High-Performance Cooling Garment

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Background

First responders and professional athletes working in hot environments need a way to cool down quickly to aid in recovery. We set out to create a device that could reduce the user's core body temperature to a healthy range over a short period of time. This device is comprised of a backpack which contains the electronic controls and cooling system, and a forearm garment. The separation of controls from the cooling sleeve was intended to allow for future interchangeable garments to be used. The adjustable cooling sleeve accommodates a wide variety of forearm sizes and restrictive clothing.

Objectives

1. Create a self contained, battery powered, portable unit.
2. Target the forearm for ease of use.
3. Incorporate thermoelectric coolers (TECs) as the main source for cooling.
4. Optimize ergonomics and comfort so that it can be worn by any individual.

Metrics

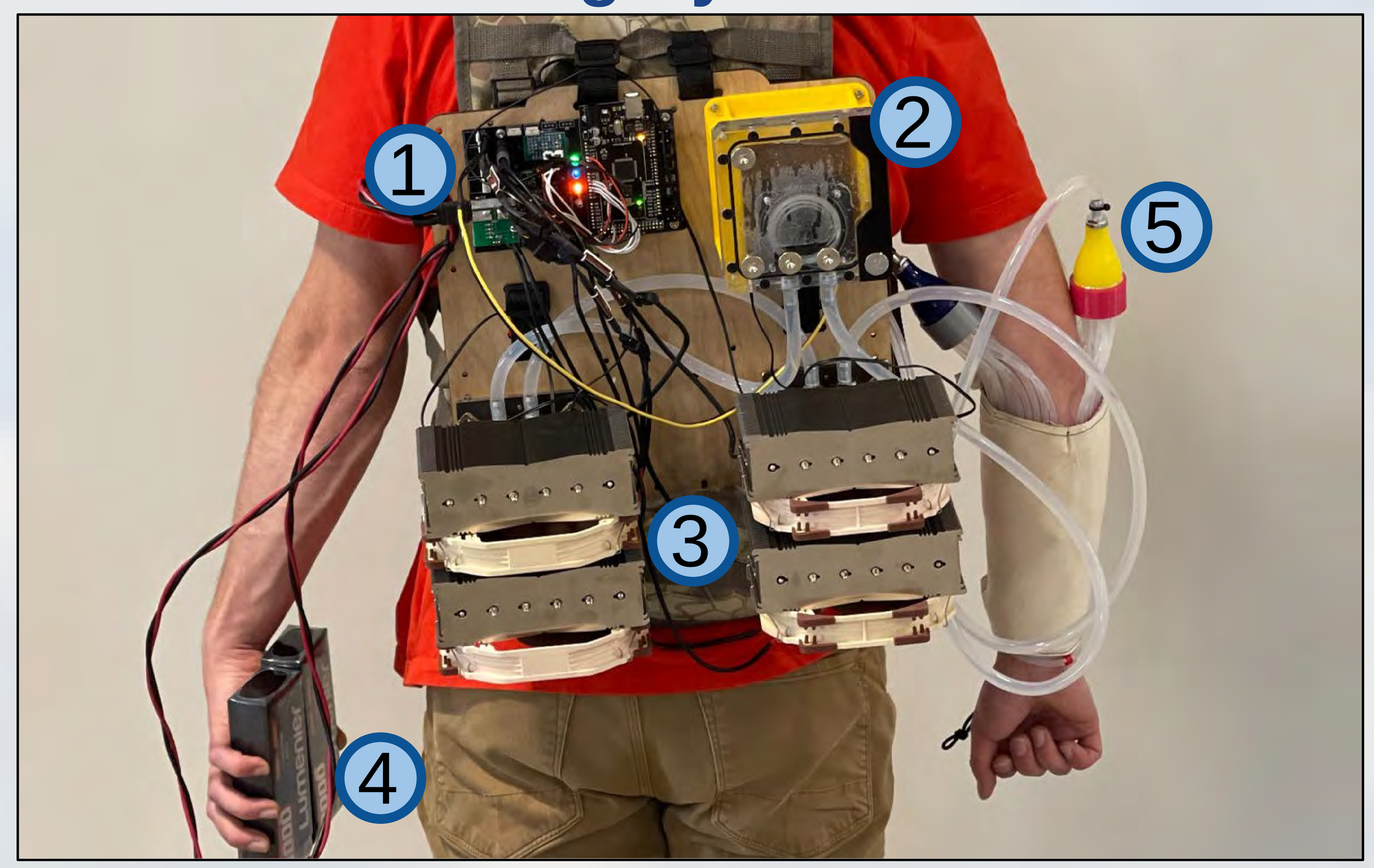
Objective	Cool body	Portable	Long-lasting	Low Cost
Metric	Cooling Power	Weight	Time before recharge	Overall cost of product
Constraint	> 50 W	< 15 lb	> 30 min	< $1000
Target	>150 W	< 8lb	> 2 hrs	< $500
Achieved	100W	15 lb	>1 hr	~$1000

Garment Design

Canvas garment filled with cooling tubes (right), fitted to the forearm with elastic drawstrings woven through grommets (left).

The coolant tubing in the garment was made from silicone to increase ergonomics, despite its unideal heat transfer coefficient. The garment itself was made out of canvas and sewn to a cotton pad to provide structural integrity and comfort. The grommets and elastic drawstring allow the garment to be pulled tight with one hand. This mechanism of fastening allows the garment to slide on and off as well as be used by multiple arm sizes.

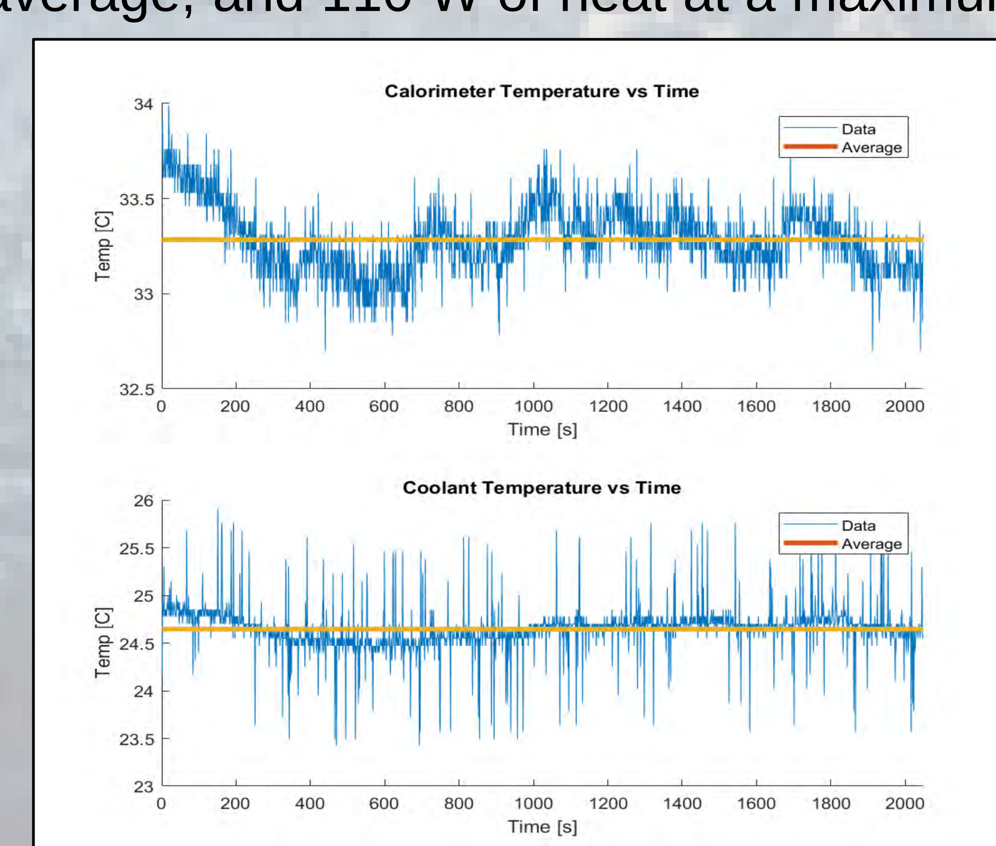
Electronic Cooling System



1. **Control board** - Powers and controls the pump, TECs, and fans while taking coolant and user temperature measurements
2. **Pump and reservoir** - D5 pump and low-profile reservoir that pump methanol coolant from the TECs to the garment
3. **Cooling tower** - TECs, double CPU coolers with fans, and a water block. This system removes heat from the coolant and radiate it into the environment
4. **Power source** - Two 6S Lithium Polymer batteries
5. **Manifolds** - FDM printed inlet and outlets joining garment's tubing to the cooling tower

Calorimeter Power Test & Results

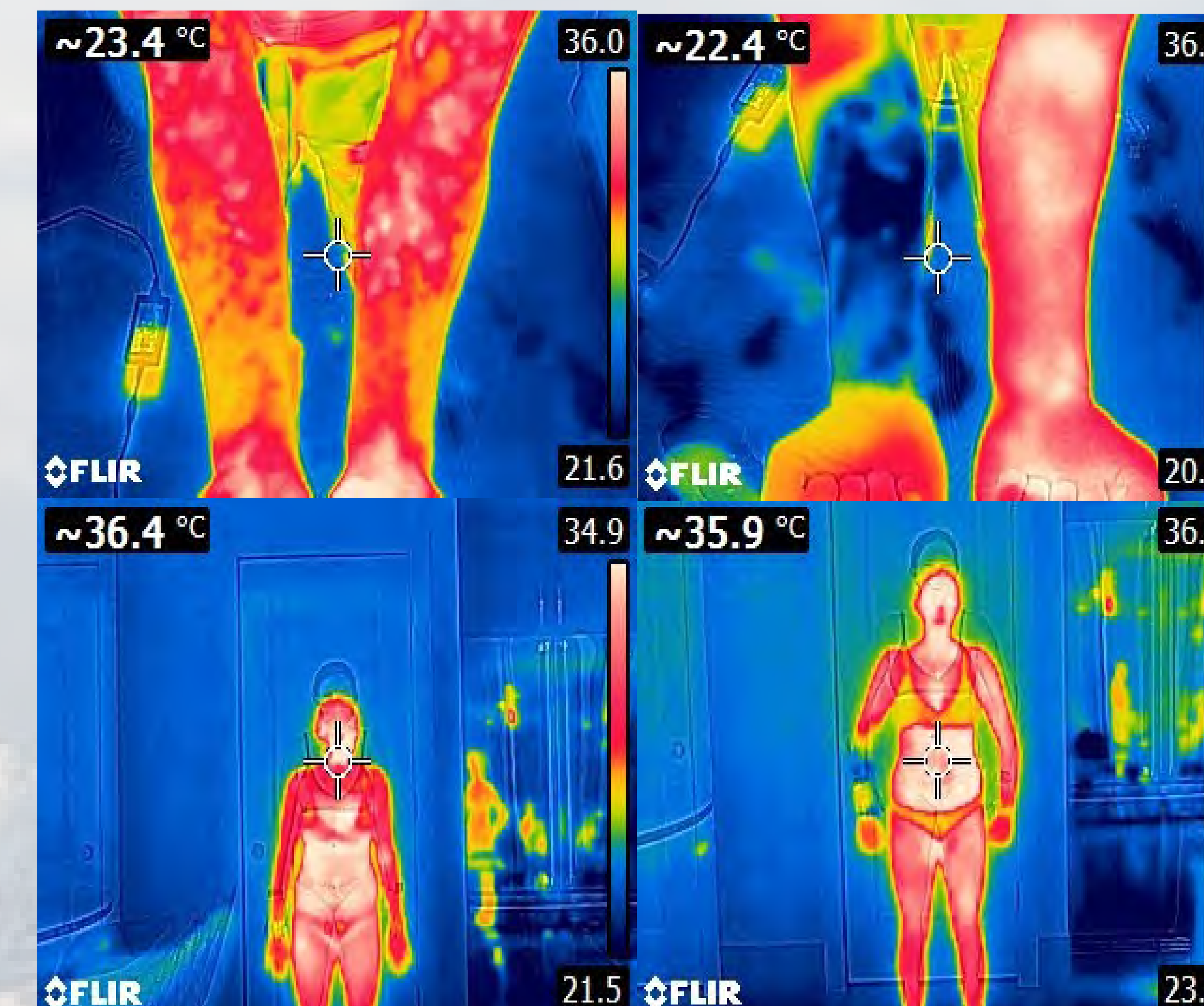
The garment was submerged in 15.14 L of water resting at 33℃ in order to simulate the human body. A power meter was used to measure the electrical energy required to keep the water at constant temperature for an entire discharge of the battery. The calorimeter experiment showed that the device can extract 92 W of heat on average, and 110 W of heat at a maximum.



The temperature distribution of the calorimeter over time (top) and the temperature of the coolant over time (bottom)

Thermal Imaging Test & Results

The subject was submerged in 38°C water for 20 minutes to raise their core body temperature by at least 2°C. The garment was placed on the subject and run at full power for 15 minutes. Next, as a control test, the subject reheated and subsequently cooled down naturally (ie. not using the garment) for 15 minutes. For both tests, a full body thermal image was taken to compare the natural versus aided cooling. The forearm heat transfer maps show the forearms before and after the garment was used, thus validating the expected cooling effects by reaching the intended local target temperature distribution of 21°C.



Local and global thermal images of subject after undergoing hyperthermic excitation. Before and after garment applied to forearm (top), control versus experimental cooling cycle (bottom).

Conclusion

We built an electronic cooling device utilizing TECs that is capable of extracting 92 W of heat on average, which effectively cooled the body locally. Due to experimental and resource limitations an analytical conclusion for the true effectiveness of the device in lowering the core body temperature could not be determined. However, the thermal imaging and calorimeter tests provide compelling evidence that the device is able to remove heat locally. To achieve global cooling, future iterations of this design would need to target a larger area with more blood flow, such as the chest. The garment and cooling system are independent, allowing for modularity that will accommodate these future garment iterations.