

INTERNATIONAL REGULATIONS FOR SAFETY OF LASER PRODUCTS AND FOR SAFETY OF LASER PROCESSING MACHINES - AN OVERVIEW -

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Introduction

Laser products or laser processing machines are complex systems which can cause a number of different hazards. Beneath the laser radiation as the primary hazard, several so-called secondary hazards can emanate from the system. Secondary hazards result both from the design of the system such as hazards by electricity, laser gases, optics and from hazards related to the application such as fume and gas emissions, fire hazards and secondary radiation (e.g. ultraviolet radiation).

To ensure a safe design and a safe use of laser products or laser processing machines, a number of regulations have to be complied with.

Generally, regulations can be assigned to

- directives (European directives),
- national laws and provisions,
- technical standards.

It shall be noted, that technical standards –if adhered to- shall facilitate to achieve compliance with safety requirements. But the required safety can also be achieved by other means; however, this asks for a comprehensive verification and documentation.

Typically, regulations are addressed to the following two areas:

A) – protection of humans against danger coefficients, e.g. by physical or chemical agents, protection of environment and neighbourhood

or

B) minimum safety requirements on a product

Ad A) Due to the manifold applications of lasers and the complex hazards, a number of different danger coefficients have to be considered within the risk assessment. In consequence, a number of regulations from different areas apply, such as:

- regulations on artificial optical radiation and especially laser radiation
- regulations on hazardous substances
- regulations on noise
- regulations on electromagnetic fields

Furthermore, a number of related regulations have to be considered, e.g.

- regulations on environmental protection
- regulations for handling of waste

Ad B) The safety requirements on products or machinery are defined in a number of legal regulations and technical standards. They range from general safety aspects of a product to special issues, such as design of safety related parts of the product or machine.

A further distinction of the regulations is the addressee or target group. It is accomplished that the standards are addressed either predominantly to the manufacturer or the user of the products.

Generally, technical standards concerning machinery safety are hierarchically subdivided into three categories:

- Type A standards (basic standards), give basic concepts, principles for design, and general aspects that can be applied to machinery
- Type B standards (generic standards) deal with one or more safety aspects or one or more types of safety-related devices that can be used across a wide range of machinery.
B1: Safety aspects
B2: Safety-related devices
- Type C standards (machinery safety standard) deal with detailed safety requirements for a particular machine or group of machines), e.g. ISO 11553-2: "Safety of machinery – laser processing machines – Part 2: Safety requirements for hand-held laser processing devices".

The understanding of the systematic structure of the regulations and the areas, relevant for the safety of laser products and laser processing machines decisively facilitates the work for laser manufacturers and users.

However, it has to be kept in mind, that the field of regulations is not a static one. Current scientific findings as well as new concepts on the safety cause a continuous review of regulations. In consequence, this obliges the manufacturer or user to keep pace with these developments.

EU Legislation

The concept of the dual areas is reflected in the European legislation with regard to product safety and occupational safety and health. The Council of the European Union lays down the regulatory framework for the safe use of a technology and for the protection of employees in Europe.

Two major articles are the basis for a number of directives, provisions and technical standards.

- Article 95* is aimed to harmonize the European Single Market and provides minimum safety requirements on a product.
- Article 137* is aimed to implement improvements of the working environment to protect workers' health and safety.

*acc. EU Treaty of Amsterdam, 1999 entered into force

The requirements are addressed on the one hand to manufacturers and on the other hand to users and responsible persons for working environment.

The articles are substantiated by a number of directives and technical specifications. In the following, some examples are given with regard to laser processing machines:

Article 95

- machinery directive (2006/42 EC, 29.12.09->)
- low voltage directive (2006/95/EC)
- directive on electromagnetic compatibility (2004/108/EC)

Article 137

- artificial optical radiation directive (2006/25/EC)
- chemical agents directive (98/24/EC)
- noise directive (2003/10/EC)
- electromagnetic fields directive (2004/40/EC)

Especially directives related to article 95 provide an important basis for manufacturers of laser processing machines, since minimum requirements for safety of machinery are defined. By this, competitive obstructions in the international trade by differing safety requirements can be minimized.

The compliance with article 137 and the subordinated directives provides the basis for the safe use of laser processing machines and the protection of workers during work.

Special emphasis shall be put on the directive on artificial optical radiation, which has been entered into force in spring 2006 and now has to be transferred into national legislation. The directive distinguishes between sources emitting laser radiation and those emitting non-coherent radiation.

This distinction is also reflected in standards, since non-coherent LEDs are now covered by the IEC 62471 "Photobiological safety of lamps and lamp systems" but not by the IEC 60825-1.

According to the "new approach", the directives only define general basic requirements. Detailed techni-

cal specifications are given in the harmonized standards.

With the CE-declaration, the manufacturer of a product or machine expresses, that he complies with the requirements given in all relevant regulations.

It shall be remarked, that the participation of laser manufactures and users in standardizing working groups is important in order to define safety requirements, which both cover the state-of-the-art and are useful in practice.

International Standards

On an international level, two different standardizing bodies exist, which both elaborate international standards on laser safety:

- International Electrotechnical Committee, IEC, and with regard to Europe the European Committee for Electrotechnical Standardization, CENELEC,
- International Standardization Organization, ISO, and with regard to Europe the European Committee for Standardization, CEN.

The respective national standardizing bodies (e.g. DIN or UNI) are represented in the international committees by delegates and experts, respectively.

In the following, relevant standards on laser safety (manufacturing and use of laser products), and on safety of laser processing machines, which are elaborated by IEC or ISO, are listed.

Field of IEC

The series of standards IEC 60825 "Safety of laser products", which are elaborated and reviewed under secretary of IEC, is the international basis of technical regulations for the safe design and use of laser products. The series now covers 14 parts containing standards and technical reports. Beneath general safety requirements, described in IEC 60825-1, the individual standards are addressed to special laser products or applications and to manufacturers and users.

General safety requirements for special laser products are given e.g. in IEC 60825-2 "Safety of laser products - Part 2: Safety of optical fibre communication systems (OFCS)". The IEC also elaborated safety standards for other groups of laser products, such as medical electrical devices, given in the IEC 60601-2-22, "Medical electrical equipment - Part 2-22: Particular requirements for the safety and essential performance of surgical, therapeutic and diagnostic laser equipment" or lasers for laser shows and outdoor applications IEC/TR 60825-3 Ed. 2.0 "Safety of laser products - Part 3: Guidance for laser displays and shows".

Beneath the laser safety standards, the IEC is responsible for a multitude of standards dealing with electrical equipment (of machines) and electrical aspects, e.g.:

- IEC 60204-1 “Safety of machinery – Electrical equipment of machines – Part 1: General requirements”;
- IEC 62061 “Safety of machinery – Functional safety of safety-related electrical, electronic and programmable electronic control systems”;
- IEC 6100-4 series “Electromagnetic compatibility (EMC)”.

Field of ISO

ISO standards cover a number of CEN standards, (or former CEN standards) written under the European directives, such as the machinery directive. Many of these CEN standards have been transferred on the ISO level by now.

Examples for general safety requirements on machinery are the so called type A –standards, e.g. the ISO 12100-1 “Safety of machinery – Basic concepts, general principles for design - Part 1: Basic terminology, methodology”.

With regard to laser safety, the EN 12626 „Safety of machinery, laser processing machines” was one of the most relevant laser machinery safety standards. In the meantime, the norm has been transferred to international level and has been replaced by the ISO 11553-1.

When designing a complex laser processing machine, a multitude of type B standards are applicable. Typical standards held by the ISO are a.o.:

- ISO 13849-1 “Safety of machinery - Safety-related parts of control systems - Part 1: General principles for design”,
- ISO 13850 Safety of machinery- Emergency stop- Principles for design”,
- ISO 11201 Acoustics - Noise emitted by machinery and equipment – Measurement of emission sound pressure levels at a work stations...”

Standards with a so-called “assumption of conformity” facilitate to declare the conformity (CE) of a product for a manufacturer, if the manufacturer complies with the requirements given in the respective standards.

Cooperation between international standardizing bodies IEC and ISO using the example of laser safety

IEC standards related to laser safety are elaborated and reviewed in the technical committee IEC TC 76 “Optical radiation safety and laser equipment”. The technical committee is further subdivided into 10 working groups, responsible for different laser safety issues and standards, respectively.

Within the ISO, the ISO/TC 172 “Optics and optical instruments“ the subcommittee SC 9 “Electrooptical Systems“ and here the working group 3 “Safety” is responsible for laser safety standards.

To coordinate the work with regard to laser safety between the two standardizing bodies IEC and ISO, a joint working group (JWG) has been established. Members of the JWG 10 are experts of IEC/TC76/WG10 and ISO/TC172/SC9 WG3.

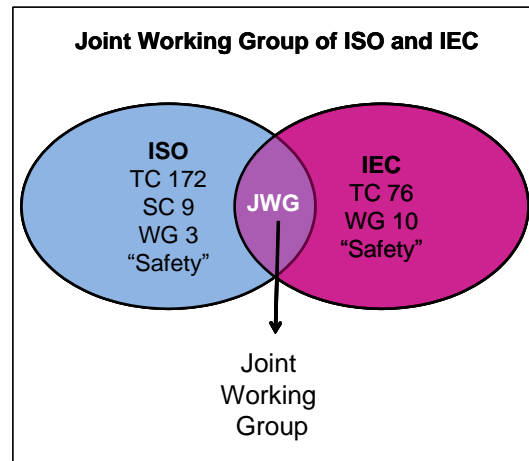


Figure 1: Collaboration of IEC and ISO with regard to laser safety

Steps of developing an international standard with regard to safety of laser processing machines

If new standards shall be elaborated, the following development steps have to be carried out (in simplified terms).

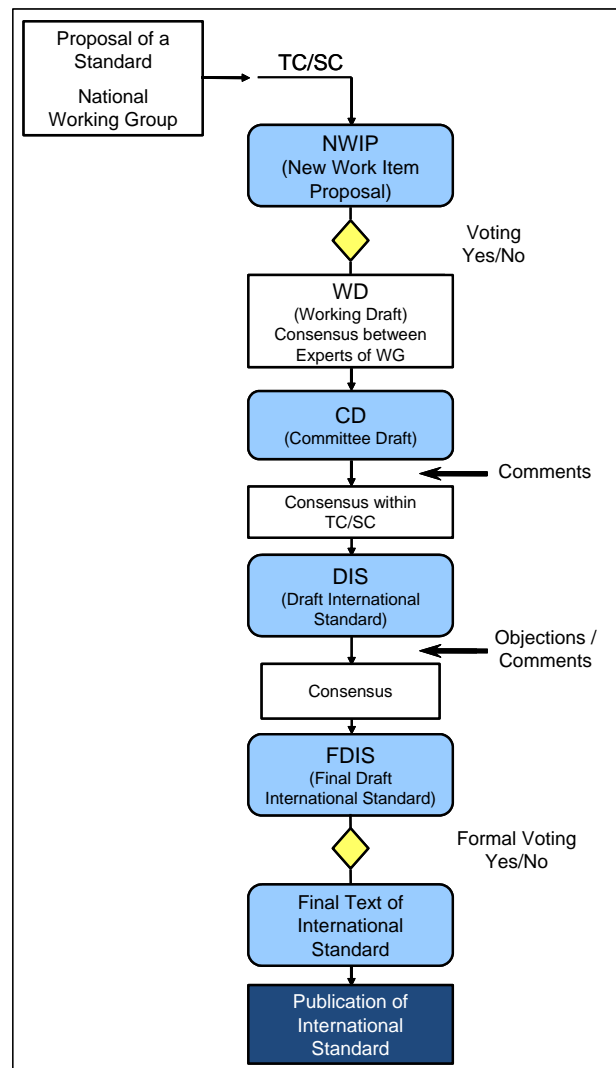


Figure 2: Steps of developing an international standard

The first step is the presentation of a new work item proposal (NWIP), followed by a voting of the member countries (P-member). If the result of the voting is positive and a sufficient number of P-members undertake to contribute actively, the accepted new work item proposal can be further discussed in the respective working group as a working draft (WD). The consensus committee draft (CD) then is disseminated to the TC/SCs* and the responsible national standardizing groups for comments. Consensus of all comments leads to the draft international standard (DIS) which subsequently is published in all member countries to enable comments and objections (from everyone). After consensus and incorporation of all comments, the standard reaches the step of a final draft international standard (F-DIS). Here, the voting is limited to consent or rejection (editorial changes are possible). In case of a positive voting, the F-DIS is published as an international standard.

Standards, developed under the terms (provisions) of a European directive, e.g. machinery directive, have to be evaluated by a CEN consultant (gen. at DIS status) with regard to their compliance to the European directives or basic standards; DIS´ being not in compliance are rejected.

The normal period for revision of a standard is 5 years.

*[WG: Working Group, JWG: Joint Working Group, SC: Sub-Committee, TC: Technical Committee]

Approach to safety of laser processing machines

Safety starts with the layout and the design of a laser processing machine, influences the commissioning and decisively determines the efficiency of the operation including maintenance and service.

The 3-step procedure given in the type A standard **ISO 12100-1** calls foremost for an inherently safe design to minimize risks associated with the use of a machine or a laser processing machine, respectively.

Protective measures taken by the designer
Step 1: Inherently safe design measures
Step 2: Safeguarding and complimentary protective measures
Step 3: Information for use - at the machine - in the instruction handbook
Protective measures taken by the user
- Organization
- Provision of additional safeguards
- Personal protective equipment

Figure 3: 3-Step Procedure given in ISO 12100-1

According to this procedure, peripheral laser screens are only additional safeguarding. Personal protective equipment (PPE) such as laser protective eyewear or protective clothing is an ancillary measure and should only be temporarily used.

The method to carry out risk assessment and risk reduction is described in **ISO 14121-1** "Safety of machinery - Risk assessment - Part 1: Principles".

Laser processing machines, usually used in industry for material processing, are subject to the provisions of the type B standard **ISO 11553-1** "Safety of machinery - Laser processing machines- Part 1: General safety requirements". The standard applicable for functionally complete systems takes up the procedures given in ISO 12100-1 and ISO 14121-1. Beneath hazard analysis and risk assessment, the standard describes safety measures against laser radiation and further hazards.

Predominantly, an inherently safe machine is required, which is expressed by following wording:

"For laser processing machines operating in locations with unrestricted and uncontrolled access the possibility that people be exposed to levels of laser radiation exceeding the accessible emission limit (AEL) for Class 1 shall be eliminated during production" (in fact should be meant: the accessible radiation should not exceed the maximum permissible exposure, MPE).

For laser processing machines operating in locations with restricted access (a typical production hall, personnel untrained in laser safety have access to), or controlled access, the possibility that people be exposed to levels of laser radiation exceeding the maximum permissible exposure (MPE) at the ocular exposure limits for 3·10⁴ seconds exposure shall be eliminated during production. Unauthorized access to danger zones (this is the laser area, personnel authorised and trained in laser safety have access to) shall be prevented by engineering measures.

However, with lower safety ranking, the standard also permits administrative control measures and personal protective equipment to reduce risks by laser radiation.

The standard defines requirements on different safety related devices, such as safety controls and safety functions, interlocks and guard control. In addition, the ISO 11553-1 describes with which information on residual risks the manufacturer has to provide the user.

The type C standard **ISO 11553-2** "Safety of machinery – Laser processing machines - Part 2: Safety requirements for hand-held laser processing devices" (HLD) is addressed to a specific group of laser devices, which are hand-held or hand-operated.- The standard deals with the specific hazards associated with the use of HLD (e.g. outdoor applications, working at heights, open process zone) and defines control measures.

Currently, the series is going to be complemented by a part 3. The draft international standard

ISO 11553-3 "Safety requirements for noise reduction and noise measurement methods" deals with noise reduction for laser processing machines and hand-held laser processing devices.

With regard to laser safety, the series of IEC 60825 standards are the basic instruments for the designer or the manufacturer of a laser product.

IEC 60825-1 contains the laser classification scheme and instructions to classify a laser product. Main parts of the standard are dealing with engineering specifications and labelling of laser products.

The last substantial changes regarding the laser classification concept took place in 2001 (A2). From January 2004, all new laser products must be classified into the classes 1, 1M, 2, 2M, 3R, 3B and 4. With the directive 2006/25/EC and standards on photobiological safety of lamps, LEDs are no longer within the scope of IEC 60825-1. Currently, the labelling is one of the areas for which alterations are discussed.

In industry, for material processing often high-power laser products classified as laser class 4 are used. However in most cases, these dangerous lasers are integral part of a machine. If the laser is fully enclosed by the machine housing, which means that the accessible laser emission is below the AEL for Class 1, the laser processing machine can be assigned to be laser-safe. These so-called "embedded laser products" can either be classified as class 1 laser products or operated "as safe as a class 1 laser product" in terms of a safe machine. To clarify this difference, some explanations are given below:

► Classification into class 1 according to IEC 60825-1 is based on strict requirements, which have to be fulfilled:

- Prevention of human access (above AEL class 1),
- Provision for foreseeable fault conditions,
- Coping of single-fault conditions.

In consequence, a class 1 laser product must be inherently safe and the user does not need to know that a laser product is integral part of the machine; e.g.

- with regard to laser guards, this implies that in fault conditions (exposure of the guard) the laser radiation is automatically isolated,
- with regard to human access (walk in access) this implies that the access is automatically detected followed by an instantaneous isolation of laser radiation.

► The machinery directive and the harmonized standards on safety of machinery require, that no hazardous laser radiation is emitted from the machine. In comparison to class 1 requirements, administrative procedures implemented by the user can also be included in the safety concept of a machine; e.g.

- with regard to laser guards, inspection intervals by operators can be used, to terminate the time of the laser resistance of passive laser guards.

As can be concluded, for every specific laser product or laser processing machine an appropriate safety concept must be drawn up (with respect to the laser classification scheme). An optimal compromise must be achieved between risk reduction according to the 3-step procedure and economic or practical demands.

ISO 60825-4 "Safety of laser products - Part 4: Laser guards" defines requirements on laser guards and testing procedures and therefore is one of the most relevant standards for designers and manufacturers of laser products and laser processing machines.

In comparison to EN 12254 "Screens for laser working places - Safety requirements and testing" which mainly applies to laser screens, the IEC 60825-4 applies both to passive and active guards. Active guards are equipped with detectors providing an automatic isolation of the laser radiation, when exposed. Also, IEC 60825-4 is not limited with regard to the maximum laser irradiance.

Two important parameters are defined in the IEC 60825-4.

► The foreseeable exposure limit (FEL) is the maximum level of exposure at the inner surface of the guard, which can occur under normal conditions and foreseeable fault conditions. It is remarked that especially the fault conditions (by a direct or specular reflected beam) decisively determine the requirements on the laser guard.

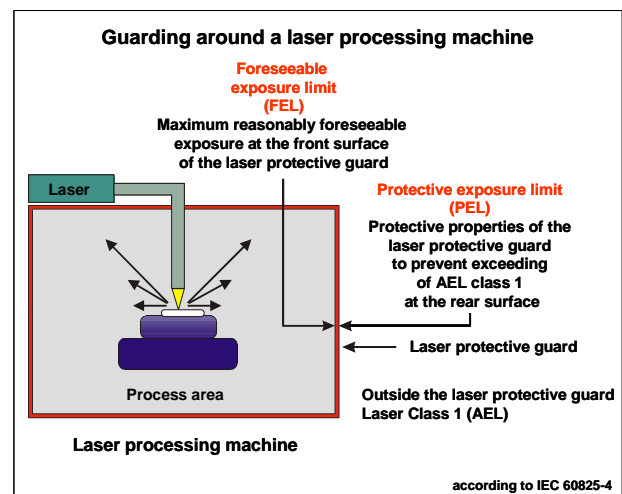


Figure 4: Foreseeable exposure limit (FEL) according to IEC 60825-1

► The protective exposure limit (PEL) is the maximum level of exposure that a specific guard (single or multi layer guard) can withstand so that the AEL of class 1 is not exceeded outside the guard. The PEL is valid only for the applied laser parameters and the specific exposure duration.

For a safe laser guard, the PEL must be higher than the FEL for a given exposure duration.

The exposure duration of passive guards depends on the surveillance of the laser guard; the so-called "inspection interval". This is the time an operator needs to identify the existence of a fault condition

causing a laser exposure of the inner surface of the guard.

The classification is as follows:

T1: 30000s inspection interval (e.g. automated machine)

T2: 100s inspection interval (short-cycle operation with intermittent inspection)

T3: 10s inspection time (continuous surveillance by an operator at the machine).

Due to the increasing number of high-power lasers, active laser guards become more relevant. High power lasers providing an excellent beam parameter product and being equipped with optics of focal length >500mm are able to cause very high irradiances at the laser guard in fault conditions (up to 10^{10} W/m²). The corresponding high requirements on the PEL often can be met only by active laser guards, which are integrated in the safety control of the laser machine.

In the informative annexes, the standard provides useful information on the laser resistance of a number of materials and exposure conditions.

The technical reports IEC/TR°60825-5 and IEC/TR 60825-14 provide additional useful information for manufacturers and users of laser products.

IEC/TR°60825-5 -Ed. 2.0 "Safety of laser products – Part 5: Manufacturer's checklist for IEC 60825-1" is designed as a list of questions which can be answered either with "yes" or "no" and has to be used in conjunction with the IEC°60825-1. It can help the manufacturers to achieve that each new or modified laser product complies with the requirements of IEC 60825-1.

The technical report **IEC/TR 60825-14 -Ed. 1.0** "Safety of laser products - Part 14: A user's guide" provides guidance on best practice in the safe use of laser products that conform to IEC 60825-1. It informs laser users about the general principles of safety management, about hazard analyses and risk assessment and about how to set up and maintain appropriate control measures.

For embedded laser products with housing (typically machines), in most cases the access of humans to hazardous laser radiation has to be prevented by the use of safety controls or safety related parts of controls (SRP/CS), such as interlocks at all openings, control of the laser shutter, etc.

Therefore, beneath the above mentioned standards directly related to laser safety, the manufacturer must comply with a number of further standards, e.g. concerning electrical equipment of machines, safety controls and SRP/CS, in order to design a safe laser processing machine.

Basic requirements on SRP/CS emanate from IEC 60825-1 and ISO 11553-1.

These are:

- Coping with single-fault conditions
- Fail-safe or redundant design of SRP/CS

These requirements typically result in control categories higher or at least cat. 3 or corresponding "required Performance Level" $PL_{r>c}$ according to ISO 13849-1. This requirement is already considered in terms of a note in ISO 11553-1.

In the following, requirements defined by the standards

- IEC 60204-1 "Safety of machinery — Part 1: General requirement"
 - IEC 13849-1 "Safety of machinery - Safety-related parts of control systems - Part 1: General principles for design"
- are discussed as examples.

IEC 60204-1 describes a number of requirements on specific safety functions of a control. These are (among others):

- Safety related stop-function, induced by a safety device
- Prevention of unexpected start-up (and acc. ISO 14118)
- Start/Stop-Control: controlled start
- Emergency Stop (and acc. ISO 13850)
- Operation control device with automatic reset facility

With regard to laser safety, the safety related stop function initiated by a safety device (e.g. an interlock at a maintenance opening) must isolate the laser beam to prevent it from entering the beam delivery system. This can either be realized by a safety shutter or by deactivation of the laser process (pump diodes) which is more convenient e.g. for fibre laser.

The start of the laser processing machine must only be possible, if all safety functions or safety measures are in the right (safe) position and ready for operation. An unintended automatic emission of laser radiation must be prevented by the safety control (interlocking).

This also includes the control of different operating modes (normal operation, maintenance, service) and the authorization of the operators (trained in laser safety or not) e.g. by key switches.

The laser processing machine must be equipped with an emergency stop control to terminate laser emission, stop all moving parts of the handling system or the machine, respectively, switch off the power supply, and discharge all stored energy.

Conformance with the above mentioned standards has to be verified by the manufacturer by visual inspection and functional tests.

The standard IEC 13849-1 defines safety requirements and provides guidance for the design principles and the integration of safety related parts of controls (SRP/CS), including software. For this purpose, parameters such as the Performance Level are established, which are required to execute a specific safety function by SRP/CS.

Therewith, for manufacturers of laser processing machines the standard poses as basis for the design of the complete laser safety control including all SRP/CS (including sensor, programmable logic control and actuator).

Currently, the type B1 standard ISO 13849-1 is going to replace the European harmonized standard EN 954-1. However, the transition period of EN 954-1 with a possible three years prolongation up to December 2012 is under discussion.

The lack of EN 954-1 is that the concept of failure probability is not included. This means, that an essential requirement of machine safety, the system failure, is not considered. As the sector standard IEC 62061 (defining Safety Integrity Level - SIL), the ISO 13849-1 introduces a new risk diagram taking into account probabilistic failure and system performance. The control categories, given in EN 954-1 are still explained as system structure but become less important concerning reliability aspects.

However, due to problems especially with regard to the availability of data for determining the Performance level, the procedures given in EN 954 can still be applied advantageously.

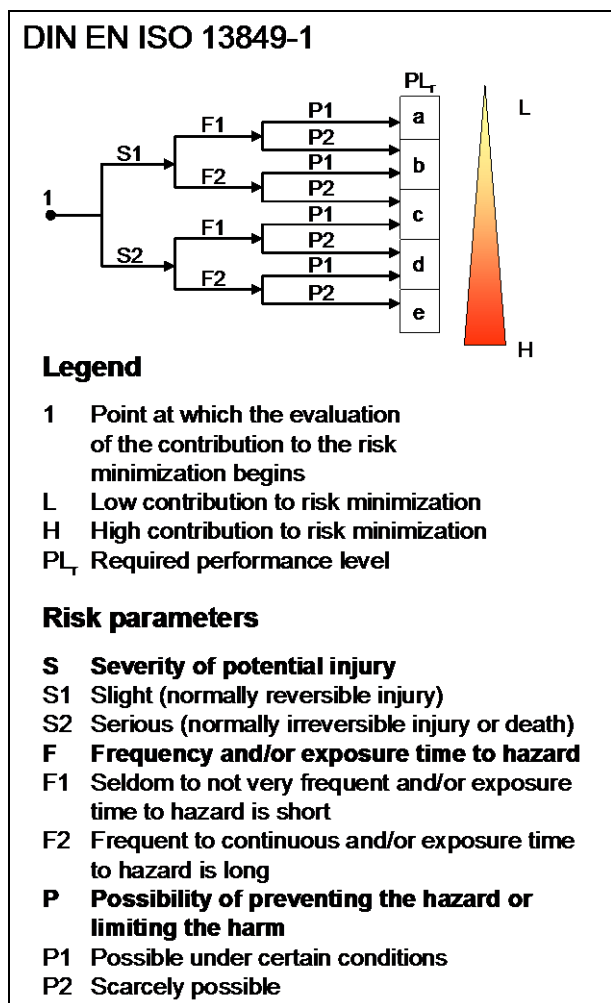


Figure 5: Risk graph for the determination of the required performance level (PL_r) for each safety function according to ISO 13849-1

To complete the overview on regulations on laser safety, we have to go back to ISO 12100-1 where we started.

Personal protective equipment is one of the lower-ranking control measures to reduce the risks of laser radiation and which has to be provided by the laser user (employer).

In Europe, two standards, the **EN 207** "Personal eye-protection – Filters and eye-protection against laser radiation (Laser eye-protectors)" and the **EN 208** "Personal eye-protection – Eye-protectors for adjustment work on lasers and laser systems (laser adjustment eye-protectors)" exist. Both were elaborated by the Technical Committee CEN/TC 85 under the mandate of the EC and the provisions of Article 95 and directive 89/686/EEC "Personal Protective Equipment" (consolidated 96/58/EEC), respectively.

The directive distinguishes three categories of PPE with regard to the risks or the requirements on the specific type of PPE. Laser eye-protectors (laser protective eyewear) can be assigned to category II (mean risks).

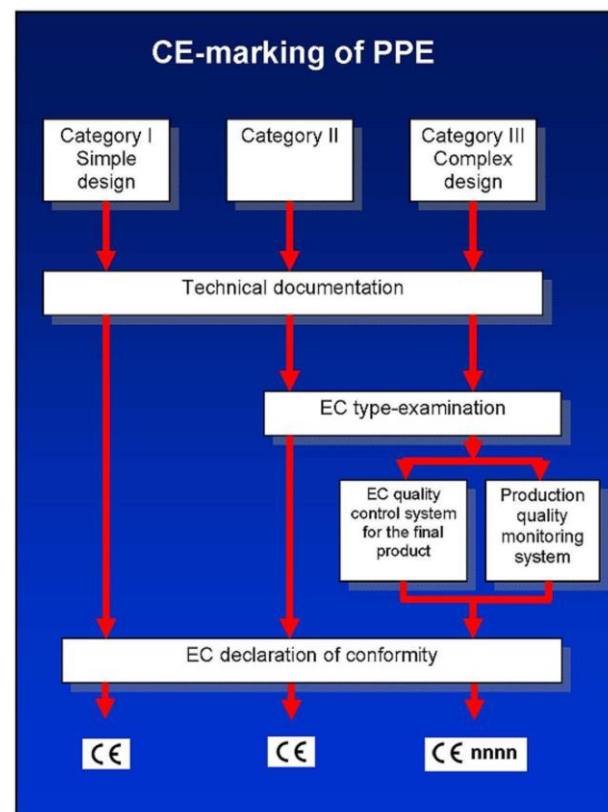


Figure 6: Requirements for EC-declaration of PPE

Apart from the technical documentation, an EC type-examination by an independent test-laboratory has to be carried out (one-time). In addition, some large manufacturers voluntarily carry out monitoring tests to ensure a constant product quality of the laser protective eyewear.

Whereas EN 208 is a special standard on eye-protectors for adjustment or alignment work on lasers (visible radiation only), the CE 207 defines

requirements on laser protective eyewear, which shall prevent the user from injuries during common laser applications in normal and fault conditions.

The EN 207 continuously has to be adapted to the development of the laser technology and the upcoming risks. With the test-condition "M" (for mode-locked lasers), it covers protection against ultrashort-pulsed laser radiation.

Currently, the test-period during which the laser protective eyewear must not lose their protective properties is under discussion (may be shortened to 5s).

It has to be remarked, that whereas for laser protective eyewear, requirements are defined in regulations and standards, the field of protective laser clothing still shows deficits. It remains to be seen, when scientific findings will be transferred to standards.

Conclusions

The international and national regulations, provisions and technical standards with regard to laser safety are very complex.

However, the systematic approach of the European legislation to structure all directives and harmonized standards helps the laser manufacturer to compile relevant requirements and information. The transformation of European standards to international standards also improves the situation.

Designers and manufacturers of ready-to-use laser processing machines must comply with a number of standards on machine safety also relevant for laser safety (to declare conformity). Especially requirements on the control of the laser radiation have to be met; they are defined in standards dealing with functional safety, safety controls and safety related parts of controls (SRP/CS), in order to prevent human access to laser radiation above the maximum permissible exposure (MPE).

Generally, regulations are based on both scientific knowledge and basic values of a community. Therefore, regulations are subject to continuous development and changes which is also reflected in regulations and standards regarding laser safety.

Existing standards dealing with laser safety provide substantial information on how to design a safe laser product or laser processing machine. However, they must cope with new developments and applications such as LED, SLD, hand-held laser processing devices or high-power laser remote welding. This applies also to personal protective equipment (PPE) against laser radiation and especially to protective clothing, for which requirements should be defined and test methods be developed.

List of cited standards and directives

IEC 60204-1	Safety of machinery – Electrical equipment of machines – Part 1: General requirements
IEC 60601-2-22	Medical electrical equipment - Part 2-22: Particular requirements for the safety and essential performance of surgical, therapeutic and diagnostic laser equipment
IEC 60825-1	Safety of laser products - Part 1: Equipment classification and requirements
IEC 60825-2	Safety of laser products - Part 2: Safety of optical fibre communication systems (OFCS)
IEC/TR 60825-3	Safety of laser products - Part 3: Guidance for laser displays and shows (Ed. 2.0)
ISO 60825-4	Safety of laser products - Part 4: Laser guards
IEC/TR°60825-5	Safety of laser products – Part 5: Manufacturer's checklist for IEC 60825-1 (Ed. 2.0)
IEC/TR 60825-14	Safety of laser products - Part 14: A user's guide (Ed. 1.0)
IEC 6100-4	Electromagnetic compatibility (EMC)
IEC 62061	Safety of machinery – Functional safety of safety-related electrical, electronic and programmable electronic control systems
IEC 62471	Photobiological safety of lamps and lamp systems
ISO 11201	Acoustics - Noise emitted by machinery and equipment – Measurement of emission sound pressure levels at a work stations
ISO 11553-1	Safety of machinery - Laser processing machines- Part 1: General safety requirements
ISO 11553-2	Safety of machinery – laser processing machines – Part 2: Safety requirements for hand-held laser processing devices
ISO°11553-3	Safety requirements for noise reduction and noise measurement methods
ISO 12100-1	Safety of machinery – Basic concepts, general principles for design - Part 1: Basic terminology, methodology
ISO 13850	Safety of machinery - Emergency stop- Principles for design
ISO 13849-1	Safety of machinery - Safety-related parts of control systems - Part 1: General principles for design
ISO 14118	Safety of machinery - Prevention of unexpected start-up
ISO 14121-1	Safety of machinery - Risk assessment - Part 1: Principles

EN 207	Personal eye-protection – Filters and eye-protection against laser radiation (Laser eye-protectors)
EN 208	Personal eye-protection – Eye-protectors for adjustment work on lasers and laser systems (laser adjustment eye-protectors)
EN 954-1	Safety of machinery - Safety-related parts of control systems - Part 1: General principles for design
EN 12254	Screens for laser working places - Safety requirements and testing
EN 12626	Safety of machinery, laser processing machines

89/686/EEC	Personal Protective Equipment Directive
(98/24/EC)	Chemical Agents directive
(2003/10/EC)	Noise directive
(2004/40/EC)	Electromagnetic fields directive
(2004/108/EC)	Directive on electromagnetic compatibility
(2006/25/EC)	Artificial optical radiation directive
(2006/42 EC)	Machinery directive
(2006/95/EC)	Low voltage directive