or building owner. This does not exclude required notification by the owner or tenant.

- *Formal legal action:* Situations may arise where the fire department should take legal action, such as shutting down a department store or requiring a fire watch.
- *Informal action*: Situations may arise where informal actions are taken, such as modifying prefire plans, providing emergency water supply, working with management to establish fire watches, or shutting down hazardous processes.
- Authority to modify requirements, accepting alternative methods and/or materials that are equal or superior in performance.
- Formal personnel instruction.

Fire Department Instruction

A program of fire department education regarding airment of sprinkler systems should include training on the following topics:

- A basic knowledge of sprinkler protection, including types of systems and the adequacy and reliability of the water supply
- An understanding of the different reasons why sprinklers are installed
- Fire department policy on procedure and practices involving sprinkler systems
- Detailed knowledge of situations that decrease or destroy the efficiency of sprinklers

Company-Level Inspections

Sprinkler impairment can be divided into water supply and water distribution problems. The design and adequacy of the water supply system is beyond the scope of this chapter. It is assumed here that the designed supply is adequate. At times, however, this assumption is not valid. An old wooden hotel in Alaska had been sprinklered, down to a sprinklered shower stall. The unconnected sprinkler riser brought the revelation that the contractor never finished the job. In addition, the Siamese connection was located so that a supply line would make it impossible to open the exit door.

Many sprinkler systems in low-rise buildings depend solely on the city water main pressure to provide adequate sprinkler flow. In many areas of the country, continuing drought has forced water supply utilities to reduce pressure to conserve water. The pressure at upper stories of low-rise buildings may be inadequate for sprinkler discharge. In this case, the owner should be required to install a pump to provide adequate pressure.

The fundamental purpose of a sprinkler system is to hit the incipient fire with enough water to control it. There are too many ways for failure to occur to cover here, but a few examples should get fire fighters looking more critically at sprinklered buildings and make routine inspections more productive.

Making the following determinations is well within the capability of adequately trained fire suppression personnel performing an inspection. Some can be determined visually; others require answers from management or maintenance personnel. Any questions should be referred to the designated fire department authority for resolution. All deficiencies should be formally documented, but the system should provide for immediate verbal reporting of serious problems. Fire department policy should direct the action to be taken in various circumstances, including notification of the fire prevention bureau.

Outside the Building

Check for several items:

- Are flow tests performed regularly to assure that the designed supply is actually available?
- Are static supply elements, such as overhead or surface tanks, or pond intake, in good condition and protected from freezing where necessary? If the system depends on pumps, is there a check on maintenance and test procedures? Is the power supply vulnerable to a fire? Is the pump on and in the automatic position?
- If the power company cuts power to the building, will the pumps fail? Are emergency

power supplies adequate? Is the emergency system tested regularly? Where a pump is installed, a manifold for testing the fire pump is usually provided. Each 2 ½" (64 mm) outlet indicates 250 gpm (946 L) of pump capacity.

- Are fire department Siamese connections available Figure 6-22? In earlier years, they were optional. In many industrial plants, fire department connections were omitted from individual buildings. As a result, when a fire main is placed out of service, the sprinklers served by that main are out of service. If there is no FDC, it is not possible to use hose lines to supply the system. All systems should have FDC connections whether or not required by code. If there is a possibility of pumping contaminated water into the sprinkler system, the check valves that prevent backflow into the domestic system should be checked regularly.
- Are FDC properly protected from damage? All openings should be capped. When caps are missing, an open pipe is a target for debris that might cut off the flow of water. The heavy brass caps popular years ago frequently were removed. Use cast iron or plastic caps to protect today's FDC.
- Are all FDC labeled to indicate the type of service and area covered? The piping from the FDC to the system is dry and thus unsupervised. Nothing is apparent if it is broken. In modern construction, connections are often quite distant from the building, under driveways and parking lots and subject to traffic pressure and corrosion. Outside valves are most often post indicator valves (PIV), which indicate open or shut Figure 6-23. At a minimum, the valves should be locked as a precaution. The best system includes an electrical central tampering alarm. Some PIVs are located horizontally in the wall of the building. Sometimes the valve is located in a curb box on the sidewalk or in the street. Often this box is difficult to locate. It may even be paved over or fire apparatus may be parked on it. A sign should be posted on the building giving distances and directions to help locate the valve box.

Inside the Building

Sprinkler valves are made to indicate their position. If the stem is protruding, the valve is open; hence, this type of device is called an OS&Y (outside, screw, and yoke) valve Figure 6-24. Are the valves open? In the best system, electrical tamper switches transmit a signal if the valve is turned. At the very least, valves should be

Figure 6-22 Fire department connection.

Figure 6-23 Post indicator valves are usually found outside of a building and control an underground valve assembly.

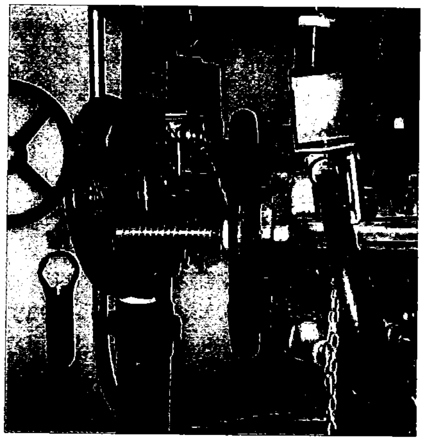


Figure 6-24 Two OS and Y valves with tamper switches. The valve on the left is closed (stem concealed) and the valve on the right is open (stem is fully out).

Courtesy of Ralph G. Johnson (nyail.com/fsd).

chained and locked to prevent tampering with them. The sprinkler valves are often hidden in locked closets. In some malls, the sprinkler valve for one store is located in another store. Signs should indicate the location, and it should be entered on the preplan.

Items to note on the inside of the building include the following:

- Is there a system for reporting any valves closed for maintenance? The system should assure that all closed valves are reopened. In a huge department store, 29 sprinkler valves were closed and 28 were open. A fire fighter fatality resulted when a fire occurred in the area covered by the closed valves.
- The details of the system for controlling shut valves and the special precautions taken when valves are shut are very much the fire department's business. This is especially the case if the sprinklers were installed by law or if exemptions were granted with respect to other code requirements.
- Is there a potential for freezing of all or portions of the sprinkler system? Are adequate precautions taken?
- Are old sprinkler systems or inadequately designed systems in use?

Dry pipe systems that have "gone wet," either for fires or by accident, are often found to be plugged by rust particles/scale carried by the inrushing water. A record should be kept of these occurrences and they should be reported to a designated authority for investigation. An accidentally discharged dry pipe system can be detected by the presence of high pressure, indicated by a pinned needle on the "air" pressure gauge on the dry pipe valve.

Often, industrial buildings and warehouses are built on speculation; the builder sometimes puts in a minimum sprinkler system to make the building attractive to tenants. The fire load introduced by the tenant may be far beyond the capacity of the system. Although specific analysis is beyond the company inspection level, some fire loads, such as boxed records, foamed plastics, aerosols, or rubber tires, are easily recognizable as being beyond the capacity of the typical sprinkler system.

One of this book's authors (Corbett) experienced the problem of undersized speculative warehouse building system designs. Any such problem must be corrected before a tenant moves in. The solution to this problem is to document the method of storage and the materials stored through the use of a "commodity letter," developed by the San Antonio Fire Department. The letter documents what is being stored in the building, how it being stored (racks, solid piles, shelves), aisle widths, and other pertinent information.

Many shopping malls are only partially sprinklered. Often a structure was built as an open mall and the stores were unsprinklered. Later, when the mall was enclosed, sprinklers were provided in the open area but not in the individual stores. In other cases, major department stores that anchor the mall are sprinklered while other stores are not. In one case, a fire in an unsprinklered central mall area broke windows in a department store and supermarket. More than 200 sprinklers were triggered in those two stores, which had to be closed for 2 months following the incident. Damage was $7 million.

Mall investors often want to keep their costs down and sometimes only provide the sprinkler main, leaving each store owner to install sprinklers. A serious hazard exists when a store under construction is left unsprinklered. All vacant stores in a mall should be required to be sprinklered because they are often rented temporarily to other occupants for storage.

The construction of a high-rise building represents a tremendous investment. The owner wants to start using or renting available space as soon as possible. This leads to a dangerous situation of construction work, with all its hazards, being carried on in an occupied building. Even if the building is sprinklered, often the most hazardous floors—those under construction—are not sprinklered because the sprinklers go in after the ceiling is in place.

The buildings department should be alerted to this hazard, and insist that the sprinklers be in service throughout the building before any partial occupancy is permitted. If the buildings department is complacent, the fire department should take every means possible to mitigate the hazard. Prospective tenants, who are relying on the sprinkler system, should be put on notice as to the hazard.

There seems to be great interest in preserving historic buildings. Often these buildings are just minimally restored. Sometimes the buildings department requires sprinklers in these structures. Often the sprinklers just cover the accessible areas and do not cover the voids. This may be a deliberate cost-saving decision. The sprinkler system is needed for life safety and property protection, and the sprinklering of the voids would make the cost prohibitive. If this is the case and the fire starts in or penetrates the void, the building may be destroyed. As noted earlier, a "fully sprinklered" renovated dormitory at the College of William and Mary was destroyed because of a void fire.

In some historic buildings, sprinklers are installed in the nonpublic areas and omitted in the public areas in deference to "historic authenticity." This is called selective placement of sprinklers. While doing restoration work, an architect recently recommended sprinklers be installed in the attic and the basement of the Old State House in Boston—but not on the intervening floors because the sprinklers were not "architecturally compatible." However, providing adequate fire protection without compromising historic values has often been accomplished.

The historic 187-year-old John C. Calhoun Mansion, called Fort Hill, is maintained on the campus of Clemson University in South Carolina. A museum of valuable art, furnishings, and historic memorabilia from the 1700s and 1800s, it has been sprinklered since 1966. In May 1988, an arsonist set a fire inside Fort Hill, but the sprinklers extinguished it with moderate damage, and the historic structure still stands. Two weeks before the fire, a visiting historic preservation conservator referred to the visible, nonauthentic sprinkler system as an embarrassment. He recommended a fixed Halon deluge system. The university wisely disregarded his recommendation.

McGill University in Montréal housed two important research units in an old mansion called the Lady Meredith House. There were no sprinklers in this structure. A basement fire spread up through the unfirestopped walls and open staircases, necessitating five alarms. Many research papers were lost. Fire officers trying to convince a director of such an enterprise to spend scarce research money on fire protection might point out that computers often are a target of thieves, and fires are often set to conceal the theft.

Are all areas of the building "seen" by sprinklers? Unsprinklered voids often exist. An old office building in Memphis, Tennessee, has been extensively modified over the years, including the installation of a light-hazard sprinkler system. The sprinklers were obstructed by air ducts, however, and the system was not properly maintained. When a fire originated in a void space, it took scores of fire fighters 3 hours to literally "dig" the fire out of the walls, cocklofts, and other concealed spaces.

The sprinkler protection of a dinner theater was impaired by the construction of a mezzanine without sprinklers underneath it. A fire occurred underneath the mezzanine and gained headway until ceiling sprinklers operated and sounded the alarm. The loss was much greater than it would have been had proper sprinkler protection been installed.

In some cases, unsprinklered voids are created by a building within the building. Offices on factory floors, special storage rooms, and mezzanines are typical of the structures that can provide a place for the fire to grow unchecked, burst out, and overpower the sprinkler system. These areas should be sprinklered or their ceilings should be of lightweight plastic panels approved for such use, which melt out when exposed to fire. Plywood will not burn through in time.

In some cases, large ceiling expanses of department stores have been fitted with panels to conceal the sprinklers. This might be dangerous. Melting and falling panels might be taken by occupants to mean the structure is failing and cause panic.

A $2 million loss occurred in a Midwest shopping mall when fire extended through a combustible void above the ceiling of the sprinklered building; the roof was a conventional metal deck. Another major loss was suffered at Tinker Air Force Base in Oklahoma, when a metal deck roof fire, started by roofers, could not be controlled by sprinklers installed only below the ceiling line.

Are sprinklers uncompromised? Sprinklers should remain unpainted and untainted by other materials. Painted sprinklers should be replaced. Spray fireproofing has been applied to sprinklers. To counter the belief that sprinklers are ugly, concealed sprinklers have been developed. A flat plate, usually enameled to match the ceiling, conceals a sprinkler. It will drop out when heated. Concealed sprinkler covers should not be painted when the ceiling is painted. Paint might interfere with the cover dropping.

Exposure protection is sometimes provided by sprinklers outside the building. In cold climates, these are subject to freezing. Protecting them from freezing should not require shutting down the entire system.

In other cases, open outside sprinklers all discharge when a valve is opened manually. Such systems are very useful and can release firefighting units for other tasks. The fire department should know the location of the valve and how to get to it when the building is closed. This information should be incorporated into the prefire plan.

Sprinkler Fraud

In 1984, the fire protection community was shocked and dismayed to learn of a major case of sprinkler fraud. As part of an investigation of an arson fire at a sprinkler installation company, a sprinkler contractor in California was discovered to have installed unconnected sprinklers that were simply glued to the ceiling. The authors were told there were a number of other similar situations. Although many new trends start in California and work eastward, let us hope this does not become a trend with sprinkler fraud. In any case, those inspecting and checking sprinkler systems should look beyond the obvious.

Management of Sprinkler Systems

Management is receiving lots of attention in the fire service today. Unfortunately, much fire service management effort is concerned with managing the fire department, rather than managing the fire problem. The integrity of sprinkler protection is a big fire management problem, and fire departments would do well to get started on managing it!

It's also a good idea to make sure that you have established sprinkler system protocols in your standard operating procedures. What company will supply the fire department connection (first or second due engine)? When is it permissible to shut down the system? What about system impairments? A good place to start is NFPA 13E, *Recommended Practice for Fire Department Operations in Properties Protected by Sprinkler and Standpipe Systems*.

Special Situations Involving Flammable Liquids

Flammable liquid fires can be controlled with sprinklers, but they present special problems:

- Most flammable liquids float on water. Thus, there is the potential for flowing flaming liquid, which can spread fire and injure fire fighters.
- Flammable liquids have a high rate of heat release.

- Flammable liquid containers can result in a BLEVE (boiling liquid/expanding vapor explosion).
- Aerosol cans may act as flaming rockets.
- Runoff water may create a significant contamination problem.

The best method for controlling flammable liquid fires is to keep the containers from overheating and control the flowing fire on the floor. The containers can be kept from overheating if the sprinklers can wet every container exposed to heat. The use of conventional sprinklers on flammable liquid fires creates the problem of controlling runoff to prevent environmental problems. It appears that foam water sprinklers would substantially reduce the problem. Isolation in a flammable liquids storage room is typically required for flammable liquids. Isolation in specially designed rooms (preventing rockets from leaving the room) for large quantities of aerosols is also required. A floor fire can be aided by the use of sills and trench floor drains that are designed to draw off spills of liquids and water to designated areas.

Protection of Glass Fire Barriers With Sprinklers

The use of glass, on both the exterior and interior of buildings, for separations that may be designed to resist fire or that may accidentally serve this purpose, is increasing. In some cases, lines of sprinklers have been used to protect the glass. It is important that all the glass be wet. In the case of hot fires, the wetting must occur early to avoid thermal shock to hot glass. Window treatments, such as draperies, should not be installed between the glass and the sprinklers.

Early Suppression/Fast Response Sprinklers

Sprinklers have a number of opportunities to fail to perform properly in high-rack storage warehouses. In addition, the supply piping for in-rack sprinklers limiting the movement of the racks themselves has been a problem.

Early suppression/fast response (ESFR) sprinklers were developed not just to control the fire, but to suppress it. This requires early discharge of a larger quantity of water—as much as 100 gpm per sprinkler in some cases. In fact, ESFR sprinklers are designed to approach the old fire fighters' slogan, "Put the wet stuff on the red stuff." Conventional sprinklers cool the ceiling and prewet surrounding storage. ESFR sprinklers dump most of the water directly on the fire.

The orifice of an ESFR sprinkler is 3/4" (19 mm) in size; conventional sprinklers have 1/2" (13 mm) openings Figure 6-25. ESFR system installations are new—in most cases, the existing piping of traditional systems is not adequate in size. Tests have indicated that ESFR sprinklers can protect rack storage of high-density plastics up to 25 feet (7.6 meters) in height without the use of in-rack sprinklers.

The use of ESFR sprinklers permits greater flexibility in warehouse layout because the need for in-rack sprinklers is eliminated for many commodities up to a specified height.

Preplanning Considerations

Here are some preplanwning considerations:

- A sketch of the system showing fire pump location, risers type (wet pipe, dry pipe, etc.), and location(s) (typically, a single riser can cover an

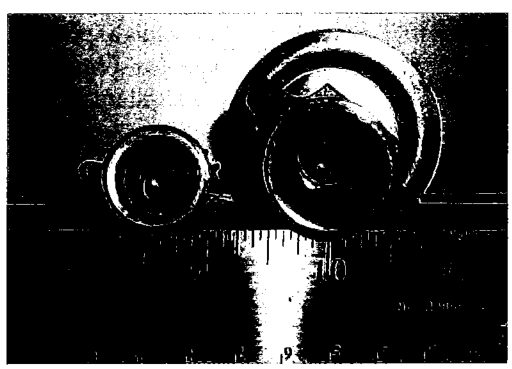


Figure 6-25 Compare the conventional sprinkler's 1/2" orifice (left) with the 3/4" orifice of an ESFR sprinkler (right).

Courtesy of Glenn Corbett.

area up to 52,000 square feet (4831 m^2) for most occupancies with a limitation of 40,000 square feet (3715 m^2) for high-piled stock warehouses and extra hazard occupancies), main control valve, and significant building details such as the location of fire barriers, stairwells, and corridors

- The total water supply demand of the system (flow in gpm and pressure in psi), which is printed on a sticker on the riser or on a metal card attached to the riser
- Any connections to the fire alarm or other systems (e.g., a **water flow switch**, which detects the movement of water in the systems and transmits a signal to the alarm system)
- Fire department connection location and the areas it serves
- Types of sprinklers, including any unusual characteristics
- Location of manual release for preaction and deluge systems

Some basic firefighting considerations for operating sprinkler systems are summarized here:

- Supply the FDC.
- Verify the main riser control is open (usually an OS&Y valve).
- Note the pressure on the main riser gauges (supply side and discharge side of the alarm valve/dry pipe valve/deluge valve). Is the discharge gauge moving, possibly indicating water flow? Are they appropriate readings (e.g., does it read zero on the supply and discharge gauges, indicating a closed valve in the street)?
- Ensure the fire pump (if present) is working and read gauges; manually start the fire pump if necessary.
- Do not close the valve until you are sure the fire is out; only close the valve after the fire has definitely been controlled. Leave a fire fighter at the valve with a radio to reopen the valve quickly if necessary.
- Do not replace sprinklers or reset dry pipe valves. Let the contractor handle it; post a fire watch if necessary until the system is restored.

Standpipe Systems

Standpipe systems—fixed networks of piping and hose valves (and sometimes hose)—are installed in tall and/or large buildings to provide quick fire attack. They have been in existence since at least 1870, perhaps even earlier. Today, there are three classes of systems, based upon their user and hose size. According to NFPA 14, *Standard for the Installation of Standpipe and Hose Systems*, these classes are:

- *Class I system:* A Class I standpipe system provides 2 ½" (64-mm) hose connections to supply water for use by fire departments and those trained in handling heavy fire streams.
- *Class II system:* A Class II standpipe system provides 1 ½" (38-mm) hose stations to supply water for use primarily by the building occupants or by the fire department during initial response.
- *Class III system:* A Class III standpipe system provides 1 ½" (38-mm) hose stations to supply water for use by building occupants and 2 ½" (64-mm) hose connections to supply a larger volume of water for use by fire departments and those trained in handling heavy fire streams.

These three classes also dictate the amount of water flow and pressure from a standpipe, which has varied over the years. Generally speaking, today Class I and III systems provide (or are capable of providing) 250 gpm (946 Lpm) at 100 psi at each hose valve. Years ago, the pressure requirement was only 65 psi, based upon the use of 2 ½" (64 mm) hose. The increase to 100 psi recognized the use of automatic and fog nozzles, although even this is not enough for nozzles that operate at 100 psi, given the friction loss in the hose. Class II standpipes supply 100 gpm (379 Lpm) at 65 psi. These are often called **houselines** and are intended for use by building occupants.

Standpipes can also be classified by the water supply provided for the systems:

- **Automatic-wet**: An automatic-wet standpipe system is a wet standpipe system that has a water supply that is capable of supplying the system demand automatically.

- **Semiautomatic-dry**: A semiautomatic-dry standpipe system is a dry standpipe system that is arranged through the use of a device, such as a deluge valve, to admit water into the system piping upon activation of a remote control device located at a hose connection.
- **Manual-dry**: A manual-dry standpipe system is a dry standpipe system that does not have a permanent water supply attached to the system.
- **Manual-wet**: A manual-wet standpipe system is a wet standpipe system connected to a small water supply for the purpose of maintaining water within the system or sharing a water supply with an automatic sprinkler system but not having a water supply capable of delivering the system demand attached to the system.

Standpipe Operations

The use of Class I and III standpipes by the fire service has had many years of success, particularly through the 1980s. These success stories are based upon the "classic" 2 ½" (64 mm) handline with smooth bore nozzle. The fire service then began to change, but the standpipe systems did not. The proliferation of 1 ¾" (44 mm) hose and lower staffing levels pushed fire departments to use the 1 ¾" (44 mm) attack line with automatic/fog nozzles, even for high-rise fires, while the standpipe pressures remained at 65 psi.

This all came to a head in 1991. At the tragic One Meridian Plaza high-rise fire in Philadelphia, improperly set pressure-reducing valves (PRVs) cut the available hose valve pressure to very low levels—the 1 ¾" (44 mm) hose with 100-psi nozzles the Philadelphia Fire Department were using were practically useless. The fire burned vertically unabated through the building until it was stopped by ten sprinklers at various locations that had been retrofitted. Three fire fighters were killed at the fire.

It is the opinion of the authors that high-rise fires must be fought with 2 ½" (64 mm) hose lines, not 1 ¾" (44 mm) or 1 ½" (38 mm) hose lines. In addition, smooth bores are the nozzle of choice because of their reach, penetration, and (importantly) low operating pressure.

Pressure-reducing valves, which are used to cut the high pressures found on the lower floors of tall high-rise standpipe risers, are a source of major concern for fire fighters. This is often the case when a few tall **zones** are used. (Zones are the individual riser segments, one on top of the other. In tall structures, there is an economic incentive to have fewer zones to avoid having to install more pumps.) It is important to ensure that the valves are tested frequently to ensure that they are set at the proper pressure. Waiting until a fire occurs to learn about this problem is too late—some of these valves are not even field adjustable!

Here are some standpipe preplanning considerations:

- A sketch of the system showing fire pump location, risers and hose valve locations, main control valve and riser isolation valves, as well as significant building details such as the location of fire barriers, stairwells, and corridors
- The type of water supply and flow/pressure characteristics
- Types of hose valves, including any pressure-reducing valves and their mode of operation (and how to adjust them)
- FDC and the areas/zones it serves (it is common to have more than one standpipe FDC serving different floors of a building) as well as the proper pressure needed to supply it
- Connections to a fire alarm system or other fire protection system

Basic firefighting considerations for operating a standpipe system include the following:

- Supply the FDC. If it is blocked/clogged, you may pump through the second-floor hose valve in a stairwell as a backup if the hose valve is not a pressure-reducing valve.
- Verify that the main control valve and riser isolation valve are open.
- Note the pressure on the main riser gauge at the ground/basement level to establish that the system is operating properly. (There should be a pressure gauge at the top of each riser as well.)
- Ensure the fire pump (if present) is working and read gauges; manually start the pump if necessary.

- Be wary of dry standpipe systems—they will take longer to fill/pressurize and may have been vandalized. (Watch out for hose valves that have been opened by vandals before the fire.)

Fire Alarm, Detection, and Communications Systems

Fire detection and alarm systems have been around for many years, dating back to the 1800s. Today, a myriad of detection devices and other hardware are available to alert occupants and (in some cases) the fire department that a fire has been detected. The design and installation standard is NFPA 72, *National Fire Alarm Code.*

Initiating devices (which transmit a "change of condition" signal) include the following:

- Manual fire alarm boxes (pull stations)
- Spot-type smoke detectors, which include photoelectric and ionization smoke detectors
- Line-type smoke detectors, which cover an area such as the projected beam detectors found in atria
- Duct smoke detectors
- Spot-type heat detectors (including nonrestorable fusible element detectors, fixed temperature detectors, restorable bimetallic strip and disc detectors, combination rate of rise/fixed temperature detectors, rate compensation detectors, etc.)
- Line-type heat detectors (including heat-sensitive wires for industrial applications such as cable trays)
- Gas detectors
- Flame detectors (ultraviolet or infrared)
- Water flow switches
- Water pressure switches
- Supervisory switches such as tamper switches on OS&Y sprinkler valves

The following indicating devices signal the "change of condition" to occupants:

- Strobes
- Horns
- Chimes, buzzers, and sirens
- Speakers
- Lamps

Despite the fact that there is a standard for fire alarm systems, no single standard has been established for the actual design of panels (although fire departments can request such within their jurisdiction according to NFPA 72). This fact has been the bane of many a fire fighter who is forced to try to decipher a fire alarm message at 3:00 in the morning. Although some improvements have been made with textual displays, fire alarm system activations can be problematic—all the more reason for preplanning!

Depending upon the age of the system, alarm and trouble signals may simply be indicated by small red and yellow lights, respectively, or may actually be printed out on a computer monitor screen in a modern system. The key is to know what the system is telling you—that is, the type of activation (e.g., elevator lobby smoke, water flow switch) and the location of the activation (e.g., second floor, fourth floor, west wing).

Often, the initiating devices are grouped by zones. These zones, in turn, may be grouped either by areas of a building or by type of device, especially in small buildings (e.g., smoke detector zone, manual pull station zone).

In addition, some fire alarm systems are co-located with other fire protection and life safety system controls in a fire command center in high-rise buildings. This arrangement allows fire fighters with portable handsets to talk with the lobby command post from telephone jacks positioned in various locations, such as stairwell landings, elevator lobbies and cabs, and so on. In the opinion of the authors, such systems are not very useful because they limit the mobility of fire fighters. High-rises and covered malls also may have public address systems, allowing officers to make announcements to the building occupants.

Fire fighters should take the following aspects of alarm and detection systems into consideration while doing their preplanning:

- Area(s) protected by the system.
- Types of detection and other initiating devices.

- Location of alarm panel and any **remote annunciators**. These small panels indicate the fire detector activation but do not provide all of the main alarm panel features; they are often placed at entry points to the building Figure 6-26.
- Type of panel and type of zoning, if present. If it is an older system with simple red, yellow, and green lamps, it is critical that you have a diagram/sheet indicating which zone corresponds to which area/type of device in the building! Otherwise, all you will know is "zone three" has been activated—but what does that mean?

Generally speaking, water flow switches are more reliable indicators of the actual location of a fire than smoke detectors, which can be "fooled" by migrating smoke. In a large or tall building with multiple detector activations, it is usually best to use the flow switches for the fire floor/area.

Do not reset the system until the device of origin has been established. Modern smoke detectors typically use a solid red light on the individual detection device to indicate activation. Use the **silence switch** on the panel if you have established that the activation is actually a false alarm. Many modern panels can store a "history" of alarm activations—scroll through them to see the sequence of activations.

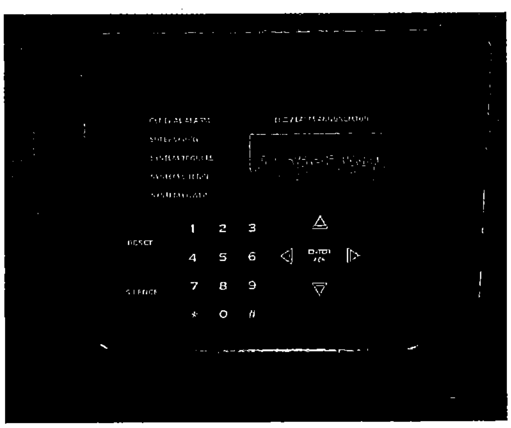


Figure 6-26 A remote annunciator.

Courtesy of Glenn Corbett.

Public Education and Alarm Systems

Smoke detectors have saved many lives in residential fires. Unfortunately, all too often these detectors are found to be missing or out of service. The educational effort stressing the importance of continuously operative smoke detectors should be intensified, particularly among low-income and non-English-speaking residents.

In some cases, smoke detectors are relied on to the exclusion of automatic sprinklers. As noted earlier, however, fire protection and fire detection are not synonymous. Only if the fire alarm is received where there is someone ready, willing, and able to respond and control the fire can detection begin to be considered protection. In some cases, the fire fighters are not available; in others, the fuel is of such a nature or the fire is so inaccessible that the fire is out of control when the fire suppression forces arrive. In the case of a high-rise building, a realistic estimate of the time between the alarm and the start of extinguishment is at least 20 minutes.

Unwarranted and Delayed Alarms

An *unwanted alarm* is defined by NFPA 72, *National Fire Alarm and Signaling Code*, as "*any alarm that occurs that is not the result of a potentially hazardous condition.*" Some communities have instituted penalties for repeated, unwanted alarms. However, such programs should have effective means to prohibit building managers from failing to transmit alarms. In several large-loss fires, such as those occurring at Los Angeles's First Interstate Bank, Philadelphia's One Meridian Place, and Houston's Westchase Hilton (a multiple-fatality incident), delay or failure to transmit the alarm received from the fire alarm control panel detectors was a factor in elevation of the fire's severity. The City of New York sued a building management company to recover the costs of fighting a fire, including subsequent medical costs, that sent 20 fire fighters to the hospital; the city charged that the building management had delayed transmitting the alarm.

Smoke Management Systems

Perhaps the most mystical of systems is the smoke management system. These systems are intended to do just what their name implies: manage smoke. Most fire fighters have limited or no experience with them.

Smoke management systems can take different forms, depending upon the building code and the design intent of the systems. These types can be categorized as follows:

- Smoke control: Usually in the form of pressurization to prevent movement into protected areas, such as **stairwell pressurization systems**
- **Purge**: Venting of smoke
- **Zoned smoke control**: A combination of pressurization and venting; typical in high-rises where the fire floor is vented and the surrounding floors, above and below, are pressurized to prevent migration
- **Air flow**: The use of high air velocity to stop smoke movement

The key to understanding the operation of a smoke management system is to look at the original design and testing criteria (including the type/size of fire it is protecting against). If designed and tested properly, you will understand what the system is supposed to do. More importantly, it will tell you what you as a fire fighter should or should *not* do with the system!

Different design requirements and guidelines exist. The *International Building Code* includes design criteria. In addition, NFPA 92, *Standard for Smoke Control Systems* contains design criteria and has detailed information that should be consulted.

These systems run the gamut from simple to complex. They can be found in atria, stadiums, covered malls, underground buildings, and older high-rises. (The requirement for "general" smoke control in high-rises was removed from the model building codes years ago; only stairwell pressurization system requirements remain.) For existing systems, you must do your homework and figure out the design criteria for such systems—don't wait until a fire occurs.

Most smoke control systems will have some type of control panel. This panel may include diagrams of the area protected. Most use toggle switches to turn on/off various parts of the system, including fans and dampers. The wrong flip of a switch can pressurize the fire floor and exhaust areas that you want to keep smoke out of—watch out!

Determine whether the system is automatic (the usual case), manual, or both. In the case of an automatic system, determine what activates it. Spot-type smoke detectors are notoriously bad initiating devices for system activation because they can be remote from the fire's actual location. Most systems use water flow switches and, in the case of atria, projected beam detectors.

In all cases, try to be present when the system is tested. You will learn a lot.

Some things to consider when preplanning a smoke management system:

- General description of the system and the type of smoke management (smoke control, zoned smoke control, purge, air flow).
- Location and extent of system.
- System design criteria. (What is it trying to achieve?)
- Is it automatic, manual, or both?
- What types of initiating devices activate the system?
- A step-by-step sequence of system operation: what turns on, what turns off, what opens and what closes, etc.
- Location and description of control panel.

Firefighting considerations for smoke management systems include the following concerns:

- Assess the system operation: Is it working properly? If not, should you shut it down?
- When activating a system manually, let all fire fighters know so they will not be endangered.

- Leave a fire fighter with a radio at the system controls to ensure quick activation/shutdown if necessary.

Other Fire Protection Systems

Fire fighters will encounter other types of protection systems, protecting specific types of hazards. These include **dry chemical systems**, **wet chemical systems** (often used for cooking hoods), **foam systems** (used for flammable liquid tank protection), **carbon dioxide systems** (sometimes used to protect materials that can be damaged by water, such as record storage vaults and for printing presses), **clean agent systems** (which are used to protect sensitive equipment and have been replacing older **Halon systems**), **water mist systems** (also used to protect sensitive equipment), and **water spray systems** (which can protect exposed LPG tanks and electrical transformers).

Each of these systems is installed to protect against a specific hazard. When preplanning these systems, understand what they are trying to do: Are they intended to put the fire out or just cool the exposed hazard? How hazardous is the agent—is it relatively harmless like water mist or deadly like a carbon dioxide discharge? Is the system **total flooding** (i.e., the agent is applied throughout the entire compartment/area) or local (i.e., the agent is applied to just the piece of equipment/hazard)?

TACTICAL CONSIDERATIONS

1. It usually falls to the fire service to maintain a memory of unusual fire hazards. There is very little "out of date" experience in the fire service. Many buildings standing in your district have been around for decades and have outlasted the careers of numerous fire fighters. Hopefully before they left, they shared their knowledge of those building hazards that have the potential to kill fire fighters. There is no reason not to know the dangerous hazards of buildings that have been around your city for any length of time. Get out and inspect them. Update preincident plans and make sure that everyone knows the hazards that may have existed for decades. Knowledge is the best survival tool we have. Know your buildings.
2. Begin with prefire planning. Prefire planning starts with a scenario of the fire potential in a building with all its ramifications. The rate at which a fire will grow is one of them. It makes a tremendous difference to know that the fire-resistive building is filled with fast-burning materials. It is likely that the usual, initial small line tactics will be ineffective and waste time that is needed to bring heavy-caliber streams into play.
3. Any location where nitrocellulose or any other especially toxic material is stored demands intensive preplanning with emphasis on defensive operations. In any given situation, one gas might be more toxic than another. SCBA may be required for these defensive operations.
4. Company officers must be well informed as to flame spread potential. Preplanning will forewarn personnel of possible flashover or heavy fire situations. Personnel should be well trained in the possibility of hidden fire. Learning by experience alone may be fatal. Tactics and equipment should be developed to deliver the water necessary to control fast-spreading, high-heat-output fires.
5. Insulation is often blown into an attic space with a large flex hose. It's quick and economical. Unlike batt insulation, which is wrapped and unrolled between the ceiling joists in long single strips and easy to pull out in sections to check for hidden fires, blown insulation represents one giant blanket of insulation. Many fires have rekindled because of undetected hot spots embedded in the insulation. During overhaul in an attic, Class A foam is recommended for final extinguishment. But even with Class A foam, hot sparks may still be burning somewhere underneath the insulation. Often, even a thermal imager may not register the heat source. When it is impractical to remove all the insulation from an attic space, it's best to post a fire watch and rotate crews for the next 24 hours to prevent a rekindle. This author speaks from experience.
6. An estimation should be made of the potential for rapid flame spread over interior finishes. For instance, many churches with exposed wood plank surfaces present the potential for extreme flame spread and, thus, a fully developed fire. Fire can develop with unimaginable speed.
   i. In a Florida church fire, photographs showed only light smoke as units arrived. Within a minute, heavy fire was rolling out of every window and door. A fire department that has not preplanned properly for this type of fire may well waste time using handlines that will be completely useless. This fire was suppressed in 14 minutes by three heavy-caliber streams positioned so as to sweep all surfaces.
7. A carpeting fire will fill a corridor with flame. It should be fought with a solid stream, directed through the fire to wet the carpet beyond the fire, thus stopping extension. A fog stream may push the fire.
8. When fighting a fire in any corridor, there could be more than two fire fighters on the hose line. Putting three or more fire fighters in reverse to quickly back out of a corridor in untenable conditions can be confusing, clumsy, and slow. Always pay attention to other doorways and rooms within the corridor that can be forced open for an area of refuge. If you're on

the nozzle and therefore the last one out on a hose line, it may be quicker to force a door into a tenable space. Then you can find a window or breach walls to make a safe exit. Have an escape plan to survive the event.

9. The traditional *below-grade*, interior attack may often result in smoke damage, which could be reduced by changing the access point where the attack is initiated. In some cases, fires in basements and laundry rooms must be attacked from the interior stairway, resulting in smoke damage to the floors above. Smoke damage can be reduced with an indirect attack such as through a basement window or by selecting an alternative entry point like a rear basement door. Of course, an exposure line should be laid to protect the door at the top of the stairway. Utilize the reach of the stream. Crews can protect the stairwell from a safe location on the floor above without standing right over a weakened floor from a basement fire.
10. Smoke can do more damage to property than the fire and water. Fire fighters should place a high priority on controlling smoke damage to the extent possible. In malls, this would include closing any available doors, particularly the sliding doors installed on the major flagship department stores.
11. A realistic estimate between alarm time and the start of extinguishment in high-rise buildings is 20 minutes.
12. The fire department should educate the management and occupants of buildings on the importance of keeping stairway doors closed. Signs should be provided, employees and occupants should be educated, and citations should be issued when necessary. It is foolish to have a law requiring enclosed stairways and then take no steps to ensure they are closed.
13. Recognize that interior stairways can emit toxic smoke and gases throughout the building. This requires an early, painstaking search of all floors above the fire. At a fire, command must designate which stairways are to be used for fire suppression and which one for evacuation. Label stairway doors with tape or marker for incoming crews
14. Fire fighters should carry sufficient wedges to hold electronically released fire doors open when operations make this necessary. Because many fire doors do not operate properly, units should be assigned to check all fire doors and close those that should be closed. Fire fighters should never advance through a doorway protected by a fusible link-tripped fire door without blocking it to prevent its closing or dropping behind them. The force of the door can kink, pinch, or sever a charged hose line, leaving the attack crew unprotected on the opposite side of the fire door.
15. In some fire departments, checking that fire doors operate properly is a routine ladder company responsibility. In any case, this responsibility should be preassigned and not left to chance. Fire doors in fire walls and both horizontal and overhead roll-up doors are triggered by fusible links, sometimes located high up in the overhead. A burst of heat might trip the fusible link. It may be impossible to raise an overhead fire door and it can be very difficult to open a sliding fire door.
16. Fire departments should keep up with current literature and training seminars on PPV. Critiques of PPV operations often do not understand the physics and science behind it. They should be made to articulate the practicality of their alternative ventilation plan and should be made to develop a body of recorded experience with PPV techniques. Vertical ventilation is effective and at times necessary, but with lightweight truss construction or built-up commercial roofs, it can be dangerous, time-consuming, and labor-intensive. Fire departments that do not have the resources or staffing should consider becoming experts at using PPV. This ventilation technique is simple, fast, and effective if used correctly with knowledge and experience. The use of PPV on initial attack should be carefully monitored.
17. Many fully enclosed air-conditioned buildings are under positive pressure. Opening a single window on the leeward side of the building in the fire area will permit the excess pressure to vent, taking much of the smoke with it. Opening several windows can weaken and dilute the effect.
18. The fundamental purpose of a sprinkler system is to hit the incipient fire with enough water to control it. An experienced apparatus driver doesn't need to be told to charge and support the sprinkler system. This simple but essential task is often overlooked at fires.
19. The sprinkler system should not be shut off as long as hot water is falling down. This is an indication of the high heat atmosphere above you.

20. If responding to a library fire, be aware that 85% of recent library fires were due to arson. Note also that older libraries often used marble for the flooring. If unsupported, as in the Library of Congress, such floors can look good after heat exposure, but fail under a fire fighter's weight.
21. Some FDC for sprinkler systems cover only certain portions (floors) of a building.
22. Fire departments should know where sectional valves are located for partial sprinkler systems. In addition, the piping of some sprinkler systems in high-rise buildings may be limited in terms of its working pressure, providing only as little as 200 psi. When supplying a fire department connection, know the pressure limitations and know which parts of the building you are supplying.
23. The fire department should not manipulate any valves or any other equipment during an inspection or test. Such action would leave the department exposed to being accused of error or negligence if a system failure occurs. Permanent files should be kept of such notification because it may be years before a problem arises.
24. A critical point for standpipes: know the pressures and flow capabilities of all standpipe systems. A standard hydraulic formula adds 25 psi for the standpipe and 5 psi per floor on top of the required friction loss calculations. Your current "high-rise pack" may be incompatible with some of the systems in your city. In addition, be wary of PRVs—know how they work and if they can be overridden. Enlist the assistance of fire prevention personnel or fire protection engineers to develop a list of all the systems in your community.
25. Company officers should drill their crews on how to set up an emergency standpipe system and a backup standpipe. In the rare event of a standpipe failure, damaged threads on numerous standpipe valves, or threads on the high-rise pack that do not match those of the standpipe valves, be prepared to recover by establishing a water supply in the stairway. This can be done by laying LDH or 2 ½" (64 mm) hose up the stairwell or by weaving a 2 ½" (64 mm) hose vertically through the windows of the stairway landings. Weaving helps support the weight of a charged vertical 2 ½" (64 mm) supply line. Attach a 2 ½" (64 mm) gated wye to the end of the hose. At a minimum, it must reach the landing of the floor below the fire floor.
26. Class I standpipes are vertical hollow tubes. If for some reason the standpipe cannot be charged at the Siamese FDC on the exterior of the building, 2 ½" (64 mm) hose lines can be laid to the first floor (or lowest level) discharge valve of the standpipe. Using the proper couplings and a Siamese connection, two 2 ½" (64 mm) lines can be attached to the discharge valve for supplying the standpipe.
27. An apparatus driver who encounters a Siamese FDC (standpipe or sprinkler connection) with frozen or rusted female swivels that cannot be freed can still make the connection by inserting two 2 ½" (64 mm) double male couplings, then attaching two 2 ½" (64 mm) double female couplings. In essence, you've created a new Siamese FDC. Figure out a way to brace or prop up this connection to support the added weight.
28. Another way to connect to a Siamese FDC with frozen or rusted female swivels is to twist the 2 ½" (64 mm) supply hose counterclockwise 4–5 turns. Insert the male coupling into the female swivel and untwist the hose clockwise to make the connection.
29. When a 2 ½" (64 mm) gated wye is attached to a standpipe discharge valve with multiple hose lines, consider supporting the weight on the valve with a hose strap or some other method. Another method is to have a tested short 10-foot (3 m) "pony" section of 2 ½" (64 mm) hose. The pony section is attached to the standpipe. All other connections are made on the hose at floor level. This keeps all the extra weight from hose lines and appliances off the standpipe valve.
30. Seasonal public assemblies, such as haunted houses, have had their share of disasters with flammable contents and decorations that have led to multiple fatalities. Many decorations in haunted houses are black to create a dark, scary atmosphere. Quick and effective ventilation efforts are critical in such public assemblies. Removing smoke and heat will introduce an increased survivable atmosphere as well as improve visibility to allow able patrons a chance to escape and search teams to quickly cover the area and rescue those who can't.

WRAP-UP

Chapter Summary

- Fire containment has always been a primary objective of fire fighters.
- Some buildings are described in codes as noncombustible. This description is not technically accurate. The local fire officer should know exactly what this means.
- Rated fire resistance is a quality ascribed to a wall, floor, or column assembly that has been tested in a standard manner to determine the length of time for which it remains structurally stable (or resists the passage of fire) when attacked by a standard fire.
- When it was learned that fire could extend up open stairways in "fireproof buildings," the concept of compartmentation—or creating fire areas no larger than one floor—was developed. Fire-resistive assemblies—fire walls, fire partitions, and fire barriers—are key elements in that approach to fire protection.
- Fire suppression and detection systems are another critical means of providing fire protection. They include automatic sprinkler systems; standpipe systems; fire alarm, detection, and communications systems; and smoke management systems.

Key Terms

Air flow The use of high air velocity to stop smoke movement.

Automatic-wet standpipe system Standpipe system attached to a water supply capable of supplying the system demand at all times; it requires no action other than opening a hose valve to provide water at hose connections.

Carbon dioxide system A fire protection system intended to protect materials that can be damaged by water; it uses carbon dioxide to suppress the fire.

Clean agent system Gaseous fire extinguishing agent that does not leave a residue when it dissipates.

Compartmentation Subdivision of a building into small areas so that fire or smoke is confined to the room or section in which it originates.

Conflagration Rapid involvement of a fire situation that goes beyond the normal attack situations that fire departments encounter.

Critical radiant flux (CRF) The amount of external radiant heat energy (measured in watts per square centimeter) below which a flame front will cease to propagate.

Demand area The "expected" area of sprinklers that will activate as anticipated by the sprinkler design standard; essentially the projected size of the fire.

Density The unit rate of water application to an area or surface; expressed in gpm/ft^2 [(L/min)/m^2].

Dry chemical system An automatic fire extinguishing system that discharges a dry chemical agent.

Egress Adequate exits within a building.

Fire barriers Assemblies that are typically 1- to 2-hour rated and used to enclose shafts, exit stairwells, exit passageways, and horizontal exits, and to separate spaces from certain hazardous areas.

Fire damper A mechanical device installed in an HVAC system at the point at which it passes through a fire-resistive assembly so as to block the spread of fire through the fire-rated assembly.

Fire partitions Assemblies that are typically 1-hour rated and are used to create fire-resistive corridors and to separate tenant spaces in covered mall buildings.

Fireproofing Material applied to structural elements or systems that provides increased fire resistance; usually serves no structural function.

Fire-rated The classification indicating in time (hours) the ability of a structure or component to withstand a standardized fire test. Does not necessarily reflect performance in an actual fire.

Fire resistance rating Quality ascribed to a wall, floor, or column assembly that has been tested in a standard manner to determine the length of time it remains structurally stable (or resists the passage of fire) when attacked by a test fire.

Fire resistant Construction designed to provide reasonable protection against fire.

Fire retardant Substance that helps delay or prevent combustion.

Fire walls Assemblies that are typically 2- to 4-hour rated and are used to create "separate buildings" within an overall structure.

Flameproof Resistant to fire.

Flammable Combustible that is capable of easily being ignited and rapidly consumed by fire. Flammables may be solid, liquid, or gas.

Foam system A firefighting system that provides for the delivery of a proportioned foam and water mixture for use in fire extinguishment.

Halon system A fire protection system that provides for the transfer of halogenated agents between fire extinguishers, supply containers, and recharge and recovery containers so that none of the halogenated agents escape into the atmosphere.

Horizontal exit A fire-rated wall typically running from one exterior wall to another, used when stairwells in a multistory building (or exterior exits in a one-story building) are too far away for egress purposes. The wall effectively creates two areas of safety on a given floor.

Houseline Class II standpipe system that supplies 100 gpm at 65 psi. Intended for use by building occupants.

Inherent fire resistance Flame resistance that is derived from an essential characteristic of the structural member.

Initiating device A system component that originates transmission of a change-of-state condition, such as in a smoke detector, manual fire alarm box, or supervisory switch.

Listing A compilation of fire-rated assemblies that have been tested by a testing laboratory and found to meet the minimum requirements of the test standard.

Manual-dry standpipe system Dry standpipe system that does not have a permanent water supply attached to the system.

Manual-wet standpipe system Wet standpipe system connected to a small water supply for the purpose of maintaining water within the system or sharing a water supply with an automatic sprinkler system, but not having a water supply capable of delivering the system demand attached to the system.

Noncombustible A material that, in the form in which it is used and under the conditions anticipated, will not aid combustion or add appreciable heat to an ambient fire.

Peened Forcible attachment of a thermocouple to a steel column or beam.

Purge Flow of air or an inert medium at a rate that will effectively remove any gaseous or suspended combustibles and replace them with air.

Remote annunciator Device indicating an off-standard or abnormal condition by both visual and audible signals.

Semiautomatic-dry standpipe system Standpipe system that is attached to a water supply capable of supplying the system demand at all times and that requires activation of a control device to provide water at hose connections.

WRAP-UP

Silence switch When flipped, the fire alarm is silenced but still active.

Smoke barrier A 1-hour fire-rated assembly that has also been designed and tested to minimize the migration of smoke.

Smoke control System that utilizes fans to produce pressure differences so as to manage smoke movement.

Smoke developed In the Steiner tunnel test, a calculation of smoke spread made by measuring the obscuration as the smoke passes a photoelectric cell placed in the stack from the test tunnel.

Stairwell pressurization system System that introduces positive pressure into a stairwell to provide a tenable environment within the stair tower in the event of a building fire.

Standard time–temperature curve The profile of the furnace temperatures that are dictated by the test standards NFPA 251, UL 263, and ASTM E-119.

Standpipe system An arrangement of piping, valves, hose connections, and allied equipment installed in a building or structure, with the hose connections located in such a manner that water can be discharged in streams or spray patterns through attached hose and nozzles, for the purpose of extinguishing a fire, thereby protecting a building or structure and its contents in addition to protecting the occupants.

Steiner tunnel test A common term that refers to NFPA 255, *Standard Method of Test of Surface Burning Characteristics of Building Materials.*

Thermocouple An electrical temperature-measuring device used in laboratory fire testing.

Total flooding Act and manner of discharging an agent for the purpose of achieving a specified minimum agent concentration throughout a compartment.

Water flow switch A switch that detects the movement of water in a sprinkler system and transmits a signal to the alarm system.

Water mist system Distribution system connected to a water supply or water and atomizing media supplies that is equipped with one or more nozzles capable of delivering water mist intended to control, suppress, or extinguish fires and that has been demonstrated to meet the performance requirements of its listing.

Water spray system Special fixed pipe system connected to a reliable fire protection water supply and equipped with water spray nozzles for specific water discharge and distribution over the surface or area to be protected.

Wet chemical system An automatic fire extinguishing system that discharges a wet chemical agent.

Zone Defined area within the protected premises.

Zoned smoke control Smoke control system that includes smoke exhaust for the smoke zone and pressurization for all contiguous smoke control zones.

Case Study

You and your engine company are dispatched to a water flow alarm in a three-story apartment building of lightweight wood-frame construction on a cold winter night. Your prefire plan shows that this building is equipped with an NFPA 13R automatic sprinkler system. Upon arrival, you can hear an electric bell ringing. You are met by a security guard who advises that there is no fire and he is unable to find an activated sprinkler head.

1. Which of the following areas are provided with sprinklers according to NFPA 13R?

A. Small bathrooms
B. Small closets

C. Kitchens
D. Unused attic

2. True or False: Sprinklers will likely be found inside the floor trusses of this building.

3. If the building was built of Type II non-combustible construction and was 8 stories, which standard would have been followed for the installation of a sprinkler system?

A. NFPA 13D
B. NFPA 13
C. ASTM E-119
D. ASTM E-84

4. True or False: The water flow switch in this system will become activated only as the result of a sprinkler activation.

Challenging Questions

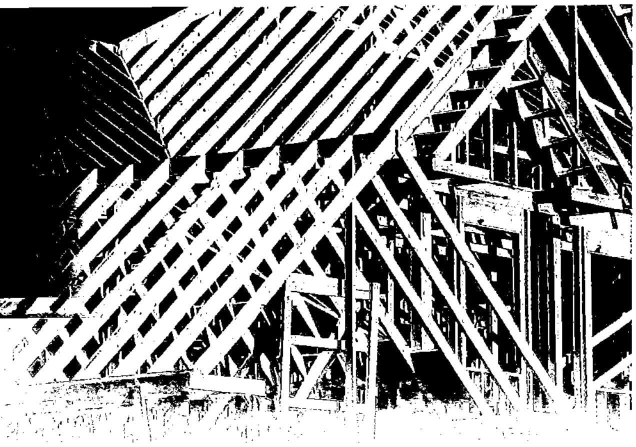
1. Define a smoke barrier and describe how it is useful in a hospital. How does a smoke barrier differ from a horizontal exit?

2. Why is it important to know that fire resistance testing for floor assemblies using the ASTM E-119/UL 263 test standards only test the floors on their underside?

3. During a fire inspection, you note carpeting on the interior walls of a day care center. What should you do to deal with this situation?

4. You are a captain of a truck company in a suburban district. You are made aware that the new covered mall in your area will be equipped with a smoke management system. What should you do to prepare utilization of this system during an actual fire?

CHAPTER 7



Wood-Frame Construction

OBJECTIVES

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

- Understand and correctly use the terminology associated with wood construction.
- Identify and describe six types of wood-frame structures classified as Type V construction.
- Identify and describe the specific fire protection differences between balloon-frame and platform-frame construction.
- Describe the construction of a platform-frame building.
- Understand how a truss is constructed and how it performs from a fire protection perspective.
- Explain the difference between firestopping and draftstopping.
- Describe the behavior of engineered and manufactured wood products under fire attack.
- Describe the different types of sheathing, siding, and roofing materials.

Case Study

Figure 7-1 The Green Bay, Wisconsin, floor collapse, August 2006.

Courtesy of Green Bay Metro Fire Department.

In August 2006, Green Bay, Wisconsin, fire fighters responded to a typical house fire—a house fire like many others that occur across the United States every day (**Figure 7-1**). The two-story, single-family home was built in 1999, using lightweight wood trusses. A fire had erupted in an unfinished area of the basement and then spread into a finished area.

Responding fire fighters, believing a person was trapped, began search operations on the first floor. One team of two fire fighters went to the right, another pair to the left. As the team on the left made its way through a foyer to a bedroom, the lightweight truss floor collapsed, sending the two fire fighters into the basement. Both fire fighters were trapped; one fire fighter, a lieutenant, was killed. A subsequent investigation determined that the floor collapsed over a basement hallway between the finished and unfinished basement areas. The collapsed truss floor was a "heated" floor with embedded heating coils in concrete covered in ceramic tiles, which added weight to the floor along the tiles.

1. How quickly do lightweight wood floor trusses collapse in a typical basement fire?
2. How common are lightweight wood truss floors with built-in heating systems?
3. Would heat from a fire be hidden from a thermal imager in a floor system like this?

Introduction

In the United States and Canada, most fires are fought by fire fighters standing on, in, or under wooden structures. These are some basic facts about **wood**:

- Wood is combustible. As it burns, its structural strength is lost. Unless the fire is checked, at some point gravity will act and a collapse will result.
- Wood construction creates combustible void spaces in which fire can hide, grow, and burst out.
- Wood in thin sections can have a very rapid flame spread.

Definitions

Some basic definitions are necessary for a better understanding of the elements of wood construction. Building terms are often local in origin, and often the construction trades use different words for components than do engineers or laypersons. The term **wood framed** is typical of the imprecise terminology common in the building field. A framed building is usually understood to be a building with a skeleton of beams and columns, in which the walls are just **curtain walls**. (These types of walls are non-load-bearing; they carry no weight other than their own weight and are installed only to keep out the weather. The frame itself carries the entire weight of the structure as well as live loads.) The opposite term is **wall bearing**, indicating a structure where the entire structural load is carried on the walls. The **wooden-walled building**, which is usually referred to as a frame building, is actually a wall-bearing building that carries the load of the structure and contents. As this brief summary suggests, the various types of structures can all be rather confusing.

Wood-Frame Terminology

A variety of terms apply to wood-frame construction. It is important that you know the proper word to describe a particular building component, as in all types of construction. In particular, you should be familiar with these terms:

- **Chamfer**: To cut off the corners of a timber to retard ignition.
- **End matched**: **Lumber** with tongues and grooves at the ends.
- **Engineered wood**: In the construction trade, this typically refers to laminated timbers. In this text, it refers to wood modified from its natural state or lumber combined to make elements.
- **Glued laminated timbers**: Planks glued together to form a solid timber Figure 7-2.
- **Heavy timber**: Lumber that is 8 inches or more in its smallest dimension. (Note: some building code definitions of heavy timber specify smaller dimensions.)
- **Joists**: Floor beams.
- **Legacy construction**: In terms of wood-frame construction, the use of solid wood members as opposed to lightweight wood trusses and wooden I-joists.
- Lumber: Wood that has been sawn and planed.
- **Matched lumber**: Tongue and grooved lumber (usually lengthwise).

Figure 7-2 Glued laminated timbers are used to form large cross sections, longer lengths, curved shapes, or any combination of these.

- **Oriented strand board (OSB)**: Board made of layers of strands of wood cut from logs, with a fairly constant width-to-length ratio. OSB is said to have less expansion from moisture. It is available in sizes larger than 4 by 8 feet (1.2 by 2.4 m). An **oriented flakeboard** is also available.
- **Plywood**: Layers of wood veneer laid in different directions, glued together under pressure.
- **Rough lumber**: Lumber that is left as sawn on all four sides.
- **Splines**: Wooden strips that fit into grooves in two adjacent planks to make a tight floor.
- **Studs**: Columns in frame buildings, usually nominal 2 by 4 inches (2 × 4) or 2 by 6 inches (2 × 6).
- Wood: A hard fibrous material forming the major part of trees. It is usually milled or otherwise processed for use in construction.
- **Wood lath**: Narrow, rough strips of wood nailed to studs. Plaster is spread on wood laths. Rarely used in new construction, wood lath is present in many existing buildings Figure 7-3.

Uses of Wood in Buildings

Wood is used in many ways. Its significance relating to fire varies with its uses—structural, non-load-bearing, or decorative:

- Wood is used structurally to carry the building loads.
- Non-load-bearing uses of wood include wood lath for carrying plaster and wood wainscoting, which is a thin grooved board used for ceilings and wall panels.
- Wood is commonly used for roofs of buildings that may appear to be of noncombustible construction.
- Wood is used for interior trim or within older partition walls of otherwise fire-resistive buildings.

Figure 7-3 Wood lath is found in older types of construction. It can pose a problem for fire fighters as they open up walls and ceilings when checking for fire extension.

© DigitalVues/Alamy Images.

Types of Wood-Frame Buildings

Wood is used to carry the major structural loads in many forms of Type V construction:

- **Log cabin**
- **Post and frame**
- **Balloon frame** (sometimes called eastern framing)
- **Platform frame** (sometimes called western framing)
- **Plank and beam**
- **Truss frame**

Log Cabin

The log cabin was not invented by Daniel Boone or Davy Crockett, but rather came to the East Coast of the United States from Sweden and to the West Coast from Russia. Prefabricated log cabins were sold in Moscow in the 1600s. It was easier for early settlers to use whole trees or slightly dressed lumber for home building than to saw trees into boards. Later, the humble log cabin would be concealed under siding or even brick veneer.

Many older buildings, even multistory buildings, are concealed log cabins. The walls of such a building carry unexpectedly heavy loads and therefore have potential for serious collapse. Know your buildings by investigating them, especially those that appear to have been masked by a veneer or another wall structure.

Log cabins are coming back into fashion. A number of companies offer dressed logs and sometimes these are prepared for assembly. The interior surfaces of many of these cabins are usually wood, often either boards or plywood, which would increase the intensity of a fire, as contrasted to the typical residential gypsum board interior. Fire departments in areas where such buildings exist should be aware of this hazard Figure 7-4.

Figure 7-4 A typical log cabin.

© Fanfo/ShutterStock, Inc.

Post and Frame

Post and frame construction came to America from England, Germany, and France. Such a building has an identifiable frame or skeleton of timber fitted together. Joints are constructed by **mortise and tenon** (socket and tongue), fitted together to transfer loads properly Figure 7-5. They are pinned with wooden pegs called **trunnels** (a New England term for a tree nail).

Post and frame buildings are the ancestors of the high-rise because they are framed, not wall-bearing, buildings. In other words, the walls are not structural or load bearing. Original post and frame buildings are part of our heritage, and every effort should be made to preserve them. Recently, new post and frame buildings have been constructed as homes and commercial buildings. Like log cabins, the interior finish often consists of wood. Many new post and frame buildings are enclosed with foam core panels. Foam core roofs present the possibility of failure.

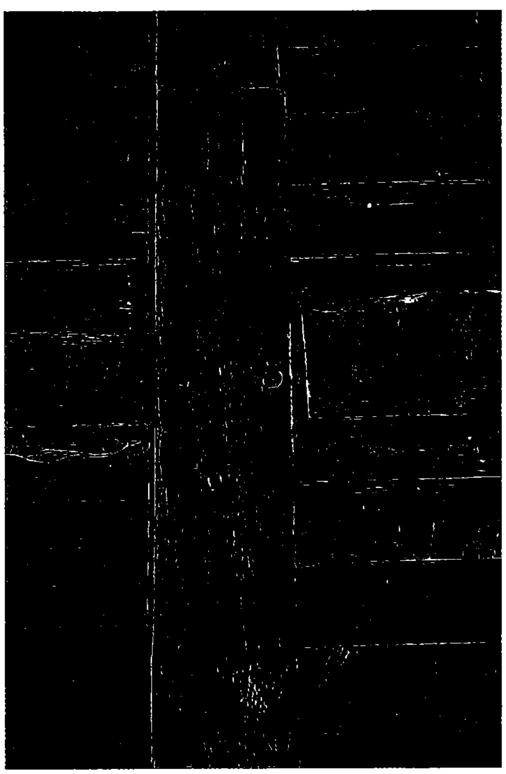


Figure 7-5 This mortise and tenon joint between a post and beam is beginning to come apart in this 100-year-old barn.

Deceptive Imitation Post and Frame

In the 1920s, many balloon-frame houses were built with the exterior finished to resemble post and frame construction. They were called **English Tudor** style homes Figure 7-6. Recently, this style has had a renaissance. Buildings of several other types of construction also have been decorated to resemble the post and frame style. Some ordinary brick wall-bearing buildings have been dressed up to give the appearance of post and frame. In one case, the fake post and frame trim was removed two decades later to modernize the building. At Walt Disney World and other amusement parks, buildings of steel construction are decorated to have a post and frame appearance.

Balloon Frame

Balloon-frame construction started in 1833. Augustine Taylor, a Chicago carpenter erecting St. Mary's Church at Fort Dearborn, is credited with hitting

Figure 7-6 An English Tudor style home.

upon the idea of fabricating a wall of ordinary studs and nailing it together rather than using a post and frame assembly method. Inexpensive machine-made nails had become available by that time, which made it possible to erect the entire wall at once without the skilled labor necessary to do the cutting and framing required for post and frame construction. This type of construction was derided by many, who said it was so light that it was like a balloon. Unfortunately, as will be seen, it can be compared to a balloon in another way. Balloon-frame construction became an almost universal construction method for multistory wooden buildings until the middle of the 1900s.

In a balloon-frame building, the studs run two or more stories high from the foundation to the eave line Figure 7-7. At the floor line, a horizontal board called a ribbon board is nailed to the studs. The joists rest on the ribbon board. The channels between the studs may be open from the cellar to the attic, and joist channels (space between the joists) are open to the stud channels. Thus, fire can spread through all the interconnected spaces from cellar to attic and across the ceiling. Present-day methods may use firestopping (discussed later in this chapter), but earlier construction methods, when many of these buildings were built, did not.

The interconnected voids can be considered to be one big balloon. This effect was once observed at a fire in an old balloon-frame house, where there was a heavy fire in the porch ceiling. Each time it was hit with a fog stream, the fire ballooned out at the rear of the building.

When balloon-frame buildings are remodeled, firestopping may or may not be installed. Installing firestopping in an old building is very costly. In one case, a historic balloon-frame college building was fully rehabilitated. Even though sprinklers were installed, fire could have raced through the voids if they were not firestopped. The final cost of the renovation was about two-thirds of the cost of a new building.

Until recently, it was reasonable to assume that any wooden building built before 1940 and more than one-story high was probably of

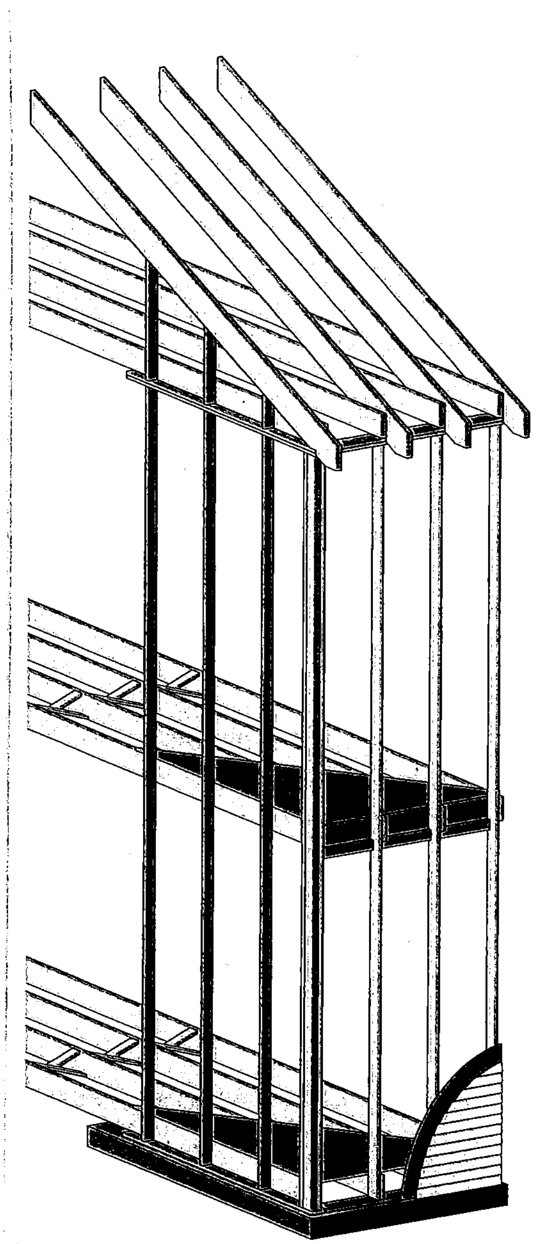


Figure 7-7 An illustration of a balloon-frame house; note the continuous studs that run from the basement to the attic, allowing a basement fire to rapidly extend.

balloon-frame construction. Later buildings used platform-frame construction. Recently, however, the Victorian-style construction has come back into favor, and expensive multistory platform-frame suburban homes are being built to look like 100-year-old farmhouses.

Some construction texts recommend balloon-frame construction as superior to platform frame for masonry-veneer houses (see the discussion of brick veneer later in this chapter). Shrinkage of the wooden building, however, could damage the brick veneer. The smaller vertical shrinkage potential associated with a balloon-framed structure contrasts with the greater horizontal shrinkage potential of platform-frame construction.

Some years ago, two six-story brick veneer apartment houses were built in an Ohio suburb using balloon-frame construction. Studs were spliced to achieve the required height. The apartment houses had many deficiencies and presented a major fire hazard. The fire chief fought successfully to have them torn down before they were ever occupied.

Fires in Balloon-Frame Buildings

The fire hazards found in balloon-frame buildings are well known. As an example, a chief officer, who was a student of Frank Brannigan in a fire science course, described a fire that the first-due company reported as "outside rubbish." The officer ordered some of the siding removed and found fire in the walls. Shortly thereafter, another officer reported that an upstairs bedroom on the opposite side of the house was untenable, even though no fire was showing. The fire had quickly crossed over through the joist channels and had literally surrounded the bedroom. A good fight saved the building, but the damage was extensive.

Another California fire demonstrated that sometimes even sprinklers cannot protect balloon-frame structures. An incendiary trash fire, which started against an exterior wall of a Victorian building, penetrated into void spaces. Responding fire fighters checked for extension but found nothing. Fire broke out 4 hours later. Much structural damage occurred before the sprinklers activated on the fire that broke out from the voids.

Plumbers (or amateur plumbers) are often the culprits for starting fires in the walls of balloon-frame buildings. Whether a plumbing torch was used to braze a copper tube or to thaw out a pipe, many a balloon-frame building (and even non-balloon-frame buildings) has succumbed to these sources of ignition.

The basement of a balloon-frame building is usually the worst place for a fire to start. It has unimpeded access to the entire structure through the unfirestopped walls. The fire will move quickly up to the top of the structure and into the attic (Figure 7-8). It is critical that fire fighters anticipate this spread, sending both truck companies and engine companies with hose lines to each of the upper floors and opening up walls to hit the spreading fire. It is also critical to get the attic/roof opened up because the fire will quickly emerge in that area. Consider designating an "extension sector" and assigning a fire officer to observe the building on all sides, watching for signs of fire spread such as blistered paint, smoke from the eaves, a sudden increase in the volume of smoke, and so on, below the operating forces or other signs that the building "built to burn" is succeeding and it is time to evacuate.

The use of **vermiculite** inside wall stud channels of a balloon-frame home, perhaps for insulation, was observed in one fire incident. The sand-like material acted as a firestop, slowing down a significant fire that had erupted in an overstuffed basement.

Platform Frame

In platform-frame construction, the first floor is built as a platform (Figure 7-9). This means the **subflooring** is laid on the joists, and the frame for the first-floor walls is erected on the first floor. The second-story joists are then placed, the second-story subfloor is laid, and the second-floor walls are erected on the second-story subfloor. The third floor, if any, is built in the same way. Three stories are typically the limit for platform-frame construction.

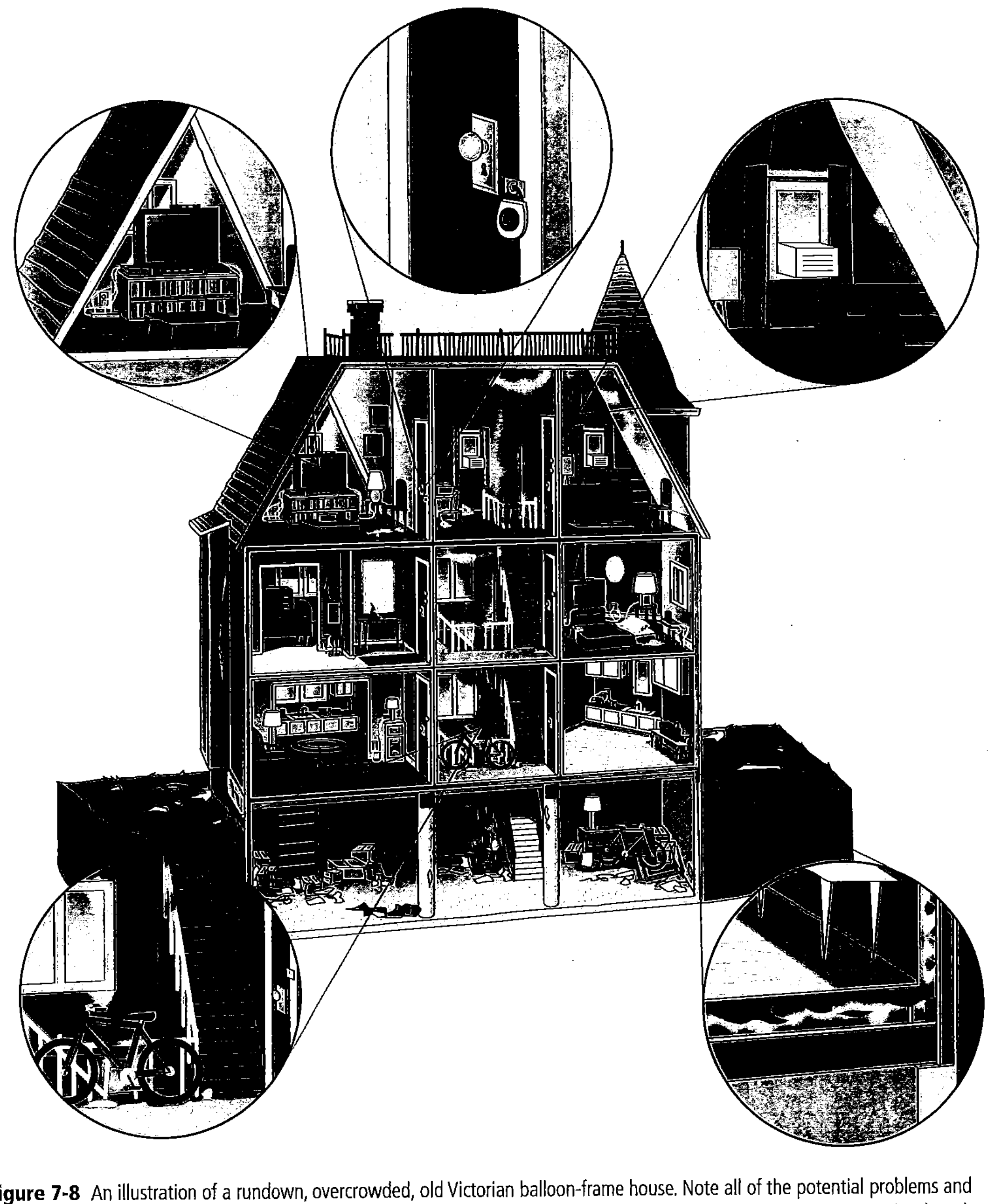


Figure 7-8 An illustration of a rundown, overcrowded, old Victorian balloon-frame house. Note all of the potential problems and danger signs that may be found in such buildings. These problems include easy upward fire spread from basement to attic when doors are open, blocked and broken interior stairs, window air conditioning units blocking access, as well as individual locks on interior doors, and very importantly, unimpeded fire spread from the basement to the attic through the exterior wall void space.

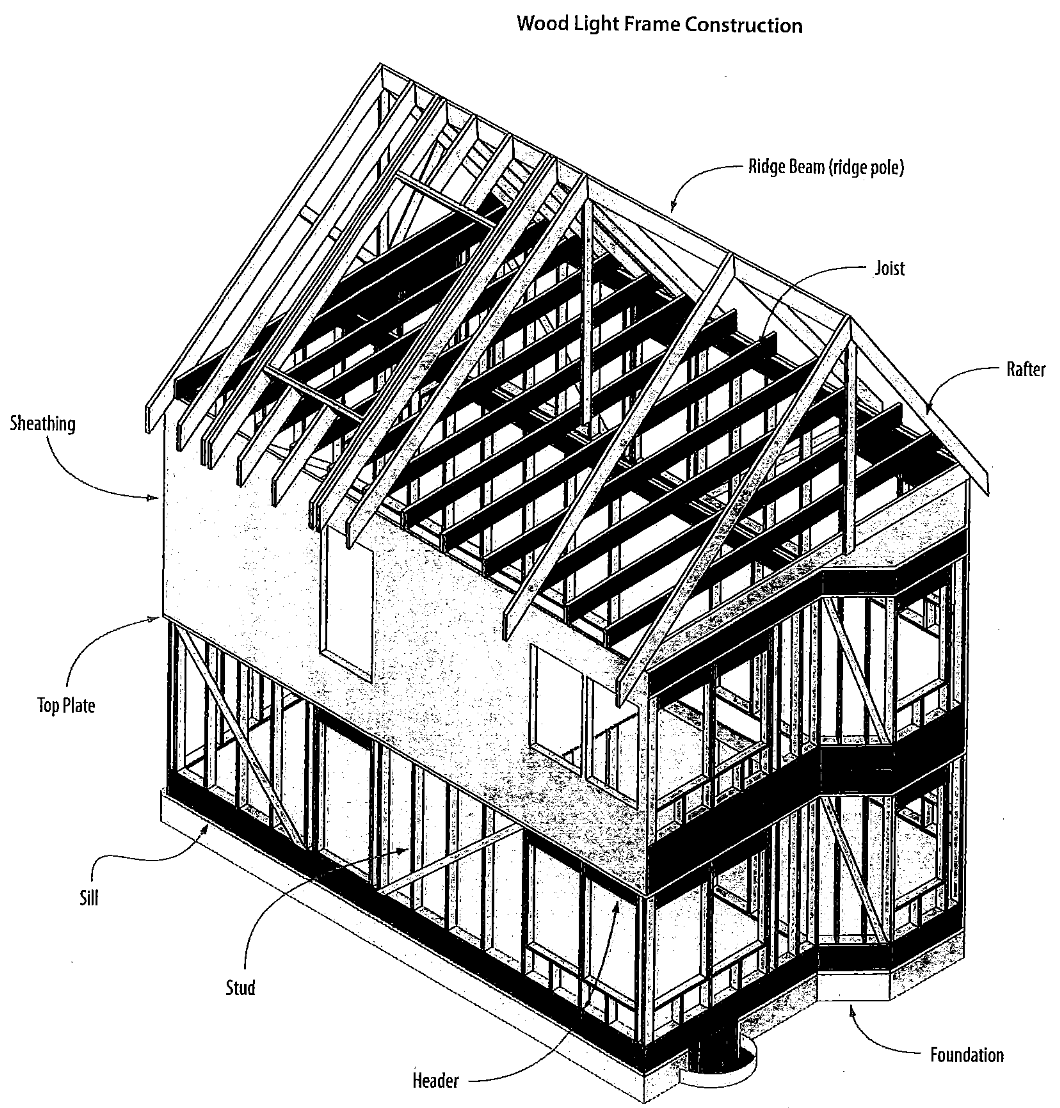


Figure 7-9 An illustration of a platform-frame house.

In a balloon-frame building, there is structural continuity from top to bottom. In contrast, in the platform-frame building, there is no continuity from top to bottom. If construction methods are as described, there are inherent barriers (the load-bearing and non-load-bearing partition walls throughout the building) to limit the spread of fire through the walls. There is a good possibility of confining a fire to one portion of the structure, even if the fire gains access to a concealed space.

However, there is one common vertical means of fire spread in both balloon-frame and platform-frame buildings: the open stairwell. In single-family homes, this is the quickest way for smoke and heat to rise to the top of the home. It is essential that this vertical "chimney" be protected by a hose line, both to prevent extension and to provide a means of egress.

Another common construction feature provides bypass for fire, and from a fire protection point view, converts a platform-frame building into a balloon-frame building. **Soffits** (false spaces above built-in cabinets, usually in a kitchen or in the undersides of stairways and projecting eaves) provide a connection, generally without a firestop, between wall and joist spaces. Furthermore, only a thin sheet of wood or composition board makes up the top of the built-in kitchen cabinets. A kitchen fire that extends into such a cabinet will enter the soffit space quickly. Fire can then extend to the joist spaces in a multistory building or to the attic spaces in a one-story building. Such soffits are often built back to back in multiple-family dwellings so that fire may extend immediately to the adjacent occupancy. Interconnection of the soffit void with pipe openings may cause fire to spread vertically throughout the building.

Constructing a Platform-Frame Building

Once a foundation and basement have been built, the **rough carpentry** of the platform frame may begin. The first-floor **sill** (usually rot and insect decay resistant) is laid on the foundation wall. The floor joists follow, usually spaced 16 or 24 inches (41 or 61 cm) on center (oc). Subflooring, in the form of plywood or OSB, is laid on top of the joists.

Bridging (or cross-bracing) is placed between the joists to keep them erect and to help share the loading placed on the floor. Floor openings are created for stairwells and the like through the use of **headers** (along the end of the opening) and **trimmers** (along the length of the opening). Essentially, the floor joists are cut short to create the opening, and the headers and trimmers are attached to the joists to carry the load around the opening.

The wood walls, consisting of studs spaced 16 inches oc with a **bottom plate** and a set of **top plates**, are next constructed on the floor itself. Once one wall has been completed, it is tilted up into place and temporarily braced to hold it in place. The other walls are then constructed, one at a time, and tilted up into place. Once all of the walls have been erected and tied together, the bracing is removed, and sheathing panels (sometimes insulating) are placed over the studs. A successive floor is built on these walls, and the process is replicated.

The top set of walls receives the roof framing. Consisting of **rafters** and a **ridge board** (sometimes called a ridge pole), the pitched frame forms a peaked roof. (Truss roofs, described later in this chapter, are an exception to this description.) **Hips** and **valleys** give the roof a variety of sloped shapes, usually for aesthetic purposes.

Stairways between floors are framed using **stringers**, placed on both sides of the steps. Stringers support the risers (vertical stair components between treads) and treads (horizontal stair components on which people place their feet). The taller the riser and smaller the tread, the steeper the set of stairs.

Plank and Beam

Architects and interior designers, looking for more attractive, economical, or at least different construction methods, have adapted industrial plank and beam construction techniques to residential, assembly, and commercial structures Figure 7-10. Instead of using multiple floor beams placed 16 inches (41 cm) apart, heavier beams are used and are spaced much farther apart. Instead of thin, rough subflooring or plywood, thick, finished tongue and groove

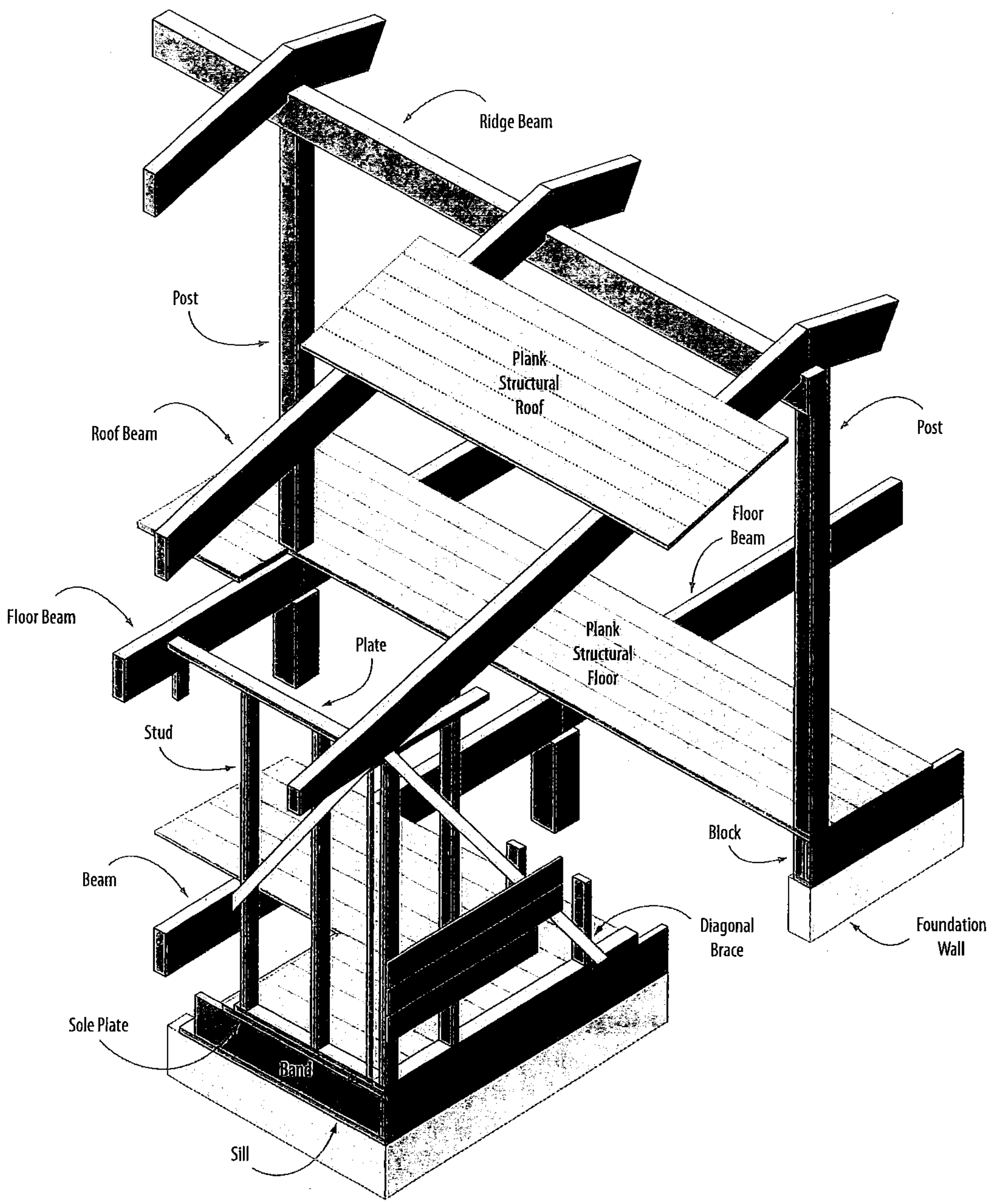


Figure 7-10 A plank and beam building.

planks are used. The planks are thick enough to span the wider gap between the beams without deflecting. The finished plank surface is the ceiling.

From a firefighting point of view, this type of construction has the positive benefit of reducing the volume of concealed space in which fire can burn shielded from hose streams. The interior finishes used, however, often have high flame spread and smoke-developing characteristics. Surface damage may be serious, even in an easily controlled fire in which collapse or hidden fire are not factors.

In some residences, to provide an open effect, partitions are only head high, except in bedrooms and bathrooms. This increases the life hazard for nighttime fires because the kitchen, dining, living, and family rooms are essentially a single open area in which fire can easily build up.

Many churches and similar buildings with high ʼn spaces are built of rigid laminated wood .nes or arches and heavy plank roofs. Any fire that reaches the surface of the wood will spread rapidly and develop into a huge volume of fire. Any intermediate structure, such as a sacristy or robing room, should be sprinklered or of built of noncombustible construction because of their particular hazard. Eliminating the intermediate fire load greatly reduces the potential for ignition of the roof.

Lightweight Trusses and Other Wooden Members

The current practice of designing buildings of lighter and lighter materials and substituting geometry for mass has led to significant strides in the architectural field. It has also created significant problems in the field of firefighting. Although we will also discuss trusses in the context of other types of construction (including lightweight wood trusses in ordinary construction, described in the chapter that discusses heavy timber construction), it is important that we have a conceptual understanding of the deadly problems that trusses (and other lightweight members) present in wood-frame construction.

Knowledge of the hazard of trusses has developed gradually in the fire service. In 1948, Frank Brannigan wrote the first article to appear in the fire service press on the then new concept of prefire planning. The article described a Navy drill hall that was converted into a warehouse. The pictures clearly show 100-foot timber trusses, but the preplan does not mention them as a hazard. Any fire department preplanning such a structure today would give serious attention to such trusses.

When the first settlers arrived in this country, huge virgin forests yielded inexpensive wooden beams and columns. Structures were massively built of wood and masonry, without regard to their weight. Times have changed, however, and today the emphasis is on lighter-weight structures. For example, lightweight gypsum panels are advertised as suitable replacements for heavier masonry shaft enclosures. The steel industry seeks lighter fireproofing for steel to replace the concrete that was once commonly used.

The weight of materials and the weight of the structure required to support heavy materials are now important cost considerations. Suppliers of materials lighter than those previously used proudly brag about weight savings. For example, the Empire State Building weighs 23 pounds (10 kg) per cubic foot, whereas modern high-rises weigh as little as 8 pounds (3.6 kg) per cubic foot.

The largest practical open areas and the maximum amount of offsite prefabrication are other important considerations in today's construction. Many of the techniques for making buildings lighter and providing large open areas without columns have been available for centuries (Figure 7-11). The hammerbeam truss, for instance, used in churches and other monumental Gothic structures, was invented in the 1200s and used for Westminster Hall (not Westminster Abbey), which still stands in London. In recent years, increased material and labor costs have forced builders to maximize the use of more economical construction techniques.

Figure 7-11 The medieval church of San Miniato al Monte relies on wooden trusses to support the roof.

Trusses are most often used as beams, but there are many trussed columns, especially in huge buildings and special-purpose structures, such as high-energy transmission lines and tall radio towers.

The truss satisfies many building requirements:

- It is lighter in weight than solid construction, thus reducing the weight of supporting walls or columns.
- It provides long clear spans, thus giving maximum flexibility in the use of space.
- Many trusses, such as lightweight wood trusses and steel bar joists, can be delivered prefabricated. Huge steel trusses can be delivered partially prefabricated, with the final connections made in the field.

Lightweight Wood Trusses

The lightweight wood truss has been in general use since the 1960s; one of the first articles on the firefighting implications of this type of construction was written by Frank Brannigan in 1971. Composed of 2- by 4-inch (51 by 102 mm) pieces of wood, the lightweight wood truss is pieced together on a factory table and subsequently joined together with light-gauge galvanized steel gusset plates (also known as "gang nails") Figure 7-12. These plates contain a series of small 3/8" (9.5 mm) "teeth" that are pressed into the wood surface; it is these small teeth that hold the whole truss together.

Figure 7-12 The remains of a lightweight wood floor truss in a wood frame apartment building. An accidental fire involving a spilled flammable liquid ignited inside the void space of this truss, ultimately leading to the involvement and collapse of the second floor, the third floor, and the roof.

Courtesy of Glenn Corbett.

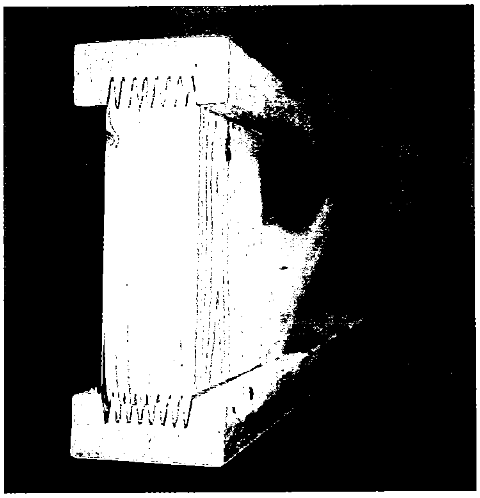


Figure 7-13 A finger joint in a lightweight wood truss.

Courtesy of American Wood Council, Leesburg, VA.

Another type of lightweight wood truss uses a **finger joint** and adhesive to join the wood truss together (Figure 7-13). The fingers at the end of the pieces of wood forming the web of the truss are fit into slits in the top and bottom chords of the truss, using phenol and resorcinol formaldehydes as an adhesive. In this case, it is friction and glue that hold the truss together. Some open-web trusses with finger joints manufactured in Oregon between 1974 and 1980 reportedly came apart at the joint in normal use.

Dangers of Lightweight Wood Truss Floors

Lightweight wood truss floors are a known hazard to fire fighters. They are built of a small cross section of wood, with the high surface-to-mass ratio characteristic of kindling. Metal gusset plates dig into the wood approximately 3/8" (9.5 mm). Heating of the gusset plate will decompose tensioned wood fibers holding the teeth. Not only is there the hazard of early collapse, but the void is also a reservoir for ›losive carbon monoxide (CO) gas waiting for a fire fighter to pull the ceiling. Firefighting tactics based on sawn joist floors will kill fire fighters if used on buildings with truss floors.

The truss floor building ordinarily gives no outward indication of its presence. The only solution is for the fire department to preplan, record, and retrieve the construction information on the fireground. During a fire, the presence of truss floors may be disclosed by smoke or fire pushing through the wall at the floor line (this is less likely in a brick veneered building). The exterior sheathing plays a critical role in whether this effect is visible.

Branniganism

Fire fighters do not belong on or under burning trusses. Nobody can predict when failure will occur. Gravity acts the moment the GRS (gravity resistance system) is not adequate by as little as one molecule.

Bolt: © iadams/Shutterstock, Inc.; Texture: © Ely Studio/Shutterstock, Inc; Steel: © Shapshot/Dreamstime.com

Dangers of Lightweight Wood Truss Roofs

Wood truss roofs are just as hazardous to fire fighters as lightweight truss floors. In addition to the likelihood of collapse under fire conditions, they present another hazard: they lack the ridge pole that is present in a legacy construction, meaning that the fire department's roof ladder hooks will hang on the roof deck sheathing (such as plywood) rather than a beam. During construction, the roof trusses must be temporarily held erect by the use of wood slats to tie them together; it is the roof itself that holds the roof trusses upright (Figure 7-14). Be wary of exposed lightweight wood roof trusses in a windstorm—many of them have fallen over like dominoes at construction sites.

A lightweight wood truss roof involved in fire is a very deadly place to be. Any attempt at ventilation must be performed using an aerial device such as a tower ladder. Expect the collapse of lightweight wood truss roofs when they are involved in fire.

Figure 7-14 A lightweight wood truss roof under construction.

The Truss Void Itself

The wood truss floor introduces a catastrophic new dimension into fire suppression in combustible buildings—a **truss void** or trussloft. The hazards of the cockloft or void between the top-floor ceiling and roof, which is not high enough to be called an attic, have long been familiar. This floor–ceiling truss void can properly be called a trussloft.

All comparative strength controversy aside, the joisted floor found in legacy construction has one tremendous advantage over the truss: each joist acts as a fire stop. The area of the void is limited. The truss void, in contrast, represents a large area in which explosive CO can accumulate. The use of trusses provides a huge increase in the volume of concealed voids in the structure. Voids are almost invariably interconnected horizontally and vertically by utility pathways. The generation and accumulation of CO in void spaces is not as well recognized by the fire service as it should be. It is both toxic and explosive. The hazard of hidden fire is as important to the fire service as collapse.

The National Fire Protection Association's (NFPA) *Fire Protection Handbook* provides good information on CO. A rule of thumb is that any exposure in which the product of concentration (in parts per million [ppm]) × duration (minutes) = 33,000 is likely to be dangerous. A 10-minute exposure to 3,500 ppm of CO would be hazardous and possibly incapacitating. Higher ppm values are even more dangerous—12,500 ppm can be fatal after a few breaths. The potential for loss of life or incapacitation of occupants from CO generated by a fire in the void even before the alarm is sounded cannot be dismissed. The flammability range of CO is from 12.5–74%; its ignition temperature is 1,128°F (609°C). When an ideal mixture of CO in air is present, a detonation can result that is sufficient to blow a building apart. Generally, a deflagration—a huge sudden burst of flame—appears.

Catastrophe Potential

A most serious threat to life safety by lateral extension exists when the trusses are extended out, either as cantilevers or as continuous beams, to support the balcony that is the only exit for occupants and the only access point for the fire department. Where the truss passes over the exterior wall, firestopping or draftstopping in the form of a sheet of gypsum board is "buttered into place" with cement. This "firestopping" is penetrated for the lighting circuits of the balcony. In any event, the use of such an unreliable barrier to the extension of fire from the void is inexcusable. In some cases, the ceiling of such a balcony is plywood, permitting early access to the void for fire originating on the balcony or coming out the window.

It is a credible scenario that the stairway exit can be involved in fire and collapse before the occupants have escaped. In many suburban areas, a typical response might consist of two engine companies and a truck, each with three or four fire fighters. It is impossible for this response to remove, via ground ladders, all the occupants of a three- or four-story truss-floored multiple-unit dwelling. Even with a greater response, it is unlikely that all the occupants could be located and removed before interior collapse forced withdrawal. The potential for a disaster should force a code requirement that the exit facilities be totally separated from the truss void.

Automatic Sprinklers and Truss Voids

Some truss-floored multiple-unit dwellings have been protected with residential sprinkler systems, meeting the requirements of NFPA 13R, *Standard for the Installation of Sprinkler Systems in Low-Rise Residential Occupancies*. The purpose of these systems is to prevent flashover, save lives, and permit the occupants to escape. There have been a significant number of successful operations. However, these are partial systems and should not be expected to provide the fire suppression or control that full sprinkler systems have provided. The sprinkler systems cover selected portions of occupied spaces. It is very likely that the sprinkler system will control any fire originating in the protected areas of an apartment. However, if the fire originates in or penetrates the void, the sprinklers will not be in a position to control the fire.

A fire in a relatively new, NFPA 13R–protected, three-story wood-frame condominium in New Jersey began on a top-floor unsprinklered balcony in a plastic bucket for discarded cigarettes. The fire spread from the bucket, up the wood balcony walls, and into the eave overhang. The unsprinklered attic ignited, and fire traveled across the entire top of the building, unimpeded due to the lack of required draftstopping. The top floor was destroyed, and water severely damaged the lower floors.

In an older 13R-sprinklered, combustible dwelling in Texas, the floor trusses were **cantilevered** out to form the exit balcony. The balcony was one entire nonfirestopped void. The firestopping at the front wall included pieces of gypsum board buttered into place with cement. Very likely it was penetrated in one or more places. A failure of one of these barriers would admit fire to the entire balcony truss void. It is not hard to envision a serious loss of life in such a structure. Unfortunately, this outcome might misguidedly deal a fatal blow to the concept of residential sprinkler protection.

In DeKalb County, Georgia, fire resulting from a plumber's propane torch developed in the truss void of an almost completed three-story apartment house. There was no contents load. The sprinkler system was operational, but the sprinklers did not fuse. A fire fighter fell through the second floor into the fire when the truss collapsed. Fortunately, his partner used a hose line that protected him from the fire until he could be rescued.

Lightweight Wooden I-Beams

The wooden beam sawn out of a tree trunk is inefficient in terms of weight and cost. Recently, the legacy construction **sawn beam** has been replaced by wooden I-beams (composite wood joists).

Look at the end of a steel I-beam. The steel is extruded through a die, so the designer can choose the most efficient shape. Both the top flange and the bottom flange are wide to cope with compressive and tensile loads. The web, which separates the top from the bottom, is thin, just sufficient to keep the top and bottom apart. The newer I-shaped beams use 2- by 4-inch boards for the upper and lower flanges and OSB for the web; in the past, these wood I-joists used plywood webs. The present-day versions are glued together using phenol and resorcinol formaldehydes, and manufactured in lengths up to 60 feet (18.3 m).

Unlike the case with the sawn beam of legacy construction, the "fat" or surplus (structurally unnecessary wood along the sides) is no longer present in these lightweight wood I-beams. A sawn wooden beam can be thought of as "containing" an I-beam with "surplus" wood along the sides. The surplus wood is what makes it possible for fire fighters to stand and operate on a burning structure. This "fat" has been the basis of interior firefighting tactics. As long as only the "fat" or surplus wood is burning, a fire fighter is relatively safe. Until it burns away, the beam is structurally sound. The gradual sagging of sawn beams due to the loss of the exterior wood often gives warning of impending collapse.

The web of the I-beam is often penetrated by utilities, and in some cases sizable holes are cut into it so that any fire gets a grip on both sides of the I-beams at the same time, guaranteeing early failures. Often, cut-off ends of I-beams are used as "firestopping." Be alert to this possibility. A Fairfax County, Virginia, fire fighter went through a wooden I-beam floor. The house was under construction, and the floor was the only fuel for the fire. In another case, a residence in Clayton County, Georgia, suffered a severe loss when wooden I-beam floors collapsed.

Recent tests of wood I-beams, as discussed in the chapter that reviews the features of fire protection, have shown failure in just over 6 minutes in a simulated basement fire at Underwriters Laboratories, Inc. (UL). In an actual 2009 fire in Clark County, Nevada, a very small fire involving a pile of textiles in a commercial building led to near-complete destruction of several wood I-beams above the fire. Despite the fact that there was no direct flame impingement on the beams, the convection heat was sufficient to destroy the joist webs and compromise their points of support.

Wood I-joists, along with lightweight wood trusses, can be considered the most dangerous of all structural members to fire fighters today; their proliferation ensures that all fire fighters across the United States will encounter them in an actual fire. They fail incredibly fast, often soon after the arrival of fire fighters on the scene. All fire fighters, including incident commanders and company officers, must be extremely vigilant and wary when it comes to them—it is critical that the location and extent of a fire be firmly established and that the potential for collapse be assessed. Given the fire service's long list of supreme sacrifices due to buildings using these lightweight structural members, the decision to "write the building off" should be at the top of the incident commanders' strategic alternatives.

Truss Frame

The U.S. Forest Products Laboratory has developed a method of construction called truss-framed construction. This is different from conventional construction in which truss roofs, and perhaps truss floors, are substituted for sawn beams. However, the structure is still held together by nails **Figure 7-15**.

Truss frame is engineered construction in which the roof and floor trusses and studs are tied into a unitized frame. The studs are an integral part of both the roof and floor trusses. There must be meticulous attention to detail in the manufacture and erection of these structures. A chief advantage of this type of construction is speed. It is sufficient to note here, however, that the small-dimension lumber (two by fours or less) will burn faster than larger solid lumber. In addition, unsupported spans in trussed structures are subject to total collapse, and the loss of a stud due to fire could precipitate the collapse of the integral roof or floor truss. The floor truss void (trussloft) in which hidden fire can spread provides a hazard to fire fighters that affects firefighting tactics. From the firefighting point of view, these are truly disposable buildings.

Truss-frame structures are plane structural components. Their design assumes that every truss member will remain in its assigned position under load. Permanent bracing must provide adequate support to hold every truss in its design position and to resist lateral forces.

Firestopping and Draftstopping

One of the major problems of combustible construction is fire spread through hidden voids. Firestopping is often required by code to be installed to prevent the spread of fire. To the best of the authors' knowledge, there are no tested standards for wood firestopping or draftstopping.

There is a difference between firestopping and draftstopping. Firestopping and draftstopping limit the spread of fire by preventing the movement of flame, hot gases, and smoke to other areas of the building. Firestops typically limit *vertical movement* through relatively small, concealed passages such as under stairs and inside walls. Firestopping material may consist of at least 2-inch (51 mm) nominal lumber, two thicknesses of 1-inch (25 mm) nominal

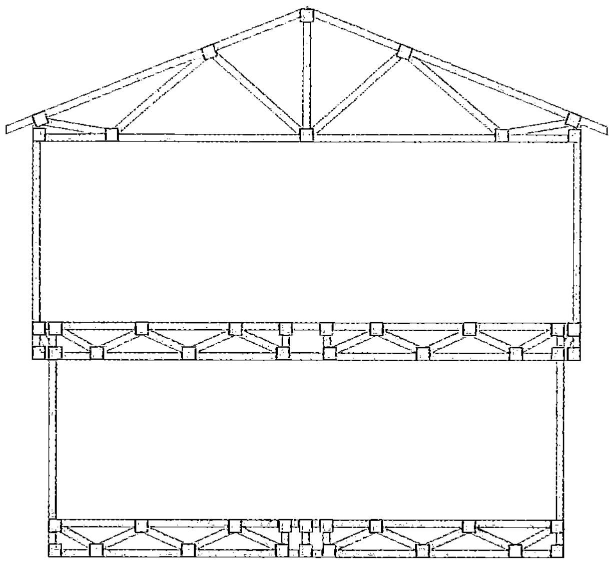


Figure 7-15 Note the points of connection in this sketch of a two-story truss-frame house.

lumber with broken up lap joints, or 23/32" (18 mm) plywood or other approved materials.

Draftstops, in contrast, limit *horizontal movement* through large concealed passages such as open-web floor trusses or attics. Draftstopping may consist of at least 1/2-inch (13 mm) gypsum board, 3/8-inch (9.5 mm) plywood, sheet metal, or other approved materials, usually applied parallel to the main framing members.

A lack of draftstopping or compromised draftstopping in the attic of multiple-unit dwellings has led to their destruction. For you to have a chance at stopping a fire in an attic, the draftstopping must be properly installed and maintained. Proper draftstopping allows you to get ahead of the fire by opening up ceilings adjacent to the involved area and "surrounding" the fire.

Types of Firestopping

This text defines two types of firestopping. *Inherent* *'topping* comes as a result of the normal building construction. This kind of firestopping is incidental to necessary structural purposes. An example is the floor-to-wall seal when a masonry panel wall is built directly on a concrete floor. It is reasonable to assume that such inherent firestopping is in place and effective.

Another type of firestopping, which we call *legal firestopping*, is installed with no other purpose than to meet the requirements of a code. Such firestopping may provide a barrier to the spread of fire in the interior voids of the building. However, this type of firestopping is often ineffective, and questions regarding legal firestopping may always remain: Was the firestopping properly and completely installed? Was the building inspector competent and vigilant? Was it tampered with penetrations after installation?

All firestopping must be in place to be effective. The lack of firestopping in one stud channel (the space formed by the sides of two studs and the exterior and interior walls) is sufficient to transmit fire all the way from the cellar to the attic. In older houses, both the exterior sheathing and the lathing on the interior walls are made of wood, so all four sides of the chimney-like stud channels are combustible.

Lack of firestopping is particularly critical in balloon-frame buildings. It is important to note that firestopping was unheard of by many builders when many of these structures were being built more than 60 years ago.

If the temperature rises and the volume remains the same, the pressure rises. Building owners do not know that leaving an "inconsequential" opening in the firestopping will, in effect, create a nozzle. Nor do they realize that if firestopping is not perfect, it might as well be omitted.

Wood firestopping is often made from the cut-off ends of joists. Unbelievably, the cut-off ends of wooden I-beams have been used as firestopping. There is, of course, no seal because the wood "cut out" to make an I-beam creates a space.

There are those who believe building practices are different on the West and East coasts. Regarding firestopping, however, the authors have observed uniformly unsatisfactory practices. Recent firestopping or draftstopping practices consist of a sheet of gypsum board "buttered" into place, or a piece of thin plywood or flake board poorly fitted (and often penetrated by utilities and wiring). These techniques are about as effective as a posted notice forbidding fire to pass.

Firestopping, once installed, often is removed or penetrated for the installation of such items as heat ducts, electrical cables, sprinkler systems, and central vacuum cleaner systems. In one case, it was removed to install the fire main requested by the fire department and was not replaced. Because the firestopping is often not necessary to an installer making an improvement or fixing an existing item, it is unlikely that it will be replaced.

Trusses create a new hazard, creating a truss void or trussloft in each floor and in the attic. When this hazard is discussed, truss proponents sometimes argue that firestopping will mitigate the problem. If draftstopping or firestopping is installed by someone who understands that its purpose is to stop a gas under pressure, and not to satisfy an inspector, it may limit the spread of fire. Note, however, that even if the draftstopping installed around the perimeter of the affected space is successful, this will not prevent the collapse of the affected area—at least 500 square feet in a single-family residential building and 1,000 square feet in other buildings. This is a large enough area to develop a severe backdraft explosion or to provide a significant collapse. In multiple-unit dwellings, the recommended location for firestopping is along the tenant separations so that the entire floor–ceiling area, above and/or below the unit on fire, is a collapse area.

Protecting Wood from Ignition

It is sobering to realize that most fires are fought by fire fighters standing on, in, or under a combustible structure. Eliminating this basic undesirable combustibility characteristic of wood as a building material has long been a goal of those interested in fire protection. Early fire prevention books extolled the virtues of whitewash in fireproofing wood. In the early 1800s, ads for products like "Blake's Patent Fireproof Paint" were common.

Attempts to protect wood by encasing it in cement-like products were found to be dangerous because the wood, not being exposed to the air, tends to decay. In a San Antonio, Texas, building, one of the authors saw wood columns that had been "fireproofed" with sheet metal cladding. Serious wood decay can occur unobserved with this practice.

Impregnation

Wood cannot be made fireproof or noncombustible. It can be made fire retardant by impregnation with mineral salts, which slow its rate of burning. Some codes accept impregnated wood use in noncombustible spaces. Impregnation is accomplished by placing the wood in a vacuum chamber, drawing out moisture from its cells, and forcing mineral salts into the wood. Sometimes the wood is pricked to increase penetration. Mineral salts do not penetrate deeply, and the removal of surface wood may destroy fire retardant treatment. Such wood is sometimes called pressure treated, but should not be confused with wood that has been pressure treated to resist decay.

Pressure treatment can significantly reduce wood's flame spread, as measured in the American Society for Testing and Materials (ASTM) E84 Steiner tunnel test. UL subjects pressure-treated wood to a test for 30 minutes rather than the usual 10 minutes. Pressure treatment can significantly reduce the hazard of wood construction. Given enough exposure to fire, treated wood will burn, although at a slower rate.

UL provides various classifications of treated lumber. For detailed information consult "Lumber, Treated (BPW)" in the latest issue of the *UL Building Materials Directory*. Such wood often is called fire retardant treated (FRT) wood.

Some chemicals previously used to impregnate the wood have leached out and corroded metal connectors. Some advertising literature for impregnated wood claims materials now used are noncorrosive.

Some years ago, to avoid parapetting fire walls through the roof, builders adopted a practice of placing FRT plywood, one sheet wide, on both sides of a firewall that did not penetrate the roof. Potential deficiencies of this method of attempting to stop the extension of the fire over the top of the firewall occur because the plywood delaminates (layers separate) and fire passes over the top of the wall. Recently, it also has been found that plywood treated with certain chemicals decays from heat and is subject to failure if walked on.

The problem is compounded if treated plywood is used not only along the line of the fire wall, but also randomly throughout many roof areas. In some cases, the entire roof is treated plywood. In an attempt to provide some sort of barrier to the spread of fire over an unparapetted fire wall, some jurisdictions require a sheet of gypsum board to be attached to the underside of the roof, on each side of the fire wall. Presently, there is no evaluation of the adequacy of this concept.

Surface Coating

The fire hazard or flame spread of wood can also be reduced by the application of intumescent coatings that swell up when heated. As a substitute for pressure impregnation, one manufacturer suggests that all surfaces be painted with the proper coating at the job site and touched up as necessary. This method eliminates the objection by carpenters that treated wood dulls cutting tools.

One of the major problems with a surface coating is the tendency for it to be spread thinner than its recommended thickness. A gallon of surface coating must not be applied to more than the area specified for it. One inspector requires that surface coating container labels be delivered to show that the required amount of coating was purchased. It is always recommended that the owner purchase the material and hire a painter to apply it, in an attempt to achieve the recommended coverage. It also needs to be reapplied at certain intervals to retain its proper function.

Applying surface coatings to existing combustible installations such as plywood does not completely solve the problem because the unexposed surface of the paneling remains untreated. However, in one fire, intumescent-coated plywood wainscoting did not burn significantly, while an untreated chair rail molding burned completely.

Dangerous Treated Wood

Plywood and lumber treated to resist insects and moisture (pressure treated) have been used for basement walls. These materials are also widely used for exterior structures such as decks. They are, of course, combustible and might cause a collapse. The fumes from such pressure-treated wood are toxic, so scraps of this wood should not be used for kindling. A fire investigator became ill and required hospitalization after spending some time investigating the ashes of a fire that had involved pressure-treated (for retarding decay) wood.

Plywood and Other Wood Building Materials

About 100 years ago, it occurred to someone that one of wood's limitations—the lack of shear strength along the grain—could be overcome by slicing the wood into thin layers, placing the layers at right angles to one another, and gluing the entire mass together. We know this product today as plywood, which is just about equally strong in all directions. This was the first of many ways in which natural wood was engineered into a useful product.

A basic problem of plywood exposed to fire is that it delaminates, which increases the surface area and the rate of heat release. Plywood can be impregnated to render it fire retardant. The problems associated with some fire-retardant plywood roofs were noted earlier in this chapter. Plywood can be used as an interior finish, as a building sheathing without structural value, and as a structural material in floors, roofs, or walls. Such construction is often described as stressed skin or diaphragm, in which the plywood provides some of the structural strength of the building, particularly in providing resistance to shear stresses.

Spliced and Laminated Timbers

The shortage of big trees from which solid timbers could be sawn led to the development of **spliced timbers**. Various metal connections are used to transfer loads so that spliced timber acts like a single timber.

In a fire, the heated metal connections can destroy the wood and the timber may fail. More recently, laminated timbers have been developed. Plank-like sections of nominal 2-inch (51 mm) (or thinner) boards are glued together under pressure to produce large arches, beams, girders, and columns. Such timbers are also known as Glulam, a trade name. Sometimes bolts are used to supplement the glue. When highly finished, these timbers are very attractive. When combined with wood planks, they can provide the necessary structural strength together with an aesthetically pleasing interior finish. Laminated timbers apparently burn like solid heavy timbers and do not delaminate like plywood.

Do not mistake laminated wooden beams (which do not delaminate) with plywood as used in wooden I-beams (which does delaminate). Laminated wood sections were spliced together to form arches for a Daytona Beach, Florida, sports arena. In a fire, the wood was only charred but the arches fell apart at the metal connections.

We usually think of arches as having a characteristic segmental arch shape. Two-hinge arches of laminated wood are available, combining in one member both column and girder. They provide a straight-walled structure with a flat roof and a clear floor area. The Forest Products Laboratory in Madison, Wisconsin, is constructed of arches that provide a floor area the equivalent of five stories in height with a 60-foot (18.3 m) span.

Paper Wrapping

Laminated timbers and other finely finished wood are shipped in a protective paper wrapper. This cover is kept on as long as possible during the construction period. This paper is hemp-reinforced and coated with a bituminous moisture repellant. It ignites readily, has a high flame spread, and could contribute to a severe loss in a building under construction. In one fire, this paper was responsible for the extension of a grass fire to piles of packaged lumber.

In another case, an addition to a hospital was under construction. A wooden snow roof was erected over the excavation. Hemp-reinforced treated paper was selected to waterproof the roof. A potbellied stove in a change room spewed out sparks. A fire could have easily sent a sheet of flame up the face of the hospital.

Planks

Tongue and groove roof planks, for plank and beam construction, were fashioned in the past by wasteful methods. Such planks are now often fabricated without waste by gluing three boards together with the center board protruding on one side and indented on the other. During a fire, such planks may separate like plywood, causing the boards to fall from the overhead. It might be wise for a fire department to run its own test on materials used locally.

Chipboard

…n wood chips are glued together to make flat sheets. These **chipboards** (also known as particleboard) are sometimes used for the floors of mobile homes. Some chipboard is water soluble and has dissolved in fires.

On a television show many years ago, large plywood or chipboard roof panels with a gypsum board interior surface were sandwiched around a thick plastic foam core to create panels. The panels were then installed between widely spaced roof beams to provide a roof that was otherwise unsupported. It could be dangerous to vent such a roof. Even away from the fire area, heat from the fire might melt some foamed plastics and the roof may fail. If the foam is uninhibited, a fierce fire with dripping plastic would be possible.

Flitch Plate Girders

Flitch plate girders are a composite of a steel plate sandwiched between two solid sawn wood joists, or in some cases, plywood (Figure 7-16). These materials present a problem to fire fighters, as failure of the connection between the wood and steel or burnout of the plywood could cause failure.

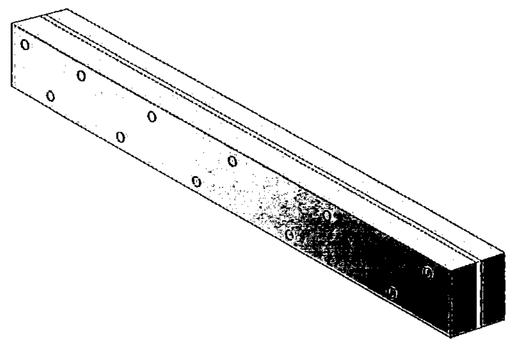


Figure 7-16 A flitch plate girder.

Sheathing

Sheathing is the covering that is applied to the studs or framing of a structure. The exterior surface covers the sheathing. Tongue and groove boards laid diagonally to provide shear strength were used in older houses. Many old houses were built without sheathing, and fire spreading though walls can come out through joints in the siding. Today, plywood is commonly used for this purpose.

In recent years, low-density black fiberboard that has been moisture- and vermin-proofed has been used in residential construction because it can be installed quickly and has relatively high insulation value. (Celotex is often misused as a generic name for any low-density fiberboard. In fact, the Celotex Company manufactures many building products, and many other companies manufacture low-density fiberboard.)

Low-density fiberboard material carries a warning: "Combustible. May burn or smolder if ignited." A common method of ignition of this material is the plumber's torch. A similar material is often used for sound conditioning. In one school, sound conditioning sheathing was applied directly over wood studs and covered with a gypsum board. Later, a plumber used a propane torch to sweat a copper pipe. The flame from the torch ran along the pipe and found the fiberboard. This caused a fire that extended vertically to the metal deck roof.

The brand-new school was destroyed. It was uninsured because it was believed to be fireproof.

As noted previously, plywood is also used for sheathing. In some cases, a building is totally sheathed in plywood. In other cases, plywood is used at the corners to provide shear strength.

Gypsum sheathing is found in some localities, particularly where combustible sheathing is not permitted. It is similar to the gypsum wallboard used in interiors. Combined with brick veneer surfacing and gypsum interior surface, it is used to provide rated fire-resistive exterior walls.

Foamed plastic is now widely used for sheathing. It may or may not be flame inhibited. In any case, if exposed to fire, it may degrade and give off noxious fumes.

Siding

The siding on a building is the outer weather surface installed over the sheathing. Many different sidings are used on frame buildings. All combustible siding readily extends fire vertically, and is easily ignited by an exterior fire such as trash or burning foliage.

Wood siding is usually **novelty siding**, laid on horizontally. Novelty siding is often called clapboard, but true clapboards, which are cut from a log in a wedge shape, are rare.

Board and batten siding consists of boards laid on vertically, butt to butt, with strips nailed over the joints. Sometimes plywood is used, and **battens** are nailed on 1-foot (30.5 cm) centers to simulate board and batten. Battens have been used on painted concrete block walls to simulate such siding.

Plywood siding (sometimes referred to as "T1-11" plywood, a trademark of the APA-Engineered Wood Association) is delivered in 4-foot-wide (1.2 m) sheets, side matched. It gives the appearance of 4-inch-wide (102 mm) strips about a half inch apart. Shingles and shakes (longer, thicker shingles are called shakes) are also used for siding. As siding, they do not present the extreme conflagration hazard of wood-shingled roofs. However, they can become ignited when burning shingles or brands fly about and set fire to rubbish or dry foliage.

Asbestos cement shingles have been used both in new construction and as a replacement over deteriorated wood siding. They are noncombustible, but the presence of wood trim, and often the old wood siding, renders a building with this type of siding as vulnerable to a grass or rubbish fire as a wooden building. Asbestos cement shingles can explode when heated, and flying particles can cause eye injuries and possible inhalation hazards.

Asphalt felt siding, also known as gasoline siding, is usually made to look like brick or stone (Figure 7-17). It is often used as replacement siding over wood. It burns readily and produces dense black smoke. Asphalt siding is very similar to asphalt roofing that meets certain roofing standards. This has led people to believe that it has some fire resistance value. It has none.

Vinyl siding is made to look like wood siding. It is a thermoplastic that will deform (droop), burn, and drip under attack from a fire (Figure 7-18). It is often used to cover up old wood siding.

Metal siding, when used on residences, is usually made up to resemble some other material. Currently, aluminum siding is made to look like clapboards.

Figure 7-17 Asphalt felt siding made to look like bricks.
Courtesy of Glenn Corbett.

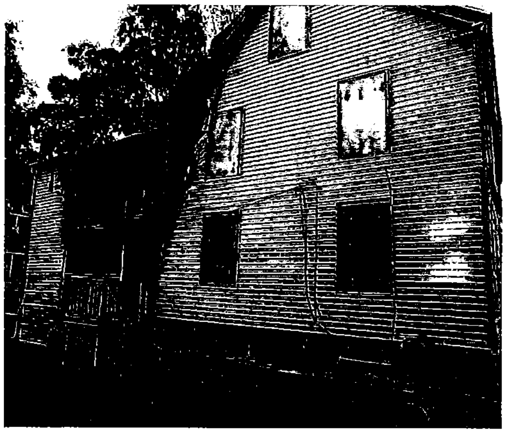


Figure 7-18 Vinyl siding melted from fire venting from an opening. Note the charred original wood siding underneath.
Courtesy of Glenn Corbett.

Embossed sheet metal has been made to look like imitation stone.

Corrugated metal siding is used on industrial buildings of wood or steel framing. Metal siding can present severe electrical hazards, both from stray electrical currents and from lightning. Thorough bonding and grounding of the siding and metal roof will do much to eliminate such hazards. This is rarely done, however, and the possibility that metal siding is energized should be a factor in firefighting.

Stucco is a thin concrete surface that can be used on any structure, such as brick, block, hollow tile, or wood. It is not correct to describe a structure as a stucco building. The correct description is of stucco over something else. In the case of wood, stucco is laid on metal lath. The lath makes it difficult to make openings in the wall. Stucco is used both in initial construction and in rehabilitation of old buildings. Some assert that the stucco makes the building safer from fire. This is untrue as far as life safety is concerned. However, the use of stucco does improve exposure protection over that of comparable wood-surfaced buildings.

In some cases, a coat of gray stucco is applied, and then a coat of red stucco is laid on over the gray. Red stucco is then removed in lines, leaving the gray stucco visible. The effect is that of brick masonry.

Brick Veneer

Brick structures have so-called good press. Brick veneer siding is popular for wood-frame residences, garden apartments, and smaller commercial buildings in areas where brick is economical. This brick is not structural; this is, it carries no load except itself. Although initially more costly than wood siding, the savings on painting over the years may make brick veneer economically attractive.

Brick veneer walls are laid up from the foundation in one wythe (one thickness of brick in a wall). Such a wall, if not attached to something, is very unstable because it is thin. In a veneered wall, galvanized steel anchors are nailed to the studs (nailing anchors to the sheathing is a poor work practice). The anchors are bent at a right angle and embedded in the mortar between two brick courses (or layers). If there is a fire in the wall, the nails may detach from the studs due to **pyrolytic decomposition**. The resultant freestanding wall is unstable. It is not stabilized by the compressive load of the structure as is a bearing wall. On the other hand, its collapse will not affect the stability of the structure. The collapse of a veneered wall of an upper story may be an impact load to a first-floor extension or an adjacent structure.

Until a few years ago, it was easy to identify a brick veneered wall compared to a solid masonry wall. All the bricks were laid as stretchers (laid lengthwise). There were no headers (laid across the wall with the ends showing). In a bearing wall, headers can be seen, usually every seventh row. More recently, the use of metal truss masonry reinforcement has made it possible to omit the headers from a solid masonry wall. If the brick wall is all stretchers, you should suspect that it is brick veneer, but you cannot be certain this is the case.

Many buildings combine brick veneer and solid brick masonry. Bearing walls may be solid masonry, while nonbearing walls may be veneer. Lower floors may be solid and upper floors veneer. This cannot be detected after the building is finished and points to the necessity for recording information about buildings as they are built.

An old wooden house in New York had been rehabilitated by the addition of a brick veneer wall. It was heavily damaged by fire. During overhaul, an interior collapse knocked down the brick wall. A lieutenant was killed while pushing an injured probationary fire fighter out of harm's way.

Stone Veneer

Natural or artificial stone and cast concrete are also used as veneer. Permastone is one trade name. Stone can be used in the same manner as brick.

Today, natural stones are very popular (Figure 7-19). Wire lath and mortar are applied to the sheathing; the stones are stacked and mortared to the wire lath base.

Wood Shingle Roofing

Wood shingles or shakes are split pieces of wood used for roofing or siding. Shakes are larger than shingles. Some of the greatest fire disasters in history have been due to the spread of fire by wood shingle roofs (Figure 7-20).

If consideration of a fire is limited to the problem of the building in which the fire originated, the wood shingle roof might be a more desirable

Figure 7-19 A stone veneer wall under construction. .
Courtesy of Glenn Corbett.

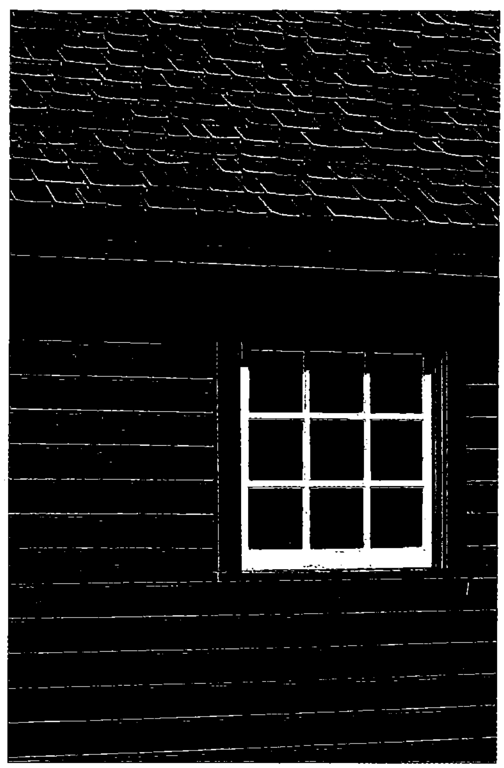


Figure 7-20 A wood shingle roof.
© Design Pics/Thinkstock.

material because by burning through, it vents the fire. However, the conflagration hazard presented by wood shingles should be the dominant consideration.

In recent years, wood shingles and shakes have made a strong comeback. It seems as if each generation must learn the lessons about these materials anew. In 1959, the NFPA warned that a major conflagration risk was present where large areas of wood shingle roofs existed. The Los Angeles conflagration of 1961 proved the prediction to be accurate. There are many areas now where the majority of houses have wood-shingled roofs. In some areas, they are permitted wherever frame buildings are permitted.

Fast fire department response, one-story buildings, wider spacing between buildings than in bygone years, and the fact that we have no extensive numbers of shingles on closely spaced 2½-story buildings that existed 50 years ago have combined to keep the conflagration rate low. But given the coincidence of hot dry weather, brush fires that engage a large portion of available firefighting forces, high winds, and a hot fire in a wood-shingled structure, the threat of conflagration is still very great.

On the afternoon of July 31, 1979, the Houston City Council was considering an ordinance with minor restrictions on the use of wood shingles. The ordinance was tabled. The day was hot and dry. At about the same time, the fire department responded to an alarm for a fire at the Woodway Square Apartments. By that evening, 30 apartment buildings were destroyed, hundreds of people were left homeless, and an estimated $44 million in damage was incurred. The fire spread because of the wood shingle roofs. Ironically, the owner of the apartments was in the process of replacing the shingle roofs. The next day, the shingle ordinance passed.

In the early evening of March 14, 1988, residents of apartments in Davis, California, also were the victims of a fire spread by wood shingles. Nine of 18 buildings in the complex were damaged. Over 100 University of California students lost personal property. Damage was in excess of $1.5 million.

Wood shingle proponents stress that brush fires are more responsible for conflagrations than shingles. The Davis and Woodway Square fires, and many other fires, however, did not involve a brush fire. They were purely structural fires. Yet, wood shingles do spread fires that begin in brush, as seen in the San Diego County firestorm of 2003. The San Diego City Council, which had rejected tougher restrictions on wood shingles, was forced to address the issue after the wildfires killed 16 people and destroyed 2,427 homes.

Testing laboratories rate wood shingles in accordance with NFPA 256, *Standard Methods of Fire Tests of Roof Coverings*. Elements considered include flame exposure, spread of flame, and resistance to burning brands or flying pieces of burning wood. Roofing materials are classified as *A*, *B*, or *C*. The least fire resistant is C rated. In addition, for wood shingles, a flying brand test is required to determine if the roofing will produce brands. Wood shingles that meet Classes A, B, or C standards are available.

Know the building code provisions governing wood shingles in your area. If rated shingles are required, bear in mind that only bundles of shingles are labeled, not individual shingles. You cannot tell treated from untreated shingles by looking at them. Note also that treated shingles exposed to weather effects will lose their effectiveness.

Tile Roofs

Some homes may feature a heavy clay tile roof instead of wood shingles. Clay tile was particularly popular in the 1920s and 1930s, although it has been in use for a very long time and is still popular today (Figure 7-21).

The Apple Valley, California, Fire Department had a narrow escape when thousands of pounds of tile collapsed while fire fighters were making a fog attack on an attic fire. As is typical, the failing roof showed no visible signs of weakness. The interior residence was clear. The fire fighters were not accustomed to thinking of roof collapse.

This incident points to the need for better exchange of information among fire departments. In January 1989, two Orange County, Florida, fire fighters died when the truss-supported tile roof of a store, in which

Figure 7-21 An older home with a clay tile roof.
Courtesy of Glenn Corbett.

the attic was involved, caved in on them. In a now famous video, three members of the Phoenix, Arizona, Fire Department fell through a tile roof supported on light trusses after ventilating the roof. Review of the fire on videotape revealed that the acceleration of the fire, immediately after ventilation, seemed to provide the final weakening of the roof supports.

Imitation Timber

Styles in interior decor seem to run in cycles. In contrast to the modern interiors that were popular a few years back, many current styles feature wood. Very often wood is made to appear structural when it is not. Often it is not even wood. Few if any of these practices are effectively regulated by code. Some of these deceptions should be noted:

- Unprotected steel beams or columns boxed in wood to look like wooden structural members.
- Unprotected steel encased in plaster surfaced to look like wood.
- False wood beams that are actually hollow wooden boxes. (The support system should be examined. Decorative beams have been found suspended from aluminum wire. In one case, they were just glued to the ceiling. The temperature up at the ceiling can be hundreds of degrees higher than it is at the floor level.)
- Polyurethane imitation wood beams and fittings such as brackets. (These are readily ignitable and burn furiously. Such imitations are often found in conjunction with plywood veneers. The hazards include massive fire load overhead and the potential for collapse.)

It is becoming fashionable to make a masonry building appear to be of wood construction. The Teton Lodge, in Teton National Park, Wyoming, is made of concrete. The wood formwork marks were left evident and the entire building stained brown. Much of the interior finish is plywood.

Brick or block buildings have been covered with a wood veneer that is mounted on furring strips, making it easy for the wood to burn on both sides. In one case, a concrete block store was covered with shingles stapled to plywood sheets and mounted on vertical wood trusses. The shingles were said to be treated, but apparently the plywood and wood trusses were not.

Making Wood Construction Safe

Wood is a uniquely renewable resource. It has served humanity for ages and will continue to do so. Unfortunately, it is combustible. The problem of its combustibility can be dealt with only by complete automatic fire sprinkler protection, being properly designed with adequate water supplies, and being competently maintained. Structures with unsprinklered floor or attic voids do not have complete sprinkler protection.

Given this protection, a wooden structure is superior from a life safety point of view to many unprotected fire-resistive structures. A case in point: visitors to Teton and Yellowstone Parks will see two hotels. One is of concrete but it was lined with plywood when last seen. There were no sprinklers. Another is an old wooden hotel that is fully sprinklered. The authors would much rather sleep in the fully sprinklered wooden hotel.

TACTICAL CONSIDERATIONS

1. Fire fighters operating on, in, or under burning wooden structures are in a hazardous situation. Wooden structures under attack from fire are on their way to collapse. Always have an exit plan and be prepared for immediate evacuation. There should be a clear signal when an emergency evacuation is ordered. Some fire departments use a series of short air-horn blasts, supplemented by an emergency radio message. Today's fire communication centers have the ability to transmit an "evacuate the building" tone over all the portable radios on the fireground, but voice transmissions over the radio alone are insufficient. All fire fighters should be trained to evacuate the building immediately upon hearing the signal. Leave the equipment behind. Don't try and retrieve it—no length of hose or tool is worth a fire fighter's life. However, if you have a tool in hand, don't drop it. You may need it in case you or your crew become trapped.
2. Fire departments should drill on "Evacuate the building!" Consider ending your hands-on training drills with this evolution. Fire fighters need to practice a quick exit in realtime. They may have only a second or two to survive the event, so make them hustle. In one training evolution, a fire fighter was using a hose strap (webbing) to operate a 2½" (64 mm) hose line. The rookie fire fighter had the strap over his head and across the shoulder. The training officer saw the potential entanglement hazard and yelled, "Look out! The wall is collapsing!" The fire fighter quickly shut down the nozzle, dropped the hose line, and ran. Not realizing the strap was over his head, it yanked him to the ground like a dog on a short leash. The training officer came up to the rookie to inform him that he did not survive the wall collapse, then proceeded to show him how to properly use the hose strap without putting it over his head.
3. Most fires are fought by fire fighters standing on, in, or under wooden structures. Thin wooded sections can have a very rapid flame spread. Remember, in newer construction, floors are stronger than roofs.
4. If fire fighters are not successful in getting ahead of the fire, confining it, and extinguishing it, building collapse is usually the final event in any structure fire.
5. Wood construction creates combustible void spaces in which fire can hide and burst out. These spaces can also collect superheated smoke and fire gases that can lead to a backdraft or smoke explosion.
6. The key word in glued laminated timbers ("Glulams") is *glue*. Glue accelerates the flame spread and burn speed, weakening what would otherwise be a large timber cross section.
7. OSB or oriented flakeboard quickly succumbs to fire—but it can also lose its structural strength and fail when it becomes saturated with water.
8. Plenty of balloon-frame construction can be found throughout the United States, and it will be here for decades to come. The key point to remember about balloon-frame structures is that they have channels between the studs that are open from the cellar to the attic. In other words, there are no firestops. Teach your crew to identify these structures. One indicator is tall, narrow windows in older construction homes.
9. The basement of a balloon-frame building is usually the worst place for a fire to start. The path of least resistance for heat is up. Without firestopping, the fire can travel throughout the entire structure unchecked. Fire will move quickly up to the attic. You need to immediately send a company to check the attic with a thermal imager.
10. When a fire has entered the inner structure of a balloon-frame building, it can quickly spread to every part of the building in all directions. Investigate all parts of the building immediately. Be aware of the potential for intense fire buildup in void spaces. Don't wait for the smoke, heat, and fire to make conditions untenable before you decide to check the attic. ICs should make use of every available thermal imager on the fireground.
11. If a fire starts in the basement, you need to quickly check the attic. If a fire starts on Floor 1, Floor 2, or above, you need to check the basement because the

wall spaces are open channels where burning embers and debris can fall from the upper stories down to the foundation. This can start a new fire from below. As fire travels up, the two fires can join, trapping fire fighters above.

12. In a balloon-frame building, the problem with an interior attack is that fire moves up through multiple stud channels. As the first channel is opened up, visibility becomes obscured with smoke and steam. If a thermal imager is not available, it's easy to miss a channel and the fire may get past you.
13. Many fire departments today lack the bent swivel tip that was used on the old controlling nozzle. With the swivel tip, the fire fighter could quickly give it a dash up and down the stud channel. This is not easily done with today's equipment. Many old Navy fog applicators can still be found, however; they are an excellent tool for extinguishing these types of fires. Another effective nozzle is a piercing nozzle. The spray produced by this nozzle converts to steam and travels through the same channel as the fire.
14. The safest and most effective way to attack a fire in a balloon-frame structure is by removing the exterior siding. Fire fighters working from ground ladders can quickly rip the siding, exposing the channels and the wall studs. The exterior sheathing is cosmetic, while the interior sheathing is often part of the interior wall. The wall studs don't always carry the weight of the wall. The 1- by 6-inch (2.5- by 15.2-cm) wood sheathing or lath and plaster carry a lot of the weight of interior walls. That's why it is best to use a piercing nozzle or fog applicator for interior attacks.
15. In a wall fire, the attic is considered an extension of the wall. Resist the urge to cut a ventilation hole in the roof. This will "complete the chimney" and draw the fire into the attic and the structural members of the roof. If the roof stays intact, the atmosphere, though charged with heat and smoke, is an oxygen-deficient atmosphere and will not sustain a fire. This allows crews to extinguish the wall fire from the exterior fire.
16. Soffits or void spaces can exist in built-in cabinets in a kitchen, the underside of stairways, bathrooms, or projecting eaves. In balloon-frame construction, these void spaces, which generally lack firestops, can be a direct path for fire to enter the wall and joist spaces and can allow the fire to quickly spread vertically and horizontally. Whenever you respond to a kitchen fire or food on the stove that is "out by occupant" (extinguished by the occupant), don't take the person's word for it. Civilians usually don't recognize that fire can extend into the walls. The cabinets above the stove must be checked with a thermal imager. If heat registers, you must remove the cabinets and open up the walls. Remove all charred wood until you reach natural wood. Then check the attic.
17. The best and fastest tactics for protecting exposures should be studied and implemented before the fire gains a serious foothold. A heavy-caliber stream from a master stream appliance directed at a specific spot on the exposure might fan out to provide effective coverage. Remember, a water curtain doesn't protect an exposure—radiant heat can travel right through the spray. You must cover the exposure with water. If water is flowing over a combustible surface, that exposure will not burn. In another case, it might be necessary to use the slower procedure of getting lines to each floor. If fire extension protection is planned for, the defense will more likely be successful. Additional resources should be called for and staged immediately. Traffic control also can become a serious problem at such spectacular fires, so call for police.
18. Fire burning in balloon-frame walls destroys the structural integrity of the building. Collapse is a serious threat—especially in buildings that have experienced previous fires. Fires in balloon-frame buildings should be observed from the exterior by a fire officer specifically assigned to that function and positioned far enough away to see the entire building. This fire officer should watch for signs of fire spread, such as heavy volumes of smoke pushing out from voids in the building, as well as intense heat buildup and structural failure, which may not be apparent from close range.
19. Don't be fooled by a simple trash bin or dumpster fire on the exterior of a balloon-frame structure. Fire may have extended into the walls or into a soffit under projecting eaves. If the walls are clear, continue to inspect the soffit void space and the attic. In one case study from Dallas, Texas, fire in a soffit void space extended up into the attic. A previous fire had weakened the structural integrity of that roof. When a fire lieutenant (not knowing the previous history) went to the roof with his crew to cut a hole for vertical ventilation, the roof collapsed. The lieutenant, who

was not wearing his SCBA face piece, fell through the roof, became trapped in the burning attic, and was killed. Fire fighters must wear their SCBA face pieces during vertical ventilation operations. There is little or no reaction time when a roof collapses—and certainly not enough time to don a face piece.

20. Traditional church fires can be quite spectacular. Where a plank beam ceiling is already or about to become involved in fire, prepare for a heavy stream attack. Solid stream tips should be used to reach the surface of the wood with maximum water flow. Fog streams, which lack penetration capabilities, are ineffective and would be eaten up by the heavy fire. When the surface is wet, the fire is extinguished. In preplanning, select locations for master stream placement so that all areas are covered. This sort of solid stream attack worked successfully at a fire in a Florida church.
21. The compression load of a truss is carried on the top chord, typically a light wood member such as a 2 by inches (5 by 10 cm) or 2 by 6 inches (5 by 15.2 cm). Loss of wood can precipitate a crushing failure in compression. The entire tensile load is carried on the bottom chord, so just one break can precipitate failure. The lightweight wood truss uses metal gang nails or gusset plates as the connectors in the web. These nails (or teeth) are only 3/8-inch (9.5 mm) deep—that's all that penetrates the wood. Keep this in mind during your risk–benefit analysis. Time is of the essence. Always cut a vent hole in a lightweight truss roof from an elevated platform or an aerial ladder, a skill that needs to be practiced because apparatus placement isn't always ideal. Remember, loss of wood or loss of a gusset plate can cause a collapse.
22. NFPA 13R deals with residential sprinklers for other than one- and two-family dwellings. One of the purposes of installing sprinklers is to prevent flashover. A sprinkler system will most likely control any fire originating in the protected area. However, if the fire originates or penetrates a void space, the sprinklers will not be in a position to control the fire. Some fire fighters are reluctant to introduce a fog applicator into an attic void space; they ask, "Isn't this technique essentially introducing a sprinkler system into that space?" In doing so, you would be creating a situation no different than if the space was already sprinklered. Sprinklers are fused by heat, not necessarily by flame contact. Consider using this tactic before opening the roof.
23. Many communities where wood construction is popular are developing farther away from urban centers, which means fire departments may have to travel greater distances with fewer members responding. Dry weather and high winds can accelerate these fires. If first-in units are understaffed, consider a "blitz attack"— a master stream tactic utilizing the booster tank. (Most booster tanks on apparatus now carry between 500 and 1,000 gallons (1893 and 3785 L) of water.) This attack needs to be backed up immediately with a supply line. When a fire is gaining momentum, you have to make the heaviest hit possible. The British thermal units (BTUs) generated by a growing fire have to be overwhelmed by gallons per minute (gpms; big fire, big water); otherwise, the fire will not go out. If a blitz attack doesn't extinguish the fire, at least it can knock the fire down to a handline-size fire (fewer gallons per minute flow). This slows the fire down, buying you some time to regroup so you can get handlines in place. As far as life hazard is concerned, if a fire is large enough to require a blitz attack, the rescue profile is probably zero.
24. In an apartment fire in Seattle, Washington, the first-in engine company was in a position where a blitz attack would have been the ideal initial tactic. When fire fighters saw people trapped on an adjacent balcony, they decided to throw a ladder and went into rescue mode instead of laying hose lines. Though no lives were lost, the delay in applying first water to slow the fire down allowed the fire gain enough headway that it ended up destroying the entire apartment complex. Remember—sometimes the best tactic to save lives and property is to put the fire out or at least to slow it down until additional units arrive.
25. In areas where many buildings have wood shingle roofs, prepare for a blitz attack to knock down the original fire quickly. Call for additional units immediately. Don't wait for confirmed extension.
26. Whether the wall is a veneer or a structural wall is immaterial to the fire fighter struck with falling bricks. Some fire fighters place too much reliance on newer helmets. No matter how strong the helmet, it is worn on a human body with limited impact resistance. The wearer of the super-helmet may find that the frontpiece becomes a belt buckle! Remember, through the helmet may be impact rated, your neck isn't.

WRAP-UP

Chapter Summary

- Type V construction includes six types of wood-frame structures—log cabins, post and frame, balloon frame, platform frame, plank and beam, and truss frame.
- In a balloon-frame building, fire can spread through all the interconnected spaces from cellar to attic and across the ceiling.
- The current practice of designing buildings of lighter and lighter materials and substituting geometry for mass has led to significant strides in the architectural field, but it has also created significant problems in the field of firefighting. Trusses are one example of such a development.
- One of the major problems of combustible construction is fire spread through hidden voids.
- Firestopping is often required by code to be installed to prevent the spread of fire. There are no tested standards for wood firestopping or draftstopping.
- Wood cannot be made either fireproof or noncombustible.
- Wood is a uniquely renewable resource, but it is always combustible. The problem of its combustibility can be dealt with only by complete automatic sprinkler protection, being properly designed with adequate water supplies, and being competently maintained.
- Structures with unsprinklered floor or attic voids do not have complete sprinkler protection.

Key Terms

Asbestos cement shingle A "fireproof" roofing shingle that is composed of cement reinforced with asbestos fibers.

Asphalt felt siding A type of siding manufactured by saturating a dry felt with asphalt, then coating it with a fine glass fiber.

Balloon frame A wooden structure in which all vertical studs in the exterior bearing walls extend the full height of the frame from sill to roof. No firestops are present within the walls.

Batten A type of siding that uses vertical strips of wood to cover joints.

Bottom plate A structural member laid on the subfloor where the vertical studs are installed.

Bridging Braces placed between parallel-frame members to prevent movement from their vertical axes. Also known as cross-bracing.

Cantilevered A type of construction in which an overhang is supported from only one end where one floor extends beyond and over a foundation wall.

Chamfer To cut off the corners of a timber to retard ignition.

Chipboard Wood chips that are glued together to make flat sheets. Often used in the floor construction of mobile homes.

Corrugated metal siding Grooved panels utilized on industrial buildings of wood or steel framing; it poses an electrical hazard from stray electrical wires or lightning.

Curtain wall A non-load-bearing wall that carries no weight other than its own. It is installed only to keep out the weather.

End matched A descriptor for lumber with tongues and grooves at the ends.

Engineered wood In the construction trade, laminated timbers. In this text, wood modified from its natural state.

English Tudor Balloon-frame structure finished to resemble post and frame construction.

Finger joints Interlocking wood pieces that are glued together to create a longer piece of dimensional lumber.

Flitch plate girder Composite of a steel plate or plywood sandwiched between two beams.

Glued laminated timber Planks glued together to form a solid timber.

Header A joist that parallels floor/roof beams and is used to create an opening.

Heavy timber Buildings constructed with non-combustible or limited-combustible exterior walls and floors made of large-dimension combustible materials. Also known as Type IV construction.

Hip The rafter at the angle where two sloping roofs or sides of a roof meet.

Joist Wooden 2 × 8's, 2 × 10's, or 2 × 12's that run parallel to one another and support a floor or ceiling and are supported in turn by larger beams, girders, or bearing walls.

Legacy construction In terms of wood-frame construction, the use of solid wood members as opposed to lightweight wood trusses and wooden I-joists.

Log cabin Structure constructed of entire tree trunks, as opposed to boards sawn from trees.

Lumber Wood that has been sawn and planed.

Matched lumber Tongue and grooved lumber (usually lengthwise).

Metal siding A type of siding that is often made to look like another type of siding—for example, stone or clapboards.

Mortise and tenon Joints that are fitted together to transfer loads properly.

Novelty siding Combustible siding laid over the sheathing of a building. This type of siding comes in many different shapes and is laid horizontally.

Oriented flakeboard Another name for OSB.

Oriented strand board (OSB) A type of board made of layers of strands of wood cut from logs, with a fairly constant width-to-length ratio.

Plank and beam Used in modern construction, a wood-frame structure built with heavier beams that are spaced much farther apart than the traditional 16 inches.

Platform frame A structure in which subflooring is laid on the joists, and the frame for the first-floor walls is erected on the first floor.

Plywood Wood panels manufactured with the grain of alternate plies laid at right angles to develop the approximate equal strength in either direction.

Plywood siding Four-foot-wide sheets that give the appearance of four-inch-wide strips about a half inch apart.

Post and frame A wood-frame structure with an identifiable frame or skeleton of timber fitted together. Joints are constructed by mortise and tenon, fitted together to transfer loads properly.

Pyrolytic decomposition The chemical decomposition of a compound into one or more other substances by heat alone; pyrolysis often proceeds combustion.

Rafters Wood members used to support the roof sheeting and loads.

Ridge board A structural member placed on the ridge of the roof onto which the upper ends of rafters are fastened.

Rough carpentry All of the wood framing members and sheathing of a building. Also known as framing.

Rough lumber Lumber that is left as sawn on all four sides.

Sawn beam Wooden beam sawn out of a tree trunk. To some extent, these beams have been replaced by the wooden I-beam due to the weight and cost of the true wooden beam.

Sill Component found on the bottom of the frame of a wood structure. It rests on and is bolted to the foundation.

Soffit False space above built-in cabinets, usually in a kitchen, or in the undersides of stairways and projecting eaves.

Spliced timber Due to the shortage of solid timbers, these members are joined together by various metal connectors to transfer loads so that the spliced timber acts as a single member.

Spline Wooden strips that fit into grooves in two adjacent planks to make a tight floor.

Stringers A component of a set of stairs used to support risers (vertical stair components between treads) and treads (horizontal stair components on which people place their feet),

Stucco An exterior plaster finish made of Portland cement.

Stud A column in a frame building, usually nominal 2 by 4 inches (2 × 4) or 2 by 6 inches (2 × 6).

Subflooring Laid on top of the joists, the structural member that serves as the base for the finished floor.

Top plate Top horizontal member of a wood-frame wall that supports the ceiling joists.

Trimmer A piece of lumber that supports a header and can be found in floor openings such as stairwells (runs perpendicular to floor joists).

Trunnel Wooden peg used to pin together mortise and tenon joints.

Truss frame Developed by the U.S. Forest Products Laboratory, a type of wood frame that substitutes sawn beams for truss members used in roofs and floors. It is held together with nails.

Truss void Found within a truss roof system, a void space located between the top floor ceiling and the roof. Also known as a cockloft.

Valley The lower slope formed by the connection of two inclined planes of a roof.

Vermiculite Mineral used as bulk insulation and as an aggregate in insulating.

Vinyl siding A thermoplastic that will deform and drip when introduced to a fire situation. Often made to look like wood siding.

Wall bearing A descriptor indicating a structure in which the entire structural load is carried on the walls; the opposite of a curtain wall.

Wood A hard fibrous material forming the major part of trees. It is usually milled or otherwise processed for use in construction.

Wood framed Building with exterior walls, interior walls, floors, and roofs made of combustible wood material.

Wood lath Narrow, rough strips of wood nailed to studs. Plaster is spread on wood laths. Generally no longer used, wood lath is present in many existing buildings.

Wooden-walled building A wall-bearing building that carries the load of the structure and the contents.

Case Study

Your last company officer often reinforced the message that the two most important things to learn in the fire service are fire behavior and building construction. You have just been promoted and have been assigned to a ladder company. You decide to hold a training drill in which you will discuss wood-frame construction.

1. While discussing different terms to be used, you mention that not all wood buildings are considered to be "wood frame." This leads to some discussion. What would be your explanation?

2. You discuss the different types of wood-frame buildings. Which type is not one that you would discuss?

A. Plank and beam
B. Bowstring
C. Balloon frame
D. Log cabin

3. While discussing lightweight wood trusses, you explain that some lightweight wood trusses are joined with metal gusset plates and others are joined with adhesive and a ________.
   - **A.** trunnel
   - **B.** flitch plate
   - **C.** finger joint
   - **D.** moment connection

4. As you move on and start to discuss the hazards associated with lightweight wood I-joists, you make certain to mention that in a simulated basement fire, they failed in just over ________ minutes.
   - **A.** 10
   - **B.** 6
   - **C.** 12
   - **D.** 15

Challenging Questions

1. Identify six examples of wood-frame buildings.
2. Describe the similarities and differences between firestopping and draftstopping.
3. Explain the possibilities of fire spread in a balloon-frame house.
4. You are a fire fighter assigned to protect an alleyway between two old wood-frame apartment buildings, both sided with asphalt shingles. What are your concerns?
5. You are an engine company officer assigned to attack a fire on the second floor of a three-story wood-frame apartment building with wood truss floors and a wood truss roof. As an engine company officer, what are your concerns for the safety of your company while operating in this building?

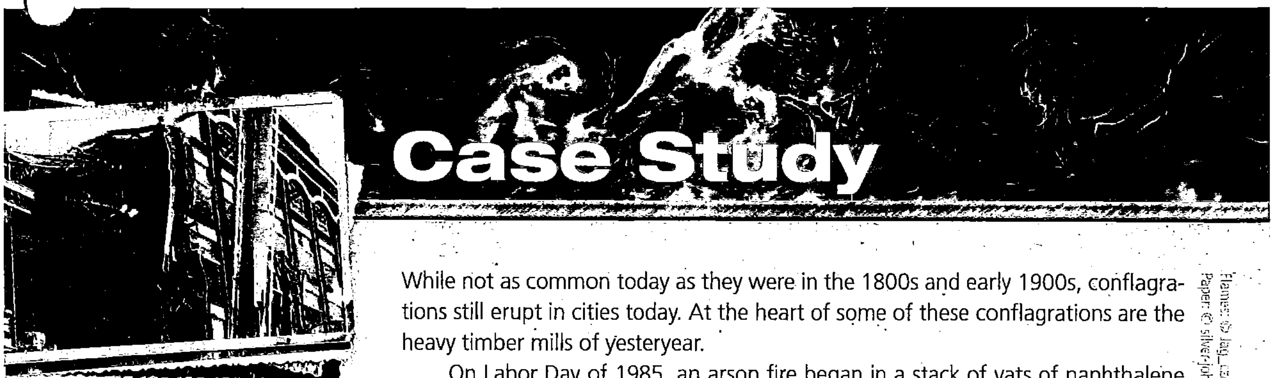
CHAPTER 8

Heavy Timber and Mill Construction

OBJECTIVES

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

- Identify and describe the characteristics of heavy timber buildings and specific characteristics of mill construction (Type IV construction).
- Identify the dimensions of heavy timber members.
- Describe why the misnomer "slow burning" is inappropriate for heavy timber buildings.
- Identify the specific hazards of these conflagration breeders.
- Identify specific problems with mill construction.
- Identify the dangers of concealed spaces in renovated mill buildings.
- Identify the differences between new heavy timber buildings and those built in the past.
- Describe the hazards of vacant heavy timber buildings and structures under demolition.



Case Study

igure 8-1 The Passaic, New Jersey, ›nflagration of Labor Day 1985.

ıurtesy of Glenn Corbett.

While not as common today as they were in the 1800s and early 1900s, conflagrations still erupt in cities today. At the heart of some of these conflagrations are the heavy timber mills of yesteryear.

On Labor Day of 1985, an arson fire began in a stack of vats of naphthalene pushed up against an old mill in Passaic, New Jersey. The fire spread rapidly to the interior of the adjoining multistory factory. Although the complex was very old, it had become the home to dozens of small businesses.

Upon their arrival, fire fighters stretched supply lines to a yard hydrant and began applying water to the fire. Unbeknownst to them, the water supply to the yard hydrant system had been shut down years earlier. They quickly ran out of water and were forced to pull out.

Fire spread throughout all of the buildings in the complex (**Figure 8-1**). It grew so massive that attempts at containment within the complex were unsuccessful. Immense quantities of radiant heat spread fire to numerous exposed three-story homes and another mill across the street. A lack of available water (the city hydrants were used to capacity) prevented the exposed mill from being extinguished with handlines at the ready. Brands landed across the river that bounded the complex, starting additional fires. Ultimately, 1 fire fighter died of a heart attack, 60 businesses were lost, and dozens of homes were consumed.

1. What threat do old mill complexes present to a community?
2. How important is the connection between fire prevention personnel and firefighting forces?
(›w is water best used in a developing conflagration?

A History of Heavy Timber and Mill Construction

Heavy timber construction, and its subcategory of **mill** construction, had its origins in medieval England. "Half timber" homes utilized exposed large-dimension, hand-hewn structural members connected with mortise and tenon joints; exterior walls featured the exposed wood members, with brick or plaster filling the gaps between them. (The aesthetic appeal of this look was revived in the English Tudor–style buildings of the 1920s and 1930s discussed in the chapter on *Wood Frame Construction*, although they were not actually constructed as half timber structures.)

Figure 8-2 The Barker Tavern in Scituate, Massachusetts, is one of the oldest remaining post and beam buildings in the United States, dating from 1624.

Courtesy of Glenn Corbett.

Half timber homes were constructed in early American settlements. Later, post and frame construction (discussed in the *Wood-Frame Construction* chapter) u‹ ˡ basic elements of the structural framework of half timber construction (Figure 8-2). Some of these buildings (such as those constructed from the Dutch sandstone of New York and New Jersey) used stone walls, whereas others used wooden walls. By the 1800s, smaller dimension wood members had replaced large timbers in residential buildings.

The use of large wooden members was not completely abandoned, however. Large structures, such as barns and churches, continued to use these timbers. From the early 1700s, churches also incorporated an important feature—masonry walls.

Also of note were the mills—that is, the factories that emerged during the Industrial Revolution. In the 1790s, the first mills established in the United States, including those in Pawtucket, Rhode Island (Figure 8-3), and Paterson, New Jersey, used large timbers for the structural frame, but maintained wooden exterior walls.

It became readily apparent that while the massive beams and columns were difficult to ignite, the exterior wooden walls of such structures were particularly vulnerable to a fire, particularly exposure fires. The construction of mills in the United States quickly shifted to masonry exterior walls (as churches had done many years earlier) during the first half of the 1800s. This new form of factory became known as "mill construction."

The specific features of mill construction were a matter of local preference and insurance regulations. It was not until the late 1800s, as a result of a movement led by insurance executive Edward Atkinson of the Boston Company, that a standardized form of mill construction emerged. Beyond his advocacy for substantial wood members (an obvious position for an insurance executive), Atkinson pushed for the elimination of concealed spaces as well as vertical elevator and stair shafts *outside the main structure.*

Mill construction fell out of favor around World War I with the arrival of reinforced concrete (Figure 8-4). While the technique of mill construction is no longer being used for new construction, many mills are still in existence in the United States.

Characteristics of mill construction include the following features:

- Exterior load-bearing and non-load-bearing walls are solid masonry, usually either brick or stone, such as granite or sandstone (Figure 8-5).
- Columns and beams are of heavy timber with cast-iron connectors used to cover joints where the fire might obtain a hold. **Chamfered columns** have beveled corners for the same reason.

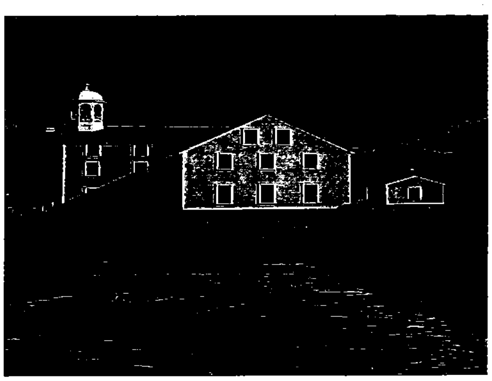


Figure 8-3 The Slater Mill in Pawtucket, Rhode Island, built in 1793.

Courtesy of Joseph E. B. Elliot/Library of Congress Prints and Photographs Division.

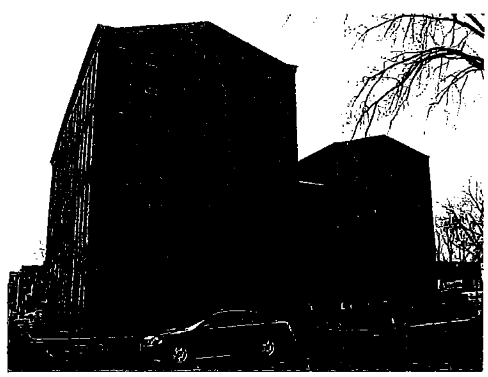


Figure 8-4 A reinforced concrete factory mimicking the look of heavy timber.

Courtesy of Glenn Corbett.

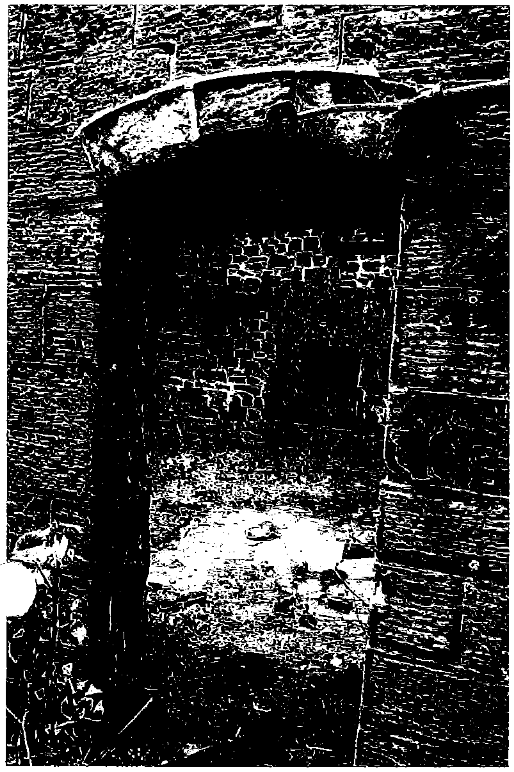


Figure 8-5 The remains of the 1836 Colt Gun Mill, Paterson, New Jersey. Note the use of sandstone for the exterior walls.

Courtesy of Glenn Corbett.

- Floors are of thick grooved, splined, or laminated planks Figure 8-6.
- Roofs of thick splined or laminated planks are supported by beams or timber arches and trusses Figure 8-7.
- Openings between floors are enclosed by adequate fire barriers.
- The ends of girders are **fire cut** to release in the event of a collapse without bringing the wall down. Sometimes a **cast-iron box** is built into the wall to receive the end of the girder. Sometimes the beams are set on a **corbelled** brick shelf Figure 8-8.
- There are **scuppers** (drains in the wall) to drain off water Figure 8-9. The combination of waterproof floors and scuppers is provided to reduce water damage on lower floors. If the scuppers do not drain, there may be a serious increase in the floor load due to retained water. The scuppers should be checked for debris. A broom handle will hold the scupper open and increase the flow. In removing the water that flowed from a ruptured sprinkler riser in a huge Navy warehouse at Norfolk, Virginia, fire fighters discovered that the concrete floors had been graded uphill to the scuppers, making them ineffective. Note that scuppers were provided in sprinklered buildings to remove water, but not in unsprinklered buildings. What did the designers think the fire department was going to use to extinguish the fire? (Fire protection is illogical at times.)
- Concealed spaces are eliminated. The finish is "open" without voids, such as can be created above dropped ceilings or behind wall sheathing. If a paneled office or display room has been constructed within the open floor area of a mill building, it may provide a destructive hiding place for fire. Such spaces can prevent detection and extinguishment.
- A large number of windows are used to provide maximum lighting to the interior of the mill. Monitors found on some peaked mill roofs provided ventilation and light to the top floor Figure 8-10.
- One-story "sawtooth" mill structures became popular around the turn the early 1900s Figure 8-11. They featured a set of windows at the vertical portion of each "tooth."
- The protection of vertical openings and the division of the building into sections by fire walls are vital. If fire walls are to have any meaning in limiting the loss to the area in which the fire starts, openings in them must

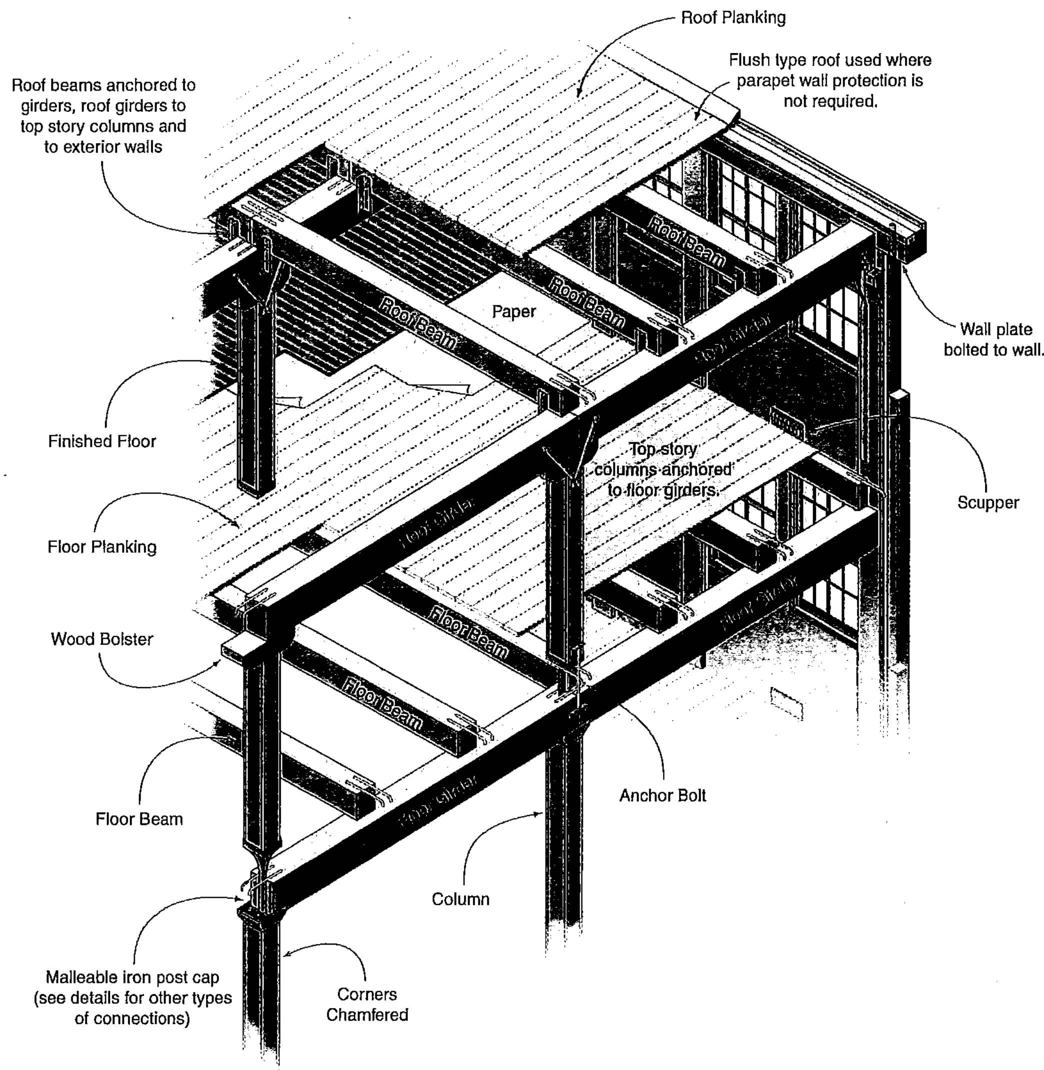


Figure 8-6 Construction of a mill floor.

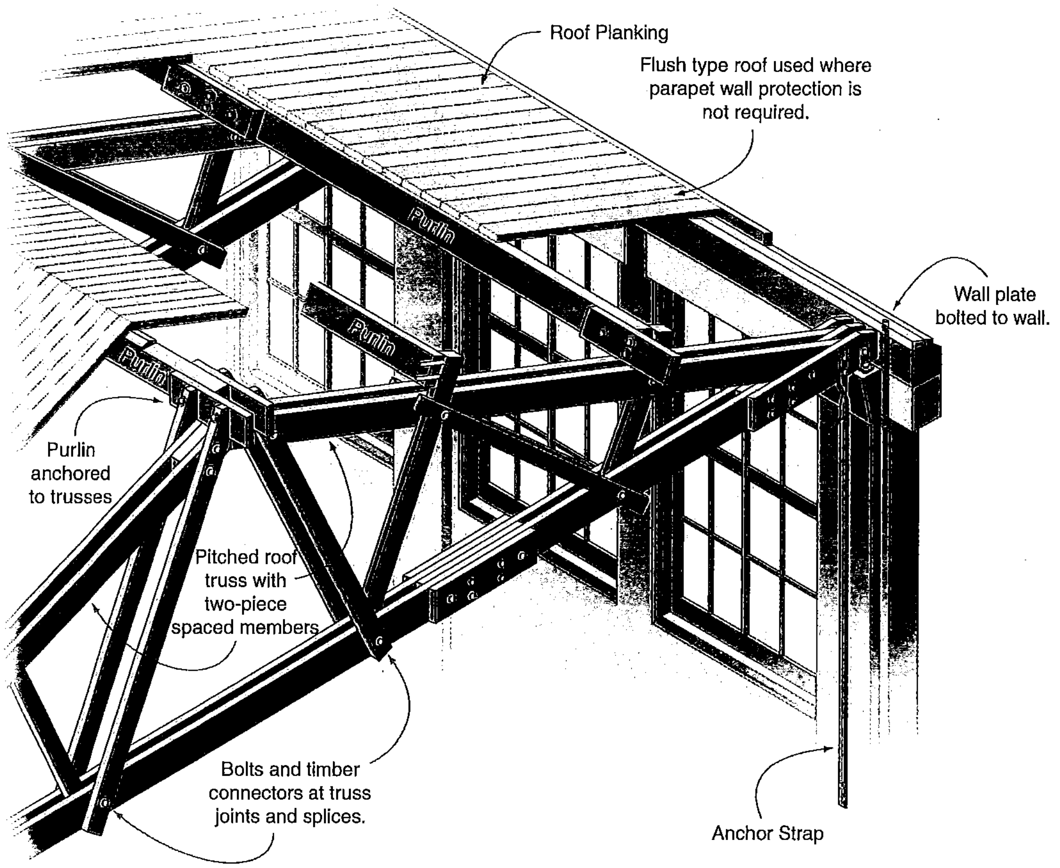


Figure 8-7 Construction of a mill roof.

be protected by operable, self-closing, or automatically closing fire doors suitable to the intensity of fire to be anticipated.

- Most important is an automatic sprinkler system with a water flow alarm and an alarm connection to the fire department. A dependable system of supervisory locks, tamper alarms, and visual checks is necessary to make sure that the sprinklers are continually in service. If repairs must be made, special fire prevention and fire suppression precautions must be taken.
- Special hazards—particularly hazardous industrial processes or hazardous materials—should be located in detached buildings.

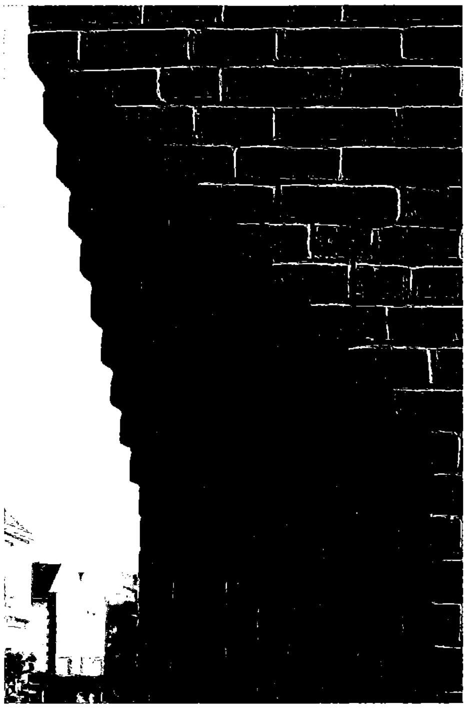


Figure 8-8 A corbelled brick shelf.

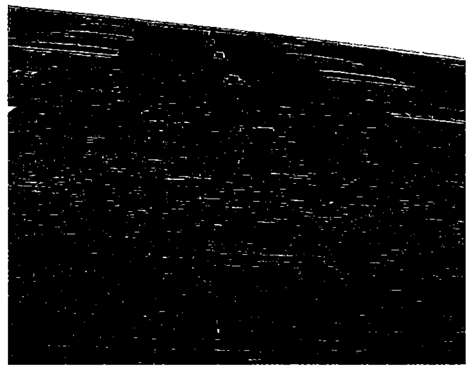


Figure 8-9 Scuppers in an exterior wall, in line with each floor.

Courtesy of Glenn Corbett.

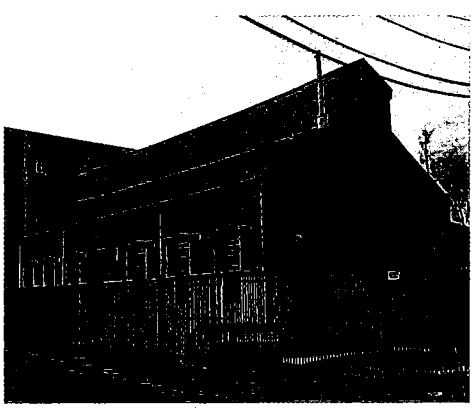


Figure 8-10 A heavy timber building with a covered-over roof monitor.

Courtesy of Glenn Corbett.

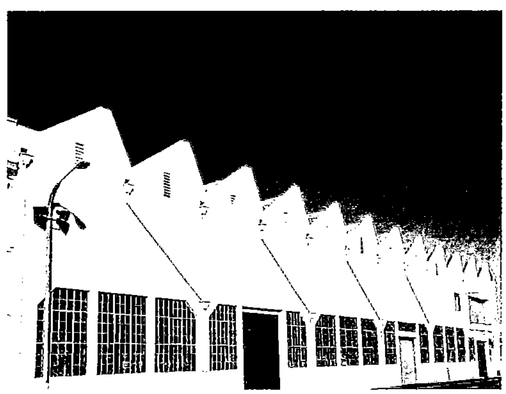


Figure 8-11 A mill with a sawtooth roof.

Properly built and maintained, a mill building can be a structure in which fires can be brought under control before the building is involved in the fire. If one or more of the vital characteristics is absent, either by original design or because of the way the building was modified, the building can become involved in the fire. Once this happens to any substantial degree, the heavy timber characteristic becomes a liability, not an asset. The so-called **slow-burning** characteristic is of no value once the fire department must fall back to defensive tactics, and in truth the structure becomes long burning. It is hard to understand how a living tree in the forest that has not been rained on in 3 months presents "serious fire danger," whereas a tree trunk used in a building that hasn't been rained on in over 100 years is "slow burning."

Branniganism

"Slow burning" is a misnomer when it comes to heavy timber buildings.

ow Burning?

Proponents of heavy timber construction often advance the term *slow burning* as an unqualified advantage because of collapse resistance. In fact, the slow-burning characteristic is an advantage only as long as the fire department can maintain interior offensive operations. Once the fire department must operate defensively, slow burning delays extinguishment and prolongs air pollution and exposure to toxins for fire fighters and civilians.

Once beyond an interior offensive attack, be prepared for a massive fire, perhaps the biggest of your career. A fully involved, multistory, heavy timber building is a **conflagration breeder** for a variety of reasons:

- Tremendous amount of radiant heat from each flaming window opening, which can ignite exposures hundreds of feet away.
- Production of numerous large fire brands (including wood planks), carried by the tremendous updraft of the fire erupting from the interior of the building, propelling them for hundreds or thousands of yards downwind.
- Large collapse zones for tall walls, which drop onto other buildings and start secondary fires.
- Fire spread to wood-frame homes that often surround these buildings.
- Shut-off sprinklers, the lack of or turned-off standpipe systems, open equipment shafts, and large open uncompartmented areas in old factories. The lack of sprinklers in most churches and synagogues.
- Improperly maintained fire doors and lack of compartmentation.
- Sealed-up window openings, particularly in old mills, including sawtoothed roof mills (Figure 8-12). Ventilation will be extremely difficult or impossible.

When fighting an uncontrollable fire in a heavy timber building, expect the fight of your life. You will need a large water supply, numerous heavy-caliber streams, a large collapse zone, an extensive brand patrol downwind, and a lot of luck to prevent a conflagration (and hopefully a few empty parking lots surrounding the burning building).

A safety note: it has been observed that stair shafts often remain intact in multistory heavy timber buildings after a fire. They can potentially be an area of refuge for evacuating fire fighters, even if the rest of the building collapses.

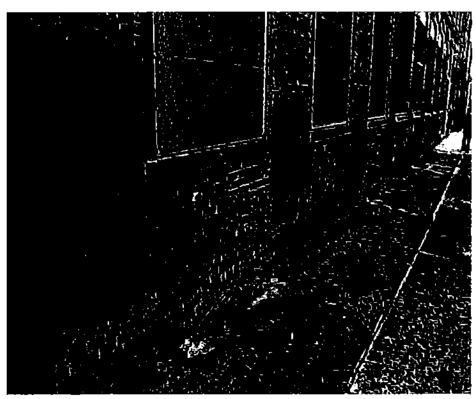


Figure 8-12 This old mill had it's basement windows completely sealed with masonry and aboveground windows covered with metal grates.

Courtesy of Glenn Corbett.

Conversions, Modifications, and Preservation of Old Heavy Timber Buildings

Many of these sturdy old buildings have been around for a long, long time, and often efforts made to remodel them have detracted from their original fire characteristics. For example, steel trusses or girders may have been inserted, making it possible to remove some columns. The new trusses, by their nature, do not have the inherent resistance of the massive wooden columns and beams they replaced. If the new trusses were of steel, 1-hour fire protection would be required for them in many codes; however, there has been many a slip between the enforcement of the code and the construction of the building.

Many such buildings are no longer used for their original purpose Figure 8-13. They are used for tenant factories, schools, storage, and discount stores, and, in some cases, are being subdivided into apartments. In many instances, the basic principles set forth earlier are seriously compromised. Fire loads are often beyond the capacity of the installed sprinklers, the sprinkler system is turned off, or the sprinkler system was removed years ago under the provisions of an older building code. Unsprinklered areas are created. The result can be and has been disaster.

The substitution of unprotected steel for heavy timber construction or the use of steel to reinforce aging or overloaded timber structures should be noted Figure 8-14. Such steel can fail early and trap fire fighters who believe they are operating in a heavy timber building. Fire departments should study alteration permits and investigate when building materials are delivered to the building being renovated.

Beams are often penetrated for electrical conduit, and in older buildings for gas pipes. Long bolts and nuts are used to attach timbers to other members. Any of these metal components can provide a path for heat to reach the interior of the building. Destruction of wood by pyrolytic decomposition may cause failure. Long solid timbers are hard to obtain, so watch for repairs consisting of spliced timbers with overlapping joints and metal connectors. These would be subject to early failure at the joint.

Figure 8-13 A self-storage facility in an old mill.
Courtesy of Glenn Corbett.

Figure 8-14 This mill was partially consumed in a large fire. Rather than tear the building down, the owner replaced the missing portion with noncombustible construction.
Courtesy of Glenn Corbett.

The Methodist Church of Gibson City, Illinois, is a building of masonry exterior walls and interior timber framing. It became necessary to remove a timber column carrying an 18-ton (16,329-kg) load. A one-story-high steel truss of steel tubes and solid steel tie bars was inserted into the building to permit the removal of the column. A description of this engineering feat was silent as to any fire protection provided to the steel. Unless the steel were protected, the truss could fail in a fire before the wooden column failed.

Full fire sprinkler protection, adequately maintained, is the only fire protection measure that can reasonably be expected to prevent a disaster in a heavy timber building. Problems arise when buildings are abandoned, are converted to multiple-unit occupancy, or are being prepared for rehabilitation into apartment or office occupancies. The fire department should anticipate these problems and plan accordingly. The political authorities are often inclined to "go easy" on a developer who promises to provide employment or housing or whatever is perceived as a good use of an aging building. In many of these conversions, assistance is provided by local government to better local economic conditions. Great pressure may be put on fire authorities to waive red tape and unrealistic regulations in a "slow-burning" building. The cost of sprinklers may be perceived as a stumbling block to the project, so this type of fire protection may be given short shrift in the renovation. In addition, there can be a question of who is responsible for the sprinkler system, particularly in a multitenant building.

Of particular note is the use of ceilings in newly renovated heavy timber buildings, particularly in the case of residential units and office spaces in mills Figure 8-15. The creation of concealed spaces (e.g., ceiling enclosures, equipment enclosures) is common in these conversions, despite the fact that current building codes do not allow such conditions. Fire fighters should point out this code violation to local building and fire code officials, who may not be aware of such an issue.

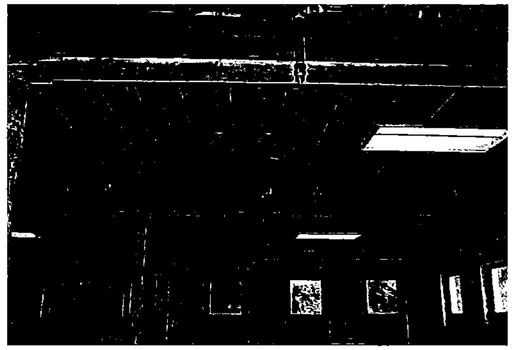


Figure 8-15 Note the sprinkler pipe "drop" in this mill conversion—is this for a future ceiling that has yet to be installed?

Courtesy of Glenn Corbett.

The fire safety of a heavy timber building depends on careful maintenance of the features listed earlier. In some cases, components such as old fire-resistive stairwell doors or elevator doors with fusible link closers may need to be upgraded and replaced.

Realistic prefire scenarios, forecasting the severe economic impacts of such a disaster, presented by top fire department offices to plant management and city officials might get attention, particularly if the loss of jobs and tax revenue is emphasized.

New Buildings of Heavy Timber Construction

While new mills are not being constructed, heavy timber construction continues to be desirable, particularly for churches and synagogues. Today, heavy timber construction is classified as **Type IV** construction. Unfortunately, a building conforming to the code definition of heavy timber construction probably lacks at least one or more of the features that the mill construction designers had learned were vital for fire safety. Typical departures from the true mill construction (and current regulations for heavy

"Dump" Buildings

"Dumps" (old, outdated, and poorly maintained buildings) are fire fighter killers. What should be done with them if your local elected officials want to save them? The obvious answer is that the building should be sprinklered. As a matter of fact, considering the hazard of fighting basement fires, some codes require sprinklers in mercantile basements or basements over a certain size.

The owners and occupants of such premises often fight the requirements for sprinklers vigorously if they are not required by code. In many cases, the building is of such low value that sprinklers cannot be paid out of "insurance savings." It costs as much to sprinkler a dump as a first-class building. But if a building is not worth sprinklering, is it worth a life? Why not abandon the outmoded concept that every dump building is worth saving? Why not identify the buildings that present an unwarranted life hazard and deal constructively with the problem created by their existence? Why not be the first fire department to write a letter like the following?

XYZ Fire Department

To the owner and occupants of the premises on 123 Blank Street:

A recent survey of your building by this department shows it to be of heavy timber construction without adequate separation into fire areas. In the event of a serious fire, the property is subject to total loss. During fires in buildings of this type, this department and other fire departments across the country have suffered unnecessary injuries and deaths. To prevent your building from becoming a death trap to our fire fighters, we recommend that you install a complete wet-pipe automatic fire sprinkler system. When these improvements have been completed and if they are maintained, it will be most unlikely that there will ever be a serious fire in your building.

We recognize that you may find these fire defense measures to be economically difficult, if not impossible. However, we have a duty to protect all of the taxpayers from the cost of injuries and to prevent the deaths of our fire fighters. Until you can comply with our recommendations, in the event of a serious fire in your building, our fire department will not permit our members to enter the building except to rescue human beings. Firefighting efforts will be confined to protecting nearby properties and extinguishing fire in your property from safe points of vantage.

In view of this determination on our part that a serious fire in your building represents an unacceptable risk of unwarranted expense to the city, and a risk to fire fighters, it would certainly seem prudent on your part to try to ensure that any fire that may occur in your building will be minor. The following recommendations are pertinent:

1. Be sure that all your employees understand that the fire department is to be called immediately in the event of fire or the smell of smoke. This is to be done before any search is undertaken or any attempt is made to fight the fire. We only have a few minutes to save your building—do not waste them. You can call us at this number: 555–1234.
2. Other pertinent recommendations [add as necessary].

Sincerely,

Fire Chief I.M. Withit

timber buildings) include cast-iron or unprotected steel columns, steel or part-steel trusses, unsprinklered void spaces (again, not permitted under building codes but found in actual buildings), highly combustible contents, unprotected vertical openings (also not typically permitted in building codes but found in actual buildings), and inadequate or no sprinkler protection.

Heavy timber structures are not being built in record numbers today, but they still find a niche for certain types of occupancies. Perhaps the most common is the modern heavy timber church, which substitutes laminated timbers (Glulam) for solid timbers (due to the inability to secure such large timbers) Figure 8-16. These churches also may use heavy timber trusses with masonry walls, including concrete block. Large places of assembly (such as indoor arenas and transit stations) have also used heavy timber construction recently Figure 8-17.

Like buildings of ordinary construction, heavy timber structures use masonry load-bearing walls and wood structural members. However, by definition, buildings of heavy timber construction have massive timbers as structural elements Table 8-1.

Be wary of architects and contractors who claim to be erecting a heavy timber structure. Many do not know the actual dimensions required. Such was the case when an architect claimed that an old downtown department store in San Antonio—which was to be incorporated into a new covered mall building—was a heavy timber structure. In fact, floor beams were nowhere near the 6- by 10-inch (15.2 by 25.4 cm) minimum dimension required by code. Construction plans and calculations had to be redone.

As theory goes, heavy timbers are difficult to ignite. They will char on the surface only. Structural stability is theoretically assured (this is the reason that testing laboratories such as Underwriters Laboratories, Inc., do not test heavy timber members—they have *inherent* fire resistance). Although this is generally true, the floors of most heavy timber structures that have been used as factories or warehouses have been soaked with a variety of flammable and combustible fluids over the years. This obviously alters the ignition and combustion characteristics of the floor planks and beams.

It is important to note that the fact that a particular material may burn slowly is much less important than how the structure is connected. All loads must be delivered to the ground; the entire path must be examined. Study the connections.

Vacant Buildings

Baltimore, Philadelphia, Lynn (Massachusetts), Minneapolis, Indianapolis, and Montréal are

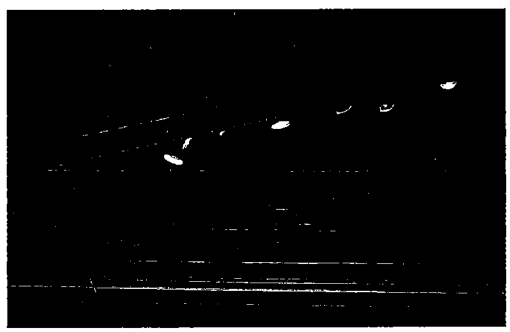


Figure 8-16 A laminated wood truss in a modern church.

Courtesy of Glenn Corbett.

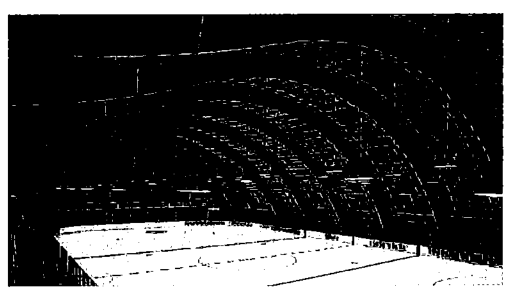


Figure 8-17 Large glued laminated timbers are used to form the roof and walls of this arena.

Courtesy of APA - The Engineered Wood Association.

Table 8-1 Minimum Dimensions of Heavy Timber Structural Members

Wood columns, sawn or glued laminated, supporting floor loads, no less than 8 inches in any dimension
Wood columns, sawn or glued laminated, supporting only roof loads, no less than 6 inches in width and 8 inches in depth
Wood beams and girders, sawn or glued laminated, supporting floor loads only, no less than 6 inches in width and 10 inches in depth
Wood beams and girders, sawn or glued laminated, supporting roof loads only, no less than 4 inches in width and 6 inches in depth
Framed or glued laminated arches (grade to floor line) and timber trusses that support floor loads, no less than 8 inches in width or depth
Framed or glued laminated arches (grade to floor line) that do not support floor loads, no less than 6 inches in width and 8 inches in depth for lower half of member height and not less than 6 inches in depth for the upper half of the member height
Framed and glued laminated arches for roofs that spring from top of walls/abutments and timber trusses that do not support floor loads, no less than 4 inches in width and 6 inches in depth

Source: NFPA® 5000™, Building Construction and Safety Code™, 2013 Edition Chapter 7, Section 7.2.5.5.1., 7.2.5.5.2., 7.2.5.5.3., page 86.

some of the cities that have suffered massive downtown fires in old combustible interior masonry buildings, some of which were heavy timber, that were being remodeled. In these types of fires, the buildings were usually wide open, with fire barriers having been removed or rendered inoperable. Sprinkler systems had been removed or disabled, and the fire had possession of the building upon fire department arrival. The only fuel was the timber interior structure of the building. Multimillion-dollar damages also were sustained by nearby structures. Many valuable assets and plans for downtown rehabilitation have gone up in smoke. In the Minneapolis fire, floors 6 through 16 of an adjacent fire-resistive high-rise office building were gutted when exposed to a fire in a department store that was being demolished. The loss was almost $100 million.

Similar problems are presented by huge structures not planned for rehabilitation but simply vacant because of economic changes. Sprinklers are often turned off to prevent freezing of the water in the pipes, and the structures, often occupied by vagrants who kindle cooking and warming fires, are an open invitation to arson. Three Detroit fire fighters died in a spectacular fire in a vacant building. Detroit had appropriated over $300,000 only days before the fire to tear down the building.

The tragic mill fire in the Worcester Cold Storage building, which was consumed on December 3, 1999, saw many of these problems lead to disaster. While this landmark fire was discussed at the very beginning of this text, it is important to reemphasize some of the important issues—an abandoned heavy timber building with homeless people starting fires, the lack of working sprinkler protection, a combustible interior finish, and almost no windows.

Full automatic sprinkler protection is absolutely necessary to prevent the heavy timber building from becoming a spectacular fire. Some such buildings have been recycled for other uses and the sprinklers eliminated. Spectacular total loss fires are a credible risk.

The reality, unfortunately, is that sprinkler protection is often turned off in these vacant buildings. That also includes "yard" hydrants within the surrounding complex Figure 8-18. (Yard hydrants—hydrants with 2½" (6.4 cm) outlets and no pumper connection—were intended for use by industrial fire

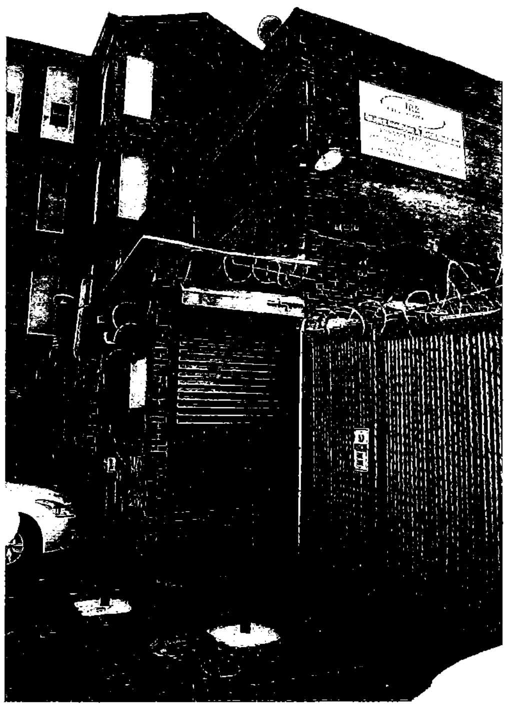


Figure 8-18 A yard hydrant in an old mill complex.
Courtesy of Glenn Corbett.

brigades, which, it was envisioned, would attach handlines to them. They were never intended to supply pumpers; they should not be used unless it is clear that doing so will not steal water from the sprinkler system.) Although the sprinkler system may be turned off, it may still be possible to feed the system through the fire department connection if the system is still intact. Attempt this only if the fire is still confined to a limited area of the building and *it is safe to do so*. Preplanning is critical.

TACTICAL CONSIDERATIONS

1. Prefire plans should call for heavy-caliber, smoothbore master streams, which provide maximum reach to cover the interior surfaces of heavy timber structures. The objective is to wet all the wooden surfaces. Due to the high British thermal unit (BTU) output and radiant heat associated with these fires, fog streams lack the velocity and penetration to be effective in these circumstances and evaporate before reaching the interior surfaces. Ineffective streams should be shut down; they waste water and rob pressure that should be used to operate master streams. Hose placement and monitor vantage points for applying large-caliber streams should be determined in advance. Dry-run drills should be undertaken. A wet drill that is effective in determining the reach of your hose streams and appliances is set up at the corner of the longest exterior wall of the building. Flow water just long enough to determine the reach and the capacity of the existing water system to effectively supply these lines.
2. Heavy timber structural elements may provide a fair measure of structural stability and a wider safety margin to operate during a fire—if the connectors and any supporting structural members are equal in rating to the largest timbers in fire resistance. If not (as is usually the case), structural collapse will be determined by failure of the weakest components. This is particularly true of timber trusses.
3. Concealed spaces (concealed floors and roof) are not permitted in heavy timber construction under the building code. Nevertheless, be wary of spaces that may have been created when an old heavy timber mill was converted to commercial work lofts or for multifamily residential use.
4. The best defense against a raging fire in an old mill of heavy timber construction is a functioning fire sprinkler system. Reliance on offensive firefighting is inadequate; access problems, radiant heat, and other unforeseen factors may inhibit manual firefighting efforts. Sprinklers are on duty 24/7 and can fuse and operate—applying water on the fire, regardless of the location and interior conditions. Apparatus operators should know the pump pressure required to support a sprinkler system. The initial pump pressure should be 100 pounds per square inch (psi). If it is a confirmed fire with fused sprinklers the maximum pump pressure should be 150 psi. Hooking up to the sprinkler Siamese connection should be an automatic task. A good driver doesn't have to be ordered by the incident commander to support an operating sprinkler system.
5. Protection against radiant heat from a fully involved mill requires the application of water directly onto the surface of the exposure buildings. The term *set up a water curtain* is often misused when protecting exposures. A water curtain is just that; it consists of water lobbed or "raining down" between the fire building and the exposure building, providing little or no exposure protection. Radiant heat waves pass right through a water curtain and can ignite the exposure building. The exposed walls and roof need to be wet from direct water application to prevent autoignition. If it's wet, it won't burn. Concentrate on exposure protection; the main body of fire in the original building is most often beyond your control.
6. Many fire departments back off from checking private fire protection systems, especially the female swivels of Siamese standpipe and sprinkler connections. They often are stuffed with trash and debris or frozen and rusted tight. This attitude can be summarized as "It's their responsibility, not ours." Not so! If you get called to a fire at this location at 2:00 in the morning, it's now your problem. Notify the fire prevention bureau of such situations. A good driver can quickly assemble the right couplings to correct the problem of frozen swivels or knows how to "back-twist" the hose counterclockwise to make the connection.
7. Expect a massive fire in a heavy timber structure in the following circumstances: if there are concealed spaces that cannot be reached with hose streams, if there

are other obstructions to interior firefighting efforts, if the contents' fire fuel has a fast, high-heat release potential, or if the building is unsprinklered. Given this massive fire, heavy water supplies will be required. A key point of the prefire plan is to determine how the water is to be applied in sufficient quantity to stop the production of heat and protect exposures.

8. Vacant heavy timber buildings that are slated for remodel or demolition may be far more hazardous than a leaking gasoline tank truck on a downtown street. Many U.S. cities undergoing urban renewal and rehabilitation have suffered massive downtown fires in these types of buildings, where the buildings were left unsecured, open to vagrants (who can start cooking and warming fires), and where sprinkler systems had been removed or disabled. Three Detroit fire fighters died in a spectacular fire in a vacant building. If the fire had a significant head start and has possession of the building upon fire department arrival, the incident commander needs to ask himself or herself, "At what point does this building no longer have any value?" Don't wear out or take risks injuring your fire fighters on loser buildings!
9. Protecting property requires a risk–benefit analysis, but it is still a core value of the fire department. Incident commanders should take calculated but limited risks in trying to save property from fire, especially in mill construction and heavy timber buildings that are occupied by businesses. Losing an operational business to a fire in a heavy timber building can have a severe economic impact on a community measured in terms of lost jobs, production, and tax revenue for the city. Fire departments should place the goal of maintaining the city's revenue and employment base high on their priority list. Speed in laying hose lines, establishing a water supply, and applying water to the fire is essential for success.
10. If the fire flow capability of available resources exceeds the required fire flow for the building, an offensive attack can be initiated. Conversely, if the fire flow requirements exceed the fire flow capability of available resources, a defensive operation is required. In other words, if you cannot deliver the required gallons per minute to extinguish this fire, you have to go defensive!

WRAP-UP

Chapter Summary

- Historically, heavy timber construction, including mill construction, has been used for large structures that have been uniquely vulnerable to fire.
- Many of these sturdy old buildings have been around for a long, long time, and often efforts made to remodel them have detracted from their original fire characteristics. For example, steel trusses or girders may have been inserted, making it possible to remove some columns. The new trusses, by their nature, do not have the inherent resistance of the massive wooden columns and beams they replaced.
- Today, heavy timber construction is classified as Type IV construction.
- Proponents of heavy timber construction often advance the term *slow burning* as an unqualified advantage because of collapse resistance.
- In fact, the slow-burning characteristic is an advantage only as long as the fire department can maintain interior offensive operations.
- Once the fire department must operate defensively, slow-burning delays extinguishment and prolongs air pollution.
- A building conforming to the code definition of heavy timber construction probably lacks at least one or more of the features that the mill construction designers had learned were vital for fire safety. Of particular note are ceilings placed directly under beams, creating dangerous concealed spaces for fire spread.
- Full fire sprinkler protection, adequately maintained, is the only fire protection measure that can reasonably be expected to prevent a disaster in a heavy timber building.
- Problems may arise when heavy timber buildings are abandoned, are converted into a multiple-unit occupancy, or are prepared for rehabilitation into apartment or office occupancies. The fire department should anticipate these problems and plan accordingly.
- Today, heavy timber structures are not being built in record numbers, but they still find a niche for certain types of occupancies such as churches and synagogues.
- Sprinkler protection is often turned off in vacant buildings made of heavy timber construction.

Key Terms

Cast-iron box An iron box built into a wall to receive the end of a girder.

Chamfered column A wooden heavy timber column that has been cut at an angle (beveled) on each of the corners to make it more difficult for fire to ignite the column at that location.

Conflagration breeder A structure that presents severe exposure problems that are capable of initiating a conflagration—a large, multiple-building fire that is not easily contained.

Corbelled A series of projections, each one stepped progressively outward from the vertical face of the wall as it rises up to support a cornice or overhanging member above.

Fire cut The end of a joist cut at an angle to permit the joist to fall out of a wall without acting like a lever and pushing the wall above it out of place.

Heavy timber Buildings constructed with noncombustible or limited-combustible exterior walls and floors made of large dimension combustible materials. Also known as Type IV construction.