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STUDY OF FLASH BURNS: THE EFFECT OF SPECTRAL
DISTRIBUTION ON THE PRODUCTION OF CUTANEOUS BURNS

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STUDY ON FLASH BURNS:
THE EFFECT OF SPECTRAL DISTRIBUTION ON THE
PRODUCTION OF CUTANEOUS BURNS

By

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ABSTRACT

Radiation from the carbon arc, modified by four Corning glass filters with successive cut-off points separated by about 1500 Å, was used to produce cutaneous burns in pigs at a constant exposure time of 0.5 sec. It was found that the 50% effective exposures for 1+, 2+ and 3+ burns increased progressively with increase in wavelength.

The effect of varying both spectral distribution and exposure times on the production of 2+ burns was also investigated. At 0.5 sec. the requirements of radiant energy of wavelength greater than 6500 Å was 27% greater than that of wavelength greater than 3600 Å. At 2.0 and 4.0 sec. it was 42% greater. The increase from 27% to 42% with increase of exposure from 0.5 to 2.0 or 4.0 sec. is significantly different at the 0.95 level of confidence. This demonstrates a failure of reciprocity of time-intensity relationships of different magnitude with the two different filters in burn production.

INTRODUCTION

Any analysis of the factors which modify thermal burns from atomic bomb radiation must take into account the effect of the spectral distribution of the energy. This spectral distribution probably varies a) from one weapon to another, b) during the course of the thermal pulse from any given bomb, and c) at different distances due to attenuation of the atmosphere. To study this in the laboratory, the focused beam of a 24" carbon arc searchlight has been modified to alter its spectral distribution and the resulting radiant energy has been tested for its capacity to cause burns.

In the first experiments (1, 2), a Pyrex glass plate which was part of a monitor system, was inserted in the beam of the arc. This eliminated most of the wavelengths below 3200 Å. Such a modified beam caused less severe burns than did equal amounts of energy from the unmodified source.

In a second experiment, (3) the beam of the carbon arc light was modified by three filter systems which passed ultraviolet, visible and infrared light respectively. It was found that more energy was required to produce a burn with infrared radiation than with the unmodified arc. This was in the ratio of 1.5:1 for 2+ and 3+ burns. and 2.6:1 for 1+ burns. It was also found that an increasing amount of energy was required to cause erythema by ultraviolet, unmodified arc, visible and infrared radiation. The erythema produced by sources containing ultraviolet radiation was uniform, pink, blanched on pressure and often disappeared only to return in about six hours to persist for 24-36 hours. The erythema caused by sources lacking ultraviolet is spotty, dark red, does not blanch on pressure and is persistent.

In the present experiment the 24" carbon arc light was modified by a series of Corning filter glasses which has cut-offs at approximately 2400, 3600, 5200 and 6600 Å and transmit to 25,000 Å. By this arrangement a comparison of the burns produced by radiant energy of varying spectral distributions at a constant time was made. In a second experiment by using two filters and four exposure times, the effect of varying both spectral distribution and exposure times was investigated. A somewhat similar type of experiment was planned by Evans and Ham to be done in human subjects (6).

METHODS

Equipment

An Army 24" carbon arc searchlight modified by an ellipsoidal mirror as described (5) was used to furnish the radiant energy. The maximum output measured by a copper sphere calorimeter is 37.2 cal/cm²/sec.

The spectral qualities of the arc beam were modified by four 3-1/8" square Corning filter glasses mounted 2-1/2" from the exposure plane. Each of these filters transmits radiation with cut-offs at intervals of about 1500 Å from the ultraviolet end of the spectrum. The manufacturer's specifications are as follows:

1. The No. 7910 filter glass is a 96% Silica ultraviolet transmitting filter with C. S. 9-54. This filter has less than 0.25% transmission at 2000 Å and greater than 70% transmission at 2540 Å. It has about 91% transmission through the spectrum from 3400 Å to 25,000 Å.

2. The No. 7380 filter glass, designated H. R. Nultra, C. S. 0-52, has less than 0.25% transmission at 3340 Å and greater than 60% at 3650 Å. It transmits approximately 90% of light from 4000 Å to 25,000 Å. By this filter the maximum erythema band at 2970 Å is eliminated. Through this filter the maximum energy obtained was 30 cal/cm²/sec.

3. Filter glass, Corning No. 3486, H. R. yellow shade yellow, C. S. 3-69, transmits less than 0.5% at all wavelengths shorter than 4930 Å, 37% at 5200 Å and about 80% at wavelengths from 5570 to 25,000 Å. With the carbon arc at maximum output this filter glass transmits an irradiance of 20 cal/cm²/sec.

4. The No. 2403 filter glass, H. R, red shade 3, C. S. 2-58 has less than 0.5% transmission at 6170 Å, 37% at 6400 Å, and about 80% at wavelengths from 6780 to 25,000 Å. The maximum irradiance of the carbon arc source transmitted is 14.4 cal/cm²/sec.

These filters will hereafter be designated as follows:

No.	Corning Identification No.	Color Specification
1	7910	C. S. 9-54
2	7380	C. S. 0-52
3	3486	C. S. 3-69
4	2403	C. S. 2-58

A preliminary curve* of the spectral distribution of the carbon arc source is shown in figure 1 and designated unmodified radiation (7). Using this curve and the average transmission curves of the filters, the spectral distribution of the incident energy for each filter was calculated. Normalized curves were then plotted to show the relative spectral distribution of the incident radiation for the four filters and unmodified radiation, when the total radiant exposures for each are equal. These curves covering the range from 3000 to 12,000 Å are shown in figure 1. From 12,000 to 26,500 Å, they approach zero in a regular manner. It will be seen that the relative spectral distribution of the radiation modified by filter 1 is almost identical to that of the unmodified radiation. The other curves are shifted to the right as the wavelength increases.

* The measurements of the spectral distribution of the carbon arc source are being made by Mr. Leo J. Krolak. Methodology and final results will be published in an University of Rochester Atomic Energy Project Report in the near future.

THIS FIGURE SHOWS THE NORMALIZED SPECTRAL ENERGY DISTRIBUTION CURVES FOR THE CARBON ARC SOURCE UNMODIFIED AND MODIFIED BY THE FOUR FILTERS USED.

Experimental Design

Experiment 1: The time was kept constant at 0.5 sec. and only the spectral qualities of the radiation were varied by means of the filter glasses. Eight levels of irradiances were used for filters 1, 2 and 3; seven for filter 4, and four for the unmodified arc. By this design the effect of energy of increasing wavelength on the 50% probability thresholds of 1+, 2+ and 3+ burns could be shown quantitatively.

This experiment was divided into two groups of animals, twelve in the first group and eight in the second. In the first, or A group, the exposures were randomized systematically so that each combination of filter and irradiance fell at least once on each side of the animal. The 21 combinations employed are listed in the tables.

In the second, or B group of animals, the randomization was systemized so that each combination fell an equal number of times in each of three rows on the flanks of the animals and three times on each animal. Fourteen combinations were studied and chosen so as to complete the data in the first group.

Experiment 2: Both the time of exposure and spectral quality were varied. Exposure times of 0.5, 1.0, 2.0 and 4.0 sec. were used with two filters, No. 2 and No. 4. From four to six irradiances were used with the eight combinations formed by the filter glasses and exposure times. The effect of time and wavelength could be determined quantitatively by this design.

An incomplete block design* was used four times to randomize the combinations. By this method a row of six exposures was considered a

 * The incomplete block design is plan 11.40, taken from Cochran, Wm. G., and Cox, Gertrude M. Experimental Designs, p. 340, 1950, (John Wiley and Sons, Inc.).

block. Three rows were produced on each side of the animal. Twenty-one animals were used. Thirty-two combinations of four irradiances for each of two filters at four exposure times were thus employed. Originally, 28 combinations were to be repeated 24 times and four repeated 18 times. By this method each of 31 combinations had an equal probability of falling with any other of 31 combinations in any one of 25 rows (or blocks) in the incomplete block design.

During the course of the experiment values of irradiance were changed, thereby, making some replications from only eight to fourteen times. However, 25 combinations were replicated 24 times according to plan.

Animals

Chester White pigs weighing approximately 10 Kg were used. Prolonged anesthesia was obtained with Dial in Urea-urethane (Ciba) 70-75 mg/Kg body weight, given by the intraperitoneal route (7). The skin was closely clipped, washed and dried before burning.

Evaluation

The lesions were evaluated twenty-four hours after production by the criteria established in this laboratory (11, 12). By this method lesions are graded 0, 1+, 2+, 3+ and 4+; 0 designates no burn; 1+ a red burn; 2+, one in which there are first tiny spots of white scattered over an erythematous area; 3+, one in which a burned area one cm² was completely white; 4+, one in which the upper layers of the skin are separated during the process of burning by the production of steam, which escapes, leaving a filmy, wrinkled, white surface. Each numbered category was further divided into mild, moderate and severe subgroups.

In experiment 1, after evaluation of the surface appearance, the lesions were biopsied and fixed in Bouin's solution, and stained by hematoxylin and eosin. The criteria chosen for grading have previously been described (3). The first obvious change noted is acidophilism of the epidermal cells. Part or all of the depth of the epidermis may be involved. As the energy increases, the epidermis begins to show gross distortion of its cells and to separate from the dermis. This is at first incomplete over the exposed surface, progressing to complete separation. As the severity increases, the collagenous fibers begin to swell and to lose their fibrillar structure and the dermis appears homogeneous as the interstitial spaces disappear. A line of horizontal demarcation can be seen between the damaged, glassy appearing dermis and the underlying tissue. The depth of damage in the dermis can be estimated by divisions on the ocular micrometer scale of the microscope. The depth of the dermis averages between 1.3 and 1.5 mm. and the dermis is subdivided into three regions, 0.5, 1.0 and greater than 1.0 mm. in depth. Damage of collagen in depth from barely perceptible to 0.5 mm. is termed superficial dermal; from 0.5 to 1.0 mm., mid-dermal; greater than 1.0 mm., deep dermal.

The criteria then are epidermal acidophilism, with part or all of the depth of the epidermis involved; transepidermal damage with part or all of the severely damaged epidermis separated from the dermis; and dermal damage, subdivided into superficial, mid and deep dermal burns.

Analysis of Data

The 50% effective exposure and 0.95 confidence intervals were estimated by the method of Litchfield, J. T., Jr. and Wilcoxon, F. (10). There was one exception. In experiment 1 the 50% effective exposures

for those lesions graded by microscopic examination were estimated by linear interpolation. This was done because the lesions were selectively biopsied.

RESULTS

Experiment 1

Table 1 shows the results of evaluation of the surface appearance of burns produced at 0.5 sec. in experiment 1, employing radiant energy from the carbon arc source alone and that modified by the four filters.

The type of radiation, the group of animals and radiant exposure cal/cm² are shown in the first three columns. The numbers and percentages of the burns produced by each combination are shown under the appropriate grade.

Table 1a shows the estimate of 50% effective exposures for 1+, 2+ and 3+ burns with 0.95 confidence intervals and serves to summarize table 1. Figure 2 is a graphic representation of these findings.

It is clearly indicated that, at 0.5 sec. exposure times, with radiant energy of increasing wavelength the 50% effective exposures of 1+, 2+ and 3+ burns increase progressively.

At the 1+ levels the confidence intervals overlap when the radiant energy is transmitted by filters 2, 3 and 4, none of which contains any ultraviolet radiation. The 50% effective exposures using these three filters is higher by two to three times that of the unmodified source.

At the 2+ level of damage, the generality holds that with increasing wavelength more energy is required. This can be stated with a 0.95 level of confidence except for the overlap with filters 3 and 4.

At the 3+ level no estimate of the 50% effective exposure can be determined for filter 4. With filters 1, 2 and 3, the generality that

Table 1.
RESULTS OF EVALUATION OF SURFACE APPEARANCE
Experiment 1. (Exposure Time: 0.5 Sec)

Source Modified by:	Grp	Radiant Exposure Cals/cm ²	No Burn	1+			2+			3+		Total
				Mild	Mod	Sev	Mild	Mod	Sev	Mild	Mod	
Filter 1	B	1.4	3 (14%)	19 (86%)								22
	A	2.3	1 (4%)	16 (69%)	7 (29%)							24
	A	3.2		7 (32%)	12 (54%)	3 (14%)						22
	B	3.6			13 (54%)	7 (29%)	3 (12%)		1 (4%)			24
	A	4.0		1 (4%)	2 (9%)	5 (22%)	8 (35%)	5 (22%)	2 (9%)			23
	A	5.0					4 (17%)	3 (12%)	7 (29%)	8 (33%)	2 (8%)	24
	B	5.6						2 (9%)	3 (14%)	12 (55%)	5 (23%)	22
	A	6.3								12 (55%)	10 (45%)	22
Filter 2	A	2.9	14 (61%)	9 (39%)								23
	B	3.3	9 (39%)	13 (50%)	3 (11%)	1 (4%)						26
	A	3.6		15 (63%)	4 (17%)	3 (12%)	2 (9%)					24
	B	4.0	1 (4%)	7 (30%)	9 (39%)	1 (4%)	4 (17%)	1 (4%)				23
	A	4.5		3 (12%)		4 (17%)	10 (42%)	1 (4%)	5 (21%)	1 (4%)		24
	A	5.7					3 (12%)	1 (4%)	14 (59%)	5 (21%)	1 (4%)	24
	B	6.5						1 (4%)	3 (13%)	15 (65%)	4 (17%)	23
	A	7.2							1 (4%)	10 (42%)	13 (54%)	24
Filter 3	B	4.2	7 (29%)	17 (71%)								24
	A	4.7	3 (12%)	13 (52%)	7 (28%)	2 (9%)						25
	A	5.3		3 (12%)	6 (25%)	4 (17%)	6 (25%)	3 (12%)	1 (4%)		1 (4%)	24
	A	5.6		1 (4%)		6 (25%)	12 (50%)	3 (12%)	2 (8%)			24
	A	6.5					6 (26%)	3 (13%)	8 (35%)	6 (26%)		23
	B	7.4					2 (9%)	3 (13%)	13 (56%)	4 (17%)	1 (4%)	23
	A	8.0							8 (35%)	8 (35%)	7 (30%)	23
	B	8.9							6 (26%)	17 (74%)		23
Filter 4	A	3.6	19 (79%)	5 (21%)								24
	B	3.8	21 (88%)	3 (12%)								24
	A	4.1	3 (13%)	19 (83%)	1 (4%)							23
	B	4.5	6 (23%)	14 (54%)	6 (23%)							26
	A	5.0		9 (37%)	7 (29%)	3 (12%)	4 (17%)	1 (4%)				24
	B	5.5	2 (8%)	3 (12%)	8 (33%)	6 (25%)	5 (21%)					24
	A	5.9	1 (4%)	1 (4%)		1 (4%)	10 (43%)	5 (22%)	4 (17%)	1 (4%)		23
Unmodified Carbon Arc	A	3.5		2 (10%)	6 (30%)	2 (10%)	6 (30%)	1 (5%)	3 (15%)			20
	B	3.9			3 (12%)		14 (58%)	3 (12%)	3 (12%)	1 (4%)		24
	B	4.3					6 (25%)	6 (25%)	6 (25%)	4 (17%)	2 (8%)	24
	A	6.0							1 (4%)	10 (42%)	13 (54%)	24

Table 1a
(Experiment 1)

50% Effective Radiant Exposure (cal/cm^2) and 0.95 Confidence Intervals for 1+, 2+ and 3+ Burns Produced by Modified and Unmodified Radiation from the Carbon Arc Source at 0.5 Sec.

Laboratory Grade	Unmodified Radiation	Filter No. 1	Filter No. 2	Filter No. 3	Filter No. 4
1+	1.4 (1.1-1.7)*	Not Determined	3.1 (2.7-3.5)	3.8 (3.4-4.2)	4.3 (2.9-6.5)
2+	3.5 (3.3-3.7)	3.9 (3.8-4.0)	4.5 (4.3-4.7)	5.4 (5.2-5.6)	5.6 (4.9-6.4)
3+	4.8 (4.5-5.1)	5.1 (4.8-5.4)	5.9 (5.6-6.2)	7.6 (7.0-8.3)	

* This 50% dose was obtained from previously published data (1).

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FIGURE 2

THIS FIGURE SHOWS THE 50% EFFECTIVE EXPOSURE AND 0.95 CONFIDENCE INTERVAL FOR THE CARBON ARC SOURCE ALONE AND MODIFIED BY 4 FILTERS AT 0.5 SECONDS EXPOSURE TIME FOR THE PRODUCTION OF 1+, 2+, AND 3+ BURNS.

Table 2
Experiment 1. (0.5 Sec)
RESULTS OF EVALUATION OF DEPTH OF DAMAGE (MICROSCOPIC)

Source Modified by:	Group	Radiant Exposure	Epidermal Acidophilism	Transepidermal		Dermal Damage		Total	% Complete Transepidermal
				Focal	Complete	Superficial	Mid		
Filter 1	A	4.0	5 (36%)	8 (57%)	1 (7%)			14	7%
	A	5.0	2 (10%)	4 (19%)	12 (57%)	2 (10%)	1 (5%)	21	72%
	B	5.6		4 (19%)	13 (62%)	3 (14%)	1 (5%)	21	81%
	A	6.3		2 (10%)	3 (15%)	12 (60%)	3 (15%)	20	90%
Filter 2	A	4.0	4 (25%)	8 (50%)	2 (12%)	2 (12%)		16	24%
	A	5.7	1 (5%)	6 (29%)	10 (48%)	4 (19%)		21	67%
	B	6.5		1 (6%)	13 (72%)	3 (17%)	1 (6%)	18	75%
	A	7.2			2 (10%)	13 (62%)	6 (29%)	21	100%
Filter 3	A	5.6	7 (44%)	8 (50%)	1 (6%)			16	6%
	A	6.5	1 (5%)	11 (50%)	7 (32%)	3 (14%)		22	46%
	B	7.4	1 (5%)	13 (59%)	5 (23%)	3 (14%)		22	37%
	A	8.0		4 (18%)	6 (27%)	11 (50%)	1 (5%)	22	82%
	B	8.9		3 (13%)	10 (43%)	8 (35%)	2 (9%)	23	87%
Filter 4	B	5.5	3 (50%)	2 (33%)	1 (16%)			6	16%
	A	5.9	8 (44%)	8 (44%)	1 (6%)	1 (6%)		18	12%
Unmodified	A	3.5	8 (61%)	3 (23%)	22 (15%)			13	15%
	B	3.9	5 (26%)	14 (74%)				19	0%
	B	4.3	5 (24%)	11 (52%)	4 (19%)	1 (5%)		21	24%
	A	6.0			8 (36%)	11 (50%)	3 (14%)	22	100%

with increasing wavelengths more energy is required is upheld with a 0.95 level of confidence.

The estimates by linear interpolation of the 50% effective exposures for complete transepidermal burns are shown in table 2a. It is seen that as the wavelength of the energy increases, the threshold for complete transepidermal burns, as judged by epidermal-dermal separation, similarly increases.

Table 2a

The 50% Effective Exposure for Complete Transepidermal Burns at 0.5 sec.

Carbon Arc Source Modified by:	50% Effective Exposure (cal/cm ²)
Unmodified	4.9
Filter 1	4.5
Filter 2	5.0
Filter 3	7.0
Filter 4	6.9

Experiment 2

To establish the relationship of the 50% effective exposures for 2+ burns produced by energy of varying spectral characteristics at varying times, experiment 2 was performed.

Table 3 shows the results of evaluation of surface appearance of burns produced in experiment 2. The first three columns show the filter glass, the exposure time, and the radiant exposure used. The number and percentages of the burns produced by each combination of filter, time and radiant exposure are shown under the appropriate grade.

Table 3.
Experiment 2.
RESULTS OF EVALUATION OF SURFACE APPEARANCE

Source Modified by:	Time (Sec)	Radiant Exposure	0 No Burn	1+			2+			3+		Total
				Mild	Mod	Sev	Mild	Mod	Sev	Mild	Mod	
Filter 2	0.5	4.2		4 (50%)	3 (37%)	1 (12%)						8
		4.7	1 (12%)	3 (37%)	4 (50%)							8
		5.1		2 (8%)	17 (68%)	1 (4%)	2 (8%)	3 (12%)				25
		5.8			7 (29%)		11 (46%)	4 (16%)	2 (8%)			24
		6.5					4 (24%)	1 (6%)	4 (24%)	7 (41%)	1 (6%)	17
		7.2							1 (8%)	8 (61%)	4 (31%)	13
	1.0	5.0		15 (68%)	7 (32%)							22
		5.4		6 (23%)	15 (54%)	2 (8%)	2 (8%)	1 (4%)				26
		5.9			8 (32%)	5 (20%)	10 (40%)	2 (8%)				25
		6.6			1 (5%)	2 (9%)	11 (50%)	6 (27%)	2 (9%)			22
	2.0	5.9		4 (16%)	13 (52%)	7 (28%)	1 (4%)					25
		6.3			8 (30%)	7 (33%)	5 (25%)	1 (5%)				21
		7.4			3 (14%)	1 (5%)	13 (59%)	5 (23%)				22
		8.0					3 (14%)	2 (10%)	9 (43%)	7 (33%)		21
	4.0	6.5		6 (26%)	2 (9%)	13 (56%)	2 (9%)					23
		7.0		4 (17%)	7 (30%)	7 (30%)	4 (17%)	1 (4%)				23
		7.5		1 (4%)	5 (21%)	8 (33%)	9 (37%)	1 (4%)				24
		8.1			1 (4%)	4 (17%)	9 (39%)	5 (22%)	2 (9%)	2 (9%)		23
Filter 4	0.5	5.1	2 (20%)	7 (70%)	1 (10%)							10
		5.8		9 (41%)	9 (41%)	3 (14%)	1 (5%)					22
		6.1		2 (9%)	17 (69%)	5 (19%)	1 (4%)	1 (4%)				26
		6.5		1 (4%)	13 (54%)	8 (33%)	2 (9%)					24
		7.1			3 (23%)	3 (23%)	6 (46%)	1 (7%)				13
	1.0	6.7	8 (80%)	2 (20%)								10
		7.0		7 (70%)	3 (30%)							10
		7.4			12 (52%)	8 (39%)	3 (13%)					23
		8.0			4 (18%)	10 (49%)	7 (32%)	1 (5%)				22
		9.0				3 (21%)	4 (29%)	3 (21%)	4 (29%)			14
		10.3						2 (14%)	2 (14%)	3 (21%)	7 (50%)	14
	2.0	8.0	2 (9%)	1 (4%)	8 (39%)	12 (52%)						23
		8.6			5 (23%)	13 (59%)	4 (18%)					22
		9.4			3 (12%)	15 (60%)	6 (24%)	1 (4%)				25
		10.2			1 (4%)	2 (8%)	5 (21%)	5 (21%)	8 (33%)	3 (12%)		24
	4.0	8.4		3 (33%)	2 (22%)	4 (44%)						9
		9.0			1 (12%)	7 (87%)						8
		9.6				15 (83%)	3 (17%)					18
		10.4			1 (9%)	9 (47%)	8 (42%)	1 (9%)				19
		11.2				2 (29%)	3 (37%)	1 (12%)	1 (12%)	1 (12%)		8
		12.0						2 (29%)	3 (37%)		3 (37%)	8

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Table 3a
(Experiment 2)

50% Effective Radiant Exposures (cal/cm²) and 0.95 Confidence Intervals for 2+ Burns produced by Varying Wavelength (2 filters) and Varying Time.

Time (sec)	Filter No. 2	Filter No. 4
0.5	5.5 (5.4-5.7)	7.0 (6.7- 7.3)
1.0	6.0 (5.6-6.4)	8.3 (8.0- 8.8)
2.0	6.6 (6.4-6.8)	9.4 (9.1- 9.8)
4.0	7.4 (7.0-8.0)	10.5 (10.0-11.0)

Table 3a summarizes this data in terms of estimates of the 50% effective exposure and 0.95 confidence interval for 2+ mild burns. The results are graphically shown in figure 3. The 50% effective exposures of energy modified by filter 4 are significantly greater than those of filter 2 at 0.5, 1.0, 2.0 and 4.0 sec. Over this range of interest it can also be seen that with increasing time the energy required to produce the same degree of damage (2+ in this case) is increased, demonstrating the failure of reciprocity as previously noted in this laboratory (11).

The potency ratios of the 50% effective exposure (E.E.₅₀) for filter 4, in relation to that for filter 2, and the 0.95 confidence interval of this ratio at each of the four exposure times for 2+ burns are shown below:

Table 4

Time (sec)	Ratio	0.95 Confidence Interval on Ratio
	$\frac{\text{E.E.}_{50} \text{ (filter 4)}}{\text{E.E.}_{50} \text{ (filter 2)}}$	
0.5	1.27	1.25 - 1.30
1.0	1.39	1.26 - 1.56
2.0	1.42	1.31 - 1.55
4.0	1.42	1.39 - 1.44

The ratio is smallest at 0.5 sec. increasing to a constant ratio of 1.42 at 2.0 and 4.0 sec. At the 0.95 level of confidence, there is a significant difference in the potency ratio at 0.5 sec. compared to that at 2.0 and 4.0 sec. The influence of wavelength on the production of cutaneous 2+ burns in the pig is significantly less at 0.5 sec. than at 2.0 and 4.0 sec.

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FIGURE 3

THIS FIGURE SHOWS THE 50% EFFECTIVE EXPOSURES OF RADIANT ENERGY MODIFIED BY FILTERS 2 AND 4 AT EACH OF THE DESIGNATED EXPOSURE TIMES FOR 2+ BURNS.

The difference between the 50% effective exposure of filter 2 and that of filter 4 at 0.5 sec. is 1.5 cal/cm^2 . The difference at 2.0 sec. is 2.8 cal/cm^2 . There is then almost a two-fold increase in the difference of the 50% effective exposures with a four-fold increase in exposure time from 0.5 sec. to 2.0 sec. This increase is significant at the 0.95 level of confidence, as shown by the comparison of the potency ratios above.

Noting that the radiation from filter 4 is of longer wavelength than that of filter 2, with a difference in their cutoff points of $3000 \text{ \AA}$, another interesting comparison can be made. With this increase in wavelength cutoff, there is an increase of 1.5 cal/cm^2 in the 50% effective exposures of radiant energy at the exposure time of 0.5 sec. By changing the exposure time from 0.5 to 4.0 sec. there was an increase of 1.9 cal/cm^2 in the 50% effective exposure of energy transmitted by filter 2. Therefore, the magnitude of the increase in 50% effective exposure at 0.5 sec. and 4.0 sec. is of the same order as that produced by the $3000 \text{ \AA}$ increase in wavelength.

DISCUSSION

That more energy is required with increase in wavelength, particularly at the 2+ and 3+ levels of damage, has been clearly indicated in experiment 1. The explanation of this relationship probably lies in the dependence upon wavelength of the reflectance of skin. It has been demonstrated (9) that reflectance of skin increases with increasing wavelength. Thus less of the incident long wavelength radiation is absorbed by the skin than that of shorter wavelengths. Therefore, to produce a

burn of given severity more energy of long than of short wavelength radiation will be required.

The two to three-fold increase in the 50% effective exposure to produce 1+ burns when radiation of wavelengths less than 3600 Å is excluded is probably the effect of the known specific photochemical action of ultraviolet radiation (4).

In experiment 2, the relationship of time of exposure, wavelength, and energy in the production of burns was explored. The effect of time and intensity was studied thoroughly in this laboratory and a failure of reciprocity was demonstrated. For any one type of radiation, as the time of exposure is increased, the amount of energy required to produce the same grade of burn is increased but not reciprocally. This failure of reciprocity is of a different magnitude with one filter than with the other, and the two curves are closer to one another at 0.5 sec.

CONCLUSIONS

1. At 0.5 sec. exposure times with radiant energy from a carbon arc source the 50% effective exposure of 1+, 2+ and 3+ burns increased progressively with increasing wavelength. Four Corning glass filters with successive cutoff points separated by 1500 Å were used to modify the source. For 2+ and 3+ burns the difference in 50% effective exposure of radiant energy produced by this successive increase in wavelength was significant at the 0.95 level of confidence.

2. At 0.5 sec. exposure times, to produce 1+ burns, the 50% effective exposure of radiant energy, where the maximum erythema band at 2980 Å

is excluded, was two to three times the dose required when this band is included. This is probably the result of the specific photochemical effect of ultraviolet radiation.

3. The 50% effective exposure at 0.5 sec. for 2+ burns produced by radiant energy of wavelength longer than 6580 Å was 27% greater than for equivalent burns produced by that longer than 3600 Å. At 2.0 and 4.0 sec. exposure times it was 42% greater. The increase from 27% to 42% is significant at the 0.95 level of confidence.

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