System Assessment and Validation for Emergency Responders (SAVER)

Personal Cooling Systems Market Survey Report

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Prepared by the National Urban Security Technology Laboratory

The *Personal Cooling Systems Market Survey Report* was prepared by the National Urban Security Technology Laboratory for the U.S. Department of Homeland Security, Science and Technology Directorate.

Cover photographs courtesy of Entrak GmbH, Polar Products Inc., RINI Technologies Inc., and Veskimo Personal Cooling Systems.

FOREWORD

The U.S. Department of Homeland Security (DHS) established the System Assessment and Validation for Emergency Responders (SAVER) Program to assist emergency responders in making procurement decisions. Located within the Science and Technology Directorate (S&T) of DHS, the SAVER Program conducts objective assessments and validations of commercial equipment and systems, and provides those results along with other relevant equipment information to the emergency responder community in an operationally useful form. The SAVER Program mission includes:

- Conducting impartial, practitioner-relevant, operationally oriented assessments and validations of emergency response equipment
- Providing information, in the form of knowledge products, that enables decision-makers and responders to better select, procure, use, and maintain emergency response equipment.

Information provided by the SAVER Program will be shared nationally with the emergency responder community, providing a life- and cost-saving asset to DHS, as well as to Federal, state, and local responders.

SAVER Program knowledge products provide information on equipment that falls under the categories listed in the DHS Authorized Equipment List (AEL), focusing primarily on two main questions for the responder community: "What equipment is available?" and "How does it perform?" These knowledge products are shared nationally with the responder community, providing a life- and cost-saving asset to DHS, as well as to Federal, state, and local responders.

The SAVER Program is managed and executed by the National Urban Security Technology Laboratory (NUSTL). NUSTL is responsible for all SAVER activities, including selecting and prioritizing program topics, developing SAVER knowledge products, coordinating with other organizations, and ensuring flexibility and responsiveness to first responder requirements. NUSTL provides expertise and analysis on a wide range of key subject areas, including chemical, biological, radiological, nuclear, and explosive weapons detection; emergency response and recovery; and related equipment, instrumentation, and technologies. For this report, NUSTL conducted a market survey of commercially available personal cooling systems (PCSs). PCSs fall under AEL reference number 01ZA-06-COOL titled Garment/Vest/Device, Cooling.

Visit the SAVER website at https://www.dhs.gov/science-and-technology/saver for more information on the SAVER Program or to view additional reports on PCSs and other technologies.

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1. INTRODUCTION

Personal cooling systems (PCSs) are used by first responders to maintain normal body temperature when working in high-temperature environments. To provide emergency responder and law enforcement organizations with information on PCSs, the System Assessment and Validation for Emergency Responders (SAVER) Program conducted a market survey on commercially available PCSs. Current PCSs used by first responders utilize one of four technologies to provide cooling. The information on PCSs that use gel/ice and phase change material (PCM) was gathered between June and September 2013 and published in May 2014 as the *Personal Cooling Systems Market Survey Report*. Information on PCSs that use either circulating liquid or ambient air as the cooling medium was gathered between August 2015 and November 2015 from vendor websites, industry publications, and a government-issued Request for Information (RFI) posted on the Federal Business Opportunities (FedBizOpps) website (https://www.fbo.gov). This market survey combines information from the previous report and the newly gathered information.

For inclusion in this report, a PCS had to meet the following criteria:

- It is a commercial off-the-shelf (COTS) product
- Can provide at least 1 hour of cooling in a warm environment
- Can be worn under protective clothing.

Due diligence was performed to develop a report that is representative of products in the marketplace.

2. PERSONAL COOLING SYSTEMS OVERVIEW

In order to work safely, rapidly, and efficiently, first responders must maintain a normal body temperature. The body functions most efficiently within a limited temperature range, usually within a few degrees of 98.6°F. Working at high temperatures can lead to fatigue, impaired concentration, heat exhaustion, and heat stroke. In addition, first responders often wear layers of personal protective equipment, which diminishes the body's normal ability to cool by evaporation of sweat from the skin. The weight, stiffness, and design of protective clothing may also raise the amount of energy responders expend, further increasing the need for cooling. PCSs maintain a microclimate around the responder, reducing the possibility of heat stress-related illnesses.

PCSs can be active or passive and are composed of 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 consistent, high-level cooling for the duration of use and can be fairly expensive. In the past, they were frequently not usable by first responders since they required the user to be tethered to a stationary source of either chilled liquid or forced air. Technological advances have allowed these systems to become portable and light enough for a first responder to use. Passive systems have no moving parts and do not require a power source. They include evaporative, gel/ice, and PCM garments, all of which provide cooling for a limited amount of time and are relatively inexpensive. Conduction is the method of heat removal for

these passive systems, and the garment is most commonly a vest. Head coverings, neck coverings, and ponchos can also be used.

2.1 Current Technologies

Brief descriptions of passive and active cooling technologies follow. This market survey addresses gel/ice, PCM, circulating liquid, and ambient air systems.

2.1.1 Evaporative Cooling

Evaporative cooling systems employ 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. Systems using evaporative cooling are readily available, inexpensive, portable, and do not require external power. However, they are not effective at high relative humidity or when there is little air movement. They also tend to remain damp, which can cause skin irritation and bacterial growth. Evaporative cooling systems are not frequently used by first responders because they are not effective if worn inside of unventilated outer garments, such as personal protective equipment.

2.1.2 Gel/Ice Pack

Gel/ice pack vests consist of a garment containing pockets that hold the gel/ice packs. Body heat, carried to the surface of the skin by the blood, is absorbed by the packs. Gel is a mixture of starch, water, and other ingredients that, when frozen, has a cooling capacity similar to ice. These passive products are relatively inexpensive, portable, have high cooling power, and provide body core temperature reduction when used for short periods. The packs can be reused many times. They are nontoxic but require approximately 5 hours of cooling time in a freezer 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, the reduction in peripheral blood flow when the skin is exposed to cold temperatures, which may eventually cause the body to retain heat and the core temperature to rise. However, studies show that gel/ice pack systems reduce heart rate, skin temperature, and body core temperature allowing work time to increase.[1,2]

2.1.3 PCM

PCM garments, frequently vests, are usually made of a wicking material that draws perspiration from the wearer. There are pockets on the inside of the garment, next to the body, that hold the PCM packs. For cooling, PCM depends on the latent heat absorbed in the phase change of a substance, frequently paraffin, from solid to liquid. The PCM packs act as heat sinks and are activated when the temperature rises above a certain level (from 55°F to 90°F) for commonly used PCMs). They work most effectively when worn close to the body. PCM vests are considered passive because they do not have any moving parts or an external power supply. They remain cold only for a limited time and may be recharged in ice water, a refrigerator, or a

[1] Muir, I,H., Bishop, P.A., Ray, P., "Effects of a Novel Ice-Cooling Technique on Work in Protective Clothing at 28 °C, 23 °C, and 18 °C WBGTs," *American Industrial Hygiene Association Journal*, 1999.

[2] McCullough, Elizabeth A., Eckels, Steve, "Evaluation of Personal Cooling Systems for Soldiers," Kansas State University, *Proceedings of the 13th International Conference on Environmental Ergonomics*, Boston, USA, August, 2009.

freezer. An advantage of PCM packs is that the time to recharge in ice water is frequently only 20 minutes. The temperatures of PCM packs are not cold enough to freeze the skin or cause condensation, and they may be worn without an undershirt. Vasoconstriction is unlikely to be a significant concern since most PCMs operate at temperatures above 55°F. Typical cooling duration is up to 3 hours depending on ambient conditions and the responder's workload. PCM packs do not provide as much cooling as gel/ice packs, but lose less cooling potential to the ambient air since the temperature difference between the PCM (at 55°F to 65°F) and ambient air is less than that between gel/ice (at 32°F) and ambient air. Paraffin-based materials are flammable and may be irritating if they come into contact with the skin. Newer PCMs are claimed to be nontoxic and nonirritating. Many studies indicate that PCM systems speed the rate of heat removal from the body and may increase work time.[3]

2.1.4 Circulating Liquid Systems

Circulating liquid products work by pumping a chilled fluid through a heat-transfer garment lined with a network of tubing, typically made from polyvinyl chloride. Metabolic heat is transferred to the circulating liquid, which is pumped back to a cooling unit where the heat is rejected. Since conduction is the primary mode of heat transfer in this type of system, the PCS garment should fit snugly in order to increase the skin-to-tubing contact area. The coolant fluid is chilled in the cooling unit, using either a vapor compression system or thermoelectric cooling, and re-circulated back to the heat-transfer garment to continuously cool the user. The cooling unit, regardless of the cooling method used, must be located external to the user's uniform since heat must be released to the ambient environment. The temperature of the liquid for the vapor compression system can be controlled by the user by varying the speed of the compressor. Both vapor compression and thermoelectric cooling require power from batteries or an electrical outlet. 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 circulating liquid 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 ice water can also be stored in a cooler which can be carried, but this greatly reduces such a system's usefulness for first responders. The system requires periodic replenishment of the ice and batteries. The temperature of the fluid in the garment can be controlled somewhat by varying the speed of the pump motor that regulates the amount of circulating liquid.

The heat transfer rate can be increased by increasing tubing coverage area, including the limbs and the neck/head area. Studies show that the cooling rate is significantly increased by enlarging the cooling coverage area.[4] These garments can be worn directly against the skin without danger of freezing. They are relatively expensive and heavy, but are very effective. Circulating liquid systems were found to significantly lower body core temperature in one human subject evaluation study.[5]

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[3] Chou C., Tochihara Y., Kim T., "Physiological and Subjective Responses to Cooling Devices on Firefighting Protective Clothing," *European Journal of Applied Physiology*, 2008.
[4] Johnson, J.K. *Evaluation of Four Portable Cooling Vests for Workers Wearing Gas Extraction Coveralls in Hot Environments*, M.S. Thesis, University of South Florida, March 2013.
[5] See note 2 above.

2.1.5 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 cooling. They typically use a battery-powered blower to circulate air through an air-distribution garment. Systems are available that weigh less than 6 pounds. Air systems work well because air cooling fosters evaporation, which is the body's primary method of heat dissipation. Product literature states that ambient air systems work best when the subject is sweating. Manikin studies, which are adjusted to keep the skin surface 100 percent saturated, show a high rate of cooling for ambient air systems. However, human subjects would have difficulty sustaining such a high rate of sweating for an extended period of time and may not show the same results. Ambient air systems are more effective when used in lower relative humidity environments. Cooled-air systems, which commonly use an air-coil immersion in an ice reservoir or a vortex tube, are not useful for first responders since they require the user to be tethered to the source of the air. They are, at times, used in conjunction with portable devices during breaks for first responders. Studies show that ambient air systems improve physiological responses of test subjects but to a lesser degree than other systems. They did improve subject's perceived comfort, perhaps because of their low weight and dryness.[6]

2.2 Applications

PCSs are used by first responders, including firefighters, police officers, hazardous-materials workers, and explosive ordinance disposal personnel when they are exposed to elevated temperatures. The leading cause of death for firefighters has been linked to cardiac events due to their performance of strenuous activities in high-temperature environments while wearing heavy equipment.[7] PCSs are also used by soldiers deployed in hot environments to lessen the likelihood of heat stress-related illnesses. Interestingly, people suffering from multiple sclerosis, whose symptoms are aggravated by increased body temperature, use PCSs to help keep cool, allowing them to live more normally even during the hot summer months or when exercising.

2.3 Standards/Regulations

ASTM International F2371-10e1, *Standard Test Method for Measuring the Heat Removal Rate of Personal Cooling Systems Using a Sweating Heated Manikin*, can be used to more objectively quantify and compare the cooling provided by different PCSs. A sweating thermal manikin system accurately simulates evaporative cooling, which is the dominant mode of heat transfer used by humans. The manikin has 20 computer controlled, independently heated thermal zones, containing embedded heaters and thermistors. A baseline test is first run to establish the heat loss from the manikin without a PCS. The computer collects temperature data from each zone and adjusts the power to the heaters to maintain the desired manikin temperatures. The power provided to the heaters is equivalent to the heat loss from the manikin. The test is repeated with a manikin that has been fitted with a PCS, and the manikin's surface temperature is kept at 95°F. The cooling rate of the PCS is quantified by subtracting the average power during the baseline

[6] Elson, John C., McCullough, Elizabeth A., Eckels, Steve, "Evaluation of Personal Cooling Systems for Military Use, Kansas State University," *Proceedings of the 15th International Conference of Environmental Ergonomics*, Queenstown, NZ, February, 2013.

[7] Fahy, Rita F., LeBlanc Paul R., Molis, Joseph L., "Firefighter Fatalities in the United States, 2012," *NFPA Journal*, July August 2013.

test from the power used during the test with the PCS. The test method calls for the test to end when the heat gained by the PCS, drops to less than 50 watts above the baseline.

ASTM International Standard F2300-10, *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 with the necessary fitness levels are available. The method assesses the performance of PCSs based on the physiological measurements of core temperature, mean skin temperature, heart rate, oxygen consumption, and whole body sweat rate.

2.4 Emerging Technologies

Advances in miniature vapor compression technology have allowed for the manufacture of PCSs that meet the size and weight requirements for a man-portable system. Digital control systems maintain the circulating liquid at the desired temperature by varying the speed of the compressor. Some of these systems weigh as little as 5 pounds and provide a substantial amount of cooling capacity for a sustained period of time. One manufacturer using vapor compression technology provided information for this market survey. Further reductions in size, weight, and price may make these products more likely to be purchased by first responders.

Research is being done on the effectiveness and portability of PCSs using high-efficiency thermoelectric cooling. Thermoelectric coolers use electrical voltages to create temperature gradients across the thermoelectric device, a phenomenon known as the Peltier effect. Research indicates that these systems may provide effective heat removal.

A vacuum desiccant cooling prototype has also been tested. This system uses vacuum cooling, desiccant cooling, and membrane technology to provide cooling capacity. It employs the latent heat of water evaporation, which is approximately seven times the latent heat of ice melting.

3. PRODUCT DATA

The products in Tables 3-1, 3-2, and 3-3, are mainly vests. This market survey report includes 13 PCM vests, 1 PCM under armor holder, 1 PCM neck cooler, 5 gel/ice vests, 3 circulating liquid vests, and 1 ambient air vest. Their prices range from $35 to $8,000.

Products are listed in alphabetical order by company. Product data was obtained directly from the manufacturer or distributor or their websites. The information obtained has not been independently validated by the SAVER program.

Features in Table 3-1 are defined as follows:

Company indicates the manufacturer or distributor of the PCS.

Product indicates the product name of the PCS.

Cost indicates the price of the PCS rounded to the nearest dollar as quoted by the vendor in U.S. dollars. If a cost range is given, this indicates that the price of the system varies according to options that the buyer may choose.

Phase change material type gives information about the type of material that provides cooling.

Weight fully loaded indicates the weight of the equipment in pounds, including all necessary inserts.

Temperature when charged indicates the temperature in °F of the PCM or gel/ice when fully solidified.

Recharging method lists the equipment or materials needed to activate the PCM or gel/ice to make it ready for use.

Hours before recharging required indicates how long the PCS will stay in a solid state and be able to provide sufficient cooling. The environmental temperature at which this cooling time was measured is indicated if it was provided by the vendor.

Time neeeded for recharging indicates the time in minutes needed to recharge using the indicated equipment or material.

Cost of one set of replacement packs indicates the cost in U.S. dollars to fully fill a garment with new PCM inserts or gel/ice packs.

50 watts of cooling for 2 hours indicates whether the PCS is able to provide 50 watts of cooling for 2 hours, the quantity used in ASTM International F2371-10, *Standard Test Method for Measuring the Heat Removal Rate of Personal Cooling Systems Using a Sweating Manikin.*

GSA schedule indicates if the PCS is available for purchase through the General Services Admininstration.

Table 3-2 has the same features, except the column titled “Phase Change Material Type” is replaced by “Composition of Gel/Ice,” and the column titled “Time Needed for Recharging” is eliminated since all of the gel/ice packs need approximately 5 hours in a freezer for recharging.

Composition of gel/ice lists the substances making up the cooling material.

Information on Company, Product, Cost, and 50 watts of cooling for 2 hours are also provided in Table 3-3. The other features are replaced by the following:

Cooling Technology indicates if circulating liquid or ambient air is used and the specific cooling method.

Weight fully loaded indicates the weight of the equipment in pounds, including vest, cooling unit, and batteries.

Power Source indicates the type of batteries or external power supply used by system. DC refers to direct current.

Battery Run Time indicates how long the PCS will run on one battery charge or set of batteries.

Size indicates the dimensions (length, width, height) of the external cooling unit in inches.

Maximum Ambient Temperature indicates the maximum ambient operating temperature at which the unit can properly function.

Table 3-1. PCSs Using PCM Product Comparison Matrix

Company	Product	Cost ($)	Phase change material type	Weight fully loaded (pounds)	Temperature when charged (°F)	Recharging method	Hours before recharging required	Time needed for recharging (minutes)	Cost of one set replacement packs ($)	50 watts of cooling for 2 hours	GSA schedule
Barbosa Cool Products*	Personal Cool Vest	135	Semi-solid thermal energy storage material	4.0	65	Refrigerator, freezer, ice water	2	Ice water 20, refrigerator 35	110	NA	NA
Black Ice LLC	Cool Collar CCX PCS	35	Hexadecane/ tetradecane	0.5	57	Refrigerator, freezer, ice water	1-1.5	Ice water 20	25	No	No
First Line Technology LLC	PhaseCore® Heat Activated Cooling Vest, Type 28 and Type 32	SWEDE Model 350-475, Standard Model 340-450	PhaseCore nontoxic, nonflammable salt mixture	3.6-4.8†	Type 28: 82.4 Type 32: 89.6	Room temp. air, refrigerator, freezer, ice water, ice	Type 28 2-3, Type 32 5-7	75°F office 95, refrigerator 25, freezer 20, ice water 8, ice 5	SWEDE (22 elements) 240, Standard (16 elements) 180	Yes	Yes
Glacier Tek	Renewable Phase Change Material (RPCM®) Cool Vest	179-199	RPCM	4.4	59	Refrigerator, freezer, ice water, anything below 59°F	2.5	Ice water 20	129	Yes	No
Glacier Tek	RPCM Cool Armor	99	RPCM	Less than 2	59	Refrigerator, freezer, ice water, anything below 59°F	2-2.5	Ice water 20	79	Yes	No
Kappler Inc.	Cool Vest with 600-gram PCM packs	368	Hexadecane	8	60-65	Refrigerator, freezer, ice water	1.5-2 at 110°F	Refrigerator 90, ice water 20	285	No	No
Lakeland Industries	Phase Change Cool Vest®	139	Alkane blend	5	58	Refrigerator, freezer, ice water	2-3	Ice water 30, refrigerator 30	110	Yes	No

Table 3-1. PCSs Using PCM Product Comparison Matrix

Company	Product	Cost ($)	Phase change material type	Weight fully loaded (pounds)	Temperature when charged (°F)	Recharging method	Hours before recharging required	Time needed for recharging (minutes)	Cost of one set replacement packs ($)	50 watts of cooling for 2 hours	GSA schedule
Polar Products Inc.	Cool58™ Phase Change Vest	101-153	Hexadecane and tetradecane	4-7.5	58	Refrigerator, freezer, ice water	2-3	Ice water 20	54-106	Yes	Yes
Steele Inc.	Steele Cool UnderVest with PCM packs, SA500	Vest 75, 4 10 ounce PCM cooling strips 70, 4 18 ounce PCM cooling strips 80	Hexadecane	3 with 10 ounce strips, 5 with 18 ounce strips	58	Refrigerator, ice water	1.7	NA	4 10 ounce cooling strips 70, 4 18 ounce cooling strips 80	Yes	No
Summitstone Corporation	HeatShield II / CM2000	180, includes one layer of panels	Nontoxic, nonflammable proprietary material	5.6 with one layer of panels	72	Freezer	4 at 120°F with 2 layers	Freezer 210	35 for one set of panels	Yes	No
Techniche International	TechKewl™ Phase Change Cooling Vest and Kool Pax™	170	C16 alkane	6	58	Refrigerator, freezer, ice water	1-3	Ice water 45	130	Yes	Yes
Texas Cool Vest	Standard Cool Vest	121	Proprietary material	4.8	65	Refrigerator, freezer, ice water	2-2.5	Ice water 20, refrigerator 60	100	Yes	Yes

GSA General Services Administration
NA Information not available.
* Information for this product is from the vendor website.
† Swede Model 4.5-4.8 pounds, Standard Model 3.6-4.0 pounds
C16 16 carbon

3.1 PCSs Using PCM Technology

3.1.1 Barbosa Cool Products, Personal Cool Vest

The Personal Cool Vest is constructed of a heavy duty nylon mesh outer shell and uses Cool Packs that maintain a 65°F temperature. The vest is available in a variety of colors: safety orange, yellow, blue, green, and black. It has adjustable straps on each side of the garment for a comfortable fit and can be worn directly against the skin without danger of frostbite. Cool Packs are nontoxic and can be used indefinitely.

3.1.2 Black Ice LLC, Cool Collar CCX PCS

The Cool Collar CCX PCS is a lightweight, ergonomically designed neoprene neck wrap which holds a 57°F rechargeable pack that lasts for up to 1.5 hours. A rapid replacement design allows for pack replacement (removal of the collar, removal of the pack, attachment of a new pack, and placement on neck) in 7 seconds or less. This product does not provide 50 watts of cooling for 2 hours but can be worn under a helmet or protective clothing.

Cool Collar CCX PCS
Courtesy of Black Ice LLC

There is a 6-month replacement warranty. The Cool Collar is not currently available on the GSA schedule but may be in the future. If purchased together, one neck wrap and two cooling packs can be purchased for $44.95. One neck wrap, two cooling packs, and a portable soft-sided cooler can be purchased for $74.95. There is a volume-purchase discount available.

3.1.3 First Line Technology LLC, PhaseCore® Heat Activated Cool Vest

PhaseCore Cooling Vests are carriers for PhaseCore elements and are available in two styles (Standard or SWEDE) and three materials (Mesh, Basic, and CarbonX®). The Standard vest has a two-piece, over-the-shoulder design and contains 16 PhaseCore Type 28 or Type 32 elements. The SWEDE vest features a front closure and contains 22 PhaseCore Type 28 or Type 32 elements. PhaseCore 28 activates at 82.4° F and PhaseCore 32 activates at 89.6°F. Since PhaseCore 28 has a lower activation temperature than PhaseCore 32, PhaseCore 28 provides a stronger cooling effect, but for a shorter time. The manufacturer recommends that workers use PhaseCore 28 elements in temperatures less than 110°F and PhaseCore 32 elements in environments greater than 110°F. These elements are made of a nontoxic, nonflammable salt mixture and sealed inside a thermal wrapper. First Line Technology is an ISO 9001:2008-certified manufacturer. PhaseCore 28 elements can last up to 4 hours and PhaseCore 32 elements up to 7 hours, with actual time depending on physical activity, body type, and environmental conditions. PhaseCore elements are designed to self-recharge at room

Standard CarbonX PhaseCore Cooling Vest
Courtesy of First Line Technology LLC

temperature and begin recharging at any temperature below their activation point: Type 28 below 82°F with 75°F or less recommended, and Type 32 under 92°F with 85°F or less recommended. They will recharge more quickly in a colder environment: 95 minutes in an office environment, 25 minutes in a refrigerator, 22 minutes in a freezer, 8 minutes in ice water, and 5 minutes on ice. If ice water is used, the elements must be removed from the vest. The vests are machine washable after removing the elements. The elements can be taken through 7,000-10,000 charge-discharge cycles before they need to be replaced. If an element is damaged in the field, the remaining elements will continue to operate normally, and the reduction in performance will be less than with vests that use fewer, larger elements.

A cooling hat liner, offered with either type of cooling element, is available for $50.00. Volume purchase discounts are offered on quantities of 100-249, 250-299, and more than 1,000 PhaseCore Cooling Vests. There is a 1-year warranty for materials and workmanship under normal use.

3.1.4 Glacier Tek, Renewable Phase Change Material (RPCM®) Cool Vest

RPCM Cool Vests feature side elastic straps and adjust over the shoulder to fit a wide range of body sizes. The vests maintain a constant 59°F temperature for up to 4 hours, depending on the model. They weigh from 4.4 pounds for the standard model to 8.8 pounds for the extended-duration model. They can be washed in a regular laundry. Glacier Tek's RPCM is officially certified "biopreferred" by the U.S. Department of Agriculture and meets the criteria of a "green" chemical as defined by the U.S. Government. It is a nontoxic, bio-based product that is an alternative to petroleum-based phase change materials. RPCM Cool Packs recharge in 20 minutes in ice water or a freezer. They may also be recharged in a refrigerator or any environment cooler than 59°F. The packs can be charged and discharged indefinitely. Packs have been cycled 60,000 times with no change in performance.

RCPM Cool Vest
Courtesy of Glacier Tek

Substantial discounts are available for government, military, and large-volume purchases. Glacier Tek offers a 1-year warranty against manufacturer defects. For military working dogs, Glacier Tek also offers a RPCM Chilly Dog Cool Vest, which weighs 3 pounds, at a price of $129.00. They have adjustable straps to fit a wide range of dog sizes.

3.1.5 Glacier Tek, RPCM® Cool Armor

RPCM Cool Armor reduces the heat stress created by wearing body armor. This product maintains 59°F for 2 hours and recharges in minutes using the same RPCM Cool Packs as the Cool Vest. It is designed to fit comfortably under all major brands of body armor without modification and can be worn directly against the skin. It is not a vest, but a Cool Pack with a holder that is to be worn under body armor. This item does not attach to the body, but attaches to the armor instead. The pack can be replaced without removing

RPCM Cool Armor
Courtesy of Glacier Tek

the body armor or uniform shirt. Cool Armor weighs less than 2 pounds and is ¾ inch thick. It contains no hazardous ingredients, which means that the cooling formula is harmless if it is accidentally ingested or enters the blood stream. The RPCM Cool Pack inside the Cool Armor can be replaced with a recharged pack in under 1 minute.

Substantial discounts are available for government, military, and large-volume purchases. Glacier Tek offers a 1-year warranty against manufacturer defects.

3.1.6 Kappler Inc., Cool Vest with 600-gram PCM Packs

The Cool Vest is a Banox Certified™ vest with 600-gram PCM packs that fit into internal pockets. Banox Certified fabrics are 100 percent cotton fabrics treated with a flame retardant finish. The vest cools to 60°F to 65°F for up to 2 hours at 110°F. It weighs 8 pounds when fully loaded with packs. An 800-gram PCM pack version is available, which provides a longer cooling duration. The vest can be worn with or without a shirt underneath. The vests are washable and reusable. They are available in one size fits all and have adjustable hook and loop closures. The packs can be reused hundreds of times.

Cool Vest with 600-gram PCM Packs
Courtesy of Kappler Inc.

A 90-day warranty for manufacturer defects is offered. There is no volume-purchase discount available.

3.1.7 Lakeland Industries, Phase Change Cool Vest®

This vest uses a cooling material that is a proprietary blend of alkanes. The inserts are nontoxic and nonflammable and can be used many times. The vest provides a 58°F temperature for 2 to 3 hours. It comes in four sizes and has an adjustable shoulder and waist. The vest is available in Banox Certified flame-retardant cotton, Nomex® material, and polycotton. The manufacturer recommends that the user wear a T-shirt or other light shirt under the vest.

There is a volume-purchase discount available.

Phase Change Cool Vest
Courtesy of Lakeland Industries

3.1.8 Polar Products Inc., Cool58™ Phase Change Cooling Vest

The Cool58 is available as a poncho vest and a zipper vest. It can be recharged in a freezer, refrigerator, or ice water. The poncho vest is one size fits most, while the zipper vest comes in four sizes. Both vests are 100 percent cotton and do not require the user to wear an undergarment. The vests use four packs, and these packs are available in three different sizes (0.88, 1.1, and 1.76 pounds each) in order to match the size of the wearer. Loaded with four packs, the total vest weights are 4, 5, and 7.5 pounds, respectively. Prices are as follows: Cool58 poncho or zipper vest with 0.88 pound packs, $100.50; with 1.1 pound packs, $112.56; with 1.76 pound packs, $152.76. The packs can be reused for years with the proper care.

Cool58 Phase Change Cooling Zipper Vest
Courtesy of Polar Products Inc.

A 6-month warranty against defects in materials and workmanship is provided. Neck bands, crown coolers, and torso vests are also available.

3.1.9 Steele Inc., Steele Cool UnderVest with PCM Packs, SA500

The SA500 UnderVest's shell fabric is available in 100 percent polyester microsuede or 100 percent Banox Certified flame retardant cotton. It has four insulated pockets which accept 10- or 18-ounce PCM cooling strips. Four heavy-duty elastic strips allow for size adjustment of the one-size-fits-all vest. The user is not required to wear an undergarment under the vest. The strips can be used indefinitely.

There is a volume-purchase discount available. A 1-year warranty on defects in material and workmanship is offered.

Steele Cool UnderVest with PCM Packs, SA500
Courtesy of Steele Inc.

3.1.10 Summitstone Corporation, Heatshield II and CM2000

Summitstone Corporation's PCSs includes a vest with available leggings. The Heatshield II can be adjusted using VELCRO® fasteners. The CM2000 has a zippered front and features vented mesh construction and tight lacing to provide back support for heavy work. It is available in one size with side adjustments allowing for variations in chest size. The vests use a layered system of cooling panels, which permits additional panels to be added to increase cooling time, e.g., three layers of cooling panels will last 8 hours at 100°F temperature. Cooling panels can also be removed to reduce weight. The vest weighs 5.6 pounds with one layer of panels. The vest should be worn with an undergarment, preferably a T-shirt. The PCM used is a nontoxic, nonflammable proprietary material. The panels are

CM2000 Vest
Courtesy of Summitstone Corporation

shipped dry and must be hydrated for at least 30 minutes and frozen before initial use. They can be purchased hydrated for an extra $10.00 per set.

There is a volume-purchase discount available. Leggings are available for $129.95. A freezer that can cool 24 panels and operates at -30°F is available for $699.00.

3.1.11 Techniche International, TechKewl™ Phase Change Cooling Vest and Cool Pax™

These cooling vests are available in a variety of styles, sizes, and fabrics, and can also be custom made. High-visibility and fire-resistant vests are available. They cool to 58°F and can be reused thousands of times. Cool Pax are activated at any temperature below 58°F and will solidify completely after 45 minutes in ice water. They are sealed inside high-strength polyurethane to ensure they do not leak. It is recommended that the user wear an undergarment under the vest.

Techkewl Phase Change Cooling Vest
Courtesy of Techniche International

A volume-purchase discount is available. Vests have a 30-day warranty, while the Cool Pax has a 1-year warranty. An insulated cooler bag is included in the purchase price of $169.99 for the vest.

3.1.12 Texas Cool Vest, Standard Cool Vest

This vest has adjustable shoulders, easy on and off zipper front, six adjustable side straps, and fits up to a 49-inch waist. The Standard cool packs contain PCM that operates at 65°F and lasts between 2 and 2.5 hours (depending on body type, ambient temperature, and the amount of physical exertion performed). Cool packs charge in ice water in 20 minutes. Recharging takes longer in a refrigerator or freezer. The vest weighs about 4.8 pounds with standard cool packs in place and is available in Supplex, Polly Cotton Twill, or Banox Certified fabric. The user should wear an undergarment under the vest. The packs can be used indefinitely if not punctured or damaged.

Standard Cool Vest
Courtesy of Texas Cool Vest

There is a volume-purchase discount available, with a larger discount for any purchase above $3,000. The vests come with a 30-day money-back guarantee, and the packs are guaranteed for 1 year against manufacturing defects. Heavy-duty and light-weight packs are available. The manufacturer also makes cooling neck bands and medical modular cooling units.

Table 3-2. PCSs Using Gel/Ice Product Comparison Matrix

Company	Product	Cost ($)	Composition of gel	Weight fully loaded (pounds)	Temperature when charged (°F)	Recharging method	Hours before recharging required	Cost of one set of replacement packs ($)	50 watts of cooling for 2 hours	GSA schedule
Polar Products Inc.	Kool Max Poncho/ Zipper Front Vest	95	Water, pulverized cellulose, sodium benzoate	Poncho 4.5, Vest 3.5-5.5 depending on size of user	32	Freezer	2-4	S/M: 8 cold packs: 20 M/L: 9 cold packs: 20 Poncho: 10 cold packs 21 L/XL: 11 cold packs: 21 XXL: 12 cold packs: 22	Yes	Yes
StaCool Industries Inc.	StaCool Industrial Vest	250 (with 2 sets of packs)	Polymer material	7	32	Freezer, dry ice	2.5-3	45	Yes, up to 3 hours	No
Steele Inc.	Six Pocket SteeleVest SA1140	198 with 15 ounce packs, 204 with 27 ounce packs	85% water, 15% food-grade cornstarch	8 for 15-ounce packs, 12 for 27-ounce packs	21-32	Freezer	2-3	48 for 15 ounce packs, 54 for 27 ounce packs	Yes, 270 watts for 2 hours	No
Steele Inc.	Trimlite Four Pocket SteeleVest SA440	182 with 15 ounce packs, 186 with 27 ounce packs	85% water, 15% food-grade cornstarch	5 for 15-ounce packs, 8 for 27-ounce packs	21-32	Freezer	2-3	32 for 15 ounce packs, 36 for 27 ounce packs	Yes, 113 watts for 2+ hours	No
Steele Inc.	Zip Cool-UnderVest SA880	182 with 15 ounce packs, 186 with 27 ounce packs	85% water, 15% food-grade cornstarch	5 for 15-ounce packs, 8 for 27-ounce packs	21-32	Freezer	2-3	32 for 15 ounce packs, 36 for 27 ounce	Yes, 113 watts for 2 hours	No

GSA General Services Administration
S/M small/medium
M/L medium/large
L/XL large/extra-large
XXL extra-extra-large

3.2 PCSs Using Gel/Ice Technology

3.2.1 Polar Products Inc., Kool Max® Vest

The Kool Max vest is available either as a poncho or a zipper-front vest. These vests use frozen, water-based Kool Max cooling packs that are inserted into insulated pockets. The gel material is nontoxic and not irritating to the skin. The vests provide between 2 and 4 hours of cooling, depending on the user's metabolism, level of activity, and ambient temperature. The poncho vest is one size fits most, while the zipper vest comes in four sizes. The poncho vest includes the vest and 10 cold packs; the small/medium, medium/large, large/extra-large and extra-extra-large zipper front vests include 8, 9, 11, and 12 cold packs, respectively. Even though the pockets are cotton and insulated, it is recommended that a light T-shirt be worn under the vest to protect the skin. The vest is available in fire-resistant material. The vest adjusts at the chest, waist, and shoulders using straps with hook and loop attachments. The vest can be cleaned using a mild soap, washed on a gentle cycle, and hang dried. The packs can be hand washed in soap and water. This vest has been tested by Kansas State University and was found to significantly lower heart rate and final body core temperature.[8]

Kool Max Poncho Vest
Courtesy of Polar Products Inc.

Polar Products also makes wrist wraps, neck wraps, and torso vests. There is a 6-month warranty against defects in materials and workmanship.

3.2.2 StaCool Industries Inc., StaCool Industrial Vest

The StaCool Industrial Vest uses 3M Thinsulate™ insulation to protect users from excessive cooling, allowing the vest to be worn directly against the skin. The outer shell is made of Dupont Cordura® nylon and holds three ThermoPaks in front and three in the back. The vest comes with two sets of ThermoPaks, which allows the user to switch sets when needed. The vests come in one size fits all and are fully adjustable at the shoulders, chest, and stomach area. The cooling gel is a polymer material that is safe, nontoxic, nonflammable, and will not cause skin irritation. This vest was developed 15 years ago and was made to withstand the heat and high humidity of Florida. It will provide 2.5 to 3 hours of cooling in a 90°F, high-humidity environment.

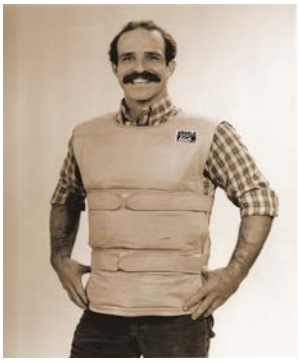
StaCool Industrial Vest
Courtesy of StaCool Industries Inc.

StaCool also makes an UnderVest. A warranty against manufacturer defects is offered. Bulk-order and military discounts are available.

[8] See note 6 above.

3.2.3 Steele Inc., Six Pocket SteeleVest SA1140

The Six Pocket SteeleVest is an over-the-head cooling vest with an optional split shoulder for easy donning and removing. It has a durable 9-ounce, Banox Certified flame-retardant cotton shell with six insulated pockets—three on the front and three on the back of the vest. While there is an inner layer of tricot to protect the user from excessive cooling, it is recommended that the user wear one to two layers between the vest and skin. The vest accepts six 27-ounce or six 15-ounce frozen gel Thermo-strips™. Four adjustable side straps and a hook and loop on the front of the vest allow for universal sizing. The vest can be dry cleaned or washed on a gentle cycle using mild detergent. The vest provides 2 to 3 hours of cooling.



Six Pocket SteeleVest SA1140
Courtesy of Steele Inc.

3.2.4 Steele Inc., TrimLite Four Pocket SteeleVest SA440

The TrimLite Four Pocket SteeleVest is a zip-front vest with a split shoulder closure for easy donning and removing. It has four insulated pockets and four adjustable side straps with a hook and loop on the front of the vest for universal sizing. It accepts both 15- and 27-ounce Thermo-strips. The strips are sectioned and flex easily to fit the torso without impeding movement. Multiple layers of micro-thin, highly breathable insulation reflect heat away from the body. The vest can be dry cleaned or washed on a gentle cycle using mild detergent.

TrimLite Four Pocket SteeleVest SA440
Courtesy of Steele Inc.

3.2.5 Steele Inc., Zip Cool-UnderVest with Thermo-strips, SA880

The Zip Cool-UnderVest's shell fabric is either polyester microsuede or Banox Certified flame-retardant cotton. The vest has four vertical insulated pockets—two in front and two in back. Zippers on the top and bottom of the pockets allow for the easy removal and replacement of Thermo-strips when wearing body armor or protective clothing. Four heavy duty elastic straps allow for size adjustment and freedom of movement. This vest has been tested by Kansas State University and was found to significantly lower heart rate and final body core temperature.[9]

Steele also manufactures neck coolers, wrist coolers, and hat and bra coolers. A 1-year warranty against defects in materials or workmanship is offered. There is a volume-purchase discount available.

Zip Cool UnderVest with Thermo-strips SA880
Courtesy of Steele Inc.

[9] See note 6 above.

Table 3-3. PCSs Using Circulating Liquid and Ambient Air Product Comparison Matrix

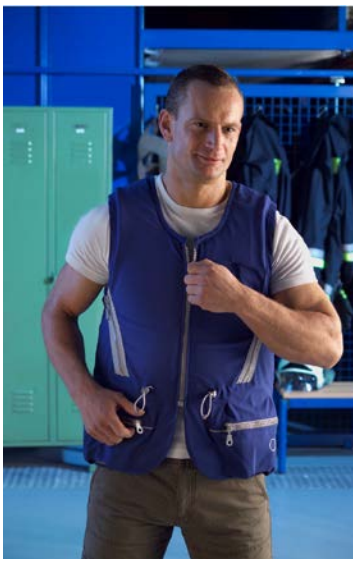
Company	Product	Cost ($)	Cooling Technology	Weight fully loaded (pounds)	Power Source	Battery Run Time (hours)	Size (inches)	Maximum Ambient Operating Temperature °F	50 watts of cooling for 2 hours
Entrak GmbH	ventilationVest	450	Ambient Air (Fan)	2.9*	Rechargeable Li-ion batteries, type 18650 3-cells	6-20†	5.7 x 3.8 x 1.1	185	Yes
Polar Products Inc.	Cool Flow® Vest System	885‡	Circulating Liquid (Ice)	40§	Rechargeable Li-ion batteries, 12 V DC external power supply	4-6	12 x 18 x 12	NA	Yes
RINI Technologies Inc.	RINI Personal Cooling System	8,000	Circulating Liquid (Vapor Compression)	8.4‖	Rechargeable Li-ion batteries, 12 V DC external power supply	4	2.7 x 5.2 x 6.7	140	Yes 150 watts at 95°F
Veskimo Personal Cooling Systems	Veskimo Personal Cooling System Backpack	966	Circulating Liquid (Ice)	11.7¶	Rechargeable Li-ion batteries, 8 AA in quick-change power pack, 12 V DC external power supply	6	21 x 7 x 6	160	Yes 150 watts at 95°F

Li-ion lithium-ion
V DC volts direct current
NA Information not available
* 2 fan units (0.6 per unit), vest (1.1)
† depends on rate of air flow
‡ 15-quart cooler, 8-foot hose, Li-ion battery, fitted vest
§ 15-quart cooler filled to capacity (38), vest (1), Li-ion battery (1)
‖ Cooling Unit (3.9) Battery (3) Vest (1.5)
¶ 4.4 quart backpack filled to capacity, Li-ion battery, vest

3.3 PCSs Using Circulating Liquid and Ambient Air

3.3.1 Entrak GmbH, ventilationVest

The ventilationVest produced by Entrak utilizes ambient air as the coolant. Air is circulated through a spacer fabric by small battery-operated fan units that are placed in outer pockets. The spacer fabric is made of three-dimensional, pressure-resistant flexible fabric. It is permeable to air and serves as a spacer between skin and clothing, allowing for better circulation of air between the user's skin and clothes. Warm air containing moisture from perspiration is continually exchanged for fresh, ambient air thus preventing any moisture buildup inside the vest. The cooling effect is based on evaporation, and the system works best when the user is perspiring.



Entrak ventilationVest
Courtesy of Entrak GmbH

The fan units in the side pockets start at the push of a button. The cooling strength can be adjusted according to the user's needs by activating either one or both air fan units, and each unit's output can be individually adjusted via three ventilation stages. The airflow is evenly distributed even with only one fan running. The maximum air delivered is 400 liters per minute for two units. The volume of air, operating time, and sound level for the three stages are provided in the table below. The system can operate for up to 9 hours on a single battery charge under normal working conditions. The vest can be worn underneath working and protective clothing and is available in sizes from small to extra-extra-extra-large. It can be washed in a standard washing machine at 104°F and air dried. The system uses a rechargeable lithium-ion battery (type 18650, 3-cells) which has approximately a 2.5 to 3-hour charge time. There is an LED display that shows the battery level. NIOSH encourages hearing loss prevention when wearing personal protective equipment (PPE) and recommends measuring the sound level at 1 meter from the PCS in dB(A) (A-weighted decibels). The system has a 40 dB(A) noise level at the high flow rate, which the company claims is very quiet. Information concerning operating time and sound levels at various flow rates can be found below.

Fan Unit in side pocket of ventilationVest
Courtesy of Entrak GmbH.

Entrak offers a 2-year warranty for the ventilationVest. A volume purchase discount is available. This product is not available on the General Services Administration (GSA) schedule.

Stage	Air volume liters/minute	Maximum Operating Time (hours)	Sound Level (dB(A))
low	200	20	30
medium	320	10	36
high	400	6	40

3.3.2 Polar Products Inc., Cool Flow® Cooling Vest System

The Cool Flow Cooling Vest System can be customized by the user. Components include an adjustable, heavy-duty, or fitted tethered cooling vest or a tethered cooling T-shirt; a 9-quart cooler with handles or a 15-quart wheeled cooler with retractable handles; 4 feet or 8 feet of insulated tubing; and an auto-drain accessory. The adjustable, heavy-duty vest is available in sizes from small to extra-extra-extra-large, while the fitted vest's sizes range from small to extra-extra-large. The heavy-duty vest is priced at $795, while the fitted vest is $695. These systems are best for stationary and limited mobility situations, such as for surgeons when operating rooms are kept warm for patient safety, in industrial situations, or for cooling of first responders at break times. The system can be used with 12V DC power source, a rechargeable lithium-ion battery pack, or automobile power. The vest has over 50 feet of insulated lines built into a lightweight vest that weighs 16 ounces with water in the lines. The vest can be spot cleaned by hand with a mild detergent and air-dried. The system will run from 4 to 6 hours before the ice has to be replaced. The temperature control switch adjusts the amount of ice water flowing through the lines. An Arctic Chiller system, which uses a 1/15 horsepower chiller to provide the required cooling, can be purchased for $650 and eliminates the need for filling, refilling, and emptying a cooler of ice and water. The system is filled with distilled water and the chiller is set at the desired temperature of between 40°F and 70°F. The chiller will maintain the vest within +/- 2 degrees for as long as desired.

Cool Flow Fitted Vest
Courtesy of Polar Products, Inc.

9-quart Cooler with Carrying Handle
Courtesy of Polar Products Inc.

There is a 1-year warranty for parts and labor for manufacturing defects only. A volume purchase discount is available. The Cool Flow Cooling Vest System is available on the GSA schedule.

3.3.3 RINI Technologies Inc., RINI Personal Cooling System

The RINI Personal Cooling System is a circulating liquid system that uses refrigeration to provide chilled water to a cooling vest. This PCS employs patented technology in a vapor compression cycle to chill water to 72°F. The water then circulates through a cooling vest worn beneath protective gear, close to the skin. The cool water absorbs heat from the body, which is then released to the system's heat exchanger, maintaining the core body temperature of the user. The chilled water flow to the cooling vest can be maintained at 72°F when operating in a 115°F ambient temperature and at 67°F when operating in a 95°F ambient temperature, providing 150 watts of cooling. The system can operate using batteries, a 12V power supply, aircraft power, or vehicle power. Rechargeable lithium-ion batteries (BB-2590/U), weighing 3 pounds, are recommended. The battery run time is 4 hours. There is also a "half size" battery available with half the run time and half the weight. The circulation and cooling unit can be worn by attaching to a belt, backpack, or a Modular Lightweight Load-carrying Equipment (MOLLE) vest. MOLLE refers to the current generation of load-bearing equipment and rucksacks utilized by a number of North Atlantic Treaty Organization armed forces, including the United States Army and the British Army. The temperature of the circulating liquid can be adjusted from 45°F to 80°F, but this is affected by the ambient temperature. The thin, flexible vests are made from fire resistant materials and are available in extra-small, small, medium, large, and extra-large sizes. A high tube density is used to provide maximum cooling.

RINI PCS
Courtesy of RINI Technologies Inc.

RINI PCS Vest
Courtesy of RINI Technologies Inc.

A volume purchase discount is available and the product comes with a 1-year warranty. The price of $8,000 for the RINI Personal Cooling System is reduced to approximately $7,000 per unit when 15 systems are purchased and approximately $6,000 per unit when 50 systems are purchased. The RINI Personal Cooling System is not available on the GSA schedule.

3.3.4 Veskimo Personal Cooling Systems, Veskimo Personal Cooling System

The Veskimo Personal Cooling System combines a lightweight, breathable vest that is worn under clothing with a 4.4-quart hydration backpack that supplies chilled ice water to the vest via a high-efficiency 12V DC pump. The pump can be powered for over 6 hours on a single charge using a lithium-ion rechargeable battery, (0.36 pounds), for 8 hours using eight alkaline AA batteries, (0.6 pounds) in the quick-change power pack, or continuously when connected to a 12V DC power supply. The lithium-ion batteries can be recharged in 4 hours. The backpack can be filled with up to 7 pounds of ice plus 1 pint or more of water for up to 4 hours of cooling. The actual duration depends upon user activity level and ambient temperature. The ice can be in the form of ice cubes, cylindrical ice blocks, or four ½-liter frozen water bottles.

The cooling rate can be adjusted using the power switch located on the left shoulder strap. The vest provides 150 watts of cooling at 95°F as mentioned in the ASTM International F2371-10 standard. The backpack also serves as a source of drinking water with the pump on or off. The backpack is constructed to military specifications using rugged 600-Denier fabric and has fully adjustable shoulder, waist, and sternum straps with quick-snap buckle closures to comfortably fit all sizes. The vest is made from fast-wicking, quick-drying, highly breathable mesh fabric. Using technology developed at the National Aeronautics and Space Administration, it incorporates a network of over 50 feet of flexible micro tubing. The vest features a zippered front, size-adjustable elastic straps and is available in small, medium, large, and extra-large sizes. Quick-disconnect fittings on a single flexible hose allow for easy connection to the water source.

Veskimo PCS Vest
Courtesy of Veskimo Personal Cooling Systems

Veskimo PCS Backpack
Courtesy of Veskimo Personal Cooling Systems

The vest can also be connected to the Veskimo 9-Quart Hand-Carry Cooler, which measures 11 x 9 x 13 inches to the top of the integral handle, houses the circulation pump, and serves as the ice and water reservoir. A 3-foot or 6-foot long hose connects the vest to the cooler, which contains twice as much ice and water as the backpack, and provides twice the length of cooling time. The cooler system can be purchased for $427. It can be carried by the user but is more suited for use on a motorcycle, all-terrain vehicle, or in a car, and can be powered by any of the power source options. Emergency responders, such as firefighters, can best use this system for quick cooling during breaks. Each firefighter could have their own vest, but fewer coolers would need to be purchased since breaks would be taken at different times. Veskimo sells a quick-disconnect adaptor fitting that allows the vest to plug into any chilled water supply, including multiple-user coolers made by other manufacturers.

There is a 1-year warranty against defects in materials and workmanship. This product is not available on the General Services Administration (GSA) schedule.

4. VENDOR CONTACT INFORMATION

Additional information on the products included in this market survey report can be obtained from the following vendors.

Table 4-1. Vendor Contact Information

Company	Product	Address/Phone Number	E-Mail/Website
Barbosa Cool Products	Personal Cool Vest	9810 Abernanthy Avenue Dallas, TX 75220 (214) 358-6857	barbosacoolproducts@gmail.com www.barbosacoolproducts.com
Black Ice LLC	Cool Collar CCX PCS	9160 Highway 64 Suite 12, Number 301 Lakeland, TN 38002 (901) 937-8129	mike@blackicecooling.com www.blackicecooling.com
Entrak GmbH	ventilationVest	Richtweg 33 Wendelstein, 90530 Germany 4(917) 433-02837	justin.lewing@entrak.dem www.entrak.de
First Line Technology LLC	PhaseCore® HeatActivated Cooling Vest	3656 Centerview Drive Suite 4 Chantilly, VA 20151 (703) 955-7510	sales@firstlinetech.com www.firstlinetech.com
Glacier Tek	RPCM® Cool Vest, RPCM Cool Armor	P. O. Box 120642 West Melbourne, FL 32912 (321) 752-4130	info@coolvest.com www.coolvest.com
Kappler Inc.	Cool Vest with 600-gram PCM packs	115 Grimes Drive Guntersville, AL 35976 (256) 505-4005	usa@kappler.com www.kappler.com
Lakeland Industries	Phase Change Cool Vest®	202 Pride Lane SW Decatur, AL 35603 (800) 645-9291	info@lakeland.com www.lakeland.com
Polar Products Inc.	Cool58™Phase Change Vest, Kool Max® Vest, Cool Flow® Cooling Vest System	3380 Cavalier Trail Stow, OH 44224 (800) 763-8423	polar@polarproducts.com www.polarproducts.com
RINI Technologies Inc.	RINI Personal Cooling System	582 South Econ Circle Oviedo, FL 32765 (407) 359-7138	dan@rintech.com www.rinitech.com
StaCool Industries Inc.	StaCool Industrial Vest	4287 NW 76th Court Ocala, FL 34482-6713 (866) 782-2665	sylvia@stacoolvest.com www.stacoolvest.com
Steele Inc.	Steele Cooling Undervest with PCM packs, Six Pocket SteeleVest, TrimLite Four Pocket SteeleVest, Zip Cool Undervest with Thermo-strips by Steele	P.O. Box 7304 Kingston, WA 98346 (360) 297-4555	steeleinc@silverlink.net www.steelevest.com
Summitstone Corporation	HeatShield II, CM2000	1661 James Wharf Road White Stone, VA 22578 (804) 435-0074	coolingvest@gmail.com www.summitstone.com

Company	Product	Address/Phone Number	E-Mail/Website
TechNiche International	TechKewl™ Phase Change Cooling Vest	1261 Liberty Way Suite A Vista, CA 92081 (888) 823-2665	sales@techniche-intl.com www.techniche-intl.com
Texas Cool Vest	Standard Cool Vest	7211 Regency Square Boulevard Suite 201 Houston, TX 77036 (713) 952-1983	sales@texascoolvest.com www.texascoolvest.com
Veskimo Personal Cooling Systems	Veskimo Personal Cooling System	31982 Paseo de Tania Suite 12, Number 301 San Juan Capistrano, CA 92765 (877) 698-3754	support@veskimo.com www.veskimo.com
Western Fire Supply, a Blue Mountain Ltd dba	Phase Change Cool Vest® (distributor)	11476 Sunrise Gold Circle Suite 1 Granite Bay, CA 95742 (916) 851-9004	steve@westernfiresupply.net www.westernfiresupply.net

5. SUMMARY

Personal Cooling Systems allow first responders to work safely and efficiently in high-temperature environments. Included in this market survey report are 15 PCSs using PCM, 5 gel/ice systems, 3 circulating liquid, and 1 ambient air system. The PCSs range in price from $35 to $475 for the PCM systems, $95 to $250 for the gel/ice systems, $900 to $8,000 for the circulating liquid systems, and $450 for the ambient air system. The gel/ice, circulating liquid and ambient air systems are all vests. Thirteen of the PCM systems are vests, one is a cooling neck collar, and one attaches directly to body armor. The vests are available in different colors, fabrics, and styles, including reflective, camouflage, and fire resistant. The user must determine if the style of vest can be worn comfortably under protective equipment or body armor and how much weight is acceptable. The vests work most effectively if worn close to the body. Cooling neck kerchiefs, head coolers, and leggings are also available. Some vendors make cooling vests for the dogs that may accompany first responders. The gel/ice, circulating liquid, and ambient air systems are all vests.

Systems that use PCM technology provide a limited amount of cooling, and are effective for a few hours. PCM systems do not shock the wearer with excessive cold, do not cause condensation, and are unlikely to cause vasoconstriction. They can be recharged in 20 minutes in ice water. Gel/ice systems may provide more cooling for a longer period of time. They usually require the user to wear an undergarment since they cool to 32°F. Condensation and vasoconstriction are potential problems if used for extended periods of time. Their main disadvantage is that they require a freezer and up to 5 hours to recharge. PCMs can range from potentially skin irritating, flammable paraffins to nontoxic renewable substances. Gel/ice materials are usually nontoxic and nonirritating to the skin if the packs were to break.

Studies done at Kansas State University show that circulating liquid systems and ambient air systems provide significant amounts of cooling.[10] The circulating liquid systems significantly reduced the test subjects' body core temperatures, heart rates, oxygen consumption, sweat rates,

[10] See note 6 above.

and skin temperature when worn under PPE. Most of the ambient air systems decreased body core temperature only slightly, but did significantly lower the test subject's heart rate, skin temperature, and oxygen consumption under PPE when compared to wearing no PCS. The subjects were also able to perceive positive differences in their comfort while wearing the air circulation systems.

One of the possible advantages of the liquid-cooled system when used under protective clothing is its ability to increase coverage of the body including the limbs and the neck/head area. Studies show that the cooling rate is significantly increased by enlarging the cooling garment coverage area. Other studies found that air-cooled systems were preferred by users, perhaps because of their low weight and no danger of leakage.[11]

Cooling duration of any PCS is affected by the ambient environment, an individual's physiology, workload, and the amount of protective clothing worn. The purchaser must look at his needs, including the price, when purchasing a PCS.

[11] Bomalaski, S.H. Chen, Y.T, Constable, S.H. "Continuous and Intermittent Personal Microclimate Cooling Strategies," *Aviation Space and Environmental Medicine*, 1991.