US ARMY SOLDIER SYSTEMS CENTER
Protecting Those Who Serve

THE WARRIOR

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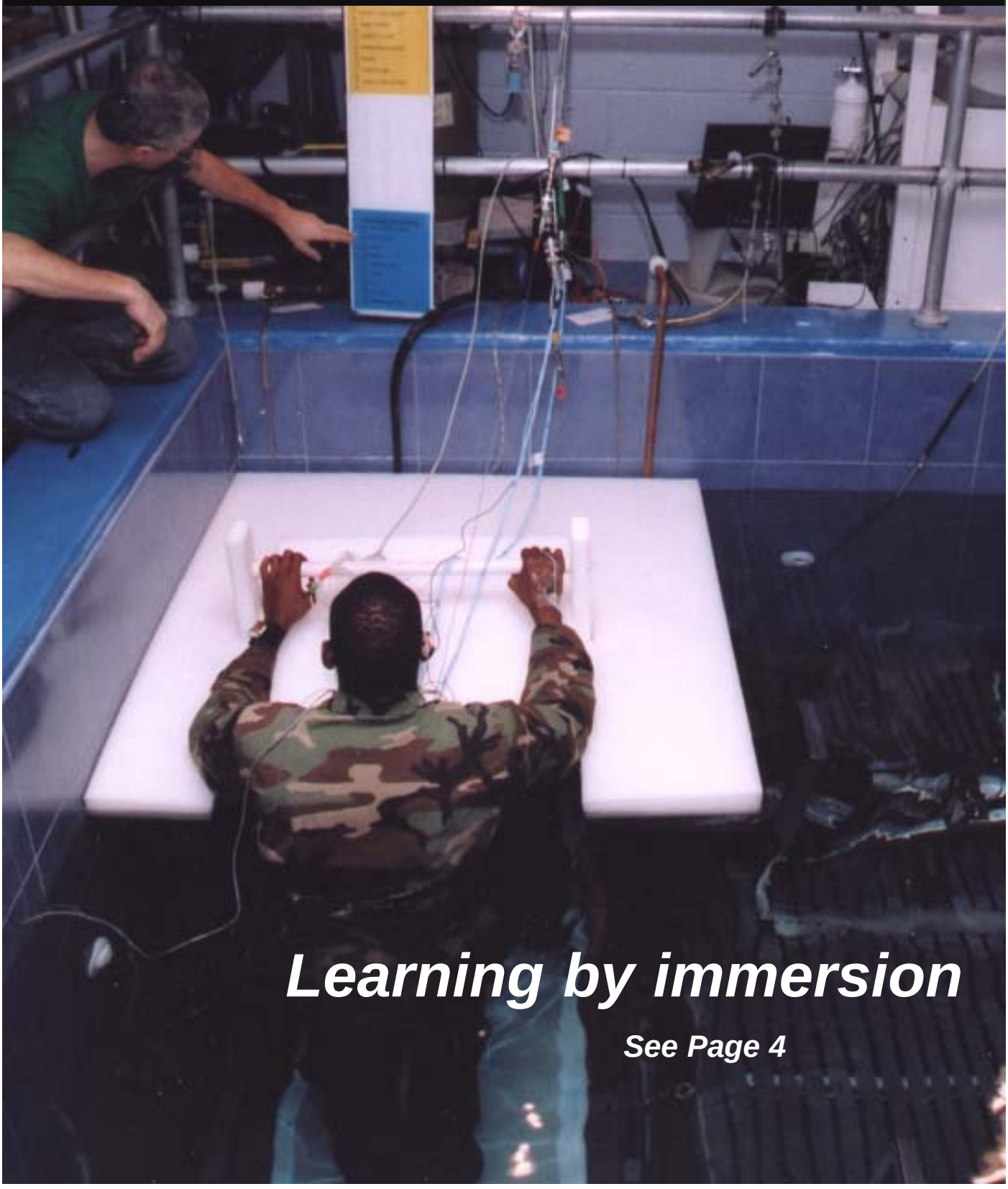

Learning by immersion

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Cover photo: Vincent Forte, research biologist at USARIEM, asks Pvt. 2 Sacorah Tillman, a human research volunteer, to rate his exertion and thermal sensation while walking on the Water Immersion Facility treadmill in cold water. (Warrior/Underhill)

THE WARRIOR
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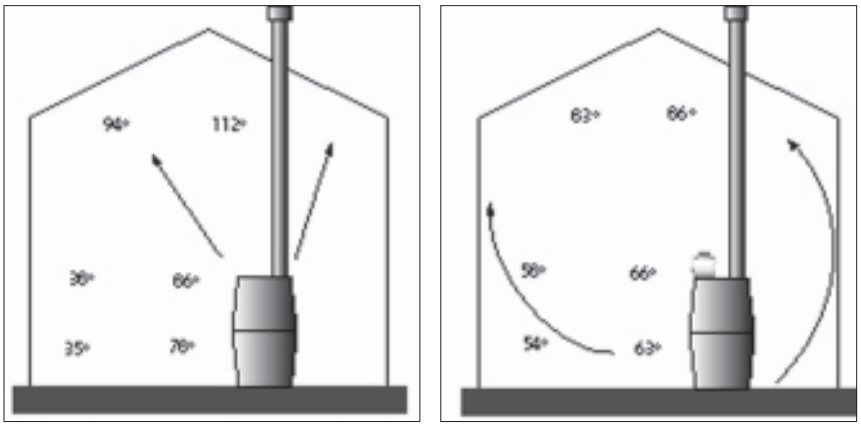
Fan distributes tent heat

At first glance, the self-powered Thermoelectric Fan used with the Army's Family of Space Heaters may appear to be a high-priced air mover.

However, when used with non-electric space heaters, the fan/tent heater combination is the most inexpensive option available to Army units for temporary space heating, costing several thousand dollars less than electric-powered forced hot air systems.

The fan was conceived and developed by the Shelters Team of Product Manager-Force Sustainment Systems at the U.S. Army Soldier Systems Center in Natick, Mass., as an accessory to space heaters that operate on liquid or solid fuel. It's manufactured by Aspen Systems, Inc. in Marlborough, Mass.

In uninsulated structures, such as tents and barracks, the forces of natural convection are so strong that air heated by the stove quickly rises to the ceiling, leaving the area near the floor much colder.



Shelter temperatures with a heater are depicted without the thermoelectric fan (left) and with the thermoelectric fan.

With the fan, heated air is circulated downward creating more even heat distribution.

Testing conducted in the Soldier Systems Center arctic chamber at minus 60 degrees F showed that the fan can increase the temperature 1 foot off the floor by more than 20 degrees F.

This is important because soldiers sleep on or near the floor, and the most difficult parts to keep warm are the feet.

"With the fan we can have the stove barely on and it will warm you throughout the tent, whereas before you had to be right on the stove to stay warm, and your backside was still cold," said Staff Sgt. Chris Harder in Fort Gordon, Ga. "I wish I had these in my unit over in Korea. It would make a huge change in wintertime comfort."

When placed on a heater surface, the self-powered fan converts a small amount of heat energy directly into electricity to drive the fan's impeller. It improves the performance of the heater by creating warmth throughout a larger area with the same fuel consumption, or it can heat the same area with less fuel.

Reduced fuel consumption, primarily JP-8 or diesel, is an important advantage because fuel must be transported along with the field unit, costing the Army as much as $12-$20 per gallon.

Logistic fuel is considerably more important than ammunition at every point along the battlefield except at the leading edge of the fighting, and even there fuel is more valued from time to time, according to Gen. Paul Kern, U.S. Army Materiel Command commander, speaking at the Society of Automotive Engineers World Congress in March 2003. Fuel use is critical to the Army because fueling stations are remote in a combat zone.

In cold climates, the Army has estimated that a single fan can save as much as 320 gallons of heating oil in one heating season.

Actual results depend on the local climate and annual "degree days," which is the difference between 65 degrees F and the day's average temperature.

Since the fan's introduction in 2000, the Defense Logistics Agency (DLA) has received orders for more than 6,000 fans.

Units can purchase the fan, currently priced at $590, through the DLA Web site at www.dscp.dla.mil or order it through the MILSTRIP system.

File photo

The Thermoelectric Fan sits atop the Space Heater Arctic. Electricity to drive the impeller is produced through heat energy.

Pvt. 2 Sacorah Tillman, a human research volunteer, focuses on a cognitive task while walking on a treadmill in the Water Immersion Laboratory tank at USARIEM. The treadmill can be adjusted to reflect varying depths soldiers encounter while wading through a swamp. (Warrior/ Underhill)

Soaked

Water Immersion Lab measures responses to heat, cold

By Curt Biberdorf
Editor

If the 14-foot depth of the Water Immersion Laboratory tank at the U.S. Army Research Institute of Environmental Medicine (USARIEM) seems excessive, there's a good reason for it.

"Visitors are always surprised at how deep it is, but once (the water) gets to temperature, we can keep it at that temperature within a few tenths of a degree," said John Castellani, a research physiologist in USARIEM's Thermal and Mountain Medicine Division. "That's the benefit of a deep tank."

Researchers at USARIEM, located at the U.S. Army Soldier Systems Center in Natick, Mass., have been using the laboratory to evaluate human responses to cold or hot environments for a variety of studies since the USARIEM building was constructed in 1968. Renovated in 2000, the lab's premier feature is its 10-foot by 10-foot stainless steel tank filled with 10,000 gallons of chlorinated water.

Besides water depth, the facility is unusual for its ability to test humans exercising on a single underwater walking treadmill or with two cycle ergometers while sitting on accompanying bolted-down stainless steel chairs.

Each type of exercise machine is independently operated and raised or lowered on separate platforms into water with an operational temperature range of 41-122 degrees F, although the majority of human exposures in test protocols range from 59-104 degrees F. Each cycle ergometer has a moveable plate system to adjust to individual leg length, and resistance is adjusted by attaching or removing fins to the wheel.

Human research volunteers are connected to a data acquisition system, a computer nearby on the platform that surrounds the tank, to measure and record physiological status.

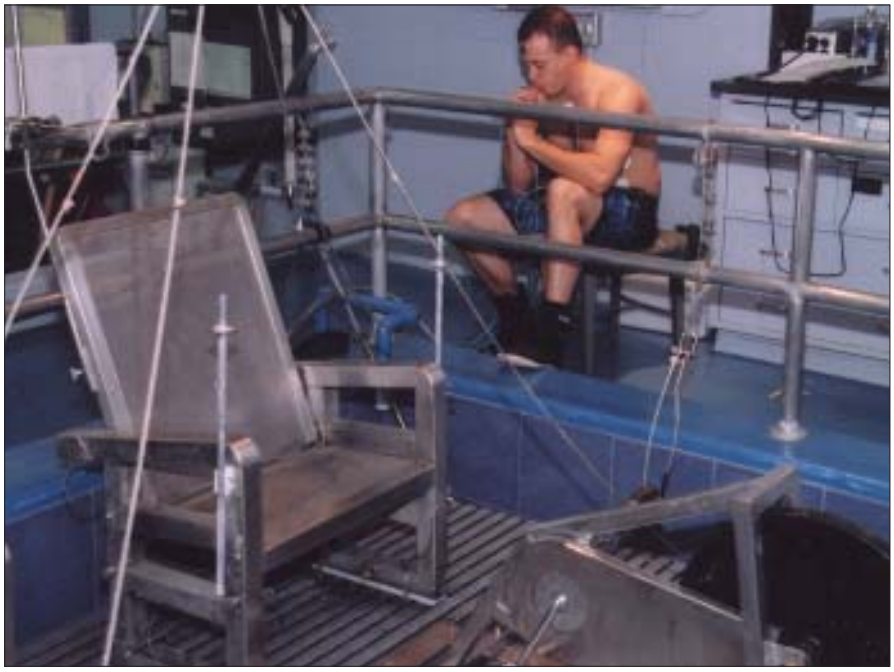
Work in the facility has been wide-ranging. The lab helped validate the core body temperature pill against conventional methods of measuring body temperature. Sometimes the exercise equipment is untouched, as with one nutrition study where the human research subjects sat still in the water.

Nearly five years ago, a commercial hot tub was acquired as a rewarming pool to help test subjects raise their body temperature quickly after soaking in chilly water, and the cold is what research has focused on in recent years.

"We're interested in how hypothermia affects humans," Castellani said. "This facility works out well because it gives you a great place to recreate a cold or cold-wet environment."

Water takes away heat 25 times faster than air, which makes it easier for researchers to reduce core body temperature without risking a cold injury that could occur in an air chamber, he said.

Motivation in studying hypothermia was spurred after four Army Rangers died while going through Ranger school at Eglin Air Force



Pvt. 2 Lance Casey, a human research volunteer, fills a tube with saliva before entering the Water Immersion Laboratory tank. Casey was participating in a sedentary cold exposure evaluation to test the affect of tyrosine supplementation on cognitive performance during cold stress. (Warrior/ Underhill)

Base, Fla., in 1995. Scientists used the water immersion lab along with the climatic chambers to pursue research on how cooling affects performance.

A repeated immersion study in 1996-1997 simulated what happens when a soldier enters the water for two hours at a time and then emerges, three times per day. By the second and third immersion, researchers learned that body temperatures decreased because the test subjects couldn't shiver as well.

Researchers also used the facility in studies to learn if exercise fatigue causes thermoregulatory fatigue. Human research volunteers exercised or remained motionless in the water, which was then followed by cold air exposure. Those exercising and fatigued had a lower body temperature because they could not keep their body heat in as well.

"The idea is to feed data into our cold (temperature) models. We're trying to add fatigue factors into the existing model, which is now good, but we're building on it," Castellani said.

The treadmill, a relatively new addition, is helpful because it can simulate wading in a swamp, which is more realistic than the cycle, said Castellani. Researchers can vary the treadmill speed, water temperature and, by raising or lowing the platform, vary the water depth to test responses at different points along the body.

A study that has just begun is looking at how long people can stay in water at different depths and temperatures. A second part of the study will take hypothermic human research volunteers into a cold chamber to test their cognitive and physical performance through a series of Special Operations Command tests.

"We don't have much information on this at the temperatures and depths we're looking at," Castellani said. "We've been able to understand that stressors soldiers undergo cause a degradation on thermal regulation. That information will help us design better physiological models."

Ultimately, the idea is to be able to predict under what conditions a soldier declines in performance and may become a casualty, he said, giving troops the information to make the right decisions and avoid harm.

Warrior/Underhill

Pvt. 2 Lance Casey, a human research volunteer, indicates he is still OK while sitting on one of two stainless steel chairs lowered into the Water Immersion Laboratory tank. Water temperatures for this study dipped into the 50s.

Welcome warmth

'Family' available to heat military tents safely, efficiently

Heating tents safely, effectively and efficiently is now much simpler thanks to the Family of Space Heaters (FOSH) developed by Product Manager-Force Sustainment Systems located at the U.S. Army Soldier Systems Center in Natick, Mass.

The FOSH uses the latest advances in combustion, power generation and microprocessor technology to provide comfort and protection for soldiers, supplies and equipment in tents during cold weather operations in the field.

The FOSH replaces the old M-1941 "Pot Belly" and M-1950 "Yukon" heaters from the World War II-era and eliminates the serious operational deficiencies and safety hazards associated with these antiquated heaters.

While many seemingly attractive commercial space heaters are available in today's marketplace, they are unjustified from a safety, performance and economic perspective, and military units should replace their stock of these heaters with standard vented military heaters.

Commercial unvented kerosene or propane-fueled heaters that release exhaust directly into the living space present a serious risk of injury or death to soldiers.

Kerosene heaters "are intrinsically dangerous and should not be used in field environments," according to the U.S. Army Center for Health Promotion and Preventative Medicine. Army Regulation 420-96 restricts the use of unvented space heaters in living quarters or enclosed locations where soldiers sleep, and the U.S Army Safety Center advises commanders not to allow the use of these heaters where soldiers work or sleep.

Besides safety hazards, commercial heaters do not meet military requirements that are satisfied with the FOSH. Some of the key capabilities of the FOSH include:

■Operation without electrical power.

Warrior/Underhill

The Space Heater Small is intended for the Soldier Crew Tent.

■Multi-fuel operation on diesel, JP-8, JP-5, kerosene, wood or coal.

■Efficient, clean-burning combustion requiring little maintenance.

■ Operation in temperatures down to minus 60 degrees F.

■Self-contained, lightweight, portable, rugged and simple to operate.

■ Exhaust vented outside the tent.

■Interfaces with and meets heating requirements for all standard military tentage.

The FOSH consists of the Space Heater Small (SHS), Space Heater Medium (SHM) or H45, Space Heater Arctic (SHA) and Space Heater Convective (SHC).

The SHM, SHA and SHS are non-powered radiant heaters that operate inside the tent, and the SHC is a self-powered convective heater that operates outside the tent. The Thermoelectric Fan (TEF) is a FOSH accessory used with the SHM and SHA heaters to circulate heated air inside the tent.

The SHM, SHA and SHS heat through radiation and natural convection. They use a newly-developed vaporizing burner tube technology that overcomes major combustion and safety problems plaguing the non-powered heater industry during the past 50 years.

In the old-type heaters, fuel would pool in the bottom of the burner to be vaporized and burned. If fuel entered faster than it could be vaporized, the burner would flood and the operator would end up with a "runaway" heater.

The patented new burner design vaporizes all fuel within the confines of a tube and eliminates pooling of raw fuel during operation and the possibility of flooding the pot.

It also provides a multi-stage liquid-to-vapor combustion process that results in much cleaner, more

Warrior/Underhill

The Space Heater Arctic is designed for tents with 100-200 square feet of floor space. All components are self-storing.

Warrior/Underhill

The barrel-shaped Space Heater Medium is used for the Army's larger tents. It yields a maximum of 45,000 BTU.

efficient combustion requiring much less burner maintenance.

A patented multi-fuel control valve is incorporated into each heater, which provides a new capability to compensate for dissimilar fuel viscosities and maintain a consistent flow rate among the various types of liquid fuels and temperatures encountered in the field. The addition of a sight glass also allows the operator to view the flame and heater operation without the need to open the lid.

The SHC is the most advanced of all four heaters. It is a self-powered, thermoelectric heater that provides forced hot-air circulation without external power normally supplied by a field generator.

The SHC generates its own electrical power, without any moving parts, through thermoelectric modules located in the combustion chamber that convert waste heat into electricity. The internal generation of electrical power gives the SHC the extra capabilities of single switch operation, completely automatic safety and temperature controls, operation without the need for a fire guard and significantly higher combustion efficiencies all without an external power supply.

To troubleshoot, the SHC comes equipped with a remote intelligent control box that tells the operator when there's a problem and how to fix it.

All fielded FOSH units are available through the Defense Supply Center Philadelphia (DSCP).

Warrior/Underhill

The Space Heater Convective is used with any tent. Unlike the others, it generates forced-air heat.

Space heaters by the numbers

Listed below are some of the specifications of the individual heaters. Costs are estimated.

Small Heater

Intended for the Soldier Crew Tent, the SHS has a maximum output of 12,000 BTU and completely self-stores all its accessories.

NSN: 4520-01-478-9207
Size: 16" L x 9" W x 14" H
Weight: 35 pounds
Cost: $660

Arctic Heater

Designed to heat the 5 and 10-man Arctic tent and other shelters with a floor area of 100-200 square feet, the SHA has a maximum output of 25,000 BTU and is completely self-storing.

NSN: 4520-01-444-2375
Size: 17" L x 9" W x 17" H
Weight: 41 pounds
Cost: $780

Medium Heater

The barrel-shaped SHM or H45 is intended for the larger GP, MGPTS, MCPS and TEMPER tents and delivers a maximum of 45,000 BTU. An 80,000 BTU model with the same footprint should be available in about two years.

NSN: 4520-01-329-3451
Size: 18" diameter x 24" tall
Weight: 65 pounds
Cost: $550

Convective Heater

The SHC can be used with any tent and has an output of 35,000 BTU. A 60,000 BTU model with a similar dimensions and weight should be available in about two years.

NSN: 4520-01-431-8927
Size: 40" L x 14" W x 18" H
Weight: 78 pounds
Cost: $6,700

Personal coolers downsized

By Curt Biberdorf
Editor

Every soldier will carry some high-temperature relief when a microclimate cooling system is incorporated into the upcoming Objective Force Warrior uniform.

Microclimate cooling has been researched and developed at the U.S. Army Soldier Systems Center in Natick, Mass., since the 1980s, beginning with the Portable Vapor Compression System, a system shaped like a vacuum cleaner canister weighing 27 pounds, leading now to a couple of prototype compact systems weighing less than 5 pounds that resemble an oversized brick.

Engineers on the Chemical Technology Team are focused on having a system that weighs less than 4 pounds by 2008 and ultimately a system weighing less than 3 pounds by 2015 that will still provide the desired cooling to enhance soldier safety and performance.

"Cooling is a medical and safety issue," said Brad Laprise, a mechanical engineer. "Comfort is a by-product. You'll never feel like you're in an air-conditioned room (with these systems), but the idea is to mitigate the soldier's heat stress, allowing them to do their jobs safely and more effectively."

Cooling can also be a force multiplier because troops can work longer without taking frequent breaks necessary because of high ambient temperatures. It also can reduce the logistics load by decreasing the amount of drinking water, said Walter Teal, a chemical engineer.

Microclimate cooling systems of various sorts are now used for different needs.

In 1989, sailors aboard ships started wearing a vest that holds ice packs slipped into its horizontal pockets front and rear. Explosive Ordnance Disposal technicians and those encapsulated in outfits protecting them from toxic agent exposure use the Personal Ice Cooling System, which pumps ice-cold water from a 2-liter bottle carried by the individual through a tube-lined cooling garment. M1 tanks and Bradley infantry fighting vehicles have built-in systems that circulate filtered and conditioned air through a Natick-designed vest worn by crewmen.

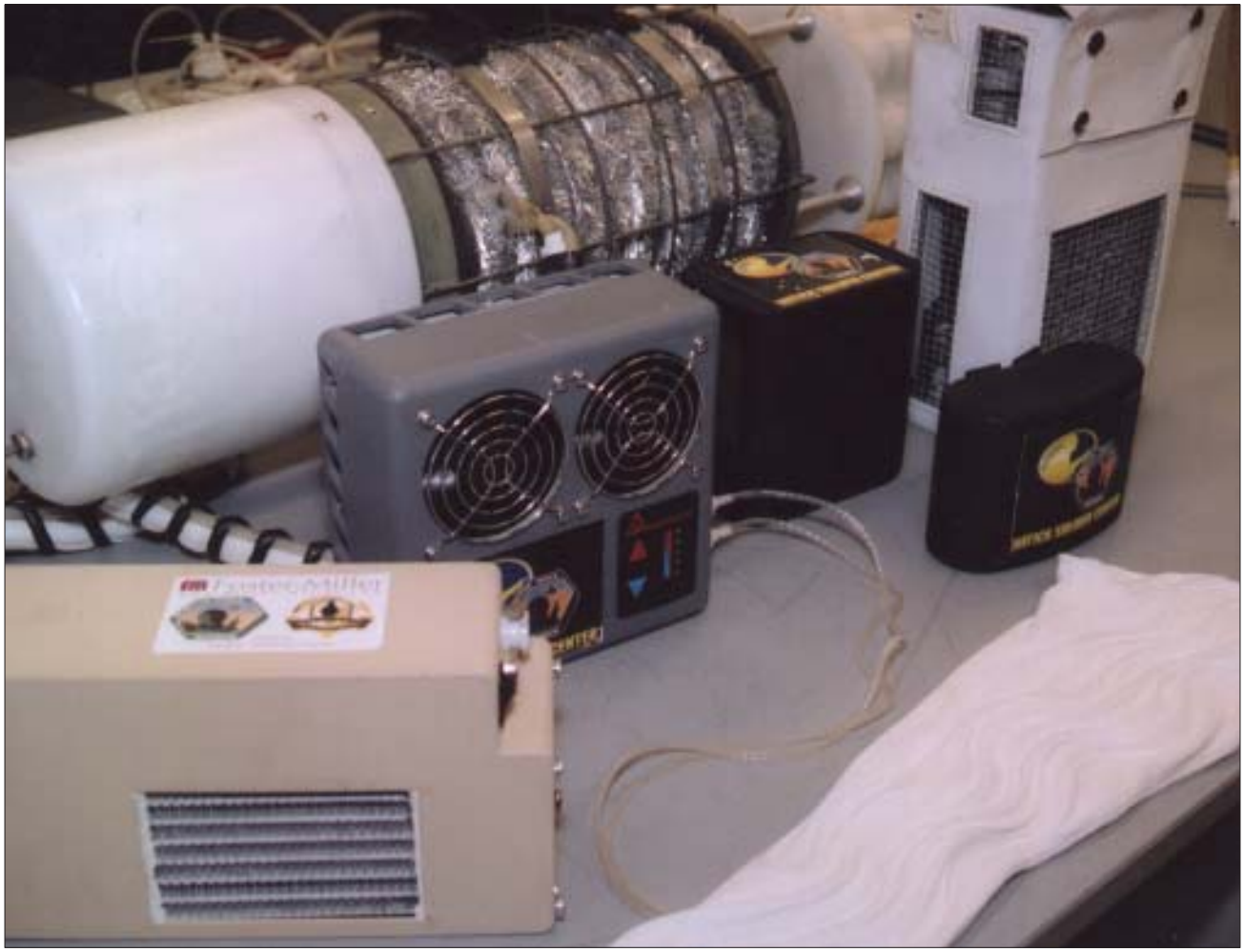
Warrior/Biberdorf

Two working personal cooler prototypes weighing less than 5 pounds have been developed in the latest step to downsizing the system toward an ideal size and weight.

Warrior/Biberdorf

These non-functional models show the future size goals for microclimate cooling systems. Engineers plan on having a system weighing less than 4 pounds by 2008 and less than 3 pounds by 2015.

The latest application of microclimate cooling will benefit Army helicopter pilots beginning next year, Laprise said. From the initial Portable Vapor Compression System to an intermediate unit weighing about 21 pounds, a system called the Advanced Lightweight Microclimate Cooling System weighing 6.6 pounds was developed by 1997, eventually leading to the Air Warrior Microclimate Cooling System program. Built



Warrior/Biberdorf

Microclimate cooling systems, which function like a refrigerator or air conditioner, started with the Portable Vapor Compression System (upper left) and was significantly downsized with the Advanced Lightweight Microclimate Cooling System (upper right). The system works together with a separate power source (not shown) and a cooling garment, demonstrated by the white sleeve (lower right).

into the helicopter, the system is worn in conjunction with a new stitchless cooling garment also designed at Natick.

In testing, pilots using the cooling system could safely extend their mission from 1.6 hours to no less than 5.3 hours, according to Teal.

Still, what works for pilots in their aircraft isn't desirable for a dismounted soldier. Laprise said it's impossible to have one microclimate system for everyone.

The personal coolers designed by Aspen Systems, Inc. in Marlborough, Mass., and Foster-Miller in Waltham, Mass., are unique prototypes using the same technology as the Advanced Lightweight Microclimate Cooling System but in a smaller package.

"These prototypes are stepping stones. The next step is to take the lessons learned from the Aspen and Foster-Miller units and go to something smaller," Teal said. "We know we are pushing the envelope of vapor compression, but we think there are things we can do to lower the weight and power use."

Vapor compression technology works the same way as a refrigerator or air conditioner. It's composed of a compressor, condenser, evaporator, thermal expansion tube, fan and pump working to move heat to the ambient environment. In the case of microclimate cooling, liquid is chilled and pumped through a vest lined with a network of tubing, removing excess body heat.

The Foster-Miller prototype provides 110 watts of cooling at 95 degrees F ambient temperature and weighs 4 pounds. The Aspen prototype weighs 4.65 pounds and provides 120 watts of cooling under the same conditions. Both require 50 watts of power, but engineers hope to achieve similar cooling capacity with only 30 watts of power in the future.

Although 300 watts of cooling is ideal, at least 100 watts of cooling is needed to lower core body temperature according to studies they've seen, Teal said. Lower cooling capacity is a trade-off for reduced weight.

Shrinking size an inch or two and trimming a few ounces here and there will work for the next phase, but Teal said breakthrough technology is needed to achieve the most compact cooler for Objective Force Warrior.

"Taking off those last two pounds will take more effort than the first 22 pounds," he said.

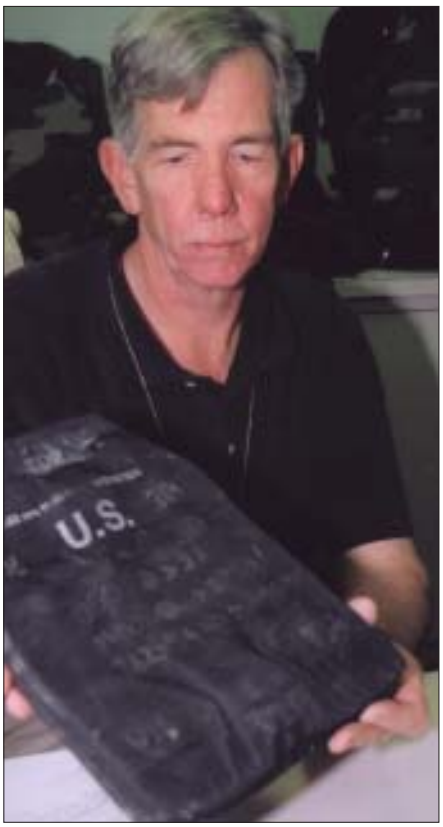
Body armor today has achieved high levels of protection, but it's still a heavy part of the troop load. New ballistic fibers may cut the weight significantly on the quest for...

Better 'battle rattle'

Story and photos by Curt Biberdorf

Two new fibers are vying to one day replace the respected but heavier Kevlar, the staple of body armor for decades, as the Army strives to enhance mobility by reducing the soldier load.

Body armor is one of the more riveting individual equipment successes, especially from the ongoing conflicts in Afghanistan and Iraq, with reports of dozens of saved lives directly attributed to the bullet and shrapnel-halting ability of the helmet, flexible vest and rigid chest plate combination worn by troops.



Philip Cunniff, a research mechanical engineer with the Ballistics Technology Team, holds a small arms protective insert that successfully stopped multiple rounds during testing.

Even though it protects well, body armor ranks with water, ammunition and weapon as the heaviest items worn or carried by troops, according to engineers on the Ballistics Technology Team at the U.S. Army Soldier Systems Center in Natick, Mass.

"The Army is putting the best available armor materials into soldiers' armor," said Philip Cunniff, a research mechanical engineer. "Part of our work in the Ballistics Technology Team is to develop new materials and techniques to lighten the load of those armor systems."

Body armor technology has advanced in the past century to protect the head and torso against high-velocity handgun bullets and fragmenting munitions, such as those from artillery shells, mortar shells, mines and grenades. Lightweight small arms protection is also now available for the torso.

The nylon "flak" vest for ground troops and steel helmet from the 1960s were replaced by Kevlar vests and helmets during the 1980s in a product called Personnel Armor System, Ground Troops (PASGT). At the users' request, performance increased with the PASGT system but weight remained about the same, according to Cunniff.

The next major change was in the 1990s with an improved version of Kevlar that helped lighten the vest by 25 percent and increased ballistic protection.

The team's objective is to reduce the weight again, this time by 25-30 percent, without losing performance. Zylon and M5 fibers show potential in meeting or exceeding that goal.

Zylon, a commercially-available fiber first developed by the Air Force in the 1980s and now produced in Japan, turned in a solid performance in testing, said Cunniff. A prototype helmet made last year with Zylon was developed as part of the Human Systems Defense Technology Objective for Ballistic Protection for Improved Survivability. The Zylon helmet weighs 1.79 pounds vs. 3 pounds for the PASGT at the same protection levels.

Cunniff said two possible roadblocks with Zylon are environmental degradation and the law requiring certain military products to be manufactured in the United States with domestic materials. Zylon has shown to break down with exposure to light, high heat and humidity, al-

Zylon (left) and M5 fibers are shown on spools. Both bring potential in reducing the weight of traditional Kevlar body armor.

Greg Kreinsen, a physical science technician with the Ballistics Technology Team, counts layers of Kevlar (top right) trims the edges (above) and sews them together (below) to replicate the soft body armor worn behind a ballistic plate in preparation for testing. Kreinsen removes an experimental body armor plate from an hydraulic press (bottom right).

though Cunniff said there may be solutions to these problems.

An alternative material to Zylon is M5, an ultra-high performance fiber developed by Magellan Systems International in Bethesda, Md.

According to a mathematical model of Cunniff's for the estimation of impact performance based on the mechanical properties of armor materials, M5 appeared to provide exceptional impact performance.

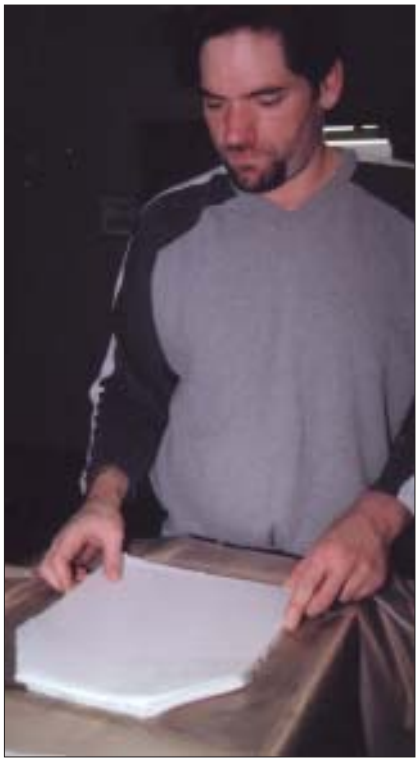
His model indicated that M5 could cut weight by at least 35 percent compared to currently available fragmentation armor at the same protection level. So far, the ballistic impact test results with a limited, relatively low-strength sample of M5 are glowing.

"We shot it, and it came out better than we expected," Cunniff said. "We found there was something wrong with the model; we underpredicted the performance of the material. Of everything we looked at, it looks like (M5) will be a really big improvement in reducing the weight of armor."

Another feature of M5 fiber is excellent thermal and flame protection. Besides helmets, fragmentation vests and composites for use in conjunction with ceramic materials for small arms protective plates, M5 fiber could also be used for structural composites for vehicles and aircraft.

"The military market for ballistic material is cyclic," Cunniff said. "The beauty of this fiber is that it should have a lot of other markets when Army demand falls. We're hoping it becomes cost-competitive to Kevlar."

The plan is to acquire sufficient quantities of M5 fiber by next fall to make a prototype helmet, vest and small arms protective plate.



"Then we can find out how well high-strength M5 performs and find out what kind of armor we can develop for Objective Force Warrior and the Army," Cunniff said.