

# American National Standard

*American National Standard  
for Safe Use of Lasers in  
Manufacturing Environments*

---



**Laser Institute  
of America**  
*Laser Applications and Safety*





**ANSI®**  
Z136.9 – 2013  
First Printing

**American National Standard  
for Safe Use of Lasers in  
Manufacturing Environments**

**Secretariat  
Laser Institute of America**

**Approved: August 6, 2013  
American National Standards Institute, Inc.**

**American  
National  
Standard**

An American National Standard implies a consensus of those substantially concerned with its scope and provisions. An American National Standard is intended as a guide to aid the manufacturer, the consumer, and the general public. The existence of an American National Standard does not in any respect preclude anyone, whether or not he or she has approved the standard, from manufacturing, marketing, purchasing, or using products, processes or procedures not conforming to the standard. American National Standards are subject to periodic review and users are cautioned to obtain the latest editions.

**CAUTION NOTICE:** This American National Standard may be revised or withdrawn at any time. The procedures of the American National Standards Institute require that action be taken periodically to reaffirm, revise, or withdraw this standard no later than five years from the date of publication. Purchasers of American National Standards may receive current information on all standards by calling or writing the American National Standards Institute.

Published by

**Laser Institute of America  
13501 Ingenuity Drive, Suite 128  
Orlando, FL 32826**

ISBN: 978-0-912035-99-4

Copyright © 2013 by Laser Institute of America.  
All rights reserved.

No part of this publication may be copied or reproduced in any form, including an electronic retrieval system or be made available on the Internet, a public network, by satellite, or otherwise, without the prior written permission of the publisher.

Printed in the United States of America.

**Foreword** (This introduction is not a normative part of ANSI Z136.9-2013, *American National Standard for Safe Use of Lasers in Manufacturing Environments*.)

In 1968, the American National Standards Institute (ANSI) approved the initiation of the Safe Use of Lasers Standards Project under the sponsorship of the Telephone Group.

Prior to 1985, Z136 standards were developed by ANSI Committee Z136 and submitted for approval and issuance as ANSI Z136 standards. Since 1985, Z136 standards are developed by the ANSI Accredited Standards Committee (ASC) Z136 for Safe Use of Lasers. A copy of the procedures for development of these standards can be obtained from the secretariat, Laser Institute of America, 13501 Ingenuity Drive, Suite 128, Orlando, FL 32826 or viewed at [www.z136.org](http://www.z136.org).

The present scope of ASC Z136 is to protect against hazards associated with the use of lasers and optically radiating diodes.

ASC Z136 is responsible for the development and maintenance of this standard. In addition to the consensus body, ASC Z136 is composed of standards subcommittees (SSC) and technical subcommittees (TSC) involved in Z136 standards development and an editorial working group (EWG). At the time of this printing, the following standards and technical subcommittees were active:

SSC-1	Safe Use of Lasers (parent document)
SSC-2	Safe Use of Lasers and LEDs in Telecommunications Applications
SSC-3	Safe Use of Lasers in Health Care
SSC-4	Measurements and Instrumentation
SSC-5	Safe Use of Lasers in Educational Institutions
SSC-6	Safe Use of Lasers Outdoors
SSC-7	Eyewear and Protective Barriers
SSC-8	Safe Use of Lasers in Research, Development, and Testing
SSC-9	Safe Use of Lasers in Manufacturing Environments
SSC-10	Safe Use of Lasers in Entertainment, Displays, and Exhibitions
TSC-1	Biological Effects and Medical Surveillance
TSC-2	Hazard Evaluation and Classification
TSC-4	Control Measures and Training
TSC-5	Non-Beam Hazards
TSC-7	Analysis and Applications
EWG	Editorial Working Group

The nine standards currently issued are:

ANSI Z136.1-2007, *American National Standard for Safe Use of Lasers* (replaces ANSI Z136.1-2000)

ANSI Z136.2-2012, *American National Standard for Safe Use of Optical Fiber Communication Systems Utilizing Laser Diode and LED Sources* (first edition)

ANSI Z136.3-2011, *American National Standard for Safe Use of Lasers in Health Care* (replaces ANSI Z136.3-2005, *American National Standard for Safe Use of Lasers in Health Care Facilities*)

ANSI Z136.4-2010, *American National Standard Recommended Practice for Laser Safety Measurements for Hazard Evaluation* (replaces ANSI Z136.4-2005)

ANSI Z136.5-2009, *American National Standard for Safe Use of Lasers in Educational Institutions* (replaces ANSI Z136.5-2000)

ANSI Z136.6-2005, *American National Standard for Safe Use of Lasers Outdoors* (replaces ANSI Z136.6-2000)

ANSI Z136.7-2008, *American National Standard for Testing and Labeling of Laser Protective Equipment* (first edition)

ANSI Z136.8-2012, *American National Standard for Safe Use of Lasers in Research, Development, or Testing* (first edition)

ANSI Z136.9-2013, *American National Standard for Safe Use of Lasers in Manufacturing Environments* (first edition)

This purpose of this American National Standard is to provide specific guidance for the safe use of lasers in manufacturing environments. It has been published as part of the ANSI Z136 series of laser safety standards. The base document of the series is the American National Standard for Safe Use of Lasers, ANSI Z136.1.

The procedures and methodologies described in this standard are based on requirements previously established in ANSI Z136.1 and are intended to give more specific practices for accomplishing laser safety, and to provide more specific user guidance for protecting individuals with the potential for laser exposure when lasers are used in manufacturing environments.

This standard includes policies and procedures to ensure laser safety in areas where lasers are used in manufacturing, including public and private industries, and product development and testing settings. In general, this standard may be used independently of ANSI Z136.1; however, instances

where additional guidance contained in ANSI Z136.1 is required are noted in the text of this document.

The body of this standard is a normative standard that applies to manufacturing environments that use lasers. The appendices, excluding Appendix A, are informative providing examples and discipline specific supplementary information.

It is expected that this standard will be periodically revised as new information and experience in the use of lasers are gained. Future revisions may have modified content and use of the most current document is highly recommended.

While there is considerable compatibility among existing laser safety standards, some requirements differ among state, federal, and international standards and regulations. These differences may have an effect on the particulars of the applicable control measures.

Occasionally questions may arise regarding the meaning or intent of portions of this standard as it relates to specific applications. When the need for an interpretation is brought to the attention of the secretariat, the secretariat will initiate action to prepare an appropriate response. Since ANSI Z136 standards represent a consensus of concerned interests, it is important to ensure that any interpretation has also received the concurrence of a balance of interests. For this reason, the secretariat is not able to provide an instant response to interpretation requests except in those cases where the matter has previously received formal consideration. Requests for interpretations and suggestions for improvements of the standard are welcome. They should be sent to ASC Z136 Secretariat, Laser Institute of America, 13501 Ingenuity Drive, Suite 128, Orlando, FL 32826.

This standard was processed and approved for submittal to ANSI by ASC Z136. Committee approval of the standard does not necessarily imply that all members voted for its approval.

Robert Thomas, Committee Chair  
Sheldon Zimmerman, Committee Vice-Chair  
Ben Edwards, Committee Secretary

**Notice**

(This notice is not a normative part of ANSI Z136.9-2013, *American National Standard for Safe Use of Lasers in Manufacturing Environments*.)

Z136 standards and recommended practices are developed through a consensus standards development process approved by the American National Standards Institute. The process brings together volunteers representing varied viewpoints and interests to achieve consensus on laser safety related issues. As secretariat to ASC Z136, the Laser Institute of America (LIA) administers the process and provides financial and clerical support to the committee.

The LIA and its directors, officers, employees, members, affiliates, and sponsors, expressly disclaim liability for any personal injury, property, or other damages of any nature whatsoever, whether special, indirect, consequential, or compensatory, directly or indirectly resulting from the publication, use of, or reliance on this document or these standards. The LIA's service as secretariat does not constitute, and LIA does not make any endorsement, warranty, or referral of any particular standards, practices, goods, or services that may be referenced in this document. The LIA also makes no guarantee or warranty as to the accuracy or completeness of any information published herein. The LIA has no power, nor does it undertake to police or enforce compliance with the contents of this document.

In issuing and making this document available, the LIA is not undertaking to render professional or other services for or on behalf of any person or entity. Nor is the LIA undertaking to perform any duty owed by any person or entity to someone else. Anyone using this document should rely on his or her own independent judgment or, as appropriate, seek the advice of a competent professional in determining the exercise of reasonable care in any given circumstances.



**Participants** At the time it approved this standard, ASC Z136 had the following members:

<i>Organization Represented</i>	<i>Name of Representative</i>
Academy of Laser Dentistry	Scott Benjamin
Altos Photonics, Inc.	Lucian Hand
American Academy of Dermatology	Mark Nestor
American College of Obstetricians & Gynecologists	Ira Horowitz
American Dental Association	Joel White
American Glaucoma Society	Michael Berlin
American Industrial Hygiene Association	R. Timothy Hitchcock
American Society for Laser Medicine & Surgery	David Sliney
American Society of Safety Engineers	Brian Biesman (Alt)
	Thomas V. Fleming
	Walter Nickens (Alt)
American Veterinary Medical Association	Kenneth Bartels
American Welding Society	Mark McLear
Association of periOperative Registered Nurses (AORN)	Evangeline Dennis
Association of Surgical Technologists	Kevin Frey
Buffalo Filter	Daniel Palmerton
Camden County College	Fred Seeber
Daniel Laser Safety	Paul Daniel, Jr.
Federal Aviation Administration (FAA)	Ricky Chitwood
Health Physics Society	Thomas Johnson
	David Sliney (Alt)
High-Rez Diagnostics	Richard Hughes
Institute of Electrical and Electronics Engineers (SCC-39)	Ron Petersen
International Imaging Industry Association (I3A)	Joseph Greco
International Laser Display Association (ILDA)	Patrick Murphy
Kentek Corporation	William Arthur
KLA-Tencor	Karl Umstadter
L*A*I International	Thomas Lieb
Laser Institute of America	Gus Anibarro
Laser Safety Consulting, LLC.	Darrell Seeley
Lawrence Berkeley National Laboratory	Ken Barat
Lawrence Livermore National Laboratory	Robert Ehrlich
Lightwave International	Roberta McHatton
Los Alamos National Laboratory	Connon Odom
National Aeronautics and Space Administration	Guy Camomilli
National Institute of Standards and Technology (NIST)	Randall Scott (Alt)
	Joshua Hadler

<i>Organization Represented</i>	<i>Name of Representative</i>
North American Association for Laser Therapy (NAALT)	Raymond Lanzafame
Power Technology, Inc.	William Burgess
Rockwell Laser Industries	William Ertle
Solta Medical Inc.	George Frangineas
TASC, Inc.	Edward Early
Underwriters Laboratories, Inc.	Peter Boden
University of Texas, Southwestern Medical Center	John Hoopman
US Department of Health and Human Services, Center for Devices and Radiological Health	Richard Felten Robert James (Alt)
US Department of Labor, Occupational Safety & Health Administration	Jeffrey Lodwick
US Department of the Air Force, Air Force Research Laboratory	Benjamin Rockwell Robert Thomas (Alt)
US Department of the Air Force, Surgeon General's Office	Edward Kelly
US Department of the Army, Army Institute of Public Health Command (AIPH)	Jeffrey Pfoutz Penelope Galoff (Alt)
US Department of the Army, Army Institute of Surgical Research	Bruce Stuck
US Department of the Navy, Naval Air Systems Command	James Sheehy
US Department of the Navy, Naval Sea Systems Command	Sheldon Zimmerman Mary Zimmerman (Alt)

*Individual Members*

Robert Aldrich  
Prem Batra  
Hong Chen  
Richard Crowson  
Jerome Dennis  
David Dewey  
Ben Edwards  
Mark Festenstein  
Donald Haes  
Robert Handren, Jr.  
Ami Kestenbaum  
David J. Lund  
Martin Mainster  
Wesley Marshall  
J. Stuart Nelson  
Patti Owens  
Jay Parkinson

*Individual Members cont'd*

Randolph Paura  
William P. Roach  
Penny J. Smalley  
Nikolay Stoev  
Paul Testagrossa  
Thomas Tierney  
Antonio Triventi  
Robert Weiner  
Anthony Zmorenski

*Emeritus Members*

James Smith  
Myron Wolbarsht

The various subcommittees that participated in the development of this standard had the following members:

*Safe Use of Lasers in Manufacturing Environments, SSC-9*

Thomas Lieb, Chair  
Randolph Paura, Vice-Chair  
Candace Soles, Secretary

Ken Barat  
Joseph Cyrek  
Paul Daniel Jr.  
Jerome Dennis  
William Ertle  
Robert Faaland  
Dennis Ford  
Clifford Greenberg  
R. Timothy Hitchcock  
Peter Keller

Don Lambert  
David Marcotte  
Jay Parkinson  
Ron Petersen  
Darrell Seeley  
David Sliney  
James Smith  
Tekla Staley  
Robert Thomas  
Scott Wohlstein

*Laser Bioeffects, TSC-1*

Bruce Stuck, Chair  
Jeffrey Pfoutz, Secretary

Robert Aldrich  
Kenneth Bartels  
Gary Bower  
Francois Delori  
Jerome Dennis  
William Ertle  
Penelope Galoff  
Jennifer Hunter  
Thomas Johnson  
Brian J. Lund  
David J. Lund  
Martin Mainster  
Wesley Marshall  
Russ McCally  
Leon McLin  
C. Eugene Moss

John O'Hagan  
Jay Parkinson  
Ron Petersen  
William P. Roach  
Benjamin Rockwell  
Noam Sapiens  
Karl Schulmeister  
James Sheehy  
David Sliney  
Robert Thomas  
Stephen Trokel  
Myron Wolbarsht  
Mary Zimmerman  
Sheldon Zimmerman  
Joseph Zuclich

*Hazard Evaluation & Classification, TSC-2*

Robert Thomas, Chair  
William P. Roach, Vice-Chair

Robert Aldrich  
Ahsan Chowdary  
Jerome Dennis  
Jerome Garden  
Kimberly Kantner  
David J. Lund  
Wesley Marshall  
Leon McLin  
Clint Meneely  
John O'Donnell  
Connon Odom  
Jay Parkinson  
Brian Pearce

Ron Petersen  
Jeffrey Pfoutz  
Timothy Reed  
Benjamin Rockwell  
Darrell Seeley  
David Sliney  
Dale Smith  
Nikolay Stoev  
Paul Testagrossa  
Stephen Trokel  
Karl Umstadter  
Robert Weiner  
Sheldon Zimmerman

*Control Measures & Training, TSC-4*

William Ertle, Chair  
R. Timothy Hitchcock,  
Vice-Chair  
Anthony Zmorenski, Secretary

Robert Aldrich  
Gus Anibarro  
William Arthur  
Ken Barat  
Prem Batra  
David Bothner  
Bryon Bowen  
Richard Crowson  
Paul Daniel, Jr.  
Jerome Dennis  
Thomas Fleming  
Penelope Galoff  
Richard Greene  
Patrick Hancock  
Robert Handren  
Mike Hart  
Roy Henderson  
John Hoopman  
Richard Hughes  
Bill Janssen  
Tom Johnson  
Kimberly Kantner  
Thomas Lieb  
David J. Lund  
Tom MacMullin  
Wesley Marshall  
Mike Wolbarsht

Mark McLearn  
C. Eugene Moss  
John O'Donnell  
John O'Hagan  
Connon Odom  
Jay Parkinson  
Ron Petersen  
William P. Roach  
Benjamin Rockwell  
Darrell Seeley  
James Sheehy  
David Sliney  
Penny J. Smalley  
Dale Smith  
Casey Stack  
Nikolay Stoev  
Bruce Stuck  
Sue Terry  
Paul Testagrossa  
Robert Thomas  
Stephen Trokel  
Karl Umstadter  
Wei-Hsung Wang  
Robert Weiner  
Stephen Wengraitis  
Scott Wohlstein  
Sheldon Zimmerman

*Non-Beam Hazards, TSC-5*

Ben Edwards, Chair  
Thomas Tierney, Secretary

Ken Barat  
Joseph Greco  
R. Timothy Hitchcock  
Richard Hughes  
C. Eugene Moss

Daniel Palmerton  
Ron Petersen  
Penny J. Smalley  
Dan Thomas

*Analysis and Applications, TSC-7*

Wesley Marshall, Chair  
Robert Thomas, Vice-Chair

Robert Aldrich  
Gary Bower  
Patrizia Coryell  
R. Timothy Hitchcock  
Connon Odom  
Jay Parkinson  
Ron Petersen  
William P. Roach  
Benjamin Rockwell

David Sliney  
Dale Smith  
Nikolay Stoev  
Bruce Stuck  
Robert Weiner  
Scott Wohlstein  
Mary Zimmerman  
Sheldon Zimmerman  
Anthony Zmorenski

*Editorial Working Group, EWG*

Ron Petersen, Chair

Ben Edwards  
Kevin Frey  
Penelope Galoff  
Richard Hughes  
Bill Janssen

Thomas Johnson  
Randy Paura  
Barbara Sams  
Paul Szajowski  
Mary Zimmerman

# Contents

SECTION	PAGE
1. General.....	1
1.1 Scope.....	1
1.2 Application.....	1
1.3 Laser Safety Programs.....	4
Table 1.1 Requirements by Laser Classification.....	3
2. Definitions.....	5
2.1 Definitions as Used in this Standard.....	5
2.2 Abbreviations and Acronyms.....	18
3. Hazard Evaluation and Classification.....	19
3.1 General.....	19
3.2 Laser Considerations.....	20
3.3 Laser and Laser System Hazard Classification Definitions.....	22
3.4 Environment in Which the Laser is Used.....	23
3.5 Personnel.....	25
4. Control Measures.....	26
4.1 General Considerations.....	26
4.2 Substitution of Alternate Control Measures.....	28
4.3 Manufacturer Control Measures.....	28
4.4 User Control Measures.....	29
4.5 Special Considerations.....	48
4.6 Laser Controlled Area Warning Signs and Equipment Labels.....	51
5. Education and Training.....	54
5.1 General.....	54
5.2 Refresher Training.....	55
5.3 Trainer Qualifications.....	55
5.4 LSO Training.....	55
5.5 User Training.....	56
5.6 Laser Safety Training and Awareness.....	56
6. Medical Examinations.....	56
6.1 Examinations Following a Suspected or Actual Laser-Induced Injury.....	56
6.2 Rationale for Other Medical Examinations.....	56
7. Non-Beam Hazards.....	57
7.1 General.....	57
7.2 Physical Agents.....	57
7.3 Chemical Agents.....	59
7.4 Biological Agents.....	60
7.5 Human Factors.....	61

SECTION	PAGE
8. Criteria for Exposures of Eye and Skin .....	61
8.1 Ocular Exposures From Point Sources and Extended Sources.....	62
8.2 MPE for Ocular Exposures .....	62
8.3 Special Qualifications for Ocular Exposures.....	64
8.4 MPE for Skin Exposure to a Laser Beam .....	65
9. Measurements .....	65
9.1 General.....	65
9.2 Point Source and Extended Source Measurements.....	65
9.3 Instruments.....	66
10. Revision of Standards Referred to in this Document.....	66
10.1 ANSI Standards .....	66
10.2 Other Standards, Guides and Codes .....	67

## Tables

Table 1. Pulse-Repetition Frequency (PRF) above which the Average Power MPE (Rule 2) Gives the Most Restrictive MPE for Repetitive-Pulse Laser Exposure.....	69
Table 2. Recommended Limiting Exposure Durations for CW and Repetitive-Pulse MPE Calculations .....	70
Table 3. Pulse Energy that Does Not Exceed the MPE for a Diffusely Reflected Beam....	71
Table 4. Simplified Method for Selecting Laser Eye Protection for Point Source Viewing (Wavelengths Between 400 nm and 1400 nm).....	72
Table 5. Maximum Permissible Exposure (MPE) for Ocular Exposure to a Laser Beam.....	73
Table 5a. Maximum Permissible Exposure (MPE) for Ocular Exposure to a Laser Beam for Ultraviolet Wavelengths from 180 nm to 400 nm.....	74
Table 5b. Maximum Permissible Exposure (MPE) for a Point Source Ocular Exposure to a Laser Beam for Wavelengths from 400 nm to 700 nm .....	75
Table 5c. Maximum Permissible Exposure (MPE) for a Point Source Ocular Exposure to a Laser Beam for Wavelengths from 700 nm to 1400 nm .....	76
Table 5d. Maximum Permissible Exposure (MPE) for Ocular Exposure to a Laser Beam for Wavelengths from 1400 nm to 10 <sup>6</sup> nm (Far Infrared).....	77
Table 6. Wavelength Dependent Parameters and Correction Factors .....	77
Table 7. Maximum Permissible Exposure (MPE) for Skin Exposure to a Laser Beam.....	78
Table 7a. Maximum Permissible Exposure (MPE) for Skin Exposure to a Laser for Wavelengths from 180 nm to 400 nm .....	78
Table 7b. Maximum Permissible Exposure (MPE) for Skin Exposure to a Laser for Ultraviolet Wavelengths from 400 nm to 1400 nm.....	79
Table 7c. Maximum Permissible Exposure (MPE) for Skin Exposure to a Laser for Wavelengths from 1400 nm to 10 <sup>6</sup> nm (1000 μm).....	79
Table 8a. Limiting Apertures and Cone Angles .....	80
Table 8b. Area of Limiting Apertures .....	81
Table 9. Measurement Apertures for Laser Classification .....	82
Table 10a. Control Measures for the Seven Laser Classes.....	83



SECTION	PAGE
Table 10b. Control Measures for the Seven Laser Classes (cont.)	84
Table 10c. Control Measures for the Seven Laser Classes (cont.)	85
Table 10d. Control Measures for the Seven Laser Classes (cont.)	85
Table 10e. Reference Hierarchy of Operator Safety Control Measures (Informative Only)	86
Table 11a. Summary of Area Warning Devices and Signs	87
Table 11b. Summary of Labeling Requirements	88
Table 11c. Summary of Protective Equipment Labeling	89

## Figures

Figure 1a. ANSI Z535.2 Compliant Laser Area Warning Sign Formats	90
Figure 1b. Sample ANSI Z535.2 & ISO 3864-2 Compliant Class 2, Class 2M or Class 3R Laser Controlled Area Warning Sign	91
Figure 1c. Sample ANSI Z535.2 & ISO 3864-2 Compliant Class 3B or Class 4 Laser Controlled Area Warning Sign	91
Figure 1d. Sample ANSI Z535.2 & ISO 3864-2 Compliant Class 4 Laser Controlled Area Warning Sign	92
Figure 1e. Sample Warning Sign for Facility Policy, for example, Outside a Temporary Laser Controlled Area During Periods of Service	92
Figure 1f. IEC Warning Logo and Information Label	93
Figure 2a. Area/Entryway Safety Controls for Class 4 Lasers Utilizing Entryway Interlocks	94
Figure 2b. Entryway Safety Controls for Class 4 Lasers without Entryway Interlocks	95
Figure 2c. Unsupervised Laser Installation for Demonstration Laser	96
Figure 2d. Supervised Laser Installation for Demonstration Laser	97
Figure 2e. Supervised Laser Installation for Demonstration Laser	98
Figure 3. Limiting Cone Angle $\gamma$ , Photochemical MPEs	99
Figure 4. Point Source MPEs for Visible and Near Infrared Pulsed Sources for Wavelengths from 400 nm to 1400 nm	100
Figure 5. MPE for Ultraviolet Radiation (Small and Extended Sources) for Exposure Duration from $10^{-9}$ to $3 \times 10^4$ s for Ocular Exposure and $10^{-9}$ to $10^3$ s for Skin Exposure	101
Figure 6. MPE for Ultraviolet (Wavelengths from 315 to 400 nm) and Infrared (Wavelengths from 1400 nm to 1000 $\mu$ m) Laser Radiation for Single Pulses or Continuous Exposure (Small or Extended Sources)	102
Figure 7. MPE for Ocular Exposure to Visible Laser Radiation (Wavelengths from 400 to 700 nm) for Single Pulses or Continuous Exposure (Small or Extended Sources)	103
Figure 8. Correction Factors $C_A$ , $C_B$ and $C_C$ used to Determine the MPE for Ocular Exposure to Laser Radiation	104
Figure 9a. Correction Factor T1 Beyond which Photochemical (Rather than Thermal) Effects Determine the MPE for Point Sources for Wavelengths from 450 nm to 500 nm	105
Figure 9b. Correction Factor T2 Used to Determine the Extended Source MPE based on Thermal Effects for Exposure Durations Greater than T2	106

SECTION	PAGE
Figure 10. Ocular Point Source MPE ( $\alpha \leq 1.5$ mrad) for Visible and Near Infrared Laser Radiation (Wavelengths from 400 nm to 1400 nm) .....	107
Figure 11. MPE Reduction Factor $C_p$ for Repetitive-Pulse Lasers and Multiple Exposures from Scanning Lasers .....	108
Figure 12. Correction Factor $K_\lambda$ Used to Determine the Corneal MPE for Wavelengths from 1200 nm to 1400 nm .....	109
 Appendix A	
Supplement to Section 1 – Laser Safety Programs .....	111
A1. Laser Safety Officer (LSO).....	111
A2. Laser Safety Committee.....	113
A3. Other Personnel Responsibilities .....	113
 Appendix B	
Calculations for Hazard Evaluation and Classification.....	115
B1. General .....	115
B2. Symbols.....	115
B3. Examples of MPE Determination .....	119
B4. Laser Classification.....	123
B5. Central-Beam Irradiance or Radiant Exposure .....	124
B6. Formulas and Examples Useful in Evaluation of Various Laser Applications.....	124
B7. The Brightness (Radiance) Units .....	130
B8. Protective Eyewear and Barriers .....	133
B9. References .....	136
Figure B1. Intrabeam Viewing – Direct (Primary) Beam .....	138
Figure B2. Flat-Top Beam Shape Compared with Gaussian Beam .....	138
Figure B3. Intrabeam Viewing – Specularly Reflected Beam.....	139
Figure B4. Viewing Diffuse Reflections .....	140
Figure B5. Beam Expansion with Distance from the Laser .....	140
Figure B6. Examples of Use of Laser Range Equations for Determining Nominal Hazard Distances .....	141
Figure B7. Nominal Hazard Zone for a Diffuse Reflection .....	142
Figure B8. Diagram of the Laser Arrangement for Example 9 .....	142
Figure B9. Determination of Limiting Cone Angle, $\gamma$ .....	143
 Appendix C	
Hazard Evaluation, Classification and Control Measures.....	144
C1. Classification.....	144
C2. Laser Protection Damage Threshold Evaluation.....	144
C3. References .....	150
Table C1. Typical Laser Classification – Continuous Wave (CW) Point Source Lasers.....	147
Table C2. Typical Laser Classification – Single-Pulse Point Source Lasers .....	148
Table C3a. Point Source MPE for the Eye for Selected CW Lasers .....	149
Table C3b. Point Source MPE for the Skin for Selected CW Lasers.....	149

SECTION	PAGE
Table C4. Point Source MPE for the Eye and MPE for the Skin for Selected Single-Pulse Lasers.....	150
 Appendix D	
Engineering and Label Control Measures .....	153
D1. Introduction.....	153
D2. Laser Product Standards .....	153
D3. Laser Notice 50 .....	153
D4. Laser Product Performance Regulations.....	154
Table D1. Engineering Controls for Laser Products.....	155
Table D2. Laser Product Labels .....	157
 Appendix E	
Guide for Organization and Implementation of Employee Laser Safety Training Programs.....	158
E1. Employee Training.....	158
E2. References .....	160
 Appendix F	
Medical Examinations .....	162
F1. Medical Referral Following Suspected or Known Laser Injury.....	162
F2. Medical Surveillance Examinations .....	162
F3. Medical Examinations .....	163
F4. Records and Record Retention .....	165
F5. Access to Records.....	165
F6. Epidemiologic Studies .....	165
F7. References .....	165
 Appendix G	
Non-Beam Hazards .....	167
G1. Physical Agents.....	167
G2. Chemical Agents.....	169
G3. Biological Agents.....	170
G4. References .....	170
Table G1a. Laser Generated Air Contaminant (LGAC) Thresholds .....	181
Table G1b. Laser Generated Airborne Contaminants .....	182
Table G1c. Control Measures for Laser Generated Air Contaminants (LGAC) .....	186
 Appendix H	
Biological Effects of the Eye and Skin .....	187
H1. Biological Effects of Laser Radiation on the Eye.....	187
H2. Biological Effects of Laser Radiation on the Skin.....	188

SECTION	PAGE
Appendix I	
Laser Products Classified Under Previous Standards .....	189
Table I1a. Comparison of National and International Standards for Classification .....	190
Table I1b. Comparison of National and International Standards for Classification (cont.).....	191
Index .....	193