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MASTER

LOS ALAMOS SCIENTIFIC LABORATORY
of the
University of California
LOS ALAMOS • NEW MEXICO

Laser Safety Program

UNITED STATES
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Laser Safety Program

by

T. E. Ehrenkranz
H. J. Ettinger

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FOREWORD

This compilation has been made and issued to show how a simple, direct safety program for a new hazard was developed.

The material was originally put together at the request of USAEC Headquarters. It is now being distributed generally as an informal report, to show a way of dealing with hazards that has been found effective in a large, diversified research laboratory.

H.C. \$ 3.00; MN 65

LASER SAFETY PROGRAM

by

T. E. Ehrenkranz and H. J. Ettinger

Health and safety personnel at the Los Alamos Scientific Laboratory are expected to become informed about the technical aspects of any new program or activity, and then develop a safety program which causes minimum interference with technical operations while ensuring an acceptably low level of exposure to hazard. Restrictive policies and procedures are limited to those necessary and sufficient to reduce hazardous exposures. Standard Operating Procedures are instituted only where appropriate: safe methods and procedures are identified, written in a formal manner, approved, and then followed.

In this Laboratory, reliance is placed basically on the safety training and safety discipline of the workers, and on their ability to recognize and respect hazards. Many of the restrictions imposed by other organizations regarding work with lasers are not used by this Laboratory. In particular, limitations on workers because of improbable or impertinent medical considerations are avoided.

The safety and industrial hygiene engineers keep in touch with work at LASL, with corresponding practices elsewhere, and with the current literature. Thus they can inform local scientists, technicians, and administrators, by memoranda or informally, of developments relating to safety. Of particular interest is the dissemination of information relating to accidents or incidents.

This compilation shows the development of a safety program for the use of lasers. Both the high intensity and monochromaticity of laser light contribute to the potential hazard; the intense output can be

concentrated on a much smaller retinal image than can other light sources. In addition to the retina, any exposed tissue may be subject to injury.

A useful tool in the LASL laser safety program is a current list of laser users. This is kept up to date through notification by the Supply and Property Department of all laser purchases and through routine safety inspections of Laboratory facilities. Each user is examined by an ophthalmologist consultant to the Industrial Medicine Group. A fundus photograph is part of the examination. Re-examination is scheduled about yearly for all users and more often for people heavily involved in laser work. The list of laser users helps in tabulating observations made during inspection visits and also serves as a mailing list for safety information memoranda.

The first example (Exhibit A) which follows is from the LASL Health and Safety Manual, dated April 1965. The second (Exhibit B) is a draft of a subsequent requirement for SOP's for laser use with a memorandum of transmittal (April 1967) showing how the SOP scope was developed in cooperation with users. There follow, in chronological order, seven memoranda; the first (Exhibit C) is an AEC Health and Safety Information release and the succeeding ones (Exhibits D - I) illustrate continuing activity of the safety and industrial hygiene workers in the program. The compilation concludes with three tables: the first is a summary of laser safety recommendations prepared during the development of the LASL program; the second, a tabulation of exposure thresholds; and the third, literature references.

C. LASERS

Lasers are devices for producing collimated beams of intense, coherent, high-frequency electromagnetic radiation with the frequency of such radiation in the visible portion of the spectrum. Such equipment is widely used in research, for communication, and even for specialized welding. The unique feature of the Laser beam which causes particular concern is the extremely high intensity of short light pulses and the high degree of collimation obtained.

At the present time, the safe threshold for exposure to a Laser beam has not been defined; therefore, all work with Lasers must be designed to minimize exposure, principally eye exposure. H-Division has set the following policies as mandatory for all Laser installations (including low power gas Lasers):

1. Lasers must be used only in controlled access areas. Doors can be locked, or signs can be posted at entrances stating that a Laser is in use. Signs can be removed or turned around when not needed.
2. Direct viewing of the Laser beam is never permitted.
3. All personnel working with Lasers should arrange eye examinations through Group H-2.
4. If personnel experience after-images, they must contact Group H-2 immediately.
5. All personnel working with Lasers must be aware of the associated hazards and the required precautions.
6. "Laser Safety Glasses" can be considered only as a supplementary safeguard. The glasses may deteriorate with time. Since the safe threshold is not known, wearing "Laser Safety Glasses" does not relax any of the other safeguards outlined in this memorandum.
7. Operating personnel should shut their eyes or look away when the Laser is fired.

Personnel using Lasers shall consider and discuss with their supervisors the following provisions as they are applicable to their work, and establish procedures suitable to their particular experiment:

1. Procedural or physical safeguards to prevent accidental activation during Laser alignment or experimentation.
2. A distinctive signal, such as a pilot light or buzzer, indicating the status of the power supply, and a countdown before pulsing.

3. Painting wall surfaces to minimize reflected beams.
4. Lighting work areas to keep the eye pupils as small as possible.
5. The associated hazards of high voltage supplies, capacitors, cryogenic coolants and flash tubes.

The requirements listed above are from "Required Procedures for Working with Lasers," memorandum from H-2, H-3, and H-5, February 19, 1965.

D. ULTRAVIOLET RADIATION

1. Introduction

Ultraviolet radiation is defined as electromagnetic radiation of wave length between 40 and 4000 Å. Above 4000 Å is the visible light range, and below 40 Å is the X- and gamma-ray region. The region between 40 and 2000 Å is called "extreme ultraviolet," and usually does not present any health hazard because radiation at this wave length is strongly absorbed by air. Between 2000 and 4000 Å are the "far" and "near ultraviolet," regions which may present a potential health hazard.

Some sources of ultraviolet radiation at Los Alamos are: welding operations, germicidal or bactericidal lamps, carbon arc lamps, mercury lamps, and black lights.

2. Effects

The effects of ultraviolet exposure are determined by radiation dosage and wave length, body organs exposed, individual sensitivity, and exposure time. The eyes are most sensitive, and overexposure to ultraviolet results in painful irritation of the conjunctiva and eyelids. Skin exposure can produce severe erythema. At 3200 Å ultraviolet radiation produces virtually no skin erythema. Exposure to 2537 and 2970 Å ultraviolet radiation produces maximum erythema effects.

Welding operations produce intense ultraviolet radiation at 2537 and 2970 Å. Germicidal lamps are designed to produce ultraviolet radiation at 2537 Å, because this wave length is most effective as a germicidal agent. Black lamps operate at 3650 Å, and therefore do not present any hazard.

OFFICE MEMORANDUM

TO : Division Leaders and Department Heads DATE: April 19, 1967

FROM : Roy Reider, Safety Director

SUBJECT: MANDATORY STANDARD OPERATING PROCEDURES FOR LASERS (SECOND DRAFT)

SYMBOL : H-3

REFERENCE : Letter of March 1, 1967, Reider to Distribution, subject: same as above.

On April 12, 1967 the first draft of subject memorandum was discussed by representatives of H-Division and groups with significant comments on it. We believe that the attached second draft incorporates all suggestions. If there are no more comments by May 15, 1967 it will be included in the LASL Health and Safety Manual as a general requirement.

In addition to minor editorial changes, this draft differs from the original in the following:

1. For c.w. lasers a written procedure will be required above 50 milliwatts rather than above 100.
2. We seek to clarify that the procedures will cover general experimental set-ups and will need to be amended only when safety aspects are significantly altered.
3. A statement was added to clarify also, that turning on equipment need not await H-Division approval.
4. Purpose of the experiment will not need to be stated.
5. Alignment procedure will not need to be outlined.

TEE:jn

Enc: Second draft

cc: Dr. H. O. Whipple, H-2, w/enc.
H. F. Schulte, H-5, w/enc.
H. Ettinger, H-5, w/enc.

OFFICE MEMORANDUM

TO : Division Leaders and Department Heads

DATE: April 19, 1967

FROM : H-2, H-3, H-5

SUBJECT: STANDARD OPERATING PROCEDURES FOR LASERS

SYMBOL : H-3

SECOND
DRAFT
SECOND

Standard operating procedures are required for pulsed lasers and c.w. lasers of more than 50 milliwatts power. This is in addition to the provisions detailed in the LASL Health and Safety Manual, Section IX C "Lasers."

The procedures are to cover a general experimental set-up and are to be revised when there is a change which significantly affects the safety of the operation, such as a change in area access controls, alignment safeguards, etc. Such changes could be cared for as an amendment to the original written procedures.

The procedure is to be reviewed by the group leaders and submitted to H-3 for approval (H-3 is to consult H-2 and H-5 as necessary. It is not intended that experimenters delay their work until H-Division approval is received.) The procedure should be posted in the laser area. It is to contain the following information:

1. Names of persons doing the work.

Note: It is recommended that persons with monocular vision, that is, with less than 20/100 vision in the poorer eye be discouraged from working with lasers. (The intent here is not to prohibit such persons from working with lasers)

for research purposes on a casual basis, but to limit their exposure by discouraging their assignment to "routine" laser work.)

2. Location of work.
3. Type of laser, approximate energy per pulse, pulse duration, or c.w. watts.
4. Access controls to laser area.
5. Description of physical and procedural safeguards which will be used during alignment.
6. Precautions that will be taken to prevent accidental charging or accidental operation of pulsed lasers.
7. Description of signals that will be used to indicate charging or imminent firing of pulsed lasers; and count-down procedure, if applicable.
8. How will eyes be protected; e.g., remote operation, or count-down, or complete enclosure of beams.

Note: Laser filter goggles may only be used for protection from stray light. Their use does not relax any of the other safeguards. Direct viewing of laser beam is never permitted.
9. Electrical safety precaution for high voltage power supplies.

HJE/TEE:jn

HEALTH and SAFETY

information

United States Atomic Energy Commission

ISSUE NO. 159

March 13, 1963

EYE HAZARDS FROM OPTICAL MASERS

MASERS are devices for producing collimated beams of intense, coherent, high frequency electromagnetic radiation. When the frequency of such radiation is in the visible portion of the spectrum, the device is known as a LASER. Such equipment is widely used in research, for communication, and even for specialized welding. Several LASERS are already in use at Los Alamos. Since these are quite new, little is really known of the effect of such intense light beams on tissue. It seems reasonable to expect that a sufficiently intense beam can cause burns and, particularly, eye damage, since eye injury can be produced by other visible light sources, such as sunlight, arc welding, and xenon flash tubes. The unique features of the LASER beam which cause particular concern are the extremely high intensity of the short pulses of light and the high degree of collimation which can be obtained.

Animal experiments using sunlight have demonstrated that the degree of eye injury is dependent on both the total amount of energy delivered per unit area and the rate at which the energy is delivered. A total dose of 20 cal/cm² delivered over a 30-second exposure period caused no damage, while 25 cal/cm² over the same exposure period caused burns; 8 cal/cm² delivered in 10 seconds also caused burns. Exposure of a rabbit's eye to the beam of a ruby LASER, whose output was 0.1 joule with a 1 cm diameter beam in a 0.5 millisecond burst, caused lesions in one burst. This corresponds to a dose of only .03 cal/cm², but delivered at a dose rate one hundred times that which produced no damage in the sunlight experiments.

Because of the high degree of collimation of the LASER beam, the intensity diminishes only slightly even at great distances. Thus, eye damage could be produced even at a distance of several miles if one looked directly into the beam. Also, surfaces of high reflectivity should not be placed in the path of the beam, since an appreciable fraction of the light may be directed into an unprotected eye. Two cases of minor retinal burns and one case of subcutaneous skin burn have been reported among persons working with LASERS. It seems likely that beams of even higher intensity will be achieved as these devices are improved. Such beams would be capable of causing serious skin burns or even igniting some materials.

March 13, 1963

Thus, the LASER is a device which must be handled with due caution and respect for the potentialities of the beam produced. Possibilities of electric shock, x-radiation from the power source and eye damage from exposure to the light from the flash tubes in the LASER also should be recognized.

Report by H-3 and H-5, Los Alamos Scientific Laboratory.

Division of Operational Safety
U. S. Atomic Energy Commission
Washington 25, D. C.

OFFICE MEMORANDUM

TO : Distribution

DATE: March 20, 1964

FROM : Safety Office

SUBJECT: ELECTRIC SHOCK FROM THE CAPACITOR POWER SOURCE OF A LASER

SYMBOL : H-3

Recently in this Laboratory an engineer suffered a potentially serious electric shock while troubleshooting a laser flashlamp with the assistance of a technician. The energy source was the 875 μ F capacitor of the laser power supply, charged to 900 V. at the time of the incident. Thus more than 300 joules were available. While this is many times larger than the "safe" threshold of capacitor shocks, the employee sustained only minor burns on the hands and temporary discomfort.

Leading up to the injury the engineer was working with the exposed terminals of the flashlamp (see schematic diagram). The coaxial cable had been connected to the flashlamp all along. The engineer had been asking his assistant, who was stationed alongside the power supply about four feet away, to turn the power on or off, as required. Neither person was facing the voltmeter when the accident occurred and it is probable that the employee forgot that his last instruction was to have the power turned on.

The following mechanical and procedural safeguards could have prevented this accident:

1. Both persons facing the voltmeter and controls of the power supply.
2. The use of a pilot light or audible signal in addition to the voltmeter to prominently indicate charge on the capacitor.

But more important than the above,

3. Initially discussing the hazards of the operation, and clearly stating what kinds of operations will be performed and what signals will be given to the helper and how he is to respond.

OFFICE MEMORANDUM

TO : Distribution DATE: June 7, 1965

FROM : H-3 and H-5

SUBJECT: LASER OPERATIONS

SYMBOL : H-3

REFERENCE: Letter of February 19, 1965, H-2, H-3 and H-5 to Distribution, subject:
"Required Procedures for Working with Lasers."

Safe eye exposure levels for laser beams will probably not be established for some years, until there will be enough experience to evaluate cumulative low power effects - if any. It follows, that if safe exposure levels are not known, then one cannot confidently assume that it is safe to look at laser beam reflections. While we realize that there is an understandable temptation to look for reflected light to verify that the instrument "lased," because of the possible hazards we urge that you adopt a safer procedure: at Sandia Corporation it is the practice to fasten carbon paper, Polaroid film or, in at least one instance, a razor blade to the target, and either count down and shut eyes when the laser is fired, or fire remotely. To check the aim of the beam it is possible to scribe a grid work or a target at the carbon paper or the film and position this over the desired spot. Other aids for adjustments used at Sandia are high intensity light bulbs with apertures, and collimating telescopes.

Note: Nitrobenzene (used in Kerr cells) is very toxic; avoid breathing vapor and skin contact.

Theodore E. Ehrenkranz
Theodore E. Ehrenkranz
Safety Engineer, H-3

Harry J. Eyttinger
Harry J. Eyttinger
Industrial Hygiene
Field Section, H-3

TEE:jn

Distribution:

List of laser users

OFFICE MEMORANDUM

TO : List of Laser Users

DATE: October 29, 1965

FROM : H-3, H-5 *TEE HJE*

SUBJECT: EYE INJURY BY LASER

SYMBOL :

The first documented eye injury caused by a laser is described in the Archives of Ophthalmology, Vol. 74, September 1965, and in Laser Focus, August 15, 1965.

The accident occurred in Oregon in February 1964. A graduate student lost the sight of his right eye when a ruby laser accidentally fired while the student, leaning over the apparatus, was adjusting a prism. The laser output was estimated to be 20 joules and the pulse duration 0.8 milliseconds. An argon flash tube was used to excite the ruby.

At the time of the accident the capacitors were charged and the argon tube accidentally fired. The second reference suggests the possibility that the capacitors re-charged due to a dielectric stress relief effect and that the student accidentally triggered the flash lamp.

In any case, it is apparent, that no effective method was used to isolate the power supply while working on the optics.

TEE/HJE:jn

OFFICE MEMORANDUM

TO : Distribution

DATE: April 22, 1966

FROM : *DR H.F.S.*
H-3 and H-5

SUBJECT: DIRECT VIEWING OF C.W. LASERS

SYMBOL: H-3

The LASL Health and Safety Manual (Section IX C, Lasers), states that direct viewing of a Laser beam is never permitted. In spite of this warning, people working with low powered C.W. Lasers have created situations where direct viewing may occur inadvertently. The assumption has been made that the relatively low power levels provide adequate protection. This is not true. Assuming a retinal image size of 3 microns, direct viewing of a 5 milli-watt C.W. Laser will produce a power density on the retina of approximately 60,000 watts/cm². Within the blink reflex time, this will result in an energy density of over 2,000 calories/cm². Even when a diverging lens system is used for holography, energy densities on the order of 75 calories/cm² can be produced on the retina.

All personnel working with C.W. Lasers are asked to review their operating procedures to eliminate any possibility of direct viewing the Laser beam.

People often ask why looking at the sun for the normal "blink-time" (1/5 - 1/7 second) does not usually produce injury, while a gas Laser might. Laser light is monochromatic and focuses to a much smaller retinal image than sunlight resulting in a relatively high power density at the retina.

HJE/TEE:jn

Distribution: Laser users

OFFICE MEMORANDUM

TO : Distribution

DATE: September 6, 1966

FROM : T. E. Ehrenkranz, Safety Engineer TEE

SUBJECT: MORE ABOUT GAS LASERS

SYMBOL : H-3

The following is a rough comparison of the image on the retina produced by a low powered gas laser and the image produced by the sun, and corresponding power densities.

Assume that a gas laser has an output of 3 milliwatts and a 3 mm beam diameter. A dark-adapted eye has a larger pupil diameter than this, so at close range such as about one meter with about 10^{-3} radian beam divergence almost all the energy could enter the eye. A realistic retinal diffracted image diameter for red laser light is $10\text{-}20\mu$ (1). Taking 15μ the energy density could be about 1500 watts/cm² on the retina, if the laser were accidentally viewed on-axis from a distance of a meter or two.

The sun's image on the retina - with 2 mm diameter light adapted pupil - is about 150μ in diameter (2). The sun's radiation is about 0.14 watt/cm² (3) and approximately 0.006 watt will enter the eye and produce a retinal power density of about 30 watts/cm².

The blink reflex limits exposure from the sun but is not quick enough to protect the eye from laser overexposures. Also, the light adapted eye admits less (laser) light and focuses it to a larger image, therefore, whenever possible one should work in a light room.

REFERENCES

- (1) Personal communication from D. E. Jones, LRL, November 8, 1965.
- (2) Duke-Elder. Textbook of Ophthalmology, Vol. VI.
- (3) Koller, Ultraviolet Radiation. Wiley, 1965.

TEE:jn

Distribution: Laser Users

OFFICE MEMORANDUM

TO : THE FILE (Lasers)

DATE: April 26, 1967

FROM : Harry J. Ettinger

SUBJECT: SURVEY OF LASER INSTALLATIONS

SYMBOL : H-5

During April 1967, Ted Ehrenkranz and Harry Ettinger inspected all active laser installations. At the present time, the following lasers are at LASL or on order:

Ruby Lasers	14
Helium Neon	32
Pulsed Argon	4
Carbon Dioxide	1

Everyone working with this equipment is aware of the potential hazards associated with the laser beam and the associated high voltage power supplies. People working with Ruby Lasers use count down procedures and/or look away when the laser is fired. Direct viewing of the beam from CW lasers (including those with outputs less than 1 milliwatt) is avoided. Some groups use laser safety glasses as a secondary means of protection. They are aware that this does not relax any of the safety requirements for laser work.

Approximately 100 people have obtained eye examinations from Group H-2, and 40 or more people are scheduled for these examinations. A schedule for follow-up examinations has not yet been set.

Three installations could be improved: (1) The Ruby Laser used by Group P-13 (Michael) automatically recharges. Rewiring to eliminate this feature is not practical since the laser is a demonstrator model on loan to LASL. (2) Personnel can walk across the 5 milliwatt CW laser beam used by Karr and Burkhardt (P-14). This is a limited access area and the beam is below eye level. (3) The 10 milliwatt CW laser beam can be reflected from the sensor used in the P-17 test setup (Hammel). Viewing of the sensor is necessary for alignment. Off-axis viewing procedures are used to minimize any reflections. These three installations will be given further attention.

Attached is a tabular summary of existing and proposed laser installations at LASL.

cp

Attachment: Summary

cc: Dr. H. Whipple, H-2, w/encl.
T. Ehrenkranz, H-3, w/encl.

Harry J. Ettinger
Engineering Section
Industrial Hygiene Group

Group	Laser Location	Laser Type	Users	Comments
J-10	Adm. Bldg.	He Ne (0.3 mw)	Peek	To be used at NTS for alignment.
J-14	Adm. Bldg.	He Ne ($\frac{1}{2}$ mw)	Westervelt	Used at NTS for alignment. Viewing only of reflection from diffuse surface.
J-14	Adm. Bldg.	He Ne (1 mw)	Westervelt	To be used for interferometer. Will be enclosed.
MP-3	--	He Ne	Hart	On order.
N-1	TA-46 Bldg. 1	Ruby (20 J)	Morrison, Cowder	Totally enclosed. Warning sign & signal. Laser goggles available. Good setup.
N-1	TA-46	He Ne (0.3 mw)	Morrison, Cowder	On order. For alignment. Beam will not be viewed directly.
N-1	TA-46	Ruby (100 J)	Morrison, Cowder	On order. To be used in Bldg. 31.
N-5	TA-46 Bldg. 1	CO ₂	Erickson	Under construction.
N-7	TA-46 Bldg. 24	Ruby (1 J, milli-sec. pulse)	Sibbit	Access control adequate. Count down; enclosed system.
P-D0	Adm. Bldg. Roof	He Ne (50 mw)	Tuck	Work discontinued.
P-7	Physics Bldg.	Ruby	Mather	Laser being transferred into area. Setup will be reviewed in the future.
P-13	Sherwood	He Ne (70 mw)	Michael	Access control adequate. Operator out of room during test.
P-13	Sherwood	He Ne	Michael	For alignment. No direct viewing of beam.

SUMMARY OF LASER SAFEGUARDS RECOMMENDED BY
TYPICAL LABORATORIES & ORGANIZATIONS

	Control of procurement	Direct viewing not permitted	Indirect viewing not permitted	Safety training	Established operating procedures	Eye examinations, periodically	After-images to be reported to medical department	Control of access to laser area	Warning devices, countdowns	Interlocks	Eliminate reflections in room	Shield optical components	Work in brightly illuminated room	Eliminate combustibles	Guard access to beam path	Approved laser glasses for reflections, or to protect casuals	Protection from electric shock and inadvertent operation	Place caps on collimators (including gas laser)	Film badge for 15 KV or higher power supply; guard against U.V.	Safeguard cryogenic equipment
Industrial Laboratory		X	X	X				X	X							X				
AEC Laboratory, Academic Sponsor		X	(2)				X	X	X	X	X	X	X	X		X	X			X
Industrial Laboratory	X	X	(2)			X	X	X	X		X		X		X		X	X		X
AEC Laboratory		X	(3) X				X	X	X		X		X		X					
Nat'l Safety Council, Campus Safety Ass'n.		X	X	X		X		X			X		X	X		X	X	X		
Ass'n. of Casualty & Surety Companies		X	(2)	X	X	X		X	X		X	X	X	X	X	X	X		X	X
Research Laboratory, Academic Sponsor		X	(1)					X			X	X	X			X	X	X		
LASL		X	(2)	X	X	X	X	X	X		X		X		X		X			X

(1) Governed by table of energy vs. distance.
(2) To be avoided

(3) Use Polaroid film targets to aim beam.

T.E.E.
H-3
5/24/65

PROPOSED LASER EXPOSURE THRESHOLDS

			On Eye	On Retina	Reference
10^{-8} J	Q-switched ruby	Allowable	X		1
2×10^{-8} J	Q-switched ruby	Allowable	X		2
10^{-7} J	Pulsed ruby	Allowable	X		3
10^{-6} J	Pulsed neodymium, 1.06 μ	Allowable	X		3
10^{-8} J	Q-switched ruby	Allowable	X		3
10^{-5} J	Pulsed ruby	Allowable	X		4
10^{-6} J	Q-switched ruby	Allowable	X		4
10^{-7} J	Pulsed ruby	Allowable	X		5
.07 J/cm ²	Q-switched ruby	Visible lesion		X	1
.03 J/cm ²	Q-switched ruby	Damage threshold		X	1
10^{-6} W	Gas laser	Allowable	X		3
.01 cal/cm ²	Gas laser	Allowable		X	6
.1 J/cm ²	Gas laser	Allowable per 1/10 sec.		X	7
10^{-6} W	Gas laser	Allowable	X		7

References

1. Geeraets and Ham.
2. Straub, New York Academy of Science, Vol. 122, 1965.
3. Goldman & Hornby, American Industrial Hygiene Association Journal, 26:553, 1965.
4. Massachusetts Institute of Technology Medical Department. Tent. 1964.
5. Jones & Montan, UCRL-7811.
6. Zaret, Archives Environmental Health, Vol. 10, April 1965.
7. British Ministry of Aviation.

T. E. Ehrenkranz, H-3
December 20, 1966

BIBLIOGRAPHY

1. Ham, W. T., Geeraets, W. J., et al. "Ocular Effects of Laser Radiation." Medical College of Virginia. Issued as DASA-1574.
2. Kohtiao, A., Newton, J., Schwell, H. "Hazards and Physiological Effects of Laser Radiation." New York Academy of Science Annals. Vol 122, 777-779 (1965).
3. Straub, H. W. "Protection of the Human Eye from Laser Radiation." New York Academy of Science Annals. Vol 122, 773-776 (1965).
4. Zaret, M. M. "The Laser Hazard." Archives of Environmental Health. Vol 10, 628-630 (1965).
5. Goldman, L., Hornby, P. "Personnel Protection from High Energy Lasers." American Industrial Hygiene Association Journal, November-December 1965. 553-557.
6. Jones, D. E., Montan, D. N. "Eye Protection Criteria for Laser Radiation." LRL Hazards Control Quarterly Report No. 16, UCRL-7811.
7. Weston, B. A. "Laser Systems, Code of Practice." U.K. Ministry of Aviation, London. NP-16327 (1965).
8. "What You Should Know About Laser Safety." Martin-Marietta Corp., Orlando (1965).
9. "The First Conference on Laser Safety." Martin Company, Orlando, Florida, and Office of the Surgeon General, U. S. Army, Orlando (1966).
10. Rathkey, A. S. "Accidental Laser Burn of the Macula." Archives of Ophthalmology. Vol 74, 346-348 (September 1965).

Notes:

1. References 1 and 2 are reports of basic research
2. References 3, 4 and 5 are of special interest for the development of a program of accident prevention.
3. References 6, 7 and 8 propose numerical values of acceptable exposures.
4. Reference 9 is a summary of the "state of the art."
5. Reference 10 documents an accidental injury.