# Is Structure Fire Smoke Killing Us?

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Hopefully, most Station Pride readers have seen, or have at least heard about, the results of research performed by Underwriters Laboratories (UL) to better understand the changing dynamics of contemporary residential structure fires. To summarize, UL found that residences are now larger, have more open floor plans, contain increased fuel loads from synthetics and composites, and are made with substantially different construction materials and methods than those built just a few decades ago. The consequences of those changes are faster fire propagation, shorter time to flashover, rapid changes in fire dynamics, shorter escape times, and shorter time to collapse. (*Kerber*) Additional UL research has identified the contaminants in today's smoke, and their greater levels of toxicity, but the acute

and chronic health effects from exposure to that smoke is still being studied. This article is intended to present currently available information so that firefighters and officers may have a more immediate understanding of the hazardous materials in today's smoke, particularly carbon monoxide (CO) and hydrogen cyanide (HCN) because of their significant toxicity.

Fire service personnel are at least generally aware of the hazards from CO, typically because of having to respond to alarms associated with combustion-based heating systems and the resulting use of gas meters. However, many may not be very familiar with the associated exposure limits. The following table summarizes the legally enforceable limit from the Occupational Safety and Health Administration (OSHA), as well as recommended limits from the National Institute for Occupational Safety and Health (NIOSH). Both agencies express those limits as an 8-hour time-weighted average (TWA) inhaled exposure, which is intended to cover a standard workday, in parts per million (ppm). As a mental reference, 1 ppm is roughly equivalent to 7/10 of a gallon in an Olympic-size swimming pool.

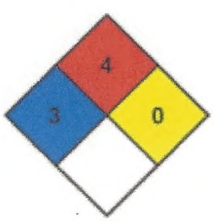
| | | CO | HCN |
|---|---|---|---|
| OSHA | Permissible Exposure Limit (PEL) | 50 ppm | 10 ppm |
| | | | |
| | Recommended Exposure Limit (REL) | 35 ppm | 5 ppm |
| | Ceiling (shouldn't be exceeded, even briefly) | 200 ppm | N/A |
| NIOSH | Immediately Dangerous to Life and Health (IDLH) | 1,200 ppm | 50 ppm |

Unlike CO, my experience is that many firefighters are not familiar with HCN, even though its existence is smoke has been known for many years. They often have no way of measuring their exposure to it, so they typically have no familiarity the associated exposure limits. Note that OSHA's PEL for HCN is 5-times less than that for CO, which is the same as saying they perceive it to be 5-times more toxic. Unfortunately, that's only the tip of the iceberg.

The Agency for Toxic Substances and Disease Registry (ATSDR), a branch of the Centers for Disease Control, has published a medical management guideline for HCN which states that it smells like bitter almond and has an odor threshold of 2 to 10 ppm (compare that to the PEL). However, the guideline also says that the odor threshold "...does not provide adequate warning of hazardous concentrations..." because HCN causes olfactory fatigue (i.e., you stop smelling it even though the airborne concentration could be unchanged or increasing) and the fact that 10% to 20% of the population can't smell it at all due to genetic traits. The guideline provides ominous warnings about the health effects of HCN exposure: (1) highly toxic by all routes of exposure and may cause abrupt onset of profound central nervous system (CNS), cardiovascular, and respiratory effects leading to death within minutes; (2) exposure to lower concentrations of hydrogen cyanide may produce eye irritation, headache, confusion, nausea, and vomiting followed in some cases by coma and death; (3) hydrogen cyanide acts as a cellular asphyxiant (prevents the utilization of oxygen in cellular metabolism), and; (4) the CNS and myocardium (heart muscle) are particularly sensitive to the toxic effects of cyanide.

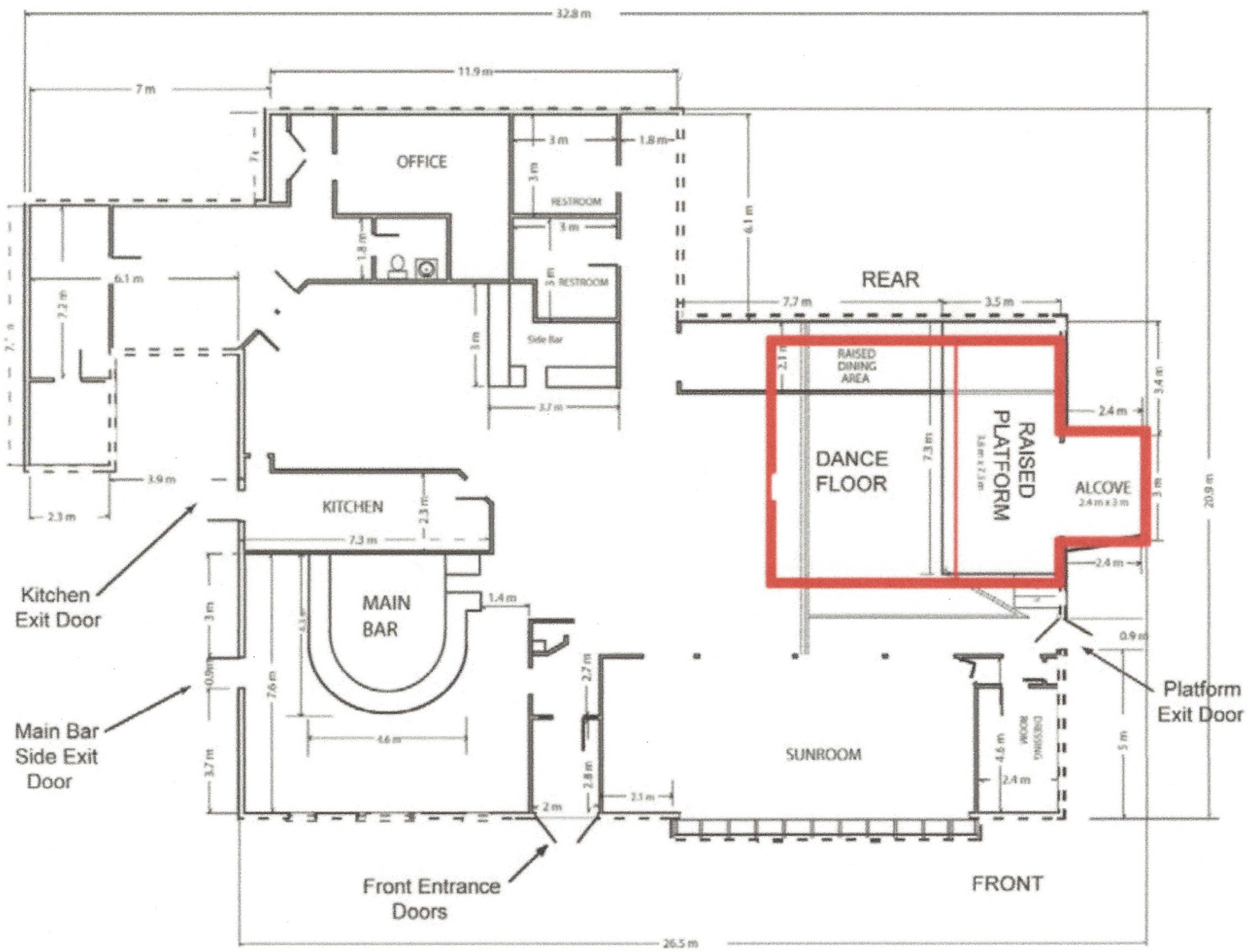
We should pay particular attention to the effect that HCN has on the cardiovascular system and myocardium for this simple reason: the most recent National Fire Protection Association (NFPA) statistics indicate the nature of injury for 51% of the 70 to 100 annual firefighter line of duty deaths in the United States is "sudden cardiac death." Furthermore, *Prehospital and Disaster Medicine*, the official journal of the National Association of EMS Physicians, has reported that "...cyanide exposure is: (1) to be expected in those exposed to smoke in closed-space fires; (2) cyanide poisoning is an important cause of incapacitation and death in smoke-inhalation victims, and; (3) that cyanide can act independently of, and perhaps synergistically with, carbon monoxide to cause morbidity and mortality." (*Marc Eckstein, MD, FACEP, and Paul Maniscalco, MPA, DrBA(c)*) I have to wonder if at least part of those 36 to 51 annual firefighter fatalities are the result of acute and/or chronic effects of CO and/or HCN from smoke inhalation? If that is the case, then I also wonder how we could better detect and mitigate or prevent such exposures?

The bottom line is that structure fires these days should be thought of and managed, at least in part, as a hazmat incident. That means personnel must be trained about the toxicological hazards and their significance, air monitoring needs to occur, an appropriate level of personal protective equipment must be worn, protective zones need to be established, and decontamination needs to occur for those exiting the hot or warm zone. If you still think that approach is even somewhat extreme, take a look at the NFPA 704 markings copied from a Safety Data Sheet (SDS) for CO (left) and HCN (right).

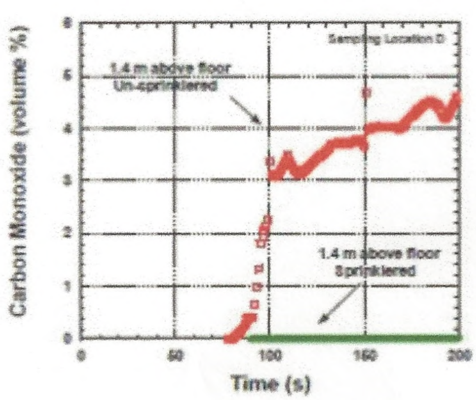



What firefighter would not be thinking they're in a hazmat situation when pulling up to a working fire at an occupancy having those markings on its exterior? Some may argue that each SDS is for a pure chemical, not the mixture that would be found in smoke. To that I say the National Institute of Science and Technology's (NIST) June 2005 report on its technical investigation of The Station nightclub fire proves that very high concentrations of these extremely toxic chemicals can develop with surprising rapidity.

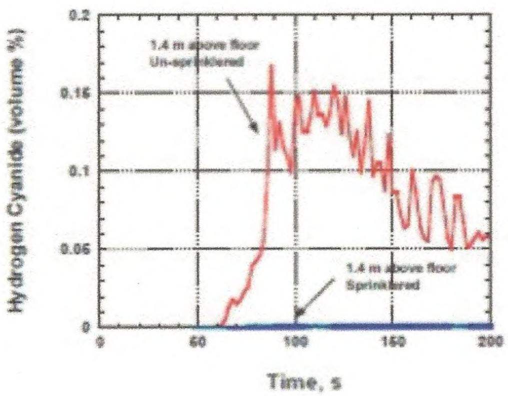
The Station fire occurred in West Warwick, RI in February of 2003 when pyrotechnic devices used by a nationally popular band ignited polyurethane foam used on the stage walls and ceiling as soundproofing. The fire then spread quickly along the walls and ceiling area over the dance floor. Smoke was visible in the exit doorways in a little more than one minute, and flames were observed breaking through a portion of the roof in less than five minutes. One hundred people died because egress from the nightclub, which was not equipped with sprinklers, was hampered by crowding at the main entrance to the building. The fire's progression was captured by a local television station's camera crew that was filming the show, which helped NIST define a clear timeline of events. The NIST investigation involved extensive use of real-scale mock-ups, measurement of key parameters during live-fire testing, and computer modeling. The parameter measurements taken at stations approximately 1/3 (Location C) and 2/3 (Location D) of the distance from the stage (raised platform) to the rear of the dance floor are particularly relevant to this article (The Station's floor plan from the NIST report is provided below). Both locations generated very similar results, so I'll provide only those for Location D in the interest of brevity.




NIST considered any room to be untenable when any of the following fire conditions occur: (1) temperature exceeds 120° C (250° F); (2) oxygen content drops below 12%, or; (3) atmosphere becomes IDLH. The graphs for CO and HCN at Location D, which was 1.4 meters (4.6 feet) above the floor, paint a dramatic picture of how quickly The Station's dance floor became untenable. Note that the readings are expressed as percentages, and understand that 1% equals 10,000 ppm. Thus, CO at Location D was approximately 20,000 ppm (17-times IDLH) and HCN was approximately 1,750 ppm (35-times IDLH) at 90 seconds after ignition. Interestingly, Location C showed consistently lower HCN readings than Location D, implying that parameter's concentration may tend to increase as distance from the fire increases.



Another graph in the NIST report showed that the rising CO and HCN levels corresponded with declining oxygen content. Yet another showed the room was untenable due to temperature at 80 seconds after ignition. Not surprisingly, the tests also revealed that the room would have remained tenable had it been equipped with fire sprinklers.




Fire and emergency medical services in the RI region paid understandably close attention to what the NIST investigation revealed, and became sensitized to the potential for HCN poisoning from smoke inhalation. Then, "…in March of 2006, a firefighter in Providence, R.I., was diagnosed with cyanide poisoning after responding to a building fire. Over a period of 16 hours, seven more firefighters were diagnosed with cyanide poisoning, including one who suffered a heart attack while working the pump panel in the front of the residential structure. It was only through a series of coincidences that emergency room physicians checked that last firefighter for cyanide poisoning." (*Rochford*)

The Providence Fire Department promptly formed a committee to investigate those casualties, then issued its report in May of 2006. They found "…overwhelming evidence exists that cyanide is present in fire smoke more commonly and in greater quantities than previously believed due to modern materials such as plastics, rubber, asphalt and polyacrylonitriles." They also found that "…the cyanide problem has gone unrecognized by firefighters and the medical community…" for several reasons, including: "…symptoms of cyanide poisoning are similar and commonly attributed to carbon monoxide poisoning; the blood test for cyanide poisoning is not readily available in most hospitals, [and]; doctors do not routinely order cyanide test on firefighters or smoke inhalation patients because the test results for cyanide commonly take from two hours to come back, making [them] diagnostically useless given that the half-life of cyanide in the body is one-hour." The committee also determined that "cyanide can cause cardiac arrhythmias and other medical conditions commonly being experienced by firefighters." (*Varone et al.*)

Varone presented the Providence report at the 2007 FDIC International conference, providing greater national awareness of the problem. Fire departments began purchasing equipment to detect and prevent exposure to HCN. In fact, air monitoring by the safety officer at a structure fire in Terre Haute, IN revealed that the exterior HCN readings were greater than those for the interior. That corroborates my previous observation that HCN concentration may increase as distance from the fire increases.

By now it should be quite evident that CO and HCN present a real and quantifiable health and safety problem for the fire service, and the public, because to the fire loads we are now encountering. Fortunately, the problem can be at least mitigated, if not prevented, by incorporating a few basic hazmat practices at structure fires. First, the problem can't be effectively managed if it can't be measured, so air monitoring for CO and HCN is a must. The exterior/downwind areas should be checked during active fire suppression and/or when there is substantial drifting smoke. The interior should be monitored before personnel may doff their SCBA. Exterior and interior monitoring should be periodically repeated until readings are consistently below any Action Level. SCBA should be worn whenever an Action Level is exceeded, whether interior or exterior . My suggestions for Action Levels would be an 8-hour time-weighted average of 35 ppm or greater for CO, and a 15-minute time-weighted average of 5 ppm or greater for HCN. Monitoring could be performed with a calibrated meter or with non-expired colorimetric tubes. Be aware that HCN, especially the calibration gas, may not be compatible with other sensors in a multi-gas meter, so it may be most practical to get a small, 1-gas meter if such a device is preferred. I'll also note that calibration gas and colorimetric tubes present an ongoing expense because they have an expiration date, and that shipping the calibration gas for a meter is expensive because it's an inhalation hazard.

Second, decontamination and PPE control requirements should be established. Potentially exposed personnel should wash at least their hands with soap and water before eating or drinking; also washing the face would be prudent. Turnout gear should get gross decontamination while on-scene. A soft bristle brush and/or fog stream can be used, but try to prevent saturation. It should then be promptly washed and dried in accordance with the manufacturer's recommendations. Demonstrating your experience by maintaining "salty" gear is a seriously bad idea because it enables persistent secondary contamination! For example, volunteers often keep their gear in their vehicle and could cause ongoing exposure to themselves, their family, or their friends. Children have far greater inhalation risk than an adult. Their lung surface area is proportionally much larger and their mass is significantly smaller, resulting in a greater dose from exposure to the same airborne concentration.

Third, personnel should be monitored for symptoms of CO or HCN poisoning, which can be delayed by up to an hour, and need to receive immediate medical treatment should they develop. Symptomatic personnel should receive medical observation for at least 4 to 6 hours. (*ATSDR)* An acceptable blood cyanide level would be 20 micrograms per decaliter (*Varone et al.)* , beyond which appropriate medical treatment must be immediately provided. "The…treatment for carbon monoxide inhalation can revive the patient, however, without a cyanide antidote kit, the lasting effects of hydrogen cyanide poisoning can create enduring medical complications." (*Rochford*)

Last, it's best to develop a written procedure and a training program so that firefighters and the emergency medical services can have a consistent understanding of the problem, how to mitigate or prevent exposure, and how to recognize and manage any symptoms that develop. I have both a procedure and a training presentation that I'm willing to share at no cost in the interest of firefighter safety.

We share a vocation/avocation that can be extremely hazardous. Smoke inhalation has previously been thought to be fairly simple and easily treatable, but it can now have lethal acute and chronic consequences. We need to change our mindset. The incorporation of basic hazmat practices at structure fires can have significant positive impact on our health and safety, as well as that of those around us. Think safety, act safely, and let's ensure that everyone goes home!

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About Kevin Hayes (1 Article)

Kevin Hayes has nearly 40 years of comprehensive volunteer emergency services experience. He started in 1978 as the first Junior Firefighter with the Tariffville (CT) Volunteer Fire Company, and currently is an airport firefighter/EMT with the U.S. Army Garrison Kwajalein Atoll in support of the Space and Missile Defense Command. Kevin previously served as Chief with the McConnells (SC) Volunteer Fire Department, as Deputy Chief with the Jefferson County (MO) Hazardous Materials Response Team, as Deputy Chief with Windsor (CT) Volunteer Ambulance Corps, and as a firefighter with several departments in MO and CT. Kevin is a certified Fire Officer II, Fire Instructor I, Hazardous Materials Specialist, and has been an EMT since 1988. He was employed by Westinghouse Electric Company and Combustion Engineering as an environment, health, safety, and human performance management professional from 1987 to 2016, including management positions in SC, MO, and CT. He has a Bachelors degree in Industrial Technology from Central Connecticut State University, and an Associates degree in Manufacturing Engineering from Hartford State Technical College. Kevin is a dedicated advocate of leadership by example, vocational and avocational safety, and continuing education.