White Paper

Reducing the Impact of Heat Stress within the Fire Service Industry through Comprehensive Analysis

Those involved with the fire service industry have to contend with numerous hazards. From toxic off-gassing and carcinogenic hazards to occupational stresses on mental and physical wellbeing, firefighters and first responders face risks day-in and day-out by the very nature of their strenuous profession. As an occupational hazard, heat stress, also known as heat illness, can present itself in a number of ways — heat stroke, heat exhaustion, heat cramps, or heat rash being most common. It is especially important for firefighters to be aware of this hazard as the risks are ever-present throughout the course of his or her work.

We evaluate key factors contributing to, and exacerbating, the industry's heat stress risks, as well as outline important preventative protocols to help alleviate the hazard. Through comprehensive risk analysis, as well as proper PPE selection for the type of incident call involved, the threat of heat stress can be mitigated within the fire service industry.

With a legacy of providing protective fabrics to the U.S. military since World War II, we are growing our commitment to protect those who protect us by bringing the Milliken ResQ™ brand to the fire service industry.

In its simplest form, heat stress is caused by extreme exposure to heat or hot environments, taxing physical activity, or a combination of both. Especially in the fire service industry, the complexity of heat stress makes the hazard a difficult one to fully address. According to a National Fire Protection Association (NFPA) report, in 2016 alone, there were 2,475 reported thermal stress injuries among firefighters[1]. The human body relies on certain physiological mechanisms to deal with normal heat stresses. As a person's core temperature rises, the body cools itself through blood vessel dilation, which in turn, releases perspiration. Perspiration, or sweat, evaporates on the surface of the skin, lowering core temperature to avoid overheating.

For many who work in physically demanding jobs, perspiration sufficiently protects the body from heat stress, and through a range of controls, such as scheduled breaks and engineered environmental controls, the effects of heat stress can be greatly lessened even in elevated temperature conditions. The fabric properties of apparel can also mitigate heat stress. The heat conductivity, the air permeability, and the moisture transport properties all contribute to the ultimate thermal comfort of a garment. These factors reduce heat stress by transporting heat and moisture to the outside of the fabric where it is dispersed and evaporated.

For first responders, however, most of the preventative controls are competing against the demands of the profession. Evaporative cooling is ineffective when wearing the three-layer personal protective equipment (PPE) system needed when entering a fire. Coupled with the severe heat and strenuous physical demands, a firefighter's risk of heat stress is multiplied.

Understanding Thermal Protection Needs

- The three-layer PPE suit known as turnout gear is an integral part of protecting firefighters, yet the THL and TTP ratings of this garment are often at odds with one another.
- TTP rating is vital to thermal protection, and THL helps to lower the chances of heat stress.

In order to perform their duties as safely as possible, firefighters must be appropriately attired to the situation. NFPA 1971: *Standard on Protective Ensembles for Structural Fire Fighting and Proximity Fire Fighting* governs structural fire PPE. While this gear is mandated for use in structural fire situations, firefighters often wear this type of attire in the course of their daily activities, including first responder calls. The emphasis on proper garment protection is in the best interest of the firefighter; yet, the necessary protection intensifies the risk of heat stress.

NFPA-certified turnout gear includes three distinct layers — an outer shell, moisture barrier and thermal liner — all of which work together to provide rigorously tested protection. These three layers insulate fire service members from thermal, physical, environmental and bloodborne pathogen hazards encountered during structural and proximity firefighting.

Adequate firefighting protection takes into account two key measures: thermal protection performance (TPP), which should achieve at least a 35 rating to meet the NFPA 1971 standard, and total heat loss (THL), which must be 205 w/m^2 (or greater) for structural fire use. TPP is arguably the most recognizable value associated with a garment's thermal performance, as it measures the ability to withstand high thermal exposures. Usually, garments achieve a higher TPP rating due to thicker, heavier fabric material. By contrast, THL measures how much heat a composite loses through evaporated and conductive conditions. A high THL rating signals better overall ability to dissipate heat, which would typically call for thinner and lighter fabric material. Thus, material requirements for high TPP contradict the material requirements for high THL.

Ideally, turnout gear would combine the highest possible TPP and THL ratings, as that would mean the turnout gear is providing high-level thermal protection without compromising the body's ability to self-regulate body temperature. However, the contradictory material requirements for high TPP and high THL have proven to be a daunting challenge. High THL has been difficult to achieve while maintaining a high TPP value required by NFPA 1971. Encouragingly, there are recent advances in PPE design and material innovation that enable significant increase in THL and wearer comfort without compromising TPP. Further advances and breakthrough material innovation are still needed to solve the challenges.

The Impact of Protective Gear

- Turnout gear fosters microclimates between a firefighter's skin and the inner layer of the gear.
- Microclimates, while helpful in keeping core temperature lower when fighting structural fires, may also work against the body's natural cooling capabilities to induce heat stress or cardiac-related illnesses.

The structure of NFPA-certified turnout gear certainly contributes to elevated heat stress risks, but it is also important to note the nature of first responder work also significantly adds to heat stress risks.

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Fighting a fire is likely to raise a person's core temperature to higher than 100.4 degrees F (38°C), which in turn, raises the risk of heat stress[2]. His or her heart rate can also rise, impacting a firefighter's performance and making them more susceptible to medical complications and heart attacks. According to the NFPA, cardiac-related events accounted for 38 percent of the firefighter deaths in 2016, and 42 percent in the past 10 years — making it the leading cause of line of duty deaths (LODD)[3].

The three-layer turnout gear system comes together to protect firefighters from a variety of elements, but it also fosters the perfect condition for a microclimate to form. Microclimates, or the climate between your body and your gear, arise when the temperature along your skin differs from the temperature found outside your turnout gear. In essence, for turnout gear to provide the best possible protection, the turnout gear should create a microclimate to keep your skin cooler when actively fighting fires.

It is important to note that turnout gear can also work against your body's cooling ability. While providing high thermal protection performance, corresponding thermal heat loss is reduced — meaning your body's cooling mechanism, sweat, is trapped inside the turnout gear to varying degrees. The resulting microclimate becomes extremely humid, and while the temperature may be lower than what is outside the turnout gear, the climate could still offer prime conditions for a heat stress episode.

Once a firefighter leaves a fire, microclimates are still at play. The climate within the turnout gear may be much warmer than conditions outside the fire. Turnout gear is very effective at limiting the heat transferred to the firefighter in a fire setting, but the microclimate can be significantly warmer than the environment outside the fire. Elevated microclimates also can arise in general first responder situations. The turnout gear, with its high thermal insultation properties, can create a warmer and more humid climate within the gear than in the environment.

Structural fires, however, account for as little as three percent of first responder incidents. Firefighters are more likely to find themselves answering first responder calls — situations where the risk of high thermal exposure is low but where manual activity is even more prevalent. Over the course of these search and rescue, medical, or accident calls, firefighters often perform their duties in their turnout gear, because burn or explosion risks may still be present or because they do not have alternative PPE at their disposal. Even when the outdoor weather is cool, the turnout gear may trap heat within the suit and diminish the effectiveness of the body's own cooling process.

A Comprehensive Approach to Mitigating Heat Stress

- NFPA 1582 is an important guide in creating and implementing an occupational medical program to protect firefighters.
- A comprehensive heat stress mitigation program looks to address the hazard before, during and after a call.
- Tailoring PPE to the type of call can be an impactful variable in alleviating heat stress.

The way forward requires balancing the need for thermal protection with a comprehensive heat stress protocol to regulate skin temperature and alleviate heat stress factors. Comprehensive risk assessment calls for an understanding of how to best protect yourself before, during and after a response call, and how to best protect yourself in light of the type of call you face.

NFPA 1582: *Standard on Comprehensive Occupational Medical Program for Fire Departments* outlines an occupational medical program to reduce risks and provide for the health, safety and effectiveness of firefighters. One key aspect of this program is receiving a medical evaluation prior to joining the service and participating in routine checkups throughout a firefighter's career. These evaluations help establish a baseline for on-site monitoring and deliver insight into overall health and wellness, which can impact your susceptibility to heat stress risk factors.

Using these medical screenings, targeted training and wellness regimens can then be implemented to help prepare a firefighter mentally, physically and psychologically for the strenuous aspects of the fire service profession. The goal is to help enhance cardiovascular functions, so the body is better conditioned to handle the strain of incidents. It also encourages firefighters to be mindful of their overall health, as health indicators like body mass index (BMI) directly impacts cardiovascular performance.

While on the job, it is important to be keyed into your instincts — both in regard to your own health indicators, as well as your colleagues'. It is largely up to fire service men and women to engage in their work while being mindful of their personal abilities and limitations, and potential hazards. Leading up to a call, as well as when responding, staying hydrated is key for one's body to properly function under increased activity in extreme environments. It is also important to understand the impact of properly sourced station wear and how it can help with moisture management when worn underneath full turnout gear. Anything worn under turnout gear can play a role in the microclimate mentioned above and how the body performs on-call and recovers post-call. Station

wear provides an often-untapped resource in controlling moisture under somewhat impermeable PPE.

While post-incident recovery plans will differ greatly between fire departments, NFPA 1584: *Standard on the Rehabilitation Process for Members During Emergency Operations and Training Exercises* strongly recommends a recovery program. In order for the body's core temperature to properly recuperate, and alleviate call-induced cardiovascular strain, a standardized protocol should include rest, rehydration and cool down practices. The protocol may depend upon the type of incident a firefighter faced. For example, recovering from active firefighting and building overhaul will differ from less strenuous, but prolonged, activity of a first responder call. This recovery process works in tandem with pre-incident conditioning to help ensure your cardiovascular system is able to withstand these rigors.

The role of PPE is vital in protecting firefighters from structural and proximity firefighting hazards. Many times, turnout gear is worn to first responder calls, when in reality, different PPE would be better suited for these calls. Turnout gear is a must for large thermal exposure situations, but for general EMS or technical rescue calls, there is far more appropriate PPE that provides burn mitigation protection while also increasing garment breathability. Lighter and more flexible protective fabrics help reduce the amount of work the body has to do in performing tasks, and in turn, help decrease fatigue and lower the risk of heat stress and heat exhaustion. By tailoring PPE to the specific call at hand, the stressors of impermeable turnout gear no longer impact firefighters outside structural fire incidents, which in turn lowers the resulting risk of higher core temperature and cardiac stresses.

In analyzing heat stress, it is important to acknowledge the parameters discussed above, as well as limitations and unknowns of the hazard. It is through dialogue and intentional feedback that firefighters, decision makers, suppliers and manufacturers can work together to shape the future of mitigating heat stress on the job. While there is no one-size-fits-all approach to prevent heat stress in the fire service, the ultimate goal is to provide meaningful education to help develop a set of best practices for your firehouse or department.

References

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Milliken AR/FR fabrics are made in the USA by experts in moisture management and fire-resistant textiles to mitigate thermal exposure hazard risks.

To learn more about what Milliken is doing to help mitigate the stress risks facing firefighters, visit textiles.milliken.com

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