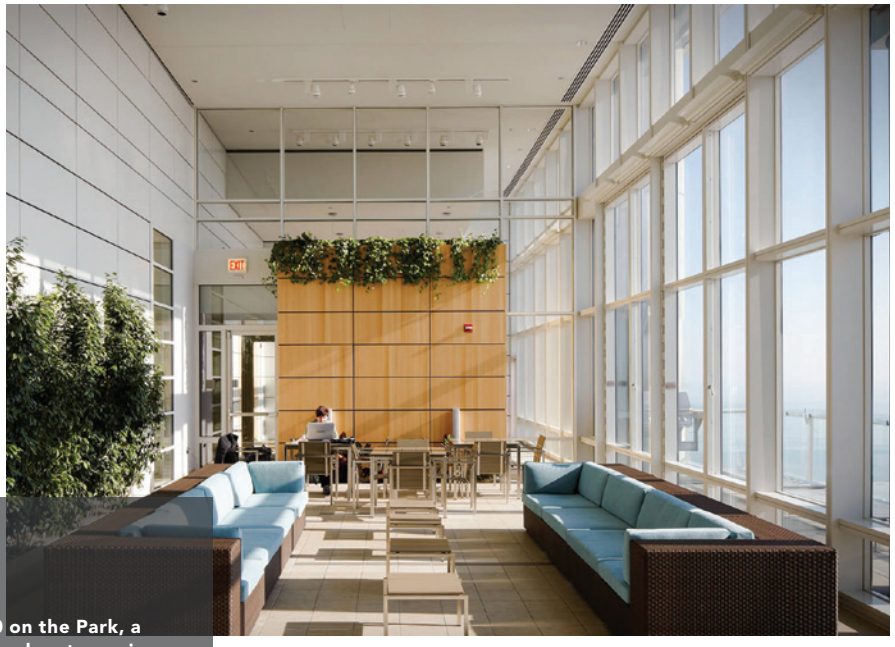
LEARNING OBJECTIVES

After reading this article, you should be able to:

- **DESCRIBE the safety and security benefits of fire-rated glazing and window systems.**
- **DISCUSS the opportunities and limitations of fire-rated glazing applications.**
- **COMPARE the competing priorities, codes, and standards related to the specification and detailing of transparent enclosures.**
- **LIST and contrast the systems and products used for fire-rate glass assemblies.**

Failure modes of glass systems under the extreme heat and pressures of building fires are reasonably well known, yet still hard to predict. In a recent fire simulation on a three-story structure built in India and studied by Underwriters Laboratories, the façade system of toughened glass and aluminum composite panels performed better than expected. That is, the glass did: As the aluminum cladding's window frames deformed and expanded under heat, "the glass panels did not break due to fire but fell to the ground in intact form," wrote the captivated research team.

In many cases, however, glass panels and structural glazings subjected to fire do fail. "Compared to other traditional materials for buildings, standard glass is typically characterized by brittle behavior and limited tensile resistance," according to Chiara Bedon, PhD, a professor at Italy's University of Trieste, who has studied structural glass systems exposed to fire. "The intrinsic properties of glass—together with typically limited thickness-to-size ratios for glazing elements, the mutual interaction of glass components with adjacent constructional elements as a part of full assemblies, and the combination of mechanical and thermal phenomena—make glass structures highly vulnerable," says Bedon.



340 on the Park, a new glass tower in Chicago designed by Solomon Cordwell Buenz to meet LEED Silver, utilizes fire-rated curtain wall glass and framing to separate communal spaces within the building allowing natural light to penetrate deeper into the spaces.

Many of those phenomena are considered in building codes, life-safety codes, and material performance standards. Products such as wire glass—including glazings with the unique look of cast and polished wire, as well as laminated and multi-laminated glazings and glass block—are engineered to block smoke and flames and to withstand high pressures and certain effects of hose streams, all of which can occur during fire events. Many types of glazings can withstand thermal shock, another key phenomenon. Glass that is fire-rated may also be impact safety-rated, though not always.

Another one of those phenomena is radiant heat. Fire-rated glass and glass ceramics, as well as other fire-protective glazing materials, are designed to block smoke and flames. But they are not always a barrier to the electromagnetic radiation emitted by fire, which can cause material combustion as well as serious or mortal injury to people nearby on the non-fire side of the glass. If the application and jurisdiction require a "barrier-to-heat" product, the glazing materials will meet such test standards as ASTM E-119 or UL 263, or both, for a specified period of time. Other criteria include the National Fire Protection Association (NFPA) standard NFPA 251, which can be considered integral to ASTM E-119.

Tests of radiation (also called radiated flux) through glass have evaluated the human effects and material combustion, measured in kilowatts per unit area. At the test distances of about five to six feet, for example, wood surfaces will combust at about 12-13 kilowatts per square meter. People cannot tolerate being subjected to radiant heat levels of just about five kilowatts per square meter. With that in mind, consider the fire radiation performance of fire safety glazings such as:

- Wired glass: 35-38 kilowatts per square meter (at 37 minutes).
- Ceramics: 75 kilowatts per square meter (at 60 minutes).

In addition, non-glass materials such as hollow metal framing do not limit radiant heat; the radiation passes through at equally dangerous levels.

Because of these significant effects, Building Teams hew to two general classes of glazing materials for architectural applications. First, *fire-protective glass* allows for applications where compartmentalization of smoke and flames is a sufficient life-safety criterion for the application, area, and size limitations allowable under the International Building Code (IBC). These situations typically include doors and openings up to 45 minutes and areas equal to or less than 25% of the total wall area. The fire-protective products meet such standards as NFPA 252 or NFPA 257—fire tests for door assemblies or windows and glass block assemblies, respectively—or the UL fire and pressure tests for windows and doors, including UL 9, UL 10B, and UL 10C.

If it is designed to block radiant heat, the product is fire-resistive glazing. These types will have a fire endurance rating, given in minutes, and also an ASTM E119 test rating indicating the ability of the glass—in combination with fire-resistive framing members—to limit a rise in temperature on the surface opposite the fire.

BENEFITS OF FIRE-RESISTIVE BARRIERS

Among the building design benefits of fire-resistive glazing is the ability to block radiant heat transfer from one building compartment to another and, in this way, protect people leaving a building through an exit corridor. This can change, for example, the character of significant areas that have typically been enclosed with only opaque surfaces.

Consider the impact on recent designs of egress stairs: Long regarded as the elevator's pesky little brother, stairways in the past have

largely been relegated to second-team status in most buildings: to be used only "in case of emergency" and more often than not to be found hidden behind obscure doors with nothing but a bright, yet vague, "EXIT" sign leading the way. Recently, however, the U.S. General Services Administration (GSA) has been on a mission to popularize the use of stairways in order to encourage health and safety initiatives, productivity, and sustainability in the workplace.

New GSA policies set in place over the last decade have required the location of stairways to be more prominent. GSA also rewards project teams for reducing elevator energy use and promoting routine stair use in an effort to encourage indoor physical activity. In this way, the GSA has implemented fire-rated glass doors and windows in more of its 8,600 federal buildings as a way to make stairways more inviting, attractive, and safer for occupants.

Many project teams have found that fire-resistive assemblies offer cost-effective ways to open up fire exits and stairways in existing buildings. They can be used to replace traditional solid metal doors and make fire exits more visible and appealing. Fire-resistive assemblies can also be used to create windows, illuminating poorly lit stairways and transforming them into integral parts of the building, rather than rendering them as the utilitarian "plan B."

The key to these initiatives is in making the invisible, visible again, according to Gensler's Robert Peck, Principal and Government & Defense Leader, who previously served as the head of the GSA's Public Building Service. Peck says the focus is on creating open and transparent stairways to "solve for flexibility and connectivity in the critical vertical dimension." When stairways are easy to find, friendly, inviting, and well-lit, they offer an obvious advantage in moving between floors that not only saves time and increases productivity, but encourages social interaction, promotes physical activity, and creates a safer workplace.

During a time when screens and automated machines have rendered workers more sedentary than ever before, it makes sense to shine the spotlight back on a simple tool: to make stairways our first team again. This was the case at The Homes at Old Colony, a public housing complex in South Boston redeveloped with a design by The Architectural Team to replace dark, isolated stairways with stairways filled with natural daylight that opened to lobbies. In this way, "residents are safer and more connected to the community," according to glass manufacturer Safti *First*. "And, by adding additional, spacious, accessible stairways leading to exits and built to code using fire-rated glass and framing, you improve emergency exit safety in the event of a fire."

In another example, for Kent State University's new College of Architecture and Environmental Design facility, designed by Weiss/Manfredi and Cleveland's Richard L. Bowen & Associates, fire-resistive glazing serves areas needing a two-hour fire rating, including stairwells and exit passageways. Along with a fire-resistive wall framing, the assemblies meet ASTM E-119 wall criteria with hose stream for up to two hours while bringing vision, transparency, and natural light further in the building. The result is a four-story, loft-like building that encourages interaction and collaboration with stairs in both the north and south façades to connect all four levels.

COURTESY APPLE

Glass innovation has been at the heart of Apple's retail strategy for more than a decade. Its latest iteration is the Apple Park Visitor Center, across the street from its $5 billion headquarters in Cupertino, Calif. The center was designed by Foster + Partners as a "delicate pavilion" that rests lightly on a glass-walled structure.

The concept can also be used for horizontal surfaces. At the Fayette County Courthouse in Lexington, Ky., multi-laminate glass protects against fire, impact, thermal shock, and radiant and conductive heat transfer. The glass is also bullet-resistant and can be combined with a glass floor framing system to create a transparent floor and ceiling assembly.

According to Deborah Berke Partners, which served as design architect of the renovation

TOP: COURTESY SAFTI FIRST; BOTTOM: TGP

Recent innovations in fire-resistive glazing include fire-rated glass floor systems. Shown here: 21c Museum Hotel, Nashville, Tenn., by Deborah Berke Partners and Perfido Weiskopf Wagstaff + Goettel (top); and the Fayette County Courthouse, Lexington, Ky., by K Norman Berry Architects and Deborah Berke Partners (bottom).

alongside Louisville-based K. Norman Berry Architects, the project is "transforming it into a mixed-use center with offices, event space, and a food and beverage outlet to renew one of Lexington's most prominent buildings for public use and return one of the city's most iconic rooms—the spectacular domed rotunda—to the people of Kentucky." To showcase the original domed area while increasing daylight and views within the adapted justice building, the fire-rated glass floor systems visually connect the lower floors to the dramatic upper domed space.

The fire-rated glass floor is a modular system that compartmentalizes the floors while providing a resilient walking surface for live loads up to 150 pounds per sf (psf). The floor must meet impact resistance and fire rating criteria, with protection against both radiant and conductive heat transfer. For the courthouse, the assembly included glass panels with a two-hour fire rating paired with a tempered, laminated walking surface glass, all supported with a steel-section framing grid, according to the manufacturer Technical Glass Products. Designed for interior applications, the assemblies can be specified with decorative color frits or sandblasted glass while still meeting the needed fire rating. If impact breakage occurs, the walking surface panels are designed to be easily swapped out.

Impact safety ratings, which describe the amount of force the glass can resist given in specific increments or classes, are often required where glass is regularly exposed to contact by people or objects. Set by the Consumer Products Safety Commission (CPSC), the Safety Standard for Architectural Glazing Materials was established under the Consumer Product Safety Act in the late 1970s "to reduce or eliminate risks of injuries associated with walking, running, or falling through or against glazing materials." In 2015, the *Federal Register* reports, CPSC standard 16 CFR 1201 was effectively replaced by a similar ANSI test standard, Z97.1, describing safety performance specifications for safety glazing materials used in buildings. ANSI Z97.1 requires all safety glazing materials, including wired glass, to survive a Class A (400 ft-lb) impact or to survive the Class B (150 ft-lb) impact—the latter designed to protect a small child, and the former for adult occupants.

In the building codes, project teams encounter definitions of hazardous locations to ensure minimum requirements safety glazing are applied.

These include large fixed glass panels near walking surfaces, vision panels built into doors, and sidelite glazing adjacent to various kinds of doors. In addition, the codes will describe glass areas "subject to human impact load"; these typically are found in athletic facilities but may also occur in certain industrial settings. In chapter 24 of the IBC, most local codes detail where safety glazing is required. One of the most complicated cases refers to "other fixed panels." These "other" cases *must use safety glazing* if all of the following are true:

- glazing panel is larger than nine sf
- lower glass edge is less than 18 inches from the floor
- top edge is more than 36 inches from the floor
- panel is less than 36 inches from a walking surface.

Adding a horizontal bar measuring 1.5 feet within 34 inches to 38 inches of the floor can eliminate the requirement for safety glazing, though Building Teams often recommend asking code inspectors to verify this exception.

LARGE-SCALE GLAZINGS

Under certain circumstances, project teams look to apply very large monolithic class panels for fire-rated applications to prevent the spread of fire, hot gases, and smoke. Novel glass-ceramic production techniques have led to the application of very large floated panels of greater than 4x8 feet.

Besides these large potential glass openings, the benefits of glass-ceramics include their ability to remain transparent under high thermal loads, assisting in emergency evacuation and rescue efforts during fires. Novel wireless glass-ceramic panels also have good aesthetic qualities, including greater clarity, distortion-free finishes, and the elimination of the yellowish tint common in previous generations of glass-ceramics. For situations requiring impact-safety ratings, glass-ceramic products are available with surface-applied safety film or in laminated safety glass—for use in door lites, transoms or sidelites, and windows—meeting the standards ANSI Z97.1 (Class A) and CPSC 16CFR1201 (Cat. I and II).

"Over the years, fire-rated glass ceramics have stepped in to give architects new materials to fill interior spaces with borrowed light while still meeting fire protection codes," according to the manufacturer Schott. "Fire-protection-rated glazing blocks smoke and flames during a fire without turning opaque, allowing building occupants to see a clear path to safely exit the building, and allowing fire fighters to see into interior corridors while fighting the fire."Recent projects using glass-ceramic applications include University Hospitals Seidman Cancer Center in Cleveland, Ohio. Led by CannonDesign and Gilbane Building Company, the new, 370,000-sf facility employs full-lite, fire-rated glass doors and transoms made with premium-grade ceramic glass and fire-rated welded steel frames.

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The glass openings help to "foster collaboration between the different departments while keeping patient needs at the forefront of interior design," according to the manufacturer of the specialized doors, TGP. The design approach also integrated goals related to accessing natural light, protecting patient privacy, and providing clear wayfinding.

Steel doors and frames with heat-barrier glazings and bullet-resistant options are being used more frequently in public buildings as well as commercial lobbies and entryways. The systems are designed to withstand structural forces in accordance with ASTM E330 of at least 1.5 times the design wind loads and of 10 seconds in duration, for both positive and negative wind effects, measured in pound force per square foot (lbf/sf).

To estimate wind pressure per square foot, project teams can multiply the square of the wind speed by 0.00256, which approximates pounds per square foot. As for ballistic performance, bullet resistance levels are given by UL 752, which categorizes levels 1 through 8. Typically, levels 1-3 are specified for the glazings in standard building applications, where the three levels correspond to increasing protection to withstand three impacts of a specific ammunition type, according to the manufacturer Insulgard. The steel frames should meet level 8 when tested per UL 752.

The fire-rated glazing for these entry doors can use multiple sheets of high-visible-light transmission glass laminated with an intumescent interlayer. The glazings meet impact safety resistance per ANSI Z97.1 and CPSC 16CFR1201 (Cat. I and II), and generally include a polyvinyl butyral (PVB) interlayer for exterior-grade performance.

While clear interlayers are a conventional choice, a rainbow of colored interlayers are also available to complement powdercoat and other architectural finishes. Any colored or tinted glazing must be reviewed for safety and security implications, however: During daylight hours, glazing with low visible light transmission (VLT) can actually hamper views into and out of building enclosures during search-and-rescue operations by firefighters and police.

In general, however, windows with safety glazing and impact-resistant glass enhance safety and security performance, according to the Window and Door Manufacturers Association (WDMA) former CEO Joel Hoiland, especially when they also provide storm resistance to protect against high winds and airborne projectiles during severe weather. Where hurricanes occur, for example, local codes or ordinances may require glass and framing of exterior fire-rated doors, windows, and walls meeting high- velocity hurricane zone (HVHZ) testing requirements. The relevant testing and listings in this area include the North American Fenestration Standard/Specification for windows, doors, and skylights, known as AAMA/WDMA CSA 101/I.S.2/A440, as well as one or more of the following:

- Florida Building Code (FBC) 1626.2, referencing the ICC's Testing Application Standard (TAS) 201 and 203 for large missile impact and cyclic wind loading
- AAMA standards for doors resisting forced entry, such as AAMA 1302.5 and 1303.5
- Testing for lateral load resistance, such as ASTM E1300
- Large missile impact-resistance standards for residential occupancies, such as ASTM E1996 and ASTM E1886.

In addition to testing standards and UL certifications, the Florida approvals and listings by the Texas Department of Insurance may be required in those states to verify the impact resistance and wind loading capabilities of doors, windows, and window-walls.

BENEFITS OF OPENING UP

Opening up building exteriors where previously there were opaque walls can provide a number of benefits to the buildings and occupants, especially when the assemblies meet other structural and protective criteria. Among the most valuable also help boost sustainability of the resulting structures.

Adding fireproof glass walls can enhance total daylighting in a variety of settings where standard practice calls for solid walls. The most effective applications include exterior envelopes using fire-rated glazing systems in perimeter locations with requirements for property lot-line protection. Per the IBC, while party walls may be used or adapted for "joint service" between two or more adjacent buildings and cannot have openings, other lot-line conditions can allow for use of glass perimeters. Another ideal application is for central corridors and gathering areas, where daylight is rare and yet visible transparency may improve building function in varied ways.

In addition, according to TGP, improving "visual connectivity" and views to the outdoors are valuable assets for not only green building but also improved functionality.

From expansive fire-rated glass curtain walls to incorporating increased fire-rated glazing in and around fire-rated doors are two techniques for promoting visibility between spaces. In this way, transparent building compartmentation and visual connections boost end-user awareness of what's happening indoors and outdoors while also maximizing outdoor views and daylight harvesting, two key precepts for indoor environmental quality (IEQ). These also support WELL Building Standards criteria and other design goals, such as high levels of transparency in retail storefront applications.

A recent project in Seattle built by the general contractor Skanska and glass contractor Goldfinch Bros. applied this thinking to the workplace for a biopharma company. Flad Architects conceived an interior solution visually connecting office areas, conferences, and common rooms with the occupant's laboratories through tall, butt-glazed glass partitions with elegant, slender framing and a ribbon transom element at the ceiling. Applications like this require fire-rated glazing to separate the labs and office workplaces with two hours of fire-resistant protection against radiant heat transfer and gasses caused by smoke and flames, according to the fire-rated glass manufacturer, Vetrotech Saint-Gobain. Yet the company also engineered the glass partitions for acoustical performance, meeting a sound transmission class (STC) rating of 46 decibels. The use of glass has helped transform how the company, Juno Therapeutics, considers communication, collaboration, and openness as part of its mission to innovate in its highly competitive field.

Even in more traditional settings, the use of fire-rated glass separations in place of opaque walls adds competitive, aesthetic, and health benefits. Examples range fromsenior living and multifamily residential projects to hospitality and resort applications. In a recent case study conceived by BraytonHughes Design Studios and constructed by Innovative Glass Solutions, a fire-rated enclosure with wood-clad framing now surrounds a historic stair leading to the tasting room of a popular winery and vineyard near Santa Rosa, Calif. Responding to the code requirement to compartmentalize the staircase and floor opening to stop migration of smoke and heat, the project team employed a fire-rated steel framing system clad with a veneer of domestic white oak to match the aesthetic of a historic barn.

In more modern settings, project teams are careful to ensure the additional glass walls and doors do not become a liability. The company Apple—which has underwritten extensive glass innovations at its retail locations around the world—recently learned this lesson at its $5 billion headquarters called Apple Park, as the San Francisco Chronicle reports. The problem? During the normal course of business, building occupants were unable to distinguish the cafeteria's glass walls from the glass automatic doors built to match the partitions. While only a few injuries have been reported, the project architect Foster and Partners has designed appliqué film in a sleek black pattern for the cafeteria partitions—before Apple employees began moving in this January. +