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BURNS TO SKIN BY

MILLISECOND LIGHT PULSES

DASA Subtask 03.062

Lab. Project 9400-12, Progress Report 1

DASA No. 1532

Willard L. Derksen
John Bracciaventi
George Mixter, Jr.

6 July 1964

PHYSICAL SCIENCES DIVISION
J. M. McGreevy, Head

Approved: E. J. JEHLE
Technical Director

Approved: I. F. FIKE, CAPTAIN, USN
Commanding Officer and Director

U. S. NAVAL APPLIED SCIENCE LABORATORY
Naval Base
Brooklyn, New York 11251

Lab. Project 9400-12
Progress Report 1

SUMMARY

The radiant energy required to produce skin burns for thermal radiation exposures with durations less than 100 milliseconds has never been measured. To determine values for durations in the order of milliseconds, burns were produced on the depilated skin of albino rats by exposure to the irradiance from a xenon flash lamp energized with 14,000 joules. The intensity of the radiant pulse peaked in 0.4 millisecond and decayed to one-half the peak value in 5 millisecond. The threshold burn - a lesion exhibiting a scab - occurred in one-half of the exposures at a distance from the lamp at which the radiant exposure was 3.5 cal/cm^2. Minor lesions of short duration occurred at 2 cal/cm^2. In general the scabs appeared thinner than those which develop as a result of exposures of longer duration.

To study the effect of pigmentation and to provide data which would be more amenable to mathematical analysis, another experiment was run with the skin made opaque with a thin black film. For the opaque situation the temperature profile history can be determined with greater certainty, since the energy is absorbed only at the surface and not in depth in the skin as in the case of the uncovered situation. For the blackened skin, a radiant exposure of only 0.35 cal/cm^2 produced scab lesions in one-half of the exposures and minor burns occurred at 0.2 cal/cm^2. The course of the burn recovery was studied pictorially.

The radiant exposure values for burns to bare and blackened rat skin will be employed to plan future experiments with human skin using short pulses. The values will also be employed as an important data point in developing a mathematical model for predicting thermal injury.

Research was conducted according to the principles of laboratory animal care as promulgated by the National Society for Medical Research.

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TABLE OF CONTENTS

FIGURES

TABLE OF CONTENTS Cont'd

FIGURES

TABLES

ADMINISTRATIVE INFORMATION

The work reported herein constitutes part of the Naval Applied Science Laboratory's FY 1964 program on the "Physical Mechanism of Thermal Injury" sponsored by the Defense Atomic Support Agency under DASA subtask 03.062 and authorized under DASA letter DASATP/926.1 of 12 August 1963.

ACKNOWLEDGMENTS

This work was performed under the direction of T. I. Monahan, Head, Physics Branch.

OBJECT

The objectives were to measure the radiant exposure to cause skin burns upon exposure to pulses of thermal radiation of a few milliseonds duration and to determine the nature and course of the resulting lesions.

INTRODUCTION

This experiment was conducted as part of the Naval Applied Science Laboratory's program of assessing the effects of nuclear detonation. The burns were produced to measure radiant exposures to cause burns for durations two decades in time shorter than previous burn experiments.

Results will be employed to determine the distances at which these burns would be expected to occur for weapon detonations with thermal pulses of this duration. The data are also expected to be useful in determining the relationship between temperature profile history and skin burns. The results will be used to study the nature of burns and the response of skin to intense flashes of light of this duration.

SOURCE CHARACTERISTICS

The radiant energy source was a commercially available photographer's flash lamp. 14,000 joules from a 2600 microfarad condenser charged to 3300 volts were discharged through the helical low pressure xenon lamp. The history of the thermal radiation flash, shown in Figure 1, peaks in 0.4 millisecond and falls to one-half of the peak value in 5 milliseconds. Ninety per cent of the energy is delivered by 10 milliseonds. For the purposes of this experiment the spectral distribution of the energy can be considered constant during the flash as shown in Figure 2. Slightly more infrared energy is present, however, in the pulse at later times than during the peak of energy delivery. The spectral absorptance of rat skin is also shown in Figure 2 and an absorptance of 0.55 is calculated for the spectrum during the irradiance peak.

EXPOSURE PROCEDURES

The rats were anesthetized with Nembutal, 4 mg for every 100 grams of weight. The albino rats, 3 to 6 months old, weighing from 200 to 300 grams, were clipped and the stubble removed with a commercially available depilatory several hours before exposure. The rats were exposed through a 35mm diameter aperture as shown in Figure 3. The temperature of the plate against which the rat rested was adjusted to control the skin temperature to 31 ± 1°C. The rat in the exposure mount was positioned near the flash lamp, as shown in Figure 3; the distance from the lamp was selected to give the desired radiant exposure.

Rat skin, like human skin, is diathermanous[2,3], consequently part of the radiant energy from the flash lamp is absorbed in depth, and the skin is heated in depth as well as on the surface. Since albino rats lack pigmentation, part of the study was made with the skin painted black to obtain a measure of the effect of pigmentation. The heat flow for the situation in which the energy is absorbed at the surface is more amenable to mathematical analysis. The depilated rat skin was painted with a graphite emulsion in a water soluble base and allowed to dry just prior to exposure.

Thermal injury resulting from the absorption of radiant energy manifests itself somewhat differently in rat skin than in human skin, although in the exposure time regime of 8 to 30 seconds, initial effects of thermal injury to human and rat skin can be shown to have the same radiant energy requirements[4]. Increasing severity of burn to human skin manifests itself first as redness or erythema, usually transient, then small and large blisters, edema and swelling, and finally scab or eschar formation. Burns to rat skin range from redness, short lived edema, to scabs of varying thickness.

RESULTS

After exposure, the rats were examined periodically until the resulting lesions had run their course and hair growth was restored. The occurrence of scabs, an effect representing injury not immediately reversible, is listed in Table 1 for the 44 exposures on bare skin and in Table 2 for the 33 exposures on blackened skin. The Tables give information on all exposures made, including pilot exposures.

In general, for albino rat skin, normal scabs, which appear in 24 hours and heal in about 8 days, tend to develop at a radiant exposure threshold of 3 cal/cm^2, with a 50 per cent occurrence at 3.5 cal/cm^2. These burns correspond to blister or second-degree burns.

Weak scabs, characterized by a late appearance (48 to 72 hours after exposure) and by short duration (2 to 5 days), appear at radiant exposures of 2 cal/cm^2 or more.

The response of blackened skin is for normal scabs to form, following radiant exposures in excess of 0.3 cal/cm^2 with 50 per cent of the population affected at 0.35 cal/cm^2. Weak scabs occurred at radiant exposures as low as 0.2 cal/cm^2.

Figures 4 through 9 show the development of the burn lesion after a radiant exposure of 0.73 cal/cm^2 on the blackened area and 3.4 cal/cm^2 on the bare skin. No effect is apparent for several hours after exposure but definite eschar forms in 24 hours. The rat is not constrained and the blackening is cleaned off by the rat, itself. The eschar grows progressively darker until it peels off on approximately the sixth day after the burning episode.

Studies of biopsies taken from areas exposed to the flash lamp reveal loss of both dehydrogenases and diaphorase from the surface epithelium and for short distances down the hair follicles. No evidence of a burn lesion developed in the dermal structures, and by the third day, regenerating epithelium almost completely covered the dermis, in most cases beneath the necrotic and still adherent epithelium. No loss of enzyme activity was found in biopsies from exposures of one second or more. The indications are that the higher temperatures, (in excess of 60°C), generated in the surface layers by the flash lamp radiation pulse are capable of inactivating this type of protein.

DISCUSSION

The radiant exposure for burns for very-low yield nuclear weapons can be estimated from the flash lamp burn data. The shape of the thermal pulse from the flash lamp corresponds roughly to that expected theoretically from a nuclear detonation of a 0.001 kiloton yield, if one assumes a pulse time scaling of

$$t_{max} = 0.032W^{1/2}.$$

Figure 10 shows the flash lamp burn data for the uncovered rat skin plotted with those derived from experiments at higher weapon yields employing a carbon-arc furnace[5]. The radiant exposures for weapon pulses intermediate between 0.001 and 40 kt need not necessarily be those indicated by the interpolation. The burn requirement for heavily pigmented skin would be much less as indicated by the flash lamp results for the blackened skin.

Data for blackened rat skin and weapon pulse exposures are not readily available. Data for blackened rat skin for square-wave pulses have been obtained for long-duration exposures and are compared with the flash lamp data in Figure 11. Simple equivalence in energy requirements to produce burns is assumed for the flash lamp pulse, that is, the energy in the pulse is as effective as if it had been delivered at constant irradiance in one millisecond.

The relationship between the brief elevated temperature episode and tissue injury for such insults, as well as the nature of the tissue injury associated with a threshold thermal burn is not known. Data points developed in these experiments will be useful in studying these relationships.

CONCLUSIONS

The radiant exposures of 3.5 and 0.35 cal/cm^2 which cause burns in uncovered and blackened rat skin, respectively, when irradiated by the very short flash lamp pulse, are less than the corresponding radiant exposures for the longer pulses associated with most tactical uses of nuclear weapons.

A significant point brought out by this experiment is the occurrence of weak scabs or minor burns which appear some time after the insult, at a radiant exposure significantly less than that at which the usual type of burn was observed.

FUTURE WORK

Additional experiments are desirable to assess more precisely the burn hazard and the occurrence of minor burns for millisecond pulses to variously pigmented human skin.

REFERENCES

1. Reflectance and Absorptance of Albino Rat Skin. NAVAPLSCIENLAB Project 5046-16, Part 1, AFSWP 1018, February 1957.

2. The Thermal Conductivity and Diathermancy of Albino Rat Skin. NAVAPLSCIEN-LAB Project 5046-16, Part 4, AFSWP 1144, April 1959.

3. The Thermal Conductivity and Diathermancy of Human Skin for Sources of Intense Thermal Radiation Employed in Flash Burn Studies. Derksen, W.L.; Murtha, T.D.; Monahan, T.I. J. Appl. Physiol. 11:2:, 1957; NAVAPLSCIENLAB Project 5046-3, Part 81, AFSWP 848, August 1955.

4. The Temperatures Associated with Radiant Energy Skin Burns. Derksen, W.L.; Monahan, T.I.; DeLhery, G.P. Temperature - Its Measurement and Control in Science and Industry; Vol. 3, Part 3, page 171, March 1961.

5. Burns to White Rat Skin for Nuclear Weapon Pulses of Intense Thermal Radiation. NAVAPLSCIENLAB Project 5046-16, Part 2, AFSWP 1070, April 1958.

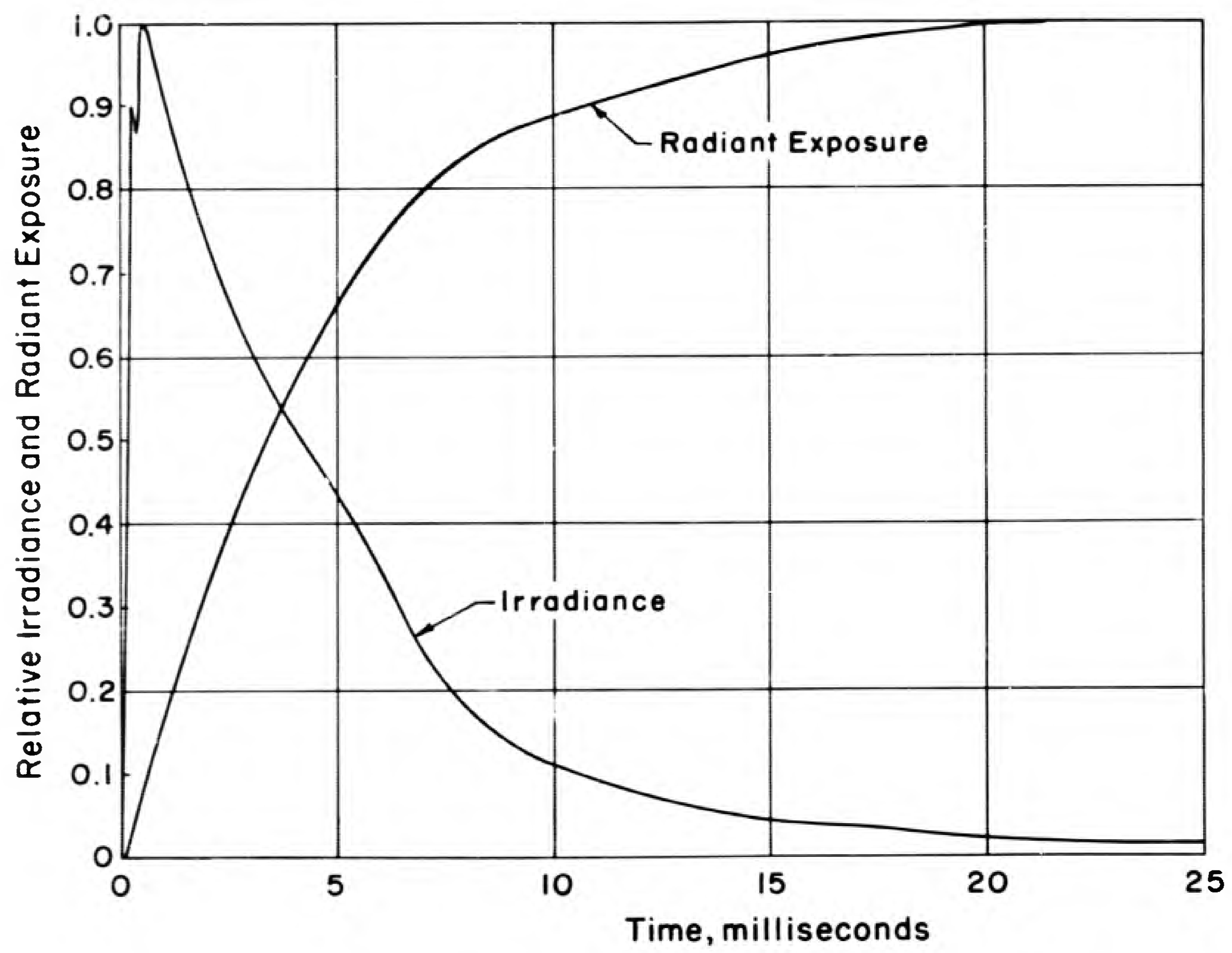

Figure 1. Irradiance and Radiant Exposure History of the Flash Lamp Pulse

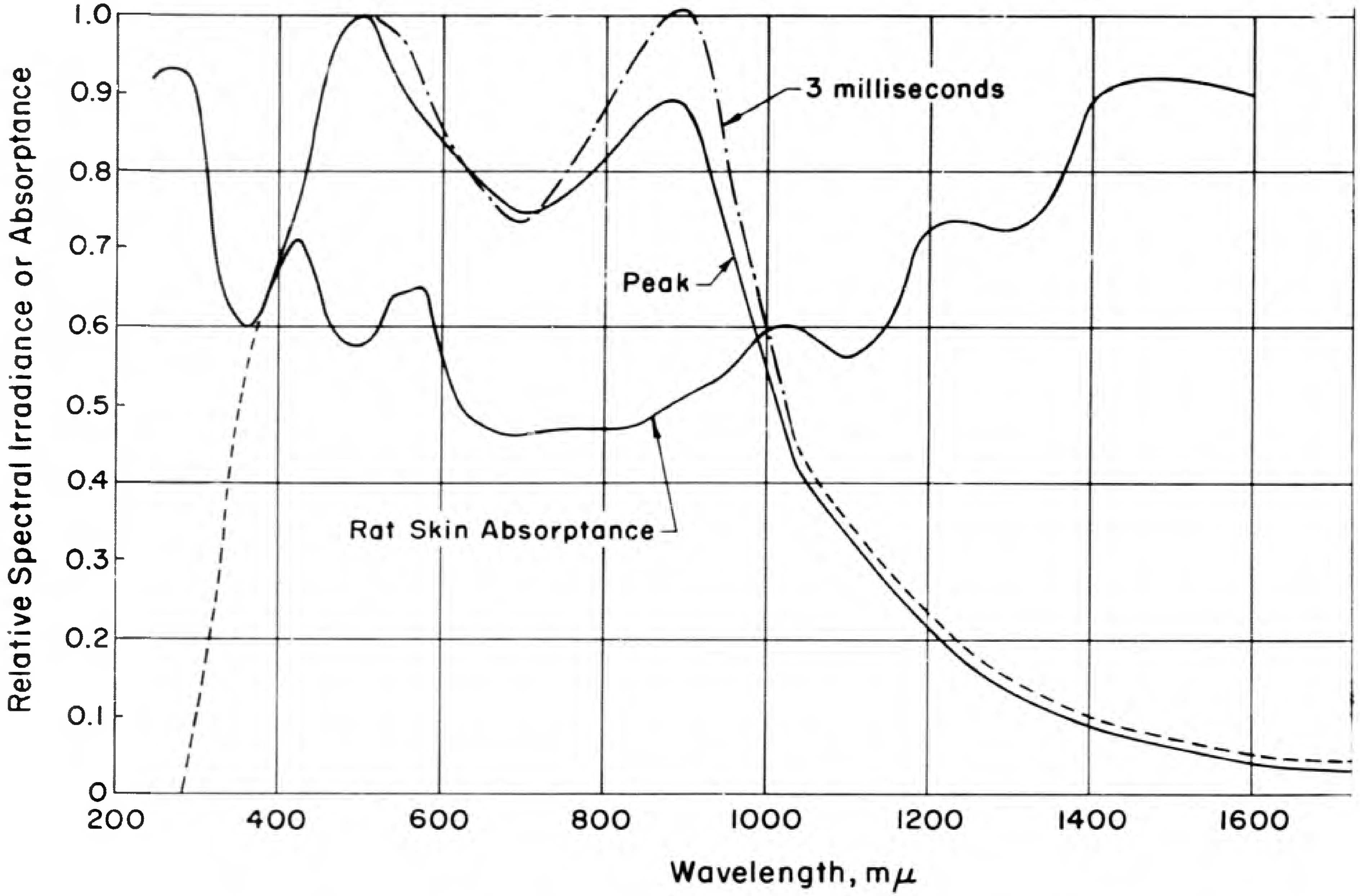

Figure 2. Spectral Distribution of the Flash Lamp Pulse and Spectral Absorptance of Albino Rat Skin

Figure 3. Rat on Temperature Controlled Exposure Plate Placed Near Flash Lamp

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Figure 4. Rat Skin Two Hours After Exposure to 0.73 cal/cm^2 on Blackened Skin and 3.4 cal/cm^2 on Bare Skin

Figure 5. Rat Skin One Day After Exposure

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Figure 6. Rat Skin Two Days After Exposure

Figure 7. Rat Skin Three Days After Exposure

Figure 8. Rat Skin Six Days After Exposure

Figure 9. Rat Skin Seven Days After Exposure

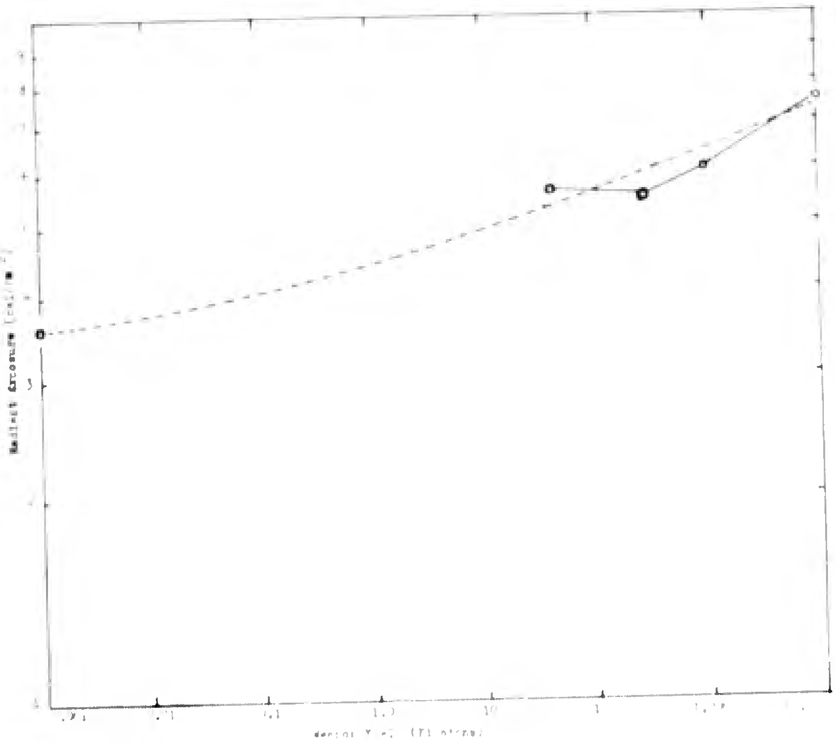

Figure 10. Radiant Exposures to Produce Burns to Albino Rat Skin as a Function of Weapon Yield

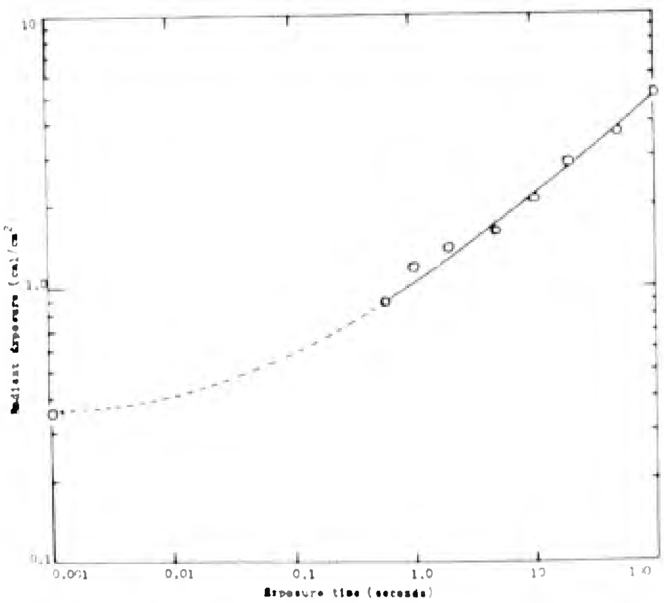

Figure 11. Radiant Exposures to Produce Burns to Blackened Rat Skin for Rectangular Pulses as a Function of Exposure Time

TABLE 1

RESPONSE OF ALBINO RAT SKIN TO
RADIANT ENERGY FROM A FLASH LAMP

Radiant Exposure Range	Expo-sures	Visible Effects	Weak Scabs	Normal Scabs	All Scabs	Normal Scabs
cal/cm^2	No.	No.	No.	No.	%	%
1.2 - 2.0	5	2	3	0	60	0
2.1 - 2.3	7	2	4	1	71	14
2.4 - 2.7	7	2	5	0	71	0
2.8 - 3.1	9	4	5	0	55	0
3.2 - 3.5	2	0	1	1	100	50
3.6 - 3.9	7	0	3	4	100	57
4.0 - 4.3	4	0	2	2	100	50
4.4 - 4.7	1	0	0	1	100	100
4.8 - 5.1	-	-	-	-		
6.0 - 6.3	2	0	0	2	100	100

TABLE 2

RESPONSE OF BLACKENED RAT SKIN
TO RADIANT ENERGY FROM A FLASH LAMP

Radiant Exposure Range	Expo-sures	Visible Effects	Weak Scabs	Normal Scabs	All Scabs	Normal Scabs
cal/cm^2	No.	No.	No.	No.	%	%
0.14-0.15	4	4			0	0
0.3-0.33	6	2	4		66	0
0.4-0.5	3		1	2	100	66
0.6-0.7	6		1	5	100	83
0.75-0.85	7			7	100	100
1.1-1.3	3			3	100	100
2 - 2.5	2			2	100	100
5 - 6	2			2	100	100

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W. L. Derksen, J. Bracciaventi and G. Mixter, Jr.
6 Jul 1964. 9 p. figs. illus. tables.
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3. Atomic weapons - Physiological effects
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