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Suggested State Regulations for Control of Radiation

Volume II
Nonionizing Radiation

LASERS

1982

Prepared by

Conference of Radiation Control Program Directors, Inc.

U.S. Nuclear Regulatory Commission

U.S. Environmental Protection Agency

and

U.S. DEPARTMENT OF HEALTH AND HUMAN SERVICES

Public Health Service

Food and Drug Administration

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FOREWORD

The laser provides a unique source of electromagnetic radiation with several properties not otherwise found in nature. The radiation is coherent and consequently can be projected over great distances and at high power levels. The physical phenomena of amplification by stimulated emission was first observed in the microwave region giving rise to the maser and was only extended to the visible region of the electromagnetic spectrum in 1960, the device being called the optical maser and laser. As used in these suggested regulations, the term "laser" applies to the wavelength region from 180 nanometers to 1 millimeter with most of the commercially available lasers at present (1982) operating in the region from 400 to 10,600 nanometers. The technology is being actively pushed below 200 nanometers. In the region around 1 nanometer, this radiation would be both ionizing and coherent with the ability to penetrate increasing distances in air. Wavelengths above 3 millimeters are in the microwave region of the electromagnetic spectrum. In the region from about 400 to 710 nanometers, laser radiation is visible to the human eye. Outside this region, the radiation is invisible, increasing the hazard; however, in the ultraviolet region at about 270 nanometers, a person may be able to detect the presence of radiation from the smell of ozone.

The critical body organs at risk are the eye and skin. At high power levels, laser radiation which is capable of cutting titanium would have little trouble cutting through tissue. The need for controls on such lasers is obvious. Not so obvious is the need for controls at low and modest power levels. Light concentrates on the retina of the eye in the spectral region from about 400 to 1,400 nanometers. Consequently at very low power levels, eye injuries can occur. The National Center for Devices and Radiological Health's Radiation Incident Registry and the literature record several laser injuries, mainly involving the eye. This illustrates an important biological fact which must be taken into account when considering laser radiation control. Exposure to laser radiation above certain limits can cause permanent impairment to the important human faculty of sight.

These Suggested State Regulations for Lasers (SSRL) follow the classification scheme for lasers in the National Center for Devices and Radiological Health's laser products performance standard (21 CFR Part 1040) and the maximum permissible exposure concepts of the ANSI laser standard Z136.1-1980. The scheme involves classifying lasers by accessible laser radiation into 4 classes: Class I, Class II, Class III, and Class IV with each succeeding class involving increasingly accessible laser radiation levels and consequently an increased risk of laser radiation injury. Class I lasers have not been shown to cause injury, while Class II and Class III lasers have the potential for causing eye injuries. The higher-power Class III lasers may also cause skin injury. Class IV lasers have the potential for causing eye and skin injuries from indirect exposures. Since the Center is primarily concerned with a manufactured laser product, their classification scheme applies to a product. Users of the SSRL should note that, as defined in Section A.2, the term "laser product" is more inclusive than the term "laser" in that a device is considered a laser product if it is intended to incorporate a laser. Since these regulations are

user oriented, the classification scheme is applied to the product, installation, and to mobile lasers such as those lasers used at temporary job sites outside a permanent installation. The format involves three parts: Part A covering General Provisions including definitions; Part B covering registration provisions; and Part C covering the laser radiation protection provisions, such as maximum permissible exposure limits, specific safety regulations on safety eyewear, signs, labels, and posting. Exemptions are listed in Parts A and B for certain classes of certified lasers.

Special attention was given to the requirements for medical surveillance for persons exposed to laser radiation. This was thought to be important for persons exposed to Class III and IV laser radiation, but the existing eye examining procedures have come under attack as being in some instances worse than potential exposure to laser radiation. It was felt by the Working Group that, by including the ANSI Z136.1 Medical Surveillance Procedures in Appendix A, appropriate procedures would be available for those who want to use them. Furthermore, it has come to the attention of the Working Group that the traumatic eye effects normally encountered in these eye exams given to laser workers can be greatly reduced by careful attention by the physician to light levels in his equipment.

Working with lasers can expose the laser worker to other hazards, such as ionizing radiation from the pump sources; air contamination from beam interaction with air or target materials or the lasing medium; electrical hazards; fire hazards; and cryogenic hazards. At least 3 deaths among laser workers occurred from electrical hazards. These hazards are not addressed in these regulations as it is assumed that other regulations or codes covering these hazards will adequately protect the worker if appropriately enforced.

These Suggested State Regulations for Lasers require the registration of laser facilities, mobile lasers, and persons servicing lasers or laser systems. An exemption is provided for certain activities and facilities involving certified laser products. All uncertified lasers must be registered. Servicing of certified laser products with accessibility to Class IIIb or Class IV laser radiation is not exempt from the registration requirements of the regulations.

In considering adoption of the laser safety regulations, a State should give weight to the total usage and exposure to laser radiation in the State, the laser safety experience in the State, the enhanced worker and public confidence in laser use, and the resource expenditure by both the Agency and laser users in the State if these regulations are to be adopted by the State.

Under Section 360F of the Public Health Service Act, no State or political subdivision of a State shall have any authority either to establish, or to continue in effect, any standard which is applicable to the same aspect of performance of an electronic product for which there is a Federal standard unless the State regulation is identical to the Federal standard. The Suggested State Regulations for Lasers has been prepared so that, if adopted by the States, there should be no conflict between their regulations and the Federal performance standards issued under Section 358 of the Public Health Service Act (42 U.S.C. 263f).

In certain portions of the model laser regulations, States are given an option as to their method of control. Two types of footnotes are used throughout. Footnotes which are designated by numbers are intended to be part of the regulations. Footnotes which are designated by asterisk(s) provide information intended to assist States in drafting their regulations, and should not be incorporated in the regulations. The regulations also contain expressions which have been set off by brackets. The bracketed portions contain either optional provisions, or are used to indicate a need for States to add appropriate language or reference to local codes.

As revision of the Suggested State Regulations for Lasers will be a periodic and continuing process, the Federal Register will be used as a mechanism for publishing a notice of availability on the SSRL, inviting interested persons to submit comments and suggestions on the latest revision. The comments are analyzed by the SSRL Working Group, and a revised draft is prepared on the basis of the analysis of comments. A Technical Review Committee, composed of representatives of the Conference of Radiation Control Program Directors and the participating Federal agencies, conducts a final review of the revised SSRL and rationale and the analysis of comments.

The Suggested State Regulations for Lasers was prepared by a Working Group appointed by the Conference of Radiation Control Program Directors. The Working Group consisted of F. J. Bradley (New York), Joseph Thiel (Texas), and William Bryan (Colorado), with Jack C. Rogers (Los Angeles County) as Chairman. Those assisting in the development of the document as Federal liaison personnel to the Working Group were Robert T. Handren (NCDRH), David D. Royston (NCDRH), Richard A. Peterson (EDRO), and Walter Payne (EDRO). Charles P. Froom (NCDRH) acted as Coordinator for the Working Group. The first SSRL draft went out for public comment in April 1978. The draft was distributed to interested Federal, State, and local officials; international, professional, and standards setting organizations; and industrial associations. There were approximately 50 responses, which provided about 600 comments. The SSRL incorporates the latest ANSI Z136.1 (1980) recommendations and also responds to the comments.

A rationale was prepared as an accompaniment to the Suggested State Regulations for Lasers to provide the States and others using and reviewing the model regulations with background information on the basis and approaches of the SSRL Working Group. As part of the rationale, there is a section on Matters for Future Consideration with one item listed in this SSRL edition.

The Suggested State Regulations for Lasers was reviewed by the Technical Review Committee composed of J. Dale McHard (Oklahoma) as Chairman, A.J. Hazle (Colorado), and Edgar D. Bailey (Texas) representing the Conference of Radiation Control Program Directors, Inc.; and representatives of the National Center for Devices and Radiological Health, FDA.

The Suggested State Regulations for Lasers was endorsed by the Executive Board of the Conference of Radiation Control Program Directors, Inc., the National Center for Devices and Radiological Health, FDA, the U.S. Environmental Protection Agency, and the U.S. Nuclear Regulatory Commission. The American National Standards Committee Z136 on the Safe Use of Lasers reviewed the final draft of the SSRL.

Selected material in this document (e.g., Tables IVa - IVc; Table VIII; Figures 3 - 12; and Appendices A, D, and E) is reproduced with permission from American National Standard Z136.1-1980, copyright 1981 by the American National Standards Institute. Copies of this standard may be purchased from the American National Standards Institute at 1430 Broadway, New York, N.Y. 10018.

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Rationale

PART A

GENERAL PROVISIONS

Sec. A.1 Scope

(a) Except as otherwise specifically exempted, these regulations apply to all persons who receive, possess, acquire, transfer, own, or use lasers which emit or may emit laser radiation. Nothing in Part C of these regulations shall be interpreted as limiting the intentional exposure of patients to laser radiation for the purpose of treatment or use commensurate with the licensed practitioners use of the healing arts.

(b) (1) Laser products certified by a manufacturer to be compliant with the Federal laser product performance standard of 21 CFR Part 1040 applicable at the date of manufacture shall be maintained in compliance with such requirements. Certified laser products which have been modified shall comply with these regulations or the Federal standard.

(2) Uncertified lasers shall meet the requirements of these regulations.

(c) If any conflict arises between the requirements of these regulations and the Federal laser product performance standard with respect to the same aspect of performance for laser products subject to the Federal standard, the requirements of the Federal standard shall apply.

Sec. A.2 Definitions. As used in these regulations:

"Accessible emission level" means the magnitude of emission from laser or collateral radiation of a wavelength and emission duration to which human access is possible as measured under the conditions specified in Section C.9 of these regulations.

"Accessible emission limit" means the maximum accessible emission level permitted within a particular class as set forth in Tables I, II, IIa, IIIa, IIIb, and V.

"Accuracy" means the degree of conformity of a measure to a standard or a true value and not the degree of repeatability or precision with which a measurement is performed.

"Act" means [cite State Radiation Control Act or appropriate State statute].

"Agency" means [cite appropriate State Agency responsible for administration of the Act].

"Aperture" means any opening in a protective housing through which radiation is emitted, thereby allowing human access to such radiation.

"Aperture stop" means an opening serving to limit the size and to define the shape of the area over which radiation is measured.

"Attenuation" means the decrease in the radiant flux of any optical beam as it passes through an absorbing and/or scattering medium.

"Certified laser product" means that the product is certified by a manufacturer pursuant to the requirements of 21 CFR Chapter I Subchapter J.

"Class I dual limits" means, for classification purposes, laser and collateral radiation in the wavelength range of greater than 400 nanometers but less than or equal to 1400 nanometers exceeds the accessible emission limits of Class I if it exceeds both:

- (1) the Class I accessible emission limits for radiant energy within any range of emission duration specified in Table I, and
- (2) the Class I accessible emission limits for integrated radiance within any range of emission duration specified in Table I.

"Class I laser" means any laser which permits human access to laser radiation less than the accessible emission limits of Table I for any combination of emission duration and wavelength range.

"Class II laser" means any laser which permits human access to laser radiation above the accessible emission limits of Table I up to the accessible emission limits of Table II and does not permit human access to laser radiation in excess of the accessible emission limits of Class I for any other emission duration or wavelength range. Class II lasers are separately designated as Class II or Class IIa. Class IIa lasers are those lasers which do not exceed the accessible emission limits of Class I for any emission duration less than or equal to 1×10^3 seconds. Class II laser designation is given to all other Class II lasers as defined above.

"Class III laser" means any laser which permits human access to laser radiation above the accessible emission limits of Table I and, if applicable, Table II, but below the accessible emission limits of Table III. Class III lasers are separately designated as Class IIIa or Class IIIb. Class IIIa lasers are those lasers with an emission duration greater than 3.8×10^{-4} second and in the wavelength range greater than 400 nanometers but less than or equal to 710 nanometers with an irradiance of less than or equal to 2.5×10^{-3} watts cm^{-2} and with a radiant power of less than or equal to 5×10^{-3} watts. Class IIIb laser designation is given to all other Class III lasers as defined above.

"Class IV laser" means any laser which permits human access to laser radiation above the accessible emission limits of Table III.

"Class I, II, III, or IV facility" means a facility which has one or more Class I, II, III, or IV lasers, respectively. In case of facilities possessing more than one laser class, the assigned facility classification shall be determined by the most hazardous class of laser contained therein.

"Collateral radiation" means any electronic product radiation, except laser radiation, emitted by a laser as a result of the operation of the laser(s) or any component of the laser product that is physically necessary for the operation of the laser(s). (The accessible emission and maximum permissible exposure limits for collateral radiation are specified in Table V.)

"Controlled area" means any area where the occupancy and activity of those within is subject to control and supervision for the purpose of protection from radiation hazards.

"Demonstration laser" means any laser manufactured, designed, intended, or used for purposes of demonstration, entertainment, advertising display, or artistic composition.

"Diffuse reflection" means the change of the spatial distribution of a beam of radiation when it is reflected in many directions by a surface or by a medium.

"Electronic product" means:

- (1) any manufactured or assembled product which, when in operation,
 - (i) contains or acts as part of an electronic circuit and
 - (ii) emits, or in the absence of effective shielding or other controls would emit, electronic product radiation, or
- (2) any manufactured or assembled article which is intended for use as a component, part, or accessory of a product described in (1) and which when in operation emits, or in the absence of effective shielding or other controls would emit, such radiation.

"Electronic product radiation" means radiation which is emitted from an electronic product as the result of the operation of an electronic circuit in such product, and includes:

- (1) any ionizing or nonionizing electromagnetic or particulate radiation, or
- (2) any sonic, infrasonic, or ultrasonic wave.

"Energy" means the capacity for doing work. Energy content is commonly used to characterize the output from pulsed lasers and is generally expressed in joules (J).

"Energy density" (see "Radiant exposure").

"Facility" means any location where one or more lasers are used or operated. The confines of any facility shall be designated by the owner of such facility. A part of a building, an entire building, or other structure or plant or, where appropriate, a specified out-of-doors location may be designated as a facility.

"Human access" means access to laser or collateral radiation by any part of the human body.

"Incident" means an event or occurrence which results in a real or suspected accidental exposure to laser radiation which caused or is likely to cause biological damage.

"Individual" means any human being.

"Integrated radiance" means radiant energy per unit area of a radiating surface per unit solid angle of emission, expressed in joules per square centimeter per steradian ($\text{J cm}^{-2} \text{sr}^{-1}$).

"Irradiance" means the radiant power incident on an element of a surface divided by the area of that element, expressed in watts per square centimeter (W cm^{-2}).

"Joule" (J) means a unit of energy: 1 joule = 1 watt second.

"Laser" means any device which can produce or amplify electromagnetic radiation of frequencies between 3×10^{11} and 1.67×10^{15} hertz (or wavelengths in air between 10^{-3} and 1.8×10^{-7} meter) by the process of controlled stimulated emission, including additional incorporated components providing for a total laser system.

"Laser energy source" means any device intended for use in conjunction with a laser to supply energy for the operation of the laser. General energy sources such as electrical supply mains or batteries shall not be considered to constitute laser energy sources.

"Laser product" means any manufactured product or assemblage of components which constitutes, incorporates, or is intended to incorporate a laser or laser system. A laser or laser system which is intended for use as a component of an electronic product shall itself be considered a laser product. (See C.4(a) for applicability requirements.)

"Laser protective device" means any device used to reduce or prevent exposure of personnel to laser radiation. Such devices may include protective eyewear, garments, engineering controls, and operational controls.

"Laser radiation" means all electromagnetic radiation emitted by a laser product within the spectral range specified in the definition of "Laser" in A.2 that is produced as a result of controlled stimulated emission or that is detectable with radiation so produced through the appropriate aperture stop having a diameter, a solid angle of acceptance, and collimating optics as specified in C.9 of these regulations.

"Laser safety officer" (LSO) means any individual, qualified by training and experience in the evaluation and control of laser hazards, who is designated by the registrant and has the authority and responsibility to establish and administer the laser radiation protection program for a particular facility or a particular mobile laser.

"Laser system" means a laser in combination with an appropriate laser energy source, with or without additional incorporated components.

"Maintenance" means the performance of those adjustments or procedures by the user to keep equipment in its intended operating condition. Maintenance does not include operation or service as defined in these regulations.

"Maximum permissible exposure" (MPE) means that level of laser or collateral radiation to which persons may be exposed without hazardous effect or adverse biological changes in the eye or skin. (The criteria for the MPE for cornea (eye) and skin are detailed in Tables IVa, IVb, IVc, and V.)

"Mobile laser" means a laser which is used at temporary job sites.

"Operable laser" means a laser system which can produce laser radiation.

"Operation" means the performance of tasks required for the equipment to perform its intended functions. It does not include maintenance or service tasks as defined in these regulations.

"Optical density" (OD) means a logarithmic expression of the optical attenuation afforded by a material.

$$OD = \log_{10} \left[\frac{(\text{incident power})}{(\text{transmitted power})} \right]$$

"Person" means any individual, corporation, partnership, firm, association, trust, estate, public or private institution, group, agency, political subdivision of this State, any other State or political subdivision or agency thereof, and any legal successor, representative, agent, or agency of the foregoing.

"Protective housing" means any panel, partition, dividing wall, or similar device which prevents human access to laser and/or collateral radiation in excess of the prescribed accessible emission limit.

"Pulse duration" means the time increment measured between the half-peak power points at the leading and trailing edges of a pulse.

"Pulse interval" means the time duration between identical points on two successive pulses.

"Radiance" means radiant power per unit area of a radiating surface per unit solid angle of emission, expressed in watts per square centimeter per steradian ($W \text{ cm}^{-2} \text{ sr}^{-1}$).

"Radiant energy" means energy emitted, transferred or received in the form of radiation, expressed in joules (J).

"Radiant exposure" means the radiant energy incident on an element of a surface divided by the area of that element, expressed in joules per square centimeter ($J \text{ cm}^{-2}$).

"Radiant power" means power emitted, transferred, or received in the form of radiation, expressed in watts (W).

"Registrant" means any person who registers a mobile laser, facility, or service organization with the Agency pursuant to these regulations.

"Safety interlock" means a device associated with the protective housing of a laser product, system or facility which prevents human access to laser and/or collateral radiation in excess of the prescribed accessible emission limit.

"Sampling interval" means the time interval during which the level of accessible laser or collateral radiation is sampled by a measurement process. The magnitude of the sampling interval in units of seconds is represented by the symbol (t).

"Secured enclosure" means an enclosure to which casual access is impeded by appropriate means, such as a door secured by lock, by latch, or by screws.

"Service" means the performance of adjustments, repairs, or procedures required to return equipment to its intended state. These adjustments and procedures usually require specialized training and/or tools. Service does not include operation or maintenance as defined in these regulations.

"Specular reflections" means mirror-like reflections.

"These regulations" mean all parts of [cite appropriate rules or regulations].

"Watt" (W) means the unit of power or radiant flux; 1 watt = 1 joule per second ($J \text{ sec}^{-1}$).

"Uncontrolled area" means any area to which access is not controlled by the registrant for purposes of protection from radiation hazards.

Sec. A.3 Exemptions

(a) All certified Class I, Class II, Class IIa, and Class IIIa laser products, except for those that allow access to Class IIIb or Class IV laser radiation during servicing, are exempted from these regulations, provided that the laser product is maintained as a certified Class I, Class II, Class IIa, or Class IIIa laser product throughout its useful life.

(b) These regulations do not apply to lasers in storage, during shipment or sale, provided such lasers are inoperable or not operated.

(c) The Agency may, upon application by persons or upon its own initiative, grant such exemptions or exceptions from the requirements of these regulations as it determines are authorized by law and will not result in undue hazard to occupational or public health and safety or to the environment.

Sec. A.4 Additional Requirements. The Agency may, by rule, regulation, or order, impose upon any person such requirements in addition to those established in these regulations as it is authorized by law and as it determines to be appropriate or necessary to reduce or eliminate any hazard which causes or threatens to cause any danger to occupational or public health and safety or to the environment.

Sec. A.5 Violations. [State to cite penalties used for enforcement of the Act.]

Sec. A.6 Impounding. [Subject to provisions of State Law.] The [cite Agency] shall have the authority in the event of any emergency to impound or order the impounding of lasers in the possession of any person who is not equipped to observe or fails to observe the provisions of this Act or any rules or regulations issued thereunder [usually specified by State statute].

Sec. A.7 Inspections.

(a) Each person shall afford the Agency at all reasonable times opportunity to inspect the laser facility or mobile laser.

(b) Each person shall make available to the Agency for inspection, upon reasonable notice, records maintained pursuant to these regulations.

Sec. A.8 Tests. Each person shall perform, upon instructions and reasonable notice from the Agency, or shall permit the Agency to perform, such reasonable tests as the Agency deems appropriate or necessary to assure compliance with these regulations.

Sec. A.9 Administrative Review. [Cite Administrative Procedures of State enabling legislation.]

Sec. A.10 Prohibited Uses. (Reserved)

Sec. A.11 Communications. All communications and reports concerning these regulations, and applications filed thereunder, shall be addressed to the Agency at its office located at [].

Sec. A.12 Severability. Insofar as the Agency may provide, each section or part thereof of these regulations shall be construed as separate, to the end that, if any section, sentence, clause, or phrase, shall be held invalid for any reason, the remainder of these regulations shall continue in full force.

PART B

REGISTRATION

Sec. B.1 Purpose. The purpose of this part is to provide for the registration of facilities, mobile lasers, and persons servicing lasers.

Sec. B.2 Scope

(a) Every person possessing a laser or laser system and persons providing laser and laser system installation, servicing, maintenance, and/or services involving the use of a laser or laser system shall register in accordance with this part.

(b) The registrant shall be subject to all applicable requirements of these regulations.

Sec. B.3 Registration Requirements

(a) All facilities, mobile lasers, and persons servicing lasers or laser systems, except as exempted in B.4, shall be registered with the Agency.

(b) Application for registration shall be made on forms furnished by the Agency or in a manner otherwise approved by the Agency. The application shall set forth all applicable information called for by Agency form "A".*

(c) The applicant or registrant shall furnish the Agency with such other information as the Agency may reasonably request.

(d) Information designated as proprietary by the applicant or registrant shall be treated as provided by law.

Sec. B.4 Exemptions from Registration Requirements.

(a) The following are exempt from the registration requirements of this part:

(1) Facilities containing only

(i) certified Class I, Class II, Class IIa, or Class IIIa laser products, and/or

(ii) certified Class IIIb laser products in the wavelength range of 400 through 710 nanometers and having a peak radiant power of less than or equal to 5×10^{-3} watts; and

(2) Mobile lasers which are certified Class I, Class II, Class IIa, and Class IIIa.

(b) Servicing of certified laser products with accessibility to Class IIIb or Class IV laser radiation is not exempt from the registration requirements of this part.

* See Appendix C

Sec. B.5 Laser Safety Officer (LSO). The registrant shall designate a laser safety officer who is responsible for laser radiation protection. Such individual shall:

(a) Be designated from such personnel as the radiation protection officer, industrial hygiene officer, safety officer, laser specialist, or laser operator.*

(b) Be qualified by training and experience in the following areas (see Appendix D):

- (1) Fundamentals of laser operation.
- (2) Biological effects of laser radiation on the eye and skin.
- (3) Relations of specular and diffuse reflections.
- (4) Laser and laser system classification.
- (5) Control measures.
- (6) Nonradiation hazards of lasers.**
- (7) Medical surveillance practices (if applicable).**
- (8) Laser terminology.**
- (9) Types of lasers, wavelengths, pulse shapes, modes, power, and energy.**
- (10) Basic radiometric units and measurement devices and techniques.**
- (11) Maximum Permissible Exposure (MPE) levels for eye and skin under all conditions.**
- (12) Laser hazard evaluations, range equations, and other calculations.**

(c) Establish and supervise a program of laser radiation safety for effective compliance with the applicable requirements of these regulations.

(d) Provide instructions concerning hazards and safety practices to individuals who may be exposed to laser radiation and to individuals who operate the lasers.

Sec. B.6 Acceptance of Laser Safety Officer. When, in the opinion of the Agency, the individual designated to be the laser safety officer does not have qualifications sufficient to carry out the requirements of C.3 of these regulations, the Agency may order the registrant to designate another individual.

* The LSO may be a part-time position when the work load for a LSO does not require a full-time effort.

** These areas are optional for Classes I, II, IIa, IIIa, and IIIb in the wavelength range of 400 through 710 nanometers and a peak radiant power of less than or equal to 5×10^{-3} watts.

Sec. B.7 Annual Report. The registrant shall notify the Agency annually of changes, if any, in the information supplied on the registration application or in the previous annual reports.

Sec. B.8 Termination of Registration. The Agency [may] [shall] terminate registration upon notification from the registrant that all lasers have been transferred to another person or are no longer operable.

Sec. B.9 Validity of Registration. Registration accepted by the Agency as properly executed shall remain valid until terminated or until declared invalid by the Agency.

Sec. B.10 Registration Shall Not Imply Approval. No person, in any advertisement, shall refer to the fact that a facility is registered with the Agency, and no person shall state or imply that any activity so registered has been approved by the Agency.

Sec. B.11 Out-of-State Laser Radiation Sources

(a) (1) Whenever any source of laser radiation is to be brought into the State, for any temporary use, the person proposing to bring such source of laser radiation into the State shall give written notice to the Agency [at least 7 working days] before such source of laser radiation is to be used in the State. The notice shall include:

- (i) the type of laser radiation source;
- (ii) the nature, duration, and scope of use; and
- (iii) the exact location(s) where the laser radiation source is to be used.

(2) If, for a specific case, the [7 working-day] period would impose an undue hardship on the person, upon application to the Agency, permission to proceed sooner may be granted.

(b) The person referred to in B.11(a) shall:

- (1) comply with all applicable regulations of the Agency;
- (2) supply the Agency with such other information as the Agency may reasonably request; and
- (3) not operate within the State on a temporary basis in excess of 180 calendar days per year.

PART C

REQUIREMENTS FOR PROTECTION AGAINST LASER RADIATION

Sec. C.1 Purpose and Scope. This part establishes regulations for protection against laser radiation. If any conflict arises between the requirements of these regulations and the Federal laser product performance standard with respect to the same aspect of performance for laser products subject to the Federal standard, the requirements of the Federal standard shall apply.

Sec. C.2 Maximum Permissible Exposure (MPE)

(a) No individual shall be exposed to levels of laser or collateral radiation higher than are specified in Tables IVa, IVb, IVc, and V. It is good practice to maintain exposure levels as far below the MPE values as is practicable.

(b) In those cases where no MPE is shown for particular wavelengths and pulse durations, all exposure shall be prohibited.

Sec. C.3 Implementation of Protective Measures. Protective measures used to avoid laser or collateral radiation shall be implemented by a laser safety officer (LSO), or in the case of those lasers not registered, an individual designated by management.

Sec. C.4 General Requirements for the Safe Operation of All Facilities

(a) Applicability. These requirements are for laser products in their intended mode of operation and include special requirements for service, testing, maintenance, and modification. During manufacture and research and development activities, some engineering controls may be inappropriate; the LSO shall specify alternate requirements to obtain equivalent laser safety protection.

(b) Engineering Controls

(1) Protective Housing. Each laser product shall have a protective housing which prevents human access during operation to laser and collateral radiation that exceeds the limits of Class I and paragraphs A and B of Table V, wherever and whenever such human access is not necessary in order for the product to perform its intended function. Wherever and whenever human access to laser radiation levels that exceed the limits of Class I and Paragraphs A and B of Table V is necessary, these levels shall not exceed the limits of the lowest laser class necessary to perform the intended function(s).

(2) Safety Interlocks

(i) A safety interlock, which shall ensure that radiation is not accessible above MPE limits, shall be provided for any portion of the protective housing which, by design, can be removed or displaced without the use of tools during normal operation or maintenance, and thereby allows access to radiation above MPE limits.

(ii) Adjustment during operation, service, testing, or maintenance of a laser containing interlocks shall not cause the interlocks to become inoperative or the radiation to exceed MPE limits outside protective housing except where a laser controlled area as specified in C.4(b)(5) is established.

(iii) For pulsed lasers, interlocks shall be designed so as to prevent firing of the laser, e.g., by dumping the stored energy into a dummy load.

(iv) For Class IIIb and Class IV continuous wave (cw) lasers, the interlocks shall turn off the power supply or interrupt the beam, e.g., by means of shutters.

(v) An interlock shall not allow automatic accessibility of radiation emission above MPE limits when the interlock is closed.

(vi) If failure of a single interlock would allow:

(a) human access to levels of laser radiation in excess of the radiant power accessible emission limit of Class IIIa laser radiation, or

(b) laser radiation in excess of the accessible emission limits of Class II to be emitted directly through the opening created by removal or displacement of that portion of the protective housing; then, either multiple safety interlocks or a means to preclude removal or displacement of the interlocked portion of the protective housing upon such failure shall be provided.

(3) Viewing Optics and Windows

(i) All viewing ports, viewing optics or display screens included as an integral part of an enclosed laser or laser system shall incorporate suitable means to attenuate the laser and collateral radiation transmitted through the port to less than the MPE and Table V limits under any conditions of operation of the laser.

(ii) Since optical systems such as lenses, telescopes, and microscopes may increase the hazard to the eye or the skin, the laser safety officer shall determine the potential hazard and specify administrative procedures and the use of controls such as interlocks or filters.

(4) Warning Systems. Each Class II, III, or IV laser product shall provide visual or aural indication during the emission of accessible laser radiation in excess of the limits for Class I except that, in the case of Class IIIb, except those which allow access only to less than 5 mW peak visible laser radiation, and Class IV lasers, this indication shall be sufficiently prior to emission of such radiation to allow appropriate action to avoid exposure. Any visual indicator shall be clearly visible through protective eyewear designed specifically for the wavelength(s) of the emitted laser radiation. If the laser and laser energy source are housed separately and can be

operated at a separation distance of greater than two meters, both laser and laser energy source shall incorporate visual or aural indicators. The visual indicators shall be positioned so that viewing does not require human access to laser radiation in excess of the MPE.

(5) Laser Controlled Area. With a Class IIIb, except those which allow access only to less than 5 mW visible peak power, or Class IV laser, a laser controlled area shall be established when exposure to the laser radiation in excess of the MPE or Table V limits is possible. The controlled area shall meet the requirements of C.4(b)(5)(i) through (iii) for Class IIIb lasers and the requirements of C.4(b)(5)(i) through (vii) for Class IV lasers:

(i) The area shall be the responsibility of the laser safety officer.

(ii) The area shall be posted as required by C.7.

(iii) Access to the laser controlled area shall be only by permission of the laser safety officer or a trained designated representative.

(iv) For Class IV indoor controlled areas, latches, interlocks, or other appropriate means shall be used to prevent unexpected entry into laser controlled areas. Such measures shall be designed to allow both rapid egress by the laser personnel at all times and admittance to the laser controlled area in an emergency condition. For such emergency conditions, a control-disconnect switch or equivalent device (panic button) shall be available for deactivating the laser.

(v) For Class IV indoor controlled areas, during tests requiring continuous operation, the individual in charge of the controlled area shall be permitted to momentarily override the safety interlocks to allow access to other authorized personnel if it is clearly evident that there is no optical radiation hazard at the point of entry and if the necessary protective devices are being worn by the entering personnel.

(vi) For Class IV indoor controlled areas, optical paths (e.g., windows) from an indoor facility shall be controlled in such a manner as to reduce the transmitted values of the laser radiation to levels at or below appropriate ocular MPE and Table V limits. When the laser beam must exit the indoor controlled area (as in the case of exterior atmospheric beam paths), the operator shall be responsible for ensuring that the beam path is limited to controlled air space* or controlled ground space when the beam irradiance or radiant exposure is above the appropriate MPE and Table V limits.

(vii) In the case of the removal of panels or protective covers and/or overriding of interlocks becomes necessary, such as for service, testing, or maintenance, and accessible laser radiation exceeds MPE and Table V limits, a temporary laser controlled area

* Contact FAA or other appropriate agencies, as necessary.

shall be established. The laser safety officer or a designated representative shall ensure that the necessary laser safety requirements for all potentially exposed individuals shall be established.

(c) Administrative and Procedural Controls

- (1) General. Unless otherwise specified, administrative and procedural controls shall apply only to Class IIIb and Class IV lasers.
- (2) Output Emission Limitations. The minimum laser radiant energy or laser power level required for the application shall be used.
- (3) Education and Training. The degree and level of education and training on laser safety concepts and procedures shall be in accordance with Appendix D of these regulations.
- (4) Operation and Maintenance. Class IIIb and Class IV lasers shall be operated and maintained only by qualified personnel.
- (5) Alignment Procedures. Alignment of laser optical systems (e.g., mirrors, lenses, and beam deflectors) shall be performed in such manner that assures that no one is exposed to laser radiation above MPE and Table V limits.
- (6) Eye Protection. Protective eyewear, as specified by the laser safety officer, shall be worn by all individuals with access to Class IV levels of laser radiation. Protective eyewear, when specified by the laser safety officer, shall be worn by all individuals with access to Class IIIb levels of laser radiation.
- (7) Service Procedures. All service procedures shall be performed by qualified personnel who, when appropriate, are trained in laser radiation protection. The service personnel shall comply with applicable information supplied by the manufacturers and instructions provided by the laser safety officer.

Sec. C.5 Additional Requirements for Special Lasers and Applications

- (a) Infrared Laser - Greater than 710 Nanometers. The beam from a Class IIIb and Class IV laser shall be terminated in fire-resistant material where necessary. Periodic inspection of absorbent material shall be made since many materials degrade with use.*
- (b) Laser Light Shows. The requirements of Appendix B shall be met.
- (c) Laser Optical Fiber Transmission System
 - (1) Laser transmission systems which employ optical cables shall be considered enclosed systems with the optical cable forming part of the protective housing.

* Many metal surfaces which appear "dull" visually can act as specular reflectors of infrared radiation.

(2) Disconnection of a connector resulting in access to radiation in excess of the applicable MPE or Table V limits shall take place in a controlled area. The use of a tool shall be required for the disconnection of a connector for service and maintenance purposes when the connector is not within a secured enclosure. All connectors shall bear the appropriate label or tag specified in C.7(c)(1)(viii).

Sec. C.6 Additional Requirements for Safe Operation

(a) Eye Protection

(1) Protective eyewear devices shall meet the following requirements:

(i) Provide a comfortable and appropriate fit all around the area of the eye.

(ii) Be in proper condition to ensure the optical filter(s) and holder provide the required optical density or greater at the desired wavelengths, and retain all protective properties during its use.

(iii) The required optical density shall be determined based on the type of potential exposure requiring protection.

(iv) Have the optical density or densities and associated wavelength(s) permanently labeled on the filters or otherwise permanently identified.

(2) At intervals not to exceed 6 months, each registrant shall examine protective eyewear devices to ensure the reliability of the protective filters and integrity of the protective filter frames. Eyewear in suspicious condition shall be discarded or tested for acceptability.

(b) Skin Protection. When there is a possibility of exposure to laser radiation which exceeds the MPE limits for skin as specified in Table IVc,* the registrant shall require the appropriate use of protective gloves, clothing, and shields.

(c) Other Personal Protective Equipment. Respirators and other personal protective equipment shall be required, as a temporary control measure, whenever engineering controls cannot provide protection from toxic air contaminants and other hazards.

(d) Service and Maintenance of Lasers. Following any service and maintenance of lasers which may affect the output power or operating characteristics, the laser safety officer shall specify whether any changes in control measures are required.

(e) Modification of Laser. Whenever deliberate modifications are made which could change the laser class and affect the output power or operating characteristics, the laser safety officer shall specify whether any changes in control measures are required.

* This need is particularly important in the ultraviolet region.

Sec. C.7 Caution Signs, Labels, and Posting(a) General

(1) Except as otherwise authorized by the Agency, signs, symbols, and labels prescribed by this section shall use the design and colors specified in Figures 1 and 2.

(2) In addition to the signs, symbols, and labels prescribed in this section, a registrant may provide near such signs, symbols, and labels any additional information which may be appropriate in aiding individuals to minimize exposure to laser or collateral radiation within a facility.

(b) Posting and Instructions

(1) The controlled area shall be conspicuously posted with an appropriate sign or signs as specified in C.7(c) and Figures 1 and 2.

(2) Operating personnel of each laser shall be provided with adequate written instructions for safe use, including clear warnings and precautions to avoid possible exposure to laser and collateral radiation in excess of the MPE and Table V limits.

(3) Service personnel shall be provided with:

(i) Adequate training and instructions for service adjustments and procedures for each laser or facility, including clear warnings or precautions to be taken to avoid possible exposure to laser or collateral radiation.

(ii) Service instructions which shall contain a listing of controls and procedures which can increase accessible emission levels of laser or collateral radiation, and a clear description of the location of displaceable portions of the protective housing or enclosure which could allow access by personnel to laser and collateral radiation in excess of the MPE and Table V limits.

(c) Labeling and Posting ^{1/}(1) Labeling Laser Products and Posting Laser Facilities

(i) Uncertified Class I lasers shall have a label including the following wording: "CLASS I LASER"; Class I facilities need not be posted.

(ii) Class II lasers which do not exceed accessible emission limits of Class I for any emission duration less than or equal to 1×10^3 seconds shall have a label with the following wording: "Class IIa Laser (or Laser Product) - Avoid Long Term Viewing of Direct Laser Radiation"; Class IIa laser facilities need not be posted.

^{1/} With respect to laser products only, the labeling requirements found in 21 CFR Part 1040 may be used in lieu of C.7(c).

(iii) Class II laser facilities need not be posted. Class II lasers other than those specified in C.7(c)(1)(ii) shall have a label with the warning logotype A specified in Figure 1 and including the following wording:

(Position 1 on the logotype)

"LASER RADIATION - DO NOT STARE INTO BEAM"

(Position 3 on the logotype)

"CLASS II LASER (OR LASER PRODUCT)"

(iv) (a) Each laser or facility classified in Class III solely because of the emission of accessible laser radiation in the wavelength range of greater than 400 but less than or equal to 710 nanometers, with an irradiance of less than or equal to 2.5×10^{-3} watts per square centimeter, and with a radiant power less than or equal to 5.0×10^{-3} watts, shall have a label and be posted with sign(s) with the warning specified in Figure 1 and including the following wording:

(Position 1 on the logotype)

"LASER RADIATION - DO NOT STARE INTO BEAM OR VIEW DIRECTLY WITH OPTICAL INSTRUMENTS"

(Position 3 on the logotype)

"CLASS IIIa LASER (OR LASER PRODUCT)"

(b) Class III lasers or facilities other than those specified in C.7(c)(1)(iv)(a) shall have a label and be posted with sign(s) with the warning specified in Figure 2 and including the following wording:

(Position 1 on the logotype)

"LASER RADIATION - AVOID DIRECT EXPOSURE TO BEAM"

(Position 3 on the logotype)

"CLASS IIIb LASER (OR LASER PRODUCT)"

(v) Class IV lasers and facilities shall have affixed a label and be posted with sign(s) with the warning specified in Figure 2 and including the following wording:

(Position 1 on the logotype)

"LASER RADIATION - AVOID EYE OR SKIN EXPOSURE TO DIRECT OR SCATTERED RADIATION"

(Position 3 on the logotype)

"CLASS IV LASER (OR LASER PRODUCT)"

(vi) Class II, III, or IV lasers, except lasers used in the practice of medicine, shall have a label(s) in close proximity to each aperture through which is emitted accessible laser or collateral radiation in excess of the limits specified in Tables 1 and 5 with the following wording as applicable:

(a) "AVOID EXPOSURE - Laser radiation is emitted from this aperture," if the radiation emitted through such aperture is laser radiation.

(b) "AVOID EXPOSURE - Hazardous electromagnetic radiation is emitted from this aperture," if the radiation emitted through such aperture is collateral radiation.

(c) "AVOID EXPOSURE - Hazardous x rays are emitted from this aperture," if the radiation emitted through such aperture is collateral x-ray radiation.

(vii) Each Class II, III, and IV laser shall state, at position 2 on the required warning logotype, the maximum output of laser radiation, the pulse duration when appropriate, and the laser medium or emitted wavelength(s).

(viii) Each noninterlocked or defeatably interlocked portion of the protective housing or enclosure which is designed to be displaced or removed during normal operation, maintenance, or servicing, and which thereby would permit human access to laser or collateral radiation, shall have labels as follows:

(a) For laser radiation in excess of the accessible emission limits of Class I but not in excess of the accessible emission limits of Class II, the wording: "CAUTION - Laser radiation when open. DO NOT STARE INTO BEAM."

(b) For laser radiation in excess of the accessible emission limits of Class I or Class II as applicable, but not in excess of the accessible emission limits of Class III, the wording: "DANGER - Laser radiation when open, AVOID DIRECT EXPOSURE TO BEAM."

(c) For laser radiation in excess of the accessible emission limits of Class III, the wording: "DANGER - Laser radiation when open. AVOID EYE OR SKIN EXPOSURE TO DIRECT OR SCATTERED RADIATION."

(d) For collateral radiation in excess of the emission limits of Table V.

(1) If the limits in paragraph A of Table V are exceeded, the wording: "CAUTION - Hazardous Electromagnetic Radiation when open"; and

(2) If the limits in paragraph B of Table V are exceeded, the wording: "CAUTION - Hazardous X-Ray Radiation."

(e) For protective housing or enclosures which provide a defeatable interlock, the words "and interlock defeated" shall be included in the labels specified in C.7(c)(1)(viii)(a), (b), (c), and (d).

(ix) (a) The word "Invisible" shall immediately precede the word "radiation" on labels and signs required by C.7(c) for wavelengths of laser and collateral radiation that are outside of the range of 400 to 710 nanometers.

(b) The words "Visible and Invisible" shall immediately precede the word "radiation" on labels and signs required by C.7(c) for wavelengths of laser and collateral radiation that are both within and outside the range of 400 to 710 nanometers.

(x) All labels placed on lasers or signs posted to laser facilities shall be positioned so as to make unnecessary, during reading, human exposure to laser or collateral radiation in excess of the MPE and Table V limits.

(xi) Labels and signs required by C.7(c) shall be clearly visible, legible, and permanently attached to the laser or facility.

Sec. C.8 Surveys. Each registrant shall make or cause to be made such radiation protection surveys as may be necessary to comply with C.8. At intervals not to exceed 6 months, surveys shall be performed which include but are not limited to:

(a) A determination that all laser protective devices are labeled correctly and functioning within the design specifications and are properly chosen for lasers in use.

(b) A determination that all warning devices are functioning within their design specifications.

(c) A determination that the laser controlled area is properly controlled and posted with accurate warning signs in accordance with C.7.

(d) A re-evaluation of potential hazards from surfaces which may be associated with Class III and Class IV beam paths.

(e) Additional surveys required to evaluate the laser and collateral radiation hazard incident to the use of lasers.

Sec. C.9 Measurement and Instrumentation. Each determination requiring a measurement for compliance with these regulations shall use instrumentation which is calibrated and designed for use with the laser that is to be tested. The date of calibration, accuracy of calibration, wavelength range, and power/energy of calibration shall be specified on a legible, clearly visible label attached to the instrument.

(a) Measurement of accessible emission(s) for classification shall be made:

(1) under those operational conditions and procedures which maximize the accessible emission levels including startup, stabilized operation, and shutdown of the laser or facility,

(2) with all controls and adjustments listed in the operating and service instructions adjusted for the appropriate maximum accessible emission level of laser radiation which is not expected to be detrimental to the functional integrity of the laser or enclosure,

(3) at points in space to which human access is possible for a given laser configuration, e.g., if operation may include removal of portions of the protective housing or enclosure and defeat of safety interlocks, measurements shall be made at points accessible in that laser configuration,

(4) with the measuring instrument detector so positioned and so oriented with respect to the laser as to result in the maximum detection of radiation by the instrument, and

(5) for a laser other than a laser system, with the laser coupled to that type of laser energy source specified as compatible by the laser fabricator, and which produces the maximum emission of accessible laser radiation from that laser.

(b) Compliance with the requirements of the regulations shall be determined by measurements or their equivalent which account for all errors and statistical uncertainties in the measurement process.

(c) Accessible emission levels for classification of laser and collateral radiation shall be based upon the following measurements:

(1) The radiant power (W) or radiant energy (J) detectable through a circular aperture stop having a diameter of 80 millimeters, except for scanned laser radiation, and within a circular solid angle of acceptance of 1×10^{-3} steradian with collimating optics of 5 diopters or less.

(2) The irradiance ($W \text{ cm}^{-2}$) or radiant exposure ($J \text{ cm}^{-2}$) equivalent to the radiant power (W) or radiant energy (J) detectable through a circular aperture stop having a diameter of 7 millimeters and, for irradiance, within a circular solid angle of acceptance of 1×10^{-3} steradian with collimating optics of 5 diopters or less, divided by the area of the aperture stop (cm^2).

(3) The radiance ($W \text{ cm}^{-2} \text{ sr}^{-1}$) or integrated radiance ($J \text{ cm}^{-2} \text{ sr}^{-1}$) equivalent to the radiant power (W) or radiant energy (J) detectable through a circular aperture stop having a diameter of 7 millimeters and within a circular solid angle of acceptance of 1×10^{-5} steradian with collimating optics of 5 diopters or less, divided by that solid angle (sr) and by the area of the aperture stop (cm^2).

(4) Accessible emission levels of scanned laser radiation shall be based upon the measurement of radiation detectable through a

stationary circular aperture stop having a 7-millimeter diameter and within the circular solid angle of acceptance with collimating optics applicable under C.9(c)(1),(2), and (3). The direction of the solid angle of acceptance shall change as needed to maximize detectable radiation, with an angular speed of up to 5 radians per second.

(d) Measurements for maximum permissible exposure shall be measured as specified in Appendix E and Tables IVa, IVb, and IVc.

Sec. C.10 Medical Surveillance. The Agency may require the registrant to provide such medical examination procedures as it considers necessary to protect the health and safety of personnel. Appendix A provides recommended procedures which apply primarily to users of Class IV lasers.

Sec. C.11 Notification of Incidents

(a) Immediate Notification. Each registrant shall notify the Agency immediately by telephone or telegraph of any incident involving any source of laser or collateral radiation possessed by the registrant and which has or may have caused:

- (1) an exposure to an individual of greater than 100 times the MPE or Table V limits of laser or collateral radiation; or
- (2) an exposure to an individual which involves the partial or total loss of sight in either eye; or
- (3) an exposure to an individual which involves perforation of the skin or other serious injury exclusive of eye injury; or
- (4) a loss of one working week or more of operation of any facility affected.

(b) Twenty-four Hour Notification. Each registrant shall notify the Agency by telephone or telegraph within 24 hours of any incident involving any source of laser or collateral radiation possessed by the registrant and which has or may have caused:

- (1) an exposure to an individual of greater than 5 times the MPE or Table V limits of laser or collateral radiation; or
- (2) an exposure to an individual with second- or third-degree burns to the skin or potential injury and partial loss of sight.

Sec. C.12 Reports of Overexposures and Excessive Levels

(a) Each registrant shall make a report in writing within 30 days to the Agency of:

- (1) each exposure of an individual to laser and collateral radiation in excess of the MPE limits,
- (2) any incident for which notification is required by C.11.

(b) Each report shall describe the extent of exposure of individuals to laser and/or collateral radiation, including estimates of each individual's

exposure; levels of laser and/or collateral radiation involved; the cause of the exposure; and corrective steps taken or planned to be taken to assure against a recurrence.

(c) Any report filed with the Agency pursuant to C.12 shall include the full name of each individual exposed, an estimate of each individual's exposure, and a description of any injuries. The report shall be prepared so that this information is stated in a separate part of the report.*

Sec. C.13 Notifications and Reports to Individuals. When a registrant is required pursuant to C.12 to report to the Agency any exposure of an individual to laser and/or collateral radiation, the registrant shall also provide to the individual a report on the exposure data included therein. Such reports shall be transmitted at a time not later than the date of transmittal to the Agency.

Sec. C.14 Records.

(a) Each registrant shall maintain current records, which shall be kept available for inspection by the Agency, showing:

- (1) The results of all surveys required under C.6(a)(2) and C.8.
- (2) The results of all instrument calibrations under C.9.
- (3) The results of medical surveillance performed under C.10.
- (4) The reports of incidents as described under C.13.

(b) The registrant shall maintain such records required by C.14 until the Agency authorizes disposition.

* This paragraph is suggested for use by states which have the authority to maintain the names of individuals as confidential information.

Table I. Class I Accessible Emission Limits
for Laser Radiation

Wavelength (nanometers)	Emission duration (seconds)	Class I - Accessible emission limits		(quantity)
		(value)	(Units)	
> 180 but ≤ 400	< 3.0 x 10 ⁴ ----- > 3.0 x 10 ⁴ -----	2.4 x 10 ⁻⁵ k ₁ k ₂ [#] ----- 8.0 x 10 ⁻¹⁰ k ₁ k ₂ [#] -----	Joules (J) [#] ----- Watts (W) [#] -----	radiant energy ----- radiant power-----
> 400	> 1.0 x 10 ⁻⁹ to 2.0 x 10 ⁻⁵ ----- > 2.0 x 10 ⁻⁵ to 1.0 x 10 ¹ ----- > 1.0 x 10 ¹ to 1.0 x 10 ⁶ ----- > 1.0 x 10 ⁶ -----	2.0 x 10 ⁻⁷ k ₁ k ₂ ----- 7.0 x 10 ⁻⁴ k ₁ k ₂ ^{3/4} ----- 3.9 x 10 ⁻³ k ₁ k ₂ ----- 3.9 x 10 ⁻⁷ k ₁ k ₂ -----	J ----- J ----- J ----- W -----	radiant energy ----- radiant energy ----- radiant energy ----- radiant power-----
but	or			
≤ 1400	> 1.0 x 10 ⁻⁹ to 1.0 x 10 ¹ ----- > 1.0 x 10 ¹ to 1.0 x 10 ⁶ ----- > 1.0 x 10 ⁶ -----	10k ₁ k ₂ ^{1/3} ----- 20k ₁ k ₂ ----- 2.0 x 10 ⁻³ k ₁ k ₂ -----	J cm ⁻² sr ⁻¹ ----- J cm ⁻² sr ⁻¹ ----- W cm ⁻² sr ⁻¹ -----	integrated radiance ----- integrated radiance ----- radiance-----
> 1400 but ≤ 2500	> 1.0 x 10 ⁻⁹ to 1.0 x 10 ⁻⁷ ----- > 1.0 x 10 ⁻⁷ to 1.0 x 10 ¹ ----- > 1.0 x 10 ¹ -----	7.9 x 10 ⁻⁵ k ₁ k ₂ ----- 4.4 x 10 ⁻³ k ₁ k ₂ ^{1/4} ----- 7.9 x 10 ⁻⁴ k ₁ k ₂ -----	J ----- J ----- W -----	radiant energy ----- radiant energy ----- radiant power-----
> 2500 but ≤ 1.0 x 10 ⁶	> 1.0 x 10 ⁻⁹ to 1.0 x 10 ⁻⁷ ----- > 1.0 x 10 ⁻⁷ to 1.0 x 10 ¹ ----- > 1.0 x 10 ¹ -----	1.0 x 10 ⁻² k ₁ k ₂ ----- 5.6 x 10 ⁻¹ k ₁ k ₂ ^{1/4} ----- 1.0 x 10 ⁻¹ k ₁ k ₂ -----	J cm ⁻² ----- J cm ⁻² ----- J cm ⁻² -----	radiant exposure ----- radiant exposure ----- radiant exposure-----

* Class I accessible emission limits for wavelengths equal to or greater than 180 nm but less than or equal to 400 nm shall not exceed the Class I accessible emission limits for the wavelengths greater than 1400 nm but less than or equal to 1.0 x 10⁶ nm with a k₁ and k₂ of 1.0 for comparable sampling intervals.

The variable in the expression is the magnitude of the sampling interval (t), in units of seconds.

Table Ia. Class Ia Accessible Emission Limits for Laser Radiation

Class Ia accessible emission limits are identical to Class I accessible emission limits except:			
Wavelength (nanometers)	Emission duration (seconds)	Class Ia-Accessible emission limits	
		(value)	(units)
>400 but ≤710	>1.0 X 10 ³	3.9 X 10 ⁻⁶	W radiant power

Table II. Class II Accessible Emission Limits for Laser Radiation

Class II accessible emission limits are identical to Class I accessible emission limits except:			
Wavelength (nanometers)	Emission duration (seconds)	Class II - Accessible emission limits	
		(value)	(units)
>400 but ≤710	>2.5 x 10 ⁻¹	1.0 x 10 ⁻³	W radiant power

Table IIIa. Class IIIa Accessible Emission Limits for Laser Radiation

Class IIIa accessible emission limits are identical to Class I accessible emission limits except:			
Wavelength (nanometers)	Emission duration (seconds)	(value)	(units)
>400 but <710	>3.8 x 10 ⁻⁴	2.5 x 10 ⁻³ OR**	Wcm ⁻² irradiance
		5.0 x 10 ⁻³	W radiant power

** Class IIIa accessible emission limits shall exceed neither of the accessible emission limits.

Table IIIb. Class IIIb Accessible Emission Limits for Laser Radiation

Class III - Accessible emission limits			
Wavelength (nanometers)	Emission duration (seconds)	(value)	(units)
>180 but <400	<2.5 x 10 ⁻¹ >2.5 x 10 ⁻¹	3.8 x 10 ⁻⁴ k ₁ k ₂ 1.5 x 10 ⁻³ k ₁ k ₂	J radiant energy W radiant power
>400 but <1400	>1.0 x 10 ⁻⁹ to 2.5 x 10 ⁻¹ >2.5 x 10 ⁻¹	10k ₁ k ₂ t ^{1/3} to a maximum value of 10	J cm ⁻² radiant exposure J cm ⁻² radiant exposure
>1400 but <1.0x10 ⁶	>1.0 x 10 ⁻⁹ to 1.0 x 10 ¹ >1.0 x 10 ¹	10 5.0 x 10 ⁻¹	J cm ⁻² radiant exposure W radiant power

The variable in the expression is the magnitude of the sampling interval (t), in units of seconds.

Table IVa. Maximum Permissible Exposure (MPE) for Direct Ocular Exposure, Intrabeam Viewing, to a Laser Beam

Wavelength, λ (μm)	Exposure Time, t (s)	Maximum Permissible Exposure (MPE) (cm^{-2})	Notes for Calculation & Measurement
<u>Ultraviolet</u>			
0.200 - 0.302	$10^{-9} - 3 \times 10^4$	3×10^{-3} J	
0.303	$10^{-9} - 3 \times 10^4$	4×10^{-3} J	
0.304	$10^{-9} - 3 \times 10^4$	6×10^{-3} J	or $0.56t^{1/4}$ J x cm^{-2} , whichever is lower.
0.305	$10^{-9} - 3 \times 10^4$	1.0×10^{-2} J	
0.306	$10^{-9} - 3 \times 10^4$	1.6×10^{-2} J	
0.307	$10^{-9} - 3 \times 10^4$	2.5×10^{-2} J	
0.308	$10^{-9} - 3 \times 10^4$	4.0×10^{-2} J	1-mm limiting aperture.
0.309	$10^{-9} - 3 \times 10^4$	6.3×10^{-2} J	
0.310	$10^{-9} - 3 \times 10^4$	1.0×10^{-1} J	
0.311	$10^{-9} - 3 \times 10^4$	1.6×10^{-1} J	See Figs. 5 & 6 for graphic representation.
0.312	$10^{-9} - 3 \times 10^4$	2.5×10^{-1} J	
0.313	$10^{-9} - 3 \times 10^4$	4.0×10^{-1} J	
0.314	$10^{-9} - 3 \times 10^4$	6.3×10^{-1} J	
0.315 - 0.400	$10^{-9} - 10$	$0.56 t^{1/4}$ J	
0.315 - 0.400	$10 - 10^3$	1J	
0.315 - 0.400	$10^3 - 3 \times 10^4$ *	1×10^{-3} W	
<u>Visible and Near Infrared*</u>			
0.400 - 0.700	$10^{-9} - 1.8 \times 10^{-5}$	5×10^{-7} J	
0.400 - 0.700	$1.8 \times 10^{-5} - 10$	$1.8t^{3/4} \times 10^{-3}$ J	7-mm limiting aperture.
0.400 - 0.550	$10 - 10^4$	10×10^{-3} J	
0.550 - 0.700	$10 - T_1$	$1.8t^{3/4} \times 10^{-3}$ J	
0.550 - 0.700	$T_1 - 10^4$	$10C_B \times 10^{-3}$ J	See App. E for multipulse limitations.
0.400 - 0.700	$10^4 - 3 \times 10^4$	$C_B \times 10^{-6}$ W	
0.700 - 1.050	$10^{-9} - 1.8 \times 10^{-5}$	$5C_A \times 10^{-7}$ J	See Figs. 4 & 11 for graphic representa- tion, & App. E & Figs. 8, 9, and 12 for correction factors.
0.700 - 1.050	$1.8 \times 10^{-5} - 10^3$	$1.8C_A t^{3/4} \times 10^{-3}$ J	
1.051 - 1.400	$10^{-9} - 5 \times 10^{-5}$	5×10^{-6} J	
1.051 - 1.400	$5 \times 10^{-5} - 10^3$	$9t^{3/4} \times 10^{-3}$ J	
0.700 - 1.400	$10^3 - 3 \times 10^4$	$320C_A \times 10^{-6}$ W	
<u>Far-Infrared</u>			
$1.4 - 10^3$	$10^{-9} - 10^{-7}$	10^{-2} J	See Table VIII for apertures. See App. E for correc- tion factors at $1.54 \mu\text{m}$. See Fig.6 for graphic representation.
	$10^{-7} - 10$	$0.56 t^{1/4}$ J	
	> 10	0.1 W	

* See Figs. 4, 5, and 6 for graphic representation.

The variables in the expressions are the magnitude of the exposure time(t) in units of seconds, and the magnitude of the wavelength (λ) in units of micrometers. This material is from American National Standard for the Safe Use of Lasers, ANSI Z136.1-1980.

NOTES: $C_A = 1$ for $\lambda = 0.400 - 0.700 \mu\text{m}$,

$C_A = 10^{2.0(\lambda^{-0.700})}$ for $\lambda = 0.700 - 1.050 \mu\text{m}$ (see Fig. 8),

$C_A = 5$ for $\lambda = 1.050 - 1.400 \mu\text{m}$,

$C_B = 1$ for $\lambda = 0.400 - 0.550 \mu\text{m}$,

$C_B = 10^{1.5(\lambda^{-0.550})}$ for $\lambda = 0.550 - 0.700 \mu\text{m}$ (see Fig. 9),

$T_1 = 10 \times 10^{2.0(\lambda^{-0.550})}$ for $\lambda = 0.550 - 0.700 \mu\text{m}$ (see Fig. 9).

Table IVb. Maximum Permissible Exposure (MPE) for Viewing a Diffuse Reflection of a Laser Beam or an Extended-Source Laser

Wavelength, λ (μm)	Exposure time, t (s)	Maximum Permissible Exposure (MPE)	Notes for Calculation & Measurement
<u>Ultraviolet</u>			
0.200 - 0.302	$10^{-9} - 3 \times 10^4$	$3 \times 10^{-3} \text{ J cm}^{-2}$	or $0.56t^{1/4} \text{ J cm}^{-2}$, whichever is lower. 1-mm limiting aperture. See Figs. 5&6 for graphic representation.
0.303	$10^{-9} - 3 \times 10^4$	$4 \times 10^{-3} \text{ J cm}^{-2}$	
0.304	$10^{-9} - 3 \times 10^4$	$6 \times 10^{-3} \text{ J cm}^{-2}$	
0.305	$10^{-9} - 3 \times 10^4$	$1.0 \times 10^{-2} \text{ J cm}^{-2}$	
0.306	$10^{-9} - 3 \times 10^4$	$1.6 \times 10^{-2} \text{ J cm}^{-2}$	
0.307	$10^{-9} - 3 \times 10^4$	$2.5 \times 10^{-2} \text{ J cm}^{-2}$	
0.308	$10^{-9} - 3 \times 10^4$	$4.0 \times 10^{-2} \text{ J cm}^{-2}$	
0.309	$10^{-9} - 3 \times 10^4$	$6.3 \times 10^{-2} \text{ J cm}^{-2}$	
0.310	$10^{-9} - 3 \times 10^4$	$1.0 \times 10^{-1} \text{ J cm}^{-2}$	
0.311	$10^{-9} - 3 \times 10^4$	$1.6 \times 10^{-1} \text{ J cm}^{-2}$	
0.312	$10^{-9} - 3 \times 10^4$	$2.5 \times 10^{-1} \text{ J cm}^{-2}$	
0.313	$10^{-9} - 3 \times 10^4$	$4.0 \times 10^{-1} \text{ J cm}^{-2}$	
0.314	$10^{-9} - 3 \times 10^4$	$6.3 \times 10^{-1} \text{ J cm}^{-2}$	
0.315 - 0.400	$10^{-9} - 10$	$0.56t^{1/4} \text{ J cm}^{-2}$	
0.315 - 0.400	$10 - 10^3$	1 J cm^{-2}	
0.315 - 0.400	$10^3 - 3 \times 10^4$	$1 \times 10^{-3} \text{ W cm}^{-2}$	
<u>Visible*</u>			
0.400 - 0.700	$10^{-9} - 10$	$10t^{1/3} \text{ J cm}^{-2} \text{ sr}^{-1}$	1-mm limiting aperture or α_{min} , whichever is greater. See App. E & Figs. 7,8,9, 11,& 12 for graphic repre- sentation & multiple pulse limitations.
0.400 - 0.550	$10 - 10^4$	$21 \text{ J cm}^{-2} \text{ sr}^{-1}$	
0.550 - 0.700	$10 - T_1$	$3.83t^{3/4} \text{ J cm}^{-2} \text{ sr}^{-1}$	
0.550 - 0.700	$T_1 - 10^4$	$21C_B \text{ J cm}^{-2} \text{ sr}^{-1}$	
0.400 - 0.700	$10^4 - 3 \times 10^4$	$2.1C_B 10^{-3} \text{ W cm}^{-2} \text{ sr}^{-1}$	
<u>Near Infrared*</u>			
0.700 - 1.400	$10^{-9} - 10$	$10C_A t^{1/3} \text{ J cm}^{-2} \text{ sr}^{-1}$	
0.700 - 1.400	$10 - 10^3$	$3.83C_A t^{3/4} \text{ J cm}^{-2} \text{ sr}^{-1}$	
0.700 - 1.400	$10^3 - 3 \times 10^4$	$0.64C_A \text{ W cm}^{-2} \text{ sr}^{-1}$	
<u>Far Infrared</u>			
1.4 - 10^3	$10^{-9} - 10^{-7}$	$10^{-2} \text{ J cm}^{-2}$	See Table VIII for apertures. See App. E for correction factors & Fig.6.
	$10^{-7} - 10$	$0.56t^{1/4} \text{ J cm}^{-2}$	
	> 10	0.1 W cm^{-2}	

* See Fig. 7 for graphic representation.

The variables in the expressions are the magnitude of the exposure time (t) in units of seconds, and the magnitude of the wavelength (λ) in units of micrometers. This material is from American National Standard for the Safe Use of Lasers, ANSI Z136.1-1980.

NOTES: $C_A = 1$ for $\lambda = 0.400 - 0.700 \mu\text{m}$,

$C_A = 10^{2.0}(\lambda^{-0.700})$ for $\lambda = 0.700 - 1.050\mu\text{m}$ (see Fig.8),

$C_A = 5$ for $\lambda = 1.050 - 1.400 \mu\text{m}$,

$C_B = 1$ for $\lambda = 0.400 - 0.550 \mu\text{m}$,

$C_B = 10^{15}(\lambda^{-0.550})$ for $\lambda = 0.550 - 0.700 \mu\text{m}$ (see Fig. 9),

$T_1 = 10 \times 10^{20}(\lambda^{-0.550})$ for $\lambda = 0.550 - 0.700 \mu\text{m}$ (see Fig. 9).

Table IVc. Maximum Permissible Exposure (MPE)
for Skin Exposure to a Laser Beam

Wavelength, λ (μm)	Exposure Time, t (s)	Maximum Permissible Exposure (MPE) (cm^{-2})	Notes for Calculation & Measurement
<u>Ultraviolet</u>			
0.200 - 0.302	10^{-9} - 3×10^4	3×10^{-3} J	or $0.56t^{1/4}$ J x cm^{-2} , which- ever is lower. 1-mm limiting aperture. See Figs. 5&6 for graphic representation.
0.303	10^{-9} - 3×10^4	4×10^{-3} J	
0.304	10^{-9} - 3×10^4	6×10^{-3} J	
0.305	10^{-9} - 3×10^4	1.0×10^{-2} J	
0.306	10^{-9} - 3×10^4	1.6×10^{-2} J	
0.307	10^{-9} - 3×10^4	2.5×10^{-2} J	
0.308	10^{-9} - 3×10^4	4.0×10^{-2} J	
0.309	10^{-9} - 3×10^4	6.3×10^{-2} J	
0.310	10^{-9} - 3×10^4	1.0×10^{-1} J	
0.311	10^{-9} - 3×10^4	1.6×10^{-1} J	
0.312	10^{-9} - 3×10^4	2.5×10^{-1} J	
0.313	10^{-9} - 3×10^4	4.0×10^{-1} J	
0.314	10^{-9} - 3×10^4	6.3×10^{-1} J	
0.315 - 0.400	10^{-9} - 10	$0.56t^{1/4}$ J	
0.315 - 0.400	10 - 10^3	1 J	
0.315 - 0.400	10^3 - 3×10^4	1×10^{-3} W	
<u>Visible and Near Infrared</u>			
0.400 - 1.400	10^{-9} - 10^{-7}	$2C_A \times 10^{-2}$ J	1-mm limiting aperture. See Figs. 6&8.
	10^{-7} - 10	$1.1C_A^{1/4}$ J	
	10 - 3×10^4	$0.2C_A$ W	
<u>Far Infrared</u>			
1.4 - 10^3	10^{-9} - 10^{-7}	10^{-2} J	1-mm limiting aperture for 1.4 to 100 μm 11-mm limiting aperture for 0.1 mm to 1 mm.
	10^{-7} - 10	$0.56t^{1/4}$ J	
	> 10	0.1 W	

The variables in the expressions are the magnitude of the exposure time (t), in units of seconds and the magnitude of the wavelength (λ) in micrometers.

Table V. Accessible Emission Limits for Collateral Radiation from Lasers or Facilities and Maximum Permissible Exposure (MPE)

- A. Accessible emission limits for collateral radiation having wavelengths greater than or equal to 180 nm but less than or equal to 1 mm are identical to the accessible emission limits of Class I laser radiation as determined from Table I for the appropriate wavelength(s) and emission duration.
1. In the wavelength range of ≤ 400 nm, for all emission durations.
 2. In the wavelength range > 400 nm, for all emission durations less than or equal to 1×10^3 seconds and, when applicable under C.4(b)(3), for all emission durations.
- B. Accessible emission limit and MPE for collateral radiation within the x-ray range of wavelengths is 0.5 milliroentgen in an hour, averaged over an area of 10 square centimeters with no dimension greater than 5 centimeters.
- C. The MPE for optical collateral radiation shall be determined as specified in Appendix E.

Table VI. Values of Wavelength Dependent
Correction Factors k_1 and k_2

Wavelength (nanometers)	k_1	k_2		
180 to 302.4	1.0	1.0		
>302.4 to 315	$\left[\frac{\lambda - 302.4}{5} \right]_{10}$	1.0		
>315 to 400	330.0	1.0		
>400 to 700	1.0	1.0		
>700 to 800	$\left[\frac{\lambda - 700}{515} \right]_{10}$	if: $t \leq \frac{10100}{\lambda - 699}$ then: $k_2 = 1.0$	if: $\frac{10100}{\lambda - 699} < t \leq 10^4$ then: $k_2 = \frac{t(\lambda - 699)}{10100}$	if: $t > 10^4$ then: $k_2 = \frac{\lambda - 699}{1.01}$
>800 to 1060	$\left[\frac{\lambda - 700}{515} \right]_{10}$			
>1060 to 1400	5.0	if: $t < 100$ then: $k_2 = 1.0$	if: $100 < t \leq 10^4$ then: $k_2 = \frac{t}{100}$	if: $t > 10^4$ then: $k_2 = 100$
>1400 to 1535	1.0	1.0		
>1535 to 1545	$t \leq 10^{-7}$ sec $k_1 = 100.0$	1.0		
	$t > 10^{-7}$ sec $k_1 = 1.0$			
>1545 to 1.0×10^6	1.0	1.0		

NOTE: The variables in the expressions are the magnitudes of the sampling interval (t), in units of seconds, and the wavelength (λ), in units of nanometers.

Table VII. Selected Numerical Solutions for k_1 and k_2

Wavelength (nanometers)	k_1	k_2					
		$t \leq 100$ sec	$t=300$ sec	$t=1000$ sec	$t=3000$ sec	$t \geq 10,000$ sec	
180	1.0						
300	1.0						
302	1.0						
303	1.32						
304	2.09						
305	3.31						
306	5.25						
307	8.32						
308	13.2						
309	20.9						
310	33.1						1.0
311	52.5						
312	83.2						
313	132.0						
314	209.0						
315	330.0						
400	330.0						
401	1.0						
500	1.0						
600	1.0						
700	1.0						
710	1.05	1	1	1.1	3.3	11.0	
720	1.09	1	1	2.1	6.3	21.0	
730	1.14	1	1	3.1	9.3	31.0	
740	1.20	1	1.2	4.1	12.0	41.0	
750	1.25	1	1.5	5.0	15.0	50.0	
760	1.31	1	1.8	6.0	18.0	60.0	
770	1.37	1	2.1	7.0	21.0	70.0	
780	1.43	1	2.4	8.0	24.0	80.0	
790	1.50	1	2.7	9.0	27.0	90.0	
800	1.56	1	3.0	10.0	30.0	100.0	
850	1.95	1	3.0	10.0	30.0	100.0	
900	2.44	1	3.0	10.0	30.0	100.0	
950	3.05	1	3.0	10.0	30.0	100.0	
1000	3.82	1	3.0	10.0	30.0	100.0	
1050	4.78	1	3.0	10.0	30.0	100.0	
1060	5.00	1	3.0	10.0	30.0	100.0	
1100	5.00	1	3.0	10.0	30.0	100.0	
1400	5.00	1	3.0	10.0	30.0	100.0	
1500	1.0						
1540	100.0*						
1600	1.0						1.0
13000	1.0						
1.0×10^6	1.0						

*The factor $k_1 = 100.0$ when $t \leq 10^{-7}$ sec, and $k_1 = 1.0$ when $t > 10^{-7}$ sec.
 Note: The variable (t) is the magnitude of the sampling interval in units of seconds.

Table VIII. Maximum Aperture Diameters (Limiting Aperture)
for Measurement Averaging

Mea- sure- ment	Exposure Duration, t (s)	Wavelength Range			
		Ultraviolet (0.2-0.4 μm)	Visible and Near-Infrared (0.4-1.4 μm)	Medium and Far-Infrared (1.4-10 ⁻² μm)	Submil- limeter (0.1-1mm)
Eye MPE	10 ⁻⁹ -3x10 ⁴	1 mm	7 mm <u>2/</u>	1 mm	11 mm
Skin MPE	10 ⁻⁹ -3x10 ⁴	1 mm	1 mm	1 mm	11 mm
Laser <u>1/</u> Classi- fication	10 ⁻⁹ -3x10 ⁴	80 mm	80 mm	80 mm	80 mm

This material is from American National Standard for the Safe Use of Lasers, ANSI Z136.1-1980.

Note: The footnote has been modified from that found in ANSI Z136.1-1980.

1/ See C.9(a)(3).

2/ When the LSO determines that laser radiation may be viewed with optical instruments, correction must be made for collecting more radiant power by using an 80 mm aperture.

For the specific case of optical viewing (beam collecting) instruments, the apertures listed for eye MPE and skin MPE apply to the exit beam of such devices.

WARNING LOGOTYPE A

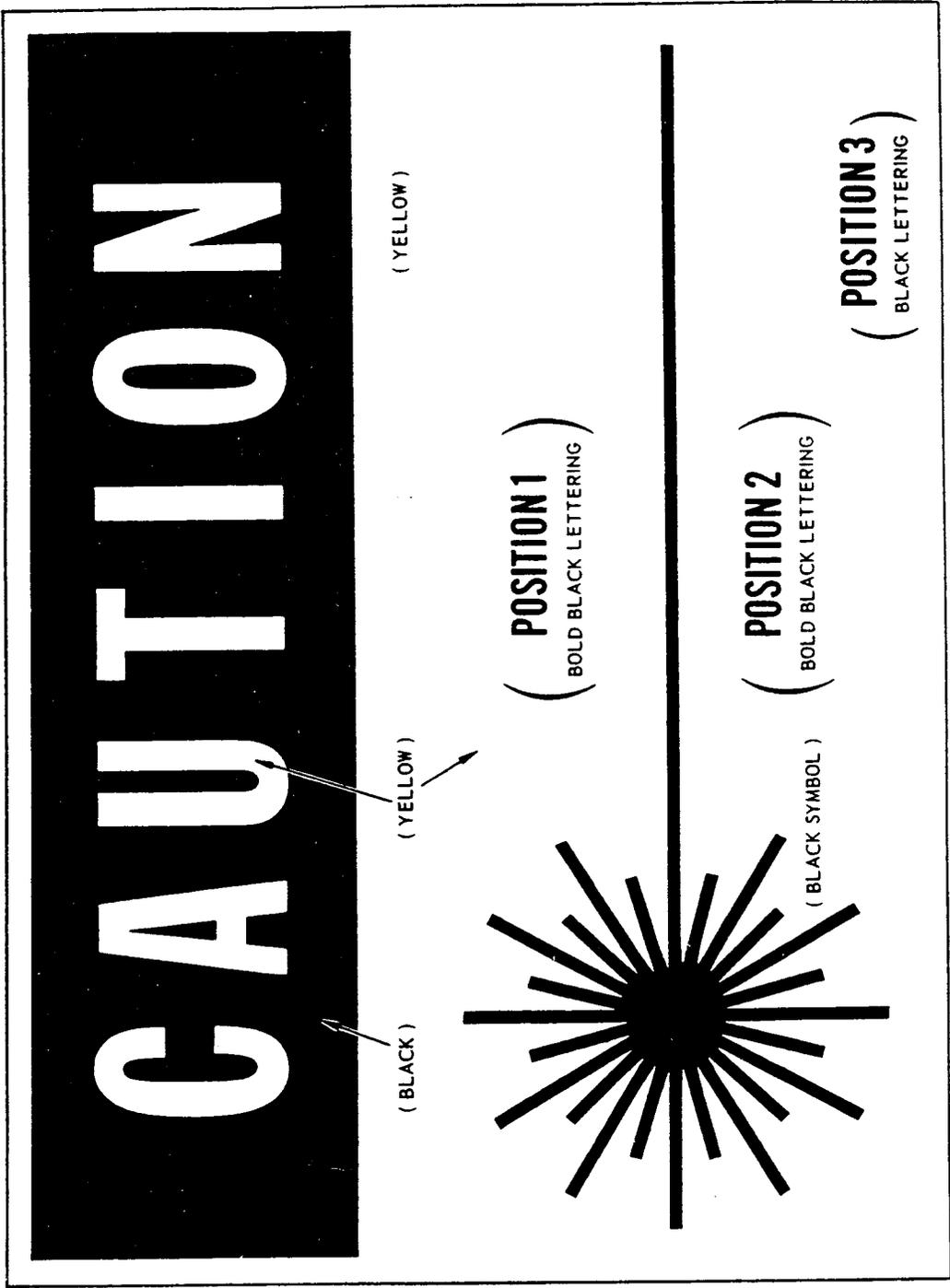


FIGURE 1

WARNING LOGOTYPE B

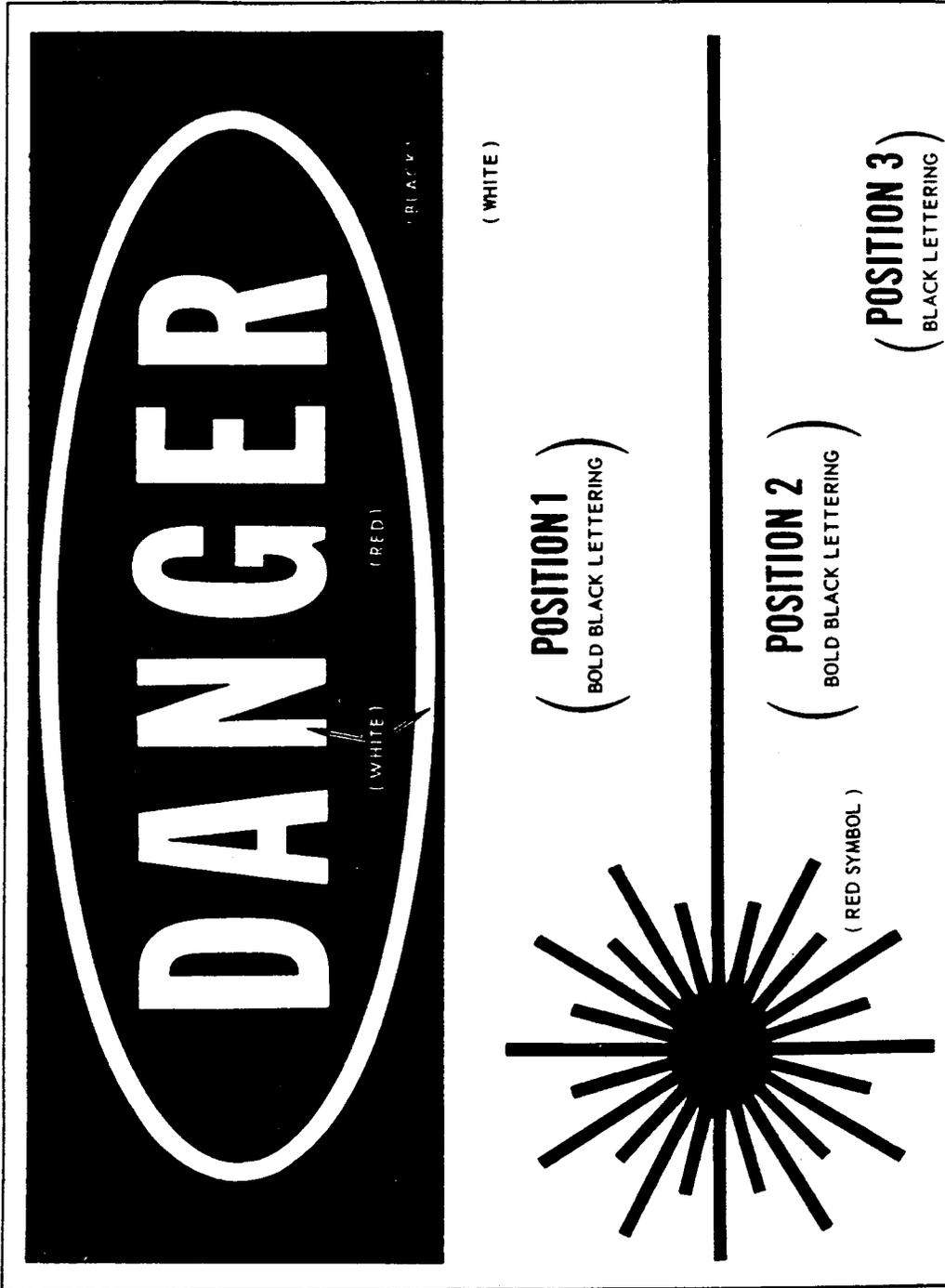
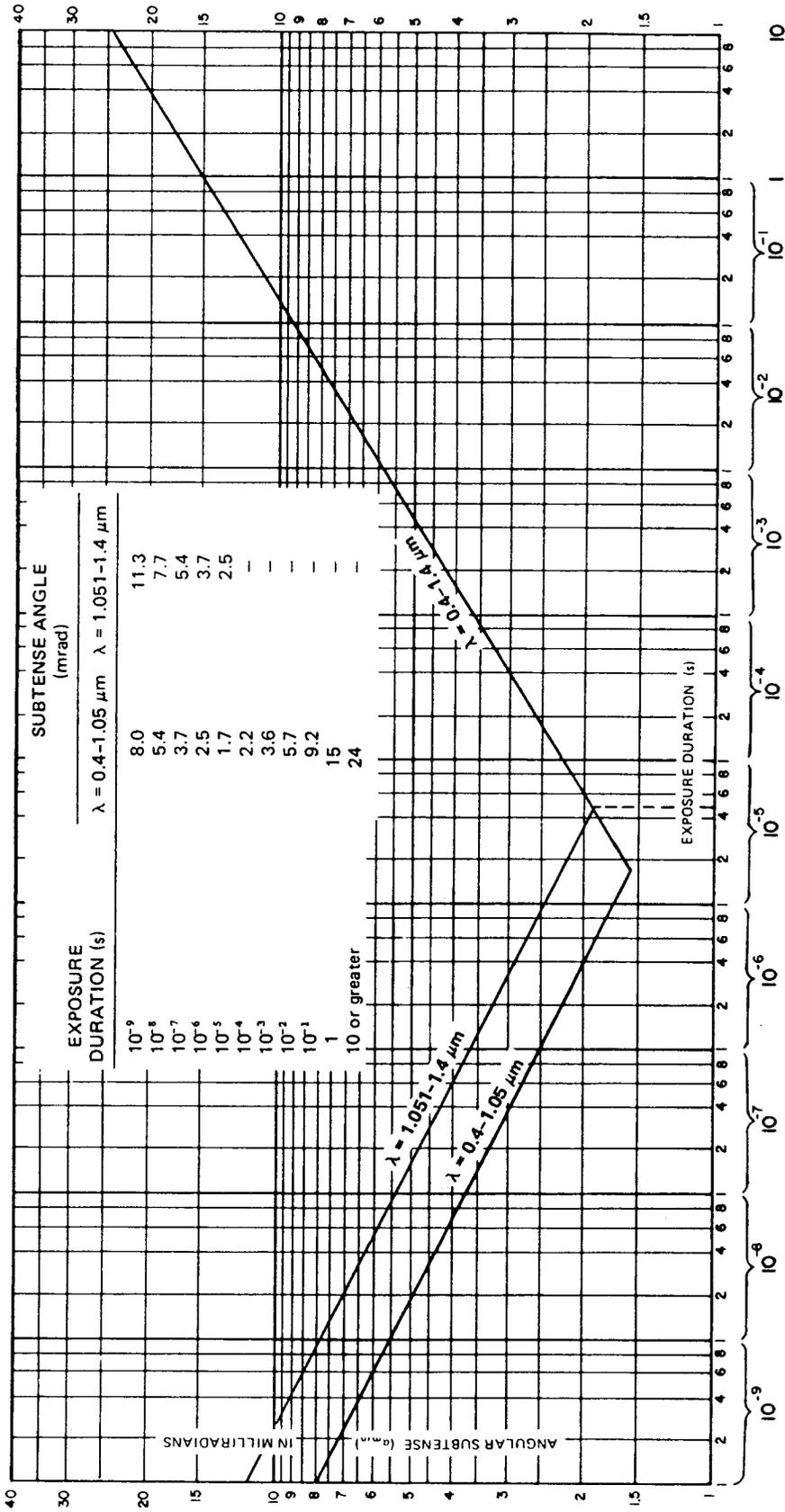
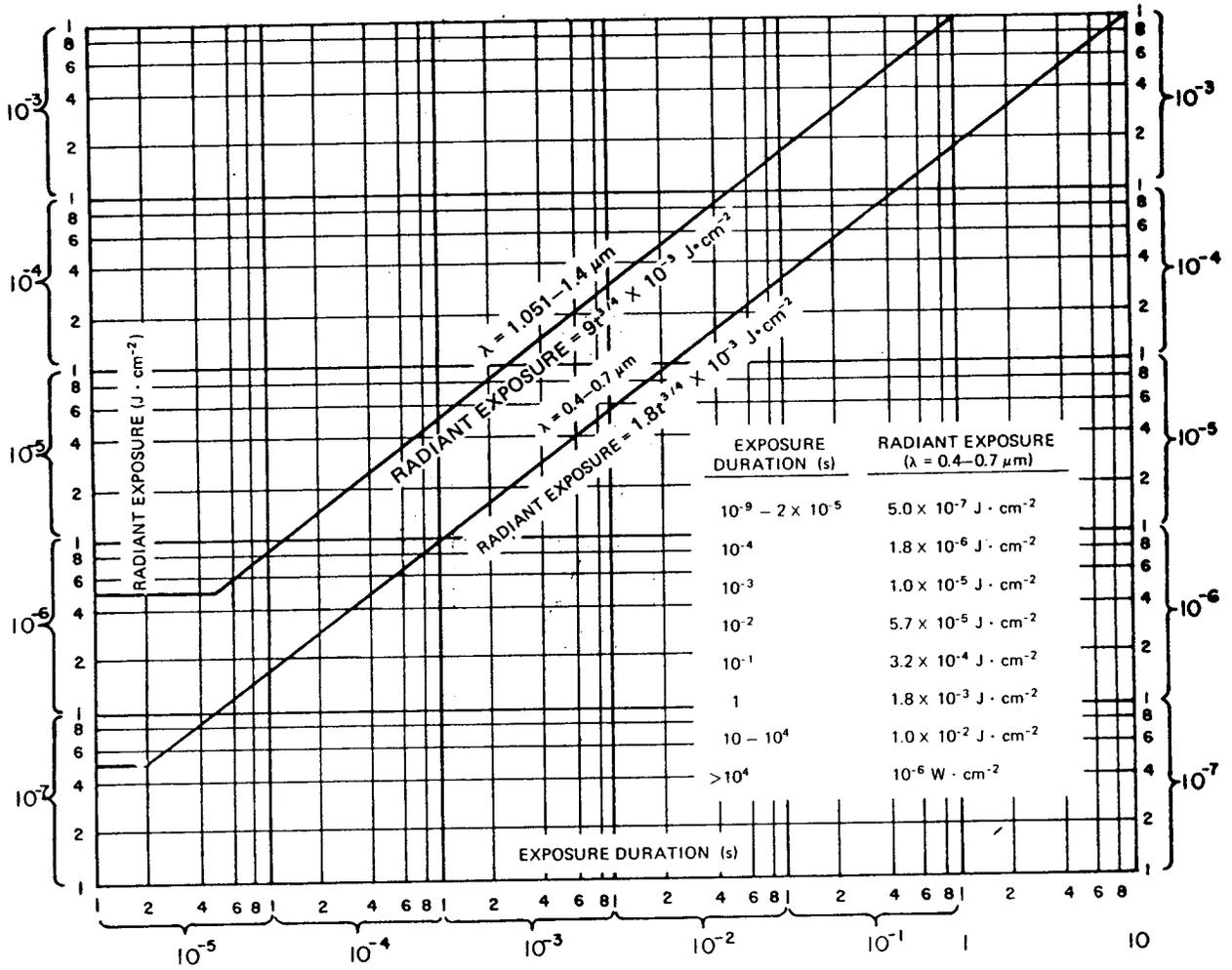


FIGURE 2



NOTE: Extended sources have an angular subtense or apparent visual angle $\geq \alpha_{\text{min}}$. Angular subtenses (apparent visual angles) $< \alpha_{\text{min}}$ are considered intrabeam viewing.

Fig. 3
Limiting Angular Subtense (Apparent Visual Angle), α_{min} ,
for $\lambda = 0.4-1.4 \mu\text{m}$



NOTE: For correction factor information at wavelengths between 0.7 μm and 1.4 μm , see Table 5.

Fig. 4
MPE for Direct Ocular Exposure to Visible and Near Infrared Radiation ($\lambda = 0.4-1.4 \mu m$), Intrabeam Viewing,* for Single Pulses or Exposures

*Angular subtense $< \alpha_{min}$ in Fig. 3.

The variable in the expression is the magnitude of the exposure duration (t) in units of seconds.

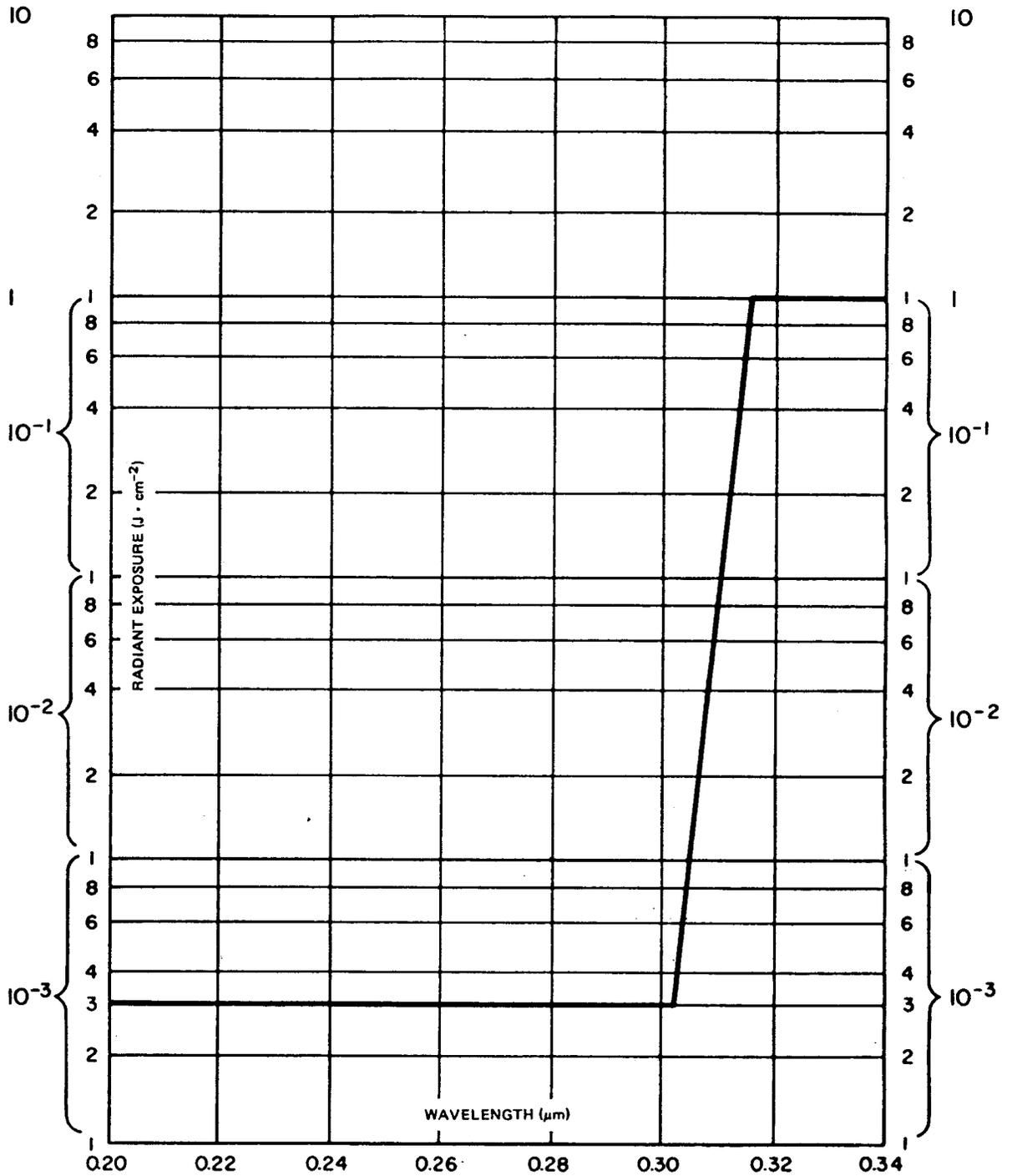
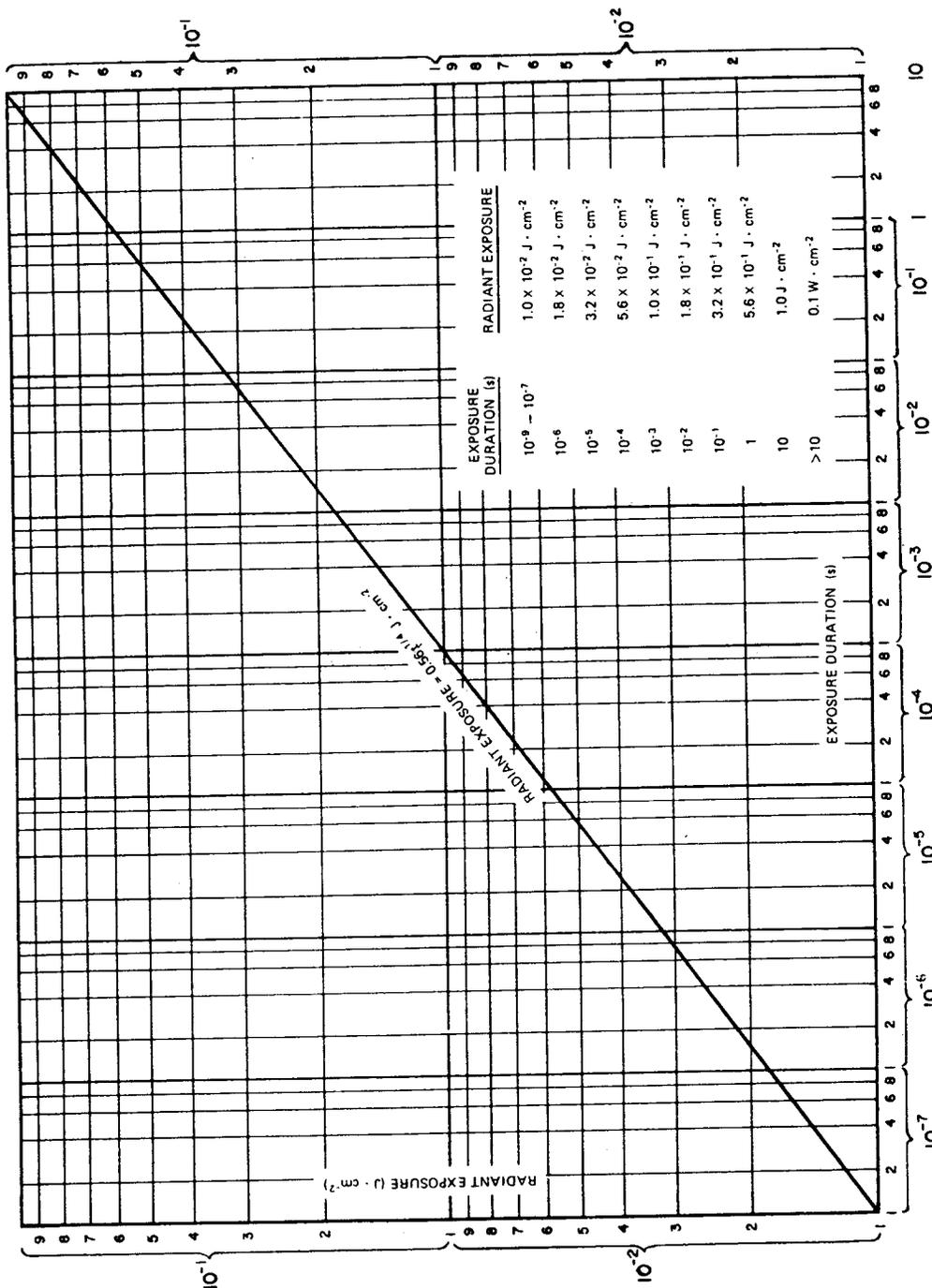


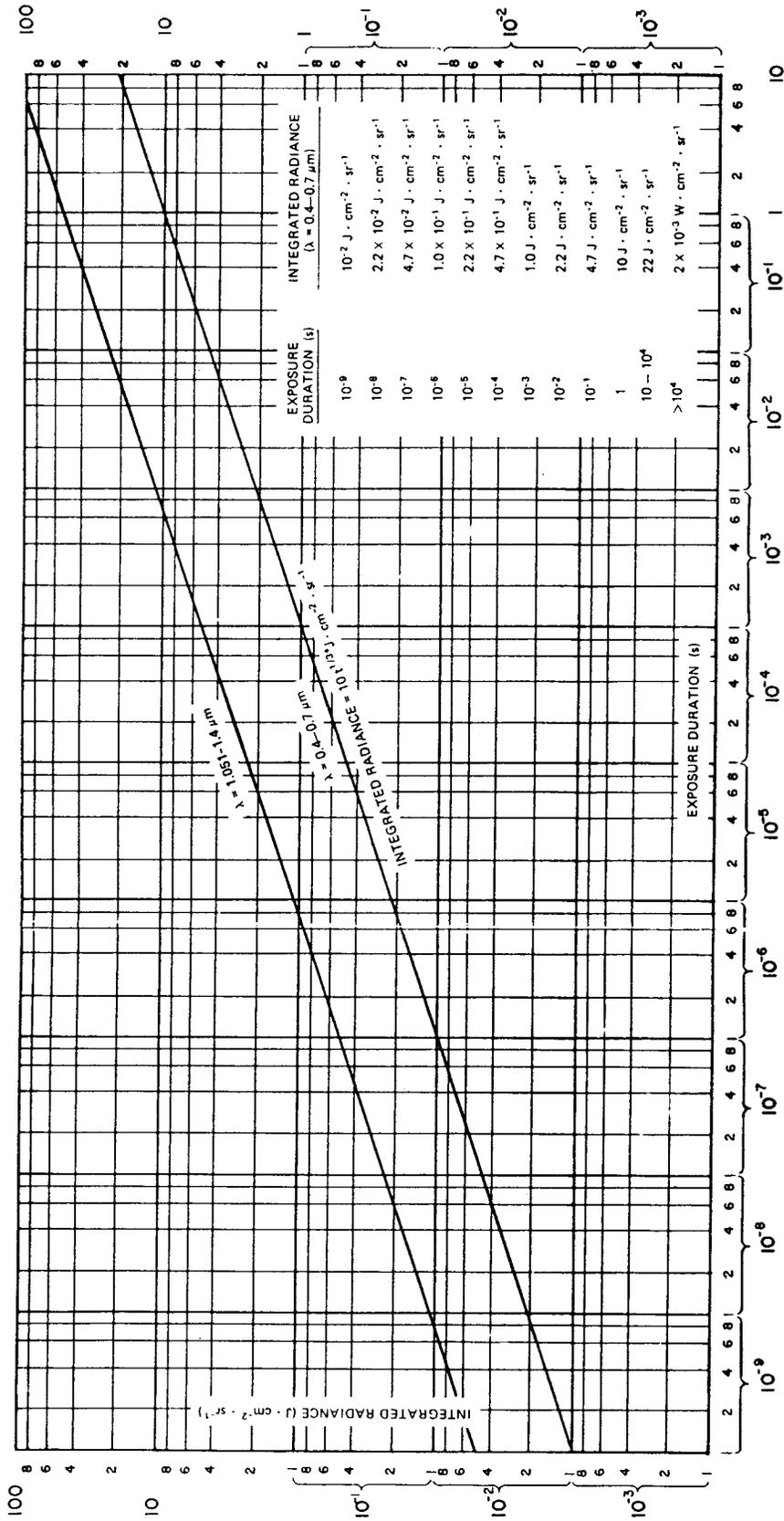
Fig. 5
MPE for Direct Ocular Exposure to Ultraviolet Radiation
for Exposure Durations from 10^{-9} to 3×10^4 s*

*Unless $0.56 t^{1/4}$ is exceeded (possible for exposure durations < 10 s at $\lambda = 0.305\text{--}0.315 \mu\text{m}$).



NOTE: For correction factors at 1.54 μm , see Appendix E, paragraph 5.
 The variable in the expression is the magnitude of the exposure duration (t) in units of seconds.

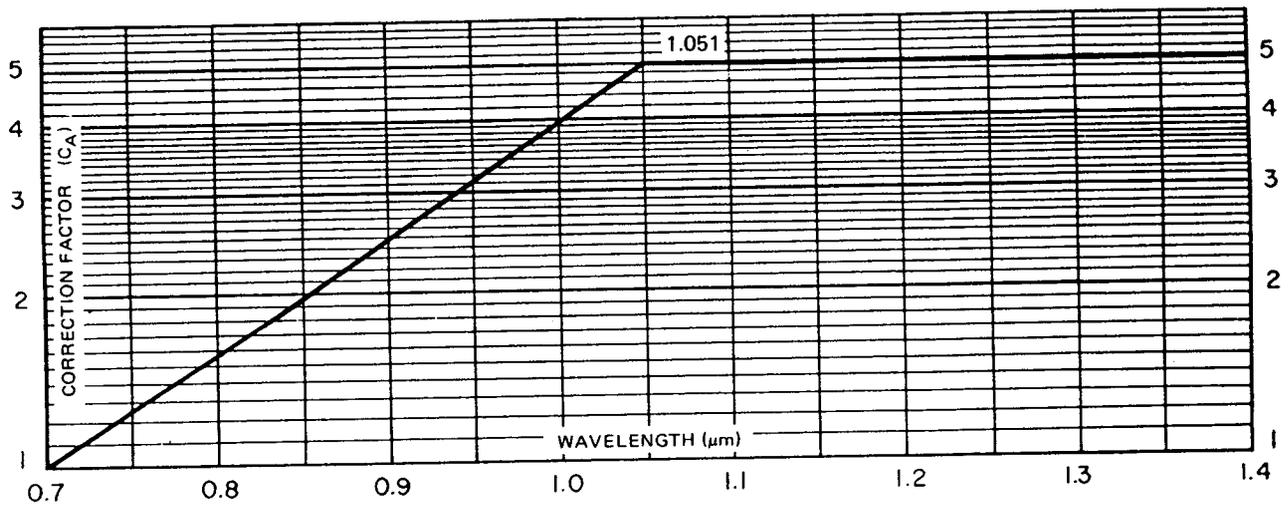
Fig. 6
 MPE for Direct Ocular Exposure to Ultraviolet and Infrared Radiation ($\lambda = 0.315-0.4 \mu m$ and $1.4 \mu m-1 mm$) for Single Pulses or Continuous Exposures



NOTE: For correction factors at wavelengths between 0.7 and 1.051 μm , see Fig. 8.
 The variable in the expression is the magnitude of the exposure duration (t) in units of seconds.

Fig. 7
 MPE for Direct Ocular Exposure to Laser Radiation ($\lambda = 0.4-0.7 \mu\text{m}$ and $1.051-1.4 \mu\text{m}$) from Extended Sources* for Single Pulses or Exposures

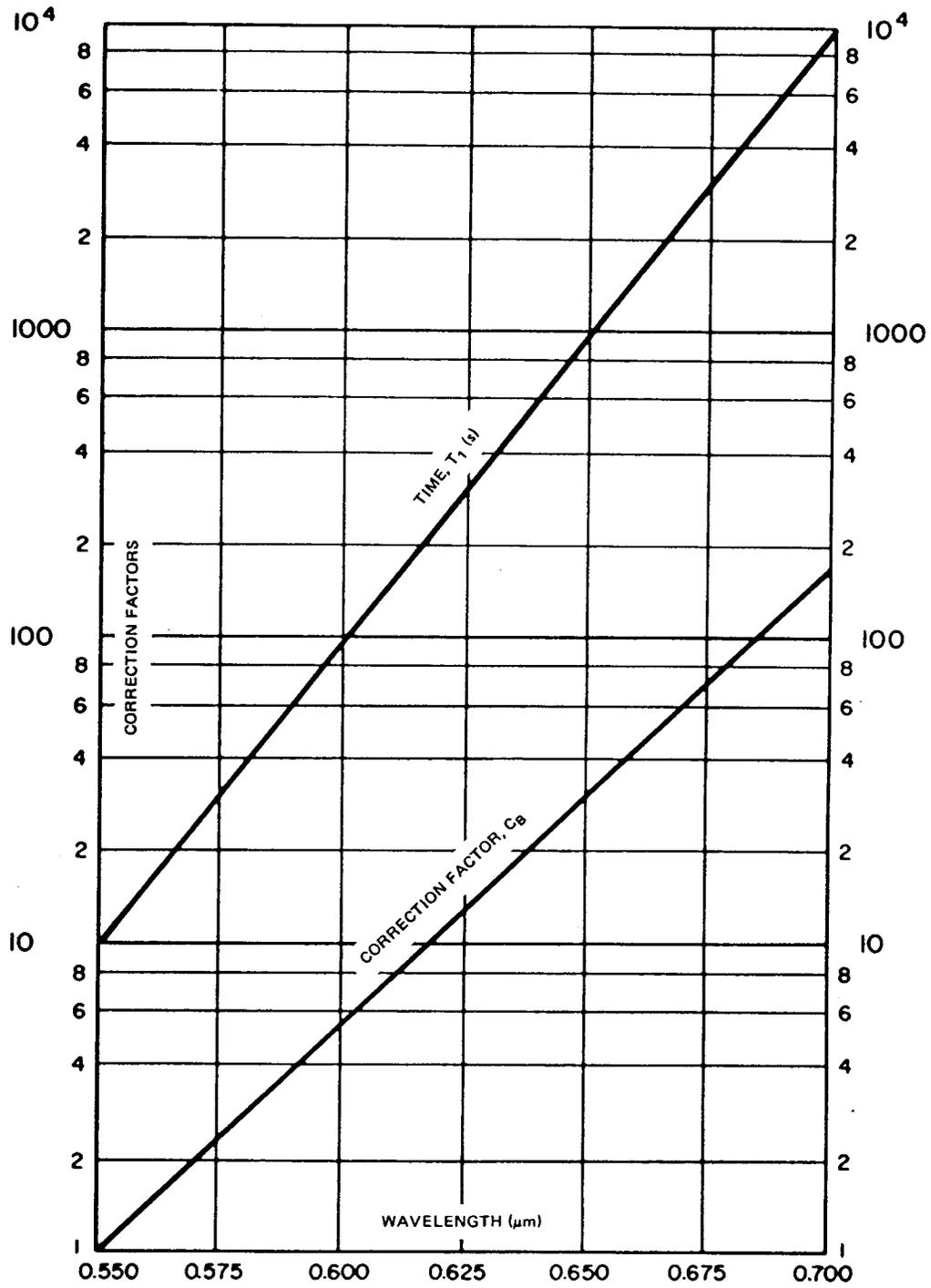
* Angular subtense $\geq \alpha_{\text{min}}$ in Fig. 3.



NOTE: $C_A = 1$ for $\lambda = 0.4-0.7 \mu\text{m}$;
 $C_A = 102.0(\lambda - 0.7)$ for $\lambda = 0.7-1.05 \mu\text{m}$
 $C_A = 5$ for $\lambda = 1.051-1.4 \mu\text{m}$

Wavelength (λ) is in units of micrometers.

Fig. 8
Correction Factor C_A for Wavelengths 0.7-1.4 μm from
Tables 5 and 6



NOTE: See Tables IVa and IVb.

Fig. 9
Correction Factors C_B and T_1 for Wavelengths 0.55-0.7 μm

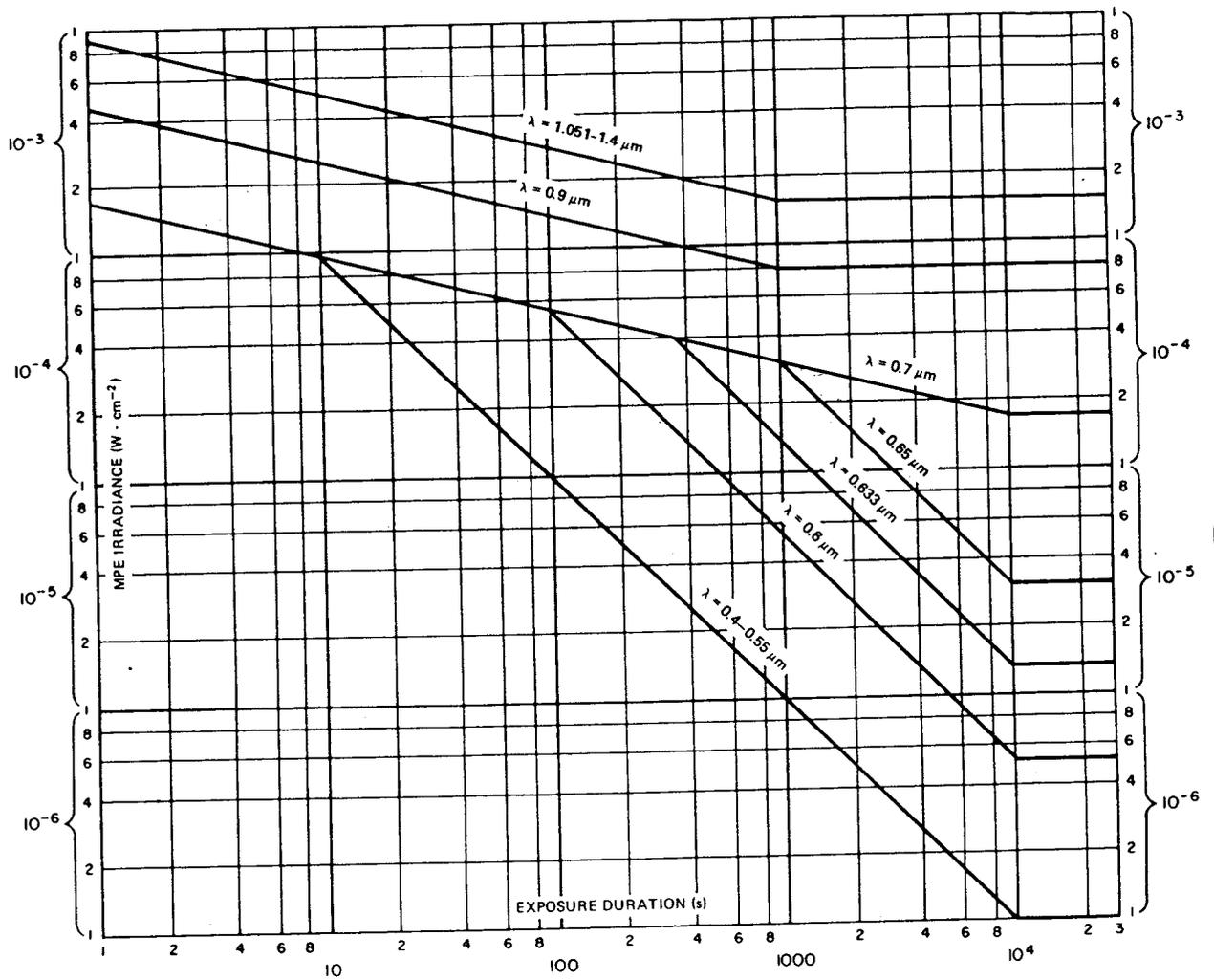


Fig. 10
Ocular MPE for Intrabeam Viewing* as a Function of Exposure Duration and Wavelengths

*Angular subtense $< \alpha_{min}$ in Fig. 3.

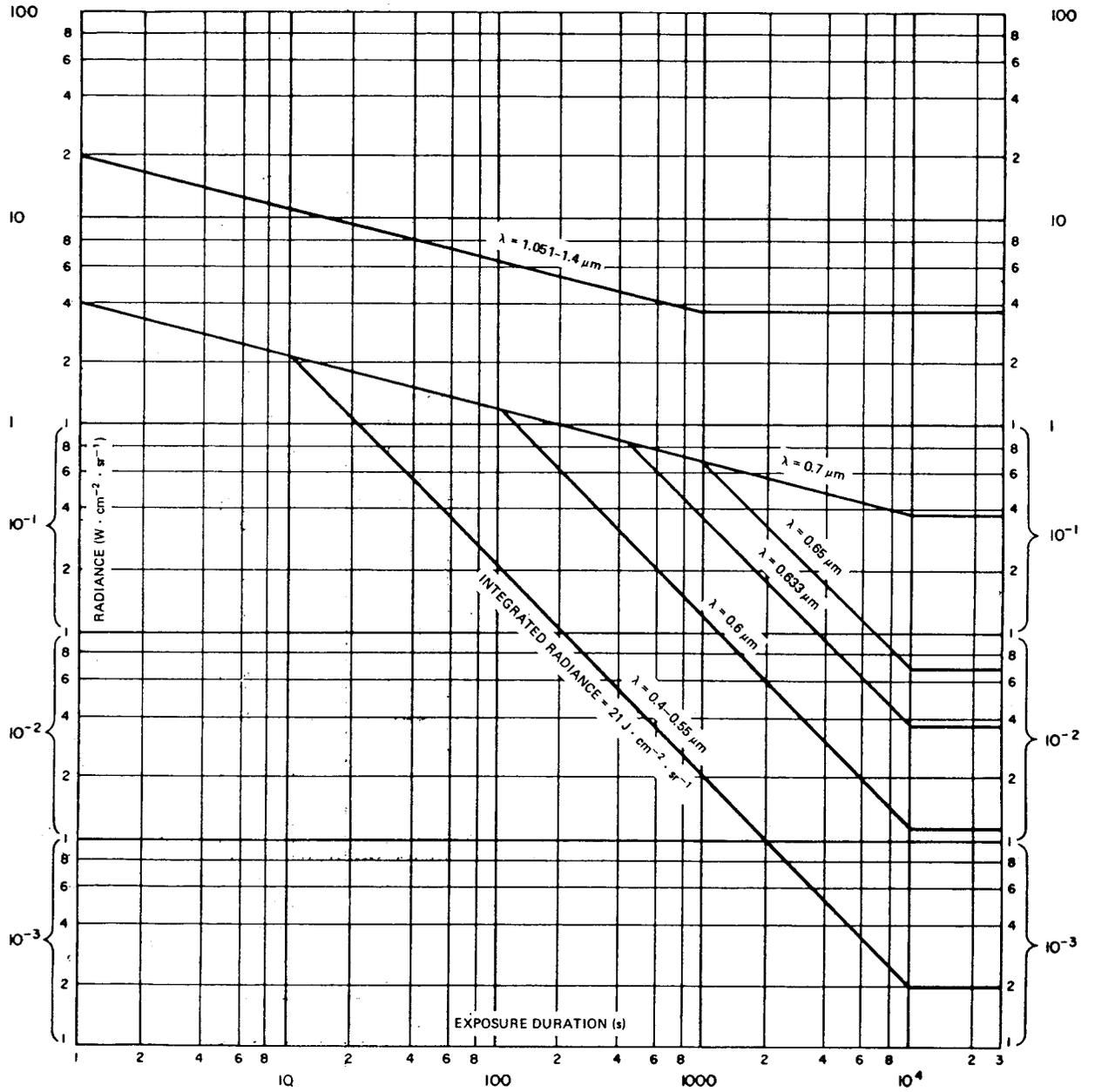
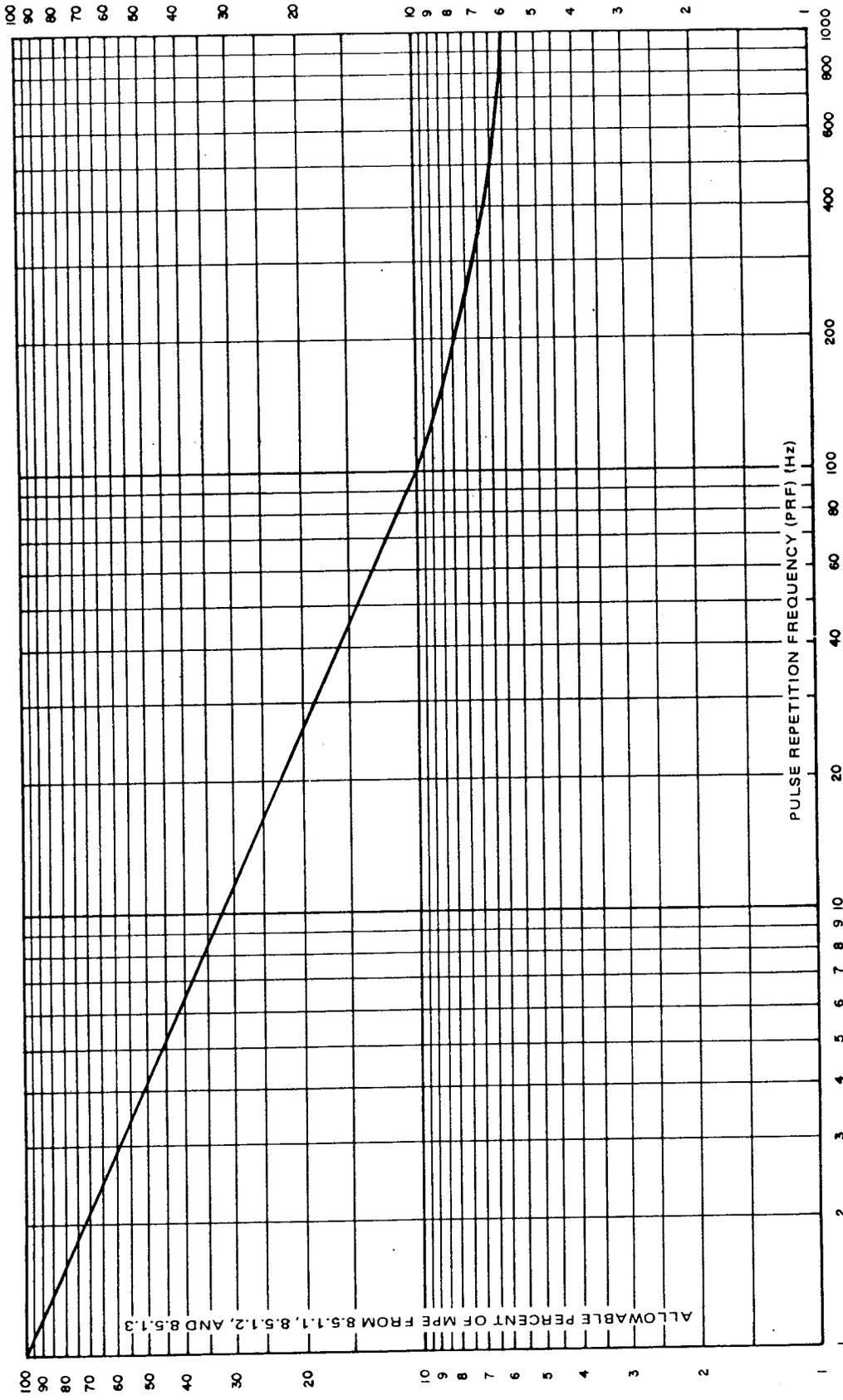


Fig. 11
 Ocular MPE for Extended Sources* as a Function of Exposure
 Duration and Wavelengths

*Angular subtense $\geq \alpha_{\text{min}}$ in Fig. 3.



NOTE: For repetition rates greater than 1000 pps, the percent MPE = 6.

Fig. 12
 Reduction of MPE for Repetitively Pulsed or Multiple Exposures from Scanning Lasers,
 Individual Pulse or Exposure Less than 10 μs

APPENDIX A

MEDICAL SURVEILLANCE

A1 Purpose of Medical Surveillance. The basic reasons for performing medical surveillance of personnel working in a laser environment are the same as for other potential health hazards. Medical surveillance examinations may include assessment of physical fitness to safely perform assigned duties, biological monitoring of exposure to a specific agent, and early detection of biologic damage or effect.

Physical fitness assessments are used to determine whether an employee would be at increased or unusual risk in a particular environment. For workers using laser devices, the need for this type of assessment is most likely to be determined by factors other than laser radiation per se. Specific information on medical surveillance requirements that might exist because of other potential exposures such as toxic gases, noise, ionizing radiation, etc., are outside the scope of this Appendix.

Direct biological monitoring of laser radiation is impossible, and practical indirect monitoring through the use of personal dosimeters is not available.

Early detection of biologic change or damage presupposes that chronic or subacute effects may result from exposure to a particular agent at levels below that required to produce acute injury. Active intervention must then be possible to arrest further biological damage or to allow recovery from biological effects. Although chronic injury from laser radiation in the ultraviolet, near-ultraviolet, blue portion of the visible, and near-red regions appears to be theoretically possible, risks to workers using laser devices are primarily from accidental acute injuries. Based upon risks involved with current uses of laser devices, medical surveillance requirements that should be incorporated into a formal standard appear to be minimal.

Other arguments in favor of performing extensive medical surveillance have been based on the fear that repeated accidents might occur and that workers would not report minimal acute injuries. The very small number of laser injuries that have been reported in the past 15 years and the excellent safety records with laser devices does not provide support to this argument.

A2 Medical Examinations

A2.1 Rationale for Examinations

A.2.1.1 Preassignment Medical Examinations. Except for examination following suspected injury, these are the only examinations required. One purpose is to establish a baseline against which damage (primarily ocular) can be measured in event of an accidental injury. A second purpose is to identify certain workers who might be at special risk from chronic exposure to selected wavelength lasers. For incidental workers, only visual acuity measurement is required. For laser workers, medical histories, visual acuity measurement and selected examination protocols are required. The wavelength of laser radiation is the determinant for which specific protocols are required (see A2.2). Examinations should be performed by or under the supervision of an ophthalmologist or other qualified physician. Certain of

the examination protocols may be performed by other qualified practitioners or technicians, under the supervision of a physician. Many ophthalmologists may prefer to perform more thorough eye examinations to assess total visual function as opposed to limiting examination to those areas that might be damaged by particular laser radiation. Some employers may find it advantageous to offer these more thorough examinations to their workers as a health benefit. For example, certain of the additional examinations, such as tonometry, may be of value in detecting unknown disease conditions; in this case glaucoma. Even though this type of problem is unrelated to work with lasers, appropriate medical intervention will promote a healthier work force. Although chronic skin damage from laser radiation has not been reported, and indeed seems unlikely, this area has not been adequately studied. Limited skin examinations are suggested to serve as a baseline until future epidemiologic study indicates whether they are needed or not.

A2.1.2 Periodic Medical Examinations. Periodic examinations are not required. At the present time no chronic health problems have been linked to work with laser radiation. Also, most uses of lasers do not result in chronic exposure of employees even to low levels of radiation. A large number of these examinations have been performed in the past and no indication of any detectable biologic change was noted. Employers may wish to offer their employees periodic eye examinations or other medical examinations as a health benefit; however, there does not appear to be any valid reason to require such examinations as part of a medical surveillance program.

A2.1.3 Termination Medical Examinations. The primary purpose of termination examinations is for the legal protection of the employer against unwarranted claims for damage that might occur after an employee leaves a particular job. The decision on whether to offer or require such examinations is left to individual employers.

A2.2 Examination Protocols

A2.2.1 Medical History. Required for preplacement examinations of all laser workers. The patient's past eye history and family eye history are reviewed. Any current complaints which he now has about his eyes are noted. Any history of skin problems is reviewed. Current and past medication use is reviewed. The patient's general health status should be inquired about with special emphasis upon diseases which can give ocular or skin problems. Certain medical conditions may cause the laser worker to be at increased risk if chronic exposure to ultraviolet or blue spectrum laser radiation is possible. Use of photosensitizing medications, such as phenothiazines and psoralens, lower the threshold for biologic effects in the cornea, lens, and retina of experimental animals. Aphakic individuals would be subject to additional retinal exposure from near-ultraviolet radiation. Unless chronic viewing of lower levels of laser radiation in these wavelengths is required, there should be no reason to deny employment to these individuals. With current laser systems, chronic exposure even to low levels of blue laser radiation is very unusual.

A2.2.2 Visual Acuity. Required for preplacement examinations for all incidental and laser workers. Distance visual acuity should be tested both with and without corrective lenses to 20/15. Results should be recorded in Snellen figures. The visual acuity at near is tested at 35 cm and recorded

in Jaeger-tested figures or Snellen figures with and without lenses, if any. Visual acuity screening instruments may be used.

A2.2.3 Manifest Refraction. Required for preplacement examinations of all laser workers when indicated. This is to measure the patient's refractive error, and the new visual acuity of the patient must be noted if the visual acuity is improved over that achieved with the patient's old lens prescription, or if he has no lenses at the time of the examination. This examination shall be carried out in all personnel whose best corrected distance visual acuity in either eye is less than 20/20.

A2.2.4 External Ocular Examination. Required for preplacement examinations for laser workers using laser systems producing radiation below 350 nm or above 1400 nm. This includes examination of brows, lids, lashes, conjunctiva, sclera, cornea, iris and pupillary size, equality, reactivity, and regularity.

A2.2.5 Examination by Slit Lamp. Required for preplacement examinations of laser workers using laser systems producing radiation below 420 nm or above 750 nm. The cornea, iris, and lens are examined with a biomicroscope and described.

A2.2.6 Examination of the Ocular Fundus with an Ophthalmoscope. Required for preplacement examinations of laser workers using laser systems producing radiation between 390 nm and 1400 nm and any aphakic worker. In the recording of this portion of the examination the points to be covered are: the presence or absence of opacities in the media; the sharpness of outline of the optic nerve; the size of the physiological cup, if present; the ratio of the size of the retinal veins to that of the retinal arteries; the presence or absence of a well-defined macula and the presence or absence of a foveolar reflex; and any retinal pathology that can be seen with a direct ophthalmoscope. Even small deviations from normal should be described and carefully localized.

A2.2.7 Skin Examination. Not required for preplacement examinations of laser workers; however, suggested for employees with history of photosensitivity or those working with ultraviolet lasers. Examination of the skin for presence of abnormal pigmentation or depigmentation, keratoses, malignancies, etc.

A2.2.8 Amsler Grid. Not required. The Amsler grid sheet is presented to each eye separately and any distortion of the grid is noted by the patient and drawn by him; may be part of a thorough ophthalmologic examination.

A2.2.9 Tonometry. Not required. This is the measurement of intraocular pressure; should be part of a thorough ophthalmologic examination.

A2.2.10 Photograph of the Posterior Pole of the Fundus. Not required. This includes the area of the macula and head of the optic nerve and should be taken in color; may be obtained by the examining physician to more fully describe retinal abnormalities. Appropriate techniques to reduce the patient's exposure to optical radiation should be employed.

A2.2.11 Other Examinations. Further examinations should be done as deemed necessary by the examiner.

A3 Medical Referral Following Suspected or Known Laser Injury. Any employee with a suspected eye injury should be referred to an ophthalmologist. Persons with skin injuries should be seen by a physician.

A4 Epidemiologic Studies. Past use of laser systems has generally been stringently controlled. Actual exposure to laser workers has been minimal or even nonexistent. It is not surprising that acute accidental injury has been rare and that the few reports of repeated eye examinations have not noted any chronic eye changes. For these reasons, examination requirements are minimal. However, animal experiments with both laser and narrow-band radiation indicate the potential for chronic damage from both subacute or chronic exposure to certain wavelengths of radiation. Lens opacities have been produced by radiation in the 295-450 nm range and are also theoretically possible from 750-1400 nm.

Photochemical retinitis appears to be possible to induce by exposure to 350-500 nm radiation. If laser systems are developed that require chronic exposure of laser workers to even low levels of radiation in these wavelength regions, it is recommended that such workers be included in the long-term epidemiologic studies and have periodic examinations of the appropriate eye structures.

Epidemiologic studies of workers with chronic skin exposure to laser radiation (particularly ultraviolet) are suggested.

A5 References

- A5.1 Friedmann, A.I., The Ophthalmic Screening of Laser Workers, Ann Occup Hyg, 21:277-279, 1978.
- A5.2 Hathaway, J.A., Stern, N., Soles, E.M., and Leighton, E., Ocular Medical Surveillance on Microwave and Laser Workers, J Occup Med, 19:683-688, 1977.
- A5.3 Hathaway, J.A., The Needs for Medical Surveillance of Laser and Microwave Workers, Current Concepts in Ergophthalmology, Societas Ergophthalmologica Internationalis, Stockholm, Sweden, 1978, pp. 139-160.

APPENDIX B

GUIDELINES FOR LASER LIGHT SHOWS

1. Each laser facility and mobile laser shall be registered in accordance with the provisions of these regulations.
2. The laser operator shall demonstrate his competency to operate the laser safely. Demonstration of competency may include, but is not limited to, proof of having taken and passed an acceptable laser training course such as given at several universities or sponsored by technical organizations.
3. Laser radiation outside the spectral range 400 to 710 nanometers shall be as low as practicable but shall not, in any case, exceed the Class I limits under any possible conditions of operation.
4. Levels of laser and collateral radiation, measured where the audience is normally located, and laser and collateral radiation measured where the operators, performers, and employees are located if the radiation is intended to be viewed by them, shall not exceed the limits of Class I during operation. Radiation which shall be measured includes reflections from targets and scattering materials. For example:
 - (a) If the average laser power collectable with appropriate apertures is below 0.39 microwatts, then the limits of Class I will not be exceeded.
 - (b) For pulsed radiation and scanning radiation treated as pulsed radiation, if the energy in a pulse or series of pulses is less than 0.2 microjoule collectable with appropriate apertures, the limits of Class I will not be exceeded.
5. Operators, performers, and employees shall be able to perform their functions without the need for exposure to laser and collateral radiation in excess of the limits of Class II when the radiation is not intended to be viewed by them. Areas where levels of laser radiation in excess of the limits of Class II exist shall be clearly identified by posting and/or through use of barriers or guards to prevent entry of operators or performers into these areas.
6. Scanning devices shall incorporate a means to turn off the beam or to prevent laser emission in case the beam stops scanning or slows down significantly. In cases where a mirror ball is used with a scanning beam, the limits of item 4 shall be met with the mirror ball stationary; or the mirror ball shall incorporate a means to turn off the beam or to prevent laser emission if the mirror ball stops rotating or slows down significantly such that the limits of item 4 or 5 are exceeded. Any such scan failure safeguard system must have a reaction time fast enough to preclude audience access to levels in excess of Class I.
7. Except as noted below, laser light shows shall be under the direct and personal supervision of a competent laser operator, as specified in item 2, and the laser beam to which human access can be gained shall not exceed the limits of Class II at any point less than (a) 3.0 meters above any surface upon which the audience or general public is permitted to stand, and

(b) 2.5 meters in lateral separation from any position where a person in the audience or general public is permitted during the performance or display, unless physical barriers are present which obstruct access by the audience or general public to such levels.

Exception: In cases where the maximum laser output power level is less than 5 milliwatts including all wavelengths and the laser beam path is located at least 6 meters above any surface upon which a person in the audience or general public is permitted to stand and at any point less than 2.5 meters in lateral separation from any position where a person in the audience or general public is permitted during the performance or display, then a laser operator need not be continuously present if other provisions of these Guidelines and Regulations are met. In other cases, upon application to the Agency, appropriate arrangements may be made for unattended operation.

8. All laser light shows shall be provided with a key operated "on-off" switch. In the case of the exception of item 7, there shall be a designated individual present who can turn off and secure the laser in case of unsafe operating conditions.

9. The maximum laser output power shall be limited to a level required to obtain the intended effect.

10. The laser system, including projector, shall be rigidly mounted to prevent unintended movement or accidental misalignment.

11. The laser operator(s) shall be situated in a position such that performers, audience, beam path(s), and laser display can be viewed at all times during laser operation.

12. Where laser output power must be limited to less than the maximum power available in order to comply with criteria 3 through 9, the laser output power shall be measured, adjusted, and recorded before it is operated at each light show. All safety devices necessary to meet criteria 3 through 9, such as scanning-beam power interlock, shall be functionally tested and recorded before each light show.

13. The laser system shall be secured against unauthorized operation.

14. The following precautions shall be taken during alignment procedures.

(a) Alignment shall be performed by a competent and qualified individual and with the laser radiation emission reduced to lowest practicable level.

(b) Only persons required to perform alignment shall be in or near the beam path(s).

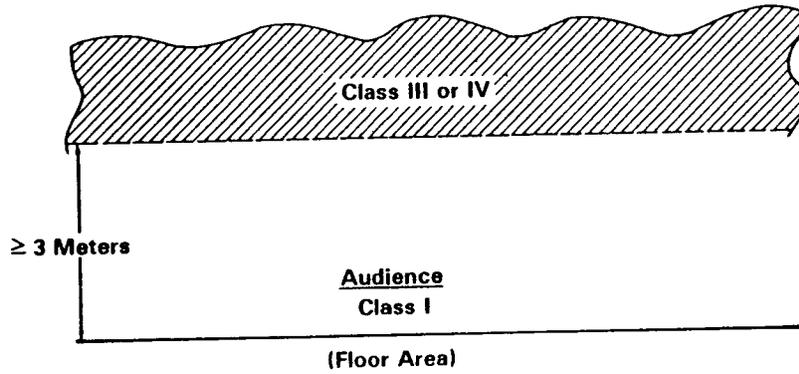
(c) Protective eyewear shall be worn where necessary to prevent hazardous exposure.

15. In addition to the requirements of B.11, before the laser light show is permitted to operate either at a permanent or temporary job site, the laser light show operator or an authorized representative shall provide the Agency with sufficient information, data, and measurements to establish

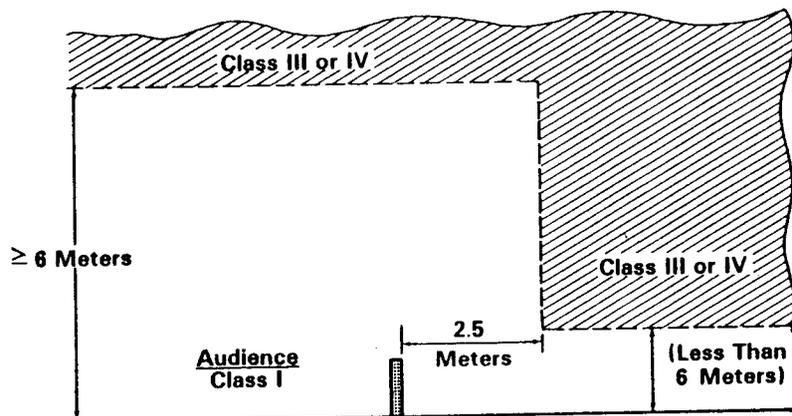
that the above criteria will be met during use. This shall include sketches showing the location of laser, operator(s), performer(s), viewers, beam paths, viewing screens, walls, mirror balls, and other reflective or diffuse surfaces which may be struck by laser beam, scanning beam patterns, scanning velocity and frequency in occupied areas and where beam strikes wall or other structure, radiometric measurement data including output power and location of all measurements. In the case of open air shows where a laser beam is projected into the sky, the information submitted shall also include beam spot size, beam divergence, and beam power measured at the projector, and a copy of the notification provided to the Federal Aviation Administration.

LASER LIGHT SHOWS
Application of Safety Criteria

OPERATOR IN CONTROL



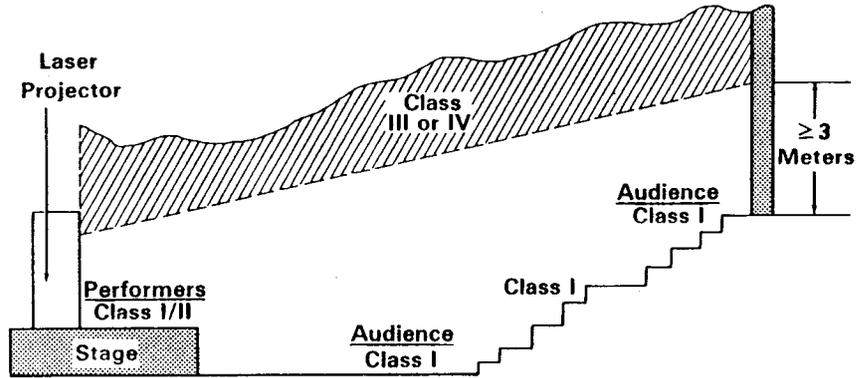
NO OPERATOR IN CONTROL
(SIDE VIEW)



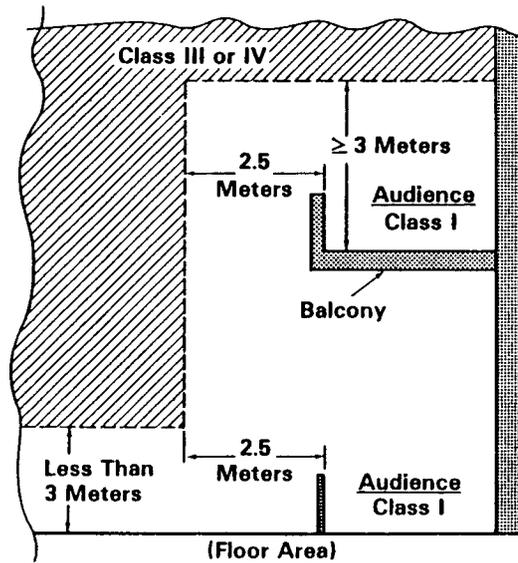
LASER LIGHT SHOWS

Application of Safety Criteria

OPERATOR IN CONTROL (RISING FLOOR LEVEL)

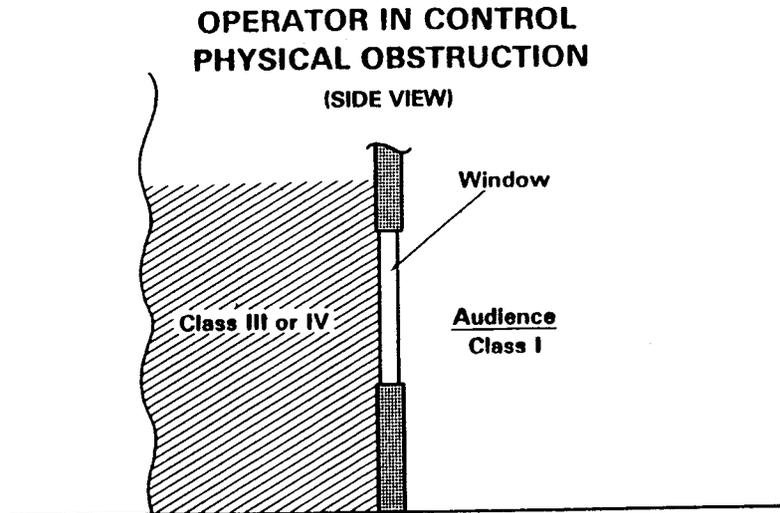
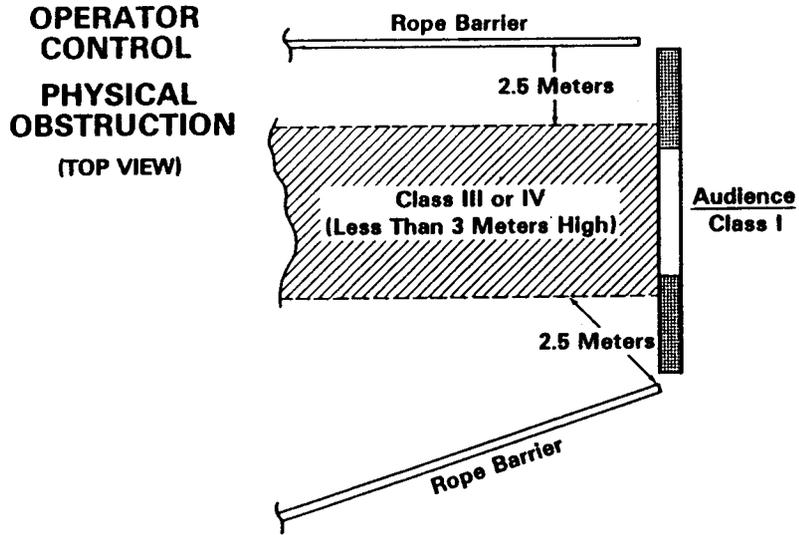


OPERATOR IN CONTROL (SIDE VIEW)



LASER LIGHT SHOWS

Application of Safety Criteria

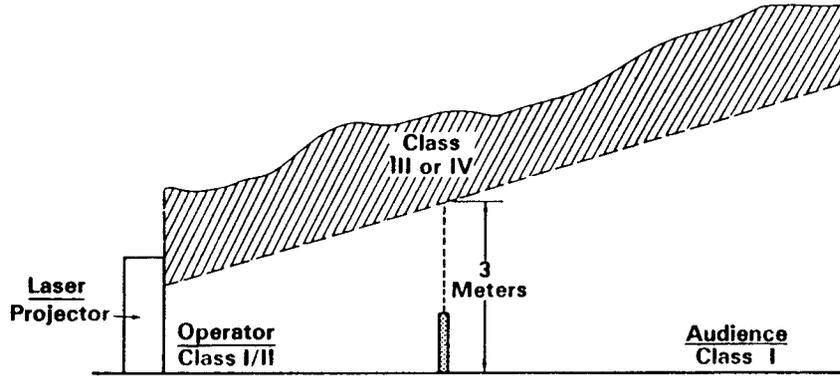


LASER LIGHT SHOWS

Application of Safety Criteria

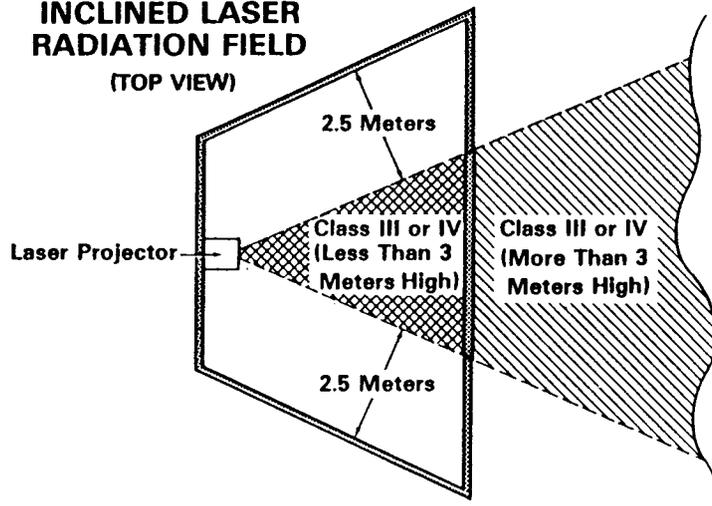
OPERATOR IN CONTROL
INCLINED LASER RADIATION FIELD

(SIDE VIEW)



OPERATOR IN CONTROL
INCLINED LASER
RADIATION FIELD

(TOP VIEW)



APPENDIX C

APPLICATION FOR REGISTRATION OF LASER FACILITY,
MOBILE LASER, OR SERVICE ORGANIZATION

Registration is required for all uncertified laser products and for certified Class IIIb (other than those exempted by B.4(a)(2)) and Class IV laser products.

1. Applicant's Name _____ Tel. No. _____

Address: _____

2. Location of use (if different from Number 1): _____

3. Type of registration: Laser Facility (), Mobile Laser (), Service Org. ().

4. Prior Laser Registration Number, if any: _____

5. Sources of laser radiation (Class IIIb and Class IV only):

a	b	c	
Wavelength Range	Number of Sources of Laser Radiation		Range of Average Power or Energy
	In Facility	Mobile	

UV (< 0.4 μm)

Visible (0.4 - 0.71 μm)

Near IR (> 0.71 - 1.4 μm)

Far IR (> 1.4 μm)

6. Name of Laser Safety Officer: _____

7. Qualifications of Laser Safety Officer (use additional sheet if required): _____

8. Authorized Agent of Applicant: _____

(Printed Name)

(Title)

9. Signatures: _____

Laser Safety Officer

Application Date

Authorized Agent

SEE ASSOCIATED INSTRUCTION SHEET BEFORE COMPLETING THIS APPLICATION.

Instruction Sheet for Registration of Sources of Laser Radiation
(For exemptions to registration requirement see Section B.4)

PLEASE PRINT OR TYPE ALL INFORMATION

Note: Care in compiling and entering all required information in the application will help to prevent undue delay and to reduce the amount of correspondence necessary. Your cooperation is earnestly solicited.

1. Applicant - The name, address, and telephone number of the person or facility in whose name the registration is to be made.
2. Location of Use - Addressor location where laser sources are operated, serviced, or manufactured. If lasers are serviced exclusively on customers' premises, so state.
3. Self-explanatory.
4. Self-explanatory.
5. Sources of Laser Radiation - Include data only for uncertified Class IIIb and Class IV laser sources, for certified Class IIIb laser sources not exempted by B.4(a)(1)(ii), and for certified Class IV laser sources. For each wavelength range, enter in column b the number of laser sources and in column c, the average power or energy of the minimum and maximum output source.

Service organizations should omit column b. In column c enter data describing lasers anticipated to be serviced during twelve-month period beginning with registration date.

Laser source manufacturing facilities, enter words "Manufacturing Facility" in column b; do not enter numbers. In column c enter data describing lasers anticipated to be manufactured during twelve-month period beginning with registration date.

6. Name of Laser Safety Officer - Name of person appointed by applicant to serve as Laser Safety Officer in compliance with Section B.5.
7. Qualifications of Laser Safety Officer - Briefly describe the Laser Safety Officer's training and experience which qualify him/her in the areas listed in B.5(b).
8. Self-explanatory.
9. Self-explanatory.

Mail [TWO] copies of your application for registration with [TWO] copies of your laser safety procedures to: [Name and address of Agency].

APPENDIX D

TRAINING

1. General

Training shall be provided in laser safety and laser health physics to all laser safety officers (LSO's) responsible for Class IIIB and Class IV Lasers. Training of LSO's responsible for Class I, Class II, Class IIA and Class IIIA lasers should be provided as needed. The degree and type of training shall be appropriate for the degree of potential laser and associated hazards. The LSO is responsible for ensuring that users of laser products are trained at a level commensurate with the users duties and the degree of hazard.

2. Laser Safety Training Topics

Topics for inclusion in a laser safety training program should include all or part of the following, as appropriate, for the class of lasers in use:

a. Description of Lasers

- i. Definitions
- ii. Lasing fundamentals
- iii. Lasing medium and types of lasers - solid, liquid, and gas
- iv. Pumping methods
- v. Optical cavities

b. Characteristics of Laser Light

- i. Directionality
- ii. Single color (monochromaticity)
- iii. Coherence
- iv. Intensity
- v. Divergency
- vi. Relations of specular and diffuse reflections

c. Biological Effects of Laser Light

- i. Damage mechanisms: thermal and non-thermal effects from pulsed and cw lasers
- ii. Eye hazard
- iii. Skin hazard
- iv. Criteria for setting Maximum Permissible Exposure (MPE) levels for eye and skin

d. Associated Hazard

- i. Electrical hazards
- ii. Explosion hazards
- iii. Chemical hazards
- iv. Fire, ionizing radiation, cryogenic hazards, and others, as applicable

e. Laser Safety

- i. Laser classifications
- ii. Control measures including personnel protective equipment
- iii. Management and user responsibilities
- iv. Medical surveillance practices (if applicable)
- v. Governmental regulatory requirements

f. Laser Health Physics

- i. Calculation of MPE limits for eye and skin under various conditions of laser use
- ii. Basic radiometric units, measurement devices and measurement techniques
- iii. Laser hazard evaluations and range equations

3. Training Guide for Laser Safety Officers Responsible for Various Laser Classifications

Training Vehicles	HIGHEST CLASS LASER				
	I	II,IIa	IIIa	IIIb	IV
Manufacturer's Guides & Operating Manuals	M	M	M	M	M
Safety Guide Literature <u>1/</u>	N/R	N/R	R	M	M
Review of Applicable Standards (ANSI, Federal, State, etc.)	N/R	N/R	R	M	M
Laser Safety Orientation Course <u>2/</u>	N/R	N/R	R	M	M

N/R Not Required
 R Recommended
 M Mandatory

1/ Such as: American National Standard for the Safe Use of Lasers, ANSI Z136.1; Laser Institute of America Laser Safety Guide; American Conference of Governmental Industrial Hygienists - A Guide for Control of Laser Hazards; or any other similar literature the Agency considers adequate.

2/ Because of the greater potential hazards from Class IIIb and IV Lasers, duration of course would be several days. This training may be done by outside specialists if not available internally.

APPENDIX E

MEASUREMENTS FOR MAXIMUM PERMISSIBLE EXPOSURE 1/

1. Limiting Aperture: The limiting aperture specified in Table VIII shall be the maximum circular area over which irradiance and radiant exposure can be averaged for measurements and calculations of all MPE values.
2. Intrabeam or Extended-Source Ocular Exposures
 - (a) For the purpose of these regulations:
 - (i) Sources such as laser arrays, diodes, and diffuse reflecting surfaces shall be considered extended sources if their angular subtense,* i.e., apparent visual angle, is equal to or greater than α_{\min} as specified in Figure 3. An extended source subtends an angle at the observer's eye equal to or greater than the angular subtense, α_{\min} as specified in Figure 3, across the greatest angular dimension of the source as viewed by the observer.
 - (ii) All other lasers, such as those with collimated beams which produce a small, i.e., nearly diffraction-limited, retinal image and also point sources, shall be considered intrabeam viewing cases and shall have an angular subtense, i.e., apparent viewing angle, less than α_{\min} as specified in Figure 3. Sources such as laser arrays, multiple diodes, or multiple diffuse reflecting surfaces shall be considered intrabeam viewing cases for any of the separate images whose angular subtense is less than α_{\min} . Any sources whose centers are separated by an angle less than α_{\min} are treated as extended sources.
 - (iii) If measurements or calculations are required, distinction shall first be made between intrabeam viewing and extended-source viewing in the 0.4 to 1.4 micrometer wavelength region.
 - (b) MPE values for direct ocular exposure to single pulses or exposures in intrabeam viewing are specified in Table IVa. Special qualifications and use requirements are provided in Appendix E(4) and (5) and Figures 4, 5, 6, and 10.

1/ When a laser emits radiation at several widely different wavelengths, or where pulses are superimposed on a continuous wave (cw) background, computation of the MPE is complex. Exposures from several wavelengths in the same time domain are additive on a proportional basis of spectral effectiveness with due allowance for all correction factors. The simultaneous exposure to pulses and cw radiation is not strictly additive (there may be synergism) and caution should be used in these situations until more data are available.

* The angular subtense is not the beam divergence of the source. It is the apparent visual angle as calculated from the source size and distance from the eye. The limiting angular subtense is that apparent visual angle which divides intrabeam viewing from extended-source viewing.

(c) MPE values for ocular exposure to extended sources for single pulses or exposures are specified in Table IVb for the cornea. Special qualifications and use requirements are provided in Appendix E(4) and (5) and Figures 5, 6, and 7.

(d) MPE values for broad band collateral radiation shall be weighted with regard to spectral content in 50 nanometer increments using Tables IVa or IVb, as appropriate.

3. MPE for Skin Exposure to a Laser Beam. MPE values for skin exposure to a laser beam are specified in Table IVc. These levels are for worst-case conditions and are based on the best available information. For repetitive-pulsed lasers, the MPE's for skin exposure are applied as follows: Exposure of the skin shall not exceed the MPE based upon a single-pulse exposure, and the average irradiance of the pulse train shall not exceed the MPE applicable for the total exposure train length.

4. Special Qualifications - Visible and Near-Infrared Multiple Pulses

(a) Multiple-Pulse Trains, Pulsed and Scanning Lasers with Multiple Exposures. The MPE for energy or power in multiple-pulse or multiple-exposure trains where the instantaneous pulse repetition frequency of any pulses within a train exceeds 1 per second has the limits specified in Appendix E(4)(a)(i) through (v).

(i) The irradiance of radiant exposure (radiance or integrated radiance) in any individual pulse in a train is limited to the MPE for a comparable pulse, as specified in Appendix E(2)(b), (c), and (3).

(ii) The average irradiance or radiant exposure (radiance or integrated radiance) for the pulse train is limited to the MPE as specified in Appendix E(2)(b), (c), and (3) for one pulse of this irradiance or radiant exposure (radiance or integrated radiance) whose duration is the same as that of the pulse train.

(iii) Any and all groups of pulses within the train are limited to the MPE of one pulse with the same duration as the group in the manner specified in Appendix E(4)(a)(ii).

(iv) For individual pulses with duration less than 10 microseconds, the MPE of Appendix E(4)(a)(i) is reduced as specified in Figure 12. In no case shall this reduction be less than the reciprocal of the number of pulses within 0.25 second when the pulse train duration is less than 0.25 second.

(v) When the individual pulse duration is 10 microseconds or greater, the MPE for an individual pulse in a train shall be calculated from the MPE for the total "on time" pulse (TOTP), which has a duration equal to the sum of all the individual pulse durations in the train, as follows: The MPE irradiance of an individual pulse within the train shall be reduced to the MPE for the TOTP. The MPE radiant exposure or integrated radiance of an individual pulse within the train shall be reduced to the MPE for the TOTP divided by the number

of pulses within the train. The following formula shall be used to evaluate the MPE applicable to each pulse:

$$\text{MPE}_{\text{single}} = \frac{\text{MPE}_{nt}}{n}$$

where n = number of pulses in the train; t = individual pulse width; and MPE_{nt} = MPE applicable to a pulse of width nt, in seconds. An additional limitation is that the average irradiance in the pulse train shall not exceed the MPE as specified in Appendix E(4)(a)(ii) and the MPE's for the individual pulses or pulsed repetition frequency shall be reduced to keep within this limitation.

(b) Repetitive pulses at repetition rates of less than 1 hertz (Hz) shall be considered additive over a 24-hour period.

(c) Pulse trains whose duration is 18 microseconds or less shall have their pulses summed into a single pulse with the applicable MPE.

(d) Pulse trains whose duration is less than 0.25 second and whose instantaneous pulse repetition frequency is 10 Hz or less shall not have their MPE's reduced by the limitations of Appendix E(4)(a)(iv).

(5) Special Qualifications - Infrared. Available data are not sufficient to define wavelength corrections relative to 1.06 micrometers (μm), over the entire infrared range (1.4 μm - 1 mm). At 1.54 μm , the MPE given in Tables IVa and IVb is increased by a factor of 10^2 for time periods shorter than 1 microsecond. However, no extrapolation to other wavelengths is justified on the basis of present information.

RATIONALE

SUGGESTED STATE REGULATIONS FOR LASERS

Part A General Provisions

Sec. A.1 Scope

All laser products manufactured on and after August 2, 1976, and any previously certified laser products, used in the State shall conform to Title 21, Part 1040 of the Code of Federal Regulations (21 CFR 1040). Existing Federal OSHA standard for the construction industry is also applicable as a minimum requirement in the States. Concern was expressed by physicians that regulations would limit the use of laser radiation as a diagnostic or therapeutic tool. These regulations will not prevent such usage. The regulations will apply to the user. These regulations have been developed recognizing compatibility with existing Federal standards.

Because the Suggested State Regulations for Lasers (SSRL) are oriented toward the user, situations will arise where certified laser products are modified. Such modified and non-certified laser products must conform to the requirements specified in the SSRL for that particular laser class.

Sec. A.2 Definitions

Where applicable, the definitions are consistent with the American National Standard for the Safe Use of Lasers, ANSI Z136.1-1980; Performance Standard for Laser Products (21 CFR 1040); and Federal OSHA Standard for Construction (29 CFR 1926.54).

The terms, exposure and emission, are used throughout the SSRL. The exposure term is applicable to users and the emission term is applicable to lasers. This has become necessary because a user may modify or assemble his own laser not subject to 21 CFR 1040. These regulations provide for the classification of such lasers.

To avoid confusion with the Federal "Certified laser product," these suggested regulations reference lasers which may or may not be a certified product.

"Class I, II, III, and IV lasers." These classes are consistent with 21 CFR 1040.

"Laser." Although these broad frequency limits go beyond available instrumentation for evaluation under present technology, there are lasers that can operate in this range and the regulations shall apply.

To avoid confusion, these regulations reference lasers, laser systems, and laser products. A laser located in a room or a building is defined as a laser facility.

Sec. A.3 Exemptions

Certified Class I, Class II, Class IIa, and Class IIIa laser products manufactured in accordance with the Federal Performance Standard for Laser Products are exempt from these regulations.

Sec. A.4 Additional Requirements

This section is consistent with the Ionizing Radiation Category of the Suggested State Regulations for Control of Radiation and is needed to cover new development uses and situations which may require additional precautions to protect the individual using the laser or the public exposed to radiation from the laser.

Sec. A.5 Violations

No wording is suggested for enforcement of violations because this will vary from State to State.

Sec. A.6 Impounding

Lasers can cause severe damage if they are used incorrectly. This provision is included in the SSRL to permit the Agency to take this severe step to ensure public health and safety. Some states may want to use other administrative or legal means to achieve the same end.

Sec. A.8 Tests

These may be tests of safety interlocks, safety eyewear, measurements of the power or energy output of the laser, and other such tests necessary to evaluate the hazard of a laser.

Sec. A.9 Administrative Review

No wording is suggested for administrative procedures as this may vary from State to State.

PART B
Registration

B.1 Purpose

Alternate wording for those States who wish to register the laser and not the facility is "...and use of laser systems." There are cases where there is no permanent facility where the laser is used in which case the State may wish to register the mobile laser.

B.3 Registration Requirements

Registration is mandatory for those facilities using lasers which could blind or burn a person using them incorrectly. Registration is also required for non-certified lasers of any class because of the need to assure adequate controls and safeguards in their use. This will assist the Agency in their laser inspection program.

B.4 Exemptions from Registration Requirements. This section provides exemptions from certain classes of certified lasers. Such certified lasers have a lower probability of causing laser radiation injuries and will permit the agency to concentrate its efforts on higher risk installations and mobile laser users.

B.5 Laser Safety Officer (LSO)

The most effective means of minimizing the hazards associated with lasers is by the instruction of personnel and the establishment of a laser safety program. The laser safety officer provides a mechanism for the accomplishment of this.

B.6 Acceptance of Laser Safety Officer. Cases may arise where the designated laser safety officer is not qualified in the opinion of the Agency to assume such a position. In such cases, Section B.6 grants authority to the Agency to require the registrant to designate a new LSO.

B.7 Annual Report. The annual report will assure that the Agency has up-to-date information on lasers in possession of registrant and the information will allow the Agency to set realistic inspection schedules.

B.8 Termination of Registration. This section provides for termination of registration if certain conditions are met.

B.9 Validity of Registration. This section provides for validation of registration and specifies that registration will remain valid until terminated or declared invalid. Some states may want to specify a certain time limit on registration.

B.10 Registration Shall Not Imply Approval. This section assures that no commercial advantage is taken of registration by registrant.

B.11 Out-of-State Laser Radiation Sources. The requirements for temporary use by out-of-state laser firms are specified. This section provides for free flow of commerce but it assures that the Agency will be notified and that laser safety requirements will be met.

PART C
Requirements for Protection Against Laser Radiation

C.2 Maximum Permissible Exposure (MPE). The maximum permissible exposure limits for laser radiation are the same as specified in the American National Standard for the Safe Use of Lasers, ANSI Z136.1-1980. The limits are based on the recommendations of ANSI Subcommittee "Biological Effects of Lasers on the Eye," Dr. M.L. Wolbarsht, Chairman, and ANSI Subcommittee "Biological Effects of Lasers on the Skin," Dr. W.H. Parr, Chairman.

C.3 Implementation of Protective Measures

This includes such things as establishing the standard operating procedures to be followed for the safe operation of the laser and instructing personnel in laser radiation safety.

In the case of mobile lasers a State may want to place additional requirements on the user, such as, obtaining certification through demonstration of ability to safely use the laser by written or practical exam.

C.4 General Requirements for the Safe Operation of all Facilities

C.4(c)(6). Laser safety eyewear should be used as a last resort for laser safety. The primary emphasis should be placed on the design, installation, and utilization of the laser equipment to eliminate the exposure of personnel. For additional information on use of laser safety eyewear, see DHEW Publication (FDA) 79-8086 "Evaluation of Commercially Available Laser Protective Eyewear."

C.5 Additional Requirements for Special Lasers and Applications

It is believed that special precautions are required for such facilities because of the high energy/power outputs of the lasers. Energy or power outputs at this level may also be capable of producing scattered radiation which exceeds the MPE and therefore represents a far greater ocular exposure hazard than if only the direct beam is hazardous.

C.6 Additional Requirements for Safe Operation

C.6(a). This will eliminate the possibility of a laser beam entering the safety goggles from behind and being reflected from the inside surface of the filter into the eye.

Some laser safety eyewear now being manufactured only has the optical density(s) and wavelength(s) specified on the case or on a tag which can easily be lost. If the optical density and wavelength are not labeled on the eyewear, this may lead to the misuse of eyewear intended for protection against one type of laser radiation being used for protection against another.

C.7 Caution Signs, Labels, and Posting

These signs, labels, and symbols are compatible with the ANSI and NCDRH standards.

C.8 Surveys

Surveys are required to provide evidence to the laser safety officer and the Agency that control measures are operational and are utilized. Surveys also provide a basis for the establishment or deletion of additional control measures in the judgement of the laser safety officer and the Agency.

C.9 Measurement and Instrumentation

When all control measures are used with a particular laser class, and there isn't any additional human access to laser or collateral radiation, then measurements aren't required. However, for classification purposes (no Federal Classification label) and for human access conditions, measurements (or their equivalent) are required to indicate that levels normally encountered are below the MPE's. Measurements should only be attempted by persons trained or experienced in laser technology and radiometry.

C.9(c)(1), (2), (3), and (4). These measurement criteria affect product performance features and labeling requirements and are identical to the Federal laser products performance standard, as amended.

C.9(d). MPEs are a user control concept and this paragraph is identical to the user standard, ANSI Z136.1-1980.

C.11 Notification of Incidents

A requirement for reporting incidents is common in State and local agency health and safety codes. The working group urges State and local officials to report all laser injuries to the National Center for Devices and Radiological Health (NCDRH) for tabulation and inclusion in the Radiation Incidents Registry.

C.14 Records

The preservation period for records has not been designated. This should be determined by individual states.

Tables

Section 360F, EFFECT ON STATE STANDARDS, of the Public Health Service Act as added by Public Law 90-602, Radiation Control for Health and Safety Act of 1968, states "Whenever any standard prescribed pursuant to section 358 with respect to an aspect of performance of an electronic product is in effect, no State or political subdivision of a State shall have any authority either to establish, or to continue in effect, any standard which is applicable to the same aspect of performance of such product and which is not identical to the Federal standard..." (42 USC 263h). It is primarily because of this statute that the product classification levels found in the tables are compatible with those levels found in the Federal Laser Product Performance Standard and not those found in the ANSI Z136.1-1980 laser standard.

Based on comments received during the review of previous drafts of the Suggested State Regulations for Lasers (SSRL), it was agreed that the use of the Federal laser products performance standard's Class I Accessible Emission Limit (AEL) as a Maximum Permissible Exposure (MPE) limit was not

appropriate. Therefore, the American National Standard Z136.1-1980 MPE's are used.

Collateral radiation from laser products includes non-coherent optical and x radiation. An example of a laser product where both collateral radiations could be present is an actively mode-locked solid state laser. Optical radiation could radiate from the pump lamp, and x radiation could radiate from the high-voltage power supply. The concept of collateral radiation is found in the Federal Performance Standard for Laser Products and this approach ensures consistency.

Table V. Since this is a performance requirement, it must be identical to the Federal laser products performance standard, as amended.

Appendix A - Medical Surveillance

This is included as a guide to States for information on medical examinations, frequency of examination, eye effects and surveillance, skin effects, and other medical evaluations for laser users.

Appendix B - Guidelines for Laser Light Shows

Because of the increasing number and current popularity of laser light shows, the pertinent requirements for such shows based on NCDRH safety criteria are summarized herein.

Appendix C - Application for Registration of Laser Facility, Mobile Laser, or Service Organization

To aid in the promulgation and implementation by individual states of the registration requirement of the Suggested State Regulations for Lasers, a suggested format for the registration form is included.

Appendix D - Training

The material on training is included, due to the importance placed on training in the SSRL to achieve laser health and safety. In addition, the material is consistent with similar material in the ANSI Z136.1-1980 standard on the Safe Use of Lasers.

Appendix E - Measurements for Maximum Permissible Exposure. Since there is a wide range of spectral, time duration, and geometric distribution of laser sources to which an individual might be exposed, the MPE measurement criteria as specified in ANSI Z136.1 guide are included to ensure a consistent interpretation of the limits.

Matters for Future Consideration

The Suggested State Regulations for Lasers is complete and up-to-date as of this writing (October 1982). It is anticipated, due to the pace of developments in several laser areas, that revisions will be necessary. In addition, it is expected that users of the SSRL will feed back their experiences and ideas for improvement in its content.

One area that may need future elaboration is "associated hazards" since, in some instances, these hazards are specific to lasers.