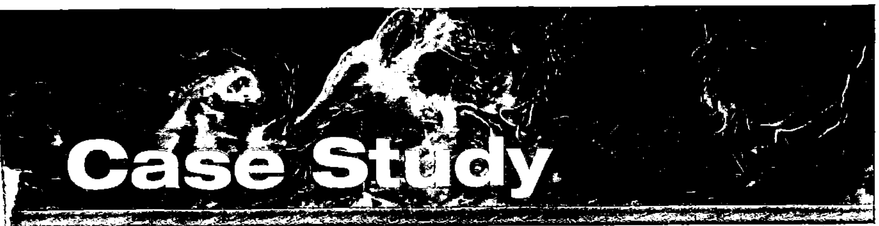
CHAPTER 13

Specific Occupancy-Related Construction Hazards

OBJECTIVES

At the conclusion of this chapter, you will be able to:

- Determine the unique design and construction details found in buildings based on occupancy type.
- Establish how occupancy-specific building code requirements dictate particular safety features.
- Identify the unique details and hazards associated with specific occupancies.
- Understand how occupancy specifics affect firefighting operations.



Case Study

Figure 13-1 The storage area on the 12th floor of the Cook County Administration Building where the fire started.

Courtesy of NIST.

Fire broke out in the Type I fire-resistive high-rise Cook County Administration Building in Chicago in 2001 (**Figure 13-1**). Starting around 5:00 p.m. in a small storage area on the 12th floor, the fire spread throughout the office suite in the unsprinklered building. Due to the lack of partitions that extended above a suspended drop ceiling, smoke was able to spread horizontally and then vertically to upper floors via HVAC ducts and penetrations. Fire fighters quickly ascended to the fire floor, encountering building occupants. The occupants were advised to go up the stairwell and exit on to another floor. Unfortunately, the occupants could not leave the stairwell—magnetic door locks prevented them from exiting the stairwell and gaining reentry to another floor. Fire fighters, believing the stairwell to be clear, opened the door to the fire floor and began to attack the fire. Six occupants trapped in the stairwell succumbed to the effects of smoke inhalation. The fire itself consumed about 14% of the 12th floor and never spread to any other floor, in contrast to the smoke migration.

1. How many unsprinklered high-rises are in your district?
2. How common are magnetic door locks on stairwell doors in high-rise buildings?
3. Which standard operating procedures would apply to the use of a stairwell for fire attack, specifically with respect to the possibility of civilians in the stairwell above the fire floor?

Introduction

Although we have classified buildings into five general categories based on construction, the type of use—the **occupancy**—also plays a role in how a building is constructed. Specific hazards affect the design and construction of a building and are often regulated by building and fire codes.

The following discussion of particular occupancy types and building hazards provides you, the fire fighter, with useful details when dealing with structures of this type. Note that the details related to codes are city specific. Although the "model" building and fire codes have attempted to standardize requirements, local jurisdictions make local amendments (changes to customize the codes for the city). In addition, a variety of editions (codes are rewritten and issued every 3 years) have been adopted. This means that you need to familiarize yourself with the actual codes in effect in your locale.

Apartment Buildings

Garden Apartments

For 10 years, Frank Brannigan investigated low-rise, combustible multiple-dwelling fires for the Center for Fire Research of the National Bureau of Standards (NBS). The NBS is now known as the National Institute of Standards and Technology (NIST). The purpose was not to uncover the fire cause, but rather to determine why the fire extended beyond the area of origin in a protected combustible construction building. Much of the material in this section is based on these fire investigations as well as the study of buildings under construction in many distinct jurisdictions.

Combustible multiple dwellings include garden apartments as well as modern row houses and townhouses and similar structures Figure 13-2. For convenience, the term *garden apartments* will be used to describe these structures. Many motels and small office buildings share the same construction characteristics.

Figure 13-2 Difficulties in accessing garden apartment fires delay fire department response and hinder rescue efforts.

term *condominium*, although commonly used or many structures, is a financial/legal term. It is not usefully descriptive term for fire fighters. It may be mportant legally in determining ownership or where he building and fire code holds individually owned ınits to a higher standard than rental units. The fallacy of considering condominiums as a separate type of building is shown by "lollipop" condos. Additional loors are built above an existing nonresidental building. In some jurisdictions, by law the condominium nust be connected to the ground. The elevator shaft is commonly owned" and serves as the tie to the ground.

:haracteristics of Garden Apartments

:xterior structural walls of garden apartments are nade of various materials:

- Solid masonry
- Brick veneer over **platform** wood frame
- Partially solid masonry, partially brick veneer on wood
- Wood

The usual height limit for these structures is three ories, although four stories is now becoming commonplace. As a consequence, many fire departments may not be able to reach victims at the rear windows of top floor apartments. Ladders may not be long enough, response strength may be inadequate to raise long ground ladders, and terrain conditions may make it impossible to move an aerial apparatus into position.

Usually individual living units are confined to one floor; however, townhouses and row houses often are multifloor units. Some apartment houses have duplex or triplex units. In some cases, one structure may have both one floor and multifloor units.

Balconies are customary in many apartments, either extended or within the exterior bounds of the building. Balconies may be made of combustible or noncombustible construction. The balcony may also provide normal access to the apartment. If the balcony is cantilevered, an interior structural fire may destroy one end of the cantilever ("seesaw") and collapse the balcony. Combustible and even partially combustible balconies have been responsible for many vertical extensions of fire.

In many of these structures, gable roof attics extend over the entire structure, with areas separated to the maximum permitted by the local code. Attic fire barriers—draftstopping—are frequently not effective because they have been compromised.

Fire department operations on peaked roofs are dangerous! Although some buildings appear to have flat roofs, they must have a pitch to drain rainwater. This pitch creates a void between the tops of horizontal ceiling beams and the sloping roof. Fire can spread laterally through this space **Figure 13-3**.

Regardless of the exterior construction of garden apartments, the interior construction is almost totally of wood, using construction techniques similar to those used in single-family homes. When these dwelling units are stacked atop one another, this structure multiplies the fire extension potential through the voids inherent in combustible construction. When steel is used in these structures, it is often not protected by any listed material or approved technique, so it must be considered unprotected.

In garden apartments, plumbing fixtures are vertically aligned, one above the other, for economy

Figure 13-3 Working from the bucket provides a safe environment for fire fighters performing roof ventilation.

and speed of construction. The necessary piping is run through vertical voids. Plumbers often weaken structural members during installation by cutting into them. The result is that a fire that starts in or penetrates this void could extend rapidly, both vertically and horizontally, as well as to the attic above. The weight of fixtures, structure cuts, and the air supply due to interconnected voids make early collapse a real hazard in these structures.

A person who must escape from a single-floor ranch home is infinitely better off than the person who must escape from the top floor of a combustible multiple dwelling. In too many cases, stairways and enclosures as well as attics overhead are combustible.

Stairways are not a place of refuge for occupants or a safe operating platform for fire fighters. For example, roof air conditioners mounted above a stairway collapsed on the first-arriving units at one apartment fire.

Educating the Management and Tenants

Most fires start in tenant spaces. All tenants in apartment complexes are at the mercy of an individual tenant who, for whatever reason, disregards basic fire prevention measures or who even starts a fire. In addition, tenants are at risk from fires starting in the public or common use spaces, whether accidental or incendiary.

Tenants should be advised to help themselves in four basic ways:

- Be fully insured for the value of all personal property.
- Keep property of unique value in a bank vault.
- Call the fire department immediately if a fire or gas leak is suspected.
- In a fire, evacuate immediately, even if the fire seems inconsequential.

Parking

Parking often presents a problem at this type of structure. Space is generally limited when it comes to parking. The preincident plan review should address this problem, including calling for a minimum of 20 feet (6.1 m) of clear width, proper turning radii, red striping of curbs, and signage. If fire officers on alarm runs or inspections observe illegal parking that would interfere with firefighting, the police should be summoned immediately. The effort to eliminate this hazard should be vigorous and followed up on until occupants understand and comply.

Building Location

Building location can be confusing and may present problems not necessarily related to street address. Even though maps are provided by the management, a map drill makes a good indoor planning exercise. In this activity, the fire officer draws an outline of the area on the board. Special difficulties, such as gullies and fences that make it difficult to get from point A to point B, should be discussed and solutions worked out beforehand. Building owners should be encouraged to provide lettering and numbering on buildings to ensure quick identification of locations in an emergency.

Natural Gas Service

Natural gas service can provide special hazards in apartment structures. Where gas service is provided, the system should be studied by the fire department. Often the service layout is made for the convenience of plumbers and meter readers, with little or no thought given to the safety of fire fighters. Usually all the gas meters in an apartment complex are located in one basement location (Figure 13-4). Individual lines are run, usually on the basement ceiling, from these meters to each apartment. Grouped together, these pipes represent a substantial weight and the hangers are often flimsy.

In one case, gas lines were located below the ceiling of the passageway between the chicken wire lockers provided to each tenant. A fire engulfed some of the lockers and one of the hangers gave way. Twenty gas pipes overhead fell down to the floor. The pipes failed, gas was released, and another fire ignited. Fortunately, the fire units were on the near side rather than the far side of the collapse. Had the units been on the other side of the collapse, a catastrophe would have occurred. In this case, the ma[illegible] pipes formed a barrier protecting the units.

Where there is no utility gas service, the apartment developer may install a large liquefied petroleum gas (LPG) storage tank. In Anne Arundel County, Maryland, an apartment complex was served from a single large gas tank. Its regulator failed, and many fires arose simultaneously throughout the complex.

Figure 13-4 Knowing where utilities are and which apartments they serve before an incident can save fire fighter lives—preplan, preplan, preplan.

Water Supply

The hydrants in many garden apartment developments are often on private mains. All hydrants should be checked periodically (Figure 13-5). Sometimes this practice raises objections from tenants because it may cause rusty water to flow. Often the fire department is forced to abandon testing.

Older apartment complexes often have undersized mains—in some cases, as small as 4 inches. The best way to establish the amount of water available is to have the owner conduct a flow test using two hydrants, a Pitot tube, and a cap gauge. With the test results graphed, you can calculate the total amount of water on hand and plan accordingly.

Figure 13-5 Private fire hydrants are sources of major concern, typically due to their limited maintenance.

Protected Combustible Construction

If you were to ask the designer or building management how a fire in one apartment would be confined and not extend to the neighboring apartments, the answer probably would be: by the fire-rated gypsum board sheathing or shell of the structure. Gypsum has excellent fire protection characteristics. It is the only construction material that does not yield heat when burned in pure oxygen. However, when binders and paper are added to make the familiar gypsum board, it yields some heat.

Effect of Fire on Gypsum Board

When gypsum board is heated by fire, it starts to deteriorate as it gives up its moisture. This process (called **calcination**), once started, appears to be irreversible. Sometimes insurance adjusters will order the burned gypsum board painted over. In a short time, paint will flake off the deteriorating walls. Removing all burned gypsum board in overhauling makes the most sense. If you do so, however, avoid charges of needless destruction by explaining the benefits of this practice.

Fire Rating of Gypsum Board

Wood-stud and floor beams combined with gypsum board can be used to construct floor–ceiling assemblies or walls that pass the American Society for Testing and Materials (ASTM) E-119 fire resistance test and earn a 1-hour or greater rating. Unfortunately, the use of fire-rated gypsum board in fire-resistive enclosures has created a myth about an almost magical ability of gypsum board to limit the extension of fire. The rating of the gypsum board cannot be separated from the test structure of which it was a part. By itself, the fact that gypsum board is rated means only that it is better than nonrated board. Gypsum board is a good material, but its applications do not always produce the results many have come to believe that it will, nor can it overcome a building's sins of omission or commission.

Underwriters Laboratories, Inc. (UL) warns that its rating is assigned to the entire tested and listed assembly, not to individual components. There are no rated ceilings, only rated floor–ceiling assemblies. The rating also assumes the structural integrity of the supporting structure.

Gypsum Board Installation

There are four principal deficiencies in the installation of gypsum board. Gypsum board commonly is nailed up over voids with a large or even infinite air supply behind the board. As heat penetrates the board and ignites the wood, there is ample air to continue combustion.

Nail heads often are not properly cemented over. Unfortunately, this heat barrier is often regarded as merely cosmetic. All nail heads in tested assemblies are covered with cement.

In some assemblies, joints are not properly taped. This also is often regarded as cosmetic and not required for unpainted surfaces. However, taping is part of the fire resistance system.

Deviations from the listing are permitted by building departments. Yet every item in a listing can be crucial. This becomes clear when we understand the procedure. If a 1-hour rating is desired and the sample lasts 1 hour and 15 minutes, the assembly is redesigned to just earn the 1-hour rating. This eliminates the added economic penalty of making the assembly "too good." Every item of a listing was put in by the manufacturer to reach a specific rating. There is nothing added for extra margins of safety.

Protective Sheathing

Though never stated explicitly in any code, the concept behind the use of gypsum board is that it provides a protective sheathing or membrane to protect the combustible structure from a fire in the contents. Some membranes can tolerate a small leak, but the gypsum sheath of a combustible structure must be as sound as the plastic bag that carries the goldfish home from the pet shop—a single pinhole can cause disaster. The penetrations of the gypsum sheath range from pinholes to sizable openings. Any penetration allows the fire to spread to the structure, thus converting a contents fire to a structural fire.

The penetrations commonly discovered in structures vary. One commonly cited penetration in the sheathing is caused by failure to close the gypsum sheath around utilities such as electrical or gas service. There are listed devices or methods for passing utilities through fire-resistive barriers, but these are rarely used in residential construction.

Failure to install the gypsum sheath behind the bathtub presents another penetration problem. Heat is conducted through the steel. Often bathtubs in adjacent apartments are located back to back. This provides a common void and breaches the supposed compartmentation. In some cases, where plastic bathtubs are used, the code often requires that the sheath be complete, but numerous untaped joints and uncovered nails have been observed.

Open doorways are sheathed in gypsum. When a door is installed, the thin wood door casing is the only sheath. This can fail rapidly. Interior vents, such as from bathrooms and kitchens, not only penetrate the sheath, but also deliver fire to the vertical voids of the building.

Attics are ventilated to prevent condensation. The lower vents are located in the soffit below the projecting eaves. There is a constant natural air flow upward through the lower vent and out the upper vent, generally at the highest point of the gable ends. Fire reaching out the window will ride this air flow "escalator" into the attic, bypassing the protective sheathing or shell.

Where a fire-rated partition wall meets a fire-rated floor, the "compartmentation" satisfies the building department; however, the floor is easily penetrated downward by a fire in today's fuels. The fire may enter the floor void and come up on the other side of the partition. Further, soffits, such as the box dropped down to provide built-in kitchen cabinets, connect the wall voids to the floor voids.

The fire-rated gypsum board myth allows for huge interconnected voids. Often the biggest void is the attic. There is no such thing as a fire-rated top floor/attic ceiling. The constant flow of air makes a rated structure impossible here.

The creation of dangerous, hidden voids is prevalent in the rehabilitation of older buildings, especially when the ceiling heights were greater than today's acceptable 8 feet—a characteristic that easily allows for renovations by dropping a ceiling. Carbon monoxide gas can accumulate in these voids. When the ceiling falls, the gas can ignite as either a backdraft or a detonation.

"Protected Combustible" Is Not "Fire Resistive"

From time to time, buildings incorporate floor–ceiling assemblies and interior walls that are fire rated according to ASTM E-119. Test methods are sometimes referred to as being "fire resistive." Such characterization should be emphatically rejected. The limited application of a complete gypsum sheath or shell, and the many defects cited here, should make it clear that the term *fire resistive* should never be applied to such a structure. In fact, the term *protected combustible* appears to be overly generous in describing this situation.

Fire Walls/Barriers and Draft Stops

Fire walls are often used to separate units in multifamily residential structures (Figure 13-6). Ideally, a masonry fire wall should be able to stop the extension of the fire without assistance from the fire department. Unfortunately, there are many possible defects

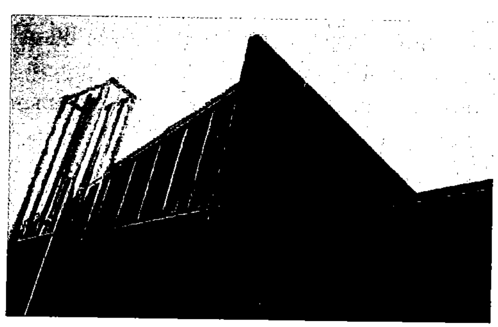


Figure 13-6 Bringing the wall through the roof line limits fire advancement.

Courtesy of the estate of Francis L. Brannigan.

in such walls. These require prompt action by the incident commander (IC) to reinforce the fire wall and cover its weaknesses.

One of the primary defects involves not bringing a masonry fire wall through the roof with a masonry parapet. Builders often resist this requirement because it is costly, and unless the wall is flashed properly, there can be leaks. In North Carolina, a builder finished off a block fire wall with brick veneer that merely rested on the wood roof. It collapsed suddenly into top floor apartments.

It is almost impossible to fit masonry tight to the roof. There will be at least small gaps. In many fires, expanding gases can force fire through the smallest opening. Furthermore, plywood delaminates and can lift up and enable the fire to pass.

Permitting overhangs or mansards to project beyond the fire wall is another potential defect in fire walls. This provides a gap for fire to pass around the end of the wall. Apparently, some codes read "the fire wall must extend to the exterior wall," and, unfortunately, this is interpreted as a limitation.

Permitting the fire wall to end at the interior of a combustible exterior wall simply enables the fire to pass around it. Often there is no exterior evidence of the fire wall's location. The fire wall should be extended straight out or in a "tee" or "ell" shape to cut off the fire.

Utilities often are passed through the fire wall. In turn, openings around these pipes may permit fire to penetrate the fire wall. The best practice is to run utility mains parallel to the building with branches into each unit. Unprotected openings frequently are cut into fire walls, particularly in attics, for maintenance purposes; they compromise the fire walls.

Openings at the basement level provide access to storage and laundry areas. These are usually designed and built with proper self-closing doors. All too frequently, however, these doors are blocked open. Ironically, in some cases, the door closer has been removed and used as a doorstop.

Permitting the fire wall to act as a party wall, or structurally as part of both buildings, creates problems. Party walls often have beams or girders from both sides in the same opening. These common openings provide a path for fire extension. Look for this in townhouses, particularly where units have adjacent doorways. Stairway headers also may be in the same opening.

Older row-frame buildings often had brick laid in the party wall stud voids as a fire wall. It doesn't work because the barrier is incomplete. The **brick nogging** (brick and mortar filling between studs) does not block the floor or attic voids (Figure 13-7).

Fire barriers (theoretically fire rated) and draft stops (nonrated) are intended to limit the combustible void area in the attic to which the fire has access. In some cases, plywood or chipboard is used for the draft stop. By far, most construction makes use of gypsum board on wood studs.

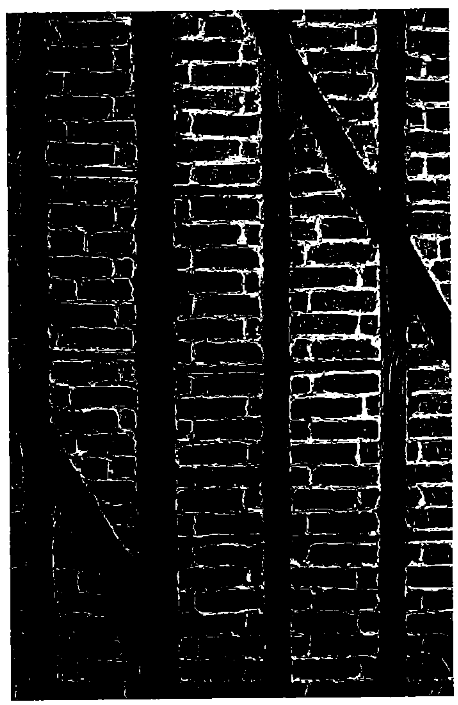


Figure 13-7 Brick nogging in a wall.

Some barriers are now being made of 2-inch (5 cm) gypsum plank in 2-feet-wide (61 cm) vertical sections. The sections are held in a steel channel. They are cut in the field to meet the slope of the roof. However, the cuts are often only approximate, producing openings for fire access.

The fire barrier may range in effectiveness from :emporarily reliable to totally useless. In no case, how-ever, can a fire barrier be regarded as even approxi-nately equal to a parapetted masonry fire wall.

There are several types of defects in these fire barriers and draft stops. Consider a fire barrier that :xtends completely from one side of the attic to the ther, including the overhang. Nails are set, and oints are backed by two by fours and taped, with no penetrations at all. Yet a fire delaminates and raises ıp the plywood so that the fire passes over the bar-ier. A similar problem exists when the fire wall is nded at the underside of the roof.

her defect exists when the barrier does not xtend out to the eaves but stops at the wall line, ius allowing the fire to roar around the end. Gyp-um board improperly backed by wood at joints and ıtermediate points presents a compromised fire arrier.

Omitted nail covering and joint taping, utilities r structural elements passing through, doorways ıt into fire barriers, and the use of scraps of gypsum ɔard all affect the integrity of fire barriers. Draft stops, though they are not rated and don't have to meet ıe fire-rated assembly requirements, nevertheless are quired to be tight and complete without openings.

When fire barriers have been placed above the idpoint of a room, both sides of the barrier are :posed to fire coming out the windows. This comes ıout because of code provisions limiting the size of e attic void. The builder wants the maximum area each section, and the fire barrier is so placed even it doesn't continue a fire separation below. There e many other defects in fire barriers produced a wide variety of builders, maintenance person-l, and tenants. It is wise to examine buildings in e and under construction for other fire barrier ıdequacies.

A Word About Sprinklers

Automatic sprinklers that protect occupied spaces will most likely only extinguish contents fires. They will rarely control any fire that originates in, or extends to, the voids because there are no sprinklers in these void areas. However, as far as tenant life safety is concerned, a system complying with the National Fire Protection Association (NFPA) 13R, *Standard for the Installation of Sprinkler Systems in Low-Rise Residential Occupancies*, is a tremendous asset.

A note of concern about NFPA 13R systems and garden apartments complexes: they often share the same water main with the hydrants that are in the complex. If this is the case and you were to hook up to a hydrant, you would be taking water from the sprinkler system. Most NFPA 13R–protected apartment buildings are required to have a 1.5" (38 mm) fire department connection (FDC)—make sure that you use it and monitor water usage.

Serving the Citizens

There is probably no class of building in which good fire planning and training can pay off more than in garden apartments. Fire departments that study why multiple-dwelling fires spread and develop tactics to cut off these fires serve the citizenry well.

Individuals who own their own homes usually have personal property or homeowners' insurance, often purchased to satisfy the mortgage holder's requirements. Renters' insurance, however, is often too inexpensive to be actively sold. The result is that a high proportion of fire victims often suffer crushing financial blows due to a wide range of fire causes, including inadequate building codes, the builders' negligence, the owners' incompetence, other tenants, or inadequate fire suppression efforts.

The knowledge the fire department gains from the day an apartment development is planned should be disseminated and become the organized property of the fire department. A system should be in place to make the information available to the IC at the fire scene. This information and the ability to make effective plans provide increased safety for all concerned.

Older Row-Frame Buildings and Townhouses

In the older parts of many cities, frame buildings were often erected in rows. These structures are contiguous and often have a common attic or cockloft; they may even have party walls that provide support to both buildings. In older construction, there may be no fire barrier between buildings. Crude attempts at making a fire barrier by using brick nogging have been made in row houses. The brick nogging does not cut the floor voids or the cockloft. Brick or stone nogging is also found in old individual houses. It served as a heat sink for winter warmth—but it also presents an additional hazard in collapse.

More recently, row houses have been given a dignified new name, *townhouses*. No matter what the name used, unless there is an adequate masonry fire wall between the separate buildings all the way through the roof, the entire structure is all one building and should be so described in stating the size for planning or fire report purposes Figure 13-8. It doesn't matter to the fire that these houses are separately described and owned on the land records. As long as fire can move from unit to unit, totally or partially unimpeded, the structure is one building.

Figure 13-8 A row of townhouses with a masonry fire wall between each home.

Tenements

Tenements got their start in the 1800s. Over the years, this type of multistory multiple dwelling of ordinary construction has come to mean substandard housing. This type of building poses many problems for fire fighters, including vertical fire spread through voids such as bathroom pipe chases, horizontal fire spread through cocklofts, compromised open stairwells linking multiple floors, and fire spread via shafts Figure 13-9.

During the 1800s and early 1900s, a series of devastating tenement fires led to fire safety "improvements." New York City—the home to thousands of tenement buildings—changed its regulations covering these structures. In turn, fire fighters in New York City began to describe tenements as "new law tenements" and "old law tenements" based on their age and type

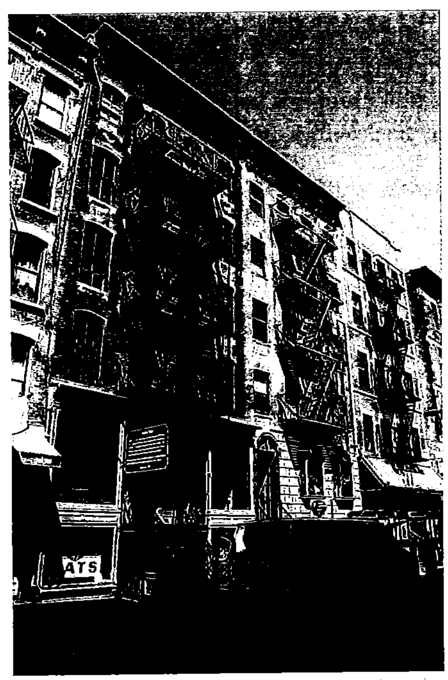


Figure 13-9 Tenement buildings pose many hazards to fire fighters.

of compliance. (The terms *new law* and *old law* are unique to New York City.)

Some of these fire safety changes included better enclosures of stairwells and more substantial apartment doors. A notable change came in the form of exterior fire escapes, which served as second means of egress for occupants and a useful platform for firefighting. By 1968, the use of fire escapes on new buildings was no longer acceptable in New York City.

The Three-Decker

This three-decker type of apartment building is typically found in New England, particularly in Massachusetts and Rhode Island Figure 13-10. These three-story flat-roofed structures have three apartment units, one on each floor, which are accessed by interior stairs. They typically do not have fire escapes. They are characterized by porches on each level, on the front and rear of the building.

It is these porches that play a critical role in fire spread. The porches offer a large surface area on which the fire can burn, providing for a large volume of fire. Rather than just having to deal with fire extension from a window on one level to the levels above, fire fighters must be prepared for a large fire that can ignite other surrounding structures via radiant heat.

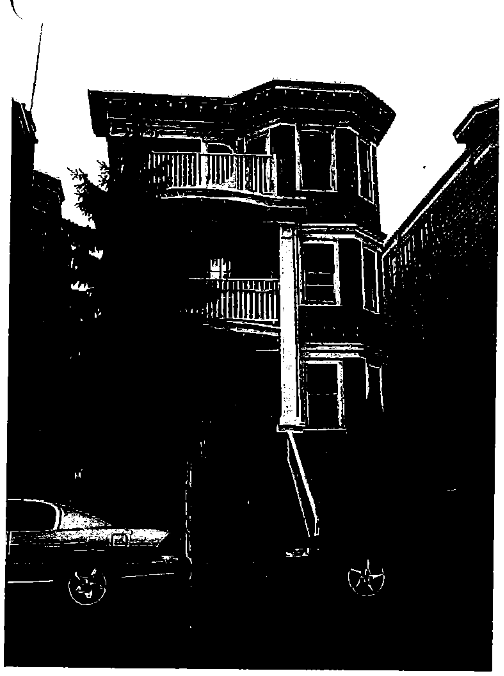


Figure 13-10 A New England three-decker.

Atria

Although **atria** have been around for centuries, it was the Hyatt Regency in Atlanta that brought them into the modern era. The architect of the hotel, John Portman, designed the 22-story structure in 1967. Atria are built for aesthetic reasons, and aesthetic reasons only.

From a fire protection standpoint, of course, atria are large voids that pass through multiple floors, allowing smoke and heat to move vertically through the building Figure 13-11. A few years ago, building codes considered atria to be openings that connected a minimum of 3 floors and were a minimum

Figure 13-11 Atria provide avenues for fire and smoke spread.

of 20 feet (6.1 m) on each side. Today, building codes only require that atria connect a minimum of 2 floors without a minimum size requirement.

Building codes specify numerous requirements for atria: full sprinkler protection throughout the building (with the exception of the top of the atrium itself if it is more than 55 feet (16.8 m) above the floor because it is felt that sprinklers will not activate so high above the floor), a smoke control system to minimize the movement of smoke onto the adjacent floors to the atrium and to move the smoke out of the building, and standby power for the building. In addition, the fire code requires that the floor of the atrium be limited to low fire hazards. Violations of this provision are seen often; moderate and high fire hazards such as upholstered furniture, cut Christmas trees, propane grills in food kiosks, and large plastic displays are encountered. This provision is difficult to enforce—and hence the desire for sprinklers at the top of tall atria.

Building codes also typically allow up to three floors to be open to the atrium—in essence, three levels with no physical barrier separation. Separations in the case of atria mean nonaesthetic materials like gypsum board and concrete block or, more commonly, wired glass or (most common) tempered glass with closely spaced (every 6 feet [1.8 m]) sprinklers to "wash" the glass during a fire. (An exception: another area allowed to be open to an atrium is the walkway found in many hotels surrounding an atrium.)

The (maximum) three levels open to the atrium are required to be included in the calculations of the smoke control system design. In essence, the designer must ensure that the volume of the open space is included in the sizing of the exhaust system, and the system must exhaust smoke from these areas. Often, the designers forget to provide a means for exhausting these areas; they forget to provide a means for moving the smoke off the floor and into the atrium itself. Exhaust fans at the roof of the atrium are incapable of drawing smoke off of the open floors, so that any smoke stagnates on the floor. It is critical that the smoke is exhausted off the floor itself or that make-up air is introduced from the remote areas of the floor to allow for movement from the floor into the atrium.

Activation of the smoke control system is usually triggered by water flow and smoke detectors. **Projected beam detectors**, which can cover large expanses of area with a single light beam, are often used for this purpose. They are often mounted on the side of the atrium, near the top.

The bottom line on atria smoke control: fire fighters should know what the system can and can't do. Establish the location of the system control panel and how it works. Ask lots of questions. Witness a test of the system if possible.

Sprinkler protection is usually fairly straightforward in buildings with an atrium. Often, the atrium and floors open to the atrium are zoned separately from the sprinklers in the rest of the building (with a separate riser for each).

Nationally, we have limited experience with actual fires in atria. In 1991, a fire occurred in the Polo Club high-rise in Denver. Although the building had an atrium, it had no sprinklers and no smoke control system (only skylights at the roof). An apartment fire filled the atrium with smoke, nearly to the bottom floor level. The mostly elderly occupants could not evacuate because of the smoke, and fire fighters had great difficulty extinguishing the fire. No one was killed despite the danger presented.

Three civilians were not so lucky in a 2007 Houston, Texas, atrium fire. An arson fire set throughout the fifth floor spread vertically to the sixth floor. Unable to access the stairwells, several surviving occupants were forced to break exterior windows and climb down aerial ladders. A fire captain almost lost his life. Unsprinklered atrium buildings, particularly office buildings, are incredibly dangerous and non-code compliant.

A recent fire with a more successful outcome occurred at the Grand Californian Hotel at the Disneyland resort in Anaheim, California, in 2005. Lights on an artificial Christmas tree ignited, burning off the top third of the tree. Sprinklers contained the fire as 2,000 hotel guests were evacuated during the 3 a.m. fire.

Houses of Worship

Houses of worship—churches, synagogues, and temples—are found in every community. They are also often some of the oldest buildings in a city. They span the five basic types of construction and can present a myriad of challenges for fire fighters.

In most cases, these buildings are open-area structures. They can have large occupant loads, often beyond code-permitted limits (especially during religious holidays). Fortunately, the occupants are typically familiar with their surroundings.

Holidays often bring candles and combustible decorations. In one case, a San Antonio, Texas, church erected a "living Christmas tree." In essence, the tree was a multitiered wood frame with evergreen branches stapled to it and lights strung around it. Platforms at each of the three levels allowed the choir to stand in the tree (hence the living tree). Upon a closer look, fire inspectors found a snake pit of wires under the tree. Unbelievably, a fan was installed to cool off the junction box and wires that were hot to the touch!

Older churches sometimes have multiple levels of seating. Galleries surround the main sanctuary, including the choir loft. These levels often have a single narrow stair, impeding egress. Another feature of older places of worship is stained glass windows. Although valuable for ventilation, such windows also are invaluable in terms of cost and heritage. Some are faced with Plexiglas™. However, the stained glass rose window (the circular window over the main entrance) does provide a location through which large-caliber streams can be trained on the roof area.

The collapse of steeples and bell towers on churches has cost many fire fighters their lives. In 2004, a stone bell tower collapsed during the overhaul stage of a Pittsburgh church fire, crashing through the vestibule and killing two fire fighters Figure 13-12.

Perhaps the most dangerous time for a place of worship, in terms of being vulnerable to a fire being initiated, is during renovations. Cutting and welding operations, burning off old paint, and other construction activities have ignited numerous churches and synagogues. One of the most spectacular fires was the 1998 New York City Central Synagogue blaze that resulted from workers installing an air-conditioning system.

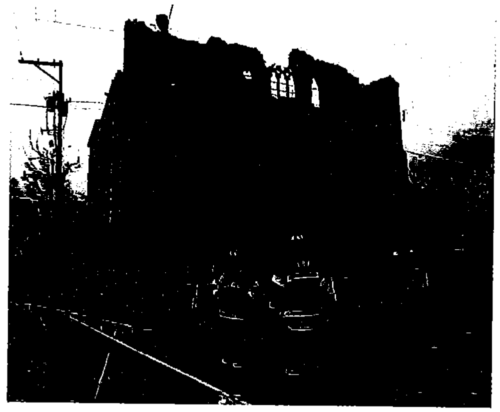


Figure 13-12 The stone bell tower collapse during the overhaul stage of the 2004 Pittsburgh church fire.

Covered Mall Buildings

A **covered mall** is essentially (under the building code) a single building enclosing a number of tenants, including retail stores, drinking and dining establishments, entertainment facilities, offices, and other similar uses where the tenants have an opening onto one or more malls. **Anchor stores**, large stores (often department stores) attached to the mall, have all of their required exits independent of the mall. Recent building codes have allowed covered mall buildings to be of unlimited area (meaning they could be measured in units of square miles, not square feet!) if they are of Type I, II, III, or IV construction and have 60 feet (18.3 m) of open space around them (for exposure protection).

The covered mall presents a problem similar to that posed by the atrium—vertical spread of heat and smoke in a fire. Malls have the added problem of horizontal spread of heat/smoke because none of the tenant spaces have a fire-rated separation from the mall. In addition, malls have large occupant loads.

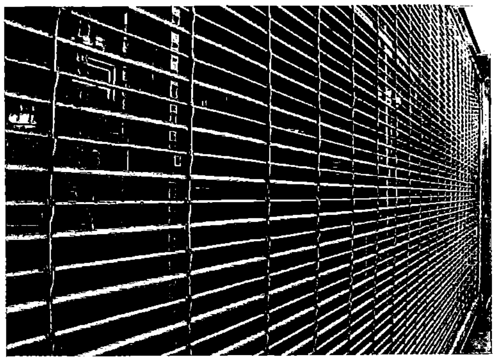


Figure 13-13 This type of grille gate allows smoke and heat to escape the tenant space.

© Peter Albrektsen/ShutterStock, Inc.

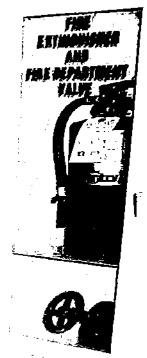


Figure 13-14 This 2.5" hose outlet is located at the entrance to a mall.

Courtesy of Glenn Corbett.

The physical separation between tenants is required to be fire rated, but typically need not go to the floor/roof deck above. Because no separation is required between the mall and the tenant space, a roll-down grille-type gate will allow smoke to move into the mall proper Figure 13-13.

Today, fire protection in malls includes complete sprinkler protection, a smoke control system, a standpipe system, an emergency voice communications system, and standby power. Leasing plans, showing tenant space locations, are also required for the fire department. *Note that older malls may have some or none of these systems—so preplanning of malls is crucial.*

The various fire protection systems in covered malls require closer analysis during your preplanning. For example, the sprinkler system will often be separately zoned for the mall proper and the tenant spaces (each will have its own risers). Most often, the feed main supplying the tenant spaces will run along the front of the store. Note the location of all control valves and what they supply.

The standpipe system, a Class I system, will have hose outlets in the mall at the entrance to each corridor and **exit passageway** (a more substantially fire-rated corridor with limitations on openings into it) at each floor level in stairwells and at exterior public entrances to the mall Figure 13-14. Some of these systems are only filled with water; thus fire fighters will be required to pressurize the system through the FDC.

The smoke control system in a covered mall is also similar to that found in an atrium. It will attempt to minimize horizontal movement of the smoke and to exhaust the smoke through the roof over the mall. You must be familiar with the operation of this system and the panel used to control the system. The emergency voice communications system will allow you to make announcements, particularly regarding which exits to use during an emergency.

Some cities have required a standardized lettering and numbering system to identify tenant locations. With letters designating blocks/rows of stores and numbers indicating particular tenants, fire fighters can more easily and quickly find the location of a store in a large covered mall building.

Factories

Although the manufacturing base is shrinking in the United States, there are still a sizable number of factories across the country. They come in all shapes and sizes, from the earliest multistory mill from the 1800s to the modern one-story automated production facility. The

Figure 13-15 A factory fire. Which potential hazards are present in this building?

key to safe firefighting operations in a factory is first to understand what is made in the structure and how it is made and also how the structure has been designed/altered to meet these manufacturing needs.

One common trait of most factories is the production equipment, which can pose a safety risk to fire fighters. These hazards include large moving parts, confined spaces, pressurized vessels, and heavy-duty energized electrical equipment. In a smoke-filled environment, fire fighters can easily get injured. The weight of the machinery in a building on fire could cause a collapse. Hazardous materials may be present. Preplanning, as always, is critical Figure 13-15.

How about the building itself? It may be difficult to navigate circular stairwells and dangerous **ship's ladders** to access equipment. In addition, there are open loading docks, limited access (including lack of windows), and adjacent storage/warehouse areas.

Hazardous Materials Production and Storage

Hazardous materials present obvious hazards to the fire fighter. "Hazmats" include the more familiar flammable and combustible liquids and more exotic substances like silane, a **pyrophoric gas** (gas that ignites in air without the introduction of an ignition source). The buildings that house these materials have come under great scrutiny in the model fire codes, especially within the last 15 years. The regulations are extensive, and it is important to understand the rules that apply to hazmat structures in your response district.

Most fire codes require the creation of a **hazardous materials management plan (HMMP)** and a **hazardous materials inventory statement (HMIS)**. In essence, the HMMP explains how the materials are to be safely used and stored, and the HMIS lists the materials present at the site, including their hazards and quantities.

The fire code sets limits on the quantities of specific types of hazmat that may be stored or used in a building. Some "exempt" quantities are permitted without requiring extensive safety features for their use and storage—the actual exempt quantity is based on the type of hazmat. Groups of these low-quantity hazardous materials are permitted in **control areas**, which are essentially areas surrounded by 1-hour-rated fire assemblies. The fire code in turn allows for multiple control areas on a given floor of the building containing hazmats, depending upon the story on which it is located. The number of control areas per floor is reduced if the location is on higher floors or on lower levels below grade.

If the amount of a hazardous material present exceeds the exempt quantity, then numerous construction requirements apply. Depending upon the type of material and its form (solid/liquid/gas), special systems or building features may be required. Mandated systems can include gas detection equipment and alarms, ventilation systems, specialized suppression systems, and the like. Construction features can include drainage and containment, classified electrical equipment for hazardous locations, fire-rated assemblies, and explosion venting.

It is best to consult the HMMP, the HMIS, and your fire inspector to understand how hazardous materials are being stored and used in a facility. Have the inspector point out the special construction details.

When it comes to explosives, building and fire codes typically permit larger size structures to store these materials when built with substantial fire-resistive construction, almost guaranteeing the restraint that increases explosive destruction. Explosion venting required under today's codes for specific explosive hazards are provided in an attempt to minimize this damage. In the past, "industry" often took an opposite tack when dealing with hazardous materials. Buildings housing hazardous processes were isolated and built of **friable** (easily disintegrated) construction elements. Years ago, one such method employed a steel frame covered with an easy-to-replace material such as cement-asbestos board. If an explosion occurred, the structure vented, and the board became dust-like particles, not missiles. After such an explosion, however, the asbestos particles represent a health hazard and all necessary precautions should be taken. Today, given the requirements for fire-resistive construction, much of the equipment is likely to survive an explosion, though pictures of the scene may appear to show total devastation.

Special-purpose buildings may be designed to channel the force of an internal explosion in a desired direction (explosion venting). Transformer stations are sometimes built with heavy walls to protect one transformer from an explosion or fire in an adjacent transformer and to direct any blast upward or outward Figure 13-16.

Figure 13-16 A hazardous materials storage warehouse.

High-Rises

There are many definitions of high-rise buildings. At the International Conference on Fire Safety in High-Rise Buildings convened in 1971 by the U.S. General Services Administration, the generally accepted definition of a high-rise was a building beyond the reach of aerial ladder equipment. Frank Brannigan protested that this definition was inadequate. The aerial ladder is a limited piece of equipment. In addition, the principal life safety question in any building is not its height but the time it takes occupants to reach a safe environment. Only a few feet from safety, 164 people died in the one-story 1977 Beverly Hills Supper Club fire.

When applied to fire department tactics, the preceding definition of high-rise buildings is acceptable and valid. Buildings of any height can present many of the problems associated with high-rises. For example, airport terminals and large shopping malls present many of the problems found in high-rise buildings. There are lessons to be learned from the study of high-rise buildings. Do not skip this section just because there are no buildings of more than a few stories in your area.

It is also a serious error to consider all high-rise buildings as a single problem. There are fire-significant construction differences among high-rises. The particular buildings in your area must be studied in detail to determine the particular potential modes of building failure.

With a few specialized exceptions, all high-rise buildings are designed to resist the effects of fire on the structural frame of the building and the floors. Whether the design concepts used are adequate to cope with all these possible effects is quite another matter.

General Classifications of High-Rise Buildings

Fire-resistive high-rise buildings have evolved over the past 150 years. The following classifications are broad and intended only for general guidance. The dates given are approximate.

Early Fire-Resistive Buildings, 1870–1930

There were many fire safety defects in buildings of this era. Some of the major defects of high-rises from this era of construction were the following:

- There were no standards for the protection of steel.
- Cast-iron columns were often unprotected.
- Terra-cotta fireproofing was compromised by concealed lightweight conduit, which expanded and tore the tile off columns.
- Segmental (curved) brick or tile arch floors were tied with exposed steel ties.
- Wooden floor beams were placed on piers creating a void under the floor, connected to all other voids by the hollow columns. In some cases, floors were leveled with cinders, often overloading the structure.

Structures in this era were built without any appreciation of the impact of vertical openings. Ornate open stairways and light wells were a standard feature, and in many cases, still remain. Open elevator shafts—a common feature in these buildings—have been replaced in many cases because new elevators must have shaft doors.

The Southern Building in Washington, D.C., is a typical early era fireproof high-rise building. It took about 70 years for an inherent defect to be made evident by a fire. A florist shop occupied the first floor, and an access stairway had been cut through the shop to the basement. A basement fire completely polluted the building with smoke via the unenclosed stairway. Hundreds of occupants had to escape down the outside fire escapes. It was feared that the fire escapes would fall off the building. Fire department ladders had to be used to brace the platforms.

Many other hazards are present in older high-rise constructions. In some cases, segmental brick and tile arches were supplanted by flat terra-cotta tile arches. In early construction, no protection was provided for the underside of the steel beams. Many such buildings still stand. Later, tile soffit blocks, or "skewbacks," were developed to provide protection to beams. These are often removed by workers, leaving the steel unprotected.

Tile arch floors were delivered on site, already manufactured to specifications. Often the specifications for the floor units were wrong and the floor had to be laid in an improvised manner, so that the finished structure lacked adequate protection.

Older buildings were built with high ceilings to provide summer ventilation. Subsequent to original construction, the ceiling may have been lowered one or more times—thereby creating a combustible void. The tiles used may have a high flame spread.

In many cases, the most recent alterations to older buildings may have been done with relatively noncombustible construction; however, this may often conceal old combustible materials. In 1963, in Jacksonville, Florida, 22 people died in the Roosevelt Hotel. A new fire-safe ceiling had been installed in the ballroom—but the old combustible ceiling had been left in place during the renovation.

Although most codes require newly installed ceiling tiles to meet flame spread requirements, it is doubtful that any code requires the removal of the old tile, despite the demonstrated hazard. One of the most common alterations of older buildings is to install new ceilings, often with void spaces to hide new utility lines, heating, ventilating, and air conditioning (HVAC), and other building systems. All too often, the original, hidden ceiling is of combustible tile. Fire inspectors and fire officers should look above dropped ceilings.

Standpipes in older buildings may also be inadequate in size. It is possible that the standpipe has not been tested and could fail in a fire. It is also possible that the standpipe outlets do not match the fire department's hose. The standpipe is a fire department tool as much as the pumper that supplies it.

Almost all older buildings have been altered at some time—walls opened up and doorways sealed up. The closure during such renovations is often not as fire resistive as the original masonry walls. Stairways may be cut through and others cut off. High-bay rooms may be made into two stories. Sometimes a wooden mezzanine is built in. In other cases, a steel bar joist floor is installed to make an intermediate story.

Live loads in older buildings may have increased over the years to a point where the building is distressed. Safes to protect computer tapes from fire, for instance, are much heavier than other safes. In some cases, unprotected steel supports may have been inserted, as might be the case in a high-rise alteration to accommodate a mechanized filing system that necessitated strengthening of the floor.

Fire loads also may have grown to high levels. This may be particularly true in the case of public buildings. Records and files accumulate. Many public buildings are domed, and the space under the dome makes a good void in which to store tons of paper. Basement rooms and attics are often similarly loaded with documents. Fire protection features are lacking.

Later High-Rise Buildings, 1930–1940

The high-rise buildings constructed after these early developments and before World War II are excellent buildings. High-rises built after World War II, in general, have poorer fire protection features when compared with many of these older high-rises. Pre–World War II buildings were universally of steel-framed construction. Floor construction and fireproofing of steel were often of concrete or tile—both good insulators that are slow to transmit heat to the floor above. The construction was heavy but no feasible alternative existed.

Relatively small floor areas were dictated by the need for natural light and air. Each floor was a well-segregated fire area in these buildings. Wall construction was frequently of wet masonry, joined to the floor so that there was an inherent firestop at the floor line. Masonry in the spandrel area (the space between the top of one window and the bottom of another) was adequate to restrict outside extension.

In these buildings, vertical shafts were enclosed in solid masonry with openings protected with proper closures. Fire department standpipes of adequate capacity were usually provided. These were wet and immediately pressurized by gravity from a tank in the building.

Exterior fire tower stairways with an atmospheric break between the building and stairway (the finest escape device available) were provided in many of the buildings of this era. Such a stairway can be compared to an enclosed tower located away from the building that is reached by a bridge open to the weather, so that smoke cannot pollute the tower (Figure 13-17). In the Empire State Building, the fire tower was built inside the building with an adjacent smoke shaft. The inadequacy of this construction was demonstrated during a fire in 1990, when the interior smoke shaft became a chimney. The fire was confined to one office suite, but five alarms were required for fire suppression and evacuation.

In these high-rise buildings, the typical office was quite spartan, though executive suites and eating clubs often were paneled with huge quantities of wood. Nevertheless, most fire loads were low. Windows could be opened in buildings of this era, which provided local

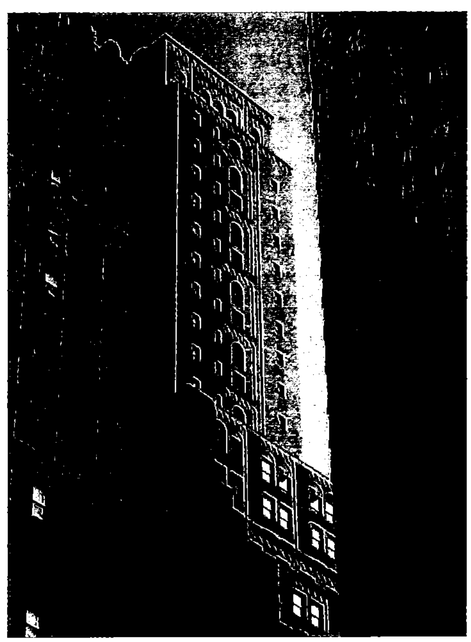


Figure 13-17 A high-rise fire tower, as seen with the arched openings in the exterior wall of the high-rise in the center of the photograph.

Courtesy of Glenn Corbett.

ventilation and relief from smoke migrating from the fire. The windows leaked, often like sieves; in turn, there was no substantial **stack effect**.

Modern High-Rise Buildings

After World War II, a number of significant developments occurred. Fire departments, apparently bemused by the lack of problems in the previous generation of structures, generally failed to realize the dimensions of the new problem. City administrations, eager to get the spectacular new buildings onto the tax rolls, didn't question the hazard of cramming thousands of people into totally enclosed megastructures that created a potential for catastrophe.

The development of fluorescent lights and air conditioning helped to remove limits to the floor area. Thus building populations could be enormously increased. As a result, many floors have substantial areas beyond the reach of hand hose streams.

Significant Construction Characteristics

There has been a definite push to lighten and thus reduce the costs of buildings. The Empire State Building, for example, weighs about 23 pounds (10.4 kg) per cubic foot. A typical modern high-rise, by comparison, weighs only 8 pounds (3.6 kg) per cubic foot.

Because of the development of better reinforcing steel and new techniques, reinforced concrete became a serious competitor to steel as a construction material in the post–World War II era. No longer could the building industry be indifferent to the weight penalty caused by concrete fireproofing of steel. In addition, the necessity for fireproofing is an apparent cost disadvantage relative to steel. Fireproofing of a steel building is a separate item in the cost estimates, whereas making concrete fire resistive is included in the cost of concrete. In addition, to serve modern high-rises, the spray-on materials and the floor–ceiling assemblies were developed to provide lighter construction.

One of the results of reducing the amount of concrete in high-rise buildings is the loss of a valuable heat sink. Every British thermal unit (Btu) that is absorbed into the concrete is one less Btu available to keep the fire from extending. This retained heat can be very distressing to fire fighters, and personnel may require frequent rotation when fighting fires in such structures. On the positive side, though, the fire's growth is slowed by this loss of heat.

There has been an extensive increase in the requirements for electrical service and communications systems in modern high-rises. Insulations are combustible, and the products of decomposition and combustion are toxic. Communications systems can breach fire and **smoke barriers** from floor to floor and from vertical shafts to horizontal voids.

Steel-truss floor–ceiling assemblies provide useful voids to carry utilities and communications or as a plenum for conditioned air, and unintentionally for fire and smoke. A most serious deficiency is the omission of fireproofing on columns within a fire-rated floor–ceiling assembly.

Slab floor concrete buildings do not have an inherent void. By dropping ceilings, useful voids are created and then connected via utility shafts. In a modern office building, possibly 25% or more of the floor volume is located in the ceiling void. Raceways for wiring are inserted in some concrete floors. Unless properly fireproofed below, heat can be transmitted to the floor above when this type of construction approach is used.

Gypsum rather than masonry is often used to enclose elevator and other shafts. In the One New York Plaza fire, gypsum enclosures were displaced, leaving the shafts unprotected and therefore hazardous to fire fighters.

In earlier buildings, there was little concern about using the exterior of the building for fire towers. Modern construction, however, discovered the value of exterior offices, particularly corner offices. With this arrangement, utilities are relegated to an interior core structure. Stairways are often located in the core, thereby eliminating the principle of remote exits. Stairways are frequently "scissor" stairways—two stairways in the same shaft. The stairways are thus quite close together. Often there is no fireproofing on the underside of the stairways, so heat or fire in one stairway can make the other untenable. If there is a standpipe, the outlets will be in alternate stairways, floor by floor. Elevators are grouped together in the core; thus, it is possible that all will be affected by the same fire.

Modern design often emphasizes an uncluttered exterior. Prefabricated panels, glass, aluminum, and other curtain wall developments make it difficult to provide a real barrier to the vertical extension of fire between the edge of the floor and the skin of the building. The enclosure of balconies by tenants or condominium owners may increase the potential for exterior vertical extension.

Windows and Glass Exteriors

Many high-rises have glass exteriors. As a consequence, it is often impossible to determine from the exterior which floors are involved in a fire. Sudden massive glass failure may cause a serious change in conditions on the fire floor. It also presents other hazards. A fire fighter was severely injured by falling glass in the One Meridian Plaza fire in Philadelphia. It appears reasonable that the building code should require an entry to the building and water supply connections that are safe from falling glass and furniture and not leave this vital requirement to chance.

Air conditioning requires fixed windows to control loss of treated air. Many buildings have no operable windows. Breaking glass is extremely hazardous because glass pieces can travel for several blocks. If windows are covered with a sunscreening plastic, the glass tends to hold together when broken and can be pulled into the building. Newer high-rises provide some windows that can be opened, and keys are located in strategic but inconspicuous locations. In other buildings, a smoke management system or tempered windows that can be broken are marked with a designated fire department reflective sticker (discussed in more detail under "Smoke Management Systems" later in this chapter).

Energy-efficient windows consist of double or sometimes triple panes of glass. They resist failure in a fire and eliminate the ventilation provided by the heat-caused failure of single-pane sashes. They are more difficult to vent from the exterior and can cause severe heat conditions to be retained in the fire area. They do resist exposure from fire below.

The Fire Command Center

Since the major overhaul of high-rise provisions in our building and fire codes in the 1970s, fire command centers have been required in high-rises. They act as the nerve center where all fire safety features are monitored and controlled.

The command center is a designated enclosed room, typically accessible from the lobby. A door is often provided directly to the exterior of the building.

A variety of equipment is provided in the fire command center: fire alarms, emergency communications to alert and direct occupants, elevator status monitors, emergency generator status and transfer switches, and fire pump status monitors. Equipment is provided to manually release magnetic door locks in stairwells, to recall elevators, and to manually control smoke management and HVAC systems.

The fire department communications system is located here as well; in the past, these systems consisted of telephone handsets that were carried up into the building and plugged into jacks in elevator cabs, stairwells, and elevator lobbies to communicate with the command center and its fire fighter communications panel. These older systems are not user friendly, however, and made it impossible for the lobby commander to immediately notify fire fighters to evacuate the building (unless a fire fighter is continually assigned to stay on the plugged-in phone with the command center—an unlikely scenario given today's personnel availability situation). As a result of the World Trade Center disaster in September 2001, the fire department is now given the authority through the model codes to require any type of communications system (typically radio signal amplifiers).

General Problems and Hazards with High-Rises

Many of the hazards presented by high-rise buildings are not solely associated with buildings of one particular era. Due to their size and form, these buildings share some common problems that fire fighters must address.

Exits

All exits should provide a clear path to the outside. In a high-rise building, the exits opened to a rear yard. The yard was then planted and enclosed with an unbroken 10-foot-high (3 m) masonry wall.

For years, the model building codes have permitted 50% of exit stairwells to terminate in the building's lobby, rather than outdoors. Although other fire protection requirements have to be met, this arrangement is confusing to occupants. During the 1993 bombing of the World Trade Center in New York, for example, the lobby filled with smoke, making the exterior door impossible to find for trapped occupants on a mezzanine onto which the stairwells discharged.

Occupancy

The occupancy of a particular building changes its problem. Offices, hotels, apartments, homes for the elderly, factories, and showrooms all pose different scenarios. Some buildings have mixed occupancies. One rigid code interpretation provided smoke detectors in occupied apartments but none in an architect's office that encompassed two apartments and had the high fire load of exposed paper contents.

Accommodation or Access Stairs

Many tenants occupy more than one floor in a building. They often find it convenient to have an accommodation or access stairway installed to connect their various office floors. Such a stairway is usually installed as an alteration and is rarely enclosed. The result is that two or more floors become one fire area, completely negating the concept of floor integrity. In the 1991 One Meridian Plaza fire in Philadelphia, fire was seen falling down through such an accommodation stairway from the 22nd to the 21st floor.

Duplex and triplex apartments (two- or three-story houses) can be found in high-rise apartments. Often, there are no exits from the upper levels. If there is an elegant restaurant located at the top of a structure, it may be a multilevel venue with an open stairway connecting the levels. All of these encroachments on good containment increase the fire area and can multiply the fire problem. In some codes, and among some designers, there is little concern about open stairways, provided the required exits are properly enclosed.

Forcible Entry

Security against crime is a serious consideration in all occupancies. Heavy doors with multiple locks may delay entry. In most cases, the forcible entry may be achieved by gypsum wallboard on studs, or gypsum block or terra-cotta tile, all of which are easily penetrated. Conversely, if the building is of reinforced masonry construction, the corridor walls are likely to be of reinforced masonry, which would be difficult to breach.

Some stairways are locked against reentry on all floors. Some codes require doors to be unlocked for reentry on certain floors, typically no more than four intervening floors between reentry floors. Other codes require automatic release of locks upon a fire alarm system activation, manual release from the lobby command center, and telephones in the stairwells every five floors. This was not the case at the Cook County Administration Building in Chicago in 2003, where six people were trapped and killed above the fire floor in the stairwell.

Elevators

The development of safe elevators that would automatically stop if the cables failed helped to make high-rise buildings practical. A complete discussion of the problems that elevators present is beyond the scope of this text. Extrication of persons trapped in stalled elevators, for example, requires a detailed knowledge of elevator construction and operating systems. Nevertheless, several facets of the "elevator problem" should be touched upon here.

In the past, the use of elevators by occupants for fire evacuation was considered dangerous and was universally warned against by signs placed in or near elevators. However, since the World Trade Center disaster in 2001, this issue is being reconsidered and a new generation of "hardened and robust" elevators and shafts are being developed for evacuation purposes. In addition, legislation making discrimination against the handicapped in employment subject to severe penalties has created a serious evacuation problem for handicapped persons who cannot use stairways.

Some Additional Points

All experience points to the possibility that, at some fires, all elevators may be totally unavailable to the fire department. This happened in the One Meridian Plaza fire. All power for lights and elevators failed. In total darkness, all equipment had to be hauled up 20 or more floors. Just imagine the problem if the loss of power occurred in a fire on the 60th floor. Preincident plans should embrace this contingency.

The fire department should be thoroughly familiar with the elevators in all high-rise buildings. They were probably installed under different codes and may have markedly different operating systems. It might be useful to appoint an officer to serve as elevator information coordinator in such a scenario.

Very tall high-rise buildings have blind shafts in which elevators serving upper floors pass many floors without door openings. In some occupancies, commercial and residential elevators open directly onto the floor, without any vestibule.

Shaft doors are often left for last-minute installation due to possible damage during construction. Inadequate makeshift barriers may be used to close these openings. The opening of one high-rise Florida hotel was rushed to accommodate a big banquet. The decorator wallpapered over the open shaft doors!

Elevator door restrictors, usually taking the form of metal angle irons, have been installed on many elevator car doors to prevent them from being opened from the inside. This approach is intended to prevent people who are in the car from falling down the shaft if the car is outside the **landing zone** (18 inches [46 cm] above or below the floor landing). It is difficult to open these doors; many people likely died at the World Trade Center on September 11, 2001, in the North Tower because they could not get out, even though they were at the lobby level.

Smoke Movement in High-Rise Buildings

A number of mechanisms affect the movement of smoke in a high-rise building.

Thermal Energy

The principal smoke-moving mechanism is the thermal energy of fire. This thermal energy can be massive. The burning rate of the fuel in the MGM Grand Hotel fire in Las Vegas, for example, was estimated at 3 tons per minute.

Atmospheric Conditions

When the atmospheric temperature is constantly decreasing as height increases, the condition is called **lapse**. Under lapse conditions, smoke will move up and away from the fire. If there is a layer of air warmer than the air below it, the condition is called **pause**, and the layer is called the **inversion layer**. It acts as a roof to rising smoke. A high-rise building may be tall enough to penetrate the inversion layer. This would cause substantial differences in the smoke conditions above and below the inversion layer.

Wind

Wind is very powerful and influences smoke movement. Note the tremendous bracing required in a high-rise to overcome the force of the wind. The wind exerts a pressure on the windward side of the building and suction on the leeward. If the windows are out and the fire is on the leeward side of the building, the suppression may be "a piece of cake." Given the same fire, the windows out, and the fire on the windward side of the building, it may be impossible to move into the fire floor.

Closely spaced high-rise buildings can create a canyon effect, where the wind increases velocity as it squeezes through a narrow opening. The wind can shift direction many times during the fire. Ground-level observations are not valid. At upper levels, the wind can blow harder and from a different direction.

Wind blowing against a building seems to split about two-thirds of the way up the building. The upper portion flows up and over the roof. The lower portion flows downward, forming a vortex next to the building. It increases in velocity as it flows downward. The effect of this wind on fire pouring out windows appears to be unevaluated in the design of high-rise structures. Refer to the chapter on fire behavior for information on wind-driven fires.

The effect of wind on the structure is becoming better understood. As previously mentioned, modern high-rise buildings weigh about 8 or 9 pounds (3.6 or 4.1 kg) per cubic foot. The result is that the top stories of some of these buildings sway noticeably in the wind. To counter this, some buildings have **tuned-mass dampers**—heavy weights installed high up in the building that are adjusted by computer to counter the wind-induced oscillations.

Stack Effect

Stack effect is the term used to describe the movement of air inside a tightly sealed building due to the difference in temperature between the air inside the building and outside the building Figure 13-18. Stack effect is most significant in cold climates in the wintertime because of the great difference between the inside and outside temperatures. Stack effect also occurs, with opposite airflow direction, when the outside temperature is greater than the inside temperature. This condition is, however, much less significant because the amount of stack effect is proportional to the difference between the two temperatures. There is a much greater difference between the inside temperature and outside temperature during the winter than during the summer. The winter differential lasts for longer periods of time. In a cold climate, a differential of about 70°F (21°C) might exist for weeks on end, whereas in the heat of summer the difference might be only about 15°F (9.4°C), mostly in the afternoon on days in which the building is occupied. Stack effect is not caused by a fire. The products of combustion ride the stack effect currents.

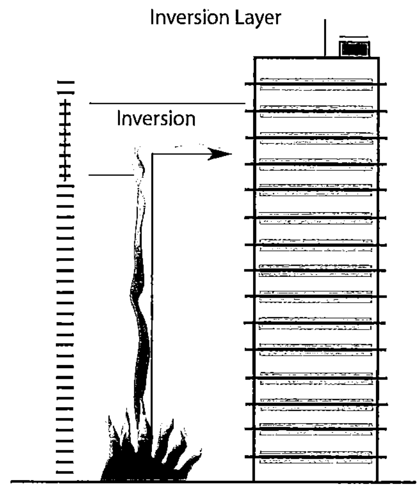


Figure 13-18 Note how the top of a high-rise may be above the inversion layer.

Winter Stack Effect

Under winter conditions, stack effect causes a movement of air from the floors into the vertical shafts, stairways, elevators, and so on in the lower portion of the building Figure 13-19. The greatest flow will be at the first floor, with the flow gradually decreasing as the height of the

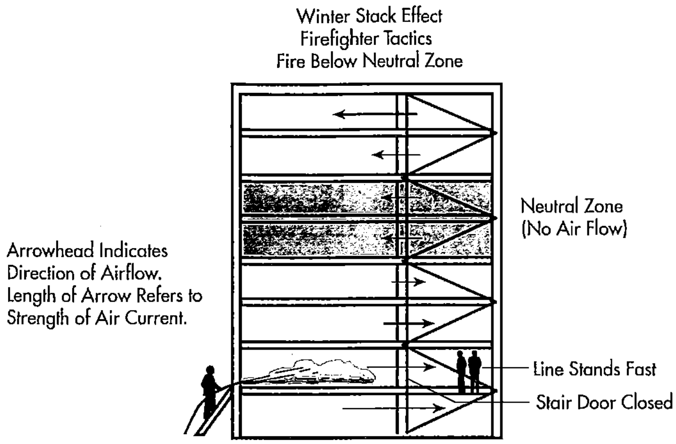


Figure 13-19 In cold climates, the winter stack effect is significant. People who live in mild climates do not always see an appreciable stack effect at fires because of the small difference in temperature. In very warm climates, summer stack effect can be experienced but is not as significant as winter stack effect because the temperature differential is much smaller.

floor above ground increases. At a point about one-third to one-half the building's height, the flow is reduced to zero; this is called the neutral zone. Above the neutral zone, the flow reverses and travels out to the floors from the shafts. The pressure increases floor by floor and is greatest at the top of the building.

If floors were completely cut off from one another, the stack effect would exist separately on each floor. Air would flow in at openings at the bottom of each floor and out the top. There would be no overall stack effect because there would be no connection between the floors. The buildings in which fires are fought do have interconnected vertical openings, stairways, elevator shafts, and pipe openings, however, so the stack effect can be significant throughout the building.

Smoke that has lost much of its thermal energy can be delivered to upper floors by the stack effect. A fire that vividly demonstrated winter stack effect occurred in a federal office building under construction in Cleveland, Ohio (Figure 13-20). The fire was ignited in a pile of rubbish on the ninth floor. Fumes from degraded and burning plastics traveled to the top floor by the stack effect. The workers started down the stairways, but were so affected by the fumes that they went into the 25th floor for refuge and started to break windows despite the hazard to those below.

Summer Stack Effect

In a sealed air-conditioned building in the summertime, the stack effect is reversed (and is often called a "reverse stack effect"). In such a case, the flow of air is downward. The situation is not as extreme as the winter situation because the differential is usually much smaller, but it still can be serious, particularly in very warm climates. In a Puerto Rican hospital in the summer, smoke pollution occurred several floors below the fire floor due to the summer stack effect.

Fire fighters experienced in fighting refrigerator plant fires have long been acquainted with **cold smoke**, which falls downward. In 1946, naval base fire fighters, under Frank Brannigan's command,

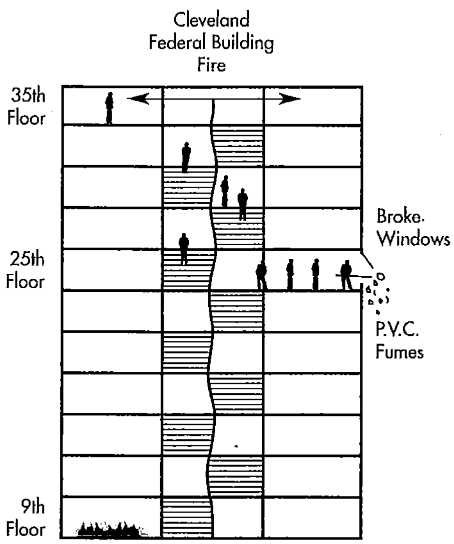


Figure 13-20 The stack effect delivered gases to the 35th floor from a minor fire on the 9th floor of a building under construction. The fire led to improved fire protection standards in buildings constructed by the U.S. General Services Administration.

assisted the Norfolk, Virginia, fire department in a refrigerator plant fire. The fire was in fungus-treated construction lumber in a cold box. The boxes surrounding the box on fire were at 0°F (-17.7°C) temperature; the box where the fire was located was at 30°F (1°C). By rigging salvage covers and setting up fans as preplanned for a similar building on the naval base, the smoke was pumped into the elevator shaft, where it fell down the shaft to the street. At that time, the term *stack effect* was unknown to fire fighters, but this was a perfect example of extreme reverse stack effect conditions.

Air Conditioning

Whether air conditioning is a significant factor in smoke movement depends on the type of system.

Individual Room Units

Individual room units that recirculate room air or draw air only from the outside, as in many recently built motels, will have no effect on the general situation. In contrast, if the individual units draw air from the corridor, then polluted air from the corridor will be drawn into the rooms.

Single-Floor Systems

Single-floor systems are seen in many smaller office buildings and in retrofitted buildings built before air conditioning became commonplace. In a typical system, the air is treated on each floor in a fan unit. Air flows from the corridor to the fan unit and is distributed through ducts that spill into the ceiling void. The air comes into the offices through openings in the ceiling tiles, then returns to the fan unit via the corridors. As a result of this arrangement, smoke from any fire on the floor will be distributed throughout the entire floor.

There may also be vents from the ducts feeding the floor above. If the building code has permitted the dangerous situation of assuming that the floor–ceiling assembly will protect the columns in the plenum space, then smoke can move along the reentrant space of the column to the voids on other floors.

Telephone service is often provided by cabinets located one above the other, with holes in the floors connecting the cabinets. Openings from the cabinet to the ceiling void provide another path for smoke distribution.

In short, the fact that the building has single-floor separate systems will not prevent smoke migration throughout the building.

Multifloor Systems

When the entire building is air conditioned by one or more building systems, the problems become severely complicated. When total building systems are used, the treated air is regarded as a precious commodity. Only certain exhausts are passed to the outside; all other air is treated and returned to the occupants. This means that any smoke from a fire would be recycled through the building. As technology progressed and energy costs rose, people realized that there are many days when the outside air is quite satisfactory and could be pumped into the building. More modern systems often have a true full-exhaust capability; they also recirculate air to save on energy costs.

Smoke Management Systems

Complete knowledge of smoke management systems is particularly important for fire fighters. Will the fire department operate this system? Will the building engineer operate it? In one high-rise, the operating station for the engineer who supposedly will operate the system in an emergency is within the main plenum of the system. Operator instructions, however, specify that the engineer should leave immediately in the event of a fire. The control room for the air-conditioning smoke management system must be invulnerable to the effects of the fire with which the system must cope.

There are those who have insisted that high-rise fires can be controlled simply by manipulating the air supply. If such a system is proposed as the primary defense, proponents should be required to provide proof of the system efficiency in a realistic fire—perhaps with the windows out and a 35-mile-per-hour (56 kph) wind blowing into the building.

One such air supply advocate argues, "Let the fire burn, but let it burn clean"—presumably so that there will be no dangerous products of combustion. This is a fallacy. Heat is a dangerous product of combustion. There is no such thing as a clean-burning, hostile fire. Even if the fire itself is burning freely, above, below, and on all sides of the fire, materials will be in various stages of degradation, generating toxic and explosive gases.

The design of smoke management systems is an extremely complicated task. A well-designed and properly maintained system can certainly supplement the primary fire defense—automatic sprinklers—but it is certainly no substitute for adequate fire protection.

Some buildings simply have breakable tempered glass windows, typically spaced on 50-foot (15.2 m) centers around the building perimeter. They must be identified in some manner; it is common for a reflective Maltese cross sticker, or a "frosted" inscription, to appear on the glass.

In larger buildings, the smoke management system can be complex and customized. The fire department must be aware of its installation and operation from the beginning. One of the possible deficiencies is that it may be necessary that the system remain running, even if not refrigerating or heating, so that smoke will reach the detectors when the building is closed. An unaware energy-conscious building manager may turn the smoke management system off over weekends and holidays.

The key to smoke management systems is to study them *before the fire*. Each system is different—because each is designed to meet some specific goal(s). It is critical that you understand exactly what the system is designed to achieve, your role in operating it, and how to shut it down if necessary. Insist on getting written documentation for the system and be present when it is tested.

Compartmentation

Some people assume that fire-resistive buildings automatically provide compartmentation that limits the transmission of fire. This is often the case in older buildings with masonry panel walls built on concrete floors, without air conditioning and without the huge number of penetrations necessary for current communications requirements. Modern buildings often have poor perimeter firestopping as well as multiple penetrations for wiring. Air-conditioning ducts also sometimes serve as smoke paths.

Pressurized Stairways

One or more of the stairways in a building may be equipped to be pressurized when fire occurs. In such a case, fans are installed to pump outside air into the stairway so that the pressure differential will keep the stairway free of smoke. This approach requires a dependable source of power and intakes located so that they will not pick up smoke from the fire. Occupants must be trained to use the proper stairway, and should be drilled on this procedure, because the noise of the fans may frighten people who are already upset and trying to escape. Because the temperature should be close to the outside temperature, there should be no stack effect. The overpressure may make opening doors difficult, and mechanical assistance may be required. The system does nothing to clear corridors.

Air Standpipes

In the wake of the World Trade Center disaster in 2001, some high-rises across the United States have been retrofitted with internal breathing air systems ("air standpipes"), essentially pressurized air piping systems for SCBA bottles. The stainless steel piping runs vertically up through the building and provides SCBA filling stations on selected floors (usually every few floors). The systems are capable of getting air from a fire department's air cascade truck. These systems allow fire fighters to avoid carrying hundreds of SCBA cylinders up to the staging area of a high-rise fire Figure 13-21.

Installation of Special Equipment

Any equipment designed to function in case of fire is, in effect, fire department equipment. Technically qualified members of the fire department should approve its installation, be familiar with its operation, and supervise its testing and maintenance by the owner or owner's contractor. The basis for this arrangement, which is opposed by some designers and building officials, is that the fire chief has unquestioned authority over firefighting operations. Of course, there is no guarantee that the concept will be upheld, but it is the position with which the fire department should start.

Figure 13-21 An air standpipe filling station in a high-rise building.

Courtesy of Rescue Air Systems, Inc.

Fire Load and Flame Spread

Consideration of the fire problem of a high-rise building must go beyond the basic structural considerations to the question of interior trim and contents. A developer who was a vociferous opponent of improved high-rise fire protection in New York City argued that his buildings could not be burned with a blowtorch when finished. He argued that the problems arose from what the tenants did, adding interior trim and contents.

In general, codes specify adequate controls on interior finish with respect to flame spread and smoke development. The difficulty is that the interior finish is often installed by the occupant without a building permit. Even when flame spread requirements are adequate to protect life safety during evacuation, fires can gain great headway in combustible trim in the interval before an effective attack can be mounted. Multiple layers of wall coverings were a major factor in an Atlanta office building fire in which 10 people died.

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The wide-open floor populated with scores of computers and associated equipment that is required by many of today's businesses has introduced a new flame spread problem. This issue was graphically illustrated by the spectacular First Interstate Bank fire. The fire spread rapidly while the guards mistakenly reset the alarms. The Los Angeles Fire Department received the first alarm from an observer in a building several blocks away. By that time, heavy fire was coming out of many of the building's windows.

Heavy fire loads may be found in special locations in high-rises such as club rooms and restaurants. Wood paneling and imitation wood beams and heavy loads of plastic are common. The wood paneling is installed on furring strips, leaving a void behind where fire can burn untouched by hose streams.

Storerooms for office supplies and telephone rooms are other high fire load areas (Figure 13-22). Not only is the wiring insulation combustible, but a typical telephone room is usually the supply room and contains boxes of equipment packed in foamed plastic.

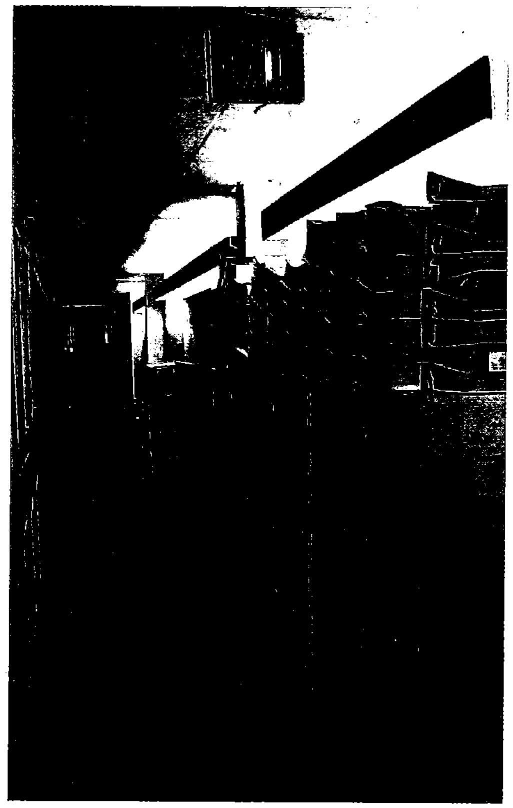

Figure 13-22 Stacks of paper, unprotected file cabinets, books, and binders will allow fire to spread rapidly.

Maintenance Operations

Maintenance operations can result in unexpectedly serious fire loads. If arranged for by a tenant, the building management may be completely unaware of this hazard. Such was the case at the Union Bank Building fire in Los Angeles on July 18, 1988. A contractor employed by a tenant was refinishing book cases with flammable liquids. When a worker brushed a solvent over an electrical outlet, fire erupted. The fire was quickly contained by the fire department, but the loss was estimated at $500,000.

Rubbish

When rubbish is gathered in high-rise buildings, it is often concentrated in one location, creating another fire load problem. The condition of the material provides a high rate of heat release. The concentration of such rubbish takes place in halls, elevators, basements, and lobbies, all particularly bad locations in terms of fire and smoke spread. Collecting rubbish on elevators tempts the potential vandal and provides the circumstances where an otherwise inconsequential fire can pollute an entire building. In one case, a rubbish fire in an elevator parked at the ninth floor contaminated the 26 floors above.

Many apartment buildings have trash chutes that deliver rubbish to huge compactor units located in the basement. Seven people died when a fire roared 35 stories up a blocked trash chute. The rubbish handling system is important. *It should be properly planned with the anticipation that there will be fires.*

Alterations to Occupied Buildings

A serious hazard exists when a building is altered or rehabilitated while it is still occupied. In a university hospital being altered, an untreated plywood wall was erected to separate the construction area from the maternity ward and nursery. The construction area had the typical fire hazards of any construction job. Fortunately, no fires occurred.

Hotels are renovated periodically. This usually involves replacing the furniture, particularly the beds. The new furniture is often stored wherever space is available, including the basement. Sometimes a floor is placed out of service and used for furniture storage. Mattresses removed from rooms may be stored in halls, awaiting disposal. Two serious fires occurred in Maryland suburban motels from such mattresses, which were inviting targets to an arsonist. The disastrous Dupont Plaza Hotel fire in San Juan, Puerto Rico, started in a large pile of new furniture that was temporarily stored in a ballroom.

Partial Occupancy of Buildings Under Construction

It is a dangerous situation to have a building partially occupied and partially under construction. Fire protection systems may not be fully operational in such structures; doors may not yet be installed on stairways and elevators. Temporary heating using LPG or combustible liquids may be used in some areas, and all the hazards of a building under construction exist. The strictest special precautions should be demanded if the building department permits partial occupancy.

Automatic Sprinklers

An examination of the disaster potential inherent in the typical enclosed structure with its occupants, fire load and fuels, and construction materials and configuration leads to one conclusion: there must be absolute assurance that the toxic gases released in a fire will be severely limited and not dependent on control by a smoke management system. In theory, this could be accomplished by limiting the quantity of fuel present. However, the combustible materials are necessary to the functions performed in the building. The only practical solution is to provide a system that will limit the amount of gas and heat produced.

The only such system available is automatic fire sprinklers. Fire department reaction time (from the time the alarm is received until water is put on the fire) is rarely the fabled 1 ½ minutes, but more typically 20 minutes or longer. Burn time between ignition and alarm, however, can be any length. The relatively short reaction time of the sprinklers, plus the fact that they can automatically transmit the alarm, makes them infinitely superior to any other fire protection system. If the sprinkler system water supply is properly tied to the domestic water system, such a system is almost foolproof. This is not to say that other systems are not necessary to supplement the sprinkler protection, but rather that sprinklers are the core of fire safety for the occupants of high-rise buildings.

What gives the developer of a high-rise the right to erect or maintain a structure that places an enormous burden on the public purse and strips the city of normal fire protection by omitting the automatic sprinkler system? At one point during the February 1991 Meridian Plaza high-rise fire in Philadelphia, there were only 16 companies available to protect the rest of the city.

The argument against sprinklers is usually an economic one, buttressed at times with arguments from some construction material suppliers and devotees of managing fires by controlling smoke. The basic argument for sprinkler protection is one of equity: the builder is creating the problem for profit, so it is up to the builder to provide the solution. This parallels what is done in the case of parking facilities, sewage facilities, and other amenities.

When the improvement of existing buildings is being discussed, many attorneys immediately dismiss any effort to improve the fire safety of an existing building as being unconstitutional. The U.S. Fire Administration asked Frank Brannigan to research the subject. He found no U.S. appellate court case that accepted a constitutional barrier to the enforcement of a new fire code to an existing building.

Checklist

There are innumerable items of information that would be useful for the IC to have at the scene (Figure 13-25). The following is merely suggestive of useful building information. Even though a sophisticated information retrieval system may not be available, this valuable building-related information should be gathered. The day is past when fire departments can depend on information known only to "Captain Joe, the old-timer," who won't always be around. The information must be institutionalized—available to all. The building may be there for a century and may outlast several generations of fire department personnel.

Structural Frame

- *Cast iron:* What is the estimated value of "fireproofing"? Are there connections from column voids to floor voids?
- *Steel:* What type of fireproofing? Are columns unprotected in plenum space?
- *Concrete:* Are there visible rods and cracks? Has there been any fire experience in this building that might have caused structural damage? Is corridor fire resistance achieved by gypsum on studs, making breaching easy?
- *Reinforced masonry:* Are corridor walls reinforced? If so, breaching would be difficult.

Floor Assemblies

- *Bar joist floor–ceiling assemblies:* What is the integrity of the floor? Early collapse is possible.
- *Concrete:* Are the floors of solid reinforced construction (good insulator and heat sink) or composite decks (Q-floors or cored slabs)?
- *Post-tensioned:* Don't drill or cut.
- *Tile arches:* Dangerous to cut because the entire panel may collapse.
- *Overloaded floors:* Potential for multistory collapse.

Floor Containment

- *Floor–ceiling assemblies:* Ceiling tile failure may permit at least partial collapse and open fire and smoke passage.
- *Unprotected columns in plenum:* Smoke and fire may pass to voids above via reentrant space.
- *Firestopping:* Is there effective firestopping in void spaces?
- *Masonry floors:* Utility openings may allow fire to pass.
- *Accommodation or access stairways:* These create huge fire areas.

Perimeter Integrity

- *Joints:* Are masonry wall to masonry floor joints solid (good inherent firestops)?
- *Panel walls:* How are exterior panel walls joined to the floor? What is their value as firestops?
- *Glass walls:* Is vertical extension of fire probable?
- *Exterior architectural panels:* Voids between panels and walls may negate firestops.
- *Contents:* High rate of heat release furnishings near windows or combustible tile ceilings increase the potential for exterior extension.
- *Lower levels:* What is the potential for exterior hose streams to block the extension of fire?

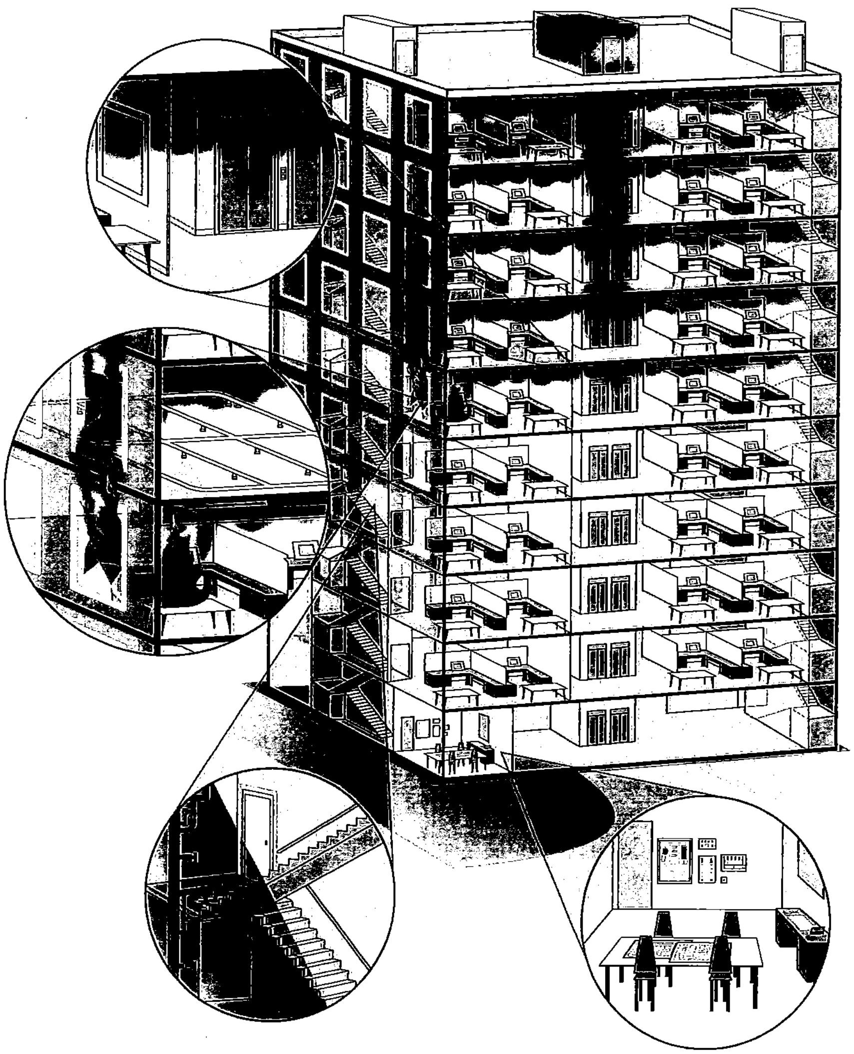

Figure 13-23 A cutaway of a high-rise fire. Although very unlikely in a fully-sprinklered high-rise, fire extension via autoexposure and in the gap between the curtain wall and floor above are possibilities. Note the avenue of potential vertical smoke spread via the typically unpressurized elevator shaft. In the stairwell, pay particular attention to the location of floor control valves for the sprinkler system on each floor, the type of standpipe hose valves and their settings, and any door locks preventing reentry on the office floors. The first floor fire command center—described on page 380—provides a number of fire protection systems, communications, and elevator, generator, and fire pump status panels and controls, as well work space for reviewing building plans stored on site.

Compartmentation

- *Integrity of compartmentation:* Are there utility openings or underfloor openings such as for computer cables? Do barriers extend to the underside of the floor above? Do fire doors function properly?
- *Gypsum board compartmentation:* Consider penetration of relatively lightweight gypsum partitions as a substitute for forcible door entry.
- *Stairways:* Are there deficiencies of stair enclosures? Are there proper operating door closures on all floors? Are stairways locked to deny entry to floors? Do all units carry forcible entry tools?
- *Elevators and other vertical shafts:* Gypsum board enclosures may be destroyed by firefighting operations.

Fire Protection Systems

- *Sprinklers*: Is the building fully sprinklered?
- *Standpipe:* Which type of standpipe system is provided and where are the hose outlets?
- *Smoke detection:* Where are smoke detectors located?
- *Smoke management*: Does the building have a smoke management system? How does it work? What is it intended to achieve? How do you operate it?
- *Fire fighter communications*: Which kind of fire fighter communications system does the building have?
- *Occupant communications*: Which type of communications are possible with building occupants? Can this system be controlled by floor or floors?
- *Equipment status:* What are the indicators for the fire pump, generator, and elevators? How are these pieces of equipment controlled from the command center?

Hospitals and Nursing Homes

Hospitals and nursing homes have a common characteristic—they are home to numerous **nonambulatory people**—that is, individuals who are not capable of self-preservation. It is up to the building, the staff, and you to protect them. Many older facilities also lack sprinkler protection, the most basic of equipment in these types of facilities. Many have relied on passive protection, such as fire doors and rated corridors. Many modern nursing homes and hospitals have sprinkler protection and an alarm system. How well protected are the facilities in your community?

In the late 1980s, a working fire broke out in an unsprinklered hospital in San Antonio. The fire erupted in the medical gas piping system, which included oxygen, inside a corridor wall. The fire, accelerated by the oxygen, incinerated the corridor wall. Nurses had followed proper protocols, evacuating the patients in the immediate area and closing all fire doors. The fire doors held the fire in check until fire fighters extinguished the fire. Thankfully, no one was killed.

The key to patient safety is to move patients horizontally, rather than vertically. Hospital and nursing home buildings are equipped with smoke barriers, 1-hour fire-rated walls that subdivide each floor into 2 or more separate areas. If a fire occurs on one side of the smoke barrier, patients may be moved through the barrier to the other side. To complement the smoke barriers, corridors are a minimum of 8 feet (2.4 m) wide to accommodate the size and width of rolling hospital beds.

Hospitals and nursing homes usually have highly trained staff. (This is one of the few occupancies for which codes recognize such training as part of the "protection package.") Hospital and nursing home staffs practice **RACE**:

- *R:* Remove all people in immediate danger to safety.
- *A:* Activate the manual pull station and have someone call 911.
- *C:* Close doors to confine the spread of smoke and fire.
- *E:* Extinguish the fire, if possible.

Hotels and Motels

On a national level, U.S. fire fighters have experienced many hotel and motel fires over the last 75 years. Some of the more notable were the fires involving the Atlanta Winecoff Hotel (1946; 119 dead); the Chicago Hotel LaSalle (1946; 61 dead); the Clark County, Las Vegas, MGM Grand (1980; 84 dead); and the Puerto Rico Dupont Plaza (1986; 87 dead). All of these incidents took place in unsprinklered hotels Figure 13-24.

The 1990 Hotel and Motel Fire Safety Act encouraged improvements in fire safety for such facilities nationwide. This encouragement was accomplished by withholding travel expenses from federal employees who did not stay in approved facilities that met minimum fire safety standards. Although sprinklers were considered critical for larger hotels, small motels were not required to meet this requirement and could get away with just smoke detection, alarms, and other passive equipment.

Figure 13-24 The Dupont Plaza hotel fire.

© Jose Fernandez/AP Images.

Fire fatalities continue to occur in hotels and motels. Although there hasn't been a "spectacular" multifatality hotel fire in recent years, numerous fires in motels have claimed the lives of small numbers of people.

Older motels typically have open walkways to access the units along the face of the building. Even without an interior corridor system, fire spread occurs through voids between the floors and particularly the space underneath the top floor and roof.

Newer hotels and motels have interior corridors that have proved to be a conduit for smoke travel. The Westchase Hilton fire in 1982 killed 12 people. Besides the front desk clerk who kept resetting the alarm (for the real fire on the fourth floor), a contributing factor was a door that did not close properly and let heat and smoke escape into the connecting hallway and up the vertical shafts.

Jails and Prisons

Like hospitals, jails are considered institutional occupancies. The inmates of a jail are, of course, restrained and are incapable of getting out of the building to save their lives. They rely on prison staff and the building for their safety.

Jails and prisons run the gamut from old to new, big to small. Some use the old technology of individual key-operated doors, whereas others have automated control systems. Some have full sprinkler protection, whereas others have none.

Currently, there are five occupancy classifications of detention facilities, depending upon their level of restraint:

- *Use Condition 1*: Free movement is permitted within the building from smoke compartment to smoke compartment as well as to the exterior.
- *Use Condition 2*: Free movement is permitted within the building from smoke compartment to smoke compartment.
- *Use Condition 3*: Free movement is permitted within the building within a smoke compartment; movement to other areas is by remote control release.

- *Use Condition 4*: Free movement is permitted within an occupied space within a smoke compartment; movement to other areas of the smoke compartment or other smoke compartments is by remote control release.
- *Use Condition 5*: Free movement is restricted from the occupied space; manual release is necessary to allow movement from the occupied space to other areas of the smoke compartment or other smoke compartments.

Numerous jail fires have occurred over the years, killing many prisoners. A fire in 2002 at the Mitchell County, North Carolina, jail killed eight inmates. This was a 1950s-era facility that required the manual opening of doors.

Some jail fires start accidentally, but others are intentionally set by the inmates. Several fires over the years have involved the use of polyurethane foam in a padded cell.

In any case, you must understand how the restraint system in the jail building that you respond to works and the "use condition." Also, does the building have a sprinkler system? (Is the sprinkler system automatic? Some old jails have dry pipe systems that must be opened manually to let water into the system.) Is it a modern jail with a smoke management system? Does it have smoke barriers like those described earlier for hospitals? Are the inmates evacuated from the building, and if so, where are they placed?

Museums and Libraries

Valuable collections of historic artifacts, books, and pieces of art have been lost to fire. Recent examples include the 1986 Los Angeles Library fire in which $22 million worth of collections were lost and the structure was damaged; an arson fire in a Holocaust museum in Terre Haute, Indiana, in 2003; and a massive fire that destroyed the Biblical Arts Center Museum in Dallas in 2005.

Unfortunately, museums and libraries are not always protected with a fire suppression system. For years, many institutions mistakenly rejected sprinklers as causing too much water damage. (They never considered the damage from a well-involved fire and subsequent water from a hose line.) In some cases, these institutions did install other types of suppression such as halon systems (which now are being phased out).

Life safety is, of course, the primary concern of fire fighters. Many museums and libraries have extensive security systems, including magnetic door locks. These systems are illegal; model building codes do not permit these systems in places of public assembly like museums and libraries. If you find them, notify your fire prevention office and/or the department of buildings.

A preincident plan for these facilities will assist greatly responders when a fire occurs. Besides the typical details of construction and fire protection systems, ensure that this plan includes salvage operation details for saving the collections. Most museums will have a detailed "disaster plan" (often required by their insurance company or grant providers), which will provide many of these details.

Library Stacks

Libraries are the original high-stack storage buildings. We are not referring to the familiar branch library here, but rather to the large main libraries that have multilevel stack areas where the books are stored Figure 13-25. There are libraries in which the stacks are open to the public, but usually, patrons do not go into the stacks; instead, stack attendants retrieve the requested books.

Most stack areas are built to a common pattern. Stack levels are about 6 feet (1.8 m) high so attendants can reach the **shelves** without a ladder. The floors are open to air circulation to prevent mildew. A better system to guarantee the spread of fire and destruction of the books in case of fire can hardly be imagined. In addition, the stacks are often structurally part of the building, so that fire damage to unprotected steel may have structural consequences.

Figure 13-25 Old multi-level library stacks with glass floors. Fire can spread easily in this situation.

Courtesy of Glenn Corbett.

Figure 13-26 Contributing factors to the fire at The Station nightclub included interior finishes, overcrowding, and the arrangement of exits—just to name a few.

© Robert E. Klein, File/AP Images.

Nightclubs

Nationally, nightclubs have been the scene of many large disasters. The most famous and largest was the 1942 Cocoanut Grove fire in Boston, which killed 492 people. The Happyland Social Club arson fire in the Bronx, New York, killed 87 people in 1990. A 2003 fire at The Station nightclub in West Warwick, Rhode Island, killed 100; it was initiated by an indoor pyrotechnics display during a concert (Figure 13-26). A similar nightclub fire in 2013 involving indoor pyrotechnics and acoustic foam insulation in Santa Maria, Brazil, killed 242 people.

Nightclubs are places where people go to have fun. The use of alcohol is a key element of that fun, resulting in patrons who often are not fully aware of their surroundings. In addition, these clubs are often overcrowded beyond code-imposed limits. Locked egress doors (often at the rear) complete the potential for a disaster.

Many fire departments have nightclubs in their response district. It is important for fire inspectors to stop by on a Saturday night while in uniform and on duty to see what is happening. Look for locked and blocked egress, dangerous decorations or performances (including indoor pyrotechnics), and, of course, overcrowding.

Many clubs operate out of old, worn-out structures. Other than in Rhode Island, many of these existing clubs are not required to retrofit sprinklers. During the course of preincident planning, note the location of exits and potential points of ventilation. Ensure that during an emergency, all exits, including the rear, are opened fully—you may possibly find people trapped there.

Figure 13-27 Large open rooms have no barriers to hinder fire advancement.

Office Buildings

Every community has an office building. Office buildings are built using all five types of construction, large and small, high-rise and low-rise. These buildings have changed over the years, from highly compartmentalized structures with offices for every worker that were once popular to the **open office plan** in which low-height partitions create cubicles for personal space but the office is essentially one large, open room **Figure 13-27**. Fire spread through a compartmentalized space is much different than a fire in an open office plan.

Fire fighters have been killed in fires in large office buildings, such as the One Meridian Plaza high-rise fire in Philadelphia where three fire fighters lost their lives. In this incident, the fire fighters became trapped and disoriented, giving the wrong floor as their location. Fire fighters have also been trapped and killed in smaller low-rise office buildings, such as a Denver fire fighter killed in 1992 when he ran out of air inside the building.

Open-Area Structures

Many large open-area structures, such as churches and arenas, are built of wood or have an exposed wood plank roof that makes up the ceiling. Such a valuable building should be fully sprinklered. The objection to sprinkler piping in an open decorative wood structure is understandable—the exposed piping detracts from the overall look of the decor. However, in some cases, the sprinkler piping is run close to beams, and sidewall sprinklers are used. A competent painter charged with making the pipes less apparent can work wonders.

If a building is not fully sprinklered, try to keep out the kindling—the minor light combustible structures or elements that can ignite the whole building. If a structure, such as a robing room, sacristy, ticket office, hot dog stand, or the like, is to be built within such a building, verify current building code requirements that likely call for the use of noncombustible construction materials and possibly sprinklers.

Frank Brannigan recommended sprinkler protection, even if only a couple of sprinklers taken off the domestic system are installed to protect these types of small enclosures in heavy-timbered buildings. Don't call it partial sprinkler protection; call it a super-extinguisher. If there is no kindling, the open-area timber structure should stand for generations.

Parking Garages

A parking garage may be partially or totally above grade and open to the atmosphere. All garage areas under buildings should be sprinklered. Note that many garages have dry standpipes without any permanent water supply. What this means is that the water you provide through the FDC will be its only supply. This also means that air will be trapped in the system and it will take some time to get water to the nozzles of your hose lines. Beware of open hose valves, opened by mischievous individuals.

Restaurants

One of the most common places for fires in a restaurant is in the kitchen. Interestingly (and oddly), the model building codes do not require a fire-rated separation between the kitchen and the dining area. Some older codes even allowed exits to pass through the kitchen and out the back door!

Although codes require cooking hood extinguishing systems, our experience with them has not been all positive. Several of the systems have failed (often due to poor maintenance), allowing a grease fire to spread into the kitchen and to the structure around the ductwork going to the roof. Broken ductwork adds to this problem. It is important to track the spread of fire into void spaces around the ducts, especially if the ducts have developed holes or breaks in the seams and allowed grease to coat these locations Figure 13-28.

When preincident planning, pay particular attention to the location of the utilities, especially gas. Also make note of the use of propane, which is (unfortunately) permitted in some circumstances for tabletop cooking. The use of propane introduces the possibility of an explosion and fire. Such an event happened along the New Jersey shore in a restaurant, where patrons (including an off-duty fire fighter) were forced to break windows to escape the fire.

Figure 13-28 Not all cooking hood systems are as well maintained as this one. Pay particular attention to them when conducting inspections.

Courtesy of Glenn Corbett.

Schools

Building code regulations concerning schools have been shaped by one particular fire—the 1958 Our Lady of Angels fire in Chicago, which killed 92 students and 3 nuns. This fire led to numerous egress improvements in schools, such as better and more frequent fire drills, lower and more accessible windows for escape, abatement of open stairwells, alarm systems, and fire-rated corridors and doors.

Schools often have some unique features. Their corridor widths are much larger than normal, 6 feet in most cases. In addition, the egress systems may be unusual. Although no longer accepted in new buildings, many old structures, particularly in warmer climates, still have these features.

Pay particular attention to potential hose stretches. In many older schools without standpipe systems, corridor lengths are particularly long. The preincident plan should also make note of special hazards such as woodworking and machine shops, chemical storage areas, and flammable/combustible liquid storage for art classes.

With concerns over violence in schools, many school districts have instituted lockdown procedures. Find out if this is the case and how it will affect your firefighting operations. As a result of the 2012 Newtown, Connecticut, school shootings, it is likely that new emphasis will be placed on increasing the physical protection features of existing schools. These enhancements will likely include bullet-resistant glass, secured lobbies, increased use of magnetic door locks, locks on exits and room doors, thicker walls, and secure classrooms.

Self-Storage Buildings

In recent years, the number of self-storage facilities has increased dramatically. These structures may be found in a variety of construction types, most notably Types I–IV.

Generally, facilities of the one-story drive-up variety are either Type II or Type III construction. Apparatus accessibility and water supply tend to be

Figure 13-29 Many multistory self-storage facilities have limited points of horizontal ventilation—windows are few and far between.

Courtesy of Glenn Corbett.

the issues of concern in these buildings, in addition to the unknown contents of the units.

It is the multistory Type I and Type IV facilities that present more of a challenge (Figure 13-29). These are often repurposed buildings that are essentially windowless (the old windows have been blocked up; sprinkler protection is mandated). Corridors are often confusing and maze-like. Stored materials are often placed as high as possible in the units. Hazardous materials are found in many units. Ascending a folding ladder may make it possible to see over the units in some buildings. Search ropes and thermal imagers are crucial pieces of equipment.

A smoky fire in one of these buildings will make it very difficult to establish which units are involved. Try to use sprinkler discharge as an indicator of the fire's location. Ventilation will be very difficult—be sure to identify your options during preplanning.

Single-Family Homes

The California Bungalow

The California bungalow has become popular all across the country. This one-story structure has a peaked roof with rafters as small as 2 by 4 or 2 by 6 inches. Often there is no ridge beam in these homes. The attic often contains a high fire load of stored materials and is reached by a small scuttle hole. The house can have one or more dormer windows.

The Cape Cod

This is traditionally a 1½-story home with a steep-pitched roof (Figure 13-30). These are platform-framed structures. The stairway to the second floor is near the front door. Bedrooms may be located on both the first and second floors.

The Ranch House

One-story ranch houses are very popular (Figure 13-31). These houses have open interiors, large attics, and extended overhangs. In some areas, these homes are spaced so close together that they create a serious exposure hazard. Fast-spreading fires in these types of houses, heavily involved on arrival of the fire department, are not uncommon.

Properly installed and maintained smoke alarms can provide a high degree of occupant life safety in these buildings because escape from them is relatively easy. Many bedrooms in the

Figure 13-30 The Cape Cod.

Figure 13-31 A ranch house.

Figure 13-32 A split-level home.

ra[illegible] house have direct routes to the outside because their windows are small and high above the floor.

One common deficiency in these dwellings is failure to place a heat detector in the attic. Heating and air-conditioning units are one potential cause of attic fires. There are known cases of attic fires in which smoke alarms in the living spaces did not activate until the attic was well involved and collapse was imminent.

The Split Level

The split level is just that—three floors joined by short-run stairways (Figure 13-32). The top level usually contains the bedrooms; the middle level, the dining room, living room, and kitchen; and the lower levels, the recreation room and laundry room. This structure is platform framed.

The Victorian

This group is a catch-all of many styles of homes of the mid- to late-1800s—the Queen Anne, Italianate, and so on (Figure 13-33). Victorians are characterized by significant amounts of ornamenta[illegible] steep-pitched roofs, and balloon-frame

Figure 13-33 A Victorian house.

construction. Many of these homes have been converted to multiple dwellings because of their large size.

Stadia

Most major American cities have a stadium, which can vary in seating capacity from a few thousand to more than 80,000. Many are open-air stadia; some are enclosed with fixed roofs or domes. Stadia are almost always of Type I construction. The type and amount of fire protection features varies, particularly with the age of the facilities. It was not until the 1980s that more rigorous code criteria were developed for these structures, particularly enclosed stadia.

One notable issue with stadia is egress travel distance—most enclosed stadia cannot meet the traditional limits on travel distance from the most remote seat to an enclosed fire-rated stairwell. New code requirements were created to deal with this problem by requiring a smoke management system in addition to sprinklers and standpipes.

Some enclosed stadia used for purposes other than sporting events—tractor pulls, trade shows, and concerts, among other things—often necessitate additional fire suppression equipment because of the inability of traditional sprinkler systems to respond to and control a fire more than 150 feet (45.7 m) below the sprinkler. In some cases, special flame detector-activated water cannons have been installed to provide fire protection.

Taxpayers and Strip Malls

As development sprawl overtook the American suburban landscape a few decades ago, a new type of neighborhood corner store appeared—the strip mall. Like its urban ancestor, the taxpayer, the strip mall provided the convenience of having a variety of shops under one roof. Although the taxpayer and the strip mall share common construction characteristics, they also have distinct differences that must be considered. In some cases, it may be difficult to distinguish between a taxpayer and a strip mall.

Taxpayers

Fire service legend tells us that the term *taxpayer* was developed to describe the practice of constructing "temporary" revenue-generating buildings on a tract of land along a city street. These buildings were designed to pay the taxes on the land until a more desirable multistory apartment or office building could be built. Whether this legend is true or not, the fact remains that thousands of taxpayers still exist in cities across America.

Taxpayers generally have the following characteristics:

- They most often are of ordinary (Type III) construction, usually with brick bearing walls and wood-joist roof members.
- They commonly are one story in height, although the two-story variety can be found in many jurisdictions with apartments on the second and third floor.
- Depending on the region, many taxpayers can have full or partial basements. Access to the basement is through metal sidewalk doors and stairs or interior "trap doors" in the stores themselves.
- They usually are limited to approximately 6–10 small stores (or other commercial establishments).
- They most often have common cockloft or attic spaces.

Many fires have been fought in taxpayers. Fire spread is typically through the cockloft above all of the stores. There are specific hazards to be wary of. The parapet above the stores is usually unsupported or poorly supported. Movement of the structure below, such as when fire causes expansion of the steel beam that usually runs across the front of the stores above the windows and doors, can cause the parapet to fall.

Hazards of inner-city taxpayers include the steel plates on the roof of check-cashing establishments (to deter entry of burglars). Rotted wood floors nder the washing machines in Laundromats are lso dangerous—a fire in the basement can cause the rst floor to collapse.

trip Malls

trip malls have the following characteristics (Figure 13-34):

- They may be of noncombustible, ordinary, or even wood-frame construction (Types II, III, and V construction, respectively).
- When of noncombustible construction, strip malls have exterior walls of concrete block or concrete tilt walls (possibly with brick veneer) with steel bar joist roof members and a metal deck supporting a built-up roof.
- Contemporary ordinary construction strip malls use concrete block for exterior walls nd solid wood joists or lightweight trusses to support a wood roof deck.
- Older ordinary construction strip malls may have large bowstring trusses.
- Some smaller strip malls may be built entirely of wood-frame construction.
- Nearly all strip malls are one story, although a two-story strip mall occasionally may be encountered.
- Based on region, strip malls may or may not have basements.

Figure 13-34 A strip mall.

- They usually are larger than the taxpayers and may have as many as 15–20 small stores and a large anchor store or two.
- Strip malls usually have greater store depth than taxpayers. Strip mall anchor stores, such as supermarkets, may be more than 150 feet (45.7 m) deep.
- They most often have common cockloft or attic spaces.

Strip Mall Surroundings

Another distinguishing feature of strip malls is the property surrounding them, which most often is a parking lot out front and along the ends, and a delivery truck driveway at the rear. The strip mall setback can be both an advantage and a disadvantage.

The parking lot can be helpful, especially from an apparatus-placement standpoint. In many cases, apparatus can be placed on four sides of the structure, and additional apparatus can be placed in close proximity in the parking lot. In some cases, a staging area can even be set up in a remote area of the parking lot, relieving the public streets of tie-ups.

Among the disadvantages of the strip mall setback are the following:

- On-site private hydrants must be used because the strip mall is too far from the public hydrants surrounding the property. In some cases, the main may be 6 or 8 inches (15 or 20 cm) in diameter and of the dead-end type. These private mains are often poorly maintained. In addition, if the building has an automatic fire sprinkler system, it often will use this same water main. It is critical that fire departments establish the supply layout (including FDC, tie-in location, and underground gate valves) and flow capabilities during preincident planning.
- The delivery truck driveway at the rear of the strip mall is often dotted with crater-size potholes that create hazards for fire apparatus. These delivery driveways also may have obstructions that can present additional hazards.

For example, these areas often are used as an easement for utilities. Fire fighters must be aware that overhead power lines may be present. Retail establishments often use these driveways for storing pallets, bins, bales, cardboard, and dumpsters, which may block the access for fire apparatus. It is best to designate these areas as fire lanes and to inspect them frequently.

Strip Mall Occupancy Types

Strip malls may have a variety of tenants. In addition to the typical delicatessen, bakery, and hardware store, occupancies can include childcare centers, nightclubs, gyms, spas, auto-body shops, and even storefront churches. From a building and fire code standpoint, it is very possible to have assembly (A), mercantile (M), business (B), and, unfortunately, hazardous (H) occupancies all in the same strip mall.

What this means to you as a fire fighter is that you will be confronted with a variety of hazards as well as a variety of occupancy types in strip malls. Hazards can include flammable liquid storage/use/sales in a paint store, a dry-cleaning store using combustible Class II cleaning liquids, flammable spray operations in a body shop, and oxidizer and corrosive material storage/sales in a swimming pool supply store. Occupant count can range from dozens of young children in a childcare center to hundreds of shoppers in a supermarket to a large group of patrons in a nightclub.

Most building codes require a fire-rated separation (also known as an occupancy separation) between different occupancy types (separating a business occupancy from an assembly occupancy, for example). These walls, which must completely separate the different occupancies, can be 1-, 2-, 3-, or 4-hour fire rated, depending on the types of occupancies being separated. A higher rating is required as the hazards and threat to life safety of the specific types of occupancies increase. Depending on the particular building code being applied, the installation of automatic sprinklers in the building can reduce the hourly rating (this practice is prohibited in some building codes).

Often, no rated separation is required between a group of strip mall tenants if all are the same occupancy type. A group of small shops selling fish, greeting cards, and books requires no separation between each shop, for example. The "demising" walls between the shops may be made of rice paper, be full of holes, and still meet the building code.

Depending on the size of the strip mall, another type of fire-rated separation—a fire wall (also known as an "area separation wall")—may be required. Building codes contain provisions that limit the size (area and height) of all buildings based on the type of construction and type of occupancy—the better the type of construction (fire resistive being the best, wood frame the worst) and the less hazardous the occupancy, the larger the building can be. When the building area becomes too large, fire walls often are required to break the structure into smaller fire areas.

These fire walls may have a 2-, 3-, or 4-hour rating and also must be constructed to allow partial collapse on either side without pulling the entire wall down. Often, these walls must be continuous from the foundation to above the roof line—from "dirt to sky." Unfortunately, building codes grant exceptions to this continuity rule by allowing some fire walls to terminate on the underside of the roof deck.

Only on-site preplanning and review of your local building codes will untangle this mess of code requirements concerning fire-rated separations. Look above the ceilings and ask questions of your building and fire inspectors. Know how the building will work for you and against you.

Strip malls of Type III and V construction that use a combustible structural roof (or floor members, in a multistory building) require the use of draft stops to compartmentalize the attic or floor void spaces. The draft stops are not required to be fire rated; they may be made of plywood or gypsum board. The intent is to have the draft stop slow the fire down and keep it confined to a given area for an indeterminate period of time. This will buy fire fighters time to get ahead of the fire if it is spreading through the attic (or floor) void space.

The requirements for the draft stops have changed over the years. Currently, draft stops are required to limit the size of attic compartments to 3,000 square feet (278.7 m²) and floor void compartments to 1,000 square feet (92.9 m²). Again, depending on the building code, the installation of automatic sprinklers can eliminate the requirement for draft stops. Conduct your own research to determine what rules apply to draft stops in your jurisdiction. When properly installed and maintained, draft stops help fireground activities. Often, however, they are compromised by holes punched in them for electrical wiring and the like. Perform frequent inspections and order repairs made where holes are noted.

One last note about preventing fire spread: some building codes require firestopping at a maximum of 20-foot (6.1 m) intervals in combustible architectural trim (projections such as cornices, mansards, overhangs, and so on). Firestopping will help prevent the fire from doing an end run on the outside of the building around yo[illegible]e attack. Know where the firestopping is located and how you can use it to your advantage.

Structural Fire Resistance

Building codes limit the size of any building based on the type of construction and occupancy group type. One way to increase the allowable area is to increase the fire resistance of the structural members—a Type II building, for example, may use unprotected (bare) steel bar joists for the roof's structure. "Fireproofing" the steel by applying a fire-resistive coating can increase the allowable area. Doing this may be necessary to permit certain occupancy types into the building. Probably the most common example is a place of assembly, especially a nightclub. Nightclubs of substantial size usually require a higher level of structural fire resistance to remain within the building code's allowable area limitations. It also may be the only occupancy within the building to have fireproofing; surrounding tenant spaces may have no structural protection.

During preincident planning visits, look at the structural members in each occupancy. Note which members are protected and which are not. Record th[illegible] facts in your preincident plan to establish w[illegible] this structural protection will help your attack.

Sprinkler Systems

Building and fire codes do not require automatic sprinklers specifically for strip malls. However, they do require sprinklers for mercantile and other types of occupancies under certain conditions. Basements also have to be sprinklered in some cases. Under some building codes, sprinklers can also dramatically increase the allowable size (including area) of a building.

Looking more closely, some building and fire codes require automatic sprinklers for retail sales rooms larger than 12,000 square feet. Most codes, therefore, require that sprinklers be installed in large anchor stores such as supermarkets. In addition, most basements in mercantile occupancies must be sprinklered. Today, new nightclubs with occupant loads over 100 (a new lower threshold because of The Station nightclub fire in Rhode Island) or over 5,000 square feet are sprinklered. Keep in mind that only certain areas of the strip mall may be sprinklered, and this only applies to new strip malls and tenants.

While conducting a preincident planning walk-through, determine the following:

- The areas of the strip mall that are sprinklered.
- Whether the system provides complete protection (including in combustible attic spaces) or protects only certain areas.
- The type of system—wet or dry (many strip malls with unheated attics often leave unleased tenant spaces unheated, necessitating a dry system).
- The location(s) of the main riser control valve(s) (which could be hidden in the closet of a tenant space).
- The location of the FDC and the areas of the building it supplies.
- Closest hydrant to the FDC.

Utilities

Fortunately, most modern strip malls have multiple utility meters/cutoffs, one for each tenant space or group of tenant spaces. The meters/cutoffs should be identified by "suite" number (the number assigned to individual tenants). Using this system, utility service to particular tenants or areas of the mall can be shut off. Note the location of the utility meter bank in your preincident plan. In many cases, the meters are on the exterior of the building, although gas meters may be in the basement in some buildings.

Forcible Entry

Another important consideration when developing firefighting strategies for strip mall fires is how you will gain access through the front and rear doors. Each can pose problems. Front doors usually are aluminum doors with glass panels. Using a through-the-lock entry technique usually is called for here and can be readily accomplished. In some cases, it is what is behind the front door—and even the large display window—that can impede access.

Electronic and computer stores and similar occupancies now are installing roll-down metal shutters, located on the inside of the store, behind the front door and display window. These shutters are secured with a padlock. This creates a double forcible entry situation. Consider the implications of ventilating the front display window, particularly how to coordinate the opening of this window with your interior attack.

The rear door of a tenant space poses an even more formidable entry problem. These doors are heavily secured to prevent break-ins and may even have drop-in metal bars. In some cases, the doors may actually be welded shut. Consider your operations for forcing these doors, including the use of metal-cutting saws. Also keep in mind that it is important to open these doors to provide a secondary means of egress for crews operating inside who are cut off from the front door. Another issue involving rear doors is identification. It is difficult to determine which door corresponds with which tenant space without the presence of a name or suite number. During your preincident planning visits, make sure the doors are identified, at least by suite number.

Firefighting Considerations

Fighting fires in strip malls raises many concerns. The following points deserve special discussion. Lateral fire spread throughout the strip mall is probably the greatest concern. Without the presence of fire-rated separations or draft stops that are continuous through the plenum space to the roof deck above, fire can spread readily from tenant space to tenant space. The ease with which this fire will spread depends on the construction of the roof members themselves.

A roof of solid wood joists with a dropped ceiling below will allow fire to spread in this void space. A roof structure of wood trusses or I-joists creates a large void space, a virtual lumberyard. Fire extension through the truss will be rapid.

A strip mall with steel bar joists and a built-up roof can be subject to a metal deck roof fire. This fire (in what is classified as a noncombustible building) can spread laterally, independently of the main body of fire below. The asphalt in the built-up roof becomes heated and then ignites, spreading fire above the roof deck and dripping hot tar into the store below through the deck seams.

The key to stopping a fire from spreading through the roof area is to get ahead of it. You must pull ceilings and apply heavy streams through the openings created. Consider the time needed to gain entry into adjacent tenant spaces—where will the fire be when you gain access?

Fires in wood truss or I-joist voids will spread rapidly due to the inherent openness of the truss. Consider the quick collapse potential. In a metal deck roof fire, cooling streams must be applied to the roof deck to cool the asphalt and stop the fire's progress.

Besides assisting the interior hose teams, ventilation can help slow horizontal fire spread through the roof area. Ventilation procedures still must be conducted safely in accordance with the type of roof. Fire fighters operating on metal decks are in danger of falling through if the cantilevered end of the deck gives way as the vent hole is cut. The wood bowstring truss poses the danger of large area collapse. In many cases, it is too dangerous to operate on top of or below these lightweight structural members when fire has taken possession of them. Consider a trench cut only when the "distance for time" is in your favor. Also, do not forget the numerous air-conditioning units and other concentrated dead loads on the roof.

Theaters

To understand the fire protection details in a theater, it is important to first understand the difference between a **stage** and a platform. By definition, a stage has a **proscenium arch and wall** (the large ornamental opening and wall that separates the audience from the stage); hanging curtains, drops, and scenery; lighting; and support rooms (dressing rooms, etc.) (Figure 13-35). A platform, in contrast, is a raised area in a building for presentations, wrestling matches, and the like, where there are no hanging curtains, drops, or scenery other than lighting and sound effects (Figure 13-36).

Stages have much more extensive fire protection requirements than platforms. Specifically, they must have a fire-resistant proscenium curtain, flame-resistant scenery, heat vents over the stage, 2-hour-rated separations between the stage and appurtenant rooms (dressing rooms, property rooms, etc.), sprinkler protection over the stage and accessory rooms, special stage exits, and a Class III standpipe with 1.5-inch hose and nozzle.

Some terrible fire tragedies have occurred in theaters. The worst was the 1903 fire in the Iroquois Theater in Chicago, where 602 people were killed in minutes. Despite the fact that the theater was only weeks old, many of the fire safety features did not work when a lamp ignited part of the velvet proscenium arch drape. The fire curtain did not drop to the stage floor, and the heat vents above the stage were nailed shut.

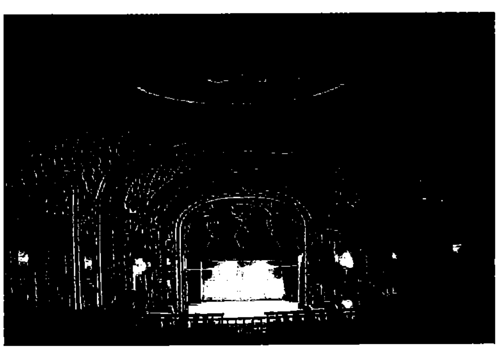

Figure 13-35 A proscenium arch in a theater.

...ces Roberts/Alamy Images.

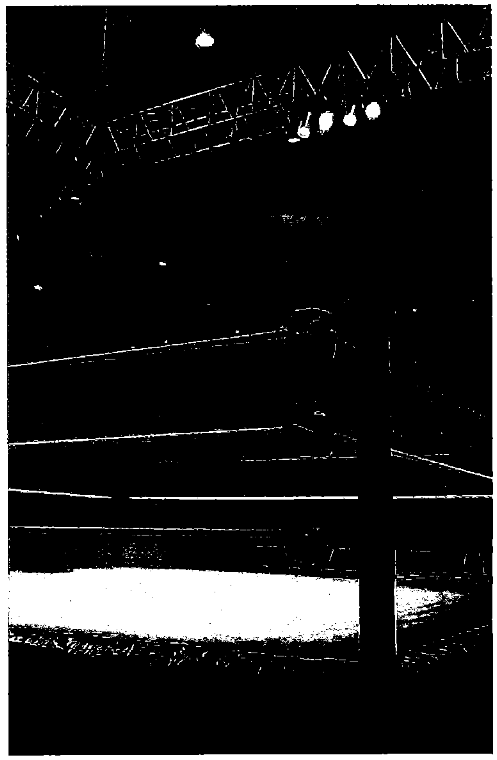

Figure 13-36 A platform used for boxing.

© Photodisc.

Branniganism

We must recognize that the key element in life safety of building occupants is not how high the building is but how long it takes an occupant to reach an area safe from all the products of combustion.

Bolt: © ...Shutterstock, Inc.; Texture: © Eky Studio/Shutterstock, Inc.; Steel: © Sharpshot/Dreamstime.com

Underground Buildings

Many buildings have basements, often used for mechanical equipment, storage, and the like. Some high-rises and other types of buildings have multiple "subbasements." Underground buildings are a relatively new concept and are beginning to proliferate across the United States.

Building codes define underground buildings as having an occupied level at least 30 feet (9.1 m) below the level of "exit discharge" (an exit discharge is typically a grade-level exit to the exterior). The code calls for the underground building to be provided with automatic sprinklers, standpipe, emergency power, a fire alarm system, a public address (PA) system, a smoke management system, and smokeproof enclosures (pressurized stairwells). When the occupied level is more than 60 feet (18.3 m) below the level of exit discharge, a smoke barrier that splits the floor level(s) roughly in half and that runs vertically up through all underground levels, must be provided.

Among the most common underground buildings are rail transit stations. Some recent examples of these are an incredible 16 stories below grade. The 9/11 museum at Ground Zero in New York is 70 feet (21.3 m) below grade. Because such buildings may house thousands of occupants at any given moment, moving these people quickly up stairwells to grade is virtually impossible. Tremendous reliance is placed on the built-in fire protection systems, attempting to protect the people where they are. It is imperative that fire departments charged with protecting underground buildings be fully informed on all aspects of their design and be able to voice their concerns.

While we have extensive experience with basement fires, we have limited experience with these super-deep buildings. The 1987 King's Cross Underground (subway) station fire in London provides some insight. In this incident, a fire developed in an escalator with wooden components, eventually flashing over and spreading fire upward through the multiline transit station Figure 13-37. A total of 31 people were killed, including a fire officer. While the King's Cross station lacked sprinklers and other fire safety features, this fire is illustrative of what may happen when these systems are impaired.

Figure 13-37 The King's Cross fire.

Warehouses

Once there was a simpler time when small fire departments had small fires, and big fire departments had big fires. Those days are gone forever! The advent of warehouse rack storage has brought potential major fire problems to Anyplace, USA. Materials may be stored in **solid piles** (either box on box or pallet load on pallet load), on shelves, or on **racks**.

Warehouse Fire Problems

Many serious fires have occurred in the long history of warehouse occupancies. The principal contributing factors have remained the same:

- Huge concentrations of fuel
- Tremendous dollar values
- Few employees per unit of area
- Failure to segregate extra-hazardous materials such as flammable liquids
- Failure to raise the bottom layer of stock above the floor, thereby preventing water damage and possible collapse
- Vulnerability to arson

- Failure of management to give serious attention to the potential fire problem
- Inadequate fire protection, either in initial design or in maintenance

High rack storage has made its way into big box discount warehouses. This introduces a significantly increased life hazard with potentially over 1,000 people in the store at any given time. The potential major fire problem of large storage is not limited to huge warehouse complexes. Storage areas of manufacturing facilities and smaller retail establishments, shipping and receiving areas, general rental storage warehouses, and outside storage adjacent to buildings present similar problems.

Such was the case in 2007, when a fire erupted on the loading dock between the Sofa Super Store retail showroom and its associated warehouse in Charleston, South Carolina. Fire spread to the unsprinklered showroom, which was constructed of concrete block with an unprotected steel bar joist. A variety of factors—high fuel load, hidden build-up of heated gases and smoke between a dropped ceiling and the roof, and breaking of the front showroom windows—led to rapid fire spread through the store and the deaths of nine firefighters.

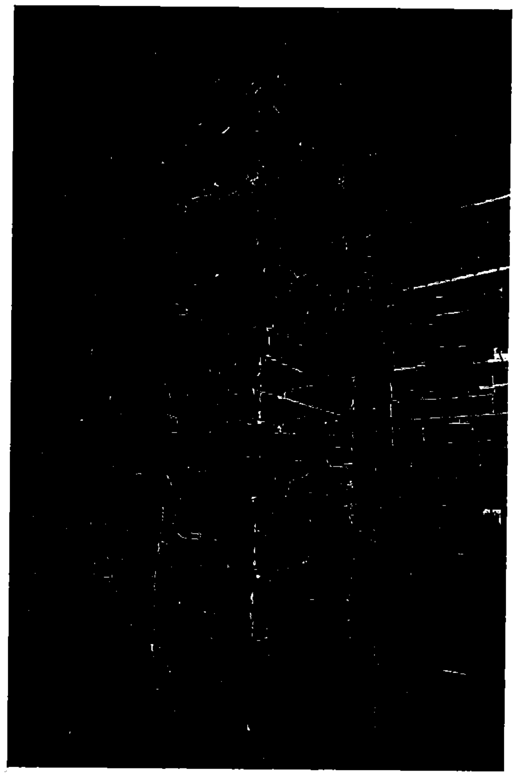

Figure 13-38 Dangerous idle pallet storage—plenty of fuel that is well ventilated.

Pallets

The problem of fire in warehouses was already significant when material was being stacked only by hand. About 50 years ago the lift truck became available. With this device, stock could be stacked on pallets, and pallets could be stacked one atop the other. This development provided a massive new dimension to the fire protection problem of warehouses. The pallet storage system provided as much as 36 times the surface area as boxes stacked solid. Initially, this problem was not universally recognized. Automatic sprinkler systems had such an excellent record that it was taken for granted that a sprinklered warehouse was safe.

Be aware that **idle pallet storage** (pallets without the product) is a dangerous practice inside of warehouses Figure 13-38. When they are piled up, the pallets resemble the wood crib used to test fire extinguishers. They should be taken outside and away from the building.

Shelving

Although pallets are still used for storing some commodities, many other items require shelving. Lift trucks also make it possible to place stock on shelves. These layers—in effect, miniature floors—create a whole new fire problem.

An estimated $14 million loss occurred in a rack storage warehouse in Kernersville, North Carolina, in March 1981. Sprinklers were not provided in the racks in a section almost 16 feet high. Although the fire had been burning for only 10 minutes when the fire department arrived, an interior attack was impossible. About 15 minutes later, the roof started to collapse. There was no FDC to the sprinkler system.

In the past, the FDC was optional. NFPA 13, *Standard for the Installation of Sprinkler Systems*, now requires the connection except for systems of 20 sprinklers or less or when permission has been obtained from the authority having jurisdiction (AHJ). Because the sprinkler system is a vital element of the fire department's suppression, the AHJ should be the fire department, and no such exception should be granted.

Modern Rack Storage Warehouses

Rack storage buildings—immense one-story warehouses in which the contents are stored on unprotected steel racks—are now found across the United States. Typically, such buildings are of noncombustible construction. The size can be unlimited. A Kmart warehouse that was destroyed by fire was as large as 33 football fields.

In these warehouses, merchandise is handled by mechanical equipment. In the most advanced warehouses, the operation is fully or partially automated. Computers keep stock records, and a signal from a computerized system operator can send the traveling elevator to the correct location. The elevator platform then ascends to the proper level, and the desired item—for example, a refrigerator, pallets of radios in polystyrene packaging, or automobile parts—is loaded onto the elevator. In some cases, the stock moves automatically all the way to the truck that will carry it to its destination.

A rack storage warehouse, depending on its height, is like a multistoried building without the fire resistance provided by even the poorest floor. Ordinary sprinklers located at the roof line are completely inadequate to control such a fire hazard. **In-rack sprinklers** must be provided at intermediate levels as well. Within certain limits, **early suppression/fast response (ESFR)** sprinklers are able to suppress a fire without in-rack sprinklers; they allow warehouse owners flexibility to move the racks without having to repipe the in-rack sprinklers.

Some warehouses have interior rail tracks so cars can be unloaded within the warehouse. A railroad car represents a major unsprinklered area within a warehouse. A fire in a loaded railroad car within the building would be a major problem. Other warehouses have very tall storage arrangements (over 50 feet [15.2 m]) with automated product retrieval systems.

Dry Storage of Boats

A special type of rack storage warehouse stacks boats several levels high in open or partially enclosed rack structures. These warehouses are usually unsprinklered. The boats are of combustible fiberglass and many contain fuel. A hot, fast-growing fire with early structural collapse can be anticipated. Preincident plans should include immediate use of heavy-caliber streams in a defensive attack for a fire in such a facility.

Warehouse Concerns

There are several contributing elements in the potential for huge loss warehouse fires:

- Modern contents of warehouses are increasingly higher hazard materials such as plastics, flammable liquids and gases, and chemicals. Even noncombustible materials are packaged in combustible containers and packaging.
- Huge quantities of material in one fire area provide fire loads that can easily overcome the best defenses.
- Higher and deeper aisles limit access and encroach on the space over the tops of piles required for effective sprinkler or hose stream operation.
- The size and construction of the buildings often make even the heaviest caliber fire streams ineffective.
- Automatic sprinkler systems as installed are often inadequate for the potential fire problem.

- Automatic sprinkler systems that are adequate for the job as installed can be defeated by changes in the operation and storage patterns of the warehouse.

The Warehouse Building

Typically, warehouses are classified as noncombustible. This term is a code classification, not necessarily an accurate description. If the building is concrete, it is inherently noncombustible—it will not burn. The building is not inherently fire resistive. Unless it is fire resistive, the building may disintegrate and collapse in a fire.

In warehouses, tilt-slab concrete construction with precast wall panels is common. The roof is necessary to stabilize the walls. In addition, concrete T-beam roofs are subject to spalling or disintegration of the concrete below the tendons. Tendons ex[illegible]d to 800°F (427°C) (less than the temperature produced by a self-cleaning oven) will lose their prestress capacity.

If the roof is a conventional metal deck built up from layers of asphalt and roofing paper, it can burn independently of the original fire, elongating the bar joists, which then push down the walls, possibly quite some distance from the original fire. At a later stage, the bar joists will collapse. In some warehouses, the racks themselves are the building's structural system.

Static Fire Defenses in Warehouses

Subdividing fire areas in a warehouse is accomplished by the use of fire walls. Fire walls in steel structures probably are not freestanding. Fire walls are considered to be **passive fire protection**, but there are few fire walls without openings. The integrity of the fire wall depends on the active closing of fire doors when a fire occurs. As many as 50% of fire doors in supposedly well-protected properties have been found to be inoperative. Overhead rolling doors are particularly susceptible to failure. In one case where 12 doors were trip tested, only 3 operated [illegible]operly.

The solid masonry wall parapeted through the roof is the most dependable fire barrier in a warehouse. However, just because you can see a wall extending through the roof, don't assume that it is an effective fire wall. It may be decorative or it may be pierced.

In some cases, fire walls are made of combined elements. Consider a high bay steel-framed warehouse. A main girder is put in place with an upward camber. The parapet brick wall is built above the girder. Concrete block is built up to the girder. The girder is sprayed with fireproofing. There is no proof that these disparate elements will function together as a fire wall. If steel attached to the girder is heated, it may move the girder.

Dynamic Fire Defenses in Warehouses

Automatic Sprinklers

The principal active defense is automatic sprinkler protection. For more than 100 years, sprinklers have had an unparalleled record of suppression or control of incipient fires. Unfortunately, this superb record cannot be taken as an indication of what can happen in a high or dense storage warehouse. Many huge warehouse losses have occurred in sprinklered buildings. In too many cases, the sprinkler protection is inadequate and fails early, sometimes before the fire department arrives.

One of the causes of failure is the early distortion and collapse of the steel roof from which the sprinkler system is suspended. This can be caused by the exposure presented by a fire in stored pallets. Factory Mutual has developed recommendations to prevent the special problems caused by idle pallets from occurring, such as putting limits on pallet pile heights and keeping them outdoors.

As these fire hazards grow in size, the concept of sprinkler protection as we have known it may be superseded by or coordinated with fixed oscillating nozzles, similar to the water cannons used in the San Antonio Alamodome described in another chapter. Such systems are now used to protect huge outdoor hazards such as large lumber piles and refineries.

Foam System Protection

Some sprinkler systems are equipped to deliver low-expansion foam. These systems are used where there is a potential for flammable liquid fire. There is also some use of high-expansion foam. The *Chicago Tribune*'s rolled-paper warehouse is protected with a massive high-expansion foam system. Twenty-two massive foam generators are mounted on the ceiling. In 6 minutes, the entire warehouse could be covered or filled with foam, 50 feet (15.2 m) deep.

Attitudes Toward Warehouse Fire Protection

Management Attitudes

A distinction in attitude can be made between the management of a major national corporation operating a distribution warehouse, which probably has a loss control department, and entrepreneurial, currently fashionable bulk distribution businesses.

The fact that such tremendous risks for potential losses are developing seems to have caught American management unaware. In the minds of many managers, the possibility of a disastrous fire is the reason why insurance is purchased. The annual cost of insurance makes it easy to factor it into the cost of the operation. Thus, the problem is disposed of by financial problem solvers. Management attitudes can, in turn, range from "There is a serious fire potential here, and it's my job to see that it doesn't happen," to "These fire types are petty bureaucrats who are warts on the backside of progress."

It is unlikely that management is fully familiar with the details of serious fires. The fire department should be as familiar as possible with the circumstances of such disasters. The more closely the predisaster situation at a facility matches the fire experience, the more credibility it has for the warehouse manager. It takes a lot to overcome the attitude that "It can't happen here."

Many years ago, a major fire occurred in the Smithsonian Institution. At a meeting afterward, Frank Brannigan was seated next to an official who he knew had bitterly opposed the installation of a fire door recommended by Harold "Bud" Nelson. The fire door had saved from damage or destruction the flag that inspired the *Star Spangled Banner* national anthem and the national stamp and coin collection. Brannigan remarked on the fact that the unwanted fire door had performed admirably. The official said, "I'm the one who opposed that door. I've learned one thing here. If you design a major building, assume there will be a major fire." When we can get management to operate from the premise that there will be a major fire sooner or later, the rest is easy.

As a code official, I've had similar experiences dealing with warehouse owners, especially when the code was first enforced. Many had never seen the high-piled stock requirements of the fire code, so they were reluctant to upgrade their fire protection, including making costly smoke removal and upgrades to the sprinkler system when a new tenant was to move in. Most of the warehouses had been built to handle less combustible materials (Class I or II), yet were supposed to handle Class IV and plastic commodities.

Fire Department Actions

With regard to these warehouse structures, the fire department has several distinct areas of interest:

- Initial planning and plan review prior to construction
- Inspection of construction and witnessing of fire protection equipment tests
- Routine and special inspections during operations
- Regular liaison with the warehouse manager
- Adequate planning for fire suppression, "if and when"

These activities can be complicated if the warehouse property is located in two or more governmental jurisdictions.

Initial Planning and Plan Review

As soon as the municipality is aware that a warehouse structure is planned, a task force should be ssembled from all concerned agencies to address ıe many considerations. The first critical need is to stablish what is being stored and how it is being tored. The San Antonio Fire Department instituted "commodity letter" program. The letter asks the enant questions about the materials themselves, here they are located in the building (diagrams), he method of storage (rack, solid pile, shelf), the isle widths, rack dimensions, and the like. The enant answers the questions on his or her own letrhead. This document then becomes a road map or inspectors to determine compliance and a peranent record of the facility. Fire departments are ncouraged to develop such letters for code complince and preincident planning efforts.

Water supply should be adequate for sprinlers and manual firefighting. Water supply for nanual firefighting should not decrease sprinle pply below that necessary for effective erf...nance. Particularly in the case of tilt-slab uildings, hydrants should be located well out of he collapse zone to avoid loss of apparatus and o prevent subjecting fire fighters to a hazardus removal operation. Beware of yard hydrants n older industrial plants, which are intended o supply handlines only—they are not intended o supply pumpers.

Electrical service to fire pumps should be unafected by a fire in the warehouse. If power must be ut to the warehouse, the pumps should continue to perate. Standby diesel power should be adequate to eplace the entire electrical pump supply.

Often the only access to such a facility is through . single guarded gate. Additional road access and/ r protected gates at distant points on the perimeer should be available for emergencies. Evacuation outes must be established in advance.

The potential for air contamination from fire moke or other air toxics and the potential for roundwater contamination from fire suppression vater should be planned for.

Insist on fire department Siamese connections eing included in the sprinkler system. Although the n-site pumping system and mains may be adequate, he nese connection is the only practical method for the fire department to supplement the sprinklers. It is also necessary to supply the system and keep up the water flow and alarm feature if the pump or main is out of service.

Inspections During Construction

Whenever acceptance tests are conducted on the sprinkler systems; fire doors, particularly overhead rolling doors; or other fire protection features, fire department personnel should be present.

Routine and Special Inspections

Every effort should be made to assure management that the fire department's efforts are directed toward maintaining the warehouse as a vital contribution to the economy of the community. If this attitude is well received, a genuine cooperative effort may be achieved. On the other hand, management may be hostile, and perhaps require that an administrative search warrant be obtained before any inspection can be made. Maybe fire departments should adopt a policy that fire fighters will go no farther during a fire than is permitted during an inspection.

Fire prevention education commends neatness. However, neat, orderly storage on racks may create the impression that there is no hazard, when in fact the warehouse may be a potential disaster. During inspections make a particular effort to note when there is an increase in the hazard classification of the commodities stored.

Storage in the aisles can extend the fire and overwhelm the sprinkler system through fire jumping aisles. The usual excuse, "It's only temporary," can be countered with, "Right, the building may not be here in the morning."

Few people are aware of how fast a fire can develop. Make sure that warehouse personnel on all shifts, including contract cleaners and guards, are instructed by management that the fire department is to be called even if a fire is only suspected. First aid or brigade firefighting must not delay the alarm. Be familiar with the stories of major fires and use them in classes and casual conversation.

Preplanning

A specific member of the fire suppression forces should be assigned as liaison officer to be completely informed on all factors that affect firefighting operations in that building. It would be the liaison officer's concern to see to it that all vital information is disseminated to all those who should have it and that preincident plans are kept updated. The warehouse manager should designate a specific senior subordinate to maintain liaison with the fire department liaison officer.

On the Fireground

All personnel should be aware of the known weak points of the warehouse structure and construction. Particular emphasis should be placed on the potential for collapses or failures:

- A combustible metal deck roof fire
- Failure of pretensioned concrete T-beams
- Failure of truss roof
- Failure of connections or splices of heavy-timbered roof
- Potential fire collapse of tilt-slab walls outward and inward

Racks may be erected across the openings at the far end of aisles, making dead-end aisles. Furthermore, some warehouses have movable racks to create more storage room. When stock is to be handled, an aisle is made by moving racks, thus closing other aisles. It is conceivable that an electrical malfunction during a fire could cause racks to shift. The operation should be carefully studied to determine any hazards that might occur during a fire.

Note that fire codes call for fire fighter access doors every 100 feet (30.5 m) in a high-piled stock warehouse. Although there will not be a door at the end of every aisle, these doors (if present) should be opened/forced early in the fire to provide emergency egress for fire fighters Figure 13-39.

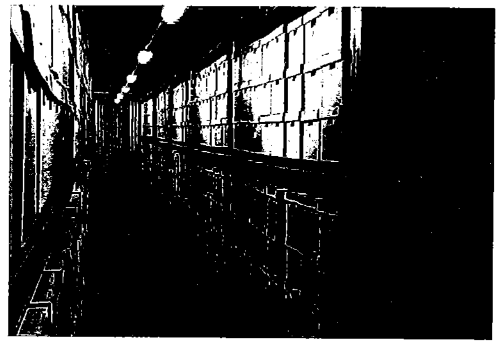

Figure 13-39 Not every aisle will provide egress from the building.

Solid Rack Shelves

After the Triangle Shirtwaist fire (New York, 1911) in which 142 people died in an unsprinklered high-rise garment factory, the garment industry moved into sprinklered high-rise buildings in midtown New York City. Garment making generates huge amounts of combustible scraps that can accumulate under cutting tables. Fires can rage under these tables, unaffected by the sprinklers. The width of garment cutting tables is permitted to be 48 inches (61 cm). Some authorities having jurisdiction have interpreted the 48-inch concept to permit several levels of unsprinklered shelving no more than 48 inches (61 cm) wide. This interpretation is disastrously mistaken.

Many racks in retail big box stores have installed shelves (to prevent sales items from falling through). Solid shelves have also been found in warehouses. This blocks sprinkler spray. The only way around this problem is to place in-rack sprinklers under each shelf, a difficult and expensive but acceptable solution.

Ventilation

With warehouse fires, an argument rages as to whether it is better to close up the building and let the sprinklers do the job or to vent it and attempt a combined manual/automatic attack. The jury is still out on that one. Partisans of each approach present convincing arguments.

The fire code used in San Antonio and many western and southwestern cities during the late

1980s and early 1990s required smoke removal fans for some higher hazard commodities. Essentially, 30,000 cubic feet per minute (cfm) fans were positioned on the roof and covered 10,000 square feet (929 m²) areas of the building. Such a system was used successfully when a fire in a walk-in dumpster filled a Sam's Wholesale Club in San Antonio with smoke. The smoke removal system mechanically exhausted the smoke quickly.

Many warehouses use mechanical smoke and heat vents along with draft curtains to ventilate a building during a fire. The vents themselves may be fusible link-activated clamshell-type openings or rectangular plastic domes that shrink under the heat of a fire and drop into the warehouse below. Draft curtains—typically made of sheet metal—are used to contain the heat from a fire below, accelerating the operation of the vent (Figure 13-40). San Antonio, Texas, has permitted the use of manually operated smoke and heat vents in warehouses, with release cables positioned at the warehouse roof's edge, avoiding the need to send fire fighters up on to the roof itself.

There has been much debate over the interaction between vents and sprinklers, with some arguing that opening a vent will slow the opening of sprinkler. In any case, they are required in building and fire codes and are installed in warehouse type buildings, including big box retail stores.

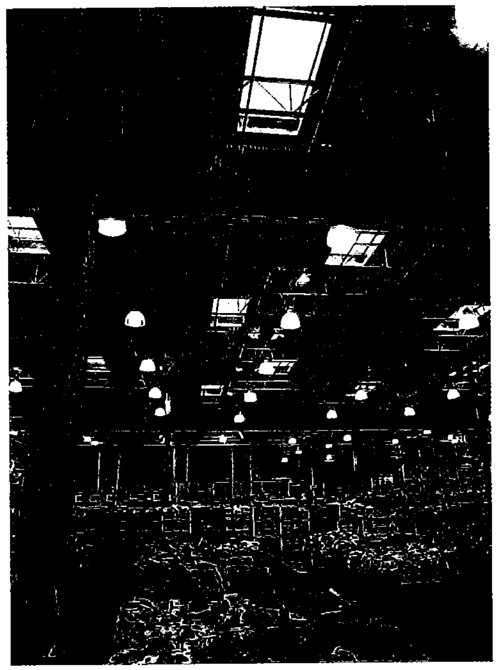

Figure 13-40 Warehouse stores with high-piled stock often incorporate smoke and heat vents with draft curtains. The curtains shown here are 4-foot-deep corrugated steel panels.

Courtesy of Glenn Corbett.

Handline Operations

In a number of warehouse fires, smoke has suddenly banked down to the floor, leaving fire fighters unsure of the way out. The hose line is the fire fighter's lifeline. "Follow the hose back to safety if lost" is one of the oldest instructions to new fire fighters. Remember, however, that a hose line fed from an interior hose outlet is not a lifeline. If interior outlets are used, lifelines should be strung to the exterior from the outlet. Use thermal imagers—they are essential.

Personal Safety

The art of warehouse protection is inexact to say the least. Impressive-looking systems have failed totally. Even if the management's planning is adequate, the execution is often faulty. All planning should place the safety of fire fighters first. This is the fire department's responsibility—no one else is going to take care of it.

TACTICAL CONSIDERATIONS

1. The evacuation of modern high-rise buildings has always been a challenging task. Fire operations primarily take place on the fire floor, the floor above, and two floors below the fire. Staging is usually two floors below the fire. Most critical is designating separate "attack" and "evacuation" stairwells; evacuation stairwells allow occupants to move safely to lower floors or out of the building, keeping them out of the "chimney" in the attack stairwell above the fire floor. Occupants should be moved to five floors below the fire, and then protected in place, if they are not evacuated completely out of the building. However, since the collapse of the World Trade Center Towers on September 11, 2001, occupants may no longer feel confident nor comfortable with anything less than total evacuation from the building. This can make evacuation an almost unmanageable problem. People will be anxious, perhaps even hysterical. A strong police presence may be required to provide the working space and order needed for fire department operations. Consider bringing in city transit buses to help shelter evacuees during inclement weather.
2. Water passes through tile arch floors easily, so a serious salvage problem should be anticipated with this type of construction. These floor units are actually arches and cutting out a tile may drop the arch. It's best to leave these floors alone. It is possible that the entire bay may collapse if the integrity of the floor is destroyed by saws. Even if personnel are protected against collapse, the collapse of a large floor section may cause an upward burst of fire.
3. Because of the falling glass hazard at high-rise fires, the preplan should include pertinent information on safe entry into the building, such as through an underground passage. Los Angeles, California, city fire fighters used an underground tunnel to enter the First Interstate building high-rise fire.
4. Interior personnel should be notified immediately if the windows blow out. This can dramatically change the situation on the fire floor for better or worse. In the Empire State Building fire, the windows failed on the windward side and pushed the fire down the hallway at the fire fighters. Winds in excess of 25 mph (40 kph) cannot be reversed with positive-pressure ventilation (PPV) fans. The situation created is called a *wind-driven fire*. (Two Fire Department City of New York [FDNY] fire fighters were killed in Brooklyn when the windows failed on the windward side of a residential high-rise, creating blow-torch-like conditions in the hallway. There was no reaction time for the fire fighters to escape.)
5. The need for search and rescue should never be overlooked. In a global economy, business employees can no longer be limited to the traditional nine-to-five work schedule. In addition to janitors, maintenance personnel, and computer technicians, a high-rise office building can have employees working around the clock. Often, they are working alone or in reduced staffing groups unknown to anyone else in the building. Don't assume a commercial high-rise building is unoccupied at 2:00 in the morning.
6. Fire fighter access to stairways may be impeded by the sheer number of people descending them. In residential occupancies, it is important to establish a firefighting stairway and an evacuation stairway. It depends on where the fire is; one objective is to get the nozzle between the fire and as many occupants as possible. Barring this strategy, if only one of the stairwells is pressurized, use that one for the evacuation stairwell. If possible, announce the designated stairway over the PA system to direct the occupants to safety.
7. There have always been two criteria for successful and efficient forcible entry: the door and locking system encountered and having the right tool for the job. It's not practical to go back to the apparatus for the right tool when you're on the 23rd floor. It may be much simpler to go through the wallboard and ignore the lock and the door altogether. This

may also be possible from apartment to apartment in upper levels of a high-rise or even in duplex and triplex apartments. The drywall is the weakest part of the wall. Wall studs that are toenailed into the bottom plate can be knocked out with any forcible entry tool.

8. Fire fighters forcing entry to a stairway door on to the fire floor may face a difficult, time-consuming task. It's easier to make the keys to the stairway door available to the attack team as they enter the lobby. This is the job of the unit assigned to lobby control. The attack crew must prepare for a burst of smoke, heat, and the possibility of fire as they open the door. Remember to keep control of the door. The stairway and landing above may suddenly become a hot, smoky chimney. Even with a designated "evacuation" stairwell, always check for occupants mistakenly descending the "attack" stairwell before opening the door to the fire floor. Make sure the standpipe connection for the attack line is made on the landing below the fire floor for the same reasons.
9. Some fire departments restrict the use of elevators by fire fighters going up to attack an upper floor fire. However, in high-rise fires, it is necessary to use them so you don't wear out your firefighting crews climbing 30+ flights of stairs while carrying heavy equipment. First-in companies will make the decision to use elevators long before a chief officer arrives on scene, so the practice should be spelled out in the department standard operating procedures (SOPs). Make sure the fire fighters assigned to run the elevators know how elevators operate in Phase I and Phase II, especially in Phase II. Elevators, especially in newer high-rise buildings, can have different Phase II sequences. Some elevators use different keys to place the car in Phase II and a totally different key to run the car from inside while in Phase II. The operator should initially stop every five floors to check the shaft for smoke. As fire fighters enter the elevator, they should all be wearing SCBA. The operator should stop well below the fire floor to allow the initial fire teams to get a quick visual orientation of a typical floor to help them maintain situational awareness once they enter a smoke-filled floor.
10. When an elevator shaft has a fire-resistive enclosure made of gypsum board, it is possible that hose streams striking the wall can disintegrate the gypsum board, making an open hole into the shaft. Holes can be unintentionally made into the shaft on the fire floor or exposure floors, without the elevator car in place. One Maryland fire fighter survived a multistory fall down an open shaft; however, two Chicago fire fighters did not and were killed when they fell through an open shaft.
11. When stack effect is a significant factor due to weather conditions, fire fighters should understand the situation created, for example, when the burn index is high. Company officers should be aware that the first smoke detector activated or the first call to the fire department may have come from a person many floors away from the scene of the actual fire. The IC should resist committing all his resources until the location of the fire is determined.
12. Stack effect can lead the IC to change tactical operations. For example, consider a fire in a high-rise building during winter. Let's say the fire is in a unit below the neutral plane and is also accessible from aerial ladders or platforms outside of the building. If conventional operations were used, the fire department would charge the standpipe and interiors crews would lay hose lines and enter the fire floor from the stairwell to attack the fire. Heat and smoke from the hallway would enter the stairwell and ride the available stack effect currents and contaminate the upper floors. An alternate attack might be to protect the interior exposures with charged hose lines but leave the door to the fire floor closed while the attack is made from the outside by aerial master streams. After the fire is knocked down, much of the smoke would vent out the windows by thermal pressure. The fire department can set up PPV fans and, (with a little luck) if the wind is blowing in the right direction, the fire floor could be quickly ventilated. The engine crew could enter with handlines and finish extinguishing the fire. The fire loss to the unit and floor would probably be the same with either attack, but the smoke damage and occupants endangered by the products of combustion throughout the building would be substantially reduced.
13. The fire department must train company officers so they are familiar with the many aspects of HVAC systems. The HVAC system can play a major role in the success of fighting a high-rise fire or turning it into a disaster. Company or chief officers who have the most experience with HVAC systems should be assigned to the command post to help the IC. All the necessary information and emergency contacts on

the structure's HVAC system should be included in the fire department's preincident plan. When a fire occurs, the knowledgeable HVAC technician should be called immediately to reduce response time and have that person report to the command post. A knowledgeable elevator technician should also be called at the same time.

14. If only certain stairwells are pressurized stairways, they should be reserved for evacuation purposes if possible.
15. Watch for signs like "Pardon our dust; we're remodeling." It may be a clue that structural components are temporarily being modified, which usually means they are not as strong as we would expect them to be. It may also mean that fire protection systems may be on hold and not readily available.
16. Rubbish is usually accumulated in the service lobby on each floor. Fire departments should be wary of using the service elevator to routinely approach all fires. Because of the prevalence of rubbish fires in high-rises, New York City fire fighters are not permitted to use the service elevator until it is declared safe.
17. Particular attention should be paid to the hazard created when the regular removal of rubbish is interrupted by a labor strike or other causes.
18. Beware of the obvious dangers of locked doors in prisons. Several fire fighters were temporarily trapped while extinguishing a fire in a county jail in New Jersey when a door closed and locked behind them.
19. Parking garages present a number of problems—especially underground garages. They are required to be sprinklered, but there are many areas where parked cars are outside the reach of the spray pattern. A car fire can go unchecked and even spread to adjacent vehicles outside the reach of the sprinkler heads. With low ceilings and no windows, smoke quickly banks down to the pavement. Finding the seat of the fire is difficult without a thermal imager. Extended hose lays are required and immediate ventilation is essential. Consider calling for extra PPV fans or a mobile ventilation unit (MVU).
20. The garage area may extend out beyond the exterior walls of the building. This was the case in Seattle where a motorcycle fire spread to the car next to it. The flames intensified and spread up the exterior B side of the building. The building had vinyl siding that allowed for rapid vertical spread. The fire broke out a window and started a full apartment fire on the fourth floor.
21. Overhead parking slabs may be designed only to carry the weight of cars. Heavier vehicles, like fire apparatus, may be restricted. One shopping mall in the Midwest consists of many buildings on a lightweight slab over the garage. No horizontal standpipe was installed. Fire apparatus cannot drive on the slab, so extremely long hose line stretches are required.
22. The high-volume fans used for PPV may be used to clear a stairway of smoke so that it can be used for evacuation. Consider the use of MVUs to pressurize stairwells beyond 20 floors. Don't worry about the production of carbon monoxide (CO) put out by the fan motors. The CO generated by fans is substantially less than the CO in the smoke being generated by the fire. Electric PPV fans are an excellent alternative, but still lack the total cfm output achievable with a motorized fan. Use an air monitor to check CO levels. After the smoke is cleared, change the ventilation plan to vent for CO. Consider using fan socks or RAM fans.
23. Expect that the rear doors of tenant spaces in a mall will be heavily secured to prevent burglary. Commit enough resources and equipment to force these doors, which are critical for horizontal ventilation. Crews need to remember to bring extra saw blades on the initial deployment. You don't want to waste time sending a fire fighter all the way back to the apparatus to get a new saw blade.
24. Opening the front display window in a retail store can provide substantial horizontal ventilation, but this must be coordinated with your interior attack hose team. Teach your fire fighters not to break windows for the sake of breaking windows. They must wait until the hose team is ready to enter. Remember, without pressurized ventilation, breaking a window will create the path of least resistance and the thermal pressure created by the fire will draw the fire right to the broken window. There are several videos showing fire fighters breaking display windows before the hose team is ready, causing a contents fire to turn into a structure fire. Don't be that fire fighter.

25. Fires can also spread horizontally below grade through a basement. Many strip mall basements do not have substantial separations between occupancies, allowing the fire to move unimpeded.
26. High-piled storage racks (rack storage) are being used in most big box warehouse stores throughout the country, even in areas that are protected by fire departments that have never faced such a fire problem. These warehouses present an extreme fire hazard and safety hazard to the life of the fire fighter. Fire officers and fire fighters alike must recognize that a completely different strategic situation exists. If the fire is attacked with standard tactics used for single-family dwellings and mercantile buildings, the fire fighters are going to be in for a big surprise, and a terrible loss of fire fighter lives may result.
27. Until the fire is knocked down, high-piled storage rack fires should be attacked with 2.5" (64 mm) hose lines or portable monitors. With the increase in fire load as well as the different types of fuels stored closely together, you need reach and gallons per minute (gpm) to safely extinguish this type of fire. Though 2.5" (64 mm) hose lines are needed for safety, the force of the streams hitting stored merchandise is going to cause storage containers or loaded pallets to fall off the shelves. Some of these containers are extremely heavy and can fall from a height of 30 feet (9.1 m). Falling merchandise can also fall against adjacent racks, causing them to collapse. The variables are great. High-piled storage racks that are involved in fire is no place for fire fighters to be working in close proximity. Use the reach of your hose line to operate from a safe distance.
28. The most important consideration in prefire planning is the safety of fire fighters. Operations at a fire in a rack storage warehouse require detailed advance study and preplanning. This must start when the structure is proposed. You cannot make it up as you go along. Fire departments whose experience is primarily in residential fires may have a "house fire" mindset, which can result in disaster in a warehouse fire.
29. Racks are simply lightweight steel structures. They have the same characteristics and weaknesses of steel when exposed to temperatures in excess of 800°F. They are subject to collapse due to the heating of steel. Fire fighters should never advance beyond the point where racks might collapse behind them. Attack the fire using 2.5" hose lines or portable monitors.
30. Due to the increase in fire load and mixed fuel classifications, venting big box warehouse roofs can be inadequate and dangerous. Outside of mill construction, most modern warehouse roofs now use lightweight steel or wood components. The amount of heat and Btu(s) produced require more than the standard 4- by 4-foot (1.2- by 1.2-m) hole, and these holes need to be made quickly while it can still withstand the weight of fire fighters. It should not be undertaken just as a routine to "get the roof." Experience limited to ventilating ordinarily single-family dwelling roofs may not be adequate. Consider using multiple PPV fans or an MVU. As more big box warehouse stores appear in communities, the need for MVUs is going to increase. It's simply a more efficient and safer way to ventilate a warehouse. An MVU can be operated by a single fire fighter.
31. No fire fighters should be permitted to move beyond the point where a defined path to safety exists. Hose lines can be repositioned and can also be confused with warehouse hose station lines that may have been deployed by employees attempting to fight the fire. When dealing with commercial structures and warehouses, it always increases the safety margin for fire fighters when lead lines or rescue ropes are deployed to help fire fighters find their way in and out of a burning warehouse. Battle lanterns and strobe lights placed at the entry/exit point also help fire fighters orient themselves toward the exits.
32. If a warehouse is heavily involved in fire upon arrival of the first fire unit, it is most likely lost. Use extreme caution in proceeding. It isn't worth getting a single fire fighter injured or killed for property that is probably insured and no longer has any salvageable value. Probably the best offensive tactic would be to supply the sprinkler systems to the maximum. Any systems or piping that has been destroyed in a collapse should be shut off at the main valve if possible to conserve water for defensive operations. Repeat, this is a defensive operation.
33. On March 27, 2007, Houston, Texas, Fire Captain Eric Abbt came within inches of his life when he became disoriented and lost. Houston fire fighters

responded to a six-story mid-rise fire in an open-concept atria building. The building was one giant open space from the roof down to the lobby. All the occupancies faced the atrium. The fire started in a dental office on the fifth floor and charged the entire building with smoke. Captain Abbt and his crew were assigned to search the fifth and sixth floors.

34. Upon entry to the atrium, there was zero visibility. The division chief assigned to the interior sector encountered zero visibility 10 feet (3 m) into the lobby. The chief had to crawl into the lobby to get some visual reference. Though there was a lot of smoke, there wasn't sufficient heat to fuse the sprinkler or to melt the fusible links to the automatic roof ventilation hatches. But even if there had been enough heat, the hatches wouldn't have opened. Six month prior, in preparation for an oncoming hurricane, the skylights and vent hatches were secured shut with sheet metal screws. After hurricane season, the screws were never removed.
35. Stairwells with roof access often have a narrow vertical ladder to a hatch that opens to the roof. The hatch usually has a padlock for security. Such was the case with the Houston mid-rise fire just discussed. But if you think a fully equipped fire fighter with SCBA and size 14 fire boots is going to be able to climb that ladder in zero visibility and use bolt cutters to clip a pad lock without falling off, think again. This might be possible during a prefire planning or a fire inspection, but it is impossible during a fire with thick black smoke. You have to find another way to access the roof. Through a series of hit-and-miss attempts, Captain Abbt was finally rescued when a window was broken out with the tip of the aerial ladder. He was semiconscious from the CO and had been out of air for over 20 minutes.
36. Local building and fire codes are sometimes more restrictive than the national codes because they are more specific to the hazards within the community.
37. Building codes usually don't require garden apartments of three stories or fewer to have a standpipe. Many apartment buildings are built to three stories to avoid this requirement. Therefore, if you come across a fire on the third floor of a three-story apartment, you will be laying hose lines from the apparatus to the fire room. If the fire is anywhere in a four-story apartment building or greater, you will be able to connect to a standpipe.
38. Three-story townhomes are becoming quite popular as single-family residences. Usually, there are two floors above the garage. The living area and kitchen are on the second floor, and the bedrooms are on the third floor. The main stair entry (one flight of stairs) is next to the garage. Many townhomes are built four to a plot. That means a fourplex of three-story townhomes. The space between them is narrow, which means the exposure problem is great, and fire apparatus have to remain in the street. It also means there is no aerial access to units in the back. Long lays are required to make the bedroom level in any of the townhomes. For the C side of the two townhomes in front and for the townhomes in the back, there is no aerial access. That means ground ladder evolutions—35-foot (10.6 m) ladders for the bedroom windows and 40- to 45-foot (12.2- to 13.7- m) ladders if you want to reach the roof.
39. Because of the height and close proximity of three-story town house structures on a single lot, many cities are adopting the NFPA 13R so the living area and bedrooms are sprinklered. That should help contain a room and contents fire. However, the garage may or may not be sprinklered, and usually the attic space is not sprinklered. This will require some preincident planning in your area where high-density neighborhoods are on the rise.
40. For a variety of reasons, some three-story townhomes have residential elevators. These elevators have a low load capacity and should *never* be used by fire fighters. Remember, during new construction, you have an open shaft: a fall hazard for fire fighters. After construction is complete, the elevator shaft is a vertical void space where fire can travel, so it needs to be checked after a fire.
41. Newer building codes require new multistory apartment buildings with exterior balconies to be sprinklered. Summer barbeques are an American tradition, but some have led to cooking fires on balconies where the overhang let flames quickly spread horizontally back into the apartment unit. If the overhang ceiling has holes, fire can enter into the space between the ceiling and the floor above. Fires on any type of unsprinklered balconies can easily spread to the floor above. Consider using a blitz attack with a 2.5" hose line or a deck gun to knock down a fully involved balcony fire before it spreads beyond your reach.

42. Vertical ventilation of a fire in an attic space with lightweight trusses is always a gamble and a race against time. Consider the indirect attack. There is no need for heroics when you're trying to extinguish an attic fire. You must realize the attic space is hot, oxygen deficient, and cannot support complete combustion. That means there is smoke and heat, but no fire—yet. Punching a hole through the roof large enough to insert a fog applicator or round nozzle is essentially creating a sprinkler system. With the expansion ratio from water to steam (1,700 times its volume), the fire will go out. Another consideration is using the gable ends of the attic space. Working off a ground ladder or aerial apparatus, this horizontal attack is putting the nozzle at the seat of the fire. The hose stream can reach to the opposite of the attic. This position is safer than roof operations. Of course, you can still try to attack the fire from the ceiling below, but remember, if you shouldn't be on top of it, you shouldn't be underneath it either.
43. Steel trusses need to be cooled. Consider an indirect attack from the safety of an aerial apparatus.
44. Bathrooms seem like the most benign rooms in a residence. In zero visibility, it's easy to figure out when you're in a bathroom and it's almost impossible to become lost or disoriented inside one, but they're a wild card. They must be thoroughly searched. For a variety of reason, including having a source for water, children and occupants hide in the bathroom as a place of refuge from a fire. On June 12, 2010, four children and one adult did just that; all five perished in that tragic apartment fire.
45. With regards to collapse, especially in older residential buildings, the bathroom floor is frequently more subject to collapse than the other floors for the following reasons:

    First, the bathroom fixtures create a heavy dead load or static fixed load. Cast-iron tubs, sinks, porcelain toilets, and tile floors can weigh up to a thousand pounds. This heavy weight is concentrated in the smallest room of the residence and, therefore, supported by fewer floor joists.

    Next, the bathroom has the most poke-through holes and concealed avenues for fire spread. With toilet drains; the holes for the hot and cold water lines for the sink, shower, and toilet; plus the lighting, heating, and ventilation systems, there are plenty of paths for vertical and horizontal fire spread. Though a fire rarely originates in a bathroom, a fire seeking the path of least resistance will be drawn to the bathroom floor, weakening the nearby floor joists.

    Finally, wood rot. Bathroom pipes leak or sweat on the outside. Water is spilled from sinks, showers and tubs, and toilets overflow. Over the years, moisture seeps down to the wood joists where they weaken from decay.
46. Bathroom collapses are usually localized collapses. That means the floor joists in the hallway should still be strong. During overhaul, sound bathroom floors with deliberate force.
47. Kitchens floors contain many of the collapse-potential problems associated with bathroom floors: poke-through holes for water lines, gas lines, and drains; and heavy concentrated loads from stoves, refrigerators, and tile floors. Before overhaul, sound kitchen floors with deliberate force or check floor joists from below when there has been extensive damage from fire.
48. Private single-family dwellings are not required by the building code to have fire-rated interior stairs. At best, traditional stairs are made of dimensional lumber but are still subject to fire and collapse. Very recently, a prefabricated stairwell manufacturer has created a wooden stair with risers and treads held together with sheet metal gusset plates. Wooden stairs without a fire-resistive soffit are vulnerable to fire damage from flames below the steps. Wooden basement or cellar stairs are often constructed without soffits and can result in early collapse. When arriving on scene, the initial company officer must determine if there is a basement. If the fire is in the basement, the crew has to be cautious with stairs leading to the front door. The porch also needs to be sounded. Don't take it for granted that you have a solid work platform.
49. When climbing sagging, fire-weakened wooden stairs, fire fighters should stay close to the inside wall. If the outer carriage beam has been destroyed and is not load bearing, the stair riser is supported on the wall side only. Weight, close to the wall, will put less stress on the stair than a size 14 fire boot walking near the outer edge—farthest from the wall.
50. Stairways and landings are the safest place to initiate an interior attack. However, any weaknesses or deterioration of its integrity may be impossible to

determine during the heat of the battle. Therefore, fire fighters should avoid bunching up on the stairway. The fire fighter on the nozzle and the company officer should be at point and the rest of the team should be spread out on the stairwell to help advance the hose line.

51. If stairs appear to be weakened or in danger of collapse, but the situation requires interior teams to remain (i.e., a rescue in progress), fire fighters could place a portable ladder or roof ladder over the weakened stair rise so fire fighters can use the ladder rungs instead of the steps. Ensure that the ladder spanning the stairs is supported by the floor below and the floor above so that if the stairs collapse, the ladder will remain in place. If this technique is not doable, exterior ground ladders must be placed at the windows of the involved floors so interior teams can have access and emergency egress.
52. Predicting a fireground outcome involves understanding gravitational forces and common sense. For example, three-story (or greater) burning wood-frame buildings collapse more frequently than burning wood-frame buildings that are one or two stories in height. If there is more weight supported by a fire-weakened support component, it will collapse. A serious fire that burns out the first floor of a two- or three-story wood-frame building presents an increased collapse potential than if the fire was on the upper floors.
53. Of the three types of wood-frame building collapses, the inward/outward collapse is the most dangerous because it gives no warning and can result in the simultaneous collapse of two or more sides of the structure.
54. Wooden structures located on a corner lot or standalone buildings are more susceptible to collapse when exposed to fire than wood-frame buildings in the center of a row of similar structures. Uninvolved buildings help shore up fire-weakened structures, supporting them if they begin to lean. This doesn't mean they are safe, so don't drop your guard.
55. Larger buildings that collapse on top of smaller buildings cause the smaller building to collapse. Try to predict this gravity-driven domino effect and prepare for it.
56. Older apartment complexes sometimes have the gas meters located in the basement. Relief valves sometimes release small amounts of natural gas, which spews the odor of mercaptan. Because natural gas is lighter than air, alarmed residents will call the fire department. To reduce the time it takes to determine the source, start the portable gas-detecting monitor while en route. It takes a few minutes for the unit to calibrate.
57. There are many places within urban areas where there are limited water supplies. These departments usually do not use water tenders. Keep in mind that modern big-city fire engines carry at least 500 gallons (1,893 L) of water. Depending on the fire situation, bringing in three engines gives you 1,500 gallons (5,678 L) of water. That's a lot of water to put out a fire. Most attack teams do not keep their nozzles fully opened for the duration of the fire; they spray water in bursts, shut down, advance, then open up again. For example, using the National Fire Academy fire flow formula, let's say you have a room fire that requires 100 gallons (379 L) of water to extinguish. With three engines, you have enough water to put this fire out 15 times without connecting to a hydrant. Again, depending on the situation, this tactic is quicker at extinguishing the fire than setting up a long lay or relay pumping operations to establish water supply.
58. City engine companies can also be rotated through at a working fire hydrant in the same way a tender fills up its tank. Depending on the situation, this may be a better option than setting up a long lay or relay pumping operations.
59. There are various styles of wood-frame houses with attached garages. Most contractors use gypsum wall board to meet the 1-hour (or greater) rating requirement for the walls. However, the nail heads and joints are not always properly taped over. This gives an avenue for a garage fire to spread into the house. When dispatched to an attached garage fire, some fire departments hesitate to attack the fire head on for fear they may push the fire throughout the house. Instead, they make entry into the house using the rule of thumb of attacking a fire from the uninvolved toward the involved. An attached garage fire is one exception to this rule. (Basement fires are another exception.) When fire fighters open the interior door into the garage, they immediately create a path of least resistance and the heat, smoke, and fire come toward them and enter the house. I have personally witnessed this tactical error more than once. What started out as a simple garage

fire escalated into a serious house fire. Despite the deficiencies of the gypsum board installation, the odds are on your side. When you arrive at a fully involved attached garage fire, attack the fire head on from the main garage door. Prop the door open with a baby ladder or a pike pole. Send the exposure line inside to protect the garage door leading into the house, but don't open it. Once the main body of fire is out, check the attic spaces and the rest of the house for extension. Using PPV fans to pressurize the house should keep smoke from the garage from entering the interior living space.

60. Fire walls are not always intact. Utilities sometimes pass through them, creating a path for extension. In strip malls or occupancies that use fire walls for separation, consider using PPV fans to pressurize the right and left exposure (exposure B and exposure D). The ceiling space must be opened in the B and D exposures to check for the extension of fire. If the attic spaces are clear, this is your first indication that the fire wall is intact. Continue to keep the exposures pressurized until the fire is extinguished. If there is light smoke, the positive pressure should push the products of combustion back toward the fire, provided the roof over the fire has been vented. This tactic is based on providing the path of least resistance for the fire. Once effective ventilation has been created over the fire (or as close as possible to the fire), the pressurization created by the fans should be more powerful than the horizontal thermal pressure created by the fire. The fans will help push the smoke back out the vent hole.
61. Row houses can extend for several hundred feet, encompassing numerous addresses along the same street. Some row housing can extend to the entire block. There are many challenges and hazards, but one of the paramount hazards is sharing a common cockloft. A trench cut is an effective ventilation tactic for cutting off the horizontal spread of the fire. The challenge for trench cutting is getting ahead of the fire. A trench cut is a labor-intensive, time-consuming tactic. The IC must send sufficient resources and equipment to complete the job in time (a minimum of six fire fighters). One of the errors truck crews commit is cutting an incomplete trench. A trench cut is not simply an elongated rectangle. A trench cut on the roof of a building can be compared to a fire break on a wildland fire. Leaving part of the roof intact makes all the effort useless if fire can still extend beyond the trench. The trench must extend from one wall to another, for example, from side A to side C. Another error ICs make is not sending a hose line up on the roof to protect the trench or to the floor below to protect the trench from the ceiling. Though the flames and other products of combustion will vent through the trench, the exposures still need to be protected from radiant heat. That can be done only with water.
62. When fighting church fires, many fire departments are nervous about breaking large stained glass windows and rightly so. They should be protected when possible; however, to the fire, it's just a window. In an unscientific poll, 90% of the pastors surveyed would rather lose the stained glass windows than lose the building. If you need to use the large, round, rose-stained glass window to vent the fire or use the master stream, break it out.
63. Large shopping malls are difficult to pressurize and vent. Consider using an MVU. Some fire departments that do not have an MVU have been successful in requiring the corporation behind the construction project to purchase an MVU for the local fire department as part of the fire suppression/life safety system before signing off on the plans of the new monstrosity being built in their community. Remember, one function of ventilation is to direct the path in the direction you want the smoke to go. Many of the large indoor malls have glass skylights or roofs. Taking the precautions for falling glass, crews can create a trench by breaking out glass and the MVU can be positioned so it can force the smoke out of the trench.
64. Though hospital emergency plans call for sheltering patients in place or rolling hospital beds to another area behind fire door enclosures, there may be occasions when patients need to be placed as low as possible. This means getting them on the floor. The best way to do this is by sliding the mattress to the floor with the patient on it, then dragging the mattress across the floor to the safe area. The mattresses usually have fabric loops sewn on the sides. Fire fighters can hook a loop with a pike pole or a body loop strap (webbing) and drag the mattress and the patient like a wagon. This is an easy evolution. Many hospitals have an unoccupied wing where arrangements can be made to train on this procedure.

65. When fighting a fire in a nightclub, send a crew to go around the perimeter to force open doors and windows. Using chain saws or circular rescue saws, turn windows into doors. Remove doors from their hinges so they do not accidentally close again. Tying them off is another good alternative. Wedging doors may not be as effective—a rushing crowd can unknowingly kick a wedge out. A swinging door can injure people or it could close and relatch, narrowing the exit way. Putting the fire out solves myriad problems, but smoke still kills.
66. Most larger new "E" occupancies are required to be sprinklered per the new fire codes; however, there are still thousands of large two-story, brick exterior, traditional school buildings that do not have sprinklers. Remember, if the building is fewer than four floors, there will not be a standpipe. Longs hose lays will be required. If the fire is in a classroom or a lab on the second or third floor, lay a 2.5" (64 mm) hose line to the top of the stairs. Attach a 2.5" (64 mm) gated wye to the end. This can accommodate up to four 1.75" (44 mm) hand lines by attaching two-1.5" (38 mm) wyes.
67. Many house plans call for decorative dormers for the attic space. Though these look like bedroom windows, they are not; however, they can be used for horizontal ventilation; they can also be used for a horizontal attack point on an attic fire when there is no life hazard on the inside. Putting a nozzle through an attic dormer is, in essence, placing the nozzle at the seat of the fire. Use the stream reach to cover the entire attic space.
68. Warehouse fires are not residential fires. Don't pull a 1.75" (44 mm) handline because it's always the line of choice. You need gpm, stream penetration, and reach. There is the potential for long lays and for the line to get snagged around corners and around storage racks. Space fire fighters out along the stretch to keep the line moving forward. It is harder to pinch or kink a 2.5" (64 mm) hose line from fallen stock than a 1.75" (44 mm) handline.
69. Fire department ground ladders can be used to brace up exterior fire escapes when it appears it may be getting overloaded with a large number of panicked residents. Do not hesitate to make this decision. Many 26-foot (7.9 m) ground ladders and 12-foot (3.7 m) roof ladders mounted on top or on the sides of fire engines go untouched at fires.
70. Be prepared to initiate stairwell support operations. This consists of spreading fire fighters out throughout the stairwell. Place one fire fighter every two floors. All firefighting equipment is then shuttled up the stairwell two floors at a time. Once additional personnel arrive, you can place additional fire fighters in the stairwell so they only have to shuttle up equipment one floor, then return for another load. This is the "Old Bucket Brigade" relay system. If the stairwell is clear of smoke, fire fighters do not need to wear coats and SCBA while they are shuttling equipment. Make sure their PPE is on a landing within their work area in case conditions suddenly change.
71. If the strategy is to contain the fire on the fire floor by letting the fuel consume itself, firefighting efforts need to be concentrated on the floor below and the floor above the fire. There is a variety of fuels from carpeting to furniture that are being heated by the fire. They are emitting toxic fumes and gases. The need to be pulled away or wetted down to prevent fire spread. All poke-through holes and HVAC vents need to be continually monitored for fire spread.
72. High-rise buildings with Type II and (sometimes) Type III standpipes have a hose cabinet or hose station in the hallways. Make sure all your fire fighters are aware of the different terms used for this appliance. In Seattle, the term *house line* is used. Ladder Co. 6 was first-in at a high-rise fire with smoke and flames showing on the eighth floor. The first two fire fighters were sent to the fire floor with a 2.5 gallon (9.5 L) pressurized pump can, a TI, and the irons. The officer told them to "Grab the house line and take it!" Not wanting to appear ignorant, the two fire fighters nodded and quickly entered the lobby. On the eighth floor, they blew right past the hose station and tried to contain the fire with the extinguisher. They were not able to extinguish the fire and had to wait for the engine company. Because this was a room fire, had they grabbed the "house line," there is a good chance they would have completely extinguished the fire. The term was explained to them after the incident.

WRAP-UP

Chapter Summary

- Occupancy plays a role in how a building is constructed.
- Combustible multiple dwellings include garden apartments as well as modern row houses and townhouses and similar structures (three-deckers).
- From a fire protection standpoint, atria are large voids that pass through multiple floors, allowing smoke and heat to move vertically through the building.
- Houses of worship span the five basic types of construction and can present a myriad of challenges for fire fighters.
- A covered mall is a single building enclosing a number of tenants, which may include retail stores, drinking and dining establishments, entertainment facilities, offices, and other similar uses where the tenants have an opening onto one or more malls.
- The key to safe operations in a factory is first to understand what is to be made in the structure and how it will be made, and also how the structure has been designed/altered to meet these manufacturing needs.
- Most fire codes require the creation of an HMMP and an HMIS that fire fighters can consult when an incident occurs at a building where hazardous materials are produced or stored.
- It is also a serious error to consider all high-rise buildings as a single problem. There are fire-significant construction differences among high-rises.
- Hospitals and nursing homes have a common characteristic—they are home to numerous nonambulatory people. It is up to the building, the staff, and fire fighters to protect them.
- Although sprinklers are considered critical for larger hotels, small motels are not required to meet this requirement.
- Like hospitals, jails are considered institutional occupancies. The inmates of a jail are restrained and are incapable of getting out of the building to save their lives. They rely on prison staff and the building for their safety.
- Unfortunately, museums and libraries are not always protected with a fire suppression system. For years, many institutions mistakenly rejected sprinklers as causing too much water damage.
- Nightclubs are places where people go to have fun. The use of alcohol is a key element of that fun, resulting in patrons who are not fully aware of their surroundings. In addition, these clubs are often overcrowded beyond code-imposed limits.
- Office buildings are built in all five types of construction, large and small, high-rise or low-rise. These buildings have changed over the years, evolving from highly compartmentalized structures with offices for every worker to the open office plan.
- Many large open-area structures, such as churches and arenas, are built of wood or have an exposed wood plank roof that makes up the ceiling. Such a valuable building should be fully sprinklered.
- When preincident planning for a restaurant, pay particular attention to the location of the utilities, especially gas.
- A smoky fire in a self-storage building will make it very difficult to establish which units are involved.
- One notable issue with stadia is egress travel distance—most enclosed stadia cannot meet the traditional limits on travel distance from the most remote seat to an enclosed fire-rated stairwell.
- Fire fighters will be confronted with a variety of hazards as well as a variety of occupancy types in strip malls.

WRAP-UP

- Because underground buildings such as rail transit stations may house thousands of occupants at any given moment, moving these people quickly up stairwells to grade is nearly impossible.
- The advent of warehouse rack storage has brought potential major fire problems to Anyplace, USA.

Key Terms

Anchor stores Large stores (often department stores) attached to the mall that have all of their required exits independent of the mall.

Atria A large open space within a structure connecting two or more floors.

Brick nogging Brick and mortar filling between studs utilized as a makeshift fire barrier.

Calcination The deterioration of a product by heating to high temperatures.

Cold smoke Smoke that falls downward.

Control area A building or portion of a building within which hazardous materials are allowed to be stored, dispensed, used, or handled in quantities not exceeding the maximum allowable quantities.

Covered mall A single building enclosing a number of tenants, including retail stores, drinking and dining establishments, entertainment facilities, offices, and other similar uses where the tenants have an opening on to one or more malls.

Early suppression/fast response (ESFR) A type of fast-response sprinkler capable of providing fire suppression of specific high-challenge fire hazards.

Exit passageway Hallways, corridors, passages, or tunnels used as exit components and separated from other parts of the building in accordance with NFPA 101: Life Safety Code.

Friable Easily disintegrated.

Hazardous materials inventory statement (HMIS) Required in most codes, this statement lists the materials, hazards, and quantities of hazardous material products within a building.

Hazardous materials management plan (HMMP) Required in most codes, this plan explains how hazardous materials are to be stored and safely used within a building.

Idle pallet storage Pallets without product.

In-rack sprinklers Sprinklers that are placed within racks to control fires where overhead sprinklers are not adequate.

Inversion layer A layer of air that is warmer than the air below.

Landing zone In reference to an elevator, this zone is 18 inches above or below the landing floor.

Lapse The condition in which the atmospheric temperature is constantly decreasing as height increases.

Nonambulatory people Individuals who are not capable of self-preservation.

Occupancy Used in building codes to refer to the intended use of a building.

Open office plan A plan in which low-height partitions create cubicles for personal space; essentially one large open room.

Passive fire protection A material that is applied to a substrate and is designed to protect it from thermal effects.

Pause In reference to atmospheric conditions, the layer of air warmer than the air below it.

Platform A raised area in a building for presentations, wrestling matches, and the like where there are no hanging curtains, drops, or scenery other than lighting and sound effects.

Projected beam detectors Used in smoke control systems. These detectors can cover large areas with a single beam of light.

Proscenium arch and wall Found on a stage, it is the large ornamental opening and wall that separates the audience from the stage.

Pyrophoric gas Gas that ignites in air without the introduction of an ignition source.

RACE An acronym: R—remove all people in immediate danger to safety; A—activate the manual pull station and have someone call 911; C—close doors to confine the spread of smoke and fire; and E—extinguish the fire, if possible.

Racks Any combination of vertical, horizontal, and diagonal members that supports stored materials.

Shelves Storage on structures that are less than 2.5 feet (0.75 meters) deep, with shelves usually 2–3 feet (0.6–0.9 meters, respectively) apart vertically, and seldom exceeding 15 feet (4.5 meters) in total height.

Ship's ladder A completely vertical stair with a width that is not more than 24 inches wide.

Smoke barrier A continuous membrane, either vertical or horizontal, such as a wall, floor, or ceiling assembly, that is designed and constructed to restrict the movement of smoke. A smoke barrier might or might not have a fire resistance rating. Such barriers might have protected openings.

Solid pile Storage that is either box on box or pallet load on pallet load.

Stack effect The vertical airflow within buildings caused by the temperature-created density differences between the building interior and exterior or between two interior spaces.

Stage Performance area in a theater that has a proscenium arch and wall; hanging curtains, drops, and scenery; lighting; and support rooms (dressing room, etc.).

Tuned-mass dampers Heavy weights installed high up in a building that are adjusted by computers to counter wind-induced oscillations.

Case Study

Your crew has been assigned several preplans for the month of June. The first building on the list is an old multibuilding manufacturing facility. You and your crew know this facility well because many false alarms have been dispatched to this address. This building has changed hands many times over the years, but now manufactures and stores many different kinds of hazardous materials. Answer the following questions about the things to look for within this building.

1. True or False: This building will be required to have an HMIS and HMMP for the premises and available to the code official.

2. This structure has separating fire walls as dictated in the code. What type of protection best describes a fire wall?

   A. Active
   B. Dynamic
   C. Passive
   D. Static

3. Sprinkler systems are known as what type of defense?

   A. Active
   B. Dynamic
   C. Passive
   D. Static

4. You note that a yard hydrant is adjacent to a warehouse on the property. True or False: You should include this hydrant in your preplans to supply one of your engine companies.

WRAP-UP

Challenging Questions

1. Describe the difference between stages and platforms.
2. Describe the actions taken by nursing staff in a hospital with respect to each letter in the acronym RACE.
3. Describe the general characteristics of taxpayers and strip malls.
4. You are the lieutenant of an engine company and have been assigned to stretch the primary attack line to the seat of a fire in a tenant space in a covered mall. What things will you have to consider in completing this assignment?
5. Describe the phenomena of both winter and summer stack effect.