

PASSIVE COOLING FOOTWEAR TO ADDRESS OCCUPATIONAL HEAT STRESS

What's the Risk?

Workers across occupations like construction, agriculture and landscaping routinely perform physically demanding tasks in high-temperature environments. Prolonged exposure to heat and humidity, combined with long work hours and limited opportunities for cooling and hydration, increases the risk of heat-related illnesses, such as heat exhaustion or heat stroke, while also contributing to fatigue, discomfort and reduced productivity. Traditional safety boots, while necessary for protection, may contribute to this risk by trapping heat and moisture around the feet, contributing to discomfort, blisters, skin irritation and other foot-health concerns.



Figure 1. Workers in outdoor occupations face heat-stress risks including sun exposure, high ambient temperatures and ongoing physical exertion.

Technology Overview

This pilot evaluated *Passive Core Temperature Thermal Management Footwear*, specialized work boots originally developed by the Wright Brothers Institute and evaluated in partnership with The Science & Engineering Corps. Originally designed to improve foot health and performance in harsh military environments, the boots were designed to balance foot protection, comfort and durability while incorporating features to improve airflow and dissipate heat in the jungle, desert and other harsh environments.

Unlike traditional work boots, which can trap heat and retain moisture, these boots incorporate specialized materials and ventilation features designed to promote airflow while reducing moisture retention. As the wearer walks, the pumping action circulates air across the bottom of the foot and out through drainage ports. Strategically placed vents further increase airflow in areas where heat and moisture tend to accumulate within the sock, while the boot materials themselves are designed to resist retaining water, even after submersion. By

reducing heat and moisture buildup without compromising protection or durability, the passive thermal management footwear is intended to support the body's natural cooling mechanisms throughout the workday.

The Passive Core Temperature Thermal Management Footwear was a semifinalist in the 2025 Safety Innovation Challenge, an annual competition hosted by the National Safety Council that recognizes innovative technologies designed to address critical workplace safety challenges.



Figure 2. The passive cooling footwear being tested across multiple military environments.

Pilot Overview

With support from a pilot grant awarded by the [Work to Zero](#) initiative at the National Safety Council, The Science & Engineering Corps partnered with Wright Brothers Institute to evaluate the passive cooling footwear through both laboratory and field testing. The objectives were as follows:

1. **Assess the performance of the boots in laboratory testing for heat dissipation, airflow and moisture control under controlled conditions compared to standard hot-weather military boots;**
2. **Gather qualitative feedback from outdoor workers on the comfort, fit, durability and overall effectiveness of the footwear to inform future design improvements;**
3. **Identify opportunities to refine the footwear design to improve performance, manufacturability and readiness for broader deployment; and**
4. **Assess compliance with applicable safety standards and identify regulatory considerations necessary for adoption across industries.**

The pilot was conducted over a nine-month period, from June 2025 to March 2026, with independent testing continuing into 2026. Early field trials were conducted in Kentucky and Ohio with limited late program assessments in Hawaii and Florida. These locations were selected to represent diverse environmental conditions, including high temperatures, high humidity and labor-intensive work environments. The industries

and worksites involved in the pilot included landscaping and lawn services, general construction, agriculture and general labor. Approximately 25 individuals were involved in the pilot program.

In addition to field trials, laboratory testing was expanded during the pilot to assess the thermal performance and moisture retention of the *Passive Core Temperature Thermal Management Footwear*. These controlled evaluations provided critical baseline data to characterize the boots' effectiveness in comparison to traditional military boots.

Pilot Findings

The pilot program yielded several notable outcomes that demonstrated the potential of the passive cooling footwear to improve worker safety, comfort and productivity across diverse environments. Key outcomes included:

1. Laboratory testing found that the passive cooling footwear dissipated heat significantly faster than conventional military boots.

Controlled laboratory testing was first conducted using established methodologies from military and academic research on footwear thermal performance^{1,2}. First, the boots were heated to 140°F (60°C) to simulate the temperatures that a worker might encounter in real-world conditions. While ambient air temperatures rarely reach this level, surfaces exposed to direct sunlight, such as asphalt, concrete, metal equipment or machinery, can easily exceed 140°F during peak summer conditions. Cooling performance was then measured at the mid-heel, mid-arch and mid-metatarsal under three conditions: (1) no induced convection (still air), (2) active convection using a fan, and (3) delayed active convection.



Figure 3. Laboratory evaluation of the boots under controlled testing conditions.

¹ Lee, M., Stenkina, M., Yeo, Y., & Lee, J.-Y. (2025). Thermal insulation of military boots using a thermal foot manikin in cold environments. *Fashion and Textiles*, 2(2025). <https://link.springer.com/article/10.1186/s40691-024-00407-6>

² Rioux, T. P., Xu, X., Gonzalez, J. A., Karis, A. J., Potter, A. W., & Castellani, M. P. (2022). *Thermal manikin and thermoregulatory modeling evaluation of PASSIVE Core Temperature Thermal Management footwear* (Technical Report). U.S. Army Research Institute of Environmental Medicine. Defense Technical Information Center (DTIC).

Across all testing conditions, the prototype boots consistently cooled more rapidly than conventional hot-weather military boots. During active convection, the mid-arch region of the prototype boots cooled by more than 24°F within the first 10 minutes, while conventional hot-weather military boots cooled by less than 2°F. The prototype boots also reached the upper threshold of the human skin thermal comfort zone³ (~95°F) in 27 minutes, compared with 60 minutes for conventional boots.



Figure 4. Cold weather testing of the boots.

Overall, the prototype boots demonstrated faster cooling rates, greater temperature reductions and consistent performance across all sensor locations compared with conventional boots (see Figure 3). Additional field evaluations conducted during colder weather in Kentucky and Ohio further illustrated the technology's heat dissipation capabilities, where cooler temperatures provided a more controlled environment for observing the footwear's ability to transfer heat and moisture. These observations were consistent with the technology's reliance on airflow to enhance evaporative and convective cooling.

**Figure 5. Boot Heat Dissipation Comparison (Active Convection Trial)
Military Boots vs. Passive Core Temperature Thermal Management Footwear**

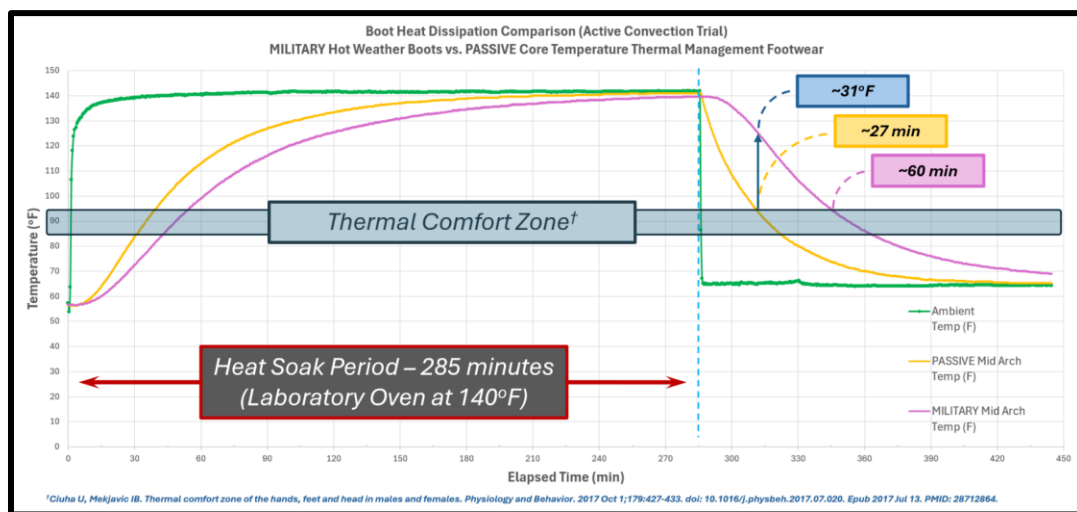


Figure 5. Laboratory testing demonstrated that PASSIVE thermal management footwear dissipated heat more rapidly than conventional military hot-weather boots following a 285-minute heat soak.

³ Ciuha, U., & Mekjavic, I. B. (2017). Thermal comfort zone of the hands, feet and head in males and females. *Physiology & behavior*, 179, 427–433. <https://doi.org/10.1016/j.physbeh.2017.07.020>

2. Workers consistently reported improved thermal comfort and breathability compared with traditional footwear.

Field evaluations and participant feedback highlighted the strengths and opportunities for improvement across three key domains: form, fit and function. Overall, participants rated the footwear positively, citing their ventilation, breathability and overall comfort while also identifying design improvements that could enhance performance and usability.

Form. Overall, participants rated the boots as "good" to "excellent" in terms of quality and reported they performed well across a variety of work environments (*walking, running equipment, performing work activities, etc.*). Ventilation and breathability were consistently identified as the footwear's greatest strengths, helping keep feet cooler during movement, in breezy conditions and while operating equipment.

Fit. Overall comfort was also rated positively, averaging 4 out of 5 in survey results. However, some participants noted that comfort was affected by the limited sizing available during the pilot. Expanding the range of available sizes was identified as an important next step to improve fit and accommodate a wider range of workers. Despite long workdays, most participants did not report changes in fatigue while wearing the footwear.

Function. Participants reported that the footwear performed well in outdoor and mixed work environments, with the cooling effect most noticeable while walking, working in breezy conditions and operating equipment. Although no workers experienced a heat-related illness during the pilot, participants reported routinely experiencing heat exposure during a typical workday, including excessive sweating, increased hydration needs and the need to take breaks to cool down. While participants found it difficult to determine whether the footwear directly reduced heat stress, they consistently reported improved ventilation and cooling compared with traditional work boots.



Figure 6. Workers from various industries tested the passive cooling footwear, providing feedback on their overall fit, function and cooling abilities.

3. The pilot expanded understanding of footwear as a component of comprehensive heat stress prevention.

Heat stress prevention has traditionally focused on interventions such as hydration, rest breaks, shade, cooling garments and administrative controls. This pilot demonstrated that footwear design may also influence worker thermal comfort by affecting heat dissipation and moisture management at the foot. While passive cooling footwear is not a replacement for established heat stress prevention measures, the findings suggest it may serve as a complementary engineering control that supports broader heat stress management strategies, particularly for workers who spend prolonged periods in hot outdoor environments.

Beyond the performance of the footwear itself, the pilot also increased awareness among participating organizations about the role of innovative technologies in heat stress management. The project incorporated discussions with employees about heat stress risks and how footwear can complement existing heat stress strategies, while also highlighting opportunities to evaluate similar cooling approaches across additional industries and occupations.

Lessons Learned

The Wright Brothers Institute and The Science & Engineering Corps cited several lessons learned throughout the duration of the pilot, including:

- **Start with small-scale pilots:** Begin with small-scale pilots, identifying select facilities, workers, or activities to trial the technology to gather initial feedback and refine the technology. This approach allows for iterative improvements and minimizes risks associated with larger investments. Incorporate feedback as quickly as possible into design updates to ensure the technology meets diverse user needs and expectations.
- **Preventative technologies require innovative metrics:** Measuring the impact of preventative technologies, such as cooling devices or footwear, can be challenging in real-world settings. A combination of field trials and laboratory evaluations should be used to comprehensively assess the technology's performance. Field trials can provide real-world insights and worker feedback, while laboratory testing offers controlled data that can validate findings and support refinement efforts.
- **Educate and engage stakeholders:** Engaging stakeholders, including employers, workers and industry representatives, early in the process is essential to building trust and overcoming barriers such as liability concerns and resistance to change. Clear communication about the technology's benefits, safety, and alignment with organizational goals can help secure buy-in and foster participation.

- **Manufacturer collaboration is essential:** During the pilot, limitations in the manufacturer's ability to scale production underscored the importance of establishing reliable manufacturing partnerships early in the commercialization process to reduce interruptions or delays.
- **Resource management and contingency planning:** The business contraction at Wright Brothers Institute in Q4 of 2025 highlighted the need for robust resource management and contingency planning. Future programs should account for potential disruptions and ensure that sufficient resources are allocated to maintain momentum and achieve objectives.

Building on the findings of this pilot, the project team plans to continue laboratory and field evaluations of the *Passive Core Temperature Thermal Management Footwear* under a broader range of environmental conditions and activities. Efforts will also focus on securing manufacturing partnerships, refining the footwear design and advancing commercialization to support broader deployment across high-risk industries. The pilot established a strong foundation for future development which will guide the next phase of product development and help position the technology for larger-scale occupational evaluations and eventual commercialization.



The Science & Engineering Corps

The Science & Engineering Corps, based in California, KY, is an applied science and engineering organization that develops and evaluates emerging technologies for defense and commercial applications. Its heat-stress mitigation technologies include passive cooling footwear and Velocity, a wearable system that integrates active cooling and hydration for military, industrial and civilian use. Through multidisciplinary engineering, field testing and technology evaluation, The Corps advances innovative concepts into practical, real-world solutions.



Wright Brothers Institute

The Wright Brothers Institute (WBI), based in Dayton, OH, was a nonprofit organization partnered with the Air Force Research Laboratory (AFRL) to drive aerospace innovation. Founded in 2002, WBI facilitated more than 1,000 collaborative technology, rapid prototyping and commercialization projects before suspending operations in late 2025. **WBI was a semi-finalist in the 2025 Safety Innovation Challenge, which focused on addressing occupational heat stress.**

Contact Us:
worktozero@nsc.org

Learn More:
nsc.org/WorktoZero

nsc
National Safety Council