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THERMAL PROTECTIVITY OF A LIGHT PONCHO MATERIAL

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GEORGE MIXTER, JR. M. D.

ABSTRACT

The critical energy of a light weight waterproof material was determined with the fabric suspended in air. The protective qualities of this fabric against radiant thermal energies was then determined, using white pigs as the indicator. Protectivity was determined for trapezoidal energy pulses of 0.6 and 5.0 sec. with fabric in contact with, and 5 mm separated from, the pig's skin. In contact with skin this poncho material increased the severity of burn; at 5 mm separation the protective index was determined to be 4.71 at 0.6 sec. and 1.67 at 5.0 sec.

NOTE: This study was carried out through the facilities of the University of Rochester Atomic Energy Project, under contract with the U. S. Atomic Energy Commission, and a portion of its expenses defrayed under a grant from the Quartermaster Corps, U. S. Army.

INTRODUCTION

In response to a specific request by the U. S. Army Quartermaster Research and Development Laboratories, the following limited studies were carried out on a light-weight poncho material. The material is described as follows: "A coated poncho fabric, nylon twill, 1.8 oz/yd², coated with a vinyl polymer to an overall weight of 7.3 oz/yd²*, as described in MIL-P-3003C, Poncho, Light Weight."

MATERIALS AND METHODS

The University of Rochester arc source (1) was used to supply radiant thermal energy of known characteristics in trapezoidal bursts of known duration. Anesthetized white pigs were used as indicators in the manner previously described (2). Burns were assessed at 18 - 24 hours by gross appearance and classified on a scale of 0 to 5+. Protectivity studies were designed to produce burns centering about the 2+ mild level. Randomization of burns over the available areas and statistical analysis by the graphical probit method were carried out as described in previous publications (3).

Step 1. Critical Energy

A. Selection of end-points

(1. 0.5 sec.) As the material is exposed to the arc output in the 1.8 cm. water-cooled aperture with free access to air, charring and smoking begin to occur at about 5 cal/cm²/sec.; the char progressively penetrates the fabric and begins to shrink. Up to the limit of the arc output (34 cal/cm²/sec), half-second exposures fail to destroy completely

*Average weight as determined in this laboratory.

less than the chosen end-point), the irradiance is increased by 10% and another piece of fabric is exposed. If the result is positive (i.e., the chosen level of damage is attained or exceeded), the irradiance is decreased by 10% for the next shot. This plan is followed for 40 - 50 shots, increasing or decreasing the irradiance by 10% each time, accordingly as the previous shot was negative or positive.

Results are then tabulated and the computation of the mean effective exposure (EE_{50}) with the 95% confidence limits is carried out as described in the reference.

C. Results

Table 1 gives the observed behavior of the unbacked fabric at 0.5 and 5.0 sec. exposures. All requirements for statistical validity are satisfied. The critical energies for 0.5 and 5.0 sec. exposures (as defined) are 3.83 and 2.92 cal/cm² respectively.

D. General Comments

1. Shrinkage and meltage were prominent. The experimental method used, involving an exposure spot 1.8 cm in diameter, may be quite misleading if extrapolated to wide-area problems.

2. Charring did not occur below 1 cal/cm²/sec. At such low irradiances, melting dominated the picture.

3. Smoking was mild at low irradiances, but when H was greater than 15 cal/cm²/sec., smoking was intense, with flakes of carbon. Brief, unsustained flare and extremely nauseous, acrid products were evolved.

Table 1

Time (sec)	Irradiance (cal/cm ² /sec)	Exposure (cal/cm ²)	Negative	Positive
0.5	5.95	2.97	1	0
	6.55	3.27	6	2
	7.2	3.6	6	7
	7.95	3.97	3	7
	8.75	4.37	2	3
	9.65	4.82	1	2
	10.65	5.32	0	1
5.0	.49	2.45	3	0
	.54	2.66	13	3
	.60	3.00	3	13
	.65	3.25	1	4
	.72	3.60	0	2
	.80	4.0	0	1

4. After the exposure, the sticky, partly melted material rapidly stiffened and regained considerable strength, but was greatly shrunken.

Step 2. Protectivity

Attempts to produce a 2+ burn at 0.5 sec. with fabric 0.5 cm separated from pig's skin were unsuccessful with the arc wide open ($34 \text{ cal/cm}^2/\text{sec}$). At 0.6 sec., significant burns were produced. Accordingly, 0.6 sec. was chosen for the short exposure both for contact and separated experiments.

A. Experimental Plan

Aside from the usual controls routinely maintained on arc output, both 0.6 sec. and 5.0 sec. exposures on bare skin were obtained as a reference point for the protective indices of the fabric in question. Thus, the results of this study are based upon a simultaneous comparison between the energy required to produce 2+ burns through fabric, and that required to produce a lesion of the same degree on the unprotected skin.

Six situations required study: bare skin, fabric contact and fabric separated, each at 0.6 and 5.0 sec. exposure. Each situation required about 5 irradiances, making a total of 30 exposures per replication. Fitting 30 exposures to each side of a pig (2 rows of 8 and 2 rows of 7 exposures each), this yields 2 replications per pig. Six pigs (12 replications) were used in the present study, totaling 360 burns.

Table 2

Bare Skin, 0.6 Sec. Exposure

H (cal/cm ² /sec)	Q (cal/cm ²)	Degree of Burn					
		0	1+ Mild	1+ Sev	2+ Mild	2+ Mod	2+ Sev
4.5	2.7		11	1			
4.95	2.91		8	4			
5.4	3.24		10	2			
5.95	3.57			4	6	1	1
6.55	3.93			0	8	4	

Table 3

Bare Skin, 5.0 Sec. Exposure

H (cal/cm ² /sec)	Q (cal/cm ²)	Degree of Burn					
		0	1+ Mild	1+ Sev	2+ Mild	2+ Mod	2+ Sev
.88	4.4			9	3		
.965	4.82			8	4		
1.04	5.1			3	7	2	
1.13	5.65			1	8	3	
1.23	6.15			0	2	7	3

Table 4

Poncho Material, Contact, 0.6 Sec. Exposure

H (cal/cm ² /sec)	Q (cal/cm ²)	Degree of Burn					
		0	1+ Mild	1+ Sev	2+ Mild	2+ Mod	2+ Sev
3.3	1.96		1	2	1		
3.6	2.16		4	1	3		
4.0	2.4		2	3	3		
4.5	2.7			1	9	1	
4.95	2.91		2	0	7	3	
5.4	3.24			1	6	0	1
5.95	3.57				2	1	1
6.55	3.93				1	3	

Table 5

Poncho Material, Contact, 5.0 Sec. Exposure

H (cal/cm ² /sec)	Q (cal/cm ²)	Degree of Burn					
		0	1+ Mild	1+ Sev	2+ Mild	2+ Mod	2+ Sev
.34	1.70	1	2	8	1		
.38	1.90			5	7		
.41	2.05		1	2	8	1	
.45	2.25		1	0	2	8	1
.49	2.45				3	4	5

Table 6

Poncho Material, 0.5 cm. Separation, 0.6 Sec. Exposure

H (cal/cm ² /sec)	Q (cal/cm ²)	Degree of Burn					
		0	1+ Mild	1+ Sev	2+ Mild	2+ Mod	2+ Sev
21.0	12.6	1	3	2	2		
23.1	13.7	1	3	3	1		
25.4	15.2	1	4	3	4		
28.0	16.8	1	5	2	4	1	
30.8	18.5		3	0	7	1	
34.0	20.4				6	2	

Table 7

Poncho Material, 0.5 cm. Separation, 5.0 Sec. Exposure

H (cal/cm ² /sec)	Q (cal/cm ²)	Degree of Burn					
		0	1+ Mild	1+ Sev	2+ Mild	2+ Mod	2+ Sev
1.33	6.65		8	4			
1.45	7.25		3	7	2		
1.6	8.0		3	7	2		
1.74	8.7		1	0	9	2	
1.92	9.6				4	8	

B. Results

The results are presented in the form of exposure-response tables 2 - 7, showing the actual results observed. Table 8 presents the calculated $2+EE_{50}$'s, with their 95% confidence limits. In addition, the latter table also gives the protective indices (3) of the fabric for the four situations investigated.

$$\underline{\text{P. I.}} = \left[\frac{2+EE_{50} \text{ subfabric}}{2+EE_{50} \text{ bare skin}} \right] t.$$

The separation factor is also calculated, expressing in the form of a ratio the increase of protection afforded by introducing an air space of 5 mm between fabric and skin, at any given exposure time.

$$\underline{\text{Sep. Factor}} = \left[\frac{2+EE_{50} \text{ subfabric separated}}{2+EE_{50} \text{ subfabric contact}} \right] t.$$

C. Discussion

In contact, this material is evidently far more absorptive of the arc output than pigs' skin. For 5 sec. exposures, the protective index is approximately 0.4, the lowest of any material ever studied in this laboratory. At this "slow" exposure, no visible change whatsoever occurred in the fabric, and it appeared likely that most of the energy absorbed by it (a large proportion of that incident upon it) was effectively transferred to the skin. The short contact, however, was not effected without some charring of the outer surface of the fabric. The 0.6 sec. exposure, then, involved an endothermic reaction (partial chemical destruction of the protective film), which is clearly reflected in the higher protective index for this exposure time.

Table 8
 Poncho Experiment
 Summary 11/12/54 - 12 Replications
 (6 Pigs, 360 Burns)

Exposure Time (Sec)	Bare Skin EE ₅₀ (cal/cm ²)	Contact		Separated 5 mm	
		EE ₅₀	P. I.	EE ₅₀	P. I.
0.6	3.44 (3.3-3.59)	2.38 (2.17-2.6)	0.69	16.2 (14.9-17.6)	4.71
Sep. Coefficient					6.8
5.0	4.81 (4.6-5.04)	1.91 (1.82-2.0)	0.397	8.05 (7.7-8.4)	1.67
Sep. Coefficient					4.2

With an air space of 0.5 cm between skin and fabric, however, the situation was quite different. Again, the protection afforded from short, high-intensity bursts of energy was greater than that from longer, less intense pulses; but in each case a very significant protection was afforded. The contrast between contact and separated, as shown by the "separation factor", was more marked in the case of this fabric than any other we have studied. At both exposure times, endothermic reactions of an unknown nature were involved, and it is quite possible that our studies of relatively small target areas were not good indications of what would happen if large areas were exposed. It is fairly safe, however, to hazard a guess that such poncho material would afford protection from twice to four times the $2+EE_{50}$ bare skin dose, provided the poncho were at no point in contact with skin. At such points, very severe burns would have to be expected.

The present study has shown results quantitatively different from those previously encountered with conventional cotton fabrics. It would be very unwise to draw too sweeping conclusions from it, other than to say that such poncho material shows potentialities for very high thermal protection. If the color were lighter, i.e., if the reflectance were higher, the protectivity would be very greatly increased.

Finally, it is worthy of notice how little bearing the "critical energy" of the fabric has upon protectivity, either in contact or in separation:

Table 9

Sec. Exposure	Q_c	2+ EE ₅₀ Contact	2+ EE ₅₀ Separated
0.5 - 0.6	3.83	2.38	16.2
5.0	2.92	1.91	8.05

In this situation, as in many others, no obvious relation can be discovered between the so-called critical energy (as evidenced by breakdown of fabric freely supported in air) and the degree of protection afforded the pig by the fabric against radiant thermal injury.

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