



# PROTECTING FIRST RESPONDERS

Real-Time Gas Detection  
For Real-Time Decisions

## THE NEW PLAN

**Gas Detection and Education**

**Help Change 'Smoke Eater' Culture and Policies**

RAE Systems, Inc.

## Summary

A global call is underway for a change in fire-service culture that instills greater safe-work practices and standards to protect emergency responders from the toxic fire smoke found in today's routine fires. No longer can firefighters safely enter smoke-filled environments without the protection of air, nor can they assume any fire ground is safe without atmospheric monitoring standards in place. While inhaling smoke used to be just part of the job, it has now become the most dangerous and deadly part of a fire-ground operation.<sup>i</sup>



<sup>ii</sup>With a nationwide increase in cardiac related deaths, cancers and other illnesses within the firefighter profession and a continued increase in smoke-inhalation deaths,<sup>iii</sup> a paradigm shift in the way fire smoke is viewed and addressed is underway as more firefighters reach out to their firefighting comrades. This white paper discusses the risks posed from today's toxic fire smoke, some practices for making first-responders safer, and the coalition of firefighters who make sure this safety message gets heard.

This eBook discusses key emergency responder airborne fire-overhaul threats and the latest gas-detection solutions capable of raising firefighter, EMS and public safety.

## Reducing Line-of-Duty Hazards

While line-of-duty deaths from heart attacks are a stark risk for those who choose to fight fires for a living or as a volunteer, the death of a single FDNY firefighter in April 2012 resonated through New York's Burroughs and outward to the ranks of fire departments across the United States.

Lt. Richard A. Nappi, a 17-year veteran of the FDNY, went into cardiac arrest and died fighting a large warehouse fire in Brooklyn, a blaze where eight other firefighters were injured. His line-of-duty funeral brought thousands of mourners out with a eulogy delivered by Mayor Michael Bloomberg as Nappi's wife and two children looked on.<sup>iv</sup> To many, the 47-year-old Nappi personified the selfless heroism for which the firefighting brotherhood is best known.



By all accounts, Nappi's dedication to the fire service went to his core.<sup>v</sup> He had been honored for saving other firefighters during a Long Island wildfire in 1995. He volunteered with other departments on his own time to provide firefighter training. And he raced from his Suffolk County home on his day off to help at the World Trade Center site on 9/11, where he tirelessly toiled for weeks alongside many other responders.

Sudden heart attacks are the number one cause of on-duty firefighter deaths in the U.S. in addition to about 1,500 firefighters suffering non-fatal cardiac arrests each year, according to Dr. Tom Hales with the U.S. National Institute for Occupational Safety and Health (NIOSH).<sup>vi</sup> At the same time, firefighters are being diagnosed with cancers at an alarming rate. Several studies over the last 20 years or so confirm that firefighters are at a significantly higher risk for certain cancers than the general population and the problem is growing as more firefighters become ill from job-related exposures to toxic and hazardous substances, including fire smoke.

One reason for this, say experts, is the use of plastics, laminates, synthetics, foams and other modern-day materials in the construction and furniture industries that release toxic gases and vapors when burned. The smoke from these materials puts first responders who are not wearing a self-contained breathing apparatus (SCBA) at risk for long-term health illness from chronic conditions or cumulative exposures or immediate death. The public also is at risk from smoke inhalation, which often results in immediate death. Inhaling smoke is the leading cause of death during structure fires.

## Firefighters Raise Alarms With Colleagues About Toxic Fire-Smoke Dangers

Yet, getting rank-and-file fighters to fully understand the health risks of fire smoke and to change procedures to reduce exposures is no simple task. Some agencies still embrace the “smoke eater” culture where firefighters shun using basic safety equipment or don’t wear breathing apparatus during active firefighting or during fire-overhaul operations. Many firefighters consider soot-covered faces and dirty bunker gear a badge of honor, and not the telltale signs of exposure to dangerous gases and particulates that are known carcinogens.

As continuing studies reveal new, blunt warnings regarding the health dangers of fire smoke, a group of dedicated firefighters and their converts are looking to create nothing short of a culture shift in the way the brotherhood views and treats smoke, all in an effort to save lives and prevent life-threatening illness.

“In some ways, our culture makes us our own worst enemy,” says Chief Rob Schnepf of the Alameda County (Calif.) Fire Department. “By raising awareness based on the latest research, we can eventually trigger a paradigm shift whereby fire smoke is scrutinized and appreciated for its impact on acute and chronic health effects on firefighters and its impact on civilians who get exposed.”



Schnepf began connecting the dots between combustion chemistry and his feeling ill after exposures to smoke, a common experience for firefighters. He conducted research, and in 2002, formalized a presentation he was giving on the topic at an annual conference, which has evolved into a focused organization known as the Fire Smoke Coalition. It provides information, and hands-on workshops and training to firefighters and medical personnel on the prevention, protection, detection and treatment of smoke inhalation.

While it’s a grassroots undertaking that has educated U.S. firefighters about smoke health risks for more than a decade, it is increasingly receiving notice by fire-service organizations worldwide. It’s also finding success by changing how smoke from residential and non-residential building fires is addressed in many departments.

“I think the effort is a game changer for our profession,” Schnepf says. “There are agencies that have made instant, and in some cases, widespread changes. There’s a huge move now of departments doing more gas detection and monitoring, and wearing SCBA for longer periods of time during overhaul. There are a lot of people really embracing the message.”

## Disturbing Numbers for Firefighters

During his talks with firefighters in the U.S., Chief Schnepf notes there is almost always someone in attendance who is either waiting on a cancer diagnosis, or they know someone who is or someone who just received a diagnosis. “That’s just the way it is,” he says.



For firefighters, exposures to compounds classified as carcinogens by the International Agency for Research on Cancer (IARC) is part of the job. These substances include benzene, diesel-engine exhaust, soot and formaldehyde. They can be inhaled, ingested or absorbed through the skin, and occur at fire scenes and the firehouse, where idling fire trucks produce diesel exhaust.<sup>vii</sup>

One of the largest studies, conducted by the University of Cincinnati (UC), reveals that firefighters face increased risk for certain cancers. The study analyzed data on 110,000 mostly full-time firefighters from information culled from 32 previously published scientific reports in order to correlate cancer and health risks for the profession.

“We believe there’s a direct correlation between the chemical exposures firefighters experience on the job and their increased risk for cancer,” says Grace LeMasters, PhD., a co-author of the study and professor of epidemiology and biostatistics at UC.<sup>viii</sup>

The study found that firefighters are twice as likely to develop testicular cancer and have higher rates of non-Hodgkin’s lymphoma and prostate cancer than non-firefighters, and confirmed that firefighters are at greater risk for multiple myeloma, a cancer that begins in the plasma cells in bone marrow.

A new multiyear study is underway to look at cancer among firefighters. NIOSH and the U.S. Fire Administration (USFA) are conducting it. It will examine the health records of more than 30,000 career firefighters to establish if these firefighters contracted cancers at a rate higher than the general public and whether the cancers are associated to on-the-job exposures. The report will be released publicly in 2014.<sup>ix</sup>

## The Toxic Twins™

There are a host of dangerous and toxic components to smoke, but two of them are getting flagged for their toxicity – carbon monoxide (CO) and hydrogen cyanide (HCN) – known as the toxic twins.<sup>x</sup> While the dangers of CO have been long understood, it is now recognized that cyanide is as bad or worse of a “silent killer” as CO or any other fire gas.<sup>xi</sup>



“We are trying to get firefighters to realize that many of the chemicals they would never consider breathing in a HazMat release are the same chemicals found in smoke at structural fires,” says Santa Clara County (California) firefighter, paramedic and HazMat specialist Katie Roberts. “Firefighters need to change their perception and acknowledge that a structure fire truly is a dangerous HazMat situation.”

In fire smoke, cyanide is an underappreciated risk that can cause severe injury or death within minutes<sup>xii xiii</sup> and can be up to 35 times more toxic than carbon monoxide, a highly toxic gas.<sup>xiv</sup> In a review of major fires over a 19-year period, cyanide was found at toxic-to-lethal levels in the blood of approximately 33 to 87 percent of smoke-inhalation fatalities.<sup>xv</sup>

Cyanide is created through the combustion process of burning or smoldering laminates, synthetics, foams, plastics and wood, and other many materials found in construction materials, furniture and upholstery items in homes and offices. As a result, the toxicity level in the smoke of a typical residential or office fire today is higher than ever. Many of these toxic gases can only be detected through the use of gas-detection instruments.<sup>xvi</sup> Cyanide and CO are dangerous components of fire smoke and each can have devastating short- and long-term health effects if inhaled.

Standard	Exposure Levels
Immediately Dangerous to Life or Health (IDLH)	50 ppm
U.S. National Institute for Occupational Safety and Health (NIOSH) Recommended Exposure Limit (REL)	4.7 ppm
Occupational Safety and Health Administration (OSHA) Permissible Exposure Limit (PEL)	10 ppm
Environmental Protection Agency (EPA) Acute Exposure Guideline Level (AEGL)	27 ppm for 10 min. or 21 ppm for 30 min.

Cyanide is an invisible gas that cannot be detected by the color or the amount of smoke emitted by a fire. It can only be detected through metering and monitoring. Exposure to large amounts of cyanide can cause convulsions, cardiac arrest, unconsciousness or rapid death. CO, also only detectable using a sensor device, can cause tissue hypoxia when inhaled, which prevents the blood from carrying sufficient oxygen, and can cause dizziness, nausea, headache and, at higher concentrations, convulsions, tachycardia and death. When inhaled together, the so-called “toxic twins” can have a synergistic effect, experts say, causing even more harm.<sup>xvii</sup>

The threats are real. In 2009, two firefighters from the Craigsville-Beaver-Cottle Fire Department in West Virginia died from smoke and thermal inhalation during a trailer fire. According to the medical examiner’s report, the carbon monoxide poisoning levels of the two victims were at about 63 percent with a toxicology report indicating both victims showed lethal doses of cyanide in their systems.<sup>xviii</sup>

While these gases are deadly, cyanide poisoning can be treated using drugs that can help reverse the effects if administered in a timely fashion. The U.S. Federal Drug Administration (FDA) has approved two drugs to treat cyanide poisoning. These are Cyanokit/Hydroxocobalamin; Cyanide Antidote Kit (CAK), which also is known as the Lilly Kit, the Pasadena Kit and the Keystone Kit; and Nithiodote. However, the CAK in its entirety is not a suggested course of treatment for Hydrogen Cyanide exposure in fire smoke as it can lower already decreased blood pressure, possibly compromising the patient’s condition further. “One of the key reasons we focus on the Toxic Twins is that we have treatments available for them,” says Schnepf.

But the Toxic Twins represent only two of many toxic gases that inhabit active fire grounds. Other chemicals and compounds include sulfur dioxide (SO<sub>2</sub>), nitrogen oxides (NO and NO<sub>2</sub>), formaldehyde, benzene and phosgene.

“There’s definitely other stuff there that poses a significant risk for our guys,” says Roberts. “There’s soot and particulates; there’s fiberglass being pulled from the ceiling and a lot of other gases that are smoldering.”

### Changing Behaviors

During his talks with firefighters, Chief Schnepf points out there is a lack of understanding as to why smoke is bad and a lack of appreciation for how dangerous it can be. Part of this is human culture, where smoke is viewed as a benevolent thing, he says, noting that we recall nostalgically the scent of smoke from around fireplaces or campfires while growing up. For firefighters, smoke is typically considered a “tactical marker” used during operations, and is not fully recognized for its health and safety impacts. For Schnepf and his Fire Smoke Coalition colleagues, the challenge lies in getting rank-and-file firefighters to understand a structural fire is nothing more than an uncontrolled HazMat incident.



It’s a message Lt. Mike Becker, an 18-year veteran of the Longmont (Colorado) Fire Department, can get behind: “I’ve gotten hits on HCN with meters at fires before,” says Becker. “Improving safety is a matter of doing a little bit better job of mop-up, providing a little bit more ventilation, keeping masks on longer, and getting the fire totally extinguished before we go in and do investigation.”

He also is a proponent of using gas-detection monitoring. “If you truly know how to use the instrument, it can be your best friend when you need to determine the safety of an environment; it keeps everyone safe and healthy,” he says. It’s why the Longmont Fire Department uses HCN single-gas meters, as well as adding HCN sensors to some of its wireless multi-gas area monitors.

While fire, HazMat and special operations teams utilize a variety of detection instruments today, wireless gas-detectors offer key benefits to fire-service agencies. These include fast deployments, centralized command monitoring and data sharing with other on-scene units or off-site experts, says Thomas Nègre, vice president for products and

**THE HIDDEN DANGERS OF FIRE SMOKE**

THE DEADLY AND LONG-TERM CONSEQUENCES OF FIRE SMOKE INHALEATION WERE HIGHLIGHTED TO FIREFIGHTERS IN MANCHESTER, DURHAM AND LEBANON WHEN CAPTAIN JASON KIRKSON, CHIEF OF FIRE DEPARTMENT, SOUTH CAROLINA VISITED THEIR FIRE BRIGADES IN MAY. FIRE HAS WRITTEN THAT EQUIPPING FIREFIGHTERS WITH METERS THAT READ DANGEROUS LEVELS OF FIRE GASES IN SMOKE IS AN INEVITABLE TASK.

THE ADVANTAGE FOR THE WORKING FIRE...  
In May was to directly reduce...  
and LEBANON on the dangers of...  
the smoke, in addition to showing them how...  
to detect the dangerous gases within the...

quickly making a difference in the way...  
firefighters look at fire smoke and the...  
associated dangers.  
The coalition had aspirations of giving...  
similar resources to other fire...  
departments to see if the same would hold true...

rigidly deployed gas detection systems...  
that could read the carbon monoxide and...  
other dangerous, harmful gases out of the...  
fire. It means for the working...  
They had previously partnered with the...  
fire service coalition to bring...  
education to their units, and...  
continued to champion the effort by...  
partnering with the program. Each...  
received two sets of meters to check for...  
dangerous fire gases.

Over the past year, the Fire Smoke...  
Coalition has been great success in raising...  
the awareness of firefighters by educating...  
open on the side of meters. Educating...  
firefighters with meters that are able to...

marketing for RAE Systems, a Silicon Valley-based manufacturer of gas-detection equipment and wireless monitoring systems.



“Wirelessly networked gas-detection systems are a force multiplier for emergency responders,” says Nègre. “These systems improve safety by providing real-time information that gives on-scene commanders greater visibility and control during HazMat incidents, structural fires or other fire-ground operations.”

At many departments in the U.S., HazMat operations are separate from the firefighting services, another cultural divide some insiders are trying to change. Because a growing number of firefighting experts today consider structural fires HazMat hot spots, calls for greater teamwork between the two entities during common structural fires are increasing. Becker is a proponent of using gas-detection equipment during HazMat and structural fires, including using standalone instruments or wireless systems that allow on-scene agencies with compatible systems to share data.

For him, wireless gas-detection instruments offer several advantages. First, they provide monitoring oversight when working with firefighters or other emergency responders who are unfamiliar with the instruments or how to read them. Similarly, on-scene firefighters can often get distracted from monitoring their instruments during the course of performing their duties. This is particularly relevant, says Becker, when monitoring rising lower explosive limits (LELs). With wireless sensors sending data back to a centralized control unit or laptop computer, the readings can be tracked and monitored by a single hazardous-materials technician, essentially providing what one firefighter calls a “guardian angel.”

Becker also sees wireless monitoring equipment as a force multiplier. “It takes one person to deploy wireless monitors at the scene, but once deployed, they are unmanned. So I can have eight sensors feeding me data in real time, and I only need one person to do a job that used to take eight people carrying detectors and tying up radio traffic to relay the readings.”

In an effort to improve safety on all calls, Becker is working within his department in Longmont to have a HazMat unit dispatched on structure fires so that gas-detection equipment can be deployed with a trained technician on-hand to monitor readings throughout a fire and overhaul operation. His department also is expected to upgrade its wireless-system software to improve interoperability of gas-detection systems within the greater Denver, Aurora and Longmont jurisdictions within the State of Colorado.

## Smoke-Awareness Training

Educating firefighters is at the heart of the Fire Smoke Coalition's mission, in addition to other emergency responder associations, such as HazMatIQ and the International Emergency Council (IEC). Experts say education is the single best way to instigate changes in department policies throughout the U.S. and beyond. Santa Clara County firefighter Roberts conducts training for HazMatIQ and the IEC, and has worked with the Fire Smoke Coalition.

"Every firefighter should be comfortable in their knowledge of carbon monoxide and cyanide," she says. "They should understand the signs and symptoms of exposure, and they should understand that they need detection equipment, just like they need axes, hoses, water and everything else."

These organizations loudly preach the benefits of firefighters wearing SCBA, not only during a conflagration but also afterwards during overhaul operations, which includes searching for possible sources of re-ignition and investigating the origin of the fire.



During hands-on demonstrations conducted at Fire Smoke Coalition workshops called "Know Your Smoke," the coalition's president and Chief of Special Operations of the Columbia (South Carolina) HazMat Team Jason Krusen gives participants a real-world view of the toxins generated in a typical residential fire.

The live-fire exercises provide the emergency-response participants with a sobering view of just how pervasive toxic smoke can be and how simple household items can become major sources of life-threatening toxins as they burn and smolder.

In one demonstration, a small hay and pallet fire was set in a drum outside of a training exercise burn room. Downwind participants quickly saw their meters spike from up to 30 feet away. Inside the burn room, meter readings jumped. A foam seat cushion was added to simulate typical household furniture, followed by a plastic pail to simulate the plastics that burn in routine structural fires. The meter readings soon exceeded IDLH (Immediate Danger to Life or Health) levels on HCN (at 50 parts per million (ppm)), and were going out of range on CO (at 500ppm). The meters were later suspended over the smoldering drums to get readings representative of cleanup or overhaul operations. The readings peaked at 16 ppm of HCN and 450 ppm of CO. This is alarming because it is common to see firefighters without SCBA during the overhaul process.

The key challenge going forward is to help class participants and smoke-danger converts apply their newfound knowledge by taking action to institute policy changes at the departmental level. Roberts plans to work with New York City Fire Captain James D'Avolio from the city's Hazardous Materials Co. #1 to develop approaches and training content designed to change perceptions about smoke hazards, especially with those "rough and tough guys" who are often resistant to change.

Says Roberts: "The other part to this is how we get new recruits leaving the academy to have this mental mindset where they look at a structure fire as a HazMat situation as opposed to 'Hey kids, it's just smoke; it's no big deal.'"

### Model Operating Procedures for Fire Smoke Safety

Increasingly, fire service organizations are realizing the inherent dangers of fire smoke and particulates, especially during cleanup operations following a fire, known as fire overhaul.

California firefighter, paramedic and HazMat specialist Katie Roberts of the Santa Clara County Fire Department, points to another Golden State department in Sacramento for developing procedures that takes into account new understandings regarding the dangers of exposure to fire smoke. These standard operating procedures (SOPs) help ensure the health and safety of its firefighters and citizens.



Here are some highlights of the SOPs used in Sacramento:

- **HOT/WARM AREAS:** Self-contained breathing apparatus (SCBA) will be used during overhaul in areas deemed Immediately Dangerous to Life and Health (IDLH).
- **COLD AREAS:** Use of a N95 respirator is the minimal requirement. Full-face respirators with P100 cartridges or SCBA are required for asbestos protection at pre-1980 structures where the building materials have been burned or disturbed.
- **PRIOR TO OVERHAUL:** Purge the work area using positive-pressure mechanical ventilation with exhaust extension tubes for gas-powered blowers. This is required even when breathing apparatus is used to "reduce the potential for dermal absorption of toxins."
- **CREW ROTATION:** If possible, rotate crews that have used three air bottles, which suggests they have spent an excessive amount of time working in a SCBA.

### Learn More: Additional Useful Information, Videos, Reference Data and Links

1. Learn more, and see videos on wireless gas detection including how to obtain remote access to real-time gas, radiation, and biometric data to enhance safety **HERE** (<http://www.raesystems.com/emergency-responder/>)
2. Watch videos on FireSmoke training seminars **HERE** (<http://www.firesmoke.org/home/videos/>)
3. Download the new Application Note, AP-236, (Monitoring Benzene and Choosing an Appropriate Monitor for Personal Protection and Compliance with Exposure Limits) **HERE** (<http://www.raesystems.com/downloads/app-notes>)
4. Download a checklist on Response Scenarios Using Wireless Detection in Public Event Safety **HERE** (<http://www.raesystems.com/public-event>)
5. Reading and additional FireSmoke information:
  - a. Fire Smoke Coalition at [www.firesmoke.org](http://www.firesmoke.org).
  - b. Firefighter cancer testimonials at [www.firefightercancersupport.org](http://www.firefightercancersupport.org).

## About RAE Systems Inc.

RAE Systems is a global sensor and wireless-system innovator that designs and manufactures a full line of fixed, portable, handheld and personal chemical- and radiation-detection instruments. The company's life- and health-saving detectors are used in 120 countries by many of the world's leading industrial organizations, emergency responders and government agencies.

RAE Systems offers a variety of rapidly deployable and custom-configurable sensor solutions for radiation monitoring. RAE Systems delivers cohesive, wirelessly connected threat-detection solutions that create a layered defense against gas and VOC threats and other gas and combustible risks. RAE Systems' solutions for Oil & Gas monitoring and protection are:

- **Versatile:** RAE Systems' easily deployable fixed and portable monitors placed in sensitive areas transmit sensor information in real-time to a central location for quick interpretation, analysis and action.
- **Wireless:** Wireless atmospheric monitoring that utilizes cost-effective equipment that is easy to install and operate can assist plant managers and operations commanders and first responders with real-time information on potential hazards.
- **Proven:** With more than 15 years of experience, RAE Systems' innovative solutions have a verified track record.

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<sup>i</sup> Fire Smoke Coalition Overview. Page 5 (28 Sep 2012). [www.firesmoke.org](http://www.firesmoke.org).

<sup>ii</sup> Fire Smoke Coalition, a division of the Cyanide Poisoning Treatment Coalition. Indianapolis, IN. <http://www.firesmoke.org>

<sup>iii</sup> Ibid.

<sup>iv</sup> Jen Chung, Gothamist website: "Thousands Gather At Firefighter Richard Nappi's Line Of Duty Funeral."

[http://gothamist.com/2012/04/22/thousands\\_gather\\_at\\_fdnv\\_line\\_of\\_duty.php#photo-1](http://gothamist.com/2012/04/22/thousands_gather_at_fdnv_line_of_duty.php#photo-1), 22 Apr 2012. (Retrieved 15 November 2012).

<sup>v</sup> Al Baker, The New York Times. "Colleagues Trace the Void Left by a Firefighter." 17 April 2012.

[http://www.nytimes.com/2012/04/18/nyregion/fire-It-richard-a-nappi-is-mourned-in-new-york-city-and-on-li.html?\\_r=0](http://www.nytimes.com/2012/04/18/nyregion/fire-It-richard-a-nappi-is-mourned-in-new-york-city-and-on-li.html?_r=0) (Retrieved 15 November 2012).

<sup>vi</sup> National Fire Protection Association (NFPA) news release: "NFPA Annual Report on Firefighter Fatalities in U.S. Shows Lowest Number of On-Duty Deaths in 34 Years." 13 June 2011. [http://www.nfpa.org/newsreleasedetails.asp?categoryid=488&itemid=51948&cookie\\_test=1](http://www.nfpa.org/newsreleasedetails.asp?categoryid=488&itemid=51948&cookie_test=1). (Retrieved 14 Nov 2012).

<sup>vii</sup> Science Daily (10 Nov 2006): "Firefighters Face Increased Risk For Certain Cancers."

<http://www.sciencedaily.com/releases/2006/11/061110080741.htm>

<sup>viii</sup> News Release from UC Health News, University of Cincinnati (10 Nov 2006) "Firefighters Face Increased Risk for Certain Cancers." Release on findings reported in the *Journal of Occupational and Environmental Medicine* about a study by Grace LeMasters, PhD, Ash Genaidy, PhD, and James Lockey, MD.

<sup>ix</sup> U.S. Centers for Disease Control and Prevention (CDC), news release: "Fire Fighter Fatality Investigation and Prevention Program." (Last updated: 06 July 2010). Sourced from National Institute for Occupational Safety and Health Division of Surveillance, Hazard Evaluation and Field Studies.

<sup>x</sup> The Toxic Twins™ is a registered trademark of the Fire Smoke Coalition.

<sup>xi</sup> Alan H. Hall, M.D. and Rob Schnepf, Fire Engineering magazine article, titled: "Cyanide: Fire Smoke's Other "Toxic Twin.""

[http://www.fireengineering.com/articles/print/volume-164/issue-12/departments/fire-service\\_ems/cyanide-fire-smokes-other-toxic-twin.html](http://www.fireengineering.com/articles/print/volume-164/issue-12/departments/fire-service_ems/cyanide-fire-smokes-other-toxic-twin.html) (01 Dec 2011).

<sup>xii</sup> Guidotti T. Acute cyanide poisoning in pre-hospital care: new challenges, new tools for intervention. *Prehosp Disaster Med.* 2006; 21(2): S40-S48.

<sup>xiii</sup> Eckstein M, Maniscalco PM. Focus on smoke inhalation - the most common cause of acute cyanide poisoning. *Prehosp Disaster Med.* 2006; 21(2):S49-S55.

<sup>xiv</sup> Tuovinen H, Blomqvist P. Modeling of hydrogen cyanide formation in room fires. Brandforsk project 321-011. SP Report 2003:10. Borås, Sweden: SP Swedish National Testing and Research Institute; 2003.

<sup>xv</sup> Alarie Y. Toxicity of fire smoke. *Crit Rev Toxicol.* 2002; 32(4):259-289.

<sup>xvi</sup> Fire Smoke Coalition, a division of the Cyanide Poisoning Treatment Coalition. Indianapolis, IN. <http://www.firesmoke.org>

<sup>xvii</sup> RAE Systems' book: "Wirelessly Networked Chemical & Radiation Detection Systems: Essential Technologies and Applications for Increased Safety in Continuous Gas and Radiation Monitoring." 2012 <http://www.amazon.com>

<sup>xviii</sup> Fire Smoke Coalition website: "FF Deaths – Lethal Levels of HCN." <http://www.firesmoke.org/2010/11/08/ff-deaths-lethal-levels-of-hcn>. Sourced from "Two firefighters die in blaze" by the Register-Herald.com and "The Adventures of Jake and Vinnie," which is the intellectual property of Art Goodrich a.k.a. ChiefReason.