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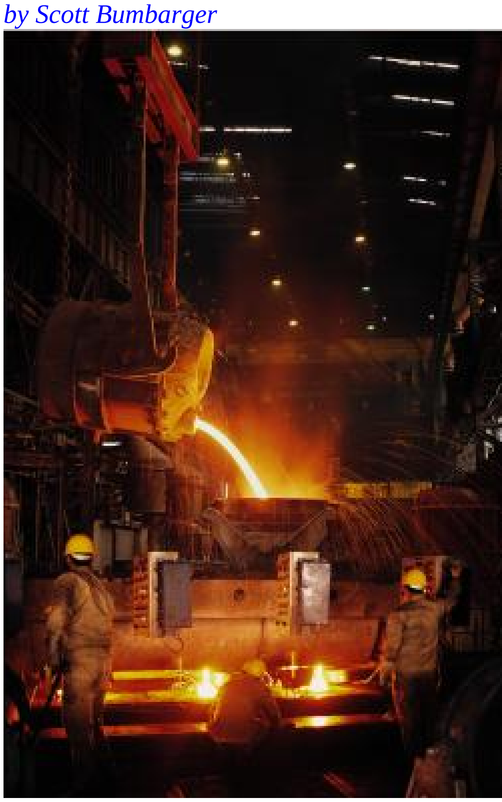
Feature Article

Reducing the Hazards of High Heat

A new fabric technology is put to the test and comes up a winner.

by Scott Bumbarger



How do you stay cool when temperatures on the job soar? This is one of the most critical workplace safety and health issues affecting managers and employees today. Whether it's the airport personnel working on hot tarmac in the blazing summer sun or the foundry worker who battles scalding waves of heat year-round, the question is vital to hundreds of thousands of American workers.

A study released recently by David Pascoe, Ph.D., Doctor of Human Bioenergetics in the Department of Health and Human Performance at Auburn University, was presented at the Southeast Regional meeting of the American College of Sports Medicine. This study concludes a revolutionary new fabric technology may provide the wearer the ability to respond physiologically to the environmental stress in a more favorable manner, thereby reducing the hazards of high-heat environments, extending work time, and increasing worker comfort

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What are the hazards of high-heat work environments? Why should employers and employees alike pay attention to the results of Pascoe's study? And what enhanced performance benefits do new cooling technologies offer? The answers may surprise you.

environments.

The Hazards of Heat

The Occupational Safety and Health Administration informs employers that a wide variety of jobs pose the potential for heat-related hazards. The OSHA Technical Manual states:

"Operations involving high air temperatures, radiant heat sources, high humidity, direct physical contact with hot objects or strenuous physical activities have a high potential for inducing heat stress in employees engaged in such operations. Such places include: iron and steel foundries, nonferrous foundries, brick-firing and ceramic plants, glass products facilities, rubber products factories, electrical utilities (particularly boiler rooms), bakeries, confectioneries, commercial kitchens, laundries, food canneries, chemical plants, mining sites, smelters and steam tunnels. Outdoor operations conducted in hot weather, such as construction, refining, asbestos removal, and hazardous waste site activities, especially those that require workers to wear semi-permeable or impermeable protective clothing, are also likely to cause heat stress among workers." (OSHA Technical Manual, Section III, Chapter 4.)

The National Institute for Occupational Safety and Health sums up the potential danger from working in hot environments this way:

"The frequency of accidents, in general, appears to be higher in hot environments than in more moderate environmental conditions. One reason is that working in a hot environment lowers the mental alertness and physical performance of an individual. Increased body temperature and physical discomfort promote irritability, anger and other emotional states which sometimes cause workers to overlook safety procedures or to divert attention from hazardous tasks." (Working in Hot Environments, NIOSH, 1992.)

Increased core body temperature and serious levels of dehydration are the primary concerns when working in high-heat environments. As core temperature rises, our bodies react by circulating blood to the skin. This increases skin temperature, allows the body to release its excess heat through the skin. If the muscles are being used for physical labor, however, less blood is available to flow to the skin and release the heat. As our skin gets hotter and approaches the temperature of the environment, the gradient between these two heat sources reduces the transfer of heat between the two.

The body also releases heat through sweating. Increased blood flow to the skin, combined with the benefits associated with heat release by the evaporative process, will allow the body to release heat to the environment. During evaporative cooling, sweat evaporates from the skin and lowers the body's temperature. However, if the body becomes dehydrated, sweating is diminished. High humidity and protective clothing also can form a dangerous barrier to evaporation.

OSHA notes that if these cooling mechanisms fail, the body stores heat instead of releasing it. This causes the body's core temperature to rise and the heart rate to increase. "As the body continues to store heat, the individual begins to lose concentration and has difficulty focusing on a task, may become irritable or sick and often loses the desire to drink," according to OSHA. "The next stage is most often fainting, and death is possible if the person is not removed from the heat stress." (OSHA Fact Sheet, "Protecting Workers in Hot Environments," 1995.)

Suit permeability, weather conditions, work rate, dehydration, environmental temperature and humidity, and radiant heat are factors that limit performance within a protective barrier suit.

Other problems may occur when the body's core temperature rises, NIOSH says: "Strength declines and fatigue occurs sooner than it would otherwise. Alertness and mental capacity also may be affected. Workers who must perform delicate or detailed work may find their accuracy suffering and others may find their comprehension and retention of information lowered."

With these hazards in mind, the American Conference of Governmental Industrial Hygienists states that "workers should not be permitted to work when their core temperature exceeds 39.5 degrees C or 103.1 degrees F." Auburn's Pascoe agrees.

"Since core temperature measures what happens to the muscles, lungs, brain and other organs, small changes become very important and very difficult for the body to handle," he said. The core temperature reflects the balance between heat that is dissipated (through conduction, convection, radiation, and evaporation) and heat storage, as a result of that produced during periods of work. Our bodies are approximately 25 percent efficient; the remainder of the energy utilization is realized as heat.

Heat Hazard Reduction

Regulating the body's core temperature in high-heat environments is clearly the main goal of heat-related safety procedures. Most commercially available ice vests or gel-pack vests reduce only skin temperatures. They are also unable to offer the heat absorption necessary to maintain core body temperatures for any sustained period.

Recently, a fabric technology has been developed that changes the way workers stay cool. This fabric consists of a lightweight, flexible, water-absorbing fiber batting sandwiched between a thermal conductive layer and a breathable exterior fabric that enhances the process of evaporative cooling. When soaked in water for just five minutes, the fiber batting absorbs and locks in water, enabling it to contain and dissipate large amounts of radiant heat energy. A thermal conducting layer conducts cooling to the body while keeping the wearer dry.

"Conventional fabrics dry out within two hours because they aren't designed to hold moisture," explained Dr. Lewis Slaten, a textile scientist and Associate Professor of Consumer Affairs at Auburn. "Contrast that with the three-layer composite fabric, which absorbs and holds moisture to provide a lasting cool for eight to twelve hours."

This dramatic performance is the result of special fibers that absorb more water than conventional fabric and suspend it in a hydrophobic fill. This creates an ideal environment for controlled, efficient evaporation. A gradual moisture release extends evaporation time, producing a long-lasting cooling effect.

Core Temperatures and Perceptions

But what happens when the evaporative qualities of the new fabric technology cannot be fully exploited? Can it help maintain low core temperatures in enclosed environments? This is especially important to workers who wear semi-permeable or impermeable protective (barrier) clothing.

In September 1999, Pascoe put the new fabric technology to the test. His research project was designed to determine the work time for a person to reach a 2 degrees C rise in core temperature while wearing a protective barrier suit (PBS) and a tap-water-activated vest made of the evaporative cooling fabric beneath a PBS. "The length of time that a person can work in a barrier suit is dependent upon several factors, such as the permeability of the suit and weather conditions. These factored together determine the length of time a person would normally be able to work in a barrier suit before experiencing the effects of heat stress," he said. "The ability to increase this time would increase the performance of the worker."

Other factors that limit performance within a protective barrier suit are work rate, dehydration, environmental temperature and humidity, and radiant heat.

This new fabric technology could eliminate the longstanding trade-offs between protection and wearers' comfort and productivity.

Pascoe found refrigerated vests reduced skin temperatures for a short length of time but caused vasoconstriction of the skin. "This retained the warmer core blood flow in the center of the body and reduced the body's ability to release heat," he explained. "So while the skin temperature was cooler, the core temperature actually rose."

By contrast, his research confirmed vests made of the three-layer evaporative cooling fabric did indeed aid the regulation of the body's core temperature, which increased work time by 16.4 percent. "This test required our subjects to increase their core temperature by two degrees," he explained. "On average, the vest made of the evaporative cooling fabric prolonged the trial by an average of 11.25 minutes. Importantly, workers in vests made of this type of fabric not only worked longer, but, after 30 minutes, perceived their work as more comfortable and less stressful than those not wearing a vest. This difference in perception of physical exertion was significantly greater at 30 minutes. They also perceived less discomfort and significantly less moisture and wetness during the trial."

Pascoe's report attributes this to either a wicking effect of the fabric's microporous lining or the vest separating and keeping the barrier suit from sticking to the skin.

"We all know that perception influences actual performance," Pascoe noted. "So the fact that our subjects thought of themselves as cooler and more comfortable, while also being able to work longer, is noteworthy."

Based on his research, he concluded a vest made of the evaporative cooling fabric not only performs better than a refrigerated vest, but also is perceived as performing better by those who used both.

"Garments made of this new fabric act as a heat sink," he said. "It actually helped to maintain the body's core temperature, enabling the subject to work comfortably."

Pascoe noted the benefits of this new fabric technology are especially important when a barrier suit or other protective clothing is worn. "Humans give off 75 percent of their energy in heat. If we can't dissipate the heat into the environment because of a barrier suit, then it can be absorbed into the vest," he explains. "Evaporative cooling is a good way of managing the heat that our bodies must release, as well as protecting us from the heat that our bodies absorb in hot environments."

Protection from Fire and High-Heat Operations

High-heat operations are those that typically involve continuous exposure to temperatures above 200 degrees F produced from radiant and conductive heat. Radiant heat exposure occurs when workers are engaged in activity near heat sources such as fire, boilers, or flames, while conductive heat exposure occurs most often from handling hot objects.

Until now, no fabric could offer the wearer both fire protection and cooling. In its flame-retardant composite configuration, the new three-layer fabric is constructed entirely of flame-resistant fibers to provide relief from heat stress while enabling the worker to comfortably wear garments with higher Thermal Protective Performance (TPP) ratings.

When subjected to insulative tests such as thermal protective performance or radiant heat tests, the "wet-activated" fabric dissipates large amounts of heat extending protection up to three times over dry garment numbers. In full-manikin testing, a coverall constructed of the flame-retardant version of the fabric was exposed to 1,800 degrees F (the equivalent exposure experienced during a severe flash fire for firefighters) for 10 seconds with no injuries indicated.

Testing performed by Intertek Testing Services on dry samples of the fire-retardant evaporative cooling fabric indicated a TPP greater than 27 on a 3/16-inch-thick composition. Additional findings during analogous Radiant Protective Performance (RPP) testing indicate that when wet activated performance soared, delivering TPP equivalent scores better than 150, with an average time-to-pain of 152.3 seconds and time-to-burn of 256.3 seconds, this represented almost 70 percent better protection time over conventional fire protection fabrics.

Solving the Hazards of High-Heat Environments

Although protection and maximizing safety are the primary concerns, comfort, weight, and functionality must also be key considerations for any type of protective apparel. By eliminating the longstanding trade-offs between protection and wearer comfort and productivity, this new fabric technology can be used as an integrated part of a protective garment or as a component of a protective outfit.

Garments such as vests, shirts, coveralls, jackets, hats, and hard hat liners are just a few of the products being manufactured to protect workers in any high-heat environment from the effects of heat stress.

Scott Bumbarger is co-founder and president of AquaTex Industries, Inc. of Huntsville, Ala., and is one of two primary inventors of the Hydroweave™ cooling fabric. He has more than 24 years of process manufacturing management experience in the textile and apparel trade.

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