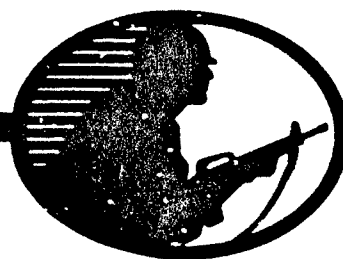


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EVALUATION OF FIVE COMMERCIAL MICROCLIMATE COOLING SYSTEMS FOR MILITARY USE



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ABSTRACT

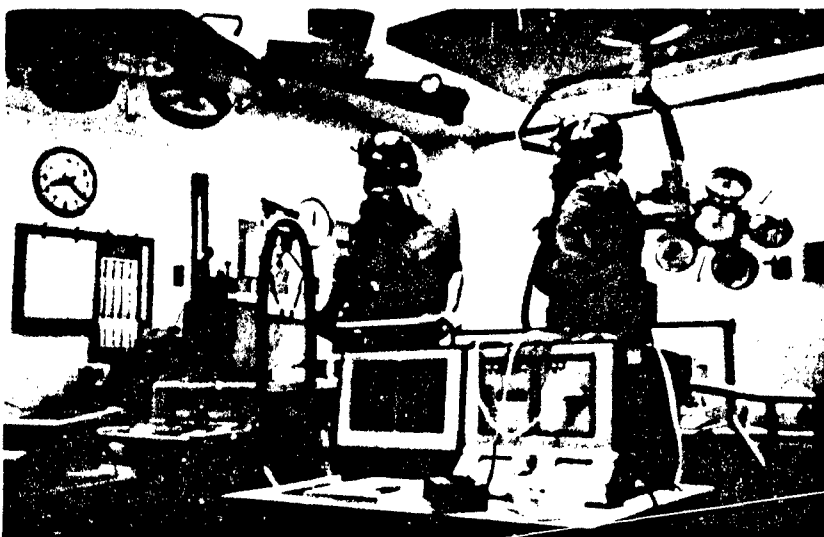
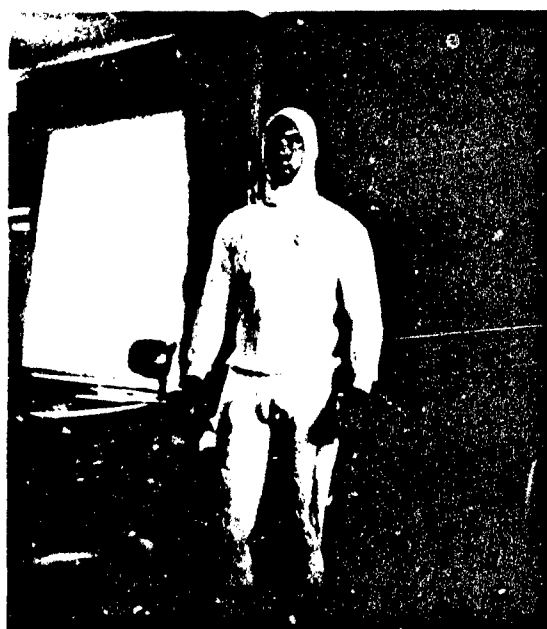
The US Army Natick Research, Development and Engineering Center (NATICK) conducted laboratory and field evaluations to examine four ice-based portable cooling systems and one thermoelectric vehicle mounted cooling system, to assess and compare their performance under laboratory and field conditions.

There were three battery-operated circulating liquid cooling garments (LSSI Mark VII, EX-OTEMP CD-2 & ILC Dover 19M1), a passive frozen gel pack vest (STEELE), and a thermoelectric circulating liquid cooling garment (Koslow Technology M-10).

The thermal manikin tests were conducted in a 35°C (95°F), 5% relative humidity, environment with the manikin surface temperature at 35°C (95°F). The manikin was dressed in the Battle Dress Overgarment (BDO) chemical ensemble in all of the tests.

Two army helicopter pilots (in AUIB, in UH-60 simulator), three EOD personnel (in BDO, M-3 TAP & EOD Bomb suit), two air force fire fighters (in BDO), two air force rapid runway repair personnel (in BDO), and two army decon personnel (in BDO), took part in five field evaluations. These personnel provided information related to compatibility, mobility, ease of operation and donning and doffing.

All five systems provided cooling ranging between 85 and 160 watts and proved adequate in the field evaluation. Each of the cooling system has logistical concerns. The ice based systems require a supply of ice. The battery-operated systems, LSSI, ILC DOVER, and EXOTEMP, require battery storage and recharging. STEELE requires more freezer space than the others systems for its coolant. The KT system requires direct electrical input from an external power source.

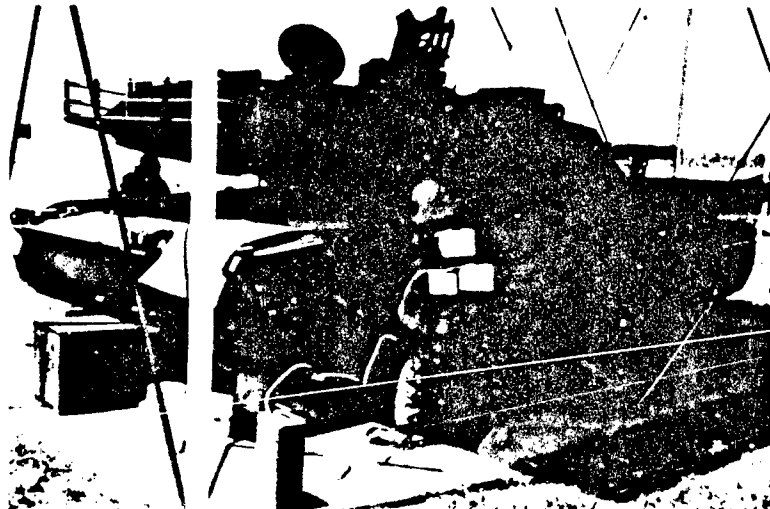


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INTRODUCTION

Operation Desert Storm (ODS) highlighted a critical military deficiency, that being the inability to perform many essential battle-field missions in hot, NBC environment. A microclimate cooling (MCC) system provides a major operational capability in a hot environment while significantly reducing heat stress related injuries and water consumption.

In an effort to support ODS with an expedient MCC capability, an extensive market survey was conducted identifying a number of potential candidates. A user design review, attended by many varied users and services, was conducted in January 1990, in an effort to display the items, identify potential users for particular MCC candidates based on operational scenarios, and set up operational tests. A screening evaluation, consisting of Thermal Manikin/Climatic Chamber evaluations and technical assessment of several commercial cooling systems was completed in February, 1991. Based on laboratory evaluation and user community feedback, five cooling systems were selected and were evaluated by various users from March to May, 1991.



METHODS

Description of cooling systems:

The LSSI MARK VII is a portable active ice system consisting of a liquid cooled vest with hood (worn underneath clothing), and a back pack (worn over clothing) that carries 2 ice packs, a pump and a battery. A water/glycol solution is circulated in a closed loop between the back pack and the cooling garment. This solution is pumped around two ice packs, cooled, and then circulated to the vest and hood to provide cooling to the head and torso. The frozen ice packs and the battery can be replaced while the backpack is worn to extend the duration of the cooling.



The EXOTEMP CD-22 is a portable active ice system consisting of a liquid cooled undergarment (shirt, hood and pants), and a back pack that carries a frozen water bottle, a pump and a battery. Water is circulated between the frozen bottle and the shirt, hood and pants to provide cooling to the torso, arms, head, legs. The ice bottle and the battery can be replaced while being worn to extend the duration of the cooling.

The ILC Dover Model 1905-M1 Cool Vest is a portable active ice system consisting of a liquid cooled vest and a back pack that carries a ziplock ice bag, a pump and a battery. Water is circulated between the ice bag and the cooling vest to



provide cooling to the torso. Ice can be added and the battery can be replaced to extend the duration of the cooling.

The Steele Vest is a passive cooling system consisting of a torso vest with six horizontal pockets that carry frozen gel strips.

The KT M-10 cooling system is a thermoelectric system consisting of a liquid cooled shirt and a thermoelectric cooling unit that requires power (20 Amps @ 28 Volts) from a vehicle or aircraft where it is mounted.

TEST DESIGN

THERMAL MANIKIN (TM) EVALUATION

a. Purpose

The purpose of this evaluation was to assess the actual cooling capability of the five cooling systems under controlled and identical conditions. The cooling rate and duration were measured and recorded. These parameters are important since they describe the total amount of cooling provided to the user by each system. The specific conditions selected for this evaluation were somewhat based on anticipated conditions in ODS. However, the intent of this portion of the evaluation was to develop comparable data between the systems under standard conditions. Care must be taken in extrapolating these results to varied field conditions.

b. Test Design

The TM is a ten-zone, heated aluminum manikin with the dimensions of the 50th percentile male. In all tests the TM wore the MCC system under the BDO. Two tests were

completed for each cooling system. The environmental conditions during the tests were 35°C (95°F) dry bulb, 5% relative humidity, and 0.9 m/s (2 mph) wind speed. The TM temperature was maintained at 35°C (95°F). Once the TM reaches thermal equilibrium, the amount of power required by the TM to maintain surface temperature due to cooling by MCC systems was recorded at one minute intervals during the cooling phase.

c. Measurements

The actual cooling capacity was calculated from the power input to the TM. The cooling rate was averaged over the first hour. The cooling capacity was calculated by multiplying the cooling rate by the cooling duration of a single ice charge.

d. Results

Results of the TM tests are shown in Table 1. The cooling rate ranged from 85 to 160 Watt. The duration ranged from 40 to 120 minutes for ice-based systems.

TABLE 1: THERMAL MANIKIN TEST RESULTS

Cooling system	Cooling Rate (watts)	*Duration (min)	**Cooling Capacity (watt-hr)
EXOTEMP CD-2	160	40	107
ILC Dover 1905-M1	135	85	191
SteeleVest	135	120	270
KT M-10	120	***	***
LSSI Mark VII	85	90	128

* Duration: time between ice change.

** Cooling capacity is calculated based on one ice change

*** KT M-10 provided continuous uninterrupted cooling.

FIELD EVALUATION

a. Purpose

The purpose of the field evaluations was to assess the effectiveness of the five MCC systems for different user applications. Personnel from five distinct areas of expertise participated in these evaluations. The areas were Army EOD, Air Force fire fighters, Air Force Rapid Runway Repair, Army Decontamination, and Army Aviators. There were never more than three personnel participating from any particular area. The evaluations all took place in the southern United States March through May. The participants were asked questions concerning, among other things, compatibility with current equipment, ease of use, and cooling system effectiveness.

b. Test Design

The participants were asked to perform tasks representative of standard tasks they would perform during an "average mission".



Data were collected by evaluators during the performance of the tasks, in one-on-one interviews, and through user surveys. The surveys were designed to get at specific areas of cooling system design with respect to its effect on soldier performance. Each cooling system

had its own survey. Questions covered donning and doffing, fit and adjustability, operability, compatibility with clothing and equipment, effect on safety during conduct of the mission, cooling system effectiveness and the potential for extending mission performance.

c. Data Analysis

All data collected during the evaluations were tallied by cooling system and then by question. The questions from the surveys were grouped under the headings shown in Table 2: Ease of Use, Effectiveness and Equipment Compatibility. These are defined as follow: Ease of Use - operation of controls, adjusting the system to fit, effect on ability to perform, restriction of body movements, donning and doffing; Effectiveness - being cooled by the system, wearing the system for extended periods, extension of mission time; Equipment compatibility - effect on fit or comfort of clothing or equipment, interference with operation of equipment worn or carried. The tallies for a particular cooling system were pooled across areas of expertise in order to give a general assessment of the system's performance.* A five point scale was developed to assign a subjective value to the the system's overall performance for each table 2 heading. The scale was as follows: 0=Unacceptable, 1=Poor, 2=Fair, 3=Good, 4=Very Good.

d. Results

The results of the tally can be found in Table 2.** None of the cooling systems were rated unacceptable overall.

* The small number of respondents precluded investigating each cooling for each occupational area individually.

** These results apply only to the clothing and equipment worn during the evaluations as well as the tasks performed. The results are not intended to be representative of any other conditions other than those already cited and will not necessarily apply to clothing, equipment or tasks worn or performed by personnel in any other MOS.

CONCLUSIONS

All items evaluated were shown to provide significant cooling. The cooling rate ranged from 85 watt for LSSI to 160 watt for EXOTEMP. Field evaluation perceived cooling agreed fairly well with lab tests.

All have logistic concerns which must be addressed by user: EXOTEMP, STEELE, ILC Dover, and LSSI require ice and freezers. EXOTEMP, LSSI AND ILC Dover also require battery storage and battery recharging. KT requires electrical connection and mounting to vehicles or aircraft.

STEELE, which has no moving parts, was more reliable and easier to use. However, it required more freezer space and has no cooling adjustments or control. Changing ice in the SteeleVest was more difficult than the other ice based systems tested.



LSSI system was the most complicated to use, required more maintenance and training, and was perceived by the test subjects to be one of the least effective. It is the heaviest of the portable systems.

ILC Dover provided adequate cooling but was slightly more difficult to use and had relatively more durability problems.

EXOTEMP was the lightest and provided the highest cooling rate but required more ice changes than the others. The full body cooling, provided by its undergarment, was well received.

KT provided adequate cooling but lacked cooling controls. Its power consumption is high enough to possibly prevent its use in some aircraft and vehicles.

Cost ranged from \$250 for STEELE (SteeleVest) to \$2600 for LSSI (Mark VII) to \$3000 for KT (M-10).

Weight ranged from 9 pounds for EXOTEMP to 17 pounds for LSSI and KT. The cooling to weight ratio, given in table 2, provides cooling comparison, on a per pound basis, for the portable cooling systems. The higher the ratio the more efficient is the cooling system. This ratio ranged from 11.9 for EXOTEMP to 22.5 for STEELE.

Cooling capacity per single ice charge ranged from 107 watts for EXOTEMP to 270 watts for STEELE.

All systems were fair to good in compatibility with clothing and equipment.

All provided adjustable or controlled cooling in some form or another with the exception of STEELE and KT.

With special thanks to:
Scott Bennett of Natick,
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TABLE 2: COMBINED TEST RESULTS

COOLING SYSTEM	COST (\$)	WEIGHT (LBS)	COOLING RATE (WATTS)	COOLING DURATION (MIN)	COOLING CAPACITY (WATT-HR)	COOLING/WEIGHT RATIO	EASE OF USE	EFFECTIVENESS	EQUIPMENT COMPATIBILITY
STEELVEST*	250	12	135	120	270	22.5	4	4	4
EXOTEMP CD-2*	1500	9	160	40	107	11.9	3	3	3
ILC DOVER 1905-M1*	500	12	135	85	191	15.9	2	3	3
LSSI MARK VII*	2600	17	85	90	128	7.5	2	2	3
KT M-10**	3000	17	120	***	***	***	3	2	3

* Based on data from EOD, Fire Fighters, Rapid Runway Repair, and Decon Personnel.

** Based on data from Aviators in UH-60 Flight Simulator.

*** KT M-10 Provided continuous uninterrupted cooling.

(Ratings reflect assessment of UH-60 Simulator Evaluator, not Natick, Behavioral Science Division Personnel.)

Ease of use: Donning, Doffing, and Operability

Effectiveness: Perceived cooling and ability to extend mission performance

Equipment Compatibility: Fit, Adjustability, and Compatibility with Clothing and Equipment

Ease of Use, Effectiveness, and Compatibility Scale:

Very Good	Good	Fair	Poor
4	3	2	1