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STUDIES ON LARGE AREA SUB-FABRIC BURNS:
THE EFFECT OF AN AIR SPACE BETWEEN A TWO LAYER SYSTEM

by

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STUDIES ON LARGE AREA SUB-FABRIC BURNS:
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ABSTRACT

It is well known that protection against radiant energy burns afforded by fabrics may be increased by creating an air space between the fabric and the underlying skin. Earlier work in this laboratory has also shown that if one layer of fabric is in contact with skin, protection of a two layer fabric system increases progressively as the space between the fabrics changes from two to five millimeters. With the magnesium source, large area sub-fabric burns were produced to determine the effects of still greater air spaces between the two layers.

With underwear material in contact with the skin of white pigs, green poplin material was placed either in contact with or at distances of from one to four centimeters from the underwear. Magnesium flash powder, in 150 gm. charges, was exploded at a distance of 20 cm. from the animals. It was found that combinations of fabric and spacing which resulted in the underwear's remaining intact resulted in the greatest protection. In general, fire-retardant treated material was superior to untreated material, and increasing the air space between the two layers decreased severity of the resulting burns.

INTRODUCTION

Observations that clothing will reduce the severity of cutaneous radiant energy burns were first made in Japan (1) following the atomic bomb explosions in Hiroshima and Nagasaki. Subsequently this effect has been studied in the field and in this and other laboratories (2,3,4,5,6,7,8,9,10,11). The effect is modified by the fabric's weight, reflectance, and composition (7,11). It is influenced by air spacing and by multiple layers (2,10).

Two thermal sources have been available in this laboratory for these investigations (12, 13): 1) A 24" carbon arc searchlight and 2) a magnesium flash powder source. With the first source small area burns can be produced; with the latter, large area burns.

Studies of the influence of an air space between two fabric layers, one of which was in contact with skin, on the production of small area burns showed that as the space between the fabrics increased from two to five mm. the amount of protection increased (3). This effect deserves further investigation. Since an air space greater than 5 mm. moves the fabric-skin system out of the focal plane of the reflecting mirror of the carbon arc source, these studies were done with the magnesium source.

Since it has also been shown that under certain conditions impregnating the material with a fire-retardant substance may either increase or decrease protection (3, 5) afforded by the fabric, fire-retardant treated material was also studied.

METHODS

Physical:

150 gms. of magnesium flash powder with an exposure time of 0.7 sec. were exploded 20 cm. from the side of the animal; this provided approximately 20 cal/cm². The method of firing has been described by Roth et al. (13).

The skin was exposed through a 3-3/4" port in a shielded animal container. A movable frame 10" x 10" supported the outer layer of fabric. The following figure depicts the arrangement used (Figure 1).

The fabrics tested were green poplin (Shade 116) weighing 5.4 oz./sq.yd., designated GR; the same fabric treated with fire-retardant material L-S123P weighing 6.6 oz./sq.yd., designated GR,FR; and 3.2 oz./sq.yd. white underwear material. These were supplied by the Quartermaster Research and Engineering Command. The underwear was placed in contact with the skin and was held by the walls of the animal container so that it was snug but not stretched. The poplin fabrics were placed in the movable frame except when they were in contact with the underwear, when they were held in a similar manner as the underwear. Both fabrics were studied in contact with the underwear and 1, 2, 3, and 4 cm. from the animal. The cloth was left in place until all burning had ceased.

Statistical Design

The untreated and treated fabrics were studied in 5 and 3 positions respectively from the animal. In addition, a control burn on bare skin was made. These nine treatments were systematically randomized so that any one might fall on any of 9 positions, on the right side and 4 on the left, of one of the six pigs used.

After the above experiment was done, it was found desirable to study the treated fabric at three and four cm. from the animal. The two treatments of each plus a bare skin burn were randomized so that any one could fall on any site on the side of the animal. Again there were 5 positions on the right side and 4 on the left.

FIGURE 1

Fig. 1. The experimental method using burning magnesium powder as the thermal source. The pig is shielded except for a 3-3/4" diameter port. Beneath this the skin is covered snugly by underwear. A movable 10" x 10" frame holds the outer layer of green poplin. The space between underwear and poplin was increased from 0 to 4 cm. by moving this frame. The pig - magnesium tray distance was kept constant at 20 cm. which gives an exposure of 20 cal/cm².

Evaluation

The burns were evaluated 24 hours after their production by the following criteria (14):

- 0 - No burn
- 1+ - Erythema
- 2+ - Patchy whiteness
- 3+ - Uniform whiteness
- 4+ - Steam bleb

The percentage of the exposed area of any grade of burns was estimated in increments of 25%.

The most severe area of the burn was biopsied and fixed in formalin at the time of evaluation of the surface appearance. The sections were stained by the standard hematoxylin and eosin method and by the modified Verhoeff's method of Hinshaw (15).

Criteria for damage as determined by microscopic examination have been described previously (16). The depth of damage in the dermis was measured with the aid of a micrometer scale in the ocular of the microscope.

Analysis of the Data

An arbitrary scoring system described previously was used (4). This system considers only the most severe burns.

Grade	Percentage	Score
1+	25	1
	50	2
	75	3
	100	4
2+	25	5
	50	6
	75	7
	100	8
3+	25	9
	50	10
	75	11
	100	12
4+	100	16

A scoring system considering only the depth of damage was used in evaluating the histological sections: complete epidermal damage was scored 1; 0-0.1 mm. of dermal damage was scored 2; 0.1-0.2, 3; 0.2-0.3, 4; etc.

RESULTS

Observations of the Behavior of the Fabric

In both experiments the outer layer of fabric was always destroyed during the exposure. The inner layer of fabric at times showed charring and at other times remained intact. Appendix 4 gives the frequency of this occurrence.

Evaluation

The results of the experimental design are listed together in Appendices 1 and 2. Although from a statistical standpoint, this is not valid, it is felt that the results obtained are independent of the biological behavior of the two sets of animals.

Appendices 1, 2, 3, 4 and 5 and Figures 2 and 3 show the results. At 20 cal/cm² the untreated fabric caused a linear decrease in burn severity as the separation increased up to 3 cm. At 4 cm. burn severity rose. At the same time, the frequency with which the underwear charred decreased up to 3 cm. and then sharply increased.

At the same energy level, the treated fabric caused a progressive decrease in burn severity throughout the range of separation studied. The frequency with which the underwear charred decreased also.

DISCUSSION

The amount of protection afforded by an increasing amount of separation of the outer fabric appears definitely related to the effect of the

FIGURE 2

THE EFFECT OF SEPARATION OF GREEN POPLIN FROM SKIN COVERED BY UNDERWEAR MATERIAL ON SEVERITY OF CUTANEOUS PORCINE BURNS (SURFACE APPEARANCE) AND FREQUENCY OF CHARRING OF UNDERWEAR MATERIAL PRODUCED BY 20 cal/cm². (EXPERIMENT 1)

FIGURE 3

THE EFFECT OF SEPARATION OF GREEN POPLIN FROM SKIN COVERED BY UNDERWEAR MATERIAL ON SEVERITY OF CUTANEOUS PORCINE BURNS (DEPTH OF DAMAGE) AND FREQUENCY OF CHARRING OF UNDERWEAR MATERIAL PRODUCED BY 20 cal/cm². (EXPERIMENT 1)

exposure on the underwear material. If the underwear remains intact, burn severity is decreased.

It was expected on the basis of previous investigations (2) that with increasing separation a reduction of burn severity would be observed. However, at 20 cal/cm² exposures, less protection was given by the untreated fabric with 4 cm. separation than with 3 cm. separation. This finding could be explained on the basis of flaming or on the lack of persistence of the outer fabric after the exposure. In these experiments the fabric was moved toward the source as well as away from the skin, so that at 4 cm. of separation the cloth is only 16 cm. from the source; it is, therefore, the recipient of a larger radiant exposure. This might well result in a shorter persistence time and consequently more severe burn. The above feature of this experiment is objectionable but cannot be avoided if the magnesium source is used.

SUMMARY AND CONCLUSIONS

1. A series of large area sub-fabric burns were produced by exploding 150 gm. of magnesium flash powder at a distance of 20 cm. from the animal. Underwear material was placed in contact with the skin, the green poplin fabric, untreated and treated with a fire retardant substance, was interposed at different distances from the skin. The behavior of the fabric was noted. The burns produced were evaluated by surface appearance and microscopic examination.
2. More protection was given by the fire-retardant treated material than by the untreated material.
3. It was observed that with increasing separation burn severity decreased.
4. Two maximum points of protection were found: one at 3 cm. separation with untreated fabric and the other at 2 cm. of separation with the treated fabric. At these points the frequency with which the underwear material remained intact was greatest.
5. The amount of protection is dependent, in a yet unpredictable fashion, upon the type of fabric, the distance of the fabric from the skin, and the amount of energy received by the outer layer of fabric.
6. It is felt that in a two layer system the persistence time of the outer layer of fabric will be a significant factor in the mechanism of protection.

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Appendix 1

Fabric	Space cm	Grade (Surface Appearance)					Score
		0	1+	2+	3+	4+	
GR	0				100%		12
	0			25%	75%		11
	0			50%	50%		10
	0				100%		12
	0				100%		12
	0				100%		12
						Total	<u>69</u>
GR	1			100%			8
	1			25%	75%		11
	1		25%	25%	50%		10
	1		25%		75%		11
	1			75%	25%		9
	1		50%		50%		10
						Total	<u>59</u>
GR	2				100%		12
	2			50%	50%		10
	2		25%	75%			7
	2			75%	25%		9
	2			50%	50%		10
	2		50%		50%		10
						Total	<u>58</u>
GR	3	50%	25%	25%			5
	3	75%		25%			5
	3			100%			8
	3			50%	50%		10
	3		25%	50%	25%		9
	3	50%	50%				2
						Total	<u>39</u>
GR	4				100%		12
	4			25%	75%		11
	4				100%		12
	4			75%	25%		9
	4			50%	50%		10
	4	25%	50%	25%			5
						Total	<u>59</u>

This table shows the grade and percent of total area burned resulting from exploding 150 gms. of magnesium powder at a distance of 20 cm. from the pig with the green poplin fabric interposed at the specified distance and underwear in contact with the skin.

Appendix 2

Fabric	Space cm	Grade (Surface Appearance)					Score
		0	1+	2+	3+	4+	
GR,FR	0				100%		12
	0			25%	75%		11
	0		25%		75%		11
	0				100%		12
	0				100%		12
	0			100%			8
						Total	66
GR,FR	1	25%	75%				3
	1	100%					0
	1		25%	50%	25%		9
	1	25%			75%		11
	1			100%			8
	1		25%	75%			7
						Total	38
GR,FR	2	100%					0
	2	100%					0
	2	50%	50%				2
	2	50%	25%	25%			5
	2	25%		75%			7
	2	50%	25%	25%			5
						Total	19
GR,FR	3	100%					0
	3	50%	25%	25%			5
	3	50%	25%	25%			5
	3	100%					0
	3	100%					0
	3	100%					0
						Total	10
GR,FR	4	100%					0
	4	100%					0
	4	100%					0
	4	50%		50%			6
	4	50%	50%				2
	4	100%					0
						Total	8

This table shows the grade and percent of total area burned resulting from exploding 150 gms. of magnesium powder at a distance of 20 cm. from the pig with the fire-retardant treated green poplin fabric interposed at the specified distance and underwear in contact with the skin.

Appendix 3

Fabric	Space (cm)				
	0	1	2	3	4
GR	69	59	58	39	59
GR, FR	66	38	19	10	8
BARE SKIN	6 burns of 4+ severity scored 16, total 96				

This table shows the total score for the burns produced by the magnesium source at a distance of 20 cm. under the specified conditions and graded by surface appearance.

Appendix 4

Fabric	Space (cm)	Underwear	
		% Char	% Intact
GR	0	84	16
	1	67	33
	2	0	100
	3	0	100
	4	50	50
GR,FR	0	84	16
	1	50	50
	2	33	67
	3	33	67
	4	0	100

This table shows the behavior of the underwear material under the specified conditions produced with the magnesium source at 20 cm. distance.

Appendix 5

Fabric	Space cm.	No Burn	Depth of Damage								Score
			Complete Epidermal	Dermal (mm.)							
				0-0.1	0.1-0.2	0.2-0.3	0.3-0.4	0.4-0.5	0.5-0.6	0.6-0.7	
GR	0				1	4	1				40
	1		1		2	1	1			1	24
	2		1		4	1					17
	3		1	2	2	1					15
	4			1	4				1		22
GR,FR	0		1		3	2					16
	1	1	1	1	2		1				16
	2	3	1		2						7
	3	4		2							4
	4	3	1	2							5
Bare Skin									2	4	46

This table shows the results of microscopic examination of the burns produced by the magnesium source at a distance of 20 cm. from the animal with one layer of fabric interposed at the specified distance, the other layer of underwear in contact with the skin.