Particulate Protection – Head to garment innovations

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DuPont has trusted PPE solutions to help keep workers safe

Thermal Apparel

PPE Solutions made with Nomex® fabrics provide inherent FR protection for flame and electric arc hazards

Mechanical Protection

Gloves made with Kevlar® fiber provide excellent protection from cut, abrasion, and thermal hazards.

Emergency Response

From fighting fires, to hazardous material cleanup, DuPont has the expertise and PPE solutions to protect ER workers.

Chemical Protection

Tyvek® & Tychem® garments provide the broadest range of demonstrated protection against chemical hazards.

Controlled Environments

Tyvek® IsoClean® garments protect sensitive processes from contamination reliably.

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Agenda

- Why are particulates an issue outside of respiratory ?
  - How can they be absorbed?
  - What protection?
  - Cleaning?
- Are standards addressing these issues?
- Should Face and respiratory protection match garment?

Why are particulates protection needs to be extended from respiratory protection?

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Exposure Routes to Toxic Substances

- SCBA protects against inhalation and ingestion
- Gear, gloves and boots provide minimum protection from particle penetration
- Is existing protection from PPE enough?

Inhalation
- Fast
- Easy

Skin Contact
- Slow
- Large area

Ingestion
- Fast
- Possible

Absorption

Distribution

Metabolizing

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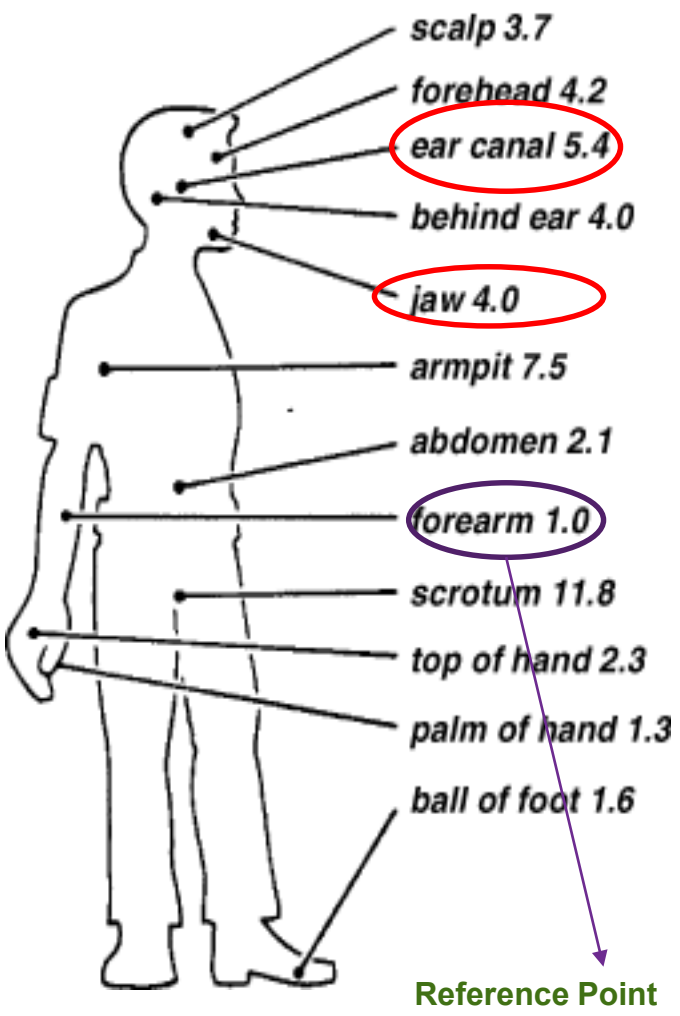
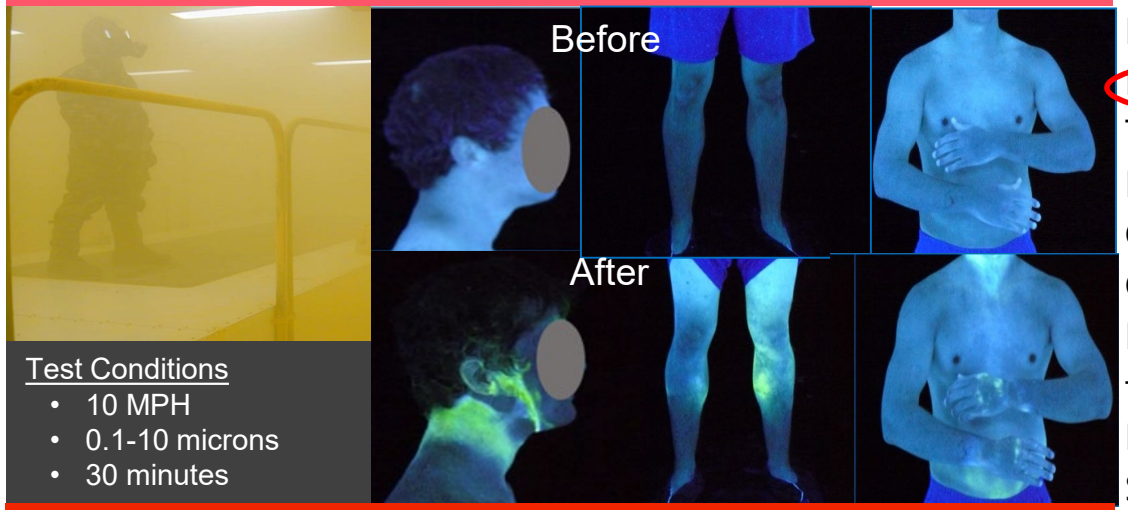
Skin Absorption Rates vs Protection



FAST
(Fluorescent Aerosol Screen Test)



Test Conditions
- 10 MPH
- 0.1-10 microns
- 30 minutes

- Scrotum, armpit, and head are the most absorptive areas
- Absorption rate increases as temperature increase
- High humidity of fireground and sweat dramatically increase skin absorption rate
- Absorption reaches to the highest level during structural firefighting

PPE	Average ($)
Helmets	350
Hoods	45
Turnout Coats	1300
Flashlights	90
Gloves	80
Glass 2 Harness	650
Pagers	150
turnout Pants	900
Leather Fire Boots	350
SCBA	3500
SCBA Face Piece	300
Corective lens holder	90
Portable Radios	1500
Thermal Image Camera	2500
Total	11805

- Current Hood Is the Least Expensive of the Entire PPE

http://www2.ca.uky.edu/agcomm/pubs/pat/pat6/pat6.pdf

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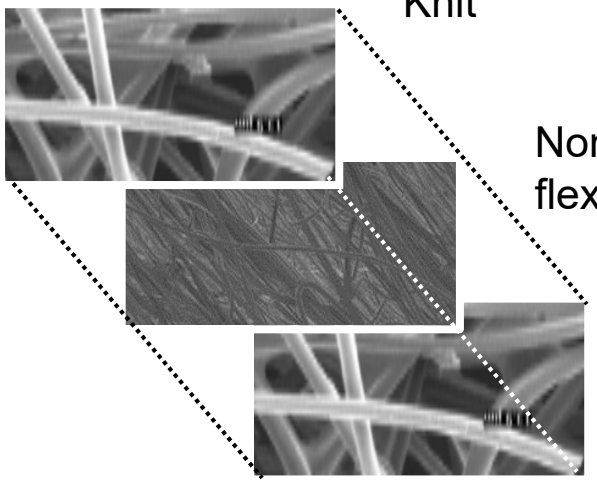
Improved particle-blocking efficiency

Nomex® Nano Flex hoods



Filtration efficiency

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Particulate blocking test conditions NFPA 1971 standard

8.71.2.2 Where a seam is necessary to create the 380 mm^2 (15 $in.^2$) composite sample, a seam shall not be included in the cut conditioned specimen.

8.71.2.3* A reference sample shall be prepared that consists of a composite constructed using two layers of 8.4 oz /yd^2 ± 0.4 oz /yd^2, 100 percent meta-aramid, 1 × 1 rib knit with a stitch count of 37 courses/in. ± 2 courses/in. and 21 wales/in. ± 2 wales per in.

8.71.3 Specimens.

8.71.3.1 Particulate-blocking-layer composite specimens shall be tested both before and after being twice subjected to the following conditioning:

(1) Specimens shall be first subjected twice to the procedure specified in 8.1.2.
(2) Specimens shall then be conditioned as specified in 8.1.3.
(3) Specimens shall then be conditioned as specified in 8.1.5.

8.71.3.2 The particulate-blocking test specimens shall be cut into at least a 150 mm (6 in.) square from the preconditioned sample.

8.71.3.2.1 One specimen shall be taken from the center of each preconditioned sample.

8.71.3.3 All specimens to be tested shall be conditioned as specified in 8.1.18.

8.71.3.4 Reference specimens shall be conditioned as specified in 8.1.18.

8.71.3.5 A total of three particulate blocking layer composite specimens shall be tested. One reference specimen shall be tested.

8.71.4 Apparatus.

8.71.4.1 The test apparatus shall be as specified in ASTM F2299/F2299M, *Standard Test Method for Determining the Initial Efficiency of Materials Used in Medical Face Masks to Penetration by Particulates Using Latex Spheres*, with the following modifications:

(1) A needle valve shall be placed between the filter holder and the air flow measurement.

8.71.5 Procedure.

8.71.5.1 Specimens shall be tested in accordance with ASTM F2299/F2299M, *Standard Test Method for Determining the Initial Efficiency of Materials Used in Medical Face Masks to Penetration by Particulates Using Latex Spheres*, with the following modifications:

(1) A reference specimen as specified in 8.71.3 shall be tested prior to the commencement of a series of testing or when the test equipment is modified or repaired.
(2) The normal outer surface of the particulate-blocking layer shall be mounted such that it faces the upstream side as oriented in the hood.
(3) If the airflow is met with the specimen in place, the upstream and downstream aerosol counts shall be recorded for a minimum of 5 counts at each particle range using a 1 minute sampling time.
(4) If the downstream count is less than 100, the sampling time shall be extended until 100 counts are obtained but not longer than 5 minutes.
(5) If the airflow is not met, the needle valve shall be closed and the OPC exhaust shall be recirculated into the downstream side to maintain a pressure drop of 249 Pa (1 in. H_2O column) across the specimen.

8.71.5.2* The latex sphere sizes used in testing shall range from 0.1 µm to 1.0 µm and shall be created using at least eight different known particle sizes from 0.1 µm to 1.0 µm.

8.71.5.3 The required airflow shall be 1.7 L/min ± 0.1 L/min in 8.71.5.1(3)

8.71.5.4 The efficiency for each specimen shall be calculated for each sequence for conditioning using the following equation:

[8.71.5.4]

$$\%\text{Efficiency} = \eta = [1 - (\text{downstream counts}/\text{upstream counts})] * 100$$

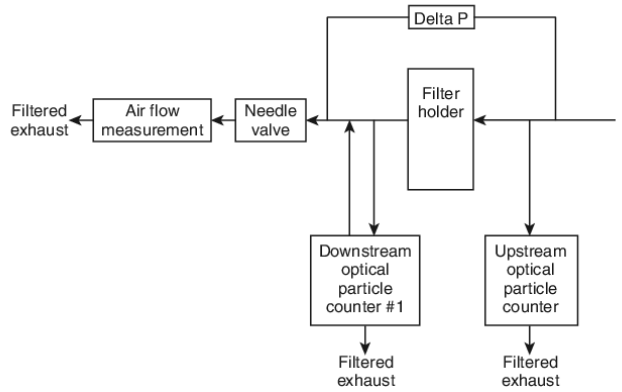

FIGURE 8.71.4.1 Diagram for Placement of the Recirculated Line.

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Proof points - viral and bacterial filtration performance

	PFE (90%)	VFE (≥95%)	BFE (≥95%)
Nomex® Nano Flex Hood (Quilted)	>95%	96.8%	97.9%
Nomex® Nano Flex Hood (Laminated)	99%	99.8%	99.9%

PFE – Particulate filtration efficiency

VFE – Viral filtration efficiency

BFE – Bacterial filtration efficiency

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Proof points - hood wear trial

Performance of hoods with and without Nomex® Nano Flex. All hoods worn by firefighters in wear trials (15 minutes wood and straw fire, 15 minutes wood and straw fire, 10 minutes wood and synthetic couch fire)

Outside of hybrid hood with and half without Nomex® Nano Flex

Inside out with Nomex® Nano Flex

Inside out without Nomex® Nano Flex

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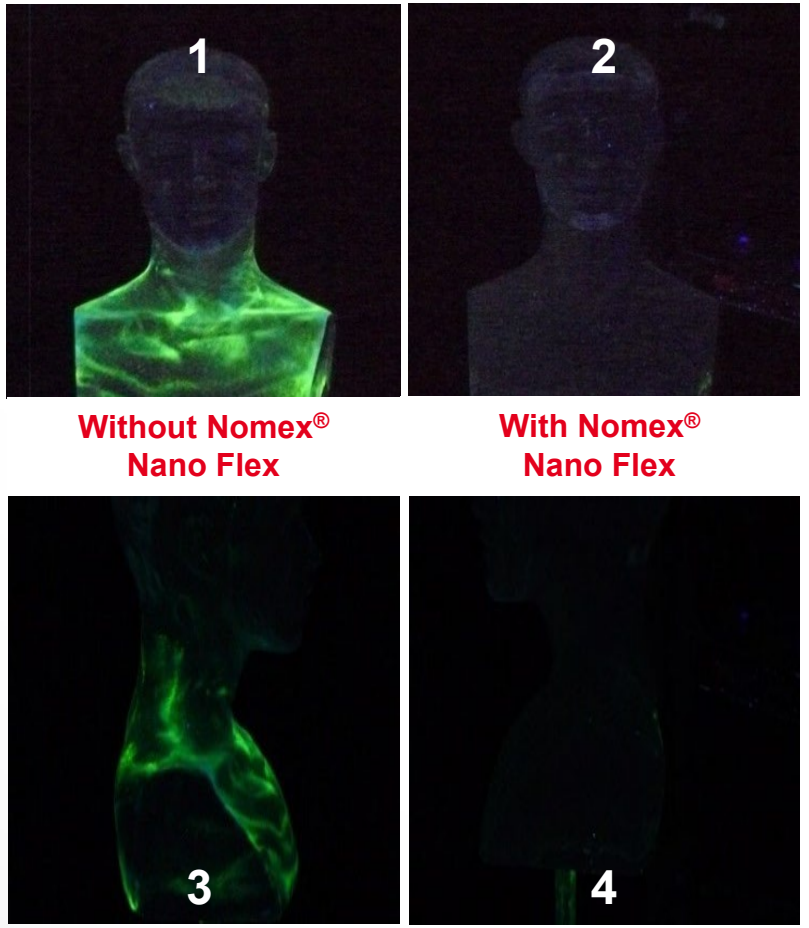
Proof points - FAST test on hoods with Nomex® Nano Flex

1 & 3 contained no Nomex® Nano Flex

2 & 4, with Nomex® Nano Flex, dramatically reduced particle penetration

Particle concentration was below detection limit

w/o barrier | w/barrier | w/o barrier | w/barrier



Without Nomex® Nano Flex | **With Nomex® Nano Flex**

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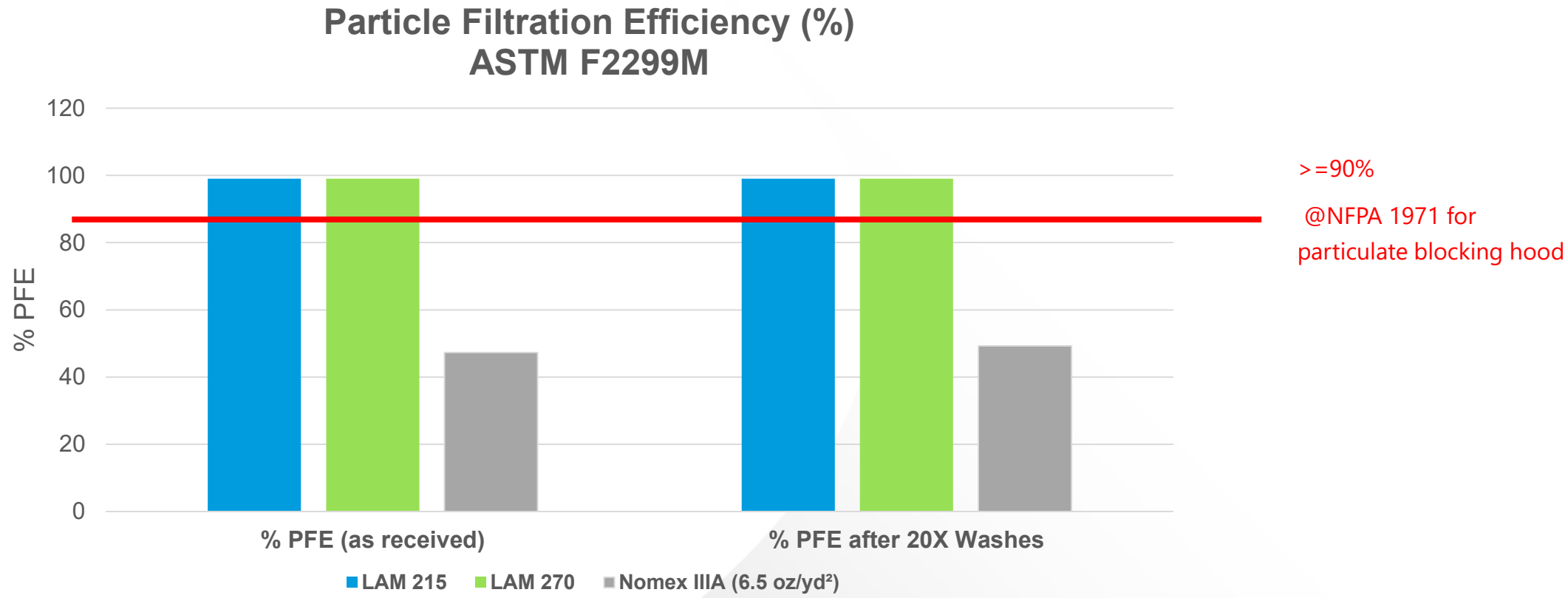
Filtration Efficiency Performance Comparison



>=90%

@NFPA 1971 for particulate blocking hood

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Thermal protection

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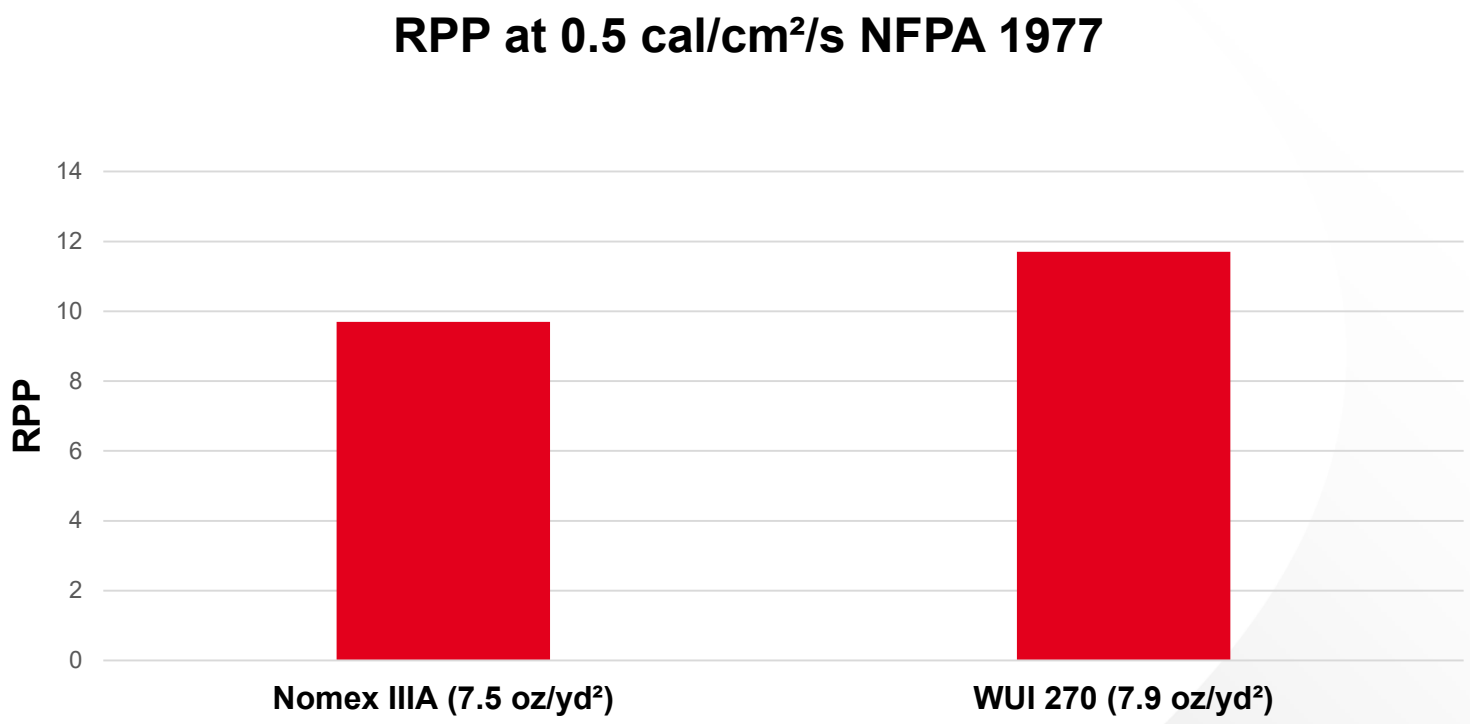
Thermal protection performance



Enhanced RPP by 20%

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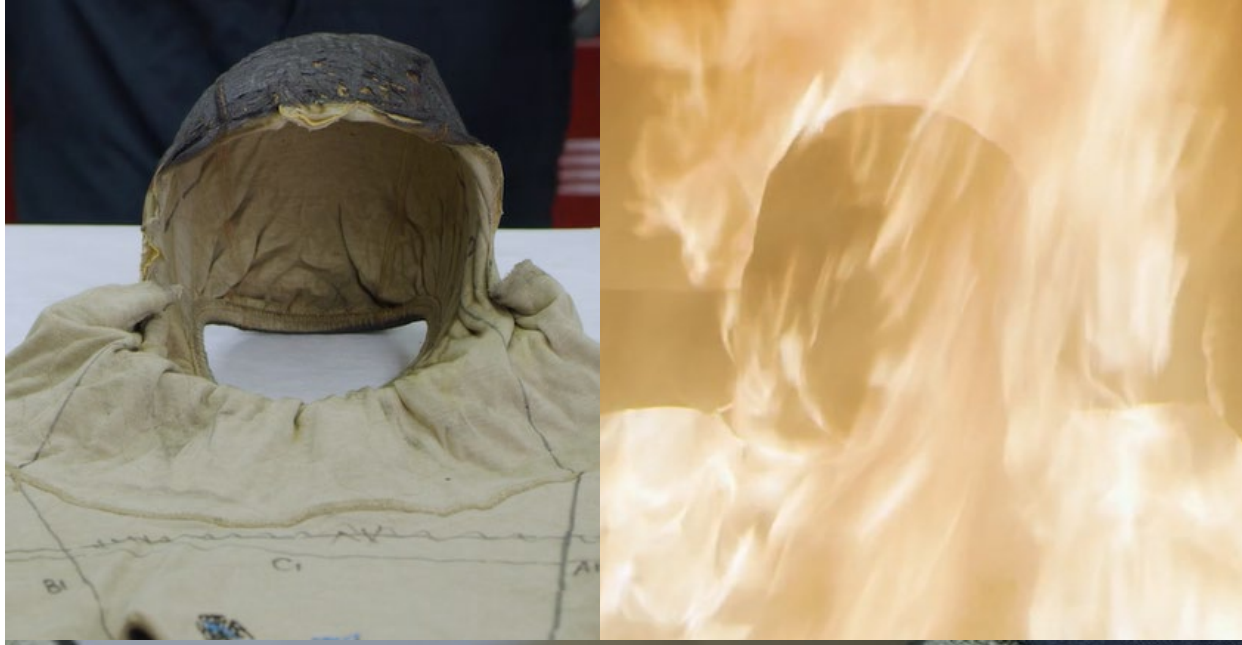
Thermal performance on Thermo-Man®

DuPont™ Thermo-Man® system
Test standard: ASTM F1930
Exposure time: 10 seconds
Heat flux: 2 cal/cm²•s
Hood material: PGI Cobra™ BarriAire™ made with Nomex® Nano Flex

No char, no melt, no drip on Nomex® Nano Flex and inner knit layer after 10 sec flashover @ 2 cal/cm²/s



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Comfort and durability

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Breathability and comfort

	LAM 215	LAM 270	NFPA 1971-2018
THL (W/m²)	609	600	≥ 205
Air permeability (cfm)	14.3	13.8	N/A

Well exceeded required THL with exceptional air permeability

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Nomex® Nano: Improved moisture management

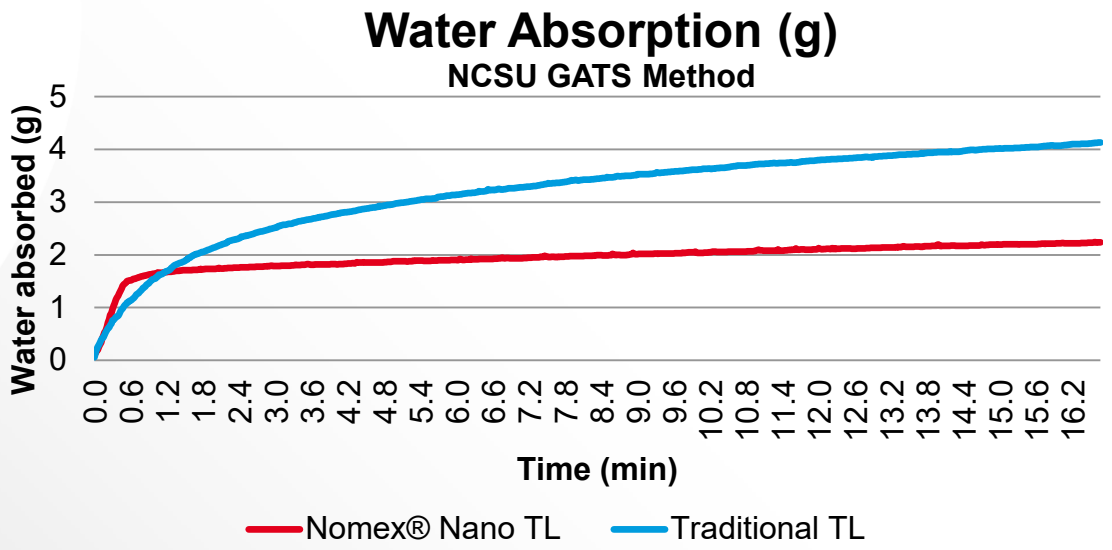
	Absorption time (min)	Water absorbed (grams)	Absorption rate (g/min)	% Evaporation
Traditional Textile	1.4	3.2	0.72	23%
Nomex® Nano	0.5	1.3	**2.14**	**43%**

High absorption rate to remove sweat quickly

High evaporation rate to drive water out of thermal liner

Low amount of water absorbed to reduce steam burn and gear weight

Validated and confirmed by numbers of wear trials in a variety of locations and climates



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Durability
(wear trials are in progress)

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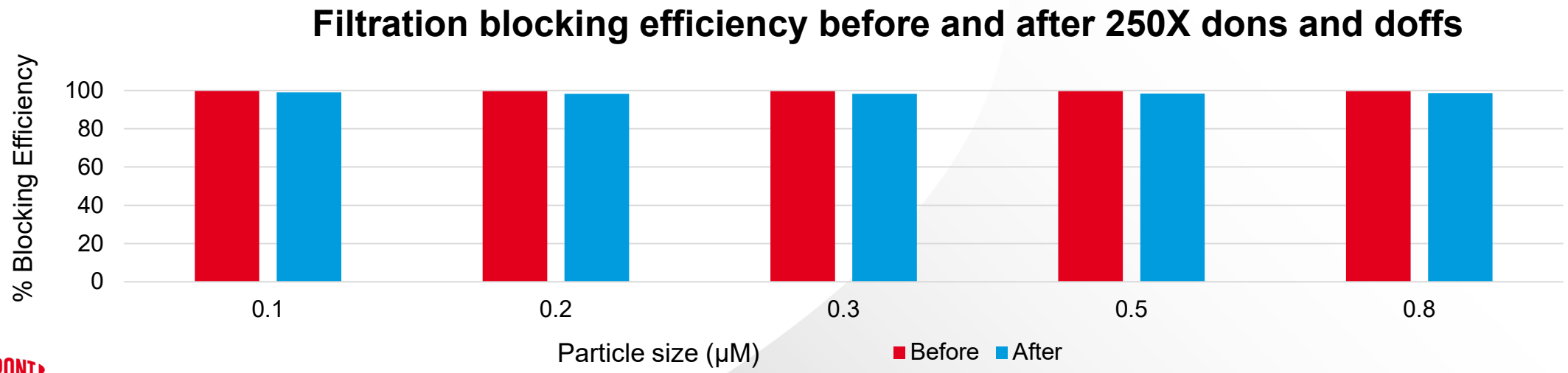
Proof points - hood durability of 250X dons and doffs

Hoods with different designs, including quilting and no quilting, from three manufacturers were evaluated at local fire station

Each trial consisted of 25X donning and doffing, followed by one NFPA 1851 recommended washing and drying

Total 10 wear trials, or 250X dons and doffs, were conducted



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Proof points - dimensional stability of hood after laundries

Dimensional stability with laundry[2]

Change in dimension[3] with laundry cycles at 2 locations

[2] AATCC TM135 v2004 machine cycle 1 wash temperature 5 drying procedure Ai with hoods as ballast to make the specified 1.8 kg minimum wash load (2.0 kg actual). Water softened to less than 25ppm total hardness.

[3] dimension changes are shrinkage reported as a positive quantity

	Hood with Nomex® Nano Flex		Hood with moisture barrier A		Hood with moisture barrier B	
Cycle	**Width, A**	**Height, B**	**Width, A**	**Height, B**	**Width, A**	**Height, B**
5	0%	< 5%	0%	< 10%	< 10%	< 15%
20	0%	< 10%	0%	< 20%	< 20%	< 30%
50	< 5%	< 15%	0%	< 30%	< 30%	< 40%
100	< 5%	< 20%	0%	< 30%	< 35%	< 45%

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Standards beyond NFPA 1971

NFPA norms:

- NFPA 1971/2018, FF PPE, turnout gears and fire hood
- NFPA 1977, wildland fire fighter
- NFPA 1851, selection and care

ISO norms:

- ISO 23616 cleaning of firefighter PPE
- ISO 21808 Fire fighter Selection, Use, Care and Maintenance (SUCAM)
- ISO 16073-9 wildland (fire hoods with particulate protection)
- ISO 11999-9 Firehood for turn-out gear – to include particulate protection
- ISO 11999-3 Firefighter turn-out gear garments– to include particulate protection

EN norms:

- EN 469 turn-out gear level 1 & 2 (separated membrane requirement)
- EN 13911 firehood (draft with fire hoods with particulate protection)

Nomex® Nano particle barrier wildland firefighting gear specifications

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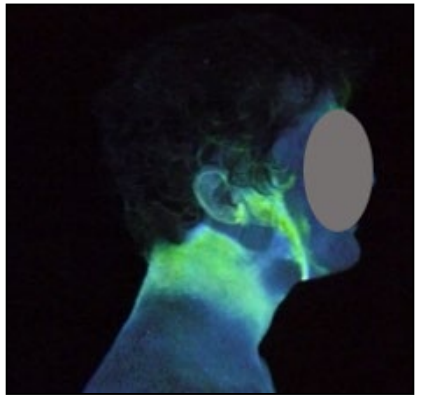
NFPA 1977 – Option for particulate barrier gear for wildland firefighting

Adding particulate blocking option
to stop smoke particles from
penetrating to a firefighter's body

Blocking performance ≥ 90%



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Nomex® Nano particulate blocking wildland firefighter gear - structure

	LAM 215	LAM 270	NFPA 1977-2016
Weight (oz/yd²)	6.5	7.9	N/A
Thickness (mil)	24.8	29.5	N/A
RPP (cal/cm²)	9.7	11.7	≥7
Breaking strength (lbs)	190	256	N/A
Tear strength (lbs)	56.8	51.3	≥5
Filtration efficiency (%)	>99	>99	N/A
THL (W/m²)	609	600	≥450
Thermal shrinkage (%)	<3	<3	≤10
Laundry shrinkage (%)	<5	<5	≤5
Air permeability (cfm)	14.3	13.7	N/A

Outperformed all performance requirements

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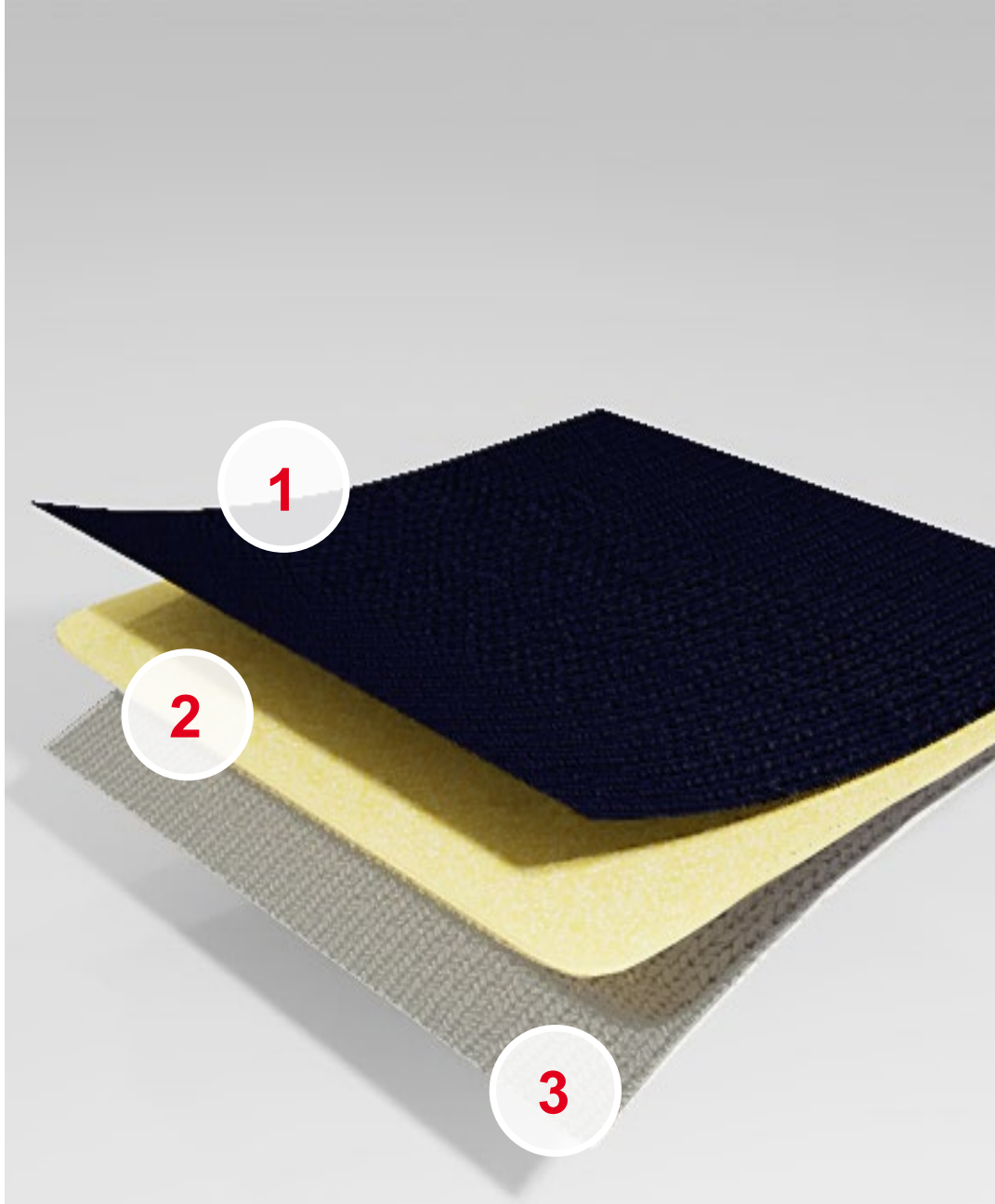
Nomex® Nano particulate blocking wildland firefighter gear - structure

1. **Outer shell** – Nomex® IIIA or Nomex® Comfort woven for strength, durability, thermal protection
2. **Middle layer** – Nomex® Nano for smoke particle protection, breathability
3. **Lining** – Nomex® knit for comfort and moisture management



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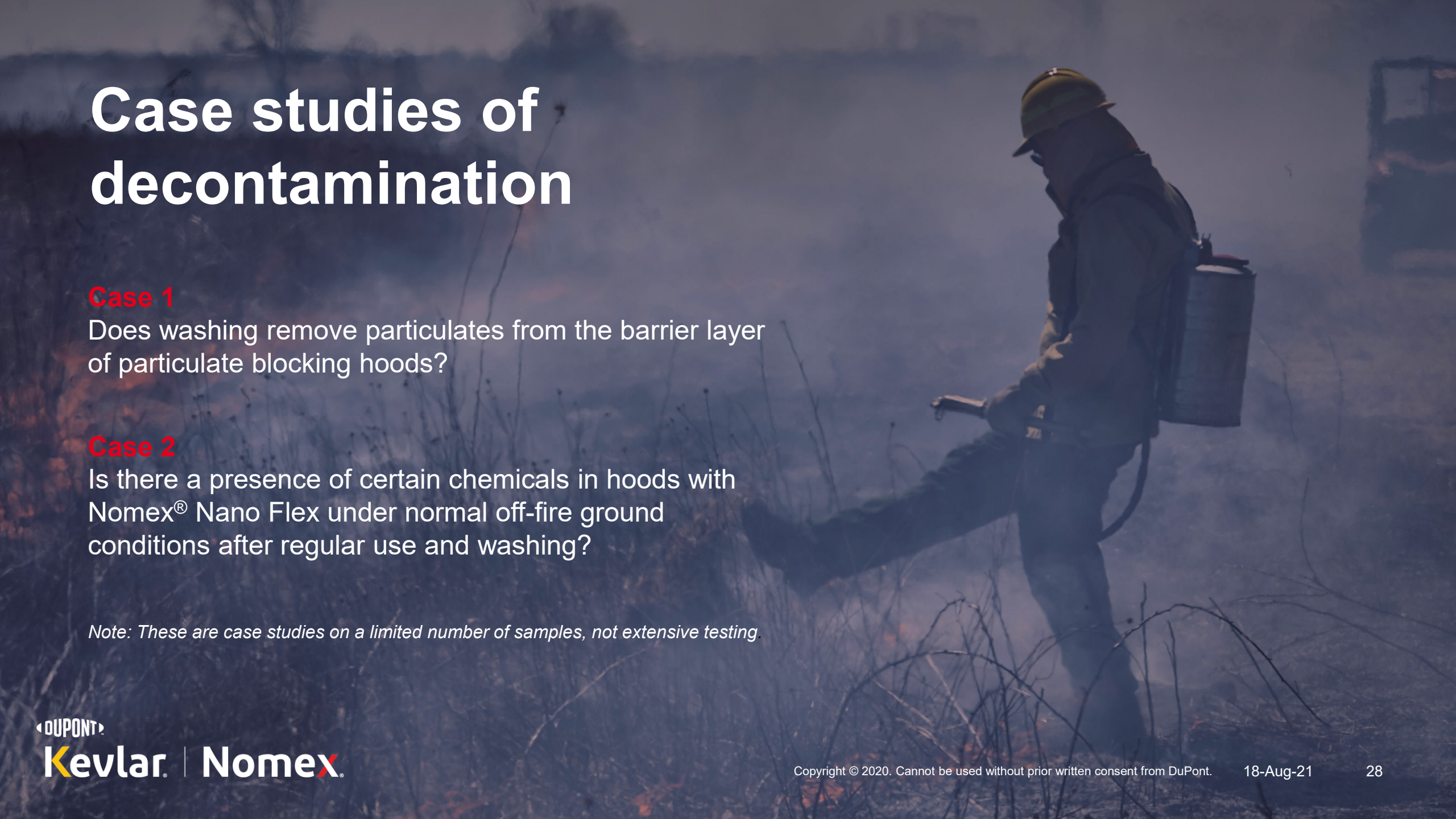
Case studies of decontamination



Case 1

Does washing remove particulates from the barrier layer of particulate blocking hoods?

Case 2

Is there a presence of certain chemicals in hoods with Nomex® Nano Flex under normal off-fire ground conditions after regular use and washing?

Note: These are case studies on a limited number of samples, not extensive testing.

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Case 1 – Visual review before and after washing

A prototype hood with Nomex® Nano Flex was worn at a fire training academy for a 40-minute flashover training exercise, then sent to DuPont for testing.

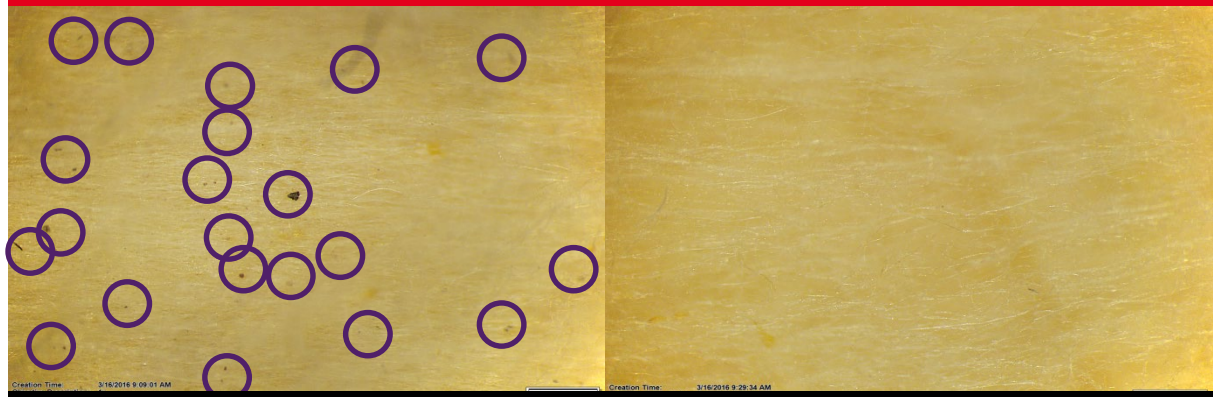
Samples from the hood were viewed under 5x microscopy before and after washing.

Washing method AATCC 135

Outer layer of the hood

As received | After washing

Nomex® Nano Flex barrier layer



As received | After washing

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Case 2 – Analysis of particulate barrier hoods for the presence of 12 chemicals

Three commercially available hoods with Nomex® Nano Flex were used **and laundered** by career firefighters for ~9 months, then sent to DuPont for analysis.

Samples from these hoods were analyzed for chemical agents to which firefighters are often exposed.[1]

[1] As identified in various studies, reports and publications

Chemical agents	Chemical class / type	As received @50C (ppm)	Saline extraction @60C (ppm)	Saline extraction @110C (ppm)	Lower limit of detection (ppm)
Benzo[a]pyrene	PAHs	ND	ND	ND	3.01
Benzo[a]anthracene		ND	ND	ND	0.85
Dibenzo[a,h]anthracene		ND	ND	ND	165.32
Naphthalene		ND	ND	ND	0.03
Anthracene		ND	ND	ND	0.05
di-2-ethylhexyl phthalate (DEHP)	Phthalates	ND	ND	ND	0.04
Benzyl butyl phthalate		ND	ND	ND	0.90
Di-n-octylphthalate		ND	ND	ND	0.04
BDE 47 (2,2,4,4 Tetrabromodiphenyl ether)	PBDEs	ND	ND	ND	0.65
BDE 99 (2,2,4,4,5 Pentabromodiphenyl ether)		ND	ND	ND	1.01
BDE 153 (2,2,4,4,5,5 Hexabromophenyl ether)		ND	ND	ND	1.79
Pentachlorophenol		ND	ND	ND	3.42

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Should respiratory protection match that of the garment?

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Different types of masks for different protection

	Social distancing	Surgical mask	N95 respirator
Intended protection	**Others** Public setting	**Wearer & others** Patients and Caregivers	**Wearer** Health worker, Firefighter
Filtration	**Droplets** > 70% @ 3 µm	**Droplets and Aerosols** Particulate >95% @ 0.3 µm Bacteria & virus >95% @ 3 µm	**Aerosols** ≥95% at 0.3 µm
Face seal fit	Loose-fitting	Loose-fitting	Tight-fitting
Standards	AATCC, WHO, AFNOR	ASTM 2100, EN 14683	USA: NIOSH (42 CFR 84) EN 149:2001 + A1: 2009
Reusable	Yes	No	No
Flammability test	No	Depends : US-yes, EU-no	Yes

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Meeting Guidance While Avoiding Additional Hazards

If you have identified a FR Hazard and your employees are in FR garments, then they should also be in FR face coverings.

Your Mask Should Match Your Garment

MATCH YOUR PROTECTION

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FR face masks

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Guidance and Standards for FR Face Coverings

NFPA 2112 Guidance

- NFPA 2112-2018 amended in June 2020 to include cloth face coverings
- FR cloth face coverings have to be made from NFPA 2112-certified components, so the fabrics have to have been already tested and certified to meet NFPA 2112.
  - The final product (the face mask/covering) does not need to be 3rd party certified itself– self-declaration is specified to enable rapid dissemination of products
- Labeling requirements for FR face coverings are reduced compared to other garments due to their size.

References:
https://www.nfpa.org/codes-and-standards/all-codes-and-standards/list-of-codes-and-standards/detail?code=2112
https://www.astm.org/Standards/F1506.htm

ASTM F1506 Guidance

- New edition of ASTM F1506-20a has been published.
- Adds flame-resistant cloth face coverings (FRCFCs) to the scope, with reduced labeling requirements:
  - The tracking identification code
  - "FRCFC ASTM F1506 – **Not arc flash face protection**".

Why?

The key is to consider physical coverage of the face covering.

FR face masks designed to meet CDC guidance and other standards for barrier face coverings are **NOT** designed, tested, and rated to provide head and face protection from arc flash hazards.

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The importance of matching your FR PPE

Face mask made from Nomex® fabric

Remained on manikin with no melting, dripping or afterflame

100% cotton face mask with carbon filtration

Fell off manikin due to non-FR elastic band and continued to burn

Water-resistant fabric face mask

Fell off manikin due to non-FR elastic band and melted

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Face Covering Options

Nomex® Nano Flex and Nomex® Nano face mask

Nomex® Nano Flex and Nomex® Nano are **highly breathable FR materials** that deliver **superior particle barrier performance** without sacrificing comfort.

PPE REDEFINED

CREWBOSS™

Nomex® Comfort face masks

The unique fabric technology of **Nomex® Comfort** provides extreme performance in a **lightweight, comfortable, highly breathable**, soft-touch fabric with **built-in flame resistance**.

Bulwark PROTECTION

PPE REDEFINED

Face masks made with Nomex®

Nomex® Fabric provides a tested and proven portfolio of FR solutions that meet or exceed global standards for heat, flame and arc flash protection.

BIG BILL®

SAF-TECH® FLAME-RESISTANT WORKWEAR

NATIONAL SAFETY APPAREL

SILVER NEEDLE INC.™ SUPERIOR FABRICS SUPERIOR DESIGN SUPERIOR PERFORMANCE

DUPONT Kevlar® | Nomex®

To learn more: www.dupont.com/personal-protection/fr-face-mask

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