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STUDIES ON SMALL AREA SUB-FABRIC FLASH BURNS

by

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THE UNIVERSITY OF ROCHESTER
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STUDIES ON SMALL AREA SUB-FABRIC FLASH BURNS

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K. M. Berkley, M. D.

ABSTRACT

In a series of 1850 exposures with a modified 2 $\frac{1}{4}$ inch carbon arc searchlight, the influence of two 5-1/2 oz. cotton poplin fabrics* alone and in combination with underwear material on the energy required to produce 2+ cutaneous burns in swine were studied.

Impregnation of both khaki and green poplin (shade 116) with fire retardant material L-S 123P* reduced the amount of energy necessary to produce a 2+ burn below that required with the untreated material, when the fabrics were spaced 2 and 5 mm. from the skin.

As a fabric is separated from the skin, the amount of absorbed energy required to produce a 2+ sub-fabric burn increases in a linear relationship with the amount of spacing.

Maximum protection was provided by a two layer combination of poplin and underwear separated by a 5 mm. air space. The energy required to produce a 2+ burn beneath two fabric layers separated by 5 mm. decreased as the exposure time increased. With two layers spaced 2 mm., the requirements were the same.

*The untreated and treated poplins were furnished by the Quartermaster Research and Engineering Center.

INTRODUCTION

Observations made in Japan (3) and in this (1, 6, 7, 8, 9) and other laboratories (11, 12) indicate that clothing will reduce the severity of flash burns. This effect is influenced by the fabric's weight, reflectance and composition (7). It is changed by multiple layers and by air spacing (1, 8).

Studies on white cotton sheeting showed that the median radiant exposure (cal/cm^2) for superficial burns increased linearly as the air space increased (1). It is desirable to see if this linear relationship of spacing will hold for other fabrics.

A controlled study has not previously been made on the influence of an air space between two fabric layers, one of which is in contact with the skin. This is a realistic situation for it is the way clothing is worn with an inner and outer garment.

The effect of flame retardant treatment is another condition that deserves more study. Unfortunately the methods of such treatment have not stabilized and are being changed in an effort to improve them. Observations on fabric treated by one process do not always agree with those made on others. Yet there is an advantage in evaluating the effects of various methods of fire-retardant treatment on the degree of protection against thermal radiation, for this is one gauge of the efficiency of the process.

Four fabrics of special interest were used alone and in conjunction with underwear for this study. They were supplied by the Quartermaster Research and Engineering Center, Natick, Massachusetts.

METHODS

Three experiments were done. In experiments 1 and 2, green poplin (shade 116) and khaki No. I poplin were studied alone and in combination with underwear material at 1.0 sec. exposure time. In experiment 3, the effect of time was investigated with the green poplin in combination with underwear material.

Equipment

A 24 inch carbon arc searchlight, modified as described by Davis et al., was the source of radiant energy (2).

The cloths were kept at a relative humidity of 65% for at least 24 hours before burning. Polished aluminum rings with a 1.7 inch aperture spaced the cloth from the animal.

The reflectance and transmittance of the fabrics over the range of the spectral distribution of the arc source were measured by using a reflectometer and universal spectrophotometer constructed by Krolak and Davis (4). The cloths and their physical characteristics are listed in the following table:

Material	Designation	Physical Constants		
		Weight (oz/sq.yd)	Reflectance	Transmittance
Underwear Material	Underwear (Undrwr)	3.2	.63	.32
Green Poplin (shade 116)	Green (Gr)	5.4	.20	.03
Green Poplin (shade 116) Fire-retardant Treated with L-S 123P Treatment	Green, FR (Gr, FR)	6.6	.24	.03
Poplin, Khaki No. I	Khaki (Kh)	5.4	.35	.08
Poplin, Khaki No. I, Fire- retardant Treat- ed with L-S 123P Treatment	Khaki, FR (Kh, FR)	6.5	.35	.06

Biological

Chester White and Yorkshire pigs weighing 20 to 30 pounds were anesthetized by the intraperitoneal route with Dial in urea-urethane (Ciba) in dosages of 60 - 70 mgm/Kg. of body weight. The hair was closely clipped and the skin was gently sponged prior to burning. Fifty, sixty and seventy-five treatments, systematically randomized, were made on each animal in experiments 1, 2 and 3 respectively. The animal was kept in contact with the fabric for approximately five seconds following the exposure.

Evaluation

The lesions were graded 24 hours after burning by surface appearance according to the following classification (10):

Grade	Surface Appearance
1+	Red (erythema)
2+	Patchy white
3+	Uniform white

Analysis of data

The median effective exposure or EE_{50} and 95% confidence intervals were estimated by the method of Litchfield and Wilcoxon (5). The median effective exposure (EE_{50}) is the lowest radiant exposure (cal/cm^2) which will produce at least the given grade of burn 50% of the time. The 95% confidence interval defines the limits of radiant exposures which 95% of the time will cover the 50% effective exposure, if the same experiment is repeated. Another useful term is median effective dose or ED_{50} which is related to the median effective exposure as follows:

$$ED_{50} = EE_{50} (1 - R), \text{ where } R \text{ is the reflectance.}$$

RESULTS

Experiments 1 and 2

The radiant energy levels at which changes in the fabrics occurred were carefully noted. As energy levels increased, the untreated poplin fabric became scorched, charred or consumed by flaming. The treated fabric underwent similar changes, except that it did not sustain combustion. However, it did flare with sufficient radiant exposure. At very high energy levels the cloth disintegrated during the exposure.

The untreated green and khaki fabrics began to flame at 6.13 and 7.6 cal/cm², respectively. However, at these radiant exposures combustion was not sustained after energy was removed unless the animal was taken from the exposure port. The cloth would then flame until consumed.

The treated green and khaki poplin began to flare at 7.6 and 15.8 cal/cm² respectively. Flaring was observed with each exposure at 12.8 cal/cm² and 17.6 cal/cm² for the green and khaki fabrics respectively. The percentage of exposures which resulted in flaming or flaring in the energy range used to produce 2+ burns is noted as "incidence" in the last column of Tables 11 and 12.

Tables 1 to 10 show the number and percentage of burns produced at 1.0 sec. exposure times and with the specified material or combination of materials. Tables 11 and 12 and Figures 1 and 2 summarize the data in terms of median effective exposure and median effective dose.

The median effective exposure required for all 2+ sub-fabric burns is higher than that necessary for bare skin alone. The suggestion of Mixer (6), that the ratio of the median effective exposure required for a sub-fabric burn to that necessary for bare skin alone be used to express the degree of protection which cloth affords, is of value to summarize these findings.

The protective indices for the fabrics are listed in order of increasing magnitude as follows:

Fabric	Protective Index
	$\frac{EE_{50} \text{ (fabric)}}{EE_{50} \text{ (bare)}}$
1. Khaki in contact	1.6
2. Khaki, FR, in contact	1.6
3. Green, FR, spaced 2 mm.	1.6
4. Green, spaced 2 mm.	1.7
5. Green, FR, spaced 5 mm.	1.7
6. Khaki, FR, spaced 2 mm.	1.9
7. Khaki, spaced 2 mm.	2.2
8. Khaki, FR, spaced 5 mm.	2.2
9. Green, spaced 2 mm. and underwear in contact	2.2
10. Underwear in contact	2.3 - 2.6
11. Green, spaced 5 mm.	2.5
12. Green, FR, spaced 2 mm. and underwear in contact	2.6
13. Khaki, spaced 5 mm.	2.8
14. Khaki, spaced 2 mm. and underwear in contact	3.0
15. Khaki, FR, spaced 2 mm. and underwear in contact	3.0
16. Green, spaced 5 mm. and underwear in contact	4.6
17. Khaki, spaced 5 mm. and underwear in contact	4.6
18. Green, FR, spaced 5 mm. and underwear in contact	4.9
19. Khaki, FR, spaced 5 mm. and underwear in contact	6.0

Experiment 3

It was observed that flaming of the untreated fabric began at irradiances of 2.4 or 1.6 cal/cm²/sec. at exposure times of 1.0 or 5.0 sec. respectively. Flaming during the exposure was the rule except at the 5.0 sec. exposure time with fabrics separated 2 mm. Flaring of the treated fabric began at irradiances of 5.0 or 2.0 cal/cm²/sec. at exposure times of 1.0 or 5.0 sec. respectively. At irradiances of 15.8 cal/cm²/sec. and above flaring was constant.

The data are shown in Tables 13 to 17, and summarized in Table 18 and Figure 3.

DISCUSSION

Since the 95% confidence intervals of the median effective exposures of 2+ burns in bare skin and under underwear material in contact with skin, overlap, it seemed justifiable to combine the experiments as determined separately in experiments 1 and 2 for purposes of comparison and discussion. The results are shown in Figure 4.

It is evident that the median effective exposures necessary for 2+ burns beneath khaki poplin, either treated or untreated with fire retardant material, or in combination with underwear, are consistently higher than those beneath green poplin, under otherwise the same conditions.

The effect of fire-retardant treatment on the median effective exposure of the khaki poplin is similar to that observed with green poplin (shade 116), namely, that less energy is necessary to produce a 2+ burn beneath the treated fabric than under the untreated fabric except when the

fabric is in contact with skin. It is suggested that there is a relationship between the difference and between the "incidence" of flaming or flaring of the treated and untreated fabric.

The effect of air spacing, using khaki and green poplin, on the median effective dose of 2+ burns is likewise similar to that reported previously (1). This can be represented by the equation

$$Q_{a_s} = Q_{a_c} + k s$$

where Q_{a_s} and Q_{a_c} are the median effective doses of 2+ burns produced beneath fabric separated from and in contact with skin respectively, s is the amount of separation expressed in millimeters, and k is an experimentally determined constant.

The values of k are:

Khaki	0.56
Khaki, FR	0.35
Green	1.0
Green, FR	0.08

Certainly the addition of underwear, when the outer layer of either green or khaki fabric, treated or untreated, is spaced 5 mm. from it, contributes a great deal to the protection afforded by any of the fabrics or combinations studied, the increase of median effective exposure varying from 1-1/2 to 4 times.

In experiment 3, the effect of exposure time on the median effective exposures necessary for combinations of green poplin fabrics spaced 2 and 5 mm. is considered.

The differences in respect to time in the median effective exposures required by burns produced beneath the two layer combinations with green poplin for the outer layer are probably explained by losses by conduction and convection.

SUMMARY AND CONCLUSIONS

1. In a series of 1850 exposures with a modified 24 inch carbon arc searchlight the effects on the median effective exposures of 2+ cutaneous burns in pigs of two 5-1/2 oz/yd² poplin fabrics, green poplin (shade 116) and khaki No. I, untreated and treated with fire-retardant material L-S 123P, used alone and in combination with 3.2 oz/yd² underwear material were studied. The effects of separation, reflectance, fire-retardant treatment and exposure time were noted in a series of three experiments.
2. With the khaki poplin, either treated or untreated, which has a reflectance of 0.35, more incident energy (median effective exposure) is required to produce a 2+ burn than with the green poplin, either treated or untreated, which has a reflectance of 0.20. The absorbed energy (median effective dose) necessary to produce a 2+ burn is the same for these two fabrics under otherwise the same conditions of separation or combination with underwear material.
3. Less incident energy was required to produce a 2+ burn beneath treated green poplin spaced 5 mm. and beneath the treated khaki poplin spaced 2 or 5 mm. than was necessary under the untreated fabric.

4. Separation of fabric from skin increases the amount of absorbed energy in cal/cm^2 required to produce 2+ burns by a constant (k) times the amount of separation expressed in millimeters.
5. All fabrics studied offered some degree of protection to the skin.
6. With increasing time, the median effective exposure for 2+ burns produced under the two layer combination of green fabric and underwear with outer layer treated or untreated and separated 2 mm. from the underwear material which is in contact with skin, tends to rise slightly or remain the same.
7. With increasing time, the median effective exposure for 2+ burns, produced under the two layer combination with outer layer of green poplin treated or untreated and separated 5 mm. decreases.

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Table 1

Test Material	Radiant Exposure (cal/cm ²)	1+			2+			3+	
		Mild	Mod	Sev	Mild	Mod	Sev	Mild	Mod
Bare Skin	3.3		9 (90%)	1 (10%)					
	3.6	1 (10%)	7 (70%)	1 (10%)	1 (10%)				
	4.0		3 (30%)	1 (10%)	5 (50%)	1 (10%)			
	4.5		1 (10%)		7 (70%)	1 (10%)	1 (10%)		
	5.0				1 (10%)	4 (40%)	3 (30%)	1 (10%)	1 (10%)
Under-wear in Contact	7.6		5 (50%)	4 (40%)		1 (10%)			
	8.4		4 (40%)	3 (30%)	1 (10%)	1 (10%)	1 (10%)		
	9.3		3 (30%)	2 (20%)	1 (10%)	4 (40%)			
	10.4			3 (30%)	1 (10%)	3 (30%)	2 (20%)	1 (10%)	
	11.5					4 (40%)	3 (30%)	3 (30%)	

This table shows the number and percentage of burns produced at 1.0 sec. exposure time in swine with the specified radiant exposure on skin unprotected or protected by underwear material in contact.

Table 2

Test Material	Radiant Exposure (cal/cm ²)	No Burn	1+			2+			3+	
			Mild	Mod	Sev	Mild	Mod	Sev	Mild	Mod
Green	5.0	2 (100%)								
Poplin	5.5	10 (100%)								
Spaced	6.1	3 (27%)	4 (36%)	1 (9%)	1 (9%)			2 (18%)		
2 mm.	6.8		1 (10%)		1 (10%)	2 (20%)	2 (20%)	2 (20%)	1 (10%)	1 (10%)
	7.6					2 (18%)	1 (9%)	3 (27%)	1 (9%)	4 (36%)
	8.4			2 (22%)				3 (33%)		4 (44%)
Green	7.6	2 (20%)	4 (40%)	1 (10%)		3 (30%)				
Poplin	8.4	1 (13%)	3 (38%)	1 (13%)	2 (25%)		1 (13%)			
Spaced	9.3		3 (33%)	2 (22%)		2 (22%)	1 (11%)	1 (11%)		
5 mm.	10.4		1 (10%)	5 (50%)		2 (20%)	2 (20%)			
	11.5		1 (10%)		2 (20%)	5 (50%)	1 (10%)	1 (10%)		

This table shows the number and percentage of burns produced in swine at 1.0 sec. exposure time with the specified radiant exposures on green poplin spaced 2 and 5 mm.

Table 3

Test Material	Radiant Exposure (cal/cm ²)	No Burn	1+			2+			3+	
			Mild	Mod	Sev	Mild	Mod	Sev	Mild	Mod
Green, FR Spaced 2 mm.	5.0	8 (80%)	2 (20%)							
	5.5	5 (50%)	4 (40%)	1 (10%)						
	6.1		4 (40%)	1 (10%)	1 (10%)		2 (20%)	2 (20%)		
	6.8		1 (10%)		1 (10%)	4 (40%)	1 (10%)	2 (20%)		1 (10%)
	7.6						1 (13%)	1 (13%)	4 (50%)	2 (25%)
Green, FR Spaced 5 mm.	8.4			2 (18%)	2 (18%)	4 (36%)		3 (27%)		
	9.3				3 (30%)	5 (50%)		2 (20%)		
	10.4					6 (60%)	3 (30%)		1 (10%)	
	11.5					4 (40%)	4 (40%)	2 (20%)		
	12.8	1 (10%)	1 (10%)			1 (10%)		7 (70%)		

This table shows the number and percentage of burns produced at 1.0 sec. exposure time in swine with the specified radiant exposure on F. R. green poplin at 2 and 5 mm. separation.

Table 4

Test Material	Radiant Exposure (cal/cm ²)	No Burn	1+			2+			3+	
			Mild	Mod	Sev	Mild	Mod	Sev	Mild	Mod
Green Poplin and Underwear Spaced 2 mm.	7.6	1 (10%)	1 (17%)	1 (17%)	1 (10%)	2 (33%)	2 (33%)	1 (10%)	1 (10%)	
	8.4		1 (10%)	2 (20%)		4 (40%)	1 (10%)			
	9.3		3 (30%)	2 (20%)		2 (20%)	2 (20%)			
	10.4	1 (33%)	1 (10%)	1 (10%)	2 (20%)	4 (40%)	1 (10%)			
	11.5					4 (40%)	2 (20%)			
	12.8					2 (67%)				
Green Poplin and Underwear Spaced 5 mm.	15.8	4 (40%)	4 (40%)	1 (10%)	1 (10%)	1 (10%)	4 (40%)	1 (11%)		
	17.6		4 (40%)	3 (30%)		2 (20%)				
	19.5		1 (10%)	1 (10%)		3 (30%)				
	21.7					5 (55%)	3 (33%)			
	24.1					2 (22%)	6 (67%)	1 (11%)		

This table shows the number and percentage of burns produced in swine at 1.0 sec. exposure time with the specified radiant exposures applied to green poplin spaced 2 and 5 mm. from underwear material which is in contact with skin.

Table 5

Test Material	Radiant Exposure (cal/cm ²)	No Burn	1+			2+		
			Mild	Mod	Sev	Mild	Mod	Sev
Green, FR and Underwear Spaced 2 mm.	6.8	1 (10%)	7 (70%)	2 (20%)				
	7.6	2 (20%)	1 (10%)	4 (40%)	1 (10%)	2 (20%)		
	8.4		2 (20%)	4 (40%)	3 (30%)	1 (10%)		
	9.3			4 (40%)	2 (20%)	1 (10%)	3 (30%)	
	10.4		2 (20%)	1 (10%)	2 (20%)	3 (30%)	1 (10%)	1 (10%)
Green, FR and Underwear Spaced 5 mm.	15.8	1 (10%)	5 (50%)	2 (20%)	2 (20%)			
	17.6		3 (30%)	4 (40%)	3 (30%)			
	19.5		1 (10%)	2 (20%)	1 (10%)	5 (50%)		1 (10%)
	21.7			1 (9%)	3 (27%)	4 (36%)	3 (27%)	
	24.1				1 (11%)	5 (55%)	2 (22%)	1 (11%)

This table shows the number and percentage of burns produced in swine at 1.0 sec. exposure time with the specified radiant exposures applied to F. R. green poplin spaced 2 and 5 mm. from underwear material which is in contact with skin.

Table 6

Test Material	Radiant Exposure (cal/cm ²)	No Burn	1+			2+		
			Mild	Mod	Sev	Mild	Mod	Sev
Under- wear in Contact	7.6	2 (18%)	5 (45%)	4 (36%)				
	8.4		3 (33%)	4 (45%)		2 (22%)		
	9.3		2 (20%)	3 (30%)	1 (10%)	2 (20%)		2 (20%)
	10.4			3 (30%)	1 (10%)	6 (60%)		
	11.5					4 (40%)	4 (40%)	2 (20%)
Bare Skin	3.3		3 (30%)	4 (40%)		3 (30%)		
	3.6			3 (30%)	2 (20%)	5 (50%)		
	4.0			1 (10%)	4 (40%)	3 (30%)	1 (10%)	1 (10%)
	4.5			1 (10%)		5 (50%)	2 (20%)	2 (20%)
	5.0		1 (10%)	1 (10%)			2 (20%)	6 (60%)

This table shows the number and percentage of burns produced at 1.0 sec. exposure time in swine with the specified radiant exposure on skin unprotected or protected by underwear material in contact.

Table 7

Test Material	Radiant Exposure (cal/cm ²)	No Burn	1+			2+			3+		
			Mild	Mod	Sev	Mild	Mod	Sev	Mild	Mod	Sev
Khaki in Contact	6.1	1 (10%)	2 (25%)	3 (38%)	1 (12%)	1 (12%)	2 (25%)	1 (12%)			
	6.8		1 (10%)	2 (20%)			4 (40%)	2 (20%)			
	7.6					1 (10%)	6 (60%)	2 (20%)	1 (10%)		
	8.4			1 (9%)		1 (9%)		6 (67%)	2 (18%)	1 (9%)	
	9.3							4 (36%)	4 (36%)	3 (27%)	
Khaki Spaced 2 mm.	7.6	5 (50%)	2 (20%)	1 (10%)		1 (10%)	1 (10%)				
	8.4	1 (10%)	1 (10%)	2 (20%)		2 (20%)	1 (10%)	2 (20%)			
	9.3		1 (10%)				1 (10%)	5 (50%)	1 (10%)	1 (10%)	1 (10%)
	10.4					1 (10%)	2 (20%)	1 (10%)	1 (10%)	5 (50%)	
	11.5						1 (10%)		2 (20%)	5 (50%)	2 (20%)
Khaki Spaced 5 mm.	9.3		1 (25%)	2 (50%)		1 (25%)					
	10.4			2 (33%)		3 (50%)	1 (17%)				
	11.5		1 (8%)	2 (17%)	2 (17%)	6 (50%)	1 (18%)				
	12.8			1 (10%)	1 (10%)	7 (70%)	1 (10%)				
	14.2					3 (33%)	6 (67%)				
	15.8					1 (25%)	2 (50%)	1 (25%)			
	17.6							1 (25%)	1 (25%)	2 (50%)	

This table shows the number and percentage of burns produced at 1.0 sec. exposure time in swine with the specified radiant exposure on khaki poplin in contact with and spaced 2 and 5 mm. from skin.

Table 8

Test Material	Radiant Exposure (cal/cm ²)	No Burn	1+			2+			3+		
			Mild	Mod	Sev	Mild	Mod	Sev	Mild	Mod	Sev
Khaki, FR	5.5	1 (10%)	3 (30%)	3 (30%)							
	6.1	1 (9%)	1 (9%)	2 (18%)		4 (36%)	2 (18%)	1 (9%)			
	6.8		1 (11%)	3 (33%)		1 (11%)		4 (45%)			
	7.6					2 (20%)	1 (10%)	5 (50%)	1 (10%)	1 (10%)	
	8.4							1 (10%)	4 (40%)	4 (40%)	1 (10%)
Khaki, FR Spaced 2 mm.	6.1	7 (78%)	1 (11%)				1 (11%)				
	6.8	4 (40%)		3 (30%)		1 (10%)		1 (10%)	1 (10%)		
	7.6	1 (10%)		1 (10%)	1 (10%)	2 (20%)	4 (40%)	1 (10%)	2 (20%)	1 (10%)	
	8.4			1 (10%)		2 (20%)	2 (20%)	2 (20%)	3 (30%)	3 (30%)	1 (10%)
	9.3						2 (20%)	1 (10%)			1 (10%)
Khaki, FR Spaced 5 mm.	7.6		2 (33%)	4 (67%)							
	8.4		1 (12%)	2 (25%)	1 (12%)	4 (50%)					
	9.3		1 (10%)	1 (10%)	1 (10%)	5 (50%)	2 (20%)				
	10.4			1 (10%)	1 (10%)	4 (40%)	3 (30%)		1 (10%)		
	11.5					3 (38%)	3 (38%)	2 (25%)			
	12.8						2 (50%)	1 (25%)			1 (25%)
	14.2								2 (100%)		

This table shows the number and percentage of burns produced at 1.0 sec. exposure time in swine with the specified radiant exposure on F. R. khaki poplin, in contact with, and spaced 2 or 5 mm. from skin.

Table 9

Test Material	Radiant Exposure (cal/cm ²)	No Burn	1+			2+			3+	
			Mild	Mod	Sev	Mild	Mod	Sev	Mild	Mod
Khaki Poplin and Under- wear Spaced 2 mm.	9.3	1 (17%)	2 (33%)	2 (33%)		1 (17%)				
	10.4	1 (20%)	1 (20%)	1 (20%)		2 (40%)				
	11.5			3 (30%)	1 (10%)	4 (40%)	2 (20%)			
	12.8			1 (10%)	1 (10%)	5 (50%)	1 (10%)	1 (10%)		1 (10%)
	14.2		1 (10%)	1 (10%)	2 (20%)	4 (40%)	2 (20%)			
	15.8			1 (25%)		3 (75%)				
	17.6		1 (25%)			2 (50%)	1 (25%)			
Khaki Poplin and Under- wear Spaced 5 mm.	14.2	5 (50%)	4 (40%)				1 (10%)			
	15.8	3 (30%)	7 (70%)							
	17.6		8 (80%)	2 (20%)						
	19.5		1 (10%)	1 (10%)	1 (10%)	4 (40%)	3 (30%)			
	21.7			1 (10%)		3 (30%)	2 (20%)	4 (40%)		

This table shows the number and percentage of burns produced in swine at 1.0 sec. exposure time with the specified radiant exposures on khaki poplin spaced 2 and 5 mm. from underwear material which is in contact with skin.

Table 10

Test Material	Radiant Exposure (cal/cm ²)	No Burn	1+			2+			3+	
			Mild	Mod	Sev	Mild	Mod	Sev	Mild	Mod
Khaki, FR and Under-wear Spaced 2 mm.	9.3		5 (50%)	1 (10%)	3 (30%)					
	10.4		4 (40%)	2 (20%)		3 (30%)	1 (10%)			
	11.5		1 (10%)	3 (30%)			2 (20%)	4 (40%)		
	12.8			3 (30%)	1 (10%)	2 (20%)	3 (30%)		1 (10%)	
	14.2		1 (11%)		1 (11%)	2 (22%)	1 (11%)	2 (22%)	1 (11%)	1 (11%)
	15.8								1 (100%)	
Khaki, FR and Under-wear Spaced 5 mm.	14.2	1 (100%)								
	15.8	3 (33%)	4 (45%)	1 (11%)	1 (11%)					
	17.6		3 (30%)	5 (50%)	1 (10%)	1 (10%)				
	19.5		5 (50%)	2 (20%)		2 (20%)	1 (10%)			
	21.7		1 (10%)	3 (30%)	2 (20%)	2 (20%)	2 (20%)			
	24.1					3 (30%)	6 (60%)	1 (10%)		

This table shows the number and percentage of burns produced in swine at 1.0 sec. exposure time with the specified radiant exposures on F. R. khaki poplin spaced 2 or 5 mm. from under-wear material which is in contact with skin.

Table 11

Test Material	Median Effective Exposure (cal/cm ²)	95% Confidence Interval	Median Effective Dose (cal/cm ²)	95% Confidence Interval	"Incidence" of Flaming or Flaring (%)
Bare Skin	4.0	3.7 - 4.3	*2.4	2.2 - 2.6	0
Underwear in Contact	9.4	8.5 - 10.4	3.5	3.1 - 3.8	0
Green, Spaced 2 mm	6.9	6.5 - 7.4	5.5	5.2 - 5.9	58%
Green, Spaced 5 mm	10.0	9.3 - 10.8	8.0	7.4 - 8.6	98%
Green, FR, Spaced 2 mm	6.3	5.9 - 6.7	4.8	4.5 - 5.1	2%
Green, FR, Spaced 5 mm	6.6	5.1 - 8.6	5.0	3.9 - 6.5	20%
Green and Underwear Spaced 2 mm	8.9	6.5 - 12.1	7.1	5.2 - 9.7	84%
Green and Underwear Spaced 5 mm	18.5	17.6 - 19.5	14.8	14.1 - 15.6	100%
Green, FR, and Underwear Spaced 2 mm	10.4	9.0 - 12.1	7.9	6.8 - 9.2	2%
Green, FR, and Underwear Spaced 5 mm	19.5	17.6 - 21.4	14.8	13.4 - 16.2	98%

* Bare skin reflectance = 0.40

This table shows the fabrics studied, the median effective exposures and median effective doses with their 95% confidence intervals for 2+ burns in swine at 1.0 sec. exposure time, and the "incidence" of flaming or flaring.

Table 12

Test Material	Median Effective Exposure (cal/cm ²)	95% Confidence Interval	Median Effective Dose (cal/cm ²)	95% Confidence Interval	"Incidence" of Flaming or Flaring (%)
Bare Skin	3.8	3.4 - 4.2	*2.3	2.0 - 2.5	0
White Underwear in Contact	9.8	9.1 - 10.6	3.6	3.4 - 3.9	0
Khaki Poplin in Contact	6.2	5.3 - 7.2	4.0	3.5 - 4.7	0
Khaki Poplin Spaced 2 mm	8.4	7.9 - 8.9	5.5	5.1 - 5.8	62%
Khaki Poplin Spaced 5 mm	10.5	9.4 - 11.8	6.8	6.1 - 7.7	92%
Khaki Poplin, FR in Contact	6.2	5.7 - 6.8	4.0	3.7 - 4.4	0
Khaki Poplin, FR Spaced 2 mm	7.2	6.6 - 7.8	4.7	4.3 - 5.0	4%
Khaki Poplin, FR Spaced 5 mm	8.4	7.5 - 9.4	5.5	4.9 - 6.1	6%
Khaki Poplin and Underwear Spaced 2 mm	11.5	9.9 - 13.3	7.5	6.4 - 8.7	100%
Khaki Poplin and Underwear Spaced 5 mm	17.5	14.0 - 21.9	11.4	9.1 - 14.2	100%
Khaki Poplin, FR and Underwear Spaced 2 mm	11.5	10.9 - 12.1	7.5	7.1 - 7.9	4%
Khaki Poplin, FR and Underwear Spaced 5 mm	23.0	20.7 - 25.6	14.9	13.5 - 16.6	76%

* Bare skin reflectance = 0.40

This table shows the number and percentage of burns produced at 1.0 sec. exposure time in swine with the specified radiant dose and test material.

Table 13

Exposure Time (sec)	Radiant Exposure (cal/cm ²)	No Burn	1+			2+		
			Mild	Mod	Sev	Mild	Mod	Sev
1.0	3.26		1 (11%)	7 (78%)	1 (11%)			
	3.62		1 (11%)	4 (44%)	2 (22%)	2 (22%)		
	4.02			6 (60%)	2 (20%)	2 (20%)		
	4.47			2 (20%)	3 (30%)	4 (40%)	1 (10%)	
	4.97						3 (30%)	7 (70%)
2.0	3.46		7 (70%)	2 (20%)	1 (10%)			
	3.84		2 (20%)	8 (80%)				
	4.28		2 (22%)	5 (56%)	2 (22%)			
	4.74			1 (10%)	3 (30%)	5 (50%)	1 (10%)	
	5.28				1 (10%)	6 (60%)	2 (20%)	1 (10%)
5.0	4.14		8 (80%)	2 (20%)				
	4.6	1 (10%)	3 (30%)	4 (40%)	2 (20%)			
	5.1			3 (30%)	4 (40%)	3 (30%)		
	5.7			2 (20%)	5 (50%)	3 (30%)		
	6.3			1 (10%)	4 (40%)	4 (40%)		1 (10%)

This table shows the number and percentage of burns produced on bare skin of swine at the specified exposure time and radiant exposure.

Table 14

Exposure Time (sec)	Radiant Exposure (cal/cm ²)	No Burn	1+			2+			3+	
			Mild	Mod	Sev	Mild	Mod	Sev	Mild	Mod
1.0	10.38	1 (10%)		1 (10%)	1 (10%)	4 (40%)	1 (10%)	3 (30%)	1 (11%)	
	11.53			2 (20%)	2 (20%)	1 (10%)	4 (40%)	1 (10%)		
	12.82			1 (10%)		5 (50%)	3 (30%)	1 (10%)		
	14.24			1 (11%)	3 (33%)	2 (22%)	2 (22%)			
	15.82				2 (20%)	4 (40%)	1 (10%)	2 (20%)		
2.0	8.04	2 (20%)	4 (40%)	1 (10%)		2 (20%)	1 (10%)		1 (10%) 1 (10%)	2 (20%)
	8.94	1 (10%)		2 (20%)	1 (10%)	2 (20%)	2 (20%)	2 (20%)		
	9.94			1 (10%)	1 (10%)	1 (10%)	4 (40%)	2 (20%)		
	11.04					5 (50%)	4 (40%)			
	12.26			1 (10%)		1 (10%)	1 (10%)	5 (50%)		
5.0	8.65	5 (50%)	4 (40%)	1 (10%)					3 (30%)	3 (30%)
	9.60	1 (10%)	4 (40%)	3 (30%)		1 (10%)		1 (10%)		
	10.70		2 (20%)	1 (10%)	4 (40%)	1 (10%)	2 (20%)			
	11.35			1 (10%)		3 (30%)	3 (30%)	3 (30%)		
	13.20						3 (30%)	1 (10%)		

This table shows the number and percentage of burns produced in swine at the specified exposure time and radiant dose with the 5.4 oz. green poplin and 3.2 oz. underwear combination separated by 2 mm.

Table 15

Exposure Time (sec)	Radiant Exposure (cal/cm ²)	No Burn	1+			2+			3+		
			Mild	Mod	Sev	Mild	Mod	Sev	Mild	Mod	Sev
1.0	15.82	2 (20%)	7 (70%)		1 (10%)						
	17.58		4 (40%)	3 (30%)		1 (10%)	2 (20%)				
	19.53		1 (10%)	1 (10%)		4 (40%)	4 (40%)				
	21.70					2 (20%)	3 (30%)	4 (40%)			
	24.12					1 (10%)	3 (30%)	3 (30%)	2 (20%)	1 (10%)	1 (10%)
2.0	13.62	2 (20%)	4 (40%)	1 (10%)	1 (10%)	2 (20%)					
	15.14		3 (30%)	4 (40%)		1 (10%)	2 (20%)				
	16.82		2 (20%)	1 (10%)		5 (50%)	2 (20%)				
	18.68			1 (11%)	1 (11%)	5 (56%)	1 (11%)	1 (11%)			
	20.76			1 (11%)			4 (45%)	2 (22%)	2 (22%)		
5.0	11.35	3 (30%)	5 (50%)	1 (10%)	1 (10%)						
	13.20		3 (30%)	2 (20%)	1 (10%)	4 (40%)					
	14.65		2 (20%)	2 (20%)	1 (10%)	4 (40%)	1 (10%)				
	16.30		1 (10%)			2 (20%)	5 (50%)	1 (10%)		1 (10%)	
	18.10					2 (20%)		6 (60%)		1 (10%)	1 (10%)

This table shows the number and percentage of burns produced in swine at the specified exposure time and radiant dose with the 5.4 oz. green poplin and 3.2 oz. underwear combination separated by 5 mm.

Table 16

Exposure Time (sec)	Radiant Exposure (cal/cm ²)	No Burn	1+			2+			3+		
			Mild	Mod	Sev	Mild	Mod	Sev	Mild	Mod	Sev
1.0	6.81		2 (50%)	2 (50%)							
	7.57		3 (50%)	2 (33%)	1 (10%)						
	8.41		1 (10%)	5 (50%)		2 (20%)	1 (10%)	1 (10%)			
	9.34		1 (10%)	1 (10%)		4 (40%)	3 (30%)	1 (10%)			
	10.38				1 (10%)	8 (80%)		1 (10%)			
	11.53				2 (33%)	2 (33%)		2 (33%)			
	12.82					2 (50%)	1 (25%)	1 (25%)			
2.0	8.04		2 (20%)	2 (20%)	3 (30%)	1 (10%)	2 (20%)				
	8.94		1 (10%)	3 (30%)		3 (30%)	2 (20%)	1 (10%)			
	9.94		1 (10%)	1 (10%)		2 (20%)	3 (30%)	2 (20%)	1 (10%)		
	11.04		1 (10%)		1 (10%)	1 (10%)	2 (20%)	2 (20%)	2 (20%)	1 (10%)	
	12.26						2 (20%)		1 (10%)	7 (70%)	
5.0	8.65	1 (10%)	7 (70%)	1 (10%)		1 (10%)					
	9.60					5 (50%)	3 (30%)	2 (20%)			
	10.70					2 (20%)	3 (30%)		3 (30%)	2 (20%)	
	11.35						1 (10%)	1 (10%)	2 (20%)	4 (40%)	2 (20%)
	13.20								6 (60%)	6 (60%)	4 (40%)

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This table shows the number and percentage of burns produced in swine at the specified exposure time and radiant exposure with the 6.6 oz. green, F. R. treated poplin and 3.2 oz. underwear material combination separated by 2 mm.

Table 17

Exposure Time (sec)	Radiant Exposure (cal/cm ²)	No Burn	1+			2+			3+			
			Mild	Mod	Sev	Mild	Mod	Sev	Mild	Mod		
1.0	15.82		3 (50%)	2 (33%)	3 (30%)	4 (40%)	1 (16%)	1 (10%) 2 (20%) 4 (40%)	1 (10%)	1 (10%) 2 (25%)		
	17.58			2 (20%)			1 (10%)					
	19.53			2 (20%)			4 (40%)					
	21.70			2 (20%)			1 (10%)					
	24.12			2 (20%)	3 (30%)	2 (20%)	4 (40%)					
	26.79						1 (25%)				1 (25%)	
2.0	15.62		2 (20%) 2 (20%)	6 (60%)	2 (20%) 1 (10%) 1 (9%) 1 (9%)	2 (20%) 2 (20%) 5 (50%) 4 (35%) 1 (9%)	2 (20%) 3 (27%) 5 (45%)	1 (9%) 3 (27%)		1 (9%) 1 (9%)		
	15.14			4 (40%)								
	16.82			2 (20%)								
	18.68			1 (9%)								
	20.76			1 (10%)	2 (20%)	3 (30%)	1 (10%)	1 (10%)			1 (10%)	
5.0	11.35	1 (10%)	2 (20%) 1 (10%)	1 (10%)	2 (20%)	4 (40%)	4 (40%)	1 (10%) 3 (30%) 3 (30%)	1 (10%) 1 (10%) 1 (10%)	1 (10%) 2 (20%)		
	13.20			1 (10%)								
	14.65			2 (20%)								
	16.30	1 (10%)		1 (10%)								
	18.10					1 (10%)	2 (20%)	1 (10%)	3 (30%)		3 (30%)	

This table shows the number and percentage of burns produced in swine at the specified exposure time and radiant dose with the 6.6 oz. green, fire retardant treated poplin and 3.2 oz. underwear combination separated by 5 mm.

Table 18

Test Material	Exposure Time (sec)	Median Effective Exposure	95% Confidence Interval	Median Effective Dose	95% Confidence Interval	"Incidence" of Flaming or Flaring (%)
Bare Skin	1.0	4.5	4.1 - 4.9	2.7	2.5 - 2.9	-
	2.0	4.7	4.4 - 5.1	2.8	2.6 - 3.1	-
	5.0	6.3	5.6 - 7.1	3.8	3.3 - 4.3	-
Green plus Underwear Spaced 2 mm	1.0	8.2	6.8 - 9.7	6.6	5.4 - 7.8	96
	2.0	8.8	8.1 - 9.5	7.0	6.5 - 7.6	70
	5.0	10.6	10.0 - 11.2	8.5	8.0 - 9.0	6
Green plus Underwear Spaced 5mm	1.0	18.2	17.3 - 19.1	14.5	13.8 - 15.3	96
	2.0	16.0	14.9 - 17.4	12.8	11.9 - 13.9	90
	5.0	14.7	14.1 - 15.2	11.7	11.3 - 12.2	74
Green, FR plus Underwear Spaced 2 mm	1.0	8.9	8.2 - 9.7	6.8	6.2 - 7.4	10
	2.0	8.9	8.4 - 9.4	6.8	6.4 - 7.1	10
	5.0	11.0	10.5 - 11.6	8.4	8.0 - 8.8	0
Green, FR plus Underwear Spaced 5 mm	1.0	19.5	12.2 - 31.2	14.8	9.3 - 23.7	94
	2.0	16.6	15.4 - 17.9	12.6	11.7 - 13.6	46
	5.0	12.4	11.2 - 13.8	9.4	8.5 - 10.5	2

This table shows the fabric combination studied, the median effective exposures and doses with their 95% confidence intervals for 2+ burns in swine at 1.0 sec. exposure time and the "incidence" of flaming or flaring.

FIG. 1

THE EFFECT OF VARYING SEPARATION AND COMBINING CLOTHS OF GREEN, UNTREATED AND FIRE RETARDANT-TREATED, POPLIN AND UNDERWEAR ON THE EE₅₀ OF 2+ BURNS IN SWINE AT 1.0 SEC. EXPOSURE TIME

THE EFFECT OF VARYING SEPARATION AND COMBINING CLOTHS OF KHAKI UNTREATED AND FIRE RETARDANT-TREATED, POPLIN AND UNDERWEAR ON THE EE_{50} OF 2+ BURNS IN SWINE AT 1.0 SEC. EXPOSURE TIME

FIG. 3

FIG. 4

THE EFFECT OF VARYING SEPARATION AND COMBINING CLOTHS OF UNTREATED AND FIRE RETARDANT-TREATED, KHAKI AND GREEN POPLIN AND UNDERWEAR ON THE EE_{50} OF 2+ BURNS IN SWINE AT 1.0 SECOND EXPOSURE TIME (EXPERIMENTS 1 AND 2)