



Continuing Education Course

Structural Fire Overhaul:

Respiratory Hazards and Personal Protective Equipment

BY JEFFREY L. HERBERT

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Structure Fire Overhaul:

Respiratory Hazards and Personal Protective Equipment

Educational Objectives

On completion of this course, students will:

- Identify the respiratory hazards to personnel during overhaul
- Describe the performance of SCBA
- Identify specific toxic gases encountered during overhaul
- Identify proper techniques/equipment for respiratory protection

BY JEFFREY L. HERBERT

EVEN AFTER THE MAIN FIRE IS EXTINGUISHED, firefighters still face many hazards in overhaul operations. However, the greatest danger is also the one that is largely ignored—poisonous gases resulting from incomplete combustion that exhausted firefighters may breathe in. In addition to examining these invisible dangers firefighters face during overhaul and the respiratory protection equipment available, this article will discuss the results of a Phoenix, Arizona, firefighter survey concerning the use of personal protective equipment (PPE) during overhaul.

During active firefighting, visibility is often zero, the structure's tenability is decreasing, and the environment is hot. The fire department thus focuses on safety and training. In the operational phase following fire extinguishment, overhaul, the emphasis on rescuing civilians and putting out the fire has passed. In practice, overhaul is a transitional phase. Although many physical hazards exist during overhaul, common sense, experience, and awareness of your surroundings usually mitigate these dangers. However, a serious respiratory hazard exists during overhaul, and firefighters often give this hazard low priority.

Firefighters know they can't survive if they breathe in superheated air or toxic gases released by fire, but they often forget that the heated fuels from the fire are still releasing toxic gases during overhaul. Firefighters often talk about carbon monoxide (CO), and they all know the feeling of a CO headache, but what other toxins are they inhaling? Air-monitoring studies have

proven that CO and other hazardous gases exist in a structure after a fire. Many of them are undetectable without monitors and are more dangerous than CO. The type and concentration of the gas depend on the fuels involved. Depending on air currents, the hazard also extends beyond the immediate structure. This area of occupational health and safety has received little attention; therefore, firefighters do not know all they should know about what they face after the fire is out.

SCBA

Wearing a self-contained breathing apparatus (SCBA) during this operational phase virtually eliminates the respiratory hazards. Positive-pressure SCBAs provide a protection factor exceeding 10,000.¹ This means that compared to the air outside of the mask, contaminants breathed in are reduced more than 10,000 times. However, often firefighters reserve wearing the SCBA for active firefighting.

The air-purifying cartridge respirator is also used for respiratory protection in the fire service. It can be attached to the SCBA face mask, eliminating the cumbersome air bottle, but it provides a protection factor of approximately 50.² What commonly occurs is that someone passes out a box of N-95 masks, which are perceived as protection from the dust and light smoke encountered during overhaul.

However, in the National Institute for Occupational Safety and Health



(1) Even after the fire is extinguished, the burned fuels may still release toxic gases. [Photos by Paul Ramirez, Phoenix (AZ) Fire Department, unless otherwise noted.]



(2) Phoenix Fire Department members wear full PPE, including SCBA, while performing overhaul on a single-story residence.

(3) Toxic gases are released when household items burn. In homes dating from the early 1970s and earlier, popcorn ceilings may contain asbestos particles.

(NIOSH) N-95 filter classification, N means “Not resistant to oil” and 95 means that the mask is 95 percent effective against particles larger than 0.3 microns.³ Particles sized between one and five microns can enter the upper airway, particles sized between 0.1 and 1.0 microns can enter the lower lungs and alveolar ducts, and particles larger than five microns will fall out of the air. As an illustration, tobacco smoke particles range in size from 0.01 to 1.0 microns, and oil smoke ranges from 0.03 to 1.0 microns. So depending on particle size, the N-95 masks may or may not filter these smoke particles suspended in the air.

Additionally, the naked eye can see only particles sized 10 microns or larger, so the dust seen in the overhaul environment would not enter the upper airway even without the N-95 mask. Finally, firefighters need to realize that the toxic gases are not particulates, and the N-95 masks offer zero protection against them.⁴

The best information available on the chemical hazards of overhaul come from two studies published in 2000 and 2001, both conducted by the Phoenix Fire Department and the University of Arizona. The 2000 study, “Characterization of Firefighter Exposures During Overhaul,” by Dawn Bolstad-Johnson, et al, monitored the air in 25 structures while firefighters were performing overhaul. (2) This was the first study of its kind, and in researching this article, I have found that many recent sources mentioning the chemical dangers of overhaul cited this work.

The study “demonstrated that maximum concentrations of contaminants in the overhaul atmosphere exceeded occupational exposure limits and could therefore result in adverse

health effects in firefighters without respiratory protection. In a variable number of fires, concentrations of acrolein, CO, formaldehyde, and glutaraldehyde exceeded their respective ceiling values; concentrations of sulfur dioxide exceeded the STEL value; and concentrations of coal tar pitch volatiles (PNAs) exceeded the OSHA PEL, ACGIH TLV, and NIOSH REL.” (2, 638)

The study noted that “among the fires sampled, there was tremendous variation in concentrations of the sampled contaminants. This variation may be explained by the diverse nature of each fire, including contents, number of rooms, commercial building vs. residential, etc.” (2, 638)

A limitation of this study is that the researchers could not always get to the incident and begin monitoring as soon as overhaul began, so the amount of each toxic gas reported may have been higher before monitoring commenced. (2, 640)

TOXIC GASES

The chemicals identified in this study illustrate the severity of the hazards posed by inhaling them. Acrolein is a suspected human carcinogen; the French used it as a chemical weapon during World War I. The Environmental Protection Agency (EPA) states, “Acute inhalation exposure to high levels [10 parts per million (ppm)] of acrolein in humans may result in death. Effects on the lung such as upper respiratory tract irritation and congestion have been noted at acrolein levels ranging from 0.17 ppm to 0.43 ppm.”⁵

Carbon monoxide is the leading cause of accidental poisoning deaths in America. This odorless, tasteless, and colorless gas is known as the “silent killer.” The Centers for Disease Control and Prevention estimates that CO poisoning claims nearly 500 lives and causes more than 15,000 visits to hospital emergency departments annually. Early symptoms of CO poisoning such as headaches, nausea, and fatigue are often mistaken for the flu, because the deadly gas goes undetected in a home. Prolonged exposure can lead to brain damage and

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even death.⁶

Hydrogen cyanide, another toxic gas present in the overhaul environment, is produced by the incomplete combustion of natural fibers (e.g., wool, silk) and synthetic polymers (e.g., polyurethane, nylon) widely used in insulation, cushioning, carpets, building materials, and home furnishings. Each year, an estimated 20,800 residential fires are attributed to mattresses, pillows, and bedding materials, all of which are highly likely to contain synthetic materials that release hydrogen cyanide when they smolder (<http://www.cyanidepoisoning.org>).

J. Curtis Varone, in “Cyanide Poisoning: How Much of a Threat?” (*Fire Engineering*, September 2006, 61), noted the following after the cyanide poisoning of a firefighter: “What the Providence (RI)

Fire Department learned in March 2006 was that not only is hydrogen cyanide a product of combustion but it may also very well be the most deadly product of combustion and the one firefighters should be concerned with above all others when fighting fires.”

In 1987, the EPA classified formaldehyde as a probable human carcinogen under conditions of unusually high or prolonged exposure. Since that time, some studies of industrial workers have suggested that formaldehyde exposure is associated with nasal cancer and nasopharyngeal cancer and possibly with leukemia. In 1995, the International Agency for Research on Cancer (IARC) concluded that formaldehyde is a probable human carcinogen. However, in a reevaluation of existing data in June 2004, the IARC reclassified formaldehyde as a known human carcinogen.⁷

Glutaraldehyde vapor in the air can cause teary eyes, a burning nose, a sore throat, coughing, and a headache. These effects can occur when the amount of glutaraldehyde in the air is about 0.1 ppm (the legal exposure limit is 0.2 ppm). Repeated exposure to glutaraldehyde can cause asthma. Asthma has occurred even in people exposed to low levels of glutaraldehyde (0.05 ppm). Glutaraldehyde is now being tested to see whether it causes cancer in animals that breathe its vapor.⁸

OTHER TOXIC MATERIALS

Toxic gases are not the only respiratory hazard that exists during overhaul. While firefighters are exposing concealed spaces such as the area behind walls, doorjambes, and attics, they are inhaling asbestos fibers, lead from paint, and respirable dust. Samples of each of these were detected in the overhaul environment in the Bolstad-Johnson study. Although single events pose a danger, the health problems that these substances can cause need to be considered not only as a one-time exposure but also on the basis of their long-term effects. Additionally, based on the vast array of possible burning materials firefighters may be called to extinguish and the fact



(4) An air-purifying respirator provides only a fraction of the respiratory protection your SCBA offers. (Photo by author.)

that the studying of overhaul is relatively new, it may be assumed that additional unknown chemical hazards are present.

BURGESS STUDY

Toxicologist Jeffery Burgess, et al, in the study “Adverse Respiratory Effects Following Overhaul in Firefighters,” used a different methodology than Dawn Bolstad-Johnson, et al.

Instead of monitoring the air during overhaul, researchers took spirometric measurements and measured serum pneumoproteins in the blood of firefighters after performing overhaul. Two groups of firefighters were used: Tucson firefighters, who used no respiratory protection, and the Phoenix firefighters, who used cartridge respirators. These measurements indicated that the cartridges did not pre-

vent increased lung permeability in the firefighters. The serum pneumoproteins indicated that firefighters were exposed to carboxyhemoglobin, acetaldehyde, formaldehyde, sulfur dioxide, respirable dust, and sulfuric acid. (1, 471)

The study notes that “these findings provide strong evidence that the current practice of removing SCBA prior to overhaul may result in exposure to respiratory toxicants and subsequent adverse health effects.” (1, 471) Note that although the Burgess study involved fewer fires than Bolstad-Johnson’s, both are cutting-edge studies of the environmental health hazards of overhaul.

Burgess, et al. studied cartridge respirators’ effectiveness to determine whether they provided a suitable alternative to the heavy SCBA. The study determined that cartridge respirators should not be worn as respiratory protection against overhaul hazards. These studies prove that overhaul presents a serious health risk to firefighters who choose not to wear SCBA and that the occupational hazard of overhaul requires further study. So why, then, do firefighters not wear their SCBA during overhaul?

PPE USE SURVEY

To evaluate firefighters’ SCBA use during overhaul, researchers created an online questionnaire and e-mailed it to 60 firefighters. Participants were requested to visit www.freewebs.com/jherbert and fill out an anonymous questionnaire regarding their use of PPE during overhaul. Forty-four of the persons solicited responded.

Fire department members above the rank of firefighter were not surveyed; the study focused on members most likely to physically perform overhaul. Analysis focused on the worker, not the supervising company or command officers. Additionally, engineers’ responses may have caused deviations in the data since they are often operating at the pump panel during overhaul. Firefighters were solicited from A, B, and C shifts, from probationary firefighters to 20-year veterans.

SCBA Use

The responses illustrate a trend of a minimal emphasis on the invisible hazards of overhaul. Gender did not seem to affect SCBA use. Out of all responses, 13.6 percent of firefighters answered that they always wear their SCBA during overhaul, 6.8 percent stated that they never wear their SCBA during overhaul, and 79.5 percent responded that they sometimes wear their SCBA during overhaul.

A possible reason for the overwhelming majority response that they sometimes use their SCBA during overhaul is that overhaul occurs during several unofficial levels of severity. During short-duration structure fires, (e.g., a contents fire), the interior crew may begin overhaul immediately without exiting the structure for rest or more air. Firefighters assigned to begin overhaul immediately after the fire is declared under control would be more likely to wear their SCBA than if assigned to overhaul later on in the process when less smoke is visible (i.e., when respiratory hazard is less perceivable). Also, if firefighters did not report to rehab or take a break in between firefighting and overhaul, they would be less likely to remove their bottle than if they had already removed their PPE and SCBA.

The survey also showed that most of the respondents wear their SCBA more than half of the time for protection against respiratory hazards and, second, for personal safety. A small percentage said they never wear SCBA. Further data indicate that the vast majority of firefighters are aware that overhaul presents hazards that often require an SCBA but peer pressure or the cumbersome properties of wearing the SCBA may prevent them from wearing the SCBA about half of the time. Compared to an N-95 mask, the SCBA bottle is heavy; the shoulder straps restrict movement; and the face mask can get covered with debris, reducing visibility.

N-95 Filter Use

In addition to SCBA use, 71.4 percent of survey respondents said they sometimes wear an N-95 mask, 19 percent said they never wear one, and 9.5 percent said they always wear one. Fifty percent believe that the N-95 offers protection against respiratory hazards, a common misconception that needs to be changed through education.

Turnouts and Gloves

Regarding wearing full turnouts with gloves and hood during overhaul, 70.5 percent responded that they sometimes wear them during overhaul, 18.2 percent always, and 11.4 percent never. This is in contrast to the use of turnouts during firefighting: 98 percent that they always wear SCBA and full turnouts during residential and commercial structure fires, 86 percent always for car fires, and 52 percent always for trash fires.

Although no studies have been conducted specifically on toxic



(5) Your SCBA is your best protection during overhaul. (Photo by author.)

skin absorption during overhaul, many of the substances known to exist in the overhaul environment can be absorbed through the skin. Turnouts may not even protect against the gases, but limiting toxic substances such as asbestos from collecting on your skin may help keep them out of your airway. Although firefighters consider having a set of dirty turnouts as a badge of honor, frequent washing, which is actually decontamination, helps to reduce contact with hazards.

Concerning turnout maintenance, National Fire Protection Association (NFPA) 1851, *Standard on Selection, Care, and Maintenance of Protective Ensembles for Structural and Proximity Fire Fighting* (2001 ed.), section 5.2.1, states: "After each use any elements that are soiled shall receive routine cleaning."

Section 5.3.1 says that an advanced cleaning of turnouts should be completed at a minimum of every six months. The Phoenix Fire Department has a turnout maintenance program in which members can have their turnouts professionally cleaned at anytime.

The 1997 Phoenix Fire Department SCBA Management Procedure (MP) 202.05B states that the use of SCBA is clearly indicated for "all personnel operating ... where invisible contaminants are suspected to be present (i.e., carbon monoxide during overhaul)." ⁹

The MP for overhaul, dating from 1995, however, does not discuss whether PPE should be worn during this phase of the operation. When the overhaul MP is revised, it should emphasize the use of turnouts and SCBA as well as offer a brief discussion of the respiratory hazards present. ¹⁰

The Occupational Safety and Health Administration (OSHA) *Respiratory Protection Standard 29 CFR 1910.134* requires a respiratory protection plan and annual refresher training for all employees required to wear respirators on the job. This includes annual fit testing and medical evaluations. The Phoenix Fire Department follows this regulation. During the annual refresher training, we present a video that stresses the importance of not relying on an N-95 mask:

"It will not shield your lungs from poisonous air during overhaul. Deadly carcinogens are present even when there's no smoke. They are invisible, tasteless, and odorless; that's why it's so easy to justify removing your respiratory protection. Don't do it! You could pay for this years down the line with a serious respiratory illness."¹¹

In the fire service, each call is different from the last, conditions are always changing, and it is often impossible to provide blanket solutions to existing issues. When it comes to overhaul, the level of PPE worn is usually a personal choice. In practice, it is similar to wearing a seat belt in the fire apparatus. Although

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everyone knows that it is the rule and the right thing to do, when a firefighter is turning out for an incident, he may remove his seat belt so he can get dressed as fast as possible. As with overhaul, the risk taken is rationalized as acceptable because the potential negative consequences seem remote.

This attitude toward overhaul needs to change. There is no rush, the incident is controlled, and a firefighter should be in shape to wear his bottle throughout the process. So it seems obvious that enforcing existing regulations would solve this health hazard, but the fire service generally shuns micromanagement, and in this area of moderately perceived risk, company and command officers rarely enforce the PPE regulations to the letter of the law.

RECOMMENDATIONS

Perhaps a few solutions could be introduced to mitigate this issue without great organizational change. Often, the utility truck responsible for refilling SCBA bottles leaves the incident before overhaul is completed, because most firefighters believe that they will not need to use their SCBA during the rest of the incident. If Command ordered the utility truck to remain on-scene until the last company was finished and reminded crews that it would be available to refill those bottles once overhaul is completed, maybe more firefighters would heed this advice while still feeling that they are making their own decisions.

Frequent crew rotation would eliminate using fatigue as an excuse for removing PPE during overhaul.

More overhaul hazards training is needed. In the survey, 29.5 percent of firefighters stated that they had never had any training on the hazards of overhaul. Although all Phoenix firefighters have received this training, it seems that it did not make a substantial impact on a large group within the department. This area could be highlighted more during annual fit testing.

Changing the fire service culture's views on overhaul may happen more quickly among the junior members. SCBA use during overhaul must be enforced in training academies nationwide.

Company officers need to be proactive in supporting SCBA use among their firefighters, and command officers need to be proactive in changing the culture's attitudes on overhaul hazards. A national review of volunteer and paid fire department members' attitudes toward wearing PPE during overhaul would reveal national trends in this area. Such a review could consider why supervisors allow firefighters to continue to disregard SCBA use for overhaul.

In a firefighter fatality investigation into a collapse that killed two firefighters during overhaul, NIOSH recommended that "fire departments should ensure that firefighters wear a full array of turnout clothing and personal protective equipment (i.e., SCBA and PASS devices) appropriate for the assigned task while participating in fire suppression and overhaul activities."¹² Although this incident involved a collapse, the NIOSH report stressed that toxic gases such as hydrogen cyanide and formaldehyde are dangerous to firefighters during overhaul. NIOSH has assembled a team of doctors as part of a task force to further investigate the prevalence of cyanide poisoning. NIOSH clearly states, "Exposures to these types of respiratory hazards can be reduced by the mandatory use of SCBA during both fire suppression and overhaul activities." (12)

Another possibility is to train certain members in using air monitors that can detect the gases present during overhaul. This is an expensive proposition compared with enforcing the use of SCBA, but it may add weight to the immediacy of the dangers to which firefighters are exposed and the validity of such enforcement.

Air-monitoring studies have shown that hazardous gases that are undetectable to our senses exist during overhaul, but more research needs to be conducted in this area to further evaluate what firefighters are exposed to and how those exposures may affect firefighter health. As an example, no study yet conducted has evaluated the effect of toxic compounds absorbed through the skin during fire suppression or overhaul. Even if the current practice of removing SCBA during overhaul is slow to change, an increased body of research proving that certain chemicals may impair firefighter health will aid the fire service as a whole when facing medical claim issues in the future. ●

ENDNOTES

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Structural Fire Overhaul: Respiratory Hazards and Personal Protective Equipment

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To receive credit and your certificate of completion for participation in this educational activity, you must complete the program post examination and receive a score of 70% or better. You have the following options for completion.

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COURSE EXAMINATION

- During overhaul, it's:
 - safe to remove your SCBA
 - a transitional period where heated objects are still generating toxic gases
 - best to remove your helmet to avoid continued neck strain
 - helpful to remove your coat
- Wearing SCBA provides a protection factor of:
 - 1,000
 - 2,500
 - 10,000
 - 100,000
- An air-purifying cartridge provides a protection factor of:
 - 25
 - 50
 - 500
 - 1,000
- N-95 masks provide what level of protection from toxic gases?
 - 95%
 - 5%
 - 90%
 - 0%
- A fire gas that was also used by the French as a chemical weapon is:
 - carbon monoxide
 - carbon dioxide
 - hydrogen cyanide
 - acrolein
- The Centers for Disease Control and Prevention estimates that annually carbon monoxide poisoning kills:
 - 275 people
 - 500 people
 - 750 people
 - 1,200 people
- According to the course text, incomplete combustion of wool and silk produces:
 - carbon dioxide
 - carbon monoxide
 - hydrogen cyanide
 - acrolein
- According to research by the Providence Fire Department, the most deadly product of combustion is:
 - carbon monoxide
 - carbon dioxide
 - hydrogen cyanide
 - acrolein
- Glutaraldehyde produces headaches and runny noses in excess of:
 - 1 ppm
 - 2 ppm
 - 0.1 ppm
 - 0.2 ppm
- The Burgess study took:
 - spirometric measurements
 - air velocity measurements
 - post-fire humidity measurements
 - hydraulic measurements
- The Burgess study indicated that during overhaul:
 - cartridge respirators provided adequate protection
 - SCBA or cartridge respirators provide adequate protection
 - SCBA is only needed for 15 minutes after knockdown
 - only SCBA should be used during overhaul
- A research study indicated that the percentage of firefighters who always wear SCBA is:
 - 27.2%
 - 32%
 - 13.6%
 - 29%
- The percentage of firefighters who always wear an N-95 mask is:
 - 22%
 - 9.5%
 - 21.3%
 - 25%

Structural Fire Overhaul: Respiratory Hazards and Personal Protective Equipment

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