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STUDIES ON FLASH BURNS:

FURTHER REPORT ON THE PROTECTIVE QUALITIES OF FABRICS, AS EXPRESSED BY A PROTECTIVE INDEX

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George Mixter, Jr., M. D.*

ABSTRACT

Exposure-response data are presented which define the protection against thermal energy afforded to the skin of Chester White pigs by certain one-and-two layer fabric combinations. A dimensionless number, called the protective index, is proposed as a quantitative measure of this protection. It is defined as the ratio between the 2-plus median effective exposure under fabric and the 2-plus median effective exposure for bare skin at the same exposure time:

$$\text{P. I.} = \frac{2+\ EE_{50}\ \text{sub-fabric}}{2+\ EE_{50}\ \text{of bare skin}}$$

For the systems studied this ratio varies from 1.38 to 11.1.

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

INTRODUCTION

A previous report by the author (1) presented data on the protective qualities of certain fabric combinations against radiant thermal energy, using anesthetized Chester White pigs as the experimental animal. This paper presents the results of similar experiments on eight additional fabric assemblies, (table 1), each one being studied at a single exposure time of 0.5 to 2.0 sec. The irradiances used were selected to center about the level of the minimal 2+ burn, as previously defined by this laboratory (2). This burn is characterized by a barely detectable, spotty whiteness or pearly opalescence. Transepidermal necrosis is usually complete, but dermal-epidermal separation is incomplete on microscopic examination.

METHODS

The source of controlled radiant thermal energy used was the modified 24" carbon arc as previously described by Davis, Krolak and Blakney (3). Chester White pigs of about 20 lbs. weight were anesthetized with Dial-urethane, 70 mgm/Kg intraperitoneally, closely clipped, washed and dried. Replications of the various exposures were objectively randomized over the 21 to 36 available positions on the pigs' sides, as well as from side to side and from pig to pig. Each system required 70 to 155 exposures; a total of 828 burns were assessed in the study of the eight protective systems. The lesions were assessed at 24 hours post-burn, and biopsies of many were taken at this time. The appearance of the microscopic sections in general resembled that seen in previous studies and is not reported in this paper.

The median or 50% effective exposure for the 2+ burn (2+ EE_{50}) was calculated by the approximate probit method of Litchfield & Wilcoxon (4), which also yields the 95% confidence limits. At this setting of time and irradiance, half the exposures will give a 2+ burn or more, and half will be less than 2+.

RESULTS

The results are summarized in the form of exposure-response tables (tables 2 - 9). The same data may be represented graphically as in Figs. 1 and 2.

For practical purposes, it is desirable to reduce the data to a simple numerical value for each combination. Table 10 presents the 2+ EE_{50}'s of each ensemble, together with the other pertinent data, from which are calculated the protective indices.

The 2+ EE_{50} of pig's skin has been investigated over a wide range of exposure times (5). Thus, the mean effective exposure beneath fabric may be related to the expected behavior of unprotected skin at that same exposure time. The ratio between these two mean effective exposures (beneath fabric vs unprotected skin) at any given exposure time has been called the protective index. Symbolically it may be defined as:

$$P.I. = \left[\frac{2+\ EE_{50}\ \text{sub-fabric}}{2+\ EE_{50}\ \text{skin}} \right]_{t_3}$$

Expressed in this fashion, the experiments show that the degree of protection afforded by these one- and two - layer systems varies markedly in response to flameproofing and to separation of the fabric from the skin. In contact with skin, both flame-resistant systems provided significantly less protection than their untreated analogues; whereas when separated from skin, the flame-resistant systems in both instances gave significantly more protection than the untreated.

FIG. 1

I LAYER 9 OZ. SATEEN

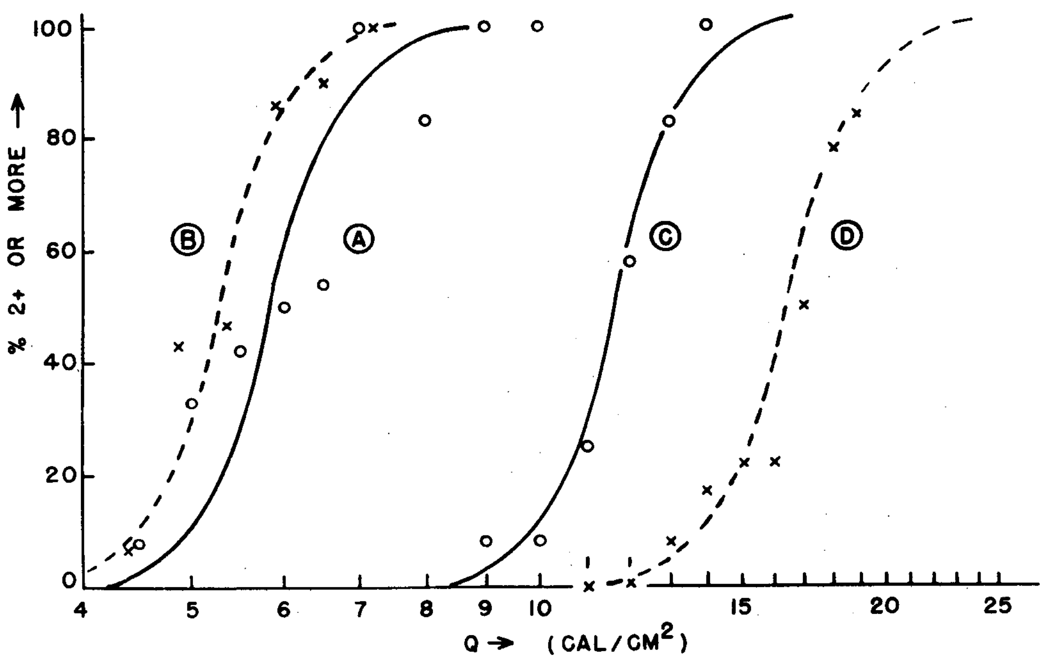
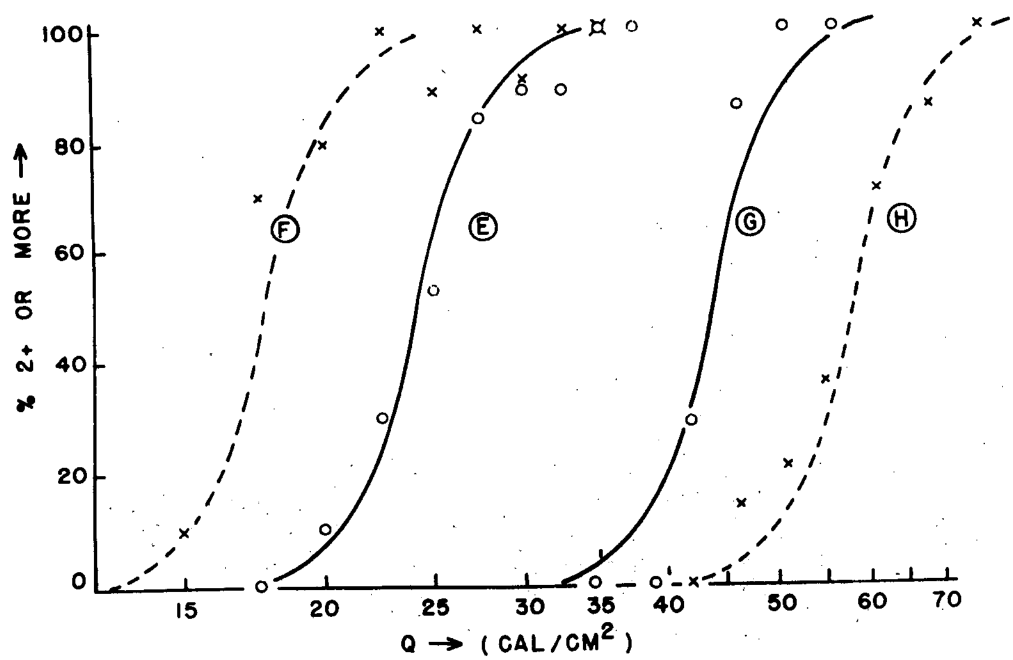


FIG. 2

"HW" 50/50"



Exposure-response data of Tables 2 - 9, plotting percent 2+ response against exposure in cal/cm^2. Solid lines, untreated fabric; dotted lines, fire-resistant treated fabric.

Although under intense irradiance the fire-resistant fabrics will give off an incandescent flare, they do not support any exothermic reaction after the exposure is completed. The same is true of the untreated fabrics in this series and in others (6), when they are in contact with skin. The flame-resistant cottons produce, and deposit on the skin, large amounts of tarry substances, whether or not an inner layer is present. In marked con-contrast to the untreated one-and-two layer systems composed purely of cotton when separated from skin, the assembly designated as G (light cotton oxford plus 50% cotton-wool, 5 mm separated from skin) failed in every instance to support post-exposure flame or flow. The "underwear" layer of this assembly charred to a bubbly surface on the exposed side, and gave off a thick smoke which failed to ignite.

DISCUSSION

In the comparative study of the thermally protective qualities of fabric assemblies, the concept of the protective index has certain marked advantages over other methods of expression.

On such a scale, where parity is 1.0, a ratio of less than unity denotes that the skin under such a system will sustain a more severe burn than if the skin were exposed without covering. Where values in excess of unity are found, the protective index affords a quantitative statement of the degree or extent of this protection, taking into account the exposure time employed.

In the case of the fabrics studied, it is clear that although all combinations gave <u>some</u> degree of protection, certain ones afforded vastly more than others. It is quickly evident that the introduction of a 5 mm air space between fabric and skin approximately doubles the amount of protection. It is equally apparent that the addition of a fire-resistant resin to the outer layer decreases protection in contact and increases it when the system is separated from the skin.

The explanations for these facts are for the most part obvious. 5 mm of air space greatly reduces the efficiency of thermal transfer between fabric and skin. The decrease of protection with fire-proofing of the outer layer (when fabric system in contact with skin) appears to result from the large amounts of tarry and watery vapors condensed on the skin when the resin-treated cotton undergoes destructive distillation.

On the other hand, the enhancement of protection afforded by fire-proofing the outer layer of the fabrics when separated from skin is not so simple. It is evident in the case of the single layer system that avoidance of post-exposure flaming is of prime importance, as has been observed in other studies (5, 6). In the case of the wool-cotton underwear, flame after exposure was absent or negligible even without resin treatment, and it seems probable that the heavy knit inner fabric acted as an effective baffle, condensing out tars and vapors from the degenerating outer layer.

The increase of protection in this instance appears to be related to several factors. The treated material is slightly lighter in color than the untreated, and presumably absorbs less energy. For a given area exposed, the treated material is approximately 25% heavier, and is by gross examination less porous. Finally, the char from the treated fabric is firm and partically opaque, thus serving as a barrier to incident radiant energy for a longer time than the untreated fabric, which has a loose and almost completely translucent ash.

It must be understood that these explanations are based upon the observed phenomena at the exposure times and irradiances studied. At short, high-irradiance exposures or at long, low-irradiance exposures, the type and degree of fabric participation may be expected to be altered, as has been shown in other studies (7). Consequently, one cannot expect that a protective index obtained for a certain exposure time may be widely extended to other exposure times.

This simplified numerical statement of protection, further, applies only to the 2+ EE_{50} level of burn, by definition, and cannot be assumed to apply to lesser or more severe degrees of damage. Finally, if the exposure-response data show marked divergence from "normal" distribution, it is not possible to make a valid statement of the 2+ EE_{50}, and the protective qualities of fabric cannot be stated in terms of protective index. For the systems studied, however, and within the stated limits, the protective index affords a useful, simple statement of comparative protection afforded.

SUMMARY AND CONCLUSIONS

1. The protective qualities of 8 fabric assemblies were studied using the carbon arc as thermal source and Chester White pigs as the indicators.

2. The introduction of air space between skin and fabric enhances the protective effect markedly.

3. Fire-proofing of the outer layer of fabric reduces protection slightly if the skin is in contact with it, but enhances protection when the fabric is separated.

4. The ratio $\frac{\text{50\% effective exposure through fabric}}{\text{50\% effective exposure on bare skin}}$ at any given exposure time is defined as the protective index of that system at that exposure time.

5. The protective index affords a convenient numerical statement of the protective qualities of fabric systems under radiant thermal energy.

BIBLIOGRAPHY

1. Mixter, G. Jr. and Pearse, H. E., Studies on Flash Burns: The Protection Afforded by 2, 4 and 6 Layer Fabric Combinations, Univ. of Roch. Atomic Energy Project Report, UR-261, (1953).

2. Perkins, J. B., Pearse, H. E. and Kingsley, H. D., Studies on Flash Burns: The Relation of the Time and Intensity of Applied Thermal Energy to the Severity of Burns, Univ. of Roch. Atomic Energy Project Report, UR-217, (1953).

3. Davis, T. P., Krolak, L. J. and Blakney, R. M., Studies of Flash Burns: The Carbon Arc Source, Univ. of Roch. Atomic Energy Project Report, UR-226, (1952).

4. Litchfield, J. T. Jr. and Wilcoxon, F., A Simplified Method of Evaluating Dose-Effect Experiments, J. Pharm. and Thera., 96:99, (1949).

5. Mixter, G. Jr., The Empirical Relation between Time and Intensity of Applied Thermal Energy in Production of 2+ Burns in Pigs, Univ. of Roch. Atomic Energy Project Report, UR-316, (1954).

6. To be published: Mixter, G. Jr., Thermal Protectivity of Fabric as a Function of its Reflectance.

7. Mixter, G. Jr. and Pearse, H. E., Studies on Flash Burns: The Influence of Exposure Time and Irradiance on the Thermal Protective Qualities of Two Fabric Assemblies, Univ. of Roch. Atomic Energy Project Report, UR-355, (1954).

Table 1

Fabric Systems Studied

Designation	Fabric		Separation from Skin (mm)	Exposure Time (sec)
	Inner	Outer		
A	None	9 oz. OG Sateen	0	0.5
B	"	FR* 9 oz. Sateen	0	0.5
C	"	9 oz. OG Sateen	2	0.5
D	"	FR* 9 oz. Sateen	2	0.5
E	50% Wool-cotton	5 oz. Green Oxford	0	1.0
F	"	FR* 5 oz. Green Oxford	0	1.0
G	"	5 oz. Green Oxford	5	2.0
H	"	FR* 5 oz. Green Oxford	5	2.0

Table 10

Summary of Date on Protective Qualities of Eight Fabric Systems

Fabric Assembly	Exposure Time (sec)	Bare Skin 2+ EE_{50} (cal/cm^2)	Sub-fabric 2+ EE_{50} (cal/cm^2)	95% Confidence Interval	Protective Index
A	0.5	3.8	5.8	5.5 - 6.1	1.53
B	0.5	3.8	5.25	5.0 - 5.5	1.38
C	0.5	3.8	11.5	10.9 - 12.2	3.0
D	0.5	3.8	16.4	15.7 - 17.1	4.3
E	1.0	4.45	24.7	23.4 - 26.1	5.5
F	1.0	4.45	17.7	16.4 - 19.4	4.0
G	2.0	5.2	44.0	42.0 - 46.0	8.5
H	2.0	5.2	58.0	54.0 - 62.0	11.1

*Treated with 25% add-on of a brominated phosphate resin.

Table 2

Summary: 1 Layer 9 oz. Sateen (Plain) Contact (A)

Time (sec)	H (cal/cm²/sec)	Q (cal/cm²)	0	1+		2+			3+	% 2+
				Mild	Sev	Mild	Mod	Sev		
0.5	9	4.5	5	5	1					8
	10	5.0	3	7	6	8				33
	11	5.5	8	2	4	6	3	1		42
	12	6.0	2	3	7	6	5	1		50
	13	6.5	2	4	5	6	6	1		54
	14	7.0				2	4	6		100
	16	8.0		1	0	1	2	6	2	83
	18	9.0				1	2	4	5	100
	20	10				1	1	2	8	100

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Table 3

Summary: Burn Response Beneath 1 Layer 9 oz. OG Sateen (FR), Contact with Skin (B)

Time (sec)	H ($cal/cm^2/sec$)	Q (cal/cm^2)	0	1+		2+			3+	% 2+ or more
				Mild	Sev	Mild	Mod	Sev		
0.5	8.8	4.4	1	9	3	1				7
	9.7	4.85		8	8	9	3			43
	10.7	5.35		2	13	8	4	1		47
	11.8	5.9			4	10	7	7		86
	13.0	6.5			3	10	6	7	2	90
	14.3	7.15				1	3	7	3	100

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Table 4

Summary 1 Layer 9 oz. Sateen (Plain), 2 mm Separated (C)

Time (sec)	H (cal/cm²/sec)	Q (cal/cm²)	0	1+		2+			3+	% 2+
				Mild	Sev	Mild	Mod	Sev		
0.5	18	9	7	3	1	1				8
	20	10	6	4	1	1				8
	22	11	5	2	2	2	0	0	1	25
	24	12	2	2	1	1	1	3	2	58
	26	13	1	1	0	0	1	2	7	83
	28	14						5	7	100

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Table 5

Summary: 1 Layer 9 oz. Sateen (FR), 2 mm Separated (D)

Time (Sec)	H ($cal/cm^2/sec$)	Q (cal/cm^2)	0	1+		2+			3+	% 2+
				Mild	Sev	Mild	Mod	Sev		
0.5	22	11	3	3						0
	24	12	0	5	1					0
	26	13	3	4	4	1				8
	28	14	0	8	2	2				17
	30	15	1	8	5	2	2			22
	32	16	0	4	10	1	3			22
	34	17	0	0	9	6	2	1		50
	36	18	0	1	3	6	7	1		78
	37.5	18.8	0	0	1	2	3			84

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Table 6

Summary: Burn Response, Chester White Pigs Beneath H-W 50/50 Contact (E)

Time (sec)	H (cal/cm^2/sec)	Q (cal/cm^2)	0	1+		2+			3+	% 2+
				Mild	Sev	Mild	Mod	Sev		
1.0	17.5	17.5	3	7						0
	20	20	1	5	3	1				10
	22.5	22.5		4	3	3				30
	25	25		1	8	5	5			53
	27.5	27.5			3	9	5	2		84
	30	30			1	5	3			89
	32.5	32.5			1	2	4	2		89
	35	35				2	3	4		100
	37.5	37.5					1	7	1	100

Table 7

Summary: Burn Response, Chester White Pigs Beneath H-W (FR) 50/50 Contact (F)

Time (sec)	H (cal/cm²/sec)	Q (cal/cm²)	0	1+		2+			3+	% 2+
				Mild	Sev	Mild	Mod	Sev		
1.0	15	15		2	7	1				10
	17.5	17.5			3	5	2			70
	20	20			2	6	2			80
	22.5	22.5				1	7	1		100
	25	25			2	7	7	3		89
	27.5					2	4	3		100
	30	30			1	1	4	2	1	90
	32.5	32.5				1	4	4		100
	35	35					1	7	1	100
	37.5	37.5				2	2	3	2	100

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Table 8

Summary: Burn Response Beneath H-W 50/50, 5 mm Separation (G)

Time (sec)	H (cal/cm^2/sec)	Q (cal/cm^2)	0	1+		2+			3+	% 2+ or more
				Mild	Sev	Mild	Mod	Sev		
2.0	15.7	31.4	4	3						0
	17.3	34.6	2	4	1					0
	19	38		9	5					0
	21	42		5	5	4				29
	23.2	46.4			2	8	3	1		86
	25.4	50.8				1	5	1		100
	28	56					1	6		100

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Table 9

Summary: Burn Response Beneath H-W (FR) 50/50, 5 mm Separation (H)

Time (sec)	H (cal/cm^2/sec)	Q (cal/cm^2)	0	1+		2+			3+	% 2+ or more
				Mild	Sev	Mild	Mod	Sev		
2.0	21	42		1	6					0
	23.2	46.4		1	5	1				14
	25.4	50.8	1	4	6	2	1			21
	28	56		1	8	4	1			36
	31	62			4	6	3	1		71
	34	68			1	2	3	1		86
	37.5	75				1	6			100

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