UR-490

THE EFFECT OF AIR SPACE ON SUB-FABRIC BURNS IN SWINE

by

K. M. Berkley

THE UNIVERSITY OF ROCHESTER
ATOMIC ENERGY PROJECT
ROCHESTER, NEW YORK

LEGAL NOTICE

This report was prepared as an account of Government sponsored work. Neither the United States, nor the Commission, nor any person acting on behalf of the Commission:

- A. Makes any warranty or representation, express, or implied, with respect to the accuracy, completeness, or usefulness of the information contained in this report, or that the use of any information, apparatus, method, or process disclosed in this report may not infringe privately owned rights; or
- B. Assumes any liabilities with respect to the use of, or for damages resulting from the use of any information, apparatus, method, or process disclosed in this report.

As used in the above, "person acting on behalf of the Commission" includes any employee or contractor of the Commission to the extent that such employee or contractor prepares, handles or distributes, or provides access to, any information pursuant to his employment or contract with the Commission.

**Price 35 cents. Available from the Office of
Technical Services, Department of Commerce,
Washington 25, D. C.**

DISCLAIMER

This report was prepared as an account of work sponsored by an agency of the United States Government. Neither the United States Government nor any agency Thereof, nor any of their employees, makes any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness, or usefulness of any information, apparatus, product, or process disclosed, or represents that its use would not infringe privately owned rights. Reference herein to any specific commercial product, process, or service by trade name, trademark, manufacturer, or otherwise does not necessarily constitute or imply its endorsement, recommendation, or favoring by the United States Government or any agency thereof. The views and opinions of authors expressed herein do not necessarily state or reflect those of the United States Government or any agency thereof.

DISCLAIMER

Portions of this document may be illegible in electronic image products. Images are produced from the best available original document.

U N C L A S S I F I E D

0

UR-490

Health and Safety

THE UNIVERSITY OF ROCHESTER
Atomic Energy Project
P. O. Box 287, Station 3
Rochester 20, New York

* * *

Contract W-7401-eng-49 between the U. S. Atomic
Energy Commission and the University of Rochester,
administered by the Department of Radiation Biology
of the School of Medicine and Dentistry.

THE EFFECT OF AIR SPACE ON SUB-FABRIC BURNS IN SWINE

by

K. M. Berkley

Division: Special Programs

Division Head: H. A. Blair

Section: Flash Burns

Section Head: J. R. Hinshaw

Date Completed: 5/3/57

Date of Issue: 6/14/57

U N C L A S S I F I E D

THE EFFECT OF AIR SPACE ON SUB-FABRIC BURNS IN SWINE

By

K. M. Berkley

ABSTRACT

The effect of separating white cotton sheeting from pig skin by an air space on the radiant exposures (cal/cm^2) necessary to produce superficial radiant energy burns, judged by gross and microscopic appearance, was studied in 1200 burns at exposure times of 0.5, 1.0, 2.0, and 5.0 seconds.

It was found that the radiant exposure increases linearly by the amount of separation measured in millimeters, and that this relationship is not dependent on the exposure time used.

INTRODUCTION

After the atomic bombing at Hiroshima, it was noted that fabrics alter the degree of burns produced by radiation. Generally, burns were more severe in exposed than in clothed areas. It was observed, 1) that light colored clothing gave more protection than dark, 2) that protection was increased by thick layers, and 3) that when burns did occur under clothing, they tended to involve regions where clothes were drawn tightly over the skin (2).

The first laboratory studies of the protective effect of clothing on flash burns were made possible by modifying a Corps of Engineers carbon arc searchlight. Morton, Kingsley and Pearse (10) tested a variety of fabrics, singly and together, in contact with the skin. They found that all fabrics gave some protection and that the light colored fabrics were more protective than darker ones. Other investigators (7, 8) in this laboratory studied quantitative effects on protectivity of reflectance, transmittance, fabric weight and exposure time in a series of experiments of several thousand burns. They concluded, 1) that absorbed or transmitted energy, rather than incident energy, determines injury (the factor of reflectance), 2) that with certain exceptions fabric weight has a linear effect upon protectivity, 3) that separation of 9 oz. sateen fabric from skin by 5 mm. enhances protection by two to four times, depending on the reflectance of the fabric. Mixer and Pearse (9) who studied two layer systems separated by 5 mm. from skin, noted significant protection despite flaming of the fabric and observed that when flaming occurred, more severe burns were produced.

Since air spacing was observed clinically at Hiroshima and Nagasaki and experimentally in this laboratory to be an effective mechanism of protection from thermal radiation burns, it was decided to study its effect quantitatively. Experiments were designed to test the hypothesis that as fabric was separated from pig skin by an air space, 50% effective exposures increase by some constant (k) times the amount of separation and that this relationship is not dependent on exposure time.

METHODS

Equipment

A 24 inch carbon arc searchlight, modified as described by Davis et al. (1) was the source of the radiant energy. The fabric studied was white cotton sheeting weighing 3.2 oz/yd² with total reflectance of 0.51 and total transmittance of 0.36 as measured in this laboratory (5) when used with carbon arc source with air backing. With the fabric in contact with pig skin the total reflectance was unchanged.

The cloth was kept at a relative humidity of 65% for at least 24 hours before burning. Polished aluminum rings spaced the cloth 2 mm., 5 mm., and 10 mm. from the animal.

Biological

Chester White and Yorkshire pigs weighing 8.9 to 15.8 Kg. were anesthetized with Dial in urea-urethane (Ciba) by the intraperitoneal route in doses of 60-70 mgm/Kg. of body weight. The hair was closely clipped and the skin was gently sponged prior to burning. Thirty burns were produced on each side of the animal.

Experimental Design

Experiment 1 was designed to determine the 50% effective exposure necessary to produce 2+ burns in skin when it is bare, covered by cloth in contact with it, or covered by cloth separated 2 mm. from it. Experiment 2 was designed to determine the 50% effective exposures with cloth separated 2 mm., 5 mm., and 10 mm. from skin. With five irradiances, four exposure times of 0.5, 1.0, 2.0, and 5.0 sec., and the three variables mentioned above, 60 combinations were formed in each experiment. The combinations were randomized so that any combination had an equal probability of falling on any area of the animal. Ten replications each were made.

Evaluation

The lesions were read and 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

The burns were also biopsied at this time. Sections were stained by Hinshaw's modification of Verhoef's method (4). The criteria of damage are the same as previously reported (3, 11), partial epidermal, complete epidermal, and dermal damage, measured in millimeters.

Analysis of Data

The 50% effective exposure and 0.95 confidence intervals were estimated by the method of Litchfield and Wilcoxon (6). The 50% effective exposure is the lowest radiant exposure in cal/cm² which will produce at least the given grade of burn 50% of the time. The 0.95 confidence interval defines the limits of radiant exposures which 95% of the time will cover the 50% effective exposure, if the same experiment is repeatedly done.

RESULTS

Experiment 1

Tables 1, 2, and 3 show the numbers and percentages of burns produced when the skin is bare, covered with cloth in contact with it, or covered with cloth separated 2 mm. from it as evaluated by surface appearance.

Tables 5, 6, and 7 show the numbers and percentages of these same burns as evaluated by depth of damage.

Table 4 shows the 50% effective exposures and 95% confidence intervals for 2+ burns:

Table 4

Time (sec)	Bare Skin	Contact	2 mm. Space
0.5	3.2 (3.0 - 3.4)	8.9 (8.3 - 9.8)	8.8 (8.3 - 9.4)
1.0	4.0 (3.8 - 4.2)	8.4 (7.9 - 9.0)	10.5 (9.7 - 11.4)
2.0	4.5 (3.9 - 5.2)	7.9 (6.8 - 9.2)	10.6 (9.6 - 11.8)
5.0	5.1 (4.7 - 5.5)	10.7 (9.8 - 11.8)	12.6 (11.8 - 13.5)

6

Table 1

Time (sec)	Radiant Exposure (cal/cm ²)	1+			2+			3+
		Mild	Mod	Sev	Mild	Mod	Sev	Mild
0.5	2.3	5 (50%)	5 (50%)					
	2.5	4 (40%)	6 (60%)					
	2.8	1 (10%)	8 (80%)		1 (10%)			
	3.1	1 (10%)	6 (60%)		3 (30%)			
	3.4	1 (10%)	1 (10%)		7 (70%)	1 (10%)		
1.0	3.3	3 (30%)	4 (40%)	3 (30%)	1 (10%)			
	3.6	1 (10%)	6 (60%)	2 (20%)	6 (56%)			
	4.0		4 (36%)	1 (9%)	6 (60%)			
	4.5	1 (10%)	2 (20%)			1 (10%)		
	5.0		1 (17%)			3 (50%)	1 (17%)	1 (17%)
2.0	3.5	5 (50%)	4 (40%)		1 (10%)			
	3.8	1 (10%)	7 (70%)	1 (10%)	1 (10%)			
	4.3		4 (40%)	3 (30%)	3 (30%)			
	4.7			3 (30%)	7 (70%)			
	5.3				6 (60%)	3 (30%)		1 (10%)
5.0	4.1		7 (70%)	1 (10%)	2 (20%)			
	4.6		7 (70%)	1 (10%)	2 (20%)			
	5.1	1 (10%)	3 (30%)		6 (60%)			
	5.7			3 (30%)	6 (60%)	1 (10%)		
	6.3				8 (80%)	1 (10%)	1 (10%)	

This table shows the numbers and percentages of burns evaluated by surface appearance produced on bare skin of swine. Experiment 1.

7
Table 2

Time (sec)	Radiant Exposure (cal/cm ²)	1+			2+			3+	
		Mild	Mod	Sev	Mild	Mod	Sev	Mild	Mod
0.5	7.9		5 (45%)		3 (27%)	3 (27%)			
	8.8		3 (33%)		3 (33%)	3 (33%)			
	9.8		1 (10%)		7 (70%)	2 (20%)			
	10.9				2 (20%)	5 (50%)	2 (20%)		1 (10%)
	12.1		1 (10%)		1 (10%)	1 (10%)	4 (40%)	1 (10%)	2 (20%)
1.0	7.6	1 (16%)	4 (67%)			1 (16%)			
	8.4	1 (16%)			5 (83%)				
	9.3		4 (40%)		5 (50%)	1 (10%)			
	10.4				6 (60%)	2 (20%)	1 (10%)	1 (10%)	
	11.5				1 (10%)	3 (30%)	2 (20%)	4 (40%)	
2.0	7.2	3 (50%)	3 (50%)						
	8.0	2 (33%)	2 (33%)	1 (16%)	1 (16%)				
	8.9		2 (33%)		3 (50%)	1 (16%)			
	9.9		1 (10%)	1 (10%)	3 (30%)	4 (40%)	1 (10%)		
	11.0				5 (55%)	1 (11%)	3 (33%)		
5.0	9.6	2 (20%)	4 (40%)	1 (10%)	3 (30%)				
	10.7		1 (10%)	4 (40%)	5 (50%)				
	11.7		1 (10%)	1 (10%)	7 (70%)	1 (10%)			
	13.2				5 (50%)	3 (30%)	2 (20%)		
	14.7			1 (10%)	1 (10%)	2 (20%)	6 (60%)		

This table shows the numbers and percentages of burns evaluated by surface appearance produced with cloth in contact with skin of swine. Experiment 1.

Table 3

Time (sec)	Radiant Exposure (cal/cm ²)	1+			2+			3+		
		Mild	Mod	Sev	Mild	Mod	Sev	Mild	Mod	Sev
0.5	7.1	4 (40%)	5 (50%)		1 (10%)					
	7.9	1 (10%)	8 (80%)	1 (10%)						
	8.8	1 (10%)	4 (40%)		5 (50%)					
	9.8		1 (10%)		8 (80%)			1 (10%)		
	10.9		2 (20%)		5 (50%)	3 (30%)				
1.0	9.3		7 (70%)	2 (20%)	1 (10%)					
	10.4		2 (20%)		7 (70%)	1 (10%)				
	11.5				3 (30%)	6 (60%)	1 (10%)			
	12.8		1 (10%)		4 (40%)	4 (40%)	1 (10%)			
	14.2				1 (10%)	3 (30%)	3 (30%)	2 (20%)	1 (10%)	
2.0	9.9		2 (33%)	2 (33%)	2 (33%)					
	11.0		2 (33%)		4 (67%)					
	12.3				4 (67%)	2 (33%)				
	13.6				3 (50%)	2 (33%)	1 (16%)			
	15.1					4 (67%)		2 (33%)		
5.0	11.4		4 (44%)	2 (22%)	3 (33%)					
	13.2		3 (30%)	2 (20%)	4 (40%)	1 (10%)				
	14.7			1 (11%)	4 (44%)	2 (22%)	1 (11%)	1 (11%)		
	16.3				2 (20%)	1 (10%)	5 (50%)	1 (10%)	1 (10%)	
	18.1					2 (18%)	5 (45%)	2 (18%)	1 (9%)	1 (9%)

This table shows the numbers and percentages of burns evaluated by surface appearance produced with cloth separated 2 mm. from skin. Experiment 1.

Table 5

Exposure Time (sec)	Radiant Exposure (cal/cm ²)	Partial Epidermal	Complete Epidermal	Dermal Damage (Depth in Millimeters)	
				0 - .15	.15 - .30
0.5	2.2	4 (40%)	6 (60%)		
	2.5	2 (20%)	8 (80%)		
	2.8	1 (9%)	9 (75%)	2 (17%)	
	3.1		8 (89%)	1 (11%)	
	3.4		3 (43%)	4 (57%)	
1.0	3.3	2 (22%)	7 (78%)	1 (11%)	
	3.6	1 (11%)	7 (78%)	2 (20%)	1 (10%)
	4.0		7 (70%)	4 (44%)	
	4.5		5 (56%)	2 (33%)	3 (50%)
	5.0		1 (17%)		
2.0	3.5	4 (40%)	6 (60%)		
	3.8	2 (22%)	7 (78%)		
	4.3	1 (10%)	8 (80%)	1 (10%)	
	4.7		3 (30%)	7 (70%)	
	5.3		3 (30%)	5 (50%)	2 (20%)
5.0	4.1	4 (40%)	6 (60%)		
	4.6	2 (20%)	8 (80%)		
	5.1	1 (10%)	8 (80%)	1 (10%)	
	5.7		7 (70%)	3 (30%)	
	6.3		3 (30%)	7 (70%)	

This table shows the numbers and percentages of burns evaluated by depth of damage produced on bare skin. Experiment 1.

Table 6

Exposure Time (sec)	Radiant Exposure (cal/cm ²)	Partial Epidermal	Complete Epidermal	Dermal Damage (Depth in Millimeters)		
				0 - .15	.15 - .30	.30 - .45
0.5	7.6		5 (45%)	5 (46%)	1 (9%)	
	8.8		3 (33%)	6 (67%)		
	9.8			11 (100%)		
	10.9			8 (80%)	1 (10%)	1 (10%)
	12.1			3 (33%)	5 (56%)	1 (11%)
1.0	7.6		6 (100%)			
	8.4		4 (67%)	2 (33%)		
	9.3		3 (33%)	6 (67%)		
	10.4			8 (80%)	2 (20%)	
	11.5			2 (22%)	7 (78%)	
2.0	7.2	2 (33%)	4 (67%)			
	8.0		5 (83%)	1 (17%)		
	8.9		6 (100%)			
	9.9		5 (50%)	4 (40%)	1 (10%)	
	11.0			5 (83%)	1 (17%)	
5.0	9.6	1 (10%)	9 (90%)			
	10.7		9 (90%)	1 (10%)		
	11.9		8 (89%)	1 (11%)		
	13.2		3 (38%)	3 (38%)	2 (25%)	
	14.7			6 (67%)	4 (44%)	1 (11%)

This table shows the numbers and percentages of burns evaluated by depth of damage produced with cloth in contact with skin. Experiment 1.

//

Table 7

Exposure Time (sec)	Radiant Exposure (cal/cm ²)	Partial Epidermal	Complete Epidermal	Dermal Damage (Depth in Millimeters)			
				0 - .15	.15 - .30	.30 - .45	.45 - .75
0.5	7.1	1 (11%)	8 (89%)				
	7.9	1 (11%)	6 (67%)	2 (22%)			
	8.6		4 (44%)	4 (44%)	1 (11%)		
	9.8		4 (44%)	3 (33%)	1 (11%)	1 (11%)	
	10.9		2 (20%)	7 (70%)	1 (10%)		
1.0	9.3		9 (90%)	1 (10%)			
	10.4		4 (40%)	6 (60%)			
	11.5		3 (33%)	5 (56%)	1 (11%)		
	12.8			7 (70%)	3 (30%)		
	14.2			3 (30%)	4 (40%)	3 (30%)	
2.0	9.9		7 (100%)				
	11.0		4 (57%)	3 (43%)			
	12.3		3 (50%)	3 (50%)			
	13.6		2 (33%)	1 (17%)	3 (50%)		
	15.1				4 (67%)	2 (33%)	
5.0	11.9		9 (100%)				
	13.2		7 (64%)	3 (27%)	1 (9%)		
	14.6		3 (33%)	3 (33%)	3 (33%)		
	16.3			3 (30%)	5 (50%)	1 (10%)	1 (10%)
	18.1				6 (60%)	3 (30%)	1 (10%)

This table shows the numbers and percentages of burns evaluated by depth of damage produced with cloth separated 2 mm. from skin. Experiment 1.

At all exposure times studied the 50% effective exposures of 2+ burns in skin are twice as high when the skin is covered by cloth in contact as when it is bare; and, in turn, the 50% effective exposures necessary with white cloth separated 2 mm. from the skin are higher than those with the cloth in contact with skin.

At the 0.5 sec. exposure time the 50% effective exposure is the same whether the cloth is in contact or separated from the skin.

It was observed that less energy is required for 2+ burns, when skin is in contact with cloth than when it is bare, as the time of exposure increases from 0.5 to 2.0 sec. However, this difference is not significant at the 95% level of confidence. With this exception, as the exposure time increases more energy is required for 2+ burns produced in skin uncovered or covered with cloth in contact or separated 2 mm.

Table 8 shows the 50% effective exposures and 95% confidence intervals for dermal damage:

Table 8

Time (sec)	Bare Skin	Contact	2 mm. Space
0.5	3.3 (3.1 - 3.6)	7.1 (5.8 - 8.7)	9.2 (8.4 - 10.0)
1.0	4.4 (4.1 - 4.8)	8.8 (8.1 - 9.5)	10.5 (9.9 - 11.2)
2.0	4.8 (4.6 - 5.0)	10.0 (8.9 - 11.3)	11.9 (10.2 - 13.8)
5.0	6.0 (5.6 - 6.4)	12.9 (12.2 - 13.6)	13.9 (12.7 - 15.3)

Twice as much energy is required to produce superficial dermal damage in skin covered by white cloth in contact or separated by 2 mm. than in uncovered skin.

The 50% effective exposures for dermal damage are consistently greater when cloth is separated from the skin by 2 mm. than when skin is uncovered. However, one might argue that the confidence intervals overlap and that there is no significant difference in the 50% effective exposures required for cloth in contact or separated from skin, except at 1.0 sec. exposure time. But, since there is a consistent elevation, the introduction of a 2 mm. air space will undoubtedly effect an increase in the amount of energy necessary to produce dermal damage just as it did for 2+ burns.

The 50% effective exposures for dermal damage produced with cloth in contact increase progressively with increasing exposure time with overlap of confidence intervals at 0.5 and 1.0 sec. and at 1.0 and 2.0 sec. exposure times.

The decrease in 50% effective exposures for 2+ burns produced with cloth in contact from 0.5 to 2.0 sec. was discussed in the comments on Table 4. It was pointed out that the confidence intervals overlapped, and, therefore, no real significance could be attached to the decrease. The increase in 50% effective exposures for dermal damage is consistent with that observed with skin uncovered and covered by cloth spaced 2 mm., and with previously reported studies. Therefore these data suggest that the decrease noted for 2+ burns with cloth in contact is not of real significance.

Experiment 2

Tables 9, 10 and 11 show the numbers and percentages of burns produced with the use of 2 mm., 5 mm., and 10 mm. spacer rings respectively.

Tables 13, 14, and 15 show the numbers and percentages of these same burns evaluated by histological criteria.

The incidence of flaming rose as the amount of air space increased. The number of such phenomena observed is shown in brackets. Flaming did not significantly alter the severity of burn observed, even though the skin was in contact with the flame for 5 sec. at each exposure.

Table 12 shows the 50% effective dose and 95% confidence interval for 2+ burns:

Table 12

Time (sec)	2 mm. Space	5 mm. Space	10 mm. Space
0.5	8.8 (8.3 - 9.3)	13.7 (12.7 - 14.7)	
1.0	11.0 (10.2 - 11.9)	13.7 (12.1 - 15.5)	20.0 (18.8 - 21.2)
2.0	11.0 (10.2 - 11.9)	14.0 (11.9 - 16.5)	21.6 (19.1 - 24.4)
5.0	13.4 (12.3 - 14.6)	18.1 (16.6 - 19.7)	24.6 (22.7 - 26.8)

By increasing separation, the 50% effective exposures for 2+ burns are raised significantly at each exposure time studied. Changing the air space from 2 mm. to 10 mm. produces a two fold increase in energy requirements at 1.0, 2.0 and 5.0 sec. exposure times.

As has been frequently observed (9), increasing the exposure time resulted in raising the 50% effective exposures required for 2+ burns in bare skin.

15

Table 9

Time (sec)	Radiant Exposure (cal/cm ²)	No Burn	1+			2+			3+		
			Mild	Mod	Sev	Mild	Mod	Sev	Mild	Mod	Sev
0.5	7.1	1 (10%)	5 (50%)	3 (30%)	1 (10%)					1 (10%)	
	7.9		5 (50%)	4 (40%)							
	8.8		3 (30%)	1 (10%)	1 (10%)	4 (40%)	1 (10%)				
	9.8			2 (20%)		6 (60%)	2 (20%)				
	10.9					8 (80%)	2 (20%)				
1.0	9.3		3 (30%)	5 (50%)		2 (20%)					
	10.4			7 (70%)		3 (30%)					
	11.5		1 (9%)	1 (9%)		8 (73%)	1 (9%)				
	12.8		1 (10%)	1 (10%)		3 (30%)	3 (30%)	2 (20%)			
	14.2			1 (10%)		2 (20%)	4 (40%)	3 (30%)			
2.0	9.9	2 (20%)	2 (20%)	1 (10%)	2 (20%)	2 (20%)	1 (10%)				
	11.0	1 (11%)	1 (11%)	1 (11%)	1 (11%)	4 (44%)	1 (11%)				
	12.3			3 (30%)		6 (60%)	1 (10%)				
	13.6					5 (56%)	3 (33%)	1 (11%)			
	15.1					2 (18%)	7 (64%)	2 (18%)			
5.0	11.9			5 (50%)	4 (40%)	1 (10%)					
	13.2		1 (10%)	1 (10%)	3 (30%)	1 (10%)	2 (20%)			1 (10%)	1 (10%)
	14.7			3 (30%)	1 (10%)	3 (30%)	3 (30%)				
	16.3				2 (18%)	5 (45%)	2 (18%)	2 (18%)			
	18.1						1 (10%)	3 (30%)	2 (20%)	4 (40%)	

This table shows the numbers and percentages of burns evaluated by surface appearance produced with cloth separated 2 mm. Experiment 2.

Table 10

Time (sec)	Radiant Exposure (cal/cm ²)	No Burn	1+			2+			3+		
			Mild	Mod	Sev	Mild	Mod	Sev	Mild	Mod	Sev
0.5	10.9	2 (20%)	6 (60%)	2 (20%)	1 (10%)	1 (10%)	5 (50%) 2 (20%)	3 (30%)	1 (10%)		
	12.1	1 (10%)	5 (50%)	2 (20%)							
	13.4	1 (10%)		3 (30%)							
	14.9	1 (10%)	1 (10%)	1 (10%)							
	16.5										
1.0	12.8	1 (10%)	2 (20%)	4 (40%)	1 (10%)	3 (30%)	2 (20%) 4 (40%) 3 (30%) [1]	1 (10%) 1 (10%) 3 (30%)	1 (10%)		
	14.2		3 (30%)	1 (10%)		6 (60%)					
	15.8			1 (10%)		6 (60%)					
	17.6					5 (50%)					
	19.5					2 (20%)					
2.0	15.1		2 (20%)	1 (10%)	1 (10%)	5 (50%)	1 (10%) 3 (30%) 3 (30%) 4 (40%) 3 (30%)	1 (10%) 2 (20%) 2 (20%)	1 (10%) 1 (10%)	1 (10%) 1 (10%) [1]	1 (10%)
	16.8		1 (10%)	1 (10%)		4 (40%)					
	18.7			1 (10%)		6 (60%)					
	20.8			1 (10%)		1 (10%)					
	23.1					2 (20%)					
5.0	16.3		4 (40%)	1 (10%)	3 (30%)	2 (20%)	1 (10%) 3 (30%) 3 (30%) 3 (30%)	3 (30%) 1 (10%)	1 (10%) 1 (10%) 1	2 (20%)	1 (10%) [1]
	18.1		1 (10%)	2 (20%)	2 (20%)	5 (50%)					
	20.0			2 (20%)		7 (70%)					
	22.4					3 (30%)					
	24.8				1 (10%)	1 (10%)					

This table shows the numbers and percentages of burns evaluated by surface appearance with cloth separated 5 mm. from skin. The figure in brackets is the number of times flaming occurred.

Experiment 2.

Table 11

Time (sec)	Radiant Exposure (cal/cm ²)	No Burn	1+			2+			Mild
			Mild	Mod	Sev	Mild	Mod	Sev	
0.5	10.8	3 (30%)	5 (50%)	1 (10%)	1 (10%)				
	12.1	1 (10%)	7 (70%)	2 (20%)					
	13.4	2 (20%)	8 (80%)						
	14.9	1 (11%)	5 (56%)	3 (33%)					
	16.5		4 (36%)	4 (36%)		2 (18%)	1 (9%)		
1.0	17.6		4 (40%)	4 (40%)	1 (10%)	1 (10%)	2 (20%) [1]		
	19.5		1 (10%)	5 (50%)		2 (20%)	1 (10%) [1]		
	21.7			1 (10%)	1 (10%)	6 (60%) [3]	3 (33%) [3]	1 (10%) [1]	
	24.1					6 (56%) [2]	4 (40%) [4]	2 (22%) [2]	
	26.8					2 (20%) [2]		4 (40%) [3]	
2.0	20.8	1 (10%)	2 (20%)	1 (10%)	2 (20%)	3 (30%)	1 (10%)		
	23.1			1 (14%)		5 (72%)	1 (14%)		
	25.6				1 (10%)	3 (30%) [3]	2 (20%) 2	3 (30%) [3]	
	28.5			1 (10%) [1]		1 (10%) [1]	3 (30%) 3	3 (30%) [3]	1 (10%)
	31.6		1 (10%) [1]						
5.0	22.4	1 (10%)	5 (50%)	2 (20%)	1 (10%)	1 (10%)	1 (10%)		
	24.9		1 (10%)		3 (30%)	5 (50%) [2]			
	27.6				1 (10%)	7 (70%) [3]	1 (10%) 1		
	31.7					3 (30%) [1]	3 (33%) 2	1 (11%) [1]	1 (11%)
	34.0		1 (8%) [1]				2 (17%) 2	2 (17%) [2]	

This table shows the numbers and percentages of burns evaluated by surface appearance of cloth separated 10 mm. from skin. The figure in brackets is the number of times flame occurred.

Experiment 2.

19
Table 13

Exposure Time (sec)	Radiant Exposure (cal/cm ²)	Partial Epidermal	Complete Epidermal	Dermal Damage (Depth in Millimeters)			
				0 - .15	.15 - .30	.30 - .45	.45 - .75
0.5	7.1		6 (86%)	1 (14%)			1 (10%)
	7.9		9 (90%)				
	8.8		7 (70%)	3 (30%)			
	9.8		5 (56%)	4 (44%)			
	10.9		5 (50%)	5 (50%)			
1.0	9.3	1 (10%)	8 (80%)	1 (10%)			
	10.4		7 (87%)	1 (13%)			
	11.5		8 (73%)	2 (18%)	1 (9%)		
	12.8		3 (30%)	7 (70%)			
	14.2			8 (80%)	2 (20%)		
2.0	9.9	2 (28%)	4 (57%)	1 (14%)			
	11.0		8 (100%)				
	12.3		6 (60%)	3 (30%)	1 (10%)		
	13.6		4 (44%)	4 (44%)	1 (11%)		
	15.1		3 (27%)	5 (46%)	3 (27%)		
5.0	11.9	3 (30%)	6 (60%)	1 (10%)			
	13.2	1 (10%)	4 (40%)	2 (20%)	2 (20%)	1 (10%)	
	14.7		5 (50%)	5 (50%)			
	16.3		4 (40%)	5 (50%)	1 (10%)		
	18.1		2 (20%)	1 (10%)	5 (50%)	1 (10%)	1 (10%)

This table shows the numbers and percentages of burns evaluated by depth of damage produced with cloth separated 2 mm. from skin. Experiment 2.

20
Table 14

Exposure Time (sec)	Radiant Exposure (cal/cm ²)	Partial Epidermal	Complete Epidermal	Dermal Damage (Depth in Millimeters)			
				0 - .15	.15 - .30	.30 - .45	.45 - .75
0.5	10.9	3 (38%)	5 (64%)				
	12.1		9 (90%)	1 (10%)			
	13.4	1 (11%)	4 (44%)	4 (44%)			
	14.9	1 (10%)	3 (30%)	6 (60%)			
	16.5		1 (10%)	6 (60%)	3 (30%)		
1.0	12.8	1 (10%)	5 (50%)	3 (30%)	1 (10%)		
	14.2		9 (90%)	1 (10%)			
	15.8		2 (22%)	6 (67%)	1 (11%)		
	17.6		4 (40%)	6 (60%)			
	19.5		1 (9%)	6 (55%)	4 (36%)		
2.0	15.1		7 (70%)	1 (10%)	1 (10%)	1 (10%)	
	16.8	1 (11%)	6 (67%)	2 (22%)			
	18.7	1 (11%)	3 (33%)	5 (55%)			
	20.8		2 (22%)	6 (67%)	1 (11%)		
	23.1		1 (10%)	2 (20%)	5 (50%)		2 (20%)
5.0	16.3	2 (20%)	8 (80%)				
	18.1		6 (60%)	4 (40%)			
	20.1		8 (80%)	2 (20%)			
	22.4		1 (10%)	9 (90%)			
	24.9		4 (40%)	1 (10%)	2 (20%)	1 (10%)	2 (20%)

This table shows the numbers and percentages of burns evaluated by depth of damage produced with cloth separated 5 mm. from skin. Experiment 2.

21
Table 15

Exposure Time (sec)	Radiant Exposure (cal/cm ²)	Partial Epidermal	Complete Epidermal	Dermal Damage (Depth in Millimeters)			
				0 - .15	.15 - .30	.30 - .45	.45 - .90
0.5	10.8	2 (40%)	3 (60%)				
	12.1	4 (44%)	5 (56%)				
	13.4	4 (67%)	2 (32%)				
	14.9	2 (28%)	5 (71%)				
	16.5	2 (18%)	8 (73%)	1 (9%)			
1.0	17.6	1 (11%)	8 (89%)				
	19.5		5 (71%)	1 (14%)	1 (14%)		
	21.7		5 (50%)	5 (50%)			
	24.1		3 (25%)	8 (67%)	1 (8%)		
	26.8			6 (67%)	2 (22%)	1 (11%)	
2.0	20.8		5 (55%)	3 (33%)	1 (11%)		
	23.1		3 (43%)	4 (57%)			
	25.6		4 (40%)	3 (30%)	2 (20%)		1 (10%)
	28.5			3 (33%)	4 (44%)	2 (22%)	
	31.6		1 (10%)			1 (10%)	8 (80%)
5.0	22.4	4 (40%)	6 (60%)				
	24.9		7 (77%)	2 (22%)			
	27.6		5 (50%)	2 (20%)	2 (20%)		1 (10%)
	31.7		2 (22%)	3 (33%)	2 (22%)	1 (11%)	1 (11%)
	34.0		1 (8%)	2 (17%)	2 (17%)	3 (25%)	4 (33%)

This table shows the numbers and percentages of burns evaluated by depth of damage produced with cloth separated 10 mm. from skin. Experiment 2.

22

Table 16 shows the 50% effective exposures and 95% confidence intervals for dermal damage:

Table 16

Time (sec)	2 mm. Space	5 mm. Space	10 mm. Space
0.5	10.85 (9.3 - 12.7)	14.0 (13.0 - 15.1)	
1.0	11.9 (11.0 - 12.9)	14.9 (13.3 - 16.7)	21.7 (19.9 - 23.6)
2.0	13.0 (11.7 - 14.4)	18.2 (16.7 - 19.8)	22.1 (19.8 - 24.8)
5.0	14.0 (13.1 - 15.0)	21.0 (18.9 - 23.3)	27.6 (25.9 - 29.6)

By the above evaluation of dermal damage, the same conclusions are drawn as for 2+ burns.

23

Experiments 1 and 2

The results of both experiments are graphically shown in Figures 1 and 2. Figure 1 shows the evaluation by surface appearance; Figure 2, by the histological criteria.

Since the 50% effective exposures necessary to produce 2+ burns judged by surface appearance and dermal damage when the cloth is separated 2 mm. from skin are determined in both experiments, 1 and 2, and since their confidence intervals overlap, it seems justified then to combine the two experiments and to see if any further relationship can be established. In Figures 3 and 4 the amount of separation has been plotted against 50% effective exposures for 2+ burns and dermal damage respectively for each of the exposure times studied. On doing this, the relationships are shown to be nearly linear and moreover parallel at 0.5, 1.0, 2.0, and 5.0 sec. exposure times. This can be expressed by

$$Q_{c_x} = Q_{c_0} + k x$$

where Q_{c_x} is the critical energy for the fabric separated a distance, x , expressed in mm., Q_{c_0} , the critical energy of a fabric in contact (i. e., 0 mm. separation) and k is a constant.

In this experiment k is approximately 1.0. Thus, the 50% effective exposure for this fabric separated from the animal equals the 50% effective exposure of a fabric with no separation plus the amount of separation expressed in millimeters.

24

FIG. 1

SURFACE APPEARANCE

THE EFFECT OF SEPARATION OF WHITE SHEETING (3.2 oz./yd.²)
ON THE EE₅₀ OF 2+ BURNS IN SWINE.

25

FIG. 2

MICROSCOPIC EVALUATION

THE EFFECT OF SEPARATION OF WHITE SHEETING (3.2 oz./yd.²)
ON THE EE₅₀ OF DERMAL DAMAGE IN SWINE.

26

FIG. 3

SURFACE APPEARANCE

THE EFFECT OF SEPARATION OF WHITE SHEETING (3.2 oz./yd.²)
ON THE EE₅₀ OF 2+ BURNS IN SWINE AT 0.5, 1.0, 2.0, AND 5.0 SEC.

27

FIG. 4

MICROSCOPIC EVALUATION

THE EFFECT OF SEPARATION OF WHITE SHEETING (3.2 oz./yd²)
ON THE EE₅₀ OF DERMAL DAMAGE IN SWINE AT 0.5, 1.0, 2.0, AND 5.0 SEC.

28

SUMMARY

1. In a detailed study of 1200 burns produced at 0.5, 1.0, 2.0, and 5.0 sec. exposure times, it is demonstrated that, when the skin is covered by white cotton sheeting 3.2 oz/yd², the 50% effective exposure necessary for burns, judged 2+ or superficial dermal damage, by gross or microscopic examination, respectively, is double that required, when it is bare.
2. The 50% effective exposures for burns judged 2+ by surface appearance and superficial dermal damage by microscopic examination increases linearly as fabric is spaced from skin. This linear relationship is parallel at 0.5, 1.0, 2.0, and 5.0 sec. exposure times.
3. For white cotton sheeting the relationship of 50% effective exposure to separation can be expressed by

$$Q_{c_x} = Q_{c_0} + k x,$$

where Q_{c_x} is the 50% effective exposure for the fabric separated at a distance x expressed in millimeters and Q_{c_0} , the 50% effective exposure of the fabric in contact (i. e., 0 mm. separation) and k is a constant. In this experiment $k = 1$.

CONCLUSION

1. The 50% effective exposures for superficial burns produced beneath white cotton sheeting increases linearly by the amount of separation, measured in millimeters.
2. This relationship is not dependent on the exposure time causing the flash burns.

BIBLIOGRAPHY

1. Davis, T. P., Krolak, L. J., Blakney, R. M., and Pearse, H. E., Modification of the Carbon Arc Searchlight for Producing Experimental Flash Burns, J.O.S.A., 44: 766, (1954).
2. Effects of Atomic Weapons, para. 6.55, Rev. Sept. 1950, U. S. Government Printing Office, (1950).
3. Hinshaw, J. R., Bales, H. W., and Pearse, H. E., The Relationship Between Surface Grade and Depth of Damage of Burns Produced by Radiant Thermal Energy, Univ. of Roch. Atomic Energy Project Report, UR-440, (1956).
4. Hinshaw, J. R., and Pearse, H. E., Histologic Techniques for the Differential Staining of Burned and Normal Tissues, Surg., Gyn., and Obs., 103: 760, (1956).
5. Krolak, L. J., and Davis, T. P., The Measurement of Diffuse Reflectance of Cloth and Skin Samples, Univ. of Roch. Atomic Energy Project Report, UR-380, (1955).
6. Litchfield, J. T., Jr., and Wilcoxon, F., A Simplified Method of Evaluating Dose-Effect Experiments, J. Pharm. and Thera., 96: 99, (1949).
7. Mixer, G., Jr., Studies on Flash Burns: Further Report on the Protective Qualities of Fabrics, as Expressed by a Protective Index, Univ. of Roch. Atomic Energy Project Report, UR-354, (1954).
8. Mixer, G., Jr., Davis, T. P., and Pearse, H. E., The Sub-Fabric Flash Burn: Quantitative Effect on Protectivity of Fabric Reflectance, Fabric Weight and Exposure Time, Univ. of Roch. Atomic Energy Project Report, UR-386, (1955).

30

BIBLIOGRAPHY (Continued)

9. Mixter, G., Jr., and Pearse, H. E., Studies on Flash Burns: The Protection Afforded by 2, 4, and 6 Layer Combinations, Univ. of Roch. Atomic Energy Project Report, UR-361, (1955).
10. Morton, J. H., Kingsley, H. D., and Pearse, H. E., Studies on Flash Burns: The Protective Effects of Certain Fabrics, Surg., Gyn., and Obs., 94: 497-501, (1952).
11. 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, (1952).