PHASECORE – SYSTEMATICKÝ PŘÍSTUP K CHLAZENÍ OSOB S VYUŽITÍM KOMBINACE MODERNÍCH LÁTEK A MATERIÁLŮ ZALOŽENÝCH NA PRINCIPU FÁZOVÉ ZMĚNY

PHASECORE – A SYSTEMATIC APPROACH TO PERSONAL COOLING UTILIZING A COMBINATION OF NEW AGE FABRICS AND PHASE CHANGE MATERIAL

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Abstract

Hazmat and CBRN suits are known as a form of Personal Protective Equipment (PPE). Most suits are designed to be impermeable barriers to keep the operator safe from becoming exposed or contaminated. These PPE suits prevent hot air generated by a users body to escape or evapoate and cool the user. Evaporative cooling is known to be the most optimal form of personal cooling, but when using PPE, this cooling method is greatly diminished and the risk for heat stress is drastically increased.

First Line Technology identified and studied a variety of Phase Change Materials (PCMs) called PhaseCore. PhaseCore is a salt based PCM designed to activate at 28°C (82°F) change from solid to liquid via heat absorption and melting. This chemical reaction provides a cooling effect of 22°C (72°F). The goal is to prevent heat stress, achieve heat equilibrium, and maintain the body core temperature within a safe range for operators working in PPE and high heat environments. The solution was PhaseCore Cooling Vests - a thermal-regulated clothing accessory that would be comfortable and cost efficient to wear under impermeable suits and PPE ensembles, thus improving the safety and effectiveness for all operators and response teams.

Key words: *personal protective equipment, cooling systems, phase-change materials*

1 INTRODUCTION

The Direct and Indirect causes of heat stress on an operator can have a lasting impact on the quality of life during their mission to make sure they safely return to their families and back to their job for the next mission. Heat Stress causes fatigue that can lead to mental mistakes which can physical injury that can compromise the mission. Fatigue also directly effects an operator's ability to stay mentally calm and work as a team.

In most cases, the hazmat and CBRN suits comprise impermeable barriers that keep the operator safe, but also does not allow hot air generated by your body to escape. There are a lot of variables that play an important role when determining heat stress impact on the operator while using Personal Protective Equipment (PPE).

Evaporative cooling is known to be the most optimal form of personal cooling, but when using PPE itis greatly diminished and the risk for heat stress is increased. Tethered water circulating systems have also proven highly effective in controlling body temperature while operating aircraft and ground vehicles. However, these types of cooling systems have logistical restrictions that prevent them from working on a dismounted solider wearing body armor, CBRN PPE, or firefighter turn out gear. Other cooling systems like Ice-Vests provide acute relief but can be considered disadvantageous in long-term applications.

2 PHASE-CHANGE MATERIALS

In 2004, First Line Technology launched the first generation of the PhaseCore brand of salt based PCMs designed to activate at 28°C (82°F). We identified and studied a variety of PCMs that absorbed or released latent heat when it changes phases. The goal is to achieve heat equilibrium and maintain the body core temperature within a safe range. The solution was to create a thermal-regulated clothing accessory that would be comfortable to wear under impermeable suits and PPE, thus improving the quality of life and thermoregulation capabilities of the operators in PPE ensembles.

PhaseCore 28 provides a gradual cooling effect that cools without overcooling so the operator never enters the heat or cold hazards. PhaseCore 28 significantly reduces the subjects' heart rates, oxygen consumption, sweat rates, and skin temperatures under the body armor as demonstrated in testing performed by the US DoD, Lund University, NIOSH, SUJCHBO and others.

PhaseCore is an endothermic (absorbing) reaction changing phases as the material melts as it is introduced to human surface temperatures and ambient heat above 28°C (82°F). As the element absorbs heat and beings to melt, it provides a gentle cooling effect of 22°C (72°F). PhaseCore Cooling Vests are a complete system and designed to be PPE agnostic. The vest materials and the element layout are strategically selected to enable evaporative cooling generated by the air flow in the fabric through your body's movement. Over time, First Line has optimized the PhaseCore elements and cooling vest design to maximize cooling and minimize weight with a single vest design that fits most male and female body types.

3 PHASECORE TESTING

In laboratory and field trials, PhaseCore 28 has been proven effective in the absence of evaporation to be an ideal solution. PhaseCore was extensively tested and evaluated by Lund University in Sweden from 2007-2011 under various environmental condition and different levels and types of PPE and has continually shown that cooling vests with PhaseCore 28 have effects both on manikins and on human subjects.

In 2008, Lund University studied the physiological and subjective responses of PhaseCore 24 and 28 vs. ice under firefighting protective clothing. This study concluded PhaseCore 28 is more effective than other cooling devices in reducing the physiological load while wearing firefighting protective clothing [1].

In 2009 Gao et.al conducted sweating manikin trials on PhaseCore 24 and 32 and determined that in order to achieve a more effective cooling effect, temperature gradient is more critical than mass and total latent heat when choosing a personal PCM cooling product. In 2010 the research team studied PhaseCore 24, 28, and 32 on a sweating manikin at 34°C and 38°C and determined that a minimum 6°C differential between body and environmental [2].

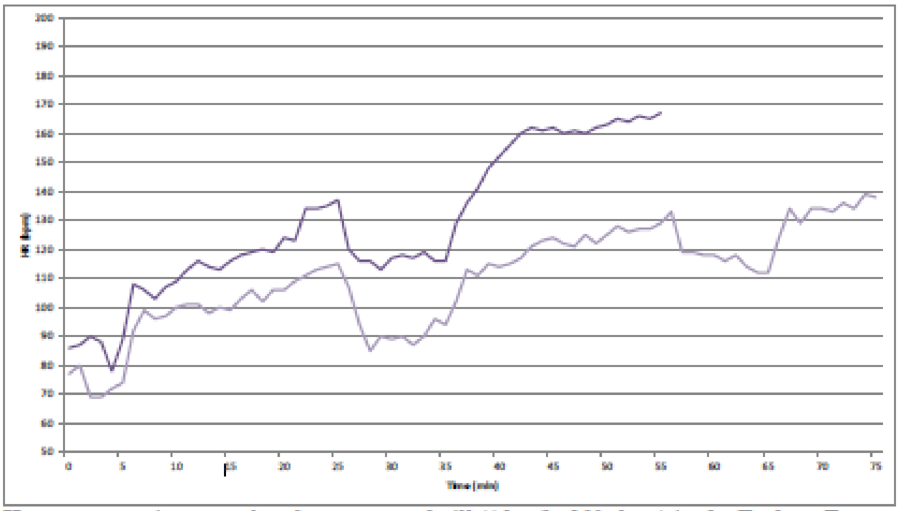
In 2011 Gao et. al. investigated if personal cooling with PhaseCore could mitigate heat strain of subjects with military clothing in very hot environment at 40°C and 45% relative humidity. Results showed that the increase of the chest skin temperature with the PCM cooling vest was alleviated about 1-3°C during the heat exposure and stayed at 35°C at the end of the 70 minutes exercise in the heat. The increase in rectal temperature was alleviated 0.2°C. Although the alleviation of the rectal temperature increase was not as effective as for the chest skin temperature, a lower chest skin temperature facilitates heat transfer form the core to peripheral areas of the body. Upper arm, thigh and calf skin temperatures with and without the cooling vest reached about 37°C at the end, which were not much affected by the PCM cooling [3].

This confirms observations from a 2009 Gao et. al. study on the effects of temperature gradients on cooling effectiveness of PCM vests in an extremely hot climate. They recorded the torso temperature was about 3°C lower at the termination of the tests with PhaseCore 28 than that without vest and determined it was statistically significant ($F=16.6$, p 0.01) [4].

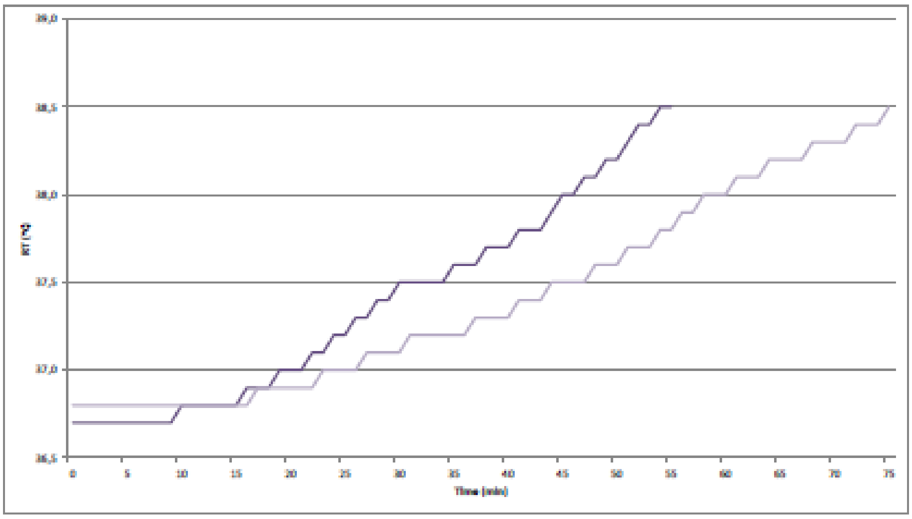
Gao et. al. demonstrated that when a military ensemble was worn over the fabric skin in both hot and dry humidity conditions, the cooling power was greatly reduced. When the protective clothing was worn, the powerful cooling mechanism of evaporation could not fully function and thus the heat loss was small. The reductions were 64% and 58% in HH and in HD, respectively. When PhaseCore 24 and 28 were introduced under the military ensemble, the torso heat loss in HH increased by 100% for PhaseCore 21, 77% for PhaseCore 24 and 58% for PhaseCore 28, respectively. However, no significant cooling effect was observed in the HD condition. The three cooling vests brought negative effect. In both humidity conditions, the sweat evaporation was greatly restricted after the cooling vests were added [5].

In 2015, The Central Laboratory at the National Institute for NBC Protection in Czech Republic began studying PhaseCore 28 and 32 on manikins and in human trials. The subject-matter of the test was the expe-rimental determination of the „cooling effect“ and its duration; and the quantity of heat that can be „removed /accumulated“ into the tested vests without any negative impact on the body regions that are in contact with the vest from the respect of their heat balance and heat exchange with the environment.

The testing demonstrated in human trials that cooling vests equipped with PhaseCore 28 elements can reduce core body temperature and heart rate levels by operators wearing PPE in all environments including hot and humid [6].



Heart rate vs. time a proband test on treadmill (4 km/h; 10° slope) in the Tychem F clothing and the undergarment at 40 ° C
The darker color curves - without vests, lighter color curves - with vest



The same as at HR for the rectal temperature.

It also found that the general problem of these materials is a slow rate of their transformation and small inner heat conductivity. In the clothing applications, the main problems are very bed conditions for heat transition from the body to the proper PCM material and a very high transition delay relating thereto. Subsequent testing in 2016 demonstrated that the addition of air flow can increase the cooling effect of PhaseCore 32 [7].

4 NEXT GENERATION PHASECORE COOLING VESTS

The XPC Vest with PhaseCore 28 was designed in response to the USAid Grand Ebola Challenge for operations in hot and humid environments. The vest incorporates all the findsings from previous PhaseCore tests. Its designed to maximize the heat transfer from body to PhaseCore element through increased surface area contact and also enable more evaporative cooling. This is possible because the XPC Vest features a proprietary 3D air mesh with antimicrobial coating that is a breathable material to optimize air circulation and facilitate evaporative cooling where possible. The vest is expandable vest with zipper side panels to ensure maximum comfort while keeping the elements close to the body. This results in a vest with great mobility and comfort that maximizes surface area coverage to optimally facilitate the heat transfer from body through fabric into element.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