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Safety of laser products –

Part 4: Laser guards

Amendement 2

Sécurité des appareils à laser –

Partie 4: Barrières laser

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FOREWORD

This amendment has been prepared by IEC technical committee 76: Optical radiation safety and laser equipment.

The text of this amendment is based on the following documents:

FDIS	Report on voting
76/263/FDIS	76/273/RVD

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

The committee has decided that the contents of the base publication and its amendments will remain unchanged until 2005. At this date, the publication will be

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- withdrawn;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

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Add the following to the existing table of contents:

Annex E (informative) Guidelines on the arrangement and installation of laser guards

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Add, after Annex D, the new Annex E as follows:

Annex E
(informative)

Guidelines on the arrangement and installation of laser guards

E.1 Overview

This informative annex addresses the arrangement and installation of guards to protect personnel against laser radiation hazards around the process zone of a laser materials processing machine. These guidelines are for use by manufacturers and/or users. The object of the annex is to encompass guarding for a stand-alone laser-processing machine (see ISO 11553[1]) and additional (often user-installed) guarding required to safely integrate a laser-processing machine. Guarding issues relating to associated hazards of laser processing (which include mechanical, electrical, fume and secondary radiation hazards) are not considered in detail in this annex.

E.2 General

E.2.1 Introduction

Laser guarding is required to isolate the laser hazard in addition to the associated hazards of laser processing. Some of the guards may form part of a laser-processing machine, additional guarding may be used to facilitate safe loading and unloading of workpieces, and for servicing.

E.2.2 Arrangement of guards

Key elements in assessing the arrangement and installation of guards around the process zone include:

a) the degree of accessibility required for workpiece handling (especially the degree of manual manipulation);

b) the method of fixing the workpiece (e.g. use of jigs and clamps);

c) the method of removal of the workpiece and any associated parts (e.g. scrap) after processing.

E.2.3 Location of guards

Good practice in determining the location of laser guards includes:

– the laser guard should be located at least 3 focal lengths away from the focal point of a focussing lens;

– laser guards with lower protective exposure limits (PELs), for example viewing windows, should not be located where the direct beam or specular reflections are expected.

E.2.4 Complete enclosure

A complete enclosure is one which meets all the requirements for a protective housing as specified in Clause 4.2.1 of IEC 60825-1 and encompasses the embedded laser and the entire process zone, such that there is no human access to hazardous radiation.

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1 Also published by the European Committee for Standardization as EN 12626.

E.2.5 Incomplete enclosure

An incomplete enclosure is one which does not provide a complete protective housing encompassing the embedded laser and the entire process zone, such that human access to hazardous radiation is possible.

If the risk of exposure is not tolerable, (to those who may be on walkways or platforms which raise them above the guards of an open topped machine) additional control measures are required.

E.2.6 Hierarchy of control of laser hazard areas

The following hierarchy of measures is recommended for keeping persons out of an area where there is an intolerable risk:

a) fit a fixed guard;

b) fit a removable guard;

c) fit an electronic protection device linked to the safety interlock chain of the machine, around the perimeter of the area (e.g. a light beam sensor) or over the area (e.g. a pressure mat);

d) provide a physical barrier plus information, instruction, training, supervision;

e) provide a means of allowing use with the operator some distance from the process zone plus personal protective equipment (PPE).

NOTE Measures (c) and (d) provide no protection from laser radiation emerging from the laser machine and should therefore only be considered where the distance of the controlled boundary from openings in the machine exceeds the "Nominal Ocular Hazard Distance" (NOHD).

E.2.7 Personal protective equipment

Personal protective equipment should only be used as a last resort where a combination of engineering and administrative controls cannot reasonably provide a sufficient level of protection. Where personal protective equipment is employed it should be supported with an adequate level of administrative control governing its use. It should only be used when a risk assessment has shown that the use of other means of risk reduction has failed to produce a sufficient degree of safety and when it is not reasonably practicable to ensure adequate protection by other means. When working with UVB and UVC, protective clothing may be required.

E.2.8 Human intervention

Where machine operations require a human access, then human intervention can be included in the risk assessment and the consideration of implications for the duration of the fault condition. Under these conditions access should be controlled and accessible only to authorised persons who have received adequate training in laser safety and servicing of the laser system involved. The area should also be restricted and not open to the public and where observers or other untrained personnel are kept from being exposed to the hazards by barriers or administrative controls.

E.3 Risk assessment

E.3.1 Introduction

Human exposure to a laser beam of the type typically used in laser materials processing can produce a moderate to severe injury, depending on laser wavelength, tissue exposed and the response of the victim. The probability of such an exposure occurring becomes the key variable element in assessing the risk of injury. The reduction of risk to tolerable levels is an iterative process. There is no standard approach to procedure and documentation for this process. Nevertheless, the steps involved are universal and are described in EN 1050.

E.3.2 General considerations

A risk assessment should be performed to identify hazardous situations and to assess the foreseeable exposure level on intended positions of a laser guard. This assessment should take into account a number of factors, including the following.

E.3.2.1 Features of the laser process zone

Relevant features include the laser power and wavelength, the focal length of optics, the degrees of freedom of the beam delivery (e.g. number of axes of movement).

E.3.2.2 Process

The nature of the process, such as cutting, drilling, welding, marking. The machine may be dedicated or offer several processes.

NOTE Reflected laser powers differ appreciably with process and material being processed.

E.3.2.3 Process control

This factor addresses in particular the time during which laser guards may be exposed under fault conditions, including those upon which the foreseeable exposure limit (FEL) is determined (e.g. the process cycle time), the inspection process (e.g. per item or per time period/ number of items), and the means and effectiveness of automatic process control intervention in the event of a fault condition becoming evident.

E.3.2.4 Manual operations

Operator intervention considerations include the need and provision for manual control, the means and effectiveness of process observation (including the location of viewing windows or cameras) and the accessibility and effectiveness of intervention in the event of a fault condition becoming evident.

E.3.2.5 Robot operations

The full range of robot movements, impact protection for the robot head and general protection of service lines and the beam delivery to the robot, and the means of limiting robot head movement and direction (e.g. software limits, hardware limits and physical limits), in particular the closest approach of the exposed laser beam to laser guards.

E.3.2.6 Workpiece

The geometry, composition and surface finish of the workpiece, and how it can affect the direction and strength of reflections during laser processing.

E.3.2.7 Clamping and fixturing

The holding and positioning of the workpiece and the related issues of reflections from surfaces and collisions of the focussing head.

E.3.2.8 Loading and unloading

The method by which the workpiece is introduced and removed, in particular whether it is manual or automatic, single piece or continuous, and the method (e.g. sliding, rolling or lifting door) and control of access to the process zone.

E.3.2.9 Beam delivery

Beam delivery considerations include the optical method (mirror or fibre) and means of inspection, positioning and movement of optical components. Considerations include the structural integrity of the mounting of beam path components, means of maintaining the condition of optical components (e.g. clean dry gas purge plus cooling supply), means of maintenance of beam alignment, provision of on-line errant and non-errant beam monitoring, and means of construction of the beam delivery enclosure.

NOTE Particular attention should be given to the use of novel (unproven) design of laser beam delivery, the exposure of the beam delivery structure to external mechanical forces (e.g. vibration) which may give rise to optical misalignment. Attention should also be given to tampering with optics or anomalous performance of lasers, especially in regard to beam pointing, and situations where the laser power is so high that the performance of beam delivery optics is uncertain.

E.3.2.10 Location of workers

The defined work area, in particular the minimum distance of permitted approach to the machine. Included in this consideration are overhead locations (e.g. crane operators, office workers on elevated walkways), steps and ladders in the vicinity.

E.3.2.11 Maintenance provision

This consideration includes the means and control of access to maintenance positions (e.g. removable panels, key control) and the provision of interlock overrides and emergency stops.

E.3.2.12 Guarding properties

The assessment of FEL and PEL under normal conditions and reasonably foreseeable fault conditions should be made for each element of guarding, including fixed and moveable walls and windows.

E.3.2.13 Guarding environment

Environmental factors that may influence the effectiveness of the guarding, including access for fork lift trucks and other moving objects that could cause significant mechanical damage, and dusty environments that could adversely affect the performance of optics and/or the protective properties of the guard.

E.4 Examples of risk assessment

E.4.1 Continuous feed of components

- Example

Laser processing unit mounted over a conveyor belt.

- Location

During normal production or maintenance, access is controlled and only accessible to authorised persons, but the area may also be unrestricted and open to observers or other untrained personnel.

During service periods, the area may also be restricted and not open to other untrained personnel.

- Key issue

The arrangement of laser guarding should include entry and exit ports to permit the feeding of components into and out of the process zone on a continuous basis.

- Possible solutions

Where the risks of excessive laser radiation are high:

– provide interlocked sliding guard, which opens to permit entry of the component, and closes prior to laser processing.

Where the risks of excessive laser radiation are medium or low (possible solutions following the risk assessment):

– provide local guarding with a brush seal to maintain enclosure during passage of component, or
– provide an open tunnel around opening(s) to restrict line-of-sight access to the laser process zone. This may be accomplished by:
  - using a labyrinth for the component entry and exit paths in order to block direct line of sight, or
  - by the use of an interlocked barrier (e.g. light guard or fencing) or a pressure mat that is approved for safety applications, to restrict the viewing position in order to prevent a direct line of sight.

E.4.2 Flatbed laser cutting and marking

- Example

Flatbed cutting table in laser job-shop environment.

- Location

During normal production or maintenance and service periods, access is controlled and only accessible to authorised persons and restricted to trained personnel only.

- Key issues

Access to the table is required for loading and unloading of sheets onto the cutting table.

- Possible solutions

Where the risks of excessive laser radiation are high (for example where hazardous laser radiation is generated from reflections which are present during normal production):

– provide full perimeter guarding to protect the operator and other personnel. Interlocked sliding guard opens to permit passage of component and closes prior to laser processing.

Where the risks of excessive laser radiation are medium or low (for example beam is directed vertically onto a flat workpiece and enclosed to within a short distance of the workpiece):

– provide free-standing guard to protect the laser operator;
– provide PPE requirement for all persons within the restricted access zone.

In all cases, provide adequate controls to ensure unauthorised and untrained persons are prevented from exposure to any hazard that may cause harm.

E.4.3 Multi-axis processing machine

- Example

Automated robotic laser welder on an automobile line.

- Location

During normal production or maintenance, access is uncontrolled and the area is unrestricted and open to observers or other untrained personnel.

During service periods, access would be controlled and only accessible to authorised persons and the area restricted and not open to other untrained personnel.

- Key issue

A fault condition in the controller could lead to the laser beam being directed at the laser guarding.

- Possible solutions

Where the risks of excessive laser radiation are high:

– provide reinforced guarding at parts of process zone enclosure indicated as vulnerable by the risk assessment. This reinforcement may be by using an active guard.

Where the risks of excessive laser radiation are medium or low:

– the elements of solution may include:
  - provide guarding which has a verified performance being tested as described in IEC 60825-4 for direct exposure to representative laser beam;
  - provide software control and hardwire limits to beam-line rotational movement;
  - provide collision protection of the beam-line 'head';
  - provide additional sensors for preventing laser emission beyond the workpiece;
  - provide control of the laser emission if the laser focusing head is stationary.

E.4.4 Laser guards for supervised areas

- Example

Temporary laser guards set up during service activities to exclude persons not involved in the servicing operation.

- Location

During normal production or maintenance, these laser guards would not be used as a protective guard.

During service periods, access would be controlled. The location is only accessible to authorised persons who are trained in laser safety. The location is not open to other untrained personnel as indicated by administrative means (e.g. warning signs).

- Key issue

Beam direction is under administrative control.

- Possible solutions

Where the risks of excessive laser radiation are high, the elements of solution include:

– ensure laser guards are opaque and are capable of at least 100 s protection from the laser beam;
– entry to the screened off area interlocked or under direct administrative control;
– use trained personnel to carry out such service operations;
– protective laser eye wear (and possibly skin wear) to be used by all those inside the controlled area.

Where the risks of excessive laser radiation are medium or low (e.g. area outside the laser guard is cleared of personnel):

– as above, except that the protection time provided by the screen may be less than 100 s provided the service engineer has ready access to the laser shutter control and laser exposure of the screen provides a clearly visible indication (e.g. smoke or strong discoloration).

E.5 Aids to risk assessment

This clause provides a list of items to be considered when assessing the risks associated with a laser-processing machine in the design of laser guards. These details should form part of a documented record of the assessment.

Note that this list is NOT comprehensive and may not include all the aspects that should be considered.

E.5.1 Equipment

- Laser
  - Type
  - Wavelength
  - CW/pulse
  - Pulse duration
  - Pulse repetition rate
  - Power (or energy)
  - Beam delivery output lens focal length
- Processing machine type
  - 2-axis machine
  - 3-axis machine
  - machine with more than 3 axis
  - robot
  - fume extraction fitted
  - process zone enclosure:
  - Class 1 AEL
  - other

E.5.2 Process machine beam delivery

- Beam delivery path monitoring:
  - by hardware control
  - by software control
- Beam delivery turning mirror monitoring:
  - by hardware control
  - by software control
- Beam delivery mechanical assembly:
  - requires use of tools
  - monitoring provided
  - by hardware control
  - by software control
  - beam focus lens control assembly
- Free space beam delivery system
- Fibre optical beam delivery system

E.5.3 Process description

- Soldering/brazing
- Heat treatment
- Marking
- Welding
- Drilling/cutting
- Cleaning
- Forming
- Rapid prototyping

E.5.4 Process machine controls

- For automatic mode operation (i.e. no operator intervention):
  - fully guarded operation
- For manual mode operation (i.e. where manual intervention during the machine cycle is intended):
  - fully guarded operation
- Method of process observation:
  - use of windows in the process zone enclosure
  - use of CCTV monitoring
  - other
- Method intended to stop the cycle if an error observed:
  - Emergency Stop
  - Normal Stop

E.5.5 Basic description of robot (see ISO 10218)

- Swing range:
  - restricted space
  - maximum space
  - safeguarded space
- Method of limiting range of motion:
  - hardware control
  - software control
- Method of safeguarded space interlocking:
  - hardware control
  - software control
- Collision sensing:
  - hardware control
  - software control
- End position control:
  - hardware control
  - software control

E.5.6 Types of processed parts

- Type of geometry
  - plate
  - other
- Type of material

E.5.7 Part fixture

- Automatic location and clamping:
  - by hardware control
  - by software control
- Manual location and clamping
- Laser beam damage potential
  - due to reflective areas on the tooling
  - due to surface finish of the tooling

E.5.8 Material flow into the process zone

- Automated continuous flow of components
- Manual singe component
- Process zone component access:
  - sliding door
  - lift door
  - rolling door