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ARMORED MEDICAL RESEARCH LABORATORY
Fort Knox, Kentucky

Project No. T-5
SPMEA 727-2

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1. PROJECT: No. T-5 - Test of Flameproofed Clothing. Third Partial Report.
Subject: Effects of Wearing Flameproofed Clothing in Hot Environments.

a. Authority: Letter, 6th Indorsement, SPMDO 421, ASF, SGO, Washington
25, D. C., 7 December 1944.

b. Purpose: To evaluate the effects of wearing two new types of flame-
proofed clothing in hot environments.

2. DISCUSSION:

The first two partial reports on this subject were studies on the effect of wearing clothing which had been flameproofed and gasproofed by CC-2, M1, impregnating mixtures. The clothing type "X" was considered unsatisfactory because the flameproofing properties disappeared quickly on use. Type "D" flameproofed clothing was considered to be satisfactory.

After these garments had been tested, the Chemical Warfare Service reported two new types of flameproofed clothing. One was treated by a foam impregnation process. Essentially the same impregnating materials were used in this as for types X and D. The other was treated by an antimony trioxide-vinylite impregnation. This latter method affords flameproof protection alone. In view of the fact that the threat of gas warfare is only potential but flame presents a constant danger to tank crewmen, the immediate need of the Armored Force is flameproofed clothing which is as acceptable as the standard issue garments.

The following study was carried out to determine (1) the heat load imposed by these two types of flameproofed garments and (2) the general acceptability of the clothing. The garments were worn by acclimatized subjects working in a hot environment simulating that which may be found in buttoned-up tanks (D.B. 120°F. - 88°F.).

3. CONCLUSIONS:

a. Clothing treated to provide protection against flame alone (antimony trioxide) had a heat load no greater than that of untreated herringbone twill.

b. Garments which were rendered gasproofed and flameproofed by the foam impregnation process also imposed a heat load like untreated herringbone twill.

c. Unlaundered, foam-process impregnated garments should not be worn since they produced marked chemical irritation of the skin.

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4. RECOMMENDATIONS:

a. That both antimony trioxide or laundered foam-process impregnated herringbone twill garments be evaluated from the standpoint of retention of adequate flameproofness following continued wear and laundering.

b. That either type of garment be considered suitable for issue to troops if flameproof qualities are found to be satisfactory.

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3 Incls.

- #1 - Appendix
- #2 - Table
- #3 - Charts 1 thru 3

APPENDIX

1. Procedure:

a. Experimental Conditions

All observations were made in the laboratory hot room during April and May, 1945. Ten (10) normal, healthy, physically fit soldiers were selected for this test. Their ages ranged from 19 to 23 years, average 21; their weights, from 134 to 184 pounds, average 153; their heights, from 66 to 71 inches, average 68. The entire test was carried out in an environment of D.B. 120°F., W.B. 88°F., R.H. 28%. This environment was selected as representative of the extreme situation to which a tank crew might be subjected when operating a buttoned-up vehicle in hot climates. The procedures described in Partial Report No. 1* were followed.

b. Clothing

The following types and assemblies were worn during this study:

- (1) Herringbone Twill, Single Layer - half wool socks, service shoes, cotton shorts, new two piece fatigue uniform of herringbone twill.
- (2) Foam Process, Flameproofed Assembly, Unlaundered Single Layer - half wool socks, service shoes, cotton shorts, unlaundered two piece uniform of flameproofed herringbone twill.
- (3) Foam Process, Flameproofed Assembly, Laundered Single Layer - half wool socks, service shoes, cotton shorts, laundered two piece uniform of flameproofed herringbone twill.
- (4) Antimony Trioxide Flameproofed Assembly, Single Layer - half wool socks, service shoes, cotton shorts, unlaundered two piece uniform of flameproofed herringbone twill.

All the flameproofed garments were prepared by Chemical Warfare Service. The foam process impregnated clothing had been subjected to an aqueous emulsion treatment. The impregnating formula was:

XXCC No. 2/ZnO/CP**/PVA[†]/ME[‡]/H₂O/28/28/28/1.4/1.4/91.6


* AMRL Project No. T-5, Test of Flameproofed Clothing, First Partial Report - Subject: Physiologic Effects of Wearing Flameproofed Clothing in Hot Environments, 17 July 1945.

** Chlorinated Paraffin

† Polyvinyl Alcohol

‡ DuPont ME (Sodium lauryl sulfate) *B*

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This impregnation rendered the garment both flameproof and gasproof. The amount of pick-up was 31 to 33%. Two sets of these garments were used, one which was unlaundered and the other which had been given one (1) CMC Formula G laundering. The antimony trioxide flameproofed garments were made from fabric which had received treatment with antimony trioxide, vinylite and pigments in a solvent of methyl ethyl ketone. The amount of pick-up of flameproofing material was 30 to 35% of the original weight of the cloth.

2. Results:

a. Heat Load

Men who had been acclimatized to marching at a D.B. 120°F., W.B. 88°F. for 13 days were used. During the period of testing each of the ten (10) subjects wore new herringbone twill, foam process unlaundered, foam process laundered and antimony trioxide garments. On each day, some men were wearing all four (4) types of treated garments according to a Latin Square. The physiological indications of the heat load imposed by the flameproofed clothing are presented in Charts 1, 2, and 3. The responses of the subjects clothed in herringbone twill were used in each of the charts as the common reference. All of the men were able to easily finish the required four (4) hours of marching. It was apparent that the heat load of the flameproofed garments was similar to that imposed by new herringbone twill fabric.

Subjectively the men preferred the laundered foam process flameproofed twill. The main objection to the antimony trioxide flameproofed twill was the impression that it was too heavy. None of the men wanted to wear the unlaundered foam process flameproofed twill because it caused considerable skin irritation. A single day's wear resulted in a marked contact dermatitis in all areas where the clothing rubbed the skin. This was so severe that in most cases the men would have refused to wear the garments another day except under direct order.

b. Physical Characteristics of the Clothing

- (1) Unlaundered, foam process flameproofed twill - This clothing was stiff and waxy with a whitish powder on the surfaces. It absorbed sweat quite readily but not to the same extent as HBT.
- (2) Laundered, foam process flameproofed twill - The general properties were similar to the unlaundered foam process garment except that the loose surface deposit of chemicals had been eliminated. The ease of wetting was not appreciably different from the unlaundered clothing.
- (3) Antimony trioxide treated herringbone twill - This garment had the appearance of untreated herringbone twill except that it had a smoother finish. It was not stiff or waxy. It wet as readily as new HBT. Because of its increased ability to absorb water, these garments in use were heavier than either HBT or foam process flameproofed twill.

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The Physiologic Responses of Working Men Clothed in Different Flameproofed Garments and in Herringbone Twill

D.B. 120°F. - W.B. 88°F.

TABLE 1

CLOTHING	NAME	RECTAL TEMPERATURE OF				PULSE RATE/MIN.				SKIN TEMPERATURE (Avg. Mtg.)			WEIGHT LOSS (Sweat) Gm./Hr.			
		0	1	2	3	4	0	1	2	3	4	Init.		1 Hr.	4 Hrs	
FLAMEPROOFED TWILL Foam Process (Laundered)	Abe	97.9	100.7	101.5	101.7	101.7	105	126	117	126	129	97.2	99.2	100.3	1126	
	Atm	98.5	101.5	102.0	101.6	101.4	114	145	132	120	126	96.8	99.0	98.3	1548	
	Bud	97.6	100.9	101.2	101.4	101.3	126	150	120	120	123	93.5	98.5	98.1	1412	
	Del	98.4	100.7	101.6	102.4	103.0	102	129	126	141	132	97.3	99.4	100.9	1404	
	Ger	98.2	101.1	102.5	103.2	104.3	108	129	132	105	120	99.5	98.6	101.6	825	
	Har	97.8	100.4	101.1	100.9	100.4	114	117	117	105	105	98.8	99.0	98.0	1246	
	Koz	98.7	100.7	101.9	102.3	102.9	93	126	120	117	132	99.0	99.1	100.5	1292	
	Nor	98.3	101.0	102.3	102.7	103.8	105	150	126	117	138	99.1	99.1	101.1	1227	
	Tol	97.9	100.4	101.1	101.3	101.3	102	117	93	105	108	98.0	93.3	98.6	1813	
	Zln	98.2	100.6	101.7	101.9	101.5	105	123	123	123	120	98.1	99.0	99.2	1230	
	AVG.	98.2	100.7	101.6	101.9	102.2	107	131	121	118	123	93.2	98.9	99.7	1312	
	HERRINGBONE TWILL	AVG.	98.2	100.7	101.6	101.9	102.2	107	131	121	118	123	93.2	98.9	99.7	1312
		Abe	97.8	100.1	100.4	99.9	100.1	105	126	108	108	120	97.7	99.1	93.2	1400
Atm		98.5	101.5	102.0	101.6	101.6	138	150	120	129	132	93.9	98.7	99.4	1280	
Bud		98.2	101.0	102.3	102.2	102.1	114	123	135	123	117	99.0	95.2	93.9	1518	
Del		98.8	100.9	101.1	101.0	100.8	105	123	108	117	114	93.9	93.9	99.0	1969	
Ger		98.9	101.5	102.6	102.8	103.7	117	144	126	120	129	97.9	99.1	101.1	994	
Har		97.8	101.2	101.7	101.7	101.8	102	129	126	108	132	97.7	99.6	99.3	1482	
Koz		98.5	100.8	101.9	101.6	101.7	120	123	120	114	117	98.2	98.7	99.4	1370	
Nor		98.0	101.0	102.4	102.7	103.7	108	132	135	108	129	97.4	99.1	101.4	1290	
Tol		98.4	101.3	102.0	102.5	102.7	90	129	117	120	117	97.4	98.6	99.2	1509	
Zln		98.5	101.6	103.4	103.3	103.1	108	135	123	144	144	97.4	99.9	100.5	1192	
AVG.		98.3	101.1	102.0	101.9	102.1	111	131	122	119	125	98.0	99.1	99.6	1400	

Table 1 line 2

TABLE 1 (Cont'd.)

CLOTHING	NAME	RECTAL TEMPERATURE OF				PULSE RATE/MIN.				SKIN TEMPERATURE (Ave. Htg.)			WEIGHT LOSS (Sweat) Gm./Hr.			
		0	1	2	3	4	0	1	2	3	4	Int.		1 Hr.	4 Hrs.	
FLAMEPROOFED TWILL Antimony Oxide Treated	Abe	97.8	100.5	101.2	101.1	101.3	96	138	117	126	132	98.0	98.5	99.0	1126	
	Atw	98.8	101.2	101.6	101.5	102.3	108	129	129	126	138	97.9	98.4	100.2	1352	
	Bud	97.9	100.6	101.2	101.3	101.0	117	126	129	120	126	98.2	98.3	98.8	1386	
	Del	98.3	101.4	102.3	102.4	102.4	132	150	120	126	132	98.4	98.4	100.1	1270	
	Ger	98.7	101.4	102.6	103.8	104.3	99	132	132	129	126	98.1	99.5	102.3	787	
	Har	98.0	100.7	101.5	101.4	101.5	114	126	117	111	114	98.2	98.7	100.2	1440	
	Koz	98.2	101.0	102.1	102.2	103.2	90	132	111	126	141	98.5	99.4	101.1	1055	
	Nor	98.5	100.7	101.7	102.3	103.3	108	126	123	120	132	98.0	99.0	100.9	1150	
	Tol	97.8	100.9	101.8	101.9	102.0	111	123	120	105	108	96.9	98.3	99.3	1547	
	Zin	98.0	100.9	102.1	102.1	102.2	111	120	108	117	126	97.8	98.6	100.4	1359	
	AVG.	98.2	100.9	101.8	102.0	102.4	109	130	121	121	128	98.0	98.7	100.2	1247	
	FLAMEPROOFED TWILL Foam Process (Unlaundered)	Abe	97.6	100.1	100.8	100.7	100.7	105	132	120	117	120	98.3	98.0	98.9	1462
		Atw	98.5	100.5	101.1	100.7	100.7	114	126	126	120	123	97.4	98.4	98.4	1788
Bud		98.4	101.2	102.0	102.1	102.2	96	126	120	132	156	98.3	99.6	98.4	1505	
Del		97.9	100.6	101.2	101.1	101.2	102	132	129	114	120	99.7	99.0	99.4	1665	
Ger		98.2	100.5	101.5	102.1	102.3	105	126	123	117	120	97.5	98.2	100.0	1062	
Har		98.1	100.9	101.8	101.8	102.0	117	159	135	120	132	98.3	98.6	99.3	1334	
Koz		98.4	100.2	101.1	101.8	102.1	108	117	114	120	120	98.2	98.4	99.7	1255	
Nor		98.4	101.0	102.4	103.1	104.2	111	141	126	144	125	97.3	99.2	101.3	1290	
Tol		98.1	101.1	101.9	101.7	102.4	96	126	108	117	117	98.5	98.1	99.2	1598	
Zin		98.5	101.5	102.5	102.7	103.0	126	138	108	129	129	98.6	99.2	99.1	1362	
AVG.		98.2	100.8	101.6	101.8	102.1	107	132	121	123	126	98.2	98.7	99.4	1426	

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CHART I

AVERAGE PHYSIOLOGIC RESPONSES OF WORKING MEN WEARING
UNLAUNDERED FOAM PROCESS FLAMEPROOFED TWILL
AND HERRINGBONE TWILL

D.B. 120° F - W.B. 88° F

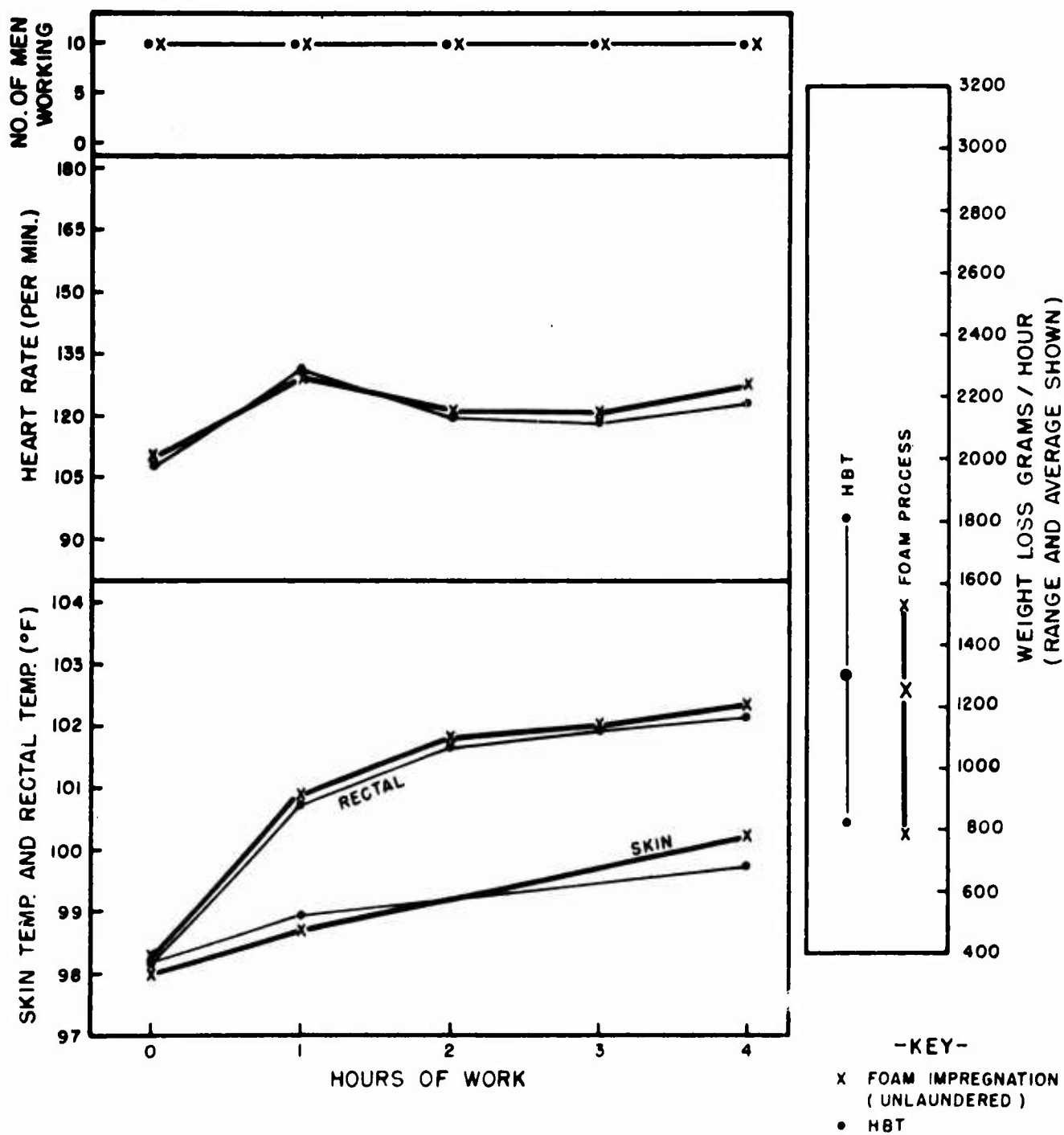


CHART I

CHART 2

AVERAGE PHYSIOLOGIC RESPONSES OF WORKING MEN WEARING LAUNDERED FOAM PROCESS FLAMEPROOFED TWILL AND HERRINGBONE TWILL

D.B. 120° F - W.B. 88° F

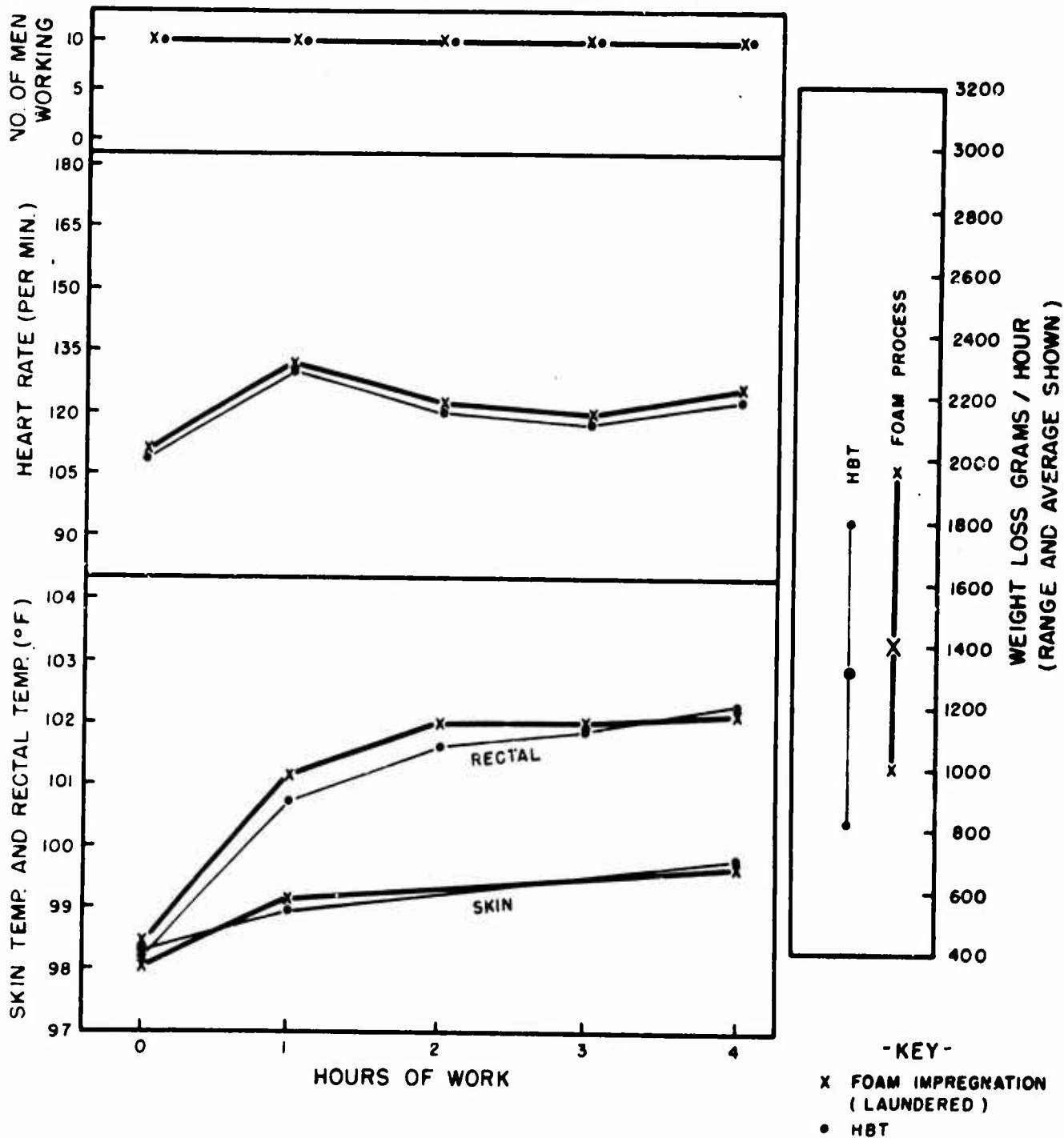


CHART 2

CHART 3

AVERAGE PHYSIOLOGIC RESPONSES OF WORKING MEN WEARING ANTIMONY TRIOXIDE FLAMEPROOFED TWILL AND HERRINGBONE TWILL

D.B. 120° F - W.B. 88° F

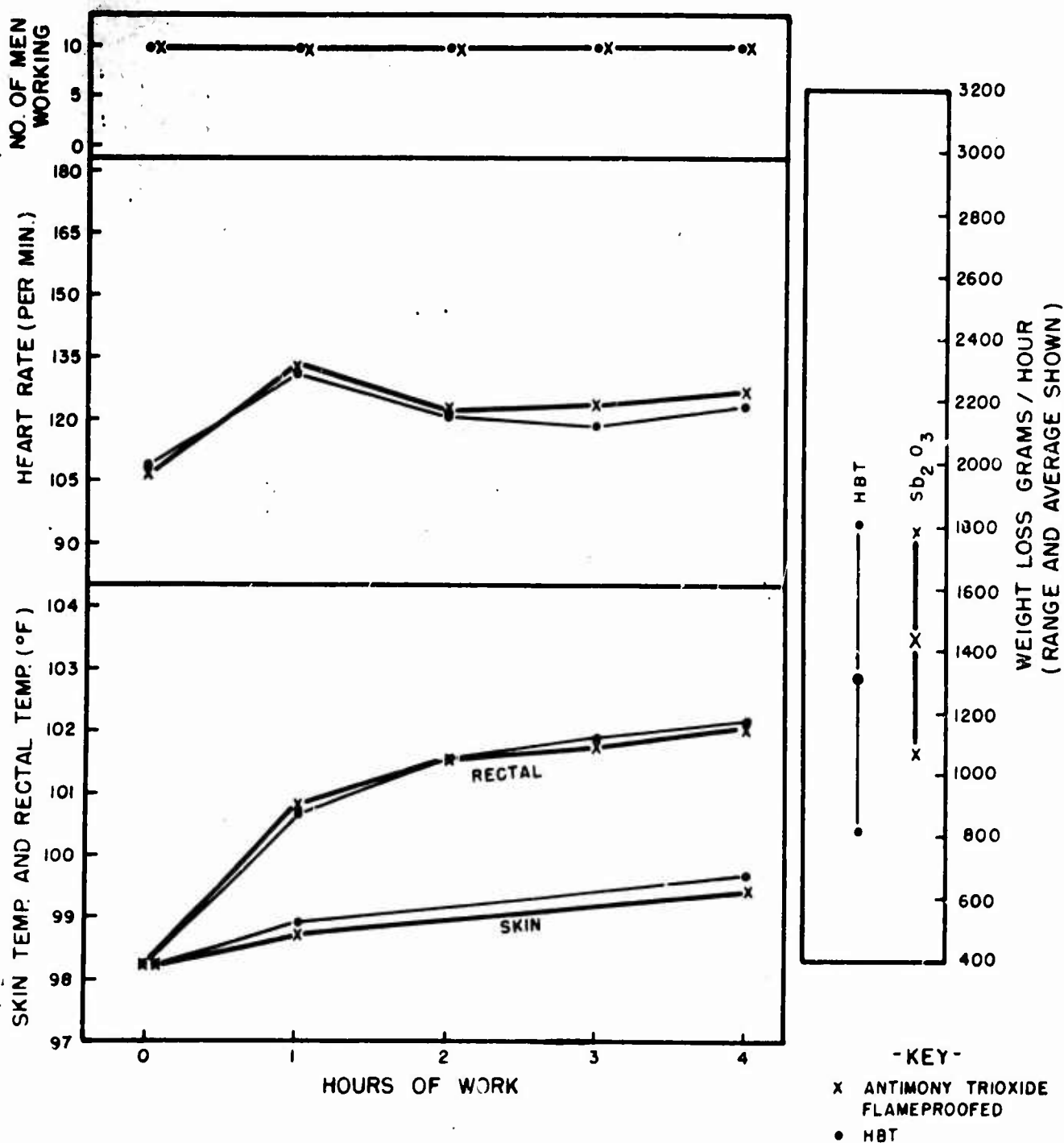


CHART 3