2024 Urban Fire Forum (UFF) Position Statement

Statement in Support of Considering Enhanced Decontamination Methodologies of PPE Following Exposure to Lithium-Ion Battery Fires

Introduction

Ample evidence leaves no doubt that the prevalence of lithium-ion battery ("LIB") fires is growing as global reliance on these mobile and stationary energy storage systems is exponentially increasing. According to CBS News a year ago, "Last year, there were more than 200 fires blamed on lithium-ion batteries in New York City. Since 2019 the city recorded 326 injuries related to these types of fires." [1]. Fire departments across the United States are reporting a greater proportion of their fire responses involving LIB technology [2].

Figure 1: Lithium Ion Battery on Fire

In addition to the rapid escalation in the intensity of fire conditions, LIB fires create several distinct contaminants during thermal decomposition due to the use of lithium, fluoride, and phosphorous-based chemistry, involvement of heavy metals, and reactions with other products of combustion to produce a wide range of highly toxic compounds [3,4]. These compounds entail hydrogen fluoride, hydrogen cyanide, various lithium, fluoride, and phosphorous gases and inorganic chemicals, heavy metals such as cobalt, manganese, and nickel, per- and polyalkylfluorinated substances (PFAS), as well as the more common polycyclic aromatic hydrocarbons (PAHs) [5].

While appropriate PPE in the form of SCBA protects against the inhalation of these substances and turnout gear lessens firefighter skin absorption exposure, significant hazards still exist for the less

volatile, water-insoluble chemicals that can remain in firefighter PPE causing prolonged contact exposure when handled and worn. The greater persistence of some of these compounds presents significant challenges for PPE decontamination.

Frequent routine cleaning of firefighter PPE has significantly increased over the past two decades changing the narrative to where sooty turnout clothing is no longer seen as a "badge of honor." The practice of performing limited PPE decontamination while on-scene prior to fire companies returning to service should be considered preliminary exposure reduction only. On-scene PPE decontamination followed by updated advanced cleaning using a sophisticated washing machine in the form of a washer/extractor have become more commonplace. Recognition of the need for specialized cleaning also exists for those situations where regular and advanced cleaning is insufficient to remove difficult contaminants. In 2020, NFPA 1851 provided greater standardization for the implementation of these cleaning processes and instituted a process of cleaning verification [6]. As a way of benchmarking the effectiveness of advanced cleaning, independent cleaning service providers ("ISPs") are evaluated for the percentage removal of a broad range of chemicals where the minimum requirement is only 50% for both semi-volatile organic compounds and heavy metals [7]. This level was set because it was the practical limit that was achievable for the majority of washer/extractor machine cleaning technology [8].

Gear CleaningMethodologies and Effectiveness [6]

Preliminary Exposure Reduction – The rinsing and light cleaning of gear on the firefighters after they exit the fireground to remove some exterior soils and contaminants from the exterior of the clothing and SCBA to make subsequent handling and transport safer and for limiting cross-contamination to the wearer, other firefighters, the apparatus, and environment.

Advanced Cleaning – Thorough cleaning performed by trained personnel intended to remove most of the common soil and products of combustion from ordinary fires and other emergencies; generally, machine-based for most items like garments, hoods, and some gloves and manual processes for other ensemble elements.

Specialized Cleaning – The application of specialized cleaning or decontamination agents or processes to remove difficult-to-remove or unusual forms of contamination that may or may not be associated with fireground exposures; typically entail more rigorous steps beyond advanced cleaning that are specific to the contaminant(s) of concern.

Lithium-Ion Battery Decontamination Strategy Considerations

Limiting PPE contamination from LIB fires that can create secondary and ongoing exposures to firefighting gear should be a priority. However, should there be PPE contamination, evaluation of the type of cleaning necessary involves three steps:

1. Determine whether advanced cleaning is sufficient or if specialized cleaning should be applied.
2. Select and apply an appropriate set of advanced or specialized cleaning procedures for providing the most effective decontamination of LIB-based and other fireground contaminants.
3. If appropriate and possible, undertake testing to confirm the removal of contaminants.

Advanced versus Specialized Cleaning

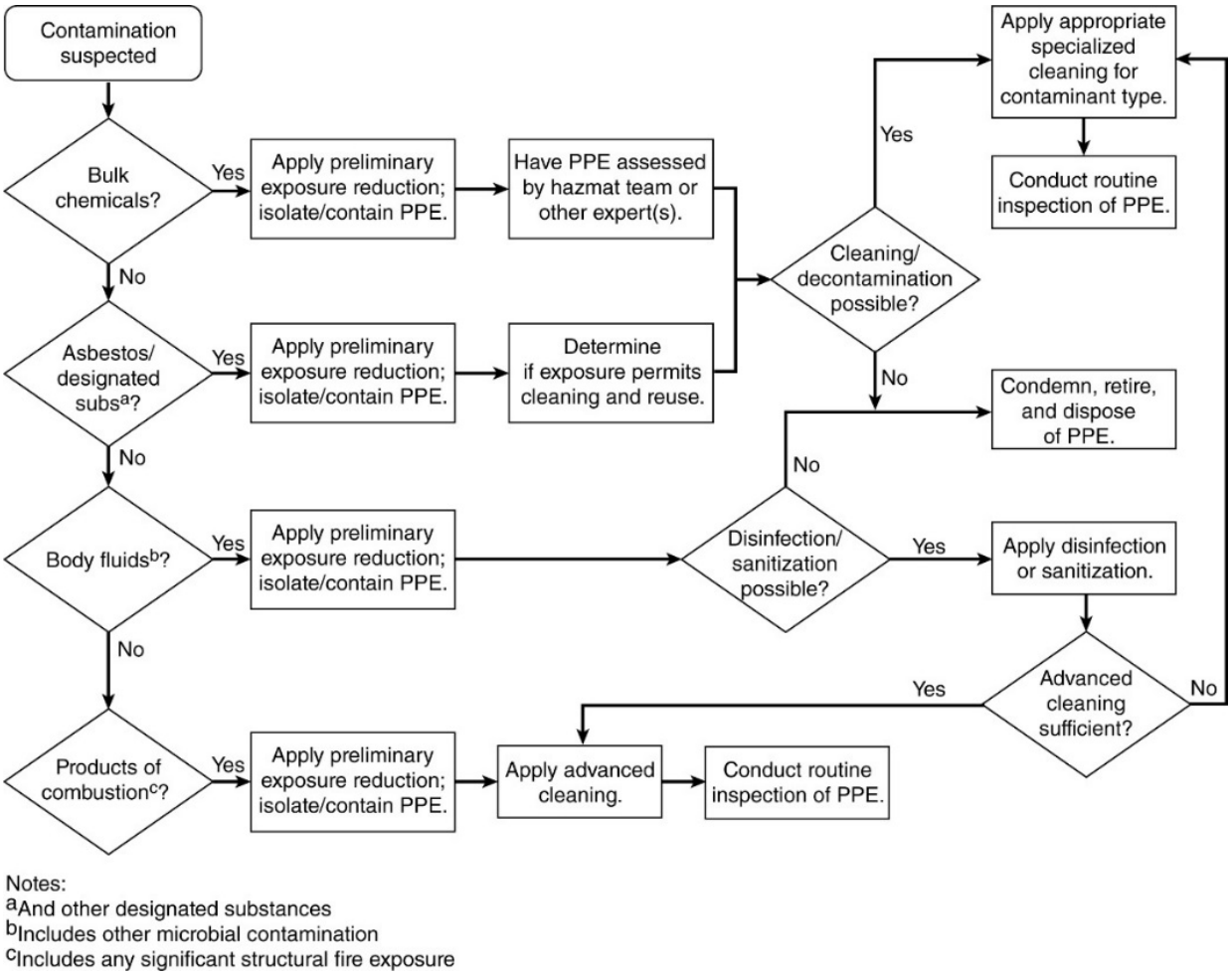


Figure 2: Decision Logic for Addressing Contamination of Firefighter PPE
(Figure 7.1.1.2(b) in NFPA 1861-2020)

To recognize the increased incidence of LIB or related technology fires, every fire or response that potentially entails exposure of firefighters to LIB fire contamination must include a separate decision for whether advanced cleaning is adequate for removing contaminants or if consideration should be given to applying some form of new technologically advanced cleaning or specialized cleaning. The

insertion of a specific decision point in the consideration of decontamination approaches is necessary to encourage the needed additional consideration of firefighter PPE contamination during LIB fires.

As with almost all fireground exposure, the application of preliminary exposure reduction on the scene consistent with department standard operating procedures or fire service practice is strongly recommended to minimize cross-contamination and secondary exposure to firefighters and others. Ideally, this practice is followed by bagging and isolating the gear until it can be properly cleaned.

Following preliminary exposure reduction, a decision based on department policy consistent with fire service best practice should then be made on whether the affected PPE be subject to advanced cleaning or specialized cleaning. Factors that can be considered for making this decision include how the following questions are answered:

1. Is the total amount and proportion of fire contents attributed to LIBs or related products considered to be high? *The greater the content of LIB technology of the fire, particularly if the origin of the fire, the more likely significant the contamination from the fire*.
2. Is the environment involving the LIB fire open (such as an electric vehicle on a highway) or closed (such as the same electric vehicle in a garage)? I*n many cases, closed environments would be more likely to cause greater exposure of firefighters to LIB fire decomposition products*.

Figure 3: Firefighter Exposure to Electric Vehicle inside Garage
(Courtesy of Fire Service Research Institute)

3. Were the assigned firefighters likely exposed to LIB fire decomposition products based on their specific fire scene roles, and length of time on scene? *Firefighters who remain proximate to the fire and are actively engaged in mitigating the fire will be more contaminated*.

4. Were any measurements taken during or after the fire suggestive of contaminants associated with LIB fire? *In sizing up a fire, the department may use a Hazmat team or other capability to assess exposures or being able to sample after overhaul to determine if certain types of chemicals are present that may associated with LIB fires*.

5. Does the department have prior experience or knowledge of other department incidents similar to the fire event that showed that some form of enhanced process or specialized cleaning has been required? *Networking within the fire service is helpful in establishing lessons learned that can be shared to provide broadly applied best practices. Many fire departments have posted information for how they have had to handle specific LIB fire challenges, including approaches for addressed contaminated gear. Some departments have specifically found that apparent persistent contamination remains despite multiple regular washings of gear*.

6. Is independent documentation available that demonstrates the ability of specific cleaning or decontamination processes as being successful in effectively removing LIB fire contaminants from firefighter PPE? *Some limited research has been performed by different organizations and suppliers of cleaning equipment and services to show how specific decontamination approaches can be used to remove LIB contamination*.

7. Does the department have resources available to conduct outside testing of PPE before and after cleaning to examine the effectiveness of the chosen type of cleaning? *The ability to properly evaluate exposed gear before and after cleaning takes the guesswork out of determining whether cleaning is successful or not in significantly reducing LIB fire contamination. Generally, this capability can be costly as it may require sacrificing some gear to attain the needed accuracy for quantifying contaminants present in gear. The testing also must be conducted correctly to avoid results that underreport contamination levels and lead to wrong conclusions (A section in this White Paper provides general guidelines for how to perform this testing)*.

If the answers to most of these questions are yes or suggestive of significant firefighter exposure to LIB fire contamination, then the situation warrants the use of applying highly capable advanced cleaning technology or specialized cleaning to the exposed firefighter PPE.

Appropriate Cleaning/Decontamination Approach

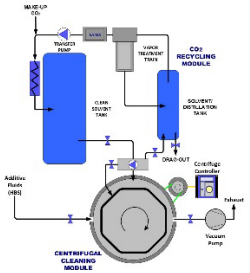
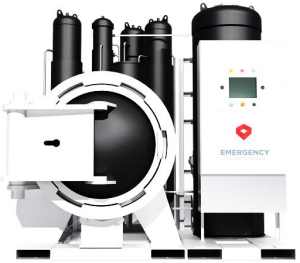
While there are many variants of cleaning approaches to remove fireground contaminants, the most common techniques are compared in Table 1. These include:

- Advanced cleaning
- Specialized cleaning
- CO_2 cleaning
- Enhanced CO_2 cleaning

Table 1 provides information on how each technique works, its perceived advantages, and disadvantages, and expected effectiveness in the removal of LIB fire contamination.

Machine-based capabilities are commonly applied to garments, hoods, and some gloves. If the technology can be adapted to other PPE items such as helmets, footwear, and SCBA, then additional benefits accrue for the cleaning approach.

Table 1: Comparison of Cleaning/Decontamination Approaches that can be applied to LIB Fire PPE Contamination

	Advanced Cleaning (Normal)	Specialized Cleaning (Soaking Approach)	Liquid CO_2 Dry Cleaning	Enhanced Liquid CO_2 Dry Cleaning
				
Description	• A programmable water/ extractor using multiple steps to inject a detergent, multiply rinse, and extract wash water from the garments that are tumbled inside the machine	• Advanced washer/extractor-based cleaning is supplemented with a presoak, the use of special detergents, and higher temperatures to better remove contaminants.	• Uses a special machine to contact items under pressurized CO_2 that provides greater removal of contaminants under dry, near ambient temperature conditions.	• Builds off principles applied in standard liquid CO_2 dry cleaning but incorporates additive packages to address the limitation of CO_2 as a solvent in removing inorganic contaminants.
Pros	• Available at many fire departments. • Capable of removing many fire ground contaminants.	• It's possible for the department to apply the required additional steps. • Many ISPs have these capabilities.	• Highly effective against organic contaminants. • Does not create wash water effluent; low energy costs. • Low impact on service life.	• Same as liquid CO2 dry cleaning with demonstrated effectiveness for full range of contaminants including inorganic chemicals.
Cons	• Limited effectiveness in removing most persistent contaminants. • Average efficiencies are just over 50. • Repeated washing reduces gear service life.	• Greater cleaning rigor may not fully remove persistent contaminants. • Must be optimized for specific contaminants. • Further decreases gear service life.	• Does not remove many inorganic contaminants such as heavy metals. • Expensive equipment (not all departments are likely to obtain or easily access capabilities).	• Expensive equipment (not all departments likely to obtain or easily access capabilities; however, price of cleaning can be comparable to enhanced advanced cleaning).
LIB?	• Questionable for removal of LIB contaminants from significantly exposed gear.	• Possible moderate effectiveness for removal of LIB fire contaminants.	• Effective for some LIB fire organic contaminants but not inorganic contaminants.	• Current data suggest high effectiveness for removing LIB fire contaminants.

Post Decontamination Testing

Not all fire departments can afford or have the wherewithal to conduct testing of PPE to ensure that an applied cleaning process removes most of the LIB fire contaminants from gear. In many cases, this testing may not be necessary because of experience at other fire departments or if prior testing has demonstrated that the selected approach generally works in related situations. Typically, if applied, some testing would be relegated to large events involving multiple companies where firefighters were significantly exposed to LIB fire contaminants.

For any testing to be meaningful, the testing should take on the following characteristics:

1. Selected gear must be tested before and after washing. *Removal effectiveness generally requires both, though only testing already washed gear can provide some insight into gear cleanliness if contamination levels are very low.*

2. Except on hard surfaces like helmet shells on certain SCBA parts, wipe sampling should not be used. *It is not effective in showing the state of gear contamination as it only shows exterior surface concentration. Many contaminants penetrate materials and onto interior layers that can come out later and expose firefighters.*

3. Clothing that is believed to be the most contaminated (based on time on scene and wearer activities) should be destructively sampled. *This means sacrificing one or more sets of gear to physically take samples from the areas with the greatest soiling.*

4. The same gear should become its baseline. *Cutting the gear in half and testing one-half uncleaned and the other half after cleaning is likely to provide the best comparison for judging contamination removal. This is because contamination levels can be highly varied across the clothing item.*

5. Testing should target relevant contaminants. *All fires involve a unique mixture of contaminants. Testing of firefighter PPE following LIB fires should include metals, including lithium, cobalt, nickel, and manganese, as well as a battery of semi-volatile organic compounds that include PAHs, phthalates, and phenols. Separate analysis may also be needed for fluorine-based chemicals that require different analytical equipment.*

6. Outside expertise should be sought to judge the results of testing and the effectiveness of the cleaning process. *The absence of standardized limits of acceptable levels for most contaminants makes it difficult to determine if appropriate removal has been achieved.*

Information from this testing, when performed, is most often used to determine if gear can be safely returned to service. Regardless of what laboratories report and outside experts opine, the ultimate authority for the decision to continue using gear that has been exposed and cleaned rests with the department.

Further Discussion, Considerations, and Recommendations

High-performance cleaning technologies such as enhanced CO_2 dry cleaning offer specific advantages for addressing the unique contamination hazards presented by an increasing number of firegrounds involving LIB decomposition products. These capabilities are not limited to LIB fire contaminants but also extend to a wide range of increasingly chemically complex fire environments that create highly toxic and persistent chemicals that remain in clothing and are not often easily removed from firefighter PPE using conventional cleaning methods.

The recognition of LIB-based fires posing significant exposure hazards is a first step in better addressing the threats of secondary contamination for firefighters following these events. It is recommended that departments "size-up" fires during and after the response to determine if significant exposures have occurred to its members from LIB fire decomposition products and to determine if specialized cleaning is needed based on an easily implemented assessment/testing approach.

It is then incumbent on the department to choose an appropriate, likely effective cleaning and decontamination approach based on industry best practice that exceeds traditional, ordinary washer/extractor based advanced cleaning. The use of specialized cleaning and enhanced CO_2 dry cleaning capabilities where studies have indicated effective removal of LIB fire contaminants should be considered.

It is understood that the availability of relatively expensive high-performance cleaning technologies is currently limited. Creative solutions are needed to access such technologies, especially when these technologies when repeatedly applied do not decrease PPE service life. Such solutions come in the form of being recognized items as part of the FEMA AFG program for equipment grants (with the appropriate qualifications) and the establishment of regional cleaning facilities to provide broader capabilities across the United States.

Ongoing research and studies are already underway or planned by multiple organizations including the Fire Protection Research Foundation to further investigate the type of contaminants emanating from LIB fires and their longer-term impact on clothing and in exposing firefighters. Advances for the improvement of best practices related to decontaminating LIB contaminated PPE should be applied to update these recommendations.

As technology becomes available organizations should consider provisions for new gear to be delivered precleaned by the manufacturer. Integrating this requirement can reduce exposure to potentially harmful substances that may accumulate during manufacturing.

Lastly, there is a benefit to the NFPA Codes and Standards development process to address this topic. Relative to cleaning and decontamination of firefighter PPE, the Technical Committee responsible for NFPA 1851 is already beginning to address this subject as a relevant area of requirements and guidelines for the fire service. That activity along with a revision of standards on general firefighter health and safety, training, and more specifically contamination control are efforts that can be expanded to address appropriate approaches for LIB fire decomposition product decontamination.

Key Takeaways and Direction

1. Fires involving exposures of firefighters to significant levels of lithium-ion battery decomposition products should be considered unique contamination events that warrant highly effective advanced cleaning or specialized cleaning
2. Emerging forms of high-performance advanced PPE cleaning currently offer one of the more effective approaches for removing the unique contamination associated with fires involving lithium-ion batteries and decomposition
3. Innovative solutions that include funding sources are still needed to make highly effective advanced and specialized cleaning technologies more accessible to the fire service for improving the removal of persistent unique contaminants.
4. Continued research should be supported to understand and address the emerging issue.
5. Active participation in the codes and standards process is important to inform standards development on this topic.

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