# High-sensitivity Measurement for Hypergol Permeation of Personal Protective Equipment Materials

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Scientists evaluated personal protective equipment (PPE) materials at the NASA White Sands Test Facility (WSTF) for breakthrough times from hypergol permeation using a new test cell design and methods compatible with ASTM [American Society for Testing and Materials] F 739-07 *Standard Test Method for Permeation of Liquids and Gases through Protective Clothing Materials under Conditions of Continuous Contact*.

The challenge fluids used in testing were hydrazine ($N_2H_4$), monomethylhydrazine (MMH), and nitrogen tetroxide (NTO). The toxicity of the $N_2H_4$ and NTO propellants has driven studies of alternative and less-toxic propellants in recent years, but no suitable alternatives have been identified for many applications, including aerospace. Therefore, the evaluation of PPE materials for compatibility and breakthrough time remains a concern for many groups working with these chemicals. Historically many commercial materials were tested, but some of these products are no longer marketed and several new products (e.g., laminated construction gloves and Viton® blends) have since come on the market. The ASTM F-739 method has also changed slightly, specifying a 2.5-cm (1-in.) cell rather than a 5-cm (2-in.) cell, which allows the use of a commercial off-the-shelf passive electrochemical detector monitor without modification.

We performed detection and data acquisition using a Draeger PAC III® monitor and data logging system. Integrating the detector sensor directly into the permeation cell minimized the collection chamber volume. That, in combination with a closed-loop configuration, maximized the sensitivity of the test system.

The PPE materials tested were obtained from gloves and Level A suits selected from those in common use at WSTF and Vandenberg Air Force Base, Lompoc, Calif. We also evaluated with this test system some PPE materials previously tested, and tested other PPE materials not previously reported.

We constructed three test cells, one for each challenge chemical, out of 300 series stainless steel. The cylindrical test cells were machined to a 2.5-cm (1-in.) inside diameter and a 2.5-cm (1-in.) depth. On the challenge side, we installed two female 0.3-cm (0.125-in.) national pipe thread (NPT) ports and one 0.635-cm (0.25-in.) NPT port for challenge chemical addition and posttest nitrogen purging to remove the challenge vapors. On the collection chamber side of the apparatus, we reamed the open end to 2.63 cm (1.04 in.) to be a slip fit on the hydrazine sensor cover of the Draeger PAC III® monitor (figure 1). The PAC III® monitor uses a different sensor cover for NTO, so we swapped it for an $N_2H_4$-style sensor cover to enable it to also slip-fit on the apparatus.

***Fig. 1.*** *Test apparatus.*

We cut test samples with a 5-cm (2-in.) die punch for uniform sizing. Thickness and weight were recorded for each sample, and were tested as received with no preconditioning. The thin, non-elastomeric samples required polytetrafluoroethylene gaskets with an inside diameter of 2.54 cm (1 in.). These gaskets were die-cut from 0.159-cm (0.0625-in.)-thick sheet stock.

Tests were initiated by acquiring a clean air baseline on the monitor, then starting the data logging mode as the hypergol propellant was added. We terminated the tests by pulling the detector monitor out of the challenge chamber if the alarm went off or after 2 hours, whichever occurred first. Breakthrough times were determined in triplicate for the PPE materials tested.

The test cells have an internal exposed area of 5.1 $cm^2$ (2 $in^2$) for the sample area, as described in ASTM F-739. With the Draeger PAC III® installed, the collection chamber volume is 13 $cm^3$ (5 $in^3$) (0.013 L). At WSTF ambient conditions, the lower sensitivity of the Draeger detector is 0.011 µg/L for $N_2H_4$, 0.016 µg/L for MMH, and 0.16 µg/L for NTO. We set the sampling frequency on the Draeger detector to one data point every 10 seconds. Using the 10-second data collection frequency for time, the ASTM-calculated breakthrough sensitivities are quite low, as shown in Table 1.

| Test Fluid | Breakthrough sensitivity. |
|---|---|
| $N_2H_4$ | $1.6 \times 10^{-4}$ µg/$cm^2$/min |
| MMH | $2.4 \times 10^{-4}$ µg/$cm^2$/min |
| NTO | $2.4 \times 10^{-3}$ µg/$cm^2$/min |

***Table 1.*** *Breakthrough sensitivity.*

The ease of integrating a commercially available electrochemical detector with the new 2.54-cm (1-in.) test cell, now prescribed by ASTM F 739, facilitates hypergol permeation testing and maximizes the sensitivity of the test system.



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