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A Pilot Study to Determine the Thermal Protective Capability of Electrically Heated Clothing and Boot Inserts

Charles A. Hickey Jr.
Arthur A. Woodward Jr.
William E. Hanlon

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Charles A. Hickey Jr.; Arthur A. Woodward Jr.; William E. Hanlon

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The Human Research and Engineering Directorate of the U.S. Army Research Laboratory conducted a pilot study to determine if the addition of electrically heated clothing components would enhance the thermal protectiveness of the extended cold weather clothing (ECWCS) ensemble. This study consisted of two separate sets of exposure trials. The first was a series of trials lasting 2 hours, and the second was a series of trials lasting 4 hours. Male soldiers were exposed to ambient air at -40°F (-40°C) at a sedentary activity level in a controlled cold chamber during all trials.

The soldiers wore three different cold weather ensembles during the 2-hour exposure trials: the ECWCS ensemble alone, the ECWCS with electrically heated glove and boot inserts (Ensemble A), and the ECWCS with electrically heated glove liner and sock (Ensemble B). Only Ensembles A and B were evaluated during the 4-hour exposure trials. During these trials, an electrically heated vest was used to supplement body heating in Ensemble A, and electrically heated underwear (shirt and pants) was used to supplement body heating in Ensemble B.

The soldiers' temperatures were monitored with thermistors placed on the tip of the middle finger, inside the large toes, and on the back below the scapula; a rectal thermistor was inserted to a depth of 10 cm. These thermistors were hardwired to a data logger, and the temperatures were recorded at 5-minute intervals during each trial.

The results of the 2-hour trials demonstrate that the use of electrically heated hand and foot wear improved the cold protection effectiveness of the ECWCS ensemble. Rates of heat loss (cooling) were reduced at all monitored body surface locations. Tolerance times (time of cold exposure required to lower any surface temperature to (50°F) [10°C]) were increased more than 120 minutes compared to 101 to 110 minutes for the ECWCS alone. The functional limit times (the length of cold exposure which lowers finger temperatures to 60°F (15.56°C), the level at which pain and loss of manual dexterity begin) for the heated ensembles were 128 to 150 minutes compared to 64 to 77 minutes for the ECWCS alone.

The results of the 4-hour trials show that the addition of heated body garments to the heated hand and foot wear did not improve effectiveness of cold protection.

14. SUBJECT TERMS

cold chamber	heated vest	heated glove liners
exposure trials	heated socks	beated boot inserts
heated underware	thermistors	heated body termperatures
	heated gloves	electrically heated clothing
	body temperatures	extended cold weather clothing system (ECWCS)

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Charles A. Hickey Jr.
Authur A. Woodward Jr.
William E. Hanlon

January 1993

Approved: ROBIN L. KEESEE
Directorate Executive

U.S. Army Research Laboratory
Human Research and Engineering Directorate
Aberdeen Proving Ground, Maryland

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INTRODUCTION

The normal, healthy human body produces heat continuously at a rate that is primarily a function of the overt physical activity in which it is engaged. This heat is dissipated almost wholly through external body surfaces. The body achieves a high degree of physiological efficiency by regulating within a narrow band the temperatures of its core, in which are located its most thermally sensitive organs. The physiological mechanisms that accomplish this thermoregulation constantly keep the body heat losses in balance with heat production over a broad range of physical activity levels and external thermal environmental conditions. When the capacity of these mechanisms is exceeded, the core temperatures begin to change following a pathway that leads to physiological malfunction, injury, and ultimately, death.

The regulation task is complicated by three kinds of factors. First, the internal structures and the geometry of the body act to produce widely varying rates of heat transfer over different areas of body surface. Secondly, body surfaces are never exposed to a completely uniform thermal environment, and these nonuniformities are constantly changing. Thus, fingers lose heat much more rapidly in the cold than do upper arms and back, and armpits are rarely exposed to solar loads as compared with bald heads. Finally, man learned how to make and use clothing to provide a barrier between his body and a hostile environment. In cold weather clothing, the barrier is insulation, which impedes heat flow from the body to the outside world. Body heat can then warm the airspace between the skin and the inner surfaces of the clothing and the clothing itself; thus, the temperature difference between the body surfaces and the environment (the microclimate beneath the clothing) is reduced. Since this difference determines the rate of heat flow, heat loss from the body is accordingly decreased.

For military personnel in a technological world, operations in cold environments often involve special problems resulting from the bulkiness of thermal protective insulation that is incorporated into cold weather clothing. The head, hands, and feet are naturally the body regions most vulnerable to cold. Yet, it is not possible to make practical hand or foot wear that fully protect these body parts during extreme cold conditions (such as air at -40°F [-40°C]). The insulation required assumes pillow-size dimensions so that handling or operating equipment is made extremely difficult or even impossible. The problem is most acute with operators of equipment whose tasks require manipulation of sensitive hand or foot controls. For example, aircraft pilots cannot operate their aircraft when wearing heavily insulated hand or foot wear. For those personnel who operate equipment with reserve sources of electrical power (e.g., aircraft, tanks, engineering vehicles), it may be feasible to use electrically heated garments to compensate for inadequate thermal protection afforded by lightly insulated clothing components.

The Field Assistance in Science Technology (FAST) Program Office at the Forces Command (FORSCOM) recognized that there was a need to improve the thermal protection for certain military personnel operating in an extreme cold weather environment and initiated an effort to do so. During this effort, the FAST office found a commercial manufacturer (Widder Enterprises) of electrically heated clothing components designed for motorcyclists and decided to investigate the practicability of using electrically heated components to improve thermal protection for military operators. Consequently, the FAST office asked the Cold Regions Test Center (CRTC) to conduct a feasibility test of the electrically heated clothing components available from Widder Enterprises. These components consisted of a vest, chaps, and gloves. CRTC conducted this test in an operational oriented field environment during the winter of 1990. The results of the test indicated that most test subjects found the vest and gloves to be effective; however, the chaps were found to fit poorly, provide inadequate heating, and to have little military potential.

Because of the findings of the CRTC feasibility test, the FAST program office asked the Human Research and Engineering Directorate (HRED) of the U.S. Army Research Laboratory (ARL) to conduct a pilot study to determine the level of thermal protection afforded by the electrically heated components (vest and gloves).

Learning of HRED's pilot study, Widder Enterprises suggested to the FAST office that heat also be supplied to the subjects' feet. The latter agreed and proposed that an electrically heated boot insert be evaluated along with the vest and gloves.

Personnel from HRED learned of another commercially available electrically heated garment system during a presentation at the U.S. Marine Corps, Quantico, Virginia. This system is a lightweight heated undergarment ensemble consisting of an undershirt, underpants, gloves, and socks. It was thought that the inclusion of this system in the pilot study would be representative of another type of heated garment. A decision was made to acquire this garment system and include it in the HRED pilot study.

Approach

During past cold chamber evaluations conducted by this directorate, it has been determined that the extended cold weather clothing system (ECWCS) provides acceptable thermal protection for approximately 2-hours exposure to an ambient air temperature of -40°F (-40°C). During these studies, subjects sat quietly for 25 minutes, followed by 5 minutes of walking on a treadmill at 3 mph (4.83 km/hour) during each half hour of exposure. At the end of the 2-hour period, almost all subjects wearing the ECWCS ensemble had finger and toe temperatures close to 50°F (10°C). At this temperature, subjects tend to feel a great deal of discomfort, and their ability to perform simple tasks is greatly impaired. Soldiers in this condition provide a sensitive vehicle for detection of the effects of enhanced thermal protection. For this study, it was decided that a more severe scenario should be followed in which the subjects remained quietly seated throughout the test-exposure period. This condition was appropriate for a number of situations in which cold vulnerability problems have been identified, and the use of heated garments is militarily feasible (e.g., those of aircraft pilots and ground vehicle operators).

OBJECTIVES

The first objective was to determine whether heated hand and foot wear alone could enhance the thermal protectiveness of the ECWCS ensemble to a measurable and useful extent. Trial exposures were limited to a maximum of 120 minutes which is the known limit of the ECWCS ensemble at -40°F (-40°C).

The second objective was to determine two factors: (a) Whether the use of heated garments over body areas in addition to hands and feet would improve the protectiveness of ECWCS, and (b) by what amount the use of these garments would extend the period of time of effective cold protection.

SUBJECTS

Four male soldiers from the U.S. Army Combat Systems Test Activity, Aberdeen Proving Ground, Maryland, volunteered to participate in this pilot study. Each soldier was briefed and given a written volunteer agreement affidavit which thoroughly explained his involvement in the study. Before signing this affidavit, they were given ample opportunity to ask and have answered all questions pertaining to this study and their participation in it. Each volunteer granted permission to have his medical record reviewed and requested that his signed affidavit be filed in his medical record. A copy of the volunteer consent affidavit is shown in Appendix A.

The Kirk U.S. Army Health Clinic reviewed each volunteer's medical record. This review was to assure that subjects had never had a history of cold intolerance or cold weather-related injury, alcoholism, or circulatory disorder and to assure that subjects were not on nor had not recently been on medication which would interfere with body temperature regulation or shivering.

TEST ENSEMBLES

Three clothing ensembles were evaluated during this study. The components used to make each ensemble are shown in Table 1. The extended cold weather clothing system (Ensemble ECWCS) was used as a reference baseline ensemble. Ensembles A and B included electrically heated clothing components and boot inserts that were used in conjunction with the ECWCS.

The commercial items evaluated during this study were off-the-shelf, electrically heated garments that were designed to operate from a 12-volt DC power source. These garments were used without modification except for replacement of the power connectors with connectors that were compatible with the DC power supplies used in this study. A description of the electrically heated components used is shown in Appendices B, C, and D.

APPARATUS

Climatic Facility Cold Chamber

The Climatic Facility includes a controlled cold chamber located in Building E3226 in the Edgewood area of Aberdeen Proving Ground, Maryland. The chamber was set for an ambient air temperature of -40°F (-40°C) and was maintained to ± 0.5°F (0.28°C) of its set point for all tests. The large cold chamber test area was covered by a wood platform to isolate the subjects' feet from the heavy stainless steel floor of the chamber. Wooden chairs were placed on this platform for the subjects.

Instrumentation

Body temperatures were measured with appropriate thermistor sensors of the Yellow Springs Instruments (YSI) 400 series. These sensors were hardwired to a YSI Model 44TH Telethermometer read-out instrument. Skin temperature sensors (3/8-inch [0.96-cm] discs) were placed on the skin with adhesive tape at the tip of the third finger of the right hand, on the inside surface of the large toe on the right foot, on the back approximately 2 inches (5.08 cm) below the right shoulder blade, and on the inside surface of the heel approximately 3 cm above the sole of the foot posterior to the ankle. Rectal temperature sensors were inserted to a depth of 10 cm.

Power Supply

A Sorenson DC Power Supply, Model DCR 40-20A, was used to regulate and maintain 12 volts DC to the clothing ensembles with electrically heated components.

Table 1

Test Ensembles

Clothing items	Ensemble ECWCS	Ensemble A	Ensemble B
ECWCS clothing components			
Polypropylene undershirt	•	•	•
Polypropylene underpants	•	•	•
Nylon cushion sole sock	•	•	•
Polyester fiberpile bibbed overalls	•	•	•
Polyester fiberpile jacket	•	•	•
Polyester batting field coat liner	•	•	•
Polyester batting field trouser liner	•	•	•
PTFE all weather rain trouser	•	•	•
PTFE all weather parka with hood	•	•	•
CVC nomex balaclava (worn under parka hood)	•	•	•
Wool trigger finger mitten insert	•		•
Extreme cold weather mitten set	•		•
White vapor barrier boots	•	•	•
Widder electrically heated apparel			
Lectric vest[a]		•	
Lectric gloves[a,b]		•	
Farnum custom products			
Electric-heated boot insert[a,b]		•	
Power Johns™ electrically heated suit			
Undershirt[a]			•
Underpants[a]			•
Gloves[a,b]			•
Socks[a,b]			•

[a]Components electrically heated during 4-hour exposure trials.
[b]Components electrically heated during 2-hour exposure trials.

PROCEDURES

Test Scenario

The subjects arrived at the test site, removed their clothes, and emplaced their own rectal temperature sensors before the start of each test day. HRED test personnel then emplaced all skin temperature sensors on each subject and helped each to don the underclothing and socks of the ensemble to be worn. The temperature sensors from each subject were then connected to the telethermometer to assure that the sensors and read-out instrument were operable and to record each subject's pretest body temperatures. The subjects then donned the intermediate layers of the clothing ensembles. Those wearing electrically heated components were connected to the power supply to conduct pretest inspections of the components and to set the thermostatic controls for each ensemble. The procedure and setting of the thermostatic controls followed manufacturers' recommendations and were repeated for all tests. Hand and foot wear were adjusted to full power, and when applicable, the body-worn components adjusted to half power. These settings were maintained for the entire scenario. When all pretest inspections and adjustments were completed, the subjects were taken into a holding room (a small, cold room with an ambient air temperature of approximately 30°F [-1.11°C]) to finish dressing. This was done so that the subjects would not become overheated before entering the test chamber. When the subjects were completely dressed, they were taken to their assigned stations in the test chamber. HRED personnel connected their sensor leads to the read-out instrumentation and the power supply cables to their uniform ensembles. The subjects were then seated for the duration of the test. The subjects' body temperatures were recorded at 5-minute intervals throughout each test period. Two-hour exposure trials were conducted with heat supplied to the hands and feet. Four-hour exposure trials were conducted with heat supplied to the hands, feet, and body.

Cold Exposure Termination Criteria

The subjects were removed from the cold chamber at the end of the test period or when any of the following occurred:

(a) a subject's skin surface temperature fell below 50°F (10°C),

(b) a subject's core (rectal) temperature fell to 95°F (35°C),

(c) a subject experienced involuntary continuous shivering for 5 minutes (as reported by the subject and confirmed by observation of an HRED investigator), or

(d) a subject reported that he was severely cold in areas not being monitored.

Test Schedule

The test schedule used for this evaluation is shown in Table 2. This schedule was made of paired comparisons balanced for a.m. and p.m. presentation. Two 2-hour test trials were conducted on the first two test days (one in a.m. and one in p.m.), and 4-hour test trials were conducted on the third and fourth test days.

Data Analysis

All the temperature data recorded from each subject during a given cold exposure trial were plotted to produce a set of temperature and time curves on a single graph. Figure 1 is a plotter printout of a representative set of such data. These graphs provide the means for deriving estimates of the most important factor used to evaluate the thermal protective effectiveness of cold weather clothing ensembles: The rate of change of temperature at each body location monitored.

Table 2

Schedule for Test Ensembles

	2-hour trials				4-hour trials	
	Day 1		Day 2		Day 3	Day 4
Subject	a.m.	p.m.	a.m.	p.m.	a.m.	a.m.
1	ECWCS	B	A	ECWCS	B[b]	A
2	B	ECWCS	ECWCS	A	A	B[b]
3	A	ECWCS	ECWCS	B	B[a]	A
4	ECWCS	A	B	ECWCS	A	B[a]

[a]Analog control
[b]Minicomputer control

To accomplish this, one must first decide about what time interval evaluations of temperature-rate changes are to be made. Subjects must be fully dressed before entering the cold environment at the test chamber. The moment the subject enters the cold chamber, the temperature difference between his body surfaces and the ambient air suffers a large step increase. In this study, a difference of 70°F (21°C) (from holding chamber at 30°F [-1.11°C] to cold chamber at -40°F [-40°C]) was noted. For soldiers dressed in heavily insulated clothing, a substantial amount of time was required to readjust the heat flow gradient across their clothing layers to the new conditions. From past experience with men wearing the ECWCS ensemble, this period of readjustment requires 30 minutes or longer, depending on the particular test conditions. In addition, during this period body surface temperatures are much affected by conditions and events experienced by the subject immediately before the onset of the low temperature exposure. Therefore, temperature data collected during this initial 30-minute exposure phase must be ignored if a true measure of the clothing ensemble behavior is to be achieved.

Ultimately, all the temperature-change curves enter a phase of near-steady change (not necessarily at the same time for every monitored location). For the data illustrated in Figure 1, this phase begins at about 30 minutes exposure time, as can be seen by examining the temperature changes before and after the 30-minute line in Figure 2.

For each curve of steady trend, a manually fitted straight line was drawn with a transparent ruler. With the ruler in place, two points on the curve were identified that defined a line identical with or parallel to the manually fitted line. The coordinates of these points were then taken from the raw data records to calculate the curve slope from

$$\text{Temperature change rate} = \frac{\Delta T}{\Delta t} = \frac{T_2 - T_1}{t_2 - t_1}$$

where

T = temperature
t = reading time

The curves thus defined have been added to the original plots in Figure 2.

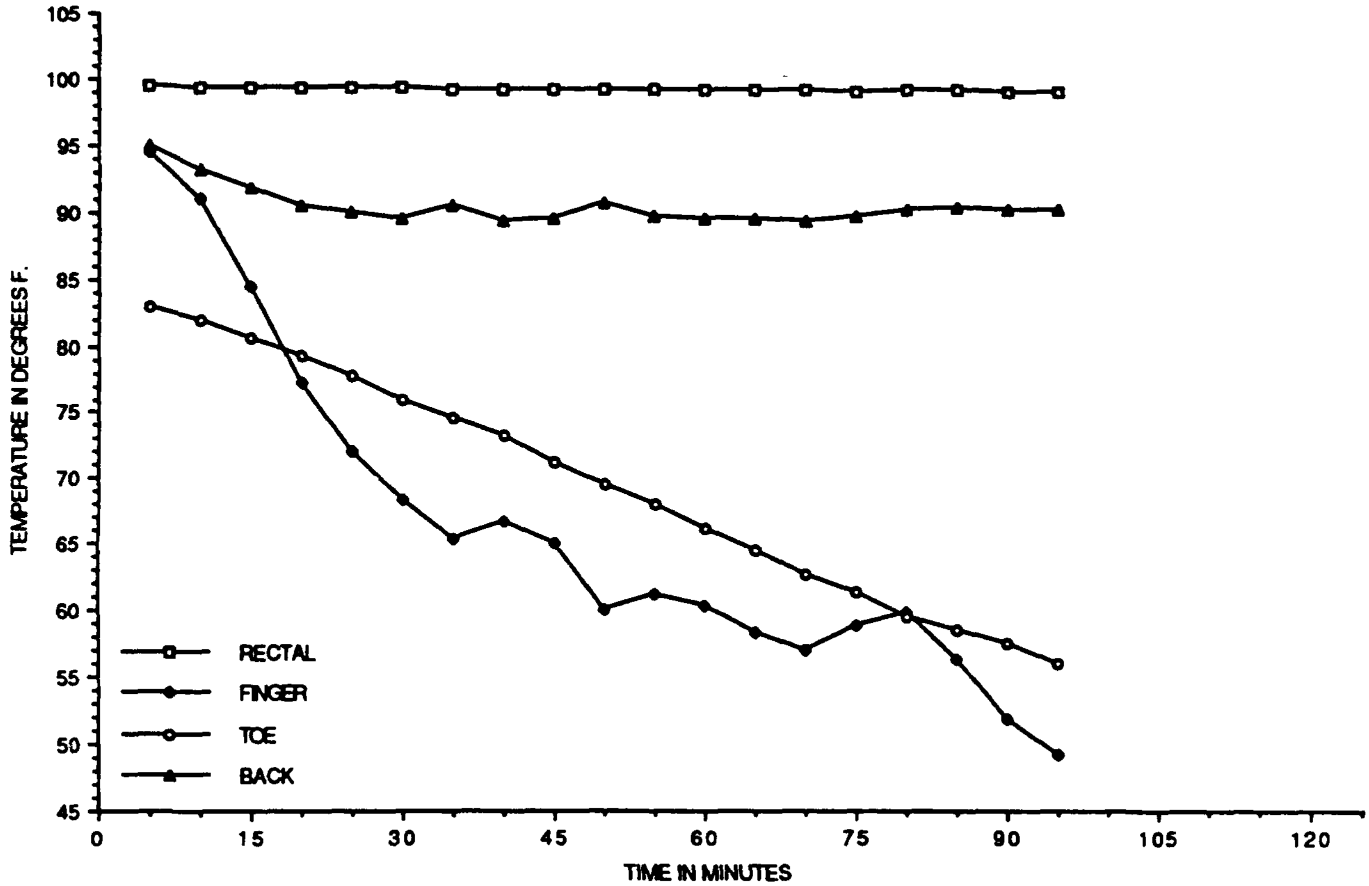

Figure 1. Body temperature for Subject Number 1 wearing unheated ECWCS uniform.

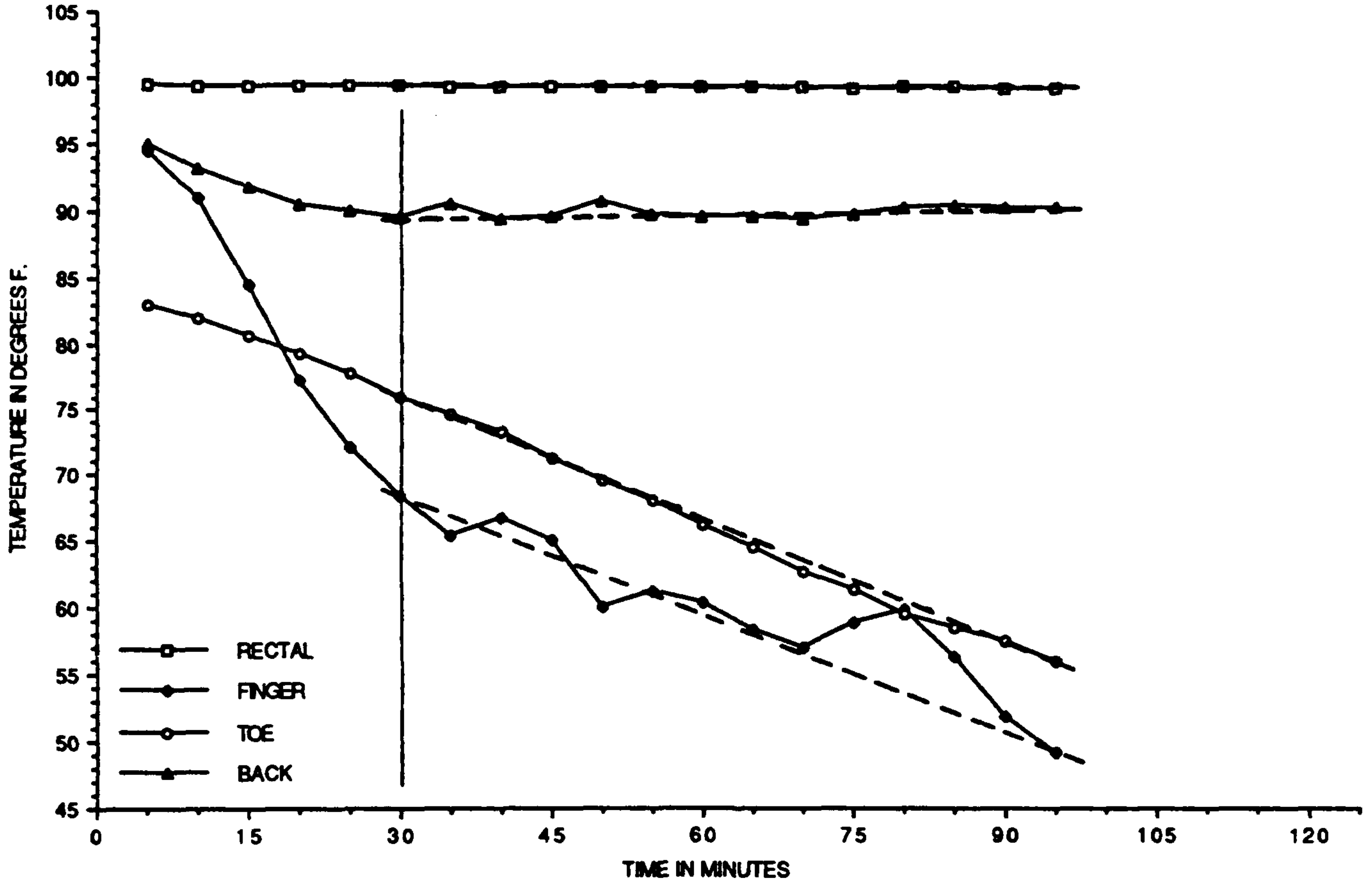

Figure 2. Determination of temperature changes rates.

RESULTS

Two-Hour Exposure Trials

The 2-hour exposure trials were conducted to determine if heated hand and foot wear alone could enhance the thermal protectiveness of the ECWCS ensemble. Graphs of all the temperature and time data recorded are presented in Appendix E. Each graph presents one subject with two sets of data: (a) an ensemble that included electrically heated hand and footwear, and (b) the control ensemble (ECWCS) worn on the same day.

During pretest trials, when a subject (HRED personnel) was wearing the electrically heated boot inserts, his heel was noticeably colder than the rest of his foot. Inspection of these inserts showed that there were no heating wires located in the heel area of the inserts. At this point, it was decided to place a skin temperature sensor on each subject's heel when Ensemble A (which included the boot inserts) was worn. HRED did not have the capability (instrumentation) to monitor heel temperatures for each subject during all trials; therefore, heel temperature data were collected only on Ensemble A.

In the result summary tables (see Tables 3 through 5), the two upper sets of data are for Ensemble A trials and the ECWCS control ensemble trials worn on the same day. The two lower sets of data are for Ensemble B and ECWCS trials worn on the same day.

Table 3 summarizes the data about rate of change of temperature at each body location monitored. This rate is a direct function of the rate of heat flow through the clothing insulation at the monitored body location and hence a direct measure of the effectiveness of the clothing insulation at that location.

Table 4 summarizes two kinds of related data. The first data column lists the tolerance times defined as the cold exposure time taken to reach any exposure termination criterion (see Procedures section on Page 6). Since the exposure periods were limited to 2 hours, a value of 120 in this column is a minimum estimate of the tolerance time. The next four data columns list, for each monitored body location, the last temperature reading before the cold exposure was terminated (i.e., at the time listed in the first data column).

A skin temperature of 60°F (15.5°C) has been established as the level of finger temperature at which most young military males begin to experience both cold-induced pain and decrements in manual task performance. It has been HRED's experience in past studies of cold protective clothing that fingers and toes differ very little in these respects. Therefore, 60°F (15.5°C) has been taken as a functional temperature limit for fingers and toes for evaluation of cold weather protective clothing ensembles. Inspection of the data in Tables 3 and 4 indicates no need at this time to define a similar limit for torso temperatures (rectal or skin).

Table 5 summarizes the data about functional tolerance times for fingers, toes, and heels. In cases when these body temperatures did not actually drop to 60°F (15.5°C) before cold exposure was terminated, the effective tolerance time was estimated by extrapolation from the terminal temperature using the values for rates of temperature change (see Table 3). For reasons that will be presented later, effective tolerance time estimates greater than 130 minutes can be taken as underestimating the true effective tolerance times.

Four-Hour Exposure Trials

The 4-hour exposure trials were conducted to determine whether the use of heated garments over body areas, in addition to hands and feet, would improve the protectiveness of the ECWCS; and if so, by what amount of time. In these trials, the subjects wore the same clothing ensembles; however, heat was supplied to the body as well as the hands and feet.

Table 3

Rates of Body Temperature Change from Effects of Heating Hands and Feet during 2-Hour Trials

Ensemble	Subject	Body temperature changes in ° F/hour[a]				
		Rectal	Finger	Toe	Back	Heel[b]
ECWCS	1	-0.3	-17.7	-18.5	0.6	
	2	-1.2	-17.1	-24.6	1.2	
	3	-0.7	-26.8	-21.0	1.5	
	4	-1.5	-17.7	-23.3	1.0	
	mean	-0.93	-19.83	-21.85	1.08	
Ensemble A	1	-0.7	-13.2	0.4	1.2	-5.5
	2	-0.7	-11.5	-5.2	0.8	-7.1
	3	-0.7	-22.1	-6.1	0.0	-8.2
	4	-0.1	-10.4	-1.3	-4.3	-8.1
	mean	-0.55	-14.30	-3.05	-0.58	-7.23
ECWCS	1	-0.4	-17.7	-20.0	3.9	
	2	-0.8	-18.7	-16.1	-0.5	
	3	-0.5	-26.6	-20.1	0.0	
	4	-0.8	-12.0	-21.9	1.4	
	mean	-0.63	-18.75	-19.53	1.21	
Ensemble B	1	-0.7	0.3	-14.6	1.5	
	2	--	-0.7	-7.8	0.0	
	3	-0.5	-0.9	-5.8	-5.3	
	4	-0.3	-0.4	-8.6	-2.6	
	mean	-0.50	-0.43	-9.20	-1.60	

[a] Negative values indicate body cooling.
[b] Heel temperature recorded for Ensemble A only.

Table 4

Tolerance Times and Terminal Temperatures from the Effects of Heating the Hands and Feet Only during 2-Hour Trials

Ensemble	Subject	Time of exposure (minutes)	Terminal temperatures in °F				
			Rectal	Finger	Toe	Back	Heel[a]
ECWCS	1	95	99.0	49.2	56.0	90.2	
	2	95	98.1	49.3	51.4	89.0	
	3	120	97.5	54.1	57.9	84.4	
	4	95	97.4	49.9	58.0	85.0	
	mean	101	98.0	50.6	55.8	87.2	
Ensemble A	1	120	98.4	61.3	89.7	90.1	71.8
	2	120	98.4	67.6	88.4	87.0	72.8
	3	120	98.0	59.0	86.0	81.6	79.6
	4	120	98.8	58.0	83.4	79.6	57.3
	mean	120	98.4	61.5	86.9	84.6	70.4
ECWCS	1	120	98.3	56.6	54.1	90.3	
	2	120	98.7	55.7	50.9	89.0	
	3	105	98.1	58.8	61.0	85.1	
	4	95	98.2	50.0	52.3	85.3	
	mean	110	98.3	55.3	54.6	87.4	
Ensemble B	1	120	98.4	101.5	74.1	85.0	
	2	120	--	97.3	88.2	90.0	
	3	120	98.5	94.8	85.6	79.9	
	4	120	98.1	94.7	86.6	81.4	
	mean	120	98.3	97.1	83.6	84.1	

[a] Heel temperatures recorded for Ensemble A only.

Table 5

Time to Reach Functional Temperature Limit from Effects of Heating Hands and Feet Only during 2-Hour Trials

Ensemble	Subject	Time (minutes) to reach 60° F.		
		Finger	Toe	Heel[c]
ECWCS	1	61	79	
	2	49	68	
	3	87	113	
	4	59	89	
	mean	64	87	
Ensemble A	1	126[a]	b	248[a]
	2	160[a]	•360[a]	228[a]
	3	114	337[a]	263[a]
	4	113	•360[a]	99
	mean	128	•360	210
ECWCS	1	85	110	
	2	84	84	
	3	98	108[a]	
	4	41	72	
	mean	77	94	
Ensemble B	1	b	178[a]	
	2	•360[a]	338[a]	
	3	•360[a]	385[a]	
	4	•360[a]	306[a]	
	mean	•360	302	

[a] Value calculated by extrapolation from slope of body change curve C (see Figure 2).
[b] Temperature constant or rising slowly; time very high but indeterminate.
[c] Heel temperatures recorded for Ensemble A only.

Heat was supplied to the upper torso in Ensemble A by the vest, and heat was supplied to the whole body in Ensemble B by the heated undershirt and pants. This trial was conducted to observe whether the additional heating would significantly increase the thermal protection provided by use of heated garments for feet and hands only.

Since none of the subjects met the cold exposure termination criteria during the 2-hour scenarios when heat was supplied to only the hands and feet, the exposure period was extended to 4 hours.

In the data summary tables (see Tables 6 through 10), results for the first 2 hours of exposure only are presented for direct comparison with the results from the 2-hour exposure trials. Results for the second half of the 4-hour trial are presented separately. Tables 6 and 7 summarize the data about rates of temperature change for Ensembles A and B respectively. Tables 8 and 9 similarly summarize body temperatures at the end of 2 hours of exposure and at the termination of the exposure according to the test criteria adopted.

Table 10 summarizes the data about time of cold exposure at which onset of task-performance degradation can be expected (60°F [15.5°C]). In this table, all values for time exceeding 240 minutes are calculated by extrapolation. These extrapolations for periods as great as 6 hours (360 minutes) are to be taken as inexact approximations only.

DISCUSSION

Effectiveness of Heated Hand and Foot Wear

Cooling rates at critical body locations are primary diagnostic values for the evaluation of cold weather clothing ensembles. Rectal temperatures give a direct measure of total body heat content. If the body is in perfect thermal balance, the rate of change of rectal temperature is 0. No practical clothing ensemble provides a uniform level of thermal protection over the whole body surface. Skin temperature cooling rates are used to monitor the effectiveness of insulation in different body regions. Where the insulation is poor locally, the skin cannot warm the inner clothing, and the skin cools at a relatively high rate.

The cooling rate data summarized in Table 3 are illuminating. Consider first the data for the ECWCS ensemble which was duplicated as a result of the paired comparison test design. The two data sets show a high degree of internal consistency and demonstrate that rigorous control exerted during experimental procedures gives quite satisfactorily repeatable results. This leads to confidence in the reliability of the data from trials of soldiers wearing the heated garments, which could not be run twice.

Second, these results clearly confirm that soldiers wearing the ECWCS ensemble are vulnerable to cold primarily at their extremities. To be sure, skin temperature was measured at only one location (on the back) other than fingers and toes. Past studies have shown that men in the ECWCS ensemble at -40°F (-40°C) experience mild chilling over the rest of their bodies, mostly in the arms and legs. In this series (2-hour exposure), a trial was terminated only on one occasion for excess cold at locations other than fingers or toes. Subject Number 3 was terminated during the ECWCS trial paired with Ensemble B because of uncontrolled shivering. This subject was unusually long-legged and the fiberpile trouser liner was too short. Several inches of his legs above the boot tops were protected with only the outer shell of the all weather trousers. For all subsequent tests, he wore an oversize liner to provide adequate cover for his legs.

Table 6

Rates of Body Temperature Change for Effects of Heating Hands, Feet, and Body during 4-Hour Trials (Ensemble A)

Ensemble/ condition	Subject	Body temperature changes in ° F/hour[a]				
		Rectal	Finger	Toe	Back	Heel
Ensemble A[b] (2-hour trials)	1	-0.7	-13.2	0.4	1.2	-5.5
	2	-0.7	-11.5	-5.2	0.8	-7.1
	3	-0.7	-22.1	-6.1	0.0	-8.2
	4	-0.1	-10.4	-1.3	-4.3	-8.1
	mean	-0.55	-14.30	-3.05	-0.58	-7.23
Ensemble A (4-hour trials: First 2 Hours)	1	-0.6	-7.2	-0.7	-1.3	-4.9
	2	-0.5	-24.2	-6.7	-1.6	-9.8
	3	-1.2	-36.0	-3.0	-1.2	-8.2
	4	-0.3	-8.0	-3.2	-1.1	-7.7
	mean	-0.65	-18.85	-3.40	-1.30	-7.65
Ensemble A (4-hour trials: second 2 hours)	1	-0.6	-12.5	-5.6	4.5	-4.9
	2	-0.5	-0.4	-6.7	5.7	-9.8
	3	-1.2	-11.4	-3.0	-1.2	-0.8
	4	-0.8	-8.0	-3.2	1.4	-5.5
	mean	-0.78	-8.08	-4.63	2.60	-5.25

[a] Negative values indicate body cooling.
[b] These values taken from Table 3 for comparisons.

Table 7

Rates of Body Temperature Change from Effects of Heating Hands, Feet, and Body during 4-Hour Trials (Ensemble B)

Ensemble/ condition	Subject	Body temperature changes in ° F/hour[a]			
		Rectal	Finger	Toe	Back
Ensemble B[b] (2-hour trials)	1	-0.7	0.3	-14.6	1.5
	2	--	-0.7	-7.8	0.0
	3	-0.5	-0.9	-5.8	-5.3
	4	-0.3	-0.4	-8.6	-2.6
	mean	-0.50	-0.43	-9.20	-1.60
Ensemble B (4-hour trials: first 2 hours)	1	-0.3	-8.9	-7.9	-2.3
	2	-0.4	-12.5	-15.9	-1.1
	3	-0.6	-0.6	-14.8	-3.3
	4	-0.3	-15.8	-16.1	-2.8
	mean	-0.40	-9.50	-13.68	-2.38
Ensemble B (4-hour trials: second 2 hours)	1	-0.1	7.1	-1.2	1.9
	2	0.3	0.6	-5.7	2.6
	3	-0.3	-13.5	-12.1	1.6
	4	-0.6	-7.6	-11.8	0.2
	mean	-0.18	-3.35	-7.70	1.58

[a] Negative values indicate body cooling.

[b] These values taken from Table 3 for comparisons.

Table 8

Tolerance Times and Terminal Temperatures for Effects of Heating Hands, Feet, and Body during 4-Hour Trials (Ensemble A)

Ensemble/ condition	Subject	Time of exposure (minutes)	Terminal temperatures in °F				
			Rectal	Finger	Toe	Back	Heel
Ensemble A[a] (2-hour trials)	1	120	98.4	61.3	89.7	90.1	71.8
	2	120	98.4	67.6	88.4	87.0	72.8
	3	120	98.0	59.0	86.0	81.6	79.6
	4	120	98.8	58.0	83.4	79.6	57.3
	mean	120	98.4	61.5	86.9	84.6	70.4
Ensemble A (4-hour trials: first 2 hours)	1	120	97.5	60.4	93.0	92.3	72.1
	2	120	98.9	52.3	81.9	92.0	63.9
	3	120	96.2	59.2	90.2	89.9	75.7
	4	120	98.1	60.1	91.5	84.0	66.2
	mean	120	97.7	58.0	89.2	89.6	69.5
Ensemble A (4-hour trials: terminal)	1	155	97.2	48.9	92.7	94.9	68.9
	2	140	98.8	52.0	81.0	93.9	61.1
	3	140	96.0	56.9	88.2	89.9	74.7
	4	170	97.4	50.1	87.5	85.2	61.6
	mean	151	97.4	52.0	87.4	91.0	66.6

[a] These values are taken from Table 4 for comparison.

Table 9

Tolerance Times and Terminal Temperatures from Effects of Heating Hands, Feet, and Body during 4-Hour Trials (Ensemble B)

Ensemble/ condition	Subject	Time of exposure (minutes)	Terminal temperatures in °F			
			Rectal	Finger	Toe	Back
Ensemble B[a] (2-hour trials)	1	120	98.4	101.5	74.1	85.0
	2	120	--	97.3	88.2	90.0
	3	120	98.5	94.8	85.6	79.9
	4	120	98.1	94.7	86.6	81.4
	mean	120	98.3	97.1	83.6	84.1
Ensemble B (4-hour trials: first 2 hours)	1	120	98.4	79.4	84.3	91.2
	2	120	98.6	80.2	67.7	86.9
	3	120	97.5	94.0	80.3	84.4
	4	120	98.0	75.3	68.1	78.0
	mean	120	98.1	82.2	75.1	85.1
Ensemble B (4-hour trials: terminal)	1	240	98.2	82.0	73.2	94.8
	2	190	98.9	80.2	56.9	90.3
	3	230	97.0	71.3	61.1	83.8
	4	210	97.1	64.4	49.6	78.9
	mean	218	97.8	74.5	60.2	87.0

[a] These values are taken from Table 4 for comparison.

Table 10

Time to Reach Functional Temperature Limit from Effects of Heating Hands, Feet, and Body during 4-Hour Trials

Ensemble/ condition	Subject	Time (minutes) to reach 60° F.		
		Finger	Toe	Heel[d]
Ensemble A[c] (2-hour trials)	1	126[a]	b	248[a]
	2	160[a]	•360[a]	228[a]
	3	114	337	263[a]
	4	113	•360[a]	99
	mean	128	•360	210
Ensemble A (4-hour trials)	1	115	b	265[a]
	2	92	327[a]	147[a]
	3	116	•360[a]	•360[a]
	4	121	•360[a]	187[a]
	mean	111	•360	>240
Ensemble B[c] (2-hour trials)	1	b	178[a]	
	2	•360[a]	338[a]	
	3	•360[a]	385[a]	
	4	•360[a]	306[a]	
	mean	•360	302	
Ensemble B (4-hour trials)	1	b	•360	
	2	b	167	
	3	270[a]	221[a]	
	4	245[a]	154	
	mean	>270	>225	

[a] Value calculated by extrapolation from slope of body temperature change curve (see Figure 2).
[b] Temperature constant or rising slowly; time very high but indeterminate.
[c] These values are taken from Table 5 for comparison.
[d] Heel temperatures recorded for Ensemble A only.

Third, the results clearly show that heated hand and foot wear substantially reduces heat loss from fingers and toes. This was true for both Ensembles A and B and for every individual subject. In addition, it is clear that other parts of the body were not significantly affected.

The data for the two test ensembles cannot properly be compared since the ensembles are qualitatively dissimilar. Yet, the data rationally reflect their differences. In the case of hand wear, Ensemble B uses heated liners worn under the Arctic mitten and wool inserts; hand cooling was reduced almost completely. Ensemble A uses a heated insulated glove which could not be worn under the Arctic mitten ensemble. Although gloves give inadequate cold protection at temperatures below freezing, the heated gloves gave better protection than that afforded by the extreme cold-weather mitten ensemble used in ECWCS. The heated boot inserts of Ensemble A drastically reduced heat loss from the toes, but the absence of heating elements in the heels of those inserts is clearly reflected in the heel cooling values - over twice the rate of cooling as compared with the toes. The heated socks in Ensemble B appeared to be consistently less effective than the boot inserts. This comparison is subject to two reservations. The Ensemble B socks appear to supply less heat to the feet than do the boot inserts, and this heat is distributed over the sides and tops of the feet as well as the soles when the socks are properly adjusted. Additional measurements of skin temperature on parts of the feet other than the toes are needed to provide a fair basis for comparison of the two types of foot heaters. In addition, the mean cooling rate of the toes in Ensemble B is distorted by the aberrant value shown for subject Number 1. When he wore Ensemble B, the electrical connectors to the socks separated twice for several minutes during the second half of the trial.

One observation of lesser import should be noted. In every trial, each subject experienced a slow drop in rectal temperature. This is expected since in every trial one or more regions of the body were cooling significantly. Each of these avenues of heat loss contributes inexorably to a drop in total body heat content as monitored by rectal temperature. The use of heated garments cannot provide long-term cold protection (greater than 4 hours) unless the amount of heat supplied can fully compensate for all regional heat losses.

During extreme exposure conditions where cold protection is required for a limited time, other data than cooling rates are required to determine the acceptability of cold weather clothing ensembles. Tables 8 and 9 summarize two kinds of such data. Tolerance time is the duration of exposure required to bring an index body temperature down to a predetermined level, in this case, a skin temperature of 50°F (10°C) or a rectal temperature of 95°F (35°C). The effectiveness of the heated hand and foot wear is clearly evident. In every trial, the heated garments provided acceptable protection for at least a 120-minute cold exposure. As seen in Table 4, in five of eight trials, the ECWCS ensemble failed to provide protection for the 120-minute exposure period. Since the trials about subjects with heat supplied to only the hands and feet were terminated at 120 minutes, the times given for these ensembles underestimate true tolerance times (i.e., acceptable cold protection was provided for at least 120 minutes).

The terminal temperature data reveal how well Ensembles A and B performed. All subjects wearing Ensemble B had terminal finger temperatures in the range of complete comfort. In Ensemble A, the subjects' fingers experienced a considerable degree of temperature drop. This is not unexpected in view of the known inadequacies of gloves (as opposed to mittens) as cold weather hand protection. With both heated ensembles, terminal temperatures of the toes were in every case well within the range of comfort. Heel temperatures of subjects in Ensemble A were over 16°F (-8.89°C) cooler than toes (see Table 4), and were enough to produce a sensation of coldness, though not excessive. Coldness in the heels was also reported in some cases by subjects wearing Ensemble B, a response not observed in the preliminary pretest trials.

For reasons described earlier, the test conditions adopted (subjects remaining sedentary throughout the cold exposure) were intended to explore whether heated garments could adequately protect soldiers whose tasks were necessarily sedentary and of a type requiring unimpeded use of hands and feet. In this circumstance, it is appropriate to base tolerance times on a skin temperature of 60°F (15.5°C), the threshold below which hands and feet begin to experience pain and a loss in ability to perform skilled tasks. Table 5 lists tolerance times taking 60°F (15.5°C) as a functional limit of skin temperature. The differences between the ECWCS ensemble and Ensembles A and B are marked. The ECWCS gives sufficient protection for a little more than 1 hour to fingers and from 1-1/2 hours to toes. Both heated ensembles provided acceptable protection to both extremities for a full 2 hours. The differences between Ensemble A and B are clearly shown and are according to the results already discussed. Even with heat supplied, gloves (Ensemble A) are limited in the degree to which they protect hands from the cold. For both Ensembles A and B, foot heating was more than adequate for periods exceeding 120 minutes. Functional tolerance times had to be calculated by extrapolation using cooling rate data. Thus determined, tolerance times up to 240 minutes must be considered as increasingly crude estimates. Times exceeding 240 minutes are not to be taken too seriously, quantitatively.

In the second series of trials designed to determine the effects of additional heated garments, the cold exposure period was extended to a maximum of 240 minutes to get better estimates of tolerance times. The data for the first 120 minutes only of these trials were used for comparison with those of the earlier trials using only heated hand and foot wear.

The values for cooling rates for subjects wearing Ensemble A are listed in Table 6. There is no evidence that the use of additional heat to the upper torso improved cold protection. Rather the effects, if significant, are consistently negative. The largest effect on mean cooling was on the fingers, but this value has to be taken as equivocal because of the large difference in values between individual subjects.

The values for terminal temperature for subjects wearing Ensemble A are listed in Table 8. These results are in agreement with those on cooling rates. The terminal finger temperatures for 4-hour scenarios were slightly lower than those of the 2-hour scenarios. The elevation in terminal temperatures of the toes and back is trivial at best, since in both ensembles these temperatures are in a comfort zone. The most significant effect of the added heated jacket may be on the core (rectal) temperatures, which were nearly 1°F (-17.2°C) lower when the heated Ensemble A vest was worn.

For subjects wearing Ensemble A, tolerance times are not listed. In only one trial did subjects' skin temperatures of toes, heels, or back drop to the 50°F (10°C) limit. After 2 hours of cold exposure, finger temperatures of subjects remained above 60°F (15.5°C) in half of the instances when Ensemble A was worn. In the remaining instances, finger temperatures of one subject dropped below 58°F (14.4°C).

The off-the-shelf design of Ensemble B did not permit operation of only the heated glove and sock liners, so all subjects wore the complete undergarment for all Ensemble trials. For the 2-hour exposure trials, the controllers were set to supply heating current to the sock and glove liners. For the 4-hour trials, the controllers were adjusted to supply heating current to the whole liner system.

The two upper sets of data in Table 7 compare the effects of the two heating modes of Ensemble B on cooling rates for a 120-minute period of cold exposure. The cooling rates of skin temperatures (fingers, toes, back) were substantially increased when full body heating was supplied. This holds true not only for the values of the means but also for three of four of the values for individual subjects. The full body heating had no effect on core temperatures.

The values for terminal temperatures for subjects wearing Ensemble B are similarly listed in Table 9. The finger and toe temperatures are substantially lower when Ensemble B is supplying full body heat. Terminal rectal and back temperatures were not affected. It should be noted that although the full body-heating mode had a negative effect on finger and toe temperatures, in no case did either of these two temperatures reach the tolerance temperature limit of 50°F (10°C).

Functional tolerance times are not separately presented. During full body heating modes of Ensemble B, no subjects' skin temperature even closely approached the functional tolerance limit of 60°F (15.5°C) at the end of the 120 minutes of cold exposure.

No data are available to account directly for the negative effect of application of full body heating with Ensemble B. The most probable explanation may lie in the circuiting. Most of the maximum heating capacity of the system is distributed over the two large garments, jacket and trousers. It may be that when these two garments are functioning, the heat supplied to the glove and sock liners is reduced.

In the second set of trials, the cold exposure was continued beyond 120 minutes. Data collected after 120 minutes revealed a distinct shift in the skin temperatures of the subjects readily observable by inspection of the plotted temperature data as illustrated by Figure 3. Beginning after 120 minutes of exposure, skin cooling rates showed a reduction and even a reversal in sign (local warming). As shown in Tables 6 and 7, this occurred when either Ensemble A or B was worn. The shift was shown not only by the cooling rate data for the four subjects but also in three-quarters of the individual records (three for each subject in a given trial--finger, toe, and back temperatures). The phenomenon is not unexpected. As local cooling occurs, the drop in the skin temperature decreases the temperature difference between the skin and the external environment resulting in a decrease in the local rate of heat loss. The amount of change in cooling rate is determined by the balance in local heat loss and the rate of heat being supplied by warm circulating blood to the area affected. The immediate, practical effect of this reduction in cooling rates is to increase the cold exposure tolerance times (time to reduce any skin temperature to 50°F [10°C]).

The mean tolerance time for all eight trials with the unheated ECWCS ensemble (see Table 4) is 106 minutes. When the heated Ensemble A is worn (see Table 8), mean tolerance time is 151 minutes (increase of 42%). With Ensemble A, the tolerance limit is only partly the result of the inherent limitations of gloves (as opposed to mittens) for cold protection. Subjects 1 and 4 reached 50°F (10°C) in finger temperature, but Subjects 2 and 3 were terminated because of continuous shivering. All four subjects reported chilling in the arms and legs. This ensemble supplied heat (plus extra insulation) to the torso but not to the limbs. This is reflected by the drop in rectal temperatures to well below 98°F (36.6°C) (see Table 8), 2°F (-16.67°C) below normal. The blood, which was needed to supply heat to the cool hands, lost further heat in passage through the arms to the hands.

When Ensemble B was worn, the mean tolerance time was 218 minutes (see Table 9), an increase of 106% compared with when unheated ECWCS was worn. With Ensemble B, heat was supplied to hands protected by arctic mittens; after 3 hours, terminal finger temperature were a very warm 97.8F (36.5°C). With this ensemble, feet were less adequately protected; however, in only one case did toe temperature drop to 50°F (10°C). Tests were terminated in the other three cases because of continuous shivering and because all four subjects experienced chilling in the arms and legs. With this ensemble, rectal temperatures also dropped below 98°F (36.6°C), but only after 3-1/2 hours of cold exposure.

Times to reach functional temperature limits (60°F [15.5°C]) in fingers and toes are shown in Table 10. These results confirm those obtained in the 2-hour exposure trials: The use of heated garments provides a large increase in the useful amount of cold protection to hands and feet of soldiers wearing the ECWCS ensemble in the extreme cold. The results also make clear (at least under the conditions by which these trials were conducted) that the use of heated garments in addition to hand and foot wear did not enhance protection of cold-vulnerable areas of the ECWCS ensemble. Rather, the use of the extra heated garments was counterproductive.

In the case of Ensemble A, the use of the heated short vest resulted in a small decrease in the time to reach functional temperature limits for the fingers. More importantly, by applying heat where it was least needed, the ensemble raised torso skin temperatures to levels at which risk of sweat induction is threatened (see Table 8).

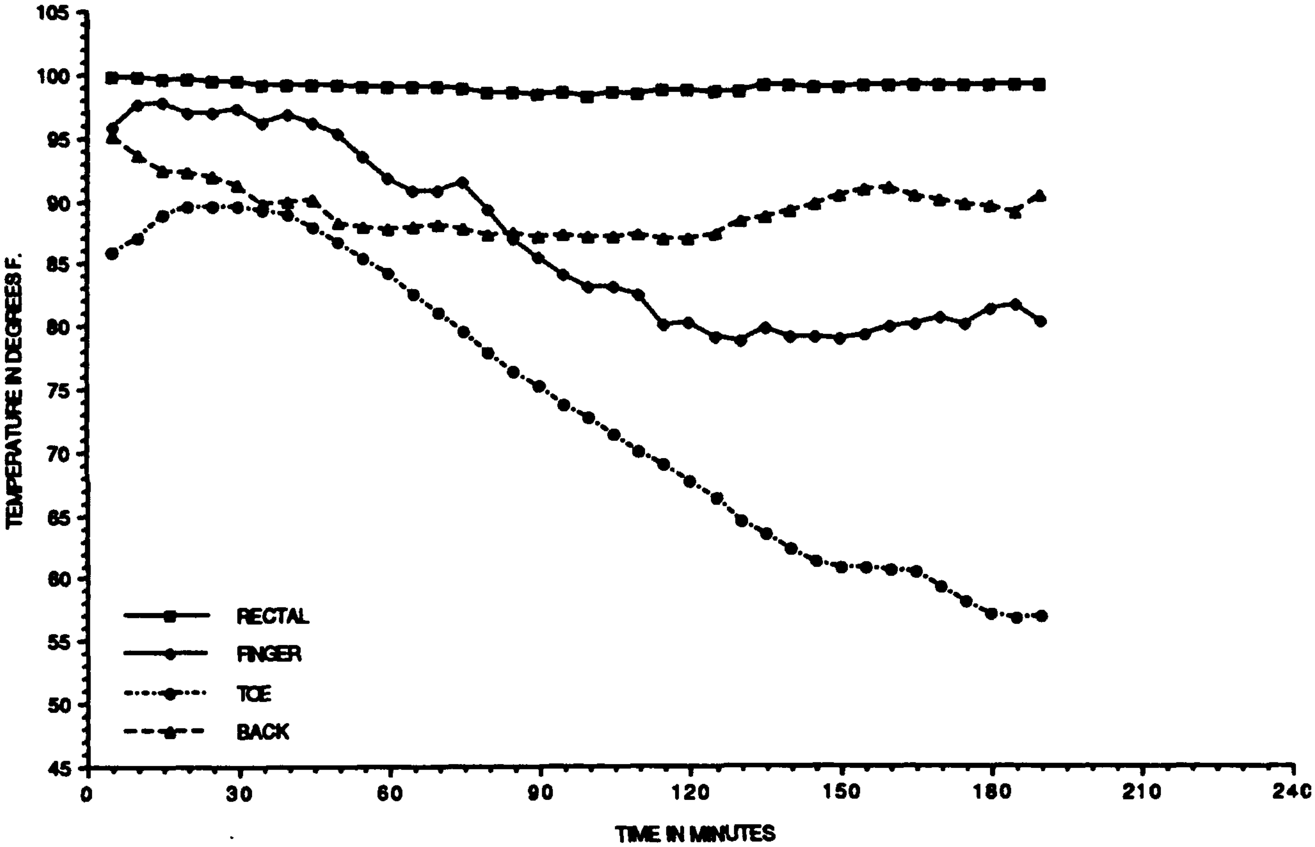

Figure 3. Body temperature changes for Subject Number 2 wearing Ensemble B with heat to hands, feet, and body.

In the case of Ensemble B, the supply of full body heat substantially reduced the time to reach functional temperature limits for both fingers and toes, and it also resulted in much lower terminal finger and toe temperatures.

It may well be that improvements in the control circuitry in both Ensembles A and B can reduce or even eliminate the negative effects of using body heating garments, but this is a secondary issue. If the use of body heating garments other than for hands and feet cannot be shown to produce substantial additional cold protection where it is most needed, one can hardly justify the large additional costs for the garments and the large increases in power consumption required for their operation.

Human Factors and Engineering Design Considerations

During this activity, certain observations were made by HRED experimenters and test subjects. Several human factors and engineering design shortcomings were noted. These shortcomings were collated as follow.

Widder Electric Riding Apparel (Ensemble A)

Lectric Gloves

It was perceived by all subjects that the thumbs felt much colder than the rest of the hand. The maximum current draw (heat output) of 1.2 amperes was obtained at a thermostatic control setting of approximately 2-1/2. Rotating the control dial to higher settings (3 through 7) did not increase the current draw or heat output to the gloves. The controller was not designed to control the gloves independent of the body garments.

Ventura Model Lectric Vest

The vest was well accepted by all subjects--it was perceived that heat was evenly distributed throughout the vest; however, all subjects stated that their arms were cold because of no sleeves. A heated jacket (vest with sleeves) should be investigated.

The vest's maximum current draw of 4.5 amperes was obtained at a thermostatic control setting of approximately 4-1/2 when gloves and vest were used. Higher control settings did not draw more amperage or increase heat output. The controller was designed to control gloves, vest, and chaps.

Farnum Hot Feet Sole Inserts (Ensemble A)

During a pretest trial, a subject stood from his seated position and noted that the soles of his feet became excessively warm (quote: "Like standing on asphalt on an August afternoon.") after 2 or 3 minutes of standing. He stated that the inserts were comfortable while sitting, but after a few minutes of standing, they became very uncomfortable. This symptom was not noted by any of the subjects during the test because they were required to remain seated for the duration of each scenario. Nonetheless, it merits further investigation.

During the same pretest trial, it was also noted that the inserts did not provide heat to the heel of the foot and that the user's heel was excessively cold and became numb. An inspection of the inserts showed that there were no heating wires located in the heel area of the inserts. At this point, it was decided that a skin temperature sensor be placed on each subjects' right heel so the heel skin temperatures could be monitored. The subjects also noted that there was a noticeable difference in heat supplied to the heel and back of the foot. The skin temperature data indicated that the average heel temperature was 16.5^{o}F (8.61^{o}C) colder than the average toe temperature by the end of a 2-hour scenario and 20.8^{o}F (-6.22^{o}C) colder at the end of 4-hours exposure. Placing heating wires throughout the insert might eliminate this problem.

The individual pin connectors (connecting each insert to power supply wire) would not stay connected on the inserts used during the pretest trials. The manufacturer sent another set of inserts (with trailerhitch type connectors) to use for the test. These inserts were used without failure. A more positive connector such as these should be incorporated in all inserts.

The heat inserts had only an on and off switch integrated into its wiring harness; therefore, the heat supplied to the inserts could not be regulated. The Hot Feet are simply on or off. When on, the inserts had a current draw of 1.75 amperes. A thermostatic control would enable a user to regulate the amount of heat supplied to the inserts.

Power Johns™ (Ensemble B)

The wiring leads from the gloves and socks to the electrical connectors were made of resistance wires. If these wires, which were not thermally insulated, were allowed to come in direct contact with bare skin in the gaps between the clothing components, mild burns (erythema persistent for more than 24 hours) can occur. This was observed during pretest trials of this system. This problem was eliminated during test trials by wrapping the resistance wiring leads with heavy electrical insulating tape and by taping the clothing together at the closures.

The subjects frequently complained that the bottoms of their feet were cold especially at their heels. The sock was a tube-design pattern which could be donned with any orientation. If the subjects donned the sock so that they did not walk directly on the heating wires, all or part of the soles of their feet were unheated. A more conventional sock pattern would guarantee that the heating wires in the sock would consistently be located in a desirable position.

On two occasions, the mating connectors between the power controllers and the suit disconnected during a test. A connector with a more positive lock should be used in this area.

Two of the four subjects noted that heat supplied to the undershirt was not evenly distributed. Subjects stated that they felt much colder at the back of the shoulders and lower back. It is not clear whether this was because of unequal distribution of insulation in military cold weather clothing or because of the placement of the heating wires in the Power Johns™ undershirt.

On one occasion, the analog power controller and its main fuse got too hot to hold firmly after a 4-hour scenario. This problem should be investigated.

Neither of the power controllers (analog or minicomputer) had any sort of detent or markings by which it could be preset to hold a desired setting. The thumbwheel switches could be inadvertently moved without the knowledge of its user. During this test, the thumbwheel switches for each controller were taped firmly in position after pretest adjustments.

CONCLUSIONS

1. The use of electrically heated hand and foot wear substantially improves the thermal protection provided by the ECWCS uniform ensemble to sedentary soldiers at an ambient air temperature of -40°F (-40°C).

2. Protection is greater for hands wearing heated gloves than for those wearing extreme cold-weather mitten ensembles.

3. The use of electrically heated body garments in addition to heated hand and foot wear does not improve the effective protection of the ECWCS uniform ensemble. In some instances, such use causes a decrease in thermal protection of the hands and feet.

4. The electrically heated garments evaluated were off-the-shelf commercially available items designed for recreational use. They are not suitable for military use without modification.

5. The use of electrically heated hand and foot wear, at the level of heat provided by the items tested, has a distinct potential for improvement of thermal protection to soldiers in a number of military situations.

RECOMMENDATIONS

1. The exploration of the effectiveness of electrically heated garments used with military cold-weather clothing ensembles should be continued.

2. The changes in the design of the items used in this study should be considered to correct the human factors and engineering design problems identified.

3. Future study should put emphasis on

(a) Monitoring skin temperatures at many more sites other than those observed in the pilot study;

(b) Evaluating of the effectiveness of electrically heated garments with military clothing ensembles other than ECWCS;

(c) Performing a more complete human factors evaluation of the most effective items tested; and

(d) Assessing the effectiveness of appropriate heated garments in scenarios where cold vulnerability problems are known to exist in a practical military situation (e.g., aircraft pilots).

APPENDIX A

VOLUNTARY AGREEMENT AFFIDAVIT

VOLUNTEER AGREEMENT AFFIDAVIT

For use of this form, see AR 70-25; the proponent agency is OTSG

PRIVACY ACT OF 1974

Authority: 10 USC 3013, 44 USC 3101, and 10 USC 1071-1087.

Principle Purpose: To document voluntary participation in the Clinical Investigation and Research Program. SSN and home address will be used for identification and locating purposes.

Routine Uses: The SSN and home address will be used for identification and locating purposes. Information derived from the study will be used to document the study, implementation of medical programs, adjudication of claims, and for the mandatory reporting of medical conditions as required by law. Information may be furnished to Federal, State and local agencies.

Disclosure: The furnishing of your SSN and home address is mandatory and necessary to provide identification and to contact you if future information indicates that your health may be adversely affected. Failure to provide the information may preclude your voluntary participation in this investigational study.

PART A(1) - VOLUNTEER AFFIDAVIT

Volunteer Subjects in Approved Department of the Army Research Studies

Volunteers under the provisions of AR 40-38 and AR 70-25 are authorized all necessary medical care for injury or disease which is the proximate result of their participation in such studies.

I, ______________________________, SSN ______________,

having full capacity to consent and having attained my ____________ birthday, do hereby volunteer/give consent as legal representative for ______________________________ to participate in ______________

Pilot Study to Determine the Thermal Protective Capability of an Electrically-
(Research study)
Heated Clothing Components and Boot Inserts

under the direction of Dr. A.A. Woodward, Human Engineering Laboratory, 278-5935

conducted at Aberdeen Proving Ground-EA, Bldg 3226.
(Name of Institution)

The implications of my voluntary participation/consent as legal representative; duration and purpose of the research study; the methods and means by which it is to be conducted; and the inconveniences and hazards that may reasonably be expected have been explained to me by

Dr. A.A. Woodward.

I have been given an opportunity to ask questions concerning this investigational study. Any such questions were answered to my full and complete satisfaction. Should any further questions arise concerning my rights/the rights of the person I represent on study-related injury, I may contact

Chief, Patient Administration Branch, ATTN: HSXR-APG-EA (SGT Walls)

at Aberdeen Proving Ground, MD 21005-5131, Phone (301) 278-2086
(Name, Address and Phone Number of Hospital (Include Area Code))

I understand that I may at any time during the course of this study revoke my consent and withdraw/have the person I represent withdrawn from the study without further penalty or loss of benefits; however, I/the person I represent may be required (military volunteer) or requested *(civilian volunteer)* to undergo certain examination if, in the opinion of the attending physician, such examinations are necessary for my/the person I represent's health and well-being. My/the person I represent's refusal to participate will involve no penalty or loss of benefits to which I am/the person I represent is otherwise entitled.

____

PART A (2) - ASSENT VOLUNTEER AFFIDAVIT *(MINOR CHILD)*

I, ______________________________, SSN ______________ having full

capacity to consent and having attained my ____________ birthday, do hereby volunteer for ______________

______________________________ to participate in ______________

____
(Research Study)

____

under the direction of ______________________________

conducted at ______________________________.
(Name of Institution)

(Continue on Reverse)

DA FORM 5303-R, MAY 88 | PREVIOUS EDITIONS ARE OBSOLETE

PART A(2) - ASSENT VOLUNTEER AFFIDAVIT *(MINOR CHILD) (Cont'd.)*

The implications of my voluntary participation; the nature, duration and purpose of the research study; the methods and means by which it is to be conducted; and the inconveniences and hazards that may reasonably be expected have been explained to me by

____

I have been given an opportunity to ask questions concerning this investigational study. Any such questions were answered to my full and complete satisfaction. Should any further questions arise concerning my rights I may contact

____

at ______________________________

(Name, Address, and Phone Number of Hospital (Include Area Code))

I understand that I may at any time during the course of this study revoke my assent and withdraw from the study without further penalty or loss of benefits; however, I may be requested to undergo certain examination if, in the opinion of the attending physician, such examinations are necessary for my health and well-being. My refusal to participate will involve no penalty or loss of benefits to which I am otherwise entitled.

____

PART B - TO BE COMPLETED BY INVESTIGATOR

INSTRUCTIONS FOR ELEMENTS OF INFORMED CONSENT: *(Provide a detailed explanation in accordance with Appendix E, AR 40-38 or AR 70-25.)*

You were presented a pretest briefing which verbally explained your involvement in a pilot study to determine the thermal protective capability of electrically heated clothing components. Afterwards, you were given the opportunity to ask questions relative to your participation in the conduct of the test, and these were answered to your satisfaction before you volunteered to participate.

To reiterate, these tests will be conducted in a carefully controlled chamber to determine if the clothing ensemble will provide you protection from the cold. The tests will start with the chamber set at -40°F.

It is necessary to monitor your skin and body core temperatures for two reasons: (1) your personal safety; and (2) to collect data relative to your performance in the clothing ensemble. You will be instrumented before dressing each day with four temperature sensors connected to read-out instrumentation located outside the chamber. These sensors will be placed as follows: Rectum, to measure inside body temperature; fingertip, large toe, and middle of back to measure skin temperatures. Observers outside the chamber will be monitoring these temperatures continually and recording all temperatures every 5 minutes. You will be removed from any individual test at any time your rectal temperature goes down to 95.0°F or any skin temperature goes down to 50°F. At these temperatures you may be uncomfortable, but at no risk whatever of cold injury.

I do ☐ do not ☐ *(check one & initial)* consent to the inclusion of this form in my outpatient medical treatment record.

SIGNATURE OF VOLUNTEER	DATE	SIGNATURE OF LEGAL GUARDIAN *(If volunteer is a minor)*

PERMANENT ADDRESS OF VOLUNTEER	TYPED NAME OF WITNESS	
	SIGNATURE OF WITNESS	DATE

REVERSE OF DA FORM 5303-R, MAY 88

VOLUNTEER AGREEMENT AFFIDAVIT (Continued)

PART B (Continued)

Two test runs (one am; one pm) may be conducted on each day. For each run you will wear one of four different clothing ensembles and will be required to sit in an environmental cold chamber set at an ambient air temperature of -40°F. Subsequent tests may require you to sit still for as long as four hours at -40°F. The clothing worn in any given test will be the full extended cold weather clothing system (ECWCS) and ensembles comprised of various electrically-heated garments that will be worn in conjunction with selected components from the ECWCS.

Subsequent tests will require you to sit still for as long as four hours at -40°F. For each test you will wear a clothing ensemble made up of various electrically-heated garments and selected ECWCS components. You will wear a different ensemble on each of the four test days.

Since you are a volunteer participant, Army Regulations (AR 40-38 and AR 70-25) require that your medical records be reviewed prior to your participation in a study. Since you are being asked to participate in a study where you will be exposed to low ambient air temperatures in an environmental chamber, your records will be medically screened by the Patients Administration Branch of Kirk Army Health Clinic. This is to assure that you have not had a history of cold intolerance or cold injury, alcoholism, or circulatory disorder; and to assure that you are not or have not recently used medications which may interfere with body temperature regulation or shivering.

You will receive no direct benefits from your paticipation in this study other than the knowledge and experience you may gain. However, the results of these tests may help the Armed Forces find a method to provide additional body heat for vehicle operators.

All data and medical information obtained about you as an individual will be considered priviledged and held in confidence. Complete confidentiality cannot be promised because information bearing on your health may be required to be reported to appropriate medical or command authorities.

The results of these tests will be confidential; that is, your identities will not be assoicated with published tests results. You have the right of access to any of the data collected on you. Any questions about this data access should be addressed to the test director, Dr. Woodward.

APPENDIX B

TEST ENSEMBLES

TEST ENSEMBLES

Ensemble A

Vest

Widder Ventura Model Lectric Vest. This garment is a waist-length sleeveless vest with a high collar. It has a urethane-coated nylon shell enclosing THINSOLATE® Thermal Insulation. The heating wires are located on the inner surface of the insulation layer. The heated collar is synthetic pile lined.

Gloves

Widder Lectric Gloves, new style (1989). These are five-finger gloves with 5-inch gauntlets. They have water-repellent nylon shells enclosing THINSOLATE® Thermal Insulation. The palms and fingers are reinforced with soft glove leather. The heating wires are located outside the insulation and supply heat to the fingers and backs of the hands. The gauntlets are insulated but not heated.

Controller

Widder Garments. This is a simple bimetal thermostat with a rheostat that controls the heating level of all the heated garments used. No control of individual garments is provided.

Boot Inserts

Farnum Style 102 Hot Feet. These are removable insoles with ribbon heating wires sandwiched between butyl rubber soles and wool fabric insulation pads. No heating wires are located under the heels. The only control is a on and off switch in the power supply cord.

Ensemble B.

Liner Undergarment

Environwear, Incorporated Power Johns™. This is a six-component heated ensemble consisting of an undershirt, underdrawers, gloves, and socks. The garments are fabricated from a lightweight knit combination of Thermax® and Lycra®. Heating wires are embedded in the knit fabric and distribute heat over the whole body area except for the neck and head. Individual components are electrically connected at garment closures at the waist, wrists, and ankles. Power is supplied to all individual components through a single umbilical connector at the undershirt waist. The gloves, socks, and underdrawers cannot be operated independently of the undershirt.

Controller I (Analog)

This is a manually operated unit that allows individual setting of the heating level for each of five body zones (hands, feet, arms, legs, and torso). Once these settings are performed, an overall temperature control is used to adjust manually the heating level of all five zones in proportion simultaneously. This controller must be used when heat is to be supplied to the socks and gloves only.

Controller II (Microprocessor)

This unit provides automatic control of the heat supplied to the five body zones. This is achieved by monitoring local skin temperature and supplying the heating current necessary to maintain that temperature at a preset level. It cannot be used to regulate the heat to the gloves, socks, or underdrawers alone.

The manufacturers' informational literature is shown in Appendices C and D.

APPENDIX C

WIDDER APPAREL AND HOT FEET INSERTS

When You Want The Best . . .

WIDDER
Lectric-Heat

The Pioneers of Electric-Heated Riding Apparel

Figure C-1. Brochure illustration of Widder Lectric vest, gloves, and controller.

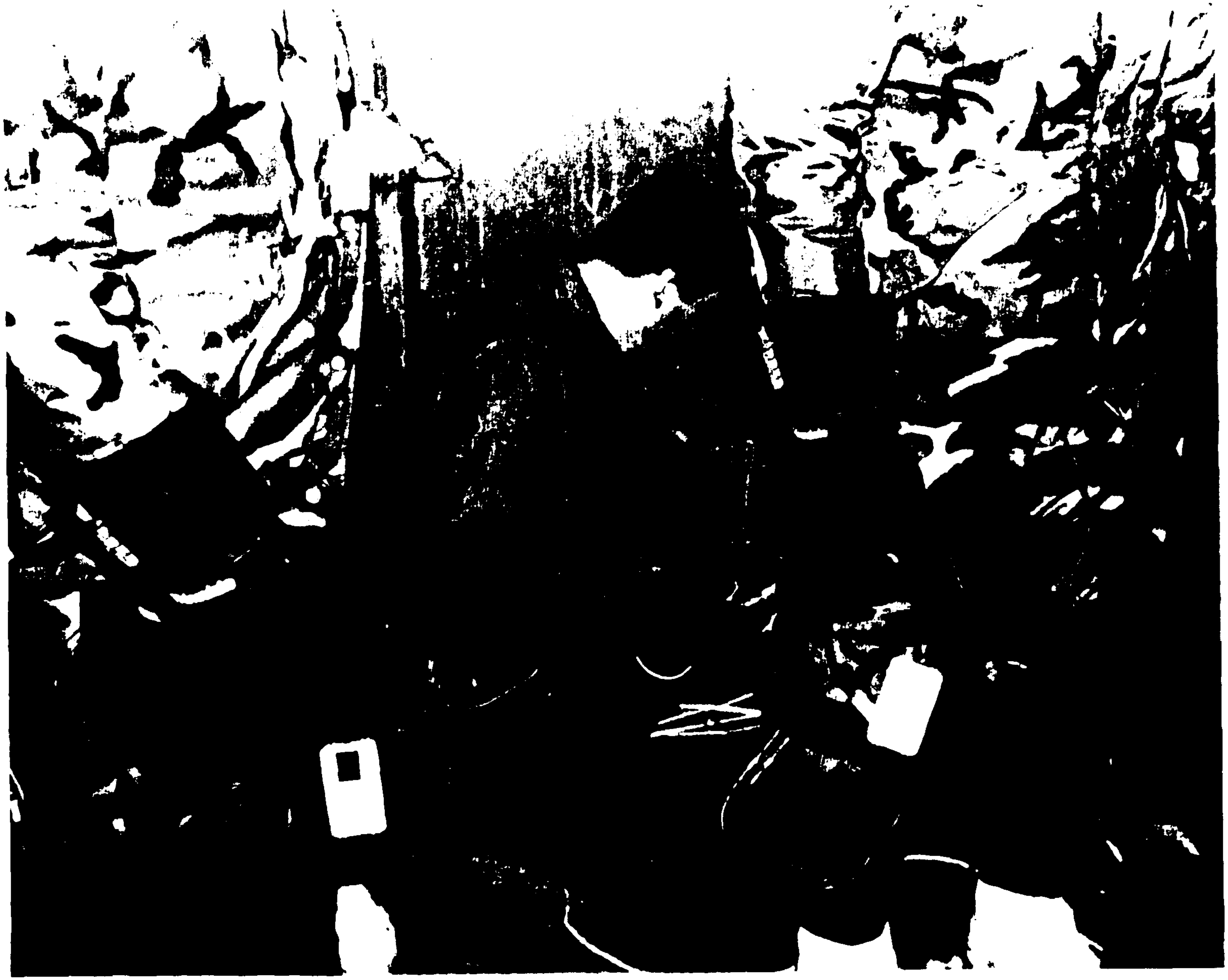

Figure C-2. Subjects wearing Ensemble A. Picture shows Widder gloves and controller.

Figure C-3. Electric boot inserts (Hot Feet) used in Ensemble A.

APPENDIX D

ENVIRONMENT, INCORPORATED POWER JOHNS™

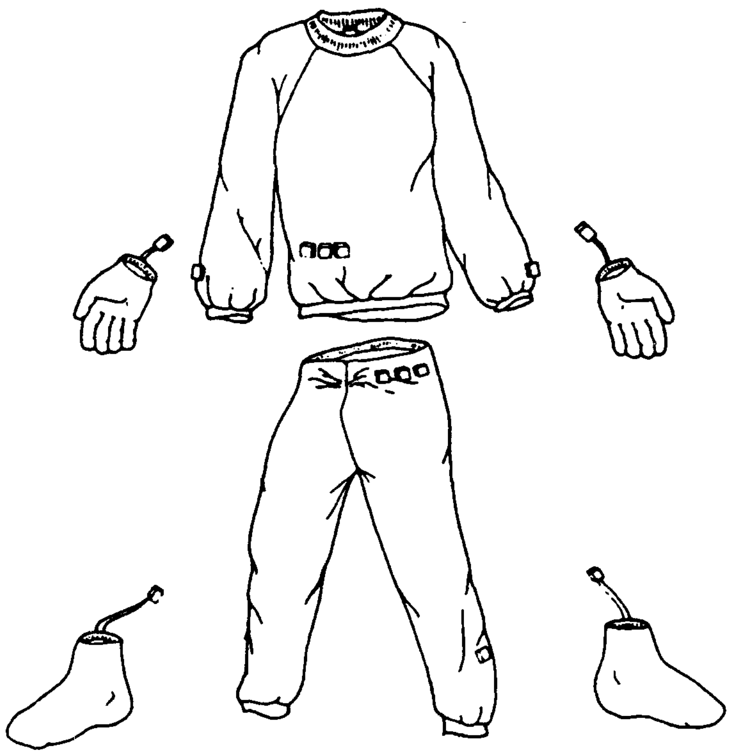

Figure D-1. Power Johns™ components.

Figure D-2. Subject wearing Power Johns™ underwear, socks, gloves, and power controller.

APPENDIX E

ORIGINAL DATA ABOUT BODY TEMPERATURES AND READING TIMES

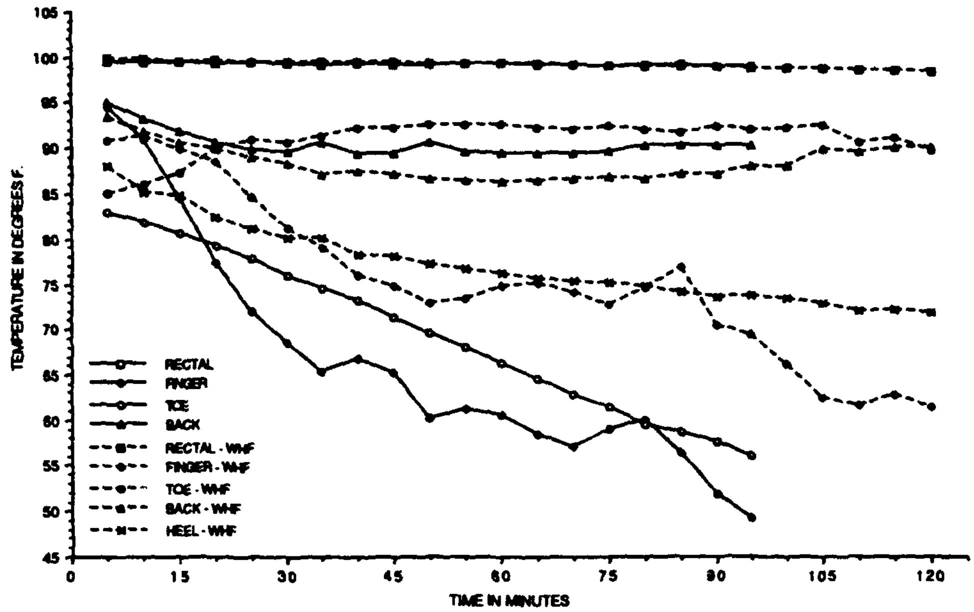

Figure E-1. Subject Number 1--ECWCS versus Widder gloves and Hot Foot during 2-hour scenario with heat supplied to hands and feet.

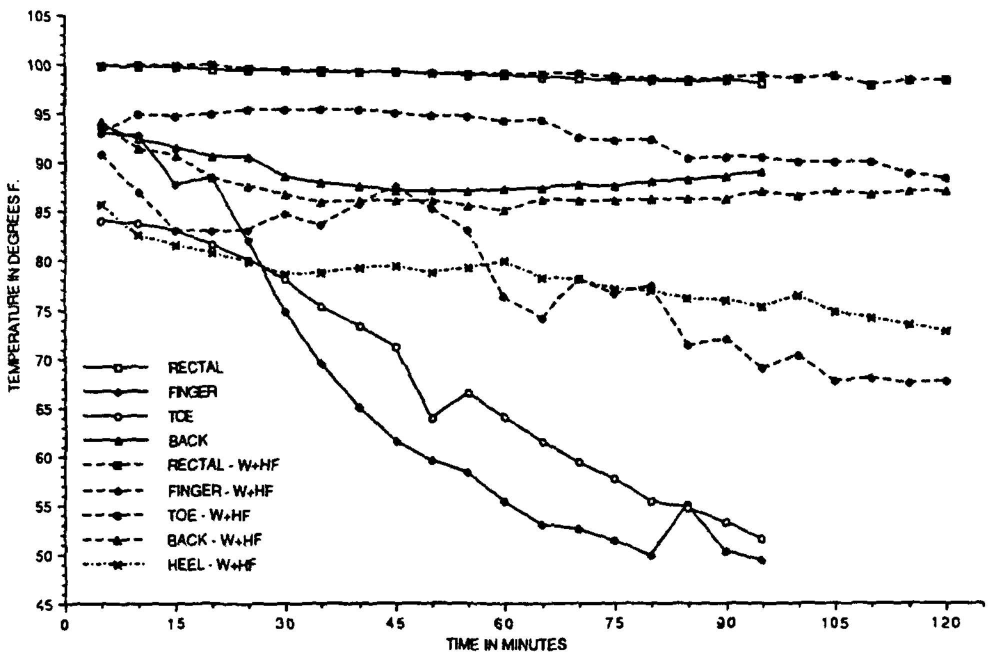

Figure E-2. Subject Number 2--ECWCS versus Widder gloves and Hot Foot during 2-hour scenario with heat supplied to hands and feet.

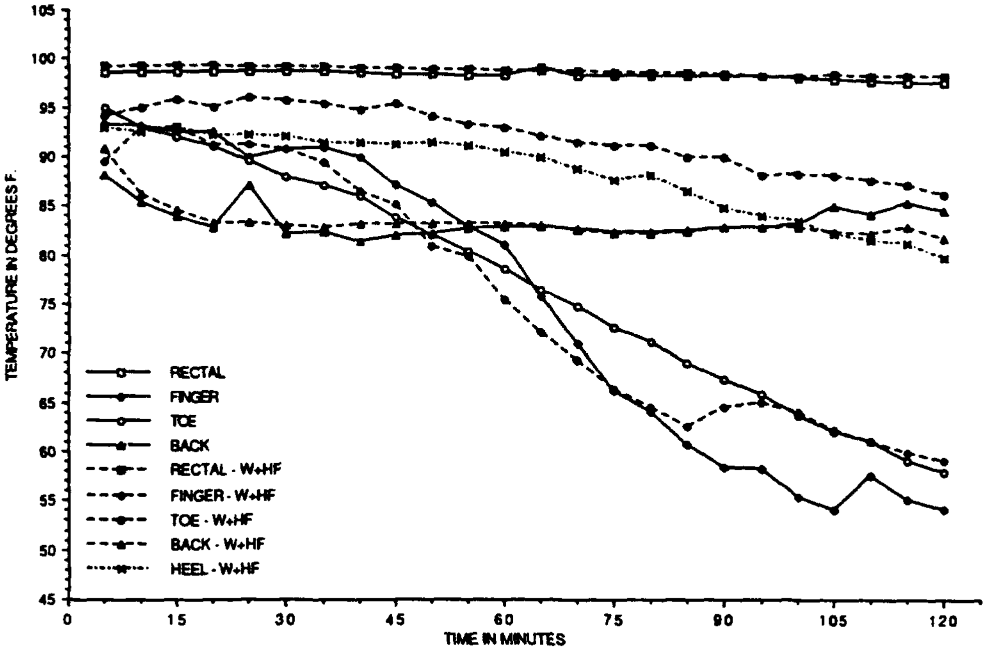

Figure E-3. **Subject Number 3--ECWCS versus Widder gloves and Hot Foot during 2-hour scenario with heat supplied to hands and feet.**

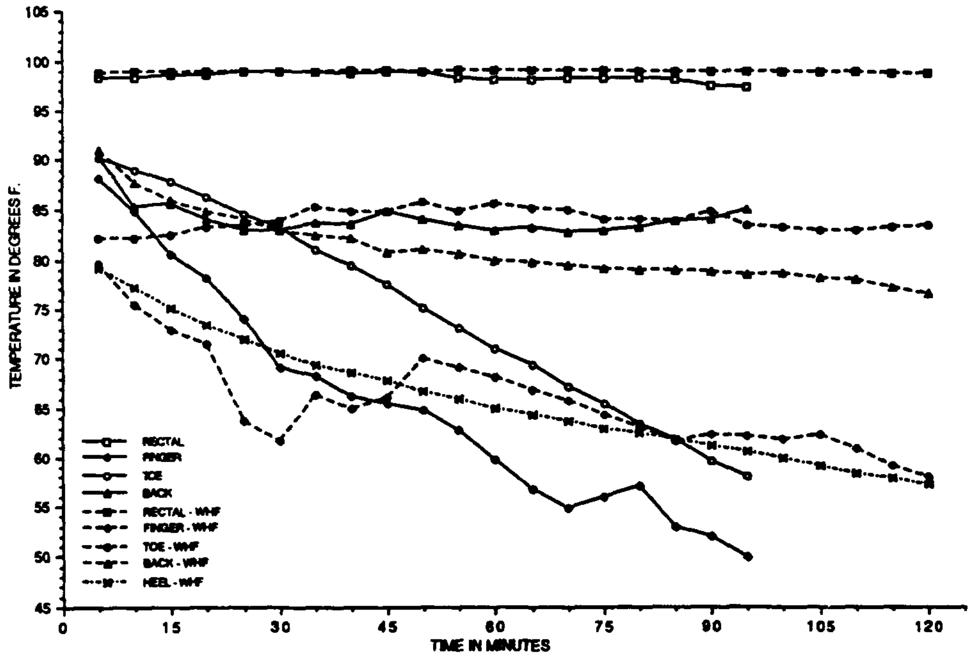

Figure E-4. **Subject Number 4--ECWCS versus Widder gloves and Hot Foot during 2-hour scenario with heat supplied to hands and feet.**

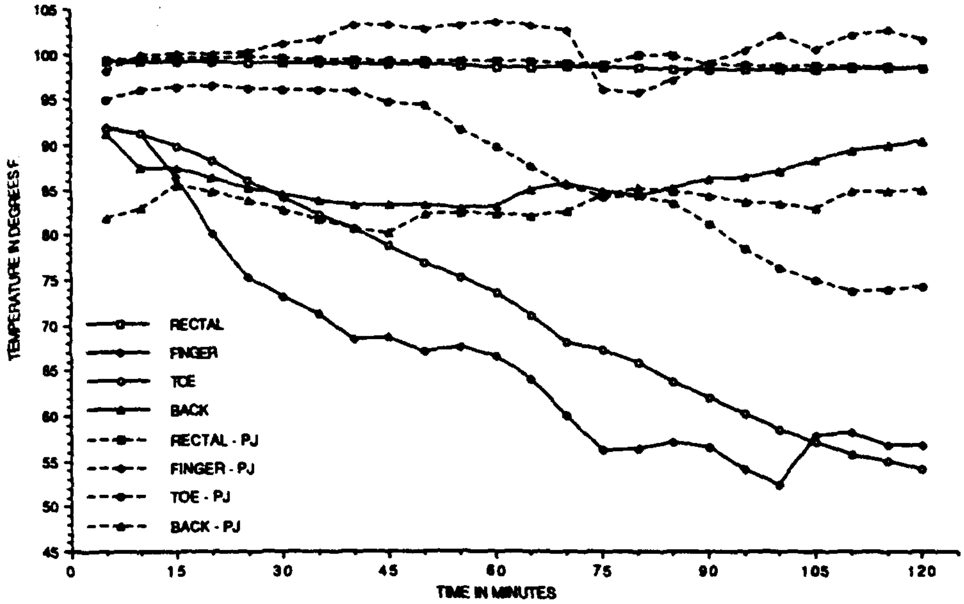

Figure E-5. Subject Number 1--ECWCS versus Power Johns ™ during 2-hour scenario with heat supplied to hands and feet.

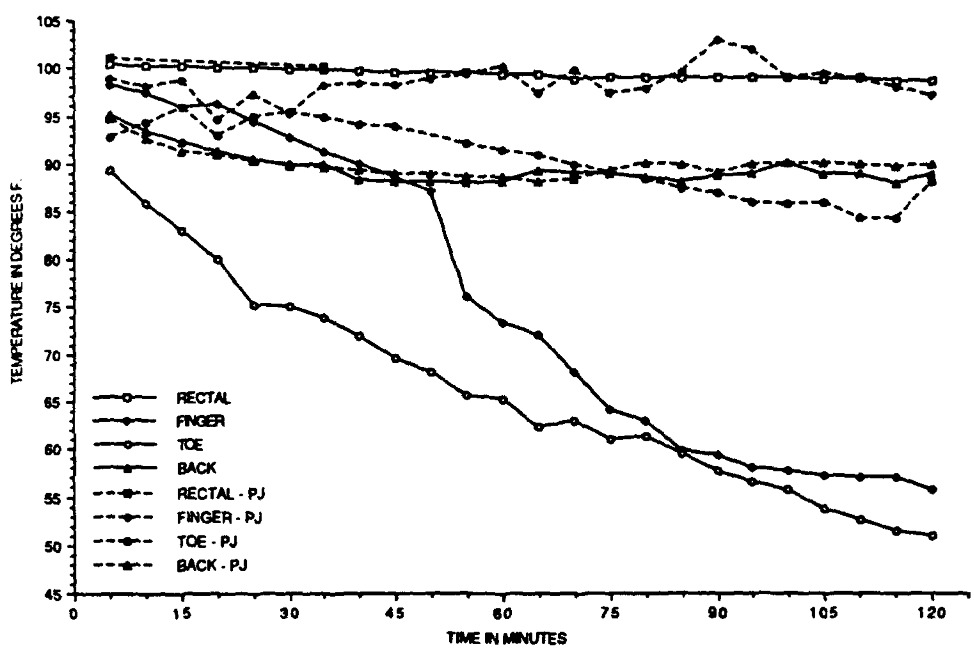

Figure E-6. Subject Number 2--ECWCS versus Power Johns ™ during 2-hour scenario with heat supplied to hands and feet.

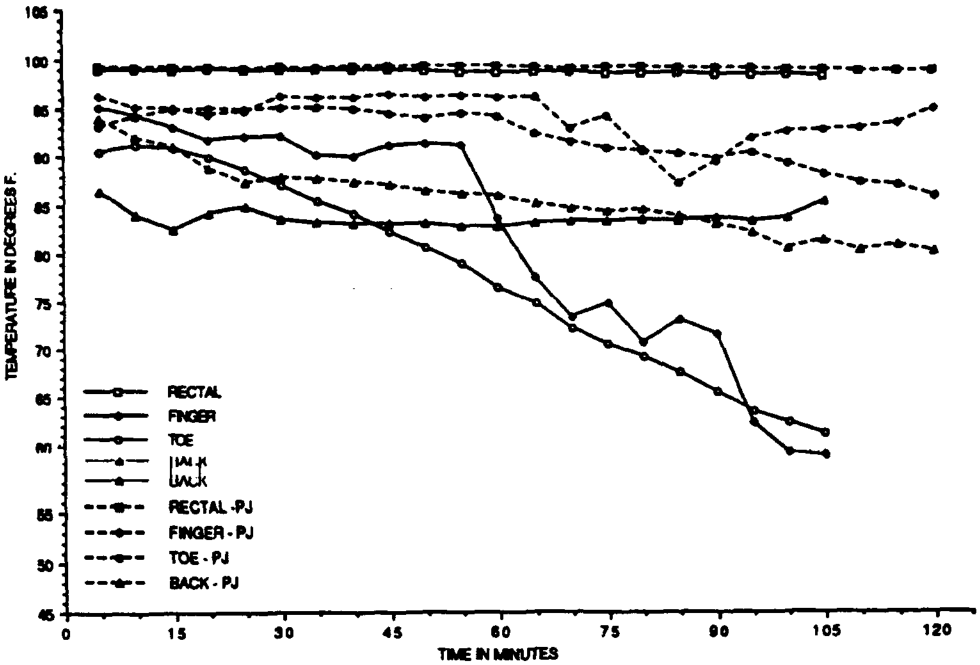

Figure E-7. **Subject Number 3--ECWCS versus Power Johns ™ during 2-hour scenario with heat supplied to hands and feet.**

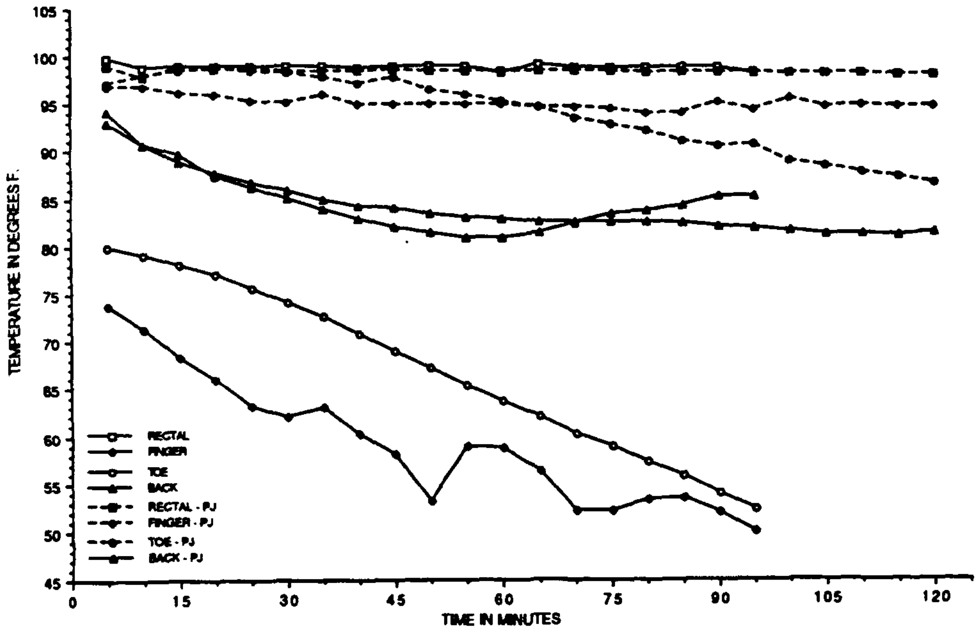

Figure E-8. **Subject Number 4--ECWCS versus Power Johns ™ during 2-hour scenario with heat supplied to hands and feet.**

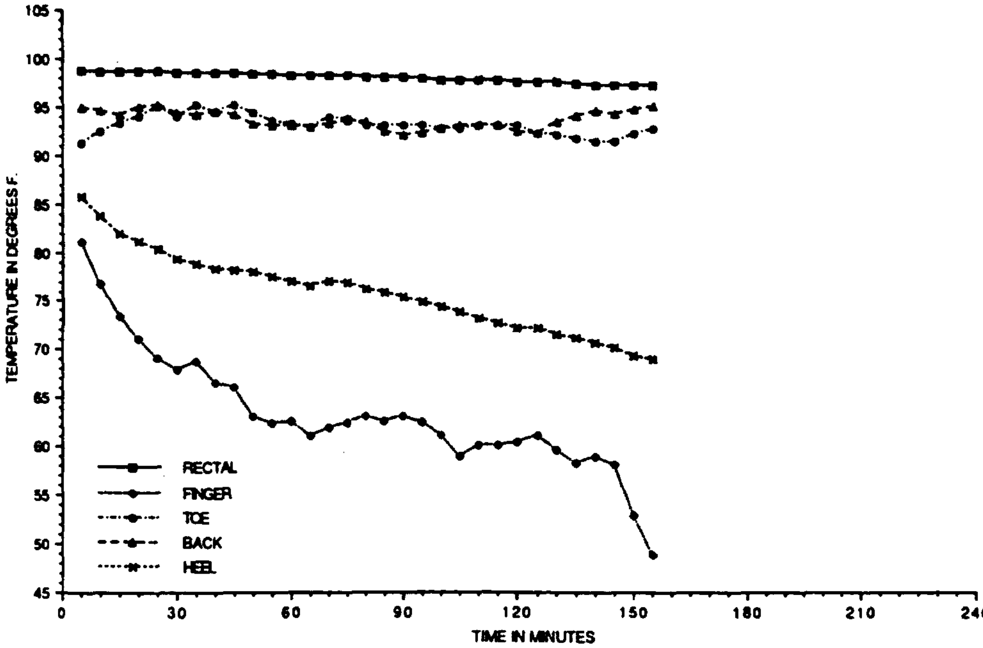

Figure E-9 Subject Number 1--Widder vest and gloves plus Hot Foot during 4-hour scenario with heat supplied to torso, hands, and feet.

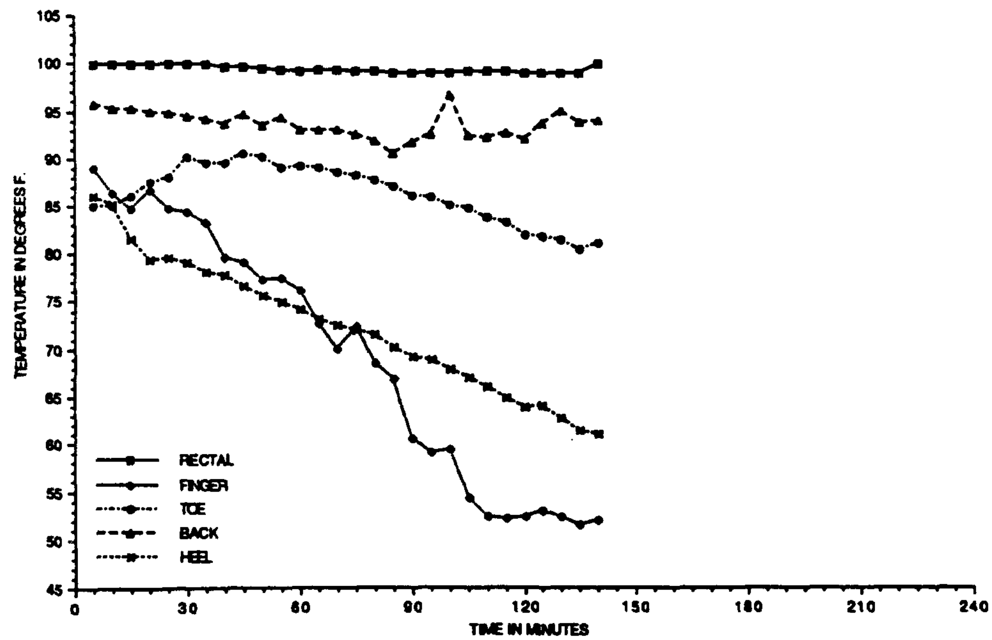

Figure E-10. Subject Number 2--Widder vest and gloves plus Hot Foot during 4-hour scenario with heat supplied to torso, hands, and feet.

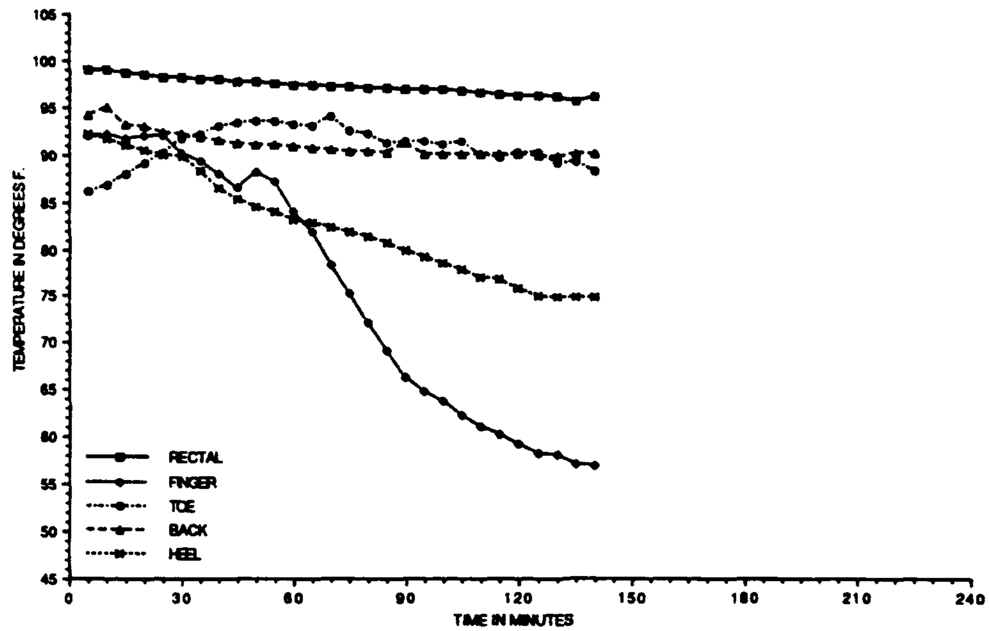

Figure E-11. Subject Number 3--Widder vest and gloves plus Hot Foot during 4-hour scenario with heat supplied to torso, hands, and feet.

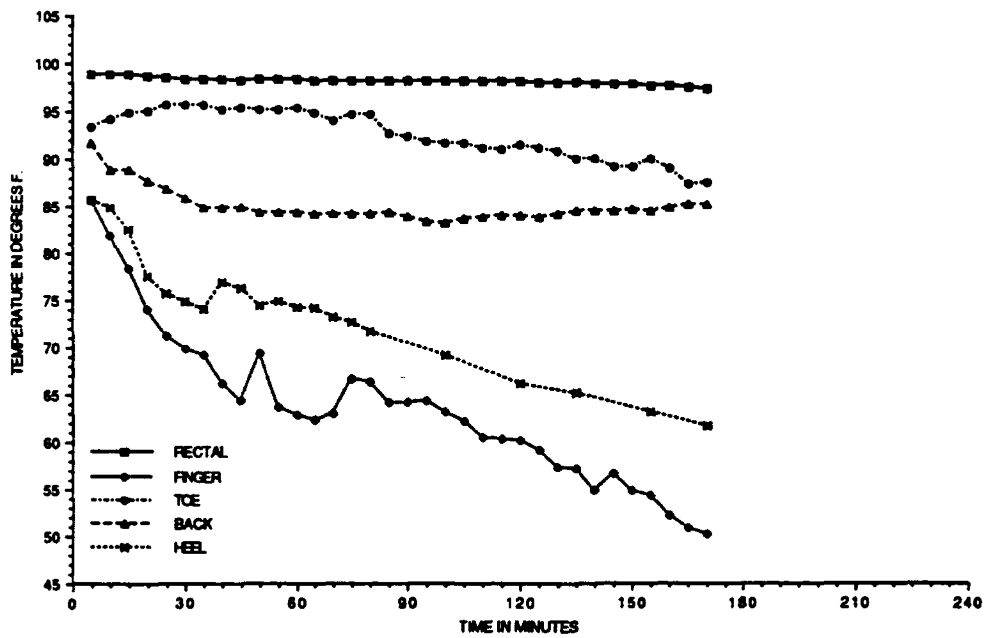

Figure E-12. Subject Number 4--Widder vest and gloves plus Hot Foot during 4-hour scenario with heat supplied to torso, hands, and feet.

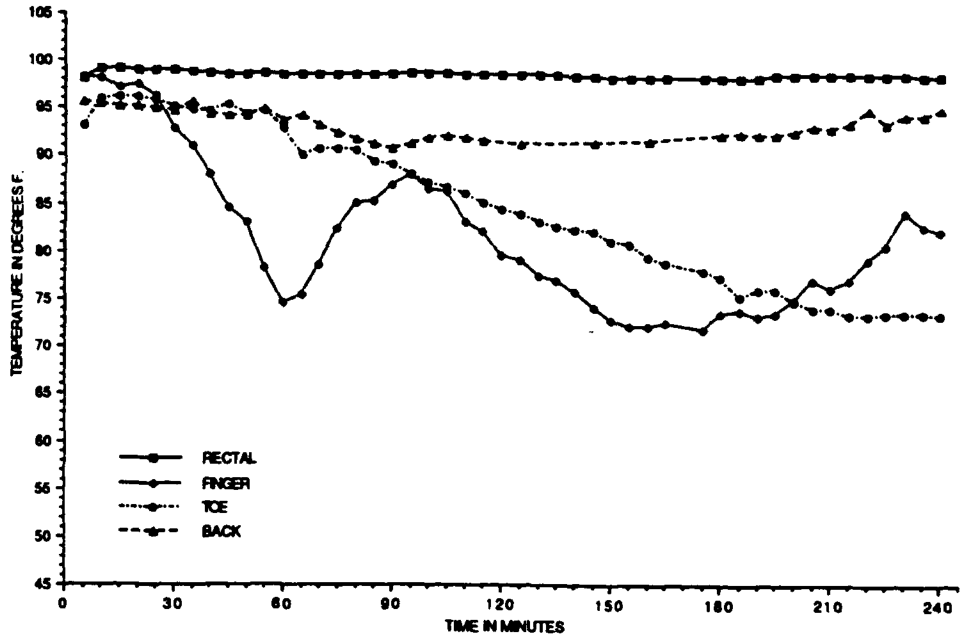

Figure E-13. Subject Number 1--Power Johns ™ with automatic controller 4-hour scenario with heat supplied to the whole body.

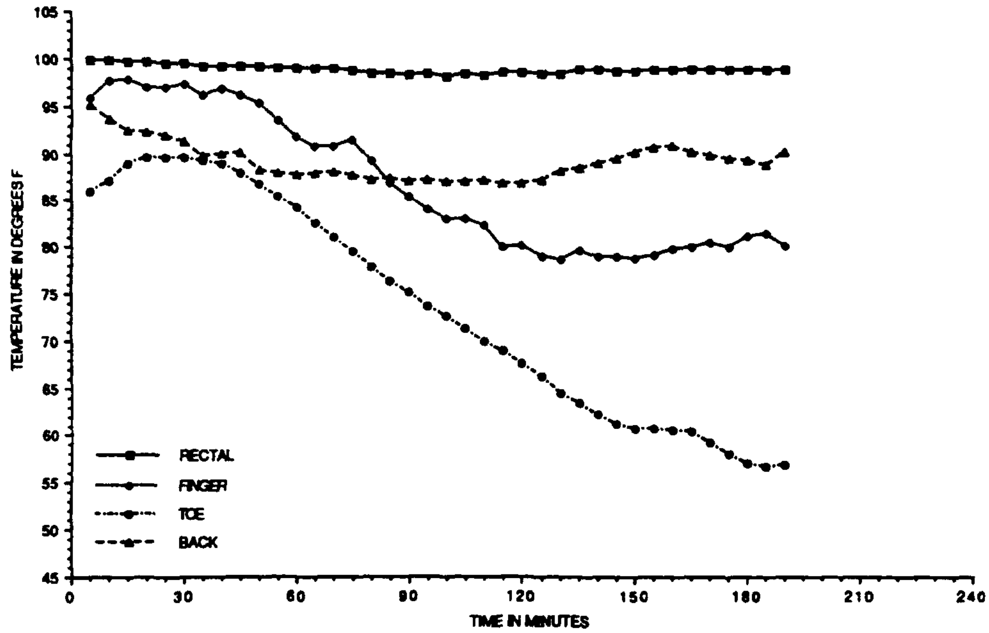

Figure E-14. Subject Number 2--Power Johns ™ with automatic controller 4-hour scenario with heat supplied to the whole body.

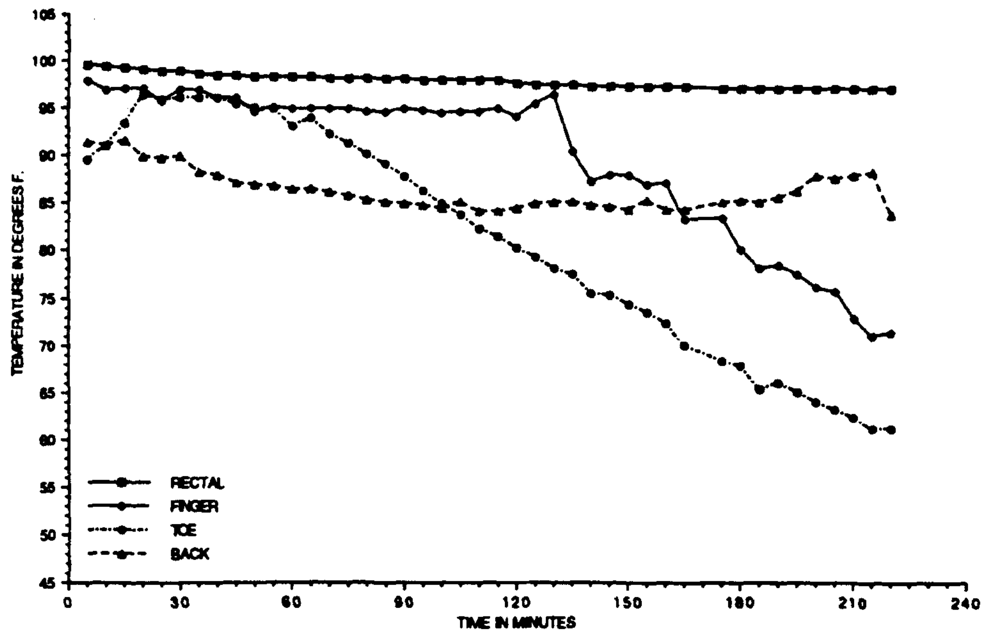

Figure E-15. Subject Number 1--Power Johns ™ with manual controller 4-hour scenario with heat supplied to the whole body.

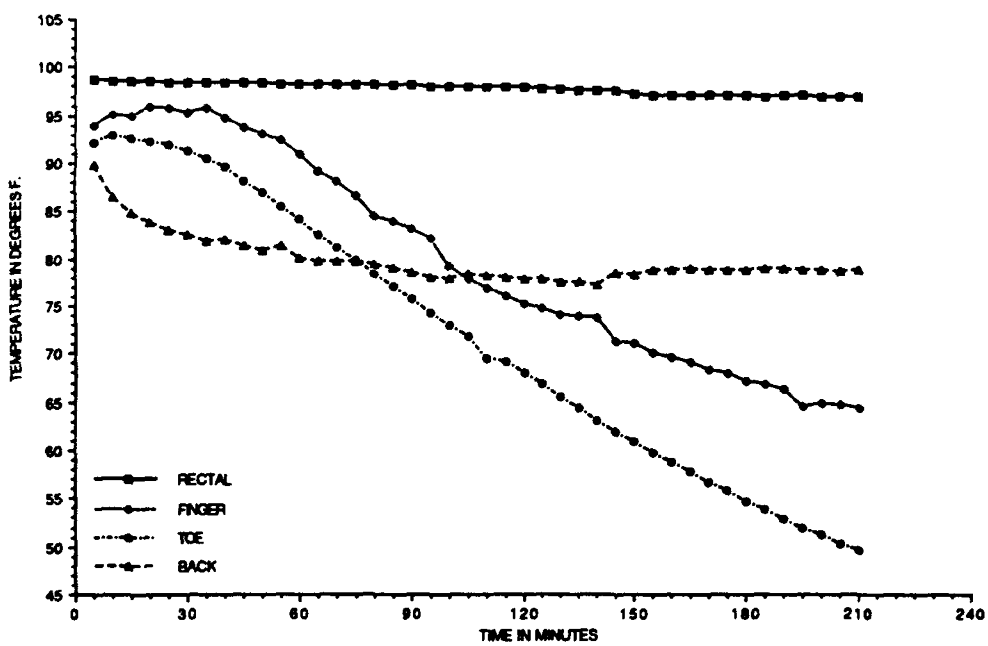

Figure E-16. Subject Number 4--Power Johns ™ with manual controller 4-hour scenario with heat supplied to the whole body.