CHAPTER TWO

THE CHALLENGE OF HIGH-RISE BUILDINGS

Is a high-rise building just like any other building, except taller?

In some respects, the answer is yes. But, in terms of fire protection and evacuation, the answer is a definite NO!

There are many reasons why emergencies in a high-rise building present a unique set of problems with which to deal. In a fire emergency, this becomes more pronounced because of the dynamics of fire in that kind of a structure, and of the increased burden on the fire fighters. We will attempt to cite those problems, and give some practical suggestions on dealing with them.

Before we discuss the specifics of the fire situations, let us look at the major, overriding concern in any emergency situation in a high-rise structure, or, for that matter, any large place of public assembly.

What that concern is constitutes the focus of this work. That concern is:

E-V-A-C-U-A-T-I-O-N

The bombing at the World Trade Center has been a catalyst for the re-examination of high-rise safety and security. It was brought to our attention that, on an average day, the combined occupancy of the Twin Towers exceeds 100,000 people. That population is greater than that of most American cities. Indeed, high-rise buildings are cities in themselves.

They are vertical cities. Although the World Trade Center is an extreme example, it is not unusual for a high-rise of moderate size to have tens of thousands of people inside during normal working hours.

The big difference between this population of this “vertical city” and a comparable population in a conventional city is that, in the vertical city, there is ONE WAY OUT. All the occupants must come to the ground level in order to evacuate.

In most low-rise buildings, we can think of evacuation in terms of minutes. However, in the high-rise building, we must think: in terms of hours, as was demonstrated at the World Trade Center.

In a later chapter, we will discuss terrorism in detail, and how it pertains to the corporate environment Here, I want to touch on why high-rise buildings are attractive targets.

Terrorism means striking terror into the civilian population by causing death and injury to a non~combatant population. The goal of the terrorist is to kill and injure as many civilians as possible, and to cause a serious disruption of the economic life of a community.

While it is little consolation to those who died at the World Trade Center, and to their families, that bombing was a failure in terms of the numbers killed. I am sure that the terrorists planned on killing thousands of people that day.

However, it is quite evident that, with a little better placement of the explosives, and more resulting fire, there could have been thousands killed.

THE CHALLENGE OF HIGH-RISE BUILDINGS (CONTINUED)

In terms of causing economic chaos, it was a resounding success. The loss of operations by the combined tenants of the World Trade Center and the cost of repairs total hundreds of millions of dollars.

Of course, the World Trade Center was also an attractive target for terrorists because it represents the economic strength of the United States. It is a capitalist icon. However, that does not diminish the fact that, in any good-size, high-rise building, it is possible to cause the death and injury of thousands of people.

Please note that, as will be discussed later, fire and bombs are the weapons of choice for almost all terrorists, domestic and foreign. It is also true that fire is an often-used weapon by non-terrorist individuals seeking retribution for one reason or another.

We do not want to cause anyone to think that the only possible reason for an emergency in a high-rise building is a terrorist attack. We are commenting on the fact that it was a terrorist act that caused us to re-think the entire issue of protection and evacuation in a high-rise environment.

There are several thousand fires in high-rise buildings each year. However, for the most part, high-rise buildings rate quite well in terms of fire safety. Much of this has to do with the fact that, because they are high-rise buildings, they must meet very strict requirements in terms of fire protection and safety. Much of this is considered in the design stages, and incorporated into the construction.

Now, as NFPA suggests, we must go back and take a second look at the level of protection that has been provided, and this look has to be with a view toward what happened at the World Trade Center, and what could happen again somewhere else.

While we take this look, let us keep in mind that fire is not the only reason for an evacuation. Gas leaks, lightning strikes, bomb threats, hazardous materials, dangerous weather conditions, and power outages are just some of the other reasons that might cause the evacuation of a high-rise or place of public assembly.

As we go through this work, the emphasis will be on the fire situation, but we want to keep the issue of evacuation in the context of any need.

One reason that we emphasize the fire scenario is that we know that fire travels and grows very quickly and, as we have stated above, evacuation of this type of structure happens very slowly. Therefore, we are not only working with the extended time for evacuation, but with the rapid time frame in which fire can spread.

This is why the normal defense procedure in a high-rise fire situation is sometimes referred to as “defend in place”. In other words, use all of the tools at our disposal to contain the fire so that we only need to evacuate a portion of the building. Of course, in the case of the World Trade Center or in a similar case, total evacuation is required. But, in many cases, it is not.

What we want to do here is to look at what the dynamics of fire are in a high-rise building, and what are all those tools with which we have to work to combat those conditions. In order “to do this, we need to understand the basics of what fire is, how fire can be fought, and how to properly use the tools we have.

THE CHALLENGE OF HIGH-RISE BUILDINGS (CONTINUED)

First, we need to look at what a high-rise building is, and how high-rise buildings can differ, depending on the type of construction used in building them. All high-rise buildings are not created equal. In fact, there are great differences in the level of fire safety that can be found in differing types of construction.

What is a high-rise building? The answer to that question can vary greatly depending on the municipality in which you are asking it. We all have an idea of what a high-rise is; we think in terms of the "skyscraper".

However, the actual definition will depend on how the fire department of a particular jurisdiction views it's own capability to fight a fire in that building.

In some municipalities, a high-rise is defined as four stories or 40 feet above ground. In other communities, it is defined as six stories or 60 feet; in still others, ten stories or 100 feet.

We are basing this study on the experience and requirements of the New York City Fire Department. For that city, 75 feet is the point at which a building becomes a high-rise. Other buildings will come under the jurisdiction of the "High-Rise Code" because of other criteria, but we will discuss that in a later chapter.

The general criteria used by a municipality to define a high-rise is usually based on these factors:

- The ability for a fire department to mount a ground attack for a fire in that building. This is where the term "horizontal high-rise" comes from. This means that a building can present the same problems to a fire department as a high-rise would, even though it is not· as tall as one might expect.
- How high the fire department can go vertically with the equipment they have for the purpose of rescue and fire fighting.
- If the construction of the building will create the "stack" effect if there is a fire in it.
- Estimated evacuation time for the occupants.

It is obvious that the concerns for a 60-story building with 30,000 occupants are different than for a 20-story building with 5,000 occupants, but the same problems are present in both buildings, just on a different scale.

If we consider all of the reasons, we will learn why fires in high-rise buildings require so much more manpower. It might be that the situation in the second building described above is of the same magnitude as the situation in the first building above, depending on the manpower available to the fire department to deal with each situation.

What are some of the problems that are unique to a high-rise building?

- Modem high-rise buildings are built to be energy efficient. This means that they make very good chimneys, allowing heat and smoke to spread upward, with little ventilation for that heat and smoke.
- Because of the vertical rise of heat and smoke, it is often difficult to find the actual seat of the fire, or to properly identify the actual "fire floor".
- Because fire fighters must transport heavy equipment upward, they become fatigued more quickly, requiring more fire fighters to respond.
- Because of the added time necessary for search and rescue, additional fire fighters are needed. Indeed, up to five times the manpower might be required to deal with a fire in a high-rise building.
- It is more difficult to get water with which to fight the fire to the upper floors. Fire fighters must pump water up to the fire floors, depending on the available piping and water supply of the building's systems.

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- In most fire situations, we should not use the most readily-available means of evacuation, the elevator. Therefore, the stairways, which might be filling with smoke, must be used by occupants. evacuating and by fire fighters moving upward.
- The fast, upward rise of smoke and heat in a high-rise can create extreme levels of heat and humidity, increasing the fatigue factor and decreasing visibility.

With the reasons listed above, we can begin to see why the design and construction can play important roles in how a fire will react in a particular building. We now want to look at some comparisons in the type of construction used in high-rise buildings.

When we look at these comparison we want to note that, for the most part, we are talking about commercial high-rise buildings, and high-rise hotels. We are not generally considering residential high-rise buildings.

In fact, the laws that pertain to fire safety in high-rise buildings in New York City, pertain basically to commercial high-rises and hotels. This too, is based on construction, as we will soon see. Most residential high-rise buildings still adhere to many of the older construction methods and design criteria. Those buildings are actually rated very high in fire safety.

Here, let us begin to review the comparative design and construction of commercial high-rise buildings. The comparison is based on the design and construction that resulted from the building codes in the City of New York during different time periods.

While I have no specific information about the building codes of all other major municipalities, I must assume that the architectural and engineering community probably adopted similar building techniques within relatively similar time periods, and there should be somewhat of a constant in design throughout the country.

In 1976, Oklahoma State University, one of the leading schools of Fire Science in the country, published a manuscript prepared in association with IFSTA, the International Fire Service Training Association, a work titled "Fire Problems In High-Rise Buildings".

Chapter One of that work deals with "Unique Fire Problems in High-Rise Buildings". Contained therein is a good description of several of the circumstances that are peculiar to the high-rise building, things that cause special problems in those buildings. The following is a part of that chapter.

LOCATING THE FIRE

The first problem that fire fighters encounter upon their arrival at a high-rise building is locating the fire. In smaller structures, the fire is usually visible. As the size of a structure increases, sources of information other than sight become significant; the larger the building, the greater the probability that information may be misleading or incomplete. Continuity of communications may many times be overlooked because of an eagerness to locate the fire. From the arrival of the first-due fire companies and until a command post is established, this continuity must exist.

Human Error - Information received regarding the locations of the fire may be inaccurate. For example, a person who rides an elevator to a given floor and encounters smoke when the elevator door opens is most likely to report a fire on that floor. The actual fire, however, may be several floors away from the location reported.

THE CHALLENGE OF HIGH-RISE BUILDINGS (CONTINUED)

Mechanical Error - The mechanical and electronic devices designed to detect smoke and heat might activate on a floor several floors above the actual fire floor, because of the dynamics of fire in a high-rise structure. Therefore, in the event a fire is reported only by an automatic device, a false location might be reported.

Physical Evidence - Again, because of the nature of the dynamics of fire in a high-rise structure, the physical evidence of a fire does not necessarily mean that the fire started on a given floor or that it is contained on that floor. It may have spread from floors below through concealed spaces, such as vertical ducting, or improperly sealed "poke-through construction." A minor fire discovered on one floor may be the only visible evidence of a major fire on that floor. Smoke emitting from an outlet should not lead the fire fighter to the assumption that the fire is contained within system ducting.

GAINING ACCESS INTO THE BUILDING

External access to high-rise structures can be very limited. Building setbacks, landscaped areas, reflecting pools, and weak structure covering underground parking and service areas can severely limit an approach to the building by aerial ladder trucks. Sealed windows may have to be broken, and breakage can create a hazard for fire fighters and others in the area.

COMBATING SMOKE SPREAD

Smoke ordinarily encountered at a fire consists of a mixture of oxygen, nitrogen, carbon dioxide, some carbon monoxide, and finely-divided particles of soot and carbon. Polyurethanes, polycarbonates, and other synthetic materials found in high-rise buildings release a miscellaneous assortment of toxic byproducts which are also contained in the smoke.

A building with sealed windows contains all the products of combustion until fire fighters do something to release them. Although no exterior leakage occurs through sealed windows, leakage does occur from floor to floor within the building.

As smoke increases, visibility decreases. Visibility during a smoldering fire may be reduced to a few feet, even though strong lights are used when smoke is trapped within a sealed building. Finding the fire under these conditions is extremely difficult.

Since heated smoke rises, vertical distribution of smoke through any opening must be anticipated.
Open stair shafts, elevator shafts, and floor-to-floor air-conditioning systems-are the main channels that carry smoke. Modem construction techniques which utilize concealed ceiling spaces to hide utility services have created new exposure problems for the fire service. In theory, each floor should act as a concrete barrier to fire from every other floor. Holes are cut through floors as various utilities are connected. In this manner, utilities are let in on any given floor from the concealed space below. Voids around piping and ducting installed in poke-through construction holes are generally required to be sealed. In practice, however, much of the resealing is left undone and, when resealing is done, it can deteriorate over time.

As a result, many fire-resistive buildings are literally full of holes. Improperly sealed poke-through construction also permits passage of smoke from floor to floor. In sealed building, where there is no possible leakage to the outside, experience has shown that smoke will be found on at least three floors, even when only a minor fire on one floor is in progress. After many floors have become smoke-filled, finding the fire floor becomes a major operation.

THE CHALLENGE OF HIGH-RISE BUILDINGS (CONTINUED)

In addition to traveling through hallways, smoke may spread horizontally through connecting ducts, concealed spaces, and through air-conditioning systems. Some modern air-conditioning systems use common ceiling spaces as return plenums, and the spread of smoke horizontally through these plenums is very rapid. The reason for the rapidity of smoke spread is that smoke, cooled by the air-conditioning systems, does not rise as it normally does but spreads horizontally instead, making it more difficult to locate the fire.

Heating and air-conditioning systems form natural channels for distribution of smoke. Forced drafts which are developed within such systems may spread smoke from floor to floor throughout the building. Systems must be shut down quickly to prevent this rapid spread of smoke.

Regardless of its temperature, smoke increases the urgency of rescue operations. Building occupants who are trapped within an area of the building because of lack of visibility will succumb unless rescued promptly. The problem of smoke toxicity is magnified in sealed buildings because there is no natural ventilation.

Smoke and gases confined in a building during a fire interfere with size-up, as well as with access and visibility for rescue and fire fighting operations. Hot, unburned products of combustion that have accumulated in a building can ignite explosively when a supply of oxygen is suddenly made available. Buildings must be ventilated quickly to prevent smoke explosions. The explosion hazard is greater in sealed buildings. If smoke and fire gases do explode, they will most likely blowout windows, which will make a fresh source of oxygen available to feed the fire.

During the early stages of a fire, smoke and fire gases are not a serious problem. Even in sealed buildings numerous areas are available into which smoke can be dissipated. Visibility thus remains at a workable level As the fire increases in size, the areas into which smoke has expanded will become more densely filled. Thus, visibility is gradually and continuously reduced until ventilation is accomplished.

Fires produce numerous toxic gases, the most common gas being carbon monoxide. A person exposed to concentrations of carbon monoxide as low as 1.3 percent in air may die within one to three minutes.

Additionally, smoke and fire gases displace oxygen within a structure. The insidious effect of an oxygen deficiency is not generally understood. Short exposures to atmospheres where oxygen content has been reduced from the normal 21% to about 15% will impair the physical performance and seriously affect judgment. Exposure to an atmosphere with less than a 16% concentration of oxygen can result in the loss of consciousness, and death.

Smoke hazards in older multi-story buildings which lack central air-conditioning systems and do not use plenum ceilings as returns is much less. Fire tend to be visible from the area where they begin, and often can be seen from the outside by fire fighters, making it much easier to identify the fire floor. In these buildings, smoke, heat, and fire gases do not have the avenues available to spread, as is the case in sealed, core construction buildings. Thus, these types of buildings are actually more fire-safe, and present much less potential hazard.

COMPARATIVE CONSTRUCTION METHODS FOR HIGH-RISE BUILDINGS

The differences we are about to discuss have come about because of one overriding factor, COST. The reasons why high-rise, and other buildings, are built as they are now, and not like they were fifty years ago, are cost-related reasons.

THE CHALLENGE OF HIGH-RISE BUILDINGS (CONTINUED)

We have all heard the saying "They don't build them like they used to." The fact is, they don't; they can't afford to. In reading about the World Trade Center bombing, we have seen comparisons made between the World Trade Center and the Empire State Building, in terms of construction and the ability to withstand a shock, such as a bombing or being hit by an airplane.

The financial reality is that it would be economically prohibitive to construct a building today the way the Empire State Building was built. That is the first cost consideration.

The second cost consideration is the cost of heating and cooling these buildings. Again, much of the reason for the newer "core" construction is for cost savings on heating and cooling. This became especially important in the early 1970's, when the World Trade Center was built, because of our first experience with a "fuel shortage", and our first experience with exorbitant fuel costs. Prior to that time, the cost of heating and cooling was not a major consideration in. building design.

Another cost factor based on construction type is maintenance. Modem high-rise buildings are more cost-effective to maintain than older design types.

The primary difference between newer and older construction is what is known as "core" construction. This is a building design that utilizes a center "core", and builds outward from that core. All essential building services are run vertically through that core.

There are other design differences, also. In order to study them, we are going to look at these differences in relation to the changes in construction in New York City.

In New York City, high-rise buildings built prior to 1945 were of markedly different construction than those built after 1968. Those built prior to 1945 generally were built under the 1938 Building Codes. Those built after 1968 were based on the 1968 Building Code. Those built in betweenJ945 and 1968 were a mixture of various code variations, much of which depended on the interpretation of the AHJ (authority having jurisdiction) for a particular building.

An interesting fact is that older high-rise buildings were considered so fire safe that, in 1954, the New York Fire Department considered reducing manpower in those districts that had a large number of high-rise buildings. Now, as we previously stated, increased manpower is required to deal with high-rise building fires.

Some of the Outstanding Differences

- Pre-1945 buildings are of heavy-weight construction, usually between 20 to 30 pounds per cubic foot.
  Post-1968 buildings are of light-weight construction, usually 8 to 10 pounds per cubic foot
- Pre-1945 buildings are very well compartmented, with slab-to-slab partitions with at least two-hour fire ratings.
  Post-l968 buildings are not built in compartment format
- Pre-1945 buildings have structural steel components encased in concrete.
  Post-1968 buildings have protection of structural steel components done by spraying on a coating of fire proofing material.
- Pre-1945 have exterior walls of masonry construction.
  Post-1968 have exterior walls constructed of glass and steel.

THE CHALLENGE OF HIGH-RISE BUILDINGS (CONTINUED)

- Pre-1945 have exterior walls substantially tied to all floors.
  Post-1968 methods of securing the exterior walls leaves a space of 6 to 12 inches, which requires additional fire stopping.
- In pre-1945 buildings, plenum-type ceilings .are generally not found.
  In post-1968 buildings, plenum ceilings are extensive and lack fire-stopping ability. They are used to return the air to the air handling systems, and for running the components of the electrical, communications, and other building systems.
- Pre-1945 buildings were generally steam-heated by compartments, and individual air conditioning units.
  Post-1968 buildings usually have central heating, ventilating, and air conditioning (HVAC) systems that serve several areas or floors.
- Pre-1945 buildings have exterior windows that can be opened to allow for venting heat and smoke.
  Post-1968 building exterior windows usually cannot be opened.
- Many high-rise buildings built between 1938 and 1968 had fire towers which could be used as "areas of safe refuge".
  Post-1968 buildings do not have fire towers.
- Pre-1945 floors are constructed of reinforced concrete.
  Post-1968 floors are lightweight, usually consisting of lightweight concrete and "Q" decking.
- Pre-1945 construction did not use core techniques.
  Post-1968 buildings almost all use core construction.
- Pre-1945 stairways are remote from each other, most of the time at opposite ends of the building.
  Post-1968 stairways are also part of the core concept, most often very close to each other in the core of the building.

These differences present two totally opposite sets of effects on the dynamics of fire in the respective buildings, and of fighting those fires.

In general, being of heavy-weight construction and being built in compartment fashion means that fires are usually very well contained in the area of origin by the slab-to-slab methods and by the exterior walls being tied into the floors.

This is the type of construction is still seen in much residential highMrise housing, accounting for the differences in relative levels of life safety.

The fact that windows can be opened to allow the venting of heat and smoke is very different from having windows that cannot be opened, which adds to the "stack" effect.

Individual steam heat and individual air conditioning units also help to contain a fire in one area. Central HVAC systems and plenum ceilings allow heat and smoke to spread, quickly, into large areas of the building.

The use of the core construction method requires all services to be run vertically through the center of the building. Along with all of the services, elevators and stairways are also run in this core.

THE CHALLENGE OF HIGH-RISE BUILDINGS (CONTINUED)

This adds to the "chimney" effect and allows fire to spread, quickly, both vertically and horizontally. It also puts the elevators and stairways very close together, in what could be one dangerous area, as opposed to having elevators and stairways at opposite ends of the building. In that case, it is highly unlikely that both stairways would be contaminated and, in some cases, the fire department will allow the use of elevators on a remote side of the building, away from the fire.

Prior to Local Law #5 and Local Law #16 in New York City, there were many variances allowed in the construction of high-rise buildings. These variances were based on the Building Codes. It is not unusual to see high-rise buildings without sprinkler systems, although the Code did call for them. This is because a variance was allowed as a "trade off' for another form of protection.

We also see attempts to "compartmentalize" core construction buildings, either as an added measure of fire safety or as a trade-off. In practice, this does not work very well because you· cannot change the basic design of the core construction, and that is very different from compartmented construction. Also, you cannot keep all of the vertical openings that are needed in core construction sealed; thus, they become a route for heat and smoke to travel.

We are providing an appendix to this work which is a reprint of New York City Local Law 5, Dealing with High-Rise Buildings and Other Buildings of Large Occupancy Concern, Where Evacuation Becomes a Major Consideration.

We might want to look at taking some of the points of these laws and putting them to work in other communities, or even incorporating some of them into a new "standard".