TECHNICAL OPERATIONS INCORPORATED
6 SCHOULER COURT · ARLINGTON 74 · MASSACHUSETTS
TELEPHONE MISSION 3-4500

NAV1.950227.029

November 11, 1955

05853

The Director
Biological and Medical Sciences Division
U.S. Naval Radiological Defense Laboratory
San Francisco Naval Shipyard
San Francisco 24, California

ATTN: Dr. E. L. Alpen, Head, Thermal Branch

Subject: AFSWP Thermal Data Handbook

Dear Sir:

We have received your letter of October 31, file 3-926/ELA:dg, and appreciate the information on erythema that it contains.

Enclosed, herewith, are revised drafts of data sheets 6a.1b and 6e.1 on which we solicit your comments. Should you feel that certain changes or corrections are necessary we shall appreciate hearing from you at your earliest convenience.

Very truly yours,

James H. Pannell

James H. Pannell

JHP:kc
Enclosures

UNCLASSIFIED

[redacted]

Contains no U.S. Navy Classified Information
IAW OPNAVINST5513.16
Signature: James Waters CAPT USN
Code: N312Q Date: 8 Feb 95

[redacted]

THERMAL EFFECTS ON PERSONNEL

FLASH BURNS OF SKIN

CRITICAL ENERGIES FOR BURNING HUMAN SKIN

Recent experiments[1] with human subjects exposed to a high-intensity carbon-arc source provide a comparatively sound basis for the prediction of effects in the field. The source equipment used at the Medical College of Virginia included an ellipsoidal mirror irradiating an area of 1.27 sq cm, and means for producing a simulated nuclear weapon pulse. Maximum irradiance, H, occurred at 0.4τ where τ is the pulse length, and the width at half-maximum was 0.43τ. With no attenuating screens the maximum irradiance was 23.5 cal/sq cm-sec averaged over an area of 0.8 sq cm and for the shortest exposures the ratio H/Q was 4.2. This pulse was without a tail but the values used for the radiant exposure, Q, are a true measure of the energy actually delivered. Consequently, in the field an exposure about ~~40~~ 7 per cent greater might be required to produce the same effect. Groups of Caucasian subjects variously pigmented were burned on the dorsal area of the upper arm. Initially, each of 14 subjects was given triplicate burns at four different exposures with the following results: (total exposure time held constant at 0.54 sec)

TABLE I

Burns Produced in Humans by Simulated Field Pulses from a Carbon-Arc Source

05853

Exposure	Burns Produced	Clinical Data
2.0 cal/sq cm	none	Some mild erythema
3.2	1° or superficial 2°	Mild edema in 64%
3.9	2°	Edema in 93% followed by blisters in 86%
4.8	deep 2° or 3°	Blisters in 100%

As the area burned was always small enough to heal without grafting, the severest burns were nominally 2°; but of those caused by 4.8 cal/sq cm it is estimated that 50% would be 3° if of larger area; however, no biopsies were performed. Consequently, the estimated exposures required for 50% probability of first, second and third degree burns are roughly 2.5, 3.5 and 5 cal/sq cm respectively, for 0.54-sec pulses. By comparison, at NRDL[2] 3.7 to 4.0 cal/sq cm were required to produce persistent erythema from pulses simulating 30 and 250 KT respectively. If allowance is made for differences in pulse shapes these numbers would be reduced to 2.8 and 3.0 cal/sq cm. See sheet 6b.1(b) for further data on reciprocity law failure.

Comparison of Simulated Nuclear Weapon Pulse with Square Wave: As a considerable volume of experimental data has been obtained by exposures at constant irradiance, a comparison was made between square-wave and simulated-field pulses delivering the same energy in the same total time. Values of H for the square-wave were about one-half those for the corresponding simulated nuclear weapon pulse. Duplicate exposures to 3.9 and 4.8 cal/sq cm were made with each pulse on each of 15 Caucasian subjects. All exposures were of 0.60 second duration. The results indicate a more severe injury from the simulated field pulse although the differences were small.

Effect of Spectral Quality (Source Temperature): Equi-energy ~~square wave~~ exposures of 0.54 second duration were given through Corning filters to 10 subjects. Each subject was exposed once to 3.9 cal/sq cm though each of 10 filters which had sharp cut-offs at the lower wavelength. The results of this experiment are presented in Table II, and show the effect of high spectral reflectance in the red.

TABLE II

Burns Produced by 3.9 cal/sq cm in 0.54 sec through Various Filters

Corning Filter	Cut-off (70% transmittance)	Burn	Clinical Data
0-53	0.320μ	2°	90% clearly defined as 2°
0-52	0.370	2°	
3-69	0.535	1°	100% 1°
3-68	0.550	none	transient erythema
3-67	0.565	"	" "
3-66	0.580	"	" "
3-73	0.590	"	" "
2-61	0.625	"	" "
3-58	0.650	"	" "
2064	0.680	"	deep transient erythema

As the wavelength at the cut-off is increased, the effective diathermancy of the skin becomes greater, resulting in a lowered temperature profile and, consequently, less severe injury. Skin is especially diathermanous in the band 0.65 - 0.85μ where the thermal energy absorbed to produce persistent erythema is increased three-fold over radiation in the visible spectrum[3].

However, it is clear that energy of wavelengths above 0.53μ is relatively ineffective in causing burns to humans, as was shown at Rochester [4], and the conclusion is that surface bursts, having an effective color temperature of 3000°K and a lower thermal partition are also relatively ineffective.

Refs.: (1) Evans, Brooks, Schmidt, Williams and Ham: Surgery 37, 280 (1955)
(2) USNRDL Thermal P.R. No. 7
(3) USNRDL-TR-46
(4) UR-236

[redacted]

THE-1357

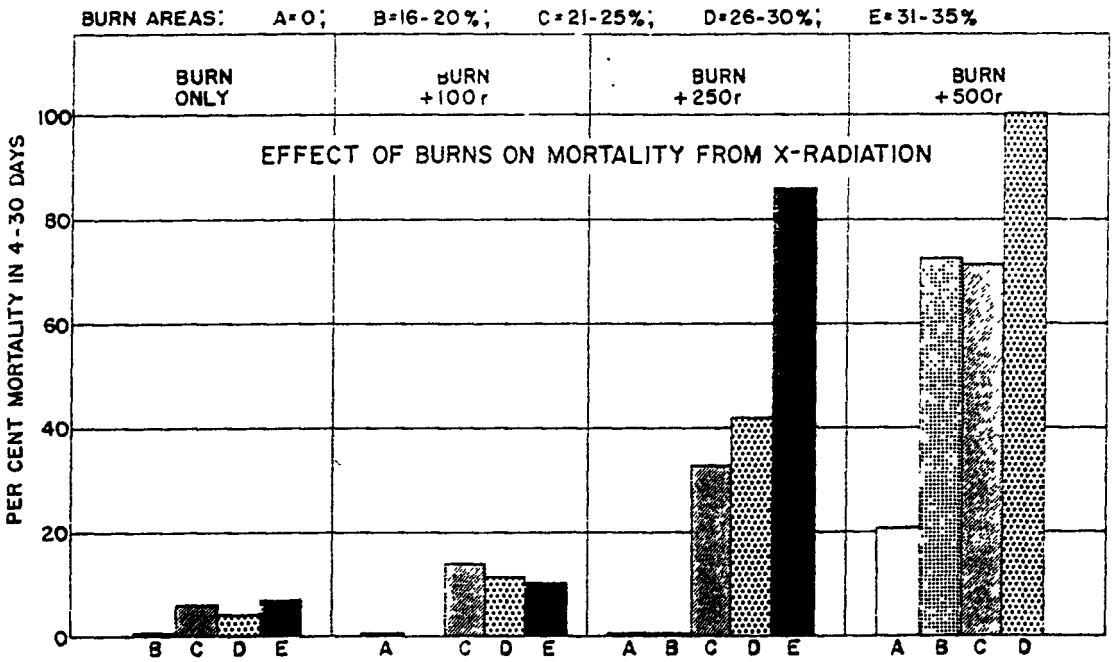
LATE DEATHS FROM COMBINED INJURY

As measures are taken to protect the individual from thermal injury, the outer boundary of the annular region of interest for casualty production contracts toward ground zero. At radii where skin burns are produced under most uniforms, the effects of blast predominate, but nuclear radiation is also a factor and under conditions where injury by missiles or by translational motion is unlikely, ionizing radiation may become the dominant lethal effect. Therefore, it is of interest to determine the probability for survival among persons exposed to sub-lethal doses of both thermal and ionizing radiation.

Thermal injury of serious proportions produces an immediate state of shock; a fall in blood, plasma, and red cell volume; a depression of respiration and body temperature, and a marked hemoglobinuria. It is accompanied by considerable pain which may lead to hysteria.

Nuclear radiation of the order of a few hundred roentgen produces only nausea within one or two hours. Massive doses, several thousand r, cause death in about 3 days. Doses of the order of 1000 r do not produce many casualties in the first hour, consequently for some tactical purposes nuclear radiation may be discounted. It is to be expected, therefore, that the augmentation of thermal casualties by radiation would not be as apparent as the converse.

Experiments with rats (1) and dogs (2) indicate that death may result from a combination of sub-lethal burn and whole-body irradiation. Thus, the lethal burn area for 50% mortality of rats within 48 hours decreases from 33%, for no radiation; to 24% for 500 r. Furthermore, deaths at later times, which are caused primarily by the radiation, are more probable for animals which were burned as well as irradiated than for those which were irradiated only. This effect is illustrated by the histogram below that shows the per cent mortality as a function of area burned and X-ray dose received among animals surviving 4 days.



Experimental: Female Sprague-Dawley rats were irradiated by a 250 KVP X-ray machine at 23 r/min and were burned by partial immersion in water at 80°C for 25 seconds or by a flash burn. Edema developed in a few hours and subsided after two days.

Confirmation of the synergistic effect of thermal and radiational injuries has been obtained by experiments on dogs. Burns were produced over 20 per cent of the body area by contact with a brass plate at 60°C. X-radiation was delivered by a 1000 KVP machine at a rate of 17r/min. The 20 per cent burn caused a mortality of 12% whereas the largest doses of radiation, 100 r, alone caused no deaths. However, a combination of the two caused a 73% mortality when no antibiotic treatment was given. All deaths resulted from infection of the blood through the burn wound by beta hemolytic streptococci. This bacteremia was successfully controlled by penicillin injections beginning 24 hours after exposure. Table I summarizes the results of this study.

TABLE I

Effects of Combined Injury on Mortality in Dogs

Injury	No. of Animals	Mortality	Clinical Data
20% burn	40	12% (5-14 days)	Similar to deep 2°
100 r	10	0%	No effects
20% burn and 25 r	25	20%	(Anemia (Septicemia
20% burn and 100 r	40	73% (8-14 days)	(Anemia, septicemia, (bronchopneumonia
20% burn and 100 r	28	14%	Penicillin therapy

Mortality of the injured dogs can be correlated in both time and frequency with the concentration of beta hemolytic streptococcus in the blood. Successful treatment with penicillin confirms the diagnosis.

In applying these results to humans, it is necessary to consider that human burns are generally more grossly infected for longer periods and successful antibiotic treatment would depend on an early identification of the bacteria present. On the other hand, depression of phagocytic activity as a result of tolerable doses of ionizing radiation may be expected to increase drastically the number of late deaths caused by septicemia.

Refs.: (1) USNRDL-420, 413, 423, 433, TR-45
(2) Brooks, Evans, Ham, Reid: Annals of Surgery 136, 533 (1952)

THE-1358