GORE®

PARTICULATE HOOD

WHITE PAPER

# ENSURING CERTIFIED PROTECTION AND LONG-LASTING DURABILITY IN PARTICULATE HOODS

**Abstract:** The fire industry has become increasingly aware of the potential relationship between exposure to fireground particulates and firefighters' safety and health. Studies have shown that some of the most vulnerable areas of firefighters' bodies are around the neck and ears, which are covered by the hood. Understanding the testing methods used to evaluate the particulate-blocking performance of particulate hoods can help you select a hood that delivers the consistent, reliable protection you need.

## INTRODUCTION

Recent studies[1] in the fire industry have increased awareness of the possible effects that exposure to fireground particulates can have on firefighters' safety and health. These studies have led the NFPA committee to advocate for measures that minimize firefighters' exposure to potentially harmful particles at the fireground. One such measure is including an option for certified particulate protection for garments and hoods in the 2018 edition of the NFPA 1971 Standard on Protective Ensembles for Structural Fire Fighting and Proximity Fire Fighting.

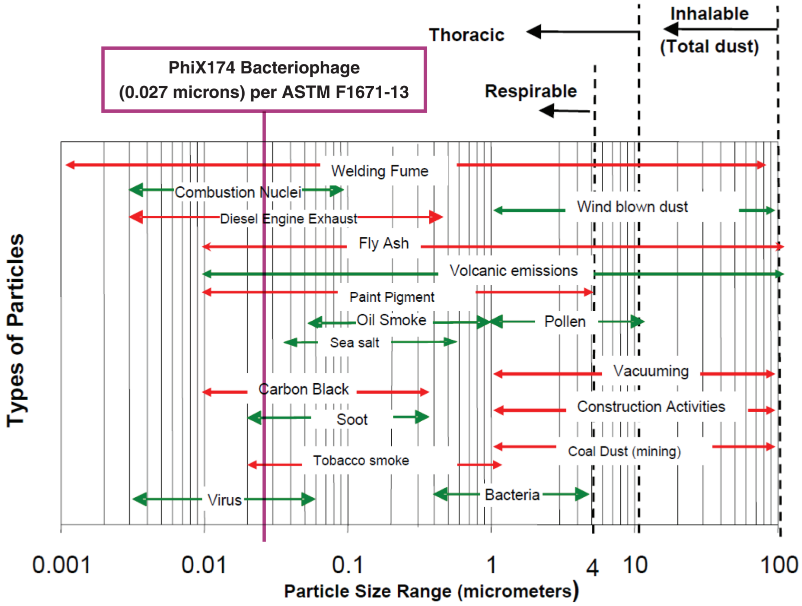
Although no studies have definitively reported that PPE products can prevent, reduce, or cure health conditions related to fireground particle exposure, including cancer, fire industry groups such as the NFPA understand and support measures that minimize firefighters' exposure to potentially harmful particles at the fireground. W. L. Gore & Associates, Inc., (Gore) recognizes these initiatives being implemented and has worked to develop a comfortable, durable product that blocks particles effectively in line with the guidance of these industry experts.

## NFPA 1971, 2018 EDITION CERTIFICATION

For the particulate-blocking hood option of the Standard, the NFPA committee specified that hoods "shall have a particulate filtration efficiency of at least 90 percent or greater for each particulate size from 0.1 to 1.0 microns."[2] Certified hoods must meet this specification out of the bag as well as after preconditioning, which includes 20 launderings and two convective heat cycles.

Figure 1 shows a chart of several particulates in the 0.1 to 1.0-micron range that are common to the fireground, such as diesel engine exhaust, oil smoke, and soot. As a reference point, the purple line denotes the size of the Phi-X174 bacteriophage used to evaluate moisture barriers in turnout gear for their viral penetration resistance. Although a moisture barrier can be used in a particulate blocking hood, it is not required.

*Figure 1: Particle size chart provided by TSI Incorporated*[3]




[1] See Appendix 1 for more information on these studies.
[2] NFPA 1971, Section 7.14.2, *Standard on Protective Ensembles for Structural Fire Fighting and Proximity Fire Fighting* (National Fire Protection Association 2018).
[3] TSI Incorporated is a global corporation that designs and produces precision measurement instruments.

To evaluate the hood's particulate-blocking capability, the NFPA committee selected the Particulate Blocking Test method. This test uses an analytical instrument to count the number of particulates ranging in size from 0.1 to 1.0 microns as they pass through a specimen containing all layers of the hood (Figure 2).

The Particulate Blocking Test is performed on 6-by-6-inch specimens as received and after preconditioning. For preconditioning, 15-by-15-inch samples are subjected to two cycles, each consisting of ten laundry cycles and one ten-minute convective heat exposure at 140°C (285°F). A 6-by-6-inch specimen is then cut from the center of each of the three preconditioned samples. Three as-received specimens and three preconditioned specimens are tested.

*Figure 2: Particulate-blocking test setup*

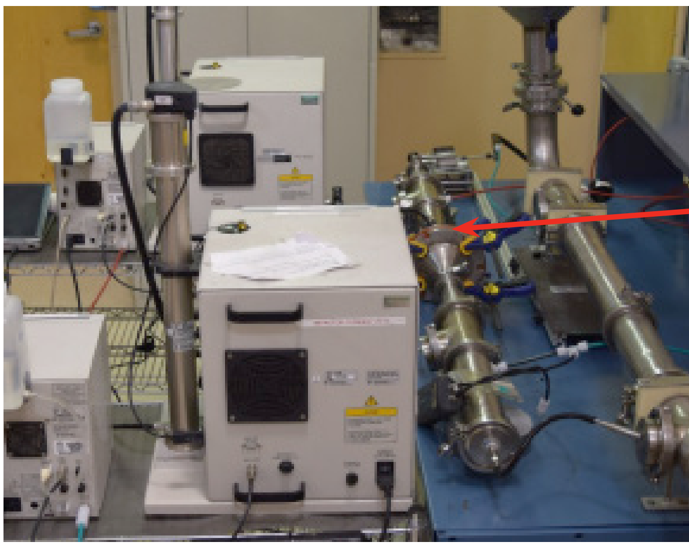
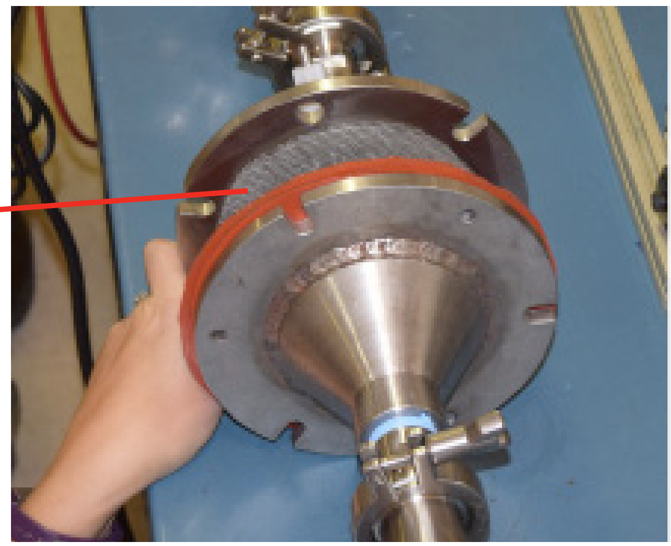


*Figure 3: Specimen positioned for test*



The test is performed as followed:

1. For each specimen, the outer-most layer is positioned facing upstream, and the inner-most layer faces downstream (Figure 3).
2. The specimen is subjected to a 1.7 liter/minute airflow containing latex spheres ranging in size from 0.1 to 1.0 microns. If this flow rate is not achieved, a needle valve is closed, and the particle counter exhaust is recirculated into the downstream side to maintain a pressure drop of 1-inch water column.
3. The number of latex spheres upstream and downstream of the specimen are counted.
4. The percent efficiency is calculated with these numbers.

If the average percent efficiency is equal to or greater than 90 percent across all particle sizes, the hood is certified.

## GORE® PARTICULATE HOOD TESTING — PROTECTION

When tested for certification to the 2018 edition of the NFPA 1971 Standard, the GORE® Particulate Hood blocked 99.9 percent of all particulates in the 0.1 to 1.0-micron range[4]. This 99.9 percent protection held true for new materials as well as samples preconditioned to the NFPA requirement.

One of Gore's core values is to ensure that its products meet the needs of the end-users in the environment in which they will be using the products — a concept referred to as fitness for use. Therefore, Gore also performed system-level testing on the GORE® Particulate Hood.

Gore contracted an independent laboratory to perform the Fluorescent Aerosol Screening Test (FAST) to compare the GORE® Particulate Hood to a traditional (i.e., non-particulate) hood[5]. This test can be used to evaluate gear for protection against aerosols. Black light images are taken to document areas of aerosol deposits on the human subject's skin.
FAST was performed as follows:

1. Black-light images were taken of the human subject before gear was donned.
2. After donning new turnout gear including gloves, footwear, helmet, SCBA, SCBA mask, and the specified hood, the human subject entered the test chamber. No station wear was worn under the gear.
3. The subject performed a routine of motions for 30 minutes inside the chamber while fluorescent amorphous silica ranging in size from 0.1 to 10.0 microns, with a median size of 0.35 microns, were blown in the chamber at a rate of 10 miles per hour.
4. After the human subject removed the turnout gear, black-light images were taken again, and visual documentation was recorded to show the amount of aerosol penetration seen on the subject's skin.

Figure 4 shows the images after FAST testing for three scenarios:

- traditional hood, donned with gaps at the hood-to-mask interface
- traditional hood, donned properly without gaps at the hood-to-mask interface
- GORE® Particulate Hood, donned properly without gaps at the hood-to-mask interface

The three bright rectangles on the left of each image are the same paint chip. This chip is used during photography as a color standard to show changes in lighting due to the amount of fluorescence on each subject's skin.

*Figure 4: FAST results for three different scenarios*


[4] Particulate blocking test was performed by IBR Laboratories, Grass Lake, Michigan.
[5] Independent testing was performed by RTI International, Research Triangle Park, North Carolina.

The image on the left shows the particulate ingress that occurred when a small gap between the SCBA mask and the hood elastic left an open path for particulates to travel. A gap as small as a few millimeters can have a drastic impact on a firefighter's level of protection. Note that the paint chip in this image appears darker compared with the other two chips; this is because the camera automatically compensated for the higher amount of fluorescence from greater particulate penetration through the interface gaps.

The middle image is an example of what everyone knows about PPE: properly donned PPE maximizes protection. It shows a traditional hood that was donned properly (i.e., the hood's elastic band was flat on the gasket around the entire SCBA mask). The areas without fluorescence that are below the ear were from the SCBA mask strap tight against the skin. However, a significant amount of particulate was still visible on this subject's skin. Therefore, to minimize this particulate ingress, additional steps still must be taken beyond wearing a properly donned traditional hood.

The image on the right shows that when a GORE® Particulate Hood was worn, no visible evidence of particulates on the subject's skin could be found.

It is often difficult to compare photographs and know just how much protection was delivered. Therefore, quantitative data was collected from the subjects' skin. The quantitative portion of FAST can be done for a head-to-toe evaluation of protective garments (Figure 5); however, Gore was focused on hoods, so 13 discrete locations on the human subject's body were sampled: 7 around the neck, 2 on the chest, 2 on the ears, and 2 in front of the ears below the temple. These locations on each subject were washed with a 0.1-molar (M) sodium hydroxide solution to collect the fluorescent particulates. The solution's fluorescence was analyzed to determine a particulate mass for each sample location.

*Figure 5: Standard locations for FAST quantitative analysis*

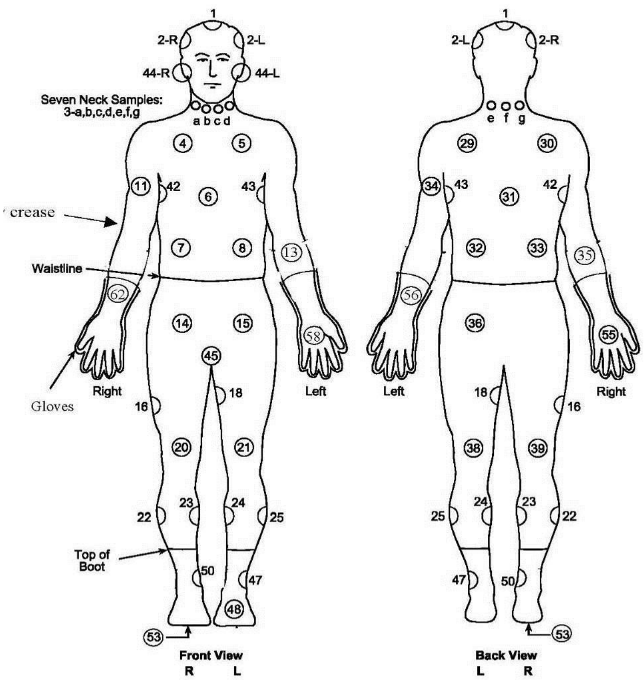


Table 1 shows the quantitative results of the 13 sample locations for each of the three hoods evaluated in the FAST test (Figure 4). The particulate ingress decreased by a factor of more than six times when comparing an improperly donned hood to a properly donned hood. And, it decreased by a factor of almost 16 when comparing a properly donned traditional hood to the GORE® Particulate Hood.

*Table 1: FAST quantitative analysis results*

| | Traditional hood donned with gaps at hood-to-mask interface | Traditional hood donned properly | GORE® Particulate Hood, donned properly |
|---|---|---|---|
| Average concentration (µg/cm$^2$) | 1.70 | 0.25 | 0.02 |
| Total mass for 13 sites (µg) | 264.6 | 38.8 | 2.47 |

## GORE® PARTICULATE HOOD TESTING — DURABILITY

Firefighting hoods are laundered frequently. Therefore, Gore felt it was also important to ensure the durability of the GORE® Particulate Hood, specifically its ability to maintain a high level of protection over an extended period.

Gore washed GORE® Particulate Hoods 100 times at a verified ISP and repeated both the Particulate Blocking Test and the FAST test to evaluate its particulate-blocking performance.

After the Particulate Blocking Test was performed, the laundered GORE® Particulate Hoods maintained the 99.9% efficiency — the same results as it received as new and after NFPA preconditioning.

Gore then compared the FAST results for two properly donned hoods: a new, traditional hood and a GORE® Particulate Hood after the 100 washes. The visual data (Figure 6) and the quantitative data (Table 2) both prove that the particulate ingress with the GORE® Particulate Hood remains significantly lower even after the laundering, which translates to excellent durability and sustained protection over time.

*Figure 6: FAST results after 100 launderings*

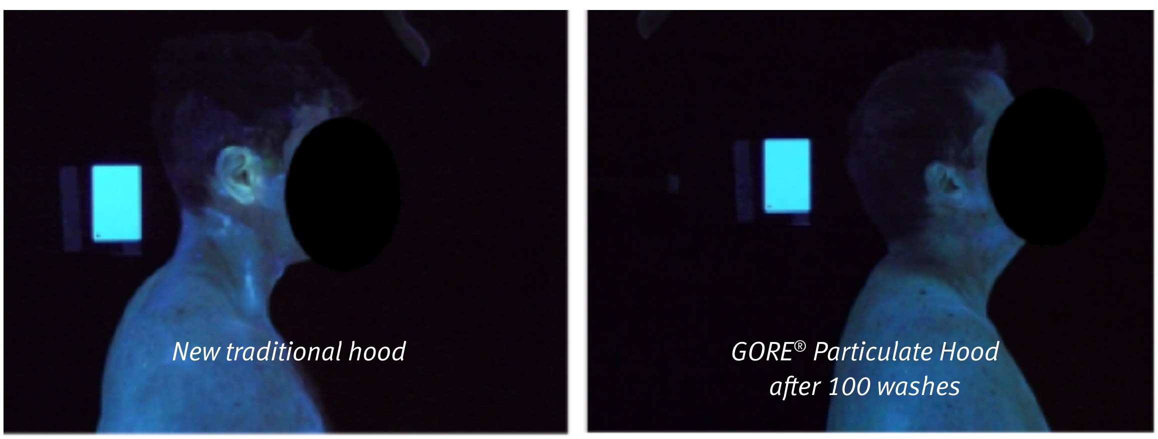


*Table 2: FAST quantitative analysis of new versus laundered hoods*

| | New traditional hood | GORE® Particulate Hood after 100 launderings |
|---|---|---|
| Average concentration (μg/cm²) | 0.25 | 0.03 |
| Total mass for 13 sites (μg) | 38.8 | 5.06 |

When the GORE® Particulate Hood materials were washed in a home laundry, similar results were seen when evaluated with the Particulate Blocking Test.

One important factor that cannot be underestimated when evaluating gear's durability is visual inspection. The GORE® Particulate Hood has an inspection opening that allows firefighters to invert the hood completely (Figure 7). By doing so, they can easily inspect the particulate blocking layer — which covers the entire hood — for cuts, holes, and tears and then turn it right-side out again.

*Figure 7: GORE® Particulate Hood inspection opening*

## SUMMARY

Recent studies have shown that it is important for firefighters to protect themselves head-to-toe from fireground particulates. The NFPA committee has responded to these studies with an option for certified particulate protection in firefighter garments and hoods as part of the 2018 edition of the NFPA 1971 Standard on Protective Ensembles for Structural Fire Fighting and Proximity Fire Fighting. This Standard specifies criteria and test methods used to certify particulate blocking hoods.

Drawing on its expertise in protective barrier technology, Gore developed the GORE® Particulate Hood, which exceeded the test requirements of the NFPA 1971 with a 99.9 percent particulate-blocking efficiency even after 100 laundry cycles at a verified ISP. To further ensure the hood's performance, Gore contracted with an independent laboratory to complete system-level testing with FAST tests, which yielded results that were a factor of almost 16 times better than a properly donned traditional hood.

It is important to understand the NFPA test method as well as other methods used in the industry when selecting a particulate-blocking hood. Not only do these tests show the importance of using a particulate hood and using it properly, but by comparing the test results of various hoods, you can select the hood that delivers the best and most reliable protection.

## APPENDIX 1

Bolstad-Johnson, D. M., Burgess, J. L., Crutchfield, C. D., et. al. *Characterization of Firefighter Exposures During Fire Overhaul* (2000). Phoenix, Arizona.

Fabian, T. Z., Borgerson, J. L., Gandhi, P. D., et. al. Fire Technology (2014). *Characterization of Firefighter Smoke Exposure*. Springer US 50:993. https://doi.org/10.1007/s10694-011-0212-2.

Fent, K. W., Eisenberg J., Evans, D., et. al. *NIOSH: Evaluation of Dermal Exposure to Polycyclic Aromatic Hydrocarbons in Fire Fighters* (2013). Cincinnati, Ohio: US Department of Health and Human Services, Centers for Disease Control and Prevention, National Institute for Occupational Safety and Health, NIOSH HETA Report No. 2010-0156-3196.

Firefighter Cancer Support Organization. *Taking Action Against Cancer in the Fire Service* (August 2013). Indianapolis, Indiana.

Horn, Gavin P., Kerber, Steve, Fent, K. W., et. al. *Cardiovascular and Chemical Exposure Risks in Modern Firefighting, Interim Report* (2016). Illinois Fire Service Institute, University of Illinois at Urbana-Champaign.

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