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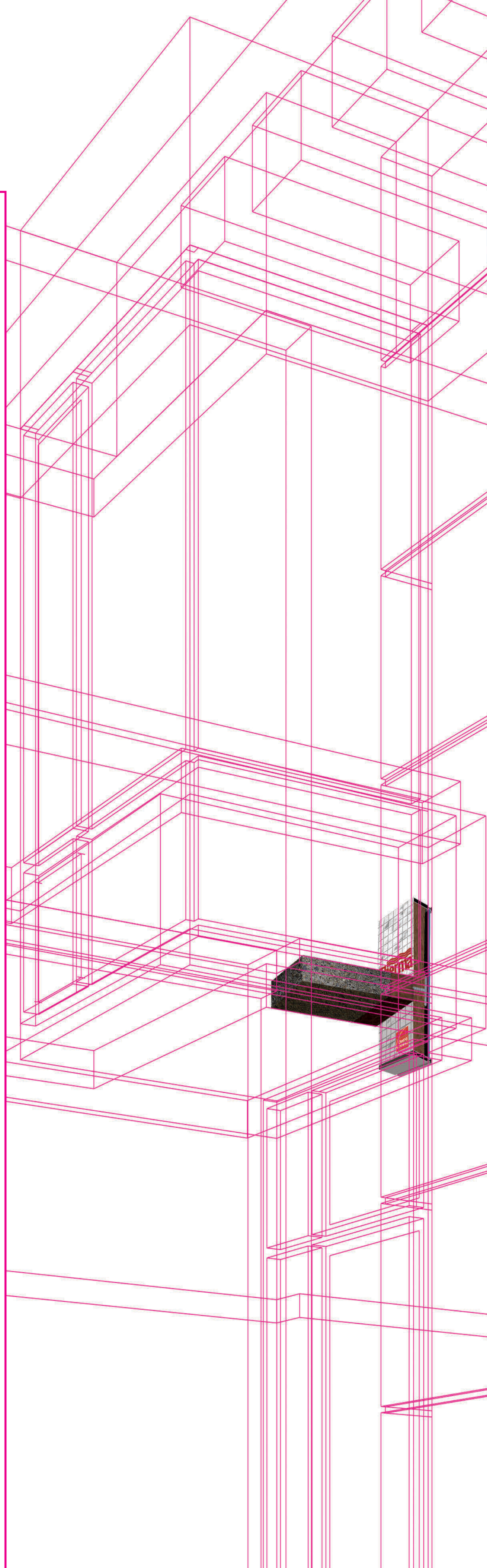

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Fire Protection

Part One

Specifying Intumescent Coating Film Thicknesses

BY BOB GLENDENNING

Specifying Intumescent Coating Film Thicknesses

All images courtesy Sherwin-Williams

PASSIVE FIRE-PROTECTION COATINGS, OR INTUMESCENT COATINGS, HAVE BEEN DESIGNED TO BUY TIME FOR BUILDING OCCUPANTS—AND THE STEEL-FRAMED STRUCTURES THEMSELVES—DURING A FIRE. APPLIED TO STRUCTURAL STEEL, THE COATINGS REACT CHEMICALLY IN FIRE, FORMING A CHAR THAT EXPANDS WITH HEAT EXPOSURE, MUCH LIKE THE REACTION TAKING PLACE WHEN LIGHTING A BLACK SNAKE FIREWORK (FIGURE 1, PAGE 6). THE COATINGS SWELL TO APPROXIMATELY 50 TIMES THEIR DRY FILM THICKNESS (DFT), TO A MAXIMUM OF 50 MM (2 IN.), THEREBY PROVIDING A THICK LAYER OF INSULATION 'CHAR' THAT REDUCES THE RATE OF HEAT TRANSFER TO THE STRUCTURAL STEEL.

Slowing the rate of heat transfer is important, as structural steel under load can quickly lose strength in a fire. Exposure to high heat for a specific period can cause the steel to eventually reach its critical failure temperature. At this state, the steel could start to collapse, possibly bringing down large building sections or even the entire structure.

Intumescent coatings help building owners avoid such catastrophic losses by providing fire resistance while responders work to contain a fire. They offer a theoretical amount of time the coated steel can resist fire before reaching its critical failure temperature, as proven within a furnace per criteria found in various test standards such as:

- the American National Standards Institute/Underwriters Laboratories (ANSI/UL) 263, *Standard for Fire Tests of Building Construction and Materials*;
- ASTM E119, *Standard Test Methods for Fire Tests of Building Construction and Materials*;
- International Organization for Standardization (ISO) 834, *Fire-Resistance Tests – Elements of Building Construction*; and
- British Standard (BS) 476, *Fire Tests on Building Materials and Structures* (Figure 2, page 6).

This time period or fire-resistance rating is based on the applied thickness of the coatings. The thickness is determined by the size, weight, and heat exposure of each structural steel member.

Figure 1

Intumescent coatings applied to a steel I-beam, or W-profile (left), create a thick char and swell to approximately 50 times their dry film thickness (DFT) in a fire (right), thereby providing protective insulation that reduces the rate of heat transfer to the steel.

Figure 2

Controlled fire tests performed on steel beams coated with intumescent coatings can help determine the fire-resistance rating for various size steel sections.

In order to assist engineers, architects, and other building professionals achieve a specified fire-resistance rating, ANSI/UL 263 and ASTM E119 list the required coating thicknesses for structural steel members from large to small. However, the specifications do not include every possible size, leaving data gaps especially for very small and large steel sections. This presents challenges for specifying proper coating DFTs.

Dangers of using extrapolated data

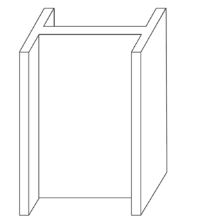
To ensure safety as well as compliance with building codes, specifiers must stipulate the appropriate coating thickness to apply to steel sections of various sizes. However, the thickness can be difficult to determine when a particular-sized steel section is not listed in the ANSI/UL 263 or ASTM E119 dataset.

Small, lightweight steel sections need a higher film thickness to achieve the desired protection compared to larger, heavier assemblies. However, as noted above, the heat exposure of each structural steel member also influences the coating thickness required to achieve a specified fire-resistance rating. The thickness is most accurately based on the steel weight (per lineal foot)/fire exposed steel perimeter (W/D) ratio of the steel section (*i.e.* the ratio of the section's weight [W] to the total square area in contact with fire [D]). The D value is an important variable, as some steel sections are fully exposed to fire, while others are protected on one or more faces due to their orientation and mounting.

When UL data is not available for a particular structural steel section, some coatings suppliers make recommendations based on extrapolated data. However, UL has said extrapolated DFT data is outside the scope of its intumescent coating certification program. This noncompliant data is considered unsafe for the following two reasons:

1. The extrapolated data might underestimate the required coating thickness, resulting in a steel section with insufficient coating DFT to achieve the desired fire resistance. These kind of sections are likely to reach their critical failure temperatures sooner than other properly coated areas.
2. Conversely, the extrapolated data might overestimate the required coating thickness, thereby causing the steel section to have a higher coating DFT than needed. In this case, the weight of the expanded char could cause the coating to delaminate and fall off, exposing the steel directly to fire without any protection in place.

Figure 3



Column Size	W/D	Required DFT (inches) for Fire Rating Duration		
		1 Hour	1.5 Hours	2 Hours
W6x12	0.45	0.129	0.247	N/A
W10x39	**0.78**	**0.072**	**0.134**	**0.198**
W10x49	0.84	0.067	0.126	0.185

Fire-resistance ratings for Column Y according to the American National Standards Institute/Underwriters Laboratories (ANSI/UL) 263, *Standard for Fire Tests of Building Construction and Materials*.

Given these potential hazards, it is advisable for specifiers to work with a coatings supplier to find a safe, workable alternative and not rely on extrapolated data when encountering structural steel section sizes outside of UL's listing.

Why does data extrapolation happen?

Building fire-resistance ratings are expressed in half-hour increments from one to three hours. In the United States, one- and two-hour ratings are common. The specified rating for a building depends on multiple factors, including building codes, type of construction, owner preferences, and insurance regulations.

When designing buildings, engineers and architects must comply with fire-resistance codes defined in ANSI/UL 263 and ASTM E119, as well as all the requirements set forth by local municipalities, state governments, building owners, and insurance firms, while minimizing costs. Therefore, lightweight steel sections are usually employed. However, design professionals might not realize some sections are smaller than those tested and listed in ANSI/UL 263 and ASTM E119. Due to lack of data, such sections will not have a defined DFT for applying intumescent coatings to achieve the required fire-resistance rating. In such cases, the parties involved might unwisely consider extrapolating data to determine the appropriate thickness.

UL has advanced its position on discouraging the use of extrapolated data in recent history, publishing stronger language against the practice. In its 2014 "The Fire & Security Authority" publication and its category code number publications—BXUV and CDWZ—that provide guidance for 263-compliant fire-resistance ratings compliant with ANSI/UL 263, UL said the average thickness of an intumescent coating "should not exceed the maximum thickness published in the individual [steel section] designs."

In 2017, UL published the following fire-resistance guideline as part of the ANSI/UL 263 BXUV guide emphasizing the need to avoid extrapolating data:

> Extrapolation of member size and/or material thickness shown in the individual designs has not been investigated and would be considered to void the existing certified assembly.[1]

Finally, in its strongest language yet, UL stated the following as part of its "Best Practice Guide for Passive Fire Protection for Structural Steelwork," published in October 2018:

> Extrapolated thicknesses that are beyond the scope of the published UL design without additional supporting test data are not considered acceptable. Additionally, extrapolated material thicknesses that are beyond the published UL design are not recognized by UL and are considered outside the scope of the UL Certification.

When engineers or architects find data is unavailable for a steel section, they have two options:

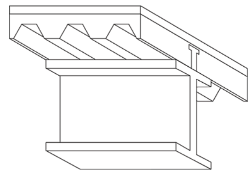
- consider an alternate steel size or profile; or
- use advanced structural engineering design principles from the American Society of Civil Engineers/ Structural Engineering Institute (ASCE/SEI) 7-16, *Minimum Design Loads For Buildings and Other Structures*, Appendix E guidelines.

This article only focuses on specifying different steel sections as the ASCE/SEI guidelines—that consider the steel strength supporting the structure and the reserve strength available to resist fire—deserve a stand-alone article.

Understanding steel section data

UL publishes a variety of categories for rating the fire resistance of steel sections, with each one having

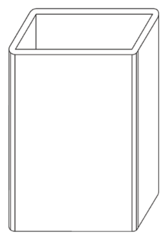
Figure 4



Beam Size	W/D	Required DFT (inches) for Fire Rating Duration		
		1 Hour	1.5 Hours	2 Hours
W6x12	0.53	0.093	0.118	0.192
W10x39	**0.93**	**0.076**	**0.099**	**0.161**
W10x49	1.01	0.072	0.095	0.154

Fire-resistance ratings for Beam N per ANSI/UL 263.

Figure 5



HSS Tube Size	A/P	W/D Equivalent	Required DFT (inches) for Fire Rating Duration		
			1 Hour	1.5 Hours	2 Hours
3 x 2 x ¼	0.21	0.72	0.149	0.223	0.331
10 x 10 x ¼	**0.23**	**0.78**	**0.137**	**0.z209w**	**0.309**
10 x 4 x ⅜	0.34	1.157	0.099	0.162	0.239

Fire-resistance ratings for hollow structural sections (HSS) Column Y as listed in ANSI/UL 263.

different test and pass criteria. Additionally, UL's coating DFT requirements differ for various steel member shapes and orientations. Due to both factors, it may be unsafe to use the published maximum intumescent coating thickness in one UL category for another listing.

Each steel type (*e.g.* beam, column, or brace) listed in UL's database has a 'section factor' to help determine the required intumescent coating DFT for meeting various fire-resistance ratings. This value is a ratio that differs depending on the style of the steel section as well as its exposure to fire. The section factor ratio W/D covers I-beam (or W-profile) sections, while the ratio A/P represents hollow structural sections (HSS) such as cylindrical (pipe) columns. The variables refer to:

- W: The weight of the section (in pounds/foot);
- A: The cross-sectional area of all sides of the HSS (in inches); and
- D and P: The heated perimeter of the section (in inches) or the total square area that would be in contact with fire.

See Figure 3 (page 7) for an example of a fully exposed W-profile. Here, D represents the section's entire surface area because it would all be in contact with direct heat from a fire. However, in Figure 4, D only includes the surface area of the steel that is not in contact with the concrete ceiling/slab above the beam. The ceiling—or any material in contact with or partially encasing a steel section—serves as a heat sink in a fire, taking heat away from the coated steel section and offering some fire resistance. In Figure 5, A is the entire surface area of an HSS section, minus any areas in contact with heat sinks.

The W/D and A/P ratios represent how quickly a steel section will heat up in a fire. One can calculate these ratios by dividing the weight (W) or area (A) by the heated perimeter (D or P). The A/P ratio can then be converted into a W/D ratio to directly compare W-profile and HSS sections.

The amount of fire protection (intumescent coating DFT) required for a steel section is inversely proportional to its section factor ratio. A larger ratio indicates less fire protection is required, and a smaller one requires the application of thicker fire protection. The examples shown in Figures 3, 4, and 5 reveal the smaller W/D and A/P ratios at the top require a greater coating DFT. They also demonstrate coating DFT requirements increase with longer fire rating durations.

It is helpful to make some direct comparisons to understand why it is impossible to use W/D and DFT data from one UL category listing to the next even when the steel section is of the same size.

In Figure 4, the required intumescent coating thickness for a two-hour fire rating for the W10x39 Beam N section is 4 mm (161 mils) DFT (marked in red). When looking at the same-sized W10x39 Column Y section in Figure 3 (marked in red), one will find a smaller W/D ratio that equates to the higher DFT requirement of 5 mm (198 mils) for the

> Underwriters Laboratories (UL) has offered some flexibility in specifying coating thicknesses for steel sections in between the established lower and upper size limits.

same two-hour rating. The Column Y section DFT is 23 percent greater than the Beam N requirement, even though the two sections are of the same size. This difference is because Beam N is in contact with concrete on one face, making its heated perimeter much smaller.

Further, the coating DFT requirements are drastically different for HSS columns requiring significantly higher intumescent coating DFTs because of their structural profile. In Figure 5, the A/P ratio has been converted to W/D for simpler comparison. The 10 x 10 x ¼ HSS Column Y has the same column section factor and a similar size to the W10x39 Column Y in Figure 3 (see red text for both). Both sections are 250 mm (10 in.) deep and have a similar weight per foot. Yet, the HSS Column Y section requires an 8-mm (309-mils) DFT for a two-hour fire rating. This value is 92 and 56 percent greater than the W10x39 Beam N and Column Y DFT requirements, respectively.

Why extrapolated data does not add up

The data limitations on the lower and upper ends of steel member sizes listed in ANSI/UL 263 and ASTM E119 are a result of UL either not testing such steel sections or determining they are unable to be protected with intumescent coatings. As mentioned, extrapolating data beyond the published limits could result in specifying an intumescent coating DFT that is either too low or high, both could result in insufficient fire protection. However, UL has offered some flexibility in specifying coating thicknesses for steel sections in between the established lower and upper size limits.

UL considers the following two scenarios acceptable in its revised fire-resistance rating guidance documents.

1. Using the minimum listed coating DFT for a particular beam size (specific W/D) on a larger steel section (greater W/D) that has a greater heat sink than the listed steel section. (The heat sink would provide some fire resistance, allowing the minimum DFT to provide a similar fire-resistance rating.)
2. Substituting a steel member for a heavier weight (greater W/D) section using the same specified coating thickness. (The heavier steel section could actually require less coating thickness for the same fire-resistance rating but using the same DFT will certainly provide the same or better protection.)

Conversely, UL lists the following scenarios as unacceptable because the applied coating may be too thick, creating the potential for delamination from the steel during a fire:

- using a coating DFT specified for a larger steel section to cover a smaller steel section with a lower W/D than is listed; and
- substituting a steel member for a lighter weight (lower W/D) section using the same specified coating thickness.

Figures 6 and 7 (pages 10 and 11) demonstrate these points for engineers and architects specifying

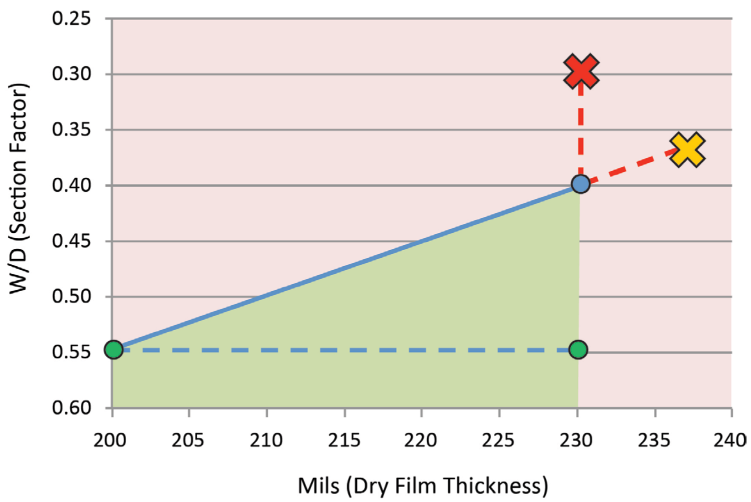
ENHANCING AESTHETICS AND PROTECTING AGAINST CORROSION

Per building fire-resistance codes defined in the American National Standards Institute/Underwriters Laboratories (ANSI/UL) 263, *Standard for Fire Tests of Building Construction and Materials*, and ASTM E119, *Standard Test Methods for Fire Tests of Building Construction and Materials*, and enforced by local municipalities, state governments, building owners, and insurance companies, all structural steel members of a building must be coated with the appropriate intumescent coating thickness based on final specifications. Coatings can be applied either in the field or offsite in a controlled facility. After the coatings have cured, applicators will use an electronic gauge to determine the resulting DFT. If insufficient, they will apply additional coating material to reach the specified thickness.

Following the application of intumescent coatings on exposed structural steel, architects often choose to apply a topcoat for a more aesthetically pleasing or colored finish. Nonexposed steel sections may also need to be covered with a protective coating in areas where durability is a concern (*e.g.* areas prone to corrosion due to exposure to weathering or wet/dry cycling). It is important to note the addition of a thick topcoat or too many layers can prevent the intumescent coating underneath from activating in a fire. This is not a concern for new construction, but it should be considered when recoating steel. Engineers, architects, and coating suppliers need to carefully plan to mitigate this potential situation. **CS**

When a steel-framed building catches fire, the fate of the structure—and the safety of occupants in, on, or around the structure—may come down to a layer of passive fire-protection coatings.

Figure 6



This image shows the lightest steel section listed in ANSI/UL 263 (0.40 W/D) and the corresponding intumescent coating DFT required for a two-hour fire rating for larger-sized steel members. Specifiers may use any point on the blue line or within the green areas below to determine the appropriate DFT. They cannot extrapolate data in the direction of the red or orange Xs and still hope to be within ANSI/UL 263 compliance.

the intumescent coating DFT for a given steel section W/D ratio. In both diagrams, one simply needs to stay within the green areas and stay out of the red sections. In this author's experience, any point on or below the blue lines is fine.

In both figures, the blue lines represent the maximum allowed data points in ANSI/UL 263 and ASTM E119. The blue line in Figure 6 terminates at a W/D ratio of 0.40, the lightest steel listed in ANSI/UL 263. The required coating DFT is plotted on the X-axis in relation to the steel section's W/D ratio on the Y-axis. For example, the blue dot shows a steel section with a W/D ratio of 0.40 requires a 6-mm (230-mils) DFT for a two-hour fire-resistance rating. The left-hand green dot shows a steel section with a 0.55 W/D ratio would require a minimum DFT of 5 mm (200 mils). However, the right-hand green dot reveals the 0.55 W/D ratio section could be coated up to a 6-mm DFT without worry. The DFT cannot exceed 5 mm for either of these steel sections because the data is not included in UL's listing. Therefore, per UL guidelines, specifiers cannot extrapolate the data to a lower W/D ratio (red X) or to a higher DFT (orange X).

When working in the other direction and looking at stronger/heavier steel sections, the same principle holds true, as shown in Figure 7. Here, the blue dot represents the lowest W/D listed in ANSI/UL 263 and ASTM E119. The two-hour DFT requirement at this W/D ratio of 1.74 is 2.5 mm (98 mils). Per UL guidelines, it is acceptable to coat sections with a greater W/D ratio. For example, 1.8 (green dot) with the same minimum 2.5-mm DFT. However, UL does not permit specifiers to extrapolate a reduced DFT for stronger steel sections (orange X) because it has not tested sections beyond the 1.74 W/D ratio. Additionally, UL does not allow specifiers to extrapolate data for lighter steel sections (red X). Specifiers must instead follow the blue line up to match a lower W/D ratio with the correct minimum DFT.

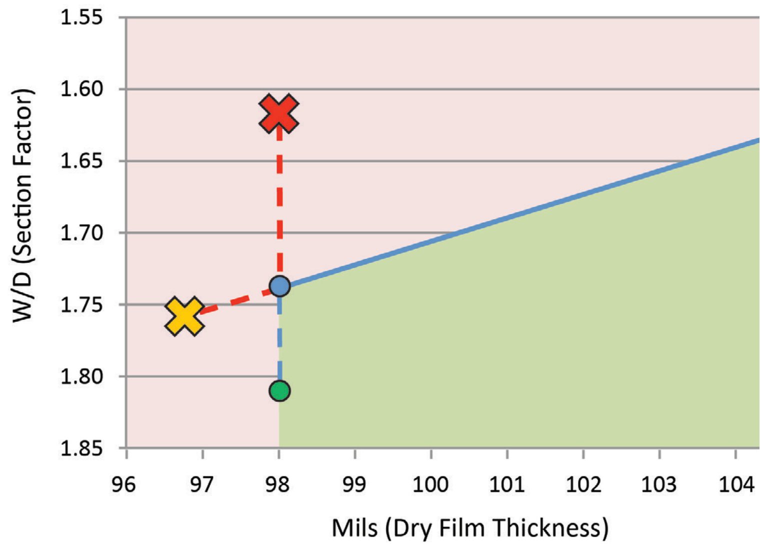
Conclusion

When a steel-framed building catches fire, the fate of the structure—and the safety of occupants in, on, or around the structure—may come down to a layer of passive fire-protection coatings. In order to ensure the steel has the appropriate fire-resistance rating, engineers and architects must specify the intumescent coating DFT for each steel section. This specification should only rely on UL's published data, and not extrapolated data, to avoid the risk of applying too little or too much coating material. As such, UL is reminding coating suppliers, subcontractors, structural engineers, architects, and fire engineers to avoid extrapolating its data. UL first published an updated position on the issue in 2014 and added language to the ANSI/UL 263 and ASTM E119 specification in 2017. Last October, UL said extrapolated thicknesses beyond published UL designs are not considered acceptable without additional supporting test data and are therefore outside the scope of the UL certification.

Intumescent coatings are universally accepted for passive fire protection applications. However, when UL data is unavailable for a particular structural steel section, one must be aware of the recommendations to employ an intumescent coating thickness based on extrapolated data. It is advisable to follow UL guidelines and find a safe, workable alternative to arrive at the proper DFT specifications. In many cases, advanced fire engineering design principles can help to resolve issues associated with unlisted steel sections. However, the applicator and the manufacturer must make the ultimate decision on the applied DFT for a given steel section.

Intumescent coatings are not the only option for passive fire protection. Alternative building systems also include cementitious fire-resistive materials and fire-rated boards, either of which may be used in combination with intumescent coatings. These passive materials work differently than coatings by providing a physical barrier of cement or gypsum, respectively, to slow down the transfer of heat to the steel substrate that is underneath the materials. These materials present their own specification challenges. **CS**

Figure 7



This graph shows the heaviest steel section listed in ANSI/UL 263 (1.74 W/D) and the corresponding intumescent coating DFT required for a two-hour fire rating for smaller-sized steel members. Again, any DFT on the blue line or within the green areas below is acceptable. It is unacceptable to extrapolate data in the direction of the red or orange Xs.

Note

[1] For more information, visit productspec.ul.com/document.php?id=BXUV.GuideInfo; http://database.ul.com/cgi-bin/XYV/template/LISEXT/1FRAME/showpage.html?name=BXUV.GuideInfo&ccnshorttitle=Fire-resistance+Ratings+-+ANSI/UL+263&objid=1074327030&cfgid=1073741.

ADDITIONAL **INFORMATION**

Author

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Abstract

Structural steel under load can quickly lose strength in a fire, eventually reaching a critical failure temperature at which the steel, and part or all of the building, could collapse. Intumescent coatings help to prevent such catastrophic losses by providing a theoretical amount of time for the coated steel to resist fire. This time period or fire-resistance rating is based on the applied thickness of the coatings that varies depending on the size, weight, and heat exposure of each structural steel member.

Every possible steel section size and coating thickness guideline is not listed in the American National Standards Institute/Underwriters Laboratories (ANSI/UL) 263, *Standard for Fire Tests of Building Construction and Materials*. Sometimes, manufacturers extrapolate the available data to recommend an intumescent coating thickness. However, this is a potentially hazardous practice, and UL has said it is unsafe to make assumptions about a coating's thickness.

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Fire-resistance rating
Intumescent coatings
Passive fire protection
Structural steel

Fire Protection

Part Two

Smoke Doors versus Fire Doors: What is the difference?

BY LORI GREENE, AHC/CDC, CCPR, FDAI, FDHI

SMOKE DOORS VERSUS FIRE DOORS
What is the difference?

Photos courtesy Allegion

ARCHITECTS OFTEN USE THE PHRASE '20-MINUTE SMOKE DOOR,' AND IT IS COMMON TO SEE A DOOR SCHEDULE CALLING FOR THESE PRODUCTS. TO PROPERLY SPECIFY DOORS, FRAMES, AND HARDWARE FOR FIRE DOOR AND SMOKE DOOR ASSEMBLIES, IT IS CRITICAL THE PROPER TERMINOLOGY IS USED AND THE CORRECT CODE REQUIREMENTS ARE REFERENCED. FIRE DOORS, EVEN THE 20-MINUTE ASSEMBLIES, ARE SUBJECT TO COMPLETELY DIFFERENT CRITERIA THAN THE NON-FIRE-RATED SMOKE DOORS.

For example, for a 20-minute fire door on an architect's door schedule, the hardware specifier will designate a labeled door and frame, positive-latching hardware, a door closer or automatic-closing device, and gasketing. All of the hardware will have to be listed or labeled for use on a fire door assembly, and any glazing in the door or sidelight would be subject to the limitations of the manufacturer's listings.

If this door is in a hospital corridor smoke partition and leads to a patient room, and the building is protected throughout by an automatic sprinkler system, the current model codes do not require a 20-minute fire door assembly. The door, frame, and hardware do not have to be listed or labeled for use as components of a fire door assembly. Additionally, the door is not required to be self- or automatic-closing. Vision panels are not limited in size and need not have fire-protection-rated glazing.

The *International Building Code* (*IBC*) and National Fire Protection Association (NFPA) 101, *Life Safety Code,* do mandate positive-

> In most cases, the hardware requirements for swinging fire door assemblies are the same regardless of the rating of the assembly. For example, fire doors must have positive-latching hardware, and closing devices.

A common location for 20-minute fire door assemblies is a residential corridor leading to dwelling or sleeping units.

latching hardware for these doors in hospital corridors. Further, the clearance around the door must be limited, but other requirements associated with 20-minute doors do not apply. Specifying 20-minute assemblies where they are not mandated by code would result in added expense and could also affect the functionality of the opening. For example, a 20-minute fire door would require a door closer, an inconvenience for patients and staff. The alternative, an automatic-closing device that holds the door open and closes the door on actuation of the fire alarm system, would be very expensive, especially when multiplied by the total number of patient rooms.

Fire doors

In the United States, common ratings of fire door assemblies are three hours, 90, 60, 45, or 20 minutes. These opening protectives are typically installed in walls that also bear a fire rating, equal to or greater the walls and opening protectives are designed to deter the spread of smoke, flames, and toxic gases during a fire event for the specified amount of time. Fire door assemblies are also required to meet the requirements of NFPA 80, *Standard for Fire Doors and Other Opening Protectives.*

In most cases, the hardware requirements for swinging fire door assemblies are the same regardless of the rating of the assembly. For example (with a few exceptions), fire doors must have positive-latching hardware, as well as closing devices ensuring the doors are closed and latched during a fire event. Generally, smoke doors without a fire rating do not have the same hardware requirements. Specifying a '20-minute smoke door' can cause confusion, and scheduling a 20-minute fire door where only a smoke door is needed will likely result in hardware that is not required for that location.

IBC mandates fire door assemblies that have a 20-minute rating in three locations:

- corridor walls required to be fire partitions with a one-hour or one-half-hour rating;
- fire partitions with a one-half-hour rating; and
- smoke barriers with a one-hour rating.

When the one-hour smoke barrier is in a health care facility, *IBC* and NFPA 101 include an exception for double-egress pairs.

A common question is why the rating of the fire door assembly (*e.g.* 20 minutes) is less than the rating of the wall (*e.g.* half-an-hour or one hour). For most applications, the fire door assembly is tested for a shorter period than the wall because of the increased fuel load that is likely to be present adjacent to the wall. A swinging fire door would be unaffected by furniture or stored items that might impact the wall's performance. If a fire door is no longer in use and it is not required for egress, NFPA 80-2016 requires the opening to be filled to maintain the rating of the wall assembly.

Although smoke control is the main concern in locations where 20-minute assemblies are required, 20-minute doors are classified as fire

doors, not smoke doors. Fire-protection-rated assemblies are tested to Underwriters Laboratories (UL) 10C, *Standard for Positive Pressure Fire Tests of Door Assemblies*, or NFPA 252, *Standard Methods of Fire Tests of Door Assemblies*. Fire-resistance-rated assemblies are tested to ASTM E119, *Standard Test Methods for Fire Tests of Building Construction and Materials,* or UL 263, *Standard for Fire Tests of Building Construction and Materials*. Smoke doors are not tested to these standards.

Smoke infiltration

UL 1784, *Standard for Air Leakage Tests of Door Assemblies and Other Opening Protectives,* applies to some fire doors and smoke doors. For example, when a fire door assembly serves as a smoke and draft control assembly, *IBC* requires the assembly to be tested in accordance with UL 1784. During this test, "the air leakage rate of the door assembly shall not exceed 3.0 cubic feet per minute per square foot [0.015424 $m^3/(s \cdot m^2)$] of door opening at 0.10 inch (24.9 Pa) of water for both the ambient temperature test and the elevated temperature exposure test."

Where air infiltration is limited to this level, it is difficult or nearly impossible to achieve these values without gasketing at the head, jambs, and meeting stiles. In most locations, a door bottom or sweep is unnecessary to limit the air leakage to the level stated in the model codes. During the UL 1784 test, the area that is at the bottom 152 mm (6 in.) of the door assembly is covered to isolate the measurement of air leakage at the head and jambs, as the leakage at the bottom of the door is of less concern. Where the code specifically states the door assembly must be tested without the bottom sealed during the test, a door bottom or sweep must be used both during the test and on the final assembly installed in the field.

If a fire door or smoke door assembly is required to limit the air leakage when tested to UL 1784, the gasketing products must be listed for this purpose and will be indicated as such in the manufacturer's catalogs. These doors will typically have an 'S Label,' which says the assembly meets the requirement when classified gasketing is installed. In addition to the model codes, the requirement for testing in accordance with UL 1784 (and the same allowable maximum) is included in NFPA 105, *Standard for Smoke Door Assemblies and Other Opening Protectives*, which make it applicable to doors that are required to comply with this standard.

Smoke doors

The main source of confusion regarding smoke doors is there are multiple locations where these

Current model codes do not require double-egress pairs in health care smoke barriers to be fire door assemblies, or to have positive-latching hardware or gasketing.

Photos courtesy Allegion/stock.adobe.com

When in doubt, it is important to contact a local architectural openings consultant, or the authority having jurisdiction (AHJ) for help.

doors are mandated by model codes, and the requirements may vary depending on whether the assembly is installed in a smoke partition, a smoke barrier, or a wall that is required to limit the transfer of smoke. Smoke doors may be required to comply with NFPA 105, but only where this is mandated by the applicable model code. Here are some examples from *IBC*.

Doors in smoke partitions

IBC prohibits louvers in doors installed in smoke partitions and requires installation to be in accordance with NFPA 105. However, the rest of the requirements for doors in smoke partitions are dependent on what is mandated by other sections of the code. For example, some sections may require doors in smoke partitions to be self- or automatic-closing by smoke detection, or to have limited air leakage when tested to UL 1784.

Each section that requires smoke partitions (*e.g.* care suite separations, elevator lobbies) must be referenced to determine the smoke door assembly requirements. Elevator lobby doors in smoke partitions are required to be self- or automatic-closing, but doors in care suite separations in Group I-2 such as hospitals and nursing homes are not. Unlike elevator lobby doors, smoke doors in care suite separations do not require gasketing. Both of these locations require positive-latching hardware. There are also prescriptive requirements in *IBC* regarding atrium doors in smoke partitions. It is critical to check the code section applicable to the doors in question.

Doors in smoke barriers

In underground buildings and in Use Group I-3 (*e.g.* detention/correctional centers), *IBC* requires doors in smoke barriers to be fire door assemblies that meet the requirements of NFPA 80. However, both the *IBC* and NFPA 101 include exceptions for smoke barrier doors in health care facilities (*e.g. IBC*: Group I-1, Condition 2, Group I-2, and ambulatory care facilities).

In these health care occupancies, double-egress door pairs that are installed in cross-corridor smoke barriers are not required to be fire door assemblies, and positive-latching door hardware is not mandated by the model codes. In Group I-1, Condition 2, the doors assemblies may be either self- or automatic-closing. Past editions of *IBC* have required Group I-2 and ambulatory care facilities to have doors that are automatic-closing by smoke detection, but the 2018 edition has changed this section slightly. It appears that self-closing doors would also be allowed where this edition of the *IBC* has been adopted.

Non-fire-rated doors in smoke barriers are not required to have limited air infiltration per UL 1784, but these doors must have astragals or rabbets at the meeting edges, and be close-fitting within operational tolerances. The maximum allowable undercut is 19 mm (¾ in.), and the doors must not have louvers or grilles. Frame stops are required at the head and jambs, and vision panels must be fire-protection-rated.

Doors required to provide an effective barrier to limit the transfer of smoke

These doors are typically smoke partition corridor doors in *IBC* Use Group I-2 (foster care facilities, detoxification centers, hospitals, nursing homes, and psychiatric hospitals), or in NFPA 101 health care occupancies. This could include patient and exam rooms, and other spaces that are not part of a vertical opening/exit (stair or shaft), and where doors do not lead to incidental use areas that requiring a fire rating. As mentioned in the example at the beginning of this article, for non-fire-rated corridor doors in these health care facilities, *IBC* and NFPA 101 do not require door closers or gasketing, but mandate positive-latching hardware.

Inspections

Both NFPA 80 and NFPA 105 include detailed requirements for inspections of fire door and smoke door assemblies. Since the 2009 editions of the model codes, the inspection requirements have been adopted by reference to these standards. Beginning with the 2007 edition of NFPA 80, fire door assemblies are required to be inspected at least annually, but the 2013 editions of NFPA 80 and 105 mandate additional inspections of fire door and smoke door assemblies after installation and maintenance work.

These inspections help ensure the doors, frames, and hardware are installed correctly and maintained properly so they function as designed and tested throughout the life of the building. The initial post-installation check should be included in the project specification in order to avoid delays during the final occupancy inspections. It is pertinent to note, the inspection requirements do not apply to doors not required to comply with NFPA 80 or NFPA 105, such as patient-room doors in a health care corridor smoke partitions.

Conclusion

When determining the requirements for door assemblies offering protection against the spread of fire or smoke, the first step is to know whether the assembly is required to be a fire door assembly complying with NFPA 80 or a smoke door in compliance with NFPA 105, or an assembly required to meet specific requirements mentioned in model codes. This will establish the requirements for labels, positive latching, self- or automatic-closing devices, glazing, and periodic inspections. If the opening is required to have limited airflow when tested to UL 1784, this will dictate whether gasketing is needed. When in doubt, it is important to contact a local architectural openings consultant, or the authority having jurisdiction (AHJ) for help. **CS**

Requirements for doors in smoke partitions vary depending on the location of the smoke partition. For example, if it surrounds an elevator lobby or separates a care suite.

ADDITIONAL **INFORMATION**

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Abstract

The code requirements for fire doors and smoke doors are often confusing. Is a 20-minute door a fire or a smoke assembly? Does a door in a smoke partition need to be self-closing and self-latching? Getting a code-compliant assembly starts with using the correct terminology. This article has summarized the requirements for fire doors and smoke doors, as determined by the *International Building Code (IBC)* and National Fire Protection Association (NFPA) 101, *Life Safety Code*.

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08 71 00–Door Hardware

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B2050–Exterior Doors and Grilles
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Egress
Fire door
Glazing
NFPA
Smoke door

Fire Protection

Part Three

Ensuring Occupant Comfort and Safety with Smoke Vents

BY THOMAS RENNER

Ensuring Occupant Comfort and **Safety with Smoke Vents**

Photos courtesy Hale Centre Theatre

THE ARCHITECTS RESPONSIBLE FOR DESIGNING A STATE-OF-THE-ART THEATER IN UTAH BETWEEN 2015 AND 2017 FACED A UNIQUE CHALLENGE IN TRYING TO LIMIT NOISE INTRUSION. AN ADJACENT INTERSTATE AND PLANES ARRIVING AND DEPARTING FROM A NEARBY AIRPORT MADE FOR NOISY NEIGHBORS FOR PATRONS ATTENDING EVENTS AT THE HALE CENTRE THEATRE IN THE CITY OF SANDY.[1]

"The sound issue was pretty intense," said architect Lyle Beecher. "We knew noise was going to be an issue."

Beecher's firm, Utah-based Beecher Walker, designed the $80-million Hale Centre Theatre, which opened in November 2017. A critical element of the solution for Beecher and his team was the installation of 20 acoustical smoke vents to guard against noise intrusion. The vents feature a sound transmission class (STC) rating of 46. This figure denotes how well a building partition attenuates airborne sound and roughly reflects the decibel reduction in noise a building component can provide.

STC ratings are included on the doors, windows, partitions, and even floors. They are generally much lower than 46 on doors and windows—a hollow door can have an STC rating of around 20 to 25, while windows are usually in the STC 26 to 28 range. Most smoke vents that are not acoustically rated have an STC value of 30 or less. The vents used at the Hale Centre Theatre include 75-mm (3-in.) thick fiberglass insulation, exceeding the 25-mm (1-in.) thickness of many smoke vents and helping contribute to their acoustic performance.

Construction materials limiting noise are particularly important at theaters and other performance venues, where interference from external forces can ruin events for guests who sometimes pay exorbitant prices to watch shows.

"In this instance, there are even helicopters that fly directly overhead," Beecher said. "The air traffic

Acoustic smoke vents were installed in the construction of the Hale Centre Theatre in Utah.

was one of the primary concerns we had when we discussed which roofing components to use. Those acoustical smoke vents are the only thing stopping noise from the outside at the loading level. We could not have any noise infiltrating the building."

The smoke vents are also supported by other acoustical elements, including 0.6-m (2-ft) thick concrete walls with carpeting installed. Additionally, the door bottoms included acoustical treatments.

The acoustical smoke vents atop the Hale Centre Theatre do more than limit noise intrusion. They are also a crucial safety feature in a venue that can host more than 1300 guests in its two auditoriums. Vents enable the escape of smoke, heat, and gases in a burning building.

"Vents will allow for the removal of heat and smoke and potentially slow the spread of fire," said Steve Martin, battalion chief for the Columbus Fire Department in Ohio. "They will also permit firefighters to see and enter the building to possibly extinguish the fire early, preventing the entire building from becoming a loss."

The vents used at the Hale Centre Theatre include gas spring operators that open the covers in snow and wind. They also have built-in dampers to ensure smooth opening and eliminate the possibility of operational, roofing, or structural damage.

"The vents solved a tremendous challenge for us," Beecher said. "The most important thing is to make sure people are safe. Those vents create a passive smoke-ventilation system that leads up through the loading level. It keeps the smoke out of the theater so everyone can exit safely."

The scoop on smoke vents

Regulations for smoke vents in commercial structures are outlined in National Fire Protection Association (NFPA) 204, *Standard for Smoke and Heat Venting*. This standard provides calculations to determine the required dimensions and spacing of smoke and heat vents. The number of smoke vents depends on the size of the building or area protected, the height of the ceilings, and the depth of the expected smoke layer, according to Robert Solomon, PE, division director for NFPA. The number of smoke vents required is also determined by local building and fire codes and the type of commercial structure.

In one example, fire destroyed a building owned by Dick Cold Storage, a business in Columbus, in 2016. More than 400 firefighters rushed to the blaze, but the building did not have smoke vents.

Without smoke vents, Martin and his team made the decision to let the fire burn itself out once they knew no one was inside. The scene was simply too dangerous to allow firefighters to enter the building. It was not until 18 hours later the fire was finally extinguished. Smoke vents would not have prevented the fire, but they would have allowed firefighters to be more aggressive in tackling the blaze. The building may not have been destroyed if smoke vents had been in place.

"Two of the biggest challenges we face in fighting any fire are heat and smoke. The heat of the fire radiates on everything surrounding it, causing the flames to spread and creating rapid degradation of structural elements," said Martin. "Buildings that do not lend themselves to ventilation, such as cold-storage buildings, are especially dangerous to firefighters. If there is no known life-safety issue, firefighters will retreat to a defensive position and fight the fire from outside the building instead of going inside."

The new Dick Cold Storage building has 18 smoke vents spaced out across 10,637 m^2 (114,500 sf). The Hale Centre Theatre, by contrast, required 20 acoustical vents over 12,356 m^2 (133,000 sf). The activation requirements were the same in both applications.

"A cold-storage facility may have a greater fuel load than a theater, which correlates to a design with a higher expected heat release rate, greater temperature outputs, and an increased smoke production rate. It may require larger, more closely spaced vents," Solomon said. "The design influences the number, size, spacing, and activation requirements. The theater scenario is largely directed at stages and the vents are essentially a key occupant life-safety feature."

Without vents to exhaust it, smoke is contained within a building, explained William Koffel, PE, FSFPE, president of the fire-protection engineering firm, Koffel Associates.

"This could impact egress, cause increased property damage, and hinder the efforts of first responders," he said.

When a fire occurs, if the incident commander determines ventilation is necessary and appropriate, firefighters will manually cut holes in the roof to serve as roof vents. However, many structures (such as the cold-storage building) are light steel construction and there may be concerns with the integrity of the roof upon which the firefighters need to work.

How smoke vents work

Underwriters Laboratories (UL)-listed smoke vents are required to open automatically and be equipped with both an interior and exterior pull release allowing firefighters to open them manually. Automatic smoke vents can be actuated either by fusible links or electrically via a heat or smoke detector or sprinkler water flow switch.

Some automatic smoke vents include a positive hold/release mechanism ensuring reliable vent operation when a fire occurs. The vent automatically

Cold-storage facility designer, Tippmann Innovation, designed the building shown in this image with 18 smoke vents.

Photos © Ryan Leasure

releases upon the melting of a UL-listed 74 C (165 F) fusible link. The curb-mounted fusible link housing allows the latch to be quickly and easily reset from the roof level.

It is also critical smoke vents open in snow and wind. If a fire occurs in inclement weather, they must operate as planned.

"NFPA 204 requires opening mechanisms to remain free and clear and undergo periodic inspection, testing, and maintenance," Solomon said. "Additionally, NFPA 204 requires automatic vents to be fail-open, meaning if there is a failure in the mechanism of the vent, it will automatically open."

Solomon added the expanded use and installation of roof-mounted solar photovoltaic (PV) arrays has the potential to impede the operation of vents.

"Anytime vents and PV systems are being installed together, including circumstances where the array is being installed on an existing building with vents, great care must be taken to ensure the array will not prevent the vent from operating or obscuring the vent area," he said.

To ensure the two systems function cohesively, design/construction professionals should ensure they are familiar with the dimensions for both vents and the PV array. When the building is being designed, they should also ensure they allow enough space for all components to work properly. Architects will have to confirm the vents are spaced out over an equal distance across the roof.

Smoke vents must have both interior and exterior pull releases and open automatically.

After a fire destroyed its previous building, Dick Cold Storage in Columbus, Ohio, rebuilt its business and made smoke vents an important component of the new structure.

Know the standard

Among the most important sections in NFPA 204 is one requiring vents to be designed so they can be inspected visually. Section 5.2.4, "Vent Design Constraints," states the supporting structure and means of actuation must be designed to allow this.

"This is very important as too often, mechanical equipment is installed in a manner that makes regular inspection, testing, and maintenance very difficult or infeasible," said Solomon. "The vent layout as presented on the contract plans is also critical. The vent size, arrangement, and geometry are often based around the location of draft curtains and intended storage configurations. Deviations for the vent location may impact their effectiveness. Any changes from the original design need to be carefully evaluated."

The decision to provide smoke and heat vents should be made by an engineer, as there are cases in which their inclusion is not appropriate.

"Vents should not be provided if the building is equipped with an early suppression, fast response (ESFR) sprinkler system or if an alternative means of smoke ventilation is provided, such as an active smoke-control or smoke-evacuation system," Solomon said.

"The benefits of smoke and heat vents are also highly dependent on the size and geometry of the building and the expected size of the fire. They are most effective in large, open spaces with high ceilings with a significant fuel load."

Vents operate best in such spaces because large, open areas allow for the escape of smoke and gases and do not contribute to the rapid buildup of smoke within the building.

Vents versus sprinklers

Smoke vents and sprinkler systems serve different fire-protection and life-safety purposes. Sprinklers control or suppress a fire until the fire department can respond to extinguish it. Smoke vents allow for smoke and heat to leave the building, which can help increase the safe egress time for building occupants. They will also allow for increased visibility for both occupants and firefighters and reduce interior temperatures for firefighting operations.

"Proper operation of an automatic sprinkler system should result in a reduction in the amount of smoke produced," Koffel said. "There are fire scenarios, especially in storage occupancies, in which a considerable amount of smoke is still produced."

This can be mitigated with the inclusion of an appropriate number of smoke vents, which open with the melting of a link.

According to Solomon, there is also some concern vents may create a vacuum effect and bring more outside air into the building or pull a fire in the direction of a smoke vent, helping it continue to grow and spread.

"While smoke and heat vents do increase entrained air into the building, the benefits from the significant reduction of the amount of smoke and superheated gases in the space usually outweigh the possible fire growth due to the entrained air," he explained.

A critical piece of fire protection

Whether the project in question is a theater in Utah or a cold-storage building in Ohio, smoke vents can be an essential part of a fire-protection plan. Lives and businesses can be saved. Theaters, especially those as technologically sophisticated as the Hale Centre, can be susceptible to fire. Technological features introduce more elements that could cause a fire, such as wiring, increased electrical load, and electric cables.

Stage technology has become so advanced, NFPA's research affiliate, the Fire Protection Research Foundation, wrote a report in 2009 addressing fire-protective measures at theaters.[2] According to the report, "it is desirable a fire-safety curtain and roof vents are activated prior to sprinklers," and the vents should be "tied to a relatively responding rate-of-rise heat detectors, preferably ceiling mounted."

"Smoke vents were such an important part of this," Beecher said about the Hale Centre project. "We know they will operate if there is an actual fire. We needed to make sure if a fire did occur, everyone could exit safely."

Cold-storage constructor Tippmann Innovation designed a state-of-the-art facility for Dick Cold Storage, and the smoke vents give Don Dick, its CEO, peace of mind a tragedy of similar proportions will not hurt his business.

"We were surprised at how quickly the team at Tippmann Innovation was able to meet with us after the fire," said Dick. "Their combined expertise and experience allowed us to immediately begin making plans to replace our warehouse. The upgraded technologies in the new facility allow us to have peace of mind about the future growth and safety of the warehouse."

The smoke vents automatically open upon the melting of a fusible link.

In many commercial industries, smoke vents play an integral part in fire-protection plans. They can be an important piece of equipment in saving lives and protecting property. CS

Notes

[1] For more, visit www.constructionspecifier.com/utah-theater-sets-stage-groundbreaking-technology.

[2] The report is available online at www.nfpa.org/-/media/Files/News-and-Research/Archived-reports/theatre.ashx?la=en.

ADDITIONAL **INFORMATION**

Author

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Abstract

Limiting noise intrusion was a unique challenge in the design of Utah's Hale Centre Theatre. An essential part of the solution was the installation of 20 acoustical smoke vents with a sound transmission class (STC) rating of 46. Further, these vents do more than simply limit noise intrusion. They are also a key safety feature. Smoke vents allow for the escape of smoke, heat, and gases in a burning building, thereby increasing safe egress time for building occupants, improving visibility for firefighters, and potentially protecting the structure against complete destruction.

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Key Words

Division 07

Fire protection

Life safety

Noise intrusion

Smoke vents

Fire Protection

Part Four

Perimeter Fire Barrier Systems

BY TONY CRIMI, P.ENG., MASC.

Perimeter Fire Barrier Systems

Taking a team approach to fire-safe construction

All images courtesy NAIMA members

BUILDING OWNERS AND OCCUPANTS OFTEN TAKE FIRE SAFETY FOR GRANTED. THEY ASSUME THAT BUILDINGS ARE CONSTRUCTED WITH FIRE SAFETY IN MIND AND SIGNIFICANT ATTENTION HAS BEEN PAID TO BUILDING CODES. NEVERTHELESS, THERE EXISTS ONE PARTICULARLY CRITICAL JUNCTURE FREQUENTLY OVERLOOKED IN FIRE-SAFE DESIGN—THE VOID SPACE BETWEEN AN EXTERIOR CURTAIN WALL AND THE EDGE OF THE FLOOR. THIS AREA CAN BE ADDRESSED BY PERIMETER FIRE BARRIER SYSTEMS.

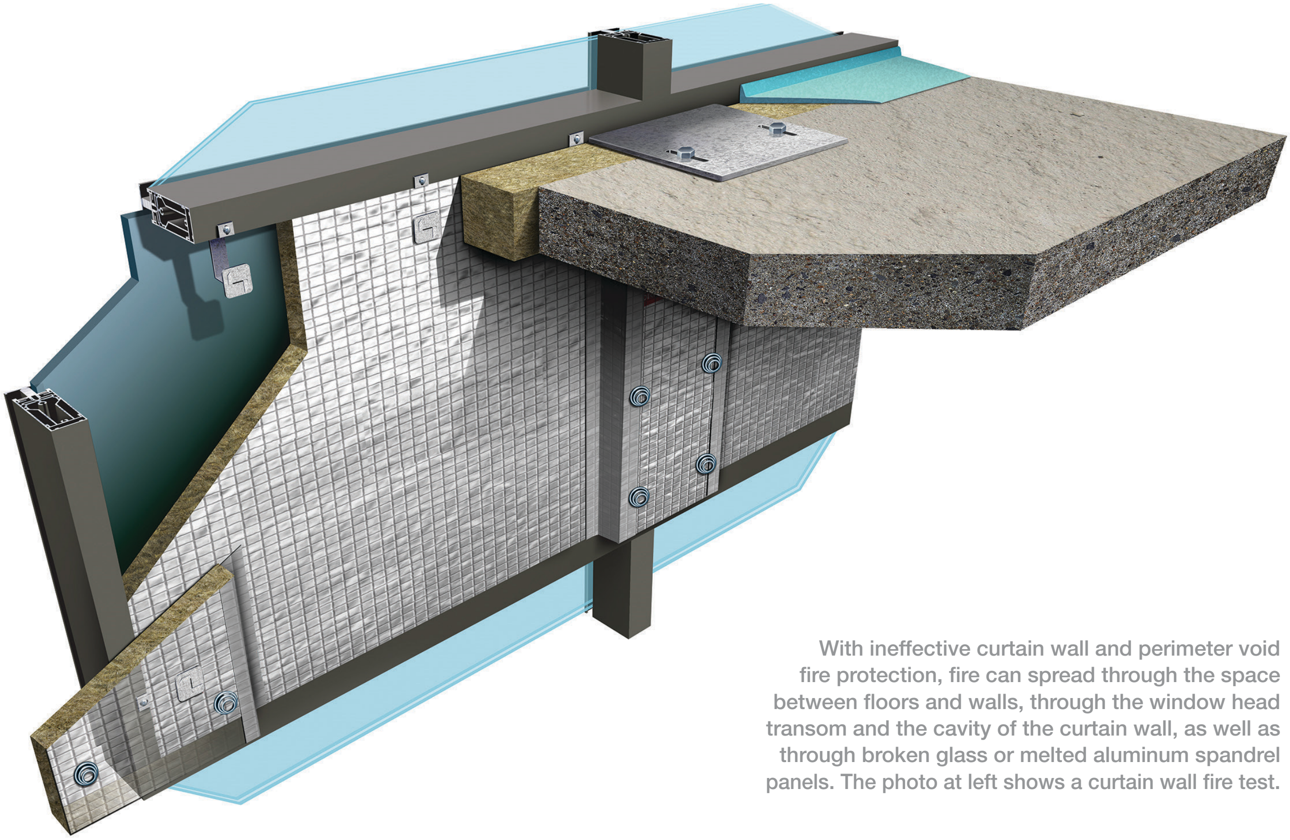
Unlike some fire safety elements addressed primarily through design and specification decisions, perimeter fire barrier systems require careful attention to design, specification, and installation to work properly. Consequently, they demand close collaboration by the architect, specifier, and general contractor to ensure each link in the chain is appropriately addressed.

This article will provide a background on the importance of perimeter fire barrier systems, as well as actionable guidance for architects, specifiers, and general contractors to ensure they deliver the level of fire safety their customers have come to expect.

Overview of fire and life safety

According to National Fire Protection Association (NFPA) statistics, there is one structure fire in the United States every 63 seconds. From 2009 to 2013, U.S. fire departments responded to an estimated average of 14,500 reported structure fires in high-rise buildings annually.[1]

During this same time period, high-rise building fires caused an annual average of 40 civilian deaths and 520 injuries, along with $154 million in direct



With ineffective curtain wall and perimeter void fire protection, fire can spread through the space between floors and walls, through the window head transom and the cavity of the curtain wall, as well as through broken glass or melted aluminum spandrel panels. The photo at left shows a curtain wall fire test.

property damage (*i.e.* not including reputation damage or litigation costs). Five property types account for three-quarters of high-rise fires:

- apartments or other multifamily housing;
- hotels;
- dormitories;
- facilities offering care for the sick; and
- office buildings.

In the early 1970s, the construction industry began to recognize fires in buildings with curtain wall construction were reaching through windows and traveling from floor to floor. Major fires in the United States and Mexico prompted suppliers, code officials, and model code groups to seek passive systems that could contain a fire at the building's perimeter. Various insulating materials were developed in an attempt to solve this challenge.

The intersection of the exterior wall and the floor assembly provides a number of different paths that may allow a fire to spread. Each of these paths is addressed by different test standards. The *International Building Code* (*IBC*) and NFPA codes establish different requirements for each potential path and addresses the means to protect the paths or to prevent the spread of fire based on each separate one.

As with all joint firestops, the intent is to confine a fire to the room of origin and prevent propagation through the floor, ceiling, or walls. With ineffective curtain wall and perimeter void fire protection, fire can spread through the space between floors and walls, through the window head transom and the cavity of the curtain wall, or through broken glass or melted aluminum spandrel panels.

Conceptually, the easiest way to look at the three paths for the fire to spread to adjacent floor levels at the exterior wall is:

- through the void spaces created between the edge of the floor and an exterior curtain wall—these are protected by perimeter fire barrier systems per ASTM E2307, *Standard Test Method for Determining Fire Resistance of Perimeter Fire Barriers Using Intermediate-scale, Multi-story Test Apparatus*, and ASTM E2393, *Standard Practice for Onsite Inspection of Installed Fire-resistive Joint Systems and Perimeter Fire Barriers*;
- via the voids or cavities within the exterior curtain wall, with fire spreading by a path within the concealed space of the exterior wall, or along the outer surface of the exterior wall—these are protected by assemblies compliant with NFPA 285, *Standard Fire Test Method for Evaluation of Fire Propagation Characteristics of Exterior Non-loadbearing Wall Assemblies Containing Combustible Components*; and

• by leapfrogging (*i.e.* spreading to the exterior and then impinging on an opening in an upper level)—this mechanism is currently addressed prescriptively, using spandrel panels or sprinkler protection, with a new ASTM test method still under development.

The perimeter fire barrier system is a unique building construction detail installed to protect against the passage of fire, hot gases, and toxic smoke through the voids between the floor slab edge and a nonrated exterior wall (usually a curtain wall). Perimeter fire barrier systems are used to resist interior propagation of fire through the gap between floor and exterior wall for a period equal to the floor's fire-resistance rating. Additionally, a building's perimeter fire barrier system should accommodate various movements, such as those induced by thermal differentials, seismicity, and wind loads.

In 1988, the 62-story First Interstate Bank Building (Los Angeles) caught fire on the 12th floor, quickly spreading to other levels after combustibles in workstations ignited. The exterior glass panels broke, providing additional oxygen, and an alternate path for the fire to travel. Flames spread through the gap in the joint between the floor/ceiling slab and the curtain wall. (The building was being retrofitted with sprinklers at the time, but the system was not operational.)

History of perimeter containment failures

There have been multiple cases showing what kind of damage can be done when fires move through improperly protected concealed spaces. In 1988, the 62-story Los Angeles tower, First Interstate Bank building, caught fire on its 12th floor. The fire spread to the 16th floor on the building after the combustibles in work stations ignited and rapidly grew. The exterior glass panels began to break, providing both additional oxygen and an alternate path for the fire to travel.

Flames spread through the gap in the joint between the floor/ceiling slab and the curtain wall. The fire vented through broken windows, first preheating combustibles on floors above before eventually igniting their contents. The

WHY MINERAL WOOL?

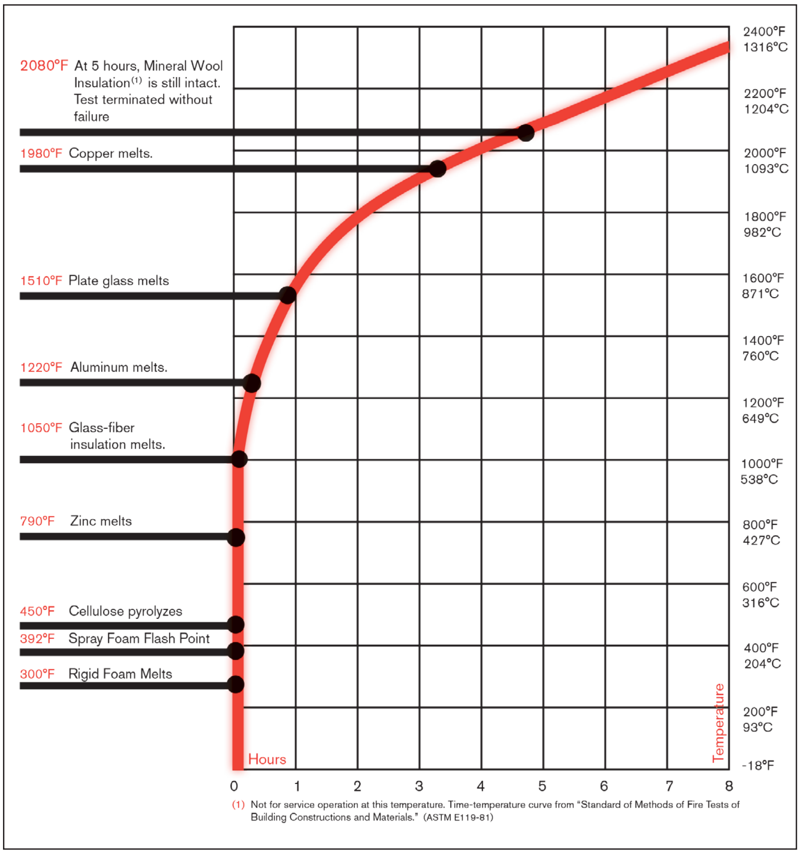
Due to the challenging nature of perimeter fire containment, mineral wool is suited to provide the necessary fire safety performance in fires. This form of manufactured vitreous fiber was initially developed in the mid-1800s by melting slag and spinning it into insulation for use in homes and industry. The term 'mineral wool' actually encompasses two products—rock wool and slag wool—that employ different raw materials in their manufacture. Rock wool is made from natural rocks like basalt or diabase, while slag wool is made primarily from iron ore blast furnace slag.

Production begins when natural rock or iron ore blast furnace slag is melted in a cupola furnace or pot. Once melted, this hot, viscous material is poured in a narrow stream onto one or more rapidly spinning wheels, which cast off droplets of molten material and creates fibers. As the material fiberizes, its surface may be coated with a binder material and/or de-dusting agent (*e.g.* mineral oil). The fiber then is collected and formed into batts or blankets for use as insulation, or baled for use in other products, such as acoustical ceiling tile, spray-applied fireproofing, and acoustical materials. Key points in the manufacturing process include:

• the cupola furnace, where the raw materials are melted;
• the blow chamber, where air (and in some cases, a binder), is sprayed over the fibers;
• a curing oven, used only in bonded-product manufacturing to bond the fiber with the binder material; and
• a cooling area.

Products made from rock and slag wool are extremely useful. They are noncombustible and do not support the growth of mildew and mold when tested in accordance with ASTM C665, *Standard Specification for Mineral-fiber Blanket Thermal Insulation for Light-frame Construction and Manufactured Housing*. Rock and slag wool fibers also are dimensionally stable and have high tensile strength. In addition to providing insulation, they absorb sound and, with a vapor retarder, help control condensation.

The physical and chemical properties of rock and slag wool are major factors in their utility. As the fibers are noncombustible and have melting temperatures in excess of 1090 C (2000 F), they are used to prevent the spread of fire. As a primary constituent of ceiling tiles and sprayed fireproofing, rock and slag wool provide fire protection as well as sound control and attenuation. The excellent thermal resistance of these wools is also a major factor in their use as commercial insulation, pipe and process insulation, insulation for ships, domestic cooking appliances, and a wide variety of other applications. CS



Mineral wool, with its high melting temperature, noncombustibility, and ability to retain strength and integrity under fire conditions, is suited to protecting openings between fire-rated floors and rated, or nonrated, exterior wall assemblies.

building was being retrofitted with sprinklers at the time, but the system was not operational, so the fire was free to spread and grow. The fire was finally contained by firefighters after 3.5 hours.

On February 12, 2005, a fire started on the 21st floor of the Windsor Tower or Torre Windsor (officially known as Edificio Windsor) in Madrid, Spain. The building was a 32-story concrete structure with a reinforced concrete central core. It was not sprinklered, and had been undergoing progressive refurbishment over a three-year period. The fire burned for 20 hours, spreading to all levels above the second floor.

At the time of construction, the Spanish building code did not require perimeter firestopping or perimeter columns and internal steel beams to be fire-protected. As a result, the original existing steelwork was left unprotected and the gap between the original cladding and floor slabs was not firestopped. In fact, these weak links in the fire protection of the building were being rectified in the refurbishment project at the time of the fire. Since the building adopted the 'open-plan' floor concept, effectively, the fire compartmentation could only be floor-by-floor (about 40 x 25 m [131 x 82 ft]). However, the lack of perimeter fire barriers in floor openings and between the original cladding and the floor slabs led to a failure of the vertical compartmentation, and the complete collapse of the building.

The challenges

A curtain-wall-clad building is a multistory structure having exterior walls that are not part of the loadbearing structure. As floor slabs are supported by interior beams and columns, there is a perimeter void or gap, typically ranging from 25 to 200 mm (1 to 8 in.), between each floor slab and the exterior curtain wall. Outside walls may be constructed using one of several materials, including glazing, light-gage metals, and gypsum wallboard.

The performance of a curtain wall during a building fire, or fire test, depends on the assembly being installed, but nonrated wall system performance significantly varies. Perimeter voids are generally hidden from view after construction. Once installed, these construction gaps are rarely inspected or re-evaluated unless renovations are made. They must be sealed to prevent spread of flames, smoke, and toxic gases in the event of a fire.

As mentioned, the intent with joint and perimeter firestopping is to confine a fire in the room of origin, preventing its propagation through the floor, ceiling, or walls. Mineral wool, with its high melting temperature, noncombustibility, and ability to retain its strength and integrity under fire conditions, is suited to protecting openings between fire-rated floors and rated or nonrated exterior wall assemblies. (For more, see "Why Mineral Wool?," page 27.)

Some insulation materials, such as foamed plastics, melt or burn at levels far below the potential temperature of a structure fire. Flames inside a building can melt aluminum and copper, and cause steel studs and panels to buckle. The loss of these structural elements allows fire to escape quickly up the outside walls. Properly installed perimeter fire barrier systems, using mineral wool insulation, have demonstrated their ability to remain in place longer, and can prevent the passage of flame and hot gases between adjacent stories of a building.

> When there is ineffective curtain wall and perimeter void protection, a fire can spread through the space between floors and walls, and the window head transom and the cavity of the curtain wall, as well as through broken glass or around melted aluminum spandrel panels.

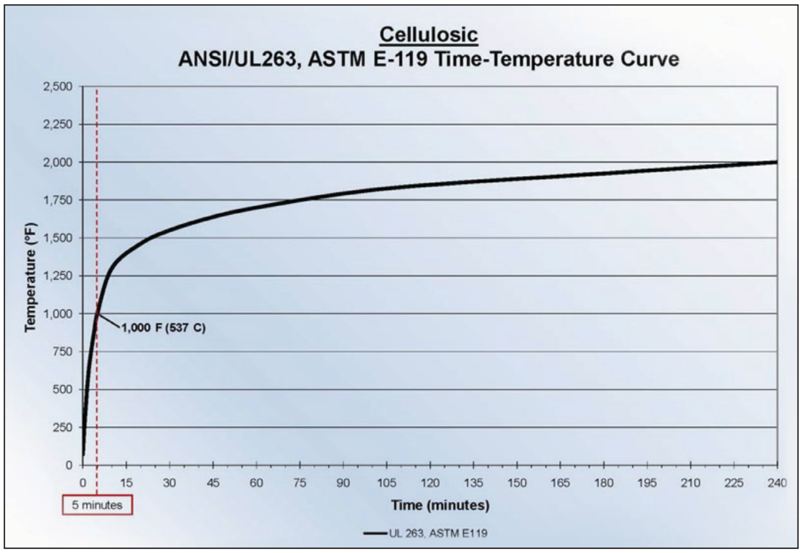
Real fire experience has shown when there is ineffective curtain wall and perimeter void protection, a fire can spread through the space between floors and walls, and the window head transom and the cavity of the curtain wall, as well as through broken glass or around melted aluminum spandrel panels.

As a result, work began on the development of materials and systems to prevent fires from spreading through unprotected joints around the perimeter of floors. Part of the subsequent success of high-rise buildings is due to their perimeter fire containment systems. At every location where two components (*e.g.* steel beams or floor slabs) are located, mineral wool installed as a part of perimeter fire barrier systems is the key contributor that provides the critical fire containment.

Evolution of ASTM E2307

Curtain wall design became common in commercial construction over the past 40 years, but there were no consensus fire test standards or testing procedures for fire protection of exterior curtain walls and floor-to-wall perimeter voids until 2004. The legacy model codes included only cursory mention of this building issue, so architects, designers, contractors, and code officials often adopted untested and uncertain solutions. Later, more effective products were developed and tested for curtain wall fire protection in accordance with ASTM E119, *Standard Test Methods for Fire Tests of Building Construction and Materials.* However, because that standard does not specifically address these unique construction joints, codes only partially addressed the fire risk.

In 2004, ASTM E2307 was developed. Evaluating the interface between a fire-resistance-rated horizontal assembly and an exterior curtain wall, this test method is used to measure and describe the response of materials, products, or assemblies to heat and flame under controlled conditions. However, it does not by itself incorporate all factors required for the fire-hazard or fire-risk assessment of the materials, products, or assemblies under actual fire conditions, using a test structure called the Intermediate-scale, Multi-story Test Apparatus (ISMA).



ASTM E119 fire exposure temperatures are based on a cellulosic time–temperature curve developed in the early 1900s.

The ISMA test simulates fire exposure in a high-rise structure where, as the fire intensifies and positive pressure builds, a fire-induced window break occurs, allowing oxygen to feed the flames. The method is meant to simulate a fire in a post-flashover condition in a compartment venting to the exterior.

The provisions of ASTM E2307 are intended to restrict the interior vertical passage of flame and hot gases from one floor to another at the location where the floor intersects the exterior wall assembly. Its use is mandated by U.S. building codes, thereby requiring the protection of openings between a floor and an exterior wall assembly to provide the same fire performance as that required for the floor.

U.S. building codes

Since their 2006 editions, both *IBC* and NFPA 5000, *Building Construction and Safety Code*, have referenced ASTM E2307 as a means of

In 2005, a fire started on the 21st floor of Torre Windsor in Madrid. The 32-story concrete building, with a reinforced concrete central core, was not sprinklered, and had been undergoing progressive refurbishment over a three-year period. At the time, the Spanish building code did not require perimeter firestopping or perimeter columns and internal steel beams to be fire-protected.

providing perimeter fire barrier joint protection installed in the space between an exterior wall assembly and a floor assembly. The 2015 *IBC* Section 715.4 requires where fire-resistance-rated floor or floor/ceiling assemblies are installed, voids that are created at the intersection of the exterior curtain wall assemblies and the floor assemblies be sealed with an approved system to prevent the interior spread of fire. It further requires those systems be tested in accordance with ASTM E2307 to provide an F rating for a period not less than the fire-resistance rating of the floor assembly.

A notable exception to the *IBC* requirement for ASTM E2307 is for glass curtain wall assemblies, when the vision glass extends to the finished floor level (*i.e.* full-height glass). In those cases, *IBC* alternatively permits the perimeter void to be protected with an approved material capable of preventing the passage of flame and hot gases sufficient to ignite cotton waste where subjected to ASTM E119 time-temperature fire conditions for the same duration as the fire-resistance rating of the floor assembly.

Where the joint between walls involves a non-fire-resistance-rated floor and an exterior curtain wall, there is no reason to try to maintain a fire-resistance rating with a rated joint system. However, spread of smoke is a concern, and, therefore, the code calls for a tight joint to protect the rapid spread of smoke from a floor of fire origin to other floors of the building. Consequently, *IBC* and NFPA 5000 still require where a fire-resistance-rated floor intersects with a nonrated spandrel wall, the void space must be protected by an approved joint system.

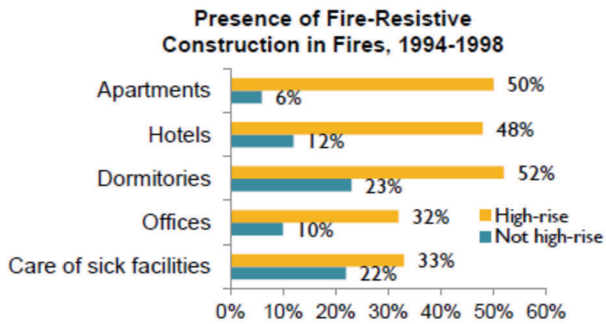
Five keys to effective perimeter fire barriers

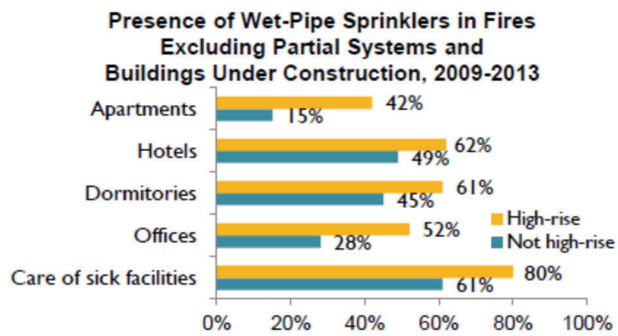
Joint systems and perimeter fire barrier systems are important elements for designers, specifiers, installers, and inspectors. These five key elements provide a simple process for a team to follow to ensure a perimeter fire barrier system is properly designed and installed.

1. Know what your local code requires.
Perhaps obvious, but this is a critical first step occasionally overlooked.

2. Specify to meet code requirements.
Once you understand the code, you can select the right products and systems. This begins by understanding the nuances of the ratings reported on labels and the manufacturer's literature.

3. Avoid improper substitutions.
This starts with the specification, but often comes down to the general contractor ensuring there are





[1] "High-rise" is defined here as 7 stories above grade. This is roughly consistent with the Life Safety Code definition of high rise as 75 feet (23 meters) in height, measured from the lowest level of fire department vehicle access to the floor of the highest occupiable story.

no inappropriate substitutions on the jobsite that run contrary to the spec and, ultimately, code. For example, spray or board foam cannot be used in place of mineral wool in a perimeter fire barrier system.

4. Install it right.
It is important to understand a building's perimeter containment system is not a single material, but rather, comprises the exterior curtain wall and the glazing, which is designed to impede the vertical spread of fire to higher floors from the room of origin in high-rise buildings. The void created between a floor and a curtain wall can range anywhere between 25 and 305 mm (1 and 12 in.) or more, which clearly requires sealing to prevent the spread of flames and products of combustion between adjacent stories.

The width of the joint, which has maximum allowable dimensions specified in the perimeter fire barrier system listings, is the distance between the edge of the framing nearest the floor and the adjacent floor edge. The void space or cavity between framing members is not considered joint space.

5. Verify the installation was done right.
Quality assurance is critical—so much so, recent editions of codes make special inspection a requirement, as discussed later in this article.

The term 'perimeter fire barrier system' refers to the assembly of materials preventing the passage of flame and hot gases at the void space between the interior surface of the wall assembly and the adjacent edge of the floor. For the purposes of ASTM E2307, the interior face is at the interior surface of the wall's framework. Tested and listed perimeter fire barrier systems do not include the interior finished wall (*e.g.* knee wall) details. This makes the systems applicable to any and all finished wall configurations. The existence of the interior wall, even if made of fire-resistant materials (*e.g.* fire-resistance-rated gypsum board), does not eliminate the need to have an appropriately tested material or system to protect the curtain wall from interior fire spread at the perimeter gap—unless that interior wall detail has been specifically tested and shown to meet the requirements of this code section.

Five rules of perimeter fire barriers

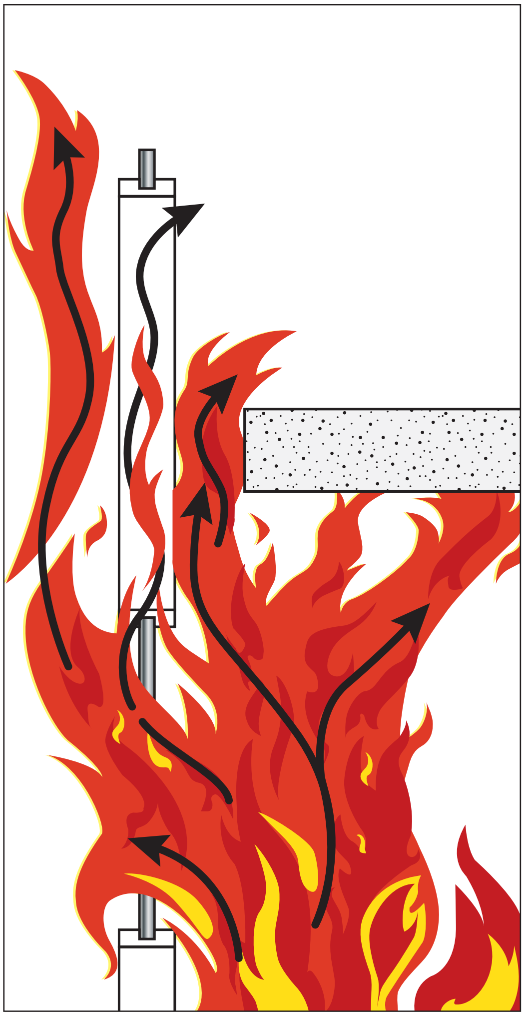
There are five basic design principles for installation of successful perimeter fire containment.

1. Install a reinforcement member or a stiffener at the safe-off area behind the spandrel insulation.
This practice prevents bowing otherwise caused by the compression-fit of the insulation.

2. Use mechanical attachments for the mineral wool spandrel insulation—adhesives and friction-fit applications do not work.
The adhesive service temperature ranges from −34 to 120 C (−30 to 250 F). Fire exposure temperatures based on ASTM E119 very quickly exceed the adhesive service temperatures, resulting in failure of the adhesive-applied attachment to hold the spandrel insulation in place.

3. Protect the mullions by using mineral wool mullion covers.
Aluminum begins to melt at 660 C (1220 F). Without the mullion protection on the fire exposure side, the aluminum mullions and transoms soften

The fire death rate per 1000 fires and the average loss per fire are generally lower in high-rise buildings than in other buildings of the same property use. The former are more likely than shorter buildings to have fire-resistive construction and wet-pipe sprinklers that help prevent fire spread. This data comes from "High-rise Building Fires Report," a November 2016 National Fire Protection Association (NFPA) report by M. Ahrens.



An illustration of the various paths a spreading fire can take.

and melt. The mechanical attachments holding the mineral wool spandrel insulation will no longer be in place, allowing the spandrel and insulation to fall out. This can result in a breach of flame and hot gases to the floor above.

4. Ensure the insulation is compression-fit (typically 25 percent, but varies by system) between the slab edge and the inside face of the spandrel insulation.
This compression-fitting of the insulation creates a seal that maintains its integrity preventing flame and hot gases from breaching through to the floor above.

5. Apply an approved smoke sealant material to the top of the insulation to provide a smoke barrier to the system.
The smoke seal is commonly spray-applied to the top of the insulation (non-fire-exposure side) forming a smoke barrier with a typical leakage rating (*i.e.* L rating) of 0. In addition, a 25-mm (1-in.) over-spray—as specified—onto the floor slab and spandrel insulation creates a continuous bond that adds to holding the perimeter insulation material in place during the fire and building movement.

Field inspection and enforcement

While proper design and testing of perimeter fire barrier joints is critical, poor installation and maintenance can lead to unacceptable real-world performance in fires. To help alleviate this, ASTM E2393 was first published in 2004. This practice covers the procedures to inspect fire-resistive joint and perimeter fire barrier systems, including methods for field verification and inspection. This standard practice provides methods by which qualified inspectors verify required fire-resistive joint systems on a project have been installed in accordance with the inspection documents.

Adoption and use of ASTM E2393 has been growing across the United States in recent years. In fact, since the publication of the 2012 *IBC*, "special inspection" is required for perimeter fire barrier systems installed in high-rise buildings, or in buildings assigned to Risk Category III or IV. Special inspection includes monitoring of materials, installation, fabrication, erection, and placement of components and connections that both require special expertise and are critical to the integrity of the building structure. Special inspections are supplemental to the typical municipal inspections required by the building department specified in *IBC*. Special inspectors monitor the materials as well as the workmanship critical to the structural and fire-resistive integrity of a given building, and bring technical expertise to the job that is not typically available in local government.

IBC clearly identifies situations in which the employment of special inspectors or special inspection agencies is mandatory. In those cases, the use of special inspectors and special inspection agencies is not discretionary.

Conclusion

The importance of balanced fire protection cannot be sufficiently stressed. The fire death rate per 1000 fires and average loss per fire are generally lower in high-rise buildings than in other buildings of the same property use. This is

Proper execution of perimeter fire barrier systems requires collaboration between architects, specifiers, general contractors, installers, and inspectors.

because high-rises are more likely to have fire-resistive construction and wet pipe sprinklers.

Perimeter fire barrier systems are an important part of effective fire-resistance-rated and smoke-resistant compartmentation systems. They have been developed for fire and life safety protection at the important curtain wall gap.

Neglecting the curtain wall/floor void means compromising the safety of people in the building. When floors are required by codes to have a fire-resistance rating, this comes with a financial cost. Improper installation or design of perimeter joint protection not only compromises fire safety, but also negates some of the building fire protection performance for which owners are paying.

Mineral wool is suited to provide the necessary fire safety performance. Its high melting temperature, coupled with dimensional stability and high tensile strength, provides the resistance needed for these critical applications. Perimeter fire barrier systems provide designs capable of maintaining continuity of the fire-resistance-rated floor to the exterior edge of the building for both rated and nonrated exterior walls. This provides vertical compartmentation for the potentially large gap areas at the edge of floor slabs, to prevent fire from spreading vertically.

Ultimately, proper execution of perimeter fire barrier systems requires collaboration between architects, specifiers, general contractors, installers, and inspectors. They need to design it according to code, specify it correctly, critically evaluate substitutions, and then install it properly. **CS**

Notes

[1] This comes from the NFPA's November 2016 publication, "High-rise Building Fires Report," by M. Ahrens. Visit www.nfpa.org/news-and-research/fire-statistics-and-reports/fire-statistics/fires-by-property-type/high-rise-building-fires.

ADDITIONAL **INFORMATION**

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Abstract

A particularly critical juncture that can be overlooked in fire safe design is the void space between an exterior curtain wall and the edge of the floor. This area is addressed by perimeter fire barrier systems, which require close collaboration by the architect, specifier, and general contractor to ensure each link in the chain is addressed appropriately. In this article, an expert from the fiberglass/rock wool/slag wool insulation world provides a background on perimeter fire barrier systems, their importance, and ways to ensure they deliver the level of fire safety required by the code.

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