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TECHNICAL REPORT

Safety of laser products –
Part 3: Guidance for laser displays and shows

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FOREWORD

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The main task of IEC technical committees is to prepare International Standards. However, a technical committee may propose the publication of a technical report when it has collected data of a different kind from that which is normally published as an International Standard, for example "state of the art".

IEC 60825-3, which is a technical report, has been prepared by IEC technical committee 76: Optical radiation safety and laser equipment.

This second edition cancels and replaces the first edition published in 1995. It constitutes a technical revision. The main changes since the first edition include clarification of the scope; specific guidance on factors to take into account regarding scanning safeguards; clarification of the records to be maintained; and modification of the requirements for the zones where unattended laser projectors are used.

The text of this technical report is based on the following documents:

Enquiry draft	Report on voting
76/371/DTR	76/379/RVC

Full information on the voting for the approval of this technical report can be found in the report on voting indicated in the above table.

This publication has been drafted in accordance with the ISO/IEC Directives, Part 2.

A list of all parts of the IEC 60825 series, published under the general title *Safety of laser products*, can be found on the IEC website.

The committee has decided that the contents of this publication will remain unchanged until the maintenance result date indicated on the IEC web site under "http://webstore.iec.ch" in the data related to the specific publication. At this date, the publication will be

- reconfirmed,
- withdrawn,
- replaced by a revised edition, or
- amended.

A bilingual version of this publication may be issued at a later date.

SAFETY OF LASER PRODUCTS –

Part 3: Guidance for laser displays and shows

1 Scope and object

1.1 Scope

This part of IEC 60825, which is a technical report, gives guidance on the planning and design, set-up and conduct of laser displays and shows that make use of high power lasers. The laser power needed to produce effective theatrical or artistic displays in large spaces such as theatres, arenas, or architectural sites is great enough to pose a severe accidental exposure hazard, even when personal exposure is very brief. For this reason, subclause 4.1.5 of IEC/TR 60825-14 specifies that only laser products that are Class 1, Class 2 or visible-beam Class 3R should be used for demonstration, display or entertainment purposes in unsupervised areas. Laser products of other classes should only be permitted under carefully controlled conditions and under the control of a trained experienced operator.

The guidance provided in this technical report is not intended to include the display or demonstration of scientific, medical or industrial laser products. However, many of the principles in this guidance may be relevant. This guidance provides recommendations for safety for those laser displays or demonstrations that are shows, artistic displays, advertising or light sculptures, or museum pieces used to demonstrate optical principles, etc.

Laser products available for use in a domestic environment or for use by people who cannot be expected to have received a suitable level of training should be Class 1, Class 2 or visible beam Class 3R. Therefore, such equipment is outside the scope of this guidance.

1.2 Object

This guidance is intended to be used by those who:

- design, manufacture, assemble, install or operate laser products that are Class 4, Class 3B, or non-visible beam Class 3R for display and entertainment purposes;
- operate arenas, theatres, planetaria, discotheques or other places where such laser products may be installed and operated; or
- are responsible for reviewing the safety of such equipment, installations or displays.

This guidance is not normative, but rather a code of practice for the design, installation, operation and evaluation of the safety of laser light shows and displays, and the equipment employed in their production. This guidance is also intended for persons who modify laser display installations or equipment.

This guidance contains safety criteria for the protection of the public or persons in the vicinity of laser displays in the course of their employment.

In some countries, there may be specific requirements, such as government permissions or notifications of shows, or prohibitions, such as against laser scanning of spectators without appropriate safeguards. This guidance is not to be understood as in conflict with such requirements but merely to be supplementary.

2 Normative references

The following referenced documents are indispensable for the application of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

IEC 60825-1:2007, *Safety of laser products – Part 1: Equipment classification and requirements.*

IEC/TR 60825-14:2004, *Safety of laser products – Part 14: A user's guide*

3 Terms and definitions

For the purposes of this document, the following terms and definitions apply.

3.1
ancillary personnel
ancillary personnel include backstage workers, ushers, security guards, technicians, food and beverage suppliers, etc., who may be working at the venue or facility at which a laser display or show is being set up or presented, but who are not directly involved with the laser display or show

NOTE Ancillary personnel may have access to areas from which spectators are excluded.

3.2
barrier
device to separate spectators from zones where potentially hazardous laser radiation exists

NOTE 1 Barriers should not be capable of being readily displaced or traversed by spectators.

NOTE 2 A barrier may be a wall, a fence, stage front, etc.

NOTE 3 Less substantial barriers such as stanchions or ropes may be used if the entire barriered area is visible to and monitored by the laser operator or other safety personnel during the laser display.

3.3
designer
person who determines the visual effects to be produced, the planning of the projections, and the locations of the equipment to be used. The designer may, in addition, act as installer or operator and may be considered to be a manufacturer or supplier

3.4
display safety record (DSR)
a written record of safety information relevant to a specific laser display or show

3.5
installer
person who places the equipment in the designated locations or participates in the adjustment and alignment to produce the desired effects. An installer may also be a manufacturer or supplier if the installation activities result in modification of the display laser product effects

3.6
laser display or show
an activity where at least one laser beam is projected onto a surface or made visible in the air, usually intended to be viewed by a non-specialist audience

NOTE This definition includes demonstrations, such as in museums or educational establishments, and laser shows such as in planetariums, nightclubs, concert halls and other entertainment venues.

3.7
laser projector
a laser, used alone or with beam-manipulating components, to produce laser displays or show effects. Laser projectors are considered laser products subject to the applicable provisions of IEC 60825-1

3.8
manufacturer
any person (or persons) who constructs, assembles or produces one or more laser projectors, or the displays or shows (physical set up of equipment) which use laser projectors. This applies whether or not the manufacture is done for profit

NOTE The equipment used to produce a laser display or show is considered to be a laser product.

3.9
mask (baffle/physical or software)
a physical mask is generally a sheet or panel of durable material (often with a small aperture in the centre for the passage of the useful laser beam) designed to stop a laser beam travelling in unwanted directions. A physical mask should be capable of withstanding, without penetration, the maximum anticipated level of laser radiation, and should not slip or move *relative to the impinging laser beam. Beams controlled by electronics or computers can have* 'software masks' so the beam is prevented from entering, or is reduced in power, in certain areas. Performance of masks, whether physical or software, should be evaluated under reasonably foreseeable single fault conditions

NOTE In some situations more formal assessments, such as described in the IEC 61508 series, may be required.

3.10
modifier
person who changes the performance, layout, or effects of a laser display or show, or who makes changes in the components of the system that impact the safety characteristics. A modifier is also considered to have the same responsibilities as a manufacturer, supplier or *designer*

3.11
operator
person who has direct operational control of the laser or projection system(s)

NOTE Operators should be trained on the hazards involved with the lasers being used and are expected to comply with the safety instructions that are provided. An operator may also be designated as the laser safety officer (see subclause 3.3 of IEC/TR 60825-14) for the laser display or show.

3.12
performers
persons who entertain the public during a show. They may be dancers, singers or other musicians, etc.

NOTE Performers are expected to have been instructed on the hazard involved with the lasers being used and may be reasonably expected to comply with the safety instructions that are provided.

3.13
performer zone
area in which only performers may be present and within which laser radiation may exceed the spectator MPE

NOTE The performer zone is usually located on a stage.

3.14
scan pattern
effect produced when a laser beam is scanned, often using a pair of mirrors mounted on galvanometers

3.15
spectator
person who is present at the laser display or show who, by location or proximity, could potentially be exposed to hazardous direct or reflected laser beams (in the absence of any safety features, or in a worse-case situation) and who is the intended audience for the laser-created effects. This does not include the laser display operator and their staff, or performers

NOTE Spectators can neither be expected to have been briefed on the safety procedures regarding the lasers in use, nor be expected to comply with safety instructions.

3.16
spectator MPE
maximum level of ambient laser radiation that may exist in a spectator zone

3.17
spectator zone
area in which spectators may be present and within which laser radiation is restricted to the spectator MPE

4 Zone limits and maximum permissible exposures (MPE) for laser radiation

4.1 Compliance with maximum permissible exposure (MPE)

Under no circumstances should any person be exposed to laser radiation in excess of the applicable eye or skin MPE. The maximum permissible level of laser radiation to which a particular group of individuals can be exposed depends on the maximum exposure time *assumed for that group.*

4.2 Spectator MPE

The level of laser radiation that may be present in a spectator zone should not exceed the MPE for direct ocular exposure of Clause 5 of IEC/TR 60825-14. The applicable MPE to be considered is determined using Tables 5, 6, or 7 of IEC/TR 60825-14 for all possible durations of exposure, t, including the maximum duration of the laser display or show, as appropriate (see below if the use of binoculars is likely). If the level of laser radiation is maintained as a result of scanning of the laser radiation, the MPE for direct ocular exposure should also not be exceeded for the response time of the scanning safeguard (see 4.11 of IEC 60825-1 and Figure 1 below) or for the CW level of the laser radiation (if there is no scanning safeguard).

Consideration should be given to any areas within the zone where the laser radiation hazard *may be greater, for example if beams are focussed or static (such as at the end of scan* patterns).

T_S is the start time of the fault.
T_E is the time when the exposure is terminated.
$T_E - T_S = T_1 + T_2 + T_3$, where T_1 is the time to react to the fault; T_2 is the time to trigger the control measure; and T_3 is the time for the control measure to become effective having been triggered.

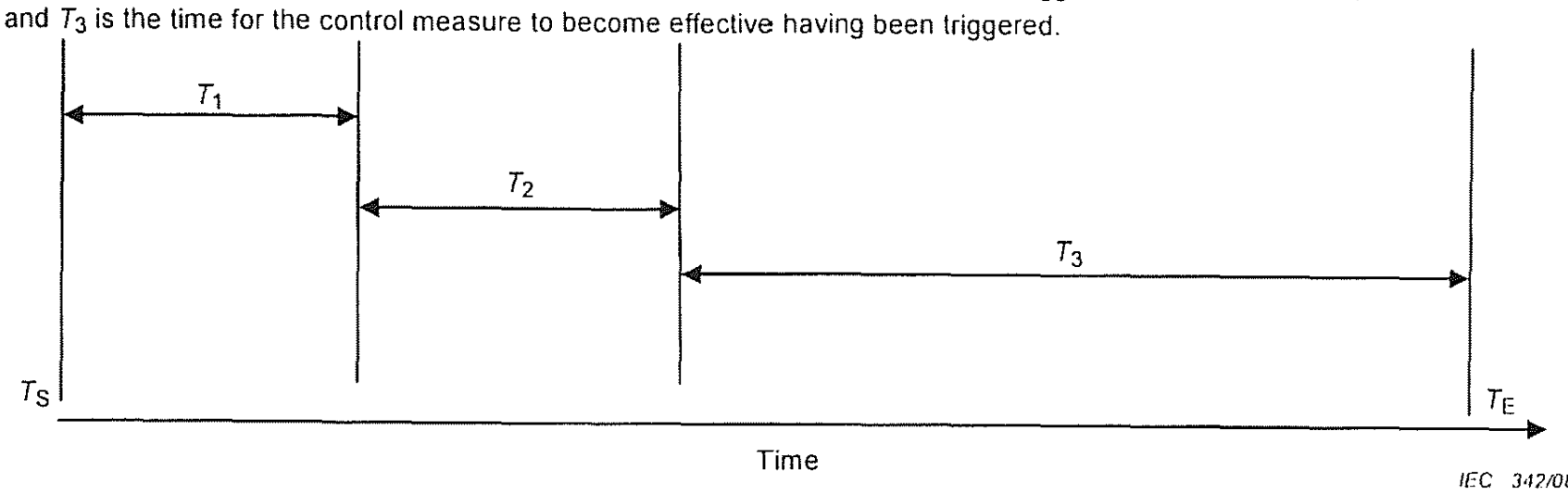

Figure 1 – Time for a scanning safeguard to be effective

Use of viewing aids, such as binoculars, can potentially increase the hazard to spectators. At some venues, such as nightclubs, planetariums and corporate events, binocular use is not a problem. However, if binocular use may be likely (e.g. at a large arena) and security is already used to prohibit cameras, recording devices, etc., it is suggested to additionally prohibit binoculars. If this is not possible (e.g. an open-air outdoor event), the Spectator MPE should be multiplied by a factor of 0,02 to account for the increased hazard.

4.3 Ancillary personnel MPE

The MPE for ancillary personnel should be the MPE for direct ocular exposure (see Table 5 or Table 6, as appropriate, of IEC/TR 60825-14). This MPE anticipates that ancillary personnel are likely to be in locations other than the spectator zones, their movements are unlikely to be controlled, and they are unlikely to be provided with protective eyewear. However, they should be instructed to avoid looking directly into any incident beams, scanners or mirrors. For this reason, exposure durations up to 0,25 seconds should be considered.

4.4 Performer MPE

The MPE for performers or operators should be the MPE for direct ocular exposure (see Table 5 or Table 6, as appropriate, of IEC/TR 60825-14) or the MPE for the skin (see Table 7 of IEC/TR 60825-14) as appropriate. Performers should be expected to have their actions choreographed, to be provided with protective eyewear and costuming if appropriate, and to be instructed in procedures to avoid exposure to laser radiation in excess of the appropriate MPE. The maximum duration of exposure should be considered.

In some cases, performers may directly control laser safety features. For example, a performer may step on a switch to indicate he or she is in a safe location before beams can be emitted into the performance area. Any such control measures must be carefully designed both for normal conditions, and for cases when a performer may be off their mark or facing the wrong way (e.g., towards the laser) during a cue.

NOTE For some installations the safety features may need to be assessed using formal procedures such as those described in the IEC 61508 series.

Table 1 – Summary of MPE selection criteria

Location	Accessible emissions in normal operation	Accessible emissions under reasonably foreseeable fault conditions
Spectator zone	MPE for direct ocular exposure	MPE for the response time of a scanning safeguard or other emission termination control
Ancillary zone	MPE for direct ocular exposure for 0,25 s assuming training in avoidance of ocular exposure	MPE for direct ocular exposure for 0,25 s assuming training in avoidance of ocular exposure
Performer zone	MPE for direct ocular exposure for 0,25 s assuming training in avoidance of ocular exposure. If ocular exposure is prevented, the skin MPE may be used	MPE for direct ocular exposure for 0,25 s assuming training in avoidance of ocular exposure

5 Safety criteria for equipment and installations

5.1 The requirements of IEC 60825-1 are applicable to laser projection equipment.

5.2 Laser apertures should be masked using a material sufficiently robust to withstand direct exposure to the laser radiation for extended periods of time. The mask should be positioned to confine the projections to the intended directions and to prevent errant laser radiation. Software masks, meaning a computer-programmed means to prevent beams in unintended directions, may be used but due consideration should be given to failure modes, especially when used to restrict exposure in the spectator zone.

5.3 Targets should be appropriately masked to prevent misdirection of a laser beam in the event that the laser becomes misaligned with the target.

5.4 Laser projectors, mirrors and targets should be rigidly mounted to prevent movement due to vibration, jarring or the wind. Appropriate consideration should be given to the duration of the installation and the type of venue.

5.5 Scanning devices and their control systems should be designed to prevent (during normal operation and under any reasonably foreseeable fault condition):

a) exposure of spectators to levels of laser radiation in excess of the relevant MPE;

b) exposure of ancillary personnel to levels of laser radiation in excess of the MPE for direct ocular exposure for 0,25 s assuming training in avoidance of ocular exposure;

c) exposure of performers, installers or operators to levels of laser radiation in excess of the MPE for direct ocular exposure for 0,25 s assuming training in avoidance of ocular exposure; if ocular exposure is prevented, the skin MPE may be used.

5.6 Each laser installation should be provided with one or more clearly identifiable and easily operated emergency shut-off controls which immediately terminate the laser radiation when required.

5.7 If the laser display or show is under the continuous control of an operator who can immediately terminate laser radiation in the event of a problem, a minimum separation of 3 m in height and 2,5 m laterally should be maintained between beams that exceed the spectator MPE and any surface upon which spectators can reasonably be expected to stand. This condition is shown in Figures 2 and 3.

NOTE If the dimensions of the room are inadequate to provide these minimum separation distances then a more detailed assessment of the risk of exposure may be required.

5.8 If the laser display or show is not under the continuous control of an operator who can immediately terminate laser radiation in the event of a problem, a minimum separation of 3 m in height and 2,5 m laterally should be maintained between beams that exceed the spectator MPE and any surface upon which spectators can stand. In addition, the spectator MPE should not be exceeded by more than a factor of 5 in the space between 3 m and 6 m above any surface upon which spectators can reasonably be expected to stand. This condition is shown in Figure 4.

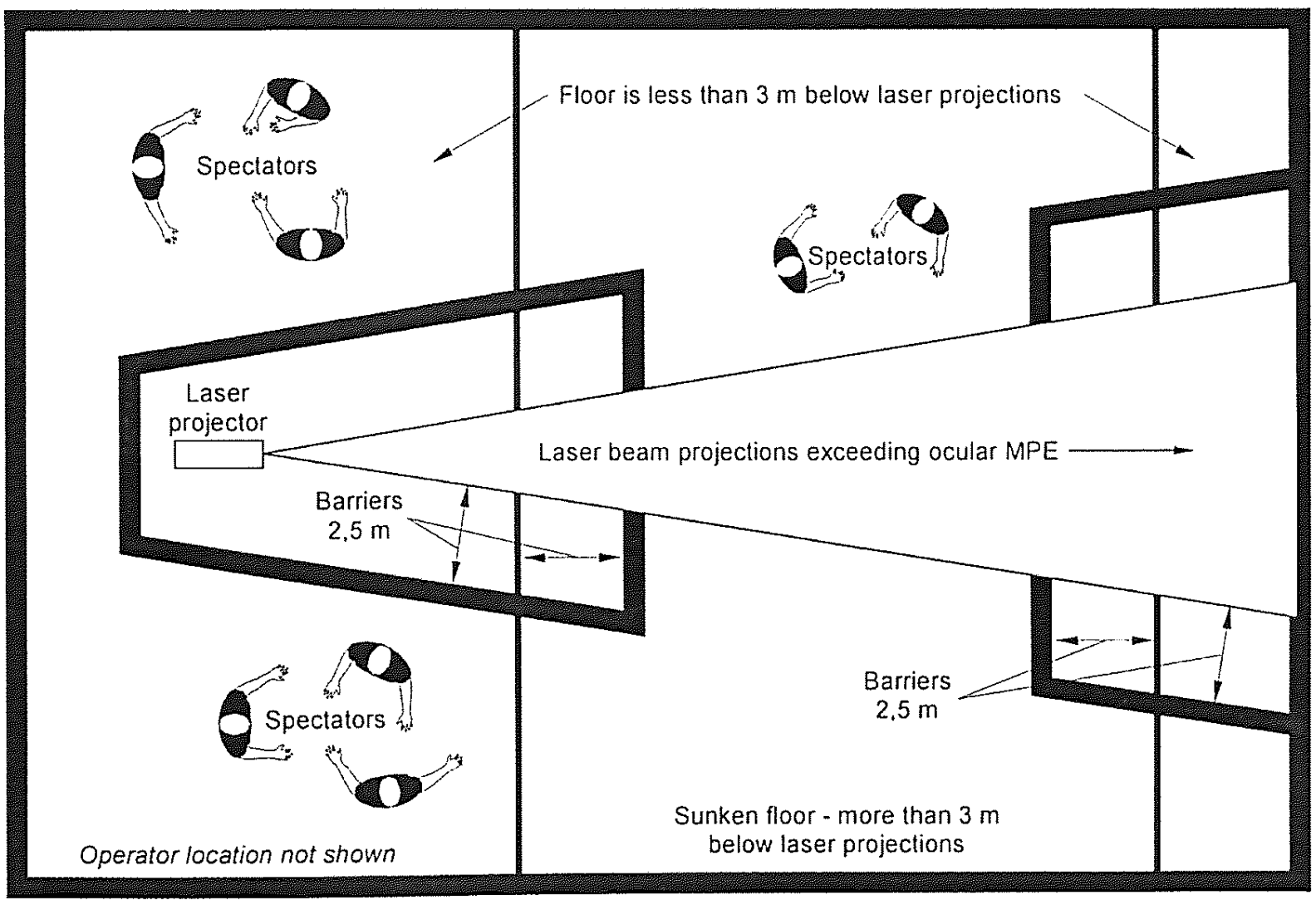

Figure 2 – Spectator separation with operator in control

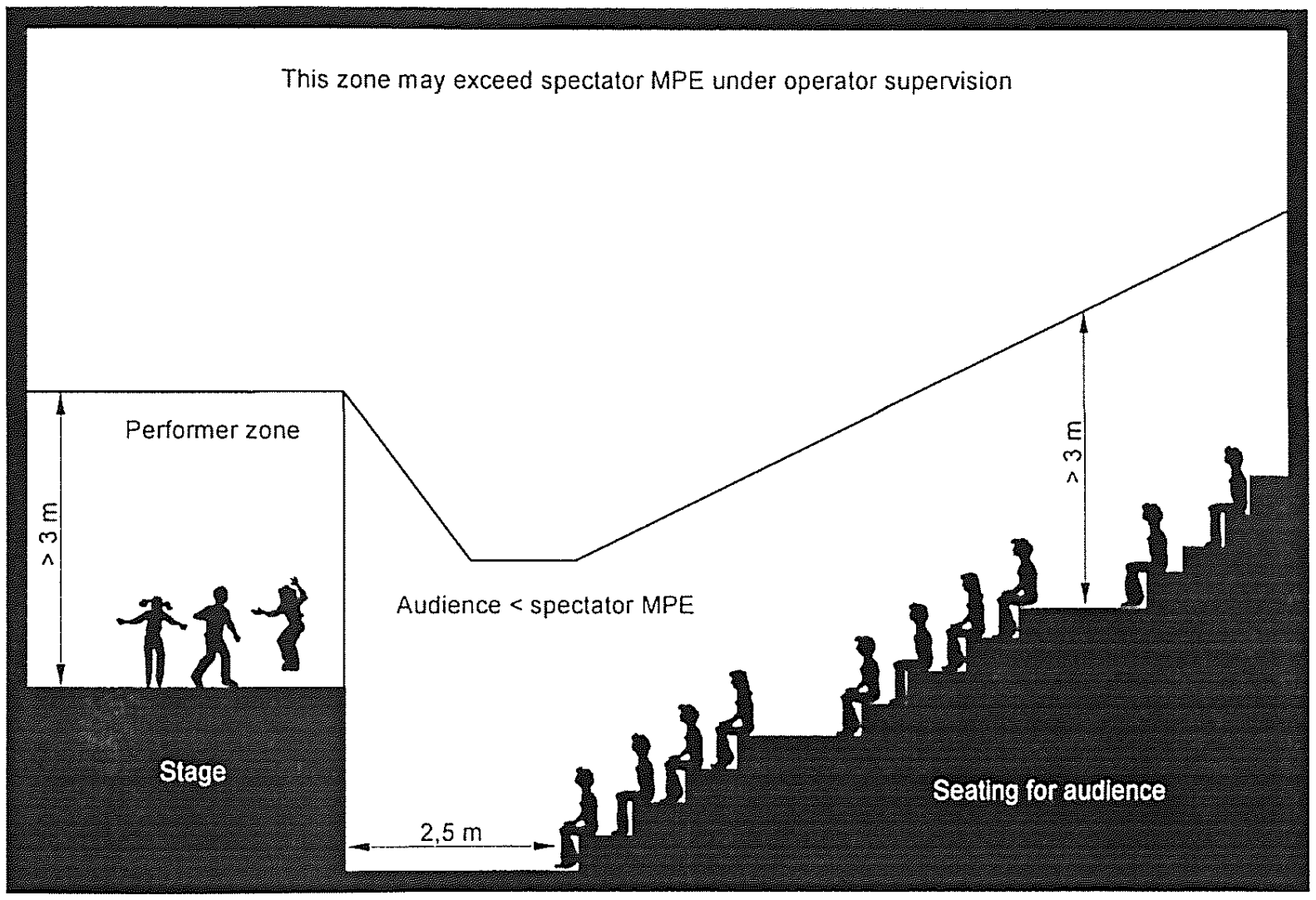

Figure 3 – Audience/spectator separation with operator in control

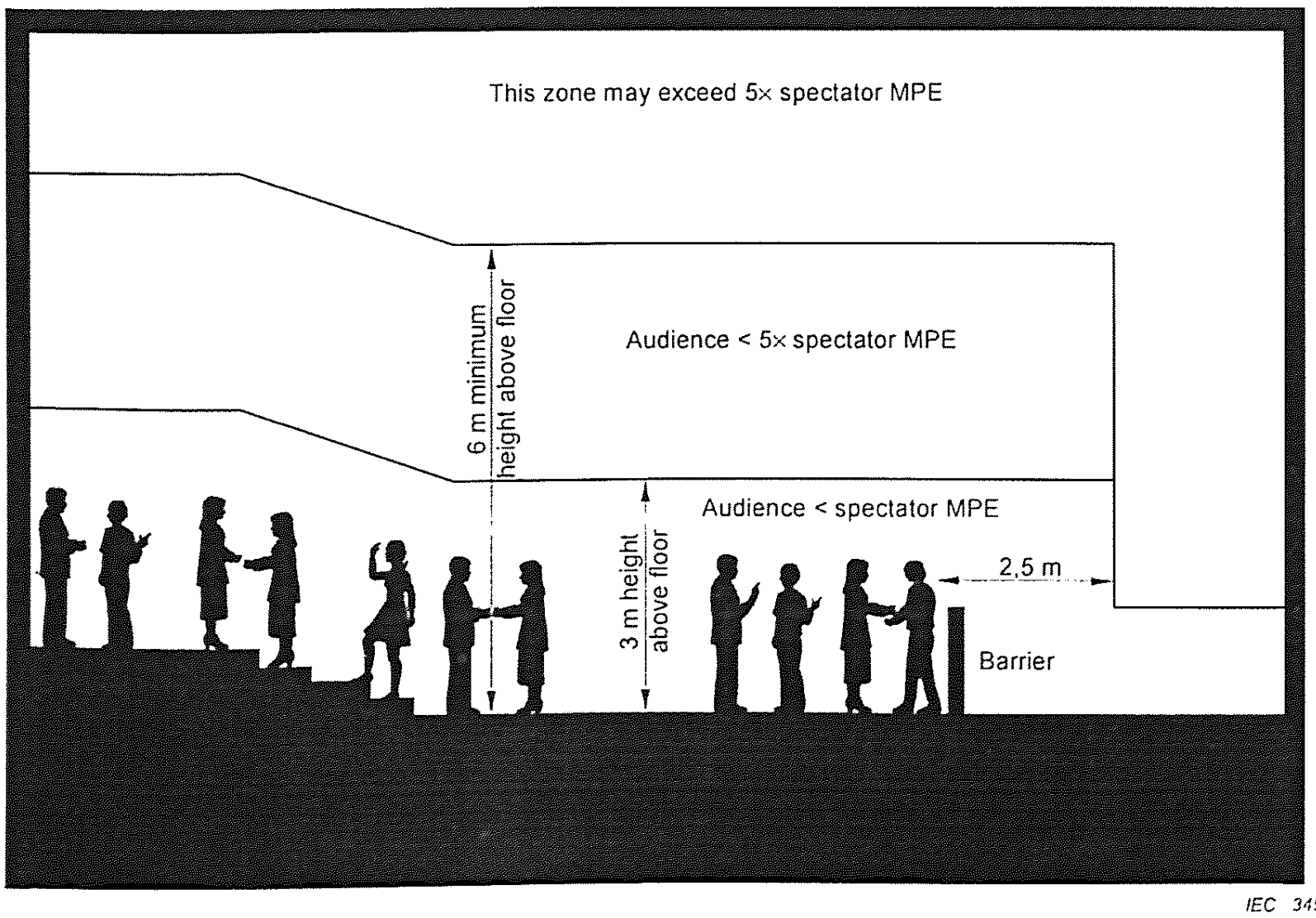

Figure 4 – Audience/spectator separation from unattended beams

6 Responsibilities of designers, installers, operators and performers

6.1 Training

6.1.1 Designers, installers, modifiers and operators should have received sufficient training in laser safety to be able to accurately assure that the MPE is not exceeded in spectator occupied areas and that the required separations are maintained between spectators and projections that exceed the MPE. Designers should also be trained to be familiar with the requirements of IEC 60825-1 and IEC/TR 60825-14 regarding the security of locations in which laser radiation levels exceed the MPE, and to provide guidance to installers regarding the posting or placement of necessary warning signs.

6.1.2 Installers, performers and ancillary personnel should be instructed in procedures, as appropriate, to avoid hazardous exposure in areas in which laser radiation levels exceed the MPE and in the proper use of safety equipment.

6.2 Planning by designers, installers and operators

6.2.1 Laser displays and shows should always be pre-planned and not improvised on the day of the event. The purpose of planning is to allow a safety assessment of any proposed display to be carried out in sufficient time for the necessary safety provisions to be made. The design of laser displays and shows should be accomplished as early as possible.

Plan and elevation drawings or sketches should be prepared showing locations of projectors, laser beams, mirrors and targets, the audience, performers and pertinent architectural features. The drawings should be checked to confirm that required separation distances are met and that spectator exposures will not exceed the applicable MPE. Contingency plans should be prepared to assure that equipment or projections do not obstruct or interfere with emergency exit routes during possible emergency conditions, e.g., fire. Plans should also take into account the environmental effects of rain, wind, etc. on targets, mirrors, etc.

6.2.2 The planning should include the designation of one or more persons to be the Laser Safety Officer (LSO).

6.2.3 Notification to national or local health and safety authorities of the laser display or show may be required and, if so required, should be made as early as possible during the planning stage. Some authorities may also have licensing requirements or require notification not later than a specified number of days prior to a show. Notification may be required to include such information as locations, dates, set-up times, names and telephone numbers of responsible persons for both the show and the venue, number and operational specifications of lasers to be used and the types and sequence of visual effects to be employed.

Notifications should also be made, as appropriate, to:

- aviation authorities for projections into navigable airspace;
- maritime authorities for projections into navigable waterways or harbours; and
- other relevant authorities for projections over rivers, lakes, shore or waterfront locations.

Notification to local aviation control authorities of planned projections into navigable airspace may also require the inclusion of geographical coordinates of the location and the azimuths and elevations of the planned projections. Specific international guidance is published by the International Civil Aviation Organization (*Manual on Laser Emitters and Flight Safety*).

6.3 Set-up and alignment

6.3.1 Ample time should be provided for set-up and alignment. The area should be cleared of unnecessary personnel. Locations where the levels of laser radiation may exceed the MPE should be posted with appropriate warning signs and barriers erected to restrict entry.

6.3.2 Alignments should be made at the lowest possible emission levels. However, it should be recognised that the ambient light level will critically influence the lowest possible emission levels for alignment work if this is being carried out by eye. A check should also be made at full operating power at the conclusion of the alignment to identify any spurious beams so that corrective action may be taken.

6.3.3 During set-up and alignment when laser beams may be projected in other than their final intended directions, laser controlled areas should be established and warning notices posted in accordance with IEC/TR 60825-14.

6.3.4 Checks should be made of controls including any scan failure safeguards and emergency stop controls to ensure proper operation. Checks should also be made that warning signs and barriers are in place as appropriate. Checks should be made that all components are securely mounted and locked into position. An auditable record of these checks should be maintained.

6.3.5 Equipment should be secured and protected against misalignment or maladjustment between alignment completion and the performance. Installation of the equipment in a secured projection booth or the employment of security personnel may be necessary.

6.3.6 Coordination with safety and security personnel should be established and agreement developed of action to be taken for notifying the operator in the event of an emergency. Spectators should not be presumed to be cooperative with laser safety procedures or to be aware of proper procedures to follow to protect themselves from exposure or to avoid exposing others to hazards. Spectators should not be permitted to bring items, such as reflective balloons, into the show site if overhead beam projections are to be used.

6.3.7 The operator should have copies of any official clearances, records of alignment and operational/pre-show checks, and operating instructions in his or her possession at the show site.

6.4 Operation

6.4.1 If the display or show is evaluated by a local jurisdiction or aviation control authority, the operator should resolve any concerns prior to beginning the laser display or show. Aviation control authorities may frequently require the operators of outdoor laser displays or shows to employ observers to warn the projector operator of approaching aircraft.

6.4.2 Prior to beginning high power operations, the operator should, if at all possible, perform a final low power alignment check to assure that components have not moved since completion of the set-up. An auditable record of this check should be maintained.

6.4.3 The operator should make certain that there is visual control of all projections during the laser display or show. It is acceptable to employ observers who are in immediate communication with the operator if the operator cannot maintain personal visual control.

6.4.4 The operator should be prepared to immediately terminate any projections that may create an imminent hazard as a result of any incident or emergency, such as unruly behaviour of the spectators or movement/failure of the safety equipment. An emergency is considered to be any situation that may result in possible exposure of spectators, performers, operators or others to laser radiation levels in excess of the limits specified in 4.2, 4.3 or 4.4 of this guidance.

6.5 Display safety record (DSR)

The Laser Safety Officer (LSO) should maintain at the show site a display safety record (DSR) containing full and detailed information on how laser safety is managed. The DSR for each laser display or show should be kept up to date at all stages of implementation (i.e. initial

design, planning, installation, alignment, operation, maintenance, servicing, modification and dismantling).

National requirements may be more specific, but the DSR should include:

a) details of the laser display or show, including equipment, location, layout of the venue, type of laser effects and beam paths in relation to spectators, ancillary personnel and performers;

b) characteristics of the laser beams, including maximum beam power, wavelength, divergence and maximum and minimum scan rates;

c) all relevant safety information relating to all stages of implementation of the laser display or show, including records of alignment procedures and pre-show checks;

d) the conclusions from the risk assessments for all stages of implementation of the laser display or show;

e) control measures in place and the rationale for them;

f) the names and contact details of designers, installers, modifiers, operators, LSO and owner of the laser display equipment;

g) contingency plans;

h) any operation and display approvals and restrictions issued by regulatory authorities (both local and national); and

i) relevant details from the laser equipment manuals conforming to 6.1 and 6.2 of IEC 60825-1.

7 Special considerations

7.1 Holographic displays

Special consideration may be appropriate for laser displays or shows that are reconstructions of holographic images. Care should be taken that laser beams used for reconstruction do not emerge in such a way that they can expose spectators or other persons to levels in excess of the limits specified in 4.2, 4.3 or 4.4 of this guidance.

7.2 Ultraviolet and blue-light laser beams

Ultraviolet (wavelengths below 400 nm) and blue-light (up to about 500 nm) beams are sometimes employed to excite fluorescence from screens or specially prepared targets. Particular care needs to be taken in such situations since the invisible radiation gives no forewarning of its presence. Ultraviolet laser beams should not be directed at the audience to excite fluorescence in clothes and cosmetics. Since the risk resulting from direct or indirect exposure to ultraviolet laser beams is related to the cumulative exposure time during the laser display or show, the photochemical MPE should not be exceeded for the foreseeable cumulative exposure duration.

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ICAO Doc 9654-AN/945, *Manual on Laser Emitters and Flight Safety*, International Civil Aviation Organization

IEC 61508 (all parts), *Functional safety of electrical/electronic/programmable electronic safety-related systems*