TECHNICAL NOTES

Development of Permeation Test Method for Zippers and Other Closures

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FOREWORD

The NFPA Technical Committee on Hazardous Materials Protective Clothing and Equipment has identified a number of deficiencies in the current permeation tests used to characterize barrier layers in Personal Protective Equipment (PPE) for CBRN (Chemical Biological Radiological Nuclear) events. One of the issues is the design of the current test cell, which does not accommodate seams, zippers and other closures.

The goal of this project is to support the initial steps necessary for developing a test cell that complies with the requirements of the evolving permeation test method, but which provides robust closure technologies that can accommodate the irregular geometries inherent for seams, closures and zippers. To achieve this goal, this project addresses the requirements for researching an air-tight and inert method of sealing the NFPA permeation test cell for accurate testing of zippers and closures on Class 2 and 3 garments.

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The content, opinions, and conclusions contained in this report are solely those of the authors.

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Project Summary for Seed Research to Create Better Permeation Tests for CBRN Standards

1. Project Outline

This research sought to explore development of a method for the permeation testing of closures in a way which accommodate the irregular geometries that are inherent for seams, closures and zippers. This initial seed project evaluates one such approach to meet the requirements for an air-tight and inert method of sealing for accurate testing of zippers and closures on NFPA Class 2 and 3 garments. The project tasks were outlined and achieved in the following manner:

1.1 Identify and obtain representative specimens of closure types

Four sets of custom test specimens were created for this test by Kappler, Inc with Zytron 500 and Lantex 300 fabrics, which are used in NFPA 1994 Class 2 and Class 3 certified garments, respectively. Three zipper configurations were chosen: an air penetrable zipper with no protective flap, an air penetrable zipper with a flap, and an airtight zipper. A fabric-only Lantex 300 sample was also used as a control.

1.2 Compare test methods

When designing a test method the following issues were considered:

1.2.1 The current diameter of the NFPA permeation cell is 1.4 inches, much smaller than the flaps used on all of the protective suits initially considered for testing. Further, zippers and closures vary in size and dimension and a swatch level test would require separate test samples to be prepared for the ends and center. The closure design in its entirety cannot be evaluated.

1.2.2 The sealing methods attempted without cell alteration (additional rubber O-rings and expanded PTFE tape) were not able to maintain pressure for any of the closure samples following the cell integrity procedure from the standard. There were two primary problems confronted. The airtight zipper had an irregular geometry which the seals could not form around. Samples with flaps have a different problem. The space under the flap cannot be sealed completely by compression, creating a channel for air in the cell to travel under the flap and out of the cell laterally. These problems would have to be solved by applying a seal, such as a curing polymer or wax which does not interact with the challenge chemical, both under the flap and around the sample perimeter.

1.2.3 If sealing was possible, new air flow conditions would need to be considered. The current NFPA permeation test uses an air collection flow and a lower volume challenge flow with no special considerations for air penetrable samples. The Class 3 closure is air penetrable, so testing those samples as the test is written would cause air to flow out from the collection side. Three other testing options exist according to the Test Operating Procedure (TOP) 8-2-501:

a. A Convective Penetration test where the challenge vapor is flowed through the sample. This test is intended for selectively permeable or absorptive fabrics and would likely result in unacceptable failure because the openings in the zipper provide no resistance to the flow of chemical challenge.
b. A Static Diffusion test ("closed top" configuration), where the challenge is applied as a liquid, the top of the cell is closed, and flow is only maintained across the collection side.
c. A Dynamic Diffusion test, where the flow rates on top and bottom of the cell are adjusted to balance the pressure across the sample.

The issues above imply that there is a distinction between chemical permeation resistance and chemical protection; an air penetrable closure will not provide permeation resistance. From the combination of these issues, it was decided that the requirements to develop a new test cell based chemical permeation test were beyond the scope of this seed project. Thus an alternative method of mounting entire zipper samples, using the existing full ensemble Man-In-Simulant-Test (MIST) facility, and evaluating closure contribution to chemical protection was adopted instead.

1.3 Devise a test methodology

The methodology chosen is essentially an altered MIST devised to isolate the closure component of a garment. To achieve this the samples were mounted onto rectangular acrylic plastic troughs meant to simulate the interior space inside a protective suit directly under a closure. Chemical protection was determined using passive sorbents which indicate the air concentration of a challenge chemical. The advantage of this approach is that air penetrable and airtight closures could be tested in their entirety using identical test conditions. The primary assumptions of this test set up are that the closure samples are able to lie flat, are approximately the same overall length, and can be sealed to the trough around the edges in an inert and airtight manner.

1.4 Perform tests to answer the following research questions:

a. Can permeation testing show a difference in protection between an air penetrable zipper, an air penetrable zipper with an additional protective flap, and an airtight zipper?
b. Is full-scale testing in the MIST chamber feasible and an alternative to current bench-scale permeation methods?
c. Does a static microclimate under the zipper have a significant impact on the resulting protection?

2. Methods and Procedures

2.1 Samples

Each set of samples had three replicates. Three fabric/zipper combinations were selected and were constructed using the same techniques as their respective NFPA certified garments. They were constructed into flat rectangular samples of approximately 56”x8” with the zipper located in the middle of the sample.

Set	Fabric	Closure
1	Lantex 300	None (control)
2	Lantex 300	-Air penetrable coated YKK zipper, 46” -No flap
3	Lantex 300	-Air penetrable coated YKK zipper, 46” -Lantex 300 flap with hook and loop closure
4	Zytron 500	-Airtight YKK zipper, 48” -No Flap

2.2 Mounting

The troughs were constructed by solvent welding acrylic plastic panels. The face of the troughs are 12”x57” around the perimeter. The interior recessed space is 1 inch deep and measures 6”x53.25”. The samples were mounted onto the face of the trough using Kappler ChemTape to cover the edges and seal the fabric to the plastic, creating an effective exposure area of 6”x53.25”. The mounted samples can be seen below.

NFPA 1994 Class 3 Material
Air Penetrable Zipper

NFPA 1994 Class 3 Material
Air Penetrable Zipper with Flap

NFPA 1994 Class 2 Material
Airtight Zipper

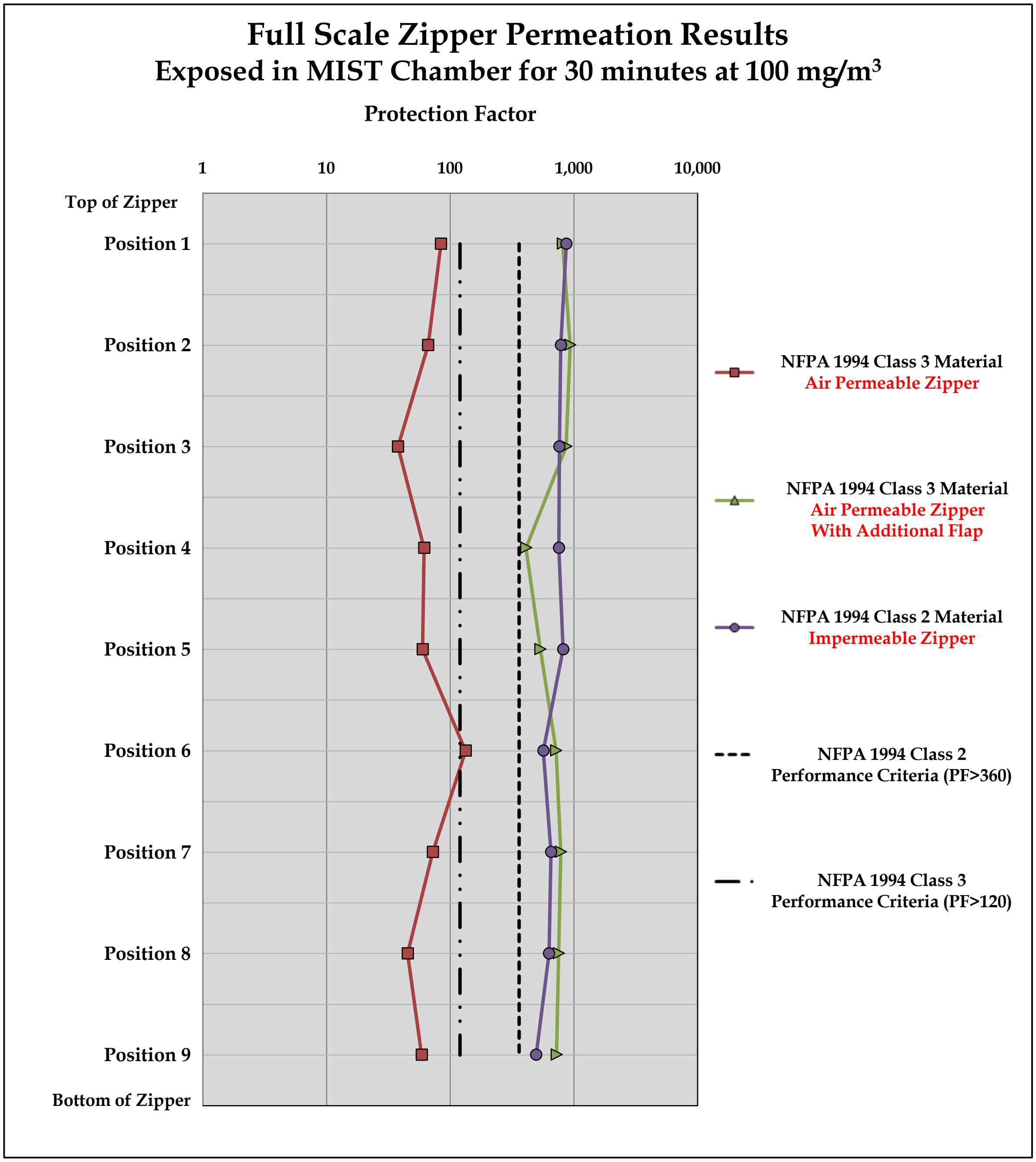
2.3 Procedures

a. 18 passive adsorbent dosimeters (PADs), identical to those used in the MIST protocol, were evenly distributed in 9 locations along the length of the zipper and 2 additional samplers were placed on the outer surface of the material
b. Three samples for each set were exposed for 30 minutes in the NCSU MIST Chamber with a MeS concentration of 100 mg/m^3
c. The chamber was set to the following conditions: Temperature: 27°C, Relative Humidity: 30-40%, and Wind Speed: 2-3 mph
d. All samples were tested with static conditions beneath the zipper (i.e. no air movement to simulate subject movement below fabric)
e. All PADs were extracted and analyzed using appropriate analytical techniques. The PAD dosages were averaged for all samples in a set, then used to calculate the protection factor, according to MIST protocol.

$$Protection\ Factor = \frac{Exposure\ Dosage\ Outside\ Protective\ Ensemble\ (mg.min/m^3)}{Exposure\ Dosage\ Inside\ Protective\ Ensemble\ (mg.min/m^3)}$$

3. Results and Discussion

The results are summarized below:



a. The air penetrable zipper with no additional flap (Class 3 material) provided an order of magnitude less protection than the other two zipper types (Average PF~70 vs. PF~700)

b. Under static conditions, the air penetrable zipper with the additional flap provided comparable protection to the airtight zipper

c. Using standard full-ensemble MIST performance criteria, the additional flap over the air penetrable zipper allowed the system to "pass" the NFPA Class 3 requirements (PF >120)

d. Under static conditions, the zipper with the additional flap also exceeded the NFPA Class 2 criteria (PF >360)

e. The Class 2 material with the airtight zipper exceeded the NFPA Class 2 criteria (PF >360)

The test was sufficient to measure protection provided by the three zipper types. These results suggest that further research is necessary since air penetrable closures used in Class 3 ensembles may contribute significantly to inward leakage. However, the static conditions do not provide an accurate assessment of the potential differences between the air penetrable and airtight zippers. Dynamic conditions simulating the normal pumping action within a suit could provide more accurate assessments.

4. Further Research

These tests were performed with static air on the interior collection side of the samples, which is not consistent with the MIST test protocol where participants are moving during the test. Incorporation of a pumping mechanism will provide the positive and negative pressures that may allow better differentiation between zippers. An additional technique could include bench-scale testing with real-time monitoring of MeS.

A different approach to the problem could be to design a new test cell able to accommodate the width of zippers with flaps, likely at least 6 inches in diameter. A casting method must be devised to properly seal around the samples. And one of the three methods mentioned in 1.2.3 must be adapted with appropriate air flow conditions for comparing air penetrable and air tight components.

This research was be performed by the Center for Research on Textile Protection and Comfort under a Memorandum of Agreement. Period of performance was 6 months. The technical project leader was Dr. Bryan Ormond, 919-524-1569, e-mail rbormond@ncsu.edu .