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SOME EFFECTS OF THICKNESS OF THE LAYER IN
PROTECTION AGAINST FLASH BURNS BY CREAMS

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ABSTRACT

The protection provided against radiant thermal energy flashes by $1/32$, $2/32$, and $3/32$ inch layers of Dow-Corning Silicone Stopcock Grease and of a "protective flash burn cream" were compared. The thicker layers of cream offer more protection than do the thinner ones. Thickness is of greater benefit with the cream which absorbs more of the incident energy (the "protective flash burn cream"). With the Silicone grease, protection is not linearly related to thickness.

INTRODUCTION

In modern warfare the soldier may frequently be exposed to brief flashes of high irradiances of radiant thermal energy. Past experience has shown that the uncovered areas of the body, especially the hands and face, are most frequently injured by this hazard, and that injuries of these parts are often incapacitating. For this reason, considerable effort has been expended to develop a cream which, when applied to the exposed skin, would offer protection against flash burns.

Fauley and Ivy (1) under the auspices of the Naval Medical Research Laboratory developed a cream which was subsequently procured for Government issue. This cream, applied in a 1/16 inch layer, was reported to offer a high degree of protection. Interest in this laboratory in the severity of damage to skin after altering reflectance led to testing the Government issue flash cream. However, because of the difficulty in applying this cream in a uniform 1/16 inch layer it was applied in a more realistic smear much as one would expect the soldier to do in the field. In reporting these results, Bales, Hinshaw, Pearse, and Basso (2) stated that not only is this Government issue cream a hazard because it ignites and burns but, in the thickness they employed (considerably less than 1/16 inch), it increased the depth of damage two fold when compared with similar exposures of bare skin.

This contradiction of Fauley and Ivy's work naturally raised the question of the effect of thickness of a cream layer in offering protection against "flash burns." To get some additional information, this experiment was designed. The 50% effective exposures necessary to produce 2+ burns (spotty white surface coagulation) under varied thicknesses of Silicone

grease which does not flame, melt or react during exposure were determined. The protective effects of thick layers of the Government issue cream were also studied.

MATERIALS AND METHODS

Young Chester White pigs, anesthetized with 60 mgm/Kgm of Dial with Urethane (Ciba) intraperitoneally, were the experimental animals. Their hair was closely clipped; the skin was sponged with water and a liquid detergent. The ambient temperature in the burning room was controlled to minimize variations in skin temperature of the anesthetized animals (3).

The radiant thermal energy source was a modified 24 inch army carbon arc searchlight (4, 5). A 4.5 cm circular exposure port was substituted for the usual 1.8 cm port to prevent disturbance of the disc of cream when positioning the pig. Each exposure was carefully centered so that maximal irradiance fell on the center of the cream disc.

The two "creams" investigated were Government issue Protective Flash Burn Cream (51-C-1690), which shall be referred to as G. I. cream, and Dow-Corning Silicone Stopcock Grease. The G. I. cream is a pasty, gray, opaque cream, the composition of which has been listed by Fauley and Ivy (1). Dow-Corning Silicone Stopcock Grease (Silicone cream) is a gray, translucent substance. It was chosen because it has not been purported to protect skin against radiant thermal energy, because it can be spread in a uniform layer with relative ease, and because it does not melt, flame or lose its shape when exposed to high temperatures.

The creams were applied in varying thicknesses with the aid of 1.5 inch square metal templates with 0.5 inch central circular ports. The size of the templates and their central ports were small to minimize variations in thickness of the layers of cream due to curvature of the pig's side. Despite this, the curvature of the pig and the sticky consistency of the G. I. cream made it impossible to obtain uniformly thick layers of this cream. Nevertheless, accuracy sufficient for the purposes of this experiment was achieved. With the aid of three different templates the Silicone cream was applied in thicknesses of approximately $1/32$, $2/32$, and $3/32$ inch while the G. I. cream was only applied with the $1/32$ and $2/32$ inch templates.

All thicknesses of both creams and a bare skin control were exposed to four or five irradiances separated by 10% increments for one second. The 24 treatments were randomly assigned exposure sites on a pig's side and 16 replications of the treatment block were carried out.

The burns were assessed by surface appearance 18 - 24 hours after exposure by the criteria established in this laboratory (6):

- 0 - No burn
- 1+ - Erythema
- 2+ - Patchy whiteness or loosened
epidermal-dermal attachment
- 3+ - Uniform whiteness
- 4+ - Steam blebs
- 5+ - Carbonization

These data were analyzed by the graphic probit method of Litchfield and Wilcoxon (7) to obtain an expression of the median effective radiant exposure for 2+ burns ($2+ EE_{50}$) for the Silicone grease in all three thicknesses and for bare skin. The data for the G. I. cream could not be analyzed in this way.

RESULTS

The experimental data are listed in the dose-response table (Appendix I) according to type of cream and thickness. Whenever possible an expression of the $2+ EE_{50}$ has been determined by graphic probit analysis. These values and their 95% confidence limits are listed in Table 1. The protective index (P. I.), a convenient expression obtained by dividing the $2+ EE_{50}$ for the cream by that of bare skin is also given in Table 1.

$$P. I. = \frac{2+ EE_{50} \text{ (cream)}}{2+ EE_{50} \text{ (bare skin)}}$$

The $2+ EE_{50}$ of 4.0 cal/cm^2 for one second bare skin burns agrees with previous studies.

With a one second exposure we were rarely able to produce a 2+ burn beneath the 1/32 and the 2/32 inch layers of G. I. cream with the irradiances permitted by the carbon arc. Since the maximal one second exposure of our arc source is 33 cal/cm^2 , this would indicate a protective index greater than eight for both thicknesses of G. I. cream. This was true even though the cream ignited and sustained a flame at its surface for several seconds after the exposure.

The Silicone cream offers much less protection, its protective index ranging from 1.5 at 1/32 inch thickness to 2.4 at 3/32 inch thickness.

Table 1

MEDIAN EFFECTIVE RADIANT EXPOSURES FOR 2+ BURNS
FOR EACH CREAM, EACH THICKNESS, AND BARE SKIN

Cream and Thickness	2+ Median Effective Exposure (cal/cm ²)	95% Confidence Limits	Protective Index
Bare Skin	4.0	3.7 - 4.3	
Silicone 1/32	6.1	5.7 - 6.6	1.5
Silicone 2/32	6.8	6.0 - 7.6	1.7
Silicone 3/32	9.5	8.9 -10.1	2.4
G. I. 1/32	> 33.0		> 8.0
G. I. 2/32	> 33.0		> 8.0

In addition it should be pointed out that the relationship between the protective indices and the thicknesses of Silicone cream is not a linear one.

DISCUSSION

The three points of interest gained from this data are: 1) that the G. I. cream in a thick layer offers a high degree of protection, whereas it was found, in previous work (2), to be a hazard in the thin smear; 2) that the Silicone cream does not protect as well as G. I. cream; and 3) that protectivity of Silicone cream was not found to be linearly related to thickness of the cream layer.

Bales, Hinshaw, Pearse and Basso (2) found twice the depth of damage beneath a thin smear of G. I. cream as that produced by the same exposure on bare skin. The protective index was only 0.56 with the 0.3 second and the 3.0 second exposures. Reflectance and transmittance studies have not been done on the thicker layers of G. I. cream, but there should be little difference from the values found by Bales et al. (2), (reflectance 0.22 and transmittance 0.02). Therefore, the explanation of the differences in the burns under a smear and under a thick layer of G. I. cream most likely lies in the fate of the absorbed energy. In the thin smear, the absorbed energy heats the entire layer of cream, and this heat is delivered directly to the skin by conduction. However, in the thicker layer the surface of the cream becomes heated from the exposure and the skin is insulated by the deep portion of the cream with a consequent significant degree of protection. The surface of the G. I. cream is modified by radiant energy whether or not the cream flames. This, too, probably dissipates some of the energy.

The fate of the incident energy on bare skin, on the thin smear of G. I. cream, and on the thick layer of G. I. cream is schematically shown in Figures 1, 2, and 3.

The transmittance of the Silicone cream, which is translucent, is obviously much greater than that of the G. I. cream, and its reflectance after application to the pig's skin is probably greater than that of the G. I. cream. If this is so, the fraction of energy absorbed at the surface of the Silicone cream must be smaller than that absorbed by the G. I. cream. For this reason, the Silicone cream can not act as an insulator to the extent that the G. I. cream does, and thickness is consequently a less important factor in the Silicone cream's ability to protect. This is schematically presented in Figure 4. The heat conductances of the Silicone and G. I. creams are unknown. Therefore, the differences in protection observed beneath thick layers of these two creams could be the result of an unusually high conductance through Silicone cream. This seems less likely than the explanation presented above.

In consideration of the observation that thickness of Silicone cream layers is not directly related to protectivity it should be pointed out that there seemed to be an inconsistent error in application of the specified thickness of this cream, the $1/32$ inch layer tending to be too thin and the $3/32$ inch layer to be too thick.

It is pointed out again that the protection afforded by thick layers of the Government issue Protective Flash Burn Cream is of theoretical interest only since the thicknesses employed here could be applied only with great difficulty even with the use of small templates. It is obvious

Figure 1

Proposed Schematic Representation Of The Distribution
Of Incident Radiant Energy
On Bare White Skin

Figure 2

Proposed Schematic Representation Of The Distribution
Of Incident Radiant Energy
On A Smear Of G. I. Cream

Figure 3

Proposed Schematic Representation Of The Distribution
Of Incident Radiant Energy On A Thick Layer
Of G. I. Cream

Figure 4

Proposed Schematic Representation
Of The Distribution Of Incident Energy
On A Thick Layer Of Silicone Cream

that a really good protective cream must have at least one of these two properties: 1) thin layers do not increase the damage from exposure to radiant energy, or 2) it can be applied only in thick layers which do not later peel, crack or lose their substance.

SUMMARY AND CONCLUSIONS

1. The 50% effective exposures necessary to produce 2+ burns ($2+ EE_{50}$) beneath 1/32, 2/32, and 3/32 inch layers of a Silicone grease were determined. These were compared with the $2+ EE_{50}$ of bare skin and with the protection offered by a "protective flash burn cream" in 1/32 and 2/32 inch thicknesses, all at one second exposure times.
2. The "protective flash burn cream" offers a high degree of protection in the thicknesses studied here, whereas in previous work it was found to be hazardous in thin smears.
3. Protection afforded by thick layers of the "protective flash burn cream" is of only theoretical interest since the uniform thicknesses employed in this study were applied with considerable difficulty even with the use of a template.
4. The "protective flash burn cream" offers much greater protection than does the Silicone grease when the two are applied in thick layers.
5. The thickness of a layer of a cream used for protection against flash burns is of great importance when a considerable portion of the incident energy is absorbed by that cream.
6. Protectivity of Silicone grease is not related directly to the thickness of the layer. However, some inconsistent errors in applying accurate thicknesses of this cream were present.

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APPENDIX I

DOSE-RESPONSE BY SURFACE GRADING FOR BARE AND CREAM COVERED PIG SKIN

Cream and Thickness	Radiant Exposure (cal/cm ²)	Surface Severity of Burn							Total Number of Burns
		0	1+		2+			3+	
			Mild	Sev	Mild	Mod	Sev		
Bare Skin	3.26		10	6					16
	3.62		5	6	5				16
	4.02			8	8				16
	4.47		1	4	8	2	1		16
Silicone 1/32	4.97	4	7	1	2				14
	5.52	3	4	3	5	1			16
	6.13	1	3	5	4	2	1		16
	6.81			4	7	2	3		16
Silicone 2/32	6.81	2	3	2	8	1			16
	7.57	2	1	4	3	5	1		16
	8.41			5	8		1		14
	9.34		1	1	2	6	1	2	13
Silicone 3/32	8.41	1	3	2		2			8
	9.34	1	3	2	8	1	1		16
	10.38	1	1	1	2	2	9		16
	11.53	1		1	3	4	5		14
	12.82			1			5	2	8