

## Wash Life Analysis of Printed Cooling Technology for Agricultural Work Applications

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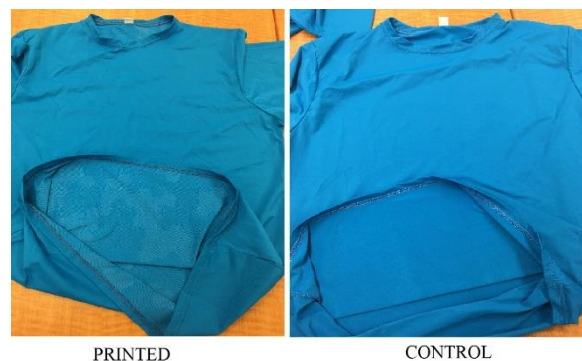
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Active cooling technology and phase change materials (PCM) have been implemented in specialized protective clothing since their development for space suits and military applications in the late 1980s (NASA, 2009). Today, PCM cooling technology can be found in consumer apparel from sports uniforms to running t-shirts (McFarlin, Henning, Venable, Williams, & Best Sampson, 2016). One such application which has not been previously explored in the literature is the implementation of PCM cooling technology in agricultural worker personal protective clothing (PPC). Migrant agricultural workers brought into the United States through the H2A program must be provided fair wages, livable housing, and daily transportation by their host employer (U.S. Citizenship and Immigration Services, 2018; U.S. Department of Labor, 2010). While daily essentials of food, water, and shelter are provided, there are no considerations given regarding clothing needs. Migrant agricultural workers endure harsh environmental conditions for extended periods of time while working in crop and livestock production. Therefore, clothing which will enhance cooling and thermal comfort while potentially reduce the onset of fatigue and heat stress should be considered for migrant workers.

In order to improve the comfort of agricultural workers, a t-shirt with a printed active cooling finish was evaluated to determine if it would meet the wash life durability and performance expectations of such an arduous application. The active cooling finish on the proprietary t-shirt assessed in this study is comprised of an encapsulated printed phase change material (PCM) applied to the back side of the fabric (Figure 1). Phase change material has a unique chemical composition that allows it to change phase when a specific temperature is reached, providing a cooling sensation to the wearer.

The purpose of this study was to determine if a printed cooling finish t-shirt could withstand a typical wash life for agricultural work applications. The following research objectives were established to accomplish the purpose of this research:

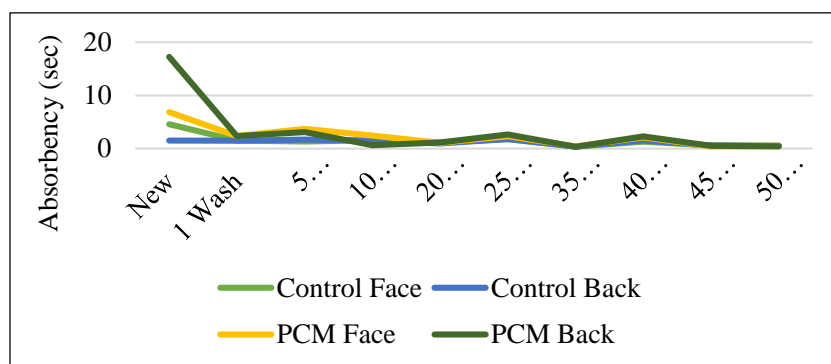
1. To determine if a 100% polyester printed PCM t-shirt can maintain its colorfastness, absorbency, dimensional stability, abrasion resistance, smoothness retention, and soil release properties over a 50 wash life cycle compared to a non-printed control t-shirt.
2. To investigate the visual change in PCM properties over the wash life of the printed t-shirt utilizing inspection microscope technology.



**Figure 1.** Printed vs. Control T-Shirts

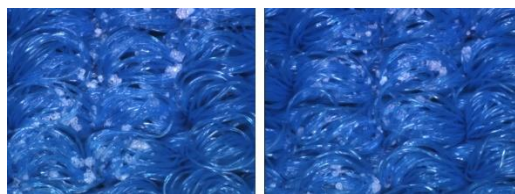
Six shirts with a printed PCM finish (printed) and six shirts without (control) (Figure 1) formed a standard four-pound laundry load and were washed 50 times to replicate a typical consumer wash life (35-50 washes). Each consumer laundering wash cycle was set on “Normal” and filled with 38g of liquid detergent and cold water. Each load dried for 40 minutes on low heat, according to consumer care label instructions. The shirts were evaluated for dimensional stability, colorfastness, crocking, abrasion resistance, soil release, smoothness retention, and moisture regain according to AATCC and ASTM standard test methods. Testing was conducted new and after 1, 5, 10, 20, 30, 35, 40, and 50 consumer laundry (CL) cycles. One printed and one control shirt were turned inside out and evaluated for the presence of PCM capsules under an inspection microscope in the same three coordinates at each test interval.

There were little to no statistically significant differences when assessing the change in abrasion, visual color differences, remaining and residual moisture, smoothness retention, or soil release over the 50 launderings. Significant differences were found for absorbency, dimensional stability, and instrumental color measurement between the printed and control t-shirts. Figure 2 illustrates the absorbency of both shirts increasing as the time to absorb water decreased. Although the printed PCM shirts began with a significantly lower absorbency on the back side of the fabric at new, compared to the control without the printed finish. Differences in shrinkage were also present. After 50 washes, the control garment shrunk by an average of -3.19%; the printed PCM shirts shrunk by an average of only -2.20%. By the end of the study, instrumental color measurement demonstrated that the control shirts had an average  $\Delta E$  value of 1.37, while the printed PCM shirts had an average  $\Delta E$  value of 1.50.



**Figure 2.** Absorbency of Control vs. Printed T-Shirts

Figure 2 illustrates the absorbency of both shirts increasing as the time to absorb water decreased. Although the printed PCM shirts began with a significantly lower absorbency on the back side of the fabric at new, compared to the control without the printed finish. Differences in shrinkage were also present. After 50 washes, the control garment shrunk by an average of -3.19%; the printed PCM shirts shrunk by an average of only -2.20%. By the end of the study, instrumental color measurement demonstrated that the control shirts had an average  $\Delta E$  value of 1.37, while the printed PCM shirts had an average  $\Delta E$  value of 1.50.



**Figure 3.** PCM at New & 50 Washes

In conclusion, the printed cooling technology did not have a significant impact on the abrasion resistance, soil release, or appearance retention properties of the t-shirt. Images taken with the inspection microscope illustrate the encapsulated PCM finish at new and after 50 washes (Figure 3). The absorbency results are supported by the degradation that is shown in these microscopic images. The PCM finish may have had a negative effect on color change, as the PCM shirts had the highest  $\Delta E$  values. However, the printed finish seems to have reduced shrinkage. Overall, results demonstrate the appropriateness of adopting such a printed cooling technology for migrant farm worker clothing applications.

**References:**

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