

INTERNATIONAL STANDARD



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



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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 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.

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

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

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

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

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

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- withdrawn,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

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INTRODUCTION

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

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

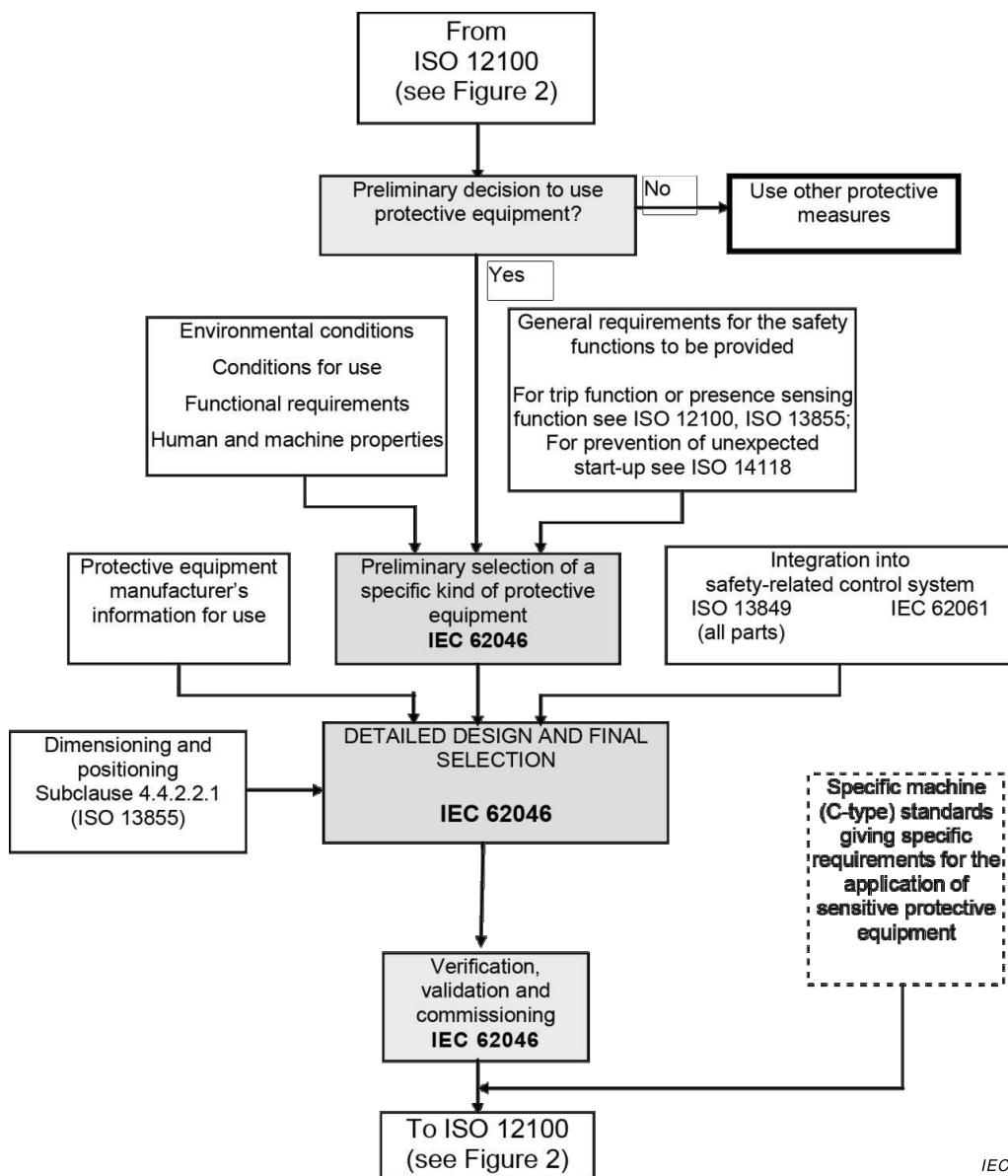
Figure 1 and Figure 2 show the general context and the intended use of this standard.

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

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

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

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



IEC

Figure 1 – Relationship of this International Standard to other standards

(see also Figure 2)

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.

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, *Safety of machinery - Functional safety of safety-related electrical, electronic and programmable electronic control systems*

ISO 12100:2010¹, *Safety of machinery – General principles for design – Risk assessment and risk reduction*

ISO 13849 (all parts), *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.

¹ ISO 12100:2010 constitutes a consolidation without technical changes of ISO 12100-1:2003, ISO 12100-2:2003, ISO 14121-1:2007 and related amendments. This consolidation does not require updates or revisions to type B- and type C- standards or other documents (e.g. for risk assessment) based on the previous standards.

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 61496-2:2013, 3.201]

3.1.2

actuation of an ESPE

detection of an object causing the OSSD(s) to go to the OFF-state

3.1.3

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 61496-3:2008, 3.301]

3.1.4

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 61496-1:2012, 3.1, modified – Note 1 to entry has been modified, Note 2 to entry has been removed]

3.1.5

detection capability

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

[SOURCE: IEC 61496-1:2012, 3.3, modified – "electro-sensitive" has been removed before "protective equipment"]

3.1.6

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 61496-1:2012, 3.4, modified – Note 1 to entry has been added]

3.1.7**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

[SOURCE: IEC 61496-1:2012, 3.5, modified – (Notes 1 and 2 to entry have been removed)]

3.1.8**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]

3.1.9**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 61496-1:2012, 3.6]

3.1.10**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.

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

3.1.11**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 61496-1:2012, 3.8]

3.1.12**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]

3.1.13

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 61496-1:2012, 3.10]

3.1.14

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]

3.1.15

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]

3.1.16

hazard zone

danger 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]

3.1.17

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

3.1.18

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 61496-2:2013, 3.204, modified – Note 1 to entry has been added]

3.1.19

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]

3.1.20

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 (OSSDs) and, where applicable, all final switching devices (FSDs) 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]

3.1.21

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]

3.1.22

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]

3.1.23

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 area

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".

3.1.24

muting

temporary automatic suspension of a safety function(s) 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 61496-1:2012, 3.16, modified – Note 1 to entry has been modified]

3.1.25

muting sensor

device used to initiate and/or terminate muting

3.1.26

OFF-state

state in which the output circuit is interrupted and does not permit the flow of current

[SOURCE: IEC 61496-1:2012, 3.17, modified – the wording of the definition has been changed]

3.1.27

ON-state

state in which the output circuit is complete and permits the flow of current

[SOURCE: IEC 61496-1:2012, 3.18, modified – the wording of the definition has been changed]

3.1.28

output signal switching device

OSSD

component of the electro-sensitive protective equipment (ESPE) 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 61496-1:2012, 3.19]

3.1.29

overall system stopping performance

T

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

[SOURCE: IEC 61496-1:2012, 3.20, modified – "electro-sensitive" has been removed before "protective equipment" and Note 1 to entry has been added]

3.1.30

periodic test

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

3.1.31

protective equipment

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

- a sensing device,
- control and monitoring devices,
- output signal switching devices,

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

3.1.32

presence sensing function

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

3.1.33

pressure-sensitive mat

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

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

3.1.34

pressure-sensitive floor

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

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

3.1.35

protective measure safety measure

measure intended to achieve risk reduction, implemented:

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

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

3.1.36

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”]

3.1.37

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 61496-2:2013 A.10, modified]

3.1.38

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 61496-1:2012, 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]

3.1.39

restart interlock

means of preventing automatic restarting of a machine after actuation of the sensing device during a hazardous part of the machine operating cycle, 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 61496-1:2012, 3.22]

3.1.40

risk

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

[SOURCE: ISO 12100:2010, 3.12]

3.1.41

risk assessment

overall process comprising a risk analysis and a risk evaluation

[SOURCE: ISO 12100:2010, 3.17]

3.1.42

safety-related part of a control system

SRPCS

part or subpart(s) 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 61496-1:2012, 3.23, modified – "SRPCS" has been added as an acronym]

3.1.43

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 61496-1:2012, 3.26 modified – "electro-sensitive" has been removed before "protective equipment(s)"]

3.1.44

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

3.1.45
stopping performance monitor
SPM

monitoring means to determine whether or not the overall system stopping performance is within the pre-set limit(s)

[SOURCE: IEC 61496-1:2012, 3.27]

3.1.46
trip function

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

3.1.47
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 1 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 first note has been moved to the definition, Note 2 has been changed to Note 1 to entry, where "automatic" has been added before "machine start-up", Note 3 has been removed]

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
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
SRPCS	Safety Related Part of 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

4 Selection of protective measures

4.1 Procedure (relationship with ISO 12100)

This procedure is an expansion of Step 2 “risk reduction by safeguarding” of the iterative 3-step method of risk reduction for the design of safe machinery, contained in Clause 4 of ISO 12100:2010 (see Figure 2).

This procedure presumes that a risk assessment has been carried out in accordance with ISO 12100, that measures have been taken to remove or reduce risks by inherently safe design, and that safeguarding by means of protective equipment is being considered.

The following characteristics shall be considered in the selection process when protective equipment and other protective measures as necessary are being evaluated as a risk reduction means:

- machine characteristics;
- environmental characteristics;
- human characteristics;
- protective equipment characteristics.

These characteristics should be considered for both normal use and reasonably foreseeable misuse.

4.2 Machine characteristics

4.2.1 Suitability of protective equipment

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

- a) possibility that the machinery will eject materials, swarf or component parts;
- b) risk of injury from thermal or other radiation;
- c) unacceptable noise levels;
- d) an environment likely to adversely affect the function of the protective equipment (see 4.3); and
- e) a material being processed that can influence the effectiveness of the protective measure.

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.

4.2.2 Suitability of protective equipment as a trip device

When protective equipment is used as a trip device (i.e. to detect the approach of a person or a part of a person), the machine shall cease hazardous operation(s) before it is possible to reach the hazardous part(s) of the machine (minimum distances are specified in ISO 13855). However, some characteristics of particular machines can preclude the use of protective equipment as a trip device.

Protective equipment is unsuitable as a trip device or as a combined trip and presence sensing device when the stopping performance of the machine is unknown, inconsistent or inadequate due, for example, to

- the reaction characteristics of the machinery control circuitry;
- inadequate braking;
- the inability of the machine to stop part-way through a cycle due, for example, to:
 - the nature of the process, where stopping would create additional hazards;
 - the method of drive, for example positive key clutches or similar mechanisms for engaging the drive so arranged that once started, the machinery can only be stopped when the cycle is complete;
 - stored energy, for example in the form of stored pressure in pneumatic reservoirs or hydraulic accumulators.

If a machine has variable speed, load or inertia, then the time used in the calculation of the minimum distance shall be the longest time to cease hazardous operation(s). All control functions that can affect the time to cease hazardous operation after operation of a trip device (e.g. speed limitation) shall have an appropriate SIL/PL for the application.

When protective equipment is unsuitable for a particular application, other protective measures such as mechanical guards can be necessary; see ISO 12100.

4.3 Environmental characteristics

The functionality of protective equipment can be affected by environmental influences such as temperature, pollution, electromagnetic disturbance, radiation, etc. The degree to which environmental influences can affect the functionality of protective equipment depends on the sensing technology used by the protective equipment. Careful evaluation of the expected

environment and the suitability of the protective equipment for use in that environment is necessary during the selection process of protective equipment.

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

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

- electromagnetic interference;
 - electrostatic discharge;
 - radio frequency interference, for example mobile telephones;
- vibration/shock;
- light interference;
 - ambient light;
 - infra-red, for example remote controls;
 - reflective surfaces;
 - other ESPEs that can emit interfering light;
- pollution;
 - water;
 - dust;
 - corrosive chemicals;
- temperature;
- humidity;
- weather conditions;
- radiation.

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

- are used in the open air (i.e. outside buildings or other protective structures);
- use, process, or produce potentially explosive material (for example paint or sawdust);
- are used in potentially explosive and/or flammable atmospheres;
- have special risks when producing or using certain materials;
- are used in mines.

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

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

4.4 Uses of protective equipment

4.4.1 General

A protective equipment may be used to provide:

- trip function; or
- presence sensing function; or
- combination trip function and presence sensing function.

4.4.2 Trip function

4.4.2.1 Distance to the hazard

Where the protective equipment is used to provide a trip function, it shall be positioned at a sufficient distance from the 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.

This distance shall take into account:

- a) protective equipment detection capability in relation to human characteristics (see 4.5) including:
 - approach speed;
 - body part penetration/encroachment
 - reaching over or under the sensing zone;
 - possibility of circumvention, and
- b) the overall system stopping performance (see 3.1.29 and 4.4.2.2);
- c) in the case of moving parts of machines (for example punch presses, surface grinders) or moving work pieces that can reduce the separation distance, the minimum distance shall apply from the furthest extension of the moving part towards the direction of approach.

4.4.2.2 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.

4.4.2.3 Positioning of protective equipment or detection zone(s)

The positioning of protective equipment or detection zone shall be in accordance with ISO 13855.

In some applications, it can be necessary to consider the relative speed of a person and a moving machine, for example, an AGV.

Some protective devices require consideration of an additional safety distance caused by, for example, uncertainty of distance measurement. The accompanying documents of the protective device will give further information.

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 unauthorised 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.

Where an initial calculation of the minimum distance gives a result that cannot be accommodated, i.e., the calculated minimum distance is too great, the following can assist in achieving an adequate stopping performance in order to meet the requirements of ISO 13855:

- a) selection of protective equipment with a better detection capability or faster response time;
- b) reduction of the overall stopping time, e.g. by improved braking, reduced speed or inertia;
- c) reduction of the overall system response time, e.g. using hard-wired connections instead of a fieldbus, using components with a faster response time, reducing the number of interposing devices;
- d) using a different configuration of approach to reduce intrusion towards the hazard, e.g. raising ground-level trip devices so that the first stride allowance is reduced.

4.4.2.4 Supplementary protective measures

Supplementary protective measures shall be provided as necessary to ensure that:

- the hazardous zone of the machine can be approached only through the detection zone of the trip device;
- unexpected start-up of the machine is prevented after a person has passed through the detection zone of the trip device to the hazardous zone of the machine.

Where such supplementary protective measures are necessary, they can include, for example:

- barriers to ensure that a person cannot approach the machine hazard from directions not protected by the protective equipment;
- provision of a restart interlock;
- provision of a presence sensing device;
- measures to prevent a person being present between the protective equipment and the hazardous zone.

If additional measures (for example obstacles) are used to prevent a person being present between the protective equipment and the hazardous zone, and if the additional measures are designed to be removable, then they shall be interlocked with the safety-related control system so that hazardous machine movement is not possible if the additional measures are not present.

If it is possible for a person to pass through the detection zone of a trip device and, when behaving in a foreseeable manner, attain a position that is hidden from the location of the reset control, supplementary protective measures (for example, time-limited additional reset control inside the safeguarded area (see 5.2.2 of ISO 13849-1:2015), presence sensing device, trapped-key system), shall be provided to prevent resetting the restart interlock when a person or part of a person is inside the safeguarded area.

4.4.3 Presence sensing function

Where the protective equipment is used to provide a presence sensing function, the machine shall remain in a non-hazardous state when a person or part of a person is present in the detection zone.

Supplementary measures shall be provided as necessary to ensure that the detection zone cannot be circumvented, for example by remaining between the detection zone and the hazardous zone or by reaching into the hazard zone. Examples of measures to prevent persons remaining between the detection zone and the hazard zone are:

- use of sloping surfaces to prevent standing on machine frame/feet, and
- making inside surfaces of fencing free of protrusions that can be climbed on.

When the protective equipment used as a presence sensing device depends on periodic testing for its safety performance, it shall be ensured that a test of the protective device is performed within an appropriate time before a person or part of a person can be in the hazardous area. If the test is not successfully performed during the predetermined time, the protective equipment OSSD(s) shall go to the OFF state.

NOTE A sufficiently high frequency of automatic periodic test can be considered to meet this requirement.

4.4.4 Combination trip and presence sensing function

Where the protective equipment is used to provide a combination trip and presence sensing function, the requirements of 4.4.2 and 4.4.3 apply.

4.5 Human characteristics

4.5.1 General

The human characteristics that shall be taken into account when selecting protective equipment are:

- approach speed and direction;
- part of human anatomy (for example finger, hand, leg, whole body) to be detected;
- human interaction with the machine, including foreseeable misuse, see ISO 12100:2010 5.4.a) and 5.4.c)).

These factors will also determine the positioning of the protective equipment. See 5.1.

4.5.2 Approach speed (K)

Approach speeds are specified in ISO 13855 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.

4.5.3 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 similar to 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.

4.5.4 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.

Where other protective measures are necessary to meet this requirement, they can include for example fixed or interlocking guards or screens or additional protective equipment.

When it is foreseeable that a person can circumvent the detection zone of a presence sensing device, for example by climbing on a machine, then additional protective measures shall be implemented. Examples of such measures can include, but are not limited to:

- modification or shielding of the machine such that climbing on it is not possible,
- manual restart interlock with good visibility to all hazard zones which can be entered after leaving the detection zone.

4.6 Protective equipment characteristics

4.6.1 ESPEs

4.6.1.1 Types of ESPEs

This standard considers ESPEs using the following sensing technologies:

- Active Opto-electronic Protective Devices (AOPD) consisting of light curtains and single or multiple light beam devices as specified in IEC 61496-2;
- Active Opto-electronic Devices operating by Diffuse Reflection (AOPDDR) as specified in IEC 61496-3.
- Vision Based Protective Devices (VBPD) using image sensing devices as specified in IEC TS 61496-4-2 or IEC TS 61496-4-3.

4.6.1.2 AOPD

An AOPD uses the principle of interruption of one or more light beams between its emitter and its receiver. When an opaque object (for example a person or part of a person) interrupts a light beam, the receiver no longer receives the emitted light and an output signal is generated. This principle is illustrated in Figure 3.

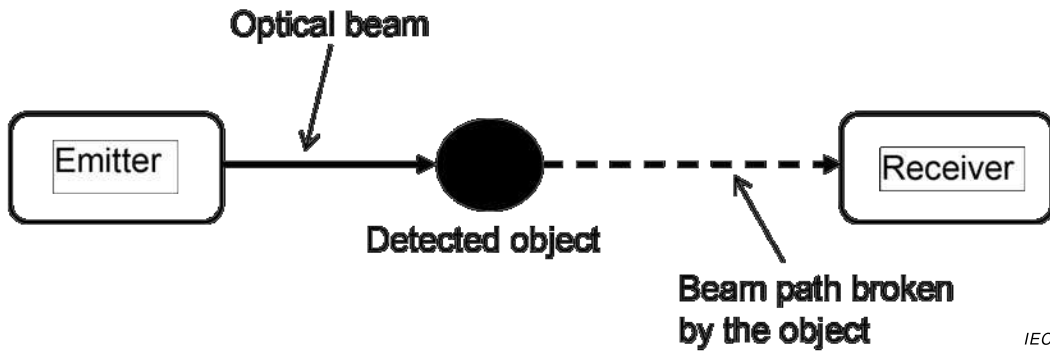


Figure 3 – Detection principle of through-beam AOPD

Through-beam devices can be used on opposing sides of a protected opening or the path can be configured by the use of mirrors to surround an area as shown in Figure 4.

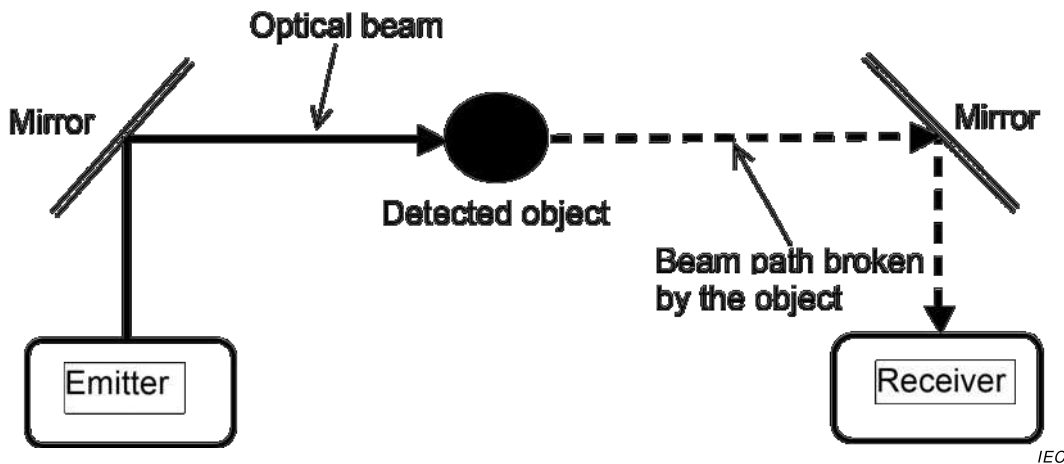


Figure 4 – Through-beam AOPD using mirrors

Retro-reflective devices use a retro-reflector to reflect the emitted light back to the receiver as shown in Figure 5.

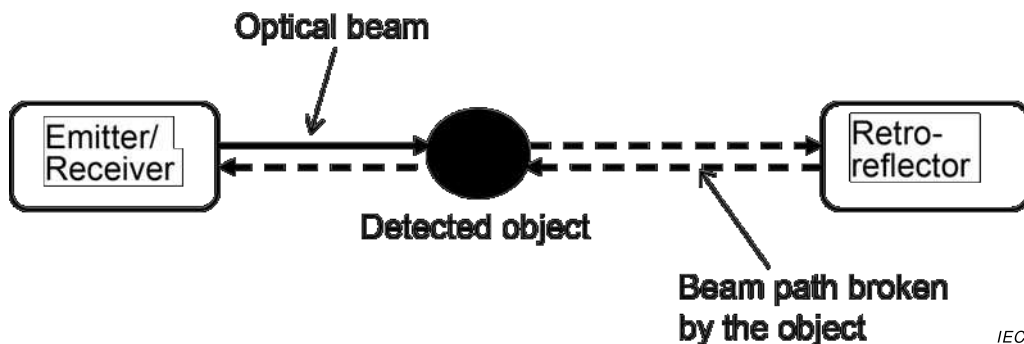
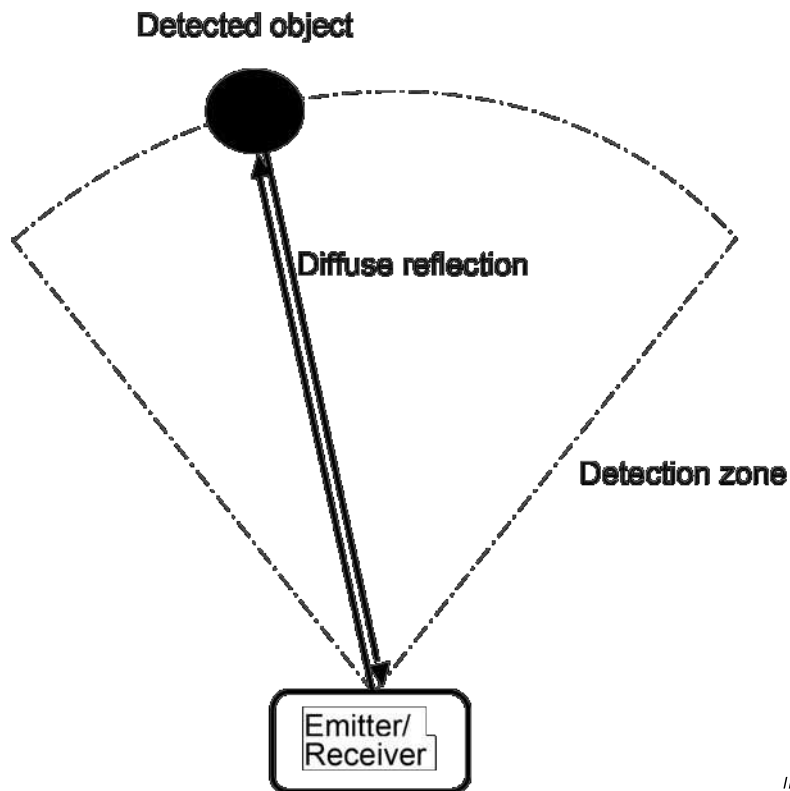


Figure 5 – Retro-reflective AOPD

4.6.1.3 AOPDDR

An AOPDDR includes an emitter and a receiver, usually in the same housing.

The emitted light is reflected back from an object by diffuse reflection and the AOPDDR determines the location of the object. When an object is detected within the defined detection zone, an output signal is generated. This principle is illustrated in Figure 6. A tolerance zone outside of and adjacent to the detection zone is necessary to achieve the required probability of detection of the specified test piece(s) within the detection zone.



IEC

Figure 6 – Detection principle of AOPDDR

An AOPDDR receives reflected light from the object, therefore an emitter fault (no light emission) or a receiver fault leads to loss of detection. The fault detection function of the AOPDDR causes a lock-out condition within the specified response time.

The detection zone can usually be configured into various shapes to take into account stationary obstacles and avoid the unwanted generation of an output signal that leads to an OFF-state of the AOPDDR. AOPDDRs can be used as combined trip and presence sensing devices to stop a machine when a person approaches it and to prevent the start-up of a machine while a person is in the hazardous zone.

4.6.1.4 VBPDs

4.6.1.4.1 VBPST

A VBPST consists of a sensing device with mechanically fixed distances (stereo base) and directions between at least two imaging devices.

The detection principle is based on the evaluation of images from the imaging devices (stereoscopic view) for the determination of distance information. This distance information is used to determine the location of an object(s). When an object or a person is detected within a predefined 3D detection zone an output signal is generated.

The principle is illustrated in Figure 7.

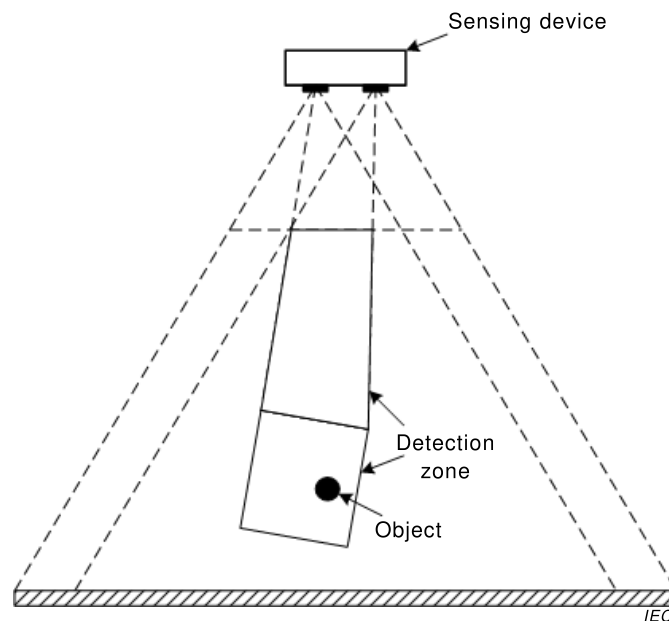


Figure 7 – Detection principle of VBPDSST

The 3D detection zone is usually configured by a software configuration program which allows various shapes of the detection zone. The VBPDSST detects objects entering into or being present in a 3D detection zone.

NOTE Requirements for VBPDSST are given in IEC TS 61496-4-3.

4.6.1.4.2 VBPDP

A VBPDP is defined as consisting of a single image-sensing device viewing on a passive reference pattern as the background and where the detection principle is based on blocking or partially preventing the view of the pattern. Information about the thickness, shape, surface characteristics or location of the object is not required for detection.

NOTE Requirements for VBPDP are given in IEC TS 61496-4-2.

4.6.2 Pressure sensitive mats and floors

Pressure sensitive mats and floors are actuated by the weight of a person on the mat or floor. They generate a signal by the use of, for example, mechanical contacts, fibre-optic sensors. Requirements for pressure-sensitive mats and floors are given in ISO 13856-1.

4.7 Optional machine control system functions associated with the application of protective equipment

4.7.1 General

Machine control system functions that can be required for specific applications include stopping performance monitoring (SPM), muting, blanking, single/double break actuation, start interlock and restart interlock, and external device monitoring (EDM). These control system functions are explained in 4.7.2 to 4.7.8.

These control system functions are optional depending on the application and may or may not be provided by the ESPE.

4.7.2 Stopping performance monitoring (SPM)

The SPM provides signals to the protective equipment related to the time taken by, and/or the amount of travel of, the hazardous parts of the machine in coming to a safe condition (for example, a stop).

NOTE Requirements for stopping performance monitoring are given in Clause A.3 of IEC 61496-1:2012.

4.7.3 Muting

4.7.3.1 General

Muting is a temporary automatic suspension of a safety function by the machine safety-related control system. It can be used to allow access by persons or by materials:

- during a non-hazardous portion of the machine cycle, or
- when safety is maintained by other means.

4.7.3.2 Mute dependent override function

Mute dependent override function allows a manual operation of the machine in order to remove material stopped in the detection zone of the protective equipment.

4.7.4 Reinitiation of machine operation by the protective equipment

In some applications, in addition to its safeguarding function, the protective equipment can be used to reinitiate cyclic operation of a machine. The following modes of re-initiation are defined in IEC 61496-1:2012:

- single break, where an actuation and de-actuation of the sensing device reinitiates machine operation;
- double break, where two consecutive actuations and de-actuations of the sensing device reinitiate machine operation.

4.7.5 Start interlock

A start interlock is a means of preventing automatic starting of hazardous operation of a machine when the power supply is switched on, or is interrupted and restored. The start interlock is reset by a deliberate human action.

4.7.6 Restart interlock

A restart interlock is a means of preventing automatic restarting of hazardous machine operation after one or more of the following:

- actuation of a safeguarding function,
- a change in operating mode of the machine,
- a change in the means of start control of the machine.

NOTE Modes of operation include inch, single stroke, automatic. Means of start control include foot switch, two-hand control, and single or double actuation of the electro-sensitive protective equipment (ESPE) sensing device.

The restart interlock is reset by a deliberate human action.

4.7.7 External device monitoring (EDM)

External device monitoring (EDM) can be used to detect failure of devices in the stopping/starting circuit, such as final switching devices and machine primary control elements (contactors, pneumatic valves, hydraulic valves).

4.7.8 Provision of machine control functions

Those functions described in 4.7.2 to 4.7.8 can either be provided as part of the protective equipment or can be built into the machine safety-related control system. When provided as part of an ESPE in accordance with IEC 61496, the requirements for these functions are given in Annex A of the appropriate part of IEC 61496. When supplied as part of the machine safety-related control system, see IEC 62061 and ISO 13849 (all parts) for requirements. See Clause 5 for application and interfacing requirements.

Care should be taken to ensure that the provision of additional switching outputs or functions external to the protective equipment (for example by external modules) does not reduce the performance of the protective equipment below that required for the risk reduction.

5 General application requirements

5.1 Positioning and configuration of the protective equipment detection zone

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. presence sensing function, trip function, or combined trip and presence sensing function (see 4.4).

The selection, positioning and configuration of the protective equipment detection zone shall be determined taking into account:

- machine characteristics (see 4.2);
- environmental characteristics (see 4.3);
- human characteristics (see 4.5);
- protective equipment characteristics (see 4.6);
- intended interaction of personnel.

Adjustments of the configuration of the protective equipment application shall require the use of means to restrict both unauthorised and inadvertent adjustment such as a key, keyword or tool. The restriction needed will depend on the application, see Clause 5 of ISO 12100:2010.

Protective equipment shall be securely held in place. The fastenings shall have means to avoid inadvertent or unintended loosening.

5.2 Integration with the safety-related control system

The protective equipment shall be connected to the control system and configured in accordance with the manufacturer's instructions and shall meet the safety requirements specification of the safety-related control system. Further information is given in ISO 13849 (all parts) and IEC 62061.

When the application requires a change or selection of the ESPE detection zone during run-time, the part or parts of the control system that execute the change or selection shall have an appropriate safety-related performance (SIL or PL, see IEC 62061 or ISO 13849-1) such that they do not adversely affect the safety-related performance of the protective function.

When using a safety-related communication system (fieldbus), the overall system response time used for calculation of the minimum distance shall take into account the worst-case response time of the communication system. This response time can vary depending on the protocol, architecture, and configuration of the communication system (See also IEC TR 62513).

5.3 Performance of protective equipment

5.3.1 General

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

Only persons with suitable experience and knowledge should select and install protective equipment. Particular care is necessary when considering features that can affect the detection capability, such as reduced resolution, blanking, muting, change of detection zones.

5.3.2 Classification of protective equipment

5.3.2.1 Classification of ESPE

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 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.

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

5.3.2.2 Type 2 ESPE periodic test duration

The duration of the periodic test of a Type 2 ESPE shall be taken into account to ensure that it is not possible for a person to enter a hazardous zone during the functional test without being detected. The periodic test duration shall not exceed 150 ms.

5.3.2.3 Classification of pressure-sensitive mats

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

Where the category of the mat system requires that a periodic functional test is performed, the duration of the functional test shall be taken into account to ensure that it is not possible for a person to enter a hazardous zone during the functional test without being detected. A restart interlock should be considered if the test duration can exceed 150 ms. When taking into account the maximum test duration, the overall response time shall not exceed 200 ms.

5.3.2.4 Relationship with the risk assessment

5.3.2.4.1 Overview

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

The safety performance of the protective equipment 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.

NOTE 1 The overall risk for each hazard depends on the severity of possible injury and the probability of occurrence of a hazardous condition. This probability of occurrence depends on the frequency of exposure, the duration of exposure, and the possibility of avoidance.

NOTE 2 The risk reduction contribution required from the protective equipment will depend on the overall risk, the degree of tolerable risk, and the level of risk reduction contribution by other protective measures. The risk reduction contribution provided by the protective equipment will depend on the sensing technology.

Reference to “low”, “medium” or “high” in the following list refers to the risk reduction contribution by the protective equipment.

- Type 2 ESPEs can fail to danger as a result 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 and Type 4 ESPEs can be suitable for applications demanding a medium to high risk reduction when their sensing technology is appropriate.
- The performance level of pressure sensitive mats shall be as required for the relevant safety-related control function contributing to the risk reduction.

Where the safety performance of the protective equipment is dependent on periodic testing (e.g. Type 2 ESPEs, Category 2 mat systems), 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 equipment supplier states fault exclusion(s) in their instructions for use, the integrator of the protective equipment shall take the fault exclusion(s) into account.

5.3.2.4.2 Target PL or SIL

A SILCL (SIL claim limit, 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), behaviour under fault conditions, etc.

5.3.2.4.3 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 PFHd value provided by the manufacturer. The device dependent PFHd values claimed for the control electronics is not restricted (for example, a manufacturer may claim a PFHd 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.

EXAMPLE If a safety function of SIL 2 is required for a system using an AOPD, from Table 1, it can be seen that a Type 2 AOPD does not meet the requirement. A Type 4 AOPD will be selected because there is no definition of Type 3 AOPD in the product standard.

5.4 Stopping performance monitoring (SPM)

Stopping performance monitoring can be necessary where stopping performance can be subject to deterioration (for example due to wear of friction brakes, pneumatic valves, hydraulic valves) leading to a hazardous situation (for example on cyclic hand-fed machines).

Stopping performance monitoring shall be provided unless one or more of the following conditions are met:

- it has been established that the stopping performance is consistent and not subject to deterioration;

NOTE As a guide, unless it can be assured that under maximum load conditions the overall system stopping performance will not deteriorate by more than 10 % over the life of the machine or over the period between thorough examinations by a competent person, stopping performance monitoring can be necessary.

- there is low frequency of demand on the stopping system (i.e. the machine stops infrequently);
- the risk assessment shows that there is no risk of serious injury even if the stopping performance deteriorates;
- the design and rating of the stopping system are adequate and an effective maintenance regime is implemented;
- stopping performance is tested at suitable intervals.

Monitoring of the stopping performance shall take place each time the machine stops, whether the stop is initiated by actuation of the protective equipment or by normal operation.

The stopping performance monitor shall prevent further machine operation when the overall system stopping performance exceeds that used for calculation of the minimum distance.

5.5 Start interlock

A start interlock shall be provided except where the risk assessment shows that the possibility of injury will not be reduced by a start interlock, for example when start interlock is already provided by other parts of the machine control system.

It shall not be possible to reset a start interlock from inside the hazardous zone.

5.6 Restart interlock

A restart interlock shall be provided except where the risk assessment shows that the possibility of injury will not be reduced by a restart interlock, for example when it is not possible for a person or part of a person to be in the hazardous zone without being detected.

Particular care should be taken in the risk assessment for mobile machines, for example where it can be possible to climb on the machine so that the protective device is not activated.

Consideration should be given to the possibility of exiting and re-entering the hazardous zone without detection via the structure of the machine or by other foreseeable methods.

It shall not be possible to reset a restart interlock from inside the hazardous zone.

A restart interlock shall be provided where protective equipment is used as a trip device for perimeter guarding.

A restart interlock shall not have a time delay greater than 0,5 s between the manual reset (e.g. press and release of a pushbutton) and the resumption of protective device operation, i.e. the OSSD(s) in the ON state.

Resetting a restart interlock of an ESPE application is always a safety-related function. Measures shall be provided to reduce the probability of the restart interlock being reset by a transient or steady-state fault condition. Such measures can include, for example, requiring both a rising and falling edge signal within a defined time (e.g. between 150 ms and 4 s) from a manually actuated reset device.

NOTE Further information can be found in ISO 13849-1:2015, Subclause 5.2.2.

5.7 Muting

5.7.1 General

Muting shall only be provided when it is necessary for the process being performed on the machine.

When an indicator is provided to show that the muting function is active, it should be considered whether the provision of the mute indicator can lead to improper attempts to access the hazardous zone.

The muting function shall be initiated and terminated automatically. This shall be achieved by the use of appropriately selected and placed sensors or by signals from the machine control system. Incorrect signals, sequence, or timing of the muting sensors or signals shall not allow a mute condition.

NOTE When muting is performed externally to the protective equipment, the OSSDs of the protective equipment continue to operate but do not cause interruption of machine operation.

The part or parts of the control system that performs the muting function shall have an appropriate safety-related performance (SIL or PL, see IEC 62061 or ISO 13849-1) and shall not reduce the safety-related performance of the protective function below that required for the application.

It shall not be possible to initiate the muting function when:

- the protective equipment OSSDs are in the OFF-state;
- the protective equipment is in the lock-out condition.

Interruption and/or restoration of the power supply to the protective equipment and/or the muting sensors shall not initiate muting or allow a muted condition to continue. Any fault in the muting circuit shall not initiate a muted condition.

It shall not be possible for muting to be initiated by an earth fault or open-circuit of the signal lines or the power supply to the muting sensors.

Where the muting function is only available in certain operating mode(s) of the machine, selection of the mode in which the muting function can be initiated shall require the use of a key, keyword, or tool.

Manual adjustment of the position or timing at which muting occurs shall require the use of a key, keyword, or tool.

When the muting function is provided, the following requirements apply:

- initiation of the muting function by two or more independent muting signals such that a single fault cannot cause a muted condition;

- termination of the muting function when any of the muting signals maintaining the function is deactivated;
- use of timing and/or sequence control of the muting signals to ensure correct muting operation;
- protection against inadvertent initiation of muting or continuous muting due to mechanical damage and/or misalignment of muting sensors;
- provision of measures to prevent circumvention of the protective equipment;
- protection against foreseeable misuse including manipulation.

In addition, the following are recommended (see also Annex D):

- initiation and/or termination of the muting function only at the appropriate times in the operating cycle, for example by provision of a mute enable signal in addition to the two or more muting signals;
- consideration of possible trapping and crushing hazards from the material being transported.

Measures shall be provided to reduce the probability of faults causing initiation or continuation of muting. These can include:

- separation of the cabling from each sensor to the muting controller;
- mechanical protection of the muting sensor cabling;
- detection of short-circuits between the muting signals, for example by detection of a simultaneous change of state of the muting signals.

Applications in which the muting time is long (for example greater than 1 hour) should be avoided. Where this is not practicable, additional measures shall be provided to reduce the probability that an accumulation of faults in the muting system leads to the loss of the protective function of the protective equipment. Examples of measures that can be suitable are:

- provision of a mute enable signal;
- termination of the muted condition when the protective field is cleared and prevention of a subsequent muting cycle until a correct muting sequence is performed;
- use of muting sensors with a test function that can reveal faults during the muted condition, for example diffuse reflective sensors with a test input. The test frequency should be related to the duration of the muting period such that the probability of undetected failure before the muting period ends is acceptable.

When an additional hardware input signal (e.g. from a conveyor) is used as a mute enable signal, this input should be monitored for at least one change of state within an appropriate time to ensure it is not the result of a fault.

5.7.2 Muting to allow access by persons

Muting may be used to allow access by a person or part of a person, only:

- during a non-hazardous portion of the machine cycle (for example a non-hazardous opening stroke of a press), or
- when safety is maintained by other means (for example for machine setting under reduced speed or power),

in order, for example, to remove/replace a workpiece.

5.7.3 Muting to allow access by materials

Muting may be used to allow access by materials only when safety is maintained by other means, for example when the presence of a loaded pallet on a conveyor prevents access to the hazardous zone by persons.

The following measures shall be provided where applicable (see informative Annex D):

- selection, positioning and configuration of the muting sensors to distinguish a person from the material that is allowed to pass through the detection zone;
- selection and positioning of the muting sensors to detect the load being conveyed but not the pallet or the transport unit, to prevent people from entering the zone by climbing onto the pallet or the transport unit;
- detecting that the goods that have to be conveyed are obstructing the access to the hazardous zone;
- installing the muting sensors sufficiently close to the ESPE so that it is not possible for persons to enter the hazardous zone undetected by immediately preceding or following the pallet or the transport system while the muting function is active;
- positioning of the ESPE or muting sensors to avoid the risks arising from the possibility of trapping of body parts, for example between the ESPE or muting sensors (or the fixed elements of the installation) and a transport unit or the product. (Example of a solution: flexible, 500 mm swing doors monitored by position sensors);

NOTE Information on minimum gaps to avoid crushing is given in ISO 13857.

- designing the access to the hazardous zone so that it is not possible for persons to enter undetected by passing through the gap between the load being conveyed and the fixed elements of the installation while the muting function is active and the product or transport unit is moving or stationary in the muting area (trapping and crushing hazards should also be considered);

limiting muting to a time that is only sufficient for the material to pass through the detection zone. When this time is exceeded, the muting function shall be cancelled and all hazardous movements stopped.

When none of these measures are applicable, muting shall not be applied.

5.7.4 Mute dependent override

5.7.4.1 General

In applications where muting is used to allow access by materials, a manually operated, mute dependent override function can be necessary to allow blockages to be removed from the detection zone of the protective equipment.

When the muting function is cancelled due for example to an incorrect muting sequence or a timeout, resulting in a product or transport unit stopped in the detection zone of the ESPE or of the muting sensors, all dangerous machine operations shall be stopped. The mute dependent override function is used to clear the detection zone so that the ESPE can be reset. Restarting the machine shall only be possible by means of a deliberate action.

EXCEPTION In the special case of exit-only muting application, the override function may also be allowed when the ESPE is in the OFF-state but no muting sensor is activated.

The mute dependent override function should only enable those movements that are necessary to permit blockages to be removed from the detection zone of the protective equipment.

In some applications, resuming normal operation after a mute dependent override can require a separate restart interlock.

Mute dependent override shall only be effective on the protective equipment that requires it. It shall not impair the effectiveness of other safety functions.

5.7.4.2 Initiation

The mute dependent override function shall not be available unless at least one of the muting sensors is actuated and the detection zone is obstructed.

Measures shall be provided to prevent initiation of the mute dependent override function due to a fault or inadvertent operation of the initiating device.

The mute dependent override function shall only be initiated by one of the following:

- when the muted ESPE and the hazardous zone are visible from the position where the override is initiated, by the use of a hold-to-run device located so that it is not possible to enter the hazardous zone whilst maintaining the action on the hold-to-run device, or,
- when the muted ESPE and the hazardous zone are visible from the position where the override is initiated, by the actuation and release of a momentary actuated device initiating a maximum override time determined by a risk assessment, or,
- when the hazardous zone is not visible from the position where the override is initiated, by the use of a spring return key operated switch (or equally secure momentary action pushbutton) located so that it is not possible to enter the hazardous zone while maintaining the action on the switch when:
 - the muted ESPE is visible from the position where the override is initiated; and
 - the area safeguarded by the ESPE can be inspected before initiation of the override; and
 - no access to the hazardous zone is possible during the override sequence; and
 - an emergency stop can be initiated from the same position.

Activation of the mute dependent override function shall not initiate movement. Initiation of movement shall be by a separate actuation of a control that may be performed by the same device, e.g., a momentary actuation of a pushbutton activates the override function, followed by a sustained action on the pushbutton which then initiates movement.

NOTE This can help reduce the possibility of a permanent override caused by a fault or manipulation of the hold-to-run device.

5.7.4.3 Termination

The mute dependent override function shall automatically terminate when any of the following conditions occur:

- all the muting sensors are de-actuated and the detection zone of the ESPE is clear;
- a pre-determined time limit has expired;
- the hold-to-run device is released;
- a lock-out condition is detected.

Termination of the mute dependent override function need not stop the conveyor, provided no hazardous situation can occur.

5.8 Reinitiation of machine operation by the protective equipment

The use of this function is restricted to applications using type 4 AOPDs used as a combined trip and presence-sensing device. Reinitiation of cyclic operation by the protective equipment shall only be considered for single-operator, hand-fed machines having repetitive, short cycle time operations.

This function requires that the AOPD is actuated and de-actuated in order to reinitiate operation of a machine.

If there is more than one AOPD safeguarding the machine, only one of them at any one time shall be capable of cycle reinitiation. Following a change of which AOPD is capable of reinitiation of cyclic operation, a restart performed by a deliberate manual action shall be necessary.

NOTE 1 In the case of cascade configuration of AOPDs with a common OSSD, this configuration is considered as only one AOPD.

The protective equipment shall not be the only means of initiating machine operation. Conventional machine start controls (for example pushbuttons, foot pedals) and appropriate mode selection (guard-only, single break re-initiation, double break re-initiation) of the protective equipment using, for example a key operated switch shall be provided.

NOTE 2 The term “guard-only” is used here to refer to a mode in which the ESPE is not used to reinitiate machine operation but solely to provide the protective function.

A start interlock and a restart interlock shall be provided.

To reduce the possibility of unexpected re-initiation, the detection capability of the protective equipment shall be not greater than 30 mm for hand detection or 50 mm for leg or whole body detection.

It shall not be possible for persons to pass through the detection zone towards the hazardous zone and so cause reinitiation of machine operation (see 4.4.2). This can require the use of additional protective measures. When this is achieved by the use of removable mechanical guards they shall be interlocked with the control system so that their removal stops the machine and prevents restarting until a manual restart has been performed.

Access to the hazardous zone shall not be possible without actuating the AOPD. The possibility of actuation of the protective equipment by the workpiece should also be considered. When single break or double break is selected, the operation conditions shall be as follows:

The first cycle of the machine shall be initiated using a conventional start control. Further cycles will be initiated after a set number of actuations and de-actuations of the AOPD, depending on which operating mode is selected (e.g. single or double break)”. Any actuation of the protective equipment during hazardous operation shall initiate a restart interlock requiring a conventional manual restart of the machine.

Machine operation shall be reinitiated as soon as practicable after the de-actuation of the AOPD and within a time commensurate with the cycle time of the machine.

When the reinitiation does not occur within the expected time, the protective equipment shall initiate a restart interlock. This time should be as short as practicable.

Reinitiation shall only occur when the duration of actuation of the protective equipment is not less than 100 ms.

Means shall be provided to prevent reinitiation during setting, maintenance and similar non-production operation modes.

A functional check of the reinitiation function is recommended before starting to use reinitiation by single break or double break.

NOTE 3 In some countries the functional check is a legal requirement.

6 Particular application requirements for specific protective equipment

6.1 AOPDs

6.1.1 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 Figure 8.

NOTE Application examples are given in Annex C.

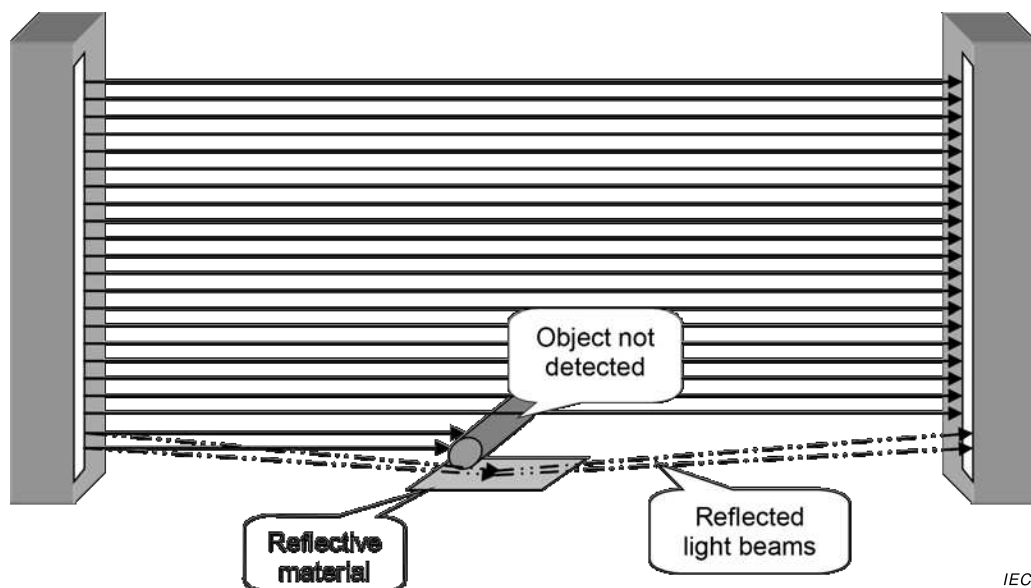


Figure 8 – Example of the effect of reflective surfaces

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.

6.1.2 Light beam device(s)

6.1.2.1 General

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 Table 2 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 6.2.2 a) of ISO 13855:2010), 400 mm shall only be used when the risk assessment allows it.

Table 2 – 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.

6.1.2.2 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 codes;
- 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.

6.1.2.3 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 Figure 9). For multiple light beam devices, the value used shall be the larger of (see Figure 10):

- 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.

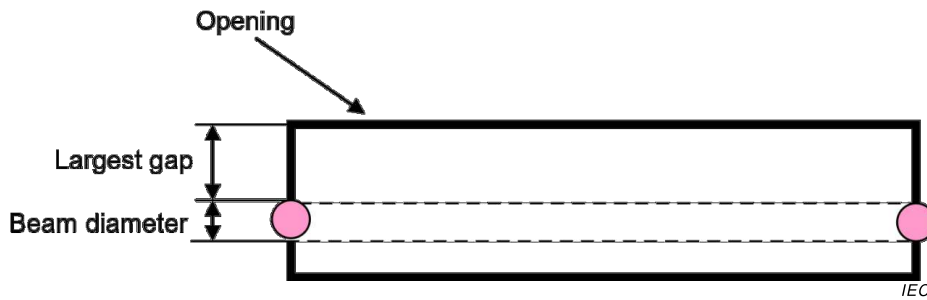


Figure 9 – Detection capability of single light beam device

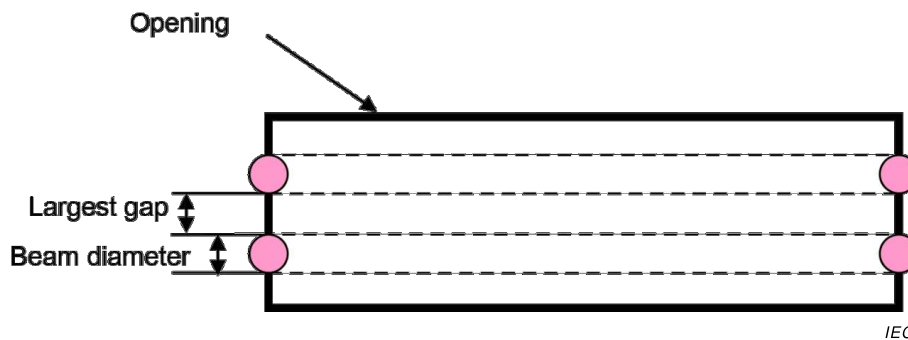


Figure 10 – Detection capability of a multiple light beam device

6.1.3 Light curtains

6.1.3.1 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 protective field.

6.1.3.2 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 codes;
- 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.

6.1.3.3 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 Figure 11). The part or parts of the control system that perform the interlocking of the removable guards shall have an appropriate safety-related performance (SIL or PL, see IEC 62061 or ISO 13849-1). The specified detection capability of the AOPD can be used to calculate the minimum safety distance only when:

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

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

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

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

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

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

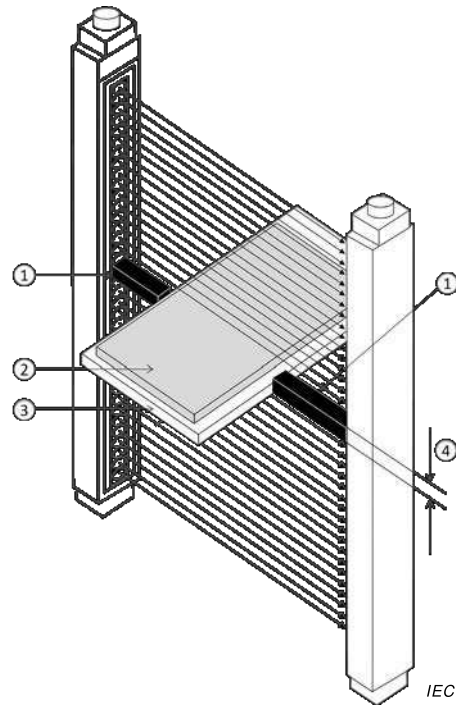
If, for a particular application, it is necessary to activate the blanking function only for a part of the machine cycle, the blanking function shall be initiated and terminated automatically. This may be achieved by the use of appropriately selected and placed sensors or, in some cases, by signals from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

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

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

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

The installation shall be such as to minimize the possibility of loss of detection capability caused by reflective surfaces in the blanked zone (see also 6.1.1).



Key

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

Figure 11 – Example of use of blanking

6.1.3.4 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. Figure 12 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.

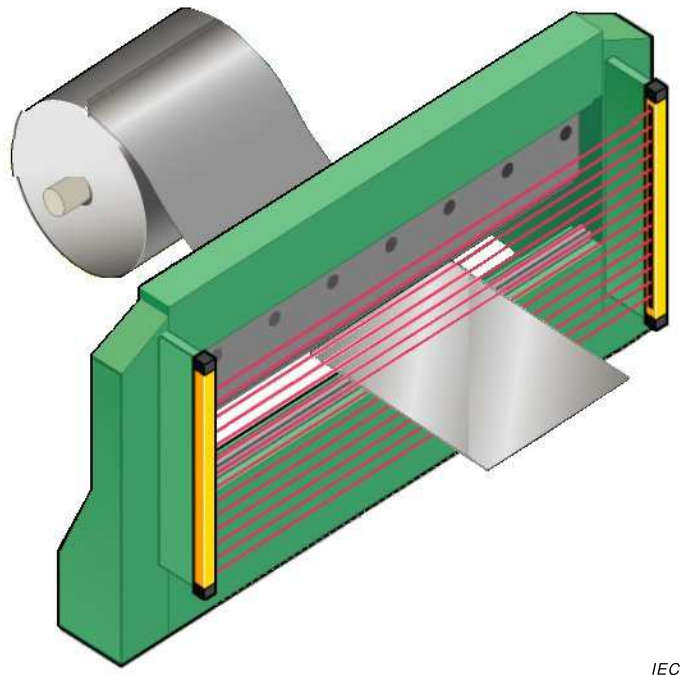


Figure 12 – Example of reduced resolution

6.2 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 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 OSSDs to the OFF-state. (See annex B4)

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

- the detection zone fully covers the hazardous zone;
- no shadow zones are created behind objects, that can allow persons to approach closer to the danger 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;
- changing floor or ground conditions (e.g. water, oil or ice present occasionally) that can influence the stopping distance;
- the hazardous zone moves together with the machine (the primary hazard is the impact or crushing caused by the moving machine);
- the direction of approach of an object can vary, for example due to changes in direction of movement of the vehicle;
- the direction of approach of a person can vary due to changes in direction of movement of the vehicle and/or the person;
- if the machine moves over uneven surfaces, the effective height of the detection zone can vary from its intended position;
- different speeds of movement shall be considered, for example:
 - speed of the machine (and AOPDDR);
 - relative speed of the machine and the object to be detected, for example
 - person,
 - bicycles,
 - forklift trucks,
 - other vehicles.

6.3 Vision based protective devices VBPD

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

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

- the detection zone fully covers the hazardous zone;
- no shadow zones are created behind objects, that can allow persons to approach closer to the danger zone than the calculated minimum distance;
- the VBPD manufacturer's instructions regarding lightning and background requirements are followed;
- the manufacturer's instructions for setting the detection zone(s) (e.g. minimum size of the detection zone) including consideration of the tolerance zone(s) are followed;
- the manufacturer's 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 followed;
- the manufacturer's instructions about zone(s) with limited detection capability shall be taken into account;
- the manufacturer's instructions about installation of the VBPD (e.g. limitation of angle or, height) are followed.

NOTE Application examples are given in Annex C.

6.4 Pressure-sensitive mats and floors

6.4.1 Pressure sensitive floors

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

6.4.2 Pressure sensitive mats

6.4.2.1 Selection criteria

Pressure sensitive mats are devices whose upper surface is deformable and that detect the 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.

6.4.2.2 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.

6.4.2.3 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.

6.4.2.4 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.

6.4.2.5 Infrequent actuation

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

6.4.2.6 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 sensing field;
- 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.

6.4.2.7 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 hazardous zone.

7 Inspection and test

7.1 General

The following tests can be applied to ensure that the protective equipment operates as intended:

- a) initial inspection and test after installation or modification. The integrator shall perform an initial inspection and test to validate the intended risk reduction is achieved, as defined in the information of use. (see 7.4),
- b) periodic inspection and test at suitable intervals or after repair (see 7.3),
- c) functional checks to ensure that the machine and protective equipment continues to operate safely between periodic inspections and tests (see 7.2).

The information for use shall specify the procedures that shall be used to perform the tests described in 7.2 and 7.3.

7.2 Functional checks

Functional checks shall be carried out on a frequent (e.g. daily) basis, depending on the risk assessment for the application. These checks shall be carried out by a suitably trained person. The checks shall include:

- a) check that the protective equipment including muting sensors (where applicable), wiring, etc. is securely mounted in position and there are no signs of modification, damage or deterioration;
- b) a check that access to the dangerous parts of machinery is only possible by actuation of the protective equipment, and that additional mechanical protection such as side and rear guards are in place and undamaged;
- c) a check of the effectiveness of the protective equipment with power on but with the machine at rest as follows:
 - 1) first establish that the protective equipment is functioning by checking the state of the appropriate indicators, and ensure that the protective equipment is not muted;
 - 2) insert the appropriate test piece into the sensing field of the protective equipment.
 - i) when an AOPD is used, the test piece shall be passed very slowly down the light curtain in three separate places: close to one transmitter/receiver column, close to the other transmitter/receiver column, and in the middle of the light curtain. The indicator light that indicates actuation (interruption) of the protective equipment (e.g. light curtain) shall change state whenever the test piece enters and leaves the protective equipment (light curtain) and shall not change state for the whole time the test piece is in the detection zone;
 - ii) when a pressure-sensitive mat or floor is used, actuate the mat/floor at several places (e.g. by standing on it) and check that the mat/floor functions (e.g. by observing indicator lights);
 - iii) when an AOPDDR is used, insert the test piece into the detection zone at various points around the boundary of the detection zone. The indicator light that indicates actuation of the AOPDDR shall change state whenever the test piece enters and leaves the detection zone and shall not change state for the whole time the test piece is in the detection zone. This check shall be performed for all the available detection zones.

Where those tests are not appropriate, the equivalent test(s) specified by the manufacturer of the protective device shall be carried out.
- 3) when the protective equipment is used as a trip device, initiate machine operation and insert the test piece into the detection zone of the protective equipment. The test piece shall only be inserted in the detection zone avoiding entering the hazard zone. Upon insertion of the test piece during hazardous operation, the dangerous parts of the machine shall come to rest, or to an otherwise safe condition, without apparent delay;
- 4) when the protective equipment is used as a presence sensing device, insert the test piece into the detection zone of the protective equipment and attempt to initiate machine operation. The test piece shall only be inserted in the detection zone as far away as possible from the hazard zone. It shall not be possible to initiate hazardous operation while the protective equipment is actuated.

- 5) In the case of pressure-sensitive mats or floors, a weight shall be used to actuate the mat/floor to avoid standing near the hazard zone during the test.

7.3 Periodic inspection and test

The period between each periodic inspection and test will depend on the machine it is fitted to and the risk reduction provided by the protective equipment but in general should not be greater than twelve months, unless otherwise stated in local regulations.

The results of the inspection and test shall be recorded and a copy of this record kept by the user.

The person carrying out the inspection and test shall ensure that the same general standards of performance are achieved as in the initial inspection and test.

The periodic inspection and test shall include:

- a) the functional tests as described in 7.2;
- b) check that the protective equipment is securely mounted in the position determined in commissioning;
- c) if the protective device is used as a presence sensing device, check that it is not possible for a person to stand between the sensing field of protective equipment (e.g. light curtain) and the danger zone;
- d) check by measurement that the overall stopping performance is within the limits specified by the integrator;
- e) a check that the distance from the hazard zone to the sensing field of the protective equipment is the same as the distance stated by the integrator/manufacturer;

NOTE A difference between the stated value and the measured value is an important indicator of a change or modification in the machine which can adversely affect the safeguarding function.

- f) ensure that it is not possible for a person to stand between the protective equipment and the danger zone without being detected unless a restart interlock is provided;
- g) visual check of the machine primary control elements (MPCE) to ensure that they are functioning correctly and are not in need of maintenance and/or replacement;
- h) visual check of the machine to ensure that there are no other mechanical or structural aspects that would prevent the machine from stopping or assuming an otherwise safe condition when called upon by the protective equipment to do so;
- i) visual check of the machine controls and connections to the protective equipment to ensure that no modifications have been made which might adversely affect the system;
- j) perform the application specific tests as described in 7.5 where applicable.

7.4 Initial inspection and test

The initial inspection and test shall be performed by suitably qualified persons who possess, or have access to, all the technical information provided by the machine and protective equipment supplier.

The results of the initial inspection and test shall be recorded, and copies of this record shall be available to the user. The results of inspection and test following repair or modification shall also be recorded and copies shall be available to the user. The results should record the name of the person who conducted the test and the date.

NOTE 1 The record can be on paper or in an appropriate electronic format. A personal signature is not necessary.

The persons performing the inspection and test shall ensure that the following general standard of performance is achieved:

- a) it shall not be possible for the dangerous parts of the machine to be set in operation while any part of a person is detected by the protective equipment; and
- b) actuation of the protective equipment during a phase of the operating cycle when there is or can be a risk shall result in the machine being brought to a non-hazardous state before any part of any person can reach a hazard. It shall not be possible for the hazardous operation to recommence until the protective equipment has been completely restored to its normal condition and the machine manually restarted.

The persons carrying out the inspection and test shall also:

- c) carry out a periodic inspection and tests as described in 7.3;
- d) check the position of the protective equipment (e.g. light curtain) to ensure that it is set at a distance from the hazard zone according to 4.4.2.1
- e) ensure that additional safeguards have been provided where necessary to prevent access to the hazard zone from any direction not safeguarded by the protective equipment;
- f) measure the overall system stopping performance, and ensure that it is the same as, or less than, the overall system stopping performance that was used to determine the required position of the protective equipment;
- g) ensure by measurement that it is not possible for a person to stand between the protective equipment and the danger zone without being detected, unless a restart interlock is provided;
- h) verify that the protective equipment detection capability has the same value as that used to determine the required position of the protective equipment;
- i) check that the protective equipment suppliers recommendations regarding reflective surfaces near the detection zone have been complied with;
- j) inspect the machine controls and connections to the protective equipment to ensure that the machine and protective equipment designer's requirements are met;
- k) check each channel of a two channel system for correct operation;
- l) check that adjustments of the protective equipment that can result in an unsafe condition require the use of a key, keyword or tool;
- m) check all functions, including the operation of the start and restart interlocks where specified, are operable;
- n) check that the protective equipment is operative in all relevant modes of operation of the machine;
- o) when it is possible to deactivate the protective equipment, check that the hazardous machine operation ceases within the specified overall response time when deactivated;
- p) when transient suppression devices (e.g., RC, diode, varistor) are used, check that they are connected in parallel with the load;

NOTE 2 A biasing diode increases the switch-off time.

- q) verify that electromechanical devices in output circuits are monitored when required by the design.

7.5 Application specific tests

After each configuration of blanking, the effective detection areas shall be verified with a test piece suitable for the stated detection capability.

Check that when the protective equipment is muted the machinery operation is no longer hazardous or safety is maintained by other means. (For example, during the up-stroke (opening) of a power press.) Check that the mute indicator (when provided) is illuminated when the protective equipment has been muted.

Test the muting and/or blanking arrangements (if fitted) and check that they are not easy to manipulate.

Check that the stopping performance monitor (where provided) is in use and is set up and functioning in the manner recommended by the supplier.

Check that it is not possible for a person to stand between the protective equipment and the danger zone without being detected when cycle reinitiation by the AOPD is used.

Where functions such as muting, blanking, and/or initiation of cyclic operation are provided, check that safety is maintained while each function and, where applicable their combination, is active.

8 Information for safe use

The integrator shall provide all necessary information for operation and maintenance.

This information shall at least contain:

- a) general description of the protective equipment safety system;
- b) the values for detection capability and response time of the protective device, when differ from those given on the type plate of the device;
- c) identification of safety related parts;
- d) wiring schematics;

NOTE This requirement is not intended to include the internal circuit diagram of the protective equipment.

- e) overview (block) diagrams;
- f) where relevant, information on the parameters of muting systems, for example the position of muting sensors;
- g) instructions for use, including guidance for periodic inspection and test;
- h) identification of residual risks;
- i) maintenance instructions;
- j) specification of the procedures that shall be used to perform the tests described in 7.2 and 7.3;
- k) environmental limits;
- l) where relevant, the information for use provided by the protective equipment manufacturer;
- m) where relevant, details of additional mechanical protection, for example protection against overreaching.
- n) Information that the person conducting the periodic inspection and tests shall have adequate competence

Annex A (informative)

Application examples

A.1 General

The examples herein 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 application of protective equipment, and have been simplified for clarity, so they are incomplete. The figures in this annex are illustrative, and are not to scale.

A.2 Protective equipment used as a trip device

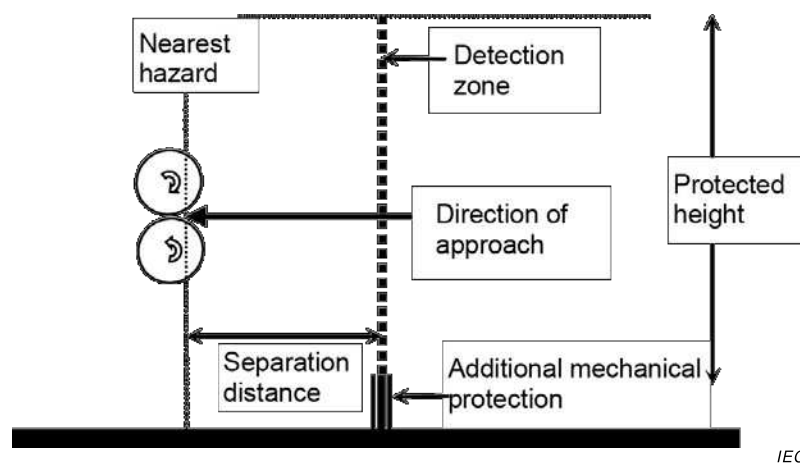


Figure A.1 – Protective equipment used as a trip device

Figure A.1 gives an example of the use of protective equipment as a trip device. In this example, the detection zone is normal to the direction of approach.

Additional mechanical protection and height of detection zone maintain safety by preventing encroachment.

A.3 Use of protective equipment as a combined trip and presence sensing device

A.3.1 Example 1

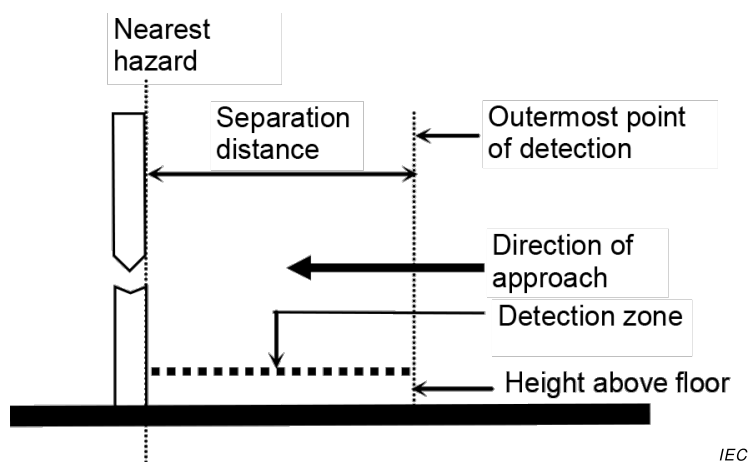


Figure A.2 – Protective equipment used as combined trip and presence sensing device – Example 1

Figure A.2 gives an example of the use of protective equipment as a combined trip and presence sensing device. In this example, the detection zone is parallel to the direction of approach.

The detection capability required depends on the height of the detection zone above the floor.

Additional means to ensure safety can be required around the sides of the detection zone.

A.3.2 Example 2

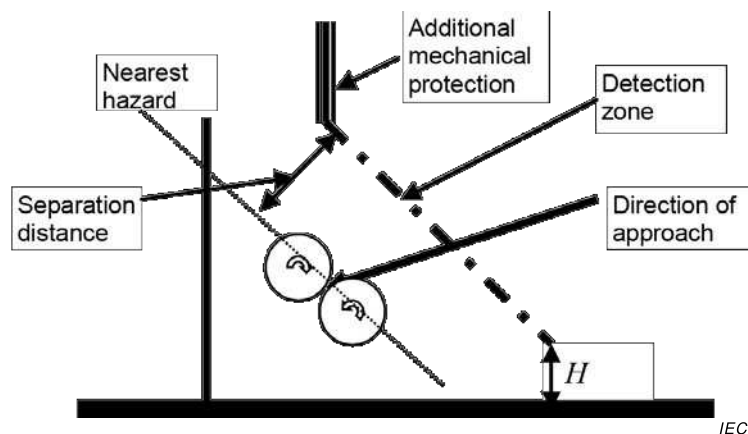


Figure A.3 – Protective equipment used as a combined trip and presence sensing device – Example 2

Figure A.3 gives an example of the use of protective equipment as a combined trip and presence sensing device. In this example, the angle of approach is greater than 30° to detection zone.

If H is 300 mm or greater, then additional mechanical protection will be needed to prevent reaching under the detection zone.

The dimension of the detection zone shall be such that it is not possible to reach the hazardous zone from the top, or additional mechanical protection shall be used.

A.3.3 Example 3: horizontal AOPD

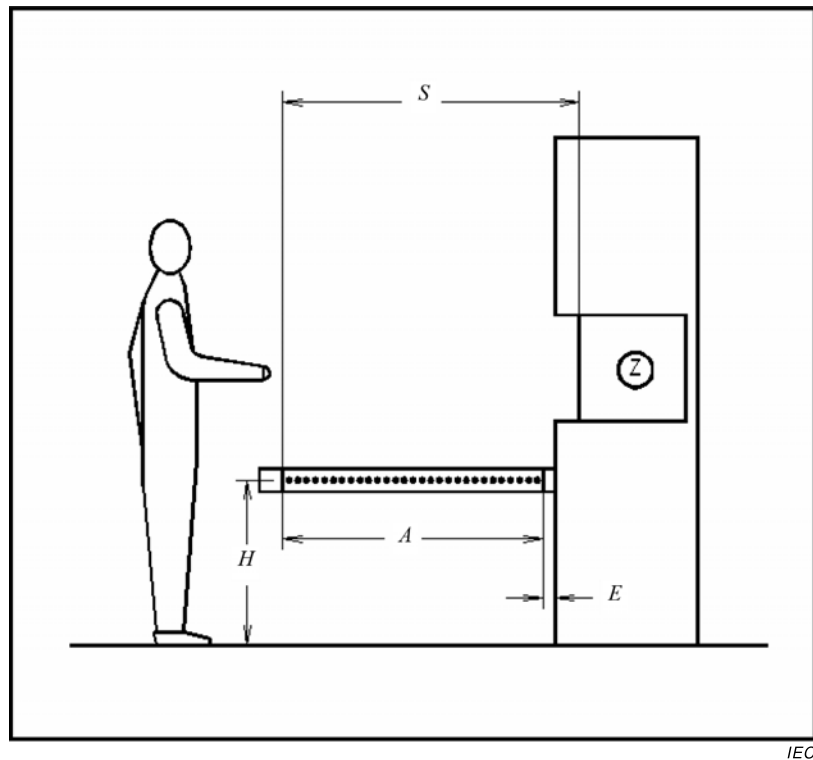


Figure A.4 – Horizontal AOPD

Figure A.4 gives an example of a machine protected with an AOPD (light curtain) used as a combined trip and presence sensing device.

- S is the minimum distance (see 4.4.2.1);
- A is the length of the detection zone;
- E is the distance from the detection zone to the mechanical guard or the machine body. This distance should be sufficiently small to prevent reaching through the gap, or standing between the detection zone and the hazardous zone, and can be specified in machine standards ("C" standards). E should be as small as practicable, generally equal to or less than d ;
- Z is the hazardous zone.

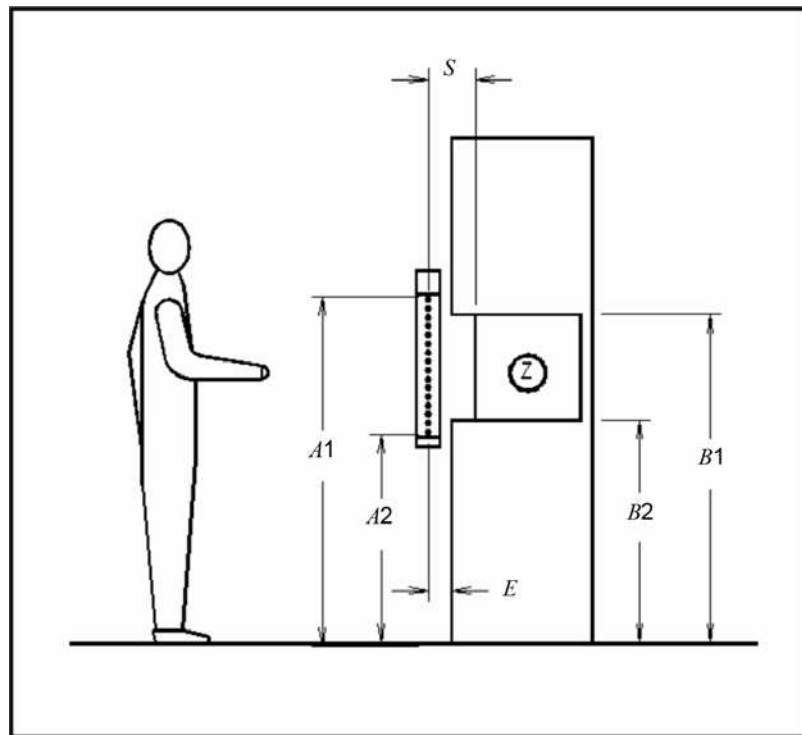
The detection zone is parallel to the direction of approach. The detection capability d required depends on the height H of the detection zone above the floor (see 4.4.2.3). ISO 13855 specifies that the height of the detection zone is not greater than 1,0 m.

$$d \leq H/15 + 50$$

Depending on the height of the detection zone from the floor (H), it can be possible to crawl underneath the detection zone and make an orthogonal approach to the hazardous zone. In this case, it is necessary to select an AOPD with a detection capability sufficient to prevent reaching through the detection zone from underneath. This requires the use of the formula from ISO 13855 for orthogonal approach.

Additional mechanical protection is necessary where it is possible to reach around the detection zone.

A.3.4 Example 4; vertical AOPD



IEC

Figure A.5 – Vertical AOPD

Figure A.5 gives an example of a machine protected with an AOPD (light curtain) used as combined trip and presence sensing device. The detection zone is normal to the direction of approach.

S is the minimum distance (see 4.4.2.1);

$A1 - A2$ is the height of the detection zone;

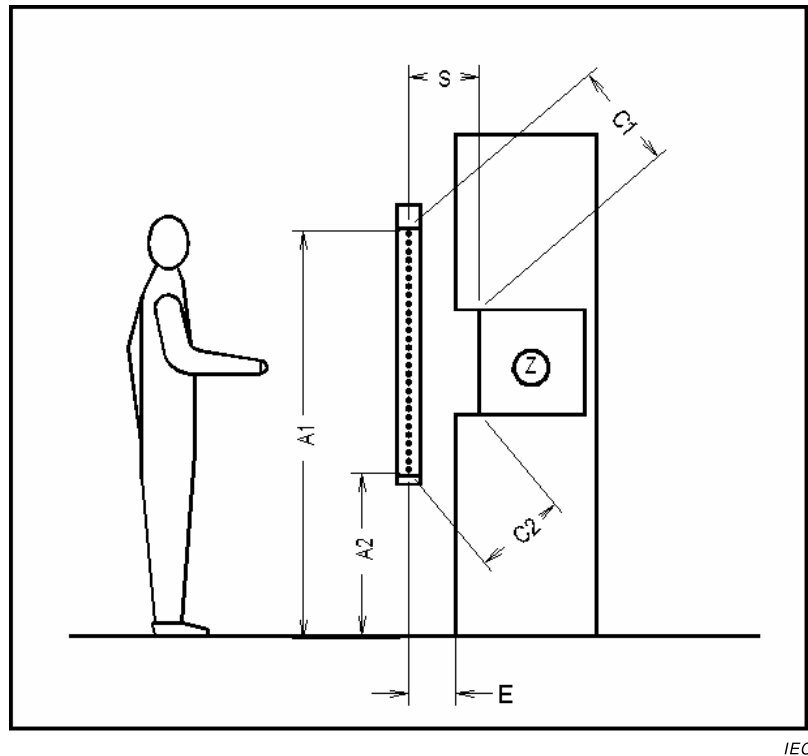
$B1 - B2$ is the height of the hazardous zone;

E is the distance from the detection zone to the mechanical guard or the machine body;

Z is the hazardous zone.

In this example, E is sufficiently small to prevent reaching under or over the detection zone or standing between the detection zone and the hazardous zone, and can be specified in machine standards ("C" standards).

When E cannot be sufficiently small, (for example because S is too great), it is necessary to use an AOPD with a greater height or additional measures to prevent reaching over or under the detection zone, or standing between the detection zone and the machine.

A.3.5 Example 5

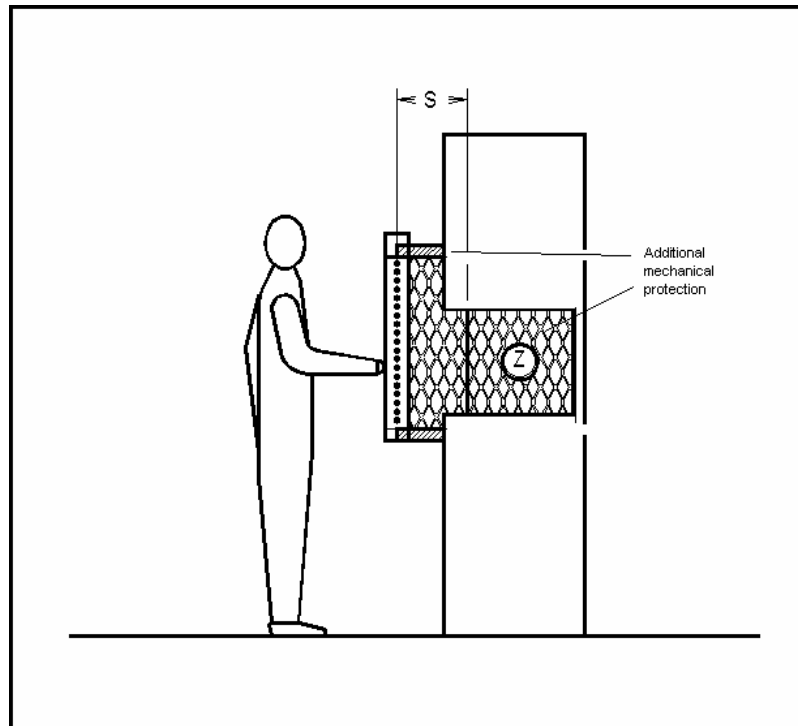
IEC

Figure A.6 – Increased minimum distance

Figure A.6 gives an example of a machine in which S is greater than in Figure A.5 and therefore E has increased. The height of the detection zone has been increased so that $C1$ and $C2$ are sufficient to prevent reaching over or under the detection zone (see ISO 13857).

Where E is sufficient to allow a person to stand between the detection zone and the machine, additional measures such as a pressure-sensitive mat, mechanical obstacles (see Figure A.7), or an additional horizontal AOPD (see Figure A.4) can be used depending on the risk assessment.

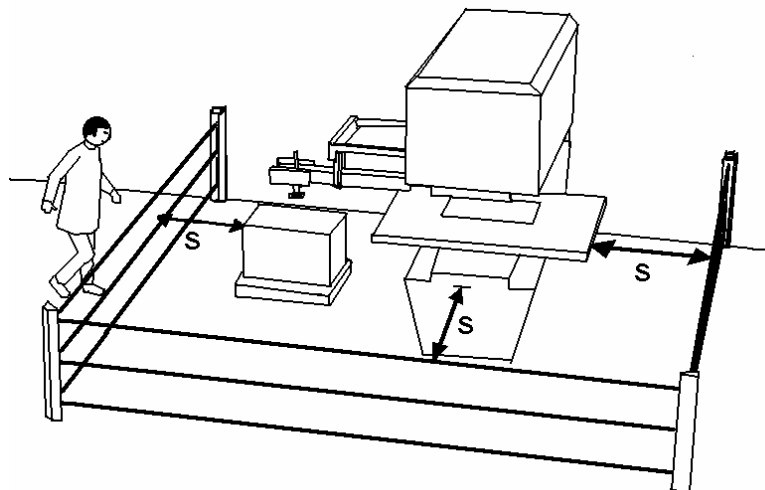
Additional protective measures (for example mechanical protection) can be necessary to prevent reaching around the detection zone (see Figure A.7).



IEC

Figure A.7 – Additional mechanical protection

A.4 Perimeter guarding



IEC

Figure A.8 – Use of a trip device

The example shown in Figure A.8 uses a multiple-beam light beam device as a trip device. A restart interlock which is reset by a deliberate human action is required, located outside the hazardous zone. Additional measures can be necessary when it is not possible to locate the reset actuator in such a position that the entire hazardous zone is visible.

The minimum distance calculation takes into account the furthest extent of hazardous movement of the machine and the stopping performance of different parts of the machine.

Annex B

(informative)

Additional recommendations for the application of AOPDDRs

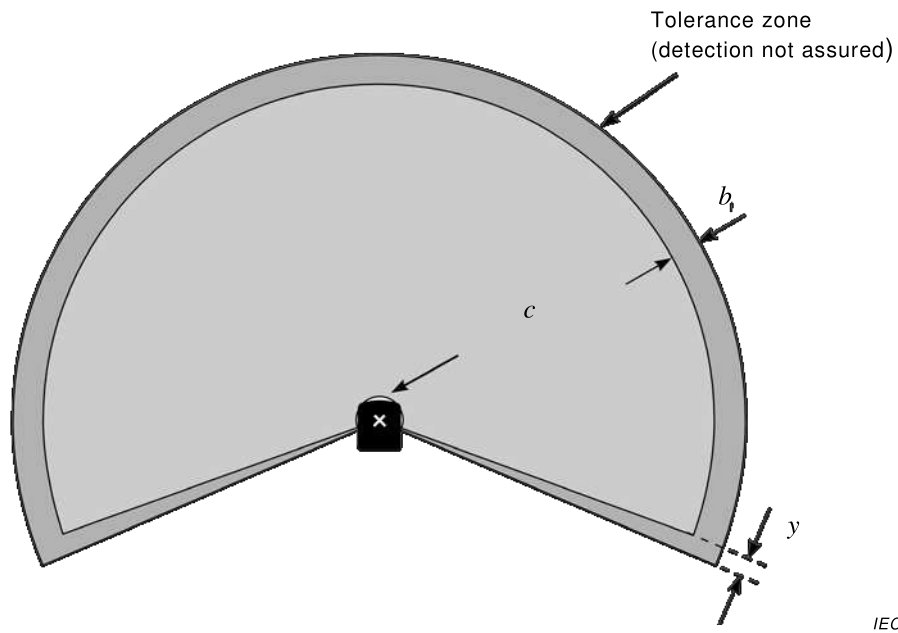
B.1 General

NOTE The figures in this annex are illustrative, and are not to scale.

When using an AOPDDR, the following points should be taken into account:

- a) Hazards should be identified and a risk assessment should be carried out (see ISO 12100).
- b) A check should be made as to whether the AOPDDR is an appropriate protective device for the application, taking into account existing machinery standards. AOPDDRs as defined in IEC 61496-3 are not suitable for finger protection.
- c) The AOPDDR accompanying documents should be checked as to whether the application requirements can be fulfilled (see 6.2).
 - environmental conditions (indoor/outdoor-use, smoke, rain, snow, temperature, etc.);
 - reflectivity of objects (for example, detection of objects that generate mirror-like reflections is not guaranteed);
 - background interference;
 - speed of movement of objects or persons;
 - shadow zones (shadow zones occur behind fixed objects. Persons within a shadow zone cannot be detected by an AOPDDR).
- d) The minimum distance should be calculated in accordance with the examples given in this annex and the AOPDDR accompanying documents.
- e) The final installation should be checked to ascertain that access to a hazardous zone without detection by the AOPDDR is not possible.

Figures B.1 and B.2 give an overview of the position of the maximum detection zone and its relationship with the tolerance zone. For further information on how to configure the detection zone, see the instruction manual of the AOPDDR.



IEC

Key

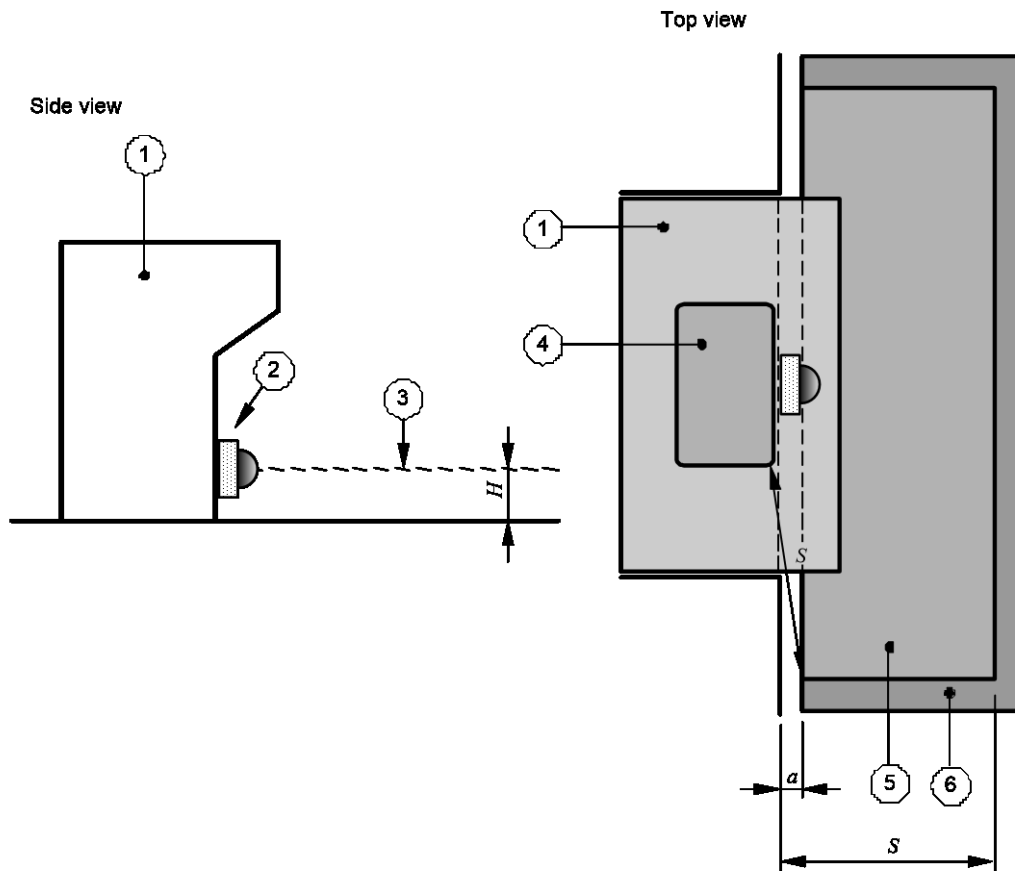
- b* zone with limited detection capability (detection not assured). The value of *b* is related to the distance measurement accuracy of the device.
- c* detection zone within which the specified test piece(s) is detected by the AOPDDR with a required minimum probability of detection.

The dimension of the tolerance zone can vary with the diameter of the test piece and the beam position (see Figure B.1, "y").

The detection zone origin is shown in Figure B.1 by a cross.

Figure B.1 – Example of the use of an AOPDDR on machinery

B.2 Example of the use of an AOPDDR on stationary machinery



IEC

Key

1. machinery
2. AOPDDR-2D
3. plane of the detection zone
4. hazard
5. detection zone
6. tolerance zone

Figure B.2 – Example of the use of an AOPDDR on stationary machinery

Calculation of the minimum distance S should be in accordance with 6.3 of ISO 13855:2010, using the following formula:

$$S = (K \times T) + C$$

$$C_{\min} = 850 \text{ mm}$$

$$S = (1\,600 \text{ mm/s} \times T) + (1\,200 \text{ mm} - 0,4 H)$$

$$H_{\min} = 15 (d - 50 \text{ mm})$$

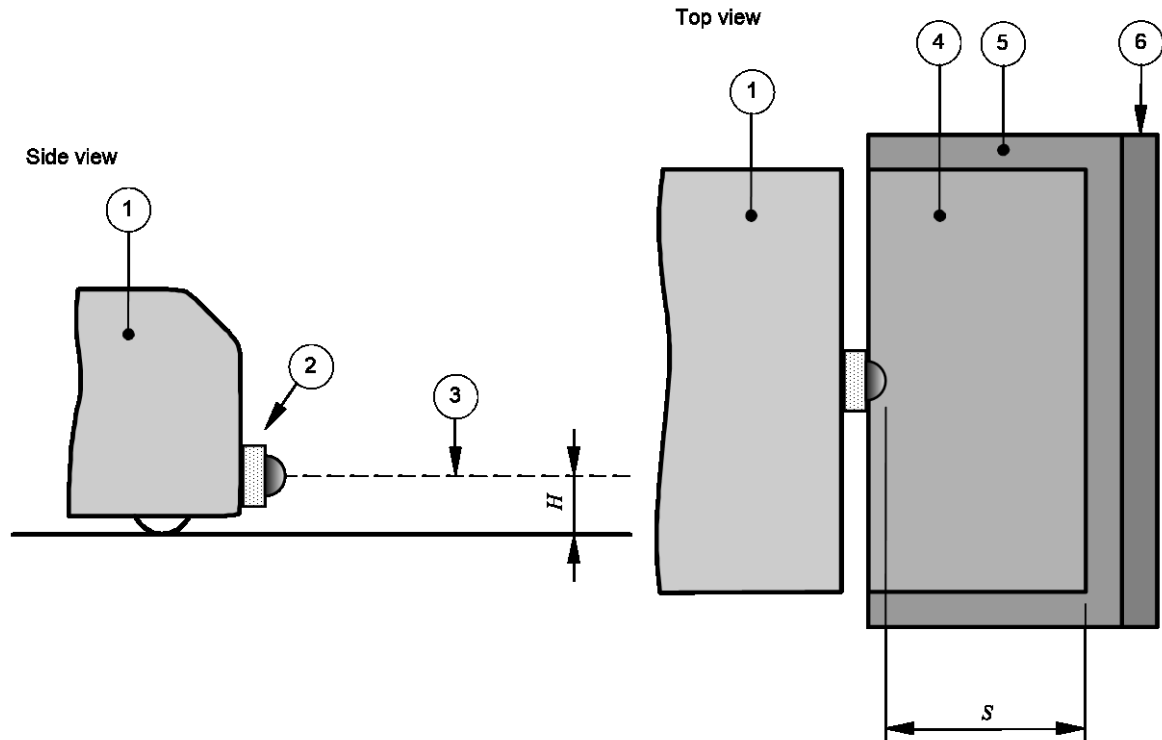
$$T = T_{\text{AOPDDR}} + T_{\text{MACHINE}}$$

When configuring the detection zone, the value of the tolerance zone should be added to the minimum distance S .

The value of a should be small enough to ensure that a person cannot approach the hazardous zone or stay between the hazardous zone and the detection zone without being detected. This can require the provision of additional mechanical protection.

The diameter of the test piece should be in accordance with the formula $d = H/15 + 50$ mm (see Formula (8) of 6.3 of ISO 13855:2010).

B.3 Example of the use of an AOPDDR on an automatic guided vehicle (AGV)



IEC

Key

- 1. AGV
- 2. AOPDDR-2D
- 3. plane of the detection zone
- 4. detection zone
- 5. tolerance zone
- 6. addition to the detection zone

Figure B.3 – Example of the use of an AOPDDR on an AGV

The determination of the minimum distance S should take into account, for example, the maximum speed of the AGV, the AOPDDR response time and the braking distance of the AGV.

The use of an AOPDDR as a protection device for AGVs may require an addition to the detection zone. The value of this addition should be determined by taking into account, for example, any overhang of parts of the AGV, the load, or the AOPDDR, the speed of movement of a person or reduced efficiency of the brakes. When setting the detection zone, the values of the tolerance zone and the required addition to the detection zone should be added to the minimum distance S .

The height of the detection plane, H , should be as near as possible to the floor and not higher than 200 mm (see H of Figure B.3 and EN 1525).

If it is possible for a person to stand between the front of the AGV and the detection zone (i.e. a in Figure B.3 is greater than 50 mm), when the AGV is at rest, then other safety measures should be provided to prevent injury when the AGV starts.

B.4 AOPDDR used for the detection of the body or parts of a body with orthogonal approach

B.4.1 Detection of a whole body

AOPDDRs intended for use as a whole-body trip device with orthogonal approach shall have a stated detection capability not exceeding 200 mm. If the reference boundary is the edge of the safeguarded aperture as shown in Figure B.4, the tolerance zone should not exceed 100 mm. If the tolerance zone exceeds 100 mm, this part exceeding 100 mm shall be protected by other means, for example fixed guarding, see also Figure B.5.

NOTE The purpose of these requirements is to ensure that a whole body cannot intrude undetected at the edge of the detection zone.

B.4.2 Detection of parts of the body

When the AOPDDR is intended for the detection of parts of a body in applications where the angle of the approach exceeds $\pm 30^\circ$ to the detection plane, the AOPDDR shall monitor a physical boundary (referred to as the "reference boundary"). Reference boundary monitoring requires a comparison of the reference distance and the distance measured by the AOPDDR. The reference distance is the distance between the AOPDDR and each point of the boundary (for example a wall) configured at the first installation. The stated detection capability shall be in the range from 30 mm to 70 mm. If the reference boundary is the edge of the safeguarded aperture as shown in Figure B.6, the tolerance zone should not exceed half of the stated detection capability (see also dimension a). If the tolerance zone exceeds half of the stated detection capability, this part exceeding the stated detection capability should be protected by other means, for example fixed guarding, see also Figure B.7.

NOTE The purpose of these requirements is to ensure that parts of a body cannot intrude undetected at the edge of the detection zone.

It shall be verified that is not possible to access the hazardous zone without being continuously present in the detection zone.

B.5 Examples of the use of an AOPDDR as a whole-body trip device

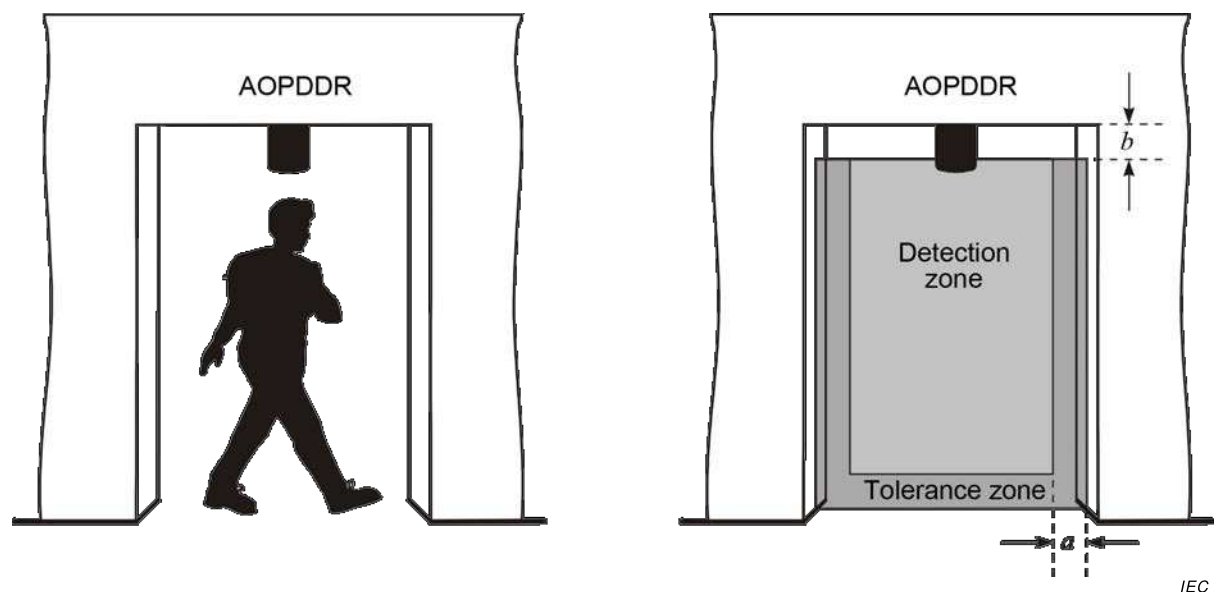


Figure B.4 – Use of an AOPDDR as a whole-body trip device – Example 1

Figure B.4 shows the use of an AOPDDR as a whole-body trip device where the reference boundary is the edge of the safeguarded aperture and the tolerance zone does not exceed 100 mm. Dimension b represents a zone that is not protected due to the physical installation, so safety shall be assured by other means, for example additional mechanical protection. Dimension a represents the tolerance zone and is technology-dependent. Consult the manufacturer's instructions for use.

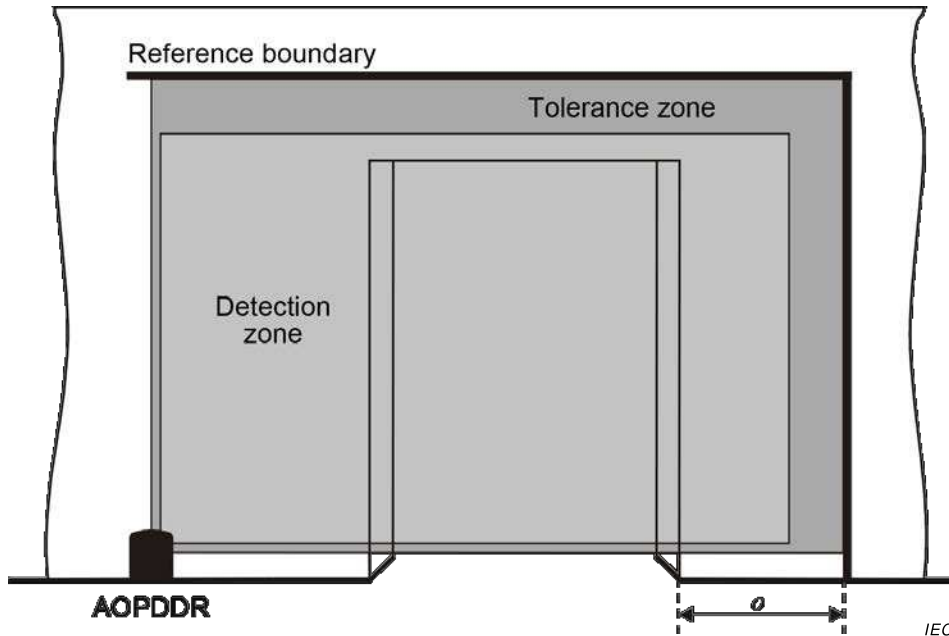


Figure B.5 – Use of an AOPDDR as a whole-body trip device – Example 2

Figure B.5 shows the use of an AOPDDR as a whole-body trip device where the reference boundary is beyond the edge of the safeguarded aperture within a physical barrier and the tolerance zone exceeds 100 mm.

If the tolerance zone exceeds 100 mm an overlap o as shown in Figure B.5 is necessary. The dimension of o shall be calculated as follows:

$$o \geq (2 \times TZ) - d$$

where

TZ is the value of the tolerance zone;

d is the stated detection capability ($d \leq 200$ mm).

B.6 Examples for the use of an AOPDDR as parts of a body trip device

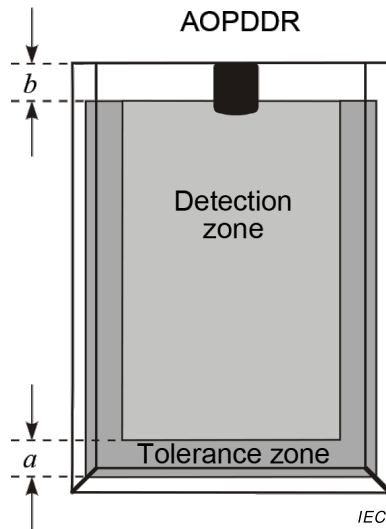


Figure B.6 – Use of an AOPDDR as parts of a body trip device – Example 1

Figure B.6 shows the use of an AOPDDR as parts of a body trip device where the reference boundary is the edge of the safeguarded aperture and the tolerance zone does not exceed half of the stated detection capability.

It is necessary that the value of a is not greater than half of the stated detection capability. Dimension b represents a zone in which there is no detection due to the physical aspect of the installation, so safety shall be assured by other means, for example additional mechanical protection.

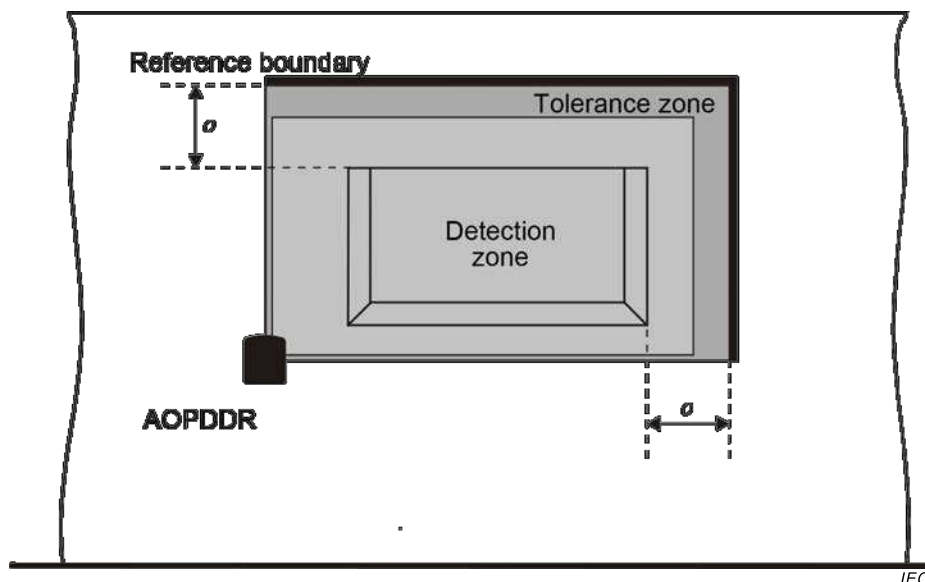


Figure B.7 – Use of an AOPDDR as parts of a body trip device – Example 2

Figure B.7 shows the use of an AOPDDR as parts of a body trip device where the reference boundary is beyond the edge of the safeguarded aperture within a physical barrier and the tolerance zone exceeds half of the stated detection capability.

If the tolerance zone exceeds half of the stated detection capability an overlap o as shown in Figure B.7 is necessary. The dimensions of o are calculated as follows:

$$o \geq (2 \times TZ) - d$$

where

TZ is the value of the tolerance zone;

d is the stated detection capability ($30 \text{ mm} \leq d \leq 70 \text{ mm}$).

Annex C

(informative)

Application example of a vision based protective system (VBPDS)

The application example (see Figure C.1) shows a robot working station. The entry of persons is prevented on 2 sides by walls or fixed guards (top view). The entry from the other 2 sides is monitored by a VBPDS. If a person enters the detection zone, the robot shall stop its movement.

The safety distance S_0 should be calculated in accordance with the examples given in IEC TS 61496-4-3:2015, Annex AA and the VBPDS accompanying documents. Furthermore, the distance to walls (a) the distance to the floor (b) and the height of the detection zone (H) should be calculated in accordance with the VBPDS accompanying documents and the risk assessment.

VBPDS could be mounted at different positions. Side view 1 and side view 2 show two possible solutions and the shape of the resulting detection zone (4) and the adjacent tolerance zone (5).

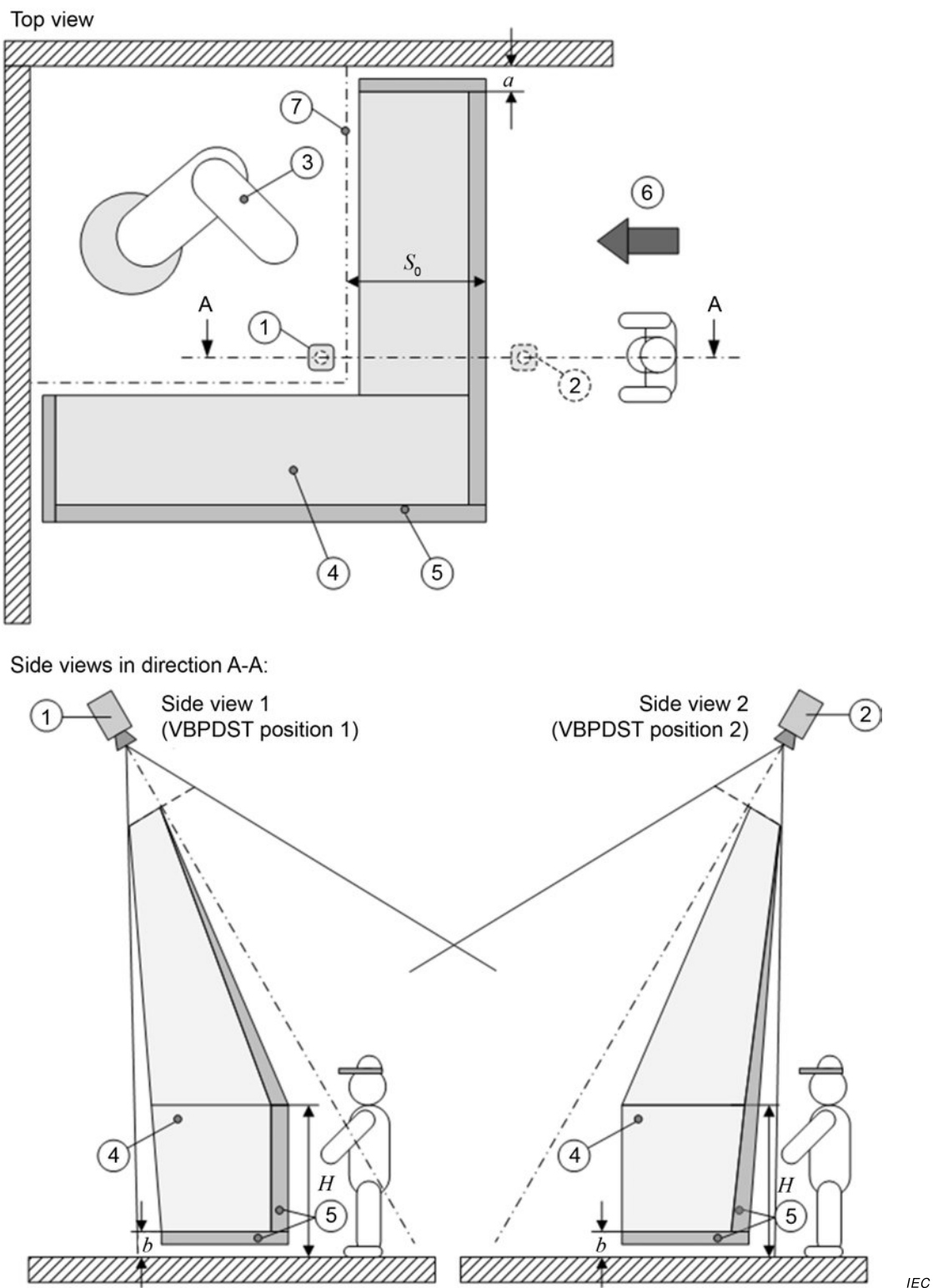


Figure C.1 – Application example of a VBPDS

Annex D (informative)

Examples for the configuration of photoelectric muting sensors when used to allow access by materials

D.1 General

The following examples are based on the assumptions that:

- photoelectric sensors are used to initiate and terminate muting;
- the detection zone of the muting sensors is within 30° of the horizontal;
- the detection zone of the muting sensors is at a height suitable to detect a person's leg(s).

These examples are provided to illustrate the principles of muting configurations. Other standards (e.g. ISO 13854) and machine-specific standards (C standards) can give specific provisions for particular applications.

NOTE 1 The figures in this annex are illustrative, and are not to scale.

The following configurations of the number, type, arrangement and control of the sensors are considered in this annex.

Two beams: T configuration (see Figure D.1) with timing control of the sensors (entry/exit).

L configuration (see Figure D.2) with timing control of the sensors (exit only).

Four beams: Parallel beams (see Figure D.3) with timing control of the sensors (entry/exit).

Parallel beams (see Figure D.3) with sequence control (entry/exit).

NOTE 2 The principles of these examples can be applicable to other configurations.

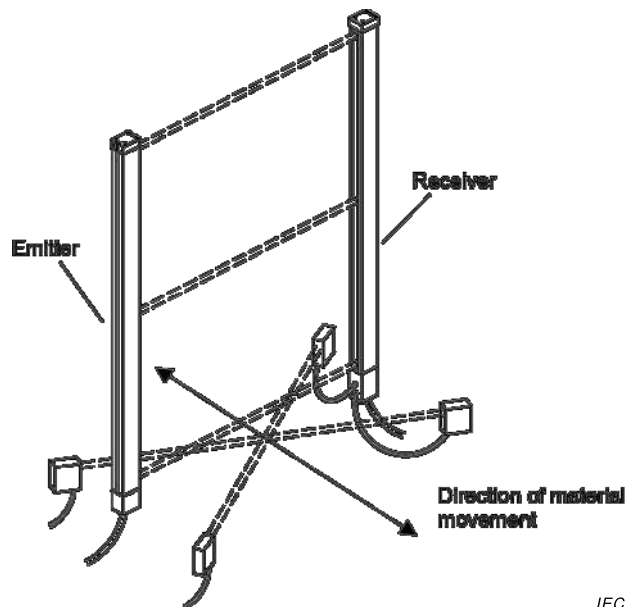


Figure D.1 – T configuration with timing control

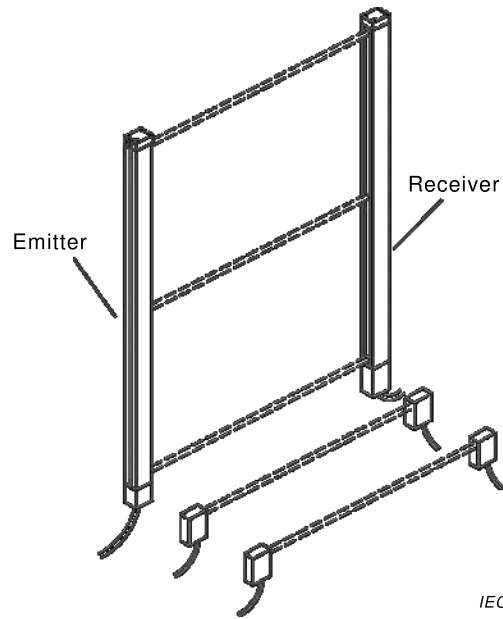


Figure D.2 – L configuration with timing control

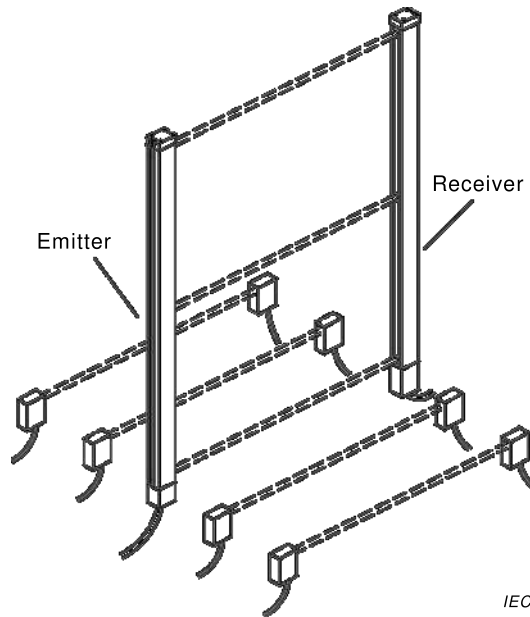
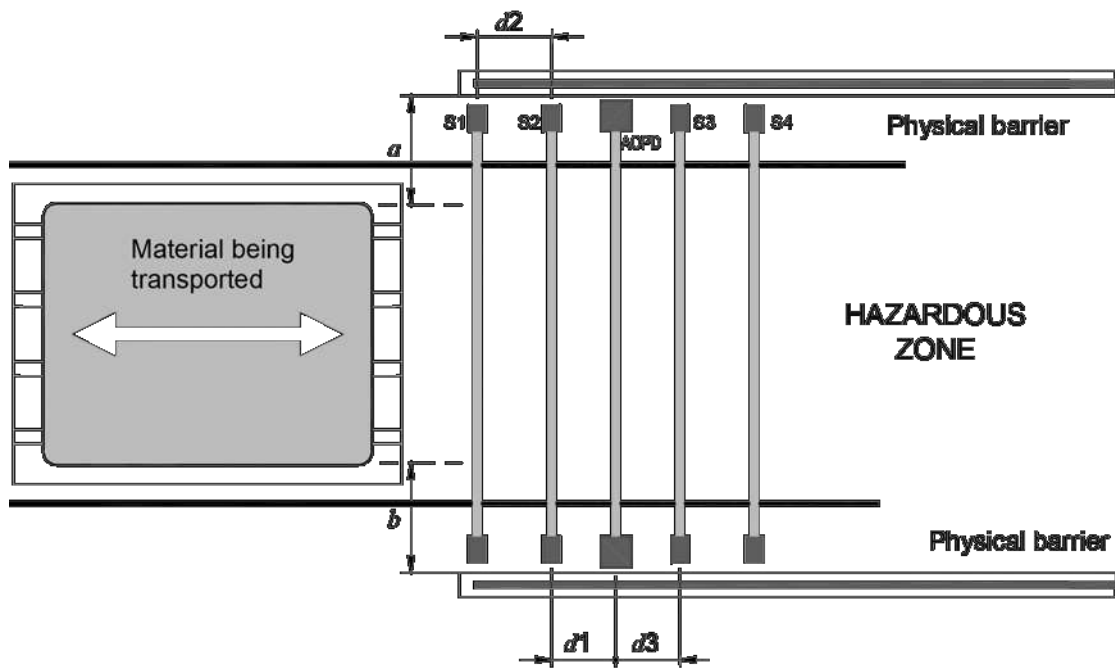


Figure D.3 – Parallel beams with timing or sequence control

D.2 Four beams

D.2.1 Four beams – Positioning of the sensors



IEC

Figure D.4 – Four parallel beams with timing control

In order to comply with 5.7.3, the arrangement should be such that a person cannot pass through the opening towards the hazardous zone while the system is in the mute condition. For example, dimensions a and b should be such that a person cannot enter alongside the material being transported. Other dimensions do not guarantee that a person cannot enter the hazardous zone. Care is necessary to avoid crushing hazards between the moving material and the fixed parts of the installation.

The muting sensors should be installed sufficiently close to the ESPE that a person attempting to enter the hazardous zone by preceding or following immediately the pallet or the transport system is detected ($d1$ and $d3 < 200$ mm).

The distance between S3 and S4 need not equal $d2$ (see Figure D.4).

The distance between S1 and S4 should be not less than 500 mm in order that a person's body cannot sustain the muting function (see figure D.5). When this is not practicable, the 4 parallel beam configuration is not suitable. This can be verified by ensuring that a vertical cylindrical object with a diameter of 500 mm cannot sustain the muting function when moved in any part of the opening at any speed up to 1,6 m/s.

The distance between any 2 muting sensors should be sufficient so that they cannot be actuated simultaneously by a person's leg ($d2 > 250$ mm).

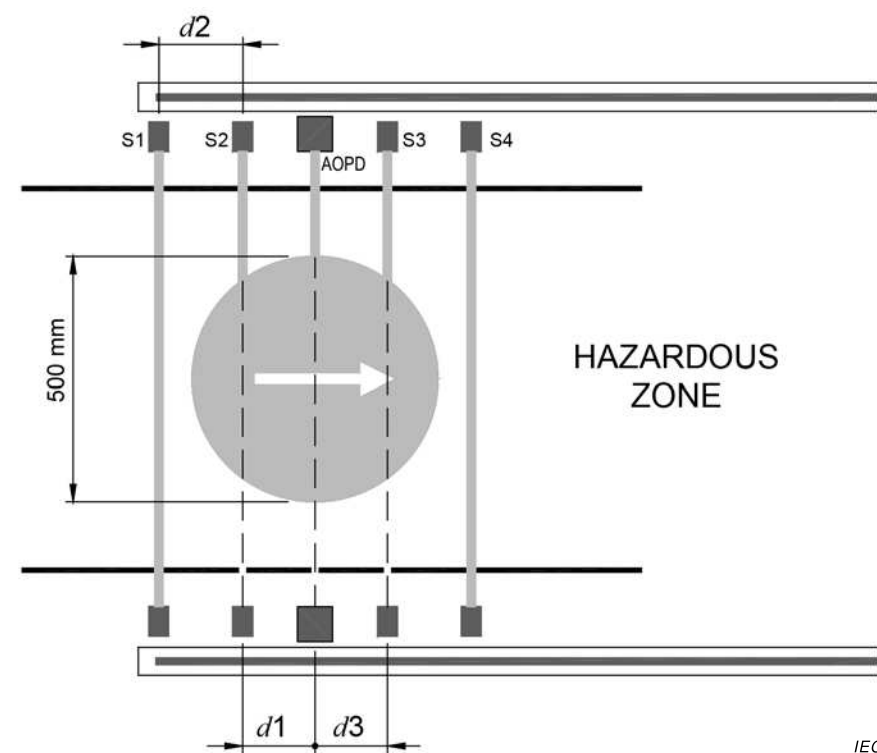


Figure D.5 – Positioning of the muting sensors to avoid muting by a person's body (plan view)

The height of the muting sensors from the plane of the conveyor should be such as to detect the load being conveyed, but not the pallet or the transport unit (see Figure D.6). When this is impractical, additional measures can be necessary to prevent people from entering the zone by climbing onto the pallet or the transport unit.

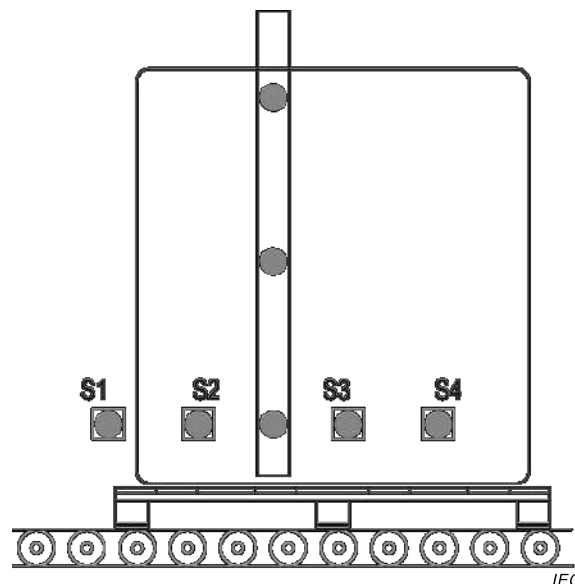


Figure D.6 – Positioning of the muting sensors (side view)

D.2.2 Four beams – timing control

The monitoring of the muting function is based on time limitation between the actuation of the sensors S1 and S2 and between the actuation of sensors S3 and S4. A maximum time limit of

4 s is recommended. The muting function is initiated by actuation of the two sensors S1, S2 within the time limit and maintained by the two sensors S3, S4; this means that for a certain time all the four sensors are activated. The muting function is terminated when S3 or S4 is deactivated. (See Figure D.7)

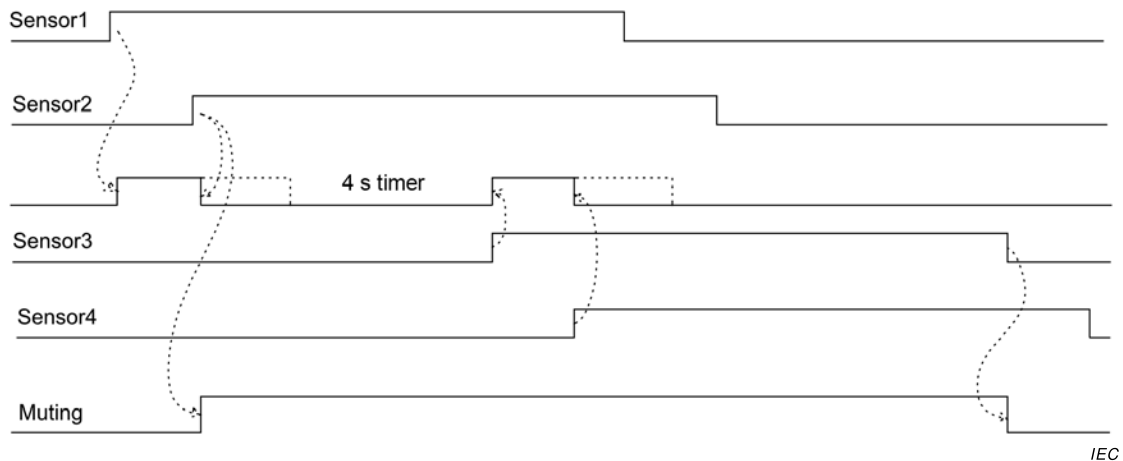


Figure D.7 – Timing diagram: four parallel beams with timing control

If the conveyor movement is reversed when the muting function is active, as soon as one of the sensors S1 or S2 is deactivated, the muting function is disabled. The system can work in both directions (entry and exit).

Crossing the beams of the sensors S1 and S2, or S3 and S4 (see Figure D.8), is not recommended because the muting function can be enabled by any object that passes through the point where the light beams of the two sensors cross.

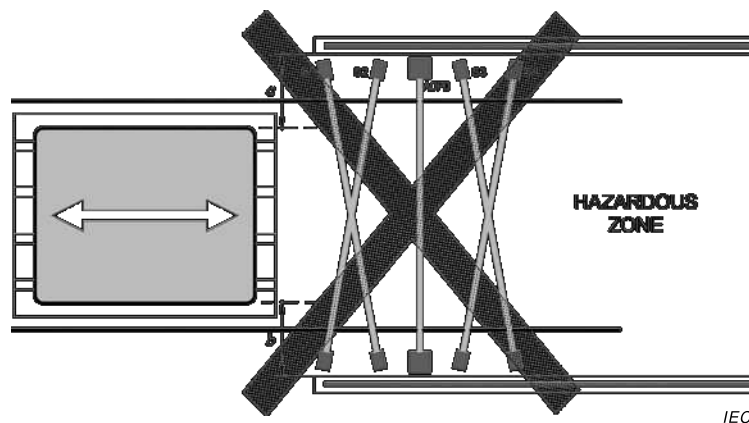


Figure D.8 – Four beams: timing control and crossed beams (not recommended)

D.2.3 Four beams – sequence control

The positioning of the sensors is the same as the four beams assembly with timing control illustrated in Figure D.9. The initiation of the muting function depends on monitoring the correct sequence of activation of the muting sensors. See Figure D.9 and Table D.1. For example, in the muted condition, if S2 is deactivated before S3 is activated, muting is terminated.

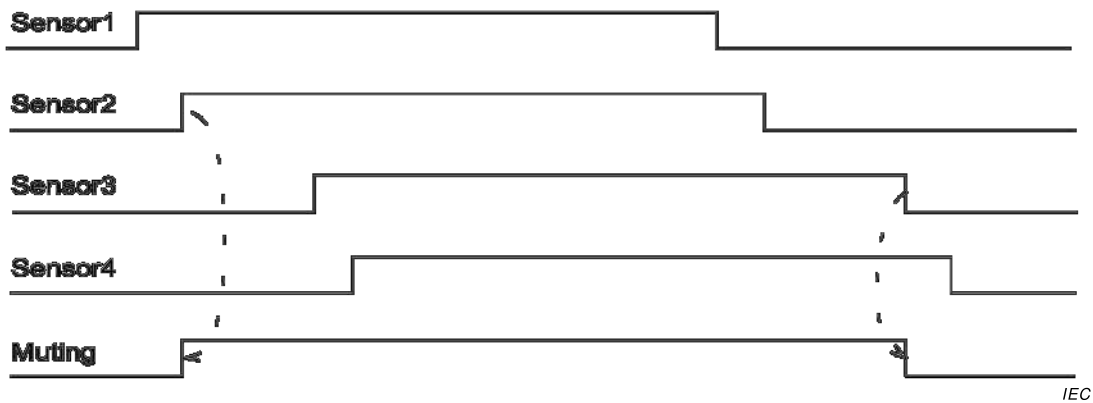


Figure D.9 – Timing diagram: four beams and sequence control

Table D.1 – Truth table, four beams – sequence control

SENSOR 1	SENSOR 2	SENSOR 3	SENSOR 4	ESPE STATUS
0	0	0	0	ACTIVE
1	0	0	0	ACTIVE
1	1	0	0	MUTED
1	1	1	0	MUTED
1	1	1	1	MUTED
0	1	1	1	MUTED
0	0	1	1	MUTED
0	0	0	1	ACTIVE
0	0	0	0	ACTIVE

Monitoring the interruption of the AOPD within the sequence can provide improved resistance to manipulation or bypassing.

D.2.4 Four beams with additional swinging doors

The openings between the pallet and the side mechanical protections shall be such that a person cannot pass undetected through these openings for all the time the pallet is crossing the gate.

To avoid the risk of crushing or shearing between the moving load and the fixed parts of the installation, a minimum gap of 500 mm is recommended.

For pallets of various dimensions and when it is foreseen that the distances each side of the pallet (*a* and *b*) can be greater than 200 mm, flexible swinging doors, with a width of at least 500 mm and electrically monitored, can be required (see Figure D.10 and 5.7.3).

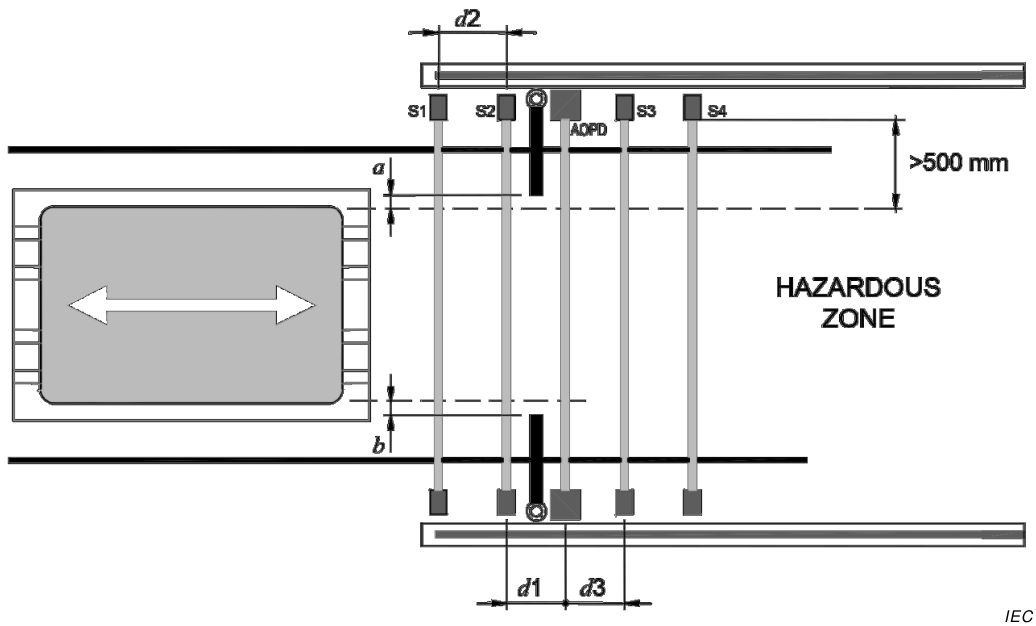


Figure D.10 – Four beams with additional swinging doors

D.2.5 Methods to avoid manipulation of the muting function

NOTE This is not an exhaustive list of methods to avoid manipulation.

A monitored limitation of the muting function to a predetermined time is recommended. Alternatively, use a muting enable command generated by the control system of the machine that will only enable the muting function when needed by the process. Figure D.11 illustrates initiation of a muting condition by activation of sensors S1 and S2 when the mute enable signal is present.

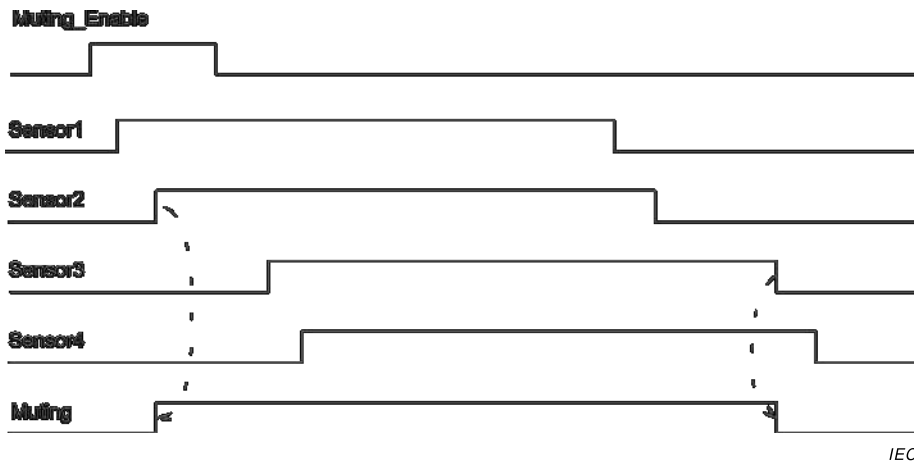


Figure D.11 – Timing diagram for mute enable signal (mute enable activated)

Figure D.12 shows that the mute condition is not activated when the mute enable signal is not present.

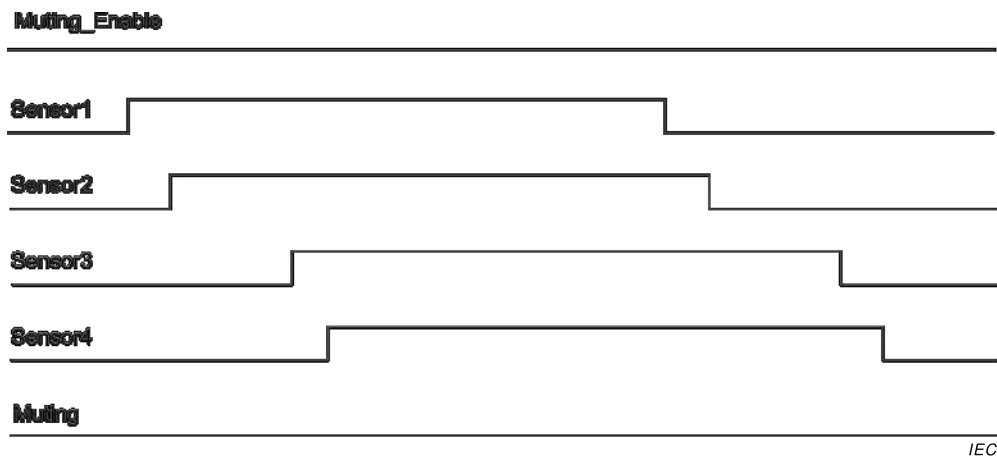


Figure D.12 – Timing diagram for mute enable signal (mute enable not activated)

In some applications, for example in conveying applications where material flow is not linked to the muting cycle, it can be necessary for the mute enable signal to be present for longer than one muting cycle, as shown in Figure D.13.

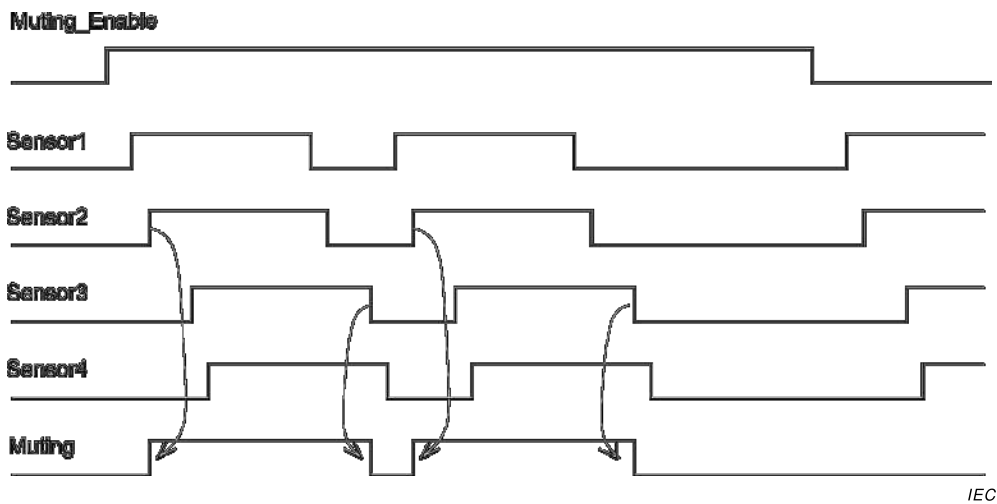


Figure D.13 – Presence of the mute enable signal during more than one mute cycle

In order to avoid manipulation of the muting function by, for example, using a piece of cardboard with the same length as the material being transported, it is recommended to use proximity muting sensors with background elimination and to install them on alternate sides of the transport system's track so that it is not possible to activate two consecutive sensors. See Figure D.14 and Figure D.15.

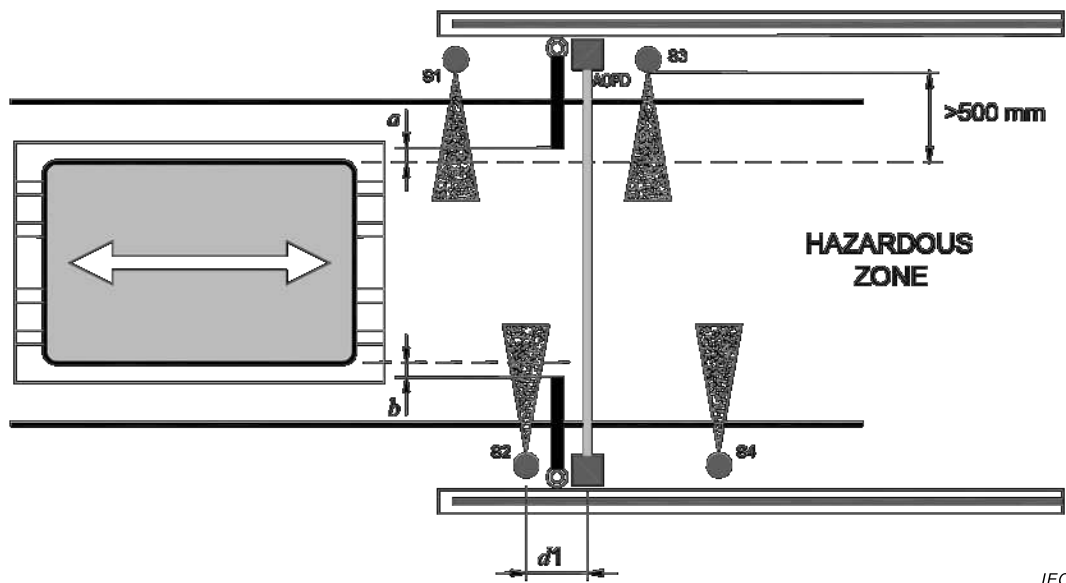


Figure D.14 – Avoidance of manipulation of the muting function (plan view)

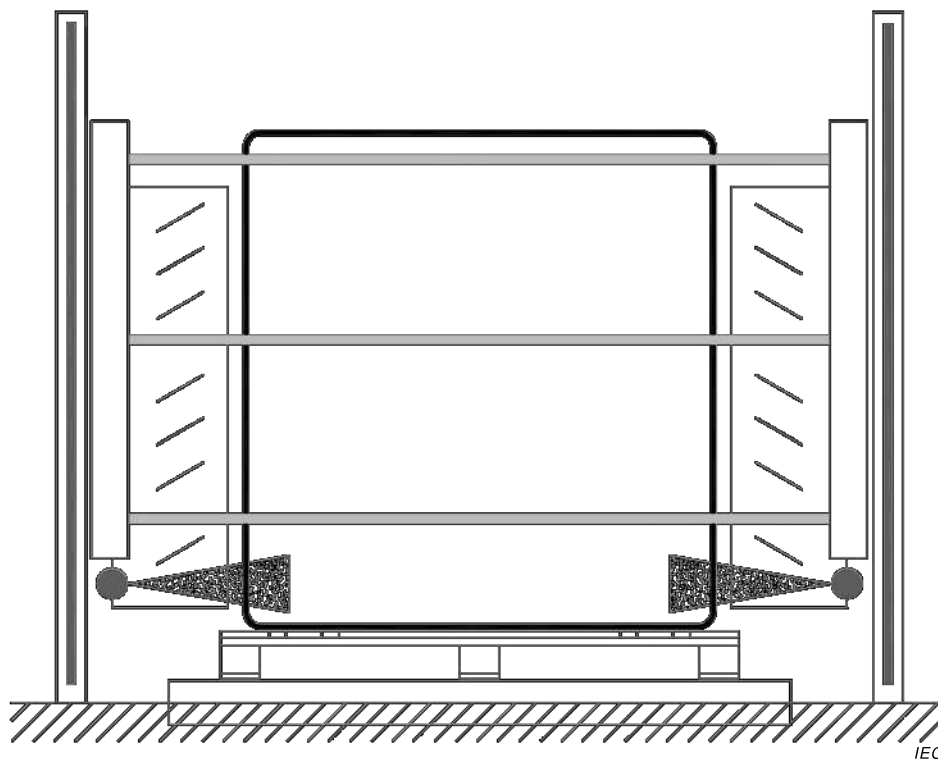


Figure D.15 – Avoidance of manipulation of the muting function (front view)

D.2.6 Connection of the sensors to a two input muting control

When the four sensors are connected to a two input muting control (see Figure D.16) a monitored timer that limits the muting function to a predetermined time is required in addition to the monitored timing between the actuation of the sensors S1 and S2 and between the actuation of sensors S3 and S4 (see D.2.8).

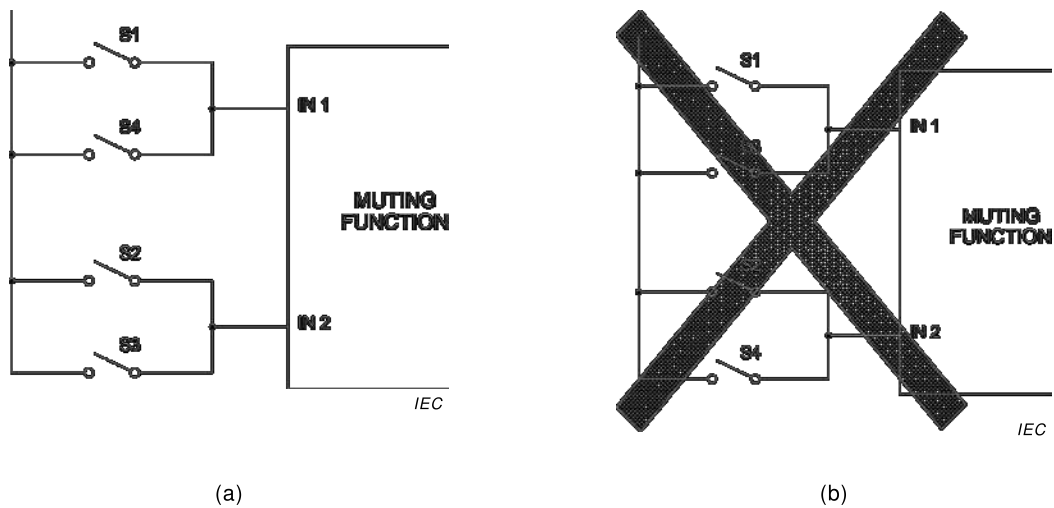


Figure D.16 – Connection of the muting sensors

Configuration (a) of Figure D.16 is preferred because it requires the actuation of all the sensors for a defined time. Configuration (b) should not be used because it will fail the verification in D.2.1 since S2 and S3 will be activated concurrently (see Figure D.5).

D.2.7 Two sensors – positioning of the sensors

The crossing point of the two light beams should be situated behind the sensing field of the ESPE in the direction of the hazard as shown in Figure D.17. The distance d_5 measured between the optical axis of the ESPE and the intersection point of the two light beams of the muting sensors should be as short as practicable in order to avoid persons entering the hazardous zone without being detected by following immediately after the pallet or the transport system. It is recommended that distance d_5 be less than or equal to 200 mm.

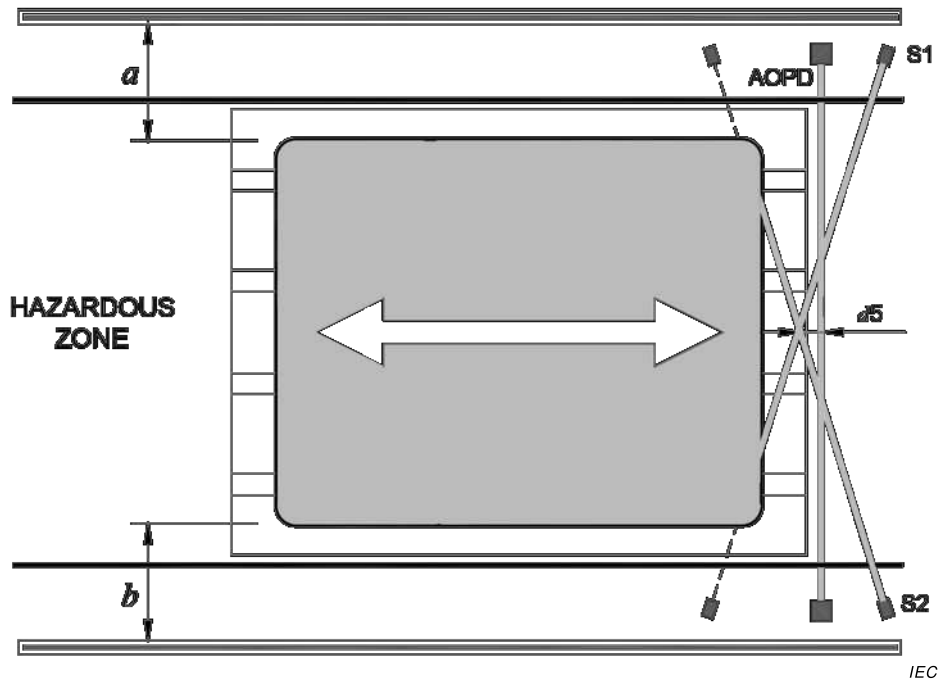
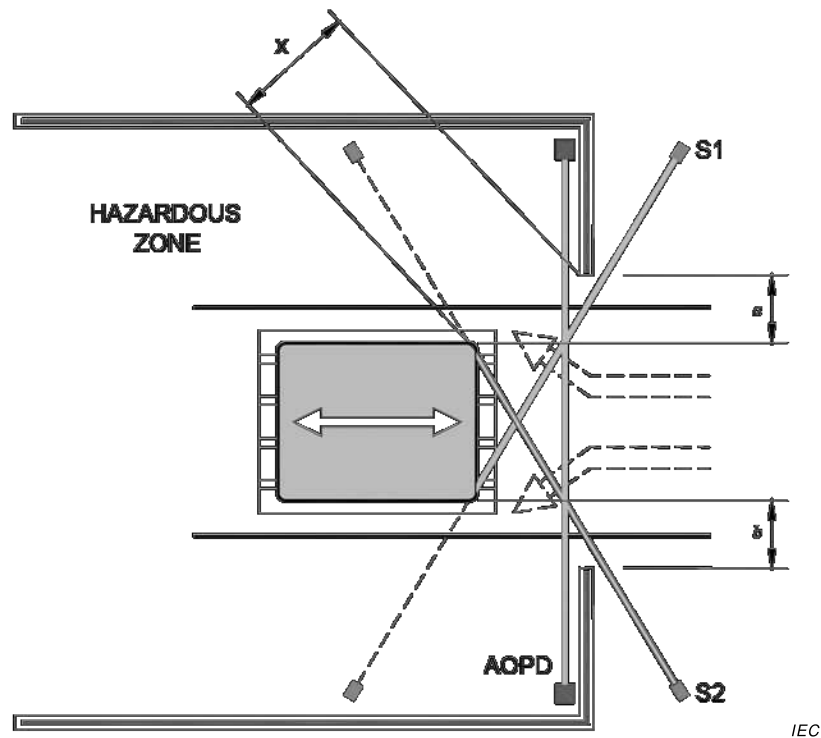


Figure D.17 – Two sensors – Crossed beams

The openings a and b between the edge of the fence and the edge of the pallet (in the position where muting is started to allow exit of material or in the position where muting is

ended to allow entry of material) should be such that a person cannot pass undetected through these openings during the time the pallet is crossing the muting area.



**Figure D.18 – Two sensors – Crossed beams
(risk of entering the hazardous zone without detection when $x > 200$ mm)**

The opening between the edge of the fence and the edge of the pallet shall be such that a person cannot pass undetected through these openings during the time the pallet is crossing the muting area. In the configuration shown in Figure D.18, it is recommended that this distance x is less than 200 mm.

The positioning of the sensors (distances $d1$ and $d2$ between the two sensors and detection zone of the ESPE, see Figure D.19 and D.20) shall be such that a cylindrical object with a diameter of 500 mm with its axis parallel to the protected area cannot activate the muting function when moved in any point of the gate at any speed up to 1,6 m/s.

EXAMPLE: If $d1 = 200$ mm, $d2 = 300$ mm, the requirement is satisfied for a dimension L (see Figure D.19) bigger than 1 000 mm. In this case $d5 = 50$ mm.

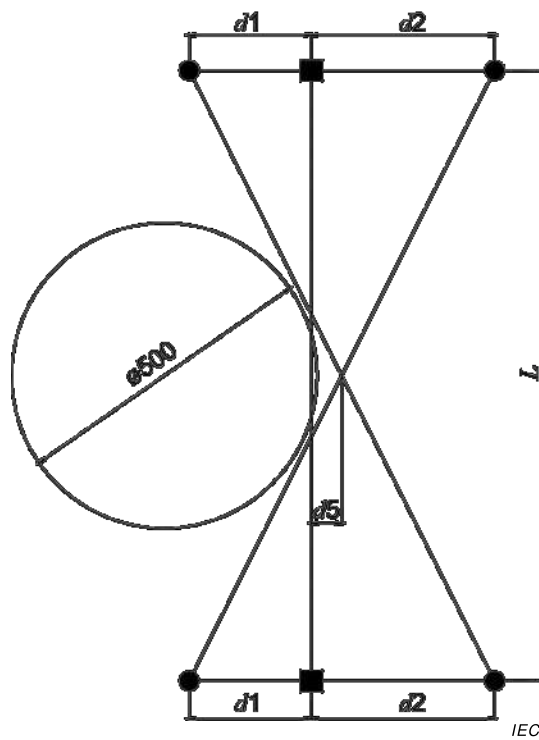


Figure D.19 – Positioning of the muting sensors

The 500 mm test object is detected by the ESPE before breaking the beams of the muting sensors (see Figure D.19).

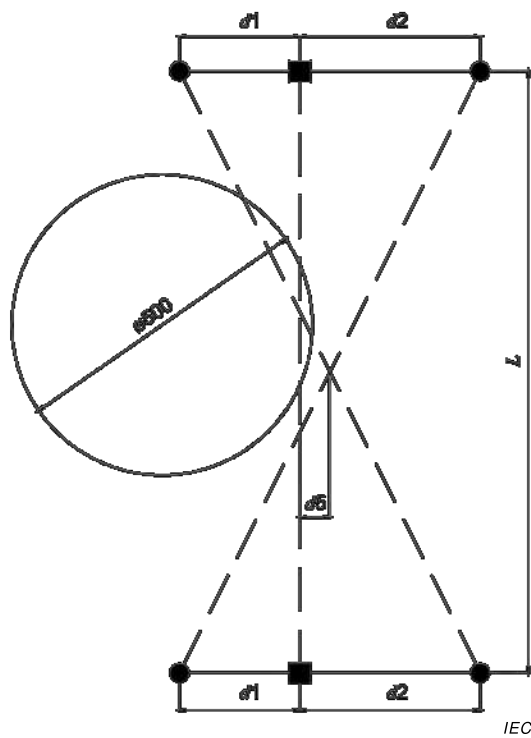


Figure D.20 – Detection of the test object

The 500 mm test object is detected by one muting sensor and then by the ESPE before being detected by the second muting sensor, therefore muting is not initiated because the sequence of activation is not correct (see Figure D.20).

D.2.8 Two sensors – timing control

The muting function should only be initiated when the two beams are activated within a time limit that is selected to suit the application, but not exceeding 4 s. If a time limit greater than 4 s is necessary, a different configuration should be used, for example 4 sensors.

The muting function should be terminated as soon as one of the two beams of the muting sensors is no longer activated. (See Figure D.21).

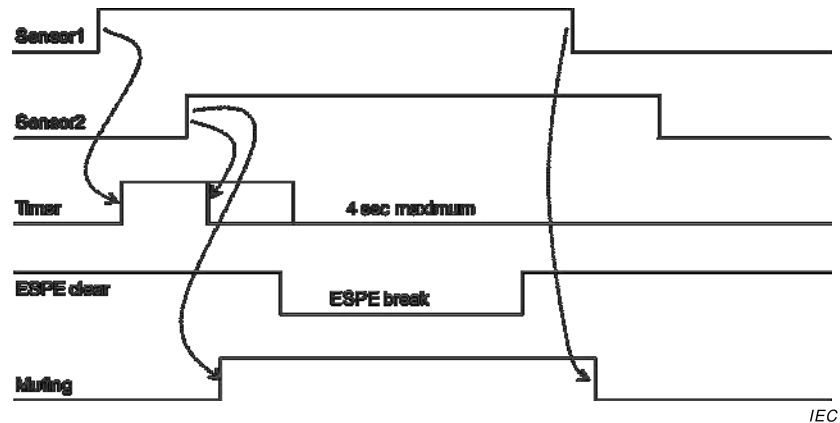


Figure D.21 – Timing diagram for two crossed beams (normal operation)

A timer that limits the duration of muting to the minimum time sufficient for the intended object to travel through the muting area, (for example a pallet).. If the set time is exceeded then the muted condition shall be terminated (See Figure D.22).

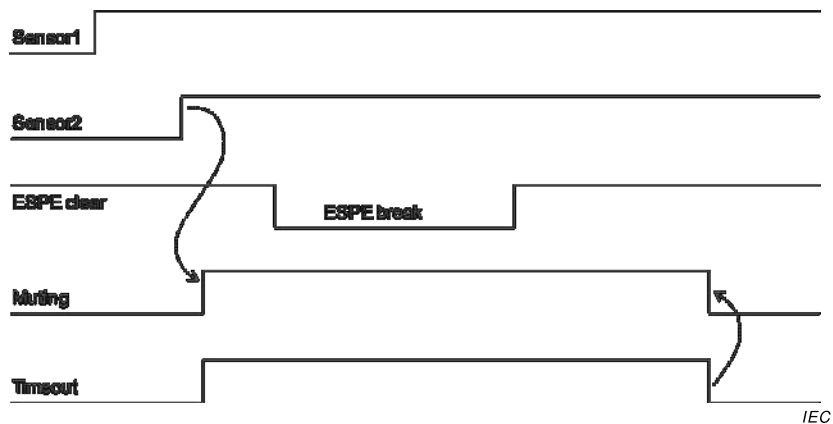


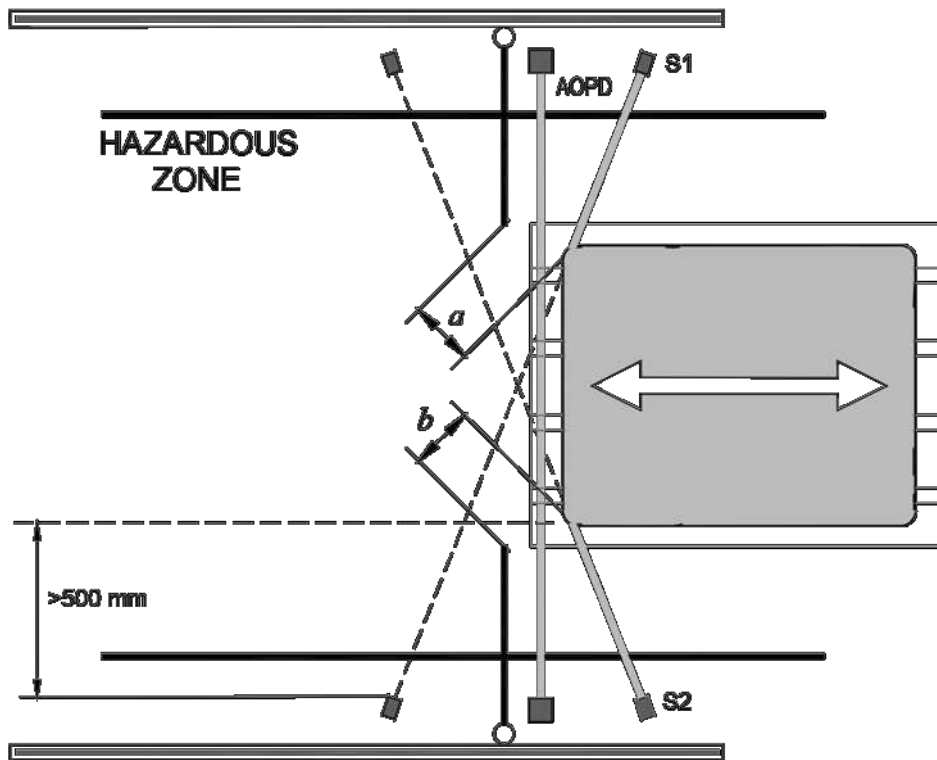
Figure D.22 – Timing diagram for two crossed beams (timeout)

If an accumulation of two or more undetected faults occurs, the muting function can be permanently active. In applications where it is not possible to differentiate between a permanent muted condition caused by an accumulation of faults and a muted condition caused by a pallet remaining in the muting area, the two crossed beam configuration is not adequate and an alternative solution or additional measures to detect faults (for example, monitoring of signals from the transport system to determine if a pallet is in the detection zone) should be provided.

D.2.9 Two muting sensor beams in combination with swinging doors

The openings between the pallet and the side mechanical protections shall be such that a person cannot pass undetected through these openings during the time the pallet is crossing the muting area.

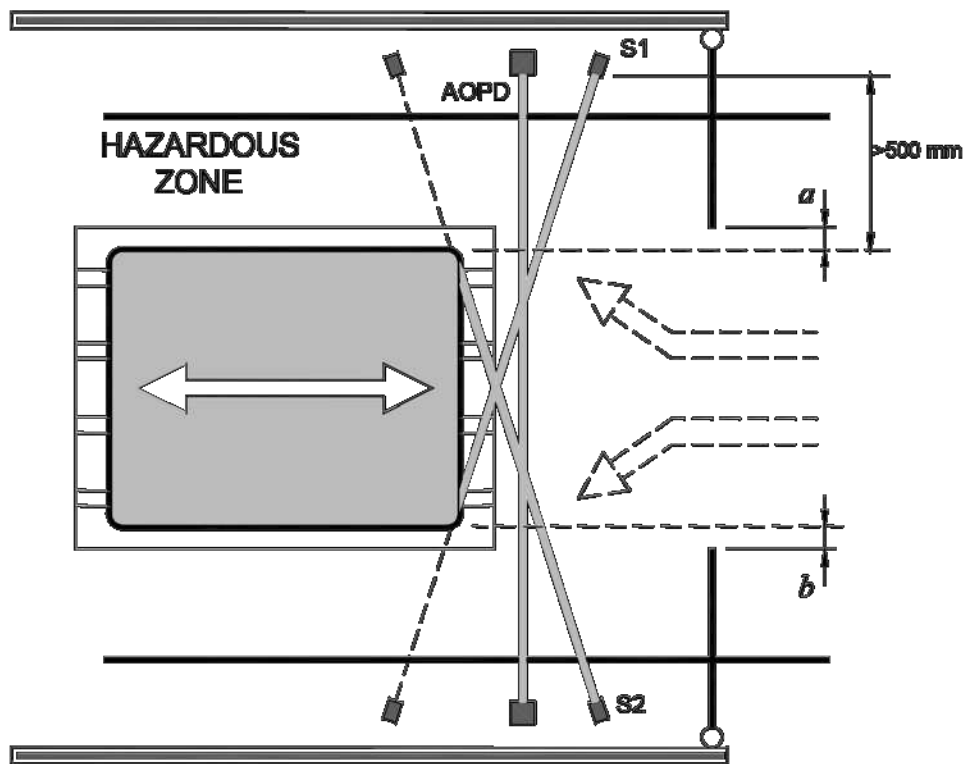
For pallets of various dimensions and when it is foreseen that the distances each side of the pallet (a and b) can be greater than 200 mm, electrically interlocked flexible swing doors with a width of at least 500 mm can be required (see Figure D.23 and 5.7.3).



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Figure D.23 – Single swinging doors in combination with a two-beam muting system (correct position)

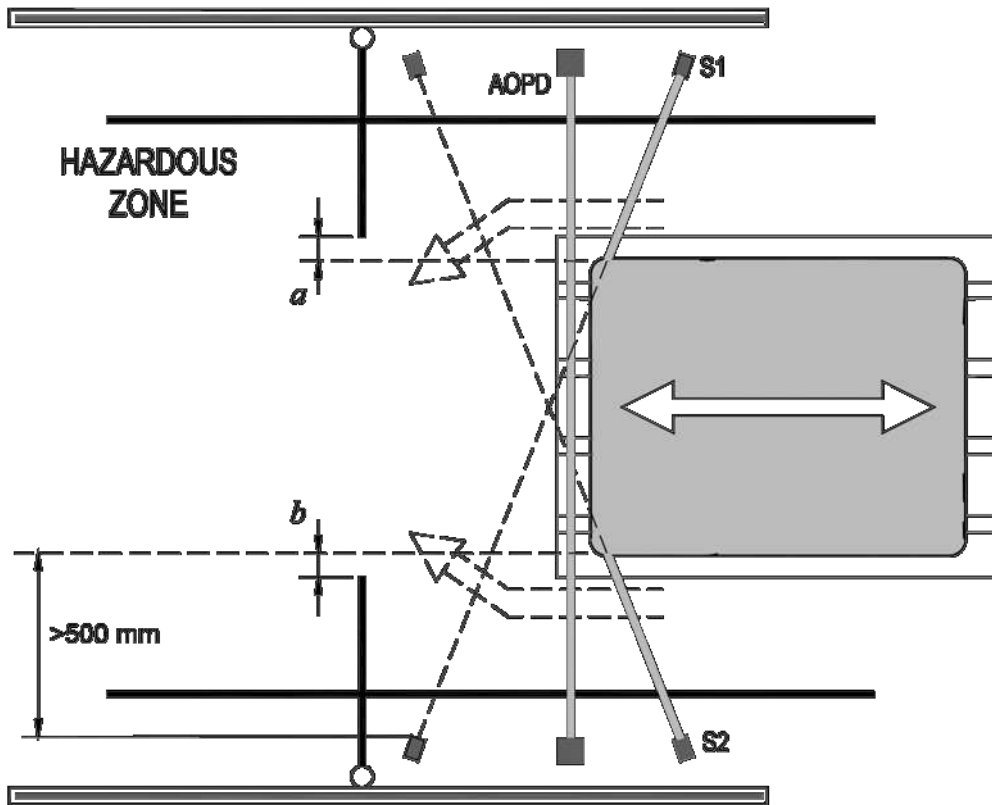
Figure D.24 shows an incorrect application, in which the swinging doors are too far from the detection zone, and access to the hazardous zone is possible by reaching in behind the pallet as shown by the dotted arrows.



IEC

**Figure D.24 – Reaching hazardous zone behind the pallet
(incorrect position of swinging doors)**

Figure D.25 shows an incorrect application, in which the swinging doors are too far from the detection zone, and access to the hazardous zone is possible by reaching in front of the pallet as shown by the dotted arrows.



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Figure D.25 – Reaching hazardous zone in front of pallet (incorrect position of swinging doors)

D.2.10 Height of the crossing point of the muting sensor beams

The crossing point of the two muting sensor beams should be positioned at the same level as, or higher than, the lowest beam of the ESPE to avoid manipulation of the system with the toe. See Figure D.26 and Figure D.27.

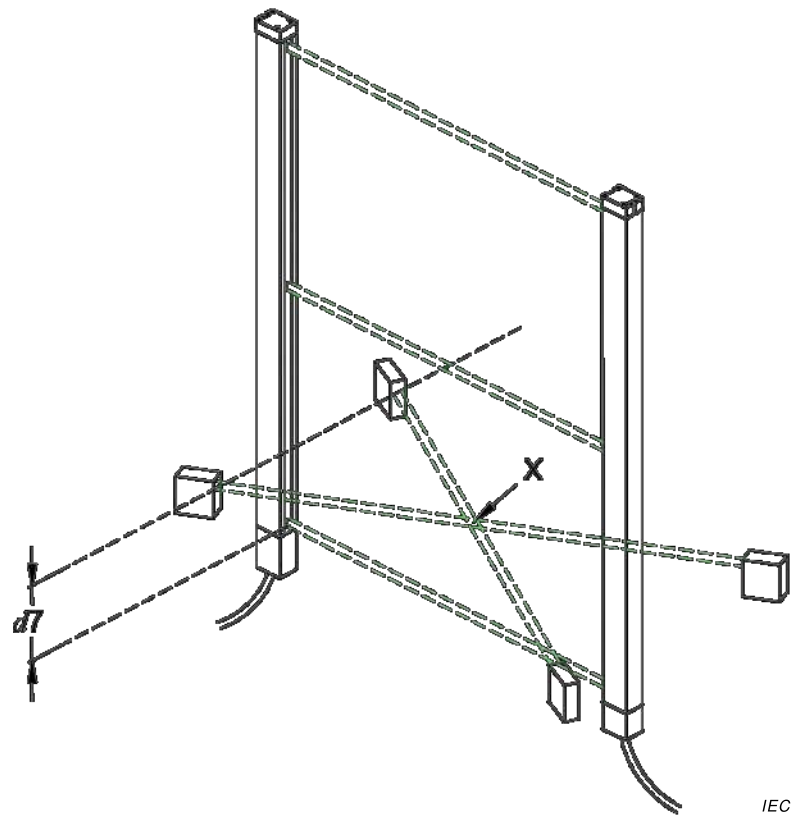
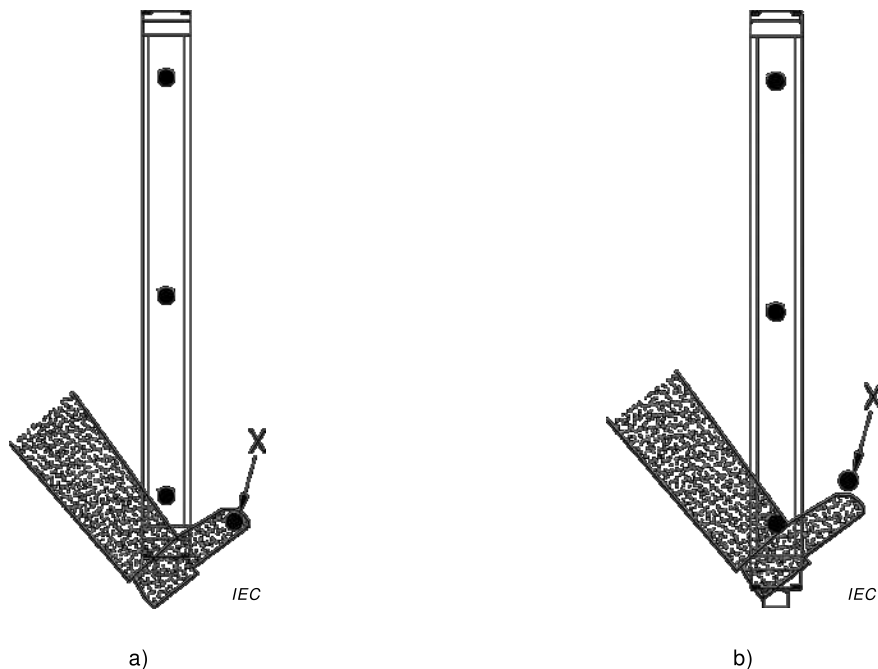


Figure D.26 – Height of crossing point



a)

b)

Figure D.27 – Interruption of the beam by foot

If $d7 \geq 0$, the lowest beam of the ESPE will be interrupted before the muting sensor beams.

D.3 Two parallel muting sensor beams – exit only

This system can be used to allow materials to exit from the hazardous area while preventing undetected entry.

The two muting sensor beams are situated behind the ESPE in the hazardous zone (see Figure D.28).

The muting function should only be initiated when the two beams are activated within a preset time to be determined by the application.

Termination of the muting function occurs as soon as the ESPE is deactivated or within 4 s from the time when one of the two beams of the muting sensors is no longer activated, whichever occurs first. The 4 s time limit is monitored.

Where the termination of the muting function is performed only by the 4 s timer, an additional distance $d8$ should be considered for the mechanical protection to avoid access by a person through the muting area when the system is still in the mute condition.

$$d8 = \text{max. speed of the pallet} \times 4 \text{ s} - 200 \text{ mm}$$

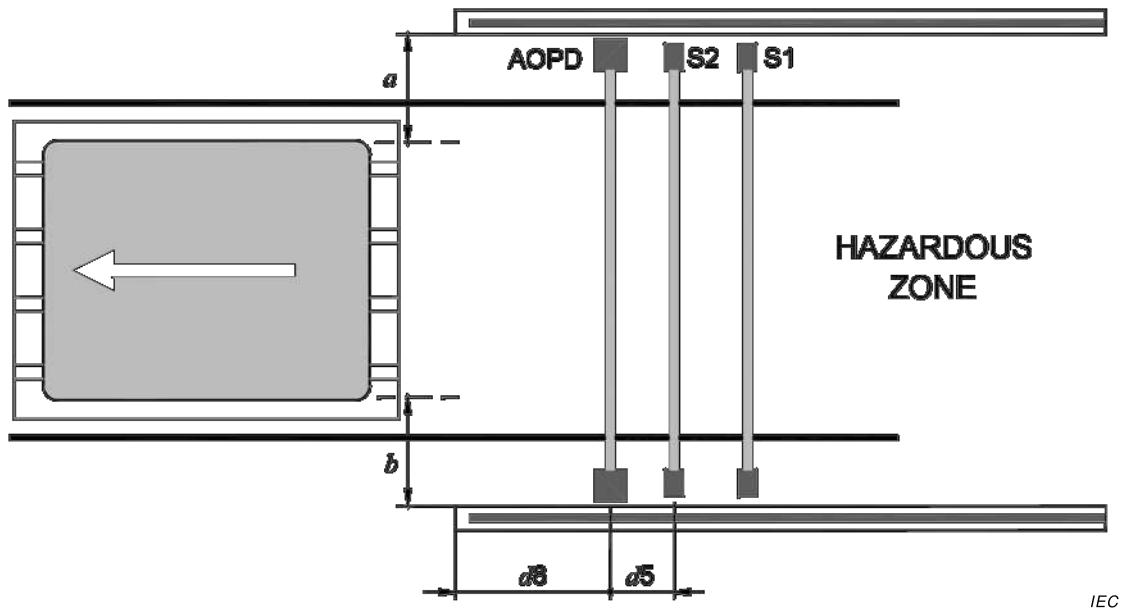


Figure D.28 – Two muting sensor beams – exit only

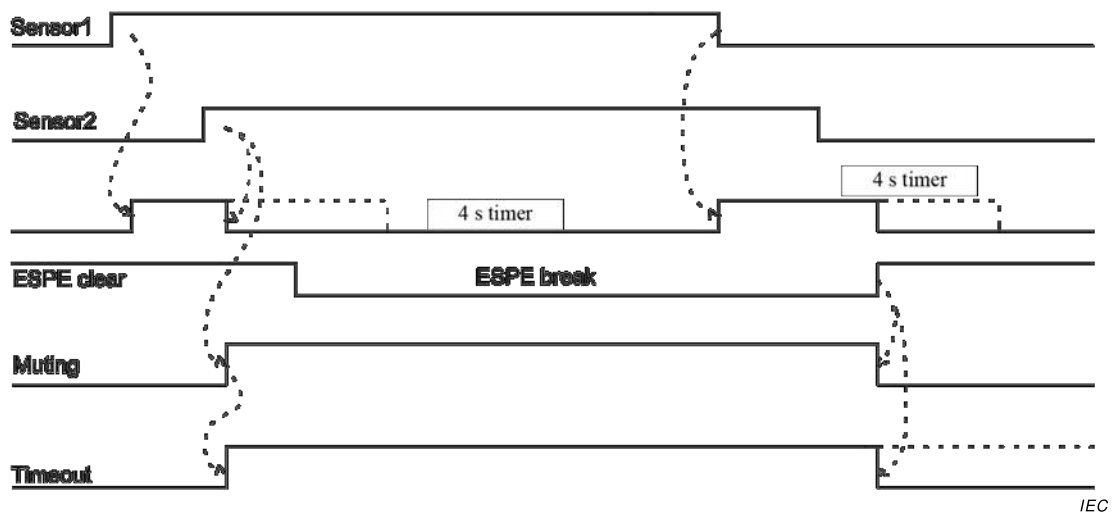


Figure D.29 – Timing diagram; two muting sensor beams – exit only, muting terminated by the ESPE

In Figure D.29, the muting function is terminated when the detection zone of the ESPE is clear (the 4 s timer has not expired).

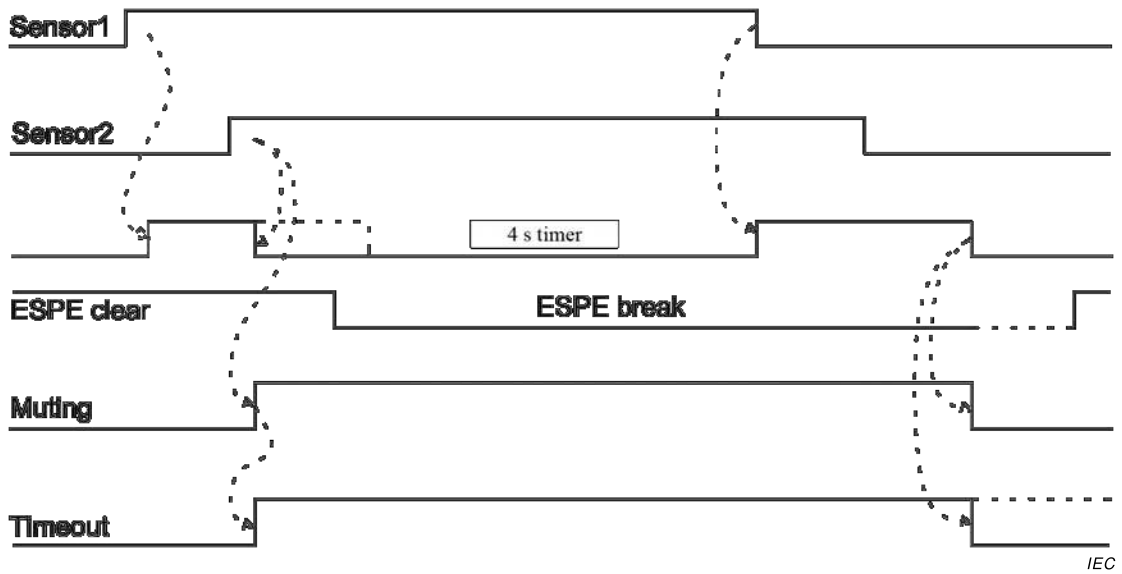


Figure D.30 – Timing diagram; two muting sensor beams – exit only, muting terminated by the 4 s timer

In Figure D.30, the muting function is terminated by the 4 s timer because when it expires, the detection zone of the ESPE remains interrupted.

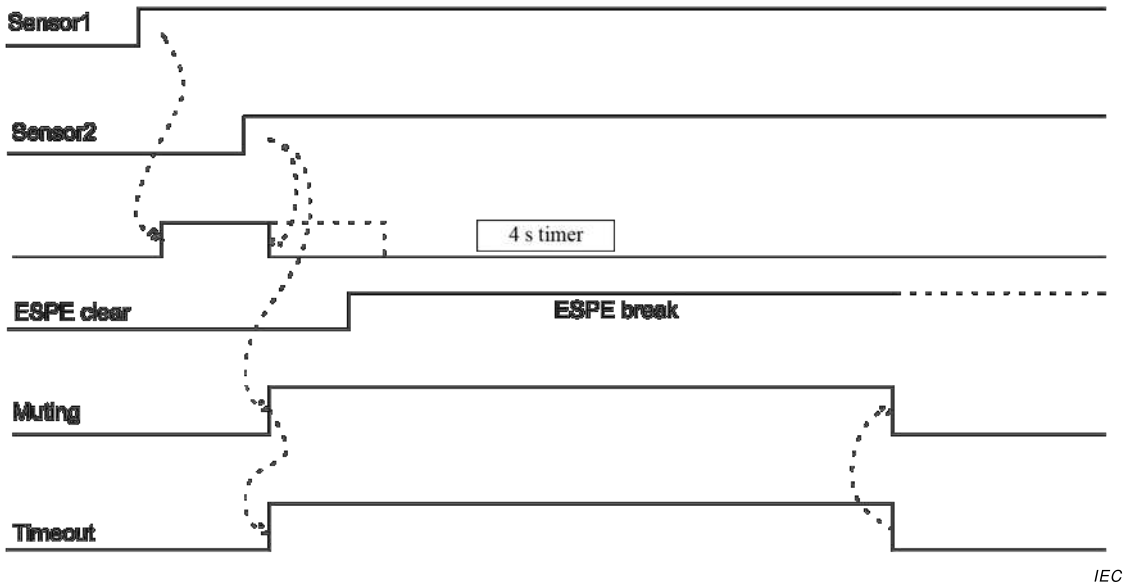


Figure D.31 – Timing diagram, muting terminated by the muting timeout

In Figure D.31, the muting cycle is terminated by the muting timeout.

D.4 Protection of conveyor systems working in a coordinated manner

When muting systems are used for protection from the risk of entering a production line incorporating several conveyor systems, careful attention should be paid to the selection of the appropriate muting configuration of the sensors.

The following example shows a production line incorporating two machines: conveyor 1 and conveyor 2. The pallets move from hazardous zone associated with conveyor 1 to hazardous zone associated with conveyor 2 (see Figure D.32). The muting system M1 allows the pallets to pass from conveyor 1 to conveyor 2. If the operator opens the door DB, the hazardous zone associated with conveyor 2 is made safe while the hazardous zone associated with conveyor 1 is not affected. The muting system M1 will protect the operator from entering the hazardous zone associated with conveyor 1. If the operator opens the door DA, the hazardous zone associated with conveyor 1 is made safe and the hazardous zone associated with conveyor 2 is not affected but in this case the muting system M1 does not give any protection to the operator if he tries to enter the hazardous zone associated with conveyor 2 because the crossing point of the two muting sensors in this case is positioned on the operator's side. The two beams T type muting assembly is not suitable for this application, a four beams with timing control or sequence control is necessary (see Figure D.33).

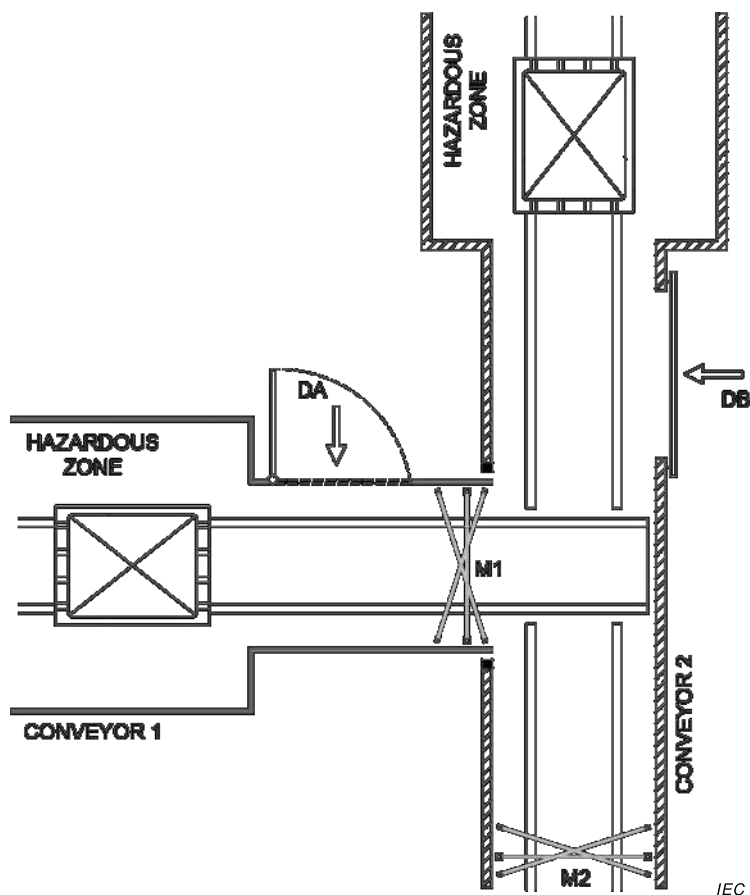


Figure D.32 – Production line incorporating two conveyors (2 hazardous zones) (incorrect application)

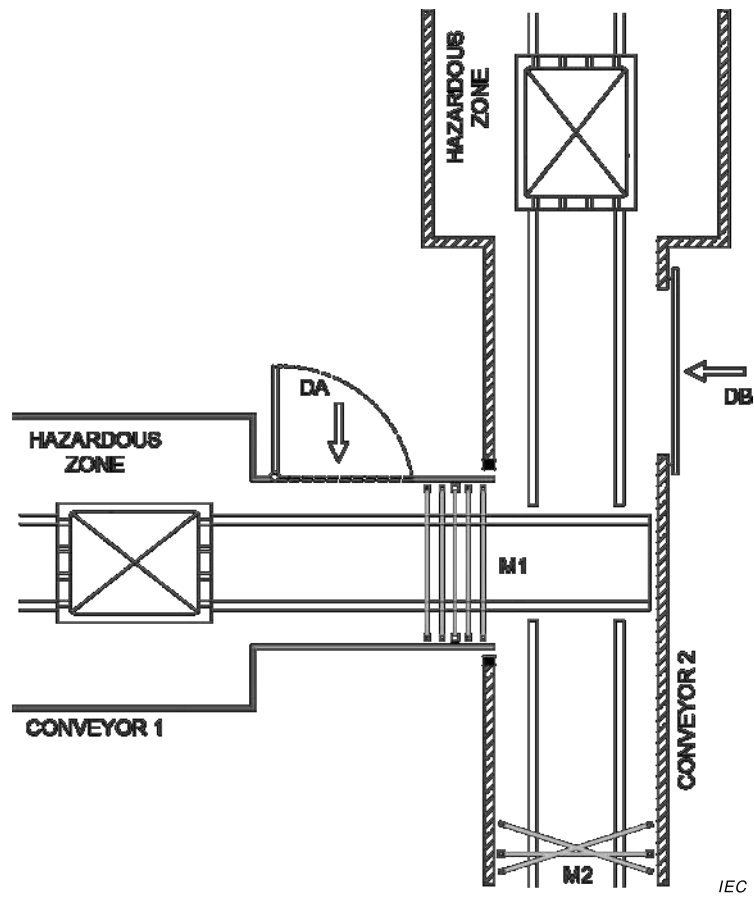


Figure D.33 – Production line incorporating two conveyors(2 hazardous zones)

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