Project No. T-11


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

2. DISCUSSION:

The Army Committee for Insect and Rodent Control desired studies on the physiological heat load of a new insect repellent herringbone twill uniform. Preliminary investigations had shown that the benzyl benzoate, vinylite resin impregnation submitted for test was effective and resisted laundering. It was the purpose of this study to determine whether or not this impregnation imposed a heat load on troops wearing the garment in hot environments.

3. CONCLUSIONS:

a. Herringbone twill uniforms impregnated with 5% benzyl benzoate and 5% vinylite resin do not impose any greater heat load on acclimatized men than ordinary herringbone twill. Tests were performed in both hot dry (D.B. 120°F, W.B. 86°F, R.H. 36%) and hot humid (D.B. 80°F, W.B. 84°F, R.H. 85%) environments.

b. All of the subjects complained of skin irritation produced by the new impregnated fatigues.
4. **RECOMMENDATIONS:**

That if the Chemical Warfare Service tests in progress indicate that this impregnation is not lost by continued wear and laundering, and does not produce a serious dermatitis, these insect repellent garments be considered suitable for issue.

Submitted by:
Steven H. Horvath, Major, SnC
Walter B. Shelley, Captain, SnC

Assisted by:
Howard Golden, Tec 3
John E. Wagar, Tec 3
Arthur E. Kunes, Tec 3
James P. Stack, Tec 3
Kenneth C. Davis, Tec 3
Robert A. Kleinman, Tec 3
William J. Robinson, Tec 3
James W. Gregg, P-4

3 Incls,
- Incl. #1 - Appendix
- Incl. #2 - Tables 1-2
- Incl. #3 - Photographs 1-3
APPENDIX

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 ± 10°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 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 attain physical fitness.

All water drunk during the test periods was a 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.

A Latin Square method of testing was used. Each of the men wore new insect repellent herringbone twill fatigues and new untreated herringbone twill uniforms once in each of the two environments. The insect repellent uniforms had been treated with 5% benzyl benzoate and 5% vinylite resin and showed an add-on of about 20%. This impregnation has been shown to be effective and to resist laundering. The test clothing had not been laundered.

Incl. #1 1
The clothing was always worn in the same manner to give greatest protection against insects; trouser legs were tucked inside of the pulled up socks, jacket shirt tucked into the waist of the trousers, and top button of the jacket buttoned. Since this reduced bellows action of clothing and gave maximum cover 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 3-10 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 and rectal temperatures were determined. After 4 hours of walking, the subject stood erect while 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.

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 I).

   b. Heat Load at a Low Dry Bulb Temperature:
      D. B. 88°F., W.B. 84°F., R.H. 85%
This simulates a typical tropical environment. Again the responses of the men indicated that the impregnation imposed no added heat load (Table 2).

c. Physical Characteristics of the Clothing:

(1) Gross Characteristics:

The insect repellent clothing resembled untreated herringbone twill in appearance (Photographs 1 and 2). The fabric was slightly more coarse than herringbone twill and it had a pungent odor. However, none of the men in the test had any complaints about the odor. The intensity of the odor diminished greatly during two usings. It is possible that the passage of large quantities of sweat through the garment leached out some of the active agent.

(2) Absorption of Sweat:

The following table presents the average data on 12 men and their clothing:

<table>
<thead>
<tr>
<th>Test</th>
<th>Clothing</th>
<th>Average Four-Hour Sweat Loss per Man (Grams)</th>
<th>Clothing Uptake of Sweat (Grams)</th>
<th>Percent of Total Sweat in Garment</th>
</tr>
</thead>
<tbody>
<tr>
<td>D.B. 120° W.B. 86°</td>
<td>Insect Repellent Uniform</td>
<td>7,274</td>
<td>658</td>
<td>9</td>
</tr>
<tr>
<td></td>
<td>Herringbone Twill Uniform</td>
<td>7,035</td>
<td>883</td>
<td>13</td>
</tr>
<tr>
<td>D.B. 88° W.B. 84°</td>
<td>Insect Repellent Uniform</td>
<td>3,410</td>
<td>778</td>
<td>23</td>
</tr>
<tr>
<td></td>
<td>Herringbone Twill Uniform</td>
<td>3,300</td>
<td>1,037</td>
<td>31</td>
</tr>
</tbody>
</table>

Incl. #1
Similar patterns in sweat uptake by the clothing occurred in both environments. In neither environment was this uptake equivalent to the water absorption capacity of the clothing, as determined by immersion studies.

The sweat uptake characteristics of the insect repellent garment are satisfactory, although slightly inferior to those of the herringbone twill uniform. The water repellency of the treated garment was manifested by the greater accumulation of sweat in the shoes resulting from funneling of sweat down the legs. The amount of sweat in the shoes at any time was dependent on the sweating rate of the individual. A high sweating rate of the right hand subject in Photograph 3 resulted in sweat being squirted from the shoes even before he had marched a single hour.

d. Skin Irritation Induced by Insect Repellent Clothing:

All men complained of skin irritation when wearing the treated clothing. This was localized to the areas of contact. Only a transitory erythema was noted in the involved areas. The irritation was generally described as similar to having sandpaper rubbed over the skin.

One man wore the insect repellent clothing for four hours on each of seven days. He complained of minor irritation on each wearing. Some men found that wearing an undershirt eliminated much of the discomfort associated with the garments. Further work on skin irritation was not conducted as extensive studies are being done elsewhere.
### Table 1

<table>
<thead>
<tr>
<th>Job</th>
<th>Initial Temperature</th>
<th>Initial HR</th>
<th>Final Temperature</th>
<th>Final HR</th>
<th>Pulse Rate/Min</th>
<th>Rectal F. Temperature</th>
<th>Rectal F. Temperature</th>
<th>Retard</th>
<th>Retard</th>
</tr>
</thead>
<tbody>
<tr>
<td>196</td>
<td>67.2°F</td>
<td>76.9°F</td>
<td>78.9°F</td>
<td>90.0°F</td>
<td>90.5°F</td>
<td>95.2°F</td>
<td>95.4°F</td>
<td>1.0</td>
<td>1.0</td>
</tr>
<tr>
<td>197</td>
<td>70.8°F</td>
<td>86.7°F</td>
<td>88.9°F</td>
<td>90.0°F</td>
<td>90.5°F</td>
<td>95.2°F</td>
<td>95.4°F</td>
<td>1.0</td>
<td>1.0</td>
</tr>
</tbody>
</table>

**D.B. 120°F** - 118°F 65°F - 69°F 260°F

The physiological response of working men clothed in insect repellent.
Insect repellent uniforms after one hour of wear at 120°F. – 85°F.

ARMORED MEDICAL RESEARCH LABORATORY

Project No. T-11

FORT KNOX, KY.

Photograph #3