Journal of Fiber Bioengineering and Informatics 9:4 (2016) 237–245
doi:10.3993/jfbim00251

Fabric Cooling by Water Evaporation

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Abstract

Clothing can provide safety and comfort for persons exposed to both cold and hot thermal environments. To assess the potential impact of clothing moisture and wetness on fabric cooling, a series of wind-tunnel tests was conducted to quantify the evaporative cooling capacity of selected fabric samples. Single-layer cotton, polyester, nylon and silk were evaluated. The results showed that onset and magnitude of evaporative cooling was determined by the amount of water contained in a fabric sample. The results also showed that an exposed "skin" exhibited more cooling when covered with a fabric than when it was not. The information obtained helps better understand the evaporative cooling process for fabrics and assist in the selection of garment materials that optimize worker comfort and safety.

Keywords: Evaporative Cooling; Fabrics Moisture; Protective Clothing

1 Background

Evaporation of water from the skin can provide significant cooling benefits for individuals exposed to hot and / or dry environments. However, clothing can complicate the evaporation process by creating a barrier to metabolic heat loss through the insulation created by the clothing itself. This, in turn, can create a humid microclimate that reduces the evaporative cooling efficiency of sweat from the skin [1]. Assessing the cooling effect of evaporation in clothing systems is very complex. Sweat may evaporate directly from the skin surface or wick into the fabric where evaporation takes place on the surface of the garment rather than on the skin surface. Both of these processes can occur simultaneously. Furthermore, excessive sweat may roll off the skin or remain trapped in the clothing system. It is assumed that sweat evaporated from the skin surface can deliver more cooling than when sweat evaporates from a garment [2]. When sweat evaporates from a garment, the location of the evaporative phase change is moved from the skin to the outer surface of the garment where heat is extracted from the external environment rather than from the surface of the skin. The overall cooling effects of sweat evaporation for clothed persons has been carried out on human subjects as well as using thermal manikins [3-6]. However, the outcomes have been difficult to related to clothing design and fabric selection because the

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data are confounded by heat loss due to the latent heat of vaporization which cannot be assessed separately [7]. The cooling generated by wet clothing, independent of body metabolic heat loss, and the associated latent heat of vaporization, have not been separated. To address this issue, a series of tests was carried out to measure the cooling created by evaporation not impacted by metabolic heat production or subsequent sweating.

2 Methods and Procedures

Wind-tunnel tests were conducted on cotton, polyester, nylon and silk fabric samples to determine the cooling generated by water evaporation from the fabric samples under controlled temperature, humidity, and air velocity conditions. The temperature drop due to water evaporation was measured using a thermocouple temperature probe imbedded into the surface of a mounting platform. A "control" configuration which did not include a fabric sample placed on the temperature sensor was used as a reference. All tests were performed three times and the data averaged.

2.1 Wind Tunnel

A negative pressure laminar air flow wind-tunnel was used for this study. The wind-tunnel measured 2.3 meters in length, 40.5 cm in height and 30.5 cm in width. Fabric samples were placed onto a mounting platform which was positioned in the center of the wind-tunnel 1.2 meters from the inlet. The air velocity was maintained at 1.5 m/sec. Air temperature was maintained at 22 °C (±2 °C) and relative humidity maintained at 15% (±5%).

2.2 Fabric Samples

Four types of fabric materials were tested. These included 100% cotton, 100% polyester, 100% nylon, and 100% silk. Each sample was 5.0 cm×6.0 cm in size.

2.3 Mounting Platform

Fabric samples were placed onto a convex shaped mounting platform made of water impermeable Styrofoam. Samples were placed onto the platform surface at a 45° angle relative to the horizontal and oriented into the wind-tunnel airflow. The platform allowed a fabric sample to lay smoothly on the surface. To prevent potential displacement of the fabric sample by the air flow, each sample was secured to the platform by four corner pins. The platform provided gravity run-off for all excess water. A precision type K fine-wire glass insulated thermocouple was embedded into the surface of the mounting platform which provided a temperature measurement of the underside of the fabric sample. The digital thermometer provided an accuracy of ±0.1 °C

2.4 Test Protocol

Fabric samples were spray irrigated with water 10 seconds prior to the start of each test run. The irrigation water was maintained at room-temperature prior to application and was applied until