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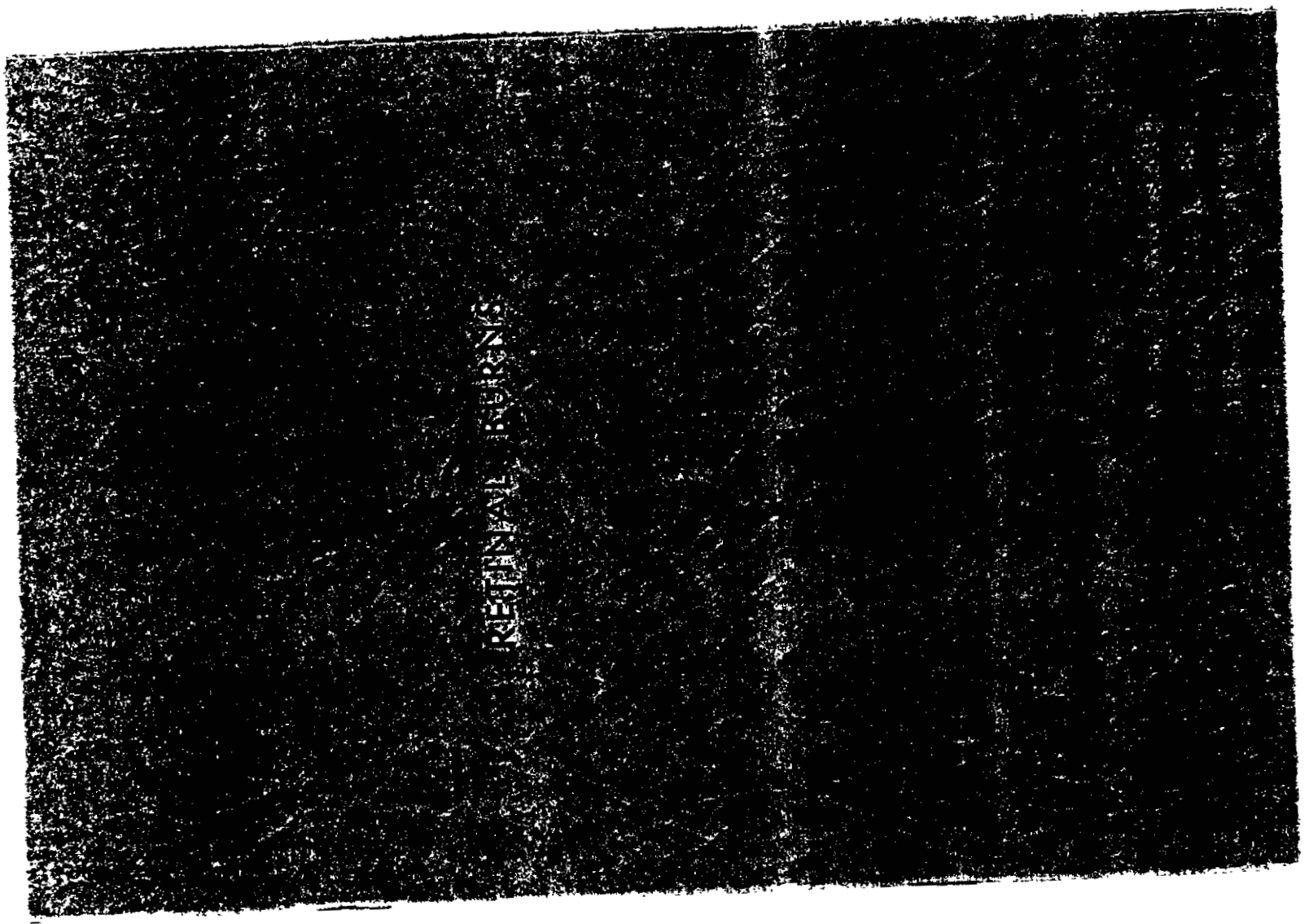

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RETINAL BURNS

Nuclear Weapons Effects Research

WALTER J. GEERAETS, M.D., WILLIAM T. HAM, JR., PH.D.
and DU PONT GUERRY, III, M.D.

THE DEPARTMENT OF OPHTHALMOLOGY AND BIOPHYSICS
MEDICAL COLLEGE OF VIRGINIA, RICHMOND, VIRGINIA

SUPPORTED BY
DEFENSE ATOMIC SUPPORT AGENCY, WASHINGTON, D. C.

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Scientific Exhibit

Annual Meeting of the AMERICAN MEDICAL ASSOCIATION

June 16-21, 1963, Atlantic City, New Jersey

OBJECTIVES

Since retinal thermal injury is the most hazardous immediate effect of nuclear explosions at distances where no other damage to biological structures would occur, it requires special attention and protective devices. Even flash-blindness, though a reversible phenomenon, is of vital importance to military personnel on the ground, on the sea, and in the air. To evaluate those hazards basic principles of spectral distribution, absorption characteristics, susceptibility of tissue to different wavelengths and thermal conduction are essential. The following research data provide a more basic understanding of eye hazards from thermal radiation.

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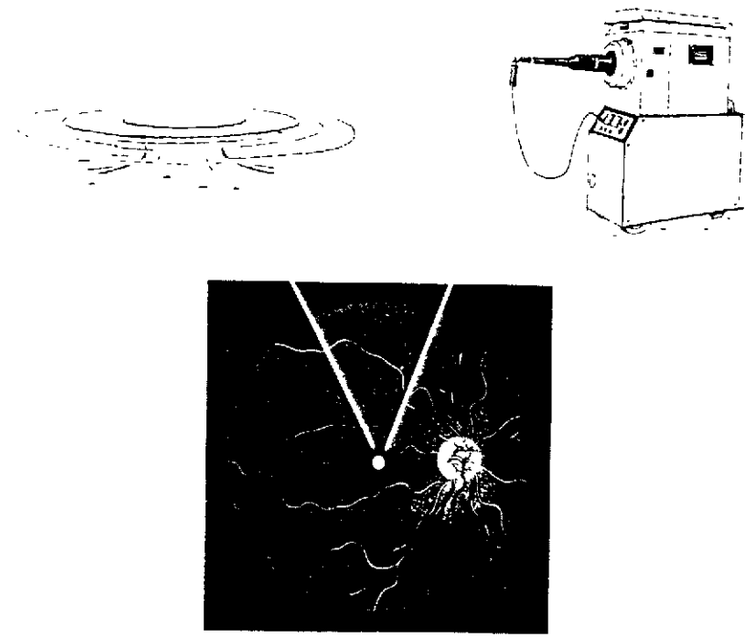
Retinal burns the most immediate effect of nuclear explosions at distances where no other damage to biological structures occurs



Research Light Coagulator simulating Nuclear Exposure in the Laboratory

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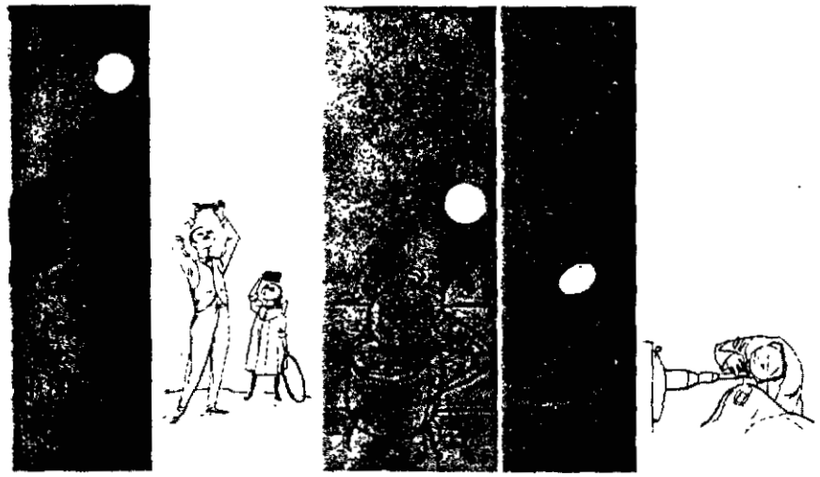
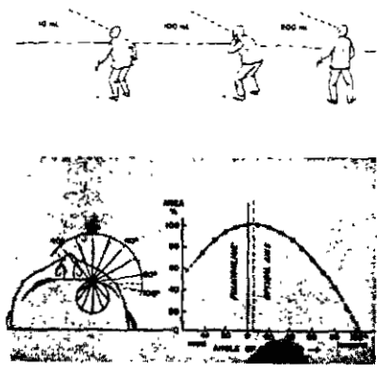
HISTORY



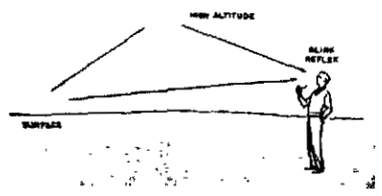
The deleterious effect of visible light on the retina following solar eclipse is known to antiquity (Socrates in Plato). Several hundred eclipse burns were observed in 1912 (Birch-Hirschfeld, A. and Stimmel, L.: Von Graefe's Arch. Ophth. 90:138, 1915). During World War II macular burns were observed in military personnel using powerful binoculars to follow Japanese planes into the sun. (Cordes, F. C.: A.J.O. 27:803, 1944). Test animals received burns at 300 nautical miles at high altitude nuclear tests in the Pacific (Biol. and Environmtl. Eff. Nuclear War, US printing, Washington, 1959). Beneficial use of high intensity light has been utilized since 1951 for clinical treatment of intraocular pathology (Meyer-Schwickerath, G.: Kl. Mbl. Augenhk. 118:194, 1951).

PHYSICAL CONSIDERATIONS



Although the size of the image of the fireball at 200 miles is much smaller than at 10 miles, the intensity of thermal radiation on the retina remains the same at both distances. The intervening atmospheric conditions, however, may modify to a variable degree the intensity of the image.

The angle of the incident light beam to the optical axis affects the light intensity on the fundus. The intensity is reduced by 50 percent at an angle of approximately 70 degrees.



Retinal exposure time depends on three major factors:

It increases with size of the weapon.
It changes with burst altitude.
It is limited by blink reflex.

The retinal image size is equal with a small pupil (day) or a large pupil (night), but the intensity changes with pupil size, being less if the pupil is small.

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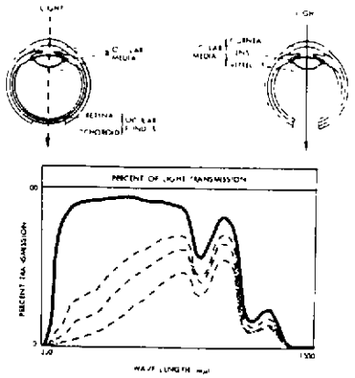
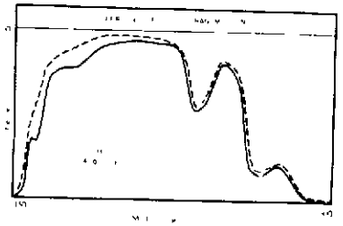
BASIC RESEARCH

Ocular Spectral Characteristics

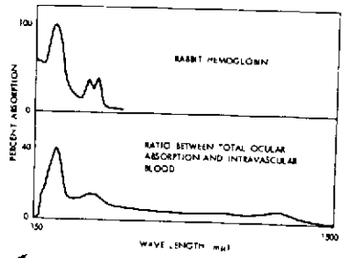


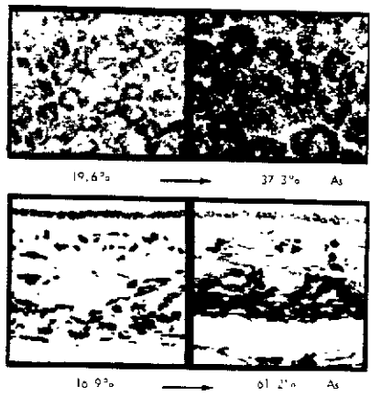
Transmission in albino eyes with choroidal vessels filled with blood and those irrigated with normal saline solution.

Spectral transmission through light, medium and dark pigmented fundi and spectral transmission of ocular media



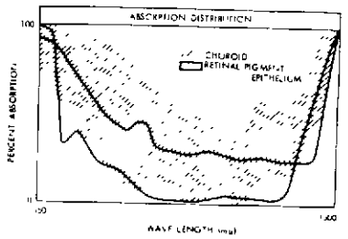
Absorption spectrum of diluted rabbit hemoglobin (top).
Ratio between absorption spectrum of blood-filled and irrigated choroidal vessels, corresponding to light absorption by intravascular blood (bottom).





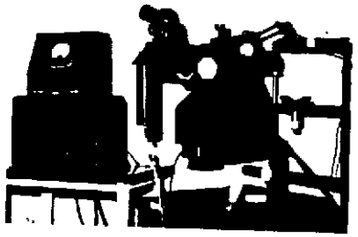
Range of absorption in human retinal pigment epithelium (area between solid lines) and choroid (shaded area).

Pigment density of retinal pigment epithelium and of the choroid varies considerably from individual to individual but also within one and the same eye.

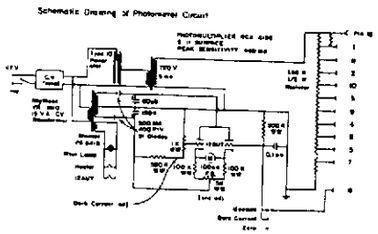


BASIC RESEARCH

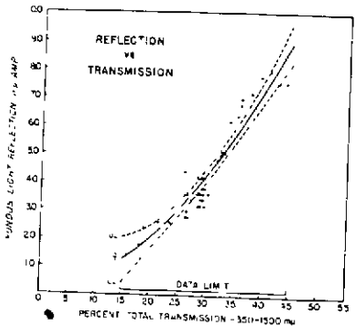
Fundus Reflectance



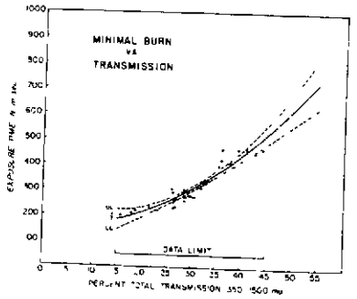
Photomultiplier tube attached to Zeiss funduscamera. This arrangement allows for estimation of pigment density by reflected light from the ocular fundus and thus allows an estimation of the susceptibility to retinal thermal injury

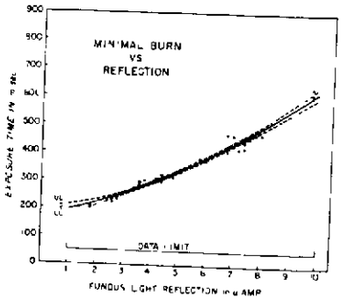


Electrical circuit diagram of the power unit.



Correlation of fundus pigment density vs. threshold burns and ocular transmission.





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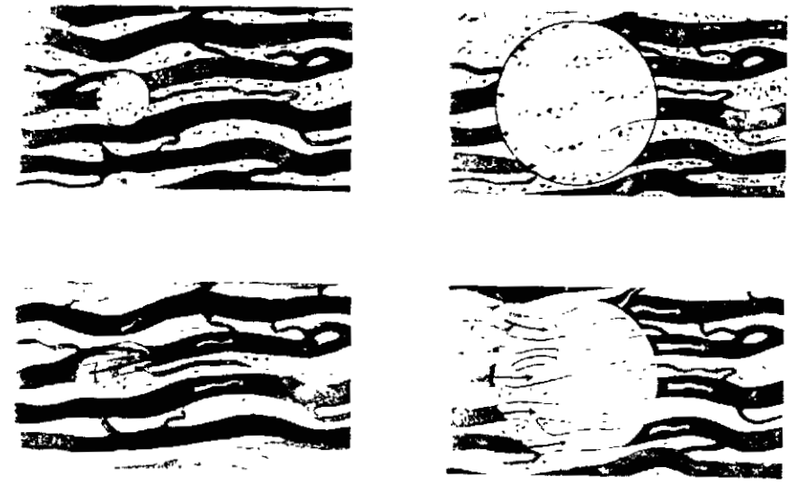
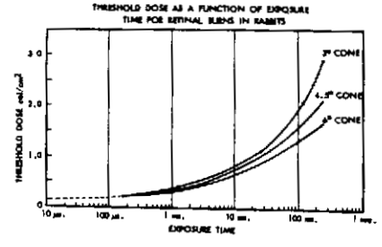
Heat Conduction by Tissue and Blood Flow



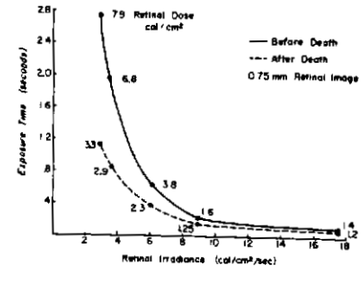
At very short exposure times tissue conduction and conduction by blood flow play an insignificant role. The energy required to produce a thermal lesion is therefore the same for both, large and small burns.

During long exposures, a large amount of heat is carried away by blood flow, thus, more energy has to be employed to produce a burn.



Threshold dose as a function of exposure time for different sizes of retinal burns in rabbits: A conduction phenomenon. Note, at very short exposure times (175 μsec) the required energy for producing a small or large burn is equal. In prolonging the exposure time the smaller burns require more energy than the larger burns since the thermal gradient is greater for the small lesion.

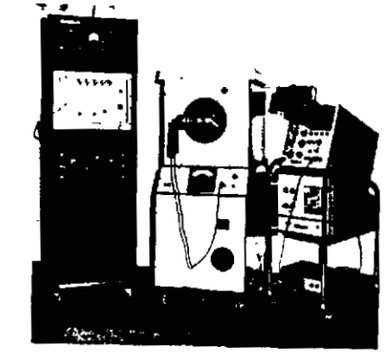
RETINAL IRRADIANCE vs EXPOSURE TIME



Influence of rate of blood flow and tissue conductivity on thermal threshold lesions. The area between the curves gives the difference of energy required for producing a lesion. Top curve represents energy with blood flow intact. Bottom curve represents energy with blood flow ceased.

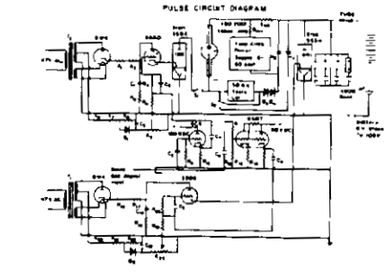
BASIC RESEARCH

Laboratory Arrangement Research Light Coagulator



High pulsed light source with digital delay generator and oscilloscope.

Electrical circuit diagram



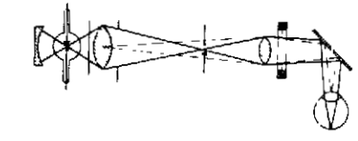
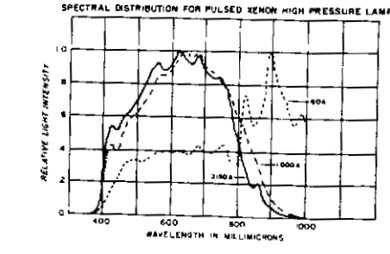
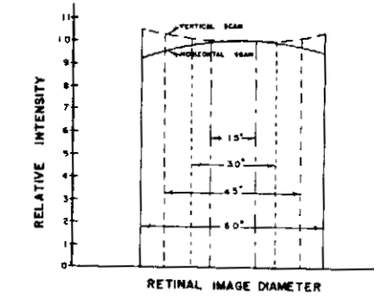


Diagram of optical system.

Spectral distribution for various currents.



RETINAL IMAGE UNIFORMITY



Variation of irradiance over the retinal image.

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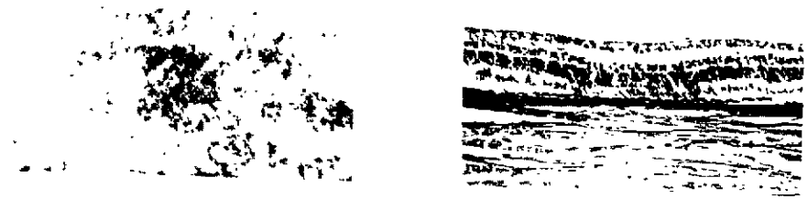
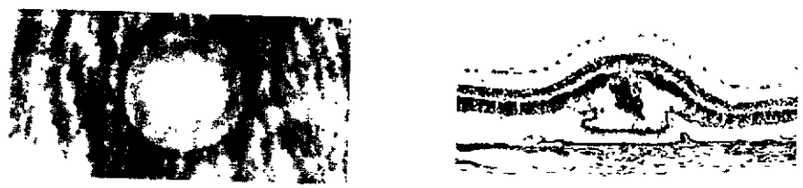
APPLIED RESEARCH

Fundus—Photographs and Histology



Mild burn.

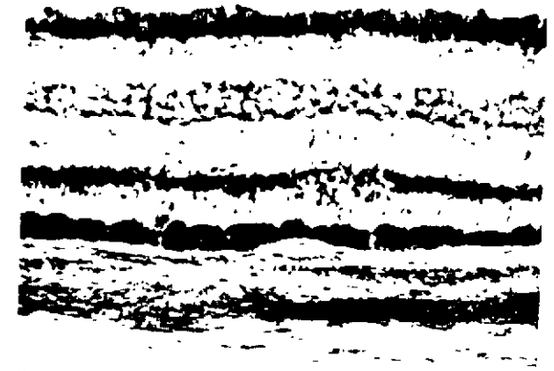


Moderate burn.

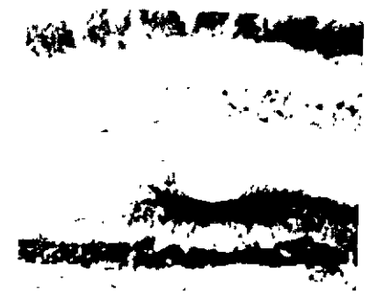
Heavy burn.

APPLIED RESEARCH

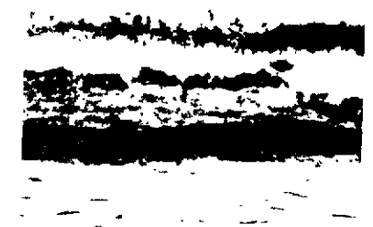
Histochemistry



Normal localization of DPN diaphorase activity in the rabbit retina



After short light exposure (175/μsec, 0.15 cal/cm^2). Note the "steep" margin between stained and unstained ellipsoids.



After long light exposure (30 msec, 1.2 cal/cm^2). Note "sloping" margin between stained and unstained ellipsoids.

The ganglion cells appear unaffected after short exposures.

Involvement of the ganglion cells after long exposures.

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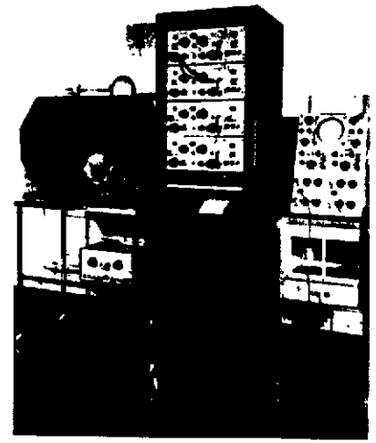
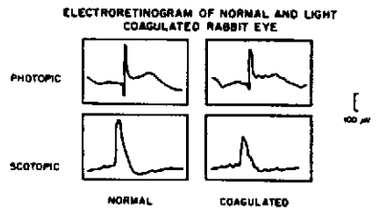
APPLIED RESEARCH

Electroretinography

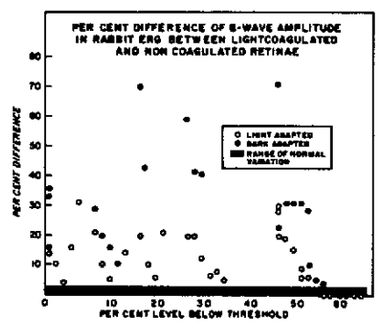
Experimental arrangement (Screened-in cage, Sanborn recorder, Tectronix Dual Oscilloscope 555).





Typical difference between tracings of normal and light exposed retina (175/μsec. 0.08 cal/cm²).

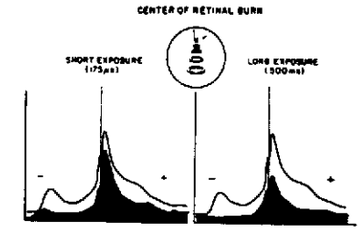
Scattergram of percent amplitude variation in subclinical exposures. Note, ERG changes with reduced B wave amplitude occurred after exposures 50 percent below energies required for a visible lesion.

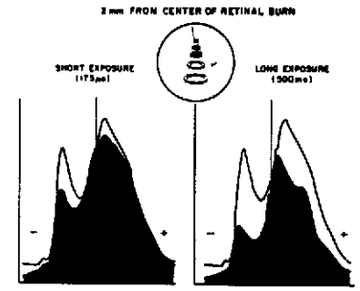


APPLIED RESEARCH

Microagarelectrophoresis and Densitometry

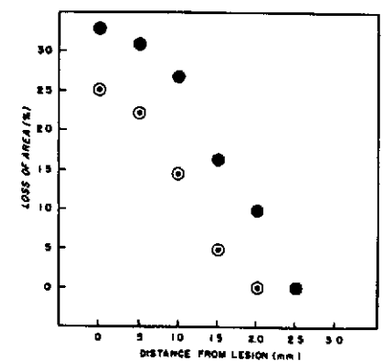
Alterations in center of light exposure. (Outer line represents normal proteinogram of the retina.)





Alterations in 2 mm distance from center of light exposure.

A relationship of area loss (%) in regard to the disc (mm) from the center of the burn. Area loss of retina with long exposure (30 msec) is indicated by solid circles. Area loss of retina with short exposure (175 μsec) is indicated by a circle with a center dot.



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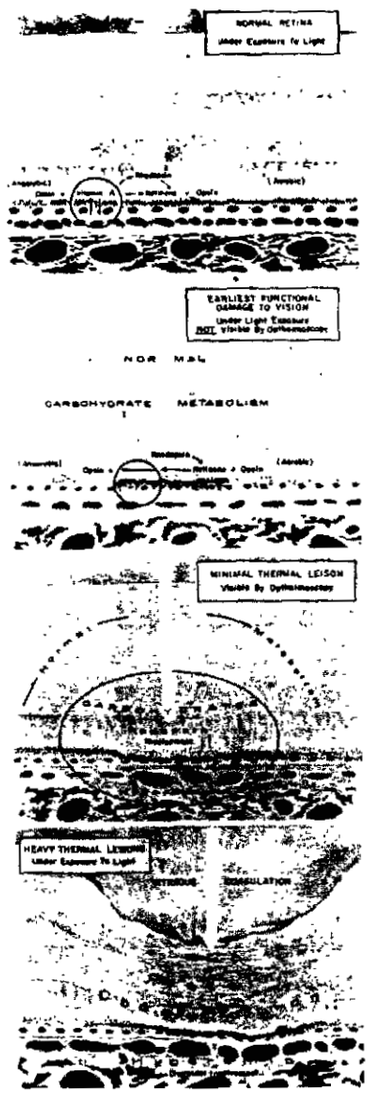
THEORY OF RETINAL DAMAGE UNDER LIGHT EXPOSURE

Normal Retina

Very mild thermal injury. Only retinal pigment epithelium is involved, causing interference with metabolic exchange.

Moderate retinal burn involving retinal respiratory enzymes, but still dependent on pigment density.

Heavy burns involve all layers of the retina, the choroid and sclera as well.



RESULTS

Large burns require *less* energy at *long* exposure times than *small* burns.

Small *and* large burns require *equal* energy at very *short* exposure times.

For *longer* exposure times the delivered energy has to be *increased* due to conduction phenomena even if the burn size is unchanged.

For long exposure times the burn lesion originates at the center of the image and grows progressively until for moderate to severe burns the lesion becomes greater than the image size. This is a heat conduction phenomenon.

Thermal conduction can be demonstrated by changes in retinal enzyme activity and electrophoretic protein pattern.

Blood flow affects greatly the amount of energy required at exposure times *greater than 0.3 sec.*, but is *insignificant below 0.03 sec.*

Fundus pigmentation influences greatly the required energy for visible as well as for functional retinal burns.

Fundus reflectance measurements allow to determine susceptibility to retinal thermal injury. Reflectance and required energy to produce a burn increase or decrease essentially linear.

Changes in the electrical potential in the retina as measured by the ERG technique occur at lower energies than those demonstrable by other laboratory means.

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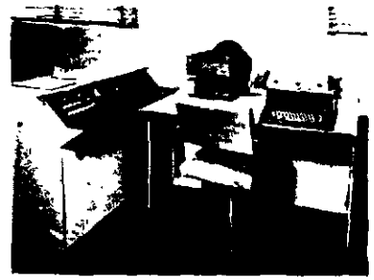
RESULTS

Computer Evaluation



PERCENT SPECTRAL ABSORPTION OF THE HUMAN EYE

Spectral Distribution	*Ocular Media*	*Pigment Epithelium (PE)*	*Choroid (Ch)*	*Entire Fundus*	*Intravascular Blood*	*TOTAL*
Uniform intensity	45	7-22	5-23	34	7	83
5800°K (roughly equal nuclear explosion)	18	6-17	4-18	26	5	46
XBO 2001	13	5-16	4-20	26	5	41

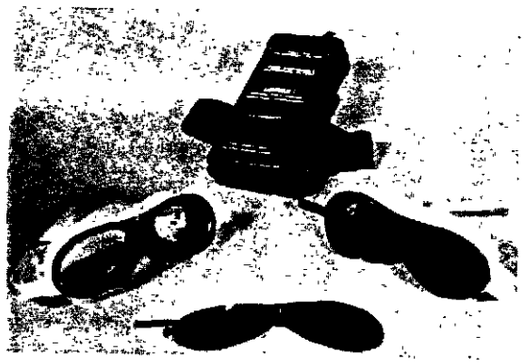
THE THERMAL DOSE DELIVERED IN 150 msec TO THE HUMAN RETINA FOR VARIOUS WEAPON YIELDS AND DISTANCES

Weapon yield KT	*Distance in Km*	*Retinal image size (mm)*	*Total thermal dose on the retina cal/cm²*	*Thermal dose on the retina in 150 msec cal/cm²*	*Average irradiance during first 150 msec on the retina cal/cm²/sec*
1	24.2	0.05	8.7	6.5	43.3
1	15.1	0.08	21.0	15.8	105.0
1	12.2	0.10	28.0	21.0	140.0
20	27.0	0.15	12.0	3.4	22.7
20	20.2	0.20	23.0	6.5	43.3
20	16.1	0.25	34.0	9.7	64.7
50	23.3	0.25	20.0	3.0	20.0
50	19.4	0.30	30.0	4.6	30.7
50	16.7	0.35	40.0	6.1	40.7
100	25.5	0.30	19.0	2.3	15.3
100	21.8	0.35	27.5	3.3	22.0
100	19.9	0.40	35.0	4.2	28.0

150 msec approximates the blink reflex. The thermal dose delivered within this time interval to the retina varies with the weapon yield, and is larger for the smaller weapons. Therefore the smaller weapons are particularly hazardous to the eye.

MILITARY PROTECTIVE DEVICES

Electromechanical goggles. The electromechanical goggle is a shutter device closing in approximately three ten-thousandths of a second. The silicon solar cells located above each lens "see" the nuclear flash. The resulting current activates electronic circuitry which fires a small detonator closing the lens shutter. The power supply and associated electronic circuitry are contained in the small white box held in the wearer's left hand.



Irreversible (one-way) phototropic goggles. Phototropic filters have the property of darkening on exposure to light. The goggle without the phototropic filter is shown on the left. The unactivated phototropic filter is in the center foreground. The goggle with the activated filter in place is on the right. The plastic pocket in the center background contains extra filters. In use, the goggles are worn with the unactivated filter in place during nighttime operations.

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