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# ARMORED MEDICAL RESEARCH LABORATORY

FORT KNOX, KENTUCKY

INDEXED

Fourth Partial Report

On

PROJECT NO. T-5 - TEST OF FLAMEPROOFED CLOTHING

Subject: Test of Physiological Heat Load of Flameproofed Clothing

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Project No. T-5

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28 September 1945





ARMORED MEDICAL RESEARCH LABORATORY  
Fort Knox, Kentucky

28 September 1945

SPMEA 727-2  
Project No. T-5

1. PROJECT: No. T-5 - Test of Flameproofed Clothing, Fourth Partial Report, Subject: Test of Physiological Heat Load of Flameproofed Clothing.

a. Authority: Letter Headquarters Army Ground Forces, Washington, D.C., File 426 (9 Sept. 1945) GNRQT-11/40812, dated 9 Sept. 1945.

b. Purpose: To determine the physiological heat load induced by the wearing of flameproofed clothing.

2. DISCUSSION:

This report is a continuation of the studies on the influence of wearing flameproofed garments on the ability of men to work in hot environments. In the present tests, a new type of commercial flameproofing, "Banflame," was evaluated from the standpoint of heat load and general acceptability to troops.

3. CONCLUSIONS:

Herringbone twill uniforms made of cloth impregnated by the "Banflame" ADG process do not impose any greater load on acclimatized men than ordinary herringbone twill. Tests were performed at both hot dry (D.B. 120°F., W.B. 86°F., R.H. 26%) and hot humid (D.B. 88°F., W.B. 84°F., R.H. 85%) environments.

4. RECOMMENDATIONS:

That if field tests show the garment to have satisfactory durability, "Banflame" treated uniforms be considered suitable for issue.

APPROVED

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- #1 - Appendix
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1. SUBJECTS, EXPERIMENTAL CONDITIONS AND PROCEDURES:

This investigation was conducted in the laboratory hot room during August and September 1945. Twelve normal healthy soldiers were studied. Their ages ranged from 20 to 31 years (average 25); heights from 67 to 71 inches (average 69); weight from 135 to 190 pounds (average 155) and surface areas from 1.7 to 2.0 square meters (average 1.9).

The clothing was tested on men in two different environments which were representative of two types of hot climates.

- a. Hot dry - D.B. 120°F., W.B. 86°F., R.H. 26%
- b. Hot humid - D.B. 88°F., W.B. 84°F., R.H. 85%

Throughout the tests, the dry and wet bulb temperatures were measured every fifteen minutes with four motor-driven fan psychrometers at a level of four feet from the floor. The values rarely varied from the desired dry or wet bulb temperature by more than 1°F. The temperature of the walls, floor and ceiling was measured twice daily. In the 120°F environment the average of these measurements was 116 ± 1°F. and in the 88°F. environment the average was 87 ± 0.3°F.

A mildly turbulent air movement in all parts of the room resulted from the combination of hot air inflow from four anemostats in the ceiling and four 16-inch fans operating on the floor in the center of the room. Wind velocity was not measured but was essentially that produced by the movement of the men marching at 3 mph.

The men lived in barracks and were in the hot room five hours each day. The standard test work consisted of carrying a 20-pound pack and walking for four continuous hours at 2.9 mph around a 67-foot track in the hot room. This work rate was previously determined to be approximately 250 Calories per hour. Acclimatization to the heat was achieved by having the men march in the hot room for 25 days before the clothing was tested. Afternoon marches were taken to maintain physical fitness.

All water drunk during the test periods was 0.1% solution of sodium chloride. In the 120°F. environment the saline solution was kept at a temperature of 96°F; in the 88°F. environment, it was kept at 88°F.

"Banflame" is the trade name for a commercial flameproofing process\* formulated by Joseph Bancroft and Sons Company. It is applied to the uncut fabric. The specific treatment received by the cloth of the garments tested was the "Banflame ADG process" which imparts a launder resistant flameproofing which is satisfactory. The ADG process is an improvement over the former

\*Phosphate-urea mixture impregnation.







Bancroft processes which have been tested at other laboratories (1,2). The add-on is approximately 20%. Tests of tensile strength have revealed it to be somewhat impaired by this impregnation. The significance of this finding is being studied elsewhere. This clothing protects against flame alone and affords no gas-proofing. It is superior to other flameproofed garments tested in that the after-glow is negligible.

A Latin Square method of testing was used. Each of the men wore new unlaundered herringbone twill fatigues which had been treated with the "Banflame" flameproofing and new untreated herringbone twill uniforms once in each of the two environments. The clothing was always worn in the same manner; trouser legs tucked inside of the pulled up socks, jacket shirt tucked into the waist of the trousers, and top button of the jacket buttoned. This affords greatest protection against flame and since it reduces bellows action of clothing, these tests were carried out with the clothing imposing a maximum heat load at the given environment.

Upon arrival in the morning, the men remained in a room at 75° F. until individually called into the hot room 8-10 minutes before beginning to walk. Each man entered the hot room completely nude, urinated, dried off any sweat present and was weighed (within 10 grams). Simultaneously the jacket and trousers he was to wear (placed in the hot room 30-45 minutes earlier) were individually weighed (within 5 grams). The subject quickly dressed in these garments and stood erect 4 minutes during which the heart rate, rectal temperature and skin temperature were determined. He then began marching. During the walking period all water drunk, urine voided, and vomitus were carefully measured. At hourly intervals, the heart rate, rectal temperature and skin temperature were measured. He then stripped completely, urinated, dried off all of the sweat and was weighed. At the same time his removed clothing was weighed. Throughout the entire test, records were kept of the general appearance and reactions of the men.

The skin temperature of five areas of the body, three covered and two uncovered (chest, forearm, calf, cheek, palm) were determined with a radiometer. For clothed areas, the clothing was pushed aside just sufficiently to permit placing of the radiometer. Undue exposure of clothed areas was avoided. The skin temperatures of individual areas were integrated into an average skin temperature by the following weighting formula based on the original formula of Hardy: chest, 0.44; forearm, 0.14; calf, 0.23; cheek, 0.10; palm, 0.09. Henceforth the term skin temperature will refer to this weighted average skin temperature. Rectal temperatures were measured with calibrated rectal thermometers.

1. NRC Project QMC, No. 27, July Progress Report, dated 10 August 1945.
2. Clothing, H.B.T., Effect of Flameproof Treatment on; Climatic Research Laboratory, Provisional Reports I-IV, Test No. 155, dated 24 May, 4 June, 14 June, 1 August 1945.







## 2. RESULTS:

### a. Heat Load at a High Dry Bulb Temperature:

D.B. 120°F., W.B. 86°F., R.H. 26%

This environment simulated that found in buttoned-up tanks operating in the summer at Camp Polk. The humidity is higher than that found in desert environments. The responses of the men working at this temperature show that impregnation imposed no added heat load on the men (Table 1).

### b. Heat Load at a Lower Dry Bulb Temperature:

D.B. 88°F., W.B. 84°F., R.H. 85%

This environment simulates a typical tropical environment. Again the response of the men indicated that the impregnation imposed no added heat load (Table 2):

### c. Physical Characteristics of the Clothing:

The "Banflame" clothing is almost indistinguishable from untreated herringbone twill in appearance (Photographs No. 1 and 2). Similar patterns in sweat uptake by the clothing occurred in both environments. The sweat uptake characteristics of the "Banflame" garment are very similar to those of the herringbone twill uniform.

The following table represents the average data on 12 men and their clothing.

TEST	CLOTHING	AVERAGE OF FOUR-HOUR SWEAT LOSS PER MAN (GRAMS)	UPTAKE OF SWEAT (GRAMS)	PERCENT OF TOTAL SWEAT IN GARMENT
D.B. 120° W.B. 86°	Flameproofed Uniform	6,923	862	12
	Herringbone Twill Uniform	7,035	883	13
D.B. 88° W.B. 84°	Flameproofed Uniform	3,601	1,004	28
	Herringbone Twill Uniform	3,300	1,037	31





d. Acceptability to Men:

Eleven of the twelve subjects stated that they preferred wearing the "Banflame" garments to wearing ordinary untreated herringbone twill uniforms. None of the men had any complaints concerning the garment. The subjective reactions of the men are of importance in view of the fact that in combat the men can wear or discard any item of clothing at will.

e. Flameproof Qualities:

Preliminary tests have indicated that herringbone twill fabrics impregnated by phosphate-urea mixtures not only have superior flameproof qualities, but are glowproof.\* These qualities are maintained following laundering and immersion in sea water. As no information was available regarding the possible effect of large amounts of sweat in leaching out the impregnation, the garments used in this test were sent to the Climatic Research Laboratory of the Quartermaster General. It is understood that this organization will report on the flameproof and glowproof qualities of the worn clothing in the near future.

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\* The Flameproofing of Army Clothing. July Progress Report: 1945 N.R.C., Project QMC, No. 27. National Research Council Laboratories, Columbia University, N. Y.





TABLE I

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

D.B. 120°F - W.B. 86°F - R.H. 26%

CLOTHING	NAME	RECTAL TEMPERATURE °F					PULSE RATE/MIN.					SKIN TEMP. (AVE. Wtg.) °F	WEIGHT LOSS (Sweat) Gm./Hr.
		0	1	2	3	4	0	1	2	3	4		
HERRINGBONE TWILL UNIFORM	Abb	98.8	100.5	100.5	100.6	100.9	90	123	111	102	111	96.6	2280
	Aur	98.6	100.9	100.9	101.1	100.7	102	117	126	120	117	97.1	1689
	Dlg	98.0	100.0	100.1	100.0	100.1	87	117	120	114	117	96.4	1722
	Irw	98.3	100.3	100.1	100.0	99.9	87	102	120	117	120	96.8	1678
	Mam	98.6	100.9	101.1	101.3	101.4	96	120	117	123	129	96.4	1624
	Mar	97.9	100.4	100.5	99.9	100.3	105	114	117	120	120	96.9	1525
	McB	98.6	100.0	100.5	100.5	100.6	99	123	126	120	108	96.4	1300
	Mol	98.0	100.4	100.3	100.3	100.3	102	114	114	108	111	97.4	1271
	Moo	97.7	100.6	100.6	100.6	100.3	96	123	120	111	117	98.3	1452
	Peb	98.2	100.7	100.8	100.5	100.3	105	117	114	114	126	97.4	1788
FLAMEPROOFED TWILL Bancroft ADG	Abb	98.3	100.5	100.5	100.5	100.4	98	117	117	115	117	97.0	1645
	Aur	98.8	100.2	100.4	100.2	100.2	87	108	117	108	105	96.8	2158
	Dlg	98.0	100.3	100.6	100.3	100.0	102	117	108	117	117	97.3	1400
	Irw	97.9	99.7	99.6	99.7	99.6	99	114	126	117	114	96.3	1755
	Mam	99.1	101.5	101.4	101.6	101.7	96	120	117	114	123	97.1	1393
	Mar	98.0	100.6	100.8	100.5	100.2	99	120	120	114	123	97.0	1872
	McB	99.1	100.4	100.6	101.1	101.1	99	120	117	114	120	97.0	1665
	Mol	98.3	100.2	100.0	99.9	99.8	102	111	126	126	129	96.8	1359
	Moo	98.1	100.9	100.7	100.7	100.6	102	123	123	114	117	97.9	1472
	Peb	98.1	100.4	100.1	100.0	100.0	96	120	117	117	114	97.6	2058
	Tho	98.6	100.4	100.4	100.4	100.4	96	111	120	120	123	96.6	1471
Wes		98.6	100.3	100.0	100.1	99.9	114	120	126	123	120	97.2	1865
AVG.		98.4	100.4	100.4	100.4	100.3	99	117	120	117	118	97.1	1659

TABLE I







TABLE II

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

D.B. 88°F - W.B. 84°F - R.H. 85%

CLOTHING	NAME	RECTAL TEMPERATURE °F					PULSE RATE/Min.					SKIN TEMP. (Avg. Wtg.) °F	WEIGHT LOSS (Sweat) Gm./Hr.
		Hours					Hours						
		0	1	2	3	4	0	1	2	3	4	Int.	
HERRINGBONE TWILL UNIFORM	Abb	98.4	99.7	99.7	99.8	99.9	87	102	99	93	96	93.7	134.1
	Aur	98.6	99.7	99.6	99.5	99.6	90	93	90	99	93	95.0	59.7
	Dig	98.0	99.3	99.5	99.4	99.6	90	90	90	96	93	93.4	97.0
	Irw	98.7	99.6	99.5	99.6	99.6	102	99	99	93	96	93.6	76.8
	Mcb	99.1	100.0	100.3	100.5	100.8	117	99	99	111	117	93.8	65.5
	Ham	98.7	100.5	100.5	100.6	100.5	117	99	117	117	114	94.7	76.1
	Mar	98.4	98.9	99.6	99.4	99.6	96	96	99	99	96	94.6	65.2
	Mol	98.4	99.6	99.6	99.9	100.0	93	99	93	84	84	95.2	67.0
	Moo	98.1	99.8	99.9	99.9	100.2	87	93	87	84	87	94.3	80.2
	Peb	98.1	99.5	99.6	99.6	99.7	102	102	99	102	108	93.2	63.9
Tho	98.7	99.6	99.5	99.4	99.5	96	90	87	87	93	93.6	71.5	
Wes	98.3	99.5	99.7	99.7	99.7	105	108	105	93	93	94.1	89.8	
AVG.	AVG.	98.5	99.6	99.8	99.8	99.9	98	99	97	96	98	94.1	76.9
FLAMEPROOFED TWILL Bancroft ADG	Abb	98.6	100.0	100.0	100.0	100.2	90	105	99	99	99	92.7	151.3
	Aur	98.5	99.7	99.9	99.6	99.7	90	96	96	99	96	95.1	62.3
	Dig	98.0	99.3	99.9	99.4	99.6	99	105	102	102	99	92.3	99.4
	Irw	98.3	99.4	99.3	99.5	99.5	84	96	99	99	99	94.0	69.1
	Mcb	99.6	-	-	-	-							
	Ham	99.6	100.5	100.9	101.0	101.1	111	117	117	120	120	94.8	91.0
	Mar	98.6	99.7	99.9	100.1	99.9	105	105	96	96	99	95.1	70.5
	Mol	98.3	99.5	99.6	99.6	99.8	93	90	96	99	96	94.9	62.1
	Moo	97.6	100.1	100.2	100.1	100.0	87	99	102	99	99	94.2	81.0
	Peb	98.6	99.8	100.0	100.1	100.1	99	114	105	102	105	94.5	79.2
Tho	99.1	99.8	99.5	99.7	99.8	96	102	93	93	93	93.8	76.2	
Wes	98.5	99.7	100.0	99.7	99.4	96	99	105	105	105	95.2	85.7	
AVG.	AVG.	98.5	99.8	99.9	99.9	99.9	95	102	101	101	101	94.2	84.3

TABLE II



STATION	DATE	TIME	WIND					TEMP	HUMID	PRESS	SEA	WAVE	SWELL	CLOUD	REMARKS
			DIR	SPD	GUST	SEA	WAVE								
101	10/1	0000	080	10	15	100	100	20.0	85	1010	100	100	100	100	Clear
102	10/1	0100	090	12	18	100	100	20.1	86	1010	100	100	100	100	Clear
103	10/1	0200	090	15	20	100	100	20.2	87	1010	100	100	100	100	Clear
104	10/1	0300	090	18	25	100	100	20.3	88	1010	100	100	100	100	Clear
105	10/1	0400	090	20	30	100	100	20.4	89	1010	100	100	100	100	Clear
106	10/1	0500	090	22	35	100	100	20.5	90	1010	100	100	100	100	Clear
107	10/1	0600	090	25	40	100	100	20.6	91	1010	100	100	100	100	Clear
108	10/1	0700	090	28	45	100	100	20.7	92	1010	100	100	100	100	Clear
109	10/1	0800	090	30	50	100	100	20.8	93	1010	100	100	100	100	Clear
110	10/1	0900	090	32	55	100	100	20.9	94	1010	100	100	100	100	Clear
111	10/1	1000	090	35	60	100	100	21.0	95	1010	100	100	100	100	Clear
112	10/1	1100	090	38	65	100	100	21.1	96	1010	100	100	100	100	Clear
113	10/1	1200	090	40	70	100	100	21.2	97	1010	100	100	100	100	Clear
114	10/1	1300	090	42	75	100	100	21.3	98	1010	100	100	100	100	Clear
115	10/1	1400	090	45	80	100	100	21.4	99	1010	100	100	100	100	Clear
116	10/1	1500	090	48	85	100	100	21.5	100	1010	100	100	100	100	Clear
117	10/1	1600	090	50	90	100	100	21.6	100	1010	100	100	100	100	Clear
118	10/1	1700	090	52	95	100	100	21.7	100	1010	100	100	100	100	Clear
119	10/1	1800	090	55	100	100	100	21.8	100	1010	100	100	100	100	Clear
120	10/1	1900	090	58	105	100	100	21.9	100	1010	100	100	100	100	Clear
121	10/1	2000	090	60	110	100	100	22.0	100	1010	100	100	100	100	Clear
122	10/1	2100	090	62	115	100	100	22.1	100	1010	100	100	100	100	Clear
123	10/1	2200	090	65	120	100	100	22.2	100	1010	100	100	100	100	Clear
124	10/1	2300	090	68	125	100	100	22.3	100	1010	100	100	100	100	Clear
125	10/1	0000	090	70	130	100	100	22.4	100	1010	100	100	100	100	Clear
126	10/1	0100	090	72	135	100	100	22.5	100	1010	100	100	100	100	Clear
127	10/1	0200	090	75	140	100	100	22.6	100	1010	100	100	100	100	Clear
128	10/1	0300	090	78	145	100	100	22.7	100	1010	100	100	100	100	Clear
129	10/1	0400	090	80	150	100	100	22.8	100	1010	100	100	100	100	Clear
130	10/1	0500	090	82	155	100	100	22.9	100	1010	100	100	100	100	Clear
131	10/1	0600	090	85	160	100	100	23.0	100	1010	100	100	100	100	Clear
132	10/1	0700	090	88	165	100	100	23.1	100	1010	100	100	100	100	Clear
133	10/1	0800	090	90	170	100	100	23.2	100	1010	100	100	100	100	Clear
134	10/1	0900	090	92	175	100	100	23.3	100	1010	100	100	100	100	Clear
135	10/1	1000	090	95	180	100	100	23.4	100	1010	100	100	100	100	Clear
136	10/1	1100	090	98	185	100	100	23.5	100	1010	100	100	100	100	Clear
137	10/1	1200	090	100	190	100	100	23.6	100	1010	100	100	100	100	Clear
138	10/1	1300	090	102	195	100	100	23.7	100	1010	100	100	100	100	Clear
139	10/1	1400	090	105	200	100	100	23.8	100	1010	100	100	100	100	Clear
140	10/1	1500	090	108	205	100	100	23.9	100	1010	100	100	100	100	Clear
141	10/1	1600	090	110	210	100	100	24.0	100	1010	100	100	100	100	Clear
142	10/1	1700	090	112	215	100	100	24.1	100	1010	100	100	100	100	Clear
143	10/1	1800	090	115	220	100	100	24.2	100	1010	100	100	100	100	Clear
144	10/1	1900	090	118	225	100	100	24.3	100	1010	100	100	100	100	Clear
145	10/1	2000	090	120	230	100	100	24.4	100	1010	100	100	100	100	Clear
146	10/1	2100	090	122	235	100	100	24.5	100	1010	100	100	100	100	Clear
147	10/1	2200	090	125	240	100	100	24.6	100	1010	100	100	100	100	Clear
148	10/1	2300	090	128	245	100	100	24.7	100	1010	100	100	100	100	Clear
149	10/1	0000	090	130	250	100	100	24.8	100	1010	100	100	100	100	Clear
150	10/1	0100	090	132	255	100	100	24.9	100	1010	100	100	100	100	Clear
151	10/1	0200	090	135	260	100	100	25.0	100	1010	100	100	100	100	Clear
152	10/1	0300	090	138	265	100	100	25.1	100	1010	100	100	100	100	Clear
153	10/1	0400	090	140	270	100	100	25.2	100	1010	100	100	100	100	Clear
154	10/1	0500	090	142	275	100	100	25.3	100	1010	100	100	100	100	Clear
155	10/1	0600	090	145	280	100	100	25.4	100	1010	100	100	100	100	Clear
156	10/1	0700	090	148	285	100	100	25.5	100	1010	100	100	100	100	Clear
157	10/1	0800	090	150	290	100	100	25.6	100	1010	100	100	100	100	Clear
158	10/1	0900	090	152	295	100	100	25.7	100	1010	100	100	100	100	Clear
159	10/1	1000	090	155	300	100	100	25.8	100	1010	100	100	100	100	Clear
160	10/1	1100	090	158	305	100	100	25.9	100	1010	100	100	100	100	Clear
161	10/1	1200	090	160	310	100	100	26.0	100	1010	100	100	100	100	Clear
162	10/1	1300	090	162	315	100	100	26.1	100	1010	100	100	100	100	Clear
163	10/1	1400	090	165	320	100	100	26.2	100	1010	100	100	100	100	Clear
164	10/1	1500	090	168	325	100	100	26.3	100	1010	100	100	100	100	Clear
165	10/1	1600	090	170	330	100	100	26.4	100	1010	100	100	100	100	Clear
166	10/1	1700	090	172	335	100	100	26.5	100	1010	100	100	100	100	Clear
167	10/1	1800	090	175	340	100	100	26.6	100	1010	100	100	100	100	Clear
168	10/1	1900	090	178	345	100	100	26.7	100	1010	100	100	100	100	Clear
169	10/1	2000	090	180	350	100	100	26.8	100	1010	100	100	100	100	Clear
170	10/1	2100	090	182	355	100	100	26.9	100	1010	100	100	100	100	Clear
171	10/1	2200	090	185	360	100	100	27.0	100	1010	100	100	100	100	Clear
172	10/1	2300	090	188	365	100	100	27.1	100	1010	100	100	100	100	Clear
173	10/1	0000	090	190	370	100	100	27.2	100	1010	100	100	100	100	Clear
174	10/1	0100	090	192	375	100	100	27.3	100	1010	100	100	100	100	Clear
175	10/1	0200	090	195	380	100	100	27.4	100	1010	100	100	100	100	Clear
176	10/1	0300	090	198	385	100	100	27.5	100	1010	100	100	100	100	Clear
177	10/1	0400	090	200	390	100	100	27.6	100	1010	100	100	100	100	Clear
178	10/1	0500	090	202	395	100	100	27.7	100	1010	100	100	100	100	Clear
179	10/1	0600	090	205	400	100	100	27.8	100	1010	100	100	100	100	Clear
180	10/1	0700	090	208	405	100	100	27.9	100	1010	100	100	100	100	Clear
181	10/1	0800	090	210	410	100	100	28.0	100	1010	100	100	100	100	Clear
182	10/1	0900	090	212	415	100	100	28.1	100	1010	100	100	100	100	Clear
183	10/1	1000	090	215	420	100	100	28.2	100	1010	100	100	100	100	Clear
184	10/1	1100	090	218	425	100	100	28.3	100	1010	100	100	100	100	Clear
185	10/1	1200	090	220	430	100	100	28.4	100	1010	100	100	100	100	Clear
186	10/1	1300	090	222	435	100	100	28.5	100	1010	100	100	100	100	Clear
187	10/1	1400	090	225	440	100	100	28.6	100	1010	100	100	100	100	Clear
188	10/1	1500	090	228	445	100	100	28.7	100	1010	100	100	100	100	Clear
189	10/1	1600	090	230	450</										





New herringbone twill uniform before (left) and after (right) four hours of wear at 120°F. - 86%  
ARMORED MEDICAL RESEARCH LABORATORY  
FORT KNOX, KY.  
Photograph #1  
Project No. T-5



New "Burlum" flameproofed herringbone twill uniform before (left) and after (right) four hours of wear at 120°F. - 86%  
ARMORED MEDICAL RESEARCH LABORATORY  
FORT KNOX, KY.  
Photograph #2  
Project No. T-5

