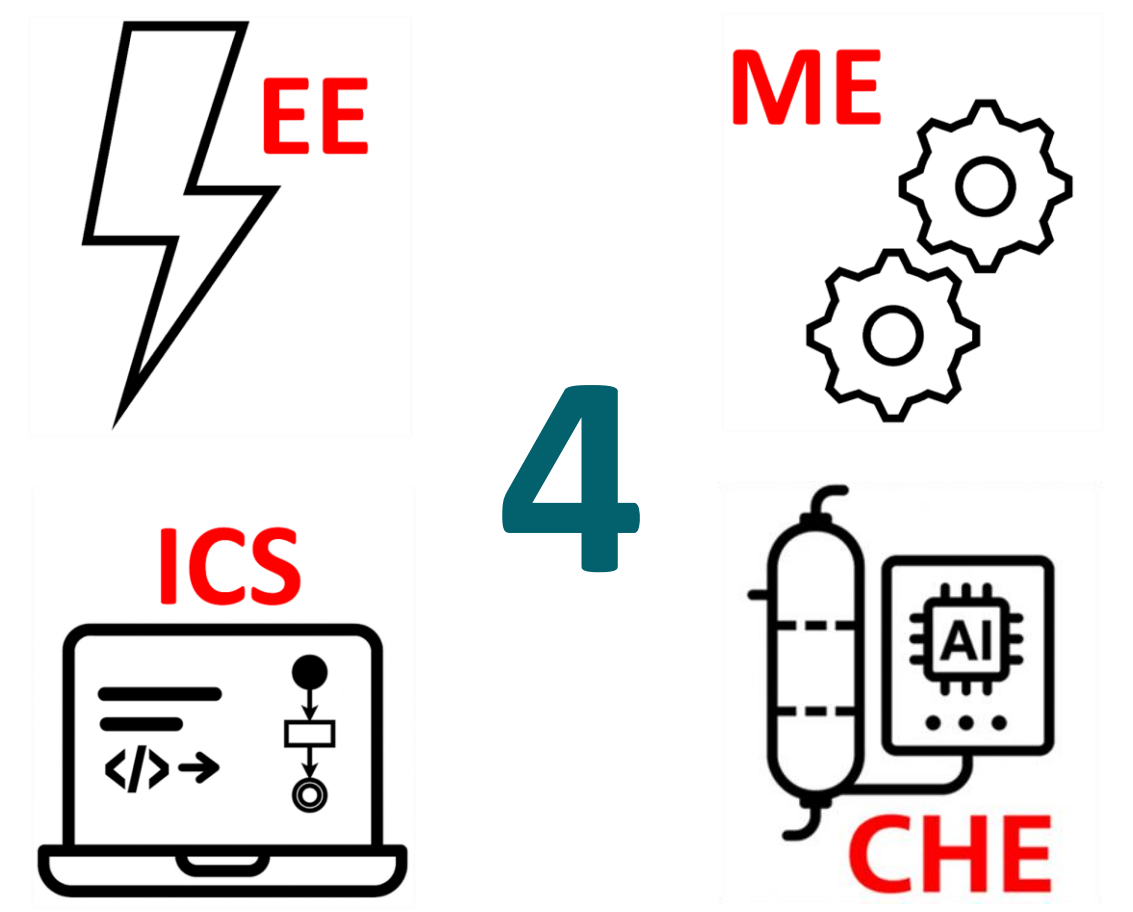


Smart PCM-Assisted Cooling Vest for Outdoor Workers in Hot Climates (KSA)

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Introduction

A smart PCM-assisted cooling vest is developed to reduce heat stress for outdoor workers in hot climates in Saudi Arabia. The system combines passive cooling using phase change materials (PCM), active liquid circulation, embedded sensing, and wireless monitoring. It is designed to improve worker comfort, reduce thermal strain, and provide supervisors with real-time visibility of worker condition and vest status.

Problem statement

Outdoor workers in Saudi Arabia are exposed to extreme heat, strong sunlight, and long working hours, which can lead to fatigue, dehydration, heat exhaustion, and heat stroke.

Constrains

Number	Functional Area	Requirement Details
1	Material Safety	The PCMs and the fluid must have a flash point above 90°C
2	Data Communication	Communication constraint: The system must use Wi-Fi for data transmission between the vest, web application, and cloud services.
3	Power Management	The rechargeable battery pack shall include an integrated Battery Management System (BMS) providing over-current, over-charge, and over-discharge protection.
4	Detachable Components	Replaceable components (Packs, Tank) detachable in ≤ 3 minutes.
5	Electrical Safety	The overall system design shall limit leakage current through any user-touchable surface to less than 2 mA under sweat or moisture conditions. [IEC 62368-1]

Specifications

Specification ID	Specification Description	Status
Specification 1	The PCM in the vest meeting gear should be in the range of 35-22 °F.	Met
Specification 2	Cooling vest should fit the global standard (The cooling vest must be designed in standardized sizes from S to 2XL, so it can comfortably and safely fit a wide range of users.)	Met
Specification 3	The cloud shall store telemetry updates for each vest at 10-20 second intervals for supervisor access.	Met
Specification 4	App displays new data within a 5 s of cloud update.	Met
Specification 5	Supervisor dashboard to accessible at 95% of field test time.	Met
Specification 6	Active reservoir thermal performance 1.0-3.6 °C.	Met
Specification 7	The system shall measure heart rate with an accuracy of ±5 bpm, SpO2 with an accuracy of ±0.5%, and skin temperature with an accuracy of ±0.3 °C.	Met
Specification 8	The battery-powered electronics subsystem shall support a 3.0 hours of operation under a defined real-world field profile (sensing, processing, wireless communication, and activation when enabled).	Met
Specification 9	The fluid loop shall have 0 mL leakage.	Met
Specification 10	The system should operate within ambient temperature 0 - 65 °C safely.	Met
Specification 11	Microcontroller sends readings via Wi-Fi to the cloud.	Met
Specification 12	Sensor readings shall be collected at a rate of 3-5 Hz and used by a PI or PID control algorithm to modulate pump operation through duty cycle control.	Met
INTEGRATED SPECIFICATIONS		
Integrated Specification 1	The total weight of the full vest (including battery & fluid) must not exceed 5 kg.	Met
Integrated Specification 2	The app shall allow the user to select cooling modes (OFF / Eco / Normal / Active) and the selected mode must be applied by the vest within a 5 seconds of the user's request.	Met
Integrated Specification 3	The vest should decrease skin temperature by ≥ 3.0°C.	Met

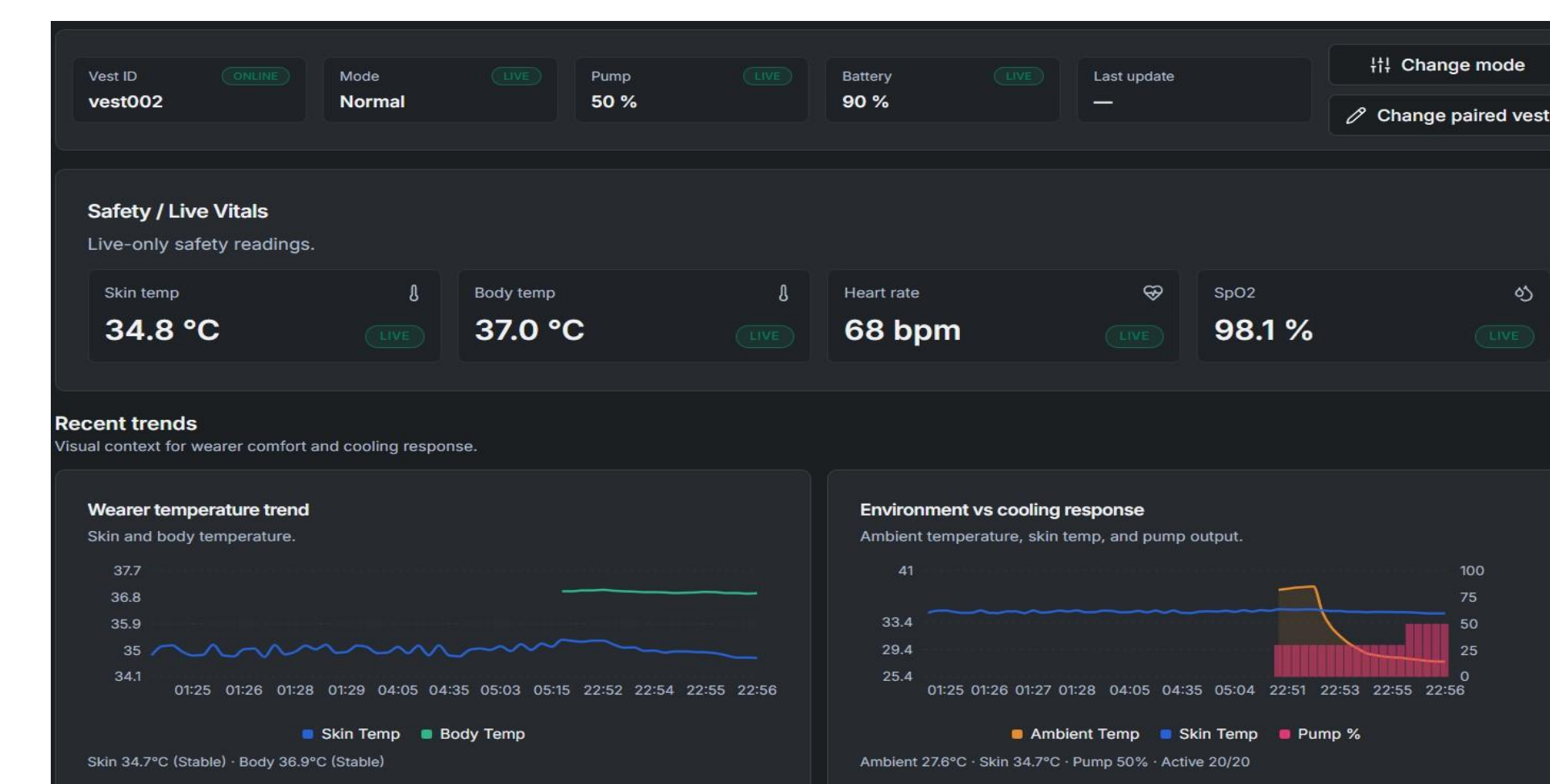
Prototype

This smart safety vest prototype utilizes a hybrid thermal management system combining passive cooling via Phase Change Materials (PCM) and active cooling through a liquid circulation system..

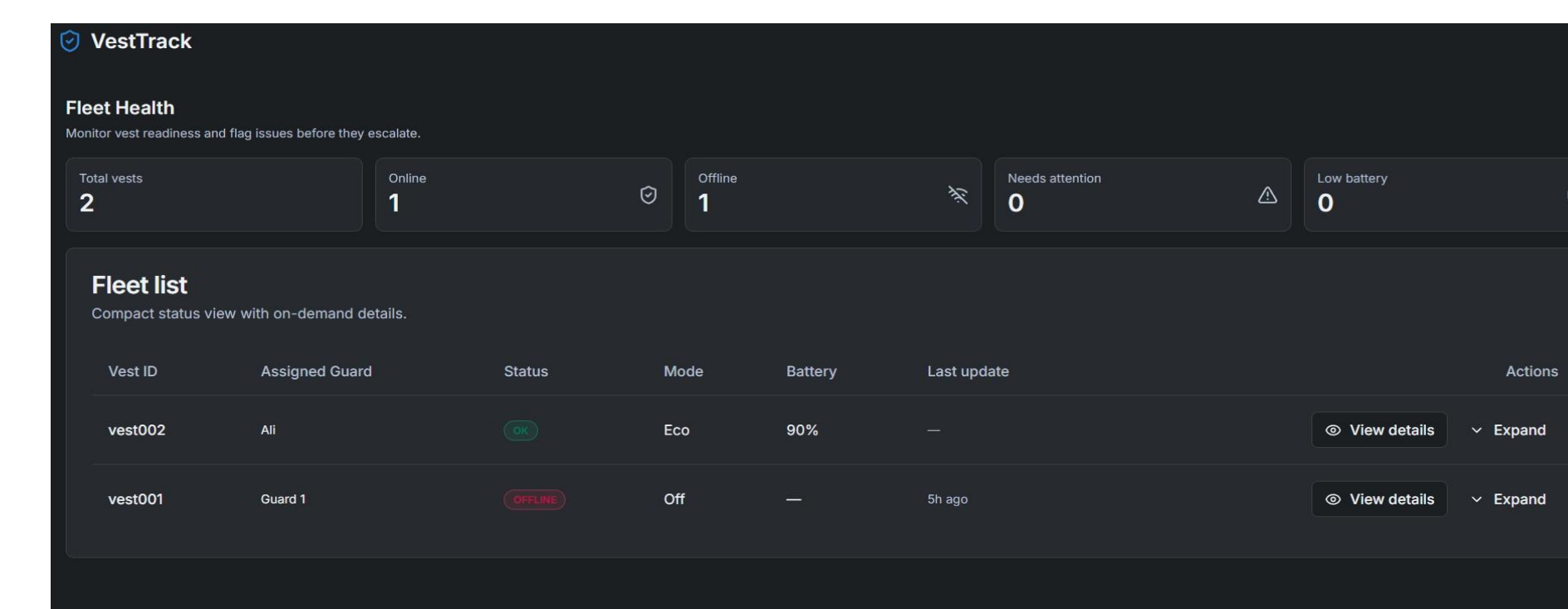


Dashboard

This dashboard provides real-time monitoring and control of a smart cooling vest system, displaying live vest status, vital signs, battery and pump performance, and temperature-response trends for thermal management.



This dashboard provides a centralized fleet-management overview for smart cooling vests, showing device availability, operational status, battery levels, assigned users, and quick access to detailed monitoring and control

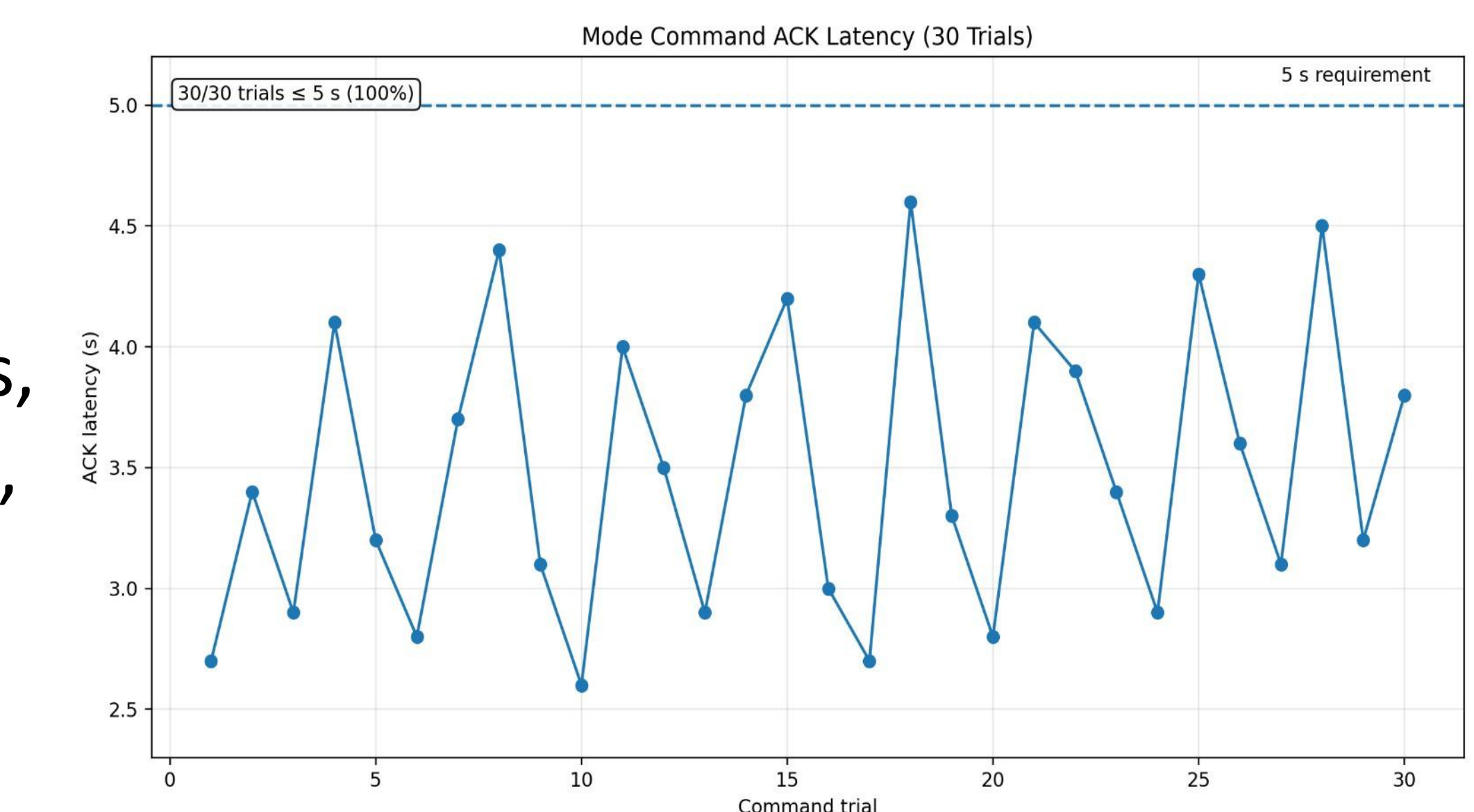
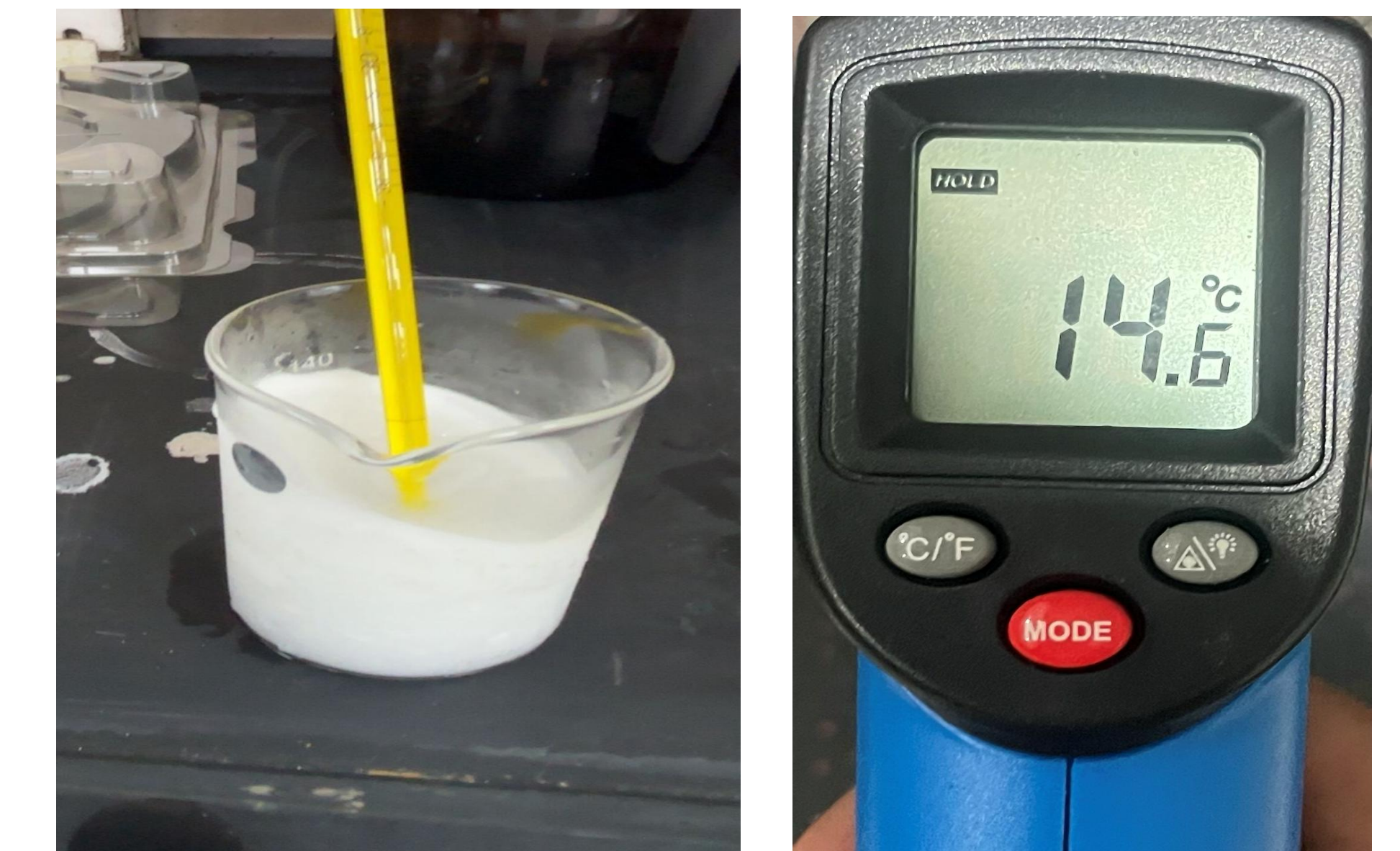


Phase Change Material



This Phase Change Material (PCM) functions as a passive thermal buffer that absorbs latent heat during its solid-to-liquid transition to maintain a stable temperature.

Testing & Validation



Conclusion

The smart PCM-assisted cooling vest improves thermal comfort and reduces heat stress for outdoor workers in Saudi Arabia by combining active-passive cooling, sensing, and cloud monitoring, enhancing safety, comfort, and performance in extreme heat.