Homeland Security
Science and Technology

TechNote

U.S. Department of Homeland Security

SAVER

System Assessment and Validation for Emergency Responders

The U.S. Department of Homeland Security (DHS) established the System Assessment and Validation for Emergency Responders (SAVER) Program to assist emergency responders making procurement decisions.

Located within the Science and Technology Directorate (S&T) of DHS, the SAVER Program conducts objective assessments and validations on commercial equipment and systems and provides those results along with other relevant equipment information to the emergency response community in an operationally useful form. SAVER provides information on equipment that falls within the categories listed in the DHS Authorized Equipment List (AEL).

The SAVER Program is supported by a network of technical agents who perform assessment and validation activities. Further, SAVER focuses primarily on two main questions for the emergency responder community: "What equipment is available?" and "How does it perform?"

For more information on this and other technologies, contact the SAVER Program Support Office.

RKB/SAVER Telephone: 877-336-2752
E-mail: saver@hq.dhs.gov
Website: https://www.rkb.us/saver

This SAVER TechNote was prepared by the National Urban Security Technology Laboratory for the SAVER Program.

NUSTL

Personal Cooling Systems

First responders, such as firefighters, policemen, and hazardous materials response teams, must frequently perform at high activity levels in extremely hot environments. Maintaining a normal body temperature is critical to working safely, rapidly, and efficiently. Normal cooling of the body by evaporation of sweat from the skin may be greatly diminished under the layers of personal protective equipment often worn by responders. The weight, stiffness, and design of protective clothing may also raise the amount of energy responders expend, further increasing the need for cooling. Personal cooling systems maintain a microclimate around the responder, reducing the possibility of heat stress-related illnesses.

How They Work

Personal cooling systems can be active or passive and comprise a cooling technology and a garment, usually a vest. Active devices usually involve a circulating fluid, e.g., air or chilled water, and require a power source. They provide maximum cooling for the duration of use and are the most expensive. Passive systems have no moving parts and do not require a power source. They provide cooling only for a limited time and are fairly inexpensive. First responders generally require portable systems, but some cooling technologies work well when the user is tethered to either a vapor compression device or a source of compressed air.

Evaporative Cooling

Evaporative cooling systems use water's ability to absorb heat as it evaporates. These systems consist of a garment and water absorption crystals, which are soaked in water before use. They are readily available, inexpensive, and do not require external power. However, they are not effective at high relative humidity or when there is little air movement. Evaporative cooling systems are not frequently used by first responders because they are not effective if worn inside of nonventilated outer garments, such as personal protective equipment.

Phase Change Technology

Phase change material (PCM) vests have pockets that hold PCM packs and are made of a wicking material that draws perspiration to the outside of the garment (Figure 1). They depend on the change of phase of a substance, frequently paraffin, from a solid to a liquid to cool the user. They act as heat sinks and are activated when the temperature rises above a certain level (from 55°F to 65°F). PCM vests are usually considered passive because they don't have any moving parts or an external power supply. However, they remain cold only for a limited time and must be recharged in a refrigerator. The temperatures of PCM packs are not cold enough to freeze the skin or cause condensation, and they can be worn without an undershirt.

Figure 1. Vest with PCM Packs (upper left) and Ice Packs (upper right)
Photo courtesy of Polar Products, Inc.

Paraffin-based materials may be irritating if they come into contact with the skin. Newer PCMs claim to be nontoxic and nonirritating. Cooling duration is up to 2 hours depending on ambient conditions and the responder's workload.

Gel or Ice Pack Vests

Gel or ice pack vests consist of a garment containing pockets that hold ice or gel packs (Figure 1). Gel is a mixture of starch, water, and other ingredients that when frozen has a cooling capacity similar to ice. These passive products are slightly heavier than phase change products, have high cooling power, and provide body core temperature reduction. They are nontoxic but require freezing to activate. Since they operate below typical dew point temperatures, water vapor from the environment can condense on the packs, which may cause skin irritation. The extreme cold may also cause vasoconstriction, ultimately leading the body to retain heat.

Liquid Circulating Products

Liquid circulating products work by pumping a chilled fluid through a heat transfer garment lined with a network of tubing (Figure 2). Metabolic heat is transferred to the circulating fluid, which is pumped back to the cooling unit where the heat is rejected. The coolant fluid is chilled in the cooling unit, using either a vapor compression system or thermoelectric cooling, and recirculated back to the heat transfer garment to continuously cool the user. Both of these methods require the cooling unit to be located external to the user's uniform since heat must be rejected to the ambient environment. Both methods also require electrical power from batteries. Advances in vapor compression technology have reduced the size, weight, and power needs of these systems, greatly enhancing their portability. Ice can also be used as the cooling source in a liquid circulation system. A battery-powered pump draws chilled ice water from a reservoir and circulates it through the garment. The ice water is usually carried in a backpack for portable units. The system requires replenishment of the ice and batteries. These garments can be worn directly against the skin without danger of freezing. They are relatively expensive and heavy but are very effective.

Figure 2. Backpack Ice-Based Liquid Circulation System

Photo courtesy of Veskimo Personal Cooling Systems™

Ambient Air Systems

Ambient air systems work by blowing air between the protective outer garments and the inner layers of clothing, increasing both convective and evaporative heat losses. They typically use a battery-powered blower to circulate air through an air distribution garment. Systems are available that weigh less than 5 pounds. Air cooling is not as efficient as water cooling because the air heat transfer coefficient is only 1/25 that of water. However, ambient air systems are fairly effective at low relative humidities.

Testing and Standards

In order to evaluate the relative effectiveness of various cooling systems, tests are performed in climatic chambers on thermal manikins. The use of thermal manikins removes the variability that results from the use of human subjects. ASTM International Standard F2300, *Standard Test Method for Measuring the Performance of Personal Cooling Systems Using Physiological Testing*, provides guidance on protocols and the types of tests to use when human volunteers are available.

Considerations

The selection of a personal cooling system depends on the conditions of use and the preferences of the user. The availability of a cooling source such as a refrigerator, freezer, or source of ice; the effect of added weight on the responder's comfort; the relative humidity of the environment; the length of time cooling is needed; and the cost all need to be considered. Some systems may require the user to remove personal protective equipment when the PCM, gel, or ice packs need to be recharged. For systems that reject heat to the environment, air or liquid supply lines must pass through the protective clothing, potentially compromising a responder's safety. Phase change materials work well initially but last only for a relatively short time unless recharged. Many first responders indicate that body core temperature reduction is one of the key factors affecting their ability to work in hot environments. Some human subject tests indicate liquid circulation systems may significantly lower body core temperatures. Air circulation systems improve most physiological responses, but to a lesser degree than some of the other systems.[1]

---

[1]McCullough, Elizabeth A., and Eckels, Steve, *Evaluation of Personal Cooling Systems for Soldiers,* Institute for Environmental Research, Kansas State University, August 2009.