HIGH-RISE BUILDINGS

Table of Contents

Page

List of Figures

List of Tables

1.0 SCOPE

This data sheet provides recommendations concerning the unique hazards associated with high-rise buildings.

1.1 Changes

October 2013. The following changes were made:

- This document has been revised to use the occupancy hazard categories as defined in Data Sheet 3-26, *Fire Protection Water Demand for Nonstorage Sprinklered Properties.*
- Added a new definition for concrete on protected steel.

2.0 LOSS PREVENTION RECOMMENDATIONS

2.1 Construction and Location

2.1.1 Ensure the fire resistance of structural and fire protection components are in accordance with the minimums in Table 1. Refer to Data Sheet 1-21, *Fire Resistance of Building Assemblies*, for further information.

Table 1. Fire-Resistance Rating Requirements for Building Elements

Building Element	*Minimum Fire-Resistance Rating (hours)*
Primary structural frame	3
Bearing walls	3
Floor construction and secondary members	2
Shafts and chases	2
Stairwell and elevator enclosures	2
Enclosures where manual firefighting equipment (standpipes, fire extinguishers, etc.) is located	2
Fire-rated, normally closed or automatic closing fire doors for openings in stairwells and enclosures	1½

2.1.2 Repair spalled or missing fireproofing. Ensure that building employees, tenants, maintenance workers, and contractors repair any fireproofing that is removed during repair or renovation of the building.

Pay particular attention to new construction, areas that have been renovated, and areas in which the fireproofing is exposed (such as basement storage areas and mechanical rooms). Inspect these areas for possible spalling prior to the installation or replacement of ceiling tiles or sheathing.

2.1.3 Include the fire resistance and performance of the concrete in the design of structural elements where high strength concrete (HSC) is proposed. Consider the behavior of HSC at elevated temperatures, and the relationship between concrete temperature and mechanical properties in the design. It is the responsibility of the designer to verify the fire resistance meets the requirements of Section 2.1.1.

2.1.4 Exterior Vertical Fire Spread

2.1.4.1 Minimize the potential for exterior vertical fire spread in buildings with one window vertically per floor by providing spandrel and window heights as follows (see Fig. 1):

A. Fixed or permanently closed windows: Ensure the distance between any floor and the bottom of the window on the next story above that floor (H) is at least 2.8 times the window height (h).

$H \geq 2.8\ h$

B. Operable windows: Ensure the distance between any floor and the bottom of the window on the next story above that floor (H) is at least 3.8 times the window height (h).

$H \geq 3.8\ h$

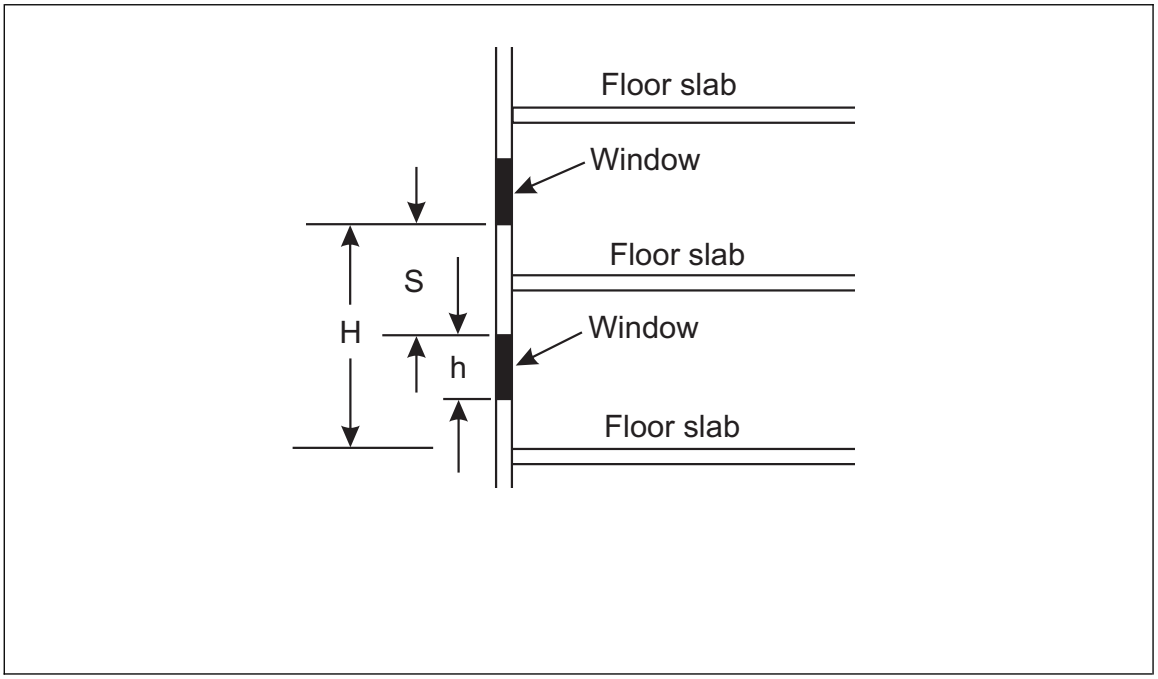

Fig. 1. Typical exterior window arrangement

2.1.4.2 Minimize the potential for exterior vertical fire spread in buildings with more than one window vertically per floor by providing window and spandrel heights as follows (see Fig. 2):

A. Fixed or permanently closed windows: Ensure the distance (H') between any floor and the top of the lower window on the floor above is at least 3.8 times the sum of the window heights (h_{TOTAL}).

$H' \geq 3.8\ h_{TOTAL}$

B. Operable windows: Ensure the distance (H') between any floor and the top of the lower window on the floor above is at least 4.8 times the sum of the window heights (h_{TOTAL}).

$h_{TOTAL} = h_1 + h_2 + ...h_n$

$H' \geq 4.8\ h_{TOTAL}$

2.1.5 Protect openings between floors found in shafts, chases and stairwells, or openings in partitions between floor areas, with FM Approved fire doors with FM Approved closers, holders and/or release devices. Ensure these are normally closed or are automatic closing fire doors having a fire rating of at least 1-½ hours (unless otherwise noted). .

2.1.6 Protect penetrations for cables, cable trays, conduits, pipes, tubes, combustion vents and exhaust vents, wires, and similar items to accommodate electrical, mechanical, plumbing, and communications systems that pass through a wall, floor, or floor/ceiling assembly constructed as a fire barrier with an FM Approved fire-stop system.

2.1.7 Ensure that fire-stopping is performed by an FM Approved Fire-Stop Contractor.

2.1.8 Where fire-stopping systems are used with the following penetrating items, limit the penetration to one floor and provide an FM Approved, F-rated through-penetration fire-stopping system with a rating of at least 1 hour, but not less than the required fire resistance rating of the fire barrier penetrated:

A. Steel, ferrous, or copper cables
B. Cable or wire with steel jackets
C. Cast-iron, steel, or copper pipes
D. Steel conduit or tubing

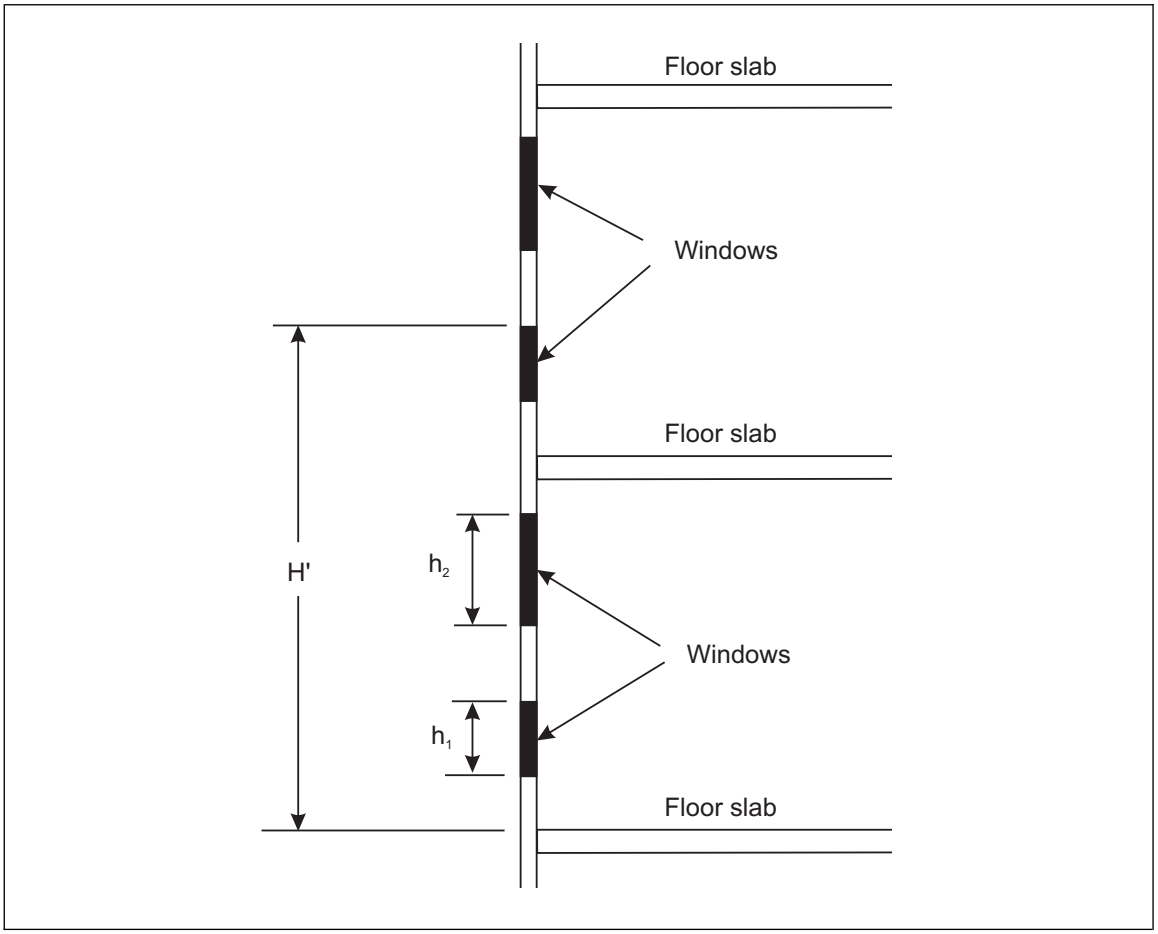

Fig. 2. More than one window per floor

2.1.9 Protect items penetrating more than one floor with an FM Approved, water leakage-rated, fire-stop system with a T-rating of at least 1 hour, but not less than the required fire resistance rating of the fire barrier penetrated.

Exception: Where penetrating items through floors are located inside a wall cavity, shaft, or chute, floor penetration fire-stop systems are not required.

2.1.10 Provide either FM Approved insulated curtain walls or noncombustible exterior walls as defined in Data Sheet 1-42, *MFLLimiting Factors*. Examples include concrete, masonry, and glass fiber insulated steel sandwich panels.

2.1.11 Seal all voids created at the intersection of the exterior curtain wall and the floor assembly with a listed, 2-hr assembly to prevent interior fire spread. Ensure exterior wall panels and frames are tightly secured at each floor to prevent outward buckling under fire exposure.

2.1.12 Provide expansion joints between floor sections with a minimum 2-hour rated FM Approved firestop assembly.

2.1.13 Ensure the fire-stopping is securely held in place and installed in accordance with its listing. Z-clips may be used to support (or to pierce) the underside of the fire-stopping and hold it in place (see Fig. 5).

2.1.14 Glass exterior cladding or curtain walls may be used as long as interior cladding, such as steel panels or gypsum board, limit the window height to within the ranges noted in Section 2.1.4.

When glass exterior cladding is used, spandrel heights must be defined by interior cladding, such as steel panels or gypsum board.

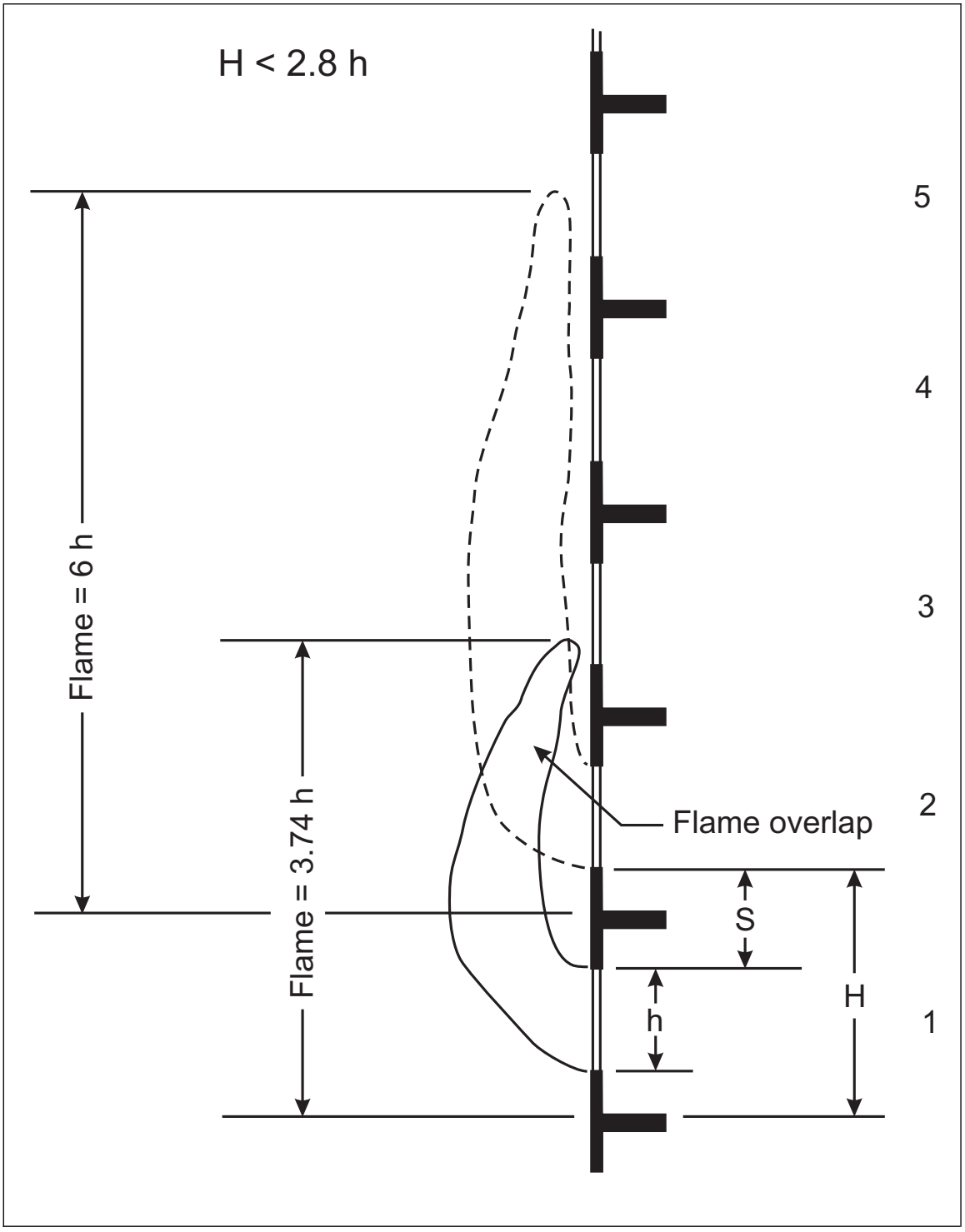

Fig. 3. Vertical flame extension when H < 2.8h

2.1.15 Ensure the glazing for glass curtain walls or windows is one of the following fire-resistant materials: 1) tempered glass, 2) laminated glass, 3) double-pane glass, 4) wired glass, 5) glass block, or 6) special glass that has passed a recognized fire test for integrity. In locations prone to tropical storms, provide windows rated for potential windborne debris (see DS 1-28, *Wind Design*.)

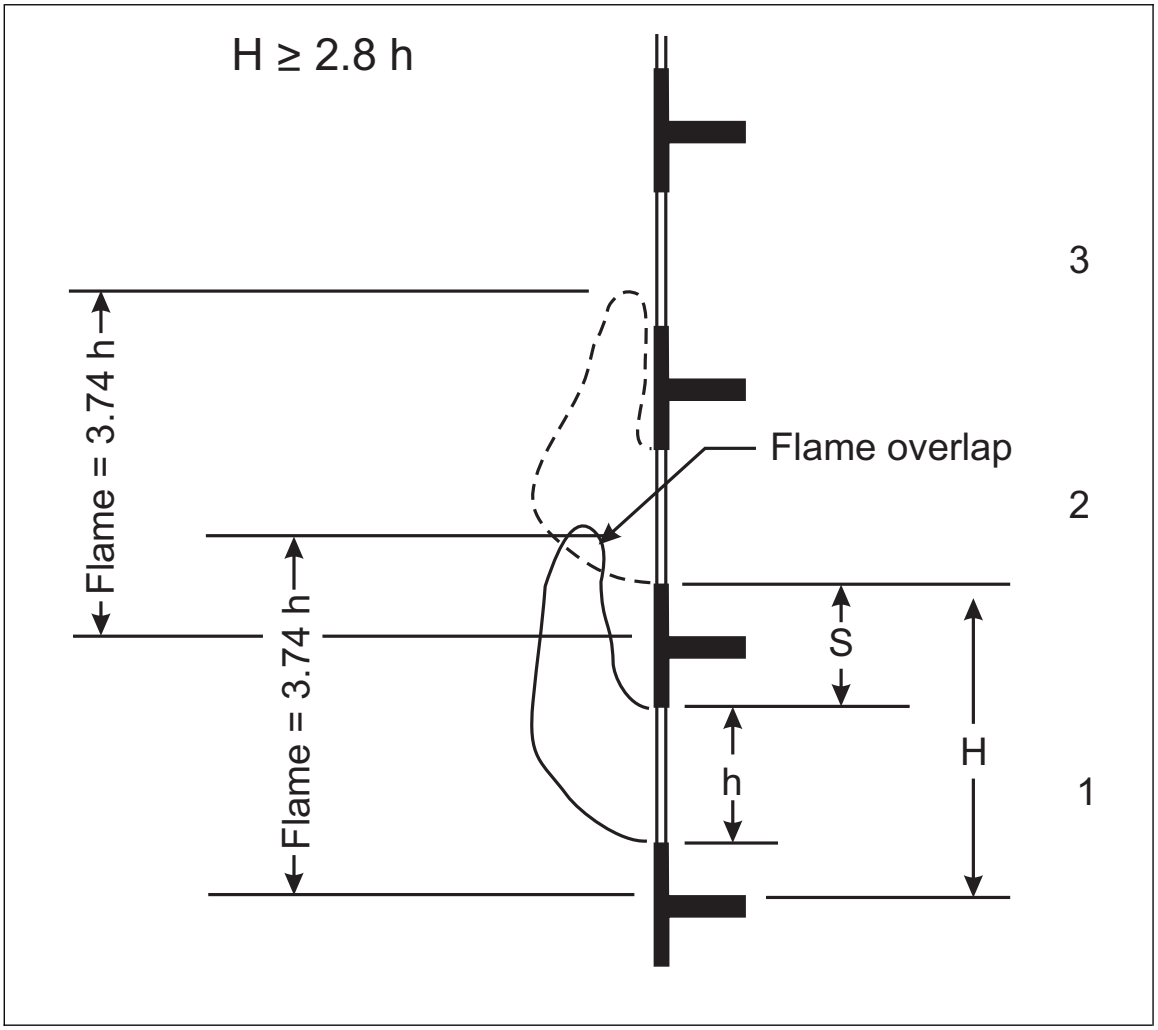

Fig. 4. Vertical flame extension when H ≥ 2.8h

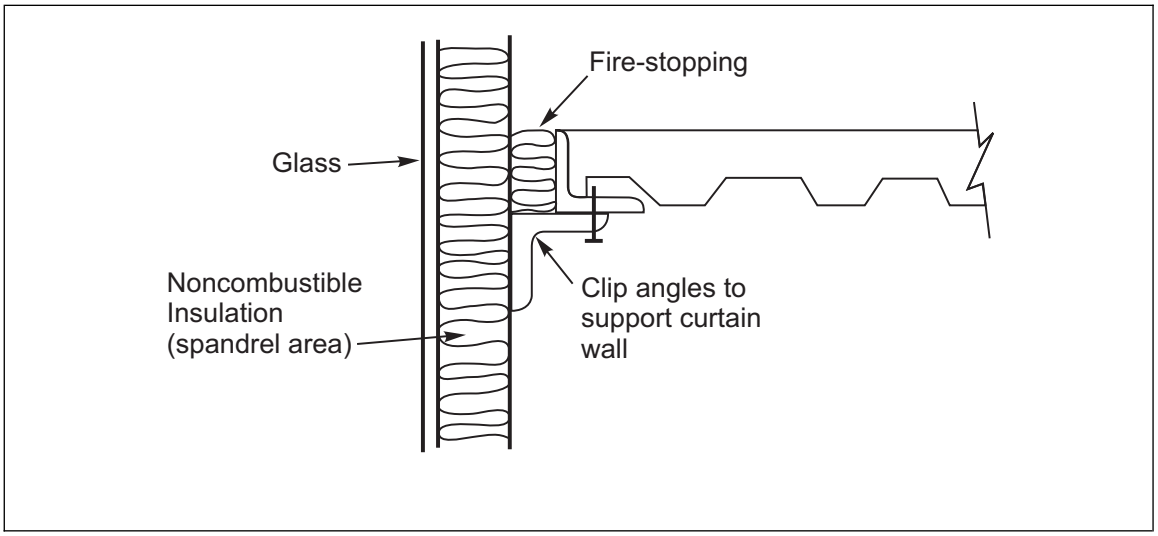

Fig. 5. Exterior glass curtain wall in metal frame; Fire-stopping friction fit in space and supported by clip angle

2.1.16 Ensure sandwich panel curtain walls using aluminum skins, combustible insulation (such as foam plastic) or no insulation are completely interrupted at each floor with a barrier of equal fire resistance to that of the floor.

2.1.17 Separate atria and other open areas that extend between multiple floors from adjacent occupied areas with a smoke-tight fire partition having a fire resistance rating of at least one hour. Protect openings with FM Approved and labeled fire doors (normally closed or automatically operated by smoke detection) with a minimum 3/4 hour fire rating. If windows are provided in the fire partition, ensure the glazing is fire-resistant by providing one of the following: 1) listed fire-rated glass with a minimum 3/4 hour fire-resistance rating, 2) minimum ¼ in. (6 mm) thick wired glass, or 3) glass block. Window frames must be fire-rated, and equipped with gasketing, and allow for glass expansion.

2.1.18 Arrange protection against natural hazards in accordance with Data Sheet 1-2, *Earthquakes;* Data Sheet 1-28, *Wind Design*; Data Sheet 1-29, *Roof Deck Securement and Above-Deck Roof Components*; Data Sheet 1-49, *Perimeter Flashing*; Roof*Nav* and the *Approval Guide*, an online source of FM Approvals.

2.1.19 Limit the potential for interior vertical fire spread by ensuring no more than two consecutive stories are interconnected, and interconnected stories are separated by 3 or more unbroken floor slabs or an adequate vertical fire break.

2.1.20 Install and protect ignitable liquid tanks, pumps, and piping systems in accordance with Data Sheets 7-32, *Ignitable Liquid Operations*, 7-50, *Compressed Gases in Portable Cylinders and Bulk Storage*, and 7-88, *Storage Tanks for Ignitable Liquids*.

2.1.21 Install and protect emergency and standby power systems in accordance with Data Sheet 5-23, *Design and Protection for Emergency and Standby Power Systems*.

2.1.22 Ensure all interior finishes are either noncombustible or Class 1 fire-rated. Protect non-Class 1 plastic material with a proper thermal barrier (see Data Sheet 1-57, *Plastics in Construction*). Do not use carpeting as an interior finish material on walls and ceilings.

2.1.23 Provide curbs, drains, and/or water-tight floors for mechanical equipment rooms, HVAC rooms, rooms with ignitable liquids, and floors directly above high-value and critical electrical equipment.

2.1.24 Provide adequate drainage arrangements for all plumbing and mechanical systems. Provide closed drainage systems rather than open drains subject to blockage and overflow (e.g., drainage systems into open sinks or open floor drains).

2.1.25 Provide floor drains in all areas subject to water spillage, overflow of washing equipment or cleaning water, or overflow from HVAC systems.

2.1.26 Provide at least one floor drain connected to the sanitary system in each public restroom.

2.1.27 Provide the number, location, and size of floor drains commensurate with avoiding standing water.

2.1.28 Provide a suitable sediment bucket in the drain body of all floor drains subject to debris-laden waste water.

2.1.29 Refer to Data Sheets 1-24, *Protection Against Liquid Damage*, and 1-40, *Flood*, for additional applicable recommendations regarding the prevention of liquid damage.

2.1.30 Use noncombustible or FM Approved pipe and duct insulation on all pipes and ducts with exposed insulation.

2.2 Protection

2.2.1 Provide sprinkler protection for all high-rise buildings wherever there are significant combustibles present. Provide individual sprinkler system designs in accordance with Data Sheet 3-26, *Fire Protection Water Demand For Nonstorage Sprinklered Properties*, based on the occupancy and hazard category to be protected.

2.2.2 Provide all atria with sprinkler protection at the roof level as well as at each floor, and under anything that projects more than 4 ft (1.2 m) into the atrium (e.g., a balcony). Ensure the floors of atria are not used for anything other than a hazard category 1 (HC-1) occupancy (see Data Sheet 3-26, *Fire Protection Water Demand for Nonstorage Sprinklered Properties*. Design the sprinkler systems in accordance with Data Sheet 3-26.

2.2.3 Install sprinklers in accordance with Data Sheet 2-0, *Installation Guidelines for Automatic Sprinklers*.

2.2.4 In buildings that are more than 420 ft (128 m) in height, provide a minimum of two risers for each sprinkler system zone. Feed alternate floors within a sprinkler system zone by different risers such that adjacent floors are not supplied from the same riser.

2.2.4.1 Locate sprinkler risers in stair enclosures a distance apart that is equal to no less than one-half of the length of the overall diagonal dimension of the floor to be served measured in a straight line between risers (see Fig. 6).

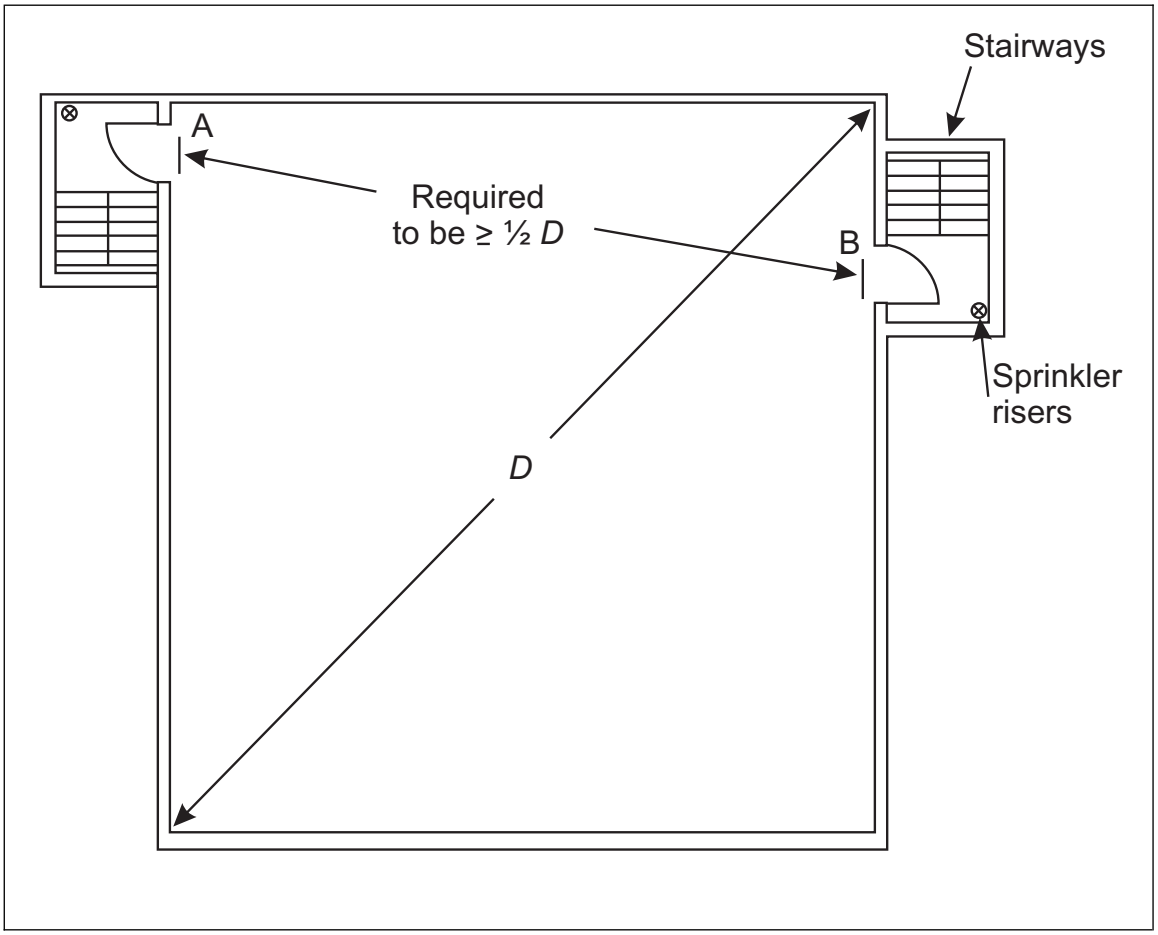

Fig. 6. Remote location of sprinkler risers

2.2.4.2 Supply required fire pumps via connections to a minimum of two water mains located in different streets. Provide separate supply piping, sized to supply the flow and pressure required by the pump, between each connection from a water main to a fire pump.

2.2.5 Provide an adequate water supply for fire protection in accordance with Data Sheet 3-26, *Fire Protection Water Demand for Nonstorage Sprinklered Properties*; Data Sheet 3-7, *Fire Protection Pumps*; and Data Sheet 2-0, *Installation Guidelines for Automatic Sprinklers*.

2.2.6 Design water supply and fire protection systems to avoid the need for pressure-reducing valves. When unavoidable, install FM Approved pressure-reducing valves in accordance with Data Sheet 3-11, *Flow and Pressure Regulating Devices for Fire Protection Service.*

2.2.7 Provide standpipes for Class III service with both 2-½ in. (64 mm) and 1-½ in. (38 mm) hose connections in accordance with Data Sheet 4-4N, *Standpipe and Hose Systems* (NFPA 14). Ensure the water supply is able to provide at least the greater of a) the sprinkler and hose demand from Section 2.2.1 or, b) a total demand of 500 gal/min (1890 L/min) plus 250 gal/min (945 L/min) for each additional standpipe

at an adequate pressure at the topmost outlet. Contact the fire service to determine needed water pressure (often 60 or 100 psi [4 to 7 bar]), taking into consideration the operating pressure for the particular nozzles used and friction loss through the hose.

2.2.8 Provide an FM Approved fire alarm system connected to a constantly attended location or listed central station. Have the alarm system monitor water flow alarms for each sprinklered floor, all smoke detectors, and heat detectors in unsprinklered areas, and provide electrical supervision for fire pumps, tanks, and reservoirs in accordance with Data Sheet 9-1, *Supervision of Property*. Install, test, and maintain the fire alarm system in accordance with Data Sheets 5-40, *Fire Alarm Systems*, and 5-48, *Automatic Fire Detection*.

2.2.9 Protect ducts for air conditioning and exhaust systems in accordance with Data Sheet 1-45, *Air Conditioning and Ventilating Systems*, and Data Sheet 7-78, *Industrial Exhaust Systems.*

2.2.10 For atria, provide a smoke control system designed and installed in accordance with NFPA 92B, *Standard for Smoke Management Systems in Malls, Atria, and Large Spaces*.

2.2.11 Install grouped electrical cables according to the National Electrical Code and Data Sheet 5-31, *Cables and Bus Bars*.

2.2.12 Ensure at least one elevator servicing each floor has the ability to be dedicated to firefighters' use. Ensure this elevator is in a protected shaft that has a 2-hour fire resistance, and is located on the building perimeter or in the central core.

2.2.13 Establish an emergency communication center for the following functions, according to the size of the building and its fire hazards:

A. The control point for emergency communication

B. The control point for emergency operation of all the building electro-mechanical systems, such as fans, elevators, smoke control, fire protection, etc.

C. The center for directing firefighting and rescue operations

2.3 Human Element

2.3.1 Have the fire alarm and smoke control systems, including alarms and shutdown devices, thoroughly inspected and tested by adequately trained personnel at least every six months. In particular, have the following equipment examined:

A. Have the system-activating devices, such as fusible links or heat or smoke detectors, checked to ensure they are not covered with residue, or are otherwise impaired.

B. Inspect fire and smoke dampers at least annually to detect damage, obstructions, and corrosion.

C. Have heat and smoke detector systems inspected and tested. Follow the manufacturers' or installers' recommendations in maintaining, inspecting, and testing the equipment.

D. Arrange the overall system so it can be adequately tested every six months by simulating emergency mode conditions.

2.3.2 Maintain an up-to-date list of control valves, by type and location, for all building services' piping systems. Label the main domestic water shutoff valve for each floor. Train staff to be able to quickly locate and close control valves. The list could be maintained by:

- Building security
- Building maintenance
- Contract cleaning crews
- Tenants

Building services include, but are not be limited to, the following:

- Fire protection systems
- Domestic water systems
- HVAC systems

- Roof and floor drain systems
- Water treatment systems
- Sewage systems

2.3.3 Train all maintenance and security staff to respond to leaks from building services' systems.

2.3.4 Include leak detection and response in written emergency plans.

2.3.5 Inspect and maintain all valves identified according to Section 2.3.2 annually as part of a standard preventive maintenance program.

3.0 SUPPORT FOR RECOMMENDATIONS

3.1 General Comments

3.1.1 Fire Protection

Although high-rise buildings may be of fire-resistive construction, the occupancy and interior finish may provide a significant combustible load. As a result, these buildings can be exposed to major fire and smoke damage requiring a large firefighting force. Fire-resistive construction and compartmentation have not prevented exterior and interior fire spread in high-rise buildings. Consequently, they are not a substitute for automatic sprinkler protection when combustibles are present.

The use of automatic sprinklers is undoubtedly the most effective measure of fire control. To the extent that sprinklers can be relied upon to control or extinguish a fire in any part of a building before substantial smoke is produced, they represent a smoke control system, as well as an extinguishing system.

3.1.2 Fire Service Operation

Fire in a high-rise building imposes more physical demands on a fire service than a similar fire in a low building. Access to the fire floor may be impossible during the early stages of the fire due to the inaccessibility of elevators and stairwells or due to evacuation of occupants.

Once in the vicinity of the fire, firefighters are confronted with heat and smoke. Automatic sprinklers will protect against smoke and fire and, therefore, will make fire extinguishing efforts more reliable. For effective manual firefighting, firesafe access to each floor of a high-rise building is needed, especially in unsprinklered buildings.

Only when the following are provided can the activities of the fire service be considered reliable and effective in fighting a fire:

- Exit and elevator enclosures with a fire-resistance rating of not less than 2 hours
- Enclosures for manual firefighting equipment (standpipes, fire extinguishers, etc.) with a fire-resistance rating of not less than 2 hours
- 1-1/2 hour fire-rated, normally closed or automatic closing fire doors for openings in stairwells and enclosures
- A two-way fire service communication system
- Fire service access to the roof
- Smoke-proof enclosures separated from the remainder of the building by not less than a 2-hr fire barrier without openings other than the required egress doors.

3.1.3 Atria

Modern high-rise buildings are being built with large open atria. These consist of a large, open core extending through the center of the building from the lobby, possibly up to the roof. There are frequently multiple levels of commercial occupancies that surround the atrium on the lower floors; these may include restaurants, night clubs, and a variety of shops. The remaining upper floors are either used for hotel rooms, offices, or other occupancies, facing the open core of the building through open corridors. Fires in an atrium with combustible occupancy, or in open areas facing the atrium, produce large volumes of heat and smoke that will rise through the atrium and possibly enter every floor.

Protection against fire and smoke exposure can be provided by complete automatic sprinkler protection, and by separating the spaces adjacent to the atrium with fire rated barriers. In conjunction with the above, a smoke removal system can be installed at or near the top of the atrium to remove heat and smoke, and prevent the spread of these hot gases to exposed areas. In addition, sprinklers installed at the ceiling will temper the hot gases and lessen the heat damage to the building structure and exhaust system.

3.1.4 Electrical Cables

Fire in wires and cables that are grouped together in one location such as junction boxes, manholes, cable trays, crawl spaces under control rooms, cable spreader rooms, above suspended ceilings, vertical chases, cable trenches, and similar places are responsible for many serious losses. Insulation failure is usually followed by arcing and overheating because of excessive electric current, which may ignite combustible insulation. The ensuing fire is often well advanced before it is discovered, and frequently, extinguishing agents cannot be applied promptly due to its inaccessibility. When the cables penetrate vertical and horizontal fire barriers, fire may spread to other areas through unprotected openings. Consequently, these openings/ penetrations need to be protected with adequately designed and rated fire stops (see Fig. 11 and Section 3.1.5, Vertical Fire Spread).

3.1.5 Vertical Fire Spread

Fire can spread vertically, both internally and externally, in a high-rise building in a number of ways. Although not always recognized as a major problem, external fire spread can occur when windows are relatively large and spaced close together vertically. If not extinguished quickly, fire on the floor of origin typically develops to a ″flashover″ state, which breaks the windows and permits flames to travel out of the broken windows and up the outside of the building. Heat from flames can break windows on floors above or can radiate through windows still intact and ignite combustibles within the story above the fire. This event can be repetitive and, under certain conditions, flame heights can grow geometrically when two or more floors are involved simultaneously. A 2005 study found that 20-40% of high-rise building fires result in fire spread beyond the room of origin. External fire spread is illustrated in Figures 7 through 10.

Fig. 7. Exterior fire spread in a high-rise building

Fig. 8. Exterior fire spread in a high-rise building

Photo courtesy of John Axford

Fig. 9. Exterior fire spread in a high-rise building

Fig. 10. Exterior fire spread in a high-rise building, as well as severe fire exposure to adjacent building

It has long been recognized that internal fire spread can occur through open stairwells or escalators, openings in otherwise enclosed stairwell or elevator shafts, ductwork or ‘‘poke-throughs’’ (utility openings in floor slabs). Poke-throughs are inherent in high-rise buildings, especially older buildings that have undergone a series of tenant alterations. Where poke-throughs are continuous (i.e., passing through many floors), such as vertical runs of electric trunk cable, they are critical to fire spread. (See Fig. 11.) Where they are limited, they create at least a passage of fire to the next floor above but, depending on fire service intervention, not necessarily any further. Typically, most continuous penetrations are located within a cutoff shaft or core in such a way that any fire passage will create minimal effect. It is desirable to provide fire stops within cutoff shafts at maximum intervals of three stories to limit damage to cables and business interruption, as well to limit the potential for vertical internal fire spread. However, limited poke-throughs are common outside the core areas, while continuous poke-throughs also occasionally occur.

Glass fiber has a lower melting temperature than mineral wool or ceramic fiber and, therefore, is not a

Fig. 11. Hole through floor slab in telephone closet allowed fire spread to the upper floors; these holes, approximately 12 by 18 in. (300 by 450 mm), were not fire stopped

recommended alternative for fire-stopping at wall/floor junctures in new construction. Wall/floor juncture fire-stopping should have a minimum fire resistance of two hours.

3.1.6 Curtain Wall

A curtain wall is an exterior non-load-bearing wall of metal, metal sandwich panel, glass, or stone veneer attached to the structure by a sub-frame of metal. Many curtain walls are sandwich panels that may or may not have an insulated core. If there is no insulated core, a full-height opening may exist within the curtain wall. A full-height opening also may exist between each floor slab and the inner surface of the curtain wall. There has been a common tendency to fill the opening between the curtain wall and the floor slab with polyurethane and other foam materials that are combustible. Consequently, it is important to determine how these openings are sealed, as fire can spread through the space between the edge of the floor slab and the curtain wall. This opening has been identified as a key element in vertical fire spread if it is not filled or is inadequately filled with fire-stopping material, or if the metal curtain exterior wall buckles under fire exposure, allowing the fire-stopping to drop out of place.

3.1.7 Compartmentation

Compartmentation can be defined as the subdivision of a floor into smaller spaces, generally not exceeding 15,000 ft^2 (1400 m^2), by fire-resistance-rated construction. Compartmentation is not a substitute for automatic sprinklers; however, in conjunction with sprinkler protection, it can be very important in limiting interior fire spread. To form an effective compartment, the construction assemblies (walls, floors, ceilings, etc.) need to have the necessary fire resistance based on the amount of fuel available in the compartment. The enclosure and structural elements need to resist the exposure from a fire involving all the combustible material in the compartment. It is vital that compartments be properly constructed and maintained to preserve integrity throughout the life of the building. Furthermore, it is imperative that the compartment have continuity. Vertical subdivision must be continuous to exterior walls or other fire-resistance-rated walls. Horizontal subdivision must be continuous from floor slab to floor slab or floor/ceiling fire-resistance-rated assembly. All openings need to be adequately protected and an penetrations sealed.

3.1.7.1 Horizontal Subdivision

Horizontal subdivision is created by fire walls, fire barriers, fire partitions, smoke barriers, and smoke partitions. Refer to the glossary in Appendix A for definitions. Walls must be tight to the floors above and below. The wall cannot stop just above the ceiling unless the ceiling is a fire-resistance-rated assembly itself. The most critical aspect of providing and maintaining horizontal subdivision is the protection of openings (personnel, HVAC, etc.) and the fire-stopping of penetrations. For further information on horizontal subdivisions, refer to Data Sheet 1-42, *MFL Limiting Factors*.

3.1.7.2 Vertical Subdivision

Vertical subdivision is created by fire-resistance-rated floors and ceilings. These assemblies must be tight to the walls. The fire-rated floor or ceiling cannot be supported by an unrated structural member, such as unprotected steel columns and beams. The most critical aspect of providing and maintaining vertical subdivision is the fire-stopping of penetrations and the intersection of the floor and exterior walls. Because building utilities have to be run from basements to upper floors, rather than provide for individual penetrations for these utilities, they are run in fire-rated shafts. The shafts create a continuous opening up through the floors, and vertical subdivision is maintained by having the shaft horizontally subdivided from occupied space.

3.1.8 High Strength Concrete (HSC)

A report issued by the American Concrete Institute (ACI) lists 49 high-rise buildings by address or building name in which HSC was used between 1972 and 2004 (Report 363R 10, dated March 2010). The use of HSC is not limited to those 49 locations. It is reported that in Chicago alone, more than 30 high-rise buildings built between 1972 and 1990 used HSC columns.

4.0 REFERENCES

4.1 FM

Data Sheet 1-1, *Firesafe Building Construction and Materials*
Data Sheet 1-2, *Earthquakes*
Data Sheet 1-12, *Ceilings and Concealed Spaces*
Data Sheet 1-21, *Fire Resistance of Building Assemblies*
Data Sheet 1-42, *MFL Limiting Factors*
Data Sheet 1-24, *Protection Against Liquid Damage*
Data Sheet 1-28, *Wind Design*
Data Sheet 1-29, *Roof Deck Securement and Above-Deck Roof Components*
Data Sheet 1-40, *Flood*
Data Sheet 1-45, *Air Conditioning and Ventilating Systems*
Data Sheet 1-49, *Perimeter Flashing*
Data Sheet 1-57, *Plastics in Construction*
Data Sheet 2-0, *Installation Guidelines for Automatic Sprinklers*
Data Sheet 3-7, *Fire Protection Pumps*
Data Sheet 3-11, *Flow and Pressure Regulating Devices for Fire Protection Service*
Data Sheet 3-26, *Fire Protection Water Demand for Nonstorage Sprinklered Properties*
Data Sheet 4-4N, *Standpipe and Hose Systems*

Data Sheet 5-23, *Design and Protection for Emergency and Standby Power Systems*
Data Sheet 5-31, *Cables and Bus Bars*
Data Sheet 5-40, *Fire Alarm Systems*
Data Sheet 5-48, *Automatic Fire Detectors*
Data Sheet 7-32, *Ignitable Liquid Operations*
Data Sheet 7-50, *Compressed Gases in Portable Cylinders and Bulk Storage*
Data Sheet 7-78, *Industrial Exhaust Systems*
Data Sheet 7-88, *Ignitable Liquid Storage Tanks*
Data Sheet 9-1, *Supervision of Property*
Approval Guide, an online resource of FM Approvals
Roof*Nav*

4.2 Other

International Building Code, 2009.
National Fire Protection Association, NFPA 13, *Installation of Sprinkler Systems.* NFPA 80A, *Exterior Fire Exposure*.
NFPA 92, *Standard for Smoke Control Systems*.
NFPA 92A, *Standard for Smoke-Control Systems Utilizing Barriers and Pressure Differences*.
NFPA 92B, *Standard for Smoke Management Systems in Malls, Atria, and Large Spaces.*
NFPA 5000, *Building Construction and Safety Code*, 2009.
Underwriter's Laboratories UL Online Certifications Directory
Warnock Hersey Certification ListingsWarnock Hersey (WH) Mark

APPENDIX A GLOSSARY OF TERMS

Adequate fire-stopping: Adequate fire-stopping includes mechanically secured or friction-fit fire-stopping with minor voids sufficient to impede upward spread of fire. Note the fire-stopping material must be fire-resistant; ordinary fiberglass thermal insulation does not qualify as fire-stopping. In high rise buildings, adequate fire-stopping has a 2-hour fire rating.

Class 1: A material or assembly that has limited combustibility such that they will not self-propagate.

Compartmentalization: The process of separating a floor area by fire-rated walls and/or partitions into smaller spaces.

Compartmentation: The International Building Code defines compartmentation as not having an open floor area that exceeds 15,000 ft^2 (1395 m^2). Walls extend from floor slab to the underside of the slab or deck above and are built with noncombustible materials. In many cases the maximum open floor area is considerably less than the above figure, and additional credit is given in determining the LE.

Concrete on Protected Steel: Concrete deck or concrete fill on steel deck, with fireproofed supporting steel frame. The fireproofing on the steel frame can be anything from a light weight, spray-applied material to clay tile masonry. Steel members entirely encased in several inches (>25 mm) of normal weight concrete is considered fire-resistive construction and not protected steel. For further details, see Data Sheet 1-1, *Firesafe Building Construction and Materials.*

Fire barrier: A fire-resistance-rated assembly designed to restrict the spread of fire and the movement of smoke in which continuity is maintained. Fire barriers are continuous fire separations with terminations at exterior walls, fire walls, another fire barrier, or the roof in order to constitute a complete fire separation. Fire barriers shall be continuous through concealed spaces, such as the space above a suspended ceiling. Openings are protected with fire doors having a minimum fire protection rating of 20 minutes.

Fire compartment: The space bounded by exterior walls or fire barriers, fire partitions or horizontal fire-rated assemblies (floors or floor-ceiling assemblies). Penetrations are sealed with fire stops and openings are protected with self closing or normally closed fire doors having the appropriate fire resistance rating. When a floor/ceiling is used to provide compartmentation or segregation of hazardous occupancies it should have a minimum one-hour fire-resistance rating.

Fire partition: An assembly designed to restrict the spread of fire in which openings are protected.

Fire reserve: Where a gravity tank is used to supply both service and fire protection water, the fire reserve inside the tank is that quantity of water that is constantly retained for fire protection.

Fire-resistive: Construction where the building frame has a fire-resistance rating and is either reinforced concrete or concrete encased steel.

Fire-stopping: An assembly to prevent interior fire spread. Fire-stopping installed between the exterior curtain wall and the edge of the floor slab is typically compressible, fire-resistant insulation.

Fire wall: A fire-resistance-rated wall designed to restrict the spread of fire in which continuity is maintained, openings are protected and penetrations sealed.

FM Approved: References to ''FM Approved'' in this data sheet mean the product or service has satisfied the criteria for FM Approval. Refer to the *Approval Guide* and Roof*Nav* for a complete listing of products and services that are FM Approved.

High-rise building: Any building with an occupied floor located more than 75 ft (23 m) above the lowest level of fire service vehicle access with the exception of:

Airport traffic control towers
Open parking garages
Amusement park structures
Bleachers
Grandstands
Stadiums
Special industrial buildings (ex. BLRB)
Buildings with high hazard occupancies

High-strength concrete: Any concrete with a 28-day compressive strength of at least 6,000 psi (41 MPa). Strengths can get as high as 20,000 psi (138 MPa).

Ignitable liquid: any ignitable, flammable or combustible liquid regardless of flashpoint.

Interconnected floors: Two or more floors connected by an unprotected, open stairway or equivalent (escalators, atria, shafts, etc.) “N” is the number of interconnected floors.

Listed: Listed by a reputable testing laboratory according to a widely recognized testing standard adopted by model building codes.

Masonry, granite, or concrete walls connected to floor slabs: The floor supports the masonry, granite or concrete wall, or is constructed so no floor-wall gap exists or can be readily created by the fire.

Perimeter flue space: The space that occurs between the edge of the floor slab and the inside surface of the curtain wall panel in modern construction. This can be several inches to more than 1 ft. wide and will allow the passage of fire, heat, smoke and water between floors. This space is usually filled with a noncombustible or fire-resistive material called “fire-stopping.”

Poke-throughs: Floor penetrations for vertical water pipes, pipes, telephone cables, etc. Protected Steel: A construction where the steel building frame has a fire-resistance rating and the steel members are covered with a fire resistant coating that can range from a light-weight, spray-on material to a denser, heavier material that is troweled on. Where steel members are entirely encased in normal weight concrete, consider the construction fire resistant rather than protected steel.

Room: Rooms can range in size from 100 ft^2 (10 m^2) to 10,000 ft^2 (1000 m^2). Room partitions may or may not have a fire rating. The partitions may extend from slab-to-slab or stop at or just above suspended ceilings. Rooms can have non-rated doors or a self-closing or normally-closed fire door. Small, subdivided rooms that will further enhance compartmentalization can be found in buildings such as hotels, apartments, or hospitals.

Smoke compartment: A portion of a floor that has been subdivided into smaller areas by slab to slab 45-minute partitions or 45-minute partitions that fit tightly to plastered or concrete ceilings, and where each room has a minimum 30 minute, self closing or normally closed fire door.

Smoke control: A method used to limit the spread of smoke from a fire by exhausting smoke from a fire floor or compartment, and pressurizing adjacent floors or compartments to prevent smoke from entering.

Smoke-proof enclosure: An exit stairway designed and constructed so that the movement of the products of combustion produced by a fire occurring in any part of the building into the enclosure is limited.

Spandrel: Exterior wall construction that extends from the top of a window on a lower floor to the bottom of the window on the floor above.

A.1 Abbreviations

ACI = American Concrete Institute
h = Window height (ft, m)
h_1 = The window height of the lower window when there is more than one window per floor.
h_2 = The window height of the upper window where there is more than one window per floor.
h_{total} = the sum of all window heights per floor.
H = The distance between any floor and the bottom of the window on the next story above that floor
H' = The distance between the top of the floor of expected fire origin and the top of the lower window on the floor above when there is more than one window per floor (in the vertical direction).
HSC = High strength concrete
n = The n^{th} floor below the lowest fire floor (e.g. n=1 is the floor directly below the lowest fire floor)
N = Actual number of interconnected fire floors.
NIST = National Institute of Standards and Technology
PFD = Public fire department
PHPCT = Partnership for High-Performance Concrete Technology
PRVs = pressure regulating valves
S = Height of the spandrel (ft, m)
S_1 = Height of the lower spandrel (ft, m)
S_2 = Height of the upper spandrel (ft, m)

APPENDIX B DOCUMENT REVISION HISTORY

October 2013. The following changes were made:

- This document has been revised to use the occupancy hazard categories as defined in Data Sheet 3-26, *Fire Protection Water Demand for Nonstorage Sprinklered Properties.*
- Added a new definition for concrete on protected steel.

July 2012. This document has been revised. The following is a list of major changes:

- An editorial review was completed. The term ″fire-safing″ was replaced with ″fire-stopping.″
- Recommendations have been added to reduce leak-related damage.
- Appendix A, Glossary of Terms, was updated

May 2008. A reference to Data Sheet 5-23, *Design and Protection for Emergency and Standby Power Systems*, was added. An editorial review was completed.

September 2000. This revision of the document has been reorganized to provide a consistent format.

January 1999. Information on fire performance of high-strength concrete was added.

March 1990. Major revision was made.

APPENDIX C BIBLIOGRAPHY

American Concrete Institute (ACI). *Report on High-Strength Concrete.* ACI 363R-10, March 2010.

Bronto Skylift: HLA Range brochure. www.bronto.fi. Retrieved April 28, 2007

″Fire Fighting Technologies detail on IFES″. www.ffti.com. Retrieved 2007-06-15.

Fireimages.net

International Building Code, 2009.

National Fire Protection Association, NFPA 13, *Installation of Sprinkler Systems.*

National Fire Protection Association, NFPA 80A, *Exterior Fire Exposure.*

NFPA 92B, *Standard for Smoke Management Systems in Malls, Atria, and Large Spaces*.

NFPA 5000, *Building Construction and Safety Code*, 2009.

NFPA 1006 Standard for Rescue Technician Professional Qualifications. 2003 Edition. National Fire Protection Association.

NFPA 1670 Standard on Operations and Training for Technical Search and Rescue Incidents. 2004 Edition. National Fire Protection Association.

Underwriter's Laboratories Fire Resistance Directory, 2009.

Visiiri 2/2006, pp. 6-7, on the heavy rescue unit of VR Railway Company in Helsinki, Finland, Liitin Oy, retrieved May 9, 2007. (Finnish)

Warnock Hersey Certification Listings, 2009.