Development of Contamination Resistance as a Measure for Firefighter Protective Clothing

PROJECT SUMMARY

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Background: Firefighters need equipment to protect them against exposure to toxic chemicals, bloodborne pathogens, smoke particulates, and penetration of water from fireground sources. In response to these known risks to firefighter safety, the National Fire Protection Association (NFPA) performance standards have adopted a few measures, including water repellency and penetration resistance to liquids and particulate challenges. To meet current performance levels, textile and garments are manufactured with materials and finishes into turnouts that may contain or release hazardous chemicals. The rightful objective of moving to eliminate potentially hazardous materials from gear must also consider whether alternatives can be substituted without causing the unintended consequence of exposing firefighters to clear and present fireground hazards. Part of the answer will require critically assessing NFPA performance requirements to determine the optimum balance between resistance to fireground contaminants and primary safety and functionality, including fire resistance and thermal comfort. It will require quantifying trade-offs associated with less toxic alternative materials and treatments. It is critical that we better understand the balance between how requirements for contamination resistance may impact firefighter exposures to hazardous products and how contamination may impact other performance metrics, such as the transfer of thermal energy.

Purpose & Aims: The project aims to improve the health and safety of firefighters by developing a strategy for incorporating appropriate contamination resistance measures in NPFA 1971 and 1851 without compromising the protection firefighters need against fireground and environmental hazards. This will be accomplished this by reviewing requirements in NFPA Standards regarding contamination resistance, assessing the impacts of contamination resistance on ensemble performance, and determining the impact of ageing on contamination resistance, performance, and exposure.

Goals & Objectives: To develop a strategy for incorporation of appropriate contamination resistance measures in NFPA 1971 and NFPA 1851, the primary goals of this project are:

- *Goal #1:* Review NFPA 1971 and NFPA 1851 requirements in an independent, transparent framework regarding contamination resistance.
- *Goal #2:* Assess the impact of contamination resistance measures on ensemble performance and exposure risks.
- *Goal #3:* Determine the impact of ageing on contamination resistance, performance, and exposure.

To accomplish these goals, the objectives of this research are as follows:

1) To critically review the NFPA 1971 and 1851 standards regarding design requirements, performance requirements, and test methodologies associated with or impacted by contamination and/or contamination resistance *(Goal #1)*
2) Select turnout composite materials representative of material construction – outer shells, moisture barriers, and thermal liners – and covering the spectrum of repellency levels and technologies – unfinished, traditional finishes, and PFAS-free alternatives *(Goal #2, #3)*
3) Age material composites through UV light, laundering, heat, and/or abrasion cycles and identify potential health exposure hazards released during this process *(Goal #3)*
4) Contaminate new and aged material composites in a realistic and controlled manner through the well-characterized Fireground Exposure Simulator (FES) at Illinois Fire Service Institute *(Goal #2, #3)*
5) Evaluate the resistance of new and aged composites to contamination by liquid challenges through repellency and penetration assessments *(Goal #2, #3)*
6) Determine the resistance of new and aged composites to contamination by chemical/particulate challenges following FES exposure through spectrophotometric and chemical analysis *(Goal #2, #3)*
7) Evaluate the effect of contamination resistance level on cleaning and staining of new and aged composite samples following FES exposure *(Goal #2, #3)*
8) Assess the impact of contamination resistance level on thermal protection performance through flashfire, radiant, and convective heat exposures on new and aged composites following FES exposure as well as chemical/liquid exposures *(Goal #2, #3)*

9) Determine the effect of contamination resistance on the thermal burden of new and aged composites following FES exposure specific to radiant load and impacts of alternative PTFE-free barriers *(Goal #2, #3)*
10) Develop recommendations for design/performance requirements and test methodologies for contamination resistance measures to be introduced to NFPA 1971 and NFPA 1851 standards *(Goal #1)*

Relevance: This work will fill a significant knowledge gap associated with contamination resistance measures, such as fluorinated and non-fluorinated repellent finishes, and their impacts on liquid, particulate, and chemical contamination, cleaning efficacy, and management of thermal energy in both a new and aged state.

Methods: Turnout composites with varying constructions and repellency treatments will be subjected to ageing through UV and laundering. Both new and aged composites will be realistically contaminated with smoke and chemicals in the Fireground Exposure Simulator. To determine performance trade-offs, clean and contaminated composites will be evaluated for their ability to resist chemical and particulate contamination, cleaning efficacy, thermal protection from convective and radiant heat, and impact of radiant load on total heat loss.

Project Tasks: The overall technical approach for the project can be summarized into two phases and eight basic tasks. The first phase of the project is focused on the selection, preparation, ageing, and contamination of material composites and includes the first four tasks. The second phase include remaining four tasks, which is aimed at evaluating the impacts and trade-offs on turnout performance.

Phase I:

- Task 1: Critical review of the NFPA 1971 and NFPA 1851 standards regarding requirements and test methods that may be impacted by contamination or contamination resistance.
- Task 2: Selecting and procuring a range of turnout composite materials from multiple manufacturers with PFAS and PFAS-free treatments.
- Task 3: Once final material selections are made, half of the samples will undergo ageing exposures to simulate the effects that ultra-violet light, laundering, heat exposure, and abrasion have on the materials and chemical finishes.
- Task 4: Following ageing, all turnout composite samples (new and aged) will be subjected to controlled, realistic smoke/soot contamination utilizing the Fireground Exposure Simulator at Illinois Fire Service Institute.

Phase II:

- The sample composites will be evaluated for (task 5) their ability to resist contamination of multiple types including liquids and particulates, (task 6) how effectively the contamination can be cleaned or released, and (task 7) how the contamination may impact the composites' ability to manage thermal energy exposures, including thermal protection and thermal comfort.
- Task 8: Disseminate research findings and improved methods as recommendations to share with the NFPA Technical Committee on Structural and Proximity Fire Fighting Protective Clothing and Equipment and the firefighting communities.

Anticipated Outcomes: This research will provide an evaluation of the impacts that contamination resistance measures have on the turnout performance and firefighter exposure to contaminants. The research findings will inform the NFPA 1971 and 1851 standards during their revision processes, and it will allow firefighters to conduct their own assessments of risk associated with potential trade-offs.

Implementation: This project is led by **North Carolina State University (NCSU) Textile Protection and Comfort Center (TPACC)** with collaborative support on the project team from the Illinois Fire Service Institute (IFSI), International Personnel Protection, Inc. (IPP), Emergency Response Tips, LLC, and the Fire Protection Research Foundation (FPRF).

The Principal Investigator (PI) for this project is Dr. R. Bryan Ormond, NC State University, Raleigh, NC, USA.
Email: rbormond@ncsu.edu.

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