NIST Technical Note XXXX

Exploratory Study on the Heating of Protective Clothing in a Convective Flow

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National Institute of
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U.S. Department of Commerce
Penny Pritzker, Secretary

National Institute of Standards and Technology
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List of Acronyms

NIST	National Institute of Standards and Technology
PPE	Personal Protective Equipment

Abstract

The overall objective of this inter-agency agreement between the United States Fire Administration (USFA) and the National Institute of Standards and Technology (NIST) is to better define the thermal limits of the operational fire environment, its impact on structural firefighting personal protective equipment (PPE), and deliver this information to the appropriate standards groups and the fire service. Without an accurate understanding of the conditions of environments in which a firefighter can safely operate, firefighters are more at risk of injuries and death.

To accomplish this, NIST will examine documented on-duty injuries and fatalities of firefighters due to thermal exposure of PPE used by structural firefighters. Further NIST will conduct laboratory thermal testing of commercially available PPE as part of this phase of the study:

1. NIST shall examine documented on-duty injuries and fatalities of firefighters due to thermal exposure of structural firefighting PPE [**?**, **?**, **?**].

2. NIST shall conduct laboratory thermal testing of commercially available structural firefighting PPE as part of this phase of the study, with a focus on convective heat transfer. The testing shall include any relevant performance requirements for structural firefighting PPE thermal exposure in NFPA 1971.

3. NIST shall conduct full-scale thermal testing of structural firefighting PPE at field test sites.

Section 1

Introduction

There is a gap in the understanding of the thermal failure temperature (melting point) of various pieces of personal protective equipment (PPE) worn or used by firefighters. As a result, there may be a misunderstanding of the thermal conditions in which a firefighter can safely operate. Ignition and melt testing on various pieces of PPE will define the thermal failure temperatures and lead to a better understanding of the conditions of a safer firefighting environment. Although there are flame and heat resistance tests in NFPA 1971, Standard on Protective Ensembles for Structural Fire Fighting and Proximity Fire Fighting [**?**] and NFPA 1981, Standard on Open-Circuit Self Contained Breathing Apparatus for Fire and Emergency Services [**?**], these tests do not provide the engineering data needed to connect laboratory based research data with field data (thermally damaged equipment) from actual fire incidents.

There have been incidents of failure of structural firefighting PPE has impacted the operational safety of firefighters. There is need to examine ways to enhance the understanding of thermal performance of structural firefighting PPE to enhance protection of firefighters.

The initial phase of this study examines the documented on-duty injuries and fatalities of firefighters due to thermal exposure of structural firefighting PPE. This phase of the study would also work with the National Fire Protection Association (NFPA) 1971 Standard on Protective Ensembles for Structural Fire Fighting technical committee on ways to enhance the operational effectiveness of structural firefighting PPE. Initial laboratory thermal testing of commercially available structural firefighting PPE shall also be conducted as part of this phase of the study.

Section 2

Prior On-Duty Injuries and Fatalities

There have been many previous fire incidents [**?**, **?**, **?**, **?**, **?**, **?**, **?**, **?**, **?**, **?**, **?**, **?**, **?**, **?**, **?**, **?**] in which changes in the flow paths are thought to have had an adverse impact on firefighter and occupant safety. Table 2.1 lists the NIOSH investigation reports from the past 15 years in which it could be determined that a flow path played a role in the related incident. This table lists the NIOSH report number, the outcome, and a brief description of the flow path details.

Based on a review of these incidents, it is clear that fires with rapidly developing or changing ventilation may lead to flow paths that are a significant hazard to the fire service during a response. The development of (or changes to) a flow path could be caused by the failure of a component of the structure, such as a door, window, or portion of a ceiling, wall or floor. Environmental conditions such as wind can generate hazardous thermal conditions within a flow path. Uncoordinated ventilation procedures can also be the cause of increased thermal hazards within a flow path.

LoDDs - Cherry Road and San Francisco as examples

Table 2.1: Flow path related LODD/LODI incidents.

NIOSH Report No.	No. of LODDs/LODIs	Flow Path Details
99-F01 [?]	3 LODDs	From apartment into hallway on 10th floor of high-rise apartment building
99-F21 [?]	2 LODDs 2 LODIs	Basement to 1st floor
F2000-04 [?]	3 LODDs 3 civilian deaths	1st floor to 2nd floor
F2000-16 [?]	1 LODD 1 LODI 1 civilian death	2nd floor hallway through 2nd floor apartment
F2000-23 [?]	1 LODD 2 LODIs	From ground level to 1st floor then to 2nd floor, flow exited through ceiling
F2000-43 [?]	1 serious LODI 2 other LODIs	1st floor to 2nd floor
F2004-02 [?]	1 LODD	1st floor to basement
F2005-02 [?]	1 LODD 4 LODIs	Rear to front of the building
F2005-04 [?]	1 LODD 9 LODIs	Basement to 1st floor
F2007-09 [?]	1 LODD 2 LODIs	3 story training burn - flow through all levels
F2007-35 [?]	4 LODIs	1st floor to 2nd floor
F2009-11 [?]	2 LODDs	Rear to front of the building
F2011-13 [?]	2 LODDs	Lower level up stairs and through entry door and garage
F2011-31 [?]	1 LODD	Fire extended from lower level apartment
F2012-28 [?]	1 LODD 1 LODI	Attic fire extended into closed porch and then into 2nd floor

Section 3

Existing Tests

Existing Tests - high thermal flux, short exposure

3.1 Thermal Protective Performance

TPP Test - PPE

3.2 ThermoMan

Thermo man - (pyro man) PPE

3.3 Flame Contact

Flame contact - helmet

While under bench scale test conditions it is less difficult to decouple convective heating from a radiant heat exposure. However with current test apparatus while convective heating is dominant, there is some level of radiant heating that is contributing to the heat transfer. Under full scale conditions in a flow path the PPE is exposed to a combination of convective and radiative heating.

Section 4

New Tests Investigated

Turnout gear material Helmets thermoplastic shell, fiberglass shell and leather shell
items examined:
Facepieces Old Scott AV 3000?, New Scott 3000HT MSA Old and New MSA 7

4.1 Heat Gun Exposure

4.2 Flow Loops

4.2.1 Plunge test

Temperature, velocity, heat flux measure?

4.2.2 Thermal Flow Loop

Temperature, velocity, heat flux

4.3 Full Scale Tests

Delco Exposures

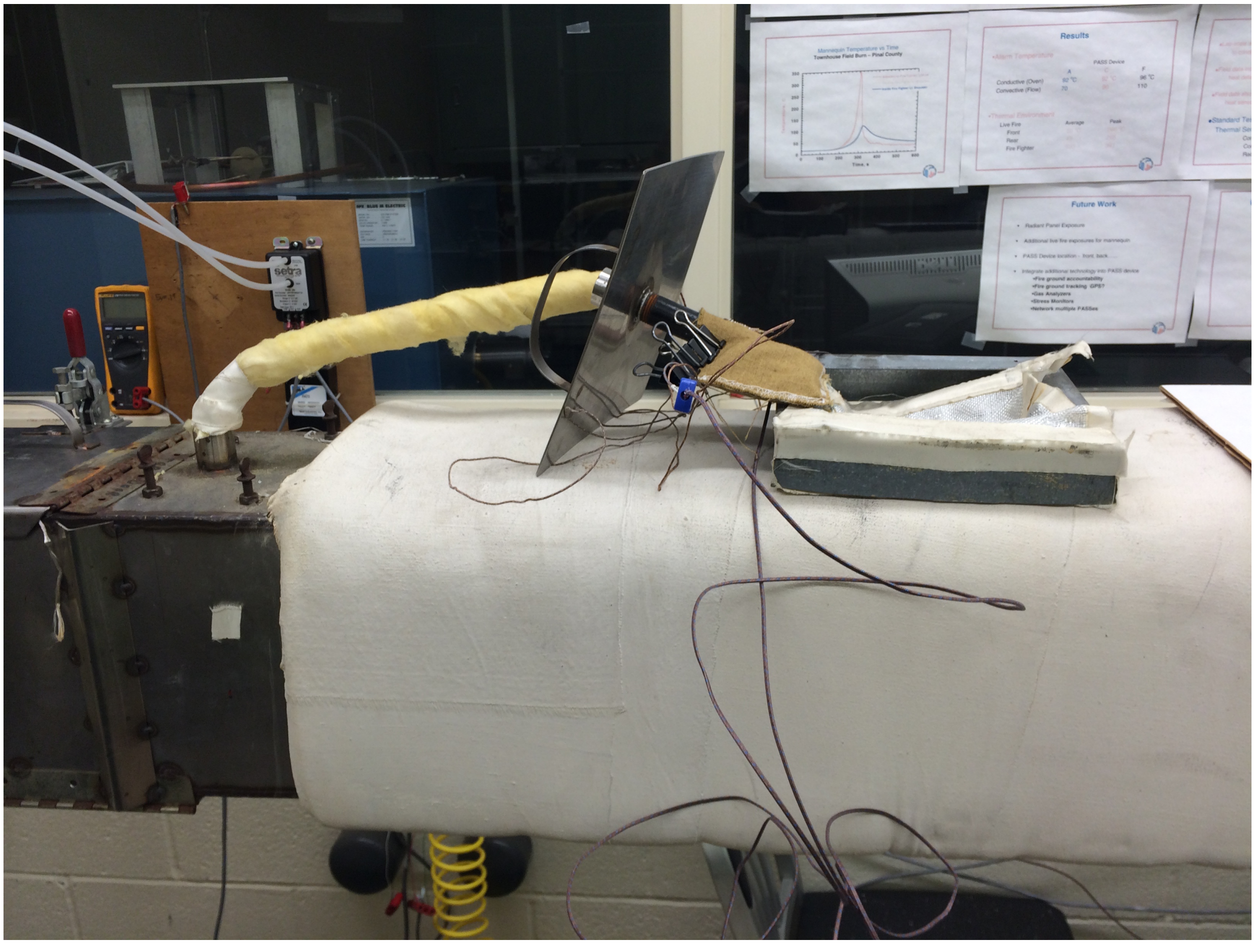

Figure 4.1: Image of plunge test apparatus configured to test a turnout gear sample.

Figure 4.2: Image of plunge test apparatus configured to test a turnout gear sample.

Section 5

Future Research

Flow loop with 20 mph and 300 to 500 F - Donnelly Substrates 2D vs 3D samples Gaps - refer to Lawson and Stroup Instrumentation - ref to Vettori Steam

Section 6

Summary

Section 7

Acknowledgments