DUPONT™

Heat Stress in the Workplace: Rethinking Comfort as a Measurable Safety Factor

How new data, testing methods, and evolving standards are changing the way PPE is evaluated

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Introduction

“Heat stress is no longer a comfort issue – it is a growing safety risk.”

says Chloé Caux-Wetherell, EMEA Marketing Manager at DuPont Personal Protection.

Heat stress is a growing workplace risk. Rising global temperatures, more frequent heatwaves, and physically demanding environments mean that workers are increasingly exposed to excessive heat during their daily tasks. Across Europe, a substantial proportion of the workforce now reports working in high-temperature conditions, highlighting that this is no longer a niche issue, but a widespread safety concern[1].

Regulatory bodies and health experts are also placing more emphasis on worker well-being. Several countries are implementing decrees, and the substantiation of comfort claims with data is on the rise.

Besides causing discomfort, heat stress has more serious implications. When the body struggles to regulate its temperature, physical strain increases, concentration declines, and decision-making becomes impaired. In safety-critical environments, this can lead to mistakes and non-compliance. Workers may even opt for comfort over protection by engaging in unsafe wearing practices, creating a major safety risk[2].

For health and safety professionals, this presents a complex challenge: how to protect workers from hazardous exposures while also managing the physiological risks associated with heat.

Heat stress management currently focuses on environmental controls and work practices, rather than personal protective equipment (PPE). However, what workers wear can significantly influence how their bodies respond to heat[3].

This e-guide explains how, when comfort is treated scientifically as a measurable factor, it becomes a powerful tool for the evolution and evaluation of protective garments that can improve both safety and performance.

1. European Agency for Safety and Health at Work (EU-OSHA). Heat at work: preventing illness and protecting workers. https://osha.europa.eu/en/highlights/heat-work-preventing-illness-and-protecting-workers
2. Kjellstrom, T. et al. (2016). Impact of heat on labour productivity and occupational health and safety https://pubmed.ncbi.nlm.nih.gov/20007118/
3. National Institute for Occupational Safety and Health (NIOSH). PPE Heat Burden. https://www.cdc.gov/niosh/heat-stress/recommendations/ppe.html

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1. What Is Heat Stress – and Why Does It Affect Safety?

According to Aldjia Begriche, Global Technical Manager at DuPont Personal Protection

“Heat stress doesn’t just make work more uncomfortable – it compromises the ability to work safely.”

Heat stress occurs when the body is unable to maintain a stable internal temperature. Under normal conditions, the body regulates heat through a combination of sweating and evaporation. As sweat evaporates from the skin, it removes heat and helps to keep core body temperature within a safe range.

However, in hot environments – or when wearing protective clothing that limits heat dissipation – this natural cooling process becomes less effective. Heat begins to build up in the body, increasing physiological strain. Core temperature rises, heart rate accelerates, and dehydration can set in[4]. Over time, this can lead to heat exhaustion or more serious heat-related illnesses.

Crucially, the effects are not limited to physical discomfort. Heat stress directly impacts cognitive performance. Studies show that workers exposed to high heat experience reduced concentration, slower reaction times, and impaired decision-making. Heat stress has also been linked to reduced productivity and an increased likelihood of errors and incidents[5].

In high-risk environments, this creates a serious safety concern. Heat stress does not just make work harder – it makes it less safe.

Recognizing Heat Stress – 5 Key Signs

- ✓ Dizziness or confusion
- ✓ Excessive sweating (or lack of sweating)
- ✓ Fatigue or weakness
- ✓ Nausea
- ✓ Elevated heart rate

What to do: Stop work immediately, move to a cooler area, hydrate, and remove PPE safely if required. Seek medical attention if symptoms persist.

4. Health and Safety Executive (HSE). Symptoms of heat stress. https://www.hse.gov.uk/temperature/employer/heat-stress.htm#symptoms
5. Kjellstrom, T. et al. (2016). https://pubmed.ncbi.nlm.nih.gov/20007118/

2. PPE: Part of the Problem – and the Solution

“When PPE is perceived as too hot or restrictive, workers may prioritize comfort over protection – creating a serious safety risk.”

says Aldjia Begriche

In the workplace, heat stress is typically managed through environmental and behavioral controls: adjusting shift patterns, increasing rest breaks, or encouraging hydration. While these measures are important, they largely address the symptoms rather than the underlying cause.

One critical factor is often underestimated: the role of personal protective equipment.

PPE is essential for protecting workers from chemical, biological, and mechanical hazards. However, it can also increase thermal burden. Protective garments may restrict airflow, limit moisture evaporation, and trap heat close to the body[6]. As a result, workers experience greater levels of discomfort and physiological strain.

This can have serious consequences. When PPE is perceived as uncomfortable, workers may shorten wear times, modify or adjust garments incorrectly, or remove layers altogether – compromising protection and increasing risk.

It is time to rethink how protective clothing is designed and assessed, especially regarding breathability and moisture control, so it can support thermoregulation rather than hinder it.

This is where a more scientific, measurable approach to comfort becomes essential.

6. NIOSH. https://www.cdc.gov/niosh/heat-stress/recommendations/ppe.html

3. Measuring Comfort in PPE

“Comfort is no longer a matter of perception. It is a measurable performance parameter.”

Historically, comfort in personal protective equipment has been assessed subjectively, based on wearer feedback such as “too hot” or “uncomfortable.” While this feedback remains valuable, it does not provide a consistent or comparable basis for evaluating PPE performance.

Advances in materials science and testing methodologies offer new opportunities to quantify comfort using objective metrics. In particular, the industry is moving towards evaluating how effectively a material supports heat and moisture transfer – key factors in maintaining thermal balance.

Regulatory organizations are also beginning to focus on controlling and assessing the risk of heat stress. In some regions, including EMEA, comfort claims are increasingly expected to be supported by measurable data and recognized test standards, such as ISO 11092 (Textiles — Physiological effects — Measurement of thermal and water vapour resistance under steady state conditions). This method tests the fabric using a sweating guarded-hotplate. For the analysis of Ret* for an entire garment ensemble, a human-shaped thermal manikin is equipped with sweating systems, temperature sensors and/or heat flux sensors. At present, ASTM F2370 (2016) is the only standard that addresses the measurement of clothing evaporative resistance using a sweating manikin.

This enables health & safety professionals to compare garment breathability on a like-for-like basis and make more informed decisions. In other words, comfort is evolving from a subjective perception into a measurable performance parameter – one that can be specified, tested, and validated.

*Resistance to Evaporative heat Transfer

4. Understanding Breathability in PPE

Breathability is a critical factor in managing heat stress. In the context of protective clothing, it refers to the ability of a material to allow heat and moisture, particularly water vapor from sweat, to escape.

When breathability is low, sweat accumulates on the skin and evaporation is restricted. This limits the body's ability to dissipate heat, increasing thermal strain and discomfort. In contrast, materials with higher breathability support more efficient moisture transfer, helping to regulate body temperature and reduce physiological stress during prolonged wear.

To enable objective comparison, breathability is assessed using standardized laboratory methods. One of the most important metrics is Water Vapour Resistance (Ret), which quantifies how much resistance a material presents to the passage of moisture vapor. Industry frameworks use Ret-based testing to classify or benchmark breathability, including identifying very low-resistance materials as extremely breathable. Such materials provide very low resistance to moisture transfer, actively supporting thermoregulation and helping to reduce heat stress. Ret is fundamentally different from air permeability; a fabric may allow air to pass through while still retaining water vapor under pressure and temperature gradients.[7]

"Breathability determines how effectively the body can regulate heat – making it a critical factor in managing heat stress."

7. Adámek, K.; Havelka, A.; Kůs, Z.; Mazari, A. (2023) The Correlation between Air and Water Vapour Permeability of Textiles.
https://doi.org/10.3390/coatings13010163

Importantly, the Ret classification allows safety professionals to compare material breathability based on measurable performance. However, defining breathability is only part of the challenge. In chemical protective clothing, for example, materials must also deliver reliable barrier performance and durability. Historically, improving breathability has often meant reducing protection; conversely, increasing protection has limited the ability of heat and moisture to escape.

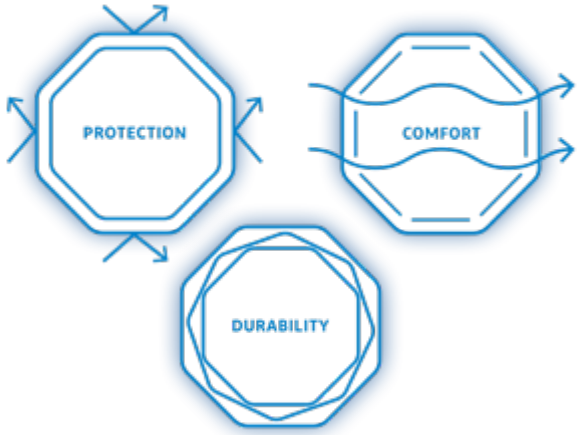
This creates a fundamental question for safety professionals and manufacturers alike: **how can breathability be improved without compromising the protective performance that PPE is designed to deliver?**

The recent development of pioneering, extremely breathable materials that retain their chemical protective properties and durability in demanding use conditions provides an answer.

5. Advancing Comfort as a Science

“The challenge is not measuring breathability – it is achieving it without compromising protection.”

says Chloé Caux-Wetherell



The development of extremely breathable chemical protective materials represents a significant breakthrough. This progress has been enabled by a deeper understanding of heat stress as a physiological process, combined with advances in how comfort and breathability can be measured objectively.

DuPont is at the forefront of this evolution, pioneering a new generation of Tyvek® material that achieves an extremely breathable classification while maintaining the chemical protection and durability required in demanding working environments. Referred to as Tyvek® APX™ fabric, the new material marks a departure from the traditional trade-off between comfort and protection, demonstrating that both can now be provided simultaneously.

A multi-scale methodology was used to evaluate wearer comfort across three interconnected levels: material performance, garment design, and physiological response.

These properties have been scientifically validated by an independent laboratory, Empa*, where a comfort evaluation was conducted as a progressive journey from predictive science to real human response. The goal is to quantify comfort not as subjective claim, but as a physiological outcome that can be predicted, measured, and validated.

*the Swiss Federal Laboratories for Materials Science and Technology

Material performance

Advanced fabric engineering has been used to optimize moisture vapor transmission while maintaining the inherent barrier properties required for protection. The Hohenstein Institute created a classification table that groups fabrics into breathability levels, based on objective laboratory measurements, primarily the water vapour resistance, commonly called Ret.

Ret indicates how much resistance a fabric creates against sweat evaporating from the body. The lower the Ret value, the easier sweat can escape, which results in a more comfortable garment.

The Hohenstein classification has 5 levels from Not or barely breathable for fabrics with a Ret of above 30 to extremely breathable for fabrics of a Ret below 6.

Garment performance

The way a fabric is converted into a finished garment, including fit, seam construction, and pattern design, has a direct impact on thermal performance. To assess this, DuPont used the sweating manikin testing to simulate heat exchange between the human body and the environment. These tests provided detailed data on the prototype garment, enabling optimization of the full system rather than the fabric in isolation.

Physiological response

When it comes to comfort, the final and most meaningful level of validation is the physiological response of the wearer. Physiological data captures the body's response to PPE in dynamic, real-life scenarios and reflects the integrated response of the human body to thermal, tactile, and psychological stimuli. Using predictive thermoregulation models, DuPont simulated how the human body responds to different combinations of clothing, activity levels, and environmental conditions. These simulations were then validated through controlled human wear trials, where parameters such as core body temperature, heart rate, and breathing frequency are measured in real time.

The results of this triple validation approach demonstrate a measurable reduction in physiological burden. Extremely breathable Tyvek® APX™ fabric can help enable a slower rise in core body temperature, reduced cardiovascular strain, and improved recovery during rest periods. In some cases, wearer responses are comparable to those observed in everyday apparel.

Introducing Tyvek® APX™
Empa Laboratory Testing

This progression from advanced material science to full physiological validation demonstrates that comfort is no longer only a subjective attribute. It is a measurable, evidence-based parameter that can be engineered to support both safety and performance, without compromising protection and durability.

Breathability vs protection comparison

Tyvek® APX™ 400 coverall	Denim jacket:	Cotton T-shirt:
⊕ Very low Ret	⊖ Higher Ret	⊖ Lower Ret
⊕ High chemical protection	⊖ Low chemical protection	⊖ Low chemical protection

6. What This Means for Safety Professionals

“Better data leads to better PPE decisions and ultimately safer workplaces.”

For health and safety professionals, the implications of these developments are significant. As heat stress becomes an increasingly recognized workplace risk, selecting PPE can no longer rely on subjective assessments of comfort or a trade-off between essential garment characteristics. Instead, decision-making can be supported by measurable, evidence-based parameters.

Metrics such as Ret and established breathability classifications provide a more objective way to evaluate how chemical protective garments will perform in use. By considering how effectively PPE supports heat and moisture transfer, and how this translates into physiological impact, safety professionals can make more informed choices that directly influence worker safety, performance, and compliance.

This also marks a shift in how comfort is understood. Rather than being viewed as a secondary or optional attribute, it is now recognized as a factor that directly affects the ability of workers to conduct tasks safely over time.

Importantly, it is no longer necessary to compromise when specifying PPE. Advances in material science have demonstrated that extremely breathable protective clothing can deliver both high levels of protection and improved thermal comfort.

Tyvek® APX™ 400 protective coverall is the first of this new generation of chemical protective garments. By achieving an extremely breathable classification while maintaining the necessary durability and protection, it provides evidence that comfort and protection can be engineered together.

As our understanding continues to evolve, the ability to specify PPE based on measurable comfort will play an increasingly important role in reducing heat stress and supporting safer working environments.

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Tyvek® APX™

This information provided herein is subject to revision as additional knowledge and experience become available. It is the user's responsibility to determine the level of toxicity, and the proper protective equipment needed. The information set forth herein reflects laboratory performance of fabrics, not complete garments, under controlled conditions. This information concerning DuPont's PPE is intended for use by persons having the technical expertise to undertake evaluation under their own specific end-use conditions, at their own discretion and risk. Anyone intending to use this information should first check that the garment selected is suitable for the intended use. Since conditions for use are outside the DuPont's control, DUPONT DE NEMOURS, INC. AND ITS AFFILIATES MAKE NO WARRANTIES, EXPRESSED OR IMPLIED, INCLUDING BUT NOT LIMITED TO WARRANTIES OF MERCHANTABILITY OR FITNESS FOR A PARTICULAR PURPOSE AND ASSUMES NO LIABILITY IN CONNECTION WITH ANY USE OF THIS PRODUCT AND INFORMATION. This information is not intended as a license to operate under or a recommendation to infringe any trademark, patent or technical information of DuPont or other persons covering any material or its use.

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