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Interested committees:

Title: BS EN 62046 Safety of machinery - Application of protective equipment to detect the presence of persons

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Introduction

This draft standard is based on national and international discussions. Your comments on this draft are invited and will assist in the preparation of the consequent standard.

For international standards, comments will be reviewed by the relevant UK national committee before sending the consensus UK vote and comments to the international committee, which will then decide appropriate action. If the international standard is approved, it is usual for the text to be published as a British Standard.

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Template for comments and secretariat observations

Date: xx/xx/20xx	Document: ISO/DIS xxxx
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1	2	(3)	4	5	(6)	7
MB	Clause No./ Subclause No./Annex (e.g. 3.1)	Paragraph/Figure/ Table/Note	Type of comment	Commend (justification for change) by the MB	Proposed change by the MB	Secretariat observations on each comment submitted
	3.1	Definition 1	ed	Definition is ambiguous and needs clarifying.	Amend to read '...so that the mains connector to which no connection...'	
	6.4	Paragraph 2	te	The use of the UV photometer as an alternative cannot be supported as serious problems have been encountered in its use in the UK.	Delete reference to UV photometer.	



44/997/CD

COMMITTEE DRAFT (CD)

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SECRETARIAT:

United Kingdom

SECRETARY:

Mrs Nyomee Hla-Shwe Tun

OF INTEREST TO THE FOLLOWING COMMITTEES:

PROPOSED HORIZONTAL STANDARD:



Other TC/SCs are requested to indicate their interest, if any, in this CD to the secretary.

FUNCTIONS CONCERNED:

☐ EMC

☐ ENVIRONMENT

☐ QUALITY ASSURANCE

☒ SAFETY

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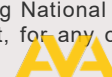
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TITLE:

Safety of machinery - Application of protective equipment to detect the presence of persons

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INTERNATIONAL ELECTROTECHNICAL COMMISSION

SAFETY OF MACHINERY – APPLICATION OF PROTECTIVE EQUIPMENT TO DETECT THE PRESENCE OF PERSONS

FOREWORD

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- International Standard IEC 62046 has been prepared by IEC technical committee 44: Safety of machinery – Electrotechnical aspects.
- This bilingual version (2018-11) corresponds to the monolingual English version, published in 2018-03.
- This first edition cancels and replaces IEC TS 62046, published in 2008. This edition constitutes a technical revision.
- This edition includes the following significant technical changes with respect to IEC TS 62046:2008:
- a) additional annexes relating to muting and vision systems,
 - b) muting requirements have been updated,
 - c) blanking requirements have been updated,
 - d) addition of IEC 61496 series Types and capping the Safety Integrity level according to IEC 62061 and performance levels according to ISO 13849-1,
 - e) alignment to changes in IEC 61496 series.

293 The text of this International Standard is based on the following documents:

FDIS	Report on voting
44/803/FDIS	44/812/RVD

294
295 Full information on the voting for the approval of this International Standard can be found in the
296 report on voting indicated in the above table.

297 The French version of this document has not been voted upon.

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

299 The committee has decided that the contents of this document will remain unchanged until the
300 stability date indicated on the IEC website under "<http://webstore.iec.ch>" in the data related to
301 the specific document. At this date, the document will be

- 302 • reconfirmed,
303 • withdrawn,
304 • replaced by a revised edition, or
305 • amended.

306

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307

308

309

INTRODUCTION

310 This International Standard provides requirements and information on the application of
311 protective equipment, which employs (a) sensing device(s) to detect person(s), in order to
312 reduce or minimize a risk from hazardous parts of machinery, without providing a physical
313 barrier.

314 The objective of this document is to assist standards writing committees responsible for
315 developing machine standards (type-C Standards), machine designers, manufacturers and
316 refurbishers, machine safety certification organizations, workplace authorities and others on
317 the proper application of protective equipment to machinery.

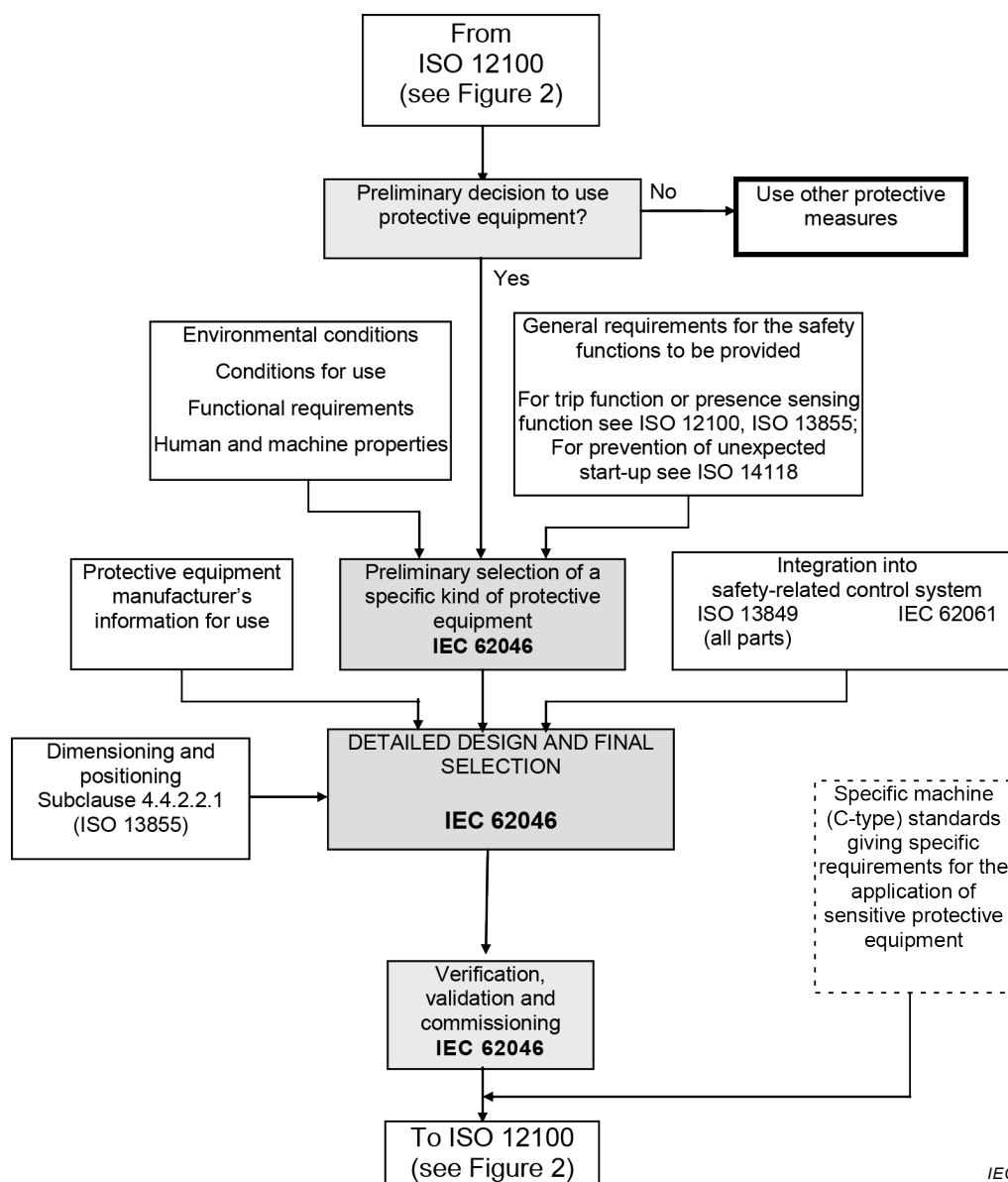
318 Figure 1 and show the general context and the intended use of this standard.

319 Clauses 1 to 5, 7 and 8 of this document apply to all protective equipment included in the scope,
320 Clause 6 contains guidance for the application of specific kinds of protective equipment.

321 The principles of this document can be useful in the application of devices using other detection
322 technologies but this document does not give specific requirements for devices other than those
323 listed above.

324 This document considers devices standardised in the IEC 61496 series and the ISO 13856
325 series. Unless a product-specific safety-related standard for devices using other sensing
326 technologies is published, their suitability as the sole means of protection from machine hazards
327 is unknown. Great care should be taken in the selection and use of devices for which there is
328 no product-specific safety-related standard because their behaviour, particularly under fault
329 conditions, is not known to be sufficiently predictable.

330 An SIL (Safety Integrity Level see IEC 62061 or IEC 61508) or PL (Performance Level, see
331 ISO 13849-1) is not sufficient as an indication of a device's suitability for use as a safeguard.
332 Suitability depends on appropriate sensing means, environmental conditions especially those
333 that can affect the detection capability, behaviour under fault conditions, etc



IEC

Figure 1 – Relationship of this International Standard to other standards

(see also)

SAFETY OF MACHINERY – APPLICATION OF PROTECTIVE EQUIPMENT TO DETECT THE PRESENCE OF PERSONS

1 Scope

This International Standard specifies requirements for the selection, positioning, configuration and commissioning of protective equipment to detect the momentary or continued presence of persons in order to protect those persons from dangerous part(s) of machinery in industrial applications. This standard covers the application of electro-sensitive protective equipment (ESPE) specified in IEC 61496 (all parts) and pressure sensitive mats and floors specified in ISO 13856-1.

It takes into account the characteristics of the machinery, the protective equipment, the environment and human interaction by persons of 14 years and older.

This document includes informative annexes to provide guidance on the application of protective equipment to detect the presence of persons. These annexes contain examples to illustrate the principles of this standard. These examples are not intended to be the only solutions to a given application and are not intended to restrict innovation or advancement of technology. The examples are provided only as representative solutions to illustrate some of the concepts of integration of protective equipment, and have been simplified for clarity, so they may be incomplete.

It is intended that this document is used in conjunction with ISO 13855.

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements 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 62061:2021, *Safety of machinery - Functional safety of safety-related electrical, electronic and programmable electronic control systems*

ISO 12100:2010, *Safety of machinery – General principles for design – Risk assessment and risk reduction*

ISO 13849-1:2015 *Safety of machinery – Safety-related parts of control systems*

ISO 13855:2010, *Safety of machinery – Positioning of safeguards with respect to the approach speeds of parts of the human body*

3 Terms, definitions and abbreviated terms

3.1 Terms and definitions

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

ISO and IEC maintain terminological databases for use in standardization at the following addresses:

- IEC Electropedia: available at <http://www.electropedia.org/>
- ISO Online browsing platform: available at <http://www.iso.org/obp>

3.1.1**active opto-electronic protective device****AOPD**

device whose sensing function is performed by opto-electronic emitting and receiving elements detecting the interruption of optical radiations generated, within the device, by an opaque object present in the specified detection zone (or for a light beam device, on the axis of the light beam)

[SOURCE: IEC 61496-2:2020, 3.201]

3.1.2**active opto-electronic protective device responsive to diffuse reflection****AOPDDR**

device, whose sensing function is performed by opto-electronic emitting and receiving elements, that detects the diffuse reflection of optical radiations generated within the device by an object present in a detection zone specified in two dimensions

[SOURCE: IEC 61496-3:2018, 3.301]

3.1.3**blanking**

optional function that permits an object of a size greater than the detection capability of the ESPE to be located within the detection zone without causing an OFF-state of the OSSD(s)

Note 1 to entry: Blanked beams are monitored for continued interruption of light..

[SOURCE: IEC 61496-1:2020, 3.1, modified – Note 1 to entry has been modified, Note 2 to entry has been removed]

3.1.4**detection capability**

sensing function parameter limit specified by the supplier that will cause actuation of the protective equipment

[SOURCE: IEC 61496-1:2020, 3.3, modified – "electro-sensitive" has been removed before "protective equipment"]

3.1.5**detection zone**

zone within which a specified test piece will be detected by the electro-sensitive protective equipment (ESPE)

Note 1 to entry: ISO 13856-1 uses the term "effective sensing area" when describing pressure-sensitive mats and floors. In this document the terms "detection zone" and "effective sensing area" are used synonymously.

[SOURCE: IEC 61496-1:2020, 3.4, modified – Note 1 to entry has been added]

3.1.6**electro-sensitive protective equipment****ESPE**

assembly of devices and/or components working together for protective tripping or presence-sensing purposes and comprising as a minimum

- a sensing device;
- controlling/monitoring devices;
- output signal switching devices and/or a safety-related data interface

[SOURCE: IEC 61496-1:2020, 3.5, modified – (Notes 1 and 2 to entry have been removed)]

3.1.7**effective sensing area, <of a pressure-sensitive mat or floor>**

part of the top surface area of the sensor or a combination of sensors of the pressure-sensitive mat or pressure-sensitive floor within which a response to an actuating force will take place

Note 1 to entry: IEC 61496-1 uses the term "detection zone" when describing electro-sensitive protective equipment. In this document the terms "detection zone" and "effective sensing area" are used synonymously.

[SOURCE: ISO 13856-1:2013, 3.4, modified – Note 1 to entry has been modified]

3.1.8

external device monitoring

EDM

means by which the electro-sensitive protective equipment (ESPE) monitors the state of control devices which are external to the ESPE

[SOURCE: IEC 61496-1:2020, 3.6]

3.1.9

failure, <of equipment>

termination of the ability of an item to perform a required function

Note 1 to entry: After failure the item has a fault.

Note 2 to entry: "Failure" is an event, as distinguished from "fault", which is a state.

Note 3 to entry: This concept as defined does not apply to items consisting of software only.

Note 4 to entry: In practice, the terms fault and failure are often used synonymously

[SOURCE: IEC 60050-191:1990, 191-04-01]

3.1.10

failure to danger

failure which prevents or delays all output signal switching devices going to, and/or remaining in the OFF-state in response to a condition which, in normal operation, would result in their so doing

[SOURCE: IEC 61496-1:2020, 3.8]

3.1.11

fault

state of an item characterized by its inability to perform a required function, excluding the inability during preventive maintenance or other planned actions, or due to lack of external resources

Note 1 to entry: A fault is often the result of a failure of the item itself, but may exist without prior failure.

Note 2 to entry: In the field of machinery, the English term 'fault' is commonly used in accordance with the definition in IEC 191-05-01, whereas the French term "défaut" and the German term "fehler" are used rather than the term "panne" and "fehlzustand" that appear with this definition.

Note 3 to entry: In practice, the terms "fault" and "failure" (see 3.1.9) are often used synonymously.

[SOURCE: IEC 60050-191:1990, 191-05-01, modified – Notes 1, 2 and 3 to entry have been added]

3.1.12

final switching device

FSD

component of the machine's safety-related control system that interrupts the circuit to the machine primary control element (MPCE) when the output signal switching device (OSSD) goes to the OFF-state

[SOURCE: IEC 61496-1:2020, 3.10]

3.1.13

hazard

potential source of harm

Note 1 to entry: The word "hazard" is generally used in conjunction with other words defining its origin or the nature of the expected injury or damage to health: electrical shock hazard, crushing hazard, shearing hazard, toxic hazard, etc.

[SOURCE: ISO 12100:2010, 3.6, modified – Note 1 to entry has been modified, Notes 2 and 3 to entry have been removed]

3.1.14**hazardous situation**

circumstance in which a person is exposed to at least one hazard

Note 1 to entry: The exposure can result in harm immediately or over a period of time.

[SOURCE: ISO 12100:2010, 3.10]

3.1.15**hazard zone**

any space within and/or around machinery in which a person can be exposed to a hazard

Note 1 to entry: The hazard:

- either is permanently present during the intended use of the machine (motion of hazardous moving elements, electric arc during a welding phase); or
- can appear unexpectedly (unintended/unexpected start-up).

[SOURCE: ISO 12100, 3.11, modified – Note 1 to entry has been added]

3.1.16**integrator**

individual or group of individuals responsible for selecting, configuring, installing and/or interfacing the protective equipment to achieve the safeguarding identified by the risk assessment

3.1.17**light beam device**

AOPD comprising one or more emitting element(s) and corresponding receiving element(s), where a detection zone is not specified by the supplier

Note 1 to entry: An array of light beam devices is sometimes referred to as a light grid. Because this term is ambiguous (see Note 1 of 3.1.19) the use of the term "light grid" is not recommended.

[SOURCE: IEC 61496-2:2020, 3.204, modified – Note 1 to entry has been added]

3.1.18**light curtain**

active opto-electronic protective device (AOPD) comprising an integrated assembly of multiple emitting elements and receiving elements forming a detection zone with a detection capability specified by the AOPD supplier

Note 1 to entry: A light curtain with a large detection capability is sometimes referred to as a light grid.

[SOURCE: IEC 61496-2:2013, 3.205, modified – "one or more" has been replaced by "multiple", "emitting" has been added]

3.1.19**lock-out condition**

condition, initiated by a fault, preventing normal operation of the protective equipment which is automatically attained when all output signal switching devices (OSSD) and, where applicable, all final switching devices (FSD) are signaled to go to the OFF-state

Note 1 to entry: Resetting the ESPE from the lock-out condition is not possible until the fault have been remedied.

[SOURCE: IEC 61496-1:2012, 3.13, modified – "electro-sensitive protective equipment (ESPE)" has been replaced by "protective equipment which is automatically attained ", Note 1 to entry has been added]

[current 61496-1 definition

condition, initiated by a fault, preventing normal operation of the electro-sensitive protective equipment (ESPE)

Note 1 to entry: All output signal switching devices (OSSDs) and, where applicable, all secondary switching

devices (SSDs) are signalled to go to the OFF-state.

3.1.20

machine primary control element

MPCE

electrically powered element that directly controls the normal operation of a machine in such a way that it is the last element (in time) to function when machine operation is to be initiated or arrested

[SOURCE: IEC 61496-1:2012, 3.14, modified – Note 1 to entry has been removed]

3.1.21

minimum distance

S

calculated distance between the safeguard and the hazard zone necessary to prevent a person or part of a person reaching the hazard zone before the termination of the hazardous machine function

Note 1 to entry: Different minimum distances may be calculated for different conditions or approaches, but the greatest of these minimum distances is used for selecting the position of the safeguard.

[SOURCE: ISO 13855:2010, 3.1.9]

3.1.22

mute dependent override function

function that allows manual operation of the machine when the detection zone of the ESPE is interrupted to allow the evacuation of objects from the muting zone

Note 1 to entry: This function can be necessary in case of a fault in the muting sequence(s) or when a blockage occurs in the transport system or when an object is already present in front of the muting sensors at “power on”.

3.1.23

muting

temporary automatic suspension of a safety function by safety-related parts of the control system

Note 1 to entry: When muting is provided as part of the protective equipment and the protective equipment is muted, the OSSD(s) remain in the ‘ON’ state upon activation of the protective equipment sensing function and safety is maintained by other means.

[SOURCE: IEC 61496-1:2020, 3.16, modified – Note 1 to entry has been modified]

3.1.24

muting sensor

device used to initiate and/or terminate muting

3.1.25

OFF-state

state of the outputs of the protective equipment that signals the actuation of the sensing function

Note 1 to entry: For example, the output circuit is interrupted and disables the flow of current.

3.1.26

ON-state

state of the outputs of the protective equipment when the sensing function is not actuated

Note 1 to entry: For example, the output circuit is closed and enables the flow of current.

3.1.27

output signal switching device

OSSD

component of the protective equipment connected to the machine control system which, when the sensing device is actuated during normal operation, responds by going to the OFF-state

[SOURCE: IEC 61496-1:2020, 3.19 modified]

573 Note to entry: In this document the OSSD is considered as one functional block. It can be designed as a single channel or dual
574 channel structure, using relays or semiconductors as switching elements. It can also be a safe data transmission system designed
575 for peer-to-peer or multi-point bus transmission.

576

577 **3.1.28**
578 **overall system stopping performance**
579 **T**

580 time interval resulting from the sum of the protective equipment response time and the time to
581 the cessation of hazardous machine operation

582 [SOURCE: IEC 61496-1:2020, 3.20, modified – "electro-sensitive" has been removed before
583 "protective equipment" and Note 1 to entry has been added]

584 **3.1.29**
585 **periodic test**

586 technique which stimulates or simulates the input of the protective equipment sensing device(s)
587 to determine if the protective equipment OSSD(s) go to the OFF-state when required to do so

588 **3.1.30**
589 **protective equipment**

590 assembly of devices using non-contact (electro-sensitive) or contact (pressure sensitive)
591 sensing means for detection of the presence of person(s) or parts of person(s) for the purpose
592 of controlling hazards associated with machinery and comprising as a minimum:

- 593 – a sensing device,
- 594 – control and monitoring devices,
- 595 – output signal switching devices,

596 Note 1 to entry: The safety related control system associated with the protective equipment, or the protective
597 equipment itself, can include additional safety features such as secondary switching devices, muting function,
598 stopping performance monitoring, etc.

599 **3.1.31**
600 **presence sensing function**

601 detection of the presence of a person, or a part of a person, while in a hazardous zone to enable
602 prevention of hazardous situations such as unexpected/unintended start-up of the machine

603 **3.1.32**
604 **pressure-sensitive mat**

605 sensitive protective equipment comprising a sensor or sensors, a control unit and one or more
606 output signal switching devices which detects a person standing on it or who steps onto it and
607 where the effective sensing area is deformed locally when the sensor(s) is actuated

608 [SOURCE: ISO 13856-1:2013, 3.1]

609 **3.1.33**
610 **pressure-sensitive floor**

611 sensitive protective equipment comprising a sensor or sensors, a control unit and one or more
612 output signal switching devices which detects a person standing on it or who steps onto it and
613 where the effective sensing area is moved as a whole when the sensor(s) is actuated

614 [SOURCE: ISO 13856-1:2013, 3.2]

615 **3.1.34**
616 **protective measure**

617 measure intended to achieve risk reduction, implemented:

- 618 – by the designer (inherent safe design, safeguarding and complementary protective
619 measures, information for use) and
- 620 – by the user (organization: safe working procedures, supervision, permit-to-work systems,
621 additional safeguards; personal protective equipment; training)

622 [SOURCE: ISO 12100:2010, 3.19, modified – "safety measure" has been added]

3.1.35

reasonably foreseeable misuse

use of a machine in a way not intended by the manufacturer, but which can result from readily predictable human behaviour

[SOURCE: ISO/IEC Guide 51:2014, 3.7, modified – "product or system" has been changed to "machine", "supplier" has been changed to "manufacturer"]

3.1.36

reduced resolution

reduction of the designed detection capability in order to ensure that objects in the detection zone of a diameter smaller than the configured detection capability does not cause an OFF-state.

[SOURCE: IEC 61496-2:2020 A.11, modified]

3.1.37

response time, <of a protective equipment>

maximum time between the occurrence of the event leading to the actuation of the sensing device and the output signal switching device (OSSD) achieving the OFF-state

Note 1 to entry: For pressure-sensitive protective devices, the event leading to the actuation of the sensing device is the application of a force within the effective sensing area.

[SOURCE: IEC 61496-1:2020, 3.21, modified – the terms "of a protective equipment" have been added to the term defined, original Notes 1 to 3 to entry have been removed and a new Note 1 to entry has been added]

3.1.38

restart interlock

means of preventing automatic restarting of a machine after deactivation of the sensing device, after a change in mode of operation of the machine, and/or after a change in the means of start control of the machine

Note 1 to entry: Modes of operation include inch, single stroke, automatic. Means of start control include foot switch, two-hand control, and single or double actuation of an electro-sensitive protective equipment (ESPE) sensing device.

[SOURCE: IEC 61496-1:2020, 3.22 modified]

3.1.39

risk

combination of the probability of occurrence of harm and the severity of that harm

[SOURCE: ISO 12100:2010, 3.12]

3.1.40

risk assessment

overall process comprising a risk analysis and a risk evaluation

[SOURCE: ISO 12100:2010, 3.17]

3.1.41

safety-related control system

SCS

part of a control system which respond(s) to input signals and generate(s) safety-related output signals

Note 1 to entry: This also includes monitoring systems.

Note 2 to entry: The combined safety-related parts of a control system start at the points where the safety-related signals are initiated and end at the output of the power control elements (see also Annex A of ISO 12100:2010).

[SOURCE: IEC 61496-1:2020, 3.23, modified – "SRPCS" has been added as an acronym]

3.1.42**start interlock**

means which prevents an automatic machine start when the electrical supply to the protection equipment(s) is switched on, or is interrupted and restored

[SOURCE: IEC 61496-1:2020, 3.26 modified – "electro-sensitive" has been removed before "protective equipment(s)"]

3.1.43**start test**

manual or automatic test which is performed after the protective equipment has been switched on in order to test its complete safety-related control system before normal machine operation is initiated

3.1.44**trip function**

stop function initiated by the detection of a person before any part of an approaching person can reach the hazard zone

3.1.45**unexpected start-up****unintended start-up**

any start-up caused by

- a start command, which is the result of a failure in, or an external influence on, the control system;
- a start command generated by inopportune action on a start control or other parts of the machine as, for example, a sensor or a power control element;
- restoration of the power supply after an interruption;
- external/internal influences (gravity, wind, self-ignition in internal combustion engines) on parts of the machine.

Note to entry: Automatic machine start-up during normal operation is not unintended, but can be considered to be unexpected from the point of view of the operator. Prevention of accidents in this case involves the use of safeguarding.

[SOURCE: ISO 12100:2010, 3.3,1 modified – the text of the note has been moved to the definition, Note 2 has been changed to Note to entry, where "automatic" has been added before "machine start-up", Note 3 has been removed]

3.1.48**safeguarded space**

area or volume enclosing a hazard zone(s) where guards and/or protective devices are intended to protect persons

[SOURCE: ISO/CD 11161:2021, 3.1.7]

3.1.49**safety-related manual control device****SRMCD**

control device which requires deliberate human action and whose actuation can result in an immediate increase of the risk(s) that may cause or result in potential harm to persons

Note to entry: Examples include actuating devices such as pushbuttons, selector switches, or foot pedals designed for functions like reset, start/restart, guard unlocking or hold-to-run control (e.g. jog, inching).

[SOURCE: ISO/CD 13855:2021, 3.1.12]

3.1.50**whole body access**

a situation where a person can be completely inside a safeguarded space

726 Note to entry: The term whole body access is used in other standards to specify the opening size for safe access.

727 [SOURCE: ISO/CD 11161:2021, 3.1.17

728

729 3.1.51

730 3.1.52

731 Verification

732 The process of evaluation to determine whether the products of a given development phase
733 satisfy the conditions imposed at the start of that phase. [IEEE-STD-610].

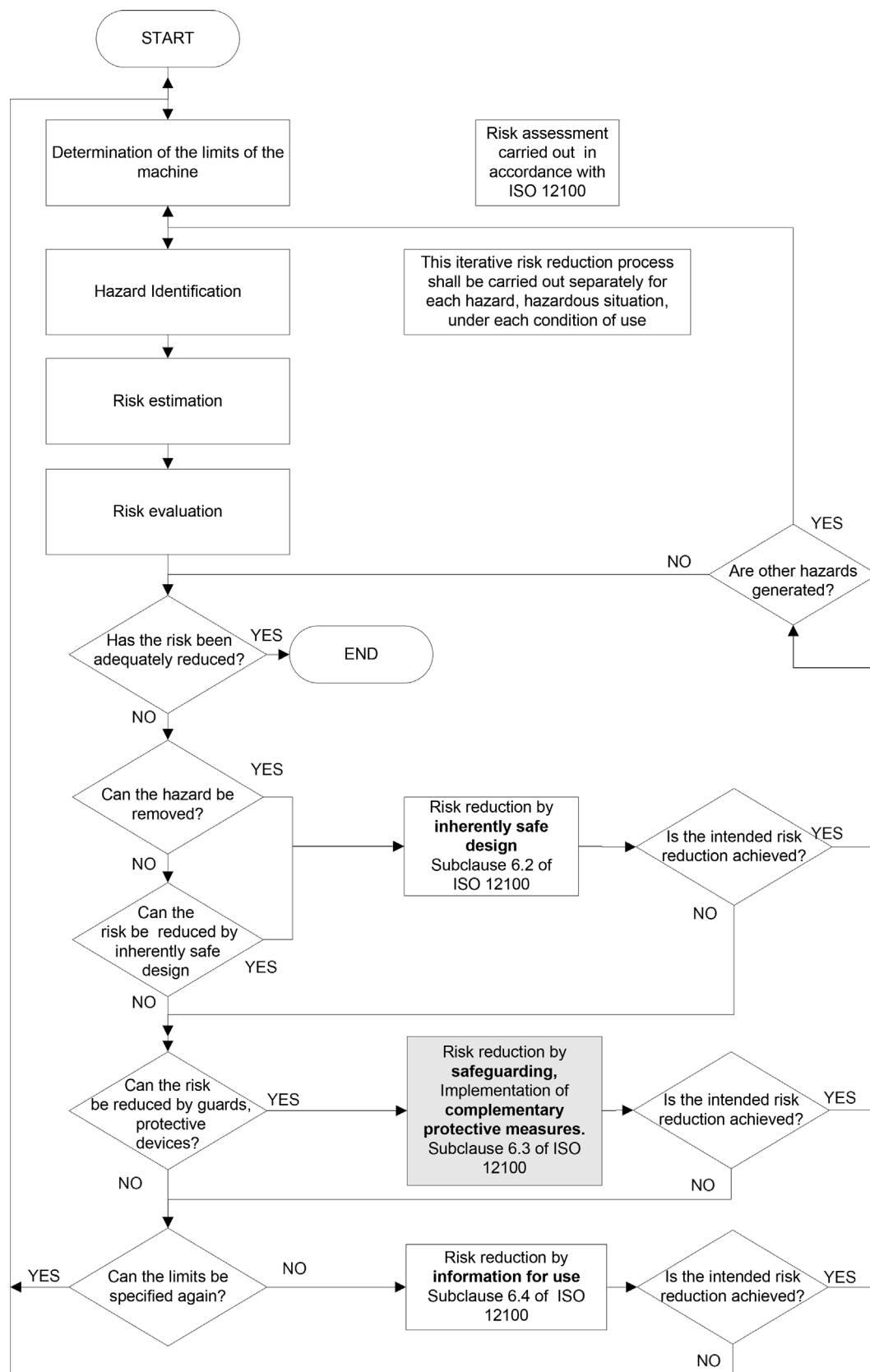
734

735 3.2 Abbreviated terms

Abbreviated term	Description
AGV	Automated Guided Vehicle
AOPD	Active Optoelectronic Protective Device
AOPDDR	Active Optoelectronic Protective Device responsive to Diffuse Reflection
ESPE	Electro-Sensitive Protective Equipment
EDM	External Device Monitoring
FSD	Final Switching Device
MPCE	Machine Primary Control Element
OSSD	Output Signal Switching Device
PFH	Average frequency of dangerous Failure per Hour (according to IEC 62061)
PFH _D	Probability of dangerous Failure per Hour (according to ISO 13849-1)
PL	Performance Level (according to ISO 13849-1)
PSPD	Pressure Sensitive Protective Device
SIL	Safety Integrity Level (according to IEC 62061)
SPM	Stopping Performance Monitor
SCS	Safety Related Control System
VBPD	Vision Based Protective Device
VBPDST	Vision Based Protective Device using Stereo vision Techniques
VBPDPP	Vision Based Protective Devices using reference Passive Pattern techniques
RPD	Radar-Based Protective Device

736 NOTE : For the purposes of this document PFH and PFH_D are equivalent.

737

4 General overview

738

IEC

739 NOTE This figure is a simplified version of Figure 2 of ISO 12100:2010.

740

Figure 2 – Risk reduction process

4.1 General

ISO 12100 :2010 in clause 6.2 recommends a risk reduction strategy based on a hierarchical approach referred to as the three-step method. To be applied in the following sequence:

Step 1. Inherently Safe design: (integration of safety concepts at the design stage)

Step 2. Technical protective measures: add protective measures against risks that cannot be removed by design

Step 3. Administrative measures: inform and warn about the residual risks

This document is an expansion of Step 2 (see Figure 2).

It is therefore assumed that the risk analysis has been carried out correctly in accordance with ISO 12100, that all the hazards associated with the machine has taken into consideration, that all necessary measures to reduce risks have been implemented through an intrinsically safe design and that additional protective measures are required to reduce residual risks.

Risk reduction, according to Step 2 can be achieved by designing, for each hazard, adequate protective devices arranged in a way:

- to reduce the probability of occurrence of the hazardous event
- to impose a limitation the exposure to the hazard duration
- to enhance the possibility of avoiding the harm or at least to reduce its intensity.

Protective equipment is turned-on in response to a defined change in a measurable property of the input. It is intended to reduce the risk generated by human interaction with the machine (operations).

Examples of protective equipment suitable to reduce risks generated by human interaction with the machine are:

sensitive protective equipment to detect persons entering or present in the hazard zone (e.g., AOPD, AOPDDR, sensitive mats).

They provide protection by reducing the probability of occurrence of the harm.

They are intended to work immediately upon a specific initiating event. Their role is to ensure that persons or parts of human body are not injured by the dangerous parts of the machine.

The "demand" of protection is generated by the person with its interaction (operations) with the machine process.

This document considers only risk reduction measures made by active protective devices

4.2 Selection of active protective devices

The goal of the selection process of a protective device is to ensure that, through a correct choice and application (and if necessary, through the integration of other safety measures)

the risks of injury for the operator are reduced an acceptable level.

For a correct selection and application of a protective device, the following factors must be considered which could otherwise adversely affect the effectiveness of the protection:

- Machine characteristics (see 4.2.1)
- user interaction including foreseeable misuse, see ISO 12100:20105. 4.a) and 5.4.c). (see 4.2.2)
- characteristics related to the work environment in which presumably the machine will have to operate (see 4.2.3)
- characteristics of the hazard zone (see 4.2.4)
- dimensions and characteristics of part of the human body (for example finger, hand, leg, whole body) to be detected (see 4.2.5)
- suitability for the application (see 4.2.6)
- safety integrity characteristics of the protective device (see 4.2.7)
- properties of the protective device (sensing technology, use restrictions) (see 4.2.8)

4.2.1 Machine characteristics

The characteristics of the machine shall be determined to ensure that the hazards are clearly identified to allow the selection of the most appropriate technology

Hazards generated by user interaction with the machine should also be considered for both intended use and reasonably foreseeable misuse.

The following characteristics of the machine/hazard shall be determined:

- time for hazard to achieve an acceptable residual risk
- all the ways that the hazard can cause injury – see ISO 12100
- operator locations
- access to the hazard zone (see 4.2.4)
- materials being processed
- machine modes of operation
- stored energy
- possible gravity fall
- parts need to enter/leave the hazard zone
- optional functions necessary (see 4.2.5)
-

4.2.2 User interaction

The way the user is required to interact with the machine must be considered. These interactions can include but are not limited to:

- loading/unloading (including frequency)
- holding workpieces
- Inspection

- 826 – Tool setting
- 827 – Cleaning/ Maintenance
- 828 – Fault finding and troubleshooting

829

830 **4.2.3 Environmental characteristics**

831

832 The functionality of protective equipment can be affected by environmental influences such as
833 temperature, pollution, electromagnetic disturbance, radiation, etc. The degree to which
834 environmental influences can affect the functionality of protective equipment depends on the
835 sensing technology used by the protective equipment. Careful evaluation of the expected
836 environment and the suitability of the protective equipment for use in that environment is
837 necessary during the selection process of protective equipment.

838

839 Specifiers of protective equipment (i.e. integrators, machine manufacturers) should have
840 appropriate information to ensure that the protective equipment is suitable for the intended use
841 under all reasonably foreseeable environments to which the protective equipment can be
842 exposed over its entire operational lifecycle. This can take the form of information for safe use
843 provided by the protective equipment manufacturer and/or information in the relevant product
844 standard. Specifiers shall request additional information if the intended operating environment
845 contains particular environmental conditions that are not addressed by the information
846 available.

847

848 Examples of environmental influences that should be considered include, but are not limited
849 to:

850

- 851 – electromagnetic interference;
- 852 • electrostatic discharge;
- 853 • radio frequency interference, for example mobile telephones;
- 854 – vibration/shock;
- 855 – light interference;
- 856 • ambient light;
- 857 • infra-red, for example remote controls;
- 858 • reflective surfaces;
- 859 • other ESPEs that can emit interfering light;
- 860 – pollution;
- 861 • water;
- 862 • dust;
- 863 • corrosive chemicals;
- 864 – temperature;
- 865 – humidity;
- 866 – weather conditions;
- 867 – radiation.

868

869 Additional and special requirements can apply to the protective equipment of machines that:

- 870 – are used in the open air (i.e. outside buildings or other protective structures);
- 871 – use, process, or produce potentially explosive material (for example paint or sawdust);
- 872 – are used in potentially explosive and/or flammable atmospheres;

- 873 – have special risks when producing or using certain materials;
874 – are used in mines.

875

876 NOTE Information specific to particular protective equipment is provided in Clause 6.

877

878 Where an application uses a combination of protective equipment sensing techniques, the
879 specifier should consider the relevant environmental characteristics for each protective
880 equipment sensing technique. In addition, consideration should be given to possible cross-
881 interference between sensing techniques.

882

883

884 **4.2.4 Characteristics of the hazard zone**

885

886 At least the following characteristics of the hazard zone shall be identified

887

- 888 • Position
- 889 • Shape (2D or 3D)
- 890 • Size (geometric characteristics)
- 891 • Number of hazard zones (separate or overlapping)
- 892 • Risk level
- 893 • Time of appearance with reference to the machine operating mode

894

895 **4.2.5 Dimensions and characteristics of the human body**

896

897 Since the main function of the protective device is to detect the human body or parts of it, it is
898 necessary to consider its anatomy (size of fingers, hands, legs), the foreseeable maximum
899 speed of their movement, the way the worker interacts with the machine including foreseeable
900 misuse

901

902 The resolution, i.e. the minimum size of an object that a protective device is able to detect must
903 be a function of the part of the body to be protected (e.g. fingers, hands, legs, arms).

904 Generally this choice should be made by consulting the instruction manual of the protective
905 device manufacturer.

906

907 **4.2.6 Suitability of protective equipment**

908 Protective equipment as described in this document is typically selected when machine
909 operation requires frequent access, personnel interaction with the machine, good visibility
910 of the machine or process, or when it is difficult to provide fixed guarding. However, some
911 characteristics of particular machines can preclude the use of protective equipment as
912 the sole protective measure.

913 The following characteristics may limit or prohibit the use of some protective equipment:

- 914 • the machine emits materials, chips, machined parts, or harmful radiation
- 915 • parts of the surface reach high temperatures.
- 916 • the level of noise generated is intolerable.
- 917 • the processed materials can adversely affect the effectiveness of the protection.

- the stopping time of the machine is not known or is variable in random mode due to non-quantifiable delays introduced by the circuit control or due to undersized brake systems.
- it is impossible to stop the machine once it has started because this it could introduce additional risks or because the machine can only be stopped at the end of the cycle.
- Expected operator training and competence

Where such situations exist, additional or other safety measures shall be provided.

NOTE An example of an additional measure that can be applied in these circumstances is local guards to prevent ejection.

4.2.7 Safety integrity characteristics of protective devices

4.2.7.1 General

The protective equipment shall be selected to achieve the safety requirements specification of the safety-related control system. Further information is given in ISO 12100, ISO 13849 (all parts) and IEC 62061.

The sensing technology selected shall be appropriate for the risk reduction required by the application.

Product standards for specific machines (type-C standards) can provide requirements or recommendations for the selection of protective equipment.

4.2.7.2 Classification of ESPE and their relationship with risk assessment

IEC 61496-1:2012 defines 3 ‘types’ of ESPE. The types differ in their performance in the presence of faults and under influences from environmental conditions:

Type 2 ESPEs employ a periodic test to reveal failures to danger. The test can be initiated internally or externally. Type 2 ESPEs can fail to danger because of a single fault between tests. For this reason, Type 2 ESPEs are unlikely to be suitable for applications demanding a medium or high-risk reduction

Type 3 ESPEs are designed to not fail to danger due to a single fault but can fail to danger due to an accumulation of faults.

Type 4 ESPEs are designed to not fail to danger due to a single fault or an accumulation of faults.

Type 3 ESPEs and Type 4 ESPEs can be suitable for applications demanding a medium to high-risk reduction when their sensing technology is appropriate.

NOTE 1 Reference to “low”, “medium” or “high” refers to the risk reduction contribution by the protective equipment.

Different sensing technologies have additional systematic aspects that are provided in the information for use supplied with the ESPE. Where additional measures are required by the information for use these shall be followed.

NOTE 2 The 'types' of IEC 61496-1 do not correspond to the categories of ISO 13849-1.

4.2.7.2.1 Target PL or SIL

A SIL (see IEC 62061) or PL (Performance Level, see ISO 13849-1) is not sufficient as a sole indication of an ESPE's suitability for use as a safeguard. Suitability depends also on appropriate sensing means, environmental conditions (especially those that can affect the detection capability), behavior under fault conditions, etc.

4.2.7.2.2 ESPE Type

Where an ESPE is used within a safety related control system, the maximum PL or SIL that can be achieved by a safety function that includes that ESPE is specified in Table 1.

Table 1 – ESPE Types and achievable PL or SIL

	ESPE Type	PL	SIL
For each ESPE Type, the PL or SIL that can be achieved by a safety function that includes that ESPE	2	a, b, c	1
	3	a, b, c, d	1, 2
	4	a, b, c, d, e	1, 2, 3

NOTE 1 The calculation of SIL or PL of the function uses the PFH value provided by the manufacturer. The device dependent PFH values claimed for the control electronics is not restricted (for example, a manufacturer may claim a PFH lower than 10^{-6} for an ESPE Type 2 SILCL 1).

NOTE 2 The ESPE correlation to SIL and PL is based on the systematic capabilities (for example environmental influences, EMC, optical performance, detection principle etc.) of the IEC 61496 series. These ESPE standards are technology-specific and primarily based on deterministic considerations.

NEED A NEW EXAMPLE

EXAMPLE If a safety function of SIL 2 is required for a system using an AOPD, from Table 1 a Type 2 AOPD does not meet the requirement. A Type 3 or Type 4 AOPD will be selected.

4.2.7.3 Classification of mats and their relationship with risk assessment

Pressure-sensitive mats and floors are specified in ISO 13856-1. Pressure-sensitive mat systems are classified according to the performance levels and categories of ISO 13849 (all parts).

The performance level of pressure sensitive mats shall be as required for the relevant safety-related control function contributing to the risk reduction.

Pressure-sensitive mats and pressure-sensitive floors shall meet at least the requirements of PL = c.

4.2.7.4 Periodic Test

The duration of the periodic test of a Type 2 ESPE shall be considered to ensure that it is not possible for a person to enter a hazard zone during the functional test without being detected. The periodic test duration shall not exceed 150ms. A restart interlock should be considered if the test duration can exceed 150ms

Where the category of the mat system requires that a periodic functional test is performed, the duration of the functional test shall be considered to ensure that it is not possible for a person to enter a hazard zone during the functional test without being

detected.. When considering the maximum test duration, the overall response time shall not exceed 200ms.

Where the safety performance of a Type 2 ESPE or of a Category 2 (according to ISO 13849-1:2015) mat systems is dependent on periodic testing, the frequency of testing should be greater than the frequency of exposure to the hazard. As a minimum, an automatic test shall be performed at each power-on of the protective equipment.

Where the protective device supplier declares fault exclusions in the instructions for use, the integrator of the protective equipment shall take the fault exclusions into account.

4.2.8 Properties and application requirements for specific protective devices

4.2.8.1 General

There are several technologies considered in this document. Each technology has a different method of detecting the presence of a person or part of a person. Each of these technologies have limitations depending on where and how they are used, It should be possible to reject some technologies due to environment and the hazard zone description. Other technologies may be more suitable due to possible additional functions i.e., muting, blanking etc.

Each type of technology is described in Annex F

- AOPD – See F.1.2
- AOPDDR – see F.1.3
- VBPDPP - see F.1.4.1
- VBPDST – see F.1.4.2
- RPD – see F.1.5
- SAFETY MATS AND FLOORS – see F.1.6

4.2.8.2 AOPDs

4.2.8.2.1 General

Light beam devices and light curtains depend for their activation on the interruption of one or more light beams. Reflective surfaces in the vicinity of the light beam(s) can reduce the ability of the AOPD to detect the intended object, as shown in 3.

AOPDs in accordance with IEC 61496-2 are Type 2, 3 or 4 ESPEs.

NOTE Application examples are given in Annex C.

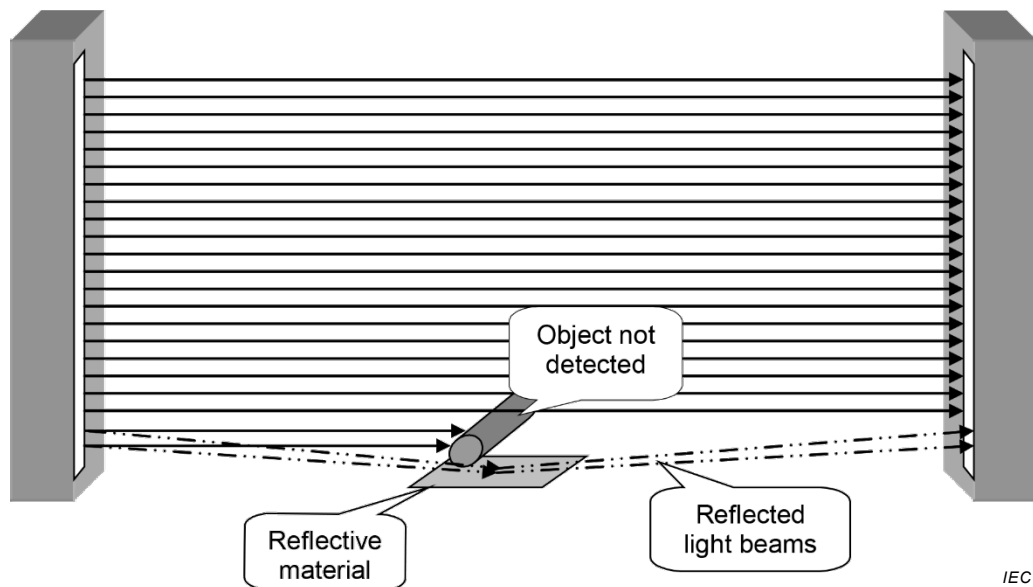


Figure 3 – Example of the effect of reflective surfaces

The AOPD manufacturer's guidance on avoiding the effect of reflective surfaces shall be followed. To achieve this throughout the lifecycle of the machine, it is necessary to consider factors such as wearing of painted surfaces, changes of process material, beam divergence, environmental influences, etc.

4.2.8.2.2 Light beam device(s)

Light beam devices may provide one or more beams. When they are used as trip devices for whole body detection in perimeter guarding, a restart interlock or a presence-sensing device is usually necessary to prevent unexpected restarting. Because light beam devices usually have no specified detection capability but only detect interruption of the beam(s), they require careful positioning to ensure they are effective.

For the calculation of the minimum distance, the response time of each beam with respect to the size and speed of the body part that will pass at each height shall be considered.

Each beam shall be able to detect an object of 120 mm diameter placed at the centre of the beam axis. This also applies where a group of emitters and/or receivers is intended to act as a single beam.

The positioning and characteristics of each beam shall take into account the possibility of

- encroachment between, over or under the beams;
- undetected penetration of parts of the body, for example hands/arms;
- crawling under, climbing through or jumping over.

The heights for 2, 3 and 4 beams given in have been found to be the best compromise between an adequate risk reduction and the most practical in application. Not all applications allow the use of multiple separate beams. Further protective measures to prevent access to the hazard zone can be required. For the lowest beam (see ISO 13855:20xx), 400 mm shall only be used when the risk assessment allows it.

Table 1 – Beam heights for light beam devices

No. of beams	Heights above reference plane, for example floor mm
4	300, 600, 900, 1 200
3	300, 700, 1 100
2	400 ^a , 900

^a For the lowest beam, 400 mm can only be used when the risk assessment allows it.

The height of the uppermost beam shall be ≥ 900 mm to prevent stepping over the detection zone. This is not applicable for single beams or for detection zones parallel to the direction of approach.

A greater number of beams can reduce the possibility of penetration or circumvention. Two beams may be used only when shown to be satisfactory by a risk assessment, for example when circumvention is difficult due to fixed obstacles in the opening.

4.2.8.2.2.1 Cross-interference

Light beam devices can be subject to cross-interference between adjacent beams, or between adjacent devices. Measures shall be taken to reduce the risk of cross interference. Such measures can include:

- measures provided by the device manufacturer, for example different beam modulation;
- secure installation and fastening;
- alternating the direction of adjacent beams;
- orientation of the beam direction;
- alignment of devices, use of light baffles and avoidance of reflective surfaces to prevent a transmitter energizing the receiver of a different light beam device.

4.2.8.2.2.2 Use of light beam devices to detect access to small openings of a machine

When light beam devices are used to detect access to small openings of a machine, the same requirements apply as if a light curtain was used, including ensuring that it is not possible to reach the hazard by reaching over or under the beam(s).

For a single beam, the detection capability value used for the calculation of the minimum safety distance shall be the sum of the effective beam diameter and the largest gap between the beam and the edge of the opening (see 4). For multiple light beam devices (see Figure 5), the value used shall be the larger of:

- a) the sum of the largest effective beam diameter and the largest gap between the beam and the edge of the opening, or
- b) the sum of twice the largest effective beam diameter and the largest gap between beams.

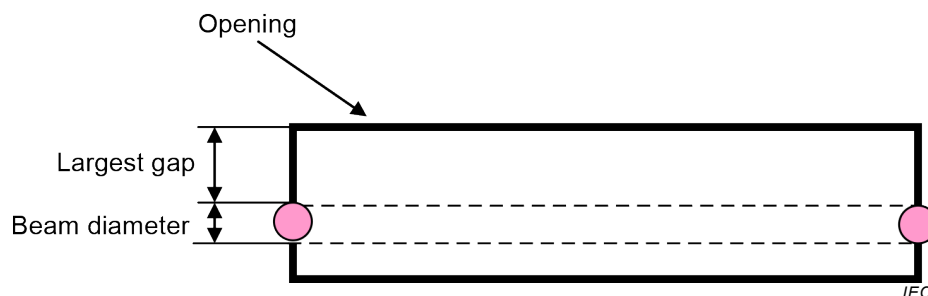


Figure 4 – Detection capability of single light beam device

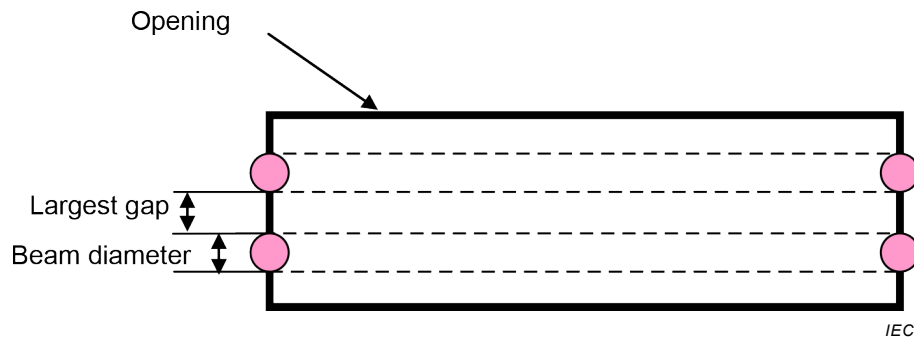


Figure 5 – Detection capability of a multiple light beam device

4.2.8.2.3 Light curtains

4.2.8.2.3.1 Orientation of the detection zone

Light curtains can be oriented in one of the following six formats (see also Annex A):

- orthogonal approach – where the detection zone is orthogonal to the direction of approach;
- parallel approach – where the detection zone is parallel to the direction of approach;
- angled approach – where the detection zone is at some other angle to the direction of approach;
- combination approach – where the detection zone combines two or more of the above;
- fixed dual format – where the detection zone can be selected to be either orthogonal or parallel to the direction of approach. The minimum distance shall be maintained in both orientations of the detection zone;
- rotating dual format – where the detection zone can be converted to a position either orthogonal or parallel to the direction of approach by rotating the light curtain about a pivot. It shall not be possible to rotate the light curtain towards the dangerous parts if the minimum distance cannot be maintained.

For minimum distance calculations, where the angle of approach is greater than 30°, it is considered as an orthogonal approach and where the angle of approach is less than 30°, it is considered as a parallel approach.

The height of the top and bottom beam of a light curtain shall be sufficient as defined in 6.5 of ISO 13855:2010, to prevent persons from accessing the hazard zone by reaching above or below the detection zone.

4.2.8.2.3.2 Cross-interference

Light curtains can be subject to cross-interference between adjacent devices. Measures shall be taken to reduce the risk of cross interference. Such measures can include:

- measures provided by the light curtain manufacturer, for example different beam modulation;
- secure installation and fastening;
- alternating the beam direction of adjacent devices;
- alignment of devices, use of light baffles and avoidance of reflective surfaces, to prevent a transmitter energizing the receiver of a different light curtain.

4.2.8.2.3.3 Blanking

Blanking may be fixed or floating. Floating blanking is a technique wherein the blanked area of the detection zone follows the location of a moving object(s) during operation.

NOTE 1 Floating blanking is used for applications in which the material or work piece can move within the detection zone.

The blanked area shall be continuously occupied by material, workpiece, fixtures, fixed guards or removable interlocking guards (see 6). The part or parts of the control system that perform

1153 the interlocking of the removable guards shall have an appropriate safety-related performance
1154 (SIL or PL, see IEC 62061 or ISO 13849-1). The specified detection capability of the AOPD can
1155 be used to calculate the minimum distance only when:

- 1156 – access through the blanked areas is completely obstructed, and
- 1157 – outside the blanked areas the stated detection capability is ensured.

1158 It cannot always be ensured that blanked areas are completely obstructed by mechanical means.
1159 In this case the dimension of the resulting gap in the detection zone determines the required
1160 minimum distance between the AOPD and the hazard zone. The relevant information provided
1161 in the user manual of the AOPD shall be considered.

1162 To prevent possible misuse, blanking shall not be available except when necessary for the
1163 operation of the machine. The blanked area or number of blanked beams shall not be greater
1164 than is needed for correct machine operation.

1165 NOTE 2 In a device designed according to IEC 61496-2, the state(s) of the beam interruption(s) within the blanked
1166 area are monitored. If the beams are not interrupted as intended, the OSSD(s) goes to the OFF-state.

1167 NOTE 3 In devices designed according to IEC 61496-2, each blanked area consists of adjacent beams. It is
1168 monitored whether the interrupted beams are adjacent to each other or not. If in a blanked area interrupted beams
1169 are found to be separate from each other, the OSSD(s) go to the OFF-state.

1170 It should not be possible to change from normal operation mode to a blanking mode (or change
1171 of type of blanking) during the working cycle of the machine unless necessary.

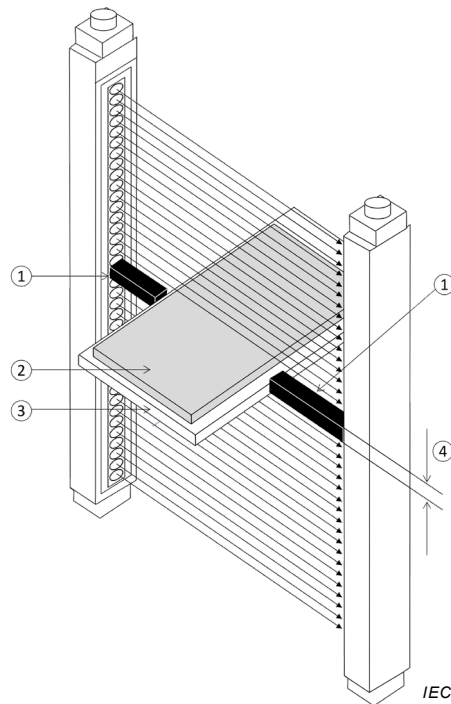
1172 If, for a particular application, it is necessary to activate the blanking function only for a part of
1173 the machine cycle, the blanking function shall be initiated and terminated automatically. This
1174 may be achieved by the use of appropriately selected and placed sensors or, in some cases,
1175 by signals from the safety-related control system. Incorrect signals, sequence, or timing of the
1176 blanking sensors or signals shall not allow a blanked condition.

1177 After each configuration, the effectiveness of the detection zone shall be verified.

1178 Information about any change of the effective resolution of the ESPE due to blanking shall be
1179 available in the information for use.

1180 The part or parts of the control system that initiate(s) the blanking function shall have an
1181 appropriate safety-related performance (SIL or PL, see IEC 62061 or ISO 13849-1) such that
1182 they do not adversely affect the safety-related performance of the protective function.

1183 The installation shall be such as to minimize the possibility of loss of detection capability caused
1184 by reflective surfaces in the blanked zone (see also 4.2.8.2.1).

**Key**

- 1. Fixed guard or interlocked removable guard
- 2. Process material
- 3. Fixed part of machine
- 4. Blanked area

Figure 63 – Example of use of blanking**4.2.8.2.3.4 Reduced resolution**

Reduced resolution (also referred to as unmonitored blanking) changes the detection capability of the AOPD. It is intended to ensure that objects in the detection zone (cables, tubes, etc.) of a diameter smaller than the detection capability are ignored. Any object equal to or larger than the detection capability shall be detected. 7 shows an example of reduced resolution applied to a decoiler.

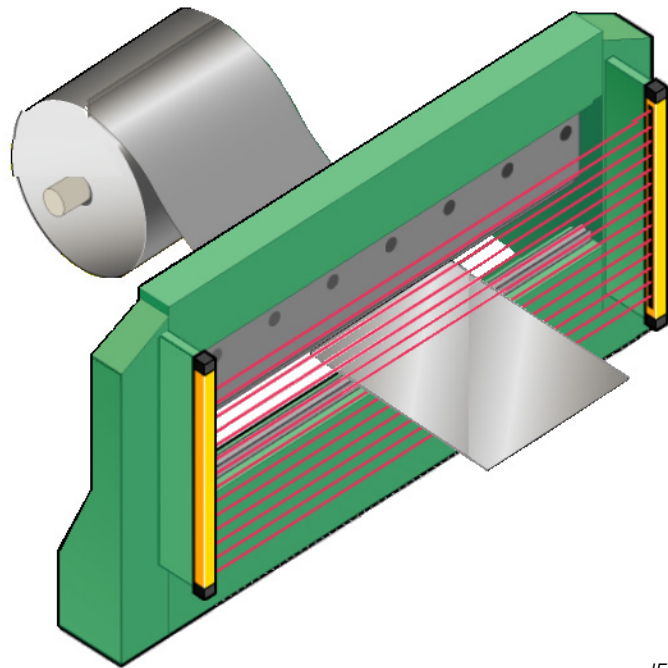
Reduced resolution can be effective over the entire detection zone or within defined fixed or moving zones.

When calculating the minimum distance for positioning of the AOPD, the detection capability of the selected reduced resolution shall be used.

Manual (i.e. non-automatic) selection of a reduced resolution mode shall only be possible by the use of a key, keyword or tool.

Automatic selection of a reduced resolution mode shall only be configurable by the use of a key, keyword or tool.

The detection capability of the selected reduced resolution shall be verified with an appropriate test piece.



IEC

Figure 7 – Example of reduced resolution

4.2.8.3 AOPDDRs

AOPDDRs are used both in static and mobile applications.

NOTE 1 Application examples are given in Annex B.

AOPDDRs in accordance with IEC 61496-3 are Type 2 or 3 ESPEs.

For vertical detection zones detecting whole body access (operating as a trip device) it shall be ensured that the AOPDDR will detect a person passing through the detection zone at 1,6 m/s and send the OSSD to the OFF-state. (See annex B4 and 5.2.1.6)

When configuring the detection zone of an AOPDDR, care shall be taken to ensure that:

- the detection zone fully covers the hazard zone;
- no shadow zones are created behind objects, that can allow persons to approach closer to the hazard zone than the calculated minimum distance;
- the AOPDDR manufacturer's instructions regarding nearby reflective surfaces and interference from the background have been taken into account;
- the instructions for setting the detection zone(s) including consideration of the tolerance zone(s) are taken into account;
- instructions about the minimum required distance between the boundary of a detection zone and objects that need not be detected (for example, walls or parts of machines) are taken into account;
- no hazard can arise in a particular application due to the presence of zone(s) with limited detection capability.

NOTE 2 It can be helpful to mark the boundary of the detection zone on the floor.

In mobile applications, there shall be no trapping or crushing hazards at the edge of the overall detection zone. In mobile applications, several additional factors shall be considered in order to maintain the minimum distance, for example:

- difficult environmental conditions;
- the physical environment (for example reflecting properties) changes as a result of the movement;
- the stopping system performance and possible deterioration;

- 1238 – changing floor or ground conditions (e.g. water, oil or ice present occasionally) that can
1239 influence the stopping distance;
- 1240 – the hazard zone moves together with the machine (the primary hazard is the impact or
1241 crushing caused by the moving machine);
- 1242 – the direction of approach of an object can vary, for example due to changes in direction of
1243 movement of the vehicle;
- 1244 – the direction of approach of a person can vary due to changes in direction of movement of
1245 the vehicle and/or the person;
- 1246 – if the machine moves over uneven surfaces, the effective height of the detection zone can
1247 vary from its intended position;
- 1248 – different speeds of movement shall be considered, for example:
 - 1249 • speed of the machine (and AOPDDR);
 - 1250 • relative speed of the machine and the object to be detected, for example
 - 1251 – person,
 - 1252 – bicycles,
 - 1253 – forklift trucks,
 - 1254 – other vehicles.

1255 **4.2.8.4 Vision based protective devices VBPD**

1256 VBPD shall be in accordance with IEC TS 61496-4-2:2014 or IEC TS 61496-4-3:2015.

1257 When configuring the detection zone of an VBPD, care shall be taken to ensure that

- 1258 – the detection zone fully covers the hazard zone;
- 1259 – no shadow zones are created behind objects, that can allow persons to approach closer to
1260 the hazard zone than the calculated minimum distance;
- 1261 – the VBPD manufacturer's instructions regarding lightning and background requirements are
1262 followed;
- 1263 – the manufacturer's instructions for setting the detection zone(s) (e.g. minimum size of the
1264 detection zone) including consideration of the tolerance zone(s) are followed;
- 1265 – the manufacturer's instructions about the minimum required distance between the boundary
1266 of a detection zone and objects that need not be detected (for example, walls or parts of
1267 machines) are followed;
- 1268 – the manufacturer's instructions about zone(s) with limited detection capability shall be taken
1269 into account;
- 1270 – the manufacturer's instructions about installation of the VBPD (e.g. limitation of angle or,
1271 height) are followed.

1272 NOTE Application examples are given in Annex C.

1273 **4.2.8.5 Pressure-sensitive mats and floors**

1274 **4.2.8.5.1 Pressure sensitive floors**

1275 Pressure sensitive floors consist of moving rigid plates that detect the presence of a person by
1276 their weight by actuating sensors, for example limit switches. Factors that shall be taken into
1277 account when selecting a pressure sensitive floor as a protective device include the
1278 construction of the floor, the environmental conditions, the behavior in the presence of faults
1279 and the operational conditions (for example the possibility of circumvention). Pressure sensitive
1280 floors shall not be used when deformation of the plate or foreign objects under the plate can
1281 render the device unable to detect a person stepping on it.

1282 **4.2.8.5.2 Pressure sensitive mats**

1283 **4.2.8.5.2.1 Selection criteria**

1284 Pressure sensitive mats are devices whose upper surface is deformable and that detect the
1285 presence of a person by their weight by deformation of the upper surface generating a signal

Factors that shall be taken into account when selecting a pressure sensitive mat as a protective device include the construction of the mat, the environmental conditions, the behavior in the presence of faults and the operational conditions (for example the possibility of circumvention).

NOTE More information on pressure sensitive mats can be found in ISO 13856-1.

4.2.8.5.2.2 Mat characteristics

The safety integrity of the mat depends on its reliability and fault resistance rather than fault detection, therefore undetected deterioration of sensing performance (for example due to slow ingress of dust, liquids or gases) can occur.

Some types of pressure sensitive mat cannot detect a person already standing on the mat when the power is switched on, or is interrupted and restored. These mats shall not be used as protective devices.

Sensitivity can be adversely affected by static loading (for example process material resting on the surface of the mat).

Cable entry points to mats shall be such that:

- there are no tripping hazards due to connecting cables;
- any dead zone adjacent to the entry point of connecting cables is not in the area intended for the detection of persons;
- the cable is not in a position where mechanical damage is likely.

When the difference in height of adjacent horizontal surfaces is 4 mm or more, a ground-flush installation or a small ramp shall be used. If a ramp is used, its slope shall not exceed 20°.

When using a combination of mats, dead areas in the detection zone shall be avoided. For guidance, see Figures B.1 and B.2 of ISO 13856-1:2013.

When a mat system is used as a trip device, the minimum distance of the mat edge from the hazard shall take into account the worst case conditions, for example the length of a person's first stride onto the mat from any possible direction of approach.

The dimensions of the mat shall be selected to prevent a person stepping over or jumping over the mat.

4.2.8.5.2.3 Environmental conditions

Environmental conditions that shall be taken into account when considering the selection of a pressure sensitive mat as a protective device include:

- surface contamination of the mat giving rise to a slipping hazard;
- irregularities of the mat mounting surface that can impair the sensitivity of the mat;
- wheeled traffic on the mat (forklift trucks or other heavy vehicles can cause damage to the mat especially when braking, accelerating or turning);
- chemicals (for example oils, solvents, cutting fluids) that can cause changes in the properties of the mat, such as swelling or hardening of the material, resulting in a change of sensitivity;

NOTE 1 The manufacturer of the mat usually gives information in the data sheet about the permissible chemical environment. Special surface coverings may also be available.

- effects of temperature. The minimum temperature range required in ISO 13856-1 is +5 °C to +40 °C. Cold environments can make the material of the mat stiff and hot environments can make the material soft, thus changing the sensitivity of the mat;

- foreign bodies such as welding splatter, swarf or sand can wear or damage the mat. Additional protective coverings specified by the manufacturer may be used.

NOTE 2 Other additional coverings can impair the sensitivity of the mat.

4.2.8.5.2.4 Frequent actuation

The safety integrity of the mat depends on its reliability and fault resistance. The mat shall be chosen to withstand the expected number of actuations and frequency of operation.

4.2.8.5.2.5 Infrequent actuation

Where mats are infrequently actuated, it will be necessary for the user to perform periodic tests to verify the mat's integrity.

4.2.8.5.2.6 Physical properties of the mat

The physical properties of the mat can cause problems in some applications. At least the following points shall be taken into account:

- permanent deformation or hardening of the mat surface can form "bridges" over parts of the detection zone;
- in most designs there is an internal air gap inside the mat. Ingress of material (small or large particles), vermin, corrosive gases or fluid can cause the mat to fail. Small holes might not be detected during maintenance.

4.2.8.5.2.7 Mounting surface

Irregularities of the floor or other mounting surface can impair the function of the mat and shall therefore be within the limits stated by the manufacturer of the mat.

The mat shall be securely fixed in place to prevent accidental or intended movement of the mat thus leaving unprotected access to the hazard zone.

4.3 Possibility of Defeating

For the evaluation of the probability of circumvention of ESPE, both aspects should be considered:

- the motivation of circumvention or defeat depending on the application of the ESPE, e.g. its usability in different working modes and usages of the machine
- the possibility or chance to circumvent or defeat the ESPE depending on its type and design, e.g. by simple wire jumpers or by changing password protected parameters

4.4 Positioning of protective equipment or detection zone(s)

Additional information regarding the positioning of protective equipment or detection zone is given in Annex A and in ISO 13855.

5 Modes of operation of protective devices**5.1 General**

The selection of the protective equipment, and its positioning and configuration with regard to the hazard is determined by the function to be performed, i.e.

- trip function, (see 5.2) or
- presence sensing function, (see 5.3)
- combination trip and presence sensing function (see 5.4).

Each of these modes of operation have different requirements and issues that must be considered and addressed. All sensing technologies may be suitable for all modes, but the specific application could result in the sensing function being inadequate.

5.2 Trip function

When protective equipment is used as a trip device (i.e. to detect the approach of a person or a part of a person), it shall be positioned at a sufficient distance from the hazardous part(s) of the machine (minimum distances are specified in ISO 13855) specific machine hazard(s) to ensure the machine can stop or otherwise reach a safe condition before any part of an approaching person can reach the hazard zone. The minimum distance shall be maintained for all foreseeable directions of approach.

5.2.1 Determination of the safety distance

For the determination of the minimum distance, it must be considered:

- the protective equipment detection capability in relation to human characteristics (see 4.2.5)
- body part penetration/encroachment
- the approach speed of the human body to the hazard
- the overall system stopping performance (see 3.1.28);
- the possibility of reaching over or under the sensing zone and possibility of circumvention of the detection zone

5.2.1.1 Protective equipment detection capability

The detection capability of the protective device shall be appropriate to the size of the dimensions and characteristics of part of the human body (for example finger, hand, leg, whole body) to be detected.

Care is necessary when considering features that can affect the detection capability, such as reduced resolution, blanking, muting, change of detection zones.

Where adjustment of the detection capability or response time is available, the parameters used to calculate the minimum distance shall be the maximum (worst case) values, or where those settings are protected against unauthorized change by requiring the use of a key, keyword, tool or other means providing a similar level of access restriction the actual settings that the application uses.

5.2.1.2 Intrusion/encroachment factor (C)

A protective equipment designed to detect large parts of the body (e.g. legs, whole body) can allow smaller parts of the body (e.g. fingers, hands) to penetrate the detection zone without being detected. When calculating the minimum distance, an additional distance (C) shall be added to take this into account.

This additional distance (C) will vary between, for example, where the protective equipment is intended to detect whole bodies but an arm can remain undetected or where the protective equipment is intended to detect hands but fingers can remain undetected. (See ISO 13855.)

Encroachment is like intrusion; however, instead of the body part penetrating the detection zone, the body is extended over the detection zone. For example, for a protective

equipment with its sensing function positioned at waist height, the body configuration of bending at the waist with an outstretched arm should be considered. In the case of a ground-level trip device, the first stride length should be considered.

NOTE The value of 1 200 mm used in ISO 13855 for C when considering ground-level trip devices includes an allowance for the first stride of a person stepping into the detection zone of the trip device.

Additional requirements are given in ISO 13855.

5.2.1.3 Approach speed (K)

Approach speeds are specified as 1 600 mm/s for normal walking and as 2 000 mm/s for normal reaching with upper limbs. Depending on the application, it can be necessary to take into account other speeds (for example use of bicycles in the vicinity, foreseeable reasons for running towards the machine, etc.).

In the case of applications on mobile machines (for example AGVs), a risk assessment shall be performed to determine the approach speed to be used. If the result of the risk assessment, or ISO 13855, does not indicate an approach speed then the speed used for the calculation shall be 1 600 mm/s or the speed of the mobile machine if greater. In some applications, it can be necessary to consider the relative speed of a person and a moving machine, for example, an AGV.

5.2.1.4 Stopping performance

The overall system stopping performance used for calculation of the minimum distance shall include the sum of:

- a) the response time of the protective equipment.
- b) the maximum machine stopping time under the most severe conditions, for example maximum load, maximum speed, etc. for the machine to stop or otherwise reach a safe condition after receiving the output signal from the protective equipment.
- c) an allowance in consideration of factors which can lead to a deterioration in performance of hydraulic, pneumatic, electrical and mechanical components, for example wear, ageing, temperature, and the accumulation of such factors as installation tolerances, time measurement accuracy, SPM accuracy, etc. A minimum allowance of 10% of b) is recommended.

5.2.1.5 Ability to circumvent protective equipment

The protective equipment shall be selected and installed so as to minimize the possibility that persons can be exposed to a hazard, due for example to circumvention by deliberately or inadvertently:

- reaching over, under or around detection zones;
- bending over detection zones;
- stepping over detection zones.
- straddling ground level detection zones;
- repositioning of the protective equipment sensing device;
- deflection of the beam(s) by using reflective surfaces that cause modification of the detection zone

When it is foreseeable that a person can circumvent the detection zone of a trip device then supplementary protective measures shall be implemented to ensure that:

- the hazard zone of the machine can be approached only through the detection