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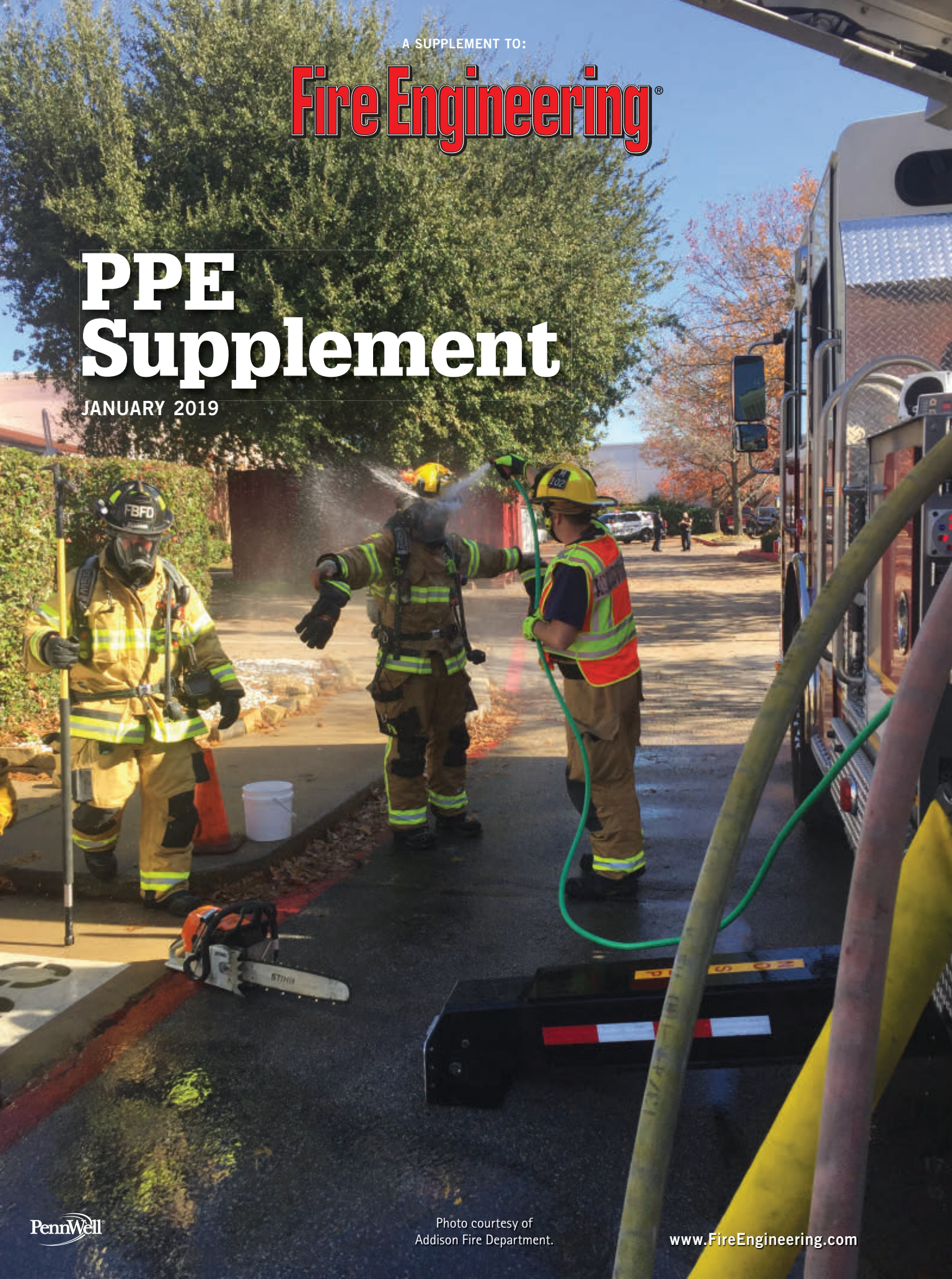

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PPE: Reshaping Contamination Control

Mitigating Contamination Through Proper PPE and On-Scene Practices

BY JEFFREY O. STULL

PERSONAL PROTECTIVE EQUIPMENT (PPE) is intended to protect against many of the hazards firefighters encounter on the fireground, and related equipment is supposed to allow personnel to safely carry out their mission. Yet, the fire service is coming to the realization that structural firefighting and several other related activities are often more "hazmat" than regular hazardous materials operations. Moreover, the PPE and related equipment should not create hazards to firefighters' health and well-being by being a source of continued contamination exposure. To this end, the fire service, PPE and other equipment manufacturers, and various service companies are rethinking their approaches on how to effectively clean the PPE and related items and render them safe for reuse.

"How Clean Is Clean?" (PPE Supplement, *Fire Engineering*, January 2018) provided guidance on a series of topics relating to treating structural fires as hazmat incidents, understanding PPE contamination and exposure, beginning contamination control on the fireground, properly triaging PPE cleaning and decontamination, applying appropriate cleaning methods, and assessing/validating cleaning effectiveness. Since that time, more collective research, new product ideas, and extensive standards activity have been reshaping how the fire service approaches fire scene contamination control, particularly as it applies to PPE. Although there has been momentum in getting acceptance of new thinking around contamination control, there are still cultural barriers and resource issues to tackle. Continued awareness and practices that are easy to implement are needed to reshape the PPE industry with respect to contamination control.

This supplement provides further information to inform the fire service and the industry of what is working, what is not working, and what still needs to be determined for advancing the fire service toward minimizing exposure to harmful contamination. New practices are emerging for proper PPE use and cleaning. These practices are being supplemented by new requirements that are or will be appearing in National Fire Protection Association (NFPA) 1500, *Standard on Fire Service Occupational Safety and Health Program*, and NFPA 1851, *Standard on the Selection, Care, and Maintenance of Protective Ensembles for Structural Fire Fighting and Proximity Fire Fighting*.

Standards as a Foundation for Change

Even though standards are voluntary in most jurisdictions, they are probably one of the largest agents for effecting changes in technology and practices within the fire service. Some of the biggest issues have arisen through debates on the applicability of specific requirements that find their way into published standards. In PPE design, use, and care, this trend has been no different. When it comes to addressing contamination control, several efforts are underway that promise to have a long-lasting impact on fire service practices.

Standards are affecting cleaning of PPE in three specific ways: (1) updating the base approach for how decisions are made on when to clean gear, (2) starting the cleaning process before the gear comes off the fireground, and (3) establishing a hierarchy for applying different forms of cleaning and decontamination. For each of these topics, there are emerging new practices for determining when to perform thorough cleaning and the type of cleaning or decontamination.

1. Deciding When to Clean. According to the 2014 edition of NFPA 1851, advanced cleaning of turnout clothing must take place at least every 12 months. However, the standard further states that turnout clothing should be subjected to advanced cleaning whenever soiled. Advanced cleaning means taking the gear out of service, which, for garments and certain other elements, means laundering them. The proposed new 2019 edition of NFPA 1851 (expected to be available in August 2019) has increased the minimum frequency for advanced cleaning to at least two annually but, more importantly, has provided better definitions of the terms that clarify when to perform cleaning.

Terminology can be confusing and, if not clear, creates ambiguity related to how departments apply requirements in the standard. The technical committee responsible for NFPA 1851 has endeavored to propose changes that help the fire service make easier distinctions for judging contamination and specifically the need for advanced cleaning. A key part of this process has been to go back to the definitions (see "Key PPE Cleaning Terms").

Most of the fire service considers soiling a natural outcome of fighting a fire. When personnel consider contamination, they think of the hazmat team and the types of products they face during specialized responses. This is not the correct way for judging clothing that has been worn in a potentially hazardous environment.

We know that products of combustion arise from fires and most of the particles and chemicals created in the combustion process can be dangerous to breathe, particularly when synthetic materials are involved as the fuels. What many firefighters do not necessarily know is that some of those same products are not only respiratory hazards but also hazard-

If You Build It, They Will Come

BY GREG HENDERSON

One of the characteristics firefighters enjoy about the fire service is its culture. On December 4, 2017, Dallas (TX) Fire-Rescue's Safety Division was charged with and set out to change some of that culture. It would be the day the Safety Division was faced with its toughest challenge. We asked, "How do we get one of the most traditional fire departments in the country to understand how real the cancer epidemic is in the fire service? How do we get them to understand that fireground contaminants are deadly? How do we get our firefighters to understand that 'clean is cool,' regarding our PPE? How do we explain to firefighters in Texas that they must wear their SCBA and PPE throughout active and postfire environments?" Over the next several months, the plan began to fall into place.

Pouring the Foundation

First and foremost, the head of your department, the chief, must be 100 percent supportive of your endeavor. Every person with the responsibility of developing and implementing such a program must mirror the same support. If the actions and rhetoric of those in high places don't match your goal, building a fireground contamination policy and program and gaining compliance will be a struggle.

Next, the process of selecting an individual from your department to build such a program will be critical to its success. The individual chosen to develop and manage such a program must have credibility throughout the organization. Selecting someone with a good work ethic and a passion for serving firefighters and their families will go a long way.

Building the Program

Build a program with the mindset that it must be effective, yet convenient. Start with the basics and build from there. My son is 13 years old, and if he walked up to me and said, "Dad, I want to bench press 200 pounds," my response would be, "Great, let's start with 50 pounds, and we will build from there." Building a contamination control program is no different; start with the basics, get members comfortable, and then add a little more to the program. The most basic and simple best practices are extremely effective at reducing contamination.

Research and data collection are critical—they will support your program and help gain credibility. There are numerous papers, studies, and NFPA standards supporting the change in culture. NFPA 1851 is a great place to start. Look at best practices in the fire service. Gather policies from other departments and assess what best fits your department. Don't feel like you have to reinvent the wheel!

Once you have completed your research and data collection, write an exposure reduction/fireground contamination program for your department. The cost of implementing an effective and a convenient program is minimal and achievable. Let's look at a couple of examples.

First, performing on-scene exposure reduction procedures can be as simple as rinsing your gear before removing any piece of your ensemble (including your SCBA and face piece) before leaving the scene. Eighty percent of the carcinogens firefighters are exposed to are water soluble. Simple and effective!

Second, the cost of extractors and locating a verified independent service provider to clean PPE can be challenging. Your department can purchase a couple of 50-gallon trash cans and be effective at initially removing contamination. Fill one can with an NFPA 1851-compliant detergent and water mixture and the second with just water. Separate the liners from the shell, place the liners in the detergent/water solution, agitate the liners with a broom handle, and let the liners soak for up to an hour. Move the liners to the water can for rinsing. Duplicate the process for the outer shells. The faster firefighters address contamination, the more effective the results. The longer a coffee stain stays on a shirt, the more difficult it is to remove. Having a written policy and procedures in place signals to the members of the department the commitment to a long and healthy career.

Educate, Educate, and Educate Some More!

What may be the most crucial component to building a fireground contamination program is educating members on why the policy and procedures were written and what the department has developed to minimize or reduce fireground contamination. If the department explains why it is asking members to do something new and different from the norm, the initial compliance will be greater. The size and structure of your department will decide how you best approach reaching your audience. You must get face-to-face with as many members, especially company officers, as possible and present your evidence for culture change. Use other departments as evidence of the movement and the seriousness of fireground contamination. Emphasize the fact that fire departments are no longer encountering burning natural material but now battling synthetic materials. No more cotton mattresses—but memory foam instead. These synthetic materials are making firefighters sick.

For your presentation, use three or four credible research projects or studies. Highlight important areas to substantiate your program development. Provide current statistics relating to cancer diagnosis and other health-related issues. Reference NFPA standards such as NFPA 1851 and explain the content and the impact. Provide pictures of contaminated gear soaking in detergent and the amount of contamination that is removed. This is a huge eye-opener. Several Web sites from major departments have video testimonies that are incredibly impactful. Keep it "meat and potatoes," or you will lose your audience quickly. Finally, highlight and go over the policy and procedures the department has adopted. Answer questions and ask for any additional input to make the program better. On average, 50 percent of your audience will comply initially; 20 percent will not. It's the other 30 percent where you need to focus your attention.

Final Thoughts

Don't forget about other areas within your department, such as training and arson investigators. Training provides an excellent opportunity to begin the culture change on day one. Keep in mind that changing culture and developing good habits do not happen overnight. They will take time, be frustrating at times, and be a grind, but there will be feelings of success. Always remember: The effort and time your department puts forth in creating this change in culture will affect members of your department and their families for many years. There is nothing more gratifying than serving those who risk so much to save others.

GREG HENDERSON is a captain in the Safety Division in the Dallas (TX) Fire-Rescue Department.

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ous by skin absorption, which can occur when the chemicals are persistent and skin contact is maintained over extended periods. Products of combustion from fires include a variety of toxic, corrosive, and carcinogenic chemicals. Thus, products of combustion—soot and fire gases—are genuinely contamination.

By incorporating products of combustion into the definition of contamination, this means that entry into any structural fire can be considered an event that warrants advanced cleaning. A recommended rule of thumb is that individual members who have to wear self-contained breathing apparatus (SCBA) by virtue of entering an immediately dangerous to life or health (IDLH) environment have clothing that is contaminated (a more straightforward determination that contamination has occurred). If clothing is contaminated with products of combustion, then advanced cleaning should be performed.

As it stands now, soiled firefighting clothing necessitates advanced cleaning. There has been no proposal to change the definition of soiling. So, if clothing is just soiled, why should it be subjected to advanced cleaning?

To overcome this issue, it is important to realize that soiling—likely to be regular sweat, body oils, and just plain dirt—does have an impact on gear performance. Yet, to get around this problem, if the clothing is simply soiled, the committee now recommends that advanced cleaning be done as needed. This approach gives the department the opportunity to assess whether clothing could be compromised or is unsafe simply because it is too dirty.

This latitude to apply advanced cleaning for soiling should not be seen as a way out of properly cleaning clothing. PPE used in structural fires should still be subject to advanced cleaning.

2. Starting the Cleaning Process at the Fire Scene. Perhaps the most controversial and difficult new practice to implement is what many have referred to as "gross decontamination" (a hazmat term) and what hopefully will become known as "preliminary exposure reduction." It is recognized that PPE is generally in its worst condition immediately coming off the fireground. Historically, firefighters have accepted this condition but perhaps have removed some parts of the ensemble, continuing to wear many items back to the station in the apparatus. These habits unnecessarily continued firefighter exposure to the contaminants from the fire scene and resulted in the spread of this contamination to other areas that should be kept relatively clean.

Although the proposed techniques for taking actions at the fire scene relative to PPE are a form of cleaning or decontamination, they are not 100 percent effective and do not negate the need for a thorough follow-up cleaning or decontamination of the gear. Studies performed by the Illinois Fire Service Institute in conjunction with its research partners have shown varying levels of contaminant removal, primarily from external surfaces, based on the investigation of several techniques. The reality is that preliminary exposure reduction is just what the name of the term implies—early removal of contaminants to avoid continued exposure and their spread *before* getting in the apparatus and going back to the station.

3. Following a Hierarchy for Applying Cleaning and Decontamination. Another point of confusion when it comes to terminology is understanding the difference between advanced cleaning and decontamination in protective clothing and equipment. In the past, these terms have sometimes been used interchangeably. However, it is now proposed that advanced cleaning be defined as the act of removing both soiling and contamination that are generally associated with products of combustion (i.e., structural firefighting). On the other hand, decontamination is applicable to a wider range of contaminants. Generally speaking, decontamination is considered specialized cleaning since ordinary cleaning procedures may fail to remove certain types of contamination. Use of sanitizers or disinfectants is a form of specialized cleaning that is specific to neutralizing biological threats associated with bloodborne pathogens and other infectious microorganisms. To make sense of how fire departments can approach cleaning and decontamination, a decision logic has been proposed that creates a step-by-step approach that is shown in Figure 1, "General Approach for Cleaning Gear," and Figure 2, "Approach for Addressing Specific Forms of Contamination."

These figures are intended to provide guidance to the fire service for determining when and how to clean or decontaminate PPE. Figure 1 breaks down the basic decisions, whereas Figure 2 differentiates handling gear according to different forms of contamination. Preliminary exposure reduction always precedes each form of cleaning. In Figure 1, the

Key PPE Cleaning Terms

Soiling—accumulated materials not considered hazardous materials or body fluids but of the nature that could degrade the performance of the clothing (e.g., dirt, sweat).

Contamination—accumulation of products of combustion and other hazardous materials that can be carcinogenic, toxic, corrosive, allergy causing, or infectious (includes body fluids and other media with microorganisms).

Products of combustion—the end products of when fuels including hydrocarbons and other material remain after combustion in a fire.

Cleaning—the act of removing soiling and contamination.

Advanced cleaning—the act of removing soiling and contamination generally associated with products of combustion.

Specialized cleaning—the act of removing hazardous materials, soiling associated with body fluids, or other forms of contamination.

Decontamination—a process of removing or neutralizing contamination.

Sanitizer—a type of antimicrobial agent used to reduce, but not necessarily eliminate, microorganisms from the inanimate environment to levels considered safe as determined by public health codes or regulations.

Disinfection—a type of antimicrobial agent that destroys or irreversibly inactivates fungi and bacteria but not necessarily their spores on inanimate surfaces and objects.

Preliminary exposure reduction—techniques for reducing soiling and contamination levels on the exterior of the PPE following incident operations (not considered cleaning or decontamination).

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Understanding On-Scene Reduction of PPE Contamination

BY TIM TOMLINSON

As we continue to progress as a fire service, we learn that some things we did before worked and others needed changing. This was influenced by experience, time, research, generational changes, and cultural acceptance. At one time, it was not "cool" to wear SCBA; then we realized the health effects associated with not wearing one. Before, we would never consider cleaning our gear; now we recognize how unsafe it is to not clean it. We are also recognizing the impact of extended contact with contamination from fires and other incidents and the need to implement additional practices that reduce our continued exposure by performing "preliminary exposure reduction" after incidents.

Preliminary exposure reduction is the process of immediately reducing soiling and contamination of chemicals, soot, and other products of combustion from turnout gear at the incident or as soon as reasonably possible after an incident. This can be done with a wet process, a dry brushing process, with water only, or with water and an NFPA 1851-compliant detergent added for possible improved contamination removal. The overall goal of preliminary exposure reduction is to remove as much contamination as soon as possible to reduce further contamination to the firefighter.

You may wonder how the NFPA 1851 Technical Committee developed the term "preliminary exposure reduction." First, we recognized that the fireground can be viewed as a hazmat incident and that, for a hazmat incident, there is a similar but more extensive process called gross decontamination. Comparatively, gross decontamination is a formal, very technical and thought-out process given the threat of specific chemical exposures. Preliminary exposure reduction is still a formal process, just less technical. This is because the contamination threats are more clearly defined in hazmat operations. Recognizing this difference, the technical committee did not want to discourage the fire service from implementing such processes for immediately reducing contamination and cross contamination after fire incidents by using a term generally associated with hazmat incidents.

(1) Preliminary exposure reduction following a structural fire. (*Photo courtesy of Addison Fire Department.)*

How to Apply Preliminary Exposure Reduction

We do know that wet exposure reduction works better than dry exposure reduction. Wet exposure reduction may consist of a garden hose hooked up to a discharge of your apparatus, a red line, or a low-volume-pressure handline. On starting preliminary exposure reduction, the best practice is for the firefighter to remain on air. Preliminary exposure reduction should be started at the head of the firefighter, allowing gravity to assist with the mechanical action of the water or water and detergent solution. The firefighter should be extensively sprayed off in a downward motion from head to toe until as much visible contamination as possible is removed from the protective clothing.

If your department is using water and a detergent, take the following differences into consideration even though the general process is similar. One difference is that the firefighter should be sprayed down and heavy debris should be removed as much as possible prior to applying a water and detergent solution. The detergent and water solution can then be applied and a soft bristle brush can be used to gently scrub the firefighter's turnout gear, aiding in removal of the contamination. The firefighter should then be rinsed off again with a gentle low-volume stream. It is currently unknown if a detergent and water solution is more effective than just water. There is work being completed to further understand this in the hope that it is one more valuable step that can be implemented to improve the overall process. When a detergent is used, it should be NFPA 1851 compliant. Moreover, some detergents have been specifically positioned for cleaning firefighter gear. Their relative effectiveness is still under review.

If your department does not have the ability to perform wet preliminary exposure reduction because of weather, the response environment, or other unforeseen conditions, a dry process can still provide a certain level of effectiveness. Dry brushing off contamination is still an effective means for performing exposure reduction and is considerably safer than a fan or an air blower, since the latter forms of dry exposure reduction can potentially aerosolize the contamination and particulates, creating potential hazards at the scene.

What Comes After Preliminary Exposure Reduction

Once preliminary exposure reduction procedures are completed at the incident, the best practice for firefighters is to remove their gear and bag it at the incident. It is recommended that the bags used for isolating the soiled gear be airtight and six mil thick. This allows gear to be transported back to the station without further cross contamination. Gear should be removed from the bag when back at the station or on arrival at your logistics center and subjected to advanced cleaning if possible. If your station or department does not have an extractor, hang your gear up and let it air dry. If you do not have a second set and you do not have the ability to wash your gear on arrival back to the station, this is more of a reason to implement preliminary exposure reduction, as it is a proactive way to reduce the amount of contamination you are exposed to each time you have to redon your gear the remainder of the shift.

Common concerns about performing preliminary exposure reduction are often voiced through the following statements: "My department does not have a second set of gear" and "If I perform exposure reduction after an incident, my gear will be wet and I will have to wear wet gear the remainder of the shift." I have yet to leave a structure fire where I was not wet. Since your gear is wet after an incident regardless, wouldn't you rather be wet with less contamination on you?

Continued on p. 10


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Continued from p. 8

Does every firefighter on the incident need exposure reduction?

This is a question that is still being debated. Ultimately, it is going to be the decision of your department and its operating procedures at an incident. As you consider this question, a few additional questions come to mind:

- Why not err on the side of caution and perform exposure reduction on all incident personnel?
- Is this realistic?
- Can we definitively say that anyone who did not enter the IDLH environment did not have exposure to smoke and other hazardous particulates?
- Does your fire department have the training and knowledge in PPE and contamination exposure to make the determination of who needs to be included in the preliminary exposure reduction process?
- Is there a legal obligation for a fire department to require all possible practices to reduce contamination to its firefighters?

The best approach may be to use a common-sense approach. If there was the potential for exposure to products of combustion and other airborne particulates, then they should be included.

Changing the mindset is not easy, but it's time to proactively take simple steps toward reducing the known health effects associated with fireground exposures. We can find a way to not do anything. Instead of getting stuck on why we can't do it, why don't we find a better way to do it so that it works within our operations? It's a small sacrifice for a larger gain. Although it is only a small piece in the overall process of contamination control, each step in the process is valuable and makes an impact on the overall improvement of the health and safety of the fire service. It should be as common as returning to the station and changing your clothes and taking a shower because you don't want to sit around wet and sweaty. Why do some want to put back on dirty gear filled with chemicals and contamination? At the very least, we should want to leave as much of the contamination as we can at the scene of the incident. It truly is basic hygiene.

TIM TOMLINSON is a driver operator/paramedic with the Addison (TX) Fire Department and chairman of the NFPA Technical Committee for NFPA 1971 and NFPA 1851.

approaches for deciding on the handling, cleaning, and disposition of protective ensembles and elements use a hierarchy of decisions involving the highest risk contaminants and soils first and then proceeding to lower risk contaminants and soils.

CBRN Exposure. The first decision involves any exposure to chemical, biological, radiological, or nuclear (CBRN) terrorism agents where following preliminary exposure reduction the PPE items are immediately condemned and removed from service given the high risks associated with CBRN terrorism agents.

Hazardous Materials Incident Exposure. The second decision involves the use of firefighting PPE in a hazardous materials incident. It is recognized that firefighters may sometimes wear their PPE in response to a hazardous materials incident, even if other types of protective clothing may be considered more appropriate for the type of exposure. Hazardous materials incidents typically involve exposure to chemicals or other substances that pose toxic, corrosive, irritating, or sensitizing hazards to the wearer. This type of ensemble use may occur without any fire threat. This section provides for decisions involving exposure to bulk chemicals present during a response that occur as the result of a fire-based incident.

For a hazardous materials incident exposure, the prescribed action following preliminary exposure including isolating and bagging the gear is to have the organization hazmat team or other qualified experts knowledgeable in hazardous materials assess the exposure to determine if decontamination is needed and is possible. If decontamination is needed, some form of specialized cleaning is required. The recommended decontamination procedures should be applied only if there is some understanding that it will be effective in removing the hazardous materials contamination. Otherwise, the PPE should be disposed of as contaminated waste.

Contamination Exposure. The third decision is for any other response where contamination of the PPE occurs. This decision is broken down into a separate set of decisions covered by Figure 2.

Soiling Exposure. If there is no contamination and the ensemble is simply soiled from ordinary dirt, sweat, or other nonhazardous materials, then it is still recommended that the ensemble and elements go through preliminary exposure reduction. If the soiling is extensive or if the ensemble elements are due for advanced cleaning, then advanced cleaning should be performed and the ensemble elements subjected to at least a routine inspection.

Figure 1. General Approach for Cleaning Gear

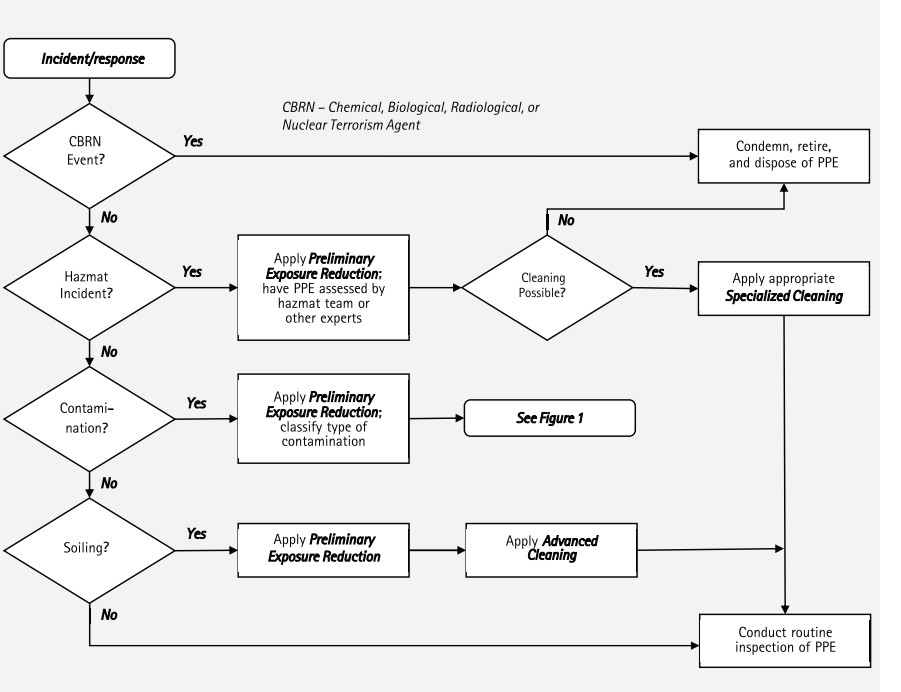

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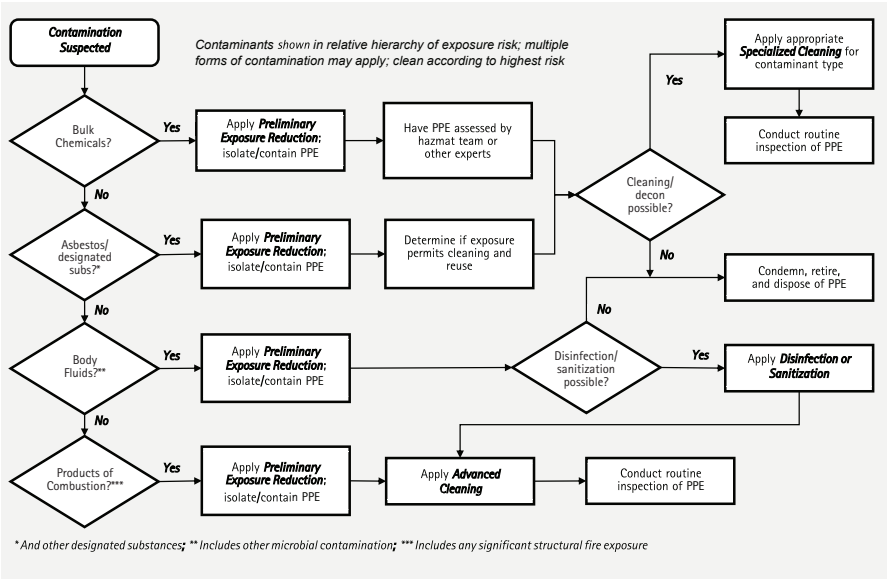
Figure 2. Approach for Addressing Specific Forms of Contamination



In Figure 2, the application of the appropriate cleaning, decontamination, disinfection, and sanitization procedures is dependent on properly classifying the contamination types to which the PPE ensemble has been exposed.

There are four general classifications of contamination.

Bulk chemicals. Exposure to chemicals can occur at any emergency scene, particularly where various types of oils, greases, and lubricants are used. Many residential structural fires can include a variety of cleaning agents and other products contained in garages, kitchens, and other portions of a house where direct liquid exposure to the chemical in its bulk form can occur. Structural fires at commercial facilities, particularly those involved in manufacturing, can likewise include a variety of chemical substances in containers that break open and cause exposure of firefighters. These exposures can be in gas/vapor, liquid, or solid form.

Depending on the nature of the chemical and its hazards, PPE contamination can take place and remain as persistent contamination, which may or may not be removed by advanced cleaning procedures. Specialized cleaning is often recommended for bulk chemical contamination and may require inquiries to the chemical supplier as well as the manufacturer of the respective protective ensemble or elements. In some cases, the organizations may conclude that depending on the hazards associated with the specific chemicals, the extent of contamination, or the lack of available decontamination procedures, the risk for reuse of the clothing may outweigh any benefits of retaining the clothing even if the clothing appears to be clean and free of contamination.

Asbestos and other designated hazardous substances. Certain types of common contaminants, such as asbestos and opioid drugs (fentanyl), and parasites such as bed bugs can require specialized cleaning or treatments for their removal from PPE items. These substances are called out separately from bulk chemical exposures because there is some history and experience for addressing ensembles and elements that have been contaminated with these substances. In particular, asbestos warrants special attention because of the direct link between asbestos exposure and mesothelioma, for which firefighters are at elevated risk.

Decontamination of PPE that has been exposed to fentanyl powders requires use of certain procedures that prevent exposure of firefighters. Conventional washing of protective ensembles and elements that have been exposed to bed bugs also will fail to kill any bed bug eggs that remain in the clothing. PPE exposure to these substances requires special consideration and often entails using specialized cleaning procedures or treatments for their removal. Depending on the risk associated with a substance, organizations may conclude that the risk for reuse of the ensemble element may outweigh any benefits for retaining the clothing item even if the ensemble element appears to be clean and free of contamination.

Body fluids and other microbial contamination. Body fluids such as blood, vomit, and various secretions are often encountered in providing emergency patient care or rescue of victims at an emergency scene. These fluids must be treated as potentially infectious; thus, PPE contaminated with body fluids must be subject to sanitization or disinfection, where disinfection represents a greater efficiency in removing potentially infectious microorganisms. Other biological contaminants can include methicillin-resistant *Staphylococcus aureus* (MRSA) and *Clostridium difficile* from medical victim contact and *Escherichia coli* from flood water contact. These contaminants require disinfection or sanitization of PPE items to reduce the microbial threat where exposure has occurred.

Disinfection and sanitization may proceed advanced cleaning or be part of the advanced cleaning process since soils associated with many body fluids must also be removed. It is important to recognize that disinfection or sanitization generally affects only the viability of the microbial contamination and may not remove the other soils associated with the contamination such as dried blood or body fluids or other liquids/solids in which the microbial contamination is found.

Products of combustion. All fires where entry is made while wearing SCBA generally will expose clothing and equipment to products of combustion. The smoke particles and fire gases easily penetrate and contaminate clothing. Depending on the length of exposure and degree to which firefighters are exposed, the levels of contamination from products of combustion will vary but always require advanced cleaning. Preliminary exposure reduction is undertaken to remove some forms of surface contamination as well as minimize the transfer of exterior contaminants to other surfaces such as apparatus seats and fire station work/living areas prior to advanced cleaning.

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Ultimately, you must use good judgment whenever deciding when and how to clean PPE. This responsibility is augmented by the development of good standard operating procedures and training of members on their individual duties. It also requires an investment on the part of the department to "protect" not only the long-term utility of PPE but, more importantly, the continuing health of the members.

Establishing a Cleaning Approach

With the trend toward more frequent cleaning of turnout clothing, many departments are investigating or adding new in-house capabilities that allow their organizations to conduct regular cleaning. This is a significant investment because the implementation of these capabilities is relatively resource-intensive and involves the following considerations:

1. Selecting an Appropriate Washing Machine. From an equipment standpoint, the key item is the washer/extractor. Although some organizations may have attempted to make do with standard washing machines, top-loading machines are no longer acceptable. Even the newer front-loading household machines do not provide the appropriate characteristics for cleaning turnout clothing, particularly when high-efficiency/low-water utilization is now the practice with this type of equipment. Instead, consider washer/extractors with the following features from a recognized company:

- An appropriate capacity (indicating the number of items that can be washed in a given load).
- Programmability for choosing the right sequence of steps for the washing process.
- Spin speeds that do not exceed 100 G.

The fire service is best served by those companies that have taken the time to understand the specific needs for cleaning turnout clothing and thus offer machines and programs tailored for fire service applications.

Proper load size is essential for effective cleaning. An overloaded washer prevents the wetted load from dropping from 11 o'clock to 5 o'clock in a clockwise wash rotation. Overloading occurs when this drop of the wash load does not happen. In addition, full loads are best for washing, as the agitation and cleaning are most efficient with full loads. Therefore, it is also important to avoid underloading the washer/extractor.

The capacity of a washer/extractor is provided both in the weight of the load, usually reported in pounds, and the overall volume of the basket, usually reported in cubic feet. As a rule of thumb, one cubic foot of washer/extractor basket allows a capacity of two garment shells or liners. For example, a 30-pound washer/extractor has a basket volume of 4.1 cubic feet. Thus, a washer/extractor with this capacity would fit four pieces. Similarly, a 60-pound washer/extractor with a 9.0-cubic-foot basket would fit nine pieces. Where there is a fractional amount of cubic feet in the washer/extractor capability, it is recommended to round up to get a whole number of garment pieces.

Laundering turnout clothing in a washer/extractor is more complex than ordinary laundering. Wash formulations (programs for how much water goes into the machine, at what temperature, and for how long, and if any chemicals/detergents are needed) are part of an appropriate wash process. Many machine providers preprogram their machines with wash formulations to address these

Figure 3. General Wash Formulations for Laundering Turnout Gear

GARMENT OUTER SHELLS

OPERATION	TIME (MIN)	TEMPERATURE	WATER LEVEL
Prewash fill, flush	—	Warm	High
Agitate	5	—	—
Drain	—	—	—
Fill	—	Maximum*	Low
Wash, add suds/detergent	—	—	—
Agitate	15	—	—
Drain	—	—	—
Rinse, fill/agitate	5	Cold	High
Drain	—	—	—
Rinse, fill/agitate	5	Cold	High
Drain	—	—	—
Rinse, fill/agitate	5	Cold	High
Drain	—	—	—
Extract at 100 Gs	6	—	—

* 40°C or 105°F

GARMENT LINERS AND HOODS

OPERATION	TIME (MIN)	TEMPERATURE	WATER LEVEL
Prewash fill, flush	—	Warm	High
Agitate	3	—	—
Drain	—	—	—
Fill	—	Maximum*	Low
Wash, add suds/detergent	—	—	—
Agitate	9	—	—
Drain	—	—	—
Rinse, fill/agitate	5	Cold	High
Drain	—	—	—
Rinse, fill/agitate	5	Cold	High
Drain	—	—	—
Rinse, fill/agitate	5	Cold	High
Drain	—	—	—
Extract at 100 Gs	5	—	—

* 40°C or 105°F

needs. The two specific wash formulations to be recommended in the 2019 edition in NFPA 1851 appear in Figure 3.

2. Deciding on a Drying Approach. Decide how to dry ensembles and elements after cleaning with the following in mind:

- Time constraints.
- Effect of the drying method on the ensembles and elements.

Drying takes up the majority of time to get ensembles and elements back in service. Nevertheless, the recommended and preferred method of drying is air or forced ventilation or drying in a drying cabinet as opposed to machine drying by tumbling action. In some cases, it might be appropriate for machine drying by tumble action of a garment liner while the garment outer shell is air dried or dried in a drying cabinet.

Air drying is the most appropriate method for drying ensembles and ensemble elements. It causes no mechanical damage and little or no shrinkage. The most efficient method of air drying involves forced air ventilation. This can be done by simply using fans to recirculate air in the room with the ensembles and elements. The basic drying room should include floor drains, a method to exchange the air to the outside environment, and drying racks for hanging ensembles and elements to provide maximum air exposure. Overall drying time will depend on the efficiency of the drying room and the ambient conditions. Heating the room or the inlet air up to 100°F can improve the efficiency of the drying process. Drying ensembles and elements in ambient air, as opposed to drying rooms, takes a considerable amount of time, depending on the ambient environmental conditions.

A drying cabinet is a suitable alternative to air drying. Drying cabinets, available from machine manufacturers, are contained cabinets where garments, gloves, and footwear can be suspended with the introduction of heated air over a specified period. This type of drying enables greater control of the air temperatures and, if properly used, can improve the efficiency of garment drying and lower utility costs.

(1) Layout of a fire department gear cleaning facility. (*Photo courtesy of McKinney Fire Department.)*

Machine drying of ensembles and elements is generally not recommended. Dryers can reach high basket temperatures during operation, potentially damaging ensembles and elements. Machine drying also includes mechanical action that can cause damage. Nevertheless, a tumble dryer with a moisture-sensing feature can dry a saturated load with higher than 105°F heat; when it reaches a percent dryness level, the heat can then be reduced or stopped. The "no heat" is the preferred method of machine drying because it effectively accomplishes forced air ventilation.

3. Determining Cleaning Locations and Department Responsibilities. Identifying the correct machine is an important part of the process of selecting cleaning equipment, but a bigger issue is where to put the machine and other cleaning equipment. The department must have sufficient space for placing the machine, including additional space for drying equipment (if selected) or hanging clothing; at least one utility sink (for washing other PPE); and the utilities to accommodate operation. Very specifically, appropriate levels of hot and cold water capacity must be provided to the machine. The current restriction on water temperature for turnout clothing is 105°F. Higher temperatures have been investigated as potentially having better cleaning effectiveness; however, as temperatures are increased, so is the wear and tear on certain clothing components that can shorten service life prematurely. Higher temperatures of up to 140°F are only permitted for certain forms of specialized cleaning, such as removing bed bug contamination. Regardless, any decision for installing laundering equipment at a fire department has to account for hot water needs.

As extractors spin out large quantities of water from the machine, the drainage system in place must be able to handle water flow rates. Though most jurisdictions do not require special handling of wastewater, check with local regulations to ensure that contaminated wastewater can be put into the sewer system at that location. Therefore, the ability to put a washer/extractor in a location takes a significant amount of planning, and departments must consider all these details before making a purchase.

Another consideration is who will be doing the laundry. Some departments have chosen to centralize laundry while others, which can afford it, have placed washer/extractors throughout their department. Allocating the responsibility for washing clothing and providing the degree of training for washing the clothing properly are important decisions. Generally, when individuals are left to washing their own gear, there can be a breakdown in the assurance that cleaning practices are carried out properly. On the other hand, assigning specific individuals (light duty or dedicated personnel) can provide more consistency in cleaning.

4. Choosing Cleaning Agents. Turnout clothing cleaning requires specific detergents to ensure removal of contaminants and ordinary fireground soils, which can be quite varied in their composition. It is possible to use standard industrial or consumer-based wash chemicals, but take care in their selection.

Many industrial wash chemicals are predicated on high alkalinity and subsequent pH adjustment by acidic sour solutions. Yet, NFPA 1851 requires that the pH indicated on the cleaning agent safety data sheet be no higher than 10.5 and no lower than 6.0. Many industrial wash chemicals cannot meet these limits. On the other hand, consumer products may not be optimized for effectively cleaning turnout clothing materials. Instead, it is better to choose wash chemicals that have been formulated specifically for turnout clothing cleaning. These chemicals should have demonstrated effectiveness in cleaning turnout gear without causing any deterioration of turnout clothing performance. Viable suppliers should be able to provide this information at the request of the fire department.

A number of supplemental cleaning agents are making their way into the fire service. Some of these cleaning agents are repositioned products that were originally touted for decontamination of military clothing against weapons of mass destruction agents. It is quite possible that these agents can work as intended, but it is much more important to ask for specific research or studies that adequately document the use of these types of products on turnout clothing.

The larger concern for any cleaning agent is its ability to remove persistent contaminants often trapped in the set and lodged in the materials themselves. As many fireground contaminants are relatively complex chemicals representing a range of compounds, the ability of a single cleaning agent to neutralize or react with fire service contaminants is a fairly broad claim.

Thus, the fire service should approach these products with the same degree of scrutiny as for the purchase of any product intended to provide seemingly high-end benefits. As with general detergents and cleaning agents, look for evidence that the product will not irreversibly affect turnout clothing performance.

5. Picking Companies for Outside Cleaning Services. One option is the use of independent service providers (ISPs) that inspect, clean, and repair firefighter turnout clothing. Many of them are independently verified by third-party certification organizations. Currently, both Intertek Testing Services (ITS) and Underwriters Laboratories (UL) verify ISPs; the listings of qualified organizations can be found at their respective Web sites.

Verified ISPs are reviewed for meeting the requirements of NFPA 1851. This verification process involves an assessment of the ISP procedures and some verification testing related to repair capabilities. Until the next edition of NFPA 1851 is accepted, there is no verification of cleaning procedures for contaminant removal. However, verified ISPs must still demonstrate adherence to the current requirements of NFPA 1851 for cleaning turnout clothing. The use of verified ISPs means that there is at least some oversight for their procedures, which are periodically monitored and reviewed.

Not all ISPs will handle all types of clothing contamination. Most ISPs will generally clean fireground contaminated clothing and many also will handle clothing that is exposed to blood or body fluids that are potentially con-

taminated with bloodborne pathogens. Beyond that, it will depend on the capabilities of the ISP as to whether cleaning is provided for specialized hazmat exposures or certain types of contaminants such as asbestos and bed bugs. Whenever dealing with an ISP, ask multiple questions about its capabilities and ascertain whether it has experience in providing services for special cleaning circumstances.

6. Ensuring Your Understanding of NFPA 1851 Requirements. In considering your cleaning options, fully investigate any equipment, products, or services that you intend to use and ensure they are consistent with the requirements of NFPA 1851. Be wary of any vendor that indicates it is "approved" by the NFPA, as the NFPA does not approve anything. ISPs that meet the respective requirements of NFPA 1851 can be verified by either ITS or UL. Likewise, there are no NFPA 1851-approved equipment items, detergents, cleaning agents, or processes. These items can comply with NFPA 1851, but there is no approval authority.

In many cases, you should be able to ask for references—other fire departments or organizations—that have purchased from these vendors. Checking with others is one good way to understand how well the cleaning worked and if there were any specific problems. There is considerably more detail in defining the appropriate turnout clothing cleaning option that is right for your organization, but taking the time to understand existing requirements, knowing your specific needs, and questioning claims are the right approach for finding the correct solution.

Beyond Turnouts

If frequent cleaning is to become the norm, then implications arise as to the impact on both the gear and the departments that choose to provide this level of cleaning. For years, many departments have struggled to outfit their members with two sets of gear. The push for two sets has been based on the argument that as one set becomes soiled or contaminated, an extra set is needed to prevent taking the unit out of service.

This two-set approach has been instrumental in ramping up the ability to more frequently clean gear and having fire department members in cleaner gear. Yet, for some departments, a two-set approach may not be the solution or even possible within their available resources. This may be because two sets are simply insufficient for a relatively busy station or create a financial burden.

In addition to the availability of clean gear, other questions arise even about the ability to clean. Generally, the focus has always been on garments and, to a lesser extent more recently, hoods, because these items can be cared for much like regular apparel. Helmets, gloves, and footwear are generally more frequently ignored. Typically, these items cannot be machine washed and sometimes are never cleaned after a fire incident. Yet, it is well recognized that these items become just as dirty as, if not more so than, the full garments.

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Evolution of a PPE Program/Implementing NFPA 1851

BY MOLLY B. RILEY

The evolution of any PPE program takes time, commitment, an incredible amount of collaboration, and a steadfast philosophy to always move forward. In 1996, the Virginia Beach (VA) Fire Department installed two turnout gear extractor and dryer systems at strategic locations in the city. The installation of these units coupled with new PPE standard operating procedures were met with strong opposition and a considerable amount of disdain for spending the funds and taking up much-needed space with such things. "What are you trying to do to us?" That was the first step in redefining our PPE program.

The implementation of NFPA 1851 in 2001 was a tremendous foundation for the fire service, as it offered guidance and expectation but mostly a standard that all members of the fire service could look to and rely on as a path forward. Compliance with this new standard created both opportunity and challenge. Being prepared for the challenges didn't keep them from coming.

The evolution of any PPE program takes time, commitment, and an incredible amount of collaboration.

Understanding the roles and responsibilities for PPE care and maintenance was difficult. What was the responsibility of the firefighter? What was fire support supposed to do? Where does Safety fit in, and how does the department make this work without constant gaps? Inconsistencies and the lack of knowledge did not help motivate needed culture change.

The initial reason to install more extractors was to eliminate apparatus from being taken out of service; cleaning your gear was an act to keep you out of trouble with the new standard operating procedures.

The department needed education and funding; the PPE program needed consistency and engagement—keep that order coming for the next several years.

Education evolved into a two-tiered program; PPE 101 was designed to educate every recruit that passed through the fire academy and an advanced program for each firefighter, company, battalion officer, and safety officer via an in-service platform. These programs focused on ensemble performance and interface, individual and department responsibility, with heavy emphasis on NFPA 1851. Continuity between suppression, safety, and fire support had arrived.

In 2008, cancer claimed the lives of two Virginia Beach firefighters within three months of each other. That was the wake-up call for any remaining holdouts. The culture was forever changed. Steady progress to fully comply with 1851 continued but came with increased need for resources and funding. Equipment, installation, and infrastructure costs rapidly mounted.

Support from the city, the department, and union leadership was essential to increase the funding toward this new reality of the fire service. Pairing funding from local and federal grants with city funds was critical to implementing these changes.

The program, now on solid ground, has seen multiple revisions to PPE procedures to hone the following best practices:

- Inspecting and cleaning gear, preliminary exposure reduction, bagging exposed gear, and showering after a call are now second nature for department personnel.
- PPE laundering systems and designated decontamination areas are available throughout the department.
- There are now two sets of gloves, a second hood, and a second set of turnout pant and coat ensembles for department members.
- In most departments, a steady increase in call volume has become the new normal. As the frequency of cleaning PPE increased and greater quantities of gear were issued, there were higher volumes of gear repairs and larger demands for loaner and replacement gear. Recent and separate incidents involving asbestos and formaldehyde exposures challenged department protocols and clearly identified the need for specific gear testing and cleaning procedures throughout the industry when hazardous chemicals are involved.

Accommodating and absorbing increased gear demands require program management reconsiderations, continual support, and financial commitment. Progressive and vigilant PPE programs must be prepared and willing to adjust with transitions that occur within the department and industry. It is incumbent on program leaders to have extensive knowledge of and objectivity about events and information surrounding PPE. Acute understanding of current and upcoming NFPA PPE standards is a necessity to maintain and prepare for program changes. Extensive knowledge and drivers of the latest components, designs, and gear on the market are paramount.

Particulate-blocking hoods are making an impact within the PPE market. Carefully and deliberately consider how current and new PPE products fit within a program; weigh considerations such as need, performance, protection, life cycle costs, and most certainly particulate and carcinogen exposure reduction.

Effective and compliant PPE programs will always require strong commitment, broad collaborative efforts, financial resources, and the drive to elevate the program to the next level for the benefit of the members it serves. These programs have influence like no other; however, never undersell the importance of individual accountability.

After 22 years, hopefully everyone can see that the question "What are you trying to do to us?" has been answered through developing a progressive NFPA-compliant program. My brothers and sisters, we are trying to save you.

MOLLY B. RILEY is procurement and contract manager for the Virginia Beach (VA) Fire Department.

Thus, the ability to clean these items effectively remains a significant variable as the trend for frequent cleaning is increased. For example, the portions of the helmet suspension that come in contact with the firefighter and the ear covers are probably not cleaned after most fires. The ability to remove these items varies significantly among manufacturers and types of products. For gloves and footwear, there are significant limitations to the ability to clean these ensemble elements uniformly. There is also the SCBA to contend with, which has a combination of soft textile parts in the harness and straps as well as several harder rubber and metal surfaces. For PPE contamination to be truly effective, you must address all parts of the ensemble.

Specific approaches for addressing the cleaning of ensemble items other than garments are described below.

1. Instituting Hand Washing Procedures for Other PPE. The basic procedures for cleaning other PPE that cannot be machine washed include having the individual performing the hand washing do the following:

- Wear examination or cleaning gloves, an apron with sleeves, and goggles.
- Separate any detachable or separate components such as ear covers, suspension covers, and goggles for helmets.
- Segregate detachable components that are textile based for separate hand washing or washing in a washer/extractor with other components such as garments or hoods.
- Use a utility sink filled with warm water at a temperature no warmer than 105°F and a mild detergent having a pH of not less than 6.0 or more than 10.5 at the detergent manufacturer's recommended ratio of detergent to water.
- Lightly scrub the exterior of the item with a soft bristle brush to reach between components.
- Thoroughly rinse the item following washing.
- Allow the item to be air dried, which can be assisted by using a towel on any hard surface to aid in drying the item after cleaning.

2. Applying Specific Procedures for Cleaning PPE Items. Depending on the type of item and the manufacturer's instructions, following are additional considerations.

Helmets. Advanced cleaning includes washing the inside and outside surfaces of the helmet carefully, using a soft brush to reach between components and into difficult-to-access spaces, and separately washing the eye/face protection with a soft cloth. It is usually not necessary to completely submerge a helmet for cleaning unless it is being inspected for damage or repairs are being performed in conjunction with the cleaning. Consult the manufacturer's instructions to determine if there are other detachable components such as the impact cap, suspension, face shield, or other items that are best to remove from the helmet shell and clean separately. Separate cleaning agents may be needed for helmet eye/face protection including face shields and goggles.

New Method for Inspecting Particulate-Blocking Hoods

BY DR. R. BRYAN ORMOND

In response to growing concerns over dermal exposure to fireground contaminants, protective hood manufacturers have introduced a variety of particulate-blocking hoods to the market over the past two to three years. These hoods can vary significantly between manufacturers, but their overall purpose and function are the same: to block smoke particles from reaching the skin on the firefighter's head and neck. Regardless of the manufacturer, this goal is achieved by one of two types of technologies. Between the inner and outer knit layers of the protective hood, particulate-blocking hoods have either a membrane-based layer similar in construction to the moisture barrier used in turnout jackets or a specialized flame-resistant nonwoven filtration layer that resembles the material used in an air filter.

In 2015, when the first particulate-blocking hoods were unveiled, they were certified to the 2013 edition of NFPA 1971, *Standard on Protective Ensembles for Structural Fire Fighting and Proximity Fire Fighting*. They met all the existing requirements for protective hoods at the time, but the standard was lacking the necessary specifications required to assess both the efficacy of particulate-blocking layers as well as the effects that they may have on thermal burden. Historically, NFPA 1971 focused on thermal and mechanical properties of hood materials to ensure adequate thermal protection and durability. During the process of revising NFPA 1971 for the 2018 edition, the Technical Committee addressed this gap by adding a particulate filtration efficiency test as well as a requirement for total heat loss for particulate-blocking hood composites.

The filtration efficiency test method that was added to the standard provides an assessment of the ability of the protective hood materials to block particles that are in the same size range as smoke particles typically encountered at a structural fire. Particulate-blocking hood composites must filter on average a minimum of 90 percent of all particles across the size range to meet the NFPA 1971 requirement. As a reference point, the materials used in traditional nonparticulate two-layer knit hoods can filter between 30 and 60 percent of particles, depending on the specific size of the particle and the knit construction.

All hoods currently on the market that are certified to NFPA 1971 (2018) meet or exceed this 90 percent filtration requirement at minimum when the fabric is in a new, unused state. However, a need still exists for a method that enables firefighters to inspect their particulate-blocking hoods on a routine or yearly basis to ensure that the filtration performance has not diminished. A logical suggestion would be to use the filtration test used for the initial certification. In fact, many manufacturers have completed durability studies of their particulate-blocking hoods up to 100 launderings and used this filtration test to evaluate the performance over time. Although this test method may be acceptable for manufacturers that are doing research and development, there are significant issues with using this method for routine or advanced inspection of hoods. One of the main issues is that the cost of this test is prohibitive for this level of inspection. With that in mind, an ideal inspection method for particulate-blocking hoods would be cost efficient; reliable; fast; sensitive enough to detect defects, holes, or damage in the materials; and simple enough to be set up either at an ISP or within the actual fire station.

To address the need for an inspection method, researchers in the Textile Protection and Comfort Center at NC State's Wilson College of Textiles are working on a research effort funded by the Federal Emergency Management Agency Assistance to Firefighters Grant Program. The objective of the overall research project is to develop a comprehensive assessment of traditional and particulate-blocking hoods ranging from thermal and particulate protection to comfort, situation awareness, and cleaning efficacy. The development of a cost-efficient and accessible inspection method for particulate-blocking hoods was initiated through the collaboration of the research group and the Technical Committee responsible for NFPA 1851.

The newly developed inspection apparatus is shown in photos 1 and 2. This apparatus was designed using readily available pieces of equipment. The basic structure or stand is a commercially available hydrostatic pressure tester that is already used by many departments

Continued on p. 24

(1–2) Test equipment with and without light sensors. (*Photos courtesy of North Carolina State University.)*

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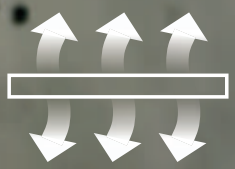

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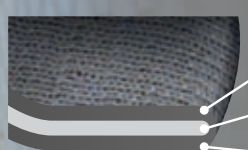

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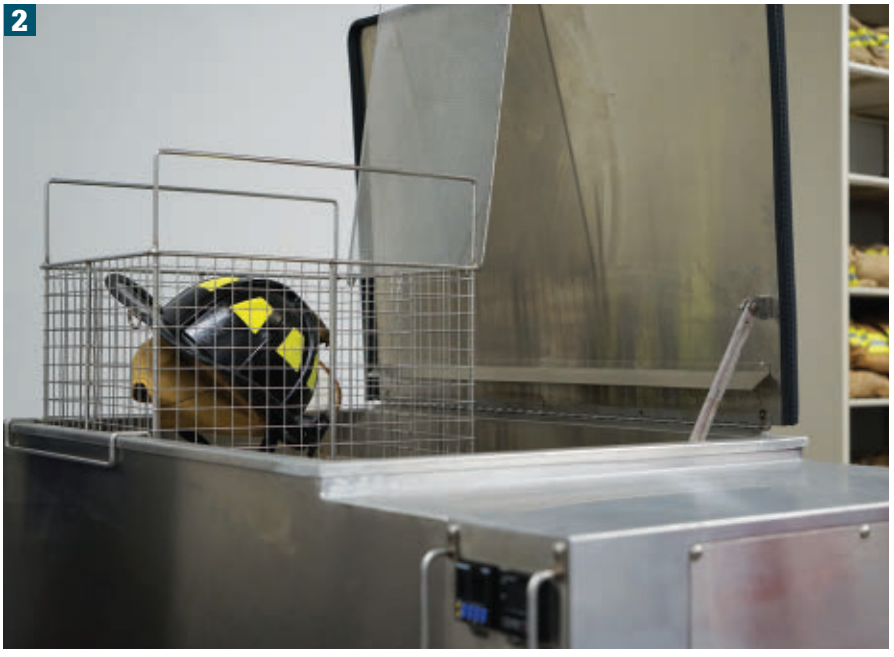
Continued from p. 22

and ISPs to inspect the water-tight integrity of moisture barriers. Slight modifications were made to the test cylinder to allow for a larger surface area of the hood fabric to be exposed to the smoke.

Additionally, a smoke generator originally intended for use by mechanics to diagnose leaks in fuel lines was included to provide the smoke for the test. The device works by having a beam of light positioned just above the fabric surface, and when no smoke is present, 100 percent of the light is transmitted from the light source to the detector. When the smoke generator is turned on, smoke fills the test cylinder below the fabric, and any smoke particles that pass through the hood sample cross the path of the light beam and decrease the amount of light that reaches the detector.

The apparatus has been used to evaluate numerous knit hood materials, particulate-blocking layers, and hood samples with holes to simulate damage. All commercially available particulate-blocking hoods that have been evaluated perform as expected on the device and allow little if any of smoke to penetrate. Any small holes or rips in hood samples were easily detected by the apparatus. At present, the method has been added to the revision of NFPA 1851 as a nondestructive method to perform annual advanced inspections on particulate-blocking hoods. The research team is continuing the development of the apparatus and is evaluating the variability between different devices as well as different operators. Additionally, the inspection method has produced very similar results for protective hood materials that were also evaluated using the NFPA 1971 particulate filtration efficiency test. This finding may be the most impactful, as the inspection method costs a fraction of that required to set up the current NFPA 1971 test, therefore making this method accessible to most fire departments around the country.

DR. R. BRYAN ORMOND is assistant professor of the Textile Protection and Comfort Center at NC State University Wilson College of Textiles.



(2) Ultrasonic cleaning equipment for firefighter helmets. (*Photo courtesy of McKinney Fire Department.)*

Gloves. The thermal protective capability of leather gloves can be seriously degraded when gloves are washed in any machine that develops excessive g-forces to extract water from the materials. Studies indicate that the outer leather shell material becomes compressed and does not fully recover once dry. This loss of thickness directly relates to a loss of thermal protection as well as a loss of dexterity, both important factors of firefighter PPE safety. The person washing the gloves can wear them. Do not wring them out but instead slightly squeeze them to remove excess water. If the gloves are heavily soiled, submerge them so the dirty wash water does not contaminate the glove interior—again, wear the glove while you wash it. If the exterior only is submerged, wash separately the glove interior with clean water and detergent followed by rinsing. Dry them most effectively by placing them on a rack or hanging them to allow water to drain from the interior. You can also use a drying cabinet. Forced air dryers are also available for gloves—the glove is mounted on a plastic pipe that blows air into the glove interior.

Footwear. Unless specifically approved by the manufacturer, do not machine wash footwear. Damage to the footwear and the machine can result. Alternative commercial machine technologies as well as specific procedures for footwear materials and construction are available; use them only after consultation with and approval from the footwear manufacturer. If the use of a soft bristle brush is difficult for cleaning the full interior of the footwear, it is recommended that you fill the footwear with a mixture of water and detergent and allow it to stand for at least 15 minutes before pouring it out of the footwear and rinsing. The interior of footwear can be particularly difficult to dry. Turning the boot upside down can allow the boot to drain easily and dry more quickly. However, given the volume of water that can come out of footwear, pooling of water from the drainage can create a slip hazard in the drying area. An alternative approach to drying footwear is to use plastic tubes or similar equipment for blowing air into the footwear interior.

Hoods. If permitted by the manufacturer, you can either machine or hand wash hoods. If you hand wash, it is important not to wring hoods to remove excess water; this will make hoods lose their shape earlier.

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3. Considering New Challenges for Particulate Blocking Hoods. Substantial work is still to be performed to understand cleaning of the new particulate-blocking hoods. These products include a barrier layer intended to prevent the passage of smoke and other harmful particulates from coming in contact with the wearer's face and neck, but this also means new challenges for how to clean and inspect these items (see "New Method for Inspecting Particulate-Blocking Hoods").

New Perspectives on Contamination

It is no mystery that structural and other fires pose significant exposures to innumerable hazardous chemicals. These chemicals pose a variety of risks—some by direct exposure during the course of the response and others from their residual contamination in the clothing and equipment used by firefighters, resulting in repeated exposures. However, the level of understanding of these chemicals and their relative exposure risk varies within the fire service.

Although it is not necessarily important to identify and realize the impacts of specific chemicals, there is the unfortunate focus sometimes on certain chemicals, which takes away from the overall objective of managing exposure reduction and contamination control for all potentially hazardous substances.

Nevertheless, some general understanding of how specific groups of chemicals pose exposure hazards, whether at the fire scene or as contamination later, can be of importance. This is partly because various groups often make certain claims about respective cleaning/decontamination products or services that emphasize certain types of chemicals that may or may not be pertinent. Collective research by a large number of investigators has provided a perspective on contamination, particularly pointing out where chemicals pose risks primarily from a respiratory pathway and those chemicals that are likely to absorb through the skin. "Firefighter Exposure: Assessing and Minimizing Dermal Risk" provides oversight of the extensive research findings in this area and its relevance to firefighter contamination control.

Revisiting Cleaning Verification and Its Impact on the Fire Service

The Fire Protection Research Foundation has conducted a study sponsored by the U.S. Department of Homeland Security to evaluate how well current laundering procedures remove contaminants. The study's objective was to establish a reliable measurement tool for assessing whether cleaning effectively removes contaminants. This is important because up until now there has been no agreed-on standardized way to compare cleaning processes to determine whether differences exist in machines, detergents, and overall approaches.

1. Understanding New Verification Procedures for Garment Cleaning. A good deal of work went into the research to support a new methodology, particularly how to consistently contaminate materials under laboratory conditions to correspond to how clothing is exposed and becomes contaminated in the field. The ensuing procedures entail detailed, repeatable steps for (1) contaminating washed but unused material specimens, (2) putting those specimens through a cleaning process, (3) extracting the contaminants, (4) determining residual amounts of remaining contaminants, and (5) comparing the results of those cleaned originally contaminated specimens with material specimens that were not cleaned.

The procedures were designed to be portable in that the verification process could be carried out at any cleaning facility working in conjunction with a qualified laboratory. As currently established, the procedures have been set up to address protective garment shell fabrics and examine three forms of contamination:

- Semivolatile organic chemicals: 10 compounds representing three classes of chemicals including polynuclear aromatic hydrocarbons (PAHs), phthalates, and substituted phenols.
- Inorganic heavy metals: antimony, arsenic, cadmium, chromium, cobalt, and lead.
- Representative bacteria: *Klebsiella pneumoniae* and *Staphylococcus aureus*.

By addressing chemical and biological forms of contamination, the cleaning verification procedures assess decontamination as part of advanced cleaning and sanitization or disinfection for microbial contamination associated with bloodborne pathogens and contact with flood water. Cleaning is carried out according to the facility's ordinary procedures but uses surrogate clothing samples and other specified materials to standardize the wash load. Results are reported as percent efficiency (removal rates) for chemical contaminants and large-scale reductions in the number of bacteria.

2. Drawing Conclusions from the Cleaning Verification Study. The respective procedures have been subjected to comparisons among different ISPs, interlaboratory testing, and the decontamination of field-used gear to ensure reliability and relevance. Figures 4 and 5 show some results for evaluating the cleaning procedures at three ISPs for both semivolatile organic compounds and heavy metals. These results point to varying levels of contaminant removal by contaminant type, particularly for the relatively persistent semivolatile organic compounds, but surprisingly similar effectiveness among the three ISPs in the removal rates even though the facilities use slightly different processes.

Cleaning verification is expected to become part of the requirements applied to ISPs and manufacturers that perform cleaning in the future edition of NFPA 1851. This requirement will provide accountability for cleaning companies in their claims with respect to removing contaminants. For the first rendition of this requirement, relatively liberal levels of contamination removal have been set to establish an initial benchmark primarily for comparison purposes. More importantly, the procedures and requirements will enable the pursuit of a more effective cleaning process and put science behind specif-

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Firefighter Exposure: Assessing and Minimizing Dermal Risk

BY DR. CHRISTINA M. BAXTER

There is a common misperception that we don't know what firefighters are exposed to during a fire. Although the complex mixture of combustion by-products is different for every fire (and for every phase of the fire), the components of the mixture have been well characterized. In general, those groups include the following:

- Particulates (i.e., carbon).
- Carbon monoxide and carbon dioxide.
- Undecomposed products, or monomers.
- Various hydrocarbons including aromatic hydrocarbons and polycyclic aromatic hydrocarbons (PAHs).
- Oxygen-containing organics including organic acids, aldehydes, and ketones (i.e., acrolein).
- Nitrogen and sulfur containing organic compounds (i.e., propylnitrile).
- Halogen-containing organics (i.e., vinyl chloride).
- Simple inorganic molecules (i.e., nitrogen oxides, sulfur oxides, and hydrogen cyanide).
- Volatile metal/nonmetal oxides and complexes (i.e., arsine).

Fires are very complex physical and chemical processes that generate heat, light, combustion products, and a number of volatilized/aerosolized substrate chemicals. The nature of the fire directly affects the types and distribution of products generated. This variation can be considerable in magnitude, even when attempts are made to duplicate fire conditions through experiments.[1] In the case of real structural fires, combustion conditions are known to vary considerably within and between fires.[2]

Most reported studies of firefighter exposure to toxic combustion products in fires have focused on the total exposure or overall dose accumulated from firefighting efforts[3-4] and training scenarios.[5-6] Some studies have focused on either the extinguishment/knockdown phase[7-8] or the overhaul phase.[9] The variability of actual fires (fuels, location, etc.) and the fire conditions makes it difficult to draw any conclusions about the relative concentrations of combustion products in the extinguishment and overhaul phases of the firefighting from any of these studies. One study involved separate measurements during the extinguishment and overhaul phases of firefighting in multiple training and actual fires.[10] In Australia, a significant number of fire situations have been simulated for characterizing the exposures from different types of fires.[11] In general, many of the same contaminants were present during both extinguishment and overhaul, but concentrations were lower during overhaul.

Table 1 characterizes the fireground hazards presented by known, common products of combustion based on detailed information from multiple fire studies. The color coding in the skin absorption hazard column represents green as limited to no threat, yellow as moderate threat, and red as significant threat. The color coding in the fire suppression and overhaul hazard columns represents green as no respiratory protection required, yellow as minimum of an air-purifying respiratory, and red as SCBA required.

Investigating Potential Routes of Exposure

The routes of exposure of airborne contaminants generated in a fire into the body include inhalation, ingestion, dermal, and injection. The most significant route of entry is through inhalation.[12] The contaminants (gases and particulates) can deposit or pass into the body through the lungs, causing acute and chronic adverse health effects. Despite the importance of this entry route, its significance within the firefighting environment should be considered in the context of firefighters' use of SCBA and their tactical methods. Airborne contaminants (gases and particulates) generally should not be ingested because of good hygiene practices and the use of SCBA.

The importance of the skin as an entry route is less certain, although one of the earliest cancer studies was conducted by Percival Pott investigating dermal soot exposure and scrotal cancer in chimney sweeps.[13] This was published more than 200 years ago. It is well established that PAHs, aromatic hydrocarbons, and acid gases will be absorbed directly from the vapor phase and penetrate the skin. The penetration rate is dependent on many factors, and the dose is also affected by the body's ability to detoxify and excrete the contaminant. There is increasing evidence reported highlighting the importance of the skin as an entry route in the context of firefighting. Given the extensive use of SCBA within the firefighting environment, the importance of the skin as an entry route has likely been underestimated.

Looking at Part A of Table 1, it is evident that dermal exposures for this group of combustion by-products is negligible at the levels measured on the fireground. Conversely, the chemicals in Part B of Table 1 represent potential dermal hazards on the fireground. These materials are volatile organic compounds (VOCs), aldehydes, PAHs, and diethyl phthalates. However, the reality is that structural fires involve a multitude of chemicals, and to collectively consider all of these chemicals can only lead to one conclusion: Structural environments must be assumed to create signifcant skin absorption hazards and always require the use of SCBA and follow-up cleaning of PPE.

Minimizing Exposure

There are many ways to reduce exposure on the fireground, although many of the known methods are "unpopular."

Wear an SCBA during all firefighting activities, including overhaul. In the United States, the Occupational Safety and Health Administration (OSHA) dictates that a fire is an IDLH environment. For carbon monoxide, hydrogen chloride, acrolein, and total PAH, the red shaded cells in Table 1 indicate the use of an SCBA as the only course of action.

Many departments do, however, allow personnel to downgrade to air-purifying respirators or no respiratory protection during the overhaul phase of operations. For some chemicals in Table 1, measured levels of carbon monoxide, nitrogen dioxide, sulfur dioxide, hydrogen cyanide, hydrogen chloride, sulfuric acid, VOCs, acrolein, formaldehyde, and phthalate diesters exceed the published permissible exposure levels, thereby *requiring respiratory protection*.

Data supporting Table 1 hazard categories for carbon monoxide show concentrations during overhaul regularly exceeding the published levels where OSHA requires the use of an SCBA. Further, the fact that overhaul conditions are also above the temperature for which air-purifying canisters are tested prove it is not a suitable

Table 1. Classification of Fireground Combustion Product Hazards

COMBUSTION BY-PRODUCT	SKIN ABSORPTION HAZARD	FIRE SUPPRESSION HAZARD	OVERHAUL HAZARD
PART A – PRIMARILY INHALATION HAZARDS AT FIREGROUND EXPOSURE CONCENTRATIONS			
Carbon Monoxide			
Nitrogen Dioxide			
Sulfur Dioxide			
Hydrogen Cyanide			
Hydrogen Chloride			
Hydrogen Fluoride			
Sulfuric Acid			
PART B – POTENTIAL INHALATION AND DERMAL HAZARDS AT FIREGROUND EXPOSURE CONCENTRATIONS			
VOCs–Benzene			
VOCs – Toluene/Xylene			
Aldehydes–Acrolein			
Aldehydes–Formaldehyde			
PAHs–Total			
Phthalate Diesters–DEHP			
GENERAL FIRE EVENTS			

KEY

Skin Absorption Hazard	NO THREAT	MODERATE THREAT	SIGNIFICANT THREAT	NO DATA
Fire Suppression/ Overhaul Hazards	NO RESPIRATOR REQUIRED	APR CAN BE USED	REQUIRES SCBA	NO DATA

ABBREVIATIONS: *VOC–Volatile Organic Compound; APR–Air-Purifying Respirator*

choice. Finally, if a department were to choose to use air-purifying respirators in this mode of operation, temperatures would have to be allowed to reach ambient levels, a CBRN canister rated for the length of time for overhaul operations (CAP-4 is rated for 60 minutes), and continuous monitoring for carbon monoxide would all be required. CAP-4 canisters are single use and range from $30 to $50 per filter for a 60-minute capability. *Operationally, the use of air-purifying respirators adds a complexity and cost of doing business that is far out of the reach of most departments.*

Wear properly fitted turnout gear. Studies in Australia have demonstrated that turnout gear compliant with NFPA 1971 reduces the PAHs, both gas phase and particulates, reaching the skin. (11)[14] Turnout gear when fitted according to the manufacturer's guidance is designed to *minimize the ingress of hot, combusted air.* It is expected that newer generation ensembles that include particulate-blocking hoods and innovative garment interfaces will have further effectiveness in limited intrusion of particulate and some fire gases.

Perform a gross decontamination as soon as feasible. Gross decontamination can range from something as simple as removing the turnout gear to minimize contact with contaminants on the gear and within the gear to something more structured like a decontamination shower on scene. It is most important to note that the most significant contamination will likely be on the hands, so *wash as quickly as possible with soap and temperate water to minimize potential for skin absorption and/or penetration.*

Specific gas-phase and particulate-based PAHs have been found inside turnout clothing. (11) This very significant finding means that firefighters cannot just rely on "spot cleaning" as a form of decontamination, as PAHs are distributed across the body, not just on the hands, neck, and face. Other research shows PAH skin absorption greatest at the shoulders, followed by the forehead, forearm, and groin and finally by ankle and hand.[15]

Finally, no scientific information is yet available on the effects of "wet wipes" on the total skin penetration of contaminants. Many commercially available wipes use alcohol, aloe, and other materials known to increase skin permeability. Although many departments are now using these tools, there is no evidence that they are more effective than traditional soap and water.

Minimize potential for secondary contamination. Removing turnout gear as soon as it is no longer required on scene, storing it in a separate compartment of the vehicle, and not bringing it into living quarters are all simple methods that can *reduce the potential for secondary contamination via particulates or via off-gassing* of materials from the turnout gear.

Shower as soon as possible following firefighting activities. Part B of Table 1 shows some chemicals that are most likely to be dermal hazards. They include the VOCs, aldehydes, PAHs, and phthalate diesters with formaldehyde, with PAHs and phthalate diesters being the most significant contributors. Although skin permeation is generally considered to be a slow process, it has been demonstrated with these materials can contribute to overall firefighter exposure on the fireground.[16] Thus, it is imperative that the materials be removed from the skin quickly.

When showering, it is important to remember to take a *temperate shower* with the temperature not exceeding the skin temperature. *Increased temperatures also increase surface blood flow, increase perspiration, and open the skin's pores.* Increased perspiration can increase the permeability coefficient for a chemical through the skin while also increasing the residence time of the chemical on the skin, especially if the chemical is water soluble.

Launder your gear. Launder gear, including turnout gear and fabric components of SCBA, to limit the potential for secondary exposures from the gear itself.

Use evidence-based decision support tools. The Emergency Response Decision Support System (ERDSS) provides evidence-based decontamination, showering, and laundering guidance for firefighters based on their role at a fire, the type of fire, and the number of entries made. This guidance is backed by scientific studies performed by the Queensland (Australia) Fire and Emergency Services. ERDSS is available free to emergency response personnel in the United States and partner countries. Registration is available at www.chemicalcompanion.org.

A complete white paper on this topic with full references is available at www.emergencyresponsetips.com.

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ic claims of cleaning effectiveness. For example, some preliminary information from the study shows some benefits from elevated temperatures for removing some chemical contaminants. Some cleaning equipment companies are applying these techniques to validate their specific claims.

Among the findings from this study is the simple adage that materials that are easy to contaminate are easy to decontaminate. Similarly, materials that are hard to contaminate are also hard to decontaminate. This preliminary finding was highlighted by the fact that finishes used on outer shell materials, although relatively outstanding in preventing liquid absorption, also may make it difficult to remove some contaminants once the fabric absorbs chemicals.

If you combine the above finding with the established knowledge that most ensembles only partially attenuate the amount of contaminant penetration into the clothing, then the problem of contamination control becomes all the more difficult, even with effective cleaning. In reality, firefighters need to have clean protective equipment whenever they enter a hazardous environment where exposure will occur and further need to remove that gear as soon as they leave

Figure 4. Comparison of Heavy Metal Decontamination Among Three ISPs

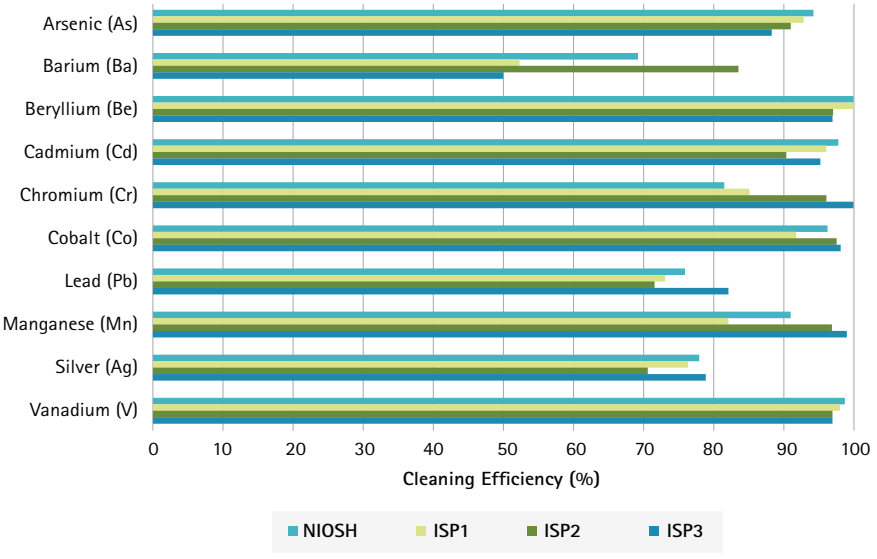
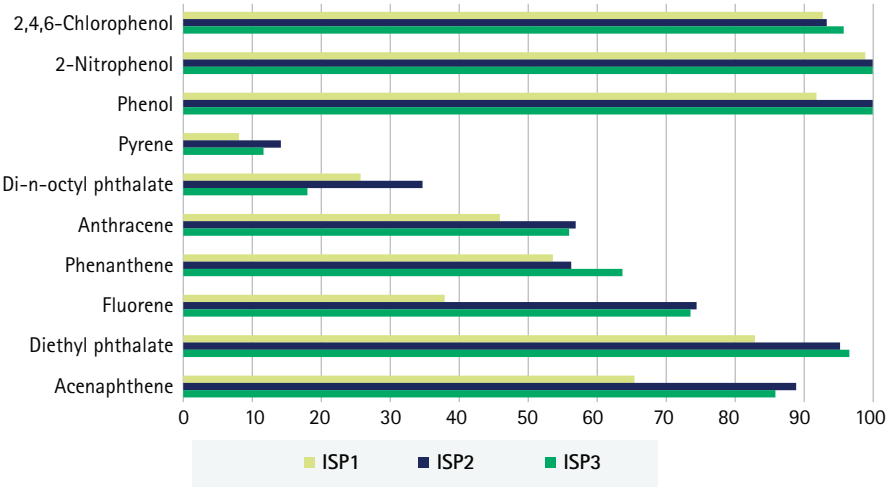


Figure 5. Comparison of Semivolatile Organic Compound Decontamination Among Three ISPs



the emergency scene to minimize their overall exposure. This type of thinking only reinforces how closely structural firefighting is starting to resemble hazmat response.

A substantial amount of information has been generated by the Fire Protection Research Foundation. The full reports, applicable videos and animations, and other information can be found on its Web site (http://www.nfpa.org/ppecleaning).

3. Realizing the Ramifications of More Frequent Cleaning. Even when it is possible to implement more frequent cleaning, there is still the issue of how cleaning can affect the long-term protective performance of the clothing and equipment. As anyone who washes their own clothing knows, regular cleaning breaks down clothing over time. In the case of turnout clothing, only rudimentary controls are built into NFPA 1971 for making this assessment. For most performance requirements, only five cycles of laundering are applied for garments. For one property—moisture barrier effectiveness—that number is increased to only 10 washing and drying cycles. Thus, if the expectation is that clothing is cleaned after every working fire, then some gear can be subjected to up to 25 cycles a year.

Many manufacturers currently indicate that clothing generally has a service life ranging from five to seven years for a moderately busy department. Although it is recognized that many components are quite rugged and durable, there remains some uncertainty as to whether frequent cleaning will cause some degradation of clothing and equipment performance.

There may come a day when the hazards being as significant as they are point toward either disposable protective clothing or disposable covers on existing protective clothing to minimize the impact of contamination. This also introduces as many problems as it does solutions because ease of donning and maintaining comfort are difficult to attain. Many manufacturers are already looking to the future with innovative clothing and equipment designs to address contamination control in various ways.

Many manufacturers are already looking to the future with innovative clothing and equipment designs.

What is clear from these issues is that conventional approaches probably will not provide long-term solutions and, therefore, other forms of technology (perhaps borrowed from other industries and adapted for the fire service) or altogether unique designs and techniques should be considered to address the minimization of continued firefighter exposure to carcinogenic and other hazardous contaminants. Still, substantial progress has been made over the past several years for increasing fire service awareness of contamination exposure hazards that has been coupled with multiple departments implementing new practices and industry developing procedures and services to support reshaping contamination control through PPE. ■

JEFFREY O. STULL is president of International Personnel Protection, Inc., which provides expertise and research on the design, evaluation, selection, and use of personnel protective clothing and equipment and related products to end users and manufacturers. He has conducted numerous studies for effectiveness and performance of protective clothing and equipment in a variety of applications. Stull is the past chairman of the American Society for Testing and Materials F23 Committee on Protective Clothing, a member of several National Fire Protection Association technical committees on emergency responder protective clothing and related equipment, a participant on the government's Interagency Board for Equipment Standardization and Interoperability, and the former lead U.S. delegate to the International Standards Organization for Protective Clothing. From 1988 to 1993, he was president of TRI/Environmental, Inc., an organization that provided certification testing and conducted research projects related to protective clothing. His career in protective clothing began as a project officer for the U.S. Coast Guard Office of Research and Development from 1983 to 1988, where he headed several programs related to personnel protection. He has a master of science degree in chemical engineering from the Georgia Institute of Technology, a master of science degree in engineering management from the Catholic University of America, and a bachelor of science degree in physical sciences from the U.S. Coast Guard Academy. He is well published in all areas related to protective clothing and equipment with several peer review articles related to different areas of protective clothing performance. He is considered one of the leading experts in the field of personal protective equipment.

Queensland Fire and Emergency Services: Promoting the Message of "Go Home Clean"

BY DR. KATHERINE M. KIRK AND DR. MICHAEL B. LOGAN

Over the past decade, the Queensland (Australia) Fire and Emergency Services (QFES) has undertaken a research program aimed at characterizing hazards posed to firefighters from toxic combustion products that may be deposited on protective clothing and skin.[1-2] Experiments have included residential fires, commercial premises fires, industrial fires, and common firefighter training scenarios, with air contaminants being measured inside and outside protective clothing and chemical deposition measured on the exterior of protective clothing and on firefighters' skin. Off-gassing of toxic combustion products from protective clothing after exposure to firefighting environments has also been investigated.

The results of this experimental program have informed practices within the QFES to improve postfire cleaning and hygiene practices. These recommendations are across a number of areas, including fireground actions, station-based hygiene, and protective clothing cleaning practices. This knowledge has also been translated into a firefighter decision support tool within the Emergency Response Decision Support Software (ERDSS).[3]

Fireground Actions

The first approach about activities around the fireground is to minimize our exposure by wearing appropriate respiratory and skin protection, establishing and maintaining operational zones, adopting our personal hygiene practices, and always having a shower at the station when returning from the incident. But the actions that can be adopted are much broader to minimize exposures.

Firefighter positioning. Opportunities for firefighters to reduce exposure to combustion products exist without compromising firefighting operations. They include setting hot, warm, and cold zones based on smoke movement as well as the fire itself; staying below the smoke layer and/or behind water curtains; and minimizing time inside the structure if possible. Use of chemical detection systems (particularly for carbon monoxide and volatile organic compounds) around the fireground is also useful for identifying and preventing unnecessary exposures in warm and cold zones. At a personal level, it is critically important that all protective clothing and equipment items are properly fitted and in place during all activities where hazards can be encountered, including during overhaul. The head, neck, and upper body are especially vulnerable areas because of the interfaces between protective clothing and equipment components.

On-site decontamination. There are activities where decontamination should occur after the firefighters' operations at the incident. To support undertaking decontamination of firefighters on site, the QFES has developed purpose-built decontamination trailers that have been positioned around the state for operational support. They incorporate showers (internal and external), a toilet, air-conditioning, and external awnings to assist with fireground hygiene and heat stress management. Although they were designed primarily with major hazmat incidents in mind, they are also well-suited to being applied to on-scene decontamination of personnel at major fire incidents.

Station-Based Hygiene

Experiments involving multiple types of fires led to polycyclic aromatic hydrocarbons (PAH), including known and suspected carcin-

(1) Firefighter exposure experiment—industrial fire simulation. (*Photos by authors.*)

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(2) QFES purpose-built decontamination trailers with (left) external awnings and (right) internal showers.

ogens, being found on firefighters' skin after active firefighting operations. As a result, the QFES recommends that all firefighters shower and change into clean clothing as soon as practical after returning to station for all types of fires. Prompt showering and changing are of benefit, as these chemicals are known to be able to be absorbed through the skin, but this process is not rapid. Early cleaning, therefore, reduces the amount of chemicals being absorbed.

Clean firefighter protective clothing should be stored in dedicated, well-ventilated areas when not in use.[4] Fire station design principles that mitigate the movement of contamination such as vehicle exhaust also promote improved hygiene.[5]

Protective Clothing Cleaning Practices

When to launder? Measurements of PAH contamination of protective clothing from various types of firefighting operations were used to make recommendations regarding frequency of laundering of protective clothing. Active firefighting operations involving chemical or flammable liquid fires resulted in the highest levels of contamination; consequently, laundering of clothing was recommended after any active firefighting at these incidents. By contrast, exterior firefighting and cold zone operations were determined to not typically require immediate postincident laundering of protective clothing unless specific potential contamination issues (such as asbestos fibers) were identified. Guidance on laundering firefighter protective clothing after specific exposure levels at a range of fire incident types has been included in the ERDSS.

Managing contaminated clothing. On the fireground, protective clothing to be laundered should be separately sealed in plastic bags and stored on the truck in a location other than the vehicle cab. This is to reduce both the direct transfer of contamination from the clothing to the cab interior surfaces and emissions from the contaminated clothing into the cab atmosphere. There are also opportunities through the use of radio frequency identification chips to keep track of the individual laundering and repair history of garments.

Education

All these practices are intended to improve the safety of our firefighters. We keep sharing this information so we are all better informed about the issues and what we can do to improve our safety. An information session relating to personal and protective clothing hygiene has been incorporated into the QFES online training program. Our firefighter recruits receive information about firefighter exposures. We have much more to do. Our future education efforts will focus on further promotion of the benefits of improved fireground and station hygiene relating to combustion products as well as encouraging personnel at major incidents to call for specialist resources such as decontamination trailers to provide assistance in this area. In short, we are aiming for firefighters to regard combustion products in the same category as chemical contamination from a hazmat incident—don't take it back with you to your truck, station, or home.

Future Directions

The journey continues for the QFES to improve its understanding of emergency responder exposures ranging from the significance of contamination of accessories like helmets, SCBA, and radios to specific activities within wildfire and rescue responses. This knowledge will be applied to educate our diverse workforce and improve our practices to minimize opportunities for exposure.

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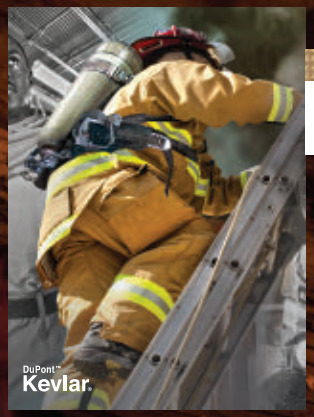

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