



BS 4803: Part 3: 1983

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British Standard

Radiation safety of laser products and systems

Part 3. Guidance for users

Sécurité du rayonnement des fabrications et systèmes laser
Partie 3. Guide pour les utilisateurs

Strahlenschutz von Laserprodukten und -systemen
Teil 3. Leitfaden für Benutzer

British Standards Institution

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BS 4803 : Part 3 : 1983

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Foreword

This revision of BS 4803 : 1972 has been prepared under the direction of the Electronic Equipment Standards Committee. It is not related to any publication of the International Electrotechnical Commission (IEC) but the UK is taking an active part in the international discussions which may result in the publication of an international standard in due course. Because BS 4803 : 1972 was seen to be out of date and limited in the advice that it gave, a revision was urgently required to meet the needs both of manufacturers and of users, and hence this revision has been published in advance of an international standard.

This British Standard gives practical guidance on the evaluation of the radiation hazards that arise from the operation of laser products and systems and it completely revises and supersedes the information given in BS 4803 : 1972. It is recognized that in terms of radiation safety it is impossible to regard laser products and systems as a single group, since hazards will vary with such factors as wavelength, power and pulse length. This standard is not specifically concerned with electrical hazards.

This revision is published in three separate Parts:

Part 1 provides definitions, algorithms and a summary of the medical considerations;

Part 2 specifies radiation safety requirements for the manufacture of laser products, including the classification of products, according to the maximum permissible exposure of eyes and skin to laser radiation.

These requirements have been concentrated into Part 2 to facilitate claims by manufacturers that their products comply with the requirements of this standard.

The classification system is closely related to that being developed by the IEC;

Part 3 provides guidance and information for users on the safe operation, maintenance and servicing of laser products used in different environments.

NOTE. Although the three Parts of this standard are available separately it is strongly recommended that all users of this standard be in possession of all three Parts.

The recommendations for maximum permissible exposure (MPE) levels are based on the most recent and reliable available scientific data on threshold levels for retinal, corneal and skin damage. In drafting this standard,

cognizance has been taken of parallel work in Committee Z-136 of the American National Standards Institute Inc. (ANSI). The values quoted in this standard are intended to be used as guides for the control of exposures and they should not be regarded as borderlines between safe and dangerous levels.

The MPE values of this standard are not intended to be applicable to patient exposure to laser radiation for the purpose of medical treatment by such radiation.

For the information of users of this Part, certain clauses in this Part contain cross-references to clauses in Part 2.

Some tables and figures in this Part are reproduced in Part 1 and Part 2. The content of certain figures in Part 2 is included in certain figures in this Part. The relevant tables and figures are annotated accordingly.

The guidance provided in BS 4803 : 1972 has been revised and extended and a larger number of worked examples illustrate the use of the tables and figures for the calculation of hazards.

As initial classification is the responsibility of the manufacturer (see Part 2 of this standard), there will be, in many cases, no requirements for radiometric measurements to be carried out by users.

The information given in appendices A and B of Part 1 : 1983, appendix A of Part 2 : 1983 and appendices A, B and C and table 1 of this Part is included for general reference and guidance purposes, but should not be regarded as definitive or exhaustive and reference should always be made to the definitive text of the appropriate Part(s) of this standard.

NOTE. It is the responsibility of users of this Part, making reference to another Part of this standard or to information derived therefrom, to ensure that account is taken of the current amendments.

WARNING NOTE. Compliance with the requirements of this standard in no way absolves the user of this standard from statutory obligations relating to health and safety at any stage of the manufacture or use of laser products and systems.

Compliance with a British Standard does not of itself confer immunity from legal obligations.

British Standard

Radiation safety of laser products and systems

Part 3. Guidance for users

Section one. General

1. Scope

This Part of BS 4803 is applicable to laser radiation from laser products and laser systems and it provides guidance and information for users on the appropriate safety measures required, relative to the class of the laser product concerned.

Laser systems that are supplied to other manufacturers for use as components of any equipment are not subject to this standard, but the final laser product is itself subject to this standard.

Potential hazards arising from collateral radiation are outside the scope of this standard.

NOTE 1. The titles of the publications referred to in this standard are listed on the inside back cover.

NOTE 2. References to Part 1 and Part 2 in this Part relate to BS 4803 : Part 1 : 1983 and BS 4803 : Part 2 : 1983 respectively.

2. Definitions

For the purposes of this standard the definitions given in BS 4803 : Part 1 apply, together with those given in BS 4727 : Part 4 : Group 01.

3. Classification and/or re-classification

If manufacturers comply with Part 2 of this standard then there will be no emergence from a laser product of any laser radiation in excess of class 1 limits, other than from the defined apertures, under normal operating conditions.

Any previously classified laser product that is subsequently modified, so as to affect any aspect of the product's performance or intended function within the scope of this standard, will require to be examined and re-classified if necessary. The person or organization performing any such modification is responsible for ensuring the re-classification and re-labelling of the laser product in accordance with clauses 30, 31, and 14 to 23 of Part 2.

NOTE. Manufacturing requirements for laser products are specified in Part 2.

Section two. Labelling (see also clause 13)

4. General

For the information of users of this Part who may be required to re-classify a laser product, the requirements are given in clauses 14 to 23 of Part 2.

Section three. Other information requirements

5. General

The information that manufacturers are required to supply to purchasers, servicing dealers and distributors of laser products is listed in clauses 24 and 25 of Part 2.

Section four. Additional requirements for specific laser products

6. General

For the information users of this Part, the requirements for specific laser products are given in clauses 26 and 27 of Part 2.

Section five. Tests

7. General

For the information of users of this Part who may be required to re-classify a laser product, the requirements for tests are given in clauses 28 and 29 of Part 2.

Section six. Safety precautions

8. General

This section provides guidance on the safety precautions to be taken by the user of a laser product in accordance with its hazard classification. The classification of the product in accordance with clause 30 of Part 2 can be used to assess the hazard of the installation, thus avoiding all measurements (see also clause 3 of this Part). This section is included for the user's information. No part of it should be considered to be imposing constraints or requirements upon the manufacturer. For installations where lasers of a higher class than class 2 are operated, a laser safety officer should be appointed. The laser safety officer should review the following precautions and advise on the appropriate controls to be implemented.

NOTE. User precautions are summarized for ease of reference in table 1.

9. Protective enclosure

Where reasonably practicable a protective enclosure should be provided for each laser installation which, when in place, should prevent human access to laser radiation in excess of the MPE level. Where the provision of such an enclosure is not reasonably practicable, then appropriate precautions should be taken to prevent access to laser radiation in excess of the MPE level.

10. Remote interlock

A remote interlock connector of a class 3B or class 4 laser product should be connected to an appropriate remote interlock.

11. Key control

When not in use, each class 3A, class 3B or class 4 laser product should be protected against unauthorized use, by removal of the key of the key control required by clause 8 of Part 2.

12. Beam stop or attenuator

Beam attenuators or beam stops of class 3A, class 3B or class 4 laser products required by clause 10 of Part 2 should be maintained and used where reasonably practicable to prevent the inadvertent exposure of persons to laser radiation.

13. Warning, mandatory and prohibition signs and supplementary signs

13.1 The points of access to areas in which class 3A, class 3B and class 4 laser products are used should, where reasonably practicable, be indicated by warning signs, which should include the symbol shown in figure 2; the appropriate mandatory signs and prohibition signs; and the appropriate supplementary signs (figure 1) identifying the precautions to be taken before access. These signs should be in accordance with 13.2 to 13.5.

13.2 The text on supplementary signs should be the same as that specified for labels in clauses 15 to 19 of Part 2, as appropriate.

13.3 The only type face used for lettering on supplementary signs should be Helvetica Medium. The minimum lettering height on supplementary signs should be 5 mm, but greater heights should be used if the sign is to be legible from distances exceeding 3 m (see figures 1 and 2).

13.4 For hazard warning signs (figure 2), the symbols and borders should be in black on a yellow background in accordance with BS 5378; the symbols should be placed centrally on the background and at least 50 % of the area of the sign should be yellow. The text of supplementary signs (figure 1) should be in black lettering on a yellow background for warning notices, in white lettering on a blue background for mandatory notices, and in white lettering on a red background for prohibition notices, in accordance with BS 5378.

13.5 In all respects, hazard warning signs, mandatory signs, prohibition signs and supplementary signs should comply with BS 5378, and supplementary signs should in addition comply with BS 5499 : Part 1.

14. Beam paths

Whenever reasonably practicable the beam emitted by each class 2, class 3A, class 3B or class 4 laser product should be terminated at the end of its useful path by a diffusely-reflecting material of appropriate reflectivity and thermal properties.

Laser beams should where reasonably practicable be enclosed (e.g. within a tube); this is one example of a protective enclosure. Open laser beam paths should be located above or below eye level where practicable.

15. Specular reflections

Care should be exercised to prevent the unintentional specular reflection of radiation from class 3B or class 4 laser products. Mirrors, lenses and beam splitters should be rigidly mounted and while the laser is emitting should be subject to controlled movements only, as required for setting up, operation and maintenance.

16. Eye protection

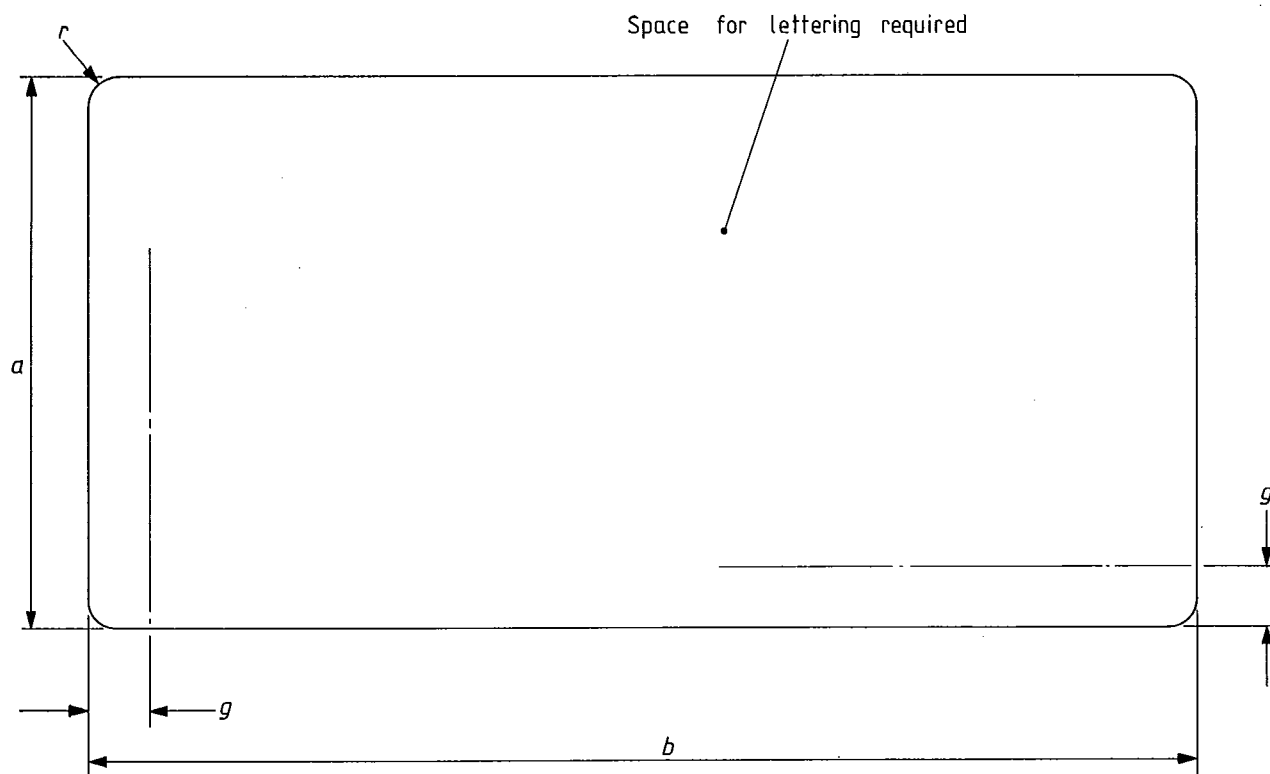
16.1 Relevant considerations. The following should be considered when specifying suitable protective eyewear:

- (a) wavelength(s) of operation;
- (b) irradiance or radiant exposure;
- (c) maximum permissible exposure (MPE);
- (d) optical density of eyewear at laser output wavelength;
- (e) visible light transmission requirements;
- (f) irradiance or radiant exposure at which damage to eyewear occurs;
- (g) need for prescription lenses;
- (h) comfort;
- (i) ventilation;
- (j) degradation of absorbing media;
- (k) strength of materials (resistance to shock);
- (l) peripheral vision requirements;
- (m) any relevant statutory regulations.

16.2 Use of eye protection. Eye protection that is designed to provide adequate protection against specific laser radiation should be used in all hazard areas where class 3B or class 4 laser products are in use and where there is a reasonably foreseeable risk of injury to eyes (see section eight). Exceptions to this are:

- (a) when engineering and administrative controls are such as to substantially eliminate potential exposure in excess of the applicable MPE;
- (b) when, owing to unusual operating requirements, the use of the eye protection is not practicable; such operating procedures should only be adopted with the approval of the laser safety officer.

16.3 Identification of eyewear. All laser protective eyewear should be clearly marked with information adequate to ensure proper choice of eyewear with particular lasers and to conform to current legislation.



The colours of the background and lettering of supplementary signs depend on the nature of the text (see clause 13).

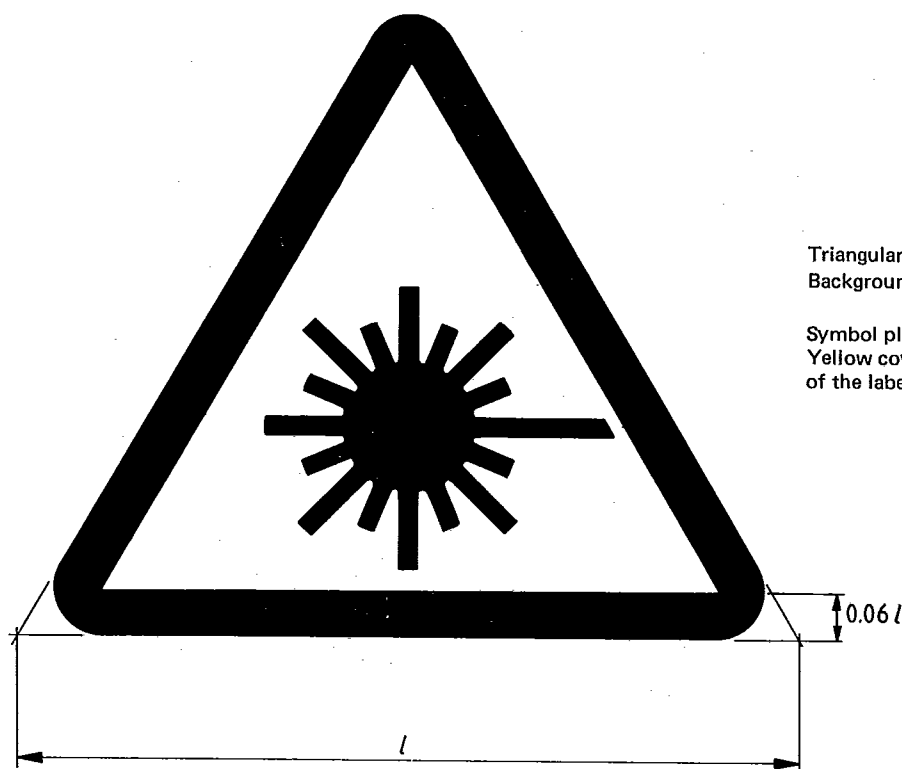
NOTE 1. The preferred sizes of signs are given in the table below (all dimensions in mm).

$a \times b$	g	r
52 x 105	5	3.2
74 x 148	7.5	4
100 x 250	12.5	5
140 x 200	10	5
140 x 250	12.5	5
140 x 400	20	6
200 x 250	12.5	6
200 x 400	20	6
250 x 500	25	8

NOTE 2. The minimum letter height should be 5 mm, but greater heights should be used if the sign is to be legible from distances exceeding 3 m. If this necessitates larger signs then preferred additional values for dimension a are 300 mm, 600 mm and 1200 mm, and other dimensions should be increased proportionately.

NOTE 3. Figure 1 of Part 2 gives information relating to supplementary labels, which are not within the scope of this Part, and contains the illustration and table of dimensions given in this figure.

Figure 1. Supplementary signs



Triangular band and symbol : black
Background : yellow

Symbol placed centrally on the background.
Yellow covers at least 50 % of the area
of the label or sign.

NOTE 1. The preferred sizes for warning signs (dimension l) are:

100, 150, 300, 600, 1200 mm

The area (A) of the sign (in m^2) should be based upon the formula:

$$A \geq \frac{L^2}{2000}$$

where L is the greatest distance (in m) from which the sign is to be understood (up to a maximum of 50 m).

NOTE 2. Figure 2 of Part 2 gives information relating to warning labels, which are not within the scope of this Part, and contains the illustration given in this figure.

Figure 2. Warning signs: hazard symbol

16.4 Required optical density. The optical density (D_λ) of laser protective eyewear is highly wavelength dependent. Where protective eyewear is required to cover a band of radiation, the minimum value of D_λ measured within the band should be quoted. The value of D_λ required to give eye protection can be calculated from the formula:

$$D_\lambda = \log_{10} \frac{H_o}{M}$$

where

H_o is the expected unprotected eye exposure level;

M is the MPE.

16.5 Eyewear selection. Protective eyewear should be comfortable to wear, provide as wide a field of view as

possible, and maintain a close fit while still providing adequate ventilation to avoid problems in misting up. Care should be taken to avoid, as far as is possible, the use of flat reflecting surfaces that might cause hazardous specular reflections. It is important that the frame and any side-pieces should give equivalent protection to that afforded by the lens(es).

17. Protective clothing

Where personnel may be exposed to levels of radiation that exceed the MPE for the skin, suitable protective clothing should be provided. Class 4 CW infra-red laser products especially are a potential fire hazard and all protective clothing worn should be made from suitable flame- and heat-resisting materials.

18. Training

Operation of class 3A, class 3B and class 4 laser products can represent a hazard not only to the user but also to other people over considerable ranges. Only persons who have received training to an appropriate level should be placed in control of such products owing to this hazard potential. The training, which may be given by the manufacturer or supplier of the products, the laser safety officer, or by an appropriate external organization, should include, but is not limited to:

- (a) familiarization with product operating procedures;
- (b) the proper use of hazard control procedures, warning signs, etc.;
- (c) the need for personal protection;
- (d) accident reporting procedures.

See also section eight.

19. Ophthalmic examinations

In the absence of specific health and safety regulations, the following recommendations should be taken into consideration.

(a) The value of routine ophthalmic examination of workers using laser products is unproven. If ophthalmic examinations are undertaken, they should be carried out by a qualified specialist and should be confined to workers using class 3B and class 4 laser products.

(b) A medical examination by a qualified specialist should be carried out within 24 h after the alleged occurrence of a suprathreshold ocular exposure. Such an examination should be supplemented by a full biophysical investigation of the circumstances under which the accident occurred. It is recommended that copies of both these studies should be referred to a central agency* and the necessary steps should be initiated to prevent recurrence of similar accidents.

(c) Pre-, interim- and post-employment ophthalmic examinations of workers using class 3B and class 4 laser products may have value for medical and/or legal reasons but are not necessarily part of a safety programme.

Table 1. Summary of user precautions

Description of hazard class Subject	Summary					
	Class 1	Class 2	Class 3A	Class 3B	Class 4	Reference clause
Remote interlock	Not required—————→			Connect to room or door circuits		10
Key control	Not required—————→		Key to be removed when laser product not in use			11
Beam attenuator	Not required—————→		When in use prevents inadvertent exposure			12
Emission indicator	Not required—————→		Indication required when laser is energized—————→			9 of Part 2
Warning signs	Not required	Summarize precautions on warning signs—————→				13
Beam termination	Not required	Terminate beam at end of useful length—————→				14
Specular reflection	No special precautions	Care to be taken	Prevent unintentional reflections—————→			15
Eye protection	No special precautions—————→			Required if engineering and administrative procedures not practicable		16
Protective clothing	No special precautions—————→			Sometimes required	Specific recommendations	17
Training	No special recommendations		Required for all operating and maintenance personnel			18

NOTE. For summary of manufacturing requirements, see appendix A of Part 2.

*The Professorial Unit, Moorfields Eye Hospital, City Road, London EC1V 2PD.

Section seven. Hazards incidental to laser operation

NOTE. Depending on the type of laser used, associated hazards involved in laser operations may include those mentioned in the following clauses.

20. Atmospheric contamination

Atmospheric contamination may arise from:

- (a) vaporized target material and reaction products from, for example, laser cutting, drilling and welding operations. These materials may well include asbestos, carbon monoxide, carbon dioxide, ozone, lead, mercury, other metals and biological material;
- (b) gases from flowing gas laser systems, or from the by-products of laser reactions, such as bromine, chlorine or hydrogen cyanide;
- (c) gases or vapours from cryogenic liquids.

21. Ultraviolet collateral radiation hazards

There may be considerable skin and eye hazard from the ultraviolet radiation associated with electronic flash lamps and CW laser discharge tubes, especially when quartz tubing is used.

22. Visible and infra-red collateral radiation hazards

The visible and near infra-red radiations emitted from unshielded electronic flash tubes and optical pump sources and target reflection and radiation may well be of sufficient intensity to produce injury.

23. Electrical and radiation hazards

Many lasers make use of high voltages. Pulsed lasers may be especially dangerous because of the stored energy in the capacitor banks. X-rays may be emitted by circuit components, if not properly shielded, at voltages above 5 kV.

24. Cryogenic liquids

Cryogenic liquids may cause burns and require special handling precautions.

25. Other hazards

The potential for explosions at the capacitor bank or optical pump systems exists during the operation of some high-power laser systems. There is a possibility of flying particles from the target area in, for example, laser cutting, drilling and welding operations. The possibility of explosions resulting from the chemicals and gases used in lasers themselves should be considered.

Section eight. Procedures for hazard control

26. General

The classification scheme relates specifically to the accessible emission from the laser product and the potential hazard based on its physical characteristics. However, environmental and personnel factors are also relevant in determining the control measures required, and a responsible person should be designated as laser safety officer, to be responsible for providing informed judgement on situations not specifically covered by this standard. (See also clause 8.)

The details given in the following clauses of this section relate to safe operation of laser products in:

- (a) display and demonstration environments, where pre-planning, delineation and control of access often provide the only reasonably practicable approach to safe operation;
- (b) laboratory and workshop environments, where engineering controls play the greatest role;
- (c) outdoor and construction environments, where administrative controls often provide the only reasonably practicable approach to safe operations.

27. Hazard evaluation for class 3B and class 4 laser products

27.1 Nominal ocular hazard distance and nominal ocular hazard area. The hazard potential for class 3B and class 4 laser products may extend over a considerable distance.

The range from the laser product at which the irradiance or radiant exposure falls below the appropriate MPE is termed the nominal ocular hazard distance (NOHD). The area within which the beam irradiance or radiant exposure exceeds the appropriate MPE is called the nominal ocular hazard area (NOHA). This area is bounded by the limits of traverse, elevation and pointing accuracy of the laser product and extends to the limit of the NOHD or to the position of any target or backstop. The exact NOHA will also depend on the nature of any material within the beam path, e.g. specular reflectors.

The NOHD is dependent on the output characteristics of the laser, the appropriate MPE, the type of optical system used and the effect of the atmosphere on beam propagation. Atmospheric turbulence can occur close to the ground, especially on sunny days. Under such conditions it is sometimes possible to exceed the nominal irradiance at a given point by a factor which, in the absence of measurements, may be assumed to be 10 for ranges in excess of 500 m. This factor may be reduced at shorter ranges. Some aperture averaging and attenuation may occur when an optical instrument is used, but these should be ignored unless they have been measured. Formulae and examples for calculating the NOHD are given in A.5.

27.2 Skin and fire hazard. There is often a skin and fire hazard with class 4 laser products and the power densities encountered with other laser products may present similar risks particularly with a focused beam.

27.3 Personal protection. The need to use personal protection against the hazardous effects of laser operation should be kept to a minimum by:

- (a) beam enclosure;
- (b) engineering design;
- (c) administrative controls.

When personnel may be exposed to potentially hazardous laser radiation (class 3B and class 4) adequate personal protection should be provided.

28. Display and demonstration laser installations

Ideally, class 1 or class 2 laser products should be used for display, demonstration or entertainment purposes. Laser products of a higher class should only be used for such purposes when either:

- (a) the laser operation is under the control of an

experienced suitably trained operator and when all people, including the general public, are excluded from exposure to levels exceeding the applicable MPE;

or

(b) administrative controls and/or fail-safe safeguards have been established/provided to ensure that all people, including the general public, are excluded from exposure to levels exceeding the applicable MPE.

NOTE. These controls/safeguards may include: hazard area delineation and control of access; rigidity and security of laser product and associated optics; limitation of beam trajectories; control or prevention of hazardous reflections; appropriate beam terminations.

29. Laboratory and workshop laser installations

29.1 Class 2 and class 3A laser products. Precautions should be taken to prevent continuous intentional viewing of the direct beam; a momentary (0.25 s) exposure as would occur in accidental viewing situations is not considered hazardous. The use of optical aids with class 3A laser products may be hazardous and the laser beam should not be intentionally aimed at people. Additional precautions for class 3A laser products are given in 30.2.

29.2 Class 3B laser products. Class 3B laser products are potentially hazardous if a direct beam or specular reflections are viewed by the unprotected eye. The following precautions should be taken to avoid direct beam viewing and to control specular reflections.

- (a) The laser product should only be operated in a controlled area.
- (b) Care should be exercised to prevent unintentional specular reflections.
- (c) The laser beam should be terminated where possible at the end of its useful path by a material that is diffusing and of such a colour and reflectivity as to make beam positioning possible while still minimizing the reflection hazards*.
- (d) Eye protection will be required if there is any possibility of viewing either the direct or the specularly reflected beam, or of viewing a diffuse reflection not complying with the conditions of (c).
- (e) The area should be indicated by a standard laser warning sign (figure 2).

29.3 Class 4 laser products. Class 4 laser products can cause injury both from the direct beam or its specular reflections and from diffuse reflections. They also present a potential fire hazard. In addition to the provisions of 29.2, the following controls should be employed to minimize these risks.

- (a) Beam paths should be enclosed whenever reasonably practicable. When this is not reasonably practicable, access should be restricted to persons wearing proper laser protection (eyewear and clothing).
- (b) Class 4 laser products should be operated by remote control whenever reasonably practicable, thereby eliminating the need for personnel to be physically present in the laser environment.
- (c) Good room illumination is important in areas where laser eye protection is worn. Light-coloured diffuse wall surfaces help to achieve this condition.
- (d) Fire is a principal hazard associated with high-powered infra-red lasers (e.g. carbon dioxide, hydrogen

fluoride, deuterium fluoride). A suitable backstop for the beam should be provided preferably in the form of an adequately cooled non-planar metal target, such as a cone. Alternatively, a sufficient thickness of firebrick or other refractory material may be used but caution should be observed with these materials as surface glazing may occur with prolonged exposure and give rise to specular reflections.

(e) Special precautions may be required to prevent unwanted reflections from far infra-red laser radiation and the beam and target area should be surrounded by a material opaque to the laser wavelength. (Even dull metal surfaces may become highly specular at the carbon dioxide wavelength of 10.6 μm .)

30. Outdoor and construction laser installations

30.1 Class 2 laser products. Where reasonably practicable the beam should be terminated at the end of its useful path and the laser should not be aimed at personnel, particularly at head height.

30.2 Class 3A laser products. The use of class 2 laser products for outdoor and construction installations is preferred. Class 3A laser products may be used (e.g. for construction applications) when high ambient light levels necessitate more power than is available from class 2 laser products. Class 3A laser products used in these circumstances require the following safety precautions.

- (a) Only suitable personnel adequately trained in its use should be assigned to install, adjust and operate the laser product.
- (b) Areas in which these laser products are used should where reasonably practicable, be indicated by a standard laser warning sign (figure 2) and supplementary label and should be treated as controlled areas.
- (c) Wherever reasonably practicable, mechanical or electronic means should be used to assist in the alignment of the laser.
- (d) Precautions should be taken to ensure that persons do not look directly into the beam (prolonged intrabeam viewing is hazardous). Direct viewing of the beam through optical instruments (e.g. theodolites) may be hazardous and should not be permitted unless specifically approved by a laser safety officer.
- (e) If the beam irradiance at the boundary of the controlled area would otherwise exceed the MPEs under any viewing conditions, including the use of 80 mm viewing optics, the beam path should be terminated within the controlled area.
- (f) The laser path should be located well above or below eye level whenever reasonably practicable.
- (g) Precautions should be taken to ensure that the laser beam is not unintentionally directed at, or misdirected by the presence of, or by the introduction into the beam of, specularly reflecting surfaces (e.g. mirrors, lenses).
- (h) When not in use, the laser should be stored in a place to which unauthorized personnel cannot gain access.

30.3 Class 3B and class 4 laser products. Class 3B and class 4 laser products in outdoor and similar environments should only be operated by suitable personnel adequately trained in their use. The following precautions, in addition to those

*Class 3B extended source viewing conditions are a minimum diffuse image diameter of 5.5 mm, a minimum viewing distance of 50 mm between screen and cornea and a maximum viewing time of 10 s.

recommended in 30.2, should be employed to minimize possible hazards.

(a) Personnel should be excluded from the beam path at all points where the beam irradiance or radiant exposure exceeds the MPEs, unless they are wearing appropriate protective eyewear and clothing. Engineering controls such as physical barriers, interlocks limiting the beam traverse and elevation, etc. should be used wherever practicable to augment administrative controls.

(b) The tracking of non-target vehicular traffic or aircraft should be prohibited within the calculated hazard distance.

(c) The beam paths should, whenever reasonably practicable, be cleared of all surfaces capable of producing unintended reflections that are potentially hazardous, or the hazard area should be extended appropriately.

(d) Although direct intrabeam viewing of class 3B laser products is usually hazardous they may be safely viewed via a diffuse reflector under the following conditions:

- (1) minimum viewing distance of 50 mm between screen and cornea; and,
- (2) maximum viewing time of 10 s; and,
- (3) minimum diffuse image diameter of 5.5 mm.

Section nine. Maximum permissible exposures

31. General

MPE levels are set below known hazard levels and are based on the best available information from experimental studies. The MPE values should be used as guides in the control of exposures and should not be regarded as precisely defined lines between safe and dangerous levels.

When a laser emits radiation at several widely different wavelengths, or where pulses are superimposed upon a CW background, calculation of the hazard may be complex.

Exposures from several wavelengths should be assumed to have an additive effect on a proportional basis according to the MPEs given in tables 3, 4 and 5, provided that:

- (a) the pulse durations or exposure times are within one order of magnitude;
- (b) the spectral regions are shown as additive by the symbols 'O' for ocular exposure and 'S' for skin exposure (see table 2).

32. Limiting apertures

An appropriate aperture should be used for all measurements and calculations of exposures. This is the limiting aperture and is defined in terms of the diameter of a circular area over which irradiance or radiant exposure are to be averaged.

NOTE. These values of ocular exposures to visible and near infra-red radiation are measured over a 7 mm diameter aperture (pupil). The MPE value should not be adjusted to account for smaller pupil diameters.

33. Repetitively-pulsed or modulated lasers

33.1 Since there is only limited information on multiple pulse exposure criteria, caution is necessary in the evaluation of exposure to repetitively-pulsed radiation. The methods given in 33.2 to 33.5 should be used to determine the MPE to be applied to repetitive exposures.

33.2 The MPE should be determined on the basis of the most restrictive of recommendations (a), (b), (c) and (d), as appropriate.

- (a) The exposure from any single pulse within the train should not exceed the MPE for a single pulse.

Table 2. Additivity of effects on eye (O) and skin (S) from different spectral regions

This table is reproduced without change from table 5 of Part 2.

Spectral region*	UV-C and UV-B 200 nm to 325 nm	UV-A 315 nm to 400 nm	Visible and IR-A 400 nm to 1400 nm	IR-B and IR-C 1400 nm to 1 mm
UV-C and UV-B 200 nm to 315 nm	O S			
UV-A 315 nm to 400 nm		O S	S	O S
Visible and IR-A 400 nm to 1400 nm		S	O S	S
IR-B and IR-C 1400 nm to 1 mm		O S	S	O S

*For definitions of spectral regions, see table 1 of Part 1.

NOTE. In this table, 'O' indicates additive for ocular exposure, and 'S' indicates additive for skin exposure. Where the wavelengths radiated are not shown as additive, the hazards should be assessed separately. For wavelengths that are shown as additive, but when the pulse durations or exposure times are not within one order of magnitude, extreme caution is required (e.g. in the case of simultaneous exposure to pulsed and CW radiation).