

Smoke Hazards in High-rise Fires – Three Things to Consider

By Capt. Mike Gagliano, Seattle Fire Department

High-rise fires are intense. Some of the most challenging fires in the history of the fire service have occurred in these types of structures and more are coming. Among the many challenges and consequences we'll discuss in future articles, none are as devastating as the effects of smoke and their associated fire gases. The high-rise environment presents some unique challenges as it relates to the impact of fire smoke. These are three you should always consider:

- 1. *Smoke kills***
- 2. *Smoke and its gases are present at varying levels in the structure***
- 3. *Smoke exposure causes unpredictable behavior to those exposed***

Smoke Kills

This should be obvious to any firefighter who is even casually engaged in the craft of fighting fire. While the percentages change from year to year, smoke is a leading killer for civilians and firefighters alike. The obvious mechanism of asphyxiation is a primary culprit and occurs in many ways. Some will be overcome by the damage that occurs to their airways or choking due to thick smoke. Others will be unable to get oxygen due to disabled respiratory or circulatory systems. Asphyxiation is a major concern in the smoke environment but is only a part of the story when it comes to the killing tendencies of smoke.

Disorientation caused by decreased visibility leads to many deaths even if the ultimate cause is something else, such as burns or asphyxiation. For firefighters, getting lost or disoriented is often the deciding factor in whether or not their air will last long enough for them to get out of the structure. Areas in the structure that were navigable upon entry become confusing when smoke density increases. Hazards such as holes in the floor are often masked by the smoke and falls or other injury-inducing incidents are more likely.

Smoke is essentially unburned fuel. As such, it is always looking for the right air/heat mixture to ignite. While many deaths are ruled to be burn-related, it is often the smoke that ignites and causes the flashover or back draft. Some smoke events are so violent that they cause structural collapse, contributing to the death of firefighters and civilians. Typically, the after action reports will site the structural failure and its direct impact on the victim as the cause of death. The cause of the collapse, however, may very well have been the smoke and its volatile reactions. In addition, many trapped firefighters survive the collapse but asphyxiate before rescue crews can provide air.

Smoke is present at different levels

Smoke finds many ways to travel in high-rise fires. The natural openings in the structure can allow smoke to most parts of the floor and may extend upward as pressure builds. HVAC systems can provide

unpredictable avenues for smoke travel until these systems are secured. Fire companies can also create openings if they are not cognizant of controlling flow paths. Openings created by initial construction and remodeling will create paths for smoke travel that should be anticipated. One of lessons learned from the One Meridian Place fire in Philadelphia (1991) is the impact penetrations in fire rated floors and walls can have on fire and smoke conditions. Fireproofing these openings was identified as a “must do” for future construction and ongoing emphasis for fire inspections.

While the factors listed above are well known by most firefighters, there are others that are equally as deadly and less obvious. Smoke and fire gasses are typically thought to travel upwards due to the heat involved in the combustion process. Upward travel is not the whole story, however. Gases actually move to all levels based on their temperature, chemical properties and the ventilation conditions.

Deborah Wallace describes some of the variables involved in gas levels at fires in her outstanding book, *In the Mouth of the Dragon: Toxic Fires in the Age of Plastics:*

Because smoke and fumes kill and injure people at a distance from the fire itself, the flow of air and gas assumes special importance in fire safety. The fire establishes its own circulation of atmosphere. Hot smoke and gases rise and travel along the ceiling, and cooler air rushes along the floor to the fire to fill the partial vacuum created by the rising, expanding heated gases. The smoke and hot gases will rise from the fire floor to upper floors by stairwells, shafts, breaches in walls or between floors for building systems, and through the ventilation system. Prevailing outdoor winds can even blow vented smoke back into the open windows of a fire buildings upper floors.

If the smoke and hot gases have no other exit, they will even travel to lower floors. This happens when pressure of the heated and expanding cloud builds up, and the upward opening can't relieve that pressure sufficiently. The smoke will diffuse downward. Also, if the smoke and heated gases impinge upon a cool surface and are suddenly and dramatically cooled, they will drop down. This plummeting is especially characteristic of decomposition products that, at equal temperatures, are heavier than air, such as hydrogen chloride (which PVC emits). Heat is the only reason for a rising hydrogen chloride plume from decomposing PVC. A low-lying “steam” or fog of acid gas is also a common emission from this plastic.

Gases such as hydrogen chloride will be present at lower levels. Carbon monoxide and similar weighted gases will disperse evenly throughout the spaces. Lighter gases such as hydrogen cyanide will rise to higher levels though even that can be deceptive. Before hydrogen cyanide rises, it can be found off-gassing from things such as carpeting. So an exposure at a lower level is very possible.

Whether from the chemical composition of a “heavier than air” gas, the heated rise of others or the swirling atmosphere that moves many gasses to varying levels, it is apparent that toxins will be present in many, varied areas.

Smoke causes unpredictable behavior in those exposed

Smoke adds another variable to the fire attack due to the impact it can have on the actions of those exposed. Whether in civilians or firefighters, the impact of smoke on exposed airways can induce panicked behavior and erratic actions.

Unpredictability is further exaggerated by the physiological impacts of the gases in smoke that limit oxygen and cause bizarre behavior and decisions. Gases such as carbon monoxide and hydrogen cyanide impact the body’s ability to transfer and absorb oxygen. When the brain is not properly oxygenated, all bets are off as to how someone will respond.

In the Southwest Supermarket fire, Bret Tarver (Phoenix Fire Department) literally fought off his rescuers due to the impact of the fire gasses on his system. This type of combative behavior would be very much in line with expected impacts from exposure to hydrogen cyanide. At a residential basement fire in Seattle, Captain Mike Milam (Seattle Fire Department) was seen standing up in a superheated fire environment due to disorientation because of smoke exposure. Fellow firefighters were pinned to the floor by the heat but recall Milam exhorting them to get out of the fire until he eventually collapsed.

Both Tarver and Milam were removed from the building only after they lost consciousness. Fortunately, paramedics were able to revive Capt. Milam. Sadly, FF Tarver didn't make it. His death is a tragic reminder of the dangers of fire smoke.

Solutions all involve Air

The simple solution is that a smoky, gas filled environment requires those inside to have clean air, however they can get it; but getting that air is not so simple. There are two primary sources of air in a high-rise fire: The air that is already there and the air you bring with you.

There are typically pockets of air in every structure involved in fire. The quality will vary depending on different factors including degree of compartmentation, temperature and types of gasses present. Finding areas with limited smoke exposure may be a viable choice. But relying on this is a dicey option given all the variables present at fires. Poor visibility, complex layouts and the limited time factors involved can make finding air problematic.

Bringing additional air and staging it at high-rise fires is also something to consider. Firefighters bring their initial bottle of air and will have staged air present at some point in the incident. The challenge here is that it will take time to get these air resources in position, especially in the earlier stages of the fire when manpower is limited and needed for fire attack.

An interesting combination of these two concepts is the firefighter air replenishment system (FARS) that combines both concepts. This building-installed “air standpipe” provides a source of air in the initial

stages of the fire should it be necessary due to a MAYDAY or other emergency. In sustained operations, which most high-rise fires will require, the system can be supplemented by arriving air units to provide a sustained supply that is present at all levels of the building, just as water standpipes are. This would save a great deal of intensive work and time, and it adds predictability to the presence of air for firefighters. In his article, "FARS — A Firefighter Safety Concept Whose Time Has Come," Chief Mario Trevino (Retired) details many areas in which the system will benefit operations in high-rise fires. Among these are enhanced firefighter safety, efficiency of operations and simplified command and control.

The conclusion is clear

However the air supply issue is addressed, the fact remains that dealing with the smoke is critical in high-rise-fires. Its presence is responsible for countless deaths of civilians and firefighters, and should be dealt with as the killer it is. Not treating smoke as a major factor in your operational planning is a sure step towards disaster.

Mike Gagliano has 29 years of fire/crash/rescue experience with the Seattle Fire Department and the United States Air Force. He is the Captain of Ladder 5 and a member of the Seattle Fire Department's Strategic Planning Leadership Group. Captain Gagliano has written numerous fire service articles, is co-author of the bestselling book [Air Management for the Fire Service](#) and the SCBA chapter of the [Handbook for Firefighter 1 & 2](#) from Pennwell. He is a member of the Fire Engineering/FDIC Advisory Board, a Director for the Firesmoke Coalition (firesmoke.org), on the advisory board of the UL-Firefighter Safety and Research Institute and teaches across the country on Air Management, Fireground Tactics, Leadership and Company Officer Development. Mike co-hosts the popular Fire Engineering radio webcast "The Mikey G. and Mikey D. Show" and partners with his wife Anne (firelife.com) to teach on strategies for developing and maintaining a strong marriage/family.